Exhibit A

Proposed Regional Reliability Standard, VAR-501-WECC-3 – Power System Stabilizer

VAR-501-WECC-3 Clean Version

A. Introduction

1. **Title:** Power System Stabilizer (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date; or
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

D. Regional Differences

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Version History

Version	Date	Action	Change Tracking
1	April 16, 2008	Permanent Replacement Standard for VAR-STD-002b-1	
1	October 28, 2008	Adopted by NERC Board of Trustees	
1	April 21, 2011	FERC Order issued approving VAR- 501-WECC-1 (FERC approval effective June 27, 2011; Effective Date July 1, 2011)	
2	November 13, 2014	Adopted by NERC Board of Trustees	
2	March 3, 2015	FERC letter order approved VAR-501-WECC-2	
3	September 21, 2016	WECC Board of Directors approved proposed VAR-501-WECC-3	Revised in-service requirement and incorporated WECC policies
3	February 9, 2017	Adopted by NERC Board of Trustees	

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.

It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner, the PSS operating zone in which the PSS is "active" providing damping to the power system. Some PSS may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard's previous version, the logged hours were totaled quarterly to meet the

98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for the commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

*** FOR INFORMATIONAL PURPOSES ONLY ***

Enforcement Dates: Standard VAR-501-WECC-3 — Power System Stabilizer

United States

Standard	Requirement	Enforcement Date	Inactive Date
VAR-501-WECC-3	TBD	TBD	

VAR-501-WECC-3 Redline Version

A. Introduction

1. ~~1.~~ **Title:** Power System Stabilizer (PSS)

~~2.~~ **Number:** VAR-501-WECC-~~2~~

2. 3~~.~~

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.

4. **Applicability:**

~~**that Power System Stabilizers (PSS) on**~~ **4.1** Generator Operator

4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators ~~**shall be kept in service.**~~, connected to the Bulk Electric System, that meet the definition of Commercial Operation.

~~1.~~ ~~**4. Applicability:**~~

~~**4.1. Generator Operators**~~

6. ~~**5.**~~ **Effective Date:** ~~On the~~ The first day of the first quarter~~,~~ following regulatory approval, except for Requirement R3.

For units placed in first-time service after ~~applicable~~ regulatory approval~~.~~, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date; or
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator~~R1.~~ ~~Generator Operators~~ shall have ~~PSS in service 98% of all operating hours for synchronous generators equipped with PSS. Generator Operators may exclude hours for R1.1 through R1.12 to achieve the 98% requirement.~~ its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: ~~Operations~~Operating Assessment]*

- ~~**R1.1.** The~~ Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor:*

Medium] [Time Horizon: Operating Assessment]

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator ~~operates for less than five percent of all hours during any calendar quarter.~~within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

~~**R1.2.** Performing maintenance and testing up to a maximum of seven calendar days per calendar quarter.~~

~~**R1.3.** PSS exhibits instability due to abnormal system configuration.~~

~~**R1.4.** Unit is operating in the synchronous condenser mode (very near zero real power level).~~

~~**R1.5.** Unit is generating less power than its design limit for effective PSS operation.~~

~~**R1.6.** Unit is passing through a range of output that is a known "rough zone" (range in which a hydro unit is experiencing excessive vibration).~~

~~**R1.7.**~~ The Generator Owner connects a generator ~~AVR is not in service.~~

~~**R1.8.** Due to component failure, the PSS may be out of service up to 60 consecutive days for repair per incident.~~

~~**R1.9.** Due to a component failure, the PSS may be out of service up to one year provided the Generator Operator submits documentation identifying the need for time to obtain replacement parts and if required to schedule an outage.~~

~~**R1.10.** Due to a component failure, the PSS may be out of service up to 24 months provided the Generator Operator submits documentation identifying the need for time for PSS replacement and to schedule an outage.~~

- ~~**R1.11.** The synchronous generator has not achieved~~to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.

- ~~**R1.12.**~~ The ~~Transmission Operator directs the~~ Generator ~~Operator to operate the synchronous~~Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS ~~is unavailable for~~ on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. ~~**Measures**~~

~~M1. Generators Operators shall provide quarterly reports to the compliance monitor and have evidence for each synchronous generator of the following:~~

~~**M1.1** The number of hours the synchronous generator was on line.~~

~~**M1.2** The number of hours the PSS was out of service with generator on line.~~

~~**M1.3** The PSS in service percentage~~

~~**M1.4** If excluding PSS out of service hours as allowed in R1.1 through R1.12, provide:~~

~~**M1.4.1** The number of hours excluded,~~

~~**M1.4.2** The adjusted PSS in-service percentage,~~

~~**M1.4.3** Date of the outage.~~

~~D.~~ Compliance

1. Compliance Monitoring Process

1.1 Compliance ~~Monitoring Responsibility~~

~~Compliance~~ **Enforcement Authority**

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring ~~Period~~and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance ~~Enforcement Authority may use one or more of the following methods to assess~~Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance~~:~~. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

~~- Reports submitted quarterly~~

~~- Spot check audits conducted anytime with 30 days notice~~

~~- Periodic audit as scheduled by the Compliance Enforcement Authority~~

~~- Investigations~~

~~- Other methods as provided for in the Compliance Monitoring Enforcement Program~~

~~The Reset Time Frame shall be a calendar quarter.~~

~~1.3 Data Retention~~

~~The~~Each Generator ~~Operators~~Operator shall keep evidence for ~~Measures M1 for~~all Requirements of the document for a period of three years plus calendar current ~~year, or since the last audit, whichever is longer~~.

1.4 Additional Compliance Information

None

~~**1.4.1** The sanctions shall be assessed on a calendar quarter basis.~~

~~**1.4.2** If any of R1.2 through R1.12 continues from one quarter to another, the number of days accumulated will be the contiguous calendar days from the beginning of the incident to the end of the incident. For example, in R1.8 if the 60 day repair period goes beyond the end of a quarter, the repair period does not reset at the beginning of the next quarter.~~

~~**1.4.3** When calculating the adjusted in-service percentage, the PSS out of service hours do not include the time associated with R1.1 through R1.12.~~

~~1.4.4 The standard shall be applied on a generating unit by generating unit basis (a Generator Operator can be subject to a separate sanction for each non- compliant synchronous generating unit or to a single sanction for multiple machines that operate as one unit).~~

~~E~~D. Regional Differences

None

~~None~~

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
~~R1~~ R2	~~Operational~~ Operations Assessment	Medium	~~There shall be a Lower Level of non-compliance if PSS is in service less than 98% but at least 90% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a Moderate Level of non-compliance if PSS is in service less than 90% but at least 80% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a High Level of non-compliance if is in service less than 80% but at least 70% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a Severe Level of non-compliance if PSS is in service less than 70% of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
			synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						required in Requirement R5.

Version History

Version	Date	Action	Change Tracking
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Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.

It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner, the PSS operating zone in which the PSS is "active" providing damping to the power system. Some PSS may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard's previous version, the logged hours were totaled quarterly to meet the

98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for the commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

*** FOR INFORMATIONAL PURPOSES ONLY ***

Enforcement Dates: Standard VAR-501-WECC-3 — Power System Stabilizer

United States

Standard	Requirement	Enforcement Date	Inactive Date
VAR-501-WECC-3	TBD	TBD	

Exhibit B

Implementation Plan for Proposed Regional Reliability Standard VAR-501-WECC-3

Standard Authorization Request

WECC-0107 VAR-501-WECC-2 SAR Form - Reformatted[1]

Applicable Standards
VAR-501-WECC-3 - Power System Stabilizers (PSS)

Requested Retirements

- VAR-501-WECC-2 - Power System Stabilizer
- This standard is based on the *WECC Policy Statement on Power System Stabilizers* (Policy). That document is owned by the WECC Control Work Group. Although it is outside of the purview of the assigned drafting team, the drafting team recommended that the assigned WECC Standing Committee initiate retirement of the Policy coincident with the effective date of this standard.

Applicable Entities[2]

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards
N/A

Effective Date
Where approval by an applicable governmental authority is required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority.

For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar

[1] Version 2 was the incoming designation. It was changed to Version 3 as the project was developed.
[2] The applicable entities changed after receipt of the Standard Authorization Request.

quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction.

For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction.

For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Regional Reliability Standard VAR-501-WECC-2 should be retired to coincide with the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective. (See above comment regarding retirement of the WECC Policy Statement on Power System Stabilizers.)

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date. Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 reduces the burden by allowing entities to address the Requirement over a longer period of time.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no undue burden. Many of the units already in service are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC guidelines, many Applicable Entities within WECC will already be in voluntary compliance.

Exhibit D

Mapping Document

Mapping Document

VAR-501-WECC-3 Power System Stabilizers
Developed as WECC-0107

Executive Summary

This project updated existing WECC Regional Reliability Standard VAR-501-WECC-2, Power System Stabilizer.[1]

The purpose of proposed Regional Reliability Standard VAR-501-WECC-3 is to ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers. VAR-501-WECC-3 includes requirements that address the following: (1) providing Transmission Operators with procedures or other documents that inform the Transmission Operator of when a power system stabilizer will be out of service; (2) having the power system stabilizer in service at all times except during specific circumstances; (3) tuning power system stabilizers to stated criteria; (4) installing and completing start-up testing of a power system stabilizer; and (5) repairing or replacing a power system stabilizer within a specified time period.

This document maps the requirements from existing Regional Reliability Standard VAR-501-WECC-2 with the requirements of proposed Regional Reliability Standard VAR-501-WECC-3. In addition, this document shows how existing WECC policies and guidelines on power system stabilizers are included in the proposed requirements.

[1] This project shows substantial redline because its format was updated to match NERC's most recent template.

Proposed Regional Reliability Standard VAR-501-WECC-3 Power System Stabilizers		
VAR-501-WECC-2 **Requirement in Approved Standard**	**VAR-501-WECC-3** **Translation to New Standard or Other Action**	**Description and Change Justification**
Applicability: Generator Operator	**Applicability:** Generator Operator Generator Owner	As discussed in more detail in this filing, the standard drafting team based its applicability determination on WECC policy and studies performed in the Western Interconnection. The applicable entities were expanded to better align with the Functional Entities performing the assigned tasks. See R3 below for source documents.
Facilities:	**Facilities:** This standard applies to synchronous generators, connected to the Bulk Electric	The standard drafting team concluded that it was not practical to determine the optimum applicability threshold for each individual power system stabilizer (PSS) because each one is unique. Further, although existing WECC policies and guidelines dictate a more stringent threshold than proposed, the technical study, Power System Stabilizer Applicability in the WECC System - Study Progress Report to WECC-0107 Drafting Team, does not necessarily support the number in the policy as a threshold for a mandatory standard.

None specified	System, that meet the definition of Commercial Operation.	As a result, the drafting team adopted the threshold included in the Bulk Electric System (BES) proceeding relying on the depth and breadth of input in that proceeding.
R1. Generator Operators shall have PSS in service 98% of all operating hours for synchronous generators equipped with PSS. Generator Operators may exclude hours for R1.1 through R1.12 to achieve the 98% requirement. *[Violation Risk Factor: Medium] [Time Horizon: Operations Assessment]*	**R1.** Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: [Violation Risk Factor: Low] [Time Horizon: Planning Horizon] • The effective date of this standard; • The PSS's Commercial Operation date, or; • Any changes to the PSS operating specifications.	The original exclusions contained in the existing standard have their origins in the still-viable but voluntary WECC Policy Statement on Power System Stabilizers, April 18, 2002, approved by the Board of Trustees. Proposed R1 and R2 are intended to encompass all of the reliability-related substance of the existing R1 (PSS operational 98% of the time) while ameliorating the administrative requirement to count hours. The difference between existing R1 and proposed R1 and R2 is a shift in focus from counting/adding up hours of operation to prove compliance, to a presumption that the PSS will be in operation 100% of the time, unless otherwise reported in advance. Elements from the existing R1 and its subsets could be contained in the written operating procedures required in proposed R1. Items for inclusion in the required

		procedures could include, but not be limited to, those items addressed in existing R1 and its subsets, such as: • *known circumstances* during which the operation of the unit will be less than optimum (existing R1.3, R1.4, R1.5, R1.6, R1.7); • *known circumstances* when the PSS has not achieved Commercial Operation (existing R1.11); or, • *known circumstances* when the Transmission Operator directs that the PSS be turned off (existing R1.12). • The balance of the existing R1 subsets are addressed in proposed R2.
	180 Days	In proposed R1 and R4, the 180-day provision window is an addition to the existing standard. In proposed R1, the Generator Operator is required to provide operating specifications to its Transmission Operator within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating speciation.

	New in the proposed standard.	In proposed R4, the Generator Owner is required to install and complete start-up testing of a PSS on its generator within 180 days of either connection to the BES or, replacement or repair of an existing PSS. A review of the eight postings[2], approximately 30 meeting minutes, and associated emails indicate the 180-day window was first introduced in Draft 14 of Posting 1, occurring on June 18, 2014. Although no time-window related comments were received during the eight postings, the drafting team did consult with compliance personnel as well as operations personnel regarding establishment of the window. From the standpoint of compliance, a date needed to be established; otherwise, the tasks might be indefinitely postponed. From an operations standpoint, concerns were raised that some allowance should be provided to address unforeseen circumstances such as the unavailability of parts or qualified personnel, or simply to

[2] The WECC WECC-0107 Project Page shows nine postings; however, the Posting 9 document was not posted for comment but was simply a clean version.

			address the one-off unforeseen circumstance. After consultation, the drafting team concluded that the 180-day window served as a reasonable window to accommodate both the compliance and the operational needs.
R1.1.	The synchronous generator operates for less than five percent of all hours during any calendar quarter.		Counting of hours is no longer required. The PSS must be in service except for specified known circumstances.
R1.2.	Performing maintenance and testing up to a maximum of seven calendar days per calendar quarter.		See below at proposed R2.
R1.3.	PSS exhibits instability due to abnormal system configuration.		See above at proposed R1.
R1.4.	Unit is operating in the synchronous condenser mode (very near zero real power level).		See above at proposed R1.
R1.5.	Unit is generating less power than its design limit for effective PSS operation.		See above at proposed R1.
R1.6.	Unit is passing through a range of output that is a known “rough zone” (range in		See above at proposed R1.

which a hydro unit is experiencing excessive vibration).		
R1.7. The generator AVR is not in service.		See above at proposed R1.
R1.8. Due to component failure, the PSS may be out of service up to 60 consecutive days for repair per incident.		See below at proposed R2.
R1.9. Due to a component failure, the PSS may be out of service up to one year provided the Generator Operator submits documentation identifying the need for time to obtain replacement parts and if required to schedule an outage.		See below at proposed R2.
R1.10. Due to a component failure, the PSS may be out of service up to 24 months provided the Generator Operator submits documentation identifying the need for time for PSS replacement and to schedule an outage.		See below at proposed R2.
R1.11. The synchronous generator has not achieved Commercial Operation.		See above at proposed R1.
R1.12. The Transmission Operator		See above at proposed R1.

directs the Generator Operator to operate the synchronous generator, and the PSS is unavailable for service.		
	R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]* • Component failure • Testing of a Bulk Electric System Element affecting or affected by the PSS • Maintenance • As agreed upon by the Generator Operator and the Transmission Operator A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.	Proposed R2 translates the remaining portions of the existing R1. In proposed R2, the PSS can be out-of-service for component failure (existing R1.8, R1.9, R1.10), testing and maintenance (existing R1.2), and as agreed upon by the parties (existing R1.12 (under this later circumstance the fact pattern may be one that was not previous known as required in proposed R1.)).
	R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating*	Proposed R3 is an addition to the existing standard and memorializes portions of existing WECC policies and procedures that are currently advisory in nature. These policies and procedures were

	Assessment] **3.1.** PSS shall be set to provide the measured, simulated, or calculated compensated Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees. **3.2.** PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage. **3.3.** PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain. **3.4.** PSS washout time constant shall be no greater than 30 seconds. **3.5**. Units that have an excitation system or PSS that is incapable	augmented by a technical study provided by the drafting team, Power System Stabilizers Use of Minimum-Load for Tuning in Proposed Requirement R3. These features have been in place within WECC, in some cases, for well over a decade. The foundation of the tuning specifications is found in the following documents, augmented by the comments received during the eight postings: • WECC Power System Stabilizer Tuning Guidelines, created by the WECC Modeling Validation Work group under the auspice of the WECC Planning Coordination Committee (PCC). • WSCC Tutorial on Power System Stabilizers, 1999, approved by the PCC[3] • WECC Policy Statement on Power System Stabilizers, April 18, 2002, approved by the Board of Trustees.

[3] Western System Coordinating Council, WECC's predecessor.

	of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.	
	R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]* • The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard. • The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.	Proposed R4 is an addition to the existing standard and memorializes portions of existing WECC policies and procedures that are currently advisory in nature. (See 180 Days for justification) (See R3 for resource documents.)

	R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*	Proposed R5 is an addition to the existing standard and memorializes portions of existing WECC policies and procedures that are currently advisory in nature.
24 Months	**24 Months**	In the Reliability Management System (RMS) agreement that preceded the existing standard, entities were required to repair or replace a faulty PSS within 12 months of failure.[4] Under the RMS, if an entity could not comply within 12 months an extension to 24 months was allowed. Historically, WECC granted numerous extensions. As a result, when the existing standard was drafted the more practical 24-month window was added to Requirement R1.10. This practical window is carried over into the proposed standard. In R5, the applicable entity is required to repair or replace a PSS within 24 months of

[4] The Reliability Management System was the precursor to the NERC mandatory standards within the Western Interconnection.

		that PSS becoming incapable of meeting the tuning specifications. Like the 180-day time window, the 24-month time window was presented to the industry in Posting 1. The 24-month window addresses the concern that "a Generator owner may unreasonably delay repair or replacement of a non-operational PSS." "The rationale for the 24 month window is that it provides the Generator Owner an ample window to either procure a replacement part[s] or to purchase and bring operational and [sic] entirely new PSS." Posting 1, Response to Comments, Western Trading Power Forum.[5]

[5] Although the language of Requirement R5 was later changed for clarification, no further requests from the industry were raised regarding the duration or reasonability of the time window.

Exhibit E

Analysis of Violation Risk Factors and Violation Severity Levels

Table of Compliance Elements

Appended

Violation Risk Factor (VRF)

The WECC-0107 VAR-501-WECC-3, Power System Stabilizer Drafting Team (DT) used the NERC-provided guidance document for VRFs[1] to determine the VRF for each requirement.

Based upon the guidance document, the DT assigned a low VRF to Requirement R1 because the requirement is administrative in nature addressing the planning horizon.

A violation of the requirement, would not, under the emergency, abnormal, or restorative conditions anticipated by the preparations, be expected to adversely affect the electrical state or capability of the Bulk Electric System (BES), or the ability to effectively monitor, control, or restore the BES.

All other requirements were assigned a medium VRF.

The remaining requirements address the operational horizon. If violated, they could directly affect the electrical state or the capability of the BES, or the ability to effectively monitor and control the BES. However, violation of these medium-risk requirements is unlikely to lead to BES instability, separation, or cascading failures.

Violation Severity Level (VSL) [2]

The DT used the NERC-provided guidance document for VSLs to determine the VSL for each requirement.

Based upon the guidance document, the DT assigned a severe VSL to Requirements R1, R4 and R5, because the requirements are binary in nature and are “pass or fail” type requirements where any degree of noncompliant performance would result in totally or mostly missing the reliability intent of the requirements.

For each of the remaining requirements, the DT assigned a gradated performance schedule with each requirement being assigned four increasing tiers for non-compliance. In each case the DT concluded that partial performance would have some reliability-related value.

[1] NERC Guidance on Violation Risk Factors
[2] NERC Guidance on Violation Severity Levels

The VSL for Requirement R2 is based on the passage of time. The longer a Generator Operator leaves its power system stabilizer out of service, the greater the VSL becomes.

The VSL for Requirement R3 is based on the cumulative number of times the Generator Owner failed to meet the prescribed performance. Each piece of the prescribed performance contributes equally to the reliability-related objective; therefore, the VSL was uniformly applied for each piece.

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Exhibit F

Summary of Development History and Complete Record of Development

Summary of Development History

Summary of Development History

The development record for proposed Regional Reliability Standard VAR-501-WECC-3 is summarized below.

I. Overview of the Standard Drafting Team

When evaluating a proposed Reliability Standard, the Commission is expected to give "due weight" to the technical expertise of the ERO.[1] The technical expertise of the ERO is derived from the standard drafting team selected by the WECC Standards Committee to lead each project in accordance with Step 3 of the WECC Reliability Standards Development Procedures.[2] For this project, the standard drafting team consisted of industry experts, all with a diverse set of experiences. A roster of the standard drafting team members is included in Exhibit I.

II. Standard Development History

A. Standard Authorization Request Development

Project WECC-0107 – Power System Stabilizer Design and Performance was initiated on February 11, 2014 with the receipt of a proposed Standard Authorization Request ("SAR"). The WECC Standards Committee approved the SAR and created a standard drafting team on March 12, 2014. The WECC Standards Committee expanded the scope of the SAR on June 25, 2014 to merge with Project WECC-0094 – VAR-501-WECC-1, Power System Stabilizer and incorporate the outcome of Project WECC-0105 – P81 VAR Redraft.

B. First Posting – Comment Period

On June 25, 2014, the WECC Standards Committee approved posting proposed Regional Reliability Standard VAR-501-WECC-3 for a 45-day public comment period. Proposed Regional

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1 Section 215(d)(2) of the Federal Power Act; 16 U.S.C. §824(d) (2) (2012).

2 The WECC Reliability Standards Development Procedures are available at https://www.wecc.biz/Reliability/Reliability%20Standards%20Development%20Procedures%20-%20FERC%20Approved%20Dec%2023%202014.pdf.

Reliability Standard VAR-501-WECC-3 was posted for a 45-day public comment period from July 1, 2014 through August 14, 2014. WECC received comments from four companies representing five of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard. Therefore, the standard was posted for an additional comment period.[3]

C. Second Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from October 15, 2014 to November 14, 2014, although the WECC Standards Committee granted an extension of time for posting comments. WECC received comments from four companies representing six of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[4]

D. Third Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from December 12, 2014 to January 12, 2015, with the standard drafting team accepting late comments until January 20, 2015. WECC received comments from five companies representing six of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[5]

E. Fourth Posting – Comment Period

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[3] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 1 (posted Sept. 26, 2014) is available at https://www.wecc.biz/Reliability/WECC-0107%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Posting%201%20Responses%20-%20clean%209-11-2014.doc.

[4] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 2 (posted Dec. 4, 2014) is available at https://www.wecc.biz/Reliability/WECC-0107%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Posting%202%20Responses%20-%20Clean%2011-26-2014.doc.

[5] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 3 (posted Feb. 2, 2015) is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%203%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%202-10-2015.doc.

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from April 17, 2015 to May 19, 2015. WECC received comments from four companies representing five of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[6]

F. Fifth Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from July 7, 2015 to August 6, 2015. WECC received comments from three companies representing five of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[7]

G. Sixth Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from September 3, 2015 to October 5, 2015. WECC received comments from three companies representing six of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[8]

H. Seventh Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from October 22, 2015 to November 23, 2015. WECC received comments from six

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[6] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 4 (posted June 12, 2015) is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%204%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%20-%206-11-2015.doc.

[7] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 5 is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%205%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%20-%209-1-2015.doc.

[8] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 6 is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%206%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%20-%2010-20-2015.doc.

companies representing five of the eight industry segments. Based on the comments received, the standard drafting team determined to make substantive changes to the proposed standard.[9]

I. Eighth Posting – Comment Period

Proposed Regional Reliability Standard was posted for another public comment period for 30 days from December 11, 2015 to January 11, 2016, with the standard drafting team accepting comments until January 22, 2016. WECC received comments from six companies. Based on the comments received, the standard drafting team made a change to the Violation Severity Level table and other non-substantive changes.[10]

J. Ninth Posting – Final Standard for WECC Standards Committee

Because only non-substantive changes were made between the eighth and ninth postings, the standard drafting team did not solicit public comments on the ninth posting of the standard. On February 18, 2016, the standard drafting team agreed to send the standard to the WECC Standards Committee with a request for ballot.

K. Ballot Period and Results

On March 8, 2016, the WECC Standards Committee approved proposed Regional Reliability Standard VAR-501-WECC-3 to be posted for ballot. The ballot pool opened on March 21, 2016 and closed on April 8, 2016. WECC held a standards briefing on April 7, 2016. Ninety-two individuals joined the ballot pool. Eighty-five individuals cast votes, reaching quorum at 92.4 percent. The standard obtained 52 affirmative votes, which was 66 percent of the weighted segment vote. As a result, the standard passed ballot on May 2, 2016.

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[9] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 7 is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%207%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%20-%2012-3-2015.doc.

[10] Project WECC-0107 – Power System Stabilizer Design and Performance Consideration of Comments for Posting 8 is available at https://www.wecc.biz/Reliability/WECC-0107%20Posting%208%20VAR-501-WECC-2%20Power%20System%20Stabilizers%20Response%20to%20Comments%20-%202-9-2016.doc.

L. WECC Board of Directors Approval

On September 21, 2016, the WECC Board of Directors approved proposed Regional Reliability Standard VAR-501-WECC-3 and the retirement of Regional Reliability Standard VAR-501-WECC-2.

M. NERC Comment Period and Board of Trustees Approval

NERC received the Regional Reliability Standard Submittal Request for VAR-501-WECC-3 on December 12, 2016. NERC posted proposed Regional Reliability Standard VAR-501-WECC-3 for a 45-day public comment period from December 12, 2016 to January 25, 2017.[11] The NERC Board of Trustees adopted proposed Regional Reliability Standard VAR-501-WECC-3 on February 9, 2017.[12]

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[11] The NERC web page for Regional Reliability Standards Under Development is available at http://www.nerc.com/pa/Stand/Pages/RegionalReliabilityStandardsUnderDevelopment.aspx.

[12] NERC, *Board of Trustees Agenda Package*, Agenda Item 4e (WECC Regional Reliability Standard VAR-501-WECC-3), *available at* http://www.nerc.com/gov/bot/Agenda%20highlights%20and%20Mintues%202013/Board_February_9_2017_Meeting_Agenda_Package_v3.pdf.

Complete Record of Development

Edit Item

Title WECC-0107 PSS Design and Performance

First Name Martin

Last Name Bauer

Email mbauer@usbr.gov

Phone Number (303) 445-2901

Organization United States Bureau of Reclamation

Alternate Contact W. Shannon Black

Request Type Standard

Issue

On June 25, 2014, the WSC changed the scope of the WECC-0107 SAR as follows:

The proposed document should be structured as follows: PSS: 1) where installed, shall be operating unless specifically exempted, 2) shall be tuned as specified, and 3) where not installed, installation shall be required - when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated.

This document will merge with WECC-0094 VAR-501-WECC-1 on Power System Stabilizers and incorporate the outcome of WECC-0105, P81 review. The P81 ballot closed July 18, 2014.

WECC's Power System Stabilizer (PSS) program currently meets the Interconnection's reliability needs; however, the associated policies and procedures are voluntary and are not always consistently implemented. This Standards Authorization Request (SAR) is designed to:

1) Update and codify WECC's PSS program,
2) Establish a minimum design-criteria for installation of new PSS-related equipment,
3) Standardize tuning procedures for that equipment, and
4) Identify those facilities to which the PSS applies.

In preparation for this SAR, WECC's Control Work Group reviewed numerous PSS-related documents under the WECC-0099 SAR (retired by the WSC on February 11, 2014) and is recommending that certain substance from those reviewed documents be excerpted and addressed in a WECC Regional Reliability Standard (RRS).

To the extent the DT identifies any additional information best suited for other WECC Document Categories, the DT also seeks permission to draft those documents accordingly.

Purpose

It is recommended that the Purpose statement of the RRS should begin with the following:

"To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the tuning and performance criteria for WECC Power System Stabilizers."

Responsible Entities Generator Owner, Reliability Coordinator

Notes

Notes:
- To ensure drafting continuity, this SAR encourages the members of the CWG to self-nominate as a means to encourage continuity between WECC-0099 and this project.
- The DT should review the NERC Functional Model and decide on the best applicable entities to meet the tasks assigned.
- The DT should review recent studies conducted concerning PSS response within WECC and consider the information when drafting requirements.

The following is a suggested structure for the proposed standard. The listed applicable entities are only a starting place. The DT should review the NERC Functional Model and assign each task to the most appropriate entity.

The DT should identify the specific facilities to which the standard applies.

R1. Each Generator Owner shall install Power System Stabilizers that meet the following criteria:
1) [DT should specify design criteria]

R2. Each Generator Owner shall tune its Power System Stabilizers to achieve the following response criteria:
1) [DT should specify tuning criteria]

R3. Each Generator Owner shall validate the performance of its Power System Stabilizers using the following methods:
1) [DT should specify]

R4. Each Generator Owner shall provide performance results to the Reliability Coordinator within [time window] of the request.

R5. Each Reliability Coordinator shall instruct the Generator Owner to make changes to the Generator Owner's Power System Stabilizer tuning, within [time window] of its review of the Power System Stabilizer performance results as required in Requirement X.

R6. Each Generator Owner shall:
1) Implement changes to its Power System Stabilizers tuning no later than [time window], as instructed by the Reliability Coordinator in Requirement X.
2) Each Generator Owner shall provide report its performance results to the Reliability Coordinator within [time window] after implementing the tuning change required in Requirement X.

Detailed Description

This SAR recommends the following:

1) The DT should consider the WECC-0099 DT's review of PSS related documents and extract from those documents the recommended substance for importation into this RRS.

2) The DT review recent studies conducted concerning PSS response within WECC and consider the information when drafting requirements.

3) The DT should establish the minimum criteria describing:

a) the circumstances and/or design criteria in which installation of PSS equipment is required,
b) a standardized approach to PSS tuning and testing,
c) a standardized approach to communication of testing data and remediation of operations identified in that data.

Preliminary Technical Assessment and Reference Documents

A preliminary Power System Stabilizer Study can be found in the Documents section of the WECC-0099 Team Site.

Does the proposed request comply with all of the following Market Interface Principles?

1. The planning and operation of bulk electric systems shall recognize that reliability is an essential requirement of a robust North American economy, 2. Standard or Criterion shall not give any market participant an unfair competitive advantage, 3. Standard or Criterion shall neither mandate nor prohibit any specific market structure, 4. Standard or Criterion shall not preclude market solutions to achieving compliance with that Standard, 5. Standard or Criterion shall not require the public disclosure of commercially sensitive information.

Reliability Principles

1. Interconnected bulk electric systems shall be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions

Related Standards/Criterion

The CWG has vigorously reviewed a number of PSS-related documents. That review can be found in the Document section of the WECC-0099 Team Site located here.

May also affect VAR-501-WECC-1 Power System Stabilizer RRS.

If the drafter is aware of any regulatory documents that may directly affect the course of a drafting team, those documents should be identified here. For example, this section would include NERC/WECC/NAESB Standards, WECC Criteria, and WECC Regional Business Practices already in place as well as proposed. Please specify the "Version" of each document to be considered.

Is this Request in response to a NERC "Fill-in-the-Blank" Standard?	No
Attachments	

****** STAFF ONLY ******

Status	Posting 2 for comment October 15 through November 20, 2014.
Comment	
WECC Tracking Number	WECC-0107
Date Assigned to SC	2/11/2014
Drafting Next Meeting	10/9/2014
Standing	
SC Assigned to Draft	
Board	
Archive/Withdrawn Date	
URL	WECC-0107 PSS Design and Performance
Grouping	WECC Standards
NERC/WECC Standard/Criterion Number	TBD

Created at 2/11/2014 3:20 PM by sblack@wecc.biz
Last modified at 9/30/2014 3:37 PM by sblack@wecc.biz

Close

From:	Projects Undergoing Standards Development
To:	Bauer, Martin
Cc:	Black, Shannon
Subject:	WECC Standards/Regional Request
Date:	Tuesday, February 11, 2014 2:29:56 PM

Dear Martin Bauer:

The Western Electricity Coordinating Council (WECC) would like to thank you for submitting a WECC Standards/Regional Criteria Request Form (Request). Your Request, received on 2/11/2014 3:20:10 PM, was assigned a WECC tracking number of WECC-0107 and given the title of WECC-0107 PSS Design and Performance.

WECC staff will work closely with you during the coming weeks to ensure your Request is deemed complete and forwarded to the Standards Request Routing Committee (SRRC). If this Request cannot be deemed complete by 3/13/2014 3:20:10 PM, WECC staff will recommend to the SRRC that the Request be deemed incomplete and be withdrawn. If it is withdrawn for being incomplete, then no further action will be taken on this Request. Please understand that this type of withdrawal does not preclude submission of a new Request covering the same material.

Before your Request can be approved by the Western Electricity Coordinating Council, it must undergo a thorough review at several stages of development. Familiarizing yourself with these steps will enhance your understanding of that process and explain the many milestones that must be met along the way. The process can be accessed at:
http://www.wecc.biz/Standards/Development/Documents/Standards_Development_Process_Approved.pdf

Sincerely,

Steve Rueckert
Director of Standards
Western Electricity Coordinating Council Phone (801) 883-6878
Cell (801) 558-0301
FAX (801) 582-3918

Attachment A
Standard Authorization Request
WECC-0107 Power System Stabilizer
VAR-501-WECC-3

Introduction

The Standard Authorization Request (SAR) is used to propose a new or revised document, to retire an existing document, request interpretation of a document, or request an exemption from a requirement contained in a document. This request is posted in its original form at the *WECC-0107 Power System Stabilizer (PSS)* project web page on the SAR Form accordion. It has been reformatted to accommodate changes to the WECC web site. This SAR was received, validated and deemed complete on February 11, 2014. On June 25, 2014, the WECC Standards Committee (WSC) expanded the scope of the original SAR as follows:

The proposed document should be structured as follows, PSS:

1) Where installed, shall be operating unless specifically exempted,
2) Shall be tuned as specified, and,
3) Where not installed, installation shall be required – when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated.

This SAR will merge with WECC-0094 - *VAR-501-WECC-1, Power System Stabilizer (PSS)*, and incorporate the outcome of WECC-0105 - *P81 VAR Redraft* review. On July 18, 2014, the P81 project ballot closed. The project passed the ballot.

Requester Information

1. Provide your contact information and your alternate's contact information:
   - Your First Name: Martin
   - Your Last Name: Bauer
   - Your Email Address: mbauer@usbr.gov
   - Your Phone Number: (303) 445-2901
   - Organization Name: United State Bureau of Reclamation
   - Alternate's First Name: W. Shannon
   - Alternate's Last Name: Black
   - Alternate's Email Address: sblack@wecc.biz
   - Alternate's Phone Number: (503) 307-5782

Type of Request

2. Specify the type of request: (select one)
    - Request to Revise an Existing WECC Regional Reliability Standard

Create, Modify or Retire a Document Questions

Provide the requested information for your request to create, modify, or retire the document.

3. Requested Action: (select one)
    - Request to Revise a WECC Regional Reliability Standard
4. Document Type: (select one)
    - WECC Regional Reliability Standard
5. Issue: Specify what industry problem this request is trying to resolve.

    WECC's PSS program currently meets the Interconnection's reliability needs; however, the associated policies and procedures are voluntary and are not always consistently implemented.

6. Proposed Remedy: Specify how this request proposes to address the issue described.

    This SAR is designed to:

    1) Update and codify WECC's PSS program,

    2) Establish a minimum design-criteria for installation of new PSS-related equipment,

    3) Standardize tuning procedures for that equipment, and,

    4) Identify those facilities to which the PSS applies.

    In preparation for this SAR, the WECC Control Work Group (CWG) reviewed numerous PSS-related documents under the WECC-0099 SAR (retired by the WSC on February 11, 2014), and is recommending that certain substance from those reviewed documents be excerpted and addressed in a WECC RRS.

    To the extent the drafting team (DT) identifies any additional information best suited for other WECC Document Categories, the DT also seeks permission to draft those documents accordingly.

    It is recommended that the Purpose statement of the RRS should begin with the following:

    "To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the tuning and performance criteria for WECC Power System Stabilizers."

7. Detailed Description

This SAR encourages the members of the CWG to self-nominate as a means to encourage continuity between WECC-0099 and this project.

The DT should: 1) review and consider the WECC-0099 DT's review of PSS-related documents and extract from those documents the recommended substance for importation into this RRS, 2) review recent studies conducted concerning PSS response within WECC and consider the information when drafting requirements, 3) review the NERC Functional Model and decide on the best applicable entities to meet the tasks assigned, and 4) identify the specific facilities to which the standard applies.

Finally, the DT should establish the minimum criteria describing: 1) the circumstances and/or design criteria in which installation of PSS equipment is required, 2) a standardized approach to PSS tuning and testing, and 3) a standardized approach to communication of testing data and remediation of operations identified in that data.

The following is a suggested structure for the proposed standard.

R1. Each Generator Owner shall install Power System Stabilizers that meet the following criteria:

1) [The DT should specify design criteria.]

R2. Each Generator Owner shall tune its Power System Stabilizers to achieve the following response criteria:

1) [The DT should specify tuning criteria.]

R3. Each Generator Owner shall validate the performance of its Power System Stabilizers using the following methods:

1) [The DT should specify the methods.]

R4. Each Generator Owner shall provide performance results to the Reliability Coordinator within [time window] of the request.

R5. Each Reliability Coordinator shall instruct the Generator Owner to make changes to the Generator Owner's Power System Stabilizer tuning, within [time window] of its review of the Power System Stabilizer performance results as required in Requirement X.

R6. Each Generator Owner shall:

1) Implement changes to its Power System Stabilizers tuning no later than [time window], as instructed by the Reliability Coordinator in Requirement X.

2) Each Generator Owner shall provide reports of its performance results to the Reliability Coordinator within [time window] after implementing the tuning change required in Requirement X.

8. Functions (select all that apply)
    - Generator Owner
    - Reliability Coordinator

9. Affected Reliability Principles: Which of the following reliability principles is MOST affected by this request? (select one)
    - **Reliability Principle 1** — Interconnected bulk electric systems shall be planned and operated in a coordinated manner to perform reliably under normal and abnormal conditions as defined in the NERC Standards.

Reference Uploads

Please reference or upload any affected Standards, Regional Business Practices, Criterion, Policies, White Papers, Technical Reports or other relevant documents. If this request is based on a conflict of law, please include a copy of, or accessible reference to, the specific law or regulatory mandate in conflict.

A preliminary Power System Stabilizer Study can be found in the Documents section of the WECC-0099 project page.

10. Additional Comment

The CWG has vigorously reviewed a number of PSS-related documents. That review can be found in the Document section of the WECC-0099 Team Site.

This project impacts VAR-501-WECC-1 Power System Stabilizer, an RRS.

Document Title	**Power System Stabilizers** **VAR-501-WECC-3** **WECC Regional Reliability Standard**
File Name	
Category	(X) Regional Reliability Standard ( ) Regional Criterion ( ) Policy ( ) Guideline ( ) Report or other ( ) Charter
Document date	
Adopted/approved by	WECC Board of Directors
Date adopted/approved	
Custodian (entity responsible for maintenance and upkeep)	Standards
Stored/filed	Approved Regional Standards
Previous name/number	This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a "Version 2"
Status	( ) in effect ( ) usable, minor formatting/editing required ( ) modification needed ( ) superseded ( ) other ______________________________ ( ) obsolete/archived)

Version	Date	Action	Change Highlights
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Project Roadmap

Completed Actions	Completed Actions
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 WECC open	July 1, 2014
9. Posting 1 WECC closed	August 14, 2014
10. Posting 1 WECC Responses posted	
11. Posting 1 NERC open	
12. Posting 1 NERC closed	
13. Posting 1 NERC Responses posted	
14. Posting 2 open	
15. NERC Quality Review	
16. Posting 2 closed	
17. Posting 2 Responses posted	
18. DT forwards request for ballot to WSC	
19. WSC approves for ballot	

20. Ballot Pool open	
21. Ballot Pool closed	
22. Joint Session noticed	
23. Joint Session	
24. Ballot open	
25. Ballot closed	
26. WSC approves forwarding to the WECC Board of Directors	
27. Posted for 30 days prior to WECC Board meeting	
28. Board meets to approve	
29. Sent to NERC	

Operational Background

Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.

PSS are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.

PSS within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).

These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES. [1]

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

[1] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection, it is seen as both an interconnection-wide issue and a local issue.

When coupled with generator operations within WECC, these physical characteristics create modal oscillations, that when not corrected by the installation and accurate operation of PSS, cause instability within the WECC Interconnection.

WECC Procedural Background

This Standards Authorization Request (SAR) to review WECC's PSS-related documents is in response to a WECC Board of Director's resolution.

On September 5, 2012, the WECC Board of Directors adopted the recommendation of the Regional Criteria Work Group that a (SAR) should be filed to evaluate VAR-502-WECC-RBP-1, WECC Power System Stabilizer (PSS) Design and Performance, a Regional Business Practice (RBP), for development as a WECC Regional Reliability Standard (RRS). Under WECC-0099, the WECC Control Work Group conducted the review concluding that a RRS should be drafted.

On February 11, 2014 during the WECC Standards Committee (WSC) meeting:

> "A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained." WSC Meeting Minutes

On June 25, 2014, the WSC changed the scope of the SAR directing that the proposed document be structured so that PSS: 1) where installed, be operating unless specifically exempted, 2) tuned as specified, and 3) where not installed, installation would be required when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated. The WSC further approved merging WECC-0094 VAR-501-WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

Standard of Review

The Federal Energy Regulatory Commission (FERC) has stated that, Regional Entity Standards or Regional Variances to a NERC Reliability Standard (Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing

NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).[2]

Proposed Structure

The proposed document would merge multiple documents and SARs.

As a result, WECC-0094 VAR-501-WECC-“1” PSS and the ballot results of the WECC-0105 P81 redraft would merge into WECC-0107 VAR-501-WECC-“2” resulting in a document applicable to the BES and having three requirements.

Applicability (Responsible Entity)

The proposed standard would be applicable to the Generator Owner and the Generator Operator.

Under the NERC Functional Model, it is the task of the Generator Operator, to “report operating and availability status of units and related equipment, such as automatic voltage regulators”, of which PSS is a part.[3] “Ultimately the Generator Operator’s role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment.”[4]

It is the role of the Generator Owner to install equipment.

Facility Threshold

The proposed standard would adopt the BES applicability threshold that includes generators: 1) with a gross individual nameplate rating greater than 20MVA, or gross plant/facility aggregate nameplate rating greater than 75 MVA, and 2) operated at 100 kV or higher. For some generators this is a lower threshold than allowed under WECC polices. Generator Operators seeking an exemption from the standard could pursue that exemption under the FERC approved exemption process.

[2] Order No. 672 at P 291. See also NERC Functional Model, Version 5, “2. Reliability Standards”, page 36.

[3] NERC Functional Model, Version 5, “Function – Generator Operation”, Tasks, page 48.

[4] NERC Functional Model, Version 5, “11 Generator Operator”, page 23.

Current

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed

Under the proposed standard, PSS would be required on those generators that meet the BES definition.

The white paper, Bureau of Reclamation (April 2014), *Power System Stabilizer Applicability in the WECC System Study Progress Report to WECC-0107 Drafting Team (Draft as of May 28, 2014)* [White Paper], examined the impact on system oscillations when PSS were included or excluded at varying thresholds.

The white paper generally concluded:

1) In the WECC system model, generator size is inversely proportional to the number of generating units;

2) The nature of system-wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions;

3) There is no technical justification to exclude application of PSS on a generating unit based on size alone; (and)

4) Adopting the Policy threshold of 30 MVA as opposed to the BES threshold will reduce the number of generators with PSS, which will decrease system damping proportionally to the number of units affected.

Requirements and Measures

Within existing NERC and WECC Standards, there are currently Requirements to model[5], plan[6], and to run[7] PSS (98% of operating hours except under twelve specified conditions).[8] The proposed standard would reframe the operating mandates creating three Requirements: 1) Requirement R1 would mandate that PSS be connected so as to allow the PSS to operate during all hours, except when specifically exempted,[9] 2) Requirement R2 would mandate minimum criteria for the tuning of PSS, and 3) Requirement R3 would require the installation of PSS whenever new generation is interconnected to the BES.

The proposed document would honor the ballot pool results of the WECC-0105 "P81" redraft endeavor (June 25 through July 18, 2014), removing documentation requirements from the Requirements and relocating them into the Measures.

[5] MOD-026-1 and MOD-032-1

[6] TPL-001-4, VAR-002-X

[7] VAR-501-WECC-1, Power System Stabilizer

[8] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

[9] After the Commercial Operation date of the unit

Implementation Plan

TBA

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

None proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS) Regional Reliability Standard**

2. **Number:** VAR-501-WECC-2

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the tuning and performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

6. **Effective Date:** This standard becomes effective on the first day of the fourth quarter following final regulatory approval.

B. Requirements

R1. Each Generator Operator shall provide to its Transmission Planner, the operating specifications for the Generator Operator's PSS, describing each condition during which its PSS will be non-operational for purposes of equipment protection or system stability, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications. *[Violation Risk Factor: Low] [Time Horizon:*

> Rationale: Requirement R1 covers the planning horizon.
>
> Requirement R1 is intended to provide the Transmission Planner with accurate and timely information for use in planning models. It was not intended for provision to the Transmission Operator because the described condition is limited and not likely to be of value to the Transmission Operator in real-time. Because this Requirement notifies the planner of a planned and repetitive event, the Measure is designed to allow for a single notification as of the Commercial Operation date or changes as they occur. This minimizes paperwork.

Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Planner the operating specifications for the Generator Operator's PSS systems, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, describing each condition during which its PSS would be non-operational for purposes of equipment protection or system stability, as required in Requirement R1.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the specifications to the Transmission Planner one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is not providing damping to the system as allowed in Requirement R1, the disabled period does not count against the 100% criterion of Requirement R2.

R2. Each Generator Operator shall have its PSS in service during all operational hours, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Power loss,
- Component failure,
- Testing of a BES Element affecting or affected by the PSS,
- Maintenance, (or)
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documented evidence that its PSS was operating to provide system damping to the Bulk-Electric System during all operational hours, except when the Generator Operator has notified the Transmission Operator that the PSS is not providing power system damping under those circumstances specified in Requirement R2.

This list of allowed exceptions in Requirement R2 is for the operating assessment horizon, is exclusive from and in addition to the listed conditions in Requirement R1 for the planning horizon.

For auditing purposes, if the Generator Operator provides evidence that a reported value below 100% was the result of measurement error, a reported value below 100% that is explained by the measurement error will be deemed acceptable evidence of compliance with Requirement R2.

For auditing purposes, if a PSS is not providing damping to the system as allowed in Requirement R1, the disabled period does not count against the 100% criterion of Requirement R2.

Where an exception to Requirement R2 is claimed, the Generator Operator will have documentation showing each of the following:

1) All hours during which the PSS was not operating as allowed by one or more of the specified exceptions;
2) An explanation for all hours during which the PSS was not operating as allowed by one or more of the specified exceptions;
3) That the Transmission Operator was notified that the PSS was not operating as allowed under a Requirement R2 exception.

R3. Each Generator Operator shall set its PSS so that the PSS provides the following performance: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide a compensated frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will not exceed ±30 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to provide a gain margin of at least 6 Db.
4) PSS washout time constant shall be no greater than 30 seconds.

Rationale: Requirement R3 covers the operating horizon.

Intent is to set the equipment so that the PSS provides damping of inter-modal oscillations and does so by meeting the specified performance criteria.

M3. Each Generator Operator will have documented evidence that its PSS was set to perform in accordance with each of the criteria stated in Requirement R3. Evidence may include, but is not limited to, a completed Attachment A for this standard that reports: 1) output limits, 2) per unit gain, 3) washout-time constant, and 4) bode plots of the PSS.

R4. Each Generator Owner shall install on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation and after the Effective Date of this standard.

Rationale: Requirement R4 covers the operating horizon.

The intent of Requirement R3 is to set tuning specifications. It does not specify a required equipment performance.

M4. Each Generator Owner will have evidence that it installed a PSS on its generator, within 180 days of either connecting a generator to the BES or replacing the voltage regulator on its existing excitation system, whenever either occurrence occurs after the Effective Date of this standard.

R5. Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that unit becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that unit becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the unit became non-operational, and 2) the date the unit was returned to service, the span of time between the two events being within 24 months of one another.

C. Measures

THIS DOCUMENT WILL BE REFORMATTED PLACING MEASURES IN THIS SECTION.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for Requirement R1 through R3 for three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements
THIS SECTION WILL BE REVISITED.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Operations Assessment	Low[10]	NA	NA	NA	There shall be a Severe[11] Level of non-compliance if PSS is found to be out of service at any time for any reason other than as allowed in requirement R1.
R2	Operations Assessment	Medium	Occurs when the Generator Operator fails to use one of the minimum tuning criteria stated in Requirement R2.	Occurs when the Generator Operator fails to use two of the minimum tuning criteria stated in Requirement R2.	Occurs when the Generator Operator fails to use three of the minimum tuning criteria stated in Requirement R2.	Occurs when the Generator Operator fails to use four or more of the minimum tuning criteria stated in Requirement R2.
R3	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[12] Level of non-compliance if a PSS is not installed in the specified time line as required in Requirement R3.

[10] **(Guidance VRF) See "Medium" definition.**

[11] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

[12] **(Guidance VSL) For R3, Severe was chosen because the violation is binary.**

Attachment A

Output Limit Settings		
Gain		
Washout Time Constant		

Bode Plots		
Excitation response with unit connected to electrical system without PSS in service. (This is a VT/Vref measured response.)		
Excitation response with PSS in service and unit connected to electrical system. This plot can be either via test or calculated based on PSS settings and measured response of the first plot.		

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Facilities

The Commercial Operation designation was chosen because the tuning of the PSS is among the last steps taken to bring the generator to full operation, either initially or after subsequence maintenance or upgrade. Without the pre-qualifying condition the Generator Operator would be required to tune the PSS out-of-sequence in order to reach compliance.

Requirement R1

The rationale behind Requirement R1 is that PSS offers damping to the system thereby enhancing system stability. Whenever possible, that damping should be provided to the system through the continuous operation of the PSS.

It should be noted that a PSS can be fully operational in accordance with Requirement R1 while not producing any damping if tuned in accordance with Requirement R2. Specifically, if the PSS is tuned to automatically disable during specific events, that unit is fully operational even though it is not providing damping to the system.

Requirement R2 and Attachment A

The rationale behind Requirement R2 is that a minimum tuning threshold should be applied to each PSS with the goal of providing a minimum threshold of damping to the system.

There is an interrelationship between the phase compensation and the washout time constant. Short washout time constants provide additional phase compensation in frequency-based PSS at the lower frequencies while dramatically reducing the gain.

A washout time constant of 10 seconds or less is recommended to quickly remove low frequency components (below 0.1 Hz) from the PSS output. The smaller time constant will reduce the influence on the system voltage from the PSS during any sustained/extended frequency deviation (i.e., loss of generation), especially if the PSS has a high gain setting.

Requirement R2, Number 5

This tuning feature was included to ensure consistent damping after the generator's PSS reaches full operation. This feature recognizes that the PSS damping contribution may be minimal or in some cases erratic until reaching full operation. During this period the PSS should be disabled.

For example, PSS output may be blocked on a 100MW generator until that generator reaches an output of 40 MW. This is done because while operating at low power the PSS contribution will be insignificant and the PSS, when in the active state is continuously modulating the field circuit of the generator causing rapid changes in the field voltage and reactive power.

Requirement R2, Number 6

This tuning feature was included to ensure that operation of the PSS is automatically disabled using control circuitry in order to protect the equipment from damage while ramping through a cavitation zone, commonly called "rough zones."

Requirement R3

The rationale for Requirement R3 is that within the Western Interconnection, PSS adds to the stability of the Bulk-Electric System through damping. Locating PSS throughout the Interconnection adds a broader geographic footprint and better disperses the location of the damping equipment. The requirement recognizes that not all generators have PSS installed; however, as those generators are upgraded, the addition of PSS to each such generator is required to ensure the reliability of the BES. At the Effective Date of this standard, the preferred type of PSS that is able to meet the tuning parameters of R2 is an integral of accelerating power type, designated PSS2A.

Consideration of Comments
Comment Report Form for WECC-0107

Power System Stabilizer (PSS) Design and Performance
WECC Regional Reliability Standard

Posting 1

The WECC-0107 PSS Drafting Team (DT) thanks everyone who submitted comments on the proposed project.

Overview

The proposed standard would be applicable to the Generator Owner and the Generator Operator.

Facility Threshold

The proposed standard adopts the BES applicability threshold.

Requirements and Measures

Within existing NERC and WECC Standards, there are currently Requirements to model[1], plan[2], and to run[3] PSS (98% of operating hours except under twelve specified conditions).[4]

The proposed standard would reframe the operating mandates creating requirements for the Generator Operator (GO) to: 1) provide the Transmission Planner with the GO's Power System Stabilizer (PSS) operating specifications, 2) to have the PSS in service during all hours unless specifically exempted, and 3) tune its PSS so that the PSS provides a specific performance.

The Generator Owner would be required to: 1) install PSS under specified circumstances occurring after the Effective Date of the standard, and 2) repair or replace and existing PSS within 24 months of the PSS becoming non-operational.

[1] MOD-026-1 and MOD-032-1
[2] TPL-001-4, VAR-002-X
[3] VAR-501-WECC-1, Power System Stabilizer
[4] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

The proposed document honors the Ballot Pool results of the WECC-0105 “P81” redraft endeavor (June 25 through July 18, 2014), removing documentation requirements from the Requirements and relocating them into the Measures.

Posting

This document was last posted for a 45-day public comment period from July 1, 2014 through August 15, 2014.

WECC distributed the notice for the posting on June 27, 2014. The Drafting Team asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from four companies representing five of the eight Industry Segments, as shown in the table on the following page.

Location of Comments

All comments received on the document can be viewed in their original format here.

Changes in Response to Comment

The Facilities section was deleted.

Requirement R2 was modified to clarify that the “testing” bullet applies to testing of a BES Element affecting or affected by the PSS. A final bullet was added allowing for non-operation “as agreed upon by the Generator Operator and the Transmission Operator.” The structure of Requirement R2 was changed to mandate a prescribed performance output as opposed to meeting a specified tuning criteria.

Requirement R3, numbered section 3 was changed so that the PSS shall be set to “provide a gain margin of at least 6 Db.” Sections 5 and 6 describing the feature of automatic disability were deleted. The drafting team believes these features should be described in any communication created as a result of Requirement R1.

The direct reference to PSS2A-type equipment was redrafted to describe specified performance as opposed to a PSS2A comparison.

Requirement R4 incorporated the Commercial Operation trigger previously included in the Facilities section.

Requirement R5 was added to ensure that the Generator Owner repairs or replaces an out-of-service PSS within 24 months of that unit becoming non-operational.

The Compliance table was updated.

Minority Comments Summary

A request to expand the Requirement R3 phase performance from 30 degrees to 45 degrees was rejected; however, the team agreed to revisit the matter.

A request to exempt certain entities was rejected, opting instead to make the document applicable to facilities meeting the Bulk-Electric System (BES) definition. Entities seeking an exemption from the BES may do so through the procedures provided by NERC as approved by FERC.

A request to exempt older units was rejected because drawing a bright line for “older” machines was deemed impractical and inequitable. An accommodation was made by requiring installation of equipment only after reaching Commercial Operation, after the Effective Date of the standard, and after either connecting to the BES or replacing the voltage regulator on an existing excitation system.

No changes were made to the Effective Date noting that existing PSS within WECC should already be meeting the Requirements and any changes or additions to the equipment would not be immediately triggers, allowing up to 24 months to reach compliance.

The twelve “exceptions” and an allowance to be out-of-service two percent of the time for any reason as allowed in the existing standard were not retained but were accommodated by creating the possibility for exemption under Requirement R1 (planning horizon), plus Requirement R2 (operational horizon), and an additional bullet in Requirement R2 that allows for being out-of-service in the event the Generator Operator and the Transmission Operator agreed it was necessary. The drafting team concluded this expanded list of possible exemptions was a reasonable proxy for the two percent.

A request to lower the Violation Severity on Requirement R1, administrative in nature, was not accepted because the language is binary in nature and mandates a “Severe” rating. The drafting team does not have a choice.

Action Plan

The team will continue its discussions on changing the phase requirement in Requirement R3. (SUBSEQUENT ENTRY: This item was addressed by redrafting the requirement. See Posting 3.)

