

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.

~~_____~~ ~~4.~~ ~~6.~~ **Applicability:**

~~4.1. Generator Operators~~

~~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 $\pm 5\%$ 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).~~

ED. Regional Differences

~~None~~

None

Table of Compliance Elements

R	Time Horizon	VRF	Violation Severity Levels			
			NA	NA	NA	
<u>R1</u>	<u>Planning Horizon</u>	<u>Low</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>The Generator Owner failed to provide its PSS operating specifications to the Transmission Planner as required in Requirement R1.</u>
<u>R1</u> <u>R2</u>	<u>Operational Operations Assessment</u>	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.	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.	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.	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.
			<u>Each Generator</u>	<u>Each Generator</u>	<u>Each Generator</u>	<u>Each Generator</u>

Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 30 minutes but less than 60 minutes.

Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 60 minutes but less than 120 minutes.

Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 120 minutes but less than 180 minutes.

Operator not having its PSS in service while synchronized in accordance with Requirement R2, for more than 180 minutes.

<u>R3</u>	<u>Operations Assessment</u>	<u>Medium</u>	<u>The Generator Owner’s PSS failed to meet any of the required performances in Requirement R3, two times or fewer during the audit period.</u>	<u>The Generator Owner’s PSS failed to meet any of the required performances in Requirement R3, three times during the audit period.</u>	<u>The Generator Owner’s PSS failed to meet any of the required performances in Requirement R3, four times during the audit period.</u>	<u>The Generator Owner’s PSS failed to meet any of the required performances in Requirement R3, five times or more during the audit period.</u>
<u>R4</u>	<u>Operational Assessment</u>	<u>Medium</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>The Generator Owner failed to install on its generator a PSS, as required in Requirement R4.</u>
<u>R5</u>	<u>Operational Assessment</u>	<u>Medium</u>	<u>NA</u>	<u>NA</u>	<u>NA</u>	<u>The Generator Owner failed to repair or replace a non-operational PSS as required in</u>

						<u>Requirement R5.</u>
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Version History

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	
<u>3</u>	<u>TBD</u>	<u>TBD</u>	

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 (E_t/V_{ref}) and using the phase characteristic of such frequency response as being the phase characteristic of GEP(s). The phase characteristic of E_t/V_{ref} is a better approximation to the phase characteristic of GEP(s) when the frequency response E_t/V_{ref} 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.

*** FOR INFORMATIONAL PURPOSES ONLY ***

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

United States

<u>Standard</u>	<u>Requirement</u>	<u>Enforcement Date</u>	<u>Inactive Date</u>
<u>VAR-501-WECC-3</u>	<u>TBD</u>	<u>TBD</u>	