NERC
NORTH AMERICAN ELECTRIC
RELIABILITY CORPORATION

January 8, 2015

VIA OVERNIGHT MAIL

Sheri Young, Secretary of the Board
National Energy Board
517 – 10th Avenue SW
Calgary, Alberta
T2R 0A8

RE: *North American Electric Reliability Corporation*

Dear Ms. Young:

The North American Electric Reliability Corporation ("NERC") hereby submits Notice of Filing of the North American Electric Reliability Corporation of Proposed Reliability Standard PRC-026-1. NERC requests, to the extent necessary, a waiver of any applicable filing requirements with respect to this filing.

Please contact the undersigned if you have any questions.

Respectfully submitted,

/s/ Holly A. Hawkins

Holly A. Hawkins
Associate General Counsel for the North American Electric Reliability Corporation

Enclosure

3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

BEFORE THE
NATIONAL ENERGY BOARD

NORTH AMERICAN ELECTRIC	**)**
RELIABILITY CORPORATION	**)**

NOTICE OF FILING OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION OF PROPOSED RELIABILITY STANDARD PRC-026-1

Gerald W. Cauley
President and Chief Executive Officer
North American Electric Reliability
Corporation
3353 Peachtree Road, N.E.
Suite 600, North Tower
Atlanta, GA 30326
(404) 446-2560
(404) 446-2595 – facsimile

Charles A. Berardesco
Senior Vice President and General Counsel
Holly A. Hawkins
Associate General Counsel
William H. Edwards
Counsel
North American Electric Reliability
Corporation
1325 G Street, N.W., Suite 600
Washington, D.C. 20005
(202) 400-3000
(202) 644-8099 – facsimile
charles.berardesco@nerc.net
holly.hawkins@nerc.net
william.edwards@nerc.net

Counsel for the North American Electric Reliability Corporation

January 8, 2015

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BEFORE THE
NATIONAL ENERGY BOARD

NORTH AMERICAN ELECTRIC)
RELIABILITY CORPORATION)

NOTICE OF FILING OF THE NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION OF PROPOSED RELIABILITY STANDARD PRC-026-1

The North American Electric Reliability Corporation ("NERC") hereby submits proposed Reliability Standard PRC-026-1 (*Relay Performance During Stable Power Swings*) (Exhibit A) in response to the Federal Energy Regulatory Commission's ("FERC") directive in Order No. 733[1] to develop a Reliability Standard addressing undesirable relay operation due to stable power swings.[2] The proposed Reliability Standard is just, reasonable, not unduly discriminatory or preferential, and in the public interest.[3] NERC also provides notice of: (i) the Implementation Plan (Exhibit B) for the proposed Reliability Standard; and (ii) the associated Violation Risk Factors ("VRFs") and Violation Severity Levels ("VSLs") (Exhibits A and F). The NERC Board of Trustees adopted proposed Reliability Standard PRC-026-1 on December 17, 2014.[4]

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1 *Transmission Relay Loadability Reliability Standard*, Order No. 733, 130 FERC ¶ 61,221 (2010) ("Order No. 733"); *order on reh'g and clarification*, Order No. 733-A, 134 FERC ¶ 61,127 (2011) ("Order No. 733-A"); *clarified*, Order No. 733-B, 136 FERC ¶ 61,185 (2011) ("Order No. 733-B").

2 Order No. 733 at P 152.

3 Unless otherwise designated, capitalized terms shall have the meaning set forth in the *Glossary of Terms Used in NERC Reliability Standards* ("NERC Glossary of Terms"), *available at* http://www.nerc.com/files/Glossary_of_Terms.pdf.

4 *See* Draft Minutes - Board of Trustees Meeting – Dec. 17, 2014, *available at* http://www.nerc.com/gov/bot/Pages/Agenda-Highlights-and-Minutes-.aspx. Minutes for the December 17, 2014 conference call were not yet available at the time of filing. The agenda package for the meeting is available at the same link.

This filing presents the technical basis and purpose of proposed Reliability Standard PRC-026-1, a summary of the development history (Exhibit G), and a demonstration that the proposed Reliability Standard meets the Reliability Standards criteria (Exhibit C).

Below, NERC also provides the following information for background purposes prior to providing the technical basis for NERC's proposed Reliability Standard in Section VI:

1) a summary of the role of stable power swings in the August 14, 2003 blackout in the United States and Canada ("2003 Blackout") as originally provided by the joint U.S.-Canada Task Force established to investigate the causes of the 2003 Blackout ("Task Force");
2) a summary of the Order No. 733 regulatory proceeding in which FERC issued its directive; and
3) a summary of NERC's informational filing[5] ("Informational Filing") in the Order No. 733 proceeding, which clarified the role of stable power swings in the 2003 Blackout.