An iterative version of the document will be forwarded to the WEC Standards Committee with a request to post for a 30-day comment period.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.[5]

[5] The appeals process is described in the Reliability Standards Development Procedures: http://www.wecc.biz/Standards/Documents/WECC%20Reliability%20Standards%20Development%20Procedures.aspx

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		**Organization**	**WECC Standards Voting Sectors**							
			1	**2**	**3**	**4**	**5**	**6**	**7**	**8**
1	Janet Smith on behalf of Baj Agrawal	Arizona Public Service Company	**X**	**X**	**X**	**X**	**X**			
2	Caitlin Liotiris	Western Power Trading Forum (WPTF)			**X**					
3	Leland McMillan	PPL Montana, LLC		**X**	**X**					
4	Cain Braveheart,	Bonneville Power Administration	**X**		**X**	**X**	**X**			

Index to Questions, Comments, and Responses

Question

1. **The WECC-0107 Drafting Team welcomes comments on all aspects of this document.**

1. **The WECC-0107 Drafting Team welcomes comments on all aspects of this document.**

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Arizona Public Service			In reference to Requirement 2, the following comments are provided: • R2: The ± 30 degrees criteria should be relaxed to ± 45 degrees and with a comment that it be generally within ±30 degrees. There are many situations where ± 30 degrees is not attainable. APS Suggests a revision to the language of this requirement, which would read: "PSS shall provide a compensated frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will generally be within±30 degrees but not exceed ±45 degrees. • R2: It should refer to minimum gain margin only. There should be no limit on higher gain margins. There are many situations where gains are based upon providing adequate damping and actual gain margin is much higher than 10 db. There are other situations where it is not even possible to know what the true gain margin is. • R2: Automatically disconnecting PSS should not be a requirement. It should simply be allowed to be off line at low loads. APS suggests a revision to the language of this requirement with would read: "PSS should be on or should be automatically enabled when the generator power output is above a threshold typically near minimum stable operating load level." In reference to Requirement 3, the following comment is provided: • There should be no reference to damping greater than that for PSS2A. It is impossible to measure such effectiveness.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
1) Issue 1 Requirement R2 "Phase": The WECC Policy Statement on Power System Stabilizers has been in effect since April 18, 2002 and has included the 30 degree threshold since that time. Historical experience indicates the 30 degree has served well to meet the reliability needs of the Interconnection. No changes were made. The drafting team agreed to continue its study in the appropriateness of the numeric value. (SUBSEQUENY ENTRY: The DT addressed APS's "30 degree" concerns in Posting 3.) 2) Issue 2: "Gain" and related ranges: The drafting team has considered your suggestions and made the following changes. • The Requirement was restructured to be a performance-based requirement as opposed to merely a requirement to set the equipment at a specified parameter. • In #3, the language was changed to reflect "a gain margin of at least" 6db as opposed to setting a minimum and a maximum. • #5 and #6 (automatically disabled) were eliminated and the concept of planned non-operation, such as through a cavitation range, was incorporated into the new Requirement R1 that allows for a "one time" notice to the Transmission Planner that the Generator Operator intends a planned non-operation for specific purposes. 3) Issue 3: PSS2A The drafting team concurs and has changed the Requirement, deleting that phrase, and cross-referenced the Requirement to the performance criteria mandated elsewhere in the document.			
WTFP			The proposed modifications to VAR-501-WECC would add mandatory and enforceable PSS design and performance requirements for generators in the Western Interconnection. The modifications would also require the installation of PSS to synchronous generators that are newly interconnected to the BES or to existing generators that are updated, modernized or renovated. In addition, the proposed modifications would change the current requirements for PSS operation contained in R1 of VAR-501-WECC-1. The comments below ask the Drafting Team

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			to provide clarity as to when PSS installation is required and to consider the impacts of the proposed modifications on older, analog units, which may have significant difficulty complying with the minimum PSS specifications that are proposed. In addition, the following comments ask the Drafting Team to either retain the current PSS operation requirements in R1 of VAR-501-WECC-1 or provide justification for the significant changes that are being proposed. The proposed modification uses the terms “renovates”, “modernizes” and “updates” to indicate when PSS installation would be required on an existing generator. However, these are not defined terms. The use of these undefined terms increases the probability that there would be different interpretations of when renovation, modernization or updates to an excitation system occur and, thus, when PSS installation is required for compliance purposes. Although the use of new regional definitions is typically not encouraged by NERC, the use of these terms may warrant the development of new regional definitions. The Drafting Team should consider developing definitions for the terms “renovates”, “modernizes”, and “updates.” Alternatively, if the Drafting Team feels that regional definitions for these terms are not appropriate, then the standard should be modified to remove the terms and include specific circumstances under which a PSS should be installed. For instance, the installation of a PSS on an existing generator could be required when nameplate capacity is increased, when investment in the excitation system exceeds a threshold value, or when capital investments are made that are intended to extend the life of the plant by a threshold number of years. In either case, the Drafting Team should provide clarity on what activities are considered renovations, upgrades, or modernization to an excitation system so that generators fully understand when installation of a PSS is required for compliance purposes. In addition, the Drafting Team should clarify that PSS installation is only required for existing generation facilities that are connected to the BES. The current language

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			appears to imply that ALL existing generators must install a PSS upon renovation, upgrade or modernization of the excitation system. The PSS specifications contained in the proposed modifications may be excessively difficult for older, analog units to comply with. WPTF urges the Drafting Team to consider how each proposed specification requirement might impact older, analog units. If the requirements are kept in their current form, the Drafting Team should consider adding an exemption for older units. Furthermore, in establishing the effective date of the standard, the Drafting Team should consider that, in order to comply with the specifications, older units may need to order new equipment and take the unit out of service to install that equipment. Therefore, additional time to implement the standard may be required. Although the current effective date would provide about one year until the standard would become effective, 18 months or more may be required for older units that will require PSS upgrades. In addition to adding PSS performance measure to the standard, the proposed modifications would substantially change the current requirements for PSS operation and eliminate potentially important exemptions for PSS operation. Yet, justification for these changes has not been provided. The Drafting Team should provide documentation supporting each proposed change to the requirement for PSS operation or should retain the existing requirements contained in R1 of VAR-501-WECC-1.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			VAR-501-WECC-1 requires that PSS be in-service for 98% of the time, except under certain conditions. The proposed modifications would change the requirement for PSS operation to 100%, except when the PSS is disabled due to power loss, component failure, testing, or maintenance. An increase to a 100% in-service requirement for PSS operation appears to increase compliance risk without providing substantial reliability benefits beyond the current 98% requirement. Furthermore, the proposed change would remove the exemptions for PSS operation for generators that operate less than 5% of all hours during a quarter, time when the AVR is out of service, units operating in synchronous condenser mode, etc. The Drafting Team should provide justification for increasing the requirement for PSS operation to 100% and also explain why each individual exemption for PSS operation should be removed. The proposed revisions to R1 would eliminate time requirements for putting a PSS back in-service following component failure (currently contained in R1.8, R1.9 and R.10). Removing these requirements could increase the amount of time a PSS is out of service, which may have adverse reliability impacts. The removal of R.12 (which exempts PSS operation during times when the Transmission Operator directs the Generator Operator to operate even though the PSS is unavailable) could also have adverse reliability impacts, which the Drafting Team should evaluate prior to proposing their elimination from the standard. The Drafting Team should consider maintaining the existing language in R1 of VAR-501-WECC-1. If the Drafting Team moves forward with the proposed changes to R1 of VAR-501-WECC-1, substantial justification for each proposed modification should be provided and the potential impacts to reliability should be considered for beach change that is proposed (including justification for each exemption that is removed).

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

1) Issue 1: Renovations

The drafting team agrees that the posted language was ambiguous. To remedy the issue, the Requirement has been redrafted to require action only when:

- The Generator Owner *connects* a generator to the BES, after achieving Commercial Operation and after the Effective Date of this standard; (or)
- The Generator Owner *replaces* the voltage regulator on its existing excitation system, after achieving Commercial Operation and after the Effective Date of this standard.

The Generator Owner is allowed six months to comply.

The drafting team believes this approach protects existing Generator Owners from a mandate to install a PSS – except under the specified circumstances. The first bullet grandfathers existing units while the second bullet links installation of new PSS to the specific event of replacing the unit's voltage regulator. The drafting team believes this latter event is a common denominator that would be undertaken by each Generator Owner during a renovation, modernization, update, or upgrade.

2) Issue 2: BES

The drafting team has deleted the Facilities section noting that by default, all Standards are applicable only to the BES Facilities, unless otherwise specified.

3) Issue 3: Older Units

The drafting team notes that no action is required until the voltage regulator is changed or the unit is connected to the BES. So long as an "older" unit does not require that servicing or is not newly connected to the BES, there is no action required regarding the "older" unit. By contrast, once the unit is identified for servicing, it would be an appropriate time to require the installation of a PSS. Finally, the drafting team opted not to adopt an exception for "older" units noting that no matter what age was specified for an "older" unit, drawing a bright line would always be inequitable for someone.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

4) Issue 4: Effective Date

The drafting team opted to make no changes to the Effective Date noting that the majority of the PSS systems within WECC should already be set as specified.

5) Issue 5: Retain R1 from the existing standard

The existing VAR-501-WECC-1 requires a Generator Operator's PSS to be in service 98% of all operating hours for synchronous generators equipped with PSS. R1.1-R1.12 gives the Generator Operator 12 specified circumstances during which it does not have to operate. As evidence, quarterly reports are filed.

These 12 events in R1 are not exhaustive of all of the actual events that could be addressed; however, as drafted they are the only events specifically considered for exclusion. As proposed Requirements R1 (planning horizon) and R2 (operational horizon) provide the Generator Owner with a broader, non-exhaustive, less restrictive set of events during which operation is not required. The counterbalance to this flexibility is the requirement that the PSS be always in-service unless specifically exempted.

It should also be noted that the basic premise of the existing standard is documentation as opposed to the newly proposed standard that is performance based.

The drafting team believes proposed Requirement R1 preserves the existing R1.3, R1.4, R1.5, R1.6, R1.7, R1.11, with the added benefit of only requiring a single reporting as opposed to a quarterly reporting. Proposed Requirement R2 preserves the existing R1.2, R1.8, R1.9, and R1.10.

Although the existing R1.12 could be covered in either the proposed R1 or R2, depending on the circumstances, the drafting team has opted to add an additional bullet to the proposed R2 to clarify treatment of the exception and to allow the Generator Operator and the Transmission Operator the opportunity to identify unforeseen circumstances in the operational horizon during which the reliability of the grid is best served if the PSS is out-of-service. R2 has been changed as follows:

R2. Each Generator Operator shall have its PSS in service during all operational hours, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

- Power loss,
- Component failure,
- Testing of a BES Element affecting or affected by the PSS,
- Maintenance, (or)
- As agreed upon by the Generator Operator and the Transmission Operator.

6) Issue 6: Removes exemption (Existing R1.1)

The focus of the proposed standard switches from merely counting hours to requiring actual performance. The existing R1.1 counts hours and creates exemptions but does not provide for performance. The purpose of the performance is to add stability to the grid. Requiring the "five percenters" to run adds a margin of stability. Arguably, these few units add only a modicum of additional reliability individually; however, when considered in the aggregate these units bring a viable resource to the stability of the Interconnection. Further, when the grid is stretched to extremes such as in days of peak load, it is the performance of the last few percentages of units that either makes or breaks "performance." Thus, the drafting team concluded the Requirements should apply to all generators meeting the BES definition.

The drafting team has discussed the benefit/burden elements of including the five-percenters and concluded that burden to have a PSS operating at all times is low compared to the benefit of having those units operating and performing when needed. To otherwise exempt them leaves a potentially valuable resource unavailable during times of peak need.

That said, the drafting team recognized that the "Section 5 Facilities" qualifier could add confusion as to "which" units the standard applies. To remedy this concern, the Facilities qualifier has been removed and the Commercial Operation feature exported to the Requirements. As a result, by default the standard only applies to those elements meeting the Bulk-Electric System (BES) definition. If a "five percenter" falls outside of the BES definition it will not be required to adhere to the standard.

Finally, under the existing R1.1. the five-percent unit is still required to provide quarterly reports. Depending on how that unit is affected by the proposed R1 and R2, the unit may be able to dramatically reduce its reporting burden.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

7) Issue 7: Requirements for putting units back on line

The existing Requirement R1, sub-parts R1.1.8, 1.9, and 1.10 require that PSS will be in operation unless it meets a listed exception. The specific exception in each of the sub-parts is "due to component failure." This exception is retained in the proposed Requirement R2.

The team notes that in each of the existing sub-parts R1.8, R1.9, and R1.10, the subsequent portion of the sentence does not create a requirement; rather, it creates a permissible condition predicated on submittal of document. The submittal of documentation neither adds nor subtracts from the reliability of the grid.

To address the concern that a Generator Owner may unreasonably delay repair or replacement of a non-operational PSS, the team has created a new Requirement stating:

R5. Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that unit becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon:* Operational Assessment*]*

M5. Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that unit becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the unit became non-operational, and 2) the date the unit was returned to service, the span of the time window between the two events being within 24 months of one another.

The rationale for the 24 month window is that it provides the Generator Owner an ample window to either procure a replacement part or to purchase and bring operational and entirely new PSS.

8) Issue 8: Removal of R.1.12

Please see response to Issue 5.

PPL Montana			Summary 1) PPL Montana, LLC (PPLM) requests this Power System Stabilizer (PSS) standard only apply to BES plants. Accordingly, Requirement R3 should be re-

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			written and the second part of R3 removed. The drafting team has not shown the benefits of indiscriminately putting PSS equipment on small facilities and ignores the Study Progress Report (April 2014) showing smaller plants have little impact on damping. Requiring the installation of PSSs on all generators (large and small) cannot be justified as a way to enhance electric system reliability. a. There is no justification for including plants too small to be part of the BES in this standard. b. Non-BES plants should be free to "renovate(ing), modernize(ing) or update(ing)" an existing excitation system without installing a PSS. 2) PPLM requests that R1 be modified to include language that allows the operator of a PSS-equipped facility to not have the PSS in-service for a small amount of time, such as in the existing PSS standard Requirement 1 which allows for a small percentage of time for the PSS to be off and includes other important exceptions (including those now in Requirement R2-5 and R2-6). Discussion PPLM commends the WECC-0107 PSS standard drafting team (SDT) for recognizing the history of PSS application in the west and the limitations of recent PSS study work. The study report completed in April, 2014 (the "report") is to be commended for the thoughtful (albeit limited) analysis put forth. Several times in this report, the author states that PSS location and tuning are critical factors for WECC grid stability. Thanks to the efforts of the SDT, the standard now contains tuning information in R2 (items 1-4) that should be helpful to all generator owners. Unfortunately, the issue of location has yet to be addressed and for reasons that are unclear, an "all generators" approach was adopted by the SDT.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			The report clearly states that PSS location is important. It appears to be possible to identify critical PSS locations because the report shows three Mode Shape Scatter Plots involving location. Unfortunately, the proposed WECC PSS standard does not address where it might be best to install PSSs, opting instead for an "all" policy where all PSSs at all locations are deemed to all be equally as effective at mode dampening. The standard is actually contrary to statements in the report that while more than half of the generators in the WECC study case are less than 75 MVA, there is "negligible" difference when turning off all 50 MVA PSSs vs turning off all 25 MVA PSSs. As the graph for the BC-Alberta outage shows (using the Malin 500 kV voltage) not only is the difference between 25 and 50 MVA "negligible," the resulting damping is positive (positive damping is good for reliability) when either the 25 or 50 MVA PSSs are turned off. Clearly, having a PSS on all plants does NOT increase reliability in any meaningful way. Thus this standard will most likely result in an over-application of PSSs. Also, please note that the consequences of failing to comply with this standard are extreme because both R1 and R3 only have one Violation Severity Level (VSL) and that is "Severe," extracting potentially large fines for small infractions whose impact on grid reliability may be inconsequential because as shown in the Malin 500kV voltage plot in the report, when entire groups of many hundreds of machines less than 50 or 25 MVA were turned off, there was "negligible" difference in reliability than when all PSSs were on. There simply is no justification for the "Severe" VSL when one machine has the PSS turned off. The report states that since 1992, the cost of installing and operating a PSS was an important consideration to the WECC and cost was correctly used to justify limiting

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			the application of PSSs to plants over a certain MVA threshold. Today, cost effectiveness cannot look at hardware purchase price alone. There are tuning costs which may actually exceed the hardware costs. There are costs that may come about to maintain compliance with a very strict standard. All of these costs point out how incorrect the statement is in the report that "Now it is not unusual to apply PSS at no additional cost." Further, PPLM requests removal of the second part of R3 which states "renovate(ing), modernize(ing) or update(ing)" an existing excitation system, no matter what size the machine or plant, will require a PSS. PPLM requests removal of the second part of R3 because as described above, the drafting team has not shown the benefit of indiscriminately putting PSS on small facilities compared to the cost and consequences. Additionally, and possibly a demonstration of the rule of unintended consequences, some GOPs may forego upgrading exciters and AVRs to avoid the cost of installing and operating (and risking a compliance violation related to) a PSS. This may actually reduce grid reliability because it may discourage the generator owner from renovating, modernizing or updating their excitation system. R1 of the new standard requires perfection in operating a PSS by requiring the PSS be on-line 100% of the time it is working. While this sounds straightforward and simple, it is very complex and results in what might be an inappropriate prioritization of operator duties and at the very least increases the possibility of a GOP compliance violation. Certainly a functional PSS improves WECC grid reliability, but it will in no way jeopardize the reliability of the WECC grid to write a standard to recognize a small tolerance for generator operator imperfection. Indeed, the SDT has noted in Requirement 2 Items 5 and 6 that there are exceptions when the PSS

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			does NOT have to be turned on. In reality, having the operator focus so intently on the PSS might actually be a serious distraction. For example, if the operator is bringing up a machine at a hydro plant, while at the same time reducing spill to keep the river flow constant for the fishery, while also at the same time moving the unit through a rough zone, while meeting the energy scheduling requirements, it may take a minute or two to bring the PSS on-line. As R1 is proposed, the one or two minute delay would appear to be a Severe violation possibly resulting in a fine. Creating this standard with perfection required in R1 is the easy part: GOPs having to live with PSS perfection at the expense of all other actions for 24x7x365 is the hard part. R1 as written is unreasonable and conflicts with R2-5 and R2-6. The SDT should restore the previous 2% exception and accompanying exclusions (see BES Definition Guidance Document II.2 BES Inclusion I2 and VAR-501-WECC-1) for R1. To show how this standard holds generator operators to an unreasonable standard of perfection, examine a comparison between the generator operator requirements and transmission operator or balancing authority requirements. Recall that Balancing Authorities are not held to perfection in the BAL standard for Control Performance Standard CPS-2 where the target is 90%. Further, Transmission operators have a full 30 minutes to get under a System Operating Limit (SOL). Certainly there are reliability consequences of the BA and TOP actions in these two areas, but only the GOP is held to perfection. Please restore the 98% requirement and the 12 exclusions as shown below in the current standard. The SDT has not justified the need for PSS perfection beyond that required of other NERC functional entities that may impact reliability more than a PSS.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

1) Issue 1: BES

The drafting team concurs that the standard should only apply to the BES. The team has removed "Section 5 Facilities" so that by default the standard only applies to the BES.

The concept of applicability by virtue of a "Commercial Operation" date has migrated to the proposed Requirement R4 making that specific Requirement tied to the Commercial Operation date as one of the qualifiers.

The proposed Requirement R4 is as follows:

R4. Each Generator Owner shall install on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation and after the Effective Date of this standard.

2) Issue 2: Justify putting PSS on smaller units.

The drafting team concurs. The document as proposed would only apply to BES units and would not require either installation or operation of a PSS on any unit not meeting the BES definition. Any unit meeting the PSS but currently excluded under the WECC PSS Policy could petition NERC/FERC for an exemption under the procedures provided.

3) Issue 3: Should include an allowance to not run (keep the 98% hours)

The drafting team notes that the focus of the document shifts away from counting hours to requiring performance of the PSS units meeting the BES definition. Rather than specify a period of time during which the PSS could be out-of-service *for any reason* (the 2% of the current standard), the proposed standard shifts to a requirement that the PSS shall be in service at all times…..*except when*

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

specifically exempted.

R1 (planning horizon) allows the GO's PSS to be out-of-service due to forward-looking circumstances foreseen by the Generator Operator. Since the GO takes the initiative to identify those circumstances, and whereas the GO is the entity that best knows the equipment, this places a great deal of flexibility into the hands of the Generator Operator.

R2 (operating horizon) allows the GO's PSS to be out-of-service due to: 1) Power loss, 2) Component failure, 3) Testing of BES Elements affecting or affected by the PSS, 4) Maintenance, and 5) (newly added) during any circumstances agreed upon by both the Generator Operator and the Transmission Operator.

This final bullet in R2 is added to allow for the unforeseen event, and the extreme (arguably non-existent) unlikelihood that keeping a PSS in service could somehow be deleterious to the grid. This is analogous to NERC EOP-002-3.1, Capacity and Energy Emergencies, Requirement R1, wherein the Balancing Authority and the Reliability Coordinator have the responsibility "to take whatever actions are needed to ensure the reliability of its respective area."

The drafting team concluded that counterbalanced again the mandate for 100% operation, the list of exemptions creates a proxy for the 2% cushion allowed by the current standard while closing the door to an indiscriminate set of excluding events.

4) Issue 4: "Severe" VSL is too severe.

The drafting team notes several observations on this comment. First, the Violation Risk Factor / Violation Severity Level (VRF/VSL) table is not considered part of the standard subject to final determination by the drafting team. Its proposals are subject to change once the document is provided to NERC/FERC.

The team believes PPL's comment is more accurately directed to the Violation Risk Factor (VRF) as opposed to the Violation Severity Level (VSL). The VRF identifies the potential ***reliability impact*** whereas the VSL defines the ***degree of compliance*** not achieved. The drafting team has reviewed the VRF and the VSL for each of the newly proposed Requirements.

The drafting team chose "low" as the VRF for Requirement R1 as it affects the planning horizon, is administrative in nature, and if violated, would not be expected to adversely affect the electrical state or capability of the bulk electric system, or the ability to effectively monitor and control the bulk electric system.

Summary Consideration:	A summary of proposed changes in included in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

The drafting team chose a "medium" VRF for the remaining Requirements as they affect the operational horizon, and if violated, these Requirements could directly affect the electrical state or the capability of the BES, or the ability to effectively monitor and control the BES, but are unlikely to lead to BES instability, separation, or cascading failures.

In developing the VSLs for each Requirement, the drafting team anticipated the evidence that would be reviewed during an audit, and developed its VSLs based on the noncompliance an auditor may find during a typical audit. The drafting team based its assignment of VSLs on the following NERC criteria:

- The "Severe" VSL assigned to Requirements R1, R2, R4 and R5 are not optional. A violation of a "binary" type requirement such as these must have a "Severe" VSL as instructed by FERC.
- Assignment of the VSLs was comparable to those included in the existing standard.
- The VSLs avoid any ambiguity by stating the specific degree of non-compliance as opposed to using ambiguous terms such as minor, major, or significant.
- The VSLs are structured so as not to create further requirements not otherwise stated in the Requirement and Measure section of the document.
- The VSLs are based on a single violation, the degree of non-compliance being reflected in the increasing VSL as additional components of the Requirement are not met.

5) Issue 5: Remove the renovation clause.

The drafting team addressed the issue in its response to WPTF. See proposed Requirement R4.

6) Issue 6: Retain the 98%.

See above at Issue 3 above.

Commenter	Yes	No	Comment
Bonneville Power Administration (BPA)			BPA agrees with the requirements as written. BPA has no additional comments at this time.

The drafting team thanks BPA for its continued support of the standards development process.

Document Title	**Power System Stabilizers** **VAR-501-WECC-3** **WECC Regional Reliability Standard**
File Name	
Category	(X) Regional Reliability Standard ( ) Regional Criterion ( ) Policy ( ) Guideline ( ) Report or other ( ) Charter
Document date	
Adopted/approved by	WECC Board of Directors
Date adopted/approved	
Custodian (entity responsible for maintenance and upkeep)	Standards
Stored/filed	Approved Regional Standards
Previous name/number	This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a "Version 2"
Status	( ) in effect ( ) usable, minor formatting/editing required ( ) modification needed ( ) superseded ( ) other ______________________________ ( ) obsolete/archived)

Version	Date	Action	Change Highlights
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Project Roadmap

Completed Actions	Completed Actions
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 WECC open	July 1, 2014
9. Posting 1 WECC closed	August 14, 2014
10. Posting 1 WECC Responses posted	
11. Posting 1 NERC open	
12. Posting 1 NERC closed	
13. Posting 1 NERC Responses posted	
14. Posting 2 open	
15. NERC Quality Review	
16. Posting 2 closed	
17. Posting 2 Responses posted	
18. DT forwards request for ballot to WSC	
19. WSC approves for ballot	

20. Ballot Pool open	
21. Ballot Pool closed	
22. Joint Session noticed	
23. Joint Session	
24. Ballot open	
25. Ballot closed	
26. WSC approves forwarding to the WECC Board of Directors	
27. Posted for 30 days prior to WECC Board meeting	
28. Board meets to approve	
29. Sent to NERC	

Operational Background

Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.

PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.

PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).

These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES. [1]

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

[1] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection, it is seen as both an interconnection-wide issue and a local issue.

When coupled with generator operations within WECC, these physical characteristics create modal oscillations that when not corrected by the installation and accurate operation of PSS cause instability within the WECC Interconnection.

WECC Procedural Background

This Standards Authorization Request (SAR) to review WECC's PSS-related documents is in response to a WECC Board of Director's resolution.

On September 5, 2012, the WECC Board of Directors adopted the recommendation of the Regional Criteria Work Group that a (SAR) should be filed to evaluate VAR-502-WECC-RBP-1[2], WECC Power System Stabilizer (PSS) Design and Performance, a Regional Business Practice (RBP), for development as a WECC Regional Reliability Standard (RRS). Under WECC-0099, the WECC Control Work Group conducted the review concluding that a RRS should be drafted.

On February 11, 2014 during the WECC Standards Committee (WSC) meeting:

> "A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained." WSC Meeting Minutes

On June 25, 2014, the WSC changed the scope of the SAR directing that the proposed document be structured so that PSS: 1) where installed, be operating unless specifically exempted, 2) tuned as specified, and 3) where not installed, installation would be required when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated. The WSC further approved merging WECC-0094 VAR-501-WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

Standard of Review

The Federal Energy Regulatory Commission (FERC) has stated that Regional Entity Standards or Regional Variances to a NERC Reliability Standard

[2] In June 2014, the WECC Board of Directors resolved to eliminate the Regional Business Practice (RBP) category defaulting to a WECC Criterion (CRT) category.

(Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).[3]

Proposed Structure

The proposed document would merge multiple documents and SARs.

As a result, WECC-0094 VAR-501-WECC-“1” PSS and the ballot results of the WECC-0105 P81 redraft would merge into WECC-0107 VAR-501-WECC-“3” resulting in a document applicable to the BES.

Facilities

The proposed standard would be applicable to units covered by the Bulk-Electric System (BES) definition.

Applicable Entities

The proposed standard would apply to the Generator Operator and the Generator Owner.

Under the NERC Functional Model, it is the task of the Generator Operator, to “report operating and availability status of units and related equipment, such as automatic voltage regulators”, of which PSS is a part.[4] “Ultimately the Generator Operator’s role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment.”[5]

It is the role of the Generator Owner to install equipment.

Current Standard

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that

[3] Order No. 672 at P 291. See also NERC Functional Model, Version 5, “2. Reliability Standards”, page 36.

[4] NERC Functional Model, Version 5, “Function – Generator Operation”, Tasks, page 48.

[5] NERC Functional Model, Version 5, “11 Generator Operator”, page 23.

addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed Standard

Under the proposed standard, PSS would be required on those generators that meet the BES definition.

The white paper, (April 2014), *Power System Stabilizer Applicability in the WECC System Study Progress Report to WECC-0107 Drafting Team (Draft as of May 28, 2014)* [White Paper], examined the impact on system oscillations when PSS were included or excluded at varying thresholds.

The white paper concluded:

1) In the WECC system model, generator size is inversely proportional to the number of generating units;

2) The nature of system-wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions;

3) There is no technical justification to either exclude or include application of PSS on a generating unit based on size alone; (and)

Requirements and Measures

Within existing NERC and WECC Standards, there are currently Requirements to model[6], plan[7], and to run[8] PSS (98% of operating hours except under twelve specified conditions).[9]

The proposed standard would reframe the requirements as follows.

Requirement R1 would require the Generator Operator to provide the Transmission Planner with the operating specifications of the Generator Operator's PSS.

Requirement R2 would mandate that PSS be in service at all times unless specifically exempted.

Requirement R3 would mandate a specific performance from the PSS as opposed to a specified tuning criterion.

Requirement R4 would mandate installation of PSS on BES units, but only after a set of specified triggering events,

Requirement R5 would mandate repair or replacement of PSS within six months of that unit becoming non-operational.

Implementation Plan

TBA

[6] MOD-026-1 and MOD-032-1

[7] TPL-001-4, VAR-002-X

[8] VAR-501-WECC-1, Power System Stabilizer

[9] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

None proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS) Regional Reliability Standard**

2. **Number:** VAR-501-WECC-2

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

6. **Effective Date:** This standard becomes effective on the first day of the fourth quarter following final regulatory approval.

NOTE: THIS DOCUMENT WILL BE REFORMATTED WHEN SUBMITTED TO NERC.

B. Requirements

R1. Each Generator Operator shall provide to its Transmission Planner, the operating specifications for the Generator Operator's PSS, describing each condition during which the PSS will be non-operational for purposes of equipment protection or system stability, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications. *[Violation Risk Factor: Low] [Time Horizon:* Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Planner the operating specifications for the Generator Operator's PSS systems, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, describing each condition during which its PSS would be non-operational for purposes of equipment protection or system stability, as required in Requirement R1.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the specifications to the Transmission Planner one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing damping to the system as allowed in Requirement R1, the disabled period does not count against the mandate of Requirement R2.

R2. Each Generator Operator shall have its PSS in service while synchronized, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*,

- Component failure,
- Testing of a BES Element affecting or affected by the PSS,
- Maintenance, (or)
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception as allowed in Requirement R2 that includes:

1) An explanation covering the bulleted exception describing the circumstances of the exception; (and)
2) That the Transmission Operator was notified that the PSS was not operating as allowed under a Requirement R2 exception.

(or)

3) Where applicable, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed that the PSS should not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Operator shall tune its PSS to meet the following:: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide a compensated frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will not exceed ±30 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to provide a gain margin of at least 6 Db.
4) PSS washout time constant shall be no greater than 30 seconds.

M3. Each Generator Operator will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3. Evidence may include, but is not limited to, a completed Attachment A for this standard that reports: 1) output limits, 2) per unit gain, 3) washout-time constant, and 4) bode plots of the PSS.

R4. Each Generator Owner shall install on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed a PSS on its generator, within 180 days of either connecting a generator to the BES or replacing the voltage regulator on its existing excitation system, whenever either event occurs after the Effective Date of this standard.

For auditing purposes, bullet one is intended to address newly connected equipment; bullet two is intended to address equipment already connected to the BES.

R5. Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that unit becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that unit becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the unit became non-operational, and 2) the date the unit was returned to service, the span of time between the two events being within 24 months of one another.

C. Measures

THIS DOCUMENT WILL BE REFORMATTED PLACING MEASURES IN THIS SECTION.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements
THIS SECTION WILL BE REVISED ONCE THE REQUIREMENTS ARE LOCKED.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[10] Level of non-compliance on any occasion that the Generator Operator is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[11] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2. (Requirement R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Operator's PSS	Occurs when the Generator Operator's PSS	Occurs when the Generator Operator's PSS	Occurs when the Generator Operator's

[10] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

[11] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
			fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	fails to meet any of the required performances in Requirement R3, three times during the audit period.	fails to meet any of the required performances in Requirement R3, four times during the audit period.	PSS fails to meet any of the required performances in Requirement R3, five time or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[12] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[13] Level of non-compliance on any occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement

[12] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

[13] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						R5 is binary.)

Attachment A

Output Limit Settings		
Gain		
Washout Time Constant		

Bode Plots		
Excitation response with unit connected to electrical system without PSS in service. (This is a VT/Vref measured response.)		
Excitation response with PSS in service and unit connected to electrical system. This plot can be either via test or calculated based on PSS settings and measured response of the first plot.		

THIS SECTION WILL BE REVISITED ONCE THE DOCUMENT IS FURTHER DEVELOPED.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Facilities

The standard applies to those units meeting the BES definition.

Requirement R1

The rationale behind Requirement R1 is that PSS offers damping to the system thereby enhancing system stability. Whenever possible, that damping should be provided to the system through the continuous operation of the PSS.

It should be noted that a PSS can be fully operational in accordance with Requirement R1 while not producing any damping if tuned in accordance with Requirement R2. Specifically, if the PSS is tuned to automatically disable during specific events, that unit is fully operational even though it is not providing damping to the system.

Requirement R2 and Attachment A

The rationale behind Requirement R2 is that a minimum tuning threshold should be applied to each PSS with the goal of providing a minimum threshold of damping to the system.

There is an interrelationship between the phase compensation and the washout time constant. Short washout time constants provide additional phase compensation in frequency-based PSS at the lower frequencies while dramatically reducing the gain.

A washout time constant of 10 seconds or less is recommended to quickly remove low frequency components (below 0.1 Hz) from the PSS output. The smaller time constant will reduce the influence on the system voltage from the PSS during any sustained/extended frequency deviation (i.e., loss of generation), especially if the PSS has a high gain setting.

Requirement R2, Number 5

This tuning feature was included to ensure consistent damping after the generator's PSS reaches full operation. This feature recognizes that the PSS damping contribution may be minimal or in some cases erratic until reaching full operation. During this period the PSS should be disabled.

For example, PSS output may be blocked on a 100MW generator until that generator reaches an output of 40 MW. This is done because while operating at low power the PSS contribution will be insignificant and the PSS, when in the active state is continuously modulating the field circuit of the generator causing rapid changes in the field voltage and reactive power.

Requirement R2, Number 6

This tuning feature was included to ensure that operation of the PSS is automatically disabled using control circuitry in order to protect the equipment from damage while ramping through a cavitation zone, commonly called “rough zones.”

Requirement R3

The rationale for Requirement R3 is that within the Western Interconnection, PSS adds to the stability of the Bulk-Electric System through damping. Locating PSS throughout the Interconnection adds a broader geographic footprint and better disperses the location of the damping equipment. The requirement recognizes that not all generators have PSS installed; however, as those generators are upgraded, the addition of PSS to each such generator is required to ensure the reliability of the BES. At the Effective Date of this standard, the preferred type of PSS that is able to meet the tuning parameters of R2 is an integral of accelerating power type, designated PSS2A.

WECC-0107 Power System Stabilizers
VAR-501-WECC-3
Response to Comments
Posting 2
December 2, 2014

WECC-0107 Power System Stabilizers (PSS)
VAR-501-WECC-3
Response to Comments

Posting 2

The WECC-0107 PSS Drafting Team (DT) thanks everyone who submitted comments on the proposed project.

Posting

This document was last posted for a 30-day public comment period from October 15, 2014 through November 14, 2014. An extension of time for the posting of responses was granted by the WECC Standards Committee.

WECC distributed the notice for the posting on October 14, 2104. The Drafting Team asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from four companies representing six of the eight Industry Segments, as shown in the table on the following page.

Location of Comments

All comments received on the document can be viewed in their original format located on the project page under the “Submit and Review Comments” accordion.

Changes in Response to Comment

- A Facilities section was added specifying the standard only applies to synchronous generation.
- Changes were made to requirement R3: 1) Section 1 to include the phrase "no-load VT/V Ref", 2) Section 3 eliminating the 6 Db gain requirement in exchange for a requirement that "gain shall be set to between 1/3 and 1/2 of maximum practical gain." The DT will address the maximum practical gain in a guidance narrative.
- The DT reviewed the NERC Functional Model, Version 5 (Model) and agreed that the Generator Owner (not the Generator Operator) was a better fit for the tasks described in Requirement R3. That change was made accordingly.
- The Requirement and Measures preamble was edited to match the intended 24 month time window specified in Requirement R5.

Minority Comments Summary

The DT reviewed and considered requests to include in the Requirements further clarification of the Requirement's meaning. The DT agreed that additional narrative would be provided in a guidance section to explain the intent of the Requirements.

Action Plan

The DT will begin drafting guidance narrative during the first week in December 2014. Once the proposed Requirements are vetted the DT will revisit the format, Measures, and associated Compliance sections of the document. On December 3, 2014, the DT will request that the WECC Standards Committee post these responses.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.[1]

[1] The appeals process is described in the Reliability Standards Development Procedures: http://www.wecc.biz/Standards/Documents/WECC%20Reliability%20Standards%20Development%20Procedures.aspx

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
4[2]	Leonard Lima	Kestrel Power								**X**
5	Cain Braveheart,	Bonneville Power Administration	**X**	**X**	**X**	**X**	**X**			
6	Caitlin Liotiris	Western Power Trading Forum (WPTF)			**X**					
7	Karen Hedlund	City of Tacoma	**X**	**X**	**X**	**X**	**X**			

[2] Comments 1, 2 and 3 were software testing and did not contain any substantive comments.

Index to Questions, Comments, and Responses

Question

1. **The WECC-0107 Drafting Team welcomes comments on all aspects of this document.**

1. **The WECC-0107 Drafting Team welcomes comments on all aspects of this document.**

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
Leonardo T. G. Lima, Kestrel Power Engineering			Requirements R1 and R2 Modern digital PSSs have thresholds, usually based on generator MW output, below which the PSS output is not added to the voltage regulator summation point (voltage error). The PSS function in the digital excitation controllers is in service and operating as expected (as commissioned), even though the PSS is not providing any additional damping. This feature is particularly relevant for hydro units with a "rough zone" associated with the turbine operation within certain MW levels. The PSS is usually commissioned to add damping for generator MW output above such "rough zone", as the PSS cannot operate effectively when the turbine is within the rough zone. Thus, it is very important to clarify that this is an operation as expected (something that needs to be described only once, as mentioned in Measure M1). Also, it is important to mention that the PSS is in service all the time (while the generator is synchronized) as required in R2. The PSS has not been "removed from service" just because its logic precludes the PSS from adding damping for generator MW output below this threshold. This issue, of the generator MW threshold above which the PSS is intended to add damping, is partially addressed in the "Guideline and Technical Basis" section of the document, but it needs to be an integral part of the Standard, either in the Requirements or in the Measures. Requirement R3 Comment 1 The PSS should compensate the phase characteristic of the generator and excitation system characteristic associated with the GEP(s) transfer function [4, 5], defined as the transfer

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			function from voltage reference set point Vref to electrical torque Te, when the rotor angle of the machine is held constant. This transfer function cannot be measured in the field, since it is impossible to hold the rotor angle position constant for the duration of the frequency response test. In other words, GEP(s) can only be estimated based on simulation results. On the other hand, the phase characteristic of GEP(s) is identical to the phase characteristic of the transfer function from Vref to terminal voltage Et, if the effects of changes in rotor angle position can be eliminated or, at least, minimized. In the Heffron-Phillips diagram [4], this is equivalent to imposing a constant rotor angle position or making the gains K4 and K5 as close as possible to zero. Therefore, to bring the gains K4 and K5 as close as possible to zero, the frequency response test has to be performed with the generation unit synchronized to the grid at its lowest stable load (in theory, K4 and K5 are zero when the power output of the generator is zero). Thus, performing the frequency response test with the generator at near full load is incorrect, resulting in an incorrect measurement of the required phase compensation for the PSS. Also, the frequency response test at near full load caries the risk of a resonance, associated with the local mode of oscillation of the unit. This resonance effect also introduces an error into the magnitude and phase characteristics of the measurement, which are eliminated when the measurement is performed at no load. The Standard should clearly state that the compensated frequency response corresponds to the phase of GEP(s) (obtained via simulation) or the phase of the frequency response Et/Vref (field test) performed at the lowest stable MW load of the generation unit. Comment 2 The frequency range of interest should be modified to 0.2 Hz to 2.0 Hz. The frequency of

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			inter-area electromechanical oscillation modes does not get as low as 0.1 Hz, ever, anywhere in the world (in any known interconnected system). The lowest inter-area oscillation frequency that I know has been recorded in an actual power system was in the Brazilian system (0.17 Hz), when the first tie-line interconnecting the North and the South of the country was energized. The frequency of this inter-area mode is presently well above 0.20 Hz, due to the completion of additional tie-lines that reinforced the North-South interconnection [1]. The requirement of ±30 degrees of phase compensation at the low frequency of 0.1 Hz results in three technical problems: a) The washout time constants have to be increased, to meet the ±30 degrees requirement, or an additional phase lag has to be introduced; b) once the PSS is commissioned to respond to such low frequencies as 0.1 Hz, it might respond to disturbances in the turbine (mechanical) system, which the PSS cannot affect or modify (add damping). In such events, the PSS would simply amplify and feedback these mechanical disturbances into the generator excitation system, affecting the voltage control and reactive power output of the unit; and c) The PSS will introduce excessive terminal voltage variations for system events which produce large or sustained off nominal frequency conditions Thus, requiring the appropriate phase compensation starting at 0.2 Hz (instead of 0.1 Hz) would automatically result in the use of lower values for the PSS washout time constants, with all the benefits associated with it. On the other hand, since there are no inter-area oscillation frequencies as low as 0.1 Hz, the effectiveness of the PSSs in providing damping to the actual inter-area oscillations in the WECC system would not be compromised. Although the focus of this WECC Standard is on system (inter-area) oscillation modes, the

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			PSSs need to provide damping to the local mode of oscillation of the unit. And, typically, these local modes have frequencies higher than 1.0 Hz. Thus, the PSS needs to provide the appropriate phase compensation for frequencies higher than 1.0 Hz. Thus, either the Standard reflects a change in the frequency range of interest (as suggested, from 0.2 Hz to 2.0 Hz) or at least it should mention that proper phase compensation is required for frequencies above 1.0 Hz for proper operation of the PSS regarding the local mode of oscillation. Comment 3 WECC should also clarify what is the proper interpretation of "gain margin of 6 dB". A gain margin calculation implies the definition of a maximum gain, and this maximum gain has to be clearly defined. The theoretical definition of gain margin is the ratio between the actual gain of the control system (in this case, the nominal PSS gain) and the maximum gain that could be used in this control system, the threshold to instability. A gain margin of 6 dB means that the nominal PSS gain should be approximately ½ of the maximum gain. In practice, noise can become a limiting factor, way before reaching the threshold of any instability (either the "theoretical" stability limit, as determined via simulation, or a "practical" stability limit, as determined via field tests during commissioning) [2]. The difficulties associated with noise become more noticeable as the phase lead requirement of the PSS increases, since increasing the phase lead compensation results in an increase in the high-frequency gain of the PSS. Kestrel has found that, in practice, the high-frequency gain of the PSS should not exceed 500 pu. The phase lead requirement and thus the PSS high frequency gain are related to the exciter and generator characteristics, as long recognized by WECC in its "Criteria to Determine

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			System Suitability for PSS" [3]. This version of the proposed Standard does not mention the suitability criteria for PSS application [3] and thus requires a PSS to be commissioned even on machines that, under that suitability criteria, would not be recommended to have a PSS installed. When a PSS is required to provide more phase compensation (to meet the ±30 degrees requirement), this will directly increase the high frequency gain of the PSS and will increase the likelihood of noise becoming a limiting factor to the PSS gain. Further increasing the PSS gain would only increase the amplification of noise at the PSS output (and injected into the excitation system), so no additional improvement in damping can be obtained. In some cases, the final PSS gain will be much lower than ½ of the theoretical maximum gain leading to instability, as observed in simulations, as simulations do not represent noise or very small time constants and delays which are present in real hardware and software PSS and voltage regulators. Thus, we suggest a text like "PSS gain shall be set to provide a gain margin of at least 6 dB with respect to the maximum PSS gain that could be achieved during field testing or commissioning". Usually, the records of the field tests with the maximum PSS gain and the nominal PSS gain are part of any PSS commissioning, so these records could be added to the list in Measure M3. References [1] I. Kamwa, R. Grondin and G. Trudel, "IEEE PSS2B versus PSS4B: The Limits of Performance of Modern Power System Stabilizers", IEEE Trans. on Power Systems, vol. 20, no 2, May 2005, pp. 903-915 [2] H. Vu and J. C. Agee, "Comparison of Power System Stabilizers for Damping Local Mode Oscillations", IEEE Trans. on Energy Conversion, vol. 8, no. 3, September 1993, pp. 533-538

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			[3] WECC Guideline, “Criteria to Determine Excitation System Suitability for PSS in WECC”, January 1993. [4] F. P. de Mello and C. Concordia, “Concepts of Synchronous Machine Stability as Affected by Excitation Control”, IEEE Trans. on Power Apparatus and Systems, vol. 88, no. 4, April 1969, pp. 316-329 [5] E. V. Larsen and D. A. Swann, “Applying Power System Stabilizers – Part I: General Concepts”, IEEE Trans. on Power Apparatus and Systems, vol. 100, no. 6, June 1981, pp. 3017-3024

Mr. Leo Lima of Kestrel joined the DT meeting and engaged the DT in discussion of Kestrel’s comments and concerns. Mr. Kestrel graciously accepted an invitation to engage in the drafting process.

In response to Kestrel’s comments, no changes were made to Requirements R1 or R2.

A change was made in Requirement R3, Section 1 to include the phrase “no-load VT/V Ref”. A change was made in Requirement R3, Section 3 eliminating the 6 Db gain requirement in exchange for a requirement that “gain shall be set to between 1/3 and 1/2 of maximum practical gain.” The DT will address the maximum practical gain in a guidance narrative.

The resulting Requirement now reads:

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

1) PSS shall be set to provide a compensated no-load VT/V Ref frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will not exceed ±30 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine’s nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
4) PSS washout time constant shall be no greater than 30 seconds. The DT noted Kestrel's request for additional guidance and clarification of the Requirements. Rather than incorporate the clarifying narrative into the Requirements, the DT concluded that adding a rationale box or guidance section in support of the Requirements would be of greater value. The DT agreed to begin drafting that narrative during the first week in December 2014. Mr. Lima agreed to participate in drafting the narrative. Kestrel raised concerns that if accepted the standard could be in conflict with existing WECC Guidelines that are under the auspice of the WECC Standing Committees, such as the WECC Operating Committee. The DT agreed with Kestrel's concern; however, making changes to guidelines is outside of the scope of this Standards Authorization Request. The DT agreed to communicate Kestrel's concerns to the appropriate Standing Committee. Kestrel requested a change from .1 Hz to .2 Hz in Requirement R3. The DT agreed the request had merit but concluded that additional technical support / research would be needed to change the .1 reference as .1 has been the WECC threshold for decades. The DT agreed to consult WECC staff and the Joint Synchronized Information Subcommittee to determine if there was any historic or substantive basis for the .1 reference.			
Cain Braveheart, Bonneville Power Administration			The Bonneville Power Administration appreciates the opportunity to provide feedback regarding WECC-0107 PSS Design and Performance but does not have any comments at this time. Thank you.
The drafting team thanks Bonneville Power for its continued support and participation in the standards development process.			
Caitlin Liotiris Western Power Trading Forum			WPTF supports the latest round of modifications the Drafting Team has made to the proposed standard. Generally, the latest changes represent a significant improvement. Specifically, WPTF appreciates the modifications to R1 and R2 which require notification of the operating specifications for the PSS and provide circumstances under which PSS may be out of service. Taken together, these two requirements should ensure GOPs keep PSSs in operation as often as is possible, thus promoting reliability in the interconnection. Further, WTPF appreciates the modifications to R4, which provide much greater clarity on when PSS installation is required on existing units. Finally, the addition of R5, which requires PSS repair or replacement within a specified time, should also enhance reliability. WPTF believes there is one substantial oversight in the current version of the standard,

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			relating to the applicability of the requirements. The current requirements for PSS operation contained in VAR-501-WECC-1 only apply to synchronous generators. However, the latest version of the standard posted for comment does not specify that the requirements are only applicable to synchronous generators. The Drafting Team should modify the language in the proposed standard to clarify that the PSS requirements are only applicable to synchronous generators. If the Drafting Team intended to expand the PSS requirements to asynchronous generators, that should be made clear in the preamble to the standard and justification for such an expansion should be provided. WPTF appreciates the opportunity to submit comments and looks forward to continue working with the Drafting Team on this project.
The drafting team added the following "Facilities" section. 5. Facilities: This standard only applies to synchronous generators."			
Karen Hedlund Tacoma Power			**General Comment** – The current WECC Policy Statement on Power System Stabilizers clearly states the requirement of PSS installation on existing generators with the statement "A PSS shall be installed on every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system". On page 8, requirements and measures line 6 states "Requirement R4 would mandate installation of PSS on BES units, but only after a set of specified triggering events". However, requirements on when existing BES generators that are not equipped with a PSS will require a PSS is not clearly stated within the proposed standard itself. R4 requires a PSS to be installed on newly-connected generators to the BES, and when the voltage regulators are replaced on existing excitation systems. Tacoma's interpretation of the standard is that PSS systems are not required to be added to existing generators until such time as the voltage regulator is replaced (R4). If this is not the intention of the DT then further clarification should be made within the

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**
			requirements of the standard. **R1** – No Comment **R2** – No Comment R3 – This Requirement requires a Generator Operator to tune its PSS to certain specifications. It is the role of the Generator Owner to replace and maintain the generating units including the voltage regulator and therefore it is the Generator Owner's responsibility to replace and tune the excitation systems. It is not clear how the Generator Operator entity would "tune its PSS" since it does not own the PSS but rather simply operates the PSS in order to supply energy to the grid. It is recommended to change the entity ownership of this requirement to Generator Owner. **R4** – No Comment **R5** - 1. On page 8 "Requirements and Measures" under Requirement 5 the replacement timeframe of 6 months conflicts with the timeframe of 24 months stated in R5 of the proposed standard. 2. Under what conditions does the term "non-operational" apply? A PSS component failure may cause the PSS to be non-operational and therefore it requires replacement under this Requirement. But consider an unusual transmission line condition where the PSS disrupts system stability and the PSS is placed in an extended non-operational or off-line mode. Is compliance achieved for this requirement by having documented evidence as described in M2 item 3 for such an event?

Summary Consideration:	See summary section located in the preamble.		
Commenter	**Yes**	**No**	**Comment**

General Comments

The drafting team concurs with your understanding of the standard based upon your comments as provided in the General Comment segment of your responses.

Requirement R3

The drafting team reviewed the NERC Functional Model, Version 5 (Model) and agreed that the generator Owner was a better fit for the task than the Generator Operator. That change was made accordingly.

Within the Model, Tasks assigned to the generator Owner include: 1) establish generating facilities ratings, limits, and operating requirements, 2) designing and authorizing maintenance of generation plant protective relaying, 3) responsibility for systems, protective relaying systems on the transmission lines connecting the generation plant to the transmission system, and Special Protection Systems, 4) maintenance of owned generating facilities, and 5) providing verified generating facility performance characteristics and data.

Requirement 5

The 24 month time window in Requirement R5 was retained. The Requirements and Measure preamble was altered to match.

If the Transmission Operator instructs that the PSS be taken off line, such an instruction does not constitute “non-operation.” The intent of the Requirement was to address those circumstances with the PSS is broken and cannot function as intended.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Posting for Comment

On December 3, 2014, the WECC Standards Committee (WSC) approved Posting 3 of this document for a 30-day comment period. Comments will open December 17, 2014 and close January 16, 2015.

Procedural Background

Standard Authorization Request (SAR) Consolidation

WECC-0094 VAR-501-WECC-"1" PSS and the ballot results of the WECC-0105 P81 redraft have been merged into WECC-0107 VAR-501-WECC-"3" resulting in a document applicable to the BES.

This Standards Authorization Request (SAR) to review WECC's PSS-related documents is in response to a WECC Board of Director's resolution.

On September 5, 2012, the WECC Board of Directors adopted the recommendation of the Regional Criteria Work Group that a (SAR) should be filed to evaluate VAR-502-WECC-RBP-1[1], WECC Power System Stabilizer (PSS) Design and Performance, a Regional Business Practice (RBP), for development as a WECC Regional Reliability Standard (RRS). Under WECC-0099, the WECC Control Work Group conducted the review concluding that a RRS should be drafted.

On February 11, 2014 during the WECC Standards Committee (WSC) meeting:

> "A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained." WSC Meeting Minutes

On June 25, 2014, the WSC changed the scope of the SAR directing that the proposed document be structured so that PSS: 1) where installed, be operating unless specifically exempted, 2) tuned as specified, and 3) where not installed, installation would be required when a generator is newly interconnected to the Bulk-Electric System (BES) or when a

[1] In June 2014, the WECC Board of Directors resolved to eliminate the Regional Business Practice (RBP) category defaulting to a WECC Criterion (CRT) category.

generator is updated. The WSC further approved merging WECC-0094 VAR-501-WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

Standard of Review

The Federal Energy Regulatory Commission (FERC) has stated that Regional Entity Standards or Regional Variances to a NERC Reliability Standard (Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).[2]

Operational Background

Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.

PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.

PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).

These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES. [3]

[2] Order No. 672 at P 291. See also NERC Functional Model, Version 5, "2. Reliability Standards", page 36.

[3] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection it is seen as both an interconnection-wide issue and a local issue.

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

When coupled with generator operations within WECC these physical characteristics create modal oscillation that when not corrected by the installation and accurate operation of PSSs causes instability within the WECC Interconnection.

Description of the Draft

Existing Standard

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed Standard

Under the proposed standard, PSS would be required on those synchronous generators that meet the BES definition.

The white paper, (April 2014), *Power System Stabilizer Applicability in the WECC System Study Progress Report to WECC-0107 Drafting Team (Draft as of May 28, 2014)* [White Paper], examined the impact on system oscillations when PSS were included or excluded at varying thresholds.

The white paper concluded:

1) In the WECC system model, generator size is inversely proportional to the number of generating units;

2) The nature of system-wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions; and,

3) There is no technical justification to either exclude or include application of PSS on a generating unit based on size alone.

Applicable Entities

The proposed standard would apply to the Generator Operator and the Generator Owner.

Under the NERC Functional Model, it is the task of the Generator Operator, to "report operating and availability status of units and related equipment, such as automatic voltage regulators", of which PSS is a part.[4] "Ultimately the Generator Operator's role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment."[5]

It is the role of the Generator Owner to install equipment.

Facilities

The proposed standard would be applicable only to synchronous units covered by the Bulk-Electric System (BES) definition.

[4] NERC Functional Model, Version 5, "Function – Generator Operation", Tasks, page 48.
[5] NERC Functional Model, Version 5, "11 Generator Operator", page 23.

Effective Date

The proposed Effective Date is the first day of the fourth quarter following final regulatory approval.

Requirements and Measures

Within existing NERC and WECC Standards, there are currently Requirements to model[6], plan[7], and to run[8] PSS (98% of operating hours except under twelve specified conditions).[9]

The proposed standard would reframe the requirements as follows.

Requirement R1 would require the Generator Operator to provide the Transmission Planner with the operating specifications of the Generator Operator's PSS.

Requirement R2 would mandate that PSS be in service at all times unless specifically exempted. It should be noted that the proposed standard no longer counts the hours to determine whether a specific percentage was met.

Requirement R3 would mandate tuning of a PSS to meet specific inter-area mode criteria.

Requirement R4 would mandate installation of PSS on applicable units, but only after a set of specified triggering events.
Requirement R5 would mandate repair or replacement of PSS within 24 months of that PSS unit becoming non-operational.

Measures and Compliance

The Measures and Compliance sections will be revisited once the substance of the Requirements has been determined. The drafting team asks that comments on the Measures and Compliance sections be held until after the Requirements are established.

[6] MOD-026-1 and MOD-032-1
[7] TPL-001-4, VAR-002-X
[8] VAR-501-WECC-1, Power System Stabilizer
[9] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 WECC open	July 1, 2014
9. Posting 1 WECC closed	August 14, 2014
10. Posting 1 WECC Responses posted	September 26, 2014
11. Posting 2 WECC open	October 15, 2014
12. Posting 2 closed	November 14, 2014
13. Posting 2 Responses posted	December 4, 2014[10]
14. Posting 3 WECC open	December 18, 2014
15. Posting 3 closed	January 19, 2015
16. Posting 3 Responses posted	
17. WSC approves for ballot	
18. Ballot Pool open	
19. Ballot Pool closed	

[10] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

20. Joint Session noticed	
21. Joint Session	
22. Ballot open	
23. Ballot closed	
24. WSC approves forwarding to the WECC Board of Directors	
25. Posted for 30 days prior to WECC Board meeting	
26. Board meets to approve	
27. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a “Version 2”

Implementation Plan

To Be Announced

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

There are no new definitions proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**

2. **Number:** VAR-501-WECC-2

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard only applies to synchronous generators.

6. **Effective Date:** This standard becomes effective on the first day of the fourth quarter following final regulatory approval.

B. Requirements and Measures

R1. Each Generator Operator shall provide to its Transmission Planner, the operating specifications for the Generator Operator's PSS, describing each condition during which the PSS will be non-operational for purposes of equipment protection or system stability, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications. *[Violation Risk Factor: Low] [Time Horizon:* Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Planner the operating specifications for the Generator Operator's PSS systems, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, describing each condition during which its PSS would be non-operational for purposes of equipment protection or system stability, as required in Requirement R1.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the specifications to the Transmission Planner one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing damping to the system as allowed in Requirement R1, the disabled period does not count against the mandate of Requirement R2.

R2. Each Generator Operator shall have its PSS in service while synchronized, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a BES Element affecting or affected by the PSS;
- Maintenance; or,
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception as allowed in Requirement R2 that includes:

1) An explanation covering the bulleted exception describing the circumstances of the exception; (and)
2) That the Transmission Operator was notified that the PSS was not operating as allowed under a Requirement R2 exception.

(or)

3) Where applicable, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed that the PSS should not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide a compensated no-load VT/V Ref frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will not exceed ±30 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.

M3. Each Generator Operator will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3. Evidence may include, but is not limited to, a completed Attachment A for this standard that reports: 1) output limits, 2) per unit gain, 3) washout-time constant, and 4) bode plots of the PSS.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of either connecting a generator to the BES or replacing the voltage regulator on its existing excitation system, whenever either event occurs after the Effective Date of this standard.

For auditing purposes, bullet one is intended to address newly connected equipment; bullet two is intended to address equipment already connected to the BES.

R5. Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that unit becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that unit becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the unit became non-operational, and 2) the date the unit was returned to service, the span of time between the two events being within 24 months of one another.

This section will be updated after the substance of the Requirements is established. The DT requests that comments on this section not be submitted until the section is complete.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[11] Level of non-compliance on any occasion that the Generator Operator is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[12] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2.

[11] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[12] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						(Requirement R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[13] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[14] Level of non-compliance

[13] (Guidance VSL) **For R1, Severe was chosen because the violation is binary.**
[14] (Guidance VSL) **For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						on any occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

Attachment A

Output Limit Settings		
Gain		
Washout Time Constant		

Voltage Step Test (greater than or equal to 80% load)		
Response with PSS at maximum Practical gain		
Response with PSS at nominal or as-commissioned gain		

Bode Plots		
Excitation response with unit connected to electrical system without PSS in service. (This is a VT/Vref measured response.)		
Excitation response with PSS in service and unit connected to electrical system. This plot can be either via test or calculated based on PSS settings and measured response of the first plot.		

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Facilities

The drafting team considered numerous approaches to setting the Facilities applicability threshold. The drafting team noted that in the approved Version 2 of this standard the 80% facilities applicability threshold was not based on a discrete technical study; rather, the 80% was derived based on sound engineering judgment designed to include 80% of the units located within the Western Interconnection.

Subsequent to approval of Version 2, the Bulk Electric System (BES) proceeding queried the industry as to the most appropriate definition of the BES, with the final decision becoming the threshold at which NERC standards would apply. When compared to the Version 2 proceedings the BES proceedings were much more in-depth, represented a greater diversity of industry viewpoints, and engaged a substantial array of subject matter experts not otherwise represented in the Version 2 filing.

Noting the additional depth and breadth of the BES when juxtaposed to the Version 2 participation the drafting team concluded that the industry has already opined on the adequate threshold at which NERC Reliability Standards should apply. As such, the drafting team opted to use the default BES threshold as it more broadly represents the consensus of the industry.

Requirement R1

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard. If the PSS is not operating in accordance with the documentation provided to the Transmission Planner, this could be considered a status change for purposes of NERC VAR-002-3, Requirement R3.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Operator to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, “active”, i.e., providing damping to the power system. Some PSS maybe programmed to become “active” at a specified MW loading level and above while others maybe be programmed to be “active” in a particular band of MW loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing). Unlike Requirement R1, the circumstances listed in Requirement R2 are not consider normal operation of the PSS.

Requirement R3

The intent of Requirement R3 is to clarify the requirements associated with the tuning of the parameters in the PSS.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, the automatic voltage regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.

~~Document Title~~	~~Power System Stabilizers~~ ~~VAR-501-WECC-3~~ ~~WECC Regional Reliability Standard~~
~~File Name~~	
~~Category~~	~~(X) Regional Reliability Standard~~ ~~( ) Regional Criterion~~ ~~( ) Policy~~ ~~( ) Guideline~~ ~~( ) Report or other~~ ~~( ) Charter~~
~~Document date~~	
~~Adopted/approved by~~	~~WECC Board of Directors~~
~~Date adopted/approved~~	
~~Custodian (entity responsible for maintenance and upkeep)~~	~~Standards~~
~~Stored/filed~~	~~Approved Regional Standards~~
~~Previous name/number~~	~~This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a "Version 2"~~
~~Status~~	~~( ) in effect~~ ~~( ) usable, minor formatting/editing required~~ ~~( ) modification needed~~ ~~( ) superseded~~ ~~( ) other ______________________________~~ ~~( ) obsolete/archived)~~

~~Version~~	~~Date~~	~~Action~~	~~Change Highlights~~
~~0.1~~	~~April 23, 2004~~	~~WECC Effective Date: VAR-502-WECC-0.1~~	
~~1~~	~~July 1, 2011~~	~~FERC Effective Date: VAR-501-WECC-1~~	
~~2~~	~~May 28, 2014~~	~~WECC Ballot Body Approved~~	~~Paragraph 81 clean-up~~

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~~Project Roadmap~~

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~~13. Posting 1 NERC Responses posted~~	
~~14. Posting 2 open~~	
~~15. NERC Quality Review~~	
~~16. Posting 2 closed~~	
~~17. Posting 2 Responses posted~~	
~~18. DT forwards request for ballot to WSC~~	

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~~19. WSC approves for ballot~~	
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~~Operational Background~~

~~Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.~~

~~PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.~~

~~PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).~~

~~These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES.~~[1]

~~WECC Physical Characteristics~~

~~The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."~~**Standard Development Timeline**

~~[1] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection, it is seen as both an interconnection-wide issue and a local issue.~~

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This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Posting for Comment

On December 3, 2014, the WECC Standards Committee (WSC) approved posting Version 3 of this document for a 30-day comment period opening December 12, 2014 and closing on January 12, 2015.

~~When coupled with generator operations within WECC, these physical characteristics create modal oscillations that when not corrected by the installation and accurate operation of PSS cause instability within the WECC Interconnection.~~

~~WECC~~ Procedural Background

Standard Authorization Request (SAR) Consolidation

WECC-0094 VAR-501-WECC-"1" PSS and the ballot results of the WECC-0105 P81 redraft have been merged into WECC-0107 VAR-501-WECC-"3" resulting in a document applicable to the BES.

This Standards Authorization Request (SAR) to review WECC's PSS-related documents is in response to a WECC Board of Director's resolution.

On September 5, 2012, the WECC Board of Directors adopted the recommendation of the Regional Criteria Work Group that a (SAR) should be filed to evaluate VAR-502-WECC-RBP-1[2], WECC Power System Stabilizer (PSS) Design and Performance, a Regional Business Practice (RBP), for development as a WECC Regional Reliability Standard (RRS). Under WECC-0099, the WECC Control Work Group conducted the review concluding that a RRS should be drafted.

On February 11, 2014 during the WECC Standards Committee (WSC) meeting:

> "A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was

[2] In June 2014, the WECC Board of Directors resolved to eliminate the Regional Business Practice (RBP) category defaulting to a WECC Criterion (CRT) category.

complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained." WSC Meeting Minutes

On June 25, 2014, the WSC changed the scope of the SAR directing that the proposed document be structured so that PSS: 1) where installed, be operating unless specifically exempted, 2) tuned as specified, and 3) where not installed, installation would be required when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated. The WSC further approved merging WECC-0094 VAR-501-WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

Standard of Review

The Federal Energy Regulatory Commission (FERC) has stated that Regional Entity Standards or Regional Variances to a NERC Reliability Standard (Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).[3]

~~**Proposed Structure**~~

~~The proposed document would merge multiple documents and SARs.~~

~~As a result, WECC-0094 VAR-501-WECC-"1" PSS and the ballot results of the WECC-0105 P81 redraft would merge into WECC-0107 VAR-501-WECC-"3" resulting in a document applicable to the BES.~~

~~**Facilities**~~

~~The proposed standard would be applicable to units covered by the Bulk-Electric System (BES) definition.~~

Operational Background

[3] Order No. 672 at P 291. See also NERC Functional Model, Version 5, "2. Reliability Standards", page 36.

Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.

PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.

PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).

These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES.[4]

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

[4] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection, it is seen as both an interconnection-wide issue and a local issue.

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When coupled with generator operations within WECC these physical characteristics create modal oscillation that when not corrected by the installation and accurate operation of PSSs causes instability within the WECC Interconnection.

Description of the Draft

Existing~~Applicable Entities~~

~~The proposed standard would apply to the Generator Operator and the Generator Owner.~~

~~Under the NERC Functional Model, it is the task of the Generator Operator, to "report operating and availability status of units and related equipment, such as automatic voltage regulators", of which PSS is a part.[5] "Ultimately the Generator Operator's role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment."[6]~~

~~It is the role of the Generator Owner to install equipment.~~

~~Current~~ Standard

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

~~[5] NERC Functional Model, Version 5, "Function – Generator Operation", Tasks, page 48.~~
~~[6] NERC Functional Model, Version 5, "11 Generator Operator", page 23.~~

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed Standard

Under the proposed standard, PSS would be required on those synchronous generators that meet the BES definition.

The white paper, (April 2014), *Power System Stabilizer Applicability in the WECC System Study Progress Report to WECC-0107 Drafting Team (Draft as of May 28, 2014)* [White Paper], examined the impact on system oscillations when PSS were included or excluded at varying thresholds.

The white paper concluded:

1) In the WECC system model, generator size is inversely proportional to the number of generating units;

2) The nature of system-wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions; and,

3) There is no technical justification to either exclude or include application of PSS on a generating unit based on size alone.

Applicable Entities

The proposed standard would apply to the Generator Operator and the Generator Owner.

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Under the NERC Functional Model, it is the task of the Generator Operator, to "report operating and availability status of units and related equipment, such as automatic voltage regulators", of which PSS is a part.[7] "Ultimately the Generator Operator's role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment."[8]

It is the role of the Generator Owner to install equipment.

Facilities

The proposed standard would be applicable only to synchronous units covered by the Bulk-Electric System (BES) definition.

Effective Date ~~; (and)~~

The proposed Effective Date is the first day of the fourth quarter following final regulatory approval.

Requirements and Measures

Within existing NERC and WECC Standards, there are currently Requirements to model[9], plan[10], and to run[11] PSS (98% of operating hours except under twelve specified conditions).[12]

The proposed standard would reframe the requirements as follows.

Requirement R1 would require the Generator Operator to provide the Transmission Planner with the operating specifications of the Generator Operator's PSS.

[7] NERC Functional Model, Version 5, "Function – Generator Operation", Tasks, page 48.
[8] NERC Functional Model, Version 5, "11 Generator Operator", page 23.
[9] MOD-026-1 and MOD-032-1
[10] TPL-001-4, VAR-002-X
[11] VAR-501-WECC-1, Power System Stabilizer
[12] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

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Requirement R2 would mandate that PSS be in service at all times unless specifically exempted. It should be noted that the proposed standard no longer counts the hours to determine whether a specific percentage was met.

Requirement R3 would mandate tuning of a PSS to meet specific ~~performance from the PSS as opposed to a specified tuning criterion.~~inter-area mode criteria.

Requirement R4 would mandate installation of PSS on ~~BES~~applicable units, but only after a set of specified triggering events~~,~~.

Requirement R5 would mandate repair or replacement of PSS within ~~six~~24 months of that PSS unit becoming non-operational.

Measures and Compliance

The Measures and Compliance sections will be revisited once the substance of the Requirements has been determined. The drafting team asks that comments on the Measures and Compliance sections be held until after the Requirements are established.

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Project Roadmap

~~Completed Actions~~	~~Completion Date~~
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 WECC open	July 1, 2014
9. Posting 1 WECC closed	August 14, 2014
10. Posting 1 WECC Responses posted	September 26, 2014
11. Posting 2 WECC open	October 15, 2014
12. Posting 2 closed	November 14, 2014
13. Posting 2 Responses posted	December 4, 2014[13]
14. Posting 3 WECC open	December 18, 2014
15. Posting 3 closed	January 19, 2015
16. Posting 3 Responses posted	

[13] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

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17. WSC approves for ballot	
18. Ballot Pool open	
19. Ballot Pool closed	
20. Joint Session noticed	
21. Joint Session	
22. Ballot open	
23. Ballot closed	
24. WSC approves forwarding to the WECC Board of Directors	
25. Posted for 30 days prior to WECC Board meeting	
26. Board meets to approve	
27. Sent to NERC	

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Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a “Version 2”

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Implementation Plan

~~TBA~~
To Be Announced

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

~~None~~There are no new definitions proposed.

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A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**
~~**Regional Reliability Standard**~~

2. **Number:** VAR-501-WECC-2

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard only applies to synchronous generators.

6. **Effective Date:** This standard becomes effective on the first day of the fourth quarter following final regulatory approval.

~~**NOTE: THIS DOCUMENT WILL BE REFORMATTED WHEN SUBMITTED TO NERC.**~~

B. Requirements and Measures

R1. Each Generator Operator shall provide to its Transmission Planner, the operating specifications for the Generator Operator's PSS, describing each condition during which the PSS will be non-operational for purposes of equipment protection or system stability, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications. *[Violation Risk Factor:*

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Low] [Time Horizon: Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Planner the operating specifications for the Generator Operator’s PSS systems, within 180 days of the PSS’s Commercial Operation date or any changes to the PSS operating specifications, describing each condition during which its PSS would be non-operational for purposes of equipment protection or system stability, as required in Requirement R1.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the specifications to the Transmission Planner one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing damping to the system as allowed in Requirement R1, the disabled period does not count against the mandate of Requirement R2.

R2. Each Generator Operator shall have its PSS in service while synchronized, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment~~]:~~*]*

- Component failure~~,~~;
- Testing of a BES Element affecting or affected by the PSS~~,~~;
- Maintenance~~, (~~; or~~),~~
- As agreed upon by the Generator Operator and the Transmission Operator.

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M2. Each Generator Operator will have documentation of each claimed exception as allowed in Requirement R2 that includes:

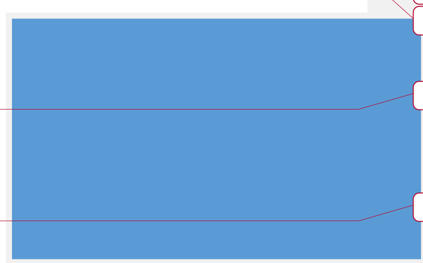
1) An explanation covering the bulleted exception describing the circumstances of the exception; (and)
2) That the Transmission Operator was notified that the PSS was not operating as allowed under a Requirement R2 exception.

(or)

3) Where applicable, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed that the PSS should not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator ~~Operator~~Owner shall tune its PSS to meet the following~~: -~~ inter-area mode criteria: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*



1) PSS shall be set to provide a compensated no-load VT/V Ref frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will not exceed ±30 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to ~~provide a gain margin of at least 6 Db.~~ between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.

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M3. Each Generator Operator will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3. Evidence may include, but is not limited to, a completed Attachment A for this standard that reports: 1) output limits, 2) per unit gain, 3) washout-time constant, and 4) bode plots of the PSS.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of either connecting a generator to the BES or replacing the voltage regulator on its existing excitation system, whenever either event occurs after the Effective Date of this standard.

For auditing purposes, bullet one is intended to address newly connected equipment; bullet two is intended to address equipment already connected to the BES.

R5. Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that unit becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that unit becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the unit became non-operational, and 2) the date the unit was returned to service, the span of time between the two events being within 24 months of one another.

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~~C. Measures~~

~~THIS DOCUMENT WILL BE REFORMATTED PLACING MEASURES IN THIS SECTION.~~

This section will be updated after the substance of the Requirements is established. The DT requests that comments on this section not be submitted until the section is complete.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document

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for a period of three years plus calendar current.

1.4 Additional Compliance Information

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Table of Compliance Elements

~~THIS SECTION WILL BE REVISED ONCE THE REQUIREMENTS ARE LOCKED.~~

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[14] Level of non-compliance on any occasion that the Generator Operator is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[15] Level of non-compliance on any occasion that the Generator Operator fails

[14] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[15] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

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R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						to have its PSS in service, except where allowed in Requirement R2. (Requirement R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, five ~~time~~times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[16] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its

[16] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[17] Level of non-compliance on any occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

[17] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**

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Attachment A

Output Limit Settings		
Gain		
Washout Time Constant		

Voltage Step Test (greater than or equal to 80% load)		
Response with PSS at maximum Practical gain		
Response with PSS at nominal or as-commissioned gain		

Bode Plots		
Excitation response with unit connected to electrical system without PSS in service. (This is a VT/Vref measured response.)		
Excitation response with PSS in service and unit connected to electrical system. This plot can be either via test or calculated based on PSS settings and measured response of the first plot.		

~~THIS SECTION WILL BE REVISITED ONCE THE DOCUMENT IS FURTHER DEVELOPED.~~

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Facilities

~~The standard applies to those units meeting the BES definition.~~
The drafting team considered numerous approaches to setting the Facilities applicability threshold. The drafting team noted that in the approved Version 2 of this standard the 80% facilities applicability threshold was not based on a discrete technical study; rather, the 80% was derived based on sound engineering judgment designed to include 80% of the units located within the Western Interconnection.

Subsequent to approval of Version 2, the Bulk Electric System (BES) proceeding queried the industry as to the most appropriate definition of the BES, with the final decision becoming the threshold at which NERC standards would apply. When compared to the Version 2 proceedings the BES proceedings were much more in-depth, represented a greater diversity of industry viewpoints, and engaged a substantial array of subject matter experts not otherwise represented in the Version 2 filing.

Noting the additional depth and breadth of the BES when juxtaposed to the Version 2 participation the drafting team concluded that the industry has already opined on the adequate threshold at which NERC Reliability Standards should apply. As such, the drafting team opted to use the default BES threshold as it more broadly represents the consensus of the industry.

Requirement R1

~~The rationale behind Requirement R1 is that PSS offers damping to the system thereby enhancing system stability. Whenever possible, that damping should be provided to the system through the continuous operation of the PSS.~~

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~~It should be noted that a PSS can be fully operational in accordance with Requirement R1 while not producing any damping if tuned in accordance with Requirement R2. Specifically, if the PSS is tuned to automatically disable during specific events, that unit is fully operational even though it is not providing damping to the system.~~

~~Requirement R2 and Attachment A~~

~~The rationale behind Requirement R2 is that a minimum tuning threshold should be applied to each PSS with the goal of providing a minimum threshold of damping to the system.~~

~~There is an interrelationship between the phase compensation and the washout time constant. Short washout time constants provide additional phase compensation in frequency-based PSS at the lower frequencies while dramatically reducing the gain.~~

~~A washout time constant of 10 seconds or less is recommended to quickly remove low frequency components (below 0.1 Hz) from the PSS output. The smaller time constant will reduce the influence on the system voltage from the PSS during any sustained/extended frequency deviation (i.e., loss of generation), especially if the PSS has a high gain setting.~~

~~Requirement R2, Number 5~~

~~This tuning feature was included to ensure consistent damping after the generator's PSS reaches full operation. This feature recognizes that the PSS damping contribution may be minimal or in some cases erratic until reaching full operation. During this period the PSS should be disabled.~~

~~For example, PSS output may be blocked on a 100MW generator until that generator reaches an output of 40 MW. This is done because while operating at low power the PSS contribution will be insignificant and the PSS, when in the active state is continuously modulating the field circuit of the generator causing rapid changes in the field voltage and reactive power.~~

~~Requirement R2, Number 6~~

~~This tuning feature was included to ensure that operation of the PSS is automatically disabled using control circuitry in order to protect the equipment from damage while ramping through a cavitation zone, commonly called "rough zones."~~

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~~Requirement R3~~

~~The rationale for Requirement R3 is that within the Western Interconnection, PSS adds to the stability of the Bulk-Electric System through damping. Locating PSS throughout the Interconnection adds a broader geographic footprint and better disperses the location of the damping equipment. The requirement recognizes that not all generators have PSS installed; however, as those generators are upgraded, the addition of PSS to each such generator is required to ensure the reliability of the BES. At the~~ Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard. If the PSS is not operating in accordance with the documentation provided to the Transmission Planner, this could be considered a status change for purposes of NERC VAR-002-3, Requirement R3.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Operator to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, “active”, i.e., providing damping to the power system. Some PSS maybe programmed to become “active” at a specified MW loading level and above while others maybe be programmed to be “active” in a particular band of MW loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing). Unlike Requirement R1, the circumstances listed in Requirement R2 are not consider normal operation of the PSS.

Requirement R3

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The intent of Requirement R3 is to clarify the requirements associated with the tuning of the parameters in the PSS.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, the automatic voltage regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.
~~**Effective Date** of this standard, the preferred type of PSS that is able to meet the tuning parameters of R2 is an integral of accelerating power type, designated PSS2A.~~

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WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 3
December 12, 2014 through January 12, 2015

Posting #3

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed documents.

Posting

This document was last posted for a 30-day public comment period from December 12, 2014 through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

WECC distributed the notice for the posting on December 3, 2014. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from five companies representing six of the eight Industry Segments, as shown in the table on the following page.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the "Submit and Review Comments" accordion.

Changes in Response to Comment

After consideration of comments received, the DT made the following changes:

Requirement R1

To eliminate confusion between information required under this document and that of NERC Standard MOD-026, Requirement R1 was changed to read as follows:

R1. Each Generator Operator shall provide to its Transmission Planner, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, its written operating procedure describing those known circumstances during which its PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). *[Violation Risk Factor: Low] [Time Horizon:* Planning Horizon*]*

Requirement R2

Requirement R2 was redrafted to eliminate duplicative notice requirements between the proposed document and other existing NERC Standards. The notification component of the proposed Requirement was removed. The requirement now reads:

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a BES Element affecting or affected by the PSS;
- Maintenance;
- As agreed upon by the Generator Operator and the Transmission Operator.

Requirement R3

Requirement R3, numbered section 1 was changed to synchronize the Requirement with the Guidance section, inter alia. The drafting team noted in its response that the numbers included in the proposed Requirement are not new; rather, they reflect thresholds already included in WECC Guidelines. The DT also noted its commitment from Posting 1 to review APS's concerns regarding the 30 degree threshold. The DT believes the following redraft addresses APS's Posting 1 concern as well as that presented for review by others in Posting 3. The Requirement now reads:

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide a compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to 1.0 Hertz or the highest frequency at which the phase of the minimum-load Vt/Vref frequency response does not exceed 90 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.

Requirement R4

The drafting team did not accept a suggestion to exchange the word "replace" with "upgrade" because the term "upgrade" was too ambiguous. The team opted for "replace" as the triggering event noting that when a voltage regulator is replaced, the PSS must also be replaced or added, and must met the specification of the proposed standard.

Requirement R5

To eliminate ambiguity in Requirement R5 the word "unit" was deleted in the Requirement and the Measure, and replaced with either "non-operating PSS" or "PSS."

Effective Date

The proposed Effective Date for this standard is the first day of the fourth quarter following final regulatory approval.

Action Plan

The DT will request that WECC staff post these responses to comments. Sections such as the Violation Severity Levels and Violation Risk Factors will be updated after the Requirements are further developed. WECC staff contacted WECC Compliance on February 10, 2015 with a request to compare proposed Requirement R1 with MOD-026-1, Verification of Models and Data for generator Excitation Control System or Plant Volt/Var Control Functions (MOD) for possible duplication.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

The WECC Standards Voting Sectors are:

1 — Transmission Sector

2 — Generation Sector

3 — Marketers and Brokers Sector

4 — Distribution Sector

5 — System Coordination Sector

6 — End Use Representative Sector

7 — State and Provincial Representatives Sector

8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
1	Kristie Cocco	Arizona Public Service Company (APS)	X	X	X	X	X			

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
2	Leonardo Lima	Kestrel Power Engineering (LLC) (Kestrel)								**X**
3	David Lemmons	Xcel Energy/Public Service Company of Colorado	**X**	**X**	**X**	**X**	**X**			
4	Sergio Banuelos	Tri-state Generation and Transmission (Tri-state)	**X**	**X**	**X**	**X**	**X**			
5	Joseph Wilson	Tacoma Power	**X**	**X**	**X**	**X**	**X**			

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

1. The drafting team welcomes comments on all aspects of the document.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
APS			To remove ambiguity, APS would like to see a fifth bullet added to R2 that addresses the condition that even when a generator is synchronized to the BES, the PSS will not be functioning when the unit is operation below the PSS threshold values. The added bullet should be closely worded to R1.5 of the current VAR-501-WECC-1. **R2.** Each Generator Operator shall have its PSS in service while synchronized, except when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for any of the following circumstances: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]* • Component failure; • Testing of a BES Element affecting or affected by the PSS; • Maintenance; or, • As agreed upon by the Generator Operator and the Transmission Operator. • Unit is generating less power than the set point where PSS is designed to be turned on. Or, if it is the drafting board's recommendation that GO's do not need to track the time when a generator is synchronized to the BES but producing less power then what is needed to run the PSS (Start up, shout down, and spinning reserve); please specifically specify that this time does not need to be tracked (PSS is available but not active).

Requirement R2, "Fifth Bullet"

Requirement R2:

The drafting team recognizes the duplication of the notification requirement in the proposed language as well as the NERC VAR-002-3, Requirement R3. The notification component of the proposed Requirement has been removed. The focus of the proposed Requirement is now on ensuring the PSS is operating as opposed to notification.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
R2. Each Generator Operator shall have its PSS in service while synchronized, except for any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]* • Component failure; • Testing of a BES Element affecting or affected by the PSS; • Maintenance; • As agreed upon by the Generator Operator and the Transmission Operator. The DT also notes it commitment from Posting 1 to further assess the “30 degree” issue raised by APS in that posting. The DT modified the Requirement R3 (as numbered on February 10, 2015) in a manner believed to meet APS’s reliability concerns. The new Requirement R3 and APS’s Posting 1 concern appears below. **Requirement R3: APS Posting 1 Comment:** In reference to Requirement 2, the following comments are provided: • R2: The ± 30 degrees criteria should be relaxed to ± 45 degrees and with a comment that it be generally within ±30 degrees. There are many situations where ± 30 degrees is not attainable. APS Suggests a revision to the language of this requirement, which would read: "PSS shall provide a compensated frequency response of the excitation system and synchronous machine such that through the frequency range from 0.1 Hertz to 1.0 Hertz the phase will generally be within±30 degrees but not exceed ±45 degrees. Proposed remedial language: **R3.** Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]* 1) PSS shall be set to provide a compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to 1.0 Hertz or the highest frequency at which the phase of the minimum-load Vt/Vref frequency response does not exceed 90 degrees. 2) PSS output limits shall be set to provide at least ±5% of the synchronous machine’s nominal terminal voltage. 3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain. 4) PSS washout time constant shall be no greater than 30 seconds.			
Kestrel			This Draft of the Standard has clarified most of the issues/comments raised in the previous round of comments.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			Unfortunately, it seems that a small inconsistency was introduced between the text in R3, item (1), and the associated explanation presented in the Guideline and Technical Basis. Requirement R3, item (1), defines the frequency range of interest from 0.1 Hz to 1.0 Hz, while the explanation in the Guideline and Technical Basis refers to 0.2 Hz as the lower end of the same frequency range. The Drafting Team should clarify which frequency range will be part of the actual Requirement R3. Our position is that the value of 0.2 Hz should be used, despite the fact that the lower value of 0.1 Hz has been used in the past. Basically, raising the lower threshold of the frequency range will have a significant positive impact on the selection of the washout time constant Tw (see item (4) of Requirement R3), allowing the selection of time constants much smaller than 30 seconds. In practice, raising the lower threshold of the frequency range of interest from 0.1 Hz to 0.2 Hz should make it relatively easy to achieve washout time constants smaller than 10 s and even smaller than 5 s in most cases. On the other hand, maintaining the lower threshold value of 0.1 Hz might require the use of larger values of Tw and would also make the PSS responsive at that lower frequency. This is problematic, due to the possibility of interaction of the PSS with the dynamic response of turbines, particularly hydro turbines. This interaction between the PSS and the turbine controls should be avoided, as the PSS might show unexpected response and even detrimental response to events such as a fast loading/unloading of the unit (fast ramp rates of hydro units) and even introducing relatively large variations in terminal voltage following events leading to large or sustained frequency deviations. A review of the literature found only one reference [1] of an oscillation frequency lower than 0.20 Hz in WECC, and that was for the system configuration prior to 1967 (prior to the energization of the Pacific Intertie) when the system operated with a very weak 230 kV interconnection. The same reference indicates that the oscillation frequency increased to 0.30 Hz after commissioning of

<table>
<tr><th>Summary Consideration:</th><th colspan="3">See summary in the preamble of this document.</th></tr>
<tr><th>Commenter</th><th>Yes</th><th>No</th><th>Comment</th></tr>
<tr><td></td><td></td><td></td><td>the Pacific Intertie. The same reference indicates the emergence of a new oscillation mode, at around 0.20 Hz, probably related to the parallel North-South path through Idaho, Utah and Arizona.

[1] R. L. Cresap and J. F. Hauer, "Emergence of a New Swing Mode in the Western Power System", IEEE Trans. on Power Apparatus and Systems, vol. 100, no 4, April 1981, pp. 2037-2045.</td></tr>
<tr><td colspan="4"><u>Inconsistency between R3, item (1) and the associated Guideline and Technical Basis</u>

Requirement R3, item (1), defines the frequency range of interest from 0.1 Hz to 1.0 Hz, while the explanation in the Guideline and Technical Basis refers to 0.2 Hz as the lower end of the same frequency range.

The concern has been addressed with updated text in Requirement R3, Bullet 1:

Requirement R3:

1) “PSS shall be set to provide a compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to 1.0 Hertz or the highest frequency at which the phase of the minimum-load Vt/Vref frequency response does not exceed 90 degrees.”</td></tr>
<tr><td>Xcel</td><td></td><td></td><td>Xcel Energy appreciates the efforts made by the WECC-0107 drafting team to improve the current PSS standard. This draft is a significant improvement over the current standard. However, Xcel Energy has some concerns related to the proposed standard, specifically related to the first three requirements.

Concern with proposed R1

As written, Xcel Energy is concerned that there could be some confusion related to the information needed under R1 compared to information required under MOD-026. Xcel Energy recommends revising the language in R1 to be as follows:

Each Generator Operator shall provide to its Transmission Planner the operating conditions for the generator describing each condition during which the PSS will be non-operational, within 180</td></tr>
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Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			days of the PSS Commercial Operation date or any changes to the operating conditions that impact the PSS operation. This language provides clarity as to what information is required under this standard as compared to the information required under MOD-026. **Concern with proposed R2** As worded, there appears to be two parts to the requirement: the first part is to have the PSS in service; the second part is to notify the Transmission operator that the PSS is not in service. Xcel Energy is concerned that the second part of the requirement puts an entity at risk of double jeopardy. Under the NERC standard VAR-002-3, R3 clearly requires that the TOP be notified of a change of status for the PSS. If an entity fails to make that notification, then it is Xcel Energy's position that the entity will be found to have violated both the proposed WECC standard and the NERC standard. It is also unclear if the notification must be made while the PSS is out of service or if notification might be made after the PSS has been returned to service, especially for a very short duration outage. Note that under the NERC standard, outages of less than 30 minutes do not require notification to the TOP. However, as worded in the WECC proposal, it is unclear if notification must be made prior to the PSS being removed from service or if notification after the PSS goes out of service is sufficient. Due to the concerns of double jeopardy, Xcel believes that a regional variance to the NERC VAR-002 standard, Requirement R1, to address the need to have the PSS in service is better than a separate standard. The NERC Requirement R1 requires that the AVR be in operation but is silent on the PSS. However, Requirement R3 in the NERC standard requires that the GOP notify the TOP of a status change of either the AVR or PSS. A WECC regional variance to Requirement R1, which could easily add the PSS to the language already approved for the AVR, would address the concerns in a reasonable manner without subjecting all GOPs

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			operating in the WECC to double jeopardy. **Concerns with proposed R3** Xcel Energy has two concerns with the proposed R3. First, there does not appear to be any differentiation for current technology versus older technology. While new electronic systems can be easily tuned to these specifications, older PSSs may not be capable of modifications to address the specified setting requirements. Also there is concern that any adjustments to the older solid state equipment may lead to equipment failure with lack of replacement parts. The drafting team must address this issue before a standard can be implemented. Second, the proposed implementation time for this standard is not acceptable for the needed tuning/setting process for the fleet of PSSs in the WECC. There are a limited number of people/entities with the expertise to test and tune the PSS. In addition, the concerns related to older technology was confirmed by Xcel Energy's consultant used for tuning the PSS systems within the PSCo fleet. If a person is to modify the settings of these older systems, the time tune and verify is much greater than the time to adjust newer digital systems. Therefore, the proposed time frame to implement R3 is unacceptable. This standard, or at least this requirement, needs a much longer time period for implementation than the proposed 12 months. **Concern with proposed R5** As worded, it is unclear when the PSS must be repaired or replaced. Reading both the requirement and the measure, it appears that the PSS must be repaired/replaced within 24 months of the generating unit becoming non-operational, which does not make logical sense. Xcel Energy believes the intent is to allow for 24 months for the PSS to be repaired/replaced if the PSS quits working. If that is the case, the drafting team should not use the word unit. In the electric industry, the word "unit" typically refers to the generator, not the PSS. Therefore, Xcel Energy recommends replacing the word unit with PSS anywhere the drafting team is referring to the actual PSS instead of the generating unit itself.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			Thank you for your efforts on improving the current PSS standard. Xcel Energy looks forward to working with the drafting team to address these issues.

Requirement R1

As written, Xcel Energy is concerned that there could be some confusion related to the information needed under Requirement R1 compared to information required under MOD-026. To address this concern the DT will request that WECC Compliance review the proposed Requirement along with MOD-026 to see if duplication exists. Requirement R1 has been redrafted as follows:

Requirement R1:

R1. Each Generator Operator shall provide to its Transmission Planner, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, its written operating procedure describing those known circumstances during which its PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR).

Requirement R2:

The drafting team recognizes the duplication of the notification requirement in the proposed language as well as the NERC VAR-002-3, Requirement R3. The notification component of the proposed Requirement has been removed. The focus of the proposed Requirement is now on ensuring the PSS is operating as opposed to notification.

R2. Each Generator Operator shall have its PSS in service while synchronized, except for any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a BES Element affecting or affected by the PSS;
- Maintenance;
- As agreed upon by the Generator Operator and the Transmission Operator.

Requirement R3

The drafting team appreciates your concern. The first bullet of Requirement R3 has been changed to read as follows. The proposed language is crafted to allow for performance by both older as well as newer units. To the extent an entity tuned in accordance with the now existing tuning guidelines, adherence to the Requirement as drafted should be viable by the proposed Effective Date.

"PSS shall be set to provide a compensated minimum-load VT/Vref frequency response of the

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
excitation system and synchronous machine such that the phase will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to 1.0 Hertz or the highest frequency at which the phase angle of the minimum-load Vt/Vref frequency response does not exceed 90 degrees." **Requirement R5 / Repair of PSS** The drafting team has redrafted the Requirement and Measure as follows: **R5.** Each Generator Owner shall repair or replace a non-operating PSS within 24 months of that non-operating PSS becoming non-operational. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]* **M5.** Each Generator Owner will have evidence that it repaired or replaced a non-operational PSS within 24 months of that non-operating PSS becoming non-operational. Evidence may include, but is not limited to, documentation of: 1) the date the PSS became non-operational, and 2) the date the PSS was returned to service, the span of time between the two events being within 24 months of one another.			
Tri-State			Tri-State Generation and Transmission (TSGT) believes that the language in R4 should be modified. TSGT suggests changing the language in the second bullet of the requirement from "The Generator Owner replaces the voltage regulator..." to "The Generator Owner upgrades the voltage regulator…" If an entity is replacing an old voltage regulator with a similar device then the entity should not be required to install PSS. TSGT is interested to know the information the standard drafting team has that supports the numbers in requirement R3. What has occurred that leads the standard drafting team to believe this new requirement is necessary? TSGT would also like to know what evidence has been found that suggests that all synchronous generators (applicable to the BES) require PSS. This requirement is a large leap from what is currently required and TSGT wonders what recent information makes this requirement necessary. There isn't sufficient information provided in the "technical basis" section of the document to support the addition of this requirement. What fundamental data has been collected or research has been done to require PSS on every applicable facility?

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Requirement R4 / Upgrade vs. Replace The drafting team has concerns with the use of the term "upgrade" as its generic application is too ambiguous. For example, if a new piece is used to repair an older piece, and the newer piece is superior to the older piece – it is unclear whether that action is an "upgrade. To remedy the ambiguity, the team opted for "replacement" as the triggering event noting that when a voltage regulator is replaced, the PSS must also be replaced or added, and must met the specifications of the standard. **Requirement R3 / Numbers** The drafting team notes that the substance of the requirement is not new in the sense that the requirement has been resident in WECC Guidelines for some time.			
Tacoma Power			Measure 3 (M3) The Requirement 3 (R3) task responsibility was changed from generator Operator to generator Owner. Measure 3 (M3) needs to change to generator Owner to be consistent. C. Compliance, 1.3 Evidence Retention The second paragraph should also include Generator Owner to be consistent with the change made to R3. Table of Compliance Elements Pertaining to R3, the Violation Security Levels need to change from Generator Operator to Generator Owner for consistency.
The drafting team appreciates Tacoma's comments. The drafting team has been in touch with Tacoma directly and indicated that Measures and Compliance will be addressed in subsequent postings. Tacoma agreed to re-submit its comments once the drafting team has solicited comments on the Measures and Compliance sections.			

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Posting for Comment

This document is in its fourth posting.

Procedural Background

Standard Authorization Request (SAR) Consolidation

WECC-0094 VAR-501-WECC-“1” PSS and the ballot results of the WECC-0105 P81 redraft have been merged into WECC-0107 VAR-501-WECC-“3” resulting in a document applicable to the BES.

This Standards Authorization Request (SAR) to review WECC’s PSS-related documents is in response to a WECC Board of Director’s resolution.

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On February 11, 2014 during the WECC Standards Committee (WSC) meeting:

> “A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained.” WSC Meeting Minutes

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[1] In June 2014, the WECC Board of Directors resolved to eliminate the Regional Business Practice (RBP) category defaulting to a WECC Criterion (CRT) category.

WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

Standard of Review

The Federal Energy Regulatory Commission (FERC) has stated that Regional Entity Standards or Regional Variances to a NERC Reliability Standard (Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).[2]

Operational Background

Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.

PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.

PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).

These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES. [3]

[2] Order No. 672 at P 291. See also NERC Functional Model, Version 5, "2. Reliability Standards", page 36.

[3] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection it is seen as both an interconnection-wide issue and a local issue.

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

When coupled with generator operations within WECC these physical characteristics create modal oscillation that when not corrected by the installation and accurate operation of PSSs causes instability within the WECC Interconnection.

Description of the Draft

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed Standard

To be updated once the document is more fully developed.

Applicable Entities

To be updated once the document is more fully developed.

Facilities

To be updated once the document is more fully developed.

Effective Date

The proposed Effective Date is the first day of the fourth quarter following final regulatory approval.

Requirements and Measures

To be updated once the document is more fully developed.

Measures and Compliance

To be updated once the document is more fully developed.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[4]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures	December 23, 2014

[4] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

17. Posting 3 Closed	January 19, 2015[5]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. Posting 4 Responses Posted	
22. WSC approves for ballot	
23. Ballot Pool open	
24. Ballot Pool closed	
25. Joint Session noticed	
26. Joint Session	
27. Ballot open	
28. Ballot closed	
29. WSC approves forwarding to the WECC Board of Directors	
30. Posted for 30 days prior to WECC Board meeting	
31. Board meets to approve	
32. Sent to NERC	

[5] This document was posted for a 30-day public comment period from December 12, 2014 through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a “Version 2”

Implementation Plan

For those entities meeting the current WECC tuning criteria, implementation of the standard should not be a concern. Should an entity need to make changes to its PSS, concerns have been raised that there are a limited number of qualified personnel to perform those changes. To meet this concern, the team notes that Requirement R5 (as currently numbered on February 17, 2015) allows for up to 24 months to repair or replace a PSS. The Effective Date has been adjusted to reflect an approximate 24 month implementation date in parallel to Requirement R5.

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

There are no new definitions proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**

2. **Number:** VAR-501-WECC-3

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators meeting the definition of Commercial Operation.

6. **Effective Date:** The first day of the first quarter following final regulatory approval, except for Requirement R3 that becomes effective on the first day of the eighth quarter following regulatory approval.

B. Requirements and Measures

R1. Each Generator Operator shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Operator's written operating procedure or other document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). *[Violation Risk Factor: Low] [Time Horizon:* Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in Requirement R1, written operating procedures or other document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the AVR.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the documentation to the Transmission Operator one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as required in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a Bulk-Electric System Element affecting or affected by the PSS;
- Maintenance;
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include but is not limited to:

- A written explanation covering the bulleted exception describing the circumstances of the exception as allowed in Requirement R2.
- Where the exception is claimed under the last bullet of Requirement R2, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R1. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Section 5) below: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide the measured, simulated, or calculated compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine’s nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.
5) Units having an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3

until the voltage regulator is either replaced or retro-fitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Operator will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Section 5 is claimed, the Generator Operator will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retro-fitted.

For auditing purposes, minimum load in Requirement R3, Section 1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of any of the conditions described in Requirement R4, whenever either event occurs after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of: 1) the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and 2) the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

The following sections will be updated after the substance of the Requirements is established. The DT requests that comments on this section not be submitted until the section is complete.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[6] Level of non-compliance on any occasion that the Generator Operator is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[7] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2.

[6] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[7] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						(Requirement R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[8] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[9] Level of non-compliance

[8] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**
[9] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						on any occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Mandate to Install a PSS

Nothing in this standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when described triggering events occur after the Effective Date of the standard, installation of PSS will become mandatory. It should be noted that a PSS is neither transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Operator to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, "active", i.e., providing damping to the power system. Some PSS may be programmed to become "active" at a specified MW loading level and above while others may be programmed to be "active" in a particular band of MW loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard's previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, the automatic voltage regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Posting for Comment

~~On December 3, 2014, the WECC Standards Committee (WSC) approved posting Version 3 of this document for a 30-day comment period. Comments will open December 17, 2014 and close January 16, 2015.~~This document is in its fourth posting.

Procedural Background

Standard Authorization Request (SAR) Consolidation

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when a generator is newly interconnected to the Bulk-Electric System (BES) or when a generator is updated. The WSC further approved merging WECC-0094 VAR-501-WECC-1 Power System Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).

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[3] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection it is seen as both an interconnection-wide issue and a local issue.

WECC Physical Characteristics

The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."

When coupled with generator operations within WECC these physical characteristics create modal oscillation that when not corrected by the installation and accurate operation of PSSs causes instability within the WECC Interconnection.

Description of the Draft

~~**Existing Standard**~~

WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)

Under WECC's current policy, a PSS is installed:

1) On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);

2) On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.

3) On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.

4) On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.

Proposed Standard

~~Under the proposed standard, PSS would be required on those synchronous generators that meet the BES definition.~~

~~The white paper, (April 2014), *Power System Stabilizer Applicability in the WECC System Study Progress Report to WECC-0107 Drafting Team (Draft as of May 28, 2014)* [White Paper], examined the impact on system oscillations when PSS were included or excluded at varying thresholds.~~

~~The white paper concluded:~~

1) ~~In the WECC system model, generator size is inversely proportional to the number of generating units;~~

2) ~~The nature of system-wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions; and,~~

3) ~~There is no technical justification to either exclude or include application of PSS on a generating unit based on size alone.~~

To be updated once the document is more fully developed.

Applicable Entities

~~The proposed standard would apply to the Generator Operator and the Generator Owner.~~

~~Under the NERC Functional Model, it is the task of the Generator Operator, to "report operating and availability status of units and related equipment, such as automatic voltage regulators", of which PSS is a part.[4] "Ultimately the Generator Operator's role is to meet generation schedules, manage fuel supplies, and provide frequency support and reactive resources without jeopardizing equipment."[5]~~

~~It is the role of the Generator Owner to install equipment.~~
To be updated once the document is more fully developed.

Facilities

~~The proposed standard would be applicable only to synchronous units covered by the Bulk-Electric System (BES) definition.~~

[4] NERC Functional Model, Version 5, "Function – Generator Operation", Tasks, page 48.
[5] NERC Functional Model, Version 5, "11 Generator Operator", page 23.

To be updated once the document is more fully developed.

Effective Date

The proposed Effective Date is the first day of the fourth quarter following final regulatory approval.

Requirements and Measures

~~Within existing NERC and WECC Standards, there are currently Requirements to model[6], plan[7], and to run[8] PSS (98% of operating hours except under twelve specified conditions).[9]~~

~~The proposed standard would reframe the requirements as follows.~~

~~Requirement R1 would require the Generator Operator to provide the Transmission Planner with the operating specifications of the Generator Operator's PSS.~~

~~Requirement R2 would mandate that PSS be in service at all times unless specifically exempted. It should be noted that the proposed standard no longer counts the hours to determine whether a specific percentage was met.~~

~~Requirement R3 would mandate tuning of a PSS to meet specific inter-area mode criteria.~~

~~Requirement R4 would mandate installation of PSS on applicable units, but only after a set of specified triggering events.~~
~~Requirement R5 would mandate repair or replacement of PSS within 24 months of that PSS unit becoming non-operational.~~
To be updated once the document is more fully developed.

Measures and Compliance

~~The Measures and Compliance sections will be revisited once the substance of the Requirements has been determined. The drafting team asks that comments on the Measures and Compliance sections be held until after the Requirements are established.~~
To be updated once the document is more fully developed.

[6] MOD-026-1 and MOD-032-1
[7] TPL-001-4, VAR-002-X
[8] VAR-501-WECC-1, Power System Stabilizer
[9] VAR-501-WECC-1, Power System Stabilizer, Requirement R1.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[10]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures	December 23, 2014

[10] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

17. Posting 3 Closed	January 19, 2015[11]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. Posting 4 Responses Posted	
22. WSC approves for ballot	
23. Ballot Pool open	
24. Ballot Pool closed	
25. Joint Session noticed	
26. Joint Session	
27. Ballot open	
28. Ballot closed	
29. WSC approves forwarding to the WECC Board of Directors	
30. Posted for 30 days prior to WECC Board meeting	
31. Board meets to approve	
32. Sent to NERC	

[11] This document was posted for a 30-day public comment period from December 12, 2014 through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a “Version 2”

Implementation Plan

~~To Be Announced~~For those entities meeting the current WECC tuning criteria, implementation of the standard should not be a concern. Should an entity need to make changes to its PSS, concerns have been raised that there are a limited number of qualified personnel to perform those changes. To meet this concern, the team notes that Requirement R5 (as currently numbered on February 17, 2015) allows for up to 24 months to repair or replace a PSS. The Effective Date has been adjusted to reflect an approximate 24 month implementation date in parallel to Requirement R5.

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

There are no new definitions proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**

2. **Number:** VAR-501-WECC-~~2~~3

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard ~~only~~ applies to synchronous generators~~.~~ meeting the definition of Commercial Operation.

6. **Effective Date:** ~~This standard becomes effective on~~ The first day of the ~~fourth~~first quarter following final regulatory approval~~.~~, except for Requirement R3 that becomes effective on the first day of the eighth quarter following regulatory approval.

B. Requirements and Measures

R1. Each Generator Operator shall provide to its Transmission ~~Planner, the operating specifications for the Generator Operator's PSS, describing each condition during which the PSS will be non-operational for purposes of equipment protection or system stability~~Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications~~.~~, the Generator Operator's written operating procedure or other document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). *[Violation Risk Factor: Low] [Time Horizon:* Planning Horizon*]*

M1. Each Generator Operator will have documented evidence that it provided to its Transmission ~~Planner the operating specifications for the Generator Operator's PSS systems, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, describing each condition during which its PSS would be non-operational for purposes of equipment protection or system stability, as required in Requirement R1.~~ Operator, within the time allotted as described in Requirement R1, written operating procedures or other

document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the AVR.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the ~~specifications~~documentation to the Transmission ~~Planner~~Operator one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing ~~damping~~an active signal to the ~~system~~AVR as ~~allowed~~required in Requirement R1, the disabled period does not count against the ~~mandate of~~ Requirement R2~~.~~ mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except ~~when the Generator Operator has notified the Transmission Operator that the PSS is removed from service for~~during any of the following ~~circumstances~~: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a ~~BES~~Bulk-Electric System Element affecting or affected by the PSS;
- Maintenance; ~~or,~~
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception ~~as allowed~~specified in Requirement R2 ~~that includes:~~. Documentation may include but is not limited to:

- ~~1) An~~A written explanation covering the bulleted exception describing the circumstances of the exception~~; (and)~~ as allowed in Requirement R2.

~~2)~~ ~~That~~Where the ~~Transmission Operator was notified that the PSS was not operating as allowed~~exception is claimed under ~~a~~the last bullet of Requirement R2 ~~exception.~~

~~(or)~~

- ~~3) Where applicable~~, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed ~~that~~ the PSS ~~should~~would not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service~~.~~ unless otherwise exempted in Requirement R1. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Section 5) below: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide ~~a~~the measured, simulated, or calculated compensated ~~no~~minimum-load VT/~~V Ref~~Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.~~1~~ 2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase ~~will~~of the Vt/Vref frequency response does not exceed ~~±30~~90 degrees.
2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.
5) Units having an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retro-fitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Operator will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3. ~~Evidence may include, but is not limited to, a completed Attachment A for this standard that reports: 1) output limits, 2) per unit gain, 3) washout time constant, and 4) bode plots of the PSS.~~

If the exception under Requirement R3, Section 5 is claimed, the Generator Operator will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retro-fitted.

For auditing purposes, minimum load in Requirement R3, Section 1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of ~~either connecting a generator to~~ any of the ~~BES or replacing the voltage regulator on its existing excitation system~~conditions described in Requirement R4, whenever either event occurs after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one ~~is intended~~only applies to ~~address newly connected~~ equipment~~; bullet two is intended to address equipment already connected~~ on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a ~~non-operating~~ PSS, within 24 months of that ~~unit~~PSS becoming ~~non-operational.~~incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced ~~a non-operational~~its PSS, within 24 months of that ~~unit~~PSS becoming ~~non-operational.~~incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of: 1) the date the ~~unit~~PSS became ~~non-operational~~incapable of meeting the Requirement R3 tuning specifications, and 2) the date the ~~unit~~PSS was returned to service, demonstrating that the span of time between the two events ~~being within~~was less than 24 months ~~of one another~~.

~~**This section**~~

The following sections will be updated after the substance of the Requirements is established. The DT requests that comments on this section not be submitted until the section is complete.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[12] Level of non-compliance on any occasion that the Generator Operator is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[13] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2.

[12] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[13] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						(Requirement R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Operator's PSS fails to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[14] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[15] Level of non-compliance

[14] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**
[15] (**Guidance VSL**) **For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						on any occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

~~Attachment A~~

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

~~Facilities~~

~~The drafting team considered numerous approaches to setting the Facilities applicability threshold. The drafting team noted that in the approved Version 2 of this standard the 80% facilities applicability threshold was not based on a discrete technical study; rather, the 80% was derived based on sound engineering judgment designed to include 80% of the units located within the Western Interconnection.~~

~~Subsequent to approval of Version 2, the Bulk Electric System (BES) proceeding queried the industry as to the most appropriate definition of the BES, with the final decision becoming the threshold at which NERC standards would apply. When compared to the Version 2 proceedings the BES proceedings were much more in-depth, represented a greater diversity of industry viewpoints, and engaged a substantial array of subject matter experts not otherwise represented in the Version 2 filing.~~

~~Noting the additional depth and breadth of the BES when juxtaposed to the Version 2 participation the drafting team concluded that the industry has already opined on the adequate threshold at which NERC Reliability Standards should apply. As such, the drafting team opted to use the default BES threshold as it more broadly represents the consensus of the industry.~~

Mandate to Install a PSS

Nothing in this standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when described triggering events occur after the Effective Date of the standard, installation of PSS will become mandatory. It should be noted that a PSS is neither transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard. ~~If the PSS is not operating in accordance with the documentation provided to the Transmission Planner, this could be considered a status change for purposes of NERC VAR-002-3, Requirement R3.~~

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Operator to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, “active”, i.e., providing damping to the power system. Some PSS ~~maybe~~may be programmed to become “active” at a specified MW loading level and above while others ~~maybe~~may be programmed to be “active” in a particular band of MW loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).~~ Unlike Requirement R1, the circumstances listed in Requirement R2 are not consider normal operation of the PSS.~~

Requirement R3

The intent of Requirement R3 is to ~~clarify~~specify the tuning requirements ~~associated with the tuning~~ of the ~~parameters in the~~ PSS.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

~~The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.~~

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS.   It is recognized that in some instances, the automatic voltage regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.

WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 4
April 17, 2015 through May 19, 2015

Posting #4

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed document.

Posting

This document was last posted for a 30-day public comment period from April 17, 2015 through May 19, 2015.

WECC distributed the notice for the posting on April 15, 2015. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from four companies representing five of the eight Industry Segments, as shown in the WECC Standards Voting Sector Table that follows.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the “Submit and Review Comments” accordion.

Changes in Response to Comment

In reviewing Requirement R1 in conjunction with the *NERC Functional Model Version 5*, the DT changed the applicable entity in Requirement R1 (and also Requirement R3) and the associated Measure from Generator Operator to Generator Owner (Tacoma comment), and also clarified “as described in the procedures required in Requirement R1” (Bureau of Reclamation comment) as follows:

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS’s Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner’s written operating procedure or other document(s) describing those known circumstances during which the Generator Owner’s PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). [Violation Risk Factor: Low] [Time Horizon: Planning Horizon]

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written operating procedures or other document(s) describing those known circumstances during which the Generator Operator’s PSS will not be providing an active signal to the AVR.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the documentation to the Transmission Operator one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in the procedures required in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

Effective Date

The Effective Date changed as follows creating a tiered compliance based on when the units are placed into service. The associated Implementation Plan and justification were added to the preamble of the document.

6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

Action Plan

The Arizona Public Service (APS) commented that the language of Requirement R3 addressing Vt/Vref implies Vt/Vref must be measured at minimum load. APS recommended the minimum load requirements be removed. Although the DT disagreed with APS, the DT took as an action item to further consider a descriptive and clarifying narrative to accompany the Requirement in the standard's guidance/rationale section.

A white paper titled *WECC-0107 VAR-501-WECC-2, Power System Stabilizers, Use of Minimum Load for Tuning in Proposed Requirement R3* was reviewed by the drafting team on July 2, 2015 and posted on the WECC-0107 project page, on the Posted for Comment accordion. The paper is not offered for comment; rather, it is provided for individual use as a decision making tool.

Not all of the DT agreed with the conclusion of the paper that minimum-load is the best premise for tuning; however, the DT did see the value as presented in the paper. The DT opted not to change the minimum-load requirement in Requirement R3 but did accommodate the imposed burden by creating a tiered Effective Date (see above).

On July 2, 2015, the DT agreed by majority vote to repost the document for 30-day comment. The project is targeted for comment from July 7 through August 6, 2015. The DT will reconvene to address comments on August 7, 2015, 10:00 a.m. to 12:00 p.m., to address comments. If no further substantive changes are made on that date, the DT will forward the project to the WECC Standards Committee on August 12, 2015 with a request for ballot.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

WECC Standards Voting Sector Table

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
B			1	2	3	4	5	6	7	8
1	Joseph Wilson	Tacoma Power	X	X	X	X	X			
2	Kristie Cocco	Arizona Public Service Company (APS)	X	X	X	X	X			
3	Erika Doot	Bureau of Reclamation	X	X						
4	David Lemmons	Xcel Energy/Public Service Company of Colorado	X	X	X	X	X			

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

The drafting team welcomes comments on all aspects of the document.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Tacoma			Requirement 1 (R1) Tacoma Power suggests separating R1 into two Requirements. The new requirement would require the Generator Owner to communicate to the Generator Operator any changes to the PSS configuration describing those known circumstances during which the PSS will not be providing an active signal to the Automatic Voltage Regulator. The Generator Owner is responsible for specification, installation, configuration and maintenance of the PSS and AVR. The second requirement would then state that the Generator Operator is responsible for communicating these changes to the Transmission Operator. Having two clear requirements outlining the communication flow between entities eliminates confusion. Measure 3 (M3) In the first paragraph change "Operator" to "Owner".
Suggested Bifurcation of Requirement R1 The DT appreciates Tacoma's request to restructure the requirement; however, the DT disagrees that the requested separation is needed. In further reviewing Requirement R1 in conjunction with the *NERC Functional Model Version 5*, the DT changed the applicable entity in Requirement R1 and the associated Measure from Generator Operator to Generator Owner, as follows: **R1.** Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written operating procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*			
AZPS			AZPS submits the following comments to WECC-0107 Posting 4: Page 3 of 25 – Description of the Draft AZPS recommends that Paragraph 1) should be modified to reflect

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			100 kV to match the new BES definition. Page 11 of 25 – A. Introduction AZPS recommends Section 5 – Facilities should be modified for clarity as follows: This standard applies to synchronous generation connected to the BES meeting the definition of Commercial Operation. Page 12 of 25 – R2 AZPS recommends the exceptions listed in R2 include operating generator below PSS threshold loading (historically this was exception R1.5). Page 13 of 25 – R3 R3 implies that Vt/Vref must be measured at minimum load. AZPS recommends that the minimum load requirement be removed for the following reasons: •For many units, full load is a better measurement point for Vt/Vref for tuning PSS. This is how it has been done historically. •Many units are barely stable at minimum load and hence it is problematic to measure Vt/Vref at minimum load. Even if it can be measured it may not be possible to measure instability gain at the minimum load. •If PSS settings are based upon calculations it is simple to use any load; however, many utilities, including AZPS, prefer to set PSS based upon actual field measurements so that there are no errors related to system models. •If minimum loading requirements are maintained, all of the existing settings will become invalid and will require that PSS of all units in AZPS system (and in other systems) be retuned and the frequency response re-measured. •If the drafting team believes Vt/Vref must absolutely be measured at minimum load, please provide sufficient technical

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			background and solutions to the problems mentioned above.

Description and Preamble

The DT appreciates AZPS' suggested changes to the document's preamble. For the next posting the entire preamble will be removed. AZPS's observations will be considered for inclusion in the final filing narrative, should the project reach that stage.

Introduction to Include BES

The DT has opted not to include the reference to BES as the BES threshold is the default for all NERC Standards.

Include Operating Generator below PSS Threshold Loading

The drafting team disagrees with this suggestion. The PSS should be in-service according to the information provided to the Transmission Operator in Requirement R1. It may not be providing an active signal to the Automatic Voltage Regulator if the generator is operating below the PSS threshold.

Removal of Minimum Load

The phrase "minimum-load VT/Vref" has been retained.

APS commented that the language of Requirement R3 addressing Vt/Vref implies Vt/Vref must be measured at minimum load. APS recommended the minimum load requirements be removed. Although the DT disagreed with APS, the DT took as an action item to further consider a descriptive and clarifying narrative to accompany the Requirement in the standard's guidance/rationale section.

Subsequent entry July 2, 2015:

On July 2, 2015, the DT met to further discuss the minimum-load issue. A white paper, *WECC-0107, Power System Stabilizers, Use of Minimum-Load for Tuning in Proposed Requirement R3*, explaining the premise for the minimum-load requirement, was presented and reviewed. The paper was posted for review at the WECC-0107 project page on the Posted for Comment accordion. The white paper is in support of using minimum-load for tuning purposes; however, not all of the DT concurs with the analysis.

The DT encourages each entity to review the white paper and make a well-reasoned decision thereafter.

In redrafting Requirement R3, the DT concluded that tuning may be completed by measurement, simulation, or calculation. (Determining the gain is not part of the Requirement.) The DT agrees with APS that actual field measurement is highly valued but also notes that actual field measurements are not the only means to meet the reliability-related task. Retaining the three options provides the field with some

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

latitude.

The DT concurs that as drafted, Requirement R3 may require retuning of existing units. To provide the field a reasonable window of compliance, the Effective Date of Requirement R3 has been modified. For new units, the requirement becomes effective with the regularly established approval date. For units already in the field and already adequately tuned to existing tuning parameters, Requirement R3 will not become effective until five years after the regulatory approval date. The new Effective Date is as follows:

6. Effective Date: The first day of the first quarter following regulatory approval, except for Requirement R3.

For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

Commenter	Yes	No	Comment
Bureau of Reclamation			The Bureau of Reclamation (Reclamation) agrees with the drafting team's explanation in M1 of the relationship between R1 and R2. However, Reclamation believes the phrasing should be "as described in the procedures required under Requirement R1," rather than "as required in Requirement R1." The updated statement would read, "For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in the procedures required under Requirement R1, the disabled period does not count against Requirement R2." In addition, this statement may be more appropriate for inclusion in M2 because evidence described in M1 is the operating specifications rather than operational information. Reclamation supports the PSS tuning specifications included in R3. Reclamation agrees with the 24-month PSS repair or replacement timeframe included in R5.

Measure M1 suggested language “as described in the procedures required under Requirement R1."

This language was accepted. The new Measure M1 now reads:

M1. Each Generator Operator will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Requirement R1, written operating procedures or other document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the AVR. For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the documentation to the Transmission Operator one time or whenever the operating specifications change thereafter. For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in the procedures required in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.			
PSCo/Xcel			Public Service Company of Colorado appreciates the efforts made by the standard drafting team to improve the existing WECC Regional Reliability Standard VAR-501-WECC-2. This proposed document is a significant improvement over the current standard. However, PSCo has identified two issues of concern with the draft document. These issues are: R4 – PSCo recommends that the drafting team add the phrase "have plans to" prior to the word install. This would allow the unit [to] address issues with the PSS without violating the requirement if the commissioning process for the PSS is delayed. As currently written, the unit would be in violation of the requirement whether it operates or not if the PSS commissioning is not completed within 180 days of the unit achieving Commercial Operation. R3 and R5 Coordination – As currently written, it is unclear if a PSS that meets the R3 item 5 exemption must be replaced under R5 of the standard. It is our understanding that the intent is to not require an older PSS be replaced within 24 months of the standard becoming effective. However, in both R3 item 5 and R5, the drafting team has used the term "incapable" which may cause confusion as to when a PSS must be replaced. The drafting team should discuss utilizing different terms in the two requirements to differentiate older equipment from equipment that has a mechanical or electrical issue occur. As an example, using the word "unable" in R3 #5 could help differentiate the two items without significantly changing the intent of the exclusion.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**

R4 – PSCo recommends that the drafting team add the phrase "have plans to" prior to the word install.

The DT does not agree with PSCo's recommendation in that the existing wording is clear and the timeframe is adequate to meet the requirement. PSCo's suggestion to include "having a plan" or "having plans to" perform a task is ambiguous and open-ended.

The DT also recognizes that under extreme circumstances there are times when a potential violation of the requirement could occur due to circumstances beyond the control of the applicable entity. (In contract terms this would be a force majeure.) Bounding all such fact patterns in a requirement is not practical.

R3 and R5 Coordination/Clarification

The DT opted not to make any further changes to Requirements R3 and R5. The language in Requirement R3 looks *forward* to ensure that a unit is tuned. By contrast, the language in Requirement R5 looks *backwardb.*

Specifically, the language in Requirement R5 "becoming incapable" indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working – AKA: they are now broken.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

16. FERC approved new WECC Reliability Standards Development Procedures	December 23, 2014
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
26. Posting 5 Responses Posted	
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot open	
32. Ballot closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	

[2] This document was posted for a 30-day public comment period from December 12, 2014 through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

35. Board meets to approve	
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a "Version 2"

Implementation Plan

VAR-501-WECC-2, Power System Stabilizers (PSS)

Standards Authorization Request

WECC-0107 VAR-501-WECC-2 Power System Stabilizer Standards Authorization Request

Approvals Required

VAR-501-WECC-2, Power System Stabilizers (PSS)

Prerequisite Approvals

- WECC Ballot Pool
- WECC Standards Committee
- WECC Board of Directors
- NERC Board of Trustees
- Federal Energy Regulatory Commission and other regulatory authorities

Applicable Entities

Generator Operator
Generator Owner

Conforming Changes to Other Standards

None required.

Effective Date

6. Effective Date: The first day of the first quarter following regulatory approval, except for Requirement R3.

For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

Justification

The document has a standardized effective date with the exception of Requirement R3.

The Effective Date recognizes that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of the Requirement R3 ameliorates the burden.

For units placed into first-time service after regulatory approval, those units will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden, while still enhancing reliability in the earlier years of this standard's implementation.

For units already in service prior to regulatory approval and tuned to existing tuning parameters, many of these units are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Interconnection at a date certain.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Retirements

This document will replace VAR-501-WECC-1, Power System Stabilizer.

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

There are no new definitions proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**

2. **Number:** VAR-501-WECC-3

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators meeting the definition of Commercial Operation.

6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written operating procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). [Violation Risk Factor: Low] [Time Horizon: Planning Horizon]

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written operating procedures or other

document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the AVR.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the documentation to the Transmission Operator one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in the procedures required in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a Bulk-Electric System Element affecting or affected by the PSS;
- Maintenance;
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include but is not limited to:

- A written explanation covering the bulleted exception describing the circumstances of the exception as allowed in Requirement R2.
- Where the exception is claimed under the last bullet of Requirement R2, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R1. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Section 5) below: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide the measured, simulated, or calculated compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0

Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.
5) Units having an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retro-fitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Section 5 is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retro-fitted.

For auditing purposes, minimum load in Requirement R3, Section 1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of any of the conditions described in Requirement R4, whenever either event occurs after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of: 1) the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and 2) the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[3] Level of non-compliance on any occasion that the Generator Owner is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[4] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2. (Requirement

[3] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[4] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[5] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[6] Level of non-compliance on any

[5] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**
[6] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	**Moderate VSL**	**High VSL**	**Severe VSL**
						occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Mandate to Install a PSS

Nothing in this standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when described triggering events occur after the Effective Date of the standard, installation of PSS will become mandatory. It should be noted that a PSS is neither transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, “active”, i.e., providing damping to the power system. Some PSS may be programmed to become “active” at a specified MW loading level and above while others may be programmed to be “active” in a particular band of MW loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Unlike the language in Requirement R5 that looks *backwards* to address units that were once operating but are no longer capable of operating (AKA: broken), Requirement R3 looks *forward* requiring that units be tuned to the specified parameters.

The intent of Requirement R3 is to specify the tuning requirements of the PSS. This is a forward-looking requirement as opposed to Requirement R5 that is a backward-looking requirement.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backwards.* Specifically, the language in Requirement R5 "becoming incapable" indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working – AKA: they are now broken.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, the Automatic Voltage Regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

~~Posting for Comment~~

~~This document is in its fourth posting.~~

~~Procedural Background~~

~~Standard Authorization Request (SAR) Consolidation~~

~~WECC-0094 VAR-501-WECC-"1" PSS and the ballot results of the WECC-0105 P81 redraft have been merged into WECC-0107 VAR-501-WECC "3" resulting in a document applicable to the BES.~~

~~This Standards Authorization Request (SAR) to review WECC's PSS-related documents is in response to a WECC Board of Director's resolution.~~

~~On September 5, 2012, the WECC Board of Directors adopted the recommendation of the Regional Criteria Work Group that a (SAR) should be filed to evaluate VAR-502-WECC-RBP-1[1], WECC Power System Stabilizer (PSS) Design and Performance, a Regional Business Practice (RBP), for development as a WECC Regional Reliability Standard (RRS). Under WECC-0099, the WECC Control Work Group conducted the review concluding that a RRS should be drafted.~~

~~On February 11, 2014 during the WECC Standards Committee (WSC) meeting:~~

> ~~"A motion was made by Mr. Joe Tarantino that was seconded by Ms. Dana Cabbell to retire WECC-0099 having determined that the assigned project was complete, and to approve the proposed iterative SAR [WECC-0107] to develop a Power System Stabilizer RRS. The motion carried by Consensus. Mr. Warren Rust abstained." WSC Meeting Minutes~~

~~On June 25, 2014, the WSC changed the scope of the SAR directing that the proposed document be structured so that PSS: 1) where installed, be operating unless specifically exempted, 2) tuned as specified, and 3) where not installed, installation would be required when a generator is newly interconnected to the Bulk Electric System (BES) or when a generator is updated. The WSC further approved merging WECC-0094 Power System~~

[1] In June 2014, the WECC Board of Directors resolved to eliminate the Regional Business Practice (RBP) category defaulting to a WECC Criterion (CRT) category.

~~Stabilizers into the document and incorporating the "P81", VAR-501-WECC-2, revisions resulting from WECC-0105 (ballot closed July 18, 2014).~~

~~**Standard of Review**~~

~~The Federal Energy Regulatory Commission (FERC) has stated that Regional Entity Standards or Regional Variances to a NERC Reliability Standard (Standard) are permissible if they set more stringent reliability requirements than the NERC Reliability Standard; or cover matters not covered by an existing NERC Reliability Standard; or if they are necessitated by a physical difference in the Bulk-Electric System (BES).~~[2]

~~Operational Background~~

~~Power System Stabilizers (PSS) are needed in the Western Interconnection to dampen operational oscillation.~~

~~PSSs are part of the Automatic Voltage Regulation (AVR) system of a generator and are designed to add or subtract torque to a generator with the goal of damping oscillations on the WECC Interconnection's Bulk-Electric System (BES) that otherwise would be amplified if the AVR is operated by itself.~~

~~PSSs within WECC (originally called Supplementary Control Systems) were developed in the 1960s in response to power system oscillations on the Pacific Intertie within the Western Interconnection. These oscillations occur at very low frequencies (<1 hertz), are very lightly dampened, and became known as "inter-area modes" (modes) of oscillation because they occurred when real power was transferred from one Western Interconnection geographic region to another (such as between the Pacific Northwest and the Southwest).~~

~~These modal oscillations are the result of a combination of many machines on one part of the Western Interconnection BES whose voltage support response to system fluctuations is not in phase with the response of machines on another part of the Interconnection's BES.~~[3]

[2] Order No. 672 at P 291. See also NERC Functional Model, Version 5, "2. Reliability Standards", page 36.

[3] While some areas of other interconnections may experience this phenomenon, it is typically seen as only a local issue, not an issue for the entire interconnection. In the Western Interconnection it is seen as both an interconnection-wide issue and a local issue.

~~WECC Physical Characteristics~~

~~The Federal Energy Regulatory Commission (FERC) Order 740, Docket No. RM09-15-000, P23, noted that "in the Western Interconnection a significant number of transmission paths are voltage or frequency stability-limited, in contrast to other regions of the [BES] where transmission paths more often are thermally-limited. Disturbances resulting in a stability-limited transmission path overload, generally, must be responded to in a shorter time frame than a disturbance that results in a thermally-limited transmission path overload. [FERC has also noted] its understanding that this physical difference is one of the reasons for the need for certain provisions of regional Reliability Standards in the Western Interconnection."~~

~~When coupled with generator operations within WECC these physical characteristics create modal oscillation that when not corrected by the installation and accurate operation of PSSs causes instability within the WECC Interconnection.~~

~~Description of the Draft~~

~~WECC currently does not have a *RRS* that specifies the threshold at which a PSS must be installed; however, WECC does have an existing *policy* that addresses that threshold. (Under WECC's current policy, a PSS is not installed on a station service generator.)~~

~~Under WECC's current policy, a PSS is installed:~~

1) ~~On synchronous generators, regardless of ownership, that are connected to the transmission system (by a generator step-up transformer to 60 kV or higher voltage);~~

2) ~~On every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the WECC report "Criteria to Determine Excitation System Suitability for PSS", (Report) dated December 1992.~~

3) ~~On every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the above mentioned Report. This applies to all machines with excitation systems updated after November 18, 1993.~~

4) ~~On every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems commissioned after November 18, 1993.~~

~~Proposed Standard~~

~~To be updated once the document is more fully developed.~~

~~Applicable Entities~~

~~To be updated once the document is more fully developed.~~

~~Facilities~~

~~To be updated once the document is more fully developed.~~

~~Effective Date~~

~~The proposed Effective Date is the first day of the fourth quarter following final regulatory approval.~~

~~Requirements and Measures~~

~~To be updated once the document is more fully developed.~~

~~Measures and Compliance~~

~~To be updated once the document is more fully developed.~~

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits / assigns a drafting team (DT)	March 12, 2014
5. DT announced / notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC Changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[4]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures	December 23, 2014

[4] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting of responses. The WSC agreed that a quality response was preferable to a timely response.

17. Posting 3 Closed	January 19, 2015[5]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
26. Posting 5 Responses Posted	
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot open	
32. Ballot closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	

[5] This document was posted for a 30-day public comment period from December 12, 2014 through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0.1	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			This document is designed to replace / retire: VAR-502-WECC-RBP-0.1, WECC Power System Stabilizer Design and Performance and to replace VAR-501-WECC-1, Power System Stabilizer with a "Version 2"

Implementation Plan

VAR-501-WECC-2, Power System Stabilizers (PSS)

Standards Authorization Request

WECC-0107 VAR-501-WECC-2 Power System Stabilizer Standards Authorization Request ~~For those entities meeting the current WECC tuning criteria, implementation of the standard should not be a concern. Should an entity need to make changes to its PSS, concerns have been raised that there are a limited number of qualified personnel to perform those changes. To meet this concern, the team notes that Requirement R5 (as currently numbered on February 17, 2015) allows for up to 24 months to repair or replace a PSS. The Effective Date has been adjusted to reflect an approximate 24 month implementation date in parallel to Requirement R5.~~

Approvals Required

VAR-501-WECC-2, Power System Stabilizers (PSS)

Prerequisite Approvals

- WECC Ballot Pool
- WECC Standards Committee
- WECC Board of Directors
- NERC Board of Trustees
- Federal Energy Regulatory Commission and other regulatory authorities

Applicable Entities

Generator Operator
Generator Owner

Conforming Changes to Other Standards

None required.

Effective Date

6. Effective Date: The first day of the first quarter following regulatory approval, except for Requirement R3.

For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

Justification

The document has a standardized effective date with the exception of Requirement R3.

The Effective Date recognizes that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of the Requirement R3 ameliorates the burden.

For units placed into first-time service after regulatory approval, those units will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden, while still enhancing reliability in the earlier years of this standard's implementation.

For units already in service prior to regulatory approval and tuned to existing tuning parameters, many of these units are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Interconnection at a date certain.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Retirements

This document will replace VAR-501-WECC-1, Power System Stabilizer.

Definitions of Terms Used in Criterion

This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.

There are no new definitions proposed.

A. Introduction

1. **Title:** **Power System Stabilizers (PSS)**

2. **Number:** VAR-501-WECC-3

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions, by establishing the performance criteria for WECC power system stabilizers

4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators meeting the definition of Commercial Operation.

6. **Effective Date:** The first day of the first quarter following ~~final~~ regulatory approval, except for Requirement R3~~ that becomes effective on the first day of the eighth quarter following regulatory approval. ~~.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator ~~**Operator**~~Owner shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator ~~**Operator's**~~Owner's written operating procedure or other document(s) describing those known circumstances during which the Generator ~~**Operator's**~~Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). [Violation Risk Factor: Low] [Time Horizon: Planning Horizon]

M1. Each Generator ~~**Operator**~~Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written operating procedures or other

document(s) describing those known circumstances during which the Generator Operator's PSS will not be providing an active signal to the AVR.

For auditing purposes, because the Requirement R1 conditions are intended to be unchanged unless otherwise notified, the Generator Operator need only provide the documentation to the Transmission Operator one time or whenever the operating specifications change thereafter.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in the procedures required in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

- Component failure;
- Testing of a Bulk-Electric System Element affecting or affected by the PSS;
- Maintenance;
- As agreed upon by the Generator Operator and the Transmission Operator.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include but is not limited to:

- A written explanation covering the bulleted exception describing the circumstances of the exception as allowed in Requirement R2.
- Where the exception is claimed under the last bullet of Requirement R2, the Generator Operator will have documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R1. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Section 5) below: *[Violation Risk Factor: Medium] [Time Horizon:* Operating Assessment*]*

1) PSS shall be set to provide the measured, simulated, or calculated compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0

Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

2) PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.
3) PSS gain shall be set to between 1/3 and ½ of maximum practical gain.
4) PSS washout time constant shall be no greater than 30 seconds.
5) Units having an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retro-fitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator ~~Operator~~Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Section 5 is claimed, the Generator ~~Operator~~Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retro-fitted.

For auditing purposes, minimum load in Requirement R3, Section 1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and commission on its generator a PSS, within 180 days of either of the following events: [Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard; (or)
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation, and after the Effective Date of this standard for its generator that is connected to the BES.

M4. Each Generator Owner will have evidence that it installed and commissioned a PSS on its generator, within 180 days of any of the conditions described in Requirement R4, whenever either event occurs after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS, within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of: 1) the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and 2) the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

~~**The following sections will be updated after the substance of the Requirements is established. The DT requests that comments on this section not be submitted until the section is complete.**~~

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

The Regional Entity shall serve as the Compliance Enforcement Authority.

For entities that do not work for the Regional Entity, the Regional Entity shall serve as the Compliance Enforcement Authority.

For Reliability Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.

1.2 Compliance Monitoring and Assessment Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Investigations

Self-Reporting

Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	There shall be a Severe[6] Level of non-compliance on any occasion that the Generator Owner is found to have failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1. (Requirement R1 is binary.)
R2	Operations Assessment	Medium	NA	NA	NA	There shall be a Severe[7] Level of non-compliance on any occasion that the Generator Operator fails to have its PSS in service, except where allowed in Requirement R2. (Requirement

[6] (Guidance VSL) For R1, Severe was chosen because the violation is binary.
[7] (Guidance VSL) For R1, Severe was chosen because the violation is binary.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						R2 is binary.)
R3	Operations Assessment	Medium	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, two times or less during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, three times during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, four times during the audit period.	Occurs when the Generator Owner's PSS fails to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[8] Level of non-compliance on any occasion that the Generator Owner is found to have failed to install on its generator a PSS, as required n Requirement R4. (Requirement R4 is binary.)
R5	Operational Assessment	Medium	NA	NA	NA	There shall be a Severe[9] Level of non-compliance on any

[8] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**
[9] **(Guidance VSL) For R1, Severe was chosen because the violation is binary.**

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						occasion that the Generator Owner is found to have failed to repair or replace a non-operational PSS as required in Requirement R5. (Requirement R5 is binary.)

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out-of-service whenever necessary.

Mandate to Install a PSS

Nothing in this standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when described triggering events occur after the Effective Date of the standard, installation of PSS will become mandatory. It should be noted that a PSS is neither transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. So long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator ~~Operator~~Owner to create a unit-specific operating plan.

The intent of the Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is, "active", i.e., providing damping to the power system. Some PSS may be programmed to become "active" at a specified MW loading level and above while others may be programmed to be "active" in a particular band of MW loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a MW loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in-service. In this standard's previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Unlike the language in Requirement R5 that looks *backwards* to address units that were once operating but are no longer capable of operating (AKA: broken), Requirement R3 looks *forward* requiring that units be tuned to the specified parameters.

The intent of Requirement R3 is to specify the tuning requirements of the PSS. This is a forward-looking requirement as opposed to Requirement R5 that is a backward-looking requirement.

The PSS transfer function should compensate the phase characteristics of the generator excitation power system (GEP) transfer function so the compensated transfer function ((PSS(s) X GEP(s)) has a phase characteristic of +/- 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set-point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires that the final PSS gain should be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or the raise of higher frequency oscillations in the closed loop response (exciter mode) or any other form if inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.

Requirement R4

Requirement R4 requires a Generator Owner to install PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems, not existing systems without PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backwards.* Specifically, the language in Requirement R5 “becoming incapable” indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working – AKA: they are now broken.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair / replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, the Automatic Voltage Regulator may require replacement as well as the PSS to achieve a functioning system.

The 24 month timeframe is sufficient to return a functional, operating PSS to service.

WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 5
July 7, 2015 through August 6, 2015

Posting #5

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed document.

Posting

This document was last posted for a 30-day public comment period from July 7 through August 6, 2015.

WECC distributed the notice for the posting on July 2, 2015. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from three companies representing five of the eight Industry Segments, as shown in the WECC Standards Voting Sector Table that follows.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the "Submit and Review Comments" accordion.

Changes in Response to Comment

In response to comments provided by Tacoma Power, the reference to the Generator Operator in Measure 1 was corrected to read Generator Owner. Additionally, numerous other formatting and style changes were made in response to NERC Quality Review.

Action Plan

Because the corrected reference is a substantive change, the document will be reposted for 30-day comment. Comments will be solicited only on the proposed correction. The document is targeted for comment from September 3 through October 5, 2015. The drafting team will reconvene on October 20, 2015 from 10:00 a.m. to 12:00 p.m. (Mountain) to address comments.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

WECC Standards Voting Sector Table

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
1	Chad Edinger	Tacoma Power	X	X	X	X	X			
2	Kristie Cocco	Arizona Public Service Company (APS)	X	X	X	X	X			
3	Joshua Anderson	Salt River Project	X	X	X	X	X			

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

The drafting team welcomes comments on all aspects of the document.

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Tacoma			Section M1: First paragraph, at the end of the paragraph, Generator Operator needs to change to Generator Owner to be consistent with R1. Second paragraph, Generator Operator needs to change to Generator Owner to be consistent with R1.
The correction has been made.			
AZPS			AZPS submits the following comments to WECC-0107 Posting 5: AZPS appreciates the Drafting Team providing a delayed implementation date as a result of Requirement R3 necessitating changes to existing practices. While AZPS believes this delayed implementation date will afford entities the time needed to achieve compliance with this revised Requirement, we would like to reiterate that measuring GEP(s) at full load has been a successful industry practice for many years. We are also aware of an Institute of Electrical and Electronics Engineers (IEEE) paper that has been provided to the Drafting Team by Mr. Pouyan Pourbeik which indicates that this transfer function is relatively invariant in its phase response to changes in load, system configuration, etc. All these factors have a second order effect on the phase response of the transfer function. As such, we would encourage the Drafting Team to revise its stance on requiring measurement at no load which is contrary to the technical evidence.
Revise Stance on Requiring Measurement at No Load The DT appreciates AZPS' request to revisit the no-load issue; however, the DT continues to hold to its position presented in the WECC-0107, Posting 5, VAR-501-WECC-3 Power System Stabilizers, Use of Minimum Load for Tuning – White Paper (currently posted at the WECC-0107 project page at the Posted for Comment accordion) that was commissioned largely at the request of APS/AZPS. The no-load concept was introduced and adopted in response to lengthy comments provided by Kestrel Power Engineering, Posting 2, Comment 1, (referencing two IEEE documents in support) where in summary Kestrel argued that performing the frequency response test "with the generator at near full load is incorrect,			

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
resulting in an incorrect measurement of the required phase compensation for the PSS…This resonance effect also introduces error into the magnitude and phase characteristics of the measurement, which are eliminated when the measurement is performed at no load.” The DT concluded that although other approaches are possible, adoption of the no-load approach enhanced the tuning process.			
Salt River Project			SRP is concerned about the change in R2 for the PSS to be "in service while synchronized, except during any of the following:" the prior requirement was for the PSS to be in service "over 98% of the time in the quarter". SRP feels that the minor difference from expecting the PSS to be in service "while Synchronized" and "over 98% of the time" does not pose a significant reliability issue. The 98% requirement provides a little flexibility in the requirement. There may be times that the PSS is not in service that do not fit precisely in the options given. As the R2 is written it appears the PSS must be in service at all times when synchronized. However, there may be small timing delays that may cause the PSS to not be "in service" every second or every cycle the generator is synchronized. SRP recommends retaining the language from the prior standard and require the PS in service over 98% of the time.
Requirement R2: 98% vs. synchronized / Request Retention of 98% Language The DT appreciates SRP’s request to revisit the 98 percent issue; however, the DT continues to hold to its existing position. The DT would point SPR to its Response to Comments to WPTF in Posting 1, Issue 5, where in summary, the DT states that Requirements R1 and R2 as proposed “provide the generator Owner with broader, non-exhaustive, less restrictive sets of events during which operation is not required. The counterbalance to this flexibility is the requirement that the PSS be always in-service unless specifically explained.” See also the DT Response to Comments to PPL Montana, Posting 1, Issue 3 (and Issue 6), where in summary the DT states “Rather than specify a period of time during which the PSS could be out-of-service *for any reason* (the 2% of the current standard), the proposed standard shifts to a requirement that the PSS shall be in service at all times…*except when specifically exempted*.”			

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
16. FERC approved new WECC Reliability Standards Development Procedures	December 23, 2014
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
26. Posting 5 Responses Posted	
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Completed Actions	Completion Date
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSS)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSS)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective.

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ameliorates the burden.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and setup. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden. Many of the units already in service prior to regulatory approval and tuned to existing tuning parameters are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS' Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR*). [Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below. *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated minimum-load Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5 percent of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between ⅓ and ½ of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5 is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

For auditing purposes, minimum load in Requirement R3, Part 3.1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, the first bullet only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install a PSS on its generator, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of a PSS solely because one is not currently installed as of the Effective Date of this standard. However, when triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of PSSs will become mandatory pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates counting hours, as required in the previous version of this standard, while allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active"; i.e., providing damping to the power system. Some PSSs may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSSs in service. In the previous version, the logged hours were totaled quarterly to meet the 98 percent in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power system (Generator Excitation Power System (GEP)) transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref), and of using the phase characteristic of that frequency response as the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between ⅓ and ½ of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSSs. The Requirement also allows a reasonable amount of time for commissioning of new PSSs.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically,*;* the language in R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement

R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the “tiered” approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
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10. Posting 1 Responses Posted	September 26, 2014
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14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures.	December 23, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
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27. Ballot Pool open	
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29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Completed Actions	Completion Date
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-~~2~~3, Power System Stabilizers (~~PSS~~PSSs)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

~~Approvals Required~~

Applicable Standards

- VAR-501-WECC-~~2~~3, Power System Stabilizers (~~PSS~~PSSs)

~~Prerequisite Approvals~~

- ~~WECC Ballot Pool~~
- ~~WECC Standards Committee~~
- ~~WECC Board of Directors~~
- ~~NERC Board of Trustees~~
- ~~Federal Energy Regulatory Commission and other regulatory authorities~~

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

~~None required.~~

N/A

Effective Date

~~6. Effective Date:~~ ~~The first~~ Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter ~~following regulatory approval, except~~after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for ~~Requirement R3.~~

by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 ~~is~~shall become effective the first day of the first calendar quarter ~~following final regulatory approval.~~

after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 ~~is~~shall become effective the first day of the first calendar quarter that is five years after ~~regulatory approval.~~ the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective.

Justification

~~The document has a standardized effective date~~ With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

~~The~~Use of this separate Effective Date ~~recognizes~~for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of ~~the~~ Requirement R3 ameliorates the burden.

~~For~~ Units placed into first-time service after regulatory approval~~, those units~~ will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden~~, while still enhancing reliability in the earlier years~~. Many of ~~this standard's implementation.~~

~~For~~the units already in service prior to regulatory approval and tuned to existing tuning parameters~~, many of these units~~ are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection~~ at a date certain~~.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

~~**Retirements**~~

~~This document will replace VAR-501-WECC-1, Power System Stabilizer.~~

Definitions of Terms ~~Used in Criterion~~

~~This section includes all newly defined or revised terms used in the proposed criterion. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed criterion is approved. When the criterion becomes effective, these definitions will be removed from the criterion and added to the WECC Glossary.~~

~~There are~~ No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (~~PSS~~PSSs)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions~~,~~ by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators ~~meeting~~that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR*)*. *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator ~~Operator's~~Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because ~~the~~ Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator ~~Operator need~~Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change ~~thereafter.~~.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in ~~the procedures required in~~ Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure~~;~~
- Testing of a Bulk ~~-~~Electric System Element affecting or affected by the PSS~~;~~
- Maintenance ~~;~~
- As agreed upon by the Generator Operator and the Transmission Operator~~.~~

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception ~~describing~~that describes the circumstances of the exception as allowed in Requirement R2.
- ~~Where the exception is claimed under the last bullet of Requirement R2, the Generator Operator will have~~ Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement ~~R1~~R2. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, ~~Section~~ Part 3.5~~)~~ below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated minimum-load VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and ~~½~~1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units ~~having~~that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or ~~retro-fitted~~retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, ~~Section~~ Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or ~~retro-fitted~~retrofitted.

For auditing purposes, minimum load in Requirement R3, ~~Section~~ Part 3.1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.

R4. Each Generator Owner shall install and ~~commission~~complete start-up testing of a PSS on its generator ~~a PSS,~~ within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard~~; (or)~~.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard ~~for its generator that is connected to the BES~~.

M4. Each Generator Owner will have evidence that it installed and ~~commissioned~~ completed start-up testing of a PSS on its generator~~,~~ within 180 days of ~~any~~either of the conditions described in Requirement R4, ~~whenever either event occurs~~and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS~~,~~ within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS~~,~~ within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of~~: 1)~~ the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and ~~2)~~ the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

~~1.1 Compliance Enforcement Authority~~

~~The Regional Entity shall serve as the~~ **1.1 Compliance Enforcement Authority**~~.~~

~~For entities that do not work for~~ NERC or the Regional Entity, ~~the Regional Entity shall serve~~or any entity as ~~the Compliance Enforcement~~otherwise designated by an Applicable Governmental Authority~~.~~

~~For~~, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability ~~Coordinators and other functional entities that work for their Regional Entity, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.~~Standards in their respective jurisdictions.

~~For responsible entities that are also Regional Entities, the ERO or a Regional Entity approved by the ERO and FERC or other applicable governmental authorities shall serve as the Compliance Enforcement Authority.~~

1.2 Compliance Monitoring and Assessment Processes~~:~~

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out ~~-~~of ~~-~~service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when ~~described~~ triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of ~~PSS~~PSSs will become mandatory~~.~~ pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. ~~So~~As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of ~~the~~ Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is~~,~~ “active~~”,~~”; i.e., providing damping to the power system. Some ~~PSS~~PSSs may be programmed to become “active” at a specified ~~MW~~megawatt loading level and above while others may be programmed to be “active” in a particular band of ~~MW~~megawatt loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a ~~MW~~megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for ~~PSS~~PSSs in ~~-~~service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks ~~*backwards*~~*backward* to address units that were once operating but are no longer capable of operating ~~(AKA: broken),~~, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

~~The intent of Requirement R3 is to specify the tuning requirements of the PSS. This is a forward-looking requirement as opposed to Requirement R5 that is a backward-looking requirement.~~

The PSS transfer function should compensate the phase characteristics of the generator ~~excitation~~, exciter, and power (GEP) system ~~(GEP)~~ transfer function so the compensated transfer function ((PSS(s) ~~X~~* GEP(s)) has a phase characteristic of ~~+/-~~ ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set ~~-~~point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires ~~that~~ the final PSS gain ~~should~~to be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or ~~the raise of~~raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

~~The drafting team considers that providing damping to the local mode is for the Generator Owner and, in particular, for the PSS commissioning engineer to address and does not require a WECC standard to be accomplished.~~

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems~~,~~ and not to existing systems ~~without PSS.~~that do not have PSSs. The Requirement also allows a reasonable amount of time for commissioning of new ~~PSS.~~PSSs.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *~~backwards~~backward*. Specifically, the language in Requirement R5, "becoming incapable~~"~~," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working~~ — AKA: they are now broken~~.

The intent of Requirement R5 is to remove the ~~"~~"tiered~~"~~" approach to PSS repair~~/~~ /replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, ~~the Automatic Voltage Regulator~~it may require (1) replacement ~~as well as~~of an AVR and (2) the existence of a PSS, OR both the ~~PSS~~AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month ~~timeframe~~time frame is sufficient to return a functional, operating PSS to service.

WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 6
September 3 through October 5, 32015

Posting #6

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed document.

Posting

This document was last posted for a 30-day public comment period from September 3 through October 5, 2015.

WECC distributed the notice for the posting on September 1, 2015. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from three companies representing six of the eight Industry Segments, as shown in the WECC Standards Voting Sector Table that follows.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the "Submit and Review Comments" accordion.

Changes in Response to Comment

The DT accepted Arizona Public Service's suggestion to delete "minimum load" from Requirement R3 and the associated Measure.

Action Plan

On October 20, 2015, the DT agreed by majority vote to post the project for a 30-day comment period. Posting is targeted for October 22 through November 23, 2015. The DT will reconvene on December 1, 2015 from 10:00 a.m. to 12:00 p.m. and again on December 3, 2015 from 2:00 p.m. to 4:00 p.m. (Mountain) to consider and respond to any comments received.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

WECC Standards Voting Sector Table

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
1	Stephanie Little	Arizona Public Service Company (APS)	X	X	X	X	X			
2	Aaron Paulson	Bonneville Power Administration	X	X	X	X	X			
3	John Fisk	TransCanada								X
4	Joseph Wilson	Tacoma Power	X	X	X	X	X			

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

The drafting team welcomes comments on all aspects of the document.

<table>
<tr><th>Summary Consideration:</th><th colspan="3">See summary in the preamble of this document.</th></tr>
<tr><th>Commenter</th><th>Yes</th><th>No</th><th>Comment</th></tr>
<tr><td>Arizona Public Service</td><td></td><td></td><td>AZPS submits the following comments to WECC-0107 Posting 6:

AZPS suggests additional flexibility be incorporated into Requirement R3, Part 3.1, as the use of multiple approaches are possible (as noted by the DT, and provided for under Requirement R3, Part 3.5) and experts disagree on the utility of measuring GEP(s) at no load (see submitted IEEE whitepaper and Kestrel Power Engineering comments). Moreover, AZPS has overwhelming evidence from years of tests based upon field measurements that GEP(s) measurement at full load provides excellent damping. Thus, AZPS recommends Requirement R3, Part 3.1 be revised to allow for the use of any load for the measurement of the Vt/Vref frequency response or GEP(s).</td></tr>
<tr><td colspan="4">Revise R3, Part 3.1 to allow use of any load for Vt/Vref Measurement

The DT agrees with AZPS and has removed the term “minimum load” from Requirement R3 and the associated measure.</td></tr>
<tr><td>Bonneville Power Administration</td><td></td><td></td><td>Bonneville has no comments.</td></tr>
<tr><td colspan="4">The drafting team would like to thank Bonneville for its continued involvement in the standards development process.</td></tr>
<tr><td>TransCanada</td><td></td><td></td><td>We have concerns with the removal of the 2% exclusion which would now require a self-report of a violation (high severity) for any non-excused period during which the PSS was not active, despite the de minimus impact to BES reliability.</td></tr>
<tr><td colspan="4">Removal of the 2~~%~~ Percent Exclusion

The DT disagrees with TransCanada and believes the added system visibility outweighs the minimal reporting burden. The DT does not believe there should be a grace period. The PSS should either be on or an explanation why should be offered.

As to the severity level, the DT notes that the Violation Severity Level (VSL) is required to be “severe” because the task is binary. The task is either done or it is not done. That said, the VSL is always coupled with the Violation Risk Factor that is listed as “Violation Risk Factor: Low.” The second element of the compliance components mitigates the severe VSL.</td></tr>
</table>

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
As to the burden, when compared to the predecessor document the design of Requirements R1 and R2 is to lessen the administrative burden by allowing for a single report for known conditions instead of the previously held requirement to track each hour and report the anomalies.			
Tacoma			1) Page 8. R1. "Each GO will have documented evidence that it provided to its TOP….written Operating Procedures…". Most modern excitation systems contain two status points. The first, PSS enabled/disabled, provides feedback for the control of the PSS. The second, PSS active/inactive, provides feedback of whether the PSS is providing an active signal to the AVR. An example of when the PSS would be enabled and inactive is online at minimum load. Requirement R1 creates an unnecessary compliance reporting burden on Generator Owners who are already equipped with a modern excitation system who already report the PSS "active/inactive" status point to the Generator Operator and Transmission Operator. Requirement R1 requires the Generator Owner to create a new document for each generating unit stating the circumstances during which the PSS will not be providing an active signal to the AVR which is unnecessary if the Generator Owner is already providing the active/inactive status to the Transmission Operator in real time. The value of this new compliance document is questionable since the Operators would already have this status available. 2) Page 8. A. Introduction, 5. Facilities "This Standard applies to synchronous generators that meet the definition of Commercial Operation". This statement is unclear and leaves room for assumptions and inconsistent application of the standard. Tacoma Power recommends a revising the wording to "This Standard applies to synchronous generators connected to the BES that meet the definition of Commercial Operation". The change would provide clarity in that the threshold at which a PSS should be installed is defined in the standard's Introduction. The WECC Policy Statement on PSS currently defines the threshold at which a PSS should be installed. With the wording change proposed above, the WECC Policy Statement on PSS could be retired when the VAR-0501-WECC-3 becomes effective, realizing a clear transfer of PSS threshold, although different, to the revised standard. The Commercial Operation is defined as a WECC Regional Term in the NERC Glossary of Terms Used in NERC Reliability Standards as

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			"Achievement of this designation indicates that the Generator Operator and Transmission Operator of the synchronous generator or synchronous condenser has received all approvals necessary for operation after completion of initial start-up testing".

Page 8. R1. Unnecessary Compliance Burden without Corresponding Value

Please see response to TransCanada above.

The drafting team believes that information provided by the generator to the Transmission Operator will provide a better understanding of the operations of the devices. This will enable the Transmission Operator to work from a more knowledgeable position. As envisioned by the drafting team, this communication will occur one time every 5-15 years, depending on how often significant changes are made to the PSS and/or AVR. Therefore, the drafting team believes the value added will outweigh the burden to the Generator Operator.

Introduction / Facilities / Add "connected to the BES"

By default, the standard only applies to the BES. The DT has added the language to the document noting its belief that the change is non-substantive and offered for clarity only.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards	December 23, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
Development Procedures.	
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
26. Posting 5 Responses Posted	
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Completed Actions	Completion Date
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSSs)

Standards Authorization Request

[WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request]

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSSs)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective.

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ameliorates the burden.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden. Many of the units already in service prior to regulatory approval and tuned to existing tuning parameters are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSSs)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**
   - **4.1** Generator Operator
   - **4.2** Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR*). [Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of PSSs will become mandatory pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active"; i.e., providing damping to the power system. Some PSSs may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSSs in service. In this standard's previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSSs. The Requirement also allows a reasonable amount of time for commissioning of new PSSs.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, “becoming incapable,” indicates the unit was previously capable of meeting the tuning requirements in

Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR and (2) the existence of a PSS, OR both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures.	December 23, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
26. Posting 5 Responses Posted	
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	
36. Sent to NERC	

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (~~PSS~~PSSs)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (~~PSS~~PSSs)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective.

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ameliorates the burden.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and ~~setup.~~set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden. Many of the units already in service prior to regulatory approval and tuned to existing tuning parameters are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (~~PSS~~PSSs)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, within 180 days of the ~~PSS'~~PSS's Commercial Operation date or any changes to the PSS operating specifications, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR). *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances when the PSS was not in service.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below~~.~~: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated ~~minimum-load Vt~~ VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5~~ percent~~% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between ~~¼~~1/3 and ~~½~~1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

~~For auditing purposes, minimum load in Requirement R3, Part 3.1, is the minimum stable load that the unit can maintain without violating environmental or other regulatory mandates.~~

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, ~~the first~~ bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install ~~a PSS~~ on its generator a PSS, as required in

						Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of ~~a PSS~~PSSs solely because ~~one~~a PSS is not currently installed as of the Effective Date of this standard. However, when triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of PSSs will become mandatory pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates ~~counting~~the requirement to count hours~~,~~ as required in the previous version of this standard~~,~~ while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active"; i.e., providing damping to the power system. Some PSSs may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSSs in service. In ~~the~~this standard's previous version, the logged hours were totaled quarterly to meet the 98~~ percent~~% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power ~~system (Generator Excitation Power System (GEP))~~(GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref~~),~~) and ~~of~~ using the phase characteristic of ~~that~~such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between ~~⅓~~1/3 and ~~½~~1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSSs. The Requirement also allows a reasonable amount of time for commissioning of new PSSs.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically~~,;~~, the language in Requirement R5, “becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR and (2) the existence of a PSS, ~~or~~OR both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 7
October 22 through November 23, 2015

Posting #7

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed document.

Posting

This document was last posted for a 30-day public comment period from October 22 through November 23, 2015.

WECC distributed the notice for the posting on October 20, 2015. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from six companies representing five of the eight Industry Segments, as shown in the WECC Standards Voting Sector Table that follows.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the “Submit and Review Comments” accordion.

Changes in Response to Comment

Requirement R1 was redrafted to include the effective date of the standard as a triggering event. To Requirement R2, the following statement was added: “This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.”

Action Plan

On December 3, 2015, the DT agreed by majority vote to post the project for a 30-day comment period. Posting is targeted for December 11, 2015 through January 11, 2016. The DT will reconvene on January 13, 2015 from 10:00 a.m. to 12:00 p.m. and again on January 21, 2016 from 10:00 a.m. to 12:00 p.m. (Mountain) to consider and respond to any comments received.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

WECC Standards Voting Sector Table

The WECC Standards Voting Sectors are:

1 — Transmission Sector
2 — Generation Sector
3 — Marketers and Brokers Sector
4 — Distribution Sector
5 — System Coordination Sector
6 — End Use Representative Sector
7 — State and Provincial Representatives Sector
8 — Other Non-Registered WECC Members and Participating Stakeholders Sector

Commenter		Organization	WECC Standards Voting Sectors							
			1	2	3	4	5	6	7	8
1	Aaron Paulsen	Bonneville Power Administration	X		X	X	X			
2	Stephanie Little	Arizona Public Service Company	X	X	X	X	X			
3	Leland McMillan	Talen Energy								X
4	Karen Hedlund	Tacoma Power	X	X	X	X	X			
5	Joshua Andersen	Salt River Project	X	X	X	X	X			
6	NV Energy	Jeff Watkins								

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

The drafting team welcomes comments on all aspects of the document.

<table>
<tr><th>Summary Consideration:</th><th colspan="3">See summary in the preamble of this document.</th></tr>
<tr><th>Commenter</th><th>Yes</th><th>No</th><th>Comment</th></tr>
<tr><td>BPA</td><td></td><td></td><td>BPA has no comment.</td></tr>
<tr><td colspan="4">The DT appreciates BPA’s continued involvement in the standards development process.</td></tr>
<tr><td>APS</td><td></td><td></td><td>AZPS has no comments.</td></tr>
<tr><td colspan="4">The DT appreciates APS’s continued involvement in the standards development process.</td></tr>
<tr><td>Talen</td><td></td><td></td><td>Talen Montana, LLC (TALN) appreciates the efforts of the drafting team and understands the desire to establish a requirement for Power System Stabilizers (PSS) that is consistent with the Automatic Voltage Regulator Requirement found in VAR-002, R1. However, TALN suggests that the drafting team consider adding the following exclusions that exist in the currently approved and effective version of the standard:

R1.3. PSS exhibits instability due to abnormal system configuration.

R1.5. Unit is generating less power than its design limit for effective PSS operation.

Additionally, TALN requests that "emergency situations" be added as an exclusion for not having the PSS in service.</td></tr>
<tr><td colspan="4">Issue 1: Recommendation adding additional exclusion from the current version

The DT believes the requested R1.3 exception is covered in the final bullet of Requirement R2:

• As agreed upon by the Generator Operator and the Transmission Operator

The DT believes the requested R1.5 exception is covered in the operating parameters covered in Requirement R1.

As to inclusion of emergencies, the DT believes this is also covered under R1.3. The concern with specifically including “emergencies” is in defining all the parameters of what constitutes an emergency and who makes that decision.</td></tr>
<tr><td>Tacoma</td><td></td><td></td><td>1) General Comment. Tacoma does not agree with the continuation of a separate WECC standard to address PSSs. The WECC should work with the NERC to include these regional requirements as regional variances in the NERC VAR or other standards rather than creating a separate WECC regional standard. The creation of separate regional standards results in an additional burden to an entity's compliance program. NERC standards already</td></tr>
</table>

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			allow for regional variances as exercised by the WECC for VAR-001-3. 2) General Comment. The Generator Owner expects to see the WECC PSS Policy Statement retired on the date that these requirements becomes effective in order to prevent conflicting requirements and an overdue burden on the Generator Owner. 3) R1 requires a Generator Owner to provide PSS operating specifications to the Transmission Owner. R2 allows an exception to the Generator Operator for the PSS to be in service "as agreed upon by the Generator Operator and the Transmission Operator". There are no requirements in the standard for the Transmission Operator to communicate back to either the Generator Owner or the Generator Operator in a timely manner. Therefore, the Generator Owner and the Generator Operator will assume compliance so long as they have submitted these items to the Transmission Operator. If this is not the intention of the WECC then a requirement should be added for the Transmission Operator. 4) R1 does not require the documentation to be sent to the Transmission Operator at the date the standard becomes effective. Therefore, the Generator Owner will not supply said documentation to the Transmission Operator until such time as a unit is commissioned for commercial operation or a PSS has been changed. If this is not the intention of the WECC then the requirement should be modified. R4 does not require the Generator Owner to install and complete testing of a PSS at the date the standard becomes effective. Therefore, the Generator Owner will assume that a PSS is not required until such time as a unit is commissioned for commercial operation or an excitation system has been replaced. If this is not the intention of the WECC then the requirement should be modified.

Issue 1: General Comment.

The DT appreciates Tacoma's continued involvement in the standards development process. The charge to the DT under the Standard Authorization Request (SAR) as approved by the WECC Standards Committee

Summary Consideration:	See summary in the preamble of this document.		
Commenter	Yes	No	Comment

(WSC) is to proceed with the development of the requested documents. Tacoma is encouraged to voice its policy concern directly to the WSC, or in the alternative to file a SAR in the appropriate forum with its specific request. Should the DT receive alternate instructions from the WSC it will pursue that change of direction accordingly.

Issue 2: General Comment.

Tacoma puts forth a reasonable statement and expectation. Ownership of the WECC Policy Statement on Power System Stabilizers (Policy) resides with the WECC Control Work Group and is governed by the associated rules of the presiding Standing Committee. The DT does not have the authority to retire that document but encourages Tacoma to bring its concerns directly to the associated Standing Committee with a request for retirement. The DT will include that recommendation in its Implementation Plan.

Issue 3: Requirement to Communicate

In an effort to avoid the creation of an additional administrative "Requirement" the DT concluded that the Measure is sufficient to meet the administrative need.

Issue 4: No Requirement to Report at the Onset

Requirement R1 has been redrafted as follows:

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: . *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date; or
- Any changes to the PSS operating specifications.

Issue 5: Requirement to Test

Requirement R4 is not intended to require any retroactive action on the part of the applicable entity. The Requirement is only forward-looking and only requires action if/when either of the two specified events occurs. The requirement was not changed.

Salt River Project			Salt River Project (SRP) has reviewed the proposed revision to VAR-

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
			501-WECC-2 and appreciates the work that has gone forth in removing the discrete instances where PSS was not expected to be in service and allowing for the Generator Owner to give the operating specifications to the Transmission Operator. It is understood that the last bullet of R2 "As agreed upon by the Generator Operator and the Transmission Operator" was to allow for other instances that may not be specifically called out in the standard. However, SRP has concerns that the instance where PSS is out of service must be agreed to by both the GOP and TOP prior to the event happening. It is easily possible to inadvertently have PSS off when unit is shut down for maintenance. Alarms are in place to detect PSS not in operation after unit has reached load where the PSS is active but, as this standard is being proposed, even a few seconds operation with PSS off will place you in violation. SRP states that it is not a reliability concern if there is a lag in the PSS becoming active the instant the generator is synchronized. SRP recommends that there be a time allowed for synchronization and then activation of PSS. SRP recommends revising R2 to be as follows: R2. Each Generator Operator shall have its PSS in service within 10 minutes of reaching the manufacturers recommended load for PSS operation except during any of the following: •Component failure •Testing of a Bulk Electric System Element affecting or affected by the PSS •Maintenance •As agreed upon by the Generator Operator and the Transmission Operator

Issue 1: Rewrite R2.

The drafting team agrees and has redrafted the Requirement as follows:

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation*

Summary Consideration:	See summary in the preamble of this document.		
Commenter	**Yes**	**No**	**Comment**
Risk Factor: Medium] [Time Horizon: Operating Assessment] • Component failure • Testing of a Bulk Electric System Element affecting or affected by the PSS • Maintenance • As agreed upon by the Generator Operator and the Transmission Operator This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.			
NV Energy			R1 requires documentation be sent to the Transmission Operator within 180 days of the PSS' Commercial Operation date or any changes to the PSS operating specifications. Since the intent of the requirement is to provide the Transmission Operator the PSS operating zone in which the PSS is active to eliminate counting hours, PSS documentation for existing generators will be needed by the TO. The existing requirement doesn't seem to clearly identify PSS documentation for existing generators and a timeframe for which it should be sent to the Transmission Operator.
Issue 1: Clarify R1 Requirement R1 has been changed to address the concern. See above response to Tacoma.			

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards	December 23, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
Development Procedures.	
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
23. Posting 6 Open	September 3, 2015
24. Posting 6 Closed	October 5, 2015
25. DT meets to respond to comments	October 20, 2015
23. Posting 7 Open	October 22, 2015
24. Posting 7 Closed	November 23, 2015
25. DT meets to respond to comments	December 3, 2015
23. Posting 8 Open	December 11, 2015
24. Posting 8 Closed	January 11, 2016
25. DT meets to respond to comments	January 13, 2016

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Completed Actions	Completion Date
27. Ballot Pool open	
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSS)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSS)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer
- This standard is based on the WECC Policy Statement on Power System Stabilizers (Policy). That document is owned by the WECC Control Work Group. Although it is outside of the purview of the assigned drafting team, the drafting team is recommending that the assigned WECC Standing Committee initiate retirement of the Policy coincident with the effective date of this standard.

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective. (See above comment regarding retirement of the WECC Policy Statement on Power System Stabilizers.)

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ameliorates the burden.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden. Many of the units already in service prior to regulatory approval and tuned to existing tuning parameters are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date, or;
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the

Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to

service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of PSS solely because a PSS is not currently installed as of the Effective Date of this standard. However, when triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of PSS will become mandatory pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active"; i.e., providing damping to the power system. Some PSS may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard's previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the “tiered” approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR and (2) the existence of a PSS, OR both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
8. Posting 1 Open	July 1, 2014
9. Posting 1 Closed	August 14, 2014
10. Posting 1 Responses Posted	September 26, 2014
11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures.	December 23, 2014

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
17. Posting 3 Closed	January 19, 2015[2]
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
22.a. Revised Posting 4 Responses Posted	July 2, 2015
23. Posting 5 Open	July 7, 2015
24. Posting 5 Closed	August 6, 2015
25. DT meets to respond to comments	August 7, 2015
23. Posting 6 Open	September 3, 2015
~~26.~~24. Posting ~~5 Responses Posted~~6 Closed	October 5, 2015
25. DT meets to respond to comments	October 20, 2015
23. Posting 7 Open	October 22, 2015
24. Posting 7 Closed	November 23, 2015
25. DT meets to respond to comments	December 3, 2015
23. Posting 8 Open	December 11, 2015
24. Posting 8 Closed	January 11, 2015
25. DT meets to respond to comments	January 13, 2015
27. Ballot Pool open	

[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.

Completed Actions	Completion Date
28. Ballot Pool closed	
29. Joint Session noticed	
30. Joint Session	
31. Ballot Open	
32. Ballot Closed	
33. WSC approves forwarding to the WECC Board of Directors	
34. Posted for 30 days prior to WECC Board meeting	
35. Board meets to approve	
36. Sent to NERC	

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3			

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSSs)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSSs)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer

- This standard is based on the WECC Policy Statement on Power System Stabilizers (Policy). That document is owned by the WECC Control Work Group. Although it is outside of the purview of the assigned drafting team, the drafting team is recommending that the assigned WECC Standing Committee initiate retirement of the Policy coincident with the effective date of this standard.

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 shall be retired immediately prior to the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective. (See above comment regarding retirement of the WECC Policy Statement on Power System Stabilizers.)

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ameliorates the burden.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no additional undue burden. Many of the units already in service prior to regulatory approval and tuned to existing tuning parameters are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSSs)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   For further detail, refer to the Implementation Plan.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, ~~within 180 days of the PSS's Commercial Operation date or any changes to the PSS operating specifications,~~ the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR~~).~~), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date, or;
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the

Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances ~~when~~during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated- VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to

service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	NA	NA	NA	The Generator Operator failed to have its PSS in service, except where allowed in Requirement R2.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection in order to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Reliability Standard should be construed to require installation of PSSs solely because a PSS is not currently installed as of the Effective Date of this standard. However, when triggering events described in the Reliability Standard occur after the Effective Date of the standard, installation of PSSs will become mandatory pursuant to the Requirements therein. It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is “active”; i.e., providing damping to the power system. Some PSSs may be programmed to become “active” at a specified megawatt loading level and above while others may be programmed to be “active” in a particular band of megawatt loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSSs in service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

The intent of Requirement R3 is to specify the tuning requirements of the PSS. Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 and 1/2 of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSSs. The Requirement also allows a reasonable amount of time for commissioning of new PSSs.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in

Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR and (2) the existence of a PSS, OR both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

WECC-0107 VAR-501-WECC-2
Power System Stabilizer Drafting Team (DT)
Response to Comments / Posting 8
December 11, 2015 through January 22, 2016

Posting #8

The WECC-0107, VAR-501-WECC-2, Power System Stabilizer Drafting Team (DT) thanks everyone who submitted comments on the proposed document.

Posting

This document was last posted for a 30-day public comment period from December 11, 2015 through January 11, 2016. The electronic portal remained open through January 22, 2016. All comments received were accepted.

WECC distributed the notice for the posting on December 4, 2015. The DT asked stakeholders to provide feedback on the proposed document through a standardized electronic template. WECC received comments from six companies, as shown in the WECC Standards Comment Table that follows.

Location of Comments

All comments received on the document can be viewed in their original format on the project page under the "Submit and Review Comments" accordion.

Changes in Response to Comment

After consideration of each comment received, the drafting team opted to make no substantive changes to the document. The drafting team did, however, make the following non-substantive changes to add clarity and readability.

In Requirement R2, the suffix sentence has been changed to read:

> "A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause."

To clarify those triggering events that would require installation of a new PSS, the Rationale section was updated as follows:

> **Mandate to Install a PSS**
>
> Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated upon the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.
>
> It should be noted that a PSS is neither Transmission nor generation.

To clarify the focus of Requirement R3 and to show the Requirement is in harmony with the WECC-0107 Standard Authorization Request, the Rationale section for Requirement R3 was updated as follows:

> "Nothing in this Regional Reliability Standard (RSS) should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS."

Action Plan

On February 18, 2016, the DT agreed by majority vote of those DT members present to forward the project to the WECC Standards Committee (WSC) with a request for ballot and associated regulatory disposition. Only non-substantive changes were made to Posting 8. Posting 9 is the document forwarded for disposition. Posting 9 will be posted to the WECC-0107 Project Page and located on the Posted for Comment accordion.

The WSC is scheduled to meet March 8, 2016.

Contacts and Appeals

If you feel your comment has been omitted or overlooked, please contact the Manager, WECC Standards Processes, W. Shannon Black, at sblack@wecc.biz. In addition, there is a WECC Reliability Standards Appeals Process.

WECC Standards Comment Table

Commenter		Organization
1	W. Shannon Black	WECC
2	Stephanie Little on Behalf of Kristie Cocco	Arizona Public Service Company
3	Hillary Dobson	Colorado Springs Utilities
4	Jeremy Voll	Basin Electric Power Cooperative
5	Laura Nelson	Idaho Power
6	Chad Edinger	City of Tacoma – Tacoma Power

Index to Questions, Comments, and Responses

Question

1. **The drafting team welcomes comments on all aspects of the document.**

The drafting team welcomes comments on all aspects of the document.

Summary Consideration:	See summary in the preamble of this document.
Commenter / Comment	**Response**
WECC	
The 30 Minute criterion in Requirement R2 needs clarification. Clarity is needed for Requirement R2 that states, "*This Requirement only applies when the PSS is out of service for a period greater than 30 minutes*." When do the 4 bullets apply? Is it when the PSS is out of service due to a component failure or maintenance that lasts longer than 30 minutes? If this is correct, then the main Requirement (R2) should be rewritten to include this exemption language. Or, is it when the bulleted occurrence(s) duration last less than 30 minutes? **Triggering Events Need Clarification** The Guidance section states, "Nothing in this Reliability Standard should be construed to require installation of PSS solely because a PSS is not currently installed as of the Effective Date of this standard. However, when *triggering events* described in the Reliability Standard occur after the Effective Date of the standard, installation of PSS will become mandatory pursuant to the Requirements therein." (emphasis added) Regarding the above-quoted language, it is unclear as to what those *triggering events* are and where in the standard they can be located. Please specify.	The drafting team (DT) appreciates your comments and has made the following changes: In Requirement R2, the suffix sentence has been changed to read: "A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause." For clarity, the drafting team has incorporated the following language into the Rationale section" **Mandate to Install a PSS** Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated upon the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS. It should be noted that a PSS is neither Transmission nor generation.

Summary Consideration:	See summary in the preamble of this document.
Commenter / Comment	**Response**
Scope and Intent of the SAR The SAR calls for the establishment of minimum design criteria for installation of new PSS-related equipment. It is not clear if the regional standard meets this requirement. If the DT intended to address this issue in the Guideline and Technical Basis (perhaps on page 15), then their intentions should be clearly stated.	The drafting team notes that the original Standard Authorization Request (SAR) called for the establishment of "minimum design-criteria for installation of new PSS-related equipment." However, on June 25, 2014, the WECC Standards Committee (WSC) changed the scope of the SAR such that the design specifications of the equipment were no longer the focus; rather, the focus became: 1) where a PSS was installed, it should be operating unless exempted, 2) should be tuned as specified, and 3) if not currently installed, should specify when installation would be required. The current draft meets both the scope of the SAR and that call of the question. That said, WECC raises an important distinction. To meet the request for clarity, the following sentence replaces the introduction sentence to the Rationale section under the Requirement R3 header. "Nothing in this Regional Reliability Standard (RSS) should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS."
Facilities The standard is not clear as to what facilities it applies to. Please specify.	The DT believes the Facilities statement is precise, to include those facilities meeting each of the specified criteria: 1) Synchronous generators; 2) Connected to the Bulk Electric System, as defined in the Glossary of Terms Used in NERC Reliability Standards (Glossary); 3) Meeting the definition of Commercial Operation, as defined in the WECC-specific section of the Glossary.

Summary Consideration:	See summary in the preamble of this document.
Commenter / Comment	**Response**
Arizona Public Service Company	
AZPS has no comments.	The drafting team appreciates AZPS' continued involvement in the standards development process.
Colorado Springs Utility	
1) Colorado Springs Utilities suggests that Requirement 3, part 3.3 be changed to include the original gain requirements or the new specification, i.e. that the gain be set to between 1/3 and 1/2 of the maximum practical gain or between 6 and 10. 2) Colorado Springs Utilities suggests clarifying Requirement 3, part 3.5 as to whether there is a mandatory timeline for the replacement or retrofitting of the voltage regulator or whether the exemption can be indefinite.	The DT appreciates Colorado's suggested input but has opted not to make that change. Although the 6 and 10 gain margin is not specified in the Requirement in those terms, the Requirement does meet that same performance result but states the range differently. To add clarity, the "dB" designation was added to the Rationale section alongside the 1/3 and 1/2 explanation, under the Requirement R3 header. Please see the above response to WECC regarding triggering events.
Basin Electric Power Cooperative	
With R2 whether you go 31 minutes or 31 days you get the same violation severity. I would suggest that there be different violation severity levels depending on the time the PSS was not on over the 30 minutes.	VSLs define the degree to which compliance with a requirement was not achieved. Each requirement requires at least one VSL. While it is preferable to have four VSLs for each requirement, some requirements do not have multiple "degrees" of noncompliant performance and may have only one as is the case with a binary requirement. The objective of the requirement is to have the PSS "in service." Since the required performance cannot be broken down into degrees of compliance, the Requirement is classified as a Pass/Fail and must be assigned a "Severe" VSL.

Summary Consideration:	See summary in the preamble of this document.
Commenter / Comment	**Response**
Idaho Power	
Idaho Power reviewed the redlined standard and has no negative feedback. Idaho Power is in support of the revision to R2 that states the requirement is only applicable when the PSS is out of service for a period greater than 30 minutes.	The drafting team appreciates Idaho Power's continued involvement in the standards development process.
City of Tacoma	
Tacoma Power requests clarity and rewording as needed for consistency on the effective date of R3. The two sections (identified below) are in contradiction as to <u>when</u> compliance to R3 needs to be achieved for units placed in service prior to final regulatory approval of this standard. Section A. Introduction, 6. Effective Date, third paragraph states "For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is **five years** after regulatory approval" Requirement R3, 3.5 reads "Units that have an excitation system or PSS that is incapable of meeting the tuning requirement of Requirement R3 **are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted** such that the PSS becomes capable of meeting the turning requirements".	The DT does not believe there is a conflict between the two dates. The Effective Date dictates when the overall document is effective. Within the document itself, there are additional triggering events such as the running of the five-year period or, in the alternative, when the hardware is either replaced or retrofitted.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed prior to final disposition.

No substantive changes were made to Posting 8. Only clarifying changes and a change to the Requirement R2 Violation Severity Level were made. Posting 9 is not offered for comment. Posting 9 is offered for ballot.

Project Roadmap

Completed Actions	Completion Date
1. SAR received	February 11, 2014
2. SAR deemed Complete/Valid/Team Site created	February 11, 2014
3. WSC approved the SAR	March 12, 2014
4. WSC solicits/assigns a drafting team (DT)	March 12, 2014
5. DT announced/notice sent to DT members	March 12, 2014
6. First DT meeting	April 8, 2014
7. WSC changed scope of SAR to subsume VAR-501-WECC-1. WSC approved posting for 45-day comment.	June 25, 2014
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9. Posting 1 Closed	August 14, 2014
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11. Posting 2 Open	October 15, 2014
12. Posting 2 Closed	November 14, 2014
13. WSC approved posting of responses and granted permission for the late posting.	December 3, 2014
14. Posting 2 Responses Posted	December 4, 2014[1]

[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting responses. The WSC agreed that quality was preferable to timeliness.

Completed Actions	Completion Date
15. Posting 3 Open	December 18, 2014
16. FERC approved new WECC Reliability Standards Development Procedures.	December 23, 2014
17. Posting 3 Closed	January 19, 2015
18. Posting 3 Responses Posted	February 2, 2015
19. Posting 4 Open	April 17, 2015
20. Posting 4 Closed	May 19, 2015
21. DT meets to respond to comments	May 28, 2015
22. Posting 4 Responses Posted	June 12, 2015
23. Revised Posting 4 Responses Posted	July 2, 2015
24. Posting 5 Open	July 7, 2015
25. Posting 5 Closed	August 6, 2015
26. DT meets to respond to comments	August 7, 2015
27. Posting 6 Open	September 3, 2015
28. Posting 6 Closed	October 5, 2015
29. DT meets to respond to comments	October 20, 2015
30. Posting 7 Open	October 22, 2015
31. Posting 7 Closed	November 23, 2015
32. DT meets to respond to comments	December 3, 2015
33. Posting 8 Open	December 11, 2015
34. Posting 8 Closed	January 11, 2016
35. DT meets to respond to comments	February 18, 2016
36. WSC Approved for Ballot	March 8, 2016

Anticipated Actions	Completion Date
1. Ballot Pool Open	March 21, 2016
2. Joint Session	April 7, 2016
3. Ballot Pool Closed	April 8, 2016
4. Ballot Opens	April 12, 2016
5. Ballot Closes	April 28, 2016
6. WSC approves – Forward to WECC Board of Directors (Board)	June 2016
7. Board approval	TBD
8. Sent to NERC	TBD
9. FERC action	TBD

Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
1	July 1, 2011	FERC Effective Date: VAR-501-WECC-1	
2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3	TBA	WECC Board of Directors Approved	Drafted tuning requirements from WECC Policy Statement on Power System Stabilizers, response to SAR WECC-0107

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSS)

Standards Authorization Request

[WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request]

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSS)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer
- This standard is based on the WECC Policy Statement on Power System Stabilizers (Policy). That document is owned by the WECC Control Work Group. Although it is outside of the purview of the assigned drafting team, the drafting team is recommending that the assigned WECC Standing Committee initiate retirement of the Policy coincident with the effective date of this standard.

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority.

For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction.

For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 should be retired coincide with the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective. (See above comment regarding retirement of the WECC Policy Statement on Power System Stabilizers.)

Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 reduces the burden by allowing entities to address the Requirement over a longer period of time.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no undue burden. Many of the units already in service are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date, or;
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the

Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to

service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	**Moderate VSL**	**High VSL**	**Severe VSL**
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.

It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active" providing damping to the power system. Some PSS may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard's previous version, the logged hours were totaled quarterly to meet the

98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, “becoming incapable,” indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the “tiered” approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

Standard Development Timeline

This section is maintained by the drafting team during the development of the standard and will be removed ~~when the standard becomes effective.~~prior to final disposition.

No substantive changes were made to Posting 8. Only clarifying changes and a change to the Requirement R2 Violation Severity Level were made. Posting 9 is not offered for comment. Posting 9 is offered for ballot.

Project Roadmap

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[1] On December 3, 2014, the WECC Standards Committee (WSC) granted the drafting team an extension of time for posting responses. The WSC agreed that quality was preferable to timeliness.

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~~23~~27. Posting 6 Open	September 3, 2015
~~24~~28. Posting 6 Closed	October 5, 2015
~~25~~29. DT meets to respond to comments	October 20, 2015
~~23~~30. Posting 7 Open	October 22, 2015
~~24~~31. Posting 7 Closed	November 23, 2015
~~25~~32. DT meets to respond to comments	December 3, 2015
~~23~~33. Posting 8 Open	December 11, 2015
~~24~~34. Posting 8 Closed	January 11, 2016
~~25~~35. DT meets to respond to comments	~~January 13~~February 18, 2016

~~[2] This document was posted for a 30-day public comment period from December 12, 2014, through January 12, 2015. Late comments were received until January 20, 2015, 10:00 a.m. (Mountain) when the drafting team met to respond to comments. The window was extended because a closing date in the mandated notice did not match text in the posted document.~~

Completed Actions	Completion Date
~~27.~~ 36. WSC Approved for Ballot ~~Pool open~~	March 8, 2016
~~28. Ballot Pool closed~~	
~~29. Joint Session noticed~~	
~~30. Joint Session~~	
~~31. Ballot Open~~	
~~32. Ballot Closed~~	
~~33. WSC approves forwarding to the WECC Board of Directors~~	
~~34. Posted for 30 days prior to WECC Board meeting~~	
~~35. Board meets to approve~~	
~~36. Sent to NERC~~	

Anticipated Actions	Completion Date
1. Joint Session	
2. Ballot Pool Open	
3. Ballot Pool Closed	
4. Ballot Opens	
5. Ballot Closes	
6. WSC approves – Forward to WECC Board of Directors (Board)	
7. Board approval	
8. Sent to NERC	
9. FERC action	

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Version History

Version	Date	Action	Change Tracking
0	April 23, 2004	WECC Effective Date: VAR-502-WECC-0.1	
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2	May 28, 2014	WECC Ballot Body Approved	Paragraph 81 clean-up
3	TBA	WECC Board of Directors Approved	Drafted tuning requirements from WECC Policy Statement on Power System Stabilizers, response to SAR WECC-0107

Implementation Plan

VAR-501-WECC-3, Power System Stabilizers (PSS)

Standards Authorization Request

WECC-0107 VAR-501-WECC-3 Power System Stabilizers Standards Authorization Request

Applicable Standards

- VAR-501-WECC-3, Power System Stabilizers (PSS)

Requested Retirements

- VAR-501-WECC-2, Power System Stabilizer
- This standard is based on the WECC Policy Statement on Power System Stabilizers (Policy). That document is owned by the WECC Control Work Group. Although it is outside of the purview of the assigned drafting team, the drafting team is recommending that the assigned WECC Standing Committee initiate retirement of the Policy coincident with the effective date of this standard.

Applicable Entities

- Generator Operator
- Generator Owner

Conforming Changes to Other Standards

N/A

Effective Date

Where approval by an applicable governmental authority is required, Reliability Standard VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard, or as otherwise provided for by the applicable governmental authority.

For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the effective date of the applicable governmental authority's order approving the standard. For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the effective date of the applicable governmental authority's order approving the standard.

Where approval by an applicable governmental authority is not required, VAR-501-WECC-3, Requirements R1, R2, R4, and R5 shall become effective on the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction. For units placed in first-time service after regulatory approval, Reliability Standard VAR-501-WECC-3, Requirement R3 shall become effective the first day of the first calendar quarter after the date the standard is adopted by the NERC Board of Trustees, or as otherwise provided for in that jurisdiction.

For units placed in service prior to final regulatory approval, Requirement R3 shall become effective the first day of the first calendar quarter that is five years after the standard is adopted by the NERC Board of Trustees.

Retirement Date

Reliability Standard VAR-501-WECC-2 ~~shall~~should be retired ~~immediately prior to~~coincide with the effective date of VAR-501-WECC-3 in the particular jurisdiction in which the revised standard is becoming effective. (See above comment regarding retirement of the WECC Policy Statement on Power System Stabilizers.)

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Justification

With the exception of Requirement R3, VAR-501-WECC-3 has a standardized Effective Date.

Use of this separate Effective Date for Requirement R3 highlights the fact that the reliability-related tasks included in Requirement R3 are a change from existing tuning parameters and could impose an entity-specific burden that is moderate to severe, depending on the existing practices of each entity. The tiered implementation of Requirement R3 ~~ameliorates the burden.~~reduces the burden by allowing entities to address the Requirement over a longer period of time.

Units placed into first-time service after regulatory approval will require initial testing, tuning, and set-up. As such, immediate compliance with Requirement R3 for new units should impose no ~~additional~~ undue burden. Many of the units already in service ~~prior to regulatory approval and tuned to existing tuning parameters~~ are currently and adequately tuned to pre-Requirement R3 parameters and need not be immediately revisited. The five-year applicability date for those units already in service lessens the burden while targeting a uniform tuning across the Western Interconnection.

Consideration of Early Compliance

Early compliance should impose no negative impacts. Because many of the Requirements are based on existing WECC policies, many Applicable Entities within WECC will already be in voluntary compliance.

Definitions of Terms

No new definitions are proposed.

A. Introduction

1. **Title:** Power System Stabilizers (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner
5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk-Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

   ~~For further detail, refer to the Implementation Plan.~~

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date, or;
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

~~This Requirement only applies when the~~A PSS that is out of service for ~~a period greater~~less than 30 minutes~~.~~ does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated VT/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	~~NA~~Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	~~NA~~Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	~~NA~~Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	~~The~~Each Generator Operator ~~failed to have~~not having its PSS in service~~, except where allowed~~ while synchronized in accordance with Requirement R2~~.~~, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit

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R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
			times or fewer during the audit period.			period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection ~~in order~~ to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

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Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this ~~standard. However, when~~ RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in ~~the Reliability Standard occur~~Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the ~~standard, installation of PSS will become mandatory pursuant to the Requirements therein.~~ RRS.

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It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner the PSS operating zone in which the PSS is "active~~"; i.e.,~~" providing damping to the power system. Some PSS may be programmed to become "active" at a specified megawatt loading level and above while others may be programmed to be "active" in a particular band of megawatt loading levels and are "non-active" only when passing through the "rough zone" or some other band. A "rough zone" is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

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Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard’s previous version, the logged hours were totaled quarterly to meet the 98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

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Requirement R3

~~The intent of Requirement R3 is to specify the tuning requirements of the PSS.~~
Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function, and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, ~~OR~~or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

From: Black, Shannon
Sent: Thursday, March 17, 2016 10:39 AM
Subject: Notice of Ballot Pool Forming/Notice of Ballot WECC-0107 VAR-501-WECC-3 Power System Stabilizers

Notice of Ballot Pool Forming/Notice of Ballot
WECC-0107 VAR-501-WECC-3
Power System Stabilizers

On March 8, 2016, the WECC Standards Committee (WSC) approved WECC-0107 for ballot in accordance with the Reliability Standards Development Procedures (Procedures).

Documents for review are located at the WECC-0107 project page on the Posted for Comment accordion.

Ballot results are scheduled to be presented to the WSC during the June 2016 WSC meeting.

Overview

In response to Standards Authorization Request WECC-0107, the Drafting Team revised tuning requirements for the standard based on the WECC Policy Statement on Power System Stabilizers. WECC-0107 requires an applicable entity to: 1) install a PSS *but only on the occurrence of specified circumstances*, 2) tune its PSS to specified criteria, 3) have its PSS in service unless otherwise allowed, 4) repair its PSS, and 5) communicate known circumstances during which a PSS will not be providing an active signal.

Ballot Participation

If you wish to vote on this project, you must first be a member of the Ballot Body *and then* specifically register for the WECC-0107 Ballot Pool.

You can join the Ballot Body and this specific Ballot Pool from the WECC Standards webpage by using the Standards Voting menu option.

The Ballot Pool and associated ballot will be conducted per the following dates.

Standards Briefing

A Standards Briefing will be held on April 7, 2016, from 2:00 p.m. to 3:00 p.m. (Mountain) to discuss the project. An announcement including Webinar information for the Standards Briefing will be dispatched separately.

Calendar Events

- Ballot Pool Open: March 21, 2016
- Standards Briefing: April 7, 2016
- Ballot Pool Closed: April 8, 2016
- Ballot Open: April 12, 2016
- Ballot Closed: April 28, 2016
- WECC Standards Committee: June 2016

If you have questions, please click here or contact WECC Standards at standards@wecc.biz.

To be removed from this WECC email distribution list, please submit your request to unsubscribe@wecc.biz.

WESTERN ELECTRICITY COORDINATING COUNCIL

155 North 400 West, Suite 200

Salt Lake City, Utah 84103-1114

From:	Black, Shannon
Subject:	WECC-0107 VAR-501-WECC-03 Power System Stabilizer Design and Performance Notice of Ballot Results
Date:	Friday, May 13, 2016 8:51:08 AM

WECC-0107 VAR-501-WECC-3
Power System Stabilizers Design and Performance
Notice of Ballot Results

On May 2, 2016, WECC-0107 VAR-501-WECC-3, Power System Stabilizer and Design Performance, a WECC Regional Reliability Standard (RRS), was approved by the associated Ballot Pool with a 66% affirmative vote. A simple majority is required to approve the project.

Ballot results and comments provided in opposition to the project can be viewed at the Standards Voting Page on the Review Ballot Results accordion.

In accordance with the Reliability Standards Development Procedures (Procedures) the WECC-0107 drafting team is requesting the WECC Standards Committee approve the project for subsequent disposition by the WECC Board of Directors (Board), NERC and FERC.

If you have questions regarding the project, please contact W. Shannon Black, sblack@wecc.biz, (503) 307-5782.

WECC

Western Electricity Coordinating Council
155 North 400 West, Suite 200
Salt Lake City, Utah 84103-1114

W. Shannon Black
WECC Consultant
(503) 307-5782
sblack@wecc.biz

MEMO

Date: June 15, 2016

To: WECC Standards Committee (WSC)

Subject: WECC-0107 VAR-501-WECC-3 (WECC VAR)

Power System Stabilizer and Design Performance

WECC Regional Reliability Standard Voting Record

On May 2, 2016, the WECC VAR, a WECC Regional Reliability Standard (RRS), was approved by the associated Ballot Pool with a 66% affirmative vote. A simple majority is required to approve the project.

Ballot results and comments provided in opposition to the project can be viewed at the Standards Voting Page on the Review Ballot Results accordion[1].

In accordance with the Reliability Standards Development Procedures, the WSC and the WECC Board of Directors (Board) are to be provided with a voting record for consideration as part of the project approval process. The Procedures also state that each member of the Ballot Pool casting a negative vote on a project is required to provide a statement explaining the reason for the negative vote.

The following is the full voting record for the WECC VAR including any explanatory narrative that may have accompanied a negative vote.

At a high level, negative votes were cast because:

- The standard does not need revision, does not offer any greater value than its predecessor, and needs further clarification; entities disagree on Violation Severity Levels; the mandates are overly prescriptive (not needed to enhance reliability); Measure M2 requiring documentation from a period prior to the standard becoming effective is inappropriate; the Requirement R4 mandate to test within a specified period could cause a violation due to scheduling issues without adding any reliability value/detriment; and, the proposed standard requires a Power System Stabilizer (PSS) on units too small to have a negative impact on reliability.

[1] The Ballot Results Link provides explanatory narrative provided with each negative vote as required In the Reliability Standards Development Procedures, Step 9 – Form the Ballot Pool and Ballot the Standards.

Ballot Name:	**WECC-0107**
	VAR-501-WECC-03 PSS Design and Performance
Total Ballot Pool:	92
Total Number of Votes:	85
Quorum:	92.4%
Weighted Vote:	66.0%
Ballot Results	The Document has Passed

Voting Sectors	Total In Ballot Pool	Votes Non-Abstain	Sector Weight	Yes Votes	Weighted Segment Vote	No Votes	Abstain	Total Votes * for Quorum	Didn't Vote
Distribution	17	15	1	10	66.7%	5	1	16	1
End User Representative	0	0	0	0	0.0%	0	0	0	0
Generation	23	20	1	14	70.0%	6	1	21	2
Marketers and Brokers	11	10	1	6	60.0%	4	1	11	0
Other Non-Registered WECC Members and Participating Stakeholders	1	0	0	0	0.0%	0	0	0	1
State and Provincial Representatives	0	0	0	0	0.0%	0	0	0	0
System Coordination	19	16	1	10	62.5%	6	2	18	1
Transmission	21	17	1	12	70.6%	5	2	19	2
Totals	92	78	5	52	**66.0%**	26	7	85	7

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	British Columbia Hydro & Power Authority (aka BC Hydro)	Transmission	Abstain	No comments.	Patricia Robertson

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	British Columbia Hydro & Power Authority (aka BC Hydro)	System Coordination	Abstain	No comments.	Patricia Robertson
WECC-0107	Northern California Power Agency	Generation	No	NCPA does not feel the standard needs revision.	Marty Hostler
WECC-0107	Arizona Public Service Company	System Coordination	No	AZPS recommends the following edit to R2 for clarity: "Each Generator Operator shall have its PSS in service while synchronized, apart from the exclusions detailed in R1, except during any of the following…" Also, AZPS suggests that the duration for a PSS being out of service without creating a violation be increased to greater than 30 minutes. The lack of a reliability impact of a generator operating without a PSS in service is evidenced by at least R4 of the current draft of the standard which supports the ability to operate without a PSS in service for up to 180 days for commissioning. While AZPS supports the intent of the change to Requirement R2, namely to remove the previous requirement to log in service hours of the PSS, we believe the present period is overly narrow.	Stephanie Little

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Arizona Public Service Company	Distribution	No	AZPS recommends the following edit to R2 for clarity: "Each Generator Operator shall have its PSS in service while synchronized, apart from the exclusions detailed in R1, except during any of the following…" Also, AZPS suggests that the duration for a PSS being out of service without creating a violation be increased to greater than 30 minutes. The lack of a reliability impact of a generator operating without a PSS in service is evidenced by at least R4 of the current draft of the standard which supports the ability to operate without a PSS in service for up to 180 days for commissioning. While AZPS supports the intent of the change to Requirement R2, namely to remove the previous requirement to log in service hours of the PSS, we believe the present period is overly narrow.	Michelle Amarantos
WECC-0107	Nevada Power Company	System Coordination	No	NV Energy does not believe that the drafting team has proposed an improvement upon the existing standard.	Eric Schwarzrock

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Nevada Power Company	Generation	No	NV Energy does not believe that the drafting team has proposed an improvement upon the existing standard.	Eric Schwarzrock
WECC-0107	Nevada Power Company	Distribution	No	NV Energy does not believe that the drafting team has proposed an improvement upon the existing standard.	Eric Schwarzrock
WECC-0107	Nevada Power Company	Transmission	No	NV Energy does not believe that the drafting team has proposed an improvement upon the existing standard.	Eric Schwarzrock
WECC-0107	Seattle City Light	Transmission	No	Please see Seattle City Light Charles (Bud) Freemans comment	Hao Li

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Arizona Public Service Company	Transmission	No	AZPS recommends the following edit to R2 for clarity: "Each Generator Operator shall have its PSS in service while synchronized, apart from the exclusions detailed in R1, except during any of the following…" Also, AZPS suggests that the duration for a PSS being out of service without creating a violation be increased to greater than 30 minutes. The lack of a reliability impact of a generator operating without a PSS in service is evidenced by at least R4 of the current draft of the standard which supports the ability to operate without a PSS in service for up to 180 days for commissioning. While AZPS supports the intent of the change to Requirement R2, namely to remove the previous requirement to log in service hours of the PSS, we believe the present period is overly narrow.	Gary Nolan

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Arizona Public Service Company	Marketers and Brokers	No	AZPS recommends the following edit to R2 for clarity: "Each Generator Operator shall have its PSS in service while synchronized, apart from the exclusions detailed in R1, except during any of the following…" Also, AZPS suggests that the duration for a PSS being out of service without creating a violation be increased to greater than 30 minutes. The lack of a reliability impact of a generator operating without a PSS in service is evidenced by at least R4 of the current draft of the standard which supports the ability to operate without a PSS in service for up to 180 days for commissioning. While AZPS supports the intent of the change to Requirement R2, namely to remove the previous requirement to log in-service hours of the PSS, we believe the present period is overly narrow.	Todd Komaromy

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Arizona Public Service Company	Generation	No	AZPS recommends the following edit to R2 for clarity: "Each Generator Operator shall have its PSS in service while synchronized, apart from the exclusions detailed in R1, except during any of the following…" Also, AZPS suggests that the duration for a PSS being out of service without creating a violation be increased to greater than 30 minutes. The lack of a reliability impact of a generator operating without a PSS in service is evidenced by at least R4 of the current draft of the standard which supports the ability to operate without a PSS in service for up to 180 days for commissioning. While AZPS supports the intent of the change to Requirement R2, namely to remove the previous requirement to log in service hours of the PSS, we believe the present period is overly narrow.	Jeri Freimuth

WECC-0107	Public Service Company of Colorado (Xcel Energy)	Generation	No	PSCo has the following concerns related to the proposed VAR-501-WECC-3 standard: On M3, the standard states that if an entity wishes to claim the exemption under Part 3.5, that entity must provide documented evidence of the date the voltage regulator was last replaced. This will require documentation from a time prior to the standard going into effect. Requiring documentation from a period prior to the standard becoming effective is inappropriate. On R4, the standard drafting team has refused to modify the language to allow an entity to have plans to complete the start-up testing of PSS and instead has developed language which requires the test to be completed within 180 days of commercial operation or retrofit of its exciter system. Xcel Energy is concerned that this hard stop date can cause a violation of the standard due to scheduling problems while not providing any impact to reliability. It is noted that this deadline is	David Lemmons

Title	Company	Sector	Vote	Comments	Created By
				regardless of whether the unit is online or not so the argument cannot be made that there is a need for the deadline. Finally, it is unclear how this requirement is materially different than MOD-026-1 Requirement R4, other than the hard stop at 180 days that the WECC standard is proposing.	
WECC-0107	Seattle City Light	Distribution	No	"If a unit is small (less than 20 MVA) and does NOT CONNECT DIRECTLY to the BES transmission system (greater than 100 kV), the unit will not have any measurable impact to the stability of the power system, and thus a power system stabilizer on such a unit should not be required. Please revise the definition of Facility (Introduction Section A, subsection 5) to take this into account. Thank you for your time and efforts in developing this standard.	Dana Wheelock

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Seattle City Light	Marketers and Brokers	No	If a unit is small (less than 20 MVA) and does NOT CONNECT DIRECTLY to the BES transmission system (greater than 100 kV), the unit will not have any measurable impact to the stability of the power system, and thus a power system stabilizer on such a unit should not be required. Please revise the definition of Facility (Introduction Section A, subsection 5) to take this into account. Thank you for your time and efforts in developing this standard.	Charles Freeman

WECC-0107	Public Service Company of Colorado (Xcel Energy)	Distribution	No	PSCo has the following concerns related to the proposed VAR-501-WECC-3 standard: On M3, the standard states that if an entity wishes to claim the exemption under Part 3.5, that entity must provide documented evidence of the date the voltage regulator was last replaced. This will require documentation from a time prior to the standard going into effect. Requiring documentation from a period prior to the standard becoming effective is inappropriate. On R4, the standard drafting team has refused to modify the language to allow an entity to have plans to complete the start-up testing of PSS and instead has developed language which requires the test to be completed within 180 days of commercial operation or retrofit of its exciter system. Xcel Energy is concerned that this hard stop date can cause a violation of the standard due to scheduling problems while not providing any impact to reliability. It is noted that this deadline is	Chad Nickell

Title	Company	Sector	Vote	Comments	Created By
				regardless of whether the unit is online or not so the argument cannot be made that there is a need for the deadline. Finally, it is unclear how this requirement is materially different than MOD-026-1 Requirement R4, other than the hard stop at 180 days that the WECC standard is proposing. For these reasons, Xcel Energy/Public Service Company of Colorado votes no on the proposed standard.	
WECC-0107	Seattle City Light	Generation	No	Refer to Charles Freeman, Seattle City Light.	Mike Haynes

WECC-0107	Public Service Company of Colorado (Xcel Energy)	Transmission	No	PSCo has the following concerns related to the proposed VAR-501-WECC-3 standard: On M3, the standard states that if an entity wishes to claim the exemption under Part 3.5, that entity must provide documented evidence of the date the voltage regulator was last replaced. This will require documentation from a time prior to the standard going into effect. Requiring documentation from a period prior to the standard becoming effective is inappropriate. On R4, the standard drafting team has refused to modify the language to allow an entity to have plans to complete the start-up testing of PSS and instead has developed language which requires the test to be completed within 180 days of commercial operation or retrofit of its exciter system. Xcel Energy is concerned that this hard stop date can cause a violation of the standard due to scheduling problems while not providing any impact to reliability. It is noted that this deadline is	Robert Staton

Title	Company	Sector	Vote	Comments	Created By
				regardless of whether the unit is online or not so the argument cannot be made that there is a need for the deadline. Finally, it is unclear how this requirement is materially different than MOD-026-1 Requirement R4, other than the hard stop at 180 days that the WECC standard is proposing. For these reasons, Xcel Energy/Public Service Company of Colorado votes no on the proposed standard.	

WECC-0107	Public Service Company of Colorado (Xcel Energy)	System Coordination	No	PSCo has the following concerns related to the proposed VAR-501-WECC-3 standard: On M3, the standard states that if an entity wishes to claim the exemption under Part 3.5, that entity must provide documented evidence of the date the voltage regulator was last replaced. This will require documentation from a time prior to the standard going into effect. Requiring documentation from a period prior to the standard becoming effective is inappropriate. On R4, the standard drafting team has refused to modify the language to allow an entity to have plans to complete the start-up testing of PSS and instead has developed language which requires the test to be completed within 180 days of commercial operation or retrofit of its exciter system. Xcel Energy is concerned that this hard stop date can cause a violation of the standard due to scheduling problems while not providing any impact to reliability. It is noted that this deadline is	Robert Staton

Title	Company	Sector	Vote	Comments	Created By
				regardless of whether the unit is online or not so the argument cannot be made that there is a need for the deadline. Finally, it is unclear how this requirement is materially different than MOD-026-1 Requirement R4, other than the hard stop at 180 days that the WECC standard is proposing. For these reasons, Xcel Energy/Public Service Company of Colorado votes no on the proposed standard.	
WECC-0107	US Bureau of Reclamation	Generation	Yes		Erika Doot
WECC-0107	US Bureau of Reclamation	Transmission	Yes		Erika Doot
WECC-0107	Pacific Gas and Electric Company	Generation	Yes		Alex Chua
WECC-0107	Salt River Project	Generation	Yes		Kevin Nielsen
WECC-0107	Salt River Project	Marketers and Brokers	Yes		William Abraham
WECC-0107	Tacoma Power	Distribution	Yes		Chad Edinger
WECC-0107	Idaho Power Company	Transmission	Yes		Laura Nelson
WECC-0107	Idaho Power Company	Distribution	Yes		Laura Nelson
WECC-0107	Idaho Power Company	Generation	Yes		Laura Nelson
WECC-0107	Idaho Power Company	System Coordination	Yes		Laura Nelson
WECC-0107	Black Hills Corporation	Transmission	Yes		Wes Wingen
WECC-0107	Talen Montana, LLC	Generation	Yes		Leland McMillan

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Inland Empire Energy Center LLC	Generation	Yes		Ben Kling
WECC-0107	Platte River Power Authority	System Coordination	Yes		John Collins
WECC-0107	Tri-State Generation & Transmission (Reliability)	System Coordination	Yes		Tracy Sliman
WECC-0107	Tri-State Generation & Transmission (Reliability)	Transmission	Yes		Tracy Sliman
WECC-0107	Platte River Power Authority	Transmission	Yes		Jeff Landis
WECC-0107	Platte River Power Authority	Generation	Yes		Tyson Archie
WECC-0107	Tacoma Power	Generation	Yes		Karen Hedlund
WECC-0107	Tacoma Power	Transmission	Yes		Joseph Wilson
WECC-0107	Tacoma Power	Marketers and Brokers	Yes		Todd Lloyd
WECC-0107	Puget Sound Energy, Inc.	Marketers and Brokers	Yes		Andrea Basinski
WECC-0107	Sacramento Municipal Utility District	System Coordination	Yes		Joe Tarantino
WECC-0107	Sacramento Municipal Utility District	Generation	Yes		Joe Tarantino
WECC-0107	Sacramento Municipal Utility District	Distribution	Yes		Joe Tarantino
WECC-0107	Sacramento Municipal Utility District	Transmission	Yes		Joe Tarantino
WECC-0107	Sacramento Municipal Utility District	Marketers and Brokers	Yes		Joe Tarantino
WECC-0107	Balancing Authority of Northern California	System Coordination	Yes		Joe Tarantino
WECC-0107	Puget Sound Energy, Inc.	System Coordination	Yes		Theresa Rakowsky
WECC-0107	Puget Sound Energy, Inc.	Distribution	Yes		Theresa Rakowsky
WECC-0107	Puget Sound Energy, Inc.	Transmission	Yes		Theresa Rakowsky
WECC-0107	Southern California Edison Company (Transmission & Distribution)	Distribution	Yes		Steven Mavis

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Southern California Edison Company (Transmission & Distribution)	Transmission	Yes		Steven Mavis
WECC-0107	Powerex, Inc.	Marketers and Brokers	Yes		Gordon Dobson-Mack
WECC-0107	British Columbia Hydro & Power Authority (aka BC Hydro)	Generation	Yes		Helen Hamilton Harding
WECC-0107	British Columbia Hydro & Power Authority (aka BC Hydro)	Distribution	Yes		Faramarz Amjadi
WECC-0107	Tri-State Generation & Transmission (Reliability)	Distribution			Janelle Gill
WECC-0107	Southern California Edison Company	Generation			Earle Saunders
WECC-0107	Tacoma Power	System Coordination			Twila Hofer
WECC-0107	Smart Wire Grid	Other Non-Registered WECC Members and Participating Stakeholders			Chifong Thomas
WECC-0107	Public Service Company of New Mexico	Marketers and Brokers			Laurie Williams
WECC-0107	Public Service Company of New Mexico	Transmission			Laurie Williams
WECC-0107	Public Service Company of New Mexico	Distribution			Laurie Williams
WECC-0107	Public Service Company of New Mexico	Generation			Laurie Williams
WECC-0107	Public Service Company of New Mexico	System Coordination			Laurie Williams
WECC-0107	Gridforce Energy Management, LLC	System Coordination			David Blackshear
WECC-0107	Bonneville Power Administration	Transmission			Donald Watkins
WECC-0107	Bonneville Power Administration	System Coordination			Francis Halpin
WECC-0107	Bonneville Power Administration	Distribution			Rebecca Berdahl

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	PacifiCorp	Marketers and Brokers			Sandra Shaffer
WECC-0107	Puget Sound Energy, Inc.	Generation			Lynda Kupfer
WECC-0107	NextEra Energy Resources, LLC	Generation			Mark Mango
WECC-0107	Salt River Project	Transmission			Steven Cobb
WECC-0107	Colorado Springs Utilities	Transmission			Shawna Speer
WECC-0107	Colorado Springs Utilities	Generation			Shawna Speer
WECC-0107	Colorado Springs Utilities	Distribution			Shawna Speer
WECC-0107	Colorado Springs Utilities	System Coordination			Shawna Speer
WECC-0107	PacifiCorp	Transmission			Sandra Shaffer
WECC-0107	PacifiCorp	Distribution			Sandra Shaffer
WECC-0107	PacifiCorp	Generation			Sandra Shaffer
WECC-0107	PacifiCorp	System Coordination			Sandra Shaffer
WECC-0107	Avista Corporation	Transmission			Bryan Cox
WECC-0107	Avista Corporation	Distribution			Bryan Cox
WECC-0107	Avista Corporation	Generation			Bryan Cox
WECC-0107	Avista Corporation	System Coordination			Bryan Cox
WECC-0107	Avista Corporation	Marketers and Brokers			Scott Kinney
WECC-0107	Seattle City Light	System Coordination			Pawel Krupa
WECC-0107	Portland General Electric Company	System Coordination			Angela Gaines
WECC-0107	Portland General Electric Company	Marketers and Brokers			Angela Gaines
WECC-0107	Portland General Electric Company	Transmission			Angela Gaines

Title	Company	Sector	Vote	Comments	Created By
WECC-0107	Portland General Electric Company	Distribution			Angela Gaines
WECC-0107	Portland General Electric Company	Generation			Angela Gaines

Regional Reliability Standards Announcement

Western Electricity Coordinating Council VAR-501-WECC-3

Comment Period Open through January 25, 2017

Now Available

The Western Electricity Coordinating Council (WECC) has requested NERC to post Regional Reliability Standards **VAR-501-WECC-3 – Power System Stabilizer** for industry review and comment as permitted by the NERC Rules of Procedure.

Commenting

Use the electronic form to submit comments. If you experience any difficulties in using the electronic form, contact Mat Bunch. The form must be submitted by **8 p.m. Eastern, Wednesday, January 25, 2017.** An unofficial Word version of the comment form is posted on the Regional Reliability Standards Under Development page.

Regional Reliability Standards Development Process

Section 300 of NERC's Rules of Procedures of the Electric Reliability Organization governs the regional reliability standards development process.

Background

The WECC Regional Reliability Standard Drafting Team was charged to address a Standard Authorization Request, in which the following changes to WECC's Power System Stabilizer (PSS) program were proposed:

1. Update and codify WECC's PSS program;
2. Establish a minimum design-criteria for installation of new PSS-related equipment;
3. Standardize tuning procedures for that equipment; and
4. Identify those facilities to which the PSS applies,

Although the technical aspects of this Regional Reliability Standard have been vetted through WECC's Regional Standards development process, the final approval process for a Regional Reliability Standard requires NERC publicly to notice and request comment on the criteria outlined in the comment form. Documents and information about this project are available on the WECC's Standards Under Development page.

For more information or assistance, contact Reliability Standards Analyst, Mat Bunch (via email) or at (404) 446-9785.

North American Electric Reliability Corporation
3353 Peachtree Rd, NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

Comment Report

Project Name:	WECC - Regional Reliability Standard | VAR-501-WECC-3
Comment Period Start Date:	12/12/2016
Comment Period End Date:	1/25/2017
Associated Ballots:	

There were 5 sets of responses, including comments from approximately 5 different people from approximately 5 companies representing 5 of the Industry Segments as shown in the table on the following pages.

Questions

1. Do you agree the development of VAR-501-WECC-3 met the “Open” criteria as outlined above? If “No”, please explain in the comment area below.

2. Do you agree the development of VAR-501-WECC-3 met the “Inclusive” criteria as outlined above? If “No”, please explain in the comment area below.

3. Do you agree the development of VAR-501-WECC-3 met the “Balanced” criteria as outlined above? If “No”, please explain in the comment area below.

4. Do you agree the development of VAR-501-WECC-3 met the “Due Process” criteria as outlined above? If “No”, please explain in the comment area below.

5. Do you agree the development of VAR-501-WECC-3 met the “Transparent” criteria as outlined above? If “No”, please explain in the comment area below.

Organization Name	Name	Segment(s)	Region	Group Name	Group Member Name	Group Member Organization	Group Member Segment(s)	Group Member Region
Southern Company - Southern Company Services, Inc.	Pamela Hunter	1,3,5,6	SERC	Southern Company	Katherine Prewitt	Southern Company Services, Inc.	1	SERC
					R. Scott Moore	Alabama Power Company	3	SERC
					William D. Shultz	Southern Company Generation	5	SERC
					Jennifer G. Sykes	Southern Company Generation and Energy Marketing	6	SERC

1. Do you agree the development of VAR-501-WECC-3 met the “Open” criteria as outlined above? If “No”, please explain in the comment area below.

Laura Nelson - IDACORP - Idaho Power Company - 1	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Bishnu Sapkota - GE - GE Power Systems Energy Consulting - 10 - WECC	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Richard Jackson - U.S. Bureau of Reclamation - 1,5	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Lynda Kupfer - Puget Sound Energy, Inc. - 1,3,5	
Answer	Yes

Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Pamela Hunter - Southern Company - Southern Company Services, Inc. - 1,3,5,6 - SERC, Group Name Southern Company	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	

2. Do you agree the development of VAR-501-WECC-3 met the "Inclusive" criteria as outlined above? If "No", please explain in the comment area below.

Bishnu Sapkota - GE - GE Power Systems Energy Consulting - 10 - WECC

Answer	No
Document Name	

Comment

We have reviewed the proposed standard VAR-501-WECC-3, Power System Stabilizers. In general, the document looks good, however, we see a need for adjustment on the requirement R3 of the document.

The requirement R3 states that the final PSS gain should be between 1/3 (10 dB) to 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain may also be associated with the interactions of the PSS with low-order torsional modes of the turbine-generator unit which may or may not be evaluated during the PSS commissioning test. Accordingly, the PSS gain may need to be kept lower than 1/3 of the maximum practical gain that can be proved during the testing. The reason for this recommendation is to avoid any potential detrimental issues associated with the above-mentioned torsional interactions. So, we would recommend to make adjustment in the statement as follows:

The final PSS gain should not be greater than 1/3 of the maximum practical gain.

Likes 0	
Dislikes 0	

Response

Pamela Hunter - Southern Company - Southern Company Services, Inc. - 1,3,5,6 - SERC, Group Name Southern Company

Answer	Yes
Document Name	

Comment

Likes 0	
Dislikes 0	

Response

Lynda Kupfer - Puget Sound Energy, Inc. - 1,3,5

Answer	Yes
Document Name	

Comment

Likes 0	
Dislikes 0	
Response	
Richard Jackson - U.S. Bureau of Reclamation - 1,5	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Laura Nelson - IDACORP - Idaho Power Company - 1	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	

3. Do you agree the development of VAR-501-WECC-3 met the "Balanced" criteria as outlined above? If "No", please explain in the comment area below.

Bishnu Sapkota - GE - GE Power Systems Energy Consulting - 10 - WECC	
Answer	No
Document Name	
Comment	
Please refer to the comment for question 2.	
Likes 0	
Dislikes 0	
Response	
Lynda Kupfer - Puget Sound Energy, Inc. - 1,3,5	
Answer	Yes
Document Name	
Comment	
Comment: Please clarify the conditions and timing under which an automatic voltage regulator without PSS, or a PSS that cannot meet the tuning requirements in R3 would have to be replaced. Our interpretation for R4 is that only if we were replacing the voltage regulator on an existing exciter would we have to add PSS to a unit that doesn't currently have it. R3.5 provides an exemption for PSS that cannot be tuned but R5 requires repair or replacement within 24 months of determining it cannot be tuned to the standard requirements. Because R3 is effective 5 years after approval for existing systems, would we then have 2 years after that to replace PSS that cannot be tuned to the specifications?	
Likes 0	
Dislikes 0	
Response	
Pamela Hunter - Southern Company - Southern Company Services, Inc. - 1,3,5,6 - SERC, Group Name Southern Company	
Answer	Yes
Document Name	
Comment	

1. Redline, page 14, Section Requirement R3, first sentence: What is RRS? Should RSS be RRS (regional reliability standard)?

2. **With regard to the draft standard section R3.3: PSS Gain shall be set to between 1/3 and 1/2 of maximum practical gain.**

The SDT should define "maximum practical gain". Is this meant to be the gain value resulting in the threshold of instability? In defining the maximum practical gain, one must account for older PSS systems and the newer dual input PSS units using the integral of accelerating power which are stable at significantly higher gains.

Likes 0	
Dislikes 0	
Response	
Laura Nelson - IDACORP - Idaho Power Company - 1	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Richard Jackson - U.S. Bureau of Reclamation - 1,5	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	

4. Do you agree the development of VAR-501-WECC-3 met the "Due Process" criteria as outlined above? If "No", please explain in the comment area below.

Richard Jackson - U.S. Bureau of Reclamation - 1,5	
Answer	No
Document Name	
Comment	

In general, Reclamation supports the changes proposed in VAR-501-WECC-3. Reclamation requests that the standard be revised to contain clarifying language regarding the allowance for a PSS to be out of service in R2: Is a PSS outage of 30 minutes considered a violation or not? During what interval is "more than 30 minutes" considered a violation – per occurrence, or a total per year?

Reclamation suggests that R3 be clarified to state that each Generator Owner shall tune its PSS to meet "ALL" the following criteria (3.1 **"and"** 3.2 **"and"** 3.3 **"and"** 3.4 **"OR"** 3.5) in order to better align with the VSL for R3 which indicates a violation if ANY of the criteria are not met.

R4 by itself can be misinterpreted to mandate installation of PSS on existing generators. To avoid confusion, BOR recommends copying the text of the "Mandate to Install a PSS" section (on page 8 of the Clean version) to a third bullet under R4.

R5 may be overly restrictive given procurement issues that entities, especially federal agencies, could experience. The clause **"or a plan to repair or replace not to exceed 36 months"** should be included to offset the possibility of unforeseen delays that could cause a possible violation beyond the entity's control.

In the Evidence Retention section, it is unclear what the phrase "plus calendar current" means

Likes 0	
Dislikes 0	
Response	
Pamela Hunter - Southern Company - Southern Company Services, Inc. - 1,3,5,6 - SERC, Group Name Southern Company	
Answer	Yes
Document Name	
Comment	

Likes 0	
Dislikes 0	
Response	
Lynda Kupfer - Puget Sound Energy, Inc. - 1,3,5	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Bishnu Sapkota - GE - GE Power Systems Energy Consulting - 10 - WECC	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Laura Nelson - IDACORP - Idaho Power Company - 1	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	

5. Do you agree the development of VAR-501-WECC-3 met the “Transparent” criteria as outlined above? If “No”, please explain in the comment area below.

Laura Nelson - IDACORP - Idaho Power Company - 1	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Bishnu Sapkota - GE - GE Power Systems Energy Consulting - 10 - WECC	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Richard Jackson - U.S. Bureau of Reclamation - 1,5	
Answer	Yes
Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	
Pamela Hunter - Southern Company - Southern Company Services, Inc. - 1,3,5,6 - SERC, Group Name Southern Company	
Answer	Yes

Document Name	
Comment	
Likes 0	
Dislikes 0	
Response	

A. Introduction

1. **Title:** Power System Stabilizer (PSS)
2. **Number:** VAR-501-WECC-3
3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.
4. **Applicability:**

   4.1 Generator Operator

   4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators, connected to the Bulk Electric System, that meet the definition of Commercial Operation.
6. **Effective Date:** The first day of the first quarter following regulatory approval, except for Requirement R3.

   For units placed in first-time service after regulatory approval, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

   For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date; or
- Any changes to the PSS operating specifications.

M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.

For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator shall have its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

- Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor: Medium] [Time Horizon: Operating Assessment]*

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

- The Generator Owner connects a generator to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.
- The Generator Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. Compliance

1. Compliance Monitoring Process

1.1 Compliance Enforcement Authority

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance Investigations
- Self-Reporting
- Complaints

1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

Each Generator Operator shall keep evidence for all Requirements of the document for a period of three years plus calendar current.

1.4 Additional Compliance Information

None

D. Regional Differences

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
R2	Operations Assessment	Medium	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	Each Generator Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
R5	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to repair or replace a non-operational PSS as required in Requirement R5.

Version History

Version	Date	Action	Change Tracking
1	April 16, 2008	Permanent Replacement Standard for VAR-STD-002b-1	
1	October 28, 2008	Adopted by NERC Board of Trustees	
1	April 21, 2011	FERC Order issued approving VAR- 501-WECC-1 (FERC approval effective June 27, 2011; Effective Date July 1, 2011)	
2	November 13, 2014	Adopted by NERC Board of Trustees	
2	March 3, 2015	FERC letter order approved VAR-501-WECC-2	
3	TBD	TBD	

Guideline and Technical Basis

PSS systems are used to minimize real power oscillations by rapidly adjusting the field of the generator to dampen the low-frequency oscillations.

It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

Mandate to Install a PSS

Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.

It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner, the PSS operating zone in which the PSS is “active” providing damping to the power system. Some PSS may be programmed to become “active” at a specified megawatt loading level and above while others may be programmed to be “active” in a particular band of megawatt loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard’s previous version, the logged hours were totaled quarterly to meet the

98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for the commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

*** FOR INFORMATIONAL PURPOSES ONLY ***

Enforcement Dates: Standard VAR-501-WECC-3 — Power System Stabilizer

United States

Standard	Requirement	Enforcement Date	Inactive Date
VAR-501-WECC-3	TBD	TBD	

A. Introduction

1. ~~1.~~ **Title:** Power System Stabilizer (PSS)

~~2.~~ **Number:** VAR-501-WECC-~~2~~

2. 3

3. **Purpose:** To ensure the Western Interconnection is operated in a coordinated manner under normal and abnormal conditions by establishing the performance criteria for WECC power system stabilizers.

4. **Applicability:**

~~that Power System Stabilizers (PSS) on~~ 4.1 Generator Operator

4.2 Generator Owner

5. **Facilities:** This standard applies to synchronous generators ~~shall be kept in service.~~, connected to the Bulk Electric System, that meet the definition of Commercial Operation.

~~1. 4. Applicability:~~

~~4.1. Generator Operators~~

6. ~~5.~~ **Effective Date:** ~~On the~~ The first day of the first quarter~~,~~ following regulatory approval, except for Requirement R3.

For units placed in first-time service after ~~applicable~~ regulatory approval~~.~~, Requirement R3 is effective the first day of the first quarter following final regulatory approval.

For units placed in service prior to final regulatory approval, Requirement R3 is effective the first day of the first quarter that is five years after regulatory approval.

B. Requirements and Measures

R1. Each Generator Owner shall provide to its Transmission Operator, the Generator Owner's written Operating Procedure or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the Automatic Voltage Regulator (AVR), within 180 days of any of the following events: *[Violation Risk Factor: Low] [Time Horizon: Planning Horizon]*

- The effective date of this standard;
- The PSS's Commercial Operation date; or
- Any changes to the PSS operating specifications.

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M1. Each Generator Owner will have documented evidence that it provided to its Transmission Operator, within the time allotted as described in the procedures required under Requirement R1, written Operating Procedures or other document(s) describing those known circumstances during which the Generator Owner's PSS will not be providing an active signal to the AVR.

For auditing purposes, because Requirement R1 conditions are intended to be unchanged unless the Transmission Operator is otherwise notified, the Generator Owner only needs to provide the documentation to the Transmission Operator one time, or whenever the operating specifications change.
For auditing purposes, if a PSS is in service but is not providing an active signal to the AVR as described in Requirement R1, the disabled period does not count against the Requirement R2 mandate to be in service except as otherwise allowed.

R2. Each Generator Operator~~R1. Generator Operators~~ shall have ~~PSS in service 98% of all operating hours for synchronous generators equipped with PSS. Generator Operators may exclude hours for R1.1 through R1.12 to achieve the 98% requirement.~~ its PSS in service while synchronized, except during any of the following: *[Violation Risk Factor: Medium] [Time Horizon: ~~Operations~~Operating Assessment]*

- ~~**R1.1.** The~~ Component failure
- Testing of a Bulk Electric System Element affecting or affected by the PSS
- Maintenance
- As agreed upon by the Generator Operator and the Transmission Operator

A PSS that is out of service for less than 30 minutes does not create a violation of this Requirement, regardless of cause.

M2. Each Generator Operator will have documentation of each claimed exception specified in Requirement R2. Documentation may include, but is not limited to:

- A written explanation covering the bulleted exception that describes the circumstances of the exception as allowed in Requirement R2.
- Documented evidence that the Generator Operator and the Transmission Operator agreed the PSS would not be operating during a specified set of circumstances, where the exception is claimed under the last bullet of Requirement R2.

For auditing purposes, the presumption is that the PSS was in service unless otherwise exempted in Requirement R2. Evidence need only be provided to prove the circumstances during which the PSS was not in service for periods in excess of 30 minutes.

R3. Each Generator Owner shall tune its PSS to meet the following inter-area mode criteria, except as specified in Requirement R3, Part 3.5 below: *[Violation Risk Factor:*

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Medium] [Time Horizon: Operating Assessment]

3.1. PSS shall be set to provide the measured, simulated, or calculated compensated Vt/Vref frequency response of the excitation system and synchronous machine such that the phase angle will not exceed ± 30 degrees through the frequency range from 0.2 Hertz to the lesser of 1.0 Hertz or the highest frequency at which the phase of the Vt/Vref frequency response does not exceed 90 degrees.

3.2. PSS output limits shall be set to provide at least ±5% of the synchronous machine's nominal terminal voltage.

3.3. PSS gain shall be set to between 1/3 and 1/2 of maximum practical gain.

3.4. PSS washout time constant shall be no greater than 30 seconds.

3.5. Units that have an excitation system or PSS that is incapable of meeting the tuning requirements of Requirement R3 are exempt from Requirement R3 until the voltage regulator is either replaced or retrofitted such that the PSS becomes capable of meeting the tuning requirements.

M3. Each Generator Owner will have documented evidence that its PSS was tuned to meet the specifications of Requirement R3.

If the exception under Requirement R3, Part 3.5, is claimed, the Generator Owner will have documented evidence describing: 1) the conditions that render the PSS incapable of meeting the tuning requirements, and 2) the date the voltage regulator was last replaced or retrofitted.

R4. Each Generator Owner shall install and complete start-up testing of a PSS on its generator ~~operates for less than five percent of all hours during any calendar quarter.~~within 180 days of either of the following events: *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

~~**R1.2.** Performing maintenance and testing up to a maximum of seven calendar days per calendar quarter.~~

~~**R1.3.** PSS exhibits instability due to abnormal system configuration.~~

~~**R1.4.** Unit is operating in the synchronous condenser mode (very near zero real power level).~~

~~**R1.5.** Unit is generating less power than its design limit for effective PSS operation.~~

~~**R1.6.** Unit is passing through a range of output that is a known "rough zone" (range in which a hydro unit is experiencing excessive vibration).~~

~~**R1.7.**~~ The Generator Owner connects a generator ~~AVR is not in service.~~

~~**R1.8.** Due to component failure, the PSS may be out of service up to 60 consecutive days for repair per incident.~~

~~**R1.9.** Due to a component failure, the PSS may be out of service up to one year provided the Generator Operator submits documentation identifying the need for time to obtain replacement parts and if required to schedule an outage.~~

~~**R1.10.** Due to a component failure, the PSS may be out of service up to 24 months provided the Generator Operator submits documentation identifying the need for time for PSS replacement and to schedule an outage.~~

- ~~**R1.11.** The synchronous generator has not achieved~~to the BES, after achieving Commercial Operation, and after the Effective Date of this standard.

- ~~**R1.12.**~~ The ~~Transmission Operator directs the~~ Generator ~~Operator to operate the synchronous~~Owner replaces the voltage regulator on its existing excitation system, after achieving Commercial Operation for its generator that is connected to the BES, and after the Effective Date of this standard.

M4. Each Generator Owner will have evidence that it installed and completed start-up testing of a PSS ~~is unavailable for~~ on its generator within 180 days of either of the conditions described in Requirement R4, and when those conditions occur after the Effective Date of this standard.

For auditing purposes of Requirement R4, bullet one only applies to equipment on its initial (first energization) connection to the BES.

R5. Each Generator Owner shall repair or replace a PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications stated in Requirement R3. *[Violation Risk Factor: Medium] [Time Horizon: Operational Assessment]*

M5. Each Generator Owner will have evidence that it repaired or replaced its PSS within 24 months of that PSS becoming incapable of meeting the tuning specifications of Requirement R3. Evidence may include, but is not limited to, documentation of the date the PSS became incapable of meeting the Requirement R3 tuning specifications, and the date the PSS was returned to service, demonstrating that the span of time between the two events was less than 24 months.

C. ~~Measures~~

~~M1. Generators Operators shall provide quarterly reports to the compliance monitor and have evidence for each synchronous generator of the following:~~

~~**M1.1** The number of hours the synchronous generator was on line.~~

~~**M1.2** The number of hours the PSS was out of service with generator on line.~~

~~**M1.3** The PSS in service percentage~~

~~**M1.4** If excluding PSS out of service hours as allowed in R1.1 through R1.12, provide:~~

~~**M1.4.1** The number of hours excluded,~~

~~**M1.4.2** The adjusted PSS in-service percentage,~~

~~**M1.4.3** Date of the outage.~~

~~D.~~ Compliance

1. Compliance Monitoring Process

1.1 Compliance ~~Monitoring Responsibility~~

~~Compliance~~ **Enforcement Authority**

NERC or the Regional Entity, or any entity as otherwise designated by an Applicable Governmental Authority, in their respective roles of monitoring and/or enforcing compliance with mandatory and enforceable Reliability Standards in their respective jurisdictions.

1.2 Compliance Monitoring ~~Period~~and Assessment Processes

- Compliance Audits
- Self-Certifications
- Spot Checking
- Compliance ~~Enforcement Authority may use one or more of the following methods to assess~~Investigations
- Self-Reporting
- Complaints

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1.3 Evidence Retention

The following evidence retention periods identify the period of time an entity is required to retain specific evidence to demonstrate compliance~~:~~. For instances where the evidence retention period specified below is shorter than the time since the last audit, the Compliance Enforcement Authority may ask an entity to provide other evidence to show that it was compliant for the full time period since the last audit.

~~- Reports submitted quarterly~~

~~- Spot check audits conducted anytime with 30 days notice~~

~~- Periodic audit as scheduled by the Compliance Enforcement Authority~~

~~- Investigations~~

~~- Other methods as provided for in the Compliance Monitoring Enforcement Program~~

~~The Reset Time Frame shall be a calendar quarter.~~

~~**1.3 Data Retention**~~

~~The~~Each Generator ~~Operators~~Operator shall keep evidence for ~~Measures M1 for~~all Requirements of the document for a period of three years plus calendar current ~~year, or since the last audit, whichever is longer~~.

1.4 Additional Compliance Information

None

~~**1.4.1** The sanctions shall be assessed on a calendar quarter basis.~~

~~**1.4.2** If any of R1.2 through R1.12 continues from one quarter to another, the number of days accumulated will be the contiguous calendar days from the beginning of the incident to the end of the incident. For example, in R1.8 if the 60 day repair period goes beyond the end of a quarter, the repair period does not reset at the beginning of the next quarter.~~

~~**1.4.3** When calculating the adjusted in-service percentage, the PSS out of service hours do not include the time associated with R1.1 through R1.12.~~

~~1.4.4 The standard shall be applied on a generating unit by generating unit basis (a Generator Operator can be subject to a separate sanction for each non- compliant synchronous generating unit or to a single sanction for multiple machines that operate as one unit).~~

~~E~~D. Regional Differences

None

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~~None~~

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
R1	Planning Horizon	Low	NA	NA	NA	The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.
~~R1~~ R2	~~Operational~~ Operations Assessment	Medium	~~There shall be a Lower Level of non-compliance if PSS is in service less than 98% but at least 90% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a Moderate Level of non-compliance if PSS is in service less than 90% but at least 80% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a High Level of non-compliance if is in service less than 80% but at least 70% or more of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while	~~There shall be a Severe Level of non-compliance if PSS is in service less than 70% of all hours during which the synchronous generating unit is on line for each calendar quarter.~~ Each Generator Operator not having its PSS in service while

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R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
			synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.	synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.	synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.	synchronized in accordance with Requirement R2, for more than 180 minutes.
R3	Operations Assessment	Medium	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.	The Generator Owner's PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.
R4	Operational Assessment	Medium	NA	NA	NA	The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.
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R	Time Horizon	VRF	Violation Severity Levels			
			Lower VSL	Moderate VSL	High VSL	Severe VSL
						required in Requirement R5.

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Version History

Version	Date	Action	Change Tracking
1	April 16, 2008	Permanent Replacement Standard for VAR-STD-002b-1	
1	October 28, 2008	Adopted by NERC Board of Trustees	
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It is necessary for large numbers of PSS devices to be in operation in the Western Interconnection to provide the required system damping while still allowing for some of these units to be out of service whenever necessary.

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Nothing in this Regional Reliability Standard (RSS) should be construed to require installation of a PSS *solely because* a PSS is not currently installed as of the Effective Date of this RRS. Rather, installation is only mandated on the occurrence of either of the triggering events described in Requirement R4, Bullet 1 or Bullet 2, after the Effective Date of the RRS.

It should be noted that a PSS is neither Transmission nor generation.

Requirement R1

Requirement R1 addresses normal operating conditions.

Requirement R1 recognizes that PSS systems have varying states, such as on, off, active, and non-active. As long as the PSS is operating in accordance with the documentation provided to the Transmission Planner, this is not considered a status change for purposes of this standard.

This Requirement eliminates the requirement to count hours as required in the previous version of this standard while also allowing the Generator Owner to create a unit-specific operating plan.

The intent of Requirement R1 is to provide the Transmission Planner, the PSS operating zone in which the PSS is “active” providing damping to the power system. Some PSS may be programmed to become “active” at a specified megawatt loading level and above while others may be programmed to be “active” in a particular band of megawatt loading levels and are “non-active” only when passing through the “rough zone” or some other band. A “rough zone” is a megawatt loading band in which the generator-turbine system could contribute to system instability.

Requirement R2

This Requirement only applies when the PSS is out of service for a period greater than 30 minutes.

Unlike Requirement R1, Requirement R2 addresses exceptions to normal operation.

The intent of Requirement R2 is to remove the previous requirement to log hours for PSS in service. In this standard’s previous version, the logged hours were totaled quarterly to meet the

98% in-service requirement. Instead of documenting the number of hours excluded, this Requirement simplifies the process by allowing the Generator Operator to communicate to the Transmission Operator the circumstances that render the PSS unavailable to the Transmission Operator (such as component failure, maintenance, and testing).

Requirement R3

Nothing in this RSS should be construed to mandate the design criteria for the *equipment* used to produce the tuning output of the PSS. Rather, Requirement R3 is intended to address the design criteria for the *tuning output* of the PSS.

Unlike the language in Requirement R5 that looks *backward* to address units that were once operating but are no longer capable of operating, Requirement R3 looks *forward*, requiring that units be tuned to the specified parameters.

The PSS transfer function should compensate the phase characteristics of the generator, exciter, and power (GEP) system transfer function so the compensated transfer function ((PSS(s) * GEP(s)) has a phase characteristic of ± 30 degrees in the frequency range.

The GEP(s) transfer function is a theoretical transfer function and its phase characteristic cannot be directly measured during field tests (only via simulation). Thus, the Requirement recognizes the practical approach of measuring the frequency response between voltage reference set point and terminal voltage (Et/Vref) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of Et/Vref is a better approximation to the phase characteristic of GEP(s) when the frequency response Et/Vref is obtained with the generator synchronized to the grid at its minimum stable power output.

In an effort to allow for reasonable wash-out time constants, the Requirement specifies 0.2 Hz as the applicable threshold. The 0.2 Hz threshold more closely aligns with the observed oscillation frequencies.

A properly tuned PSS should provide positive damping to the local mode of oscillation, which typically has a frequency higher than 1.0 Hz.

This Requirement modifies the requirement associated with the adjustment of the PSS gain. The standard no longer defines the PSS gain in terms of gain margin but instead requires the final PSS gain to be between 1/3 (10 dB) and 1/2 (6 dB) of the maximum practical gain that could be achieved during PSS commissioning. The maximum practical gain might be associated with the excessive noise or raised higher-frequency oscillations in the closed loop response (exciter mode) or any other form if there is inadequate closed-loop performance, as determined during PSS commissioning. It is now part of Measure M3 to show the field test results that led to the determination of the maximum practical gain.

Requirement R4

Requirement R4 requires a Generator Owner to install a PSS on new applicable units or when excitation systems are replaced or retrofitted on existing applicable units. This Requirement applies to new excitation systems and not to existing systems that do not have PSS. The Requirement also allows a reasonable amount of time for the commissioning of new PSS.

Requirement R5

Unlike the language in Requirement R3 that looks *forward* to ensure that a unit is tuned, Requirement R5 looks *backward.* Specifically, the language in Requirement R5, "becoming incapable," indicates the unit was previously capable of meeting the tuning requirements in Requirement R3, but is no longer capable. Restated, Requirement R5 addresses units that were previously working but are now no longer working.

The intent of Requirement R5 is to remove the "tiered" approach to PSS repair/replacement following a failure. A simple, streamlined approach to allow the Generator Owner sufficient time to repair or replace a broken PSS has been written. Consideration has been given for the need to procure parts or new equipment, schedule an equipment/unit outage, and install and test the repaired or replaced PSS. It is recognized that in some instances, it may require (1) replacement of an AVR, and (2) the existence of a PSS, or both the AVR and the PSS may need to be replaced to achieve a functioning system.

The 24-month time frame is sufficient to return a functional, operating PSS to service.

*** FOR INFORMATIONAL PURPOSES ONLY ***

Enforcement Dates: Standard VAR-501-WECC-3 — Power System Stabilizer

United States

Standard	Requirement	Enforcement Date	Inactive Date
VAR-501-WECC-3	TBD	TBD	

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Exhibit G

Technical Justification White Papers

Exhibit G-1

Power System Stabilizer Applicability in the WECC System: Study Progress Report to WECC-0107 Drafting Team

Power System Stabilizer Applicability in the WECC System

Study Progress Report to WECC-0107 Drafting Team

Shawn Patterson

Bureau of Reclamation

April 2014

Introduction

Power System Stabilizers (PSS) are essential to the stability of the WECC interconnection. Their development and application were critical to the early interconnection, and their continued application on generators over the decades has provided a tangible benefit to the reliability of the WECC system. Therefore, there is a general interest in maintaining the practice of applying PSS in WECC generators, which is countered by a general interest in not requiring PSS on all generators. Balancing these two positions is less than straightforward and requirement thresholds have ultimately been determined without the benefit of technical data. Recently, a study report was provided by Dmitry Kosterev to support PSS standard drafting team discussion. This report is meant to augment that of Dr. Kosterev.

Background

Originally, stabilizers were applied to a handful of strategically located generators, but by the early 1970’s, the recommendation was made to apply PSS to all generators 75 MVA and greater. Due to their location in the system, many units smaller than 75 MVA also included PSS at this time. Studies were performed in 1974 to establish a recommendation on minimal percentage of PSS equipped generators that should be online at any given time. The recommendation of applying PSS to units 75 MVA and larger was in place until the “Criteria to Determine Excitation System Suitability for PSS in WSCC System” report was released in 1992. This study recommended considering the application of PSS on all existing units of 75 MVA or larger, and all new machines with continuously acting voltage regulators. The WECC PSS Policy Statement, approved in 2002, required PSS on all existing units 75 MVA and greater, and all units of 30 MVA and larger, with new excitation systems considered suitable.

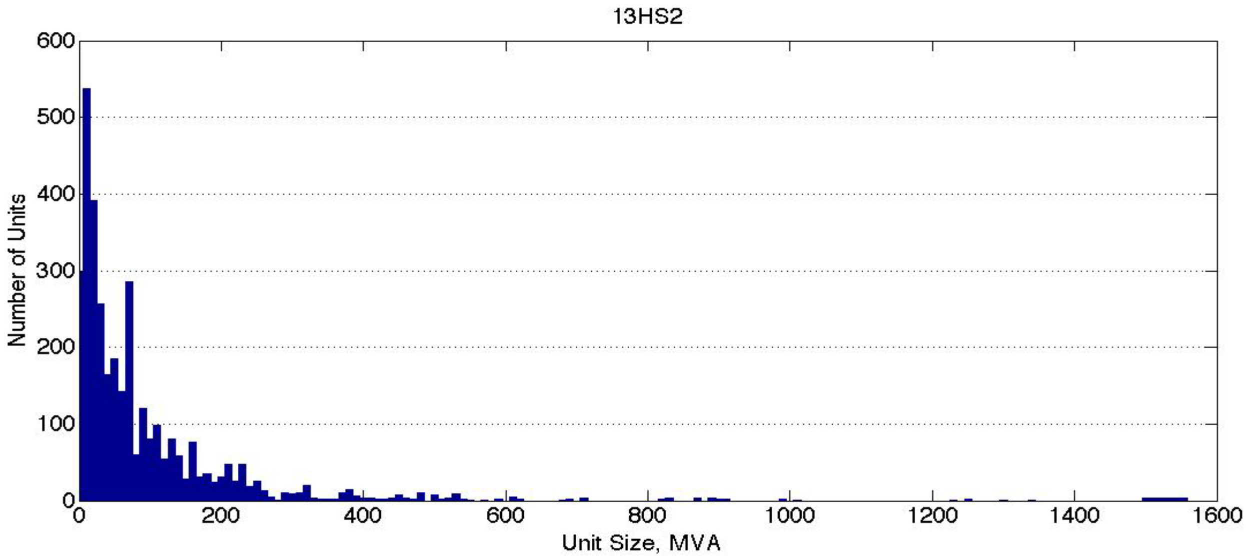
The PSS represented in the current WECC model database reflects the history of the recommendations and requirements of the last 40 years, that is, nearly all units greater than 75 MVA are equipped with PSS, nearly half the units sized between 30 MVA and 75 MVA are equipped with PSS, and less than 25 percent of units smaller than 30 MVA have PSS.

Meaningful studies of PSS application, or for any generator equipment are difficult. With over 3,000 generators in the connected system, the impact of any single unit is nearly impossible to see. The effects of PSS are distributed throughout the system. Their influence depends largely on the varying system conditions. In some cases the response of a particular unit may be of great important to the overall system behavior, but in another case, have no impact. So the type of sensitivity study presented by Dr. Kosterev is a likely attempt to determine the wide scale effect of PSS throughout the system. However, conclusions based on such a study can be easily misinterpreted. Given the history of PSS application in the WECC, the results of such a study are predictable: Policy or recommendations have resulted in nearly uniform application of PSS on units greater than 75 MVA, therefore the results are sensitive to removing them from large numbers of these units. Removing PSS on units 30 to 75 MVA affects about half of them, so the results are sensitive, but not as much as the first case. Removing PSS on units less than 25 MVA affects almost no units, with the expected system impact.

Study Methodology

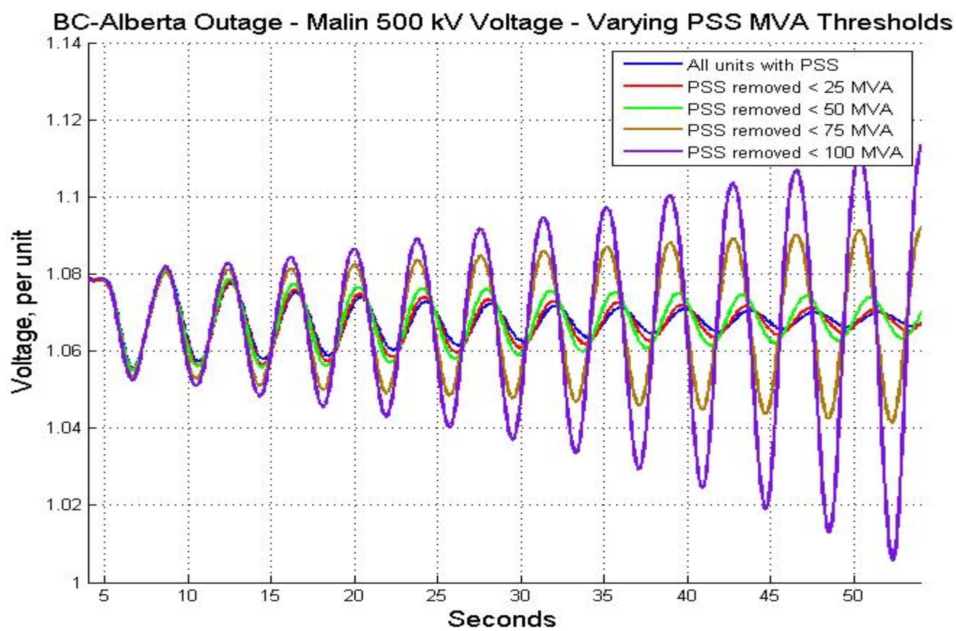
To examine the sensitivity of removing PSS from large groups of generators, then they all must at least have a PSS than can be removed. Therefore, Dr. Kosterev's study was performed, as similar as possible (same case, same disturbance) but with PSS installed on all possible units, i.e., units with excitation systems that allow a PSS input signal. This entailed the creation of about 1,200 PSS models to add to the existing 1,500 PSS models in the cases examined. As expected, most of these models were applied to units smaller than 75 MVA, but some were applied to much larger units that did not have PSS represented in the cases. There were 55 generators in the case, mostly smaller than 50 MVA, which have excitation system models that cannot accept a PSS signal.

An important factor to keep in mind when considering the WECC system is that more than half of the approximately 3,000 synchronous machines modeled are less than 75 MVA in size.


13HS2
Number of Units
Unit Size, MVA
0
100
200
300
400
500
600
0
200
400
600
800
1000
1200
1400
1600

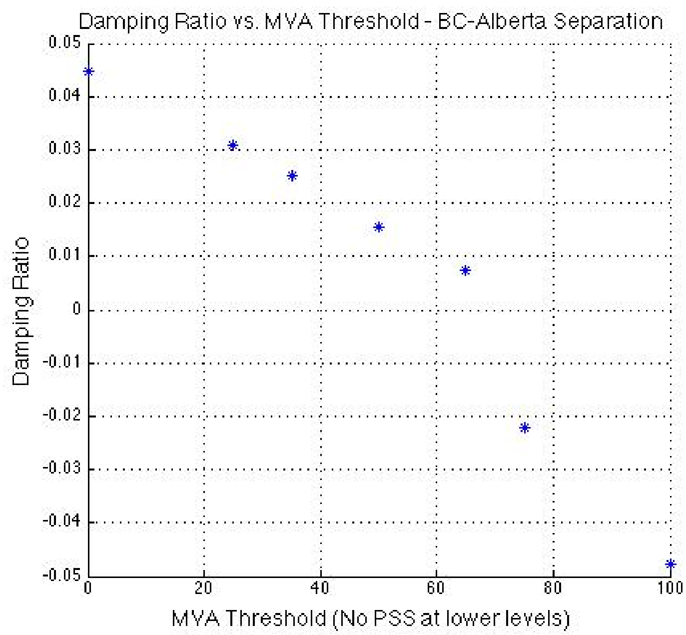
Results

Simulations of the BC-Alberta separation with the same 13HS case resulted in voltage swings at the Malin 500 kV bus to compare to the other report as follows:

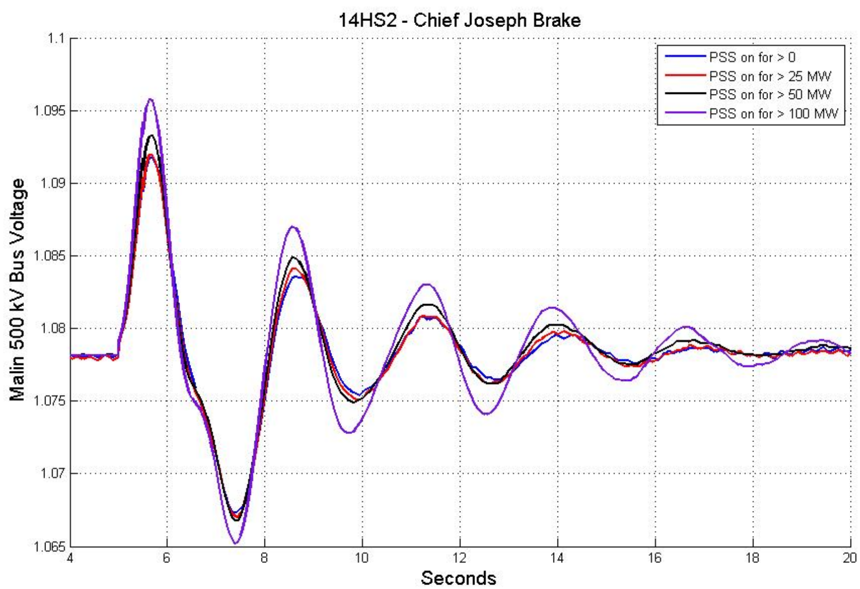


At first glance, comparison of the above figure to the original study appears largely the same. The differences are that in this case, there is an increased sensitivity to units less than 75 MVA, with noticeable impacts this time of units sized between 25 MVA to 50 MVA, and even those smaller than 25 MVA. The major difference between the studies is that unlike the previous one, there is no clear dividing line between 25 MVA and 50 MVA where the difference is negligible.

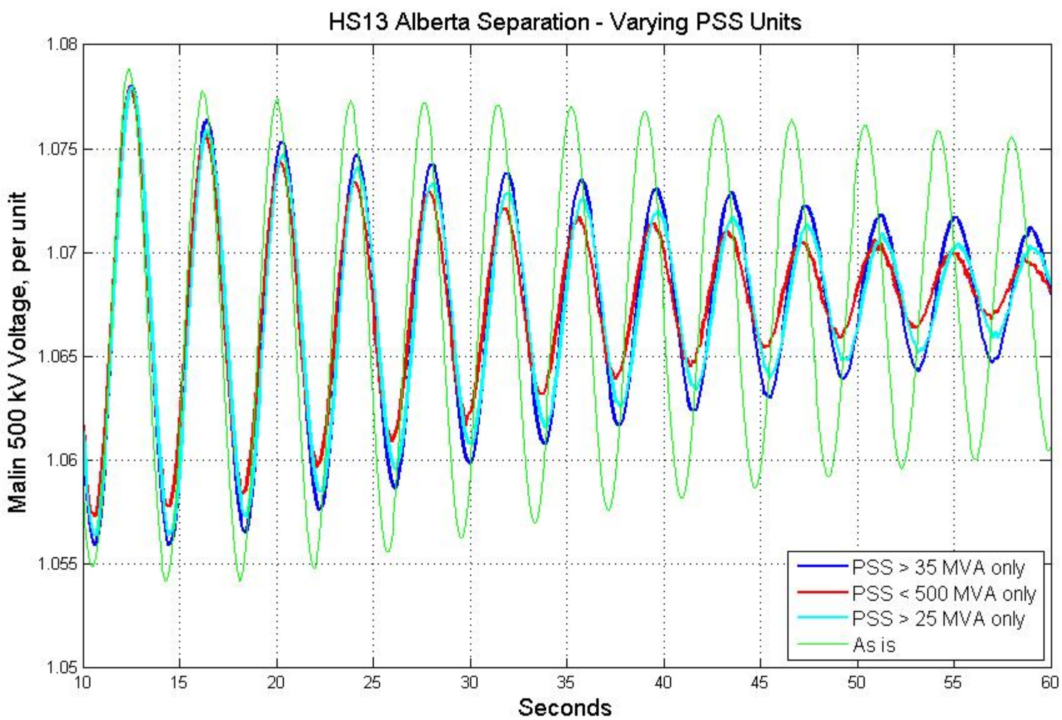
When considering figures like the one above, it is important to observe that the differences in damping, that is, the impact of each case, cannot be compared simply by the amplitude of the swings as the time progresses to the right of the graph. The comparison must be made between the calculated effective damping ratio of each signal. The graph below shows that the estimated damping from each of the above cases, with results from some additional simulations, when plotted against the threshold where all PSS are turned of is surprisingly somewhat linear, suggesting that the relationship between number of generators and MVA rating is roughly inversely proportional. (Note: the damping ratio calculation probably needs to be re-evaluated for the cases where it is negative. All damping estimates were made during the same simulation time frames, where the degree of nonlinearity may be different between positively damped cases and negatively damped cases.)



Similar results were obtained using a different base case and simulating a different disturbance, shown below:

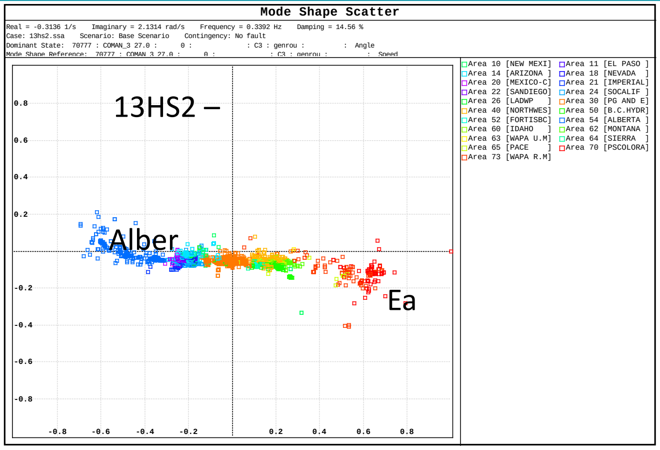


The figure below compares the Alberta separation case, this time including the reference base case, i.e., the existing model without additional PSS. Also shown is the simulation with PSS turned off on nearly all units greater than 500 MW, which affected a total capacity of more than 45,000 MW. Yet the results are better damped system than that where PSS was applied on all units greater than 25 MW, where only about 15,000 MW were left without PSS. The implication from this comparison is that for this case PSS application based on total unit capacity is not as effective as the number of units with PSS.

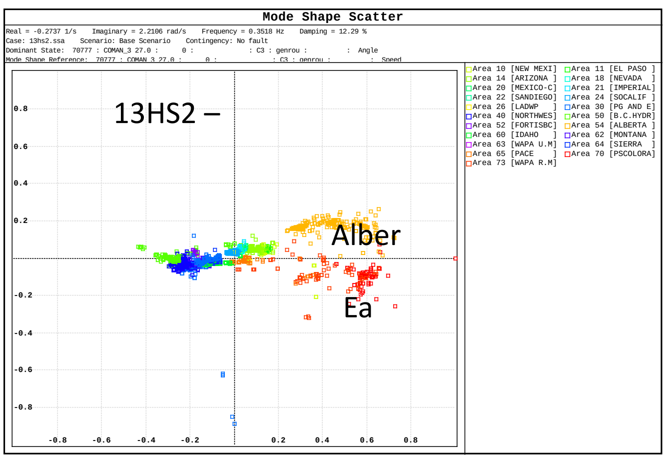


These results are neither surprising nor unique to this case. The effectiveness of a PSS and its contribution to damping inter-area oscillations depends on a great number of variables. As demonstrated in these examples, the relative size of the generator is not the most influential variable. It can further be demonstrated that the most important considerations in this example are generator location and how the PSS is tuned.

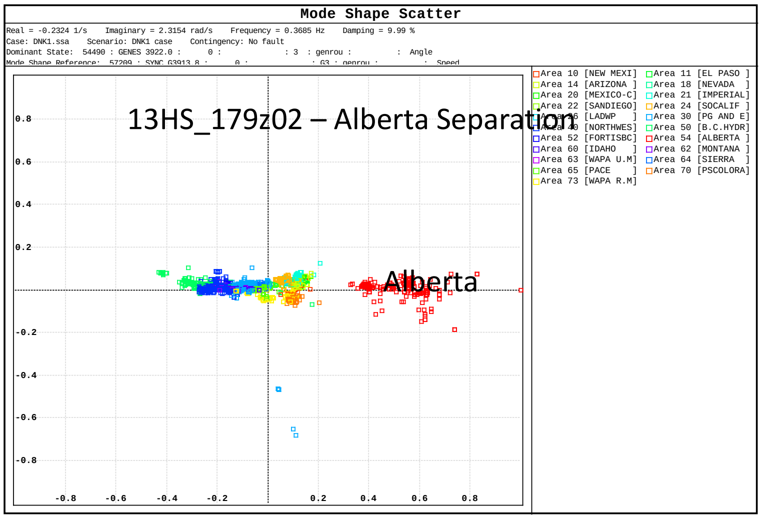
The following figure illustrates how one of the major modes of oscillation in this case appears throughout the WECC system. Each point represents one generator, and the graph shows that the mode of oscillation consists primarily of the generators in blue oscillating against the generators in red. PSS will be more effective for this mode on these units, whereas PSS on units in the center of the plot will not be as important.



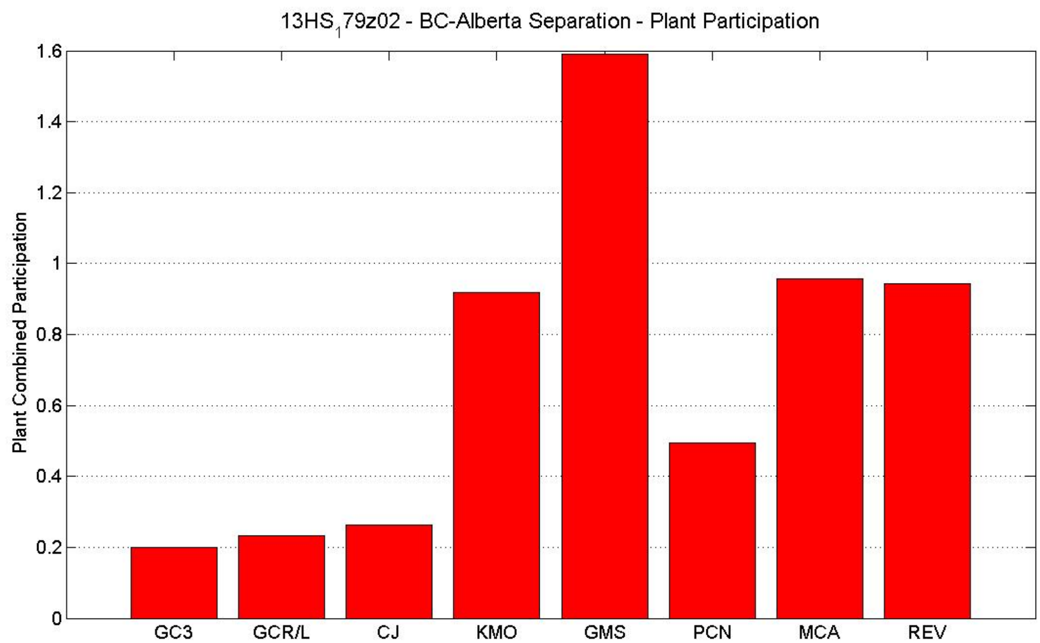
The other major mode of oscillation in this case is shown in the next figure, where the oscillation consists of a different combination of generators.



When the net load flow of this case is increased, the first oscillation mode is altered, becoming dependent on a new combination of generators, shown below.



As an example for comparison, the following figure depicts the relative amount of importance of eight different plants in the northwest part of the system in the oscillation mode in the case above. What is significant to the point is that the relative importance to this oscillation does not correlate with unit size.



PSS Applicability Based on Generator Size

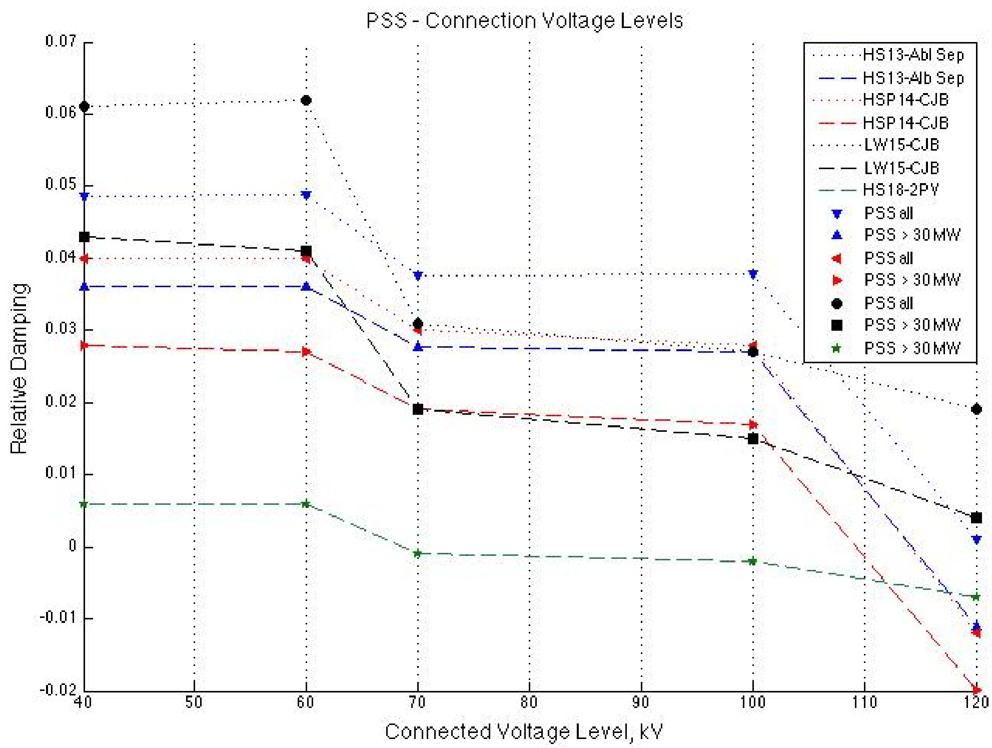
The results of this study suggest there is no clear generator size threshold below which the application of PSS does not provide a significant benefit. However, conclusions regarding units below 10 MVA based on the WECC database cannot be given full consideration due to the known lack of and quality of representation of many of these generators.

The nearly universal application of automatic voltage regulators (AVR) greatly enhances steady state stability as well as transient stability margins in a power system. However, they also introduce a destabilizing effect in the WECC system at natural system resonances at frequencies below 1.0 Hz. The PSS was developed to correct the destabilizing effect of the AVRs, and therefore improve the damping of these low frequency oscillations. The original application required retrofitting existing units, and equipping new excitation systems with first generation PSS, which required a substantial cost. This is unquestionably the reason a cutoff point in generator size was set.

The 1992 WECC study and resulting criteria recommendations, recognizing that there is no technical justification for excluding generators with new excitation systems, included considering PSS for all new systems regardless of unit size. At that time, this seemed more reasonable as the cost of PSS was declining. Since then, the cost of adding PSS to a new excitation system has become significantly less as all new systems are digitally implemented. Now it is not unusual to apply PSS at no additional cost.

Studies Comparing Connection Voltage and Minimum Unit MVA

Simulations conducted using 4 different base cases and 3 different disturbances are summarized in the following:



Cases/Disturbances used/simulated/Oscillation Frequency:

2013 Heavy Summer/Alberta Separation/0.26 Hz

2014 Heavy Spring/Chief Joseph Brake/0.36 Hz

2015 Light Winter/Chief Joseph Brake/0.41 Hz

2018 Heavy Summer/Double Palo Verde Unit Trip/0.21 Hz

For each case/scenario, PSS application was varied as follows:

PSS only on all units connected > 40 kV

PSS only on all units connected > 60 kV

PSS only on all units connected > 70 kV

PSS only on all units connected > 100 kV

PSS only on all units connected > 120 kV

PSS only on all units connected > 40 kV, Units > 30 MVA

PSS only on all units connected > 60 kV, Units > 30 MVA

PSS only on all units connected > 70 kV, Units > 30 MVA

PSS only on all units connected > 100 kV, Units > 30 MVA

PSS only on all units connected > 120 kV, Units > 30 MVA

All cases and disturbances show basically the same sensitivity to varying connection voltage and unit size.

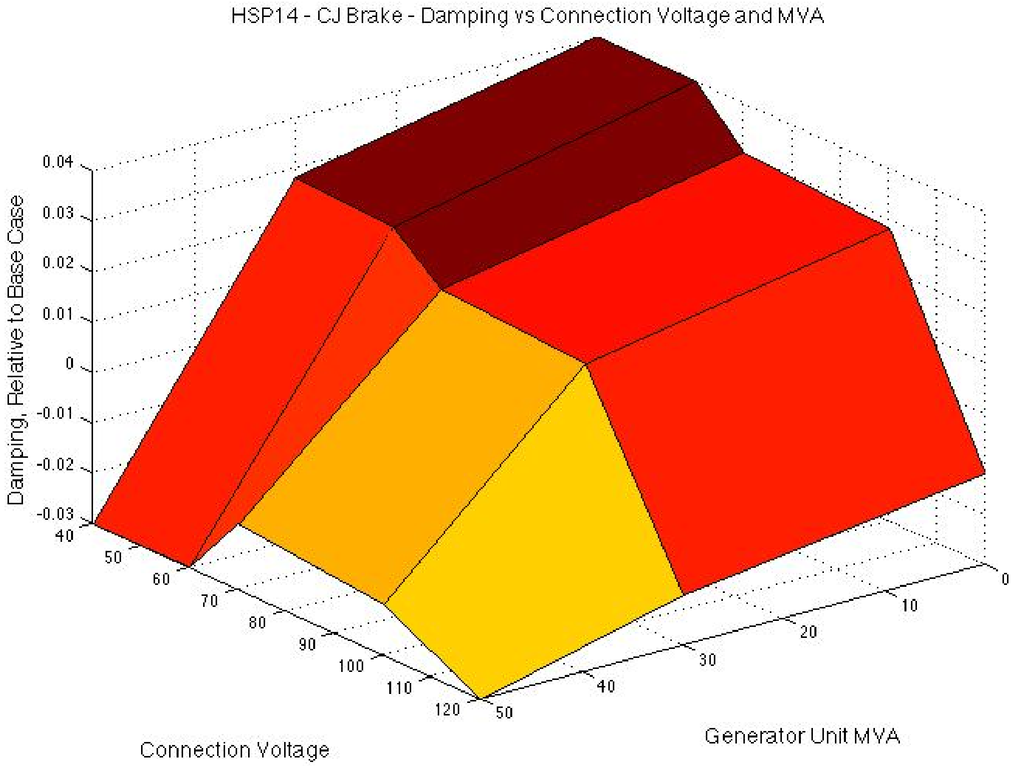
There is very little difference between a minimum connection voltage of 60 kV and 40 KV (not many units connected below 60 KV).

The lowest noticeable change in minimum connection voltage occurs at 70 kV.

There is very little difference between a minimum connection voltage of 70 kV and 100 KV (not many connection voltages in the range).

Removing PSS on units connected at 120 kV and below has a significant impact on the results.

Additional variation of unit size, units 50 MVA and less, was conducted for the HSP 14 Chief Joseph Brake scenario, and is summarized in the following figure:



Conclusions

Generating unit MVA rating is, in general, not directly proportional to its impact on damping of particular modes of oscillation.

Generally speaking, in the WECC system model, generator size is inversely proportional to the number of generating units.

The nature of system wide modes of oscillation and the effectiveness of individual generating units on these modes varies with the system topology and the instantaneous operating point conditions.

There is no technical justification to exclude application of PSS on a generating unit based on size alone.

Raising the threshold for PSS applicability from the current 30 MVA will reduce the number of generators with PSS, which will decrease system damping proportionally to the number of units affected.

Exhibit G-2

Technical Justification WECC-0107 Power System Stabilizer Requirement R3

Technical Justification WECC-0107 Power System Stabilizer Requirement R3

VAR-501-WECC-3

WECC-0107 Drafting Team (DT)

With special thanks to the time and expertise of Kestrel Consulting, Mr. Leo Lima

July 2, 2015

155 North 400 West, Suite 200

Salt Lake City, Utah 84103-1114

Executive Summary

The white paper was commissioned in response to a comment by Arizona Public Service (APS) in response to Posting 4 of the WECC-0107 project.

APS raised the following concerns:

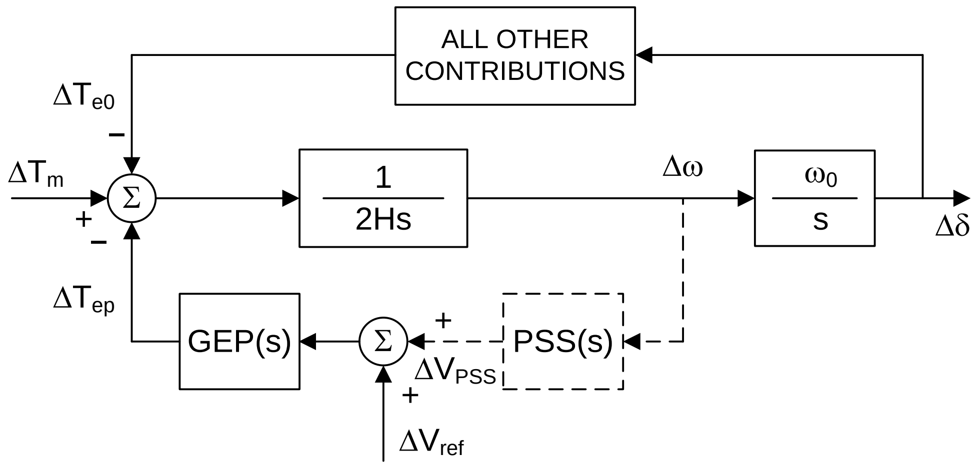
> "R3 implies that Vt/Vref must be measured at minimum load. AZPS recommends that the minimum load requirement be removed for the following reasons:
>
> - For many units, full load is a better measurement point for Vt/Vref for tuning PSS. This is how it has been done historically.
> - Many units are barely stable at minimum load and hence it is problematic to measure Vt/Vref at minimum load. Even if it can be measured it may not be possible to measure instability gain at the minimum load.
> - If PSS settings are based upon calculations it is simple to use any load; however, many utilities, including AZPS, prefer to set PSS based upon actual field measurements so that there are no errors related to system models.
> - If minimum loading requirements are maintained, all of the existing settings will become invalid and will require that PSS of all units in AZPS system (and in other systems) be retuned and the frequency response re-measured.
> - If the drafting team believes Vt/Vref must absolutely be measured at minimum load, please provide sufficient technical background and solutions to the problems mentioned above."

The conclusion of the paper is that conducting tuning at minimum-load is an acceptable approach to tuning; albeit, only one approach. Not all members of the drafting team agree with the conclusion of the paper. As such, the reader is encouraged to review the data, determine the entity-specific impacts, and proceed accordingly within the parameters of the Reliability Standards Development Procedures (Procedures) posted on the WECC Standards home page.

Using Minimum Load for PSS Tuning

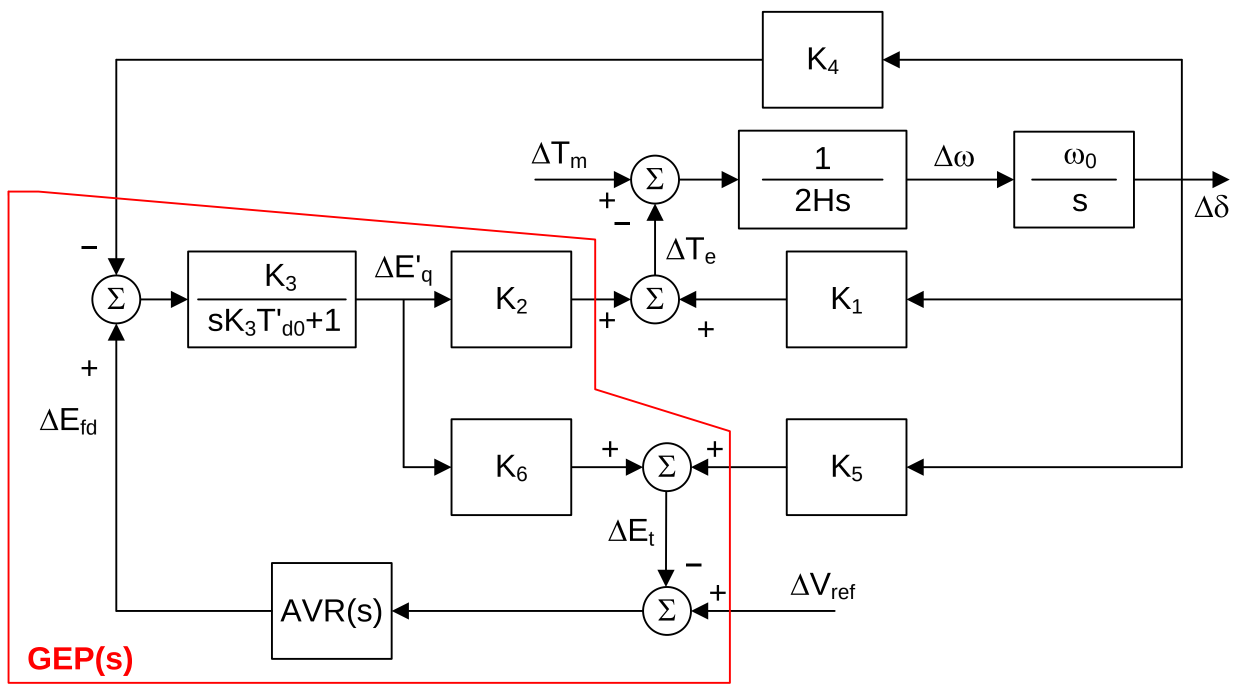
To provide damping over the frequency range of interest, the PSS transfer function PSS(s) should compensate the phase characteristic of the transfer function GEP(s) shown as Figure 1 in [2] and reproduced here (see Figure 1).

Figure 1 – Definition of the GEP(s) Transfer Function



The transfer function GEP(s) is (in the associated theory) defined with the machine operating connected to a large system (infinite bus) at near full power output. This transfer function GEP(s) can also be defined based on the Heffron-Phillips diagram presented in [1], as shown in Figure 2.

Figure 2 – Definition of GEP(s) Based on the Heffron-Phillips Diagram



Mathematically, the transfer function GEP(s) is defined as the transfer function from voltage reference to electrical torque disregarding all contributions to electrical torque that are derived from changes in the rotor angle position δ (or, equivalently, considering a constant rotor speed [2]):

$$GEP(s) = \left.\frac{\Delta T_e}{\Delta V_{ref}}\right|_{\delta=const}$$

In practice, the GEP(s) transfer function cannot be directly measured:

a) There are no transducers to measure the electrical (air-gap) torque
b) There is no practical way to hold the rotor angle position δ constant (or, equivalently, to hold the rotor speed constant) and, thus, eliminate the contributions to electrical torque derived from changes in rotor angle.

From Figure 2, it is possible to see that the GEP(s) transfer function could be indirectly obtained by measuring the transfer function from ΔV_{ref} to ΔE_t, considering the rotor angle δ constant:

$$GEP(s) \approx \left.\frac{K_2}{K_6}\frac{\Delta E_t}{\Delta V_{ref}}\right|_{\delta=const}$$

Since K_2 and K_6 in Figure 2 are real values (constants), the phase characteristic of GEP(s) is identical to the phase characteristic of the transfer function $\Delta E_t/\Delta V_{ref}$, **if the frequency response between V_{ref} and E_t can be measured without the influence from changes in rotor angle position δ**.

Another way to look at the same problem is to eliminate or minimize the contributions coming from the gains K_1, K_4 and K_5. The gain K_1 does not (directly) impact the transfer function from ΔV_{ref} to ΔE_t, as long as contributions from gains K_4 and K_5 are indeed eliminated or minimized.

The expressions for the gains K_4 and K_5, shown in [1], show that these constants approach zero as the initial rotor angle δ_0 approaches zero. This is a condition associated with the operation of the generator synchronized to the large system at minimum load (theoretically with power output equal to zero, although this is a very difficult condition to sustain in a stable manner on most power plants). Therefore, the Standard requires measuring the frequency response from ΔV_{ref} to ΔE_t at the minimum stable load of the generation unit.

Additionally, the frequency response test performed with the generation unit at higher loads or near full load will have the risk of reaching a resonance with any poorly damped electromechanical oscillations modes, particularly the local mode of the unit.

Practical Example

Figure 3 illustrates the practical aspects related to the field measurement of the frequency response between ΔV_{ref} to ΔE_t. The simulated phase characteristic of the transfer function was obtained with the generator synchronized to the large system (infinite bus) at zero power output, the theoretical condition that leads to the gains K_4 and K_5 to become zero.

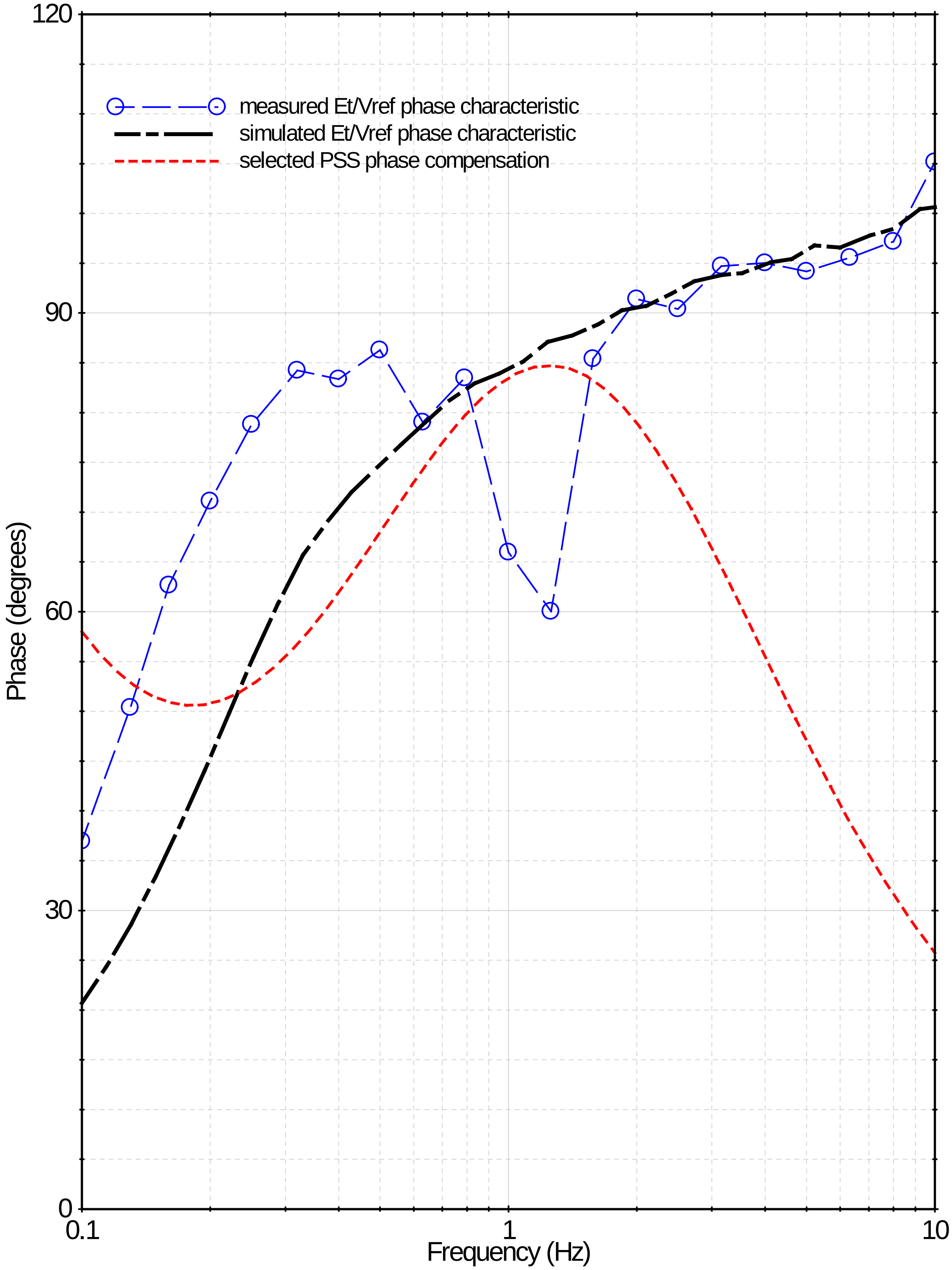
The simulated phase characteristic of $\Delta E_t/\Delta V_{ref}$ (or, equivalently, the phase characteristic of GEP(s)) results in a phase lag, with negative values for the phase. This phase lag characteristic has been plotted in Figure 3 with a positive value, to make it easier to compare with the required phase lead compensation of the PSS transfer function that should compensate the phase lag of GEP(s).

The frequency response test could not be performed at a very low load, and was performed with the unit dispatched near 50% of its load, due to emissions control and limits on how long the unit could operate at such low loads. Once again, the measurements result in phase lag characteristics (negative phase angles) that are plotted in Figure 3 with a positive sign.

A comparison of the simulated and measured phase characteristics show a very good agreement for frequencies above 0.6 Hz, with the exception of the measured points near the resonance with the local mode of oscillation for this unit, around 1.3 Hz. On the other hand, the field measurements resulted in significant additional phase lag for lower frequencies (below 0.6 Hz), as much as 25 degrees at 0.2 Hz.

Considering the requirement that the PSS phase compensation should be within +/– 30 degrees of the requirement, this difference of 25 degrees at 0.2 Hz is very significant. This difference is sufficient to modify the effectiveness of the PSS in providing damping at the lower oscillation frequencies associated with inter-area modes, the fundamental objective behind this proposed Regional Variance.

Figure 3 – Practical Example of the Measurement and Simulation of the PSS Phase Compensation Requirement



References

[1] F. P. de Mello and C. Concordia, “Concepts of Synchronous Machine Stability as Affected by Excitation Control,” IEEE Trans. on Power Apparatus and Systems, vol. 88, no. 4, April 1969, pp. 316-329

[2] E. V. Larsen and D. A. Swann, “Applying Power System Stabilizers – Part I: General Concepts,” IEEE Trans. on Power Apparatus and Systems, vol. 100, no. 6, June 1981, pp. 3017-3024

Exhibit H

Western Electricity Coordinating Council Policies and Guidelines on Power System Stabilizers

Exhibit H-1

Western Electricity Coordinating Council Policy Statement on Power System Stabilizers

WESTERN ELECTRICITY COORDINATING COUNCIL
POLICY STATEMENT ON POWER SYSTEM STABILIZERS

Technical studies and operations experience support a continuing need for power system stabilizer (PSS) (supplementary excitation control) to improve dynamic operation and allow non-oscillatory attainment of desired loading levels in the western interconnected power system. It is necessary for large numbers of these devices to be available for operation in the WECC in order to provide the required system damping while allowing for some of them to be out of service. Accordingly, the following requirements are adopted:

1. The following criteria shall be used to determine when a PSS shall be installed on a synchronous generator, regardless of ownership, that is connected to the transmission system (by generator step-up transformer to 60 kV or higher voltage):
   a) A PSS shall be installed on every existing synchronous generator that is larger than 75 MVA and is equipped with a suitable excitation system as defined in the report “Criteria to Determine Excitation System Suitability for PSS”, dated December 1992 (available on WECC Website, www.wecc.biz).
   b) A PSS shall be installed on every existing synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, if the excitation system is updated so that it becomes a suitable excitation system as defined in the report mentioned in 1a above. This section applies to all machines whose excitation system is updated at any time after November 18, 1993.
   c) A PSS shall be installed on every synchronous generator that is larger than 30 MVA, or is part of a complex that has an aggregate capacity larger than 75 MVA, and is equipped with suitable excitation systems as defined in paragraph 1a, and is commissioned after November 18, 1993.
   d) A PSS is not required on a station service generator.

2. When a generator that is equipped with a functional PSS is on line, the PSS shall be in operation except for the following reasons:
   a) Maintenance and testing
   b) PSS exhibits instability due to nonstandard transmission line configuration
   c) PSS does not operate properly due to a failed component
   d) Unit is operating in the synchronous condenser mode (very near zero power level)
   e) When a unit is generating less power than its design limit for effective PSS operation
   f) When a unit is passing through a range of output that is a known “rough zone”

   The aggregate MVA of the synchronous machines that are on line and equipped with a functioning PSS shall not fall below the level identified in the most recent power system stabilizer study commissioned by the WECC.

3. When a synchronous generator that is equipped with a PSS is operating in the pump mode (P/G unit), and is connected to a transmission system such that the PSS does not produce negative damping, the PSS should be in service.

4, PSS equipment shall be tested and calibrated in conjunction with AVR testing and calibration. This will be done as often as is necessary to maintain reliable PSS performance in accordance with the “WECC PSS Tuning Criteria” (available on WECC Website, www.wecc.biz). PSS recalibration must be performed if AVR response parameters are modified. When a PSS is taken out of service because of a failed component, the party responsible will be expected to perform the needed repairs (or replacement) in a responsible and timely manner.

5. A PSS is not required for a synchronous condenser.

Approved by TSS on January 11, 2002

Approved by PCC on March 1, 2002

Approved by OC on February 28, 2002

Approved by BOT on April 18, 2002

Exhibit H-2

Western Electricity Coordinating Council Power System Stabilizer Tuning Guidelines

WECC Power System Stabilizer Tuning Guidelines

Forward

This document is not intended to be a detailed tuning procedure for a specific piece of equipment. The intent is to meet the inter-area needs of WECC; local system needs may dictate additional requirements. It is intended for the experienced tuning engineer as the minimum criteria needed to tune a PSS. A detailed tuning procedure should be developed for the specific PSS being tuned. This guideline is meant to be an aid in the development of the tuning procedure.

Background

The basic intent of adding a Power System Stabilizer (PSS) is to enhance damping to extend power transfer limits. The very nature of a PSS limits its effectiveness to small excursions about a steady state operating point. The small excursions about an operating point are typically the result of an electrical system that is lightly damped which can cause spontaneous growing oscillations, known as system modes of oscillation.

Enhanced damping is required when a weak transmission condition exists along with a heavy transfer of load. In the WECC, inter-area modes of oscillation occur between 0.1 and 1.0 Hz. with the predominant mode at approximately 0.3 Hz.

A PSS works in conjunction with the excitation system of a synchronous machine to modify the torque angle of the shaft to increase damping. The performance of the excitation system is critical in the overall capability of a PSS. Tuning of a PSS shall only be accomplished after the excitation system has been tuned and calibrated.

On new equipment, PSS may be software incorporated in digital automatic voltage regulators. AVR terminal voltage and current measurements are used to compute accelerating power and synthetic speed (integral of accelerating power). PSS cost can be low if PSS is required in competitive power plant procurement specifications. Procurement specifications should include requirement for tuning during commissioning and a requirement for stability program model and data.

Objective

PSS typically utilizes phase compensation and adjusting phase compensation is the main task in PSS tuning. Phase compensation is accomplished by adjusting the PSS to compensate for phase lags through the generator, excitation system, and power system such that PSS provides torque changes in phase with speed changes. Tuning should be performed when system configurations and operating conditions result in the least damping. Verification should demonstrate that instability is not introduced through normal operating ranges as well as expected faults.

Items of concern

PSS benefits to the WECC system are significant, however, there is potential for equipment damage. Some areas of concern are:

- PSSs are manufactured as both analog and digital types. Testing methods may not be identical with both types of PSSs.
- PSS modification of torque angles by varying excitation can excite turbine generator shaft torsionals where shaft torsionals are less than 20 hertz. This is especially true for PSSs that utilize speed as input. Typically torsional filters are used to remove the torsional contribution to the input to the PSS.
- PSS output can interfere with transient response of excitation systems. Therefore output limits are usually incorporated in the PSS scheme.
- PSS can interact with underexcitation limiters. Thus the limiters must be tuned to work in conjunction with the PSS.
- Rapid load changes can result in large VAR swings from PSS response that utilize electric power. Upgrading to type 2 PSS input (integral of accelerating power) may solve this problem.

PSS Input Types

PSS are designed with various types of inputs. They include speed, frequency, power, accelerating power and integral of accelerating power. The PSS may derive these quantities from generator terminal voltage and current measurements. Current practice is to digitally derive a synthetic speed measurement (integral of accelerating power) from generator terminal voltage and current measurements.

PSS Tuning

The tuning of PSS differs based on the type of input. However, in general tuning of PSS consists of the following:

Verifying the functionality of all aspects of the PSS equipment.

This includes the compensating features, limits, and protections. All potentiometers, if so equipped, should have smooth and continuous control throughout their range.

PSS Output Limiter

Set output limits so that PSS cannot move generator terminal voltage beyond a predetermined value. Typical range of settings is from ±5% to ±10% of rated generator terminal voltage. Asymmetrical limits may be employed.

Protection and Alarms

PSS output protection should be coordinated with the output limiter. Since the output limiter provides a wider range of signals than can be tolerated in steady-state operation, several methods may be used to obtain security from driving the excitation system beyond the normal operating limits. These methods include voltage-sensitive switches, auxiliary timing circuits and limiter meters.

The voltage sensitive switch usually measures generator terminal voltage and disconnects the PSS signal from the excitation system when the terminal voltage exceeds a preset limit. The auxiliary timer method uses a circuit to monitor the PSS output level, and if the level exceeds a preset limit for a given time, the PSS signal is removed from the excitation system.

If protection removes the PSS from service an alarm should actuate.

Washout

There is an interrelationship between the phase compensation and the washout time constant. Short washout time constants provide additional phase compensation in frequency-based PSS at the lower frequencies while dramatically reducing the gain.

A washout time constant of 10 seconds or less is recommended to quickly remove low frequency components (below 0.1 Hz) from the PSS output. The smaller time constant will reduce the influence on the system voltage from the PSS during any sustained/extended frequency deviation (i.e., loss of generation), especially if the PSS has a high gain setting.

Phase Compensation

Identify inter-area modes of oscillation. Measure generator and excitation system response without PSS. Tune PSS to provide as close to 0 degrees of phase shift as possible at the inter-area frequency or frequencies.

If local stability concerns require PSS settings resulting in an inter-area phase shift other than zero, the setting shall in no case result in a phase shift in excess of 30 degrees at inter-area modes.

The PSS provides substantial phase shift so that the electrical torque provided by the generator is approximately in phase with speed. The goal is to eliminate phase lag as best as possible throughout a wide range of frequencies of interest, then adjust gain as outlined below.

Gain Test

A gain as high as practicable is required for best contribution to system damping. Since the maximum gain that is safely usable depends upon many factors, it is best determined by test. The gain test shall be performed under operating conditions that result in maximum overall system gain so that the true gain margin is identified. Generally, this occurs with the unit loaded to at least 80% of full load. If shaft torsionals are of concern, the torsionals shall be monitored during the gain test.

A test for the maximum safely usable gain may be made with the PSS fully operative and either PSS output, field voltage, or generator terminal voltage deviation being recorded, by slowly advancing the gain until a small rapid oscillation, usually in the frequency range from 1 to 3 hertz, is just sustained or growing. High initial response systems may oscillate at 4 to 8 hertz. Record per unit gain at this point. For good stability of the control loop, the gain should be reduced to 1/2 to 1/3 of this value. In this determination of gain, care must be taken that the PSS signal is not being clipped by the limits. Noise in the control signal increases as the gain is increased. If they should reach the point of being clipped by the limits before the oscillation is sustained, influence of the PSS is diminished and a false indication of allowable gain will result. In severe cases, the limits may so nullify PSS action that no oscillation can be produced. If a sustained oscillation cannot be obtained because of large blocks of parallel generation not controlled by PSS, then set the gain to 1/2 the point of clipping.

It’s difficult to test effectiveness and optimal gain for interarea oscillations. Special tests and signal processing, however, may be devised for certain large units at critical locations. It’s generally not possible to test for robustness under stressed conditions including major outages; therefore it is strongly recommend that the optimal gain and effectiveness of the PSS be validated by simulation.

Commissioning Tests:

Perform an impulse response by injecting a large signal into the AVR (5-10%) and identify local mode damping. Verify local mode oscillation damping has improved, or, at a minimum, has not been degraded.

Additionally, non-take over type underexcitation limiters (UEL) must be coordinated with the PSS to ensure stable performance during limiter operation. After the gain is set, underexcite the machine until the UEL becomes active and perform a step and/or an impulse response test while monitoring the output power (MW). Ensure that the UEL is not interacting with the PSS in such a way that the damping level is reduced or instability is observed (since the PSS reduces the gain margin in the UEL control and vice versa). If instability is observed, retuning of the UEL or PSS is required. Coordination should be performed with all appropriate limiters in the AVR.

Appendix A: Simplified Power System Stabilizer Tuning Procedure for Hydro Units with Static Exciters

This procedure assumes that the unit in test will remain stable when the Power System Stabilizer is removed from service.

1. Attach equipment as indicated in Figure 1. Disconnect the Power System Stabilizer (PSS) from the Automatic Voltage Regulator (AVR) summing junction. Perform a frequency response of the terminal voltage (V_t) vs. V_{signal} with the unit at full load. See Figure 7 for an example result of a machine equipped with a static exciter.

2. From the V_t frequency plot, establish the phase delay of the exciter and generator (for example 154^o at 0.4Hz).

3. Tune the Washout and PSS to provide phase lead in the frequency range of 0.1Hz to 1.0Hz equal the phase lag of V_t. The phase lead angle is equal to $90^o+180^o-{}^-26^o=296^o$ or ${}^-64^o$. 90^o is derived from Pe lagging the terminal voltage by 90^o. The 180^o is to compensated for the ${}^-1$ of the PSS.

4. Turn the gain of the PSS to near 0. Synchronize the unit. Ensure that the PSS output is not connected to the AVR summing junction (test switch 2 is open).

5. Perform a frequency response of Pe vs. V_{signal}. This will indicate the frequency of the local mode oscillation. However this will not indicate the inter-area oscillations, as they are very difficult to excite with a single machine connected to a very strong bus.

6. Now that the local mode phase and frequency are known with the help of pole-zero placement techniques, the PSS settings can be calculated.

7. Use a modeling program or equivalent mathematical program to verify PSS settings are going to result in the proper phase in the inter-area (0.1Hz to 1.0Hz), and provide indication of the local mode damping.

8. Apply settings to PSS with gain turned down. Ensuring test switch 2 is open. Connect test equipment to the PSS, replacing the Watt Transducer output (PSS input) with V_{signal}. Connect the PSS output to test equipment as in Figure 2.

9. Compare the frequency response of the model and actual equipment (Figure 4) to ensure correct operation of the PSS. Note the –1 illustrated in the model is sometimes achieved by reversing the output of the watt transducer, or by reversing the PT/CT connection to the watt transducer.

10. Reconnect the watt transducer to the PSS. With the machine on-line at a reasonable loading, connect the PSS (test switch 2).

11. Slowly increase the PSS gain until Pe begins to oscillate. Turn the gain down to 1/3.

12. Replace V_{signal} with a variable isolated DC source. Adjust the DC source to provide a step in V_t equivalent to 0.5% change.

13. Close test switch 1 while monitoring Pe (Figure 5). If unit starts to become unstable, remove PSS from service (open test switch 2).

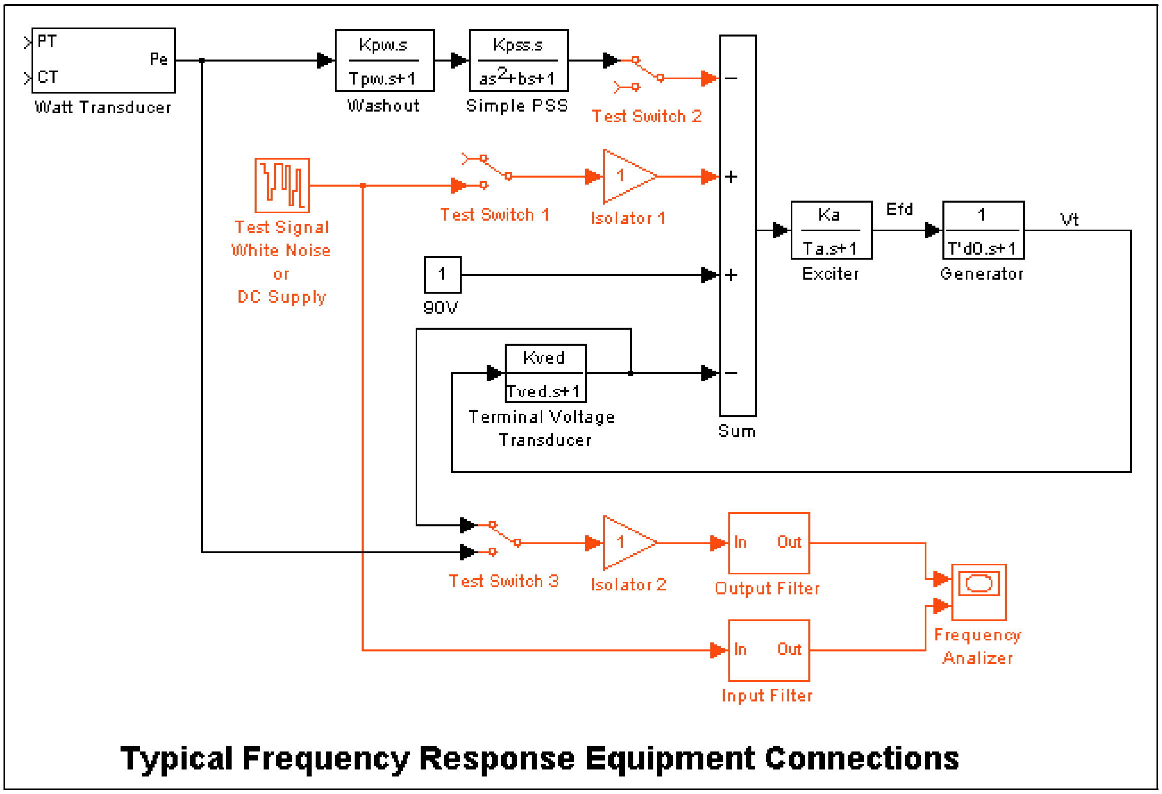


Figure 1

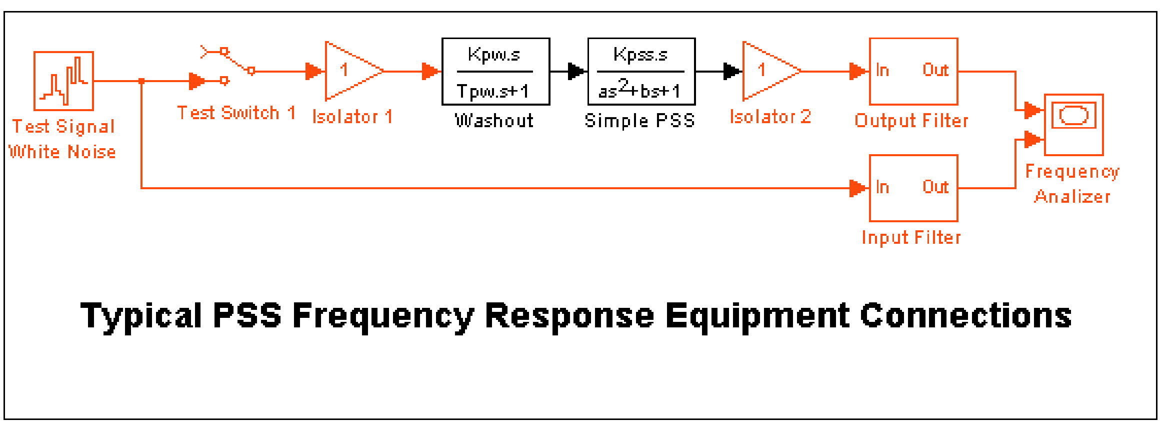


Figure 2

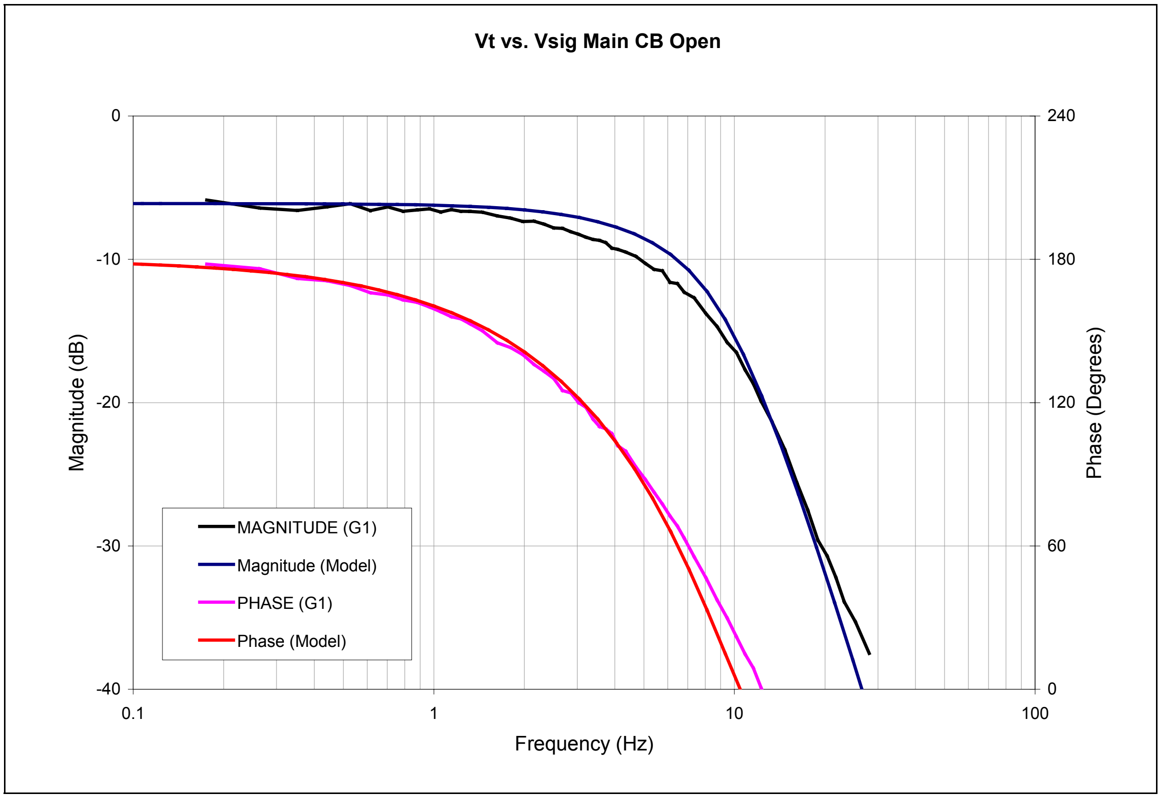


Figure 3

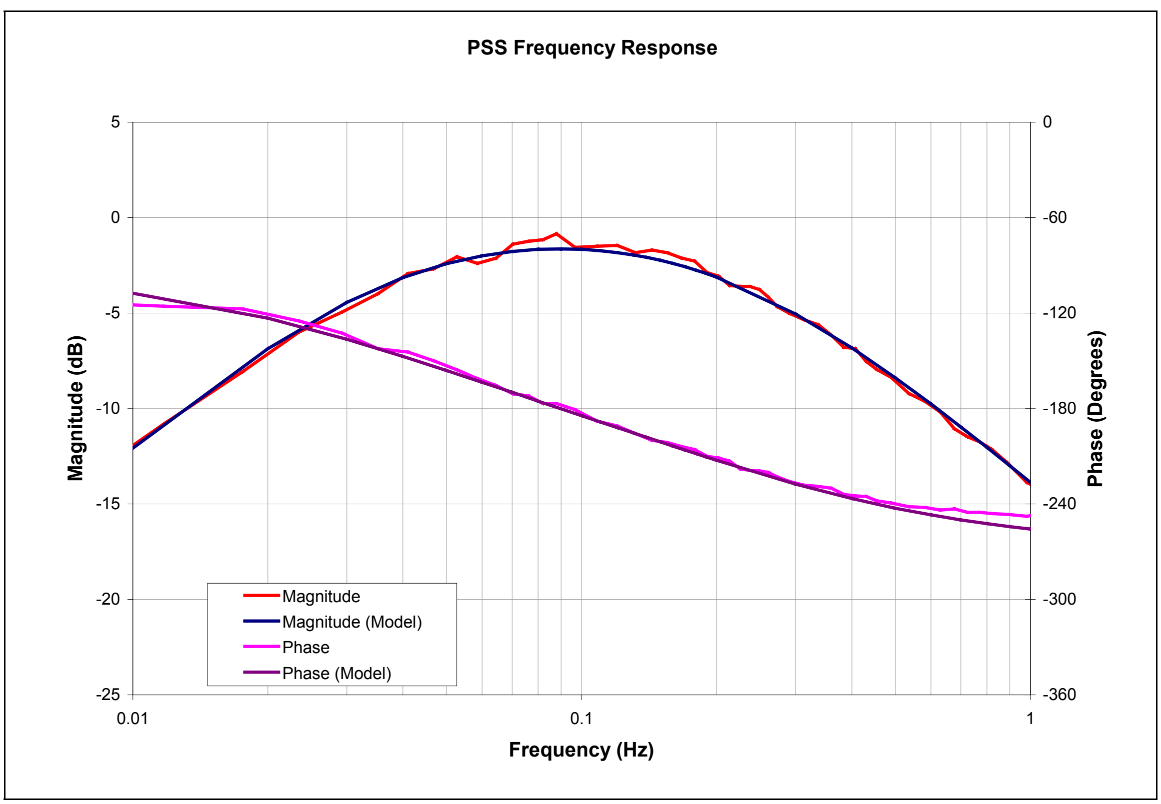


Figure 4

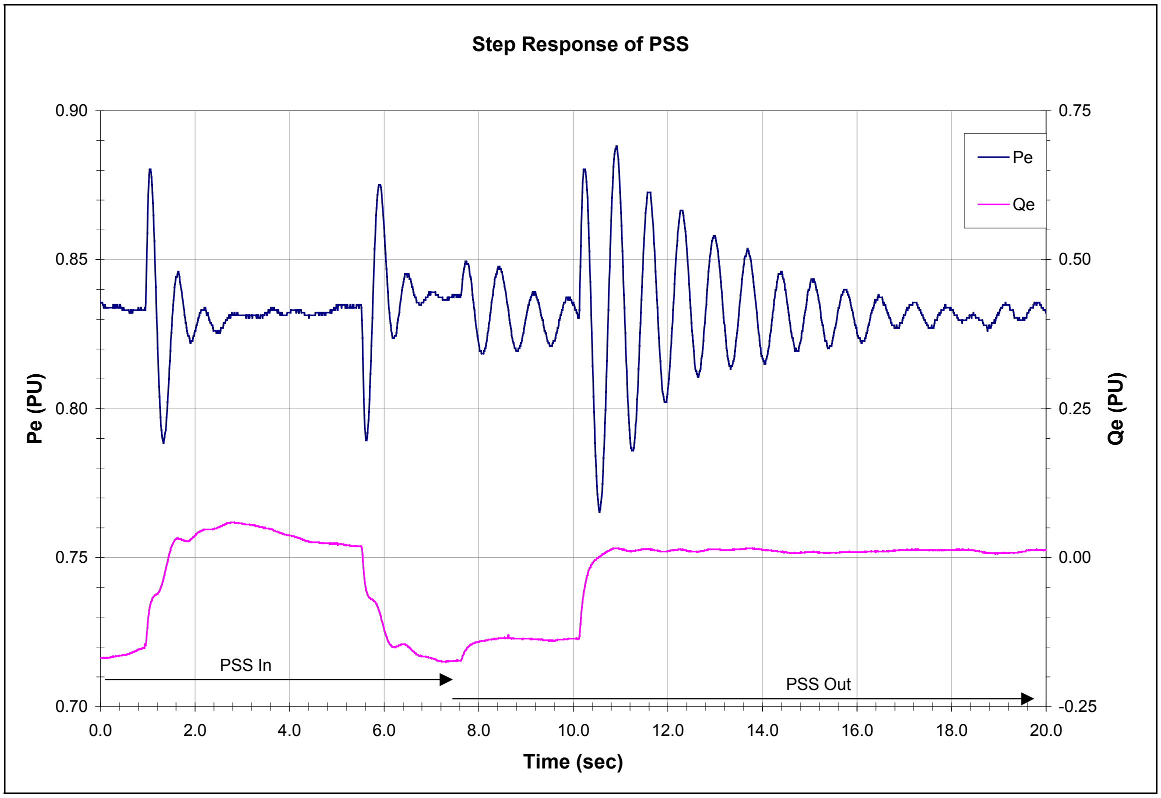


Figure 5

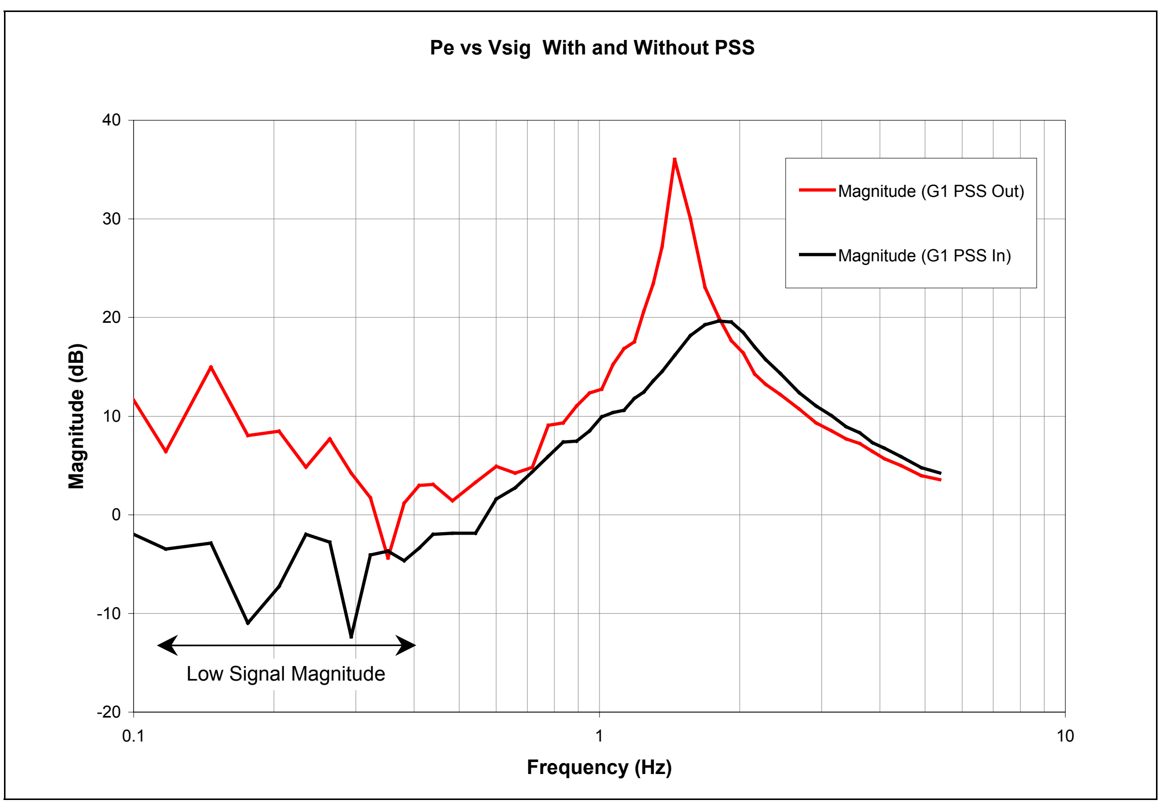


Figure 6

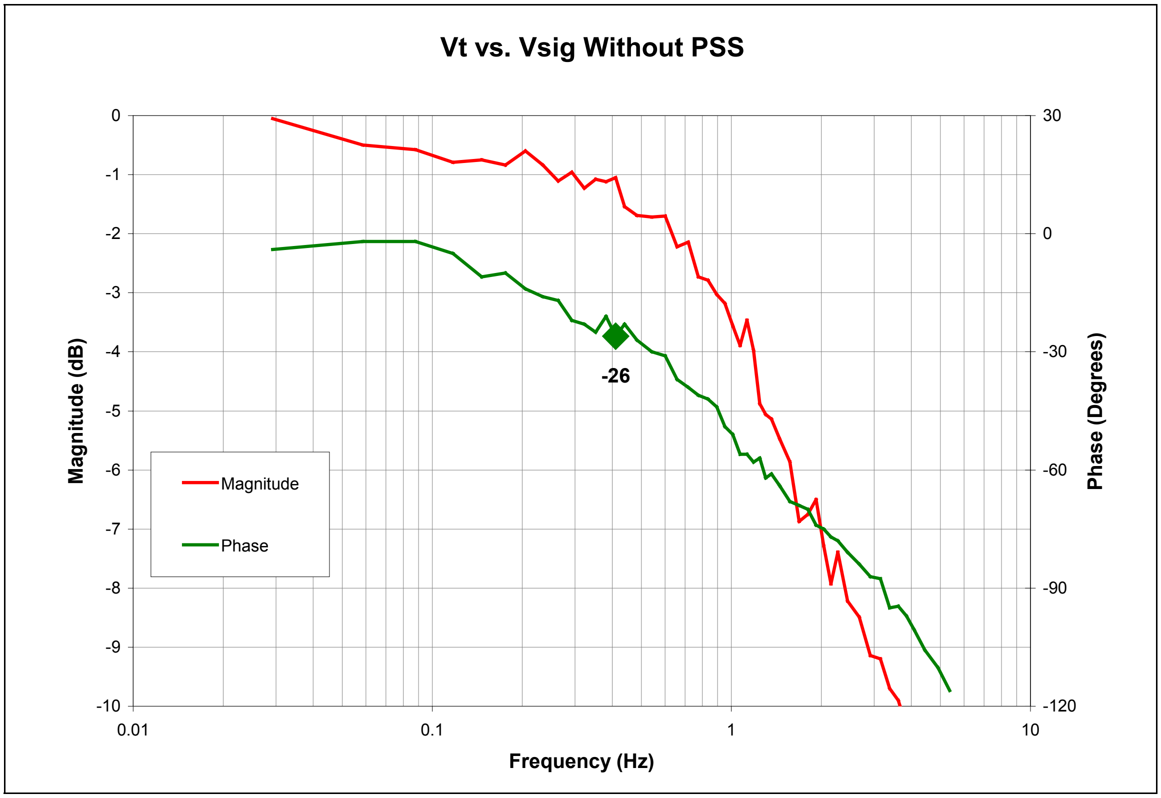

Vt vs. Vsig Without PSS
Magnitude (dB)
Phase (Degrees)
Frequency (Hz)
Magnitude
Phase
-26
0
-1
-2
-3
-4
-5
-6
-7
-8
-9
-10
30
0
-30
-60
-90
-120
0.01
0.1
1
10

Figure 7

WECC Submission:

Model Verification:

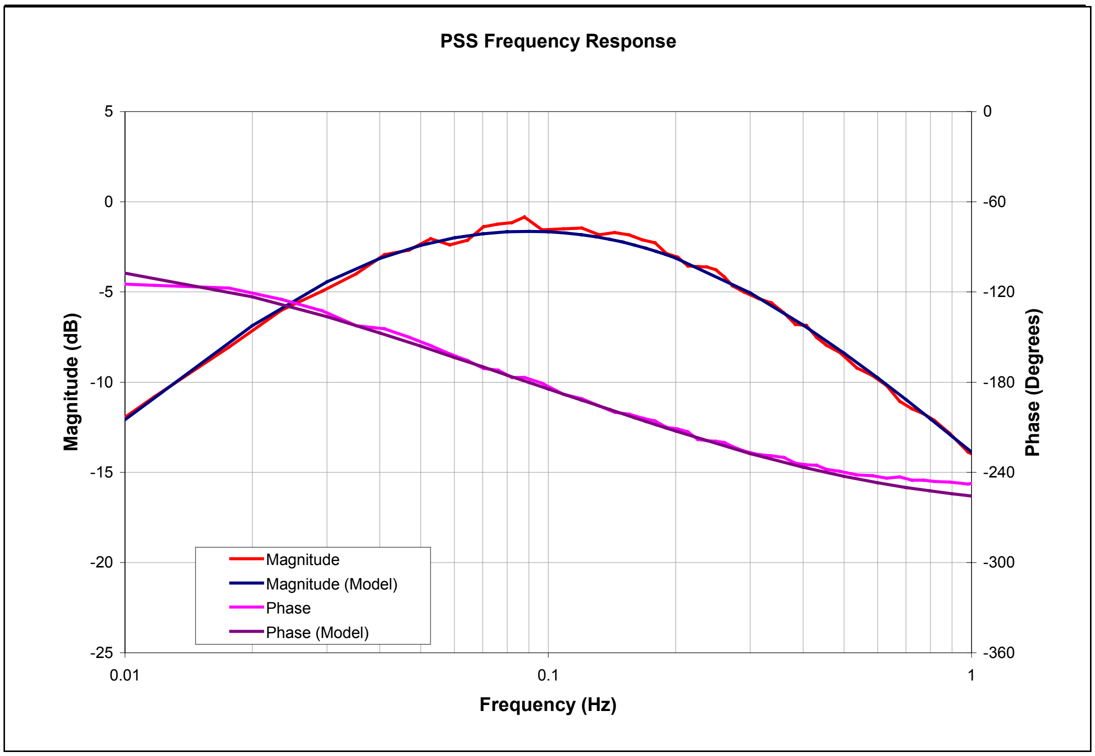


Figure 8 Model Verifcation

IEEEST Model for WECC

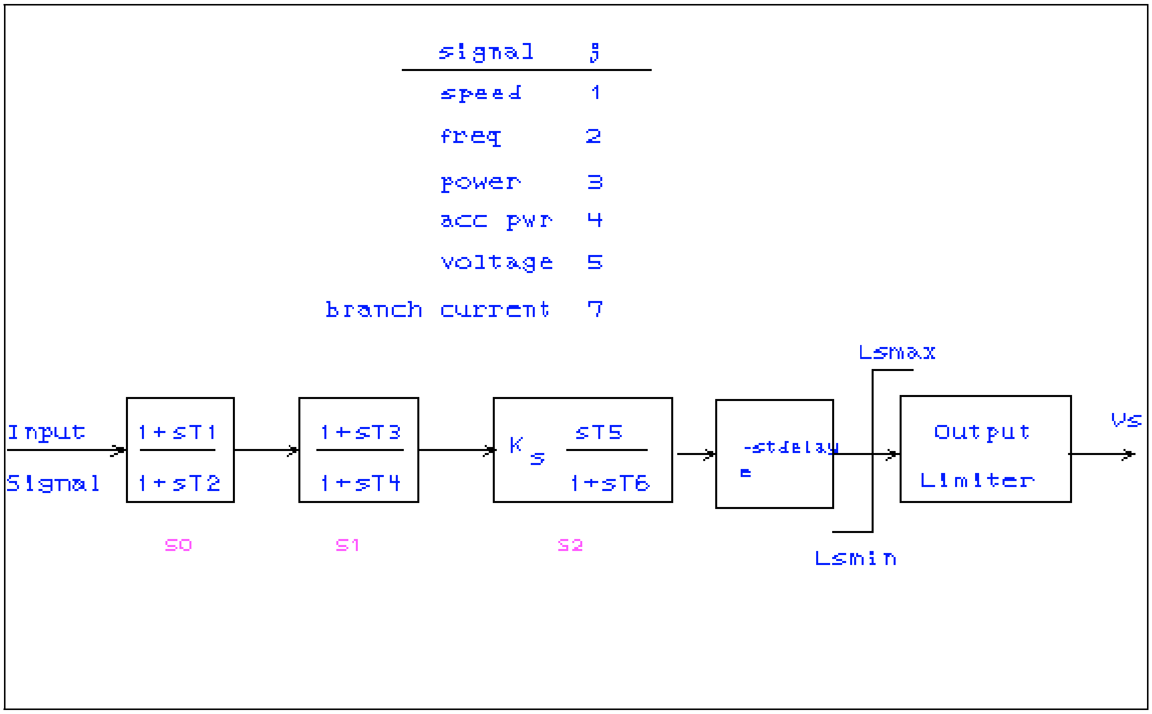


Figure 9 IEEEST Model

Bus No.	Bus Name	PSS/E MODEL	ID	T1	T2	T3	T4	T5	T6	Ks	Lsmax	Lsmin	Tdelay
6021	KCL G1 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6022	KCL G2 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6023	KCL G3 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00
6024	KCL G4 13.8	IEEEST	1	0.00	0.00	0.00	0.75	1.00	4.20	-4.10	0.10	-0.10	0.00

Figure 10 Model Parameters

Exhibit H-3

Criteria to Determine Excitation System Suitability for Power System Stabilizers in Western Systems Coordinating Council System

CRITERIA TO DETERMINE EXCITATION SYSTEM SUITABILITY FOR PSS IN WSCC SYSTEM

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(This report was approved by Technical Studies Subcommittee at Meeting #100 in San Diego, California on January 20, 1993)

Table of Contents

1.0 PURPOSE

In evaluating the list of machines 75 MVA and above that are not equipped with Power System Stabilizers (PSS), WSCC System Review Work Group (SRWG) encountered some WSCC members who reported that their exciters were "not fast enough" to warrant installation of PSS. The "not fast enough" terminology raised questions regarding the need for a definitive criterion to address whether or not an excitation system is fast enough to be suitable for PSS. The Modelling Working Group (MWG) was given the assignment to develop a criterion to assess whether an excitation system is fast enough for PSS installation. This report presents the results of the investigation.

2.0 CONCLUSIONS AND RECOMMENDATIONS

2.1 Conclusions

The combination of the generator, the excitation system, and the power system (GEP) to which the generator is connected is considered to be too slow to justify PSS installation if the closed loop GEP phase lag between machine terminal voltage and voltage regulator reference input ($\partial E_t/\partial E_{ref}$) exceeds that of the following third order benchmark system in the frequency range of interest (0.1 to 1.0 Hz).

$$T(S) = \frac{(6.28)^3}{(S+.628)(S+6.28)(S+62.8)} \qquad (1)$$

The magnitude and phase of the benchmark system are shown in Figure 1. The benchmark system has a phase lag of 135° at 1.0 Hz.

Conversely, if the phase lag of GEP is less than that of the benchmark system in the frequency range of interest, the generator should be considered suitable for PSS that is, if GEP phase lag curve falls above T(s) phase lag curve in Figure 1, then the generator is considered suitable for PSS.

It should be noted that PSS suitability of the generator based upon the above criteria does not necessarily justify PSS installation irrespective of the cost. There are several other factors such as size of the unit, capacity factors and cost of retrofitting which should be given due consideration.

2.2 Recommendations

The modelling work group recommendations are as follows:

1. All existing generators of 75 MVA or larger should be considered for PSS.
2. All new machines with continuously acting voltage regulators should be considered for PSS.
3. If the phase lag of $\partial E_t/\partial E_{ref}$ (closed loop) is larger than the phase lag of the benchmark system defined by equation (1), then the combined system (GEP) is considered to be too slow for PSS installation. Conversely, if the combined system phase lag is less than that of the benchmark, the combined system is judged suitable for PSS considerations.
4. The frequency range of interest for PSS suitability considerations is from 0.1 Hz to 1.0 Hz.
5. The phase lag of the GEP should be either directly measured or should be calculated from programs such as EPRI's Small Signal Stability Program (SSSP). The measured data is preferable whenever possible.

3.0 BACKGROUND

- PSS is needed to neutralize the negative damping action of voltage regulators.

- High gain, fast acting voltage regulators create negative damping, but the same voltage regulators are also most suitable for PSS.

- High gain and fast acting are relative terms. There is no precise definition. IEEE Standards 421.2-1990 defines the high initial response system.

- High initial response systems are defined as those with voltage response time of 0.1 or less.

- Ignoring the precise definition, a high initial response or a fast acting excitation system is that where generator main field can reach its maximum value within 0.1 seconds of demand.

- The 0.1 seconds is not a hard limit and many exciters with larger response time are generally fast enough for PSS purposes.

- Examples of <u>very fast</u> acting excitation systems are:
  - Static excitation systems
  - ALTHYREX excitation systems

In these systems, the voltage regulator is used to control the firing angle of thyristors. There is negligible delay in reaching the desired field voltage.

- Examples of <u>fast</u> acting excitation systems are:
  - Westinghouse brushless excitation systems
  - General Electric SCPT excitation systems.

  In these regulators, an additional time constant of alternator is involved. The voltage regulator controls excitation of the alternator which, in turn, controls the main generator field.

- Examples of relatively <u>slow</u> excitation systems are:
  - Amplidyne regulator excitation systems
  - MAG-A-STAT regulator excitation systems

  These systems are comprised of at least two additional time constants other than the generator main field time constant. The frequency response is characterized by steep phase and gain decay past 1 to 2 Hz range. Generally, these systems do not create any significant undamping due to voltage regulator action.

4.0 STUDY RESULTS

Industry experts were contacted and a limited literature review was conducted to find if there exists any such criteria which can define an excitation system's suitability for PSS. No such criteria was found.

- WSCC's interest in PSS is primarily for the damping of low frequency intertie mode in the frequency range of 0.1 Hz to 1.0 Hz. PSS on almost any excitation system (slow or fast) can contribute some positive damping at these low frequency modes when PSS is tuned properly.

- Effective damping contribution of PSS depends upon many factors in addition to the type of excitation system. Some of these are:
  - Unit size (MVA)
  - Unit inertia (H)
  - Type of PSS signal (speed, frequency, accelerating power)
  - Frequency of oscillations
  - Location of the unit in the interconnected system

- A more appropriate question would be how effective a PSS is effective enough to justify the cost. In other words, how much positive damping should it contribute for it to be cost effective.

- An individual unit contributes very little to the overall damping of intertie mode. It is practically impossible to determine the incremental damping using time simulation stability studies.

- A more appropriate tool to determine the incremental contribution to the damping is an eigenvalue study. Even then, the incremental damping due to PSS on a unit is generally a very small number due to large interconnected system and depends heavily on the system and loads represented.

4.1 Absolute Damping

To establish uniformity of criteria, the damping calculations are made on two benchmark systems shown in Figure 2. Most eigenvalue studies were conducted using the benchmark system #1 of Figure 2 with the parameters listed below.

- Unit MVA varied from 50 to 1000
- Unit Inertia Constant (H) varied from 1 to 3
- Type of PSS input signal (speed, frequency)
- Type of exciter (AC4, DC1)
- System Inertia

These study results are tabulated in Table 1.

The absolute damping from Table 1 have been plotted in Figures 3a to 3d as a function of unit inertia and unit MVA. It is seen that PSS contribution to damping varies greatly as a function of many of the factors listed above.

4.2 Relative Damping

In an effort to reduce the variation of PSS damping contribution, a new method called Relative Damping Contribution (RDC), was used to study PSS suitability. Relative damping contribution is relatively independent of the size and inertia of the interconnected system and is a measure of the relative contribution of the PSS on the study unit. RDC is defined as follows:

$$RDC = \Delta\sigma_{abs} \times \frac{E_{sys} + E_{unit}}{E_{unit}}$$

Where $\Delta\sigma_{abs}$ = Change in damping of the intertie mode due to PSS (rad/s)
E_{sys} = Stored energy (MWS) of the system not including the study unit.
E_{unit} = Stored energy (MWS) of the study unit.

- Figure 4a shows impact of unit MVA with inertia constant "H" fixed at 3 pu. Three curves are shown for different input signals and different type of exciters. RDC for some is seen to decrease, for others, seen to increase and for yet others stay relatively constant with unit size. The RDC varies from a high of .07 rad/s to a low of .03 rad/s.

- Figure 4b shows the impact of unit inertia constant "H" on RDC for various parameters. In each case, the inertia is seen to have a significant impact on RDC. The smaller the inertia, the smaller is RDC. The graph suggests that PSS may not be cost effective on units with relatively small inertia.

- Figure 4c shows the impact of varying study machine inertia with system inertia reduced to 1/4 of the benchmark case value. The oscillation frequency doubles to around 0.85 Hz and the RDC values are much larger than those in Figures 4a and 4b. The increased RDC values are due to increased effective PSS gain at the higher oscillation frequency. The 0.44 Hz frequency case RDC values from Figure 3 are also shown for comparison.

- Selected eigenvalue studies were also conducted using the Benchmark System #2 in Figure 2. Once again, inertia was varied. Surprisingly, for this system, the RDC values are much larger than for the Benchmark System #1 and the RDC values reduce with increased inertia. These results are shown graphically in Figure 4d and are tabulated in Table 1.

Based upon study results summarized above, it is concluded that RDC values vary greatly depending upon the system and its inertia, excitation system and type of PSS input signal.

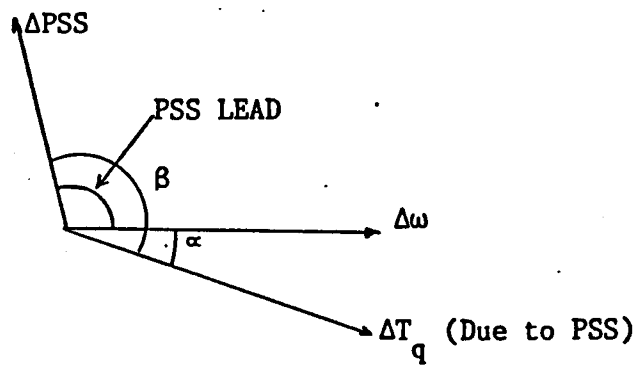
4.3 Phase Lag Criteria

A much simpler approach of determining the PSS suitability based upon phase lag of GEP (generator excitation system and the power system combined) was investigated. The combined system closed loop transfer function which PSS has to work through is denoted as GEP(s) and is discussed in detail in Reference 1. GEP(s) is given by:

$$GEP(s) = \frac{K_2}{K_6}\left(\frac{\partial E_t}{\partial E_{ref}}\right)$$

E_t is the generator terminal voltage and E_{ref} is the voltage regulator reference input. K_2 and K_6 are constants and depend upon the operating point (generator loading and system strength). K_2 and K_6 are constants for a given unit loading and the power system.

For PSS to be effective, it must overcome the phase lag of $\partial E_t/\partial E_{ref}$ in the frequency range of interest (0.1 to 1.0 Hz). A typical second order PSS frequency response is shown in Figure 5. It produces a peak phase compensation of 110° for lead-lag ratio of 10. A more typical value is a lead-lag ratio of 6 with a peak phase compensation of 100° The phasor diagram below shows the relationship between various quantities of interest. For practical purposes, the phase between PSS input signal (ΔPSS) and torque due to PSS (ΔT_q) is the same as that between ΔE_{Ref} and ΔE_t (Ref. 1). For typical speed or frequency input PSS, the PSS signal would usually provide 90° to 100° lead represented by the phasor ΔPSS as shown in the phasor diagram below.



The angle β represents lag of $\partial E_t/\partial E_{ref}$ and positions the torque component due to PSS input. For most effective PSS, ΔT_q should be in phase with $\Delta\omega$. However, reasonable effective damping may still occur as long as the angle α is less than 45°. For α greater than 45° PSS effectiveness starts to reduce fast. It would thus be reasonable to say that for PSS to be effective, the phase lag between ΔT_q and ΔPSS which is the same as the phase of $\partial E_t/\partial E_{ref}$ should be less than 135°.

One complication to this simple approach is that both PSS(s) and $\partial E_t/\partial E_{ref}$ phase lags are functions of frequency. Thus, specifying phase at one given frequency may be too simplistic. Since our highest frequency of interest for PSS application is 1.0 Hz, it would be reasonable to propose a maximum phase lag of 135° at 1.0 Hz.

A simple third order transfer function with corner frequencies at 0.1, 1.0 and 10.0 Hz is used as a benchmark for determining PSS effectiveness. The transfer function is shown on next page and its frequency response is shown in Figure 1.

$$T(s) = \frac{(6.28)^3}{(S+.628)(S+6.28)(S+62.8)} \qquad (1)$$

The proposed criteria is as follows:

> If the phase lag of $\partial E_t/\partial E_{ref}$ (closed loop) is larger than the phase lag of the benchmark system defined by equation (1), then the combined system is considered to be too slow for PSS installation. Conversely, if $\partial E_t/\partial E_{ref}$ phase lag is less than that of the benchmark, the combined system is judged suitable for PSS considerations.

The main advantage of such a criteria is that it is very simple to understand and apply. $\partial E_t/\partial E_{ref}$ can be easily measured or can be calculated using program such as EPRI's Small Signal Stability program (SSSP). The main disadvantage of this approach is that unlike previously discussed methods, it does not give any quantitative answer to PSS effectiveness.

4.4 Application of Phase Lag Criteria

An example of how the criteria can be applied follows. A measured $\partial E_t/\partial E_{ref}$ for a 250 MVA unit with Westinghouse brushless exciter system in a strong system environment is compared with the proposed T(s) in Figure 6a. It is clearly seen that $\partial E_t/\partial E_{ref}$ phase lag is less than T(s) phase lag in the frequency range of interest (0.1 to 1 Hz). Thus, this system would be considered suitable for PSS. Notice that phase has a large dip near 1.6 Hz due to local mode. This is very typical for a heavily loaded unit and $\partial E_t/\partial E_{ref}$ phase lag at the local mode should not be used as a criteria for PSS.

Figure 6b compares $\partial E_t/\partial E_{ref}$ phase to T(s) phase for a relatively slow excitation system. Comparison indicates that this system is inferior to the benchmark because $\partial E_t/\partial E_{ref}$ phase lag exceeds T(s) phase lag in the frequency range of interest and, hence, the system will not be suitable for PSS.

The proposed criteria should not be considered as absolute. Actual frequencies of interest, PSS settings, and type of input signal have significant impact on how much damping will be contributed by PSS on a particular unit in a particular environment. Figs. 7a, 7b, and 7c show the combined open loop frequency response of the proposed benchmark system with three different PSS settings. It is seen that the phase lags vary widely. Figure 7a shows relatively flat phase in 0.1 to 1.0 Hz range. Figure 7b shows a response which is less flat but has a wide bandwidth and 7c shows significant phase lag for frequency higher than 0.5 Hz but stays flat between 0.5 to 2.0 Hz.

There is another factor which is not directly covered by this criteria. That is the gain of $\partial E_t/\partial E_{ref}$. Usually systems which have large phase lag in the frequency range of interest also show a large attenuation and, thus, PSS effectiveness for systems with large phase lags would be even lower due to gain considerations. Thus, the proposed criteria does indirectly account for the gain of the combined system.

5.0 STUDY DETAILS

All studies were conducted using an eigenvalue program from Power Math Associates called SSR/EIGEN.

5.1 System Representation

Two benchmark systems have been studied. Benchmark System #1 representation is shown in Figure 2a. The study machine data is taken from a typical 900 MVA unit in WSCC system. The impedances and X/R ratio are for typical 500 kV lines. The Benchmark System #2 representation is shown in Figure 2b.

5.2 Excitation System Representation

The types of excitation systems have been studies. Figure 8a shows a typical AC4 type excitation system. Figure 8b shows a typical DC1 type excitation system.

5.3 PSS Representation

Power system stabilizer was represented by a two-stage lead/lag circuit with a washout stage as shown in Figure 8. The lead/lag time constants were fixed at 0.2 and 0.02 seconds throughout the study.

5.4 Input Signals

Two kinds of PSS input signals were used, speed and frequency. These are the most commonly used PSS input signals. Another commonly used signal is accelerating power which was not used in these studies.

5.5 Study Method

There are a large number of variables and studying all of them would have been out of scope of this study. Therefore, a selected number of variables were chosen to investigate the application of the method. PSS optimization consisted of optimizing PSS gain only. The gain optimization consisted of first finding the PSS instability gain. This was done by increasing the PSS gain until the PSS eigenvalue became unstable. The optimum PSS gain was taken as one-third of the instability gain.

PSS's contribution to damping was calculated by running a case with zero PSS gain and comparing the real parts of intertie mode from the one-third of instability gain case to the zero PSS gain case.

5.6 Sample Run

A sample eigenvalue case is attached as Exhibit 1.

6.0 REFERENCES

1. E. V. Larsen, D. A. Swann, "Applying Power System Stabilizer: Part I General Concepts", IEEE Trans. on PAS Vol. 100, No. 6, June 1981, pp. 3017-3024.

2. "Criteria and Definitions for Excitation Systems for Synchronous Machines". IEEE Standards 421-72, December, 1972.

3. "IEEE Guide for Identification, Testing, and Evaluation of the Dynamic Performance of Excitation Control System," IEEE Standards 421.2 - 1990.

4. C. Concordia, F. P. DeMello, "Concepts of Synchronous Machine Stability As Affected by Excitation Control", IEEE Trans PAS Vol. 88, Apr. 1969, pp 316-329.

TABLE – 1

(Benchmark System 1)

SPEED DEV INPUT PSS EXCITER TYPE AC-4

CASE #	Esys MWS	Study M/C MVA	H	Sigma For Case NO PSS	WITH PSS	DeltaSigma Absolute	RDC	Freq (Hz)
1	35000	1000	3	-0.000405	-0.005466	0.005061	0.064106	0.44
2	35000	500	3	-0.000071	-0.002150	0.002080	0.050601	0.44
3	35000	250	3	0.000191	-0.000742	0.000933	0.044473	0.44
4	35000	100	3	0.000375	0.000034	0.000341	0.040124	0.44
5	35000	50	3	0.000440	0.000274	0.000167	0.039080	0.44
1	35000	1000	3	-0.000405	-0.005466	0.005061	0.064107	0.44
7	35000	1000	2	0.000135	-0.001826	0.001961	0.036284	0.44
8	35000	1000	1	0.000441	0.000170	0.000271	0.009760	0.44

FREQUENCY INPUT PSS EXCITER TYPE AC-4

CASE #	Esys MWS	Study M/C MVA	H	Sigma For Case NO PSS	WITH PSS	DeltaSigma Absolute	RDC	Freq (Hz)
9	35000	1000	3	-0.000405	-0.003217	0.002812	0.035619	0.44
10	35000	500	3	-0.000071	-0.001512	0.001442	0.035077	0.44
11	35000	250	3	0.000191	-0.000552	0.000743	0.035421	0.44
12	35000	100	3	0.000375	0.000074	0.000301	0.035372	0.44
13	35000	50	3	0.000440	0.000288	0.000153	0.035806	0.44
9	35000	1000	3	-0.000405	-0.003217	0.002812	0.035620	0.44
14	35000	1000	2	0.000135	-0.001299	0.001434	0.026535	0.44
15	35000	1000	1	0.000441	0.000152	0.000289	0.010418	0.44

FREQUENCY INPUT PSS EXCITER TYPE DC-1

CASE #	Esys MWS	Study M/C MVA	H	Sigma For Case NO PSS	WITH PSS	DeltaSigma Absolute	RDC	Freq (Hz)
16	35000	1000	3	-0.000161	-0.003082	0.002922	0.037006	0.44
17	35000	500	3	0.000007	-0.001722	0.001729	0.042072	0.44
18	35000	250	3	0.000216	-0.000732	0.000948	0.045197	0.44
19	35000	100	3	0.000382	-0.000022	0.000404	0.047490	0.44
20	35000	50	3	0.000443	0.000235	0.000209	0.048919	0.44
16	35000	1000	3	-0.000161	-0.003082	0.002922	0.037006	0.44
21	35000	1000	2	0.000268	-0.001385	0.001653	0.030579	0.44
22	35000	1000	1	0.000489	-0.000015	0.000504	0.018154	0.44
19	35000	100	3	0.000382	-0.000022	0.000404	0.047490	0.44
23	35000	100	2	0.000456	0.000232	0.000224	0.039406	0.44
24	35000	100	1	0.000496	0.000430	0.000066	0.023226	0.44

Table- 1 Continued)

(Benchmark System # 1 Results Continued)

FREQUENCY INPUT PSS EXCITER TYPE DC-1

CASE #	Esys MWS	Study M/C MVA	H	Sigma For Case NO PSS	WITH PSS	DeltaSigma Absolute	RDC	Freq (Hz)
25	8750	100	3	-0.000823	-0.006814	0.005991	0.180729	0.85
26	8750	100	2	0.0008619	-0.002209	0.003071	0.137423	0.85
27	8750	100	1	0.001734	0.0008777	0.000856	0.075783	0.85
28	35000	100	3	-0.00044	-0.00191	0.001470	0.172970	0.85

Benchmark System 2

FREQUENCY INPUT PSS EXCITER TYPE DC-1

CASE #	Esys MWS	Study M/C MVA	H	Sigma For Case NO PSS	WITH PSS	DeltaSigma Absolute	RDC	Freq (Hz)
31	140000	100	3	-0.058750	-0.060021	0.001271	0.594404	0.43
32	140000	100	2	-0.058780	-0.059780	0.001000	0.701000	0.43
33	140000	100	1	-0.058800	-0.059360	0.000560	0.784560	0.43
34	35000	100	3	-0.234900	-0.243000	0.008100	0.953100	0.85

NOTES:

1. RDC=Absolute DelSig*((Esys+Eunit)/Eunit)
2. For Cases 25,26,27 Tie Bus M/C MVA=2500
3. For Case 28 Tie Line Imped Reduced by 4
4. For Cases31,32,33 Tie Bus MVA=40000
5. For Case 34 Tie Bus MVA Reduced To 10000

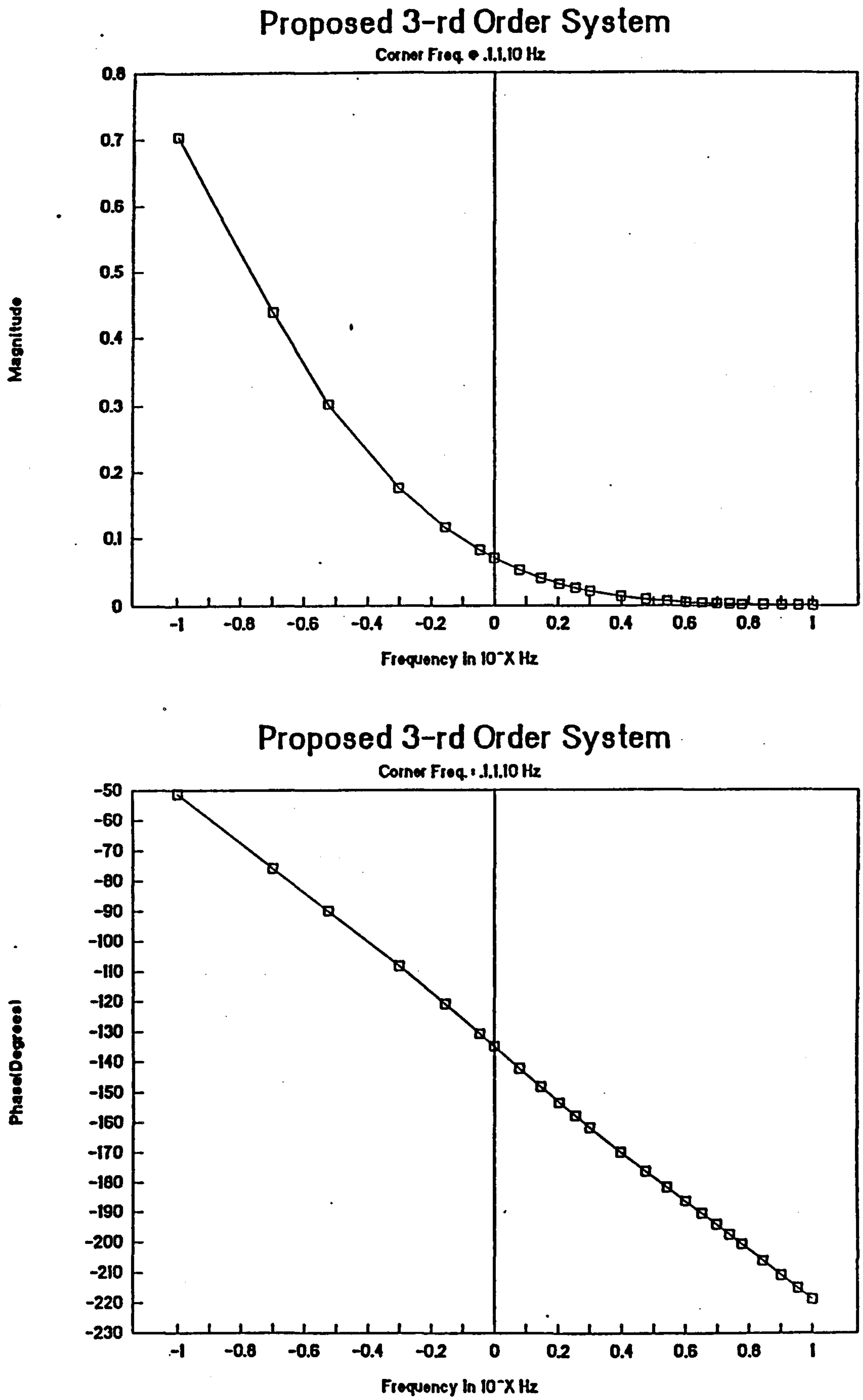
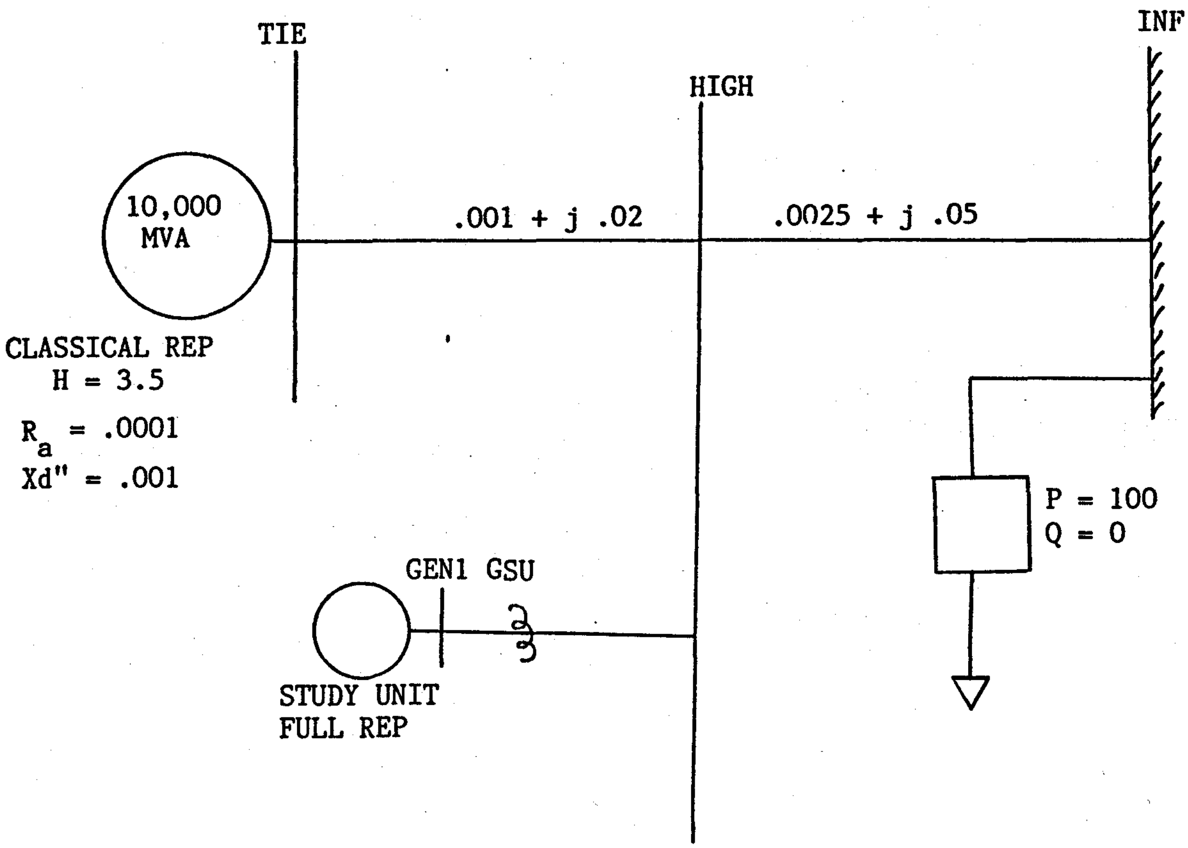
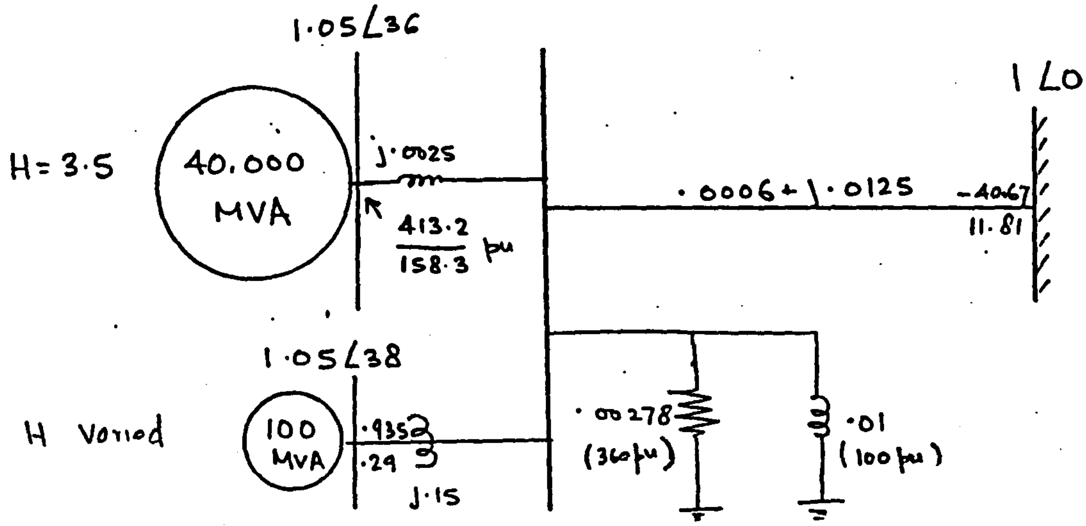

Proposed 3-rd Order System
Corner Freq. @ .1,1,10 Hz
Magnitude
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Frequency in 10^X Hz
Proposed 3-rd Order System
Corner Freq. : .1,1,10 Hz
Phase(Degrees)
-50
-60
-70
-80
-90
-100
-110
-120
-130
-140
-150
-160
-170
-180
-190
-200
-210
-220
-230
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Frequency in 10^X Hz

Fig. 1



All impedance data are in pu on 100 MVA base
GSU = 15% on study unit MVA base

Fig. 2a



BENCH MARK SYSTEM 2

All values on 100 MVA Base Including Power Flows

Fig. 2b

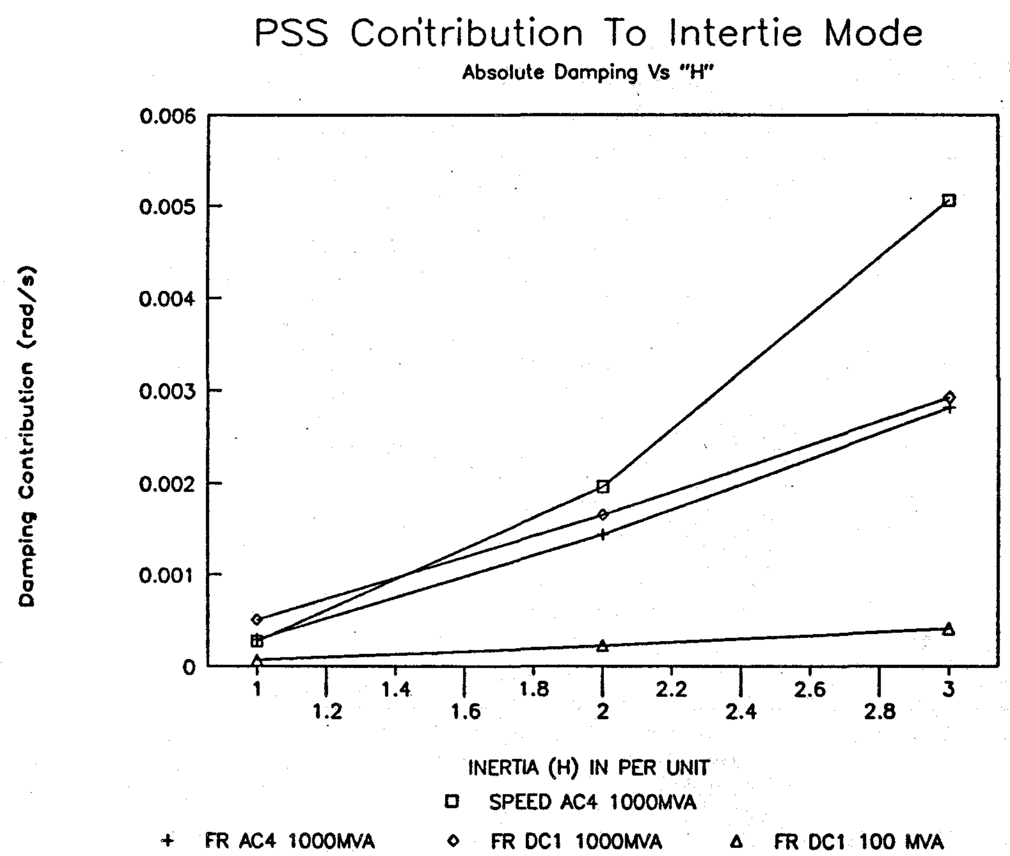

PSS Contribution To Intertie Mode
Absolute Damping Vs "H"
Damping Contribution (rad/s)
0.006
0.005
0.004
0.003
0.002
0.001
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
INERTIA (H) IN PER UNIT
SPEED AC4 1000MVA
FR AC4 1000MVA
FR DC1 1000MVA
FR DC1 100 MVA

Fig. 3b

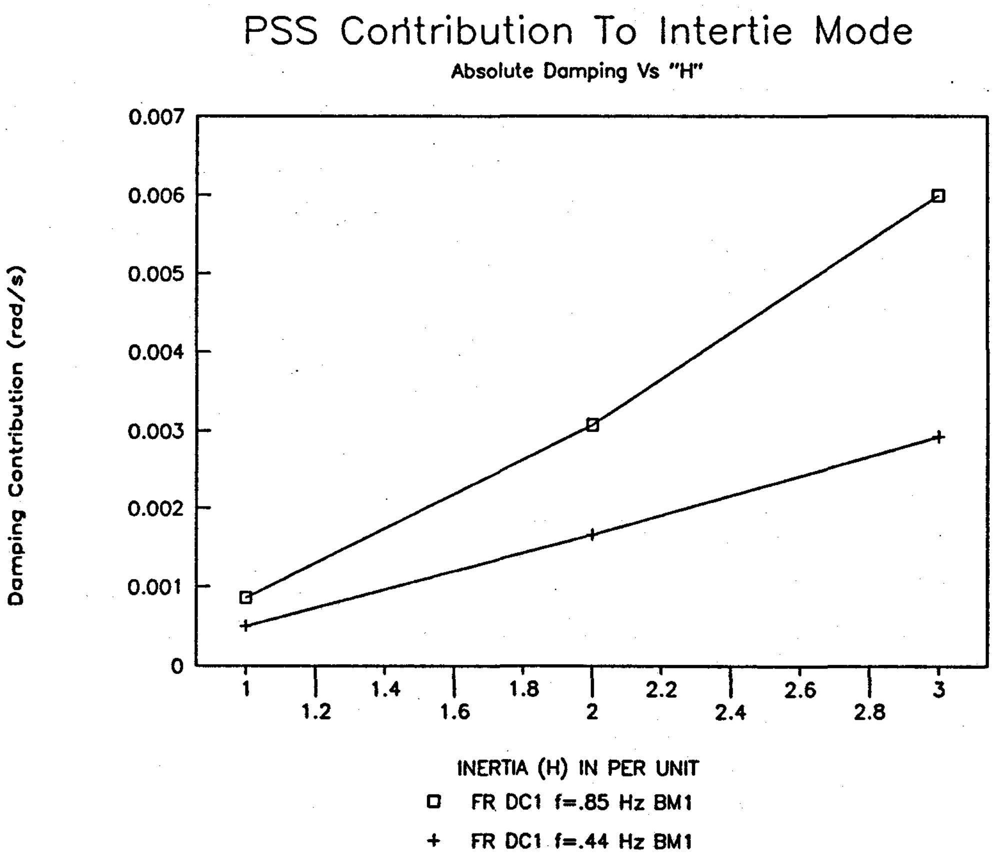

PSS Contribution To Intertie Mode
Absolute Damping Vs "H"
Damping Contribution (rad/s)
0.007
0.006
0.005
0.004
0.003
0.002
0.001
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
INERTIA (H) IN PER UNIT
FR DC1 f=.85 Hz BM1
FR DC1 f=.44 Hz BM1

Fig. 3c

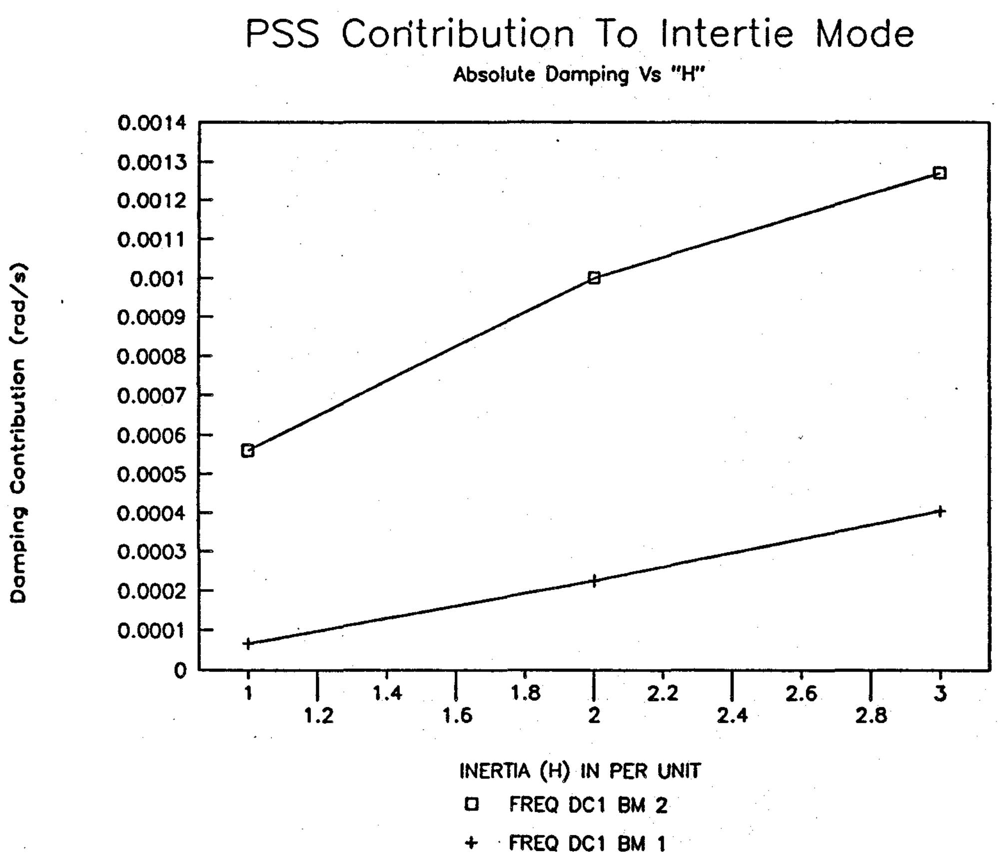

PSS Contribution To Intertie Mode
Absolute Damping Vs "H"
Damping Contribution (rad/s)
0.0014
0.0013
0.0012
0.0011
0.001
0.0009
0.0008
0.0007
0.0006
0.0005
0.0004
0.0003
0.0002
0.0001
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
INERTIA (H) IN PER UNIT
FREQ DC1 BM 2
FREQ DC1 BM 1

Fig. 3d

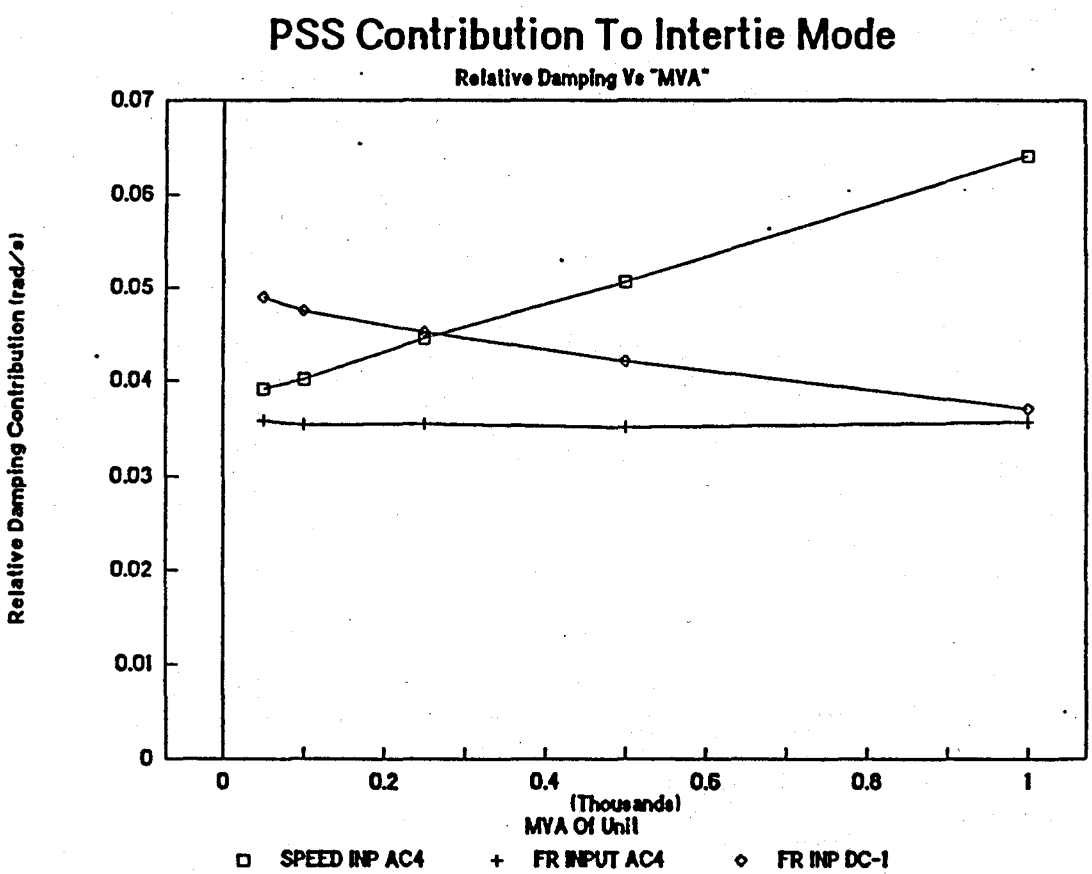

PSS Contribution To Intertie Mode
Relative Damping Vs "MVA"
Relative Damping Contribution (rad/s)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
0
0.2
0.4
0.6
0.8
1
(Thousands)
MVA Of Unit
SPEED INP AC4
FR INPUT AC4
FR INP DC-1

FIG. 4a

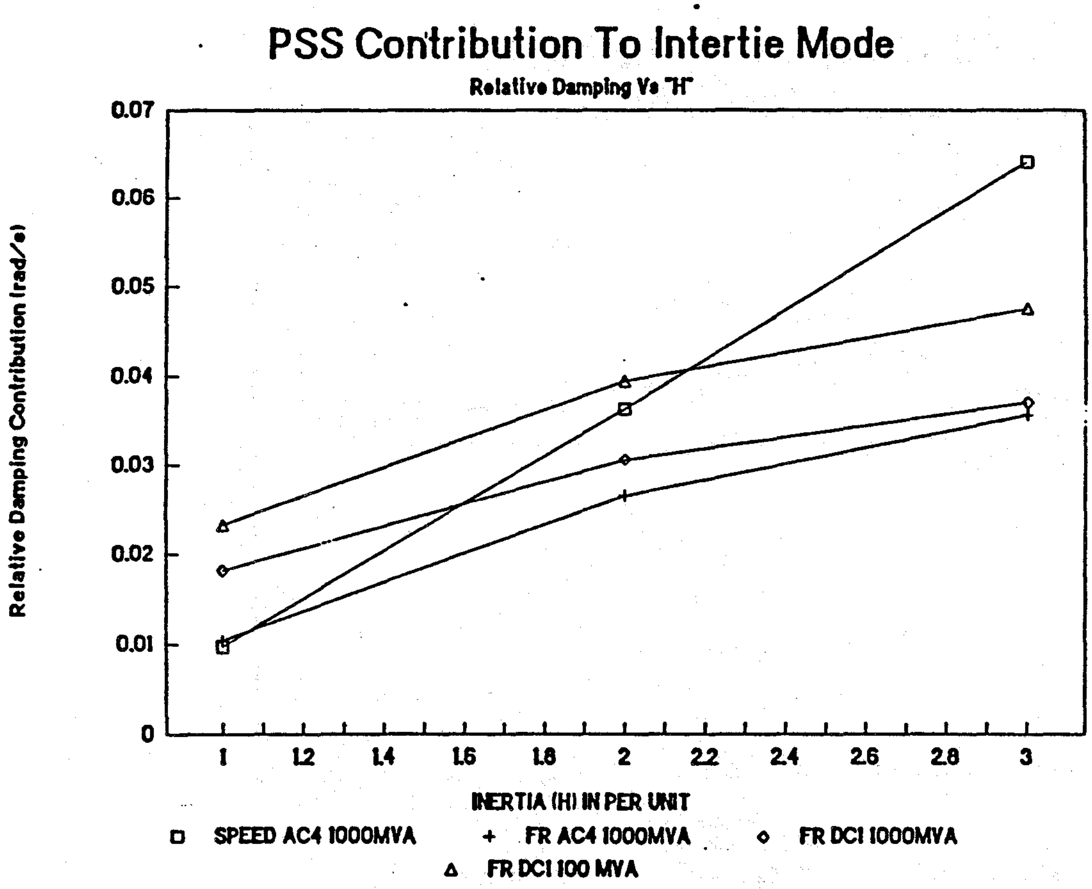

PSS Contribution To Intertie Mode
Relative Damping Vs "H"
Relative Damping Contribution (rad/s)
0.07
0.06
0.05
0.04
0.03
0.02
0.01
0
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
INERTIA (H) IN PER UNIT
SPEED AC4 1000MVA
FR AC4 1000MVA
FR DC1 1000MVA
FR DC1 100 MVA

FIG. 4b

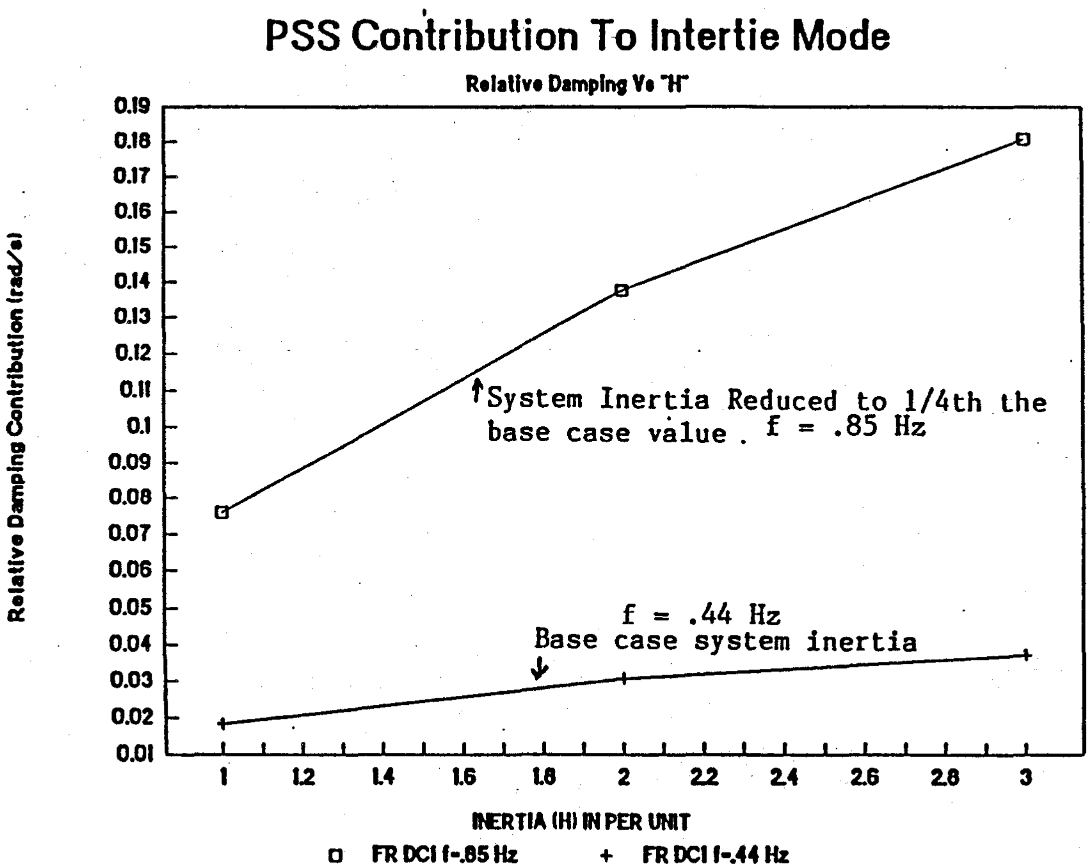

PSS Contribution To Intertie Mode
Relative Damping Vs "H"
Relative Damping Contribution (rad/s)
0.19
0.18
0.17
0.16
0.15
0.14
0.13
0.12
0.11
0.1
0.09
0.08
0.07
0.06
0.05
0.04
0.03
0.02
0.01
System Inertia Reduced to 1/4th the base case value . f = .85 Hz
f = .44 Hz
Base case system inertia
1
1.2
1.4
1.6
1.8
2
2.2
2.4
2.6
2.8
3
INERTIA (H) IN PER UNIT
FR DCI f=.85 Hz
FR DCI f=.44 Hz

FIG. 4c

PSS Contribution To Intertie Mode

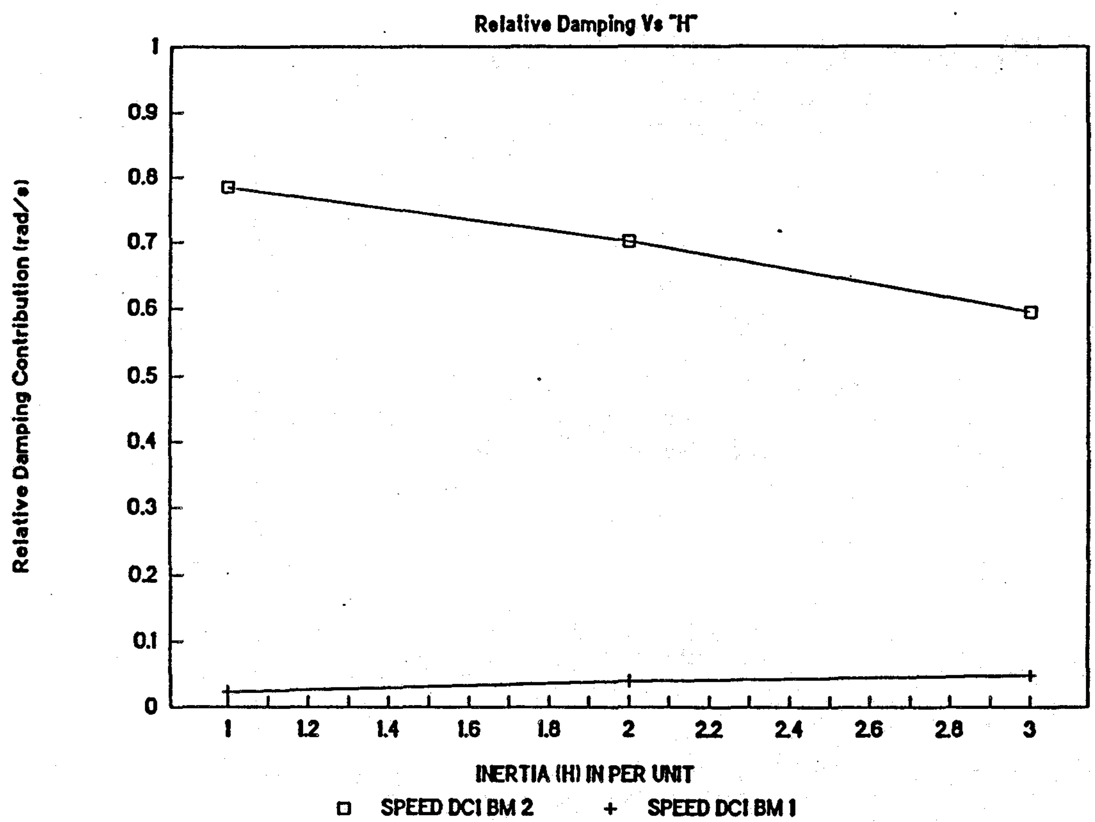
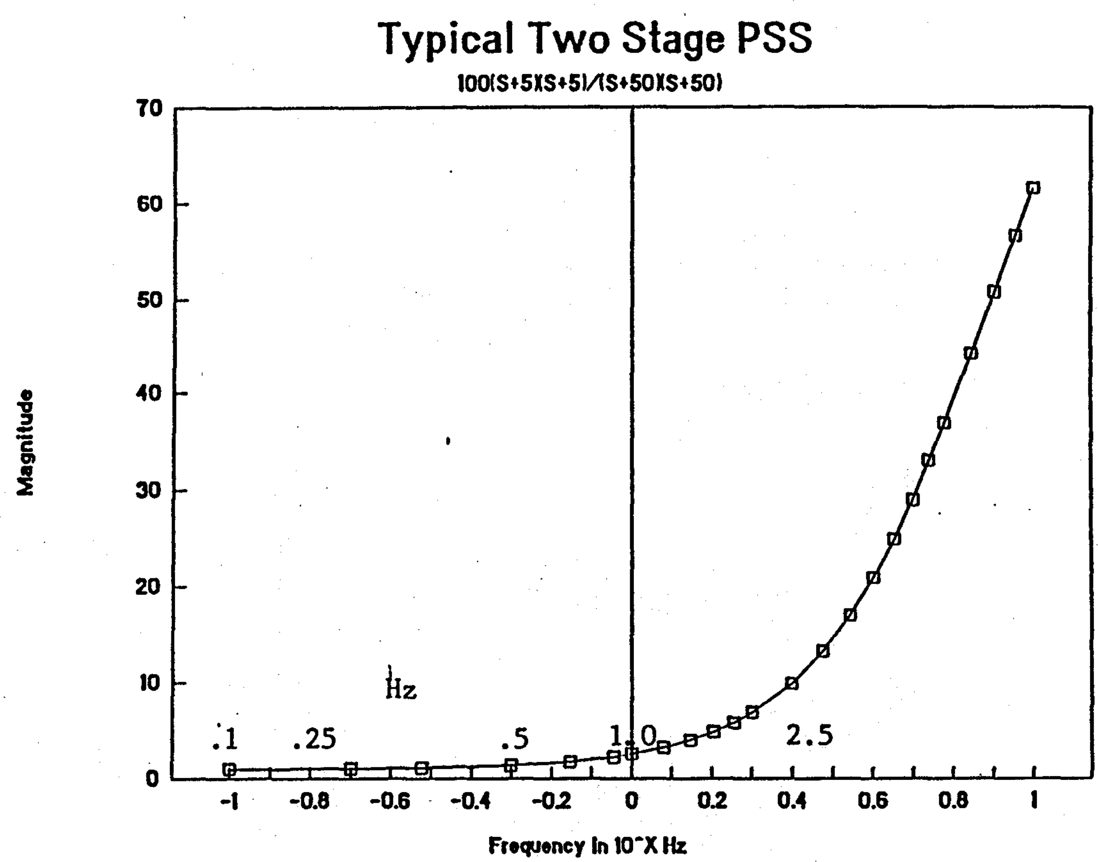


FIG. 4d


Typical Two Stage PSS
100(S+5)(S+5)/(S+50)(S+50)
Magnitude
Hz
.1
.25
.5
1.0
2.5
Frequency in 10^X Hz
70
60
50
40
30
20
10
0
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

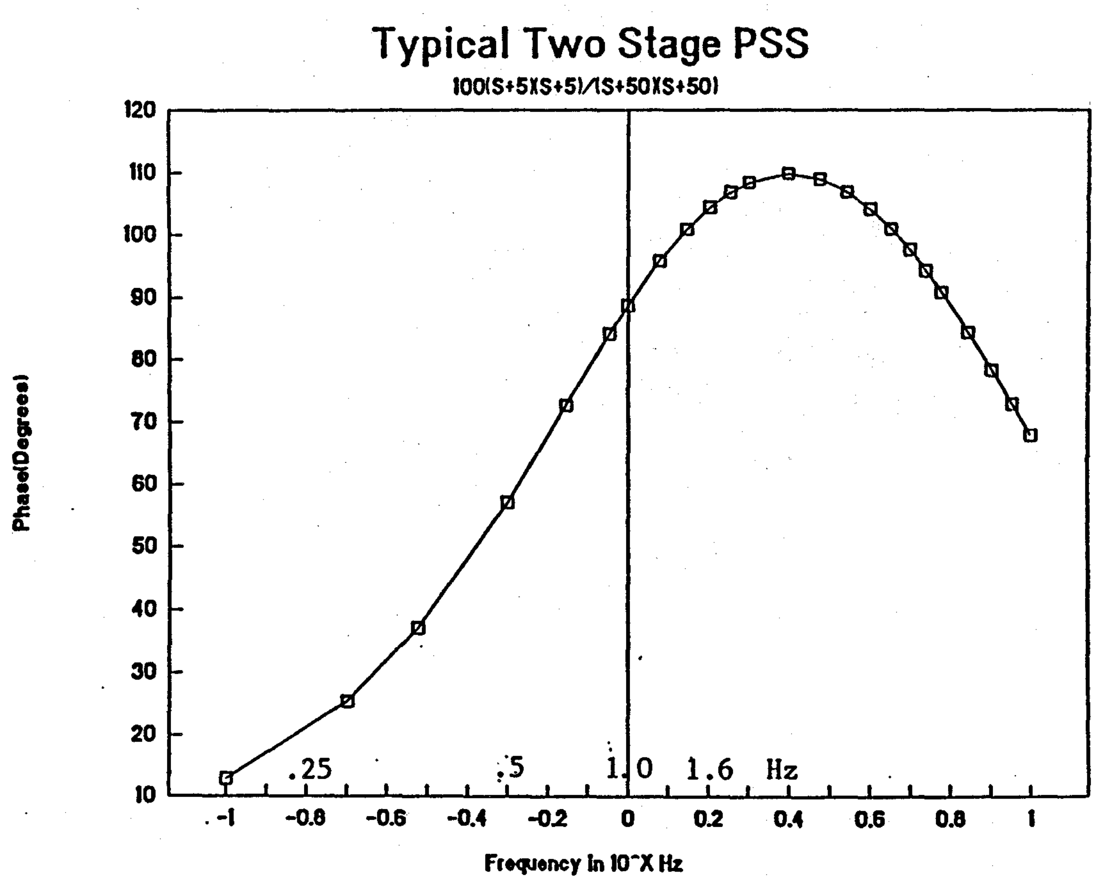
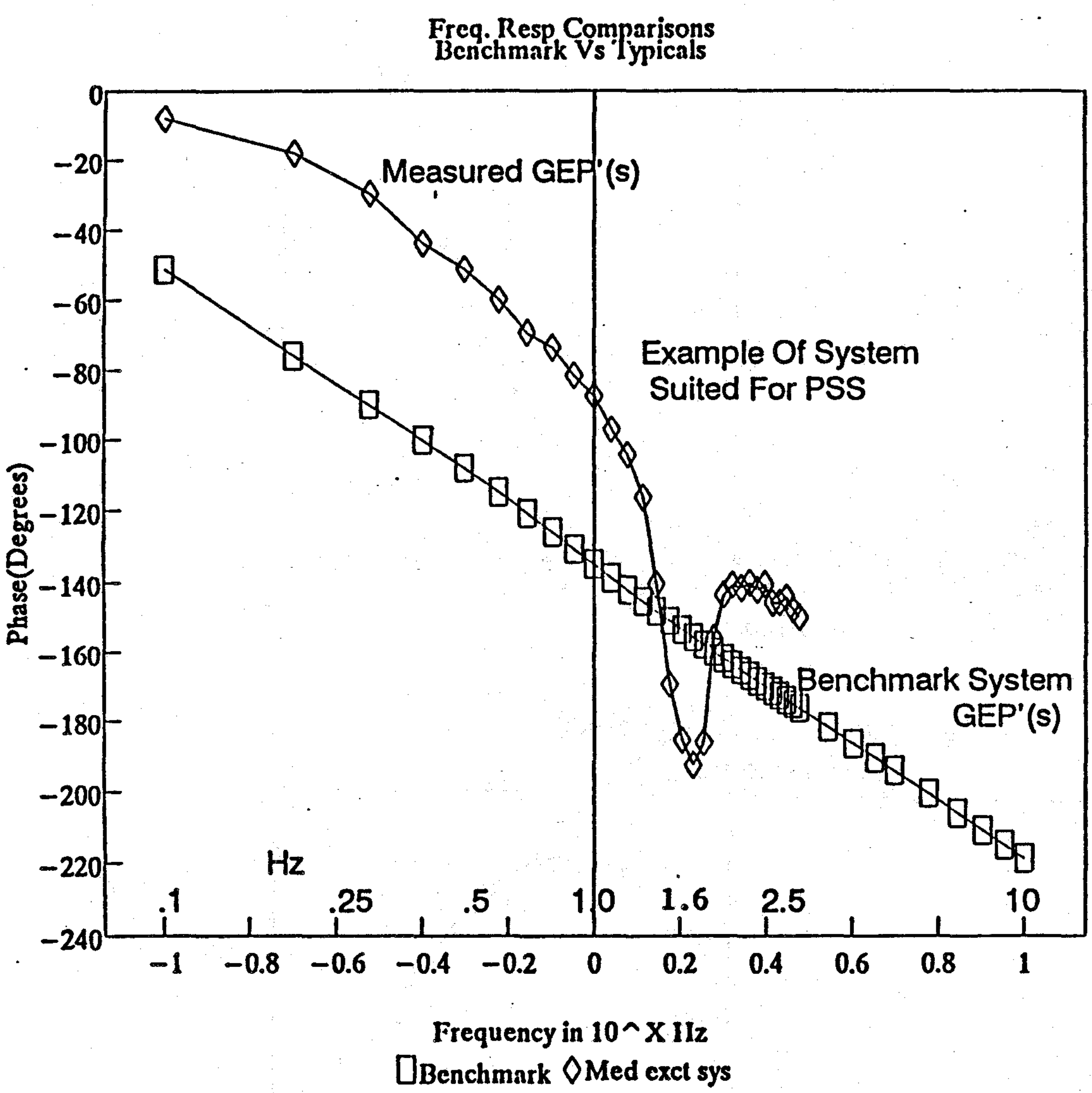
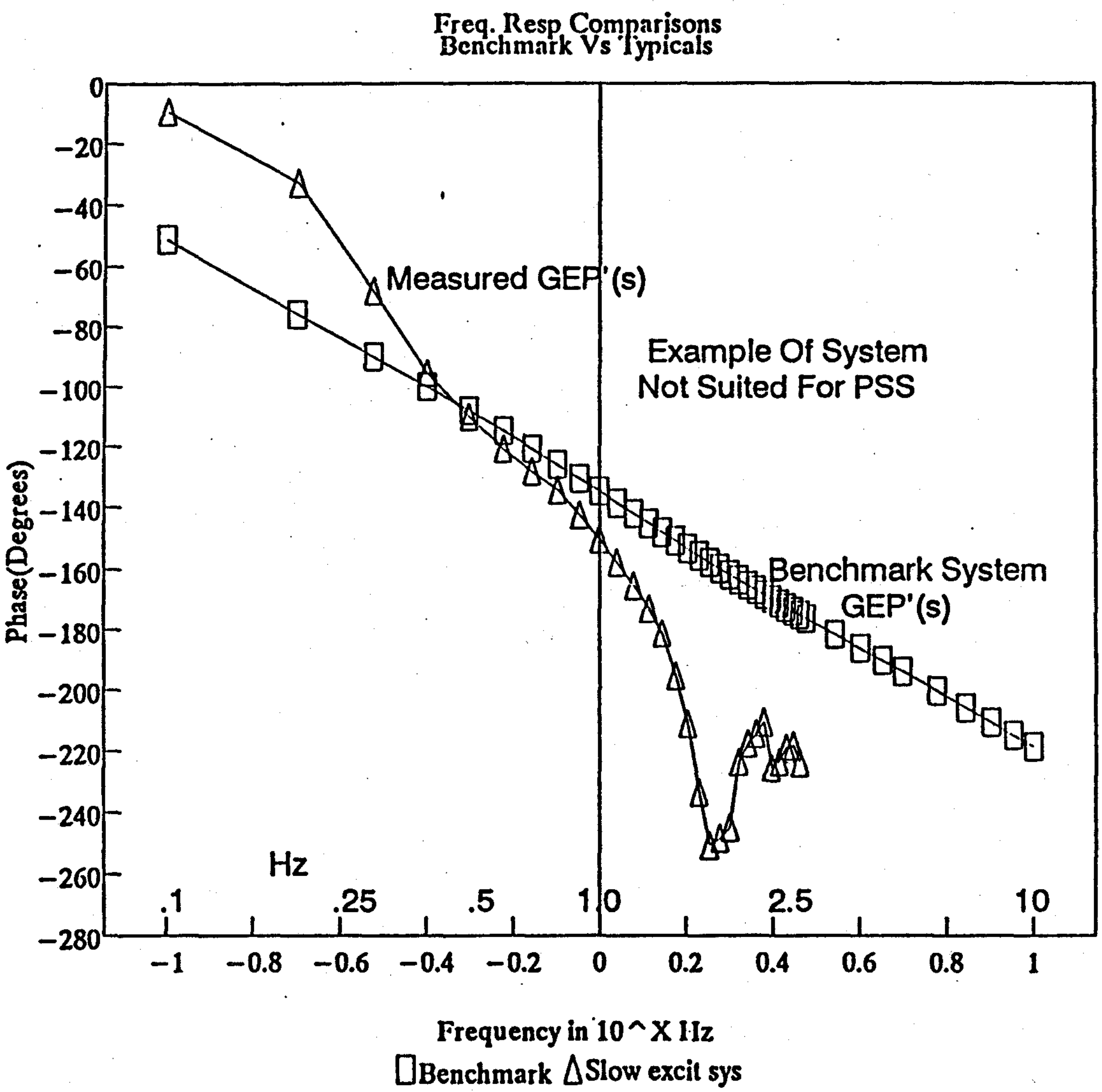

Typical Two Stage PSS
100(S+5)(S+5)/(S+50)(S+50)
Phase(Degrees)
.25
.5
1.0
1.6
Hz
Frequency in 10^X Hz
120
110
100
90
80
70
60
50
40
30
20
10
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1

FIG. 5



Freq. Resp Comparisons
Benchmark Vs Typicals
Measured GEP'(s)
Example Of System
Suited For PSS
Benchmark System
GEP'(s)
Phase(Degrees)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
Hz
.1
.25
.5
1.0
1.6
2.5
10
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Frequency in 10^X Hz
□Benchmark ◇Med exct sys

FIG. 6a

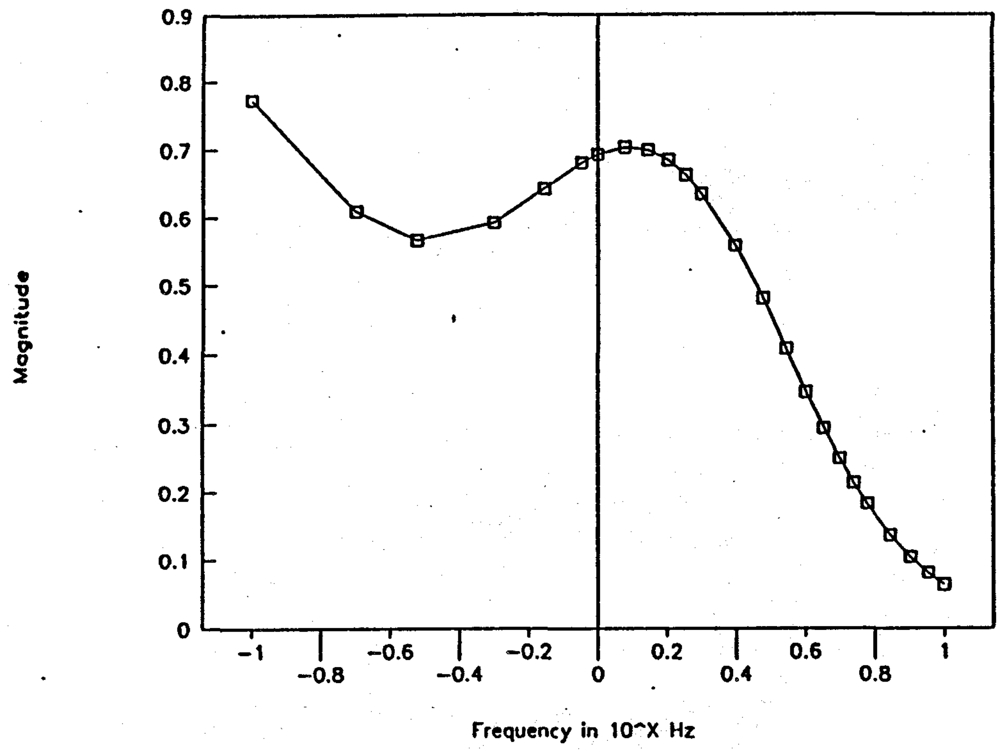


Freq. Resp Comparisons
Benchmark Vs Typicals
Phase(Degrees)
0
-20
-40
-60
-80
-100
-120
-140
-160
-180
-200
-220
-240
-260
-280
Measured GEP'(s)
Example Of System
Not Suited For PSS
Benchmark System
GEP'(s)
Hz
.1
.25
.5
1.0
2.5
10
-1
-0.8
-0.6
-0.4
-0.2
0
0.2
0.4
0.6
0.8
1
Frequency in 10^X Hz
Benchmark Slow excit sys

FIG. 6b

PSS(s)=(1+.5s)(1+.5s)/(1+.05s)(1+.05s)

GEP'(s) has corner freq. @ .1,1,10 Hz (BENCHMARK SYSTEM)



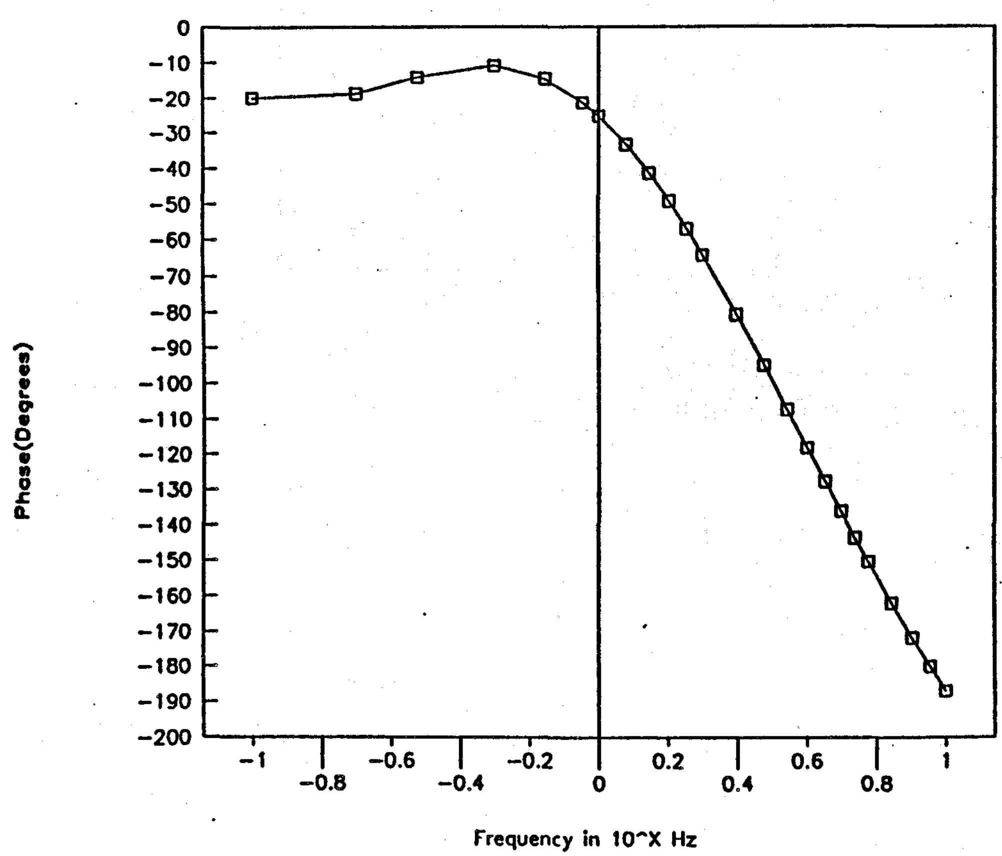
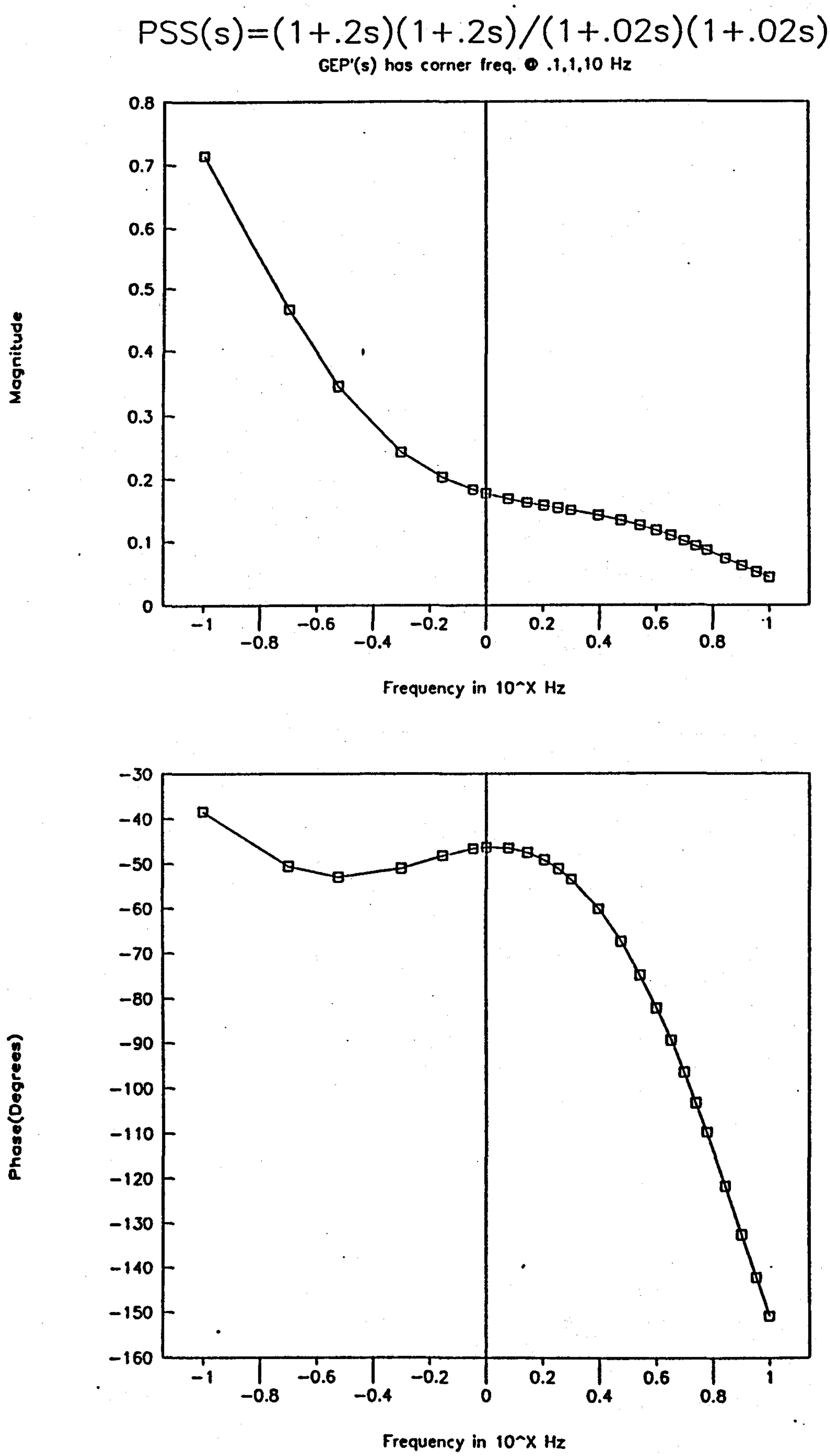


FIG. 7a

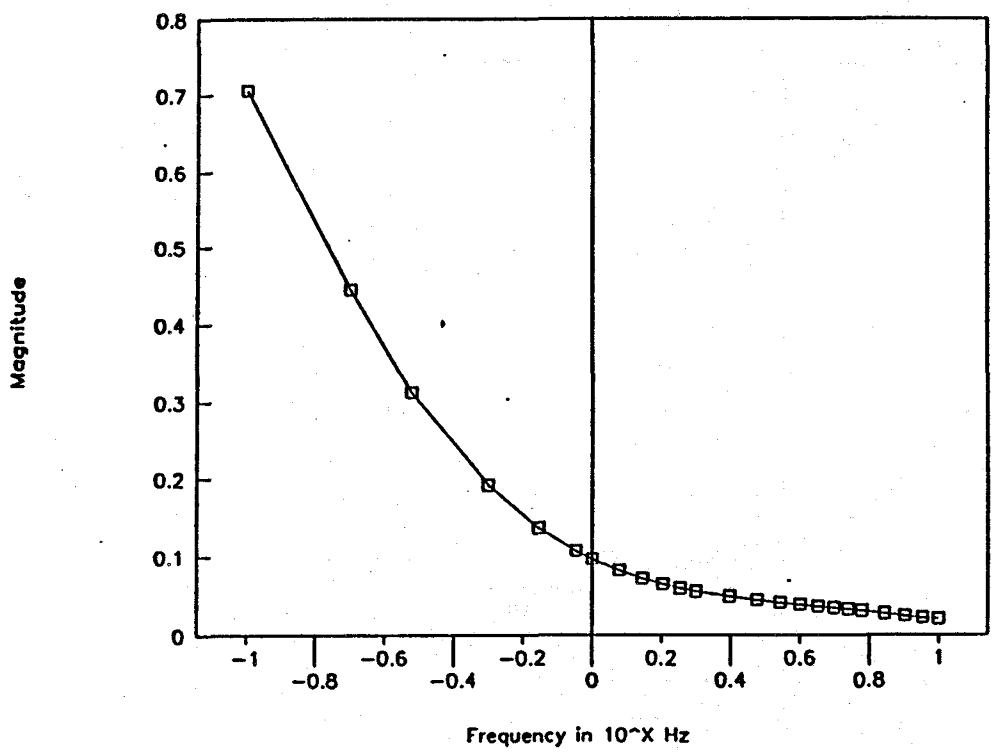


PSS(s)=(1+.2s)(1+.2s)/(1+.02s)(1+.02s)
GEP'(s) has corner freq. @ .1,1,10 Hz
Magnitude
Frequency in 10^X Hz
Phase(Degrees)
Frequency in 10^X Hz

FIG. 7b

PSS(s)=(1+.1s)(1+.1s)/(1+.01s)(1+.01s)

GEP'(s) has corner freq. @ .1,1,10 Hz



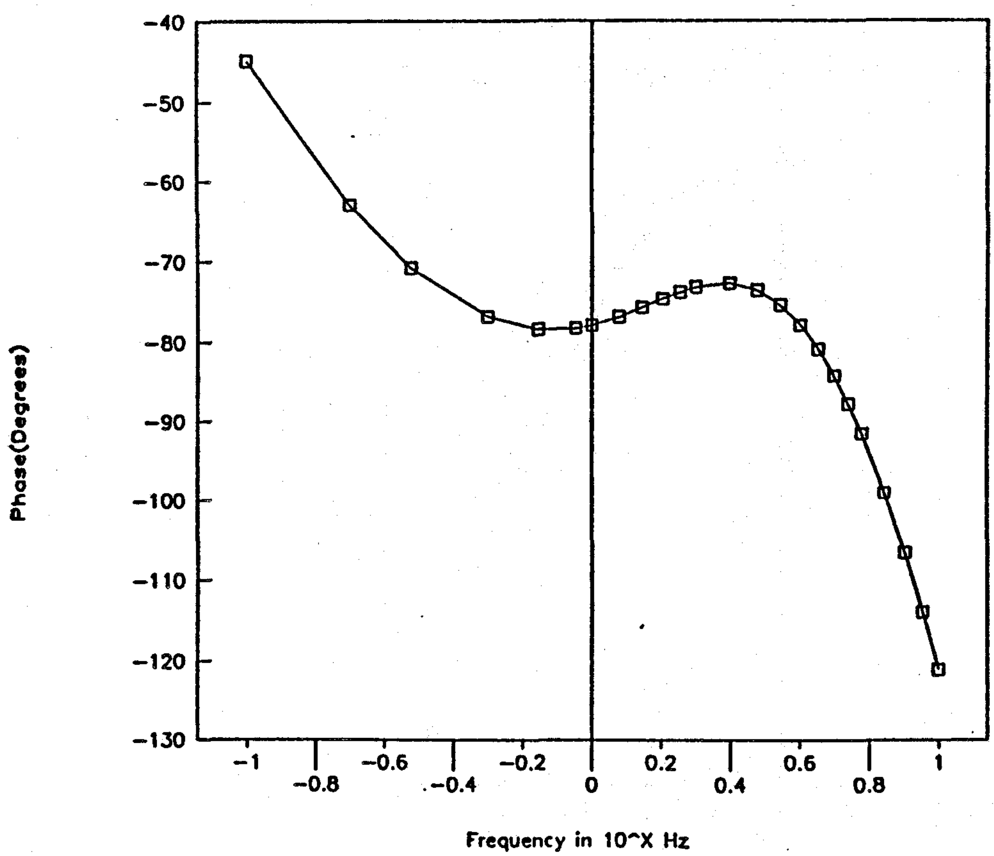


FIG.. 7c

CASES WITH TYPE "AC4" EXCITER

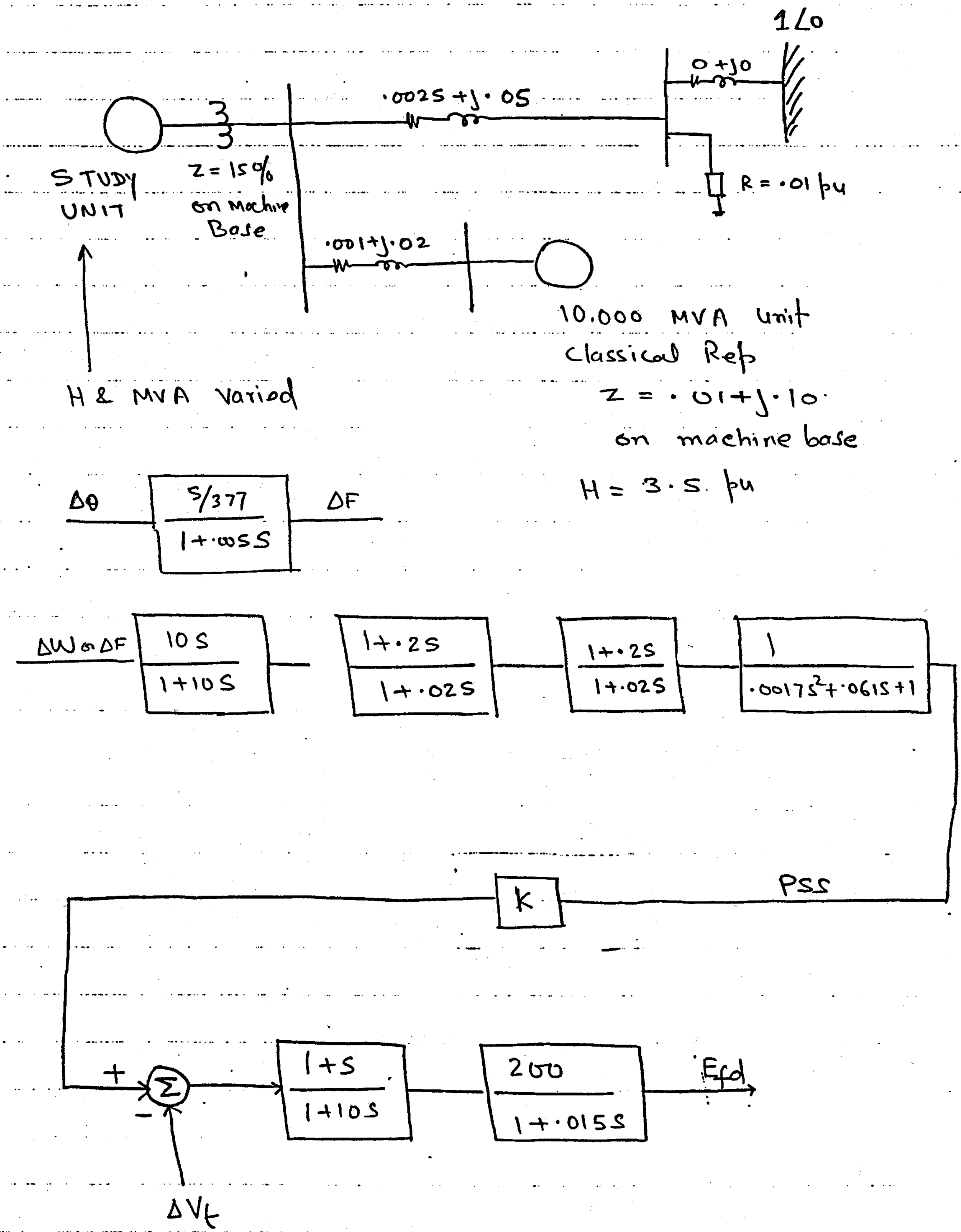
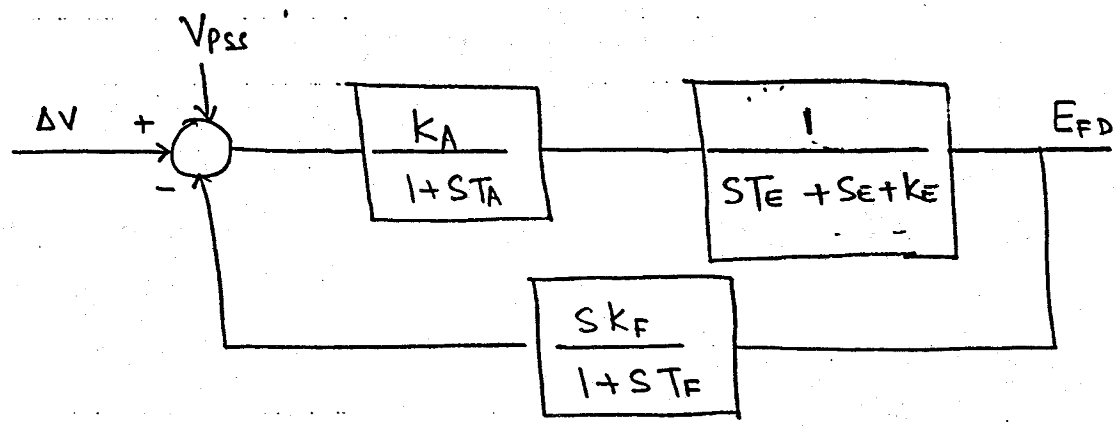


Fig. 8a

CASES WITH TYPE "DC1" EXCITER

WSCC TYPE A (IEEE DC1) EXC. SYS.

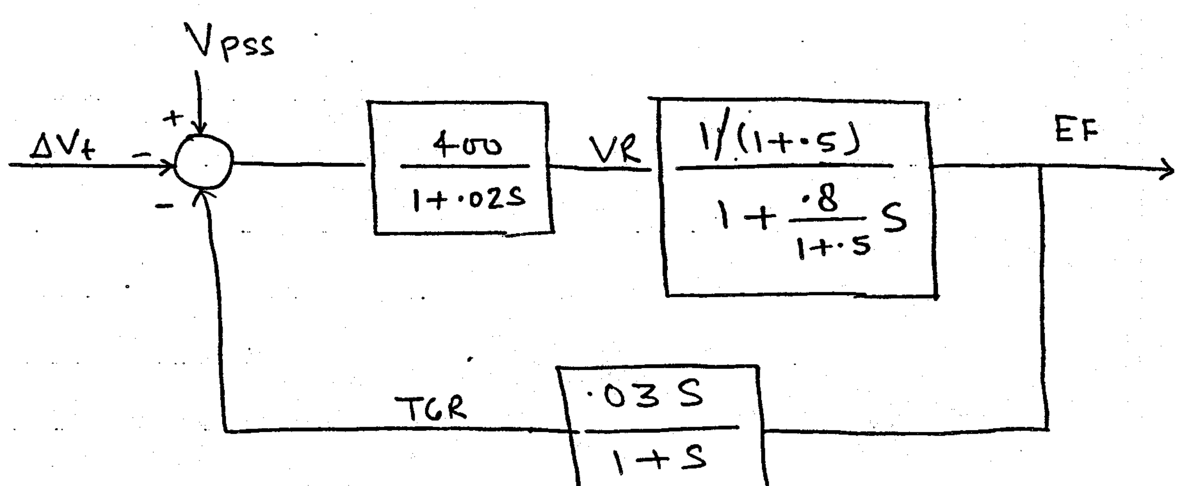
Use Typical values from Committee Paper (PAS - Feb 81)



$K_A = 400$ $T_A = .02$ $K_E = 1$ $T_E = .8$ $S_E(.75) = .5$

$K_F = .03$ $T_F = 1.0$

SSR/EIGEN PROGRAM MODEL



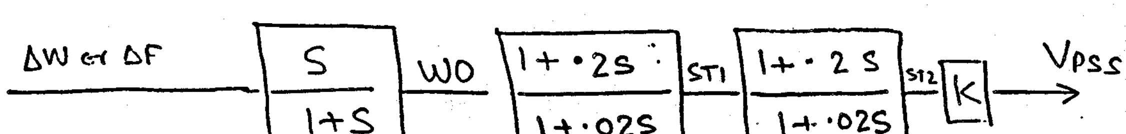


Fig. 8b

3-13-92

PSS Effectiveness Study For Modeling Work Group

EXHIBIT 1

MVA=100 H=1

SYSTEM BASE MVA 100.0 HFAC 1. XC INCREMENTED THROUGH 0 STEPS

GENERATOR 1 HAS A TWO AXIS MODEL, IS NAMED GEN1 AND CONNECTED TO BUS GEN1
MVA 100.0 XL 0.1300 RA 0.0019 VT 1.0000 DEL 8.5000
VOLTAGE REGULATOR OUTPUT NAMED VFU1
XD 1.760 XDP 0.220 XDPP 0.175 TDOP 4.200 TDOPP 0.032
XQ 1.680 XQP 0.400 XQPP 0.175 TQOP 0.600 TQOPP 0.066

MECHANICAL SYSTEM IS 1 MASS CLASSICAL, GENERATOR IS 1, EXCITER IS 1
MASS 1 J 2.0000 D 0.00000E+00

GENERATOR 2 HAS A SIMPLE MODEL, IS NAMED INFBUS AND CONNECTED TO BUS INFBUS
MVA 100.0 XL 0.0000 RA 0.0000 VT 1.0000 DEL 0.0000

GENERATOR 3 HAS A SIMPLE MODEL, IS NAMED TIEBUS AND CONNECTED TO BUS TIEBUS
MVA 9999.0 XL 0.1000 RA 0.0100 VT 1.0000 DEL 0.0000

MECHANICAL SYSTEM IS 1 MASS CLASSICAL, GENERATOR IS 1, EXCITER IS 1
MASS 1 J 7.0000 D 0.00000E+00

BRANCH DATA

I	FROM BUS	TO BUS	XL	R	XC	INCR XC
1	GEN1	HIGH500	0.15000	0.00000	0.00000	0.00000
2	HIGH500	INFBUS	0.05000	0.00250	0.00000	0.00000
3	HIGH500	TIEBUS	0.02000	0.00100	0.00000	0.00000
4	INFBUS		0.00000	0.01000	0.00000	0.00000

RESULTS FROM YMAT: NODE, COMPLEX VOLTAGE, CURRENT, AND POWER

GEN1	1.713	0.2560	1.558	0.1226	0.9000	0.6295E-01
INFBUS	1.732	0.0000E+00	172.8	-0.3502E-01	99.74	0.2022E-01
TIEBUS	1.732	0.0000E+00	-1.113	-0.8755E-01	-0.6424	0.5055E-01

COMPUTED MACHINE PARAMETERS ON THE SYSTEM BASE:

FOR MACHINE GEN1 , STEADY STATE FIELD CURRENT IS 2.0563
Ld 1.760000 LF 1.725260 LD 1.720000 LAD 1.630000
Lq 1.680000 LG 1.876953 LQ 1.604000 LAG 1.550000
rd 0.190000E-02 rF 0.108962E-02 rD 0.149208E-01
rq 0.190000E-02 rG 0.829795E-02 rQ 0.130218E-01

EIGEN/SSR (OS/2 Version) : MWG PSS STUDY
Files: MWGC1.dat & MWG2.aux

MVA=100 H=1 EXCITATION Type= WSCC-A (DC1)

PSS Input=Frequency PSS Gain=1.71 (1/3-rd Inst Gain)

EXHIBIT 1 (Con)

****** PAL100.BAT ******** RUN ON 3-13-1992 AT 11:26

N EQUALS 19

ROOTR	ROOTI	ROOTR	ROOTI
0.00043082	2.74720948	0.00043082	-2.74720948
-0.78729832	0.73452675	-0.78729832	-0.73452675
-1.00000000			
-2.31568320	24.14473273	-2.31568320	-24.14473273
-2.95828698	376.93396058	-2.95828698	-376.93396058
-5.49357252			
-16.16845157	18.86731404	-16.16845157	-18.86731404
-18.97577702			
-19.11602928	376.99116136	-19.11602928	-376.99116136
-28.97073243			
-69.97648295	2.95416821	-69.97648295	-2.95416821
-192.47686559			

TIME FOR THIS DATA SET WAS 0.07 MINUTES

1	VFU1	1.15800E-3			EFDU1		
3	VRU1	400.	0.02		-TGRU1	-VTU1	PSSU1
3	EFDU1	.6667	.5333		VRU1		
4	TGRU1	.03	1.0		EFDU1		
1	VTU1	.577			GEN1VT		
5	PSSU1	1.71	.02	.2	LLGU1		
5	LLGU1	1.00	.02	.2	WSOU1		
4	WSOU1	1.00	1.00		GEN1FR		
4	GEN1FR	.00265	.005		GEN1TH		

EIGEN/SSR (OS/2 Version) : MWG PSS STUDY
Files: MWGC1.dat & MWG2.aux

MVA=100 H=1 EXCITATION Type= WSCC-A (DC1)

EXHIBIT 1 (con)

PSS Input=Frequency PSS Gain=0.0 (NO PSS CASE)

****** PAL100.BAT ******** RUN ON 3-13-1992 AT 11:21

N EQUALS 19

ROOTR	ROOTI	ROOTR	ROOTI
0.00049617	2.74719061	0.00049617	-2.74719061
-0.78766041	0.73428038	-0.78766041	-0.73428038
-1.00000000			
-1.50595726	22.06111436	-1.50595726	-22.06111436
-2.95825088	376.93397776	-2.95825088	-376.93397776
-5.49366107			
-19.11602928	376.99116134	-19.11602928	-376.99116134
-25.93509745	10.58805510	-25.93509745	-10.58805510
-31.23094562	2.67823436	-31.23094562	-2.67823436
-50.00000000			
-50.00000000			
-200.00000000			

TIME FOR THIS DATA SET WAS 0.07 MINUTES

1	VFU1	1.15800E-3			EFDU1			
3	VRU1	400.	0.02		-TGRU1	-VTU1	PSSU1
3	EFDU1	.6667	.5333		VRU1		
4	TGRU1	.03	1.0		EFDU1		
1	VTU1	.577			GEN1VT		
5	PSSU1	0.00	.02	.2	LLGU1		
5	LLGU1	1.00	.02	.2	WSOU1		
4	WSOU1	1.00	1.00		GEN1FR		
4	GEN1FR	.00265	.005		GEN1TH		

EIGEN/SSR (OS/2 Version) : MWG PSS STUDY
Files: MWGC1.dat & MWG2.aux

MVA=100 H=1 EXCITATION Type= WSCC-A (DC1)

PSS Input=Frequency PSS Gain=5.13 (INST GAIN)

EXHIBIT 1 (Con)

****** PAL100.BAT ******** RUN ON 3-13-1992 AT 11:24

N EQUALS 19

ROOTR	ROOTI	ROOTR	ROOTI
0.00030027	2.74724779	0.00030027	-2.74724779
-0.01133703	29.46794079	-0.01133703	-29.46794079
-0.78657350	0.73501835	-0.78657350	-0.73501835
-1.00000000			
-2.95835889	376.93392579	-2.95835889	-376.93392579
-5.49339562			
-10.05562814	15.94679594	-10.05562814	-15.94679594
-16.44960286			
-19.11602928	376.99116141	-19.11602928	-376.99116141
-29.01969293			
-63.46248782			
-119.56301604			
-168.71710211			

TIME FOR THIS DATA SET WAS 0.07 MINUTES

1	VFU1	1.15800E-3			EFDU1			
3	VRU1	400.	0.02		-TGRU1	-VTU1	PSSU1
3	EFDU1	.6667	.5333		VRU1		
4	TGRU1	.03	1.0		EFDU1		
1	VTU1	.577			GEN1VT		
5	PSSU1	5.13	.02	.2	LLGU1		
5	LLGU1	1.00	.02	.2	WSOU1		
4	WSOU1	1.00	1.00		GEN1FR		
4	GEN1FR	.00265	.005		GEN1TH		

Exhibit I

Standard Drafting Team Roster for Project WECC-0107 Power System Stabilizer Design and Performance

Below find a biographical snapshot for the members of the WECC-0107 VAR-501-WECC-03, Power System Stabilizer Drafting Team.[1]

Alex Chua, Pacific Gas and Electric	Mr. Chua is a subject matter expert for power generation systems. He is currently working for Pacific Gas and Electric. He has over 13 years of experience in the electrical industry and contributes to industry working groups organized by IEEE, NERC, and WECC.
David Lemmons, Xcel Energy	Mr. Lemmons began his career in the electric industry with Southwestern Public Service Company (SPS) in Amarillo, Texas, in 1989. He spent eight years in the rates and regulation department where he performed rate of return analyses, designed rates and worked with other regulatory issues. In 1997, Mr. Lemmons transferred to the energy trading department during the merger between SPS and Public Service Company of Colorado (PSCo). In this capacity, with Xcel Energy and its predecessor, New Century Energies, he analyzed the electric system loads and resources for day-ahead and real-time operations and trading — working with generation and fuel procurement to ensure resources were ready and available to serve loads. In 2001, Mr. Lemmons took the position of Senior Manager, Market Operations, representing Xcel Energy at electric reliability, RTO development and system operation meetings throughout the United States, as well as providing support for state and Federal regulatory proceedings. Mr. Lemmons has chaired the WECC-0083 BAL-002-WECC-1 Standard Drafting Team, the NERC Project 2007-12 Standard Drafting team and is a team member on the NERC Project 2010-14.1 Standard Drafting Team. In 2013, Mr. Lemmons took his current position, Senior Consultant, Standards Policy and Compliance. In this position, Mr. Lemmons is responsible for working with power plants to ensure compliance with Reliability Standards, train plant operators as needed and to represent Xcel Energy generation in the development of new standards. He holds a Master of Science degree in finance and economics from West Texas A&M University.

[1] Mr. Martin Bauer of the United States Bureau of Reclamation resigned from the drafting team on May 13, 2014. Mr. Waylon Bowers, United States Corps of Engineers resigned from the drafting team on April 14, 2015. Mr. Guy Colpron of Idaho Power resigned from the drafting team on June 24, 2015. Mr. Travis Dor of the Colorado Springs Utility is recorded as "inactive."

Greg Anderson, Southern California Edison	Mr. Anderson is the Subject Matter Expert for generation and excitation systems for the Southern California Edison Company. He has over 33 years of experience in the utility industry, with responsibilities for coordinating WECC testing of generation assets. He has been a WECC participant since 1997 and a member of the Control Work Group since 2003.
John Amos, Siemens Wind Power	Mr. Amos is the Head of Siemens Wind Power Engineering Americas. He has worked in the power generation industry for almost 25 years including large turbine generator research, development and design, fossil power plant application engineering, and wind turbine engineering. He has actively participated in IEEE, IEC, ANSI and several other standards and codes organizations in various capacities over the past 20 years (mainly in working groups/committees, review boards, and voting member).
Shane Kronebusch, L&S Electric, Inc.	Mr. Kronebusch is the Lead Electrical Engineer and Subject Matter Expert for generation and excitation systems for L&S Electric, Inc. He has over 26 years of experience in the utility industry. Prior to joining L&S Electric in 2010, his responsibilities included coordinating and preforming WECC testing of generation assets as an employee of BC Hydro Generation Engineering and Maintenance Services. He has been a member of the WECC Control Work Group since 2006.