I. Notices and Communications

Notices and communications with respect to this filing may be addressed to the following:

[5] NERC Jul. 21, 2011 Informational Filing in Response to Order 733-A on Rehearing, Clarification, and Request for an Extension of Time, Docket No. RM08-13-000, *available at* http://www.nerc.com/FilingsOrders/us/NERC%20Filings%20to%20FERC%20DL/Informational_Filing_on_Order_733-A.pdf.

Charles A. Berardesco
Senior Vice President and General Counsel
Holly A. Hawkins
Associate General Counsel
William H. Edwards
Counsel
North American Electric Reliability Corporation
1325 G Street, N.W., Suite 600
Washington, D.C. 20005
(202) 400-3000
(202) 644-8099 – facsimile
charles.berardesco@nerc.net
holly.hawkins@nerc.net
william.edwards@nerc.net

Valerie L. Agnew
Director of Standards
North American Electric Reliability Corporation
3353 Peachtree Road, N.E.
Suite 600, North Tower
Atlanta, GA 30326
(404) 446-2560
(404) 446-2595 – facsimile
valerie.agnew@nerc.net

II. Summary

On March 18, 2010, in Order No. 733, FERC approved Reliability Standard PRC-023-1 (*Transmission Relay Loadability*) and directed NERC to develop a new Reliability Standard that requires the use of protective relay systems that can differentiate between faults and stable power swings and retirement, when necessary, of protective relay systems that cannot meet this requirement.[6] In its Notice of Proposed Rulemaking ("NOPR") preceding its Order,[7] FERC cited the findings of the Task Force's final report[8] ("Final Blackout Report") on the causes of the 2003 Blackout.[9] FERC explained that the cascade during the 2003 Blackout was accelerated by zone 3/zone 2 relays that operated because they could not distinguish between a dynamic, but

[6] Order No. 733 at P 150.
[7] *Transmission Relay Loadability Reliability Standard*, Notice of Proposed Rulemaking, 127 FERC ¶ 61,175 (2009) ("Order No. 733 NOPR").
[8] U.S.-Canada Power System Outage Task Force, *Final Report on the August 14, 2003 Blackout in the United States and Canada: Causes and Recommendations* (Apr. 2004), *available at* http://energy.gov/sites/prod/files/oeprod/DocumentsandMedia/BlackoutFinal-Web.pdf.
[9] Order No. 733 NOPR at PP 52-54.

stable power swing and an actual fault.[10] FERC therefore directed NERC to develop a Reliability Standard addressing undesirable relay operation due to stable power swings.[11]

Proposed Reliability Standard PRC-026-1 meets this directive from Order No. 733 by helping to prevent the unnecessary tripping of Bulk Electric System Elements in response to stable power swings. As explained in NERC's Informational Filing[12] and in detail in Section IV.B below, the fourteen lines associated with the 2003 Blackout discussed in Order No. 733 and in the Final Blackout Report by the Task Force did not trip due to stable power swings. Nonetheless, it is important for power system reliability that protection systems are secure to prevent undesired operation during stable power swings while allowing a dependable means to separate the system in the event of an unstable power swing.

The proposed Reliability Standard aims to improve reliability by ensuring that relays are expected to not trip in response to a stable power swing during non-Fault conditions in the future. The proposed Reliability Standard requires at-risk Elements to be identified by the Planning Coordinator and the respective Generator Owners and Transmission Owners to be notified of the Elements. Generator Owners and Transmission Owners that apply load-responsive protective relays (identified in Attachment A of the proposed Reliability Standard) must determine whether their relays meet certain criteria (Attachment B of the proposed Reliability Standard). Additionally, a subsequent determination must be made if the relays have not been evaluated according to the Attachment B criteria in the last five calendar years for Elements identified by the Planning Coordinator. This provides assurance that relays will continue to be secure for stable power swings if any changes in system impedance occur. If

10 Order No. 733 at P 130.

11 *Id*. P 152.

12 Informational Filing at 4-5.

relays do not meet the proposed Attachment B criteria, the applicable Generator Owner and Transmission Owner must develop and implement a Corrective Action Plan to modify the Protection System so that the relays meet the criteria. The proposed Reliability Standard was developed with input from the NERC Planning Committee's System Protection and Control Subcommittee ("SPCS"). The SPCS, with support from the System Analysis and Modeling Subcommittee ("SAMS"), issued a report, *Protection System Response to Power Swings*[13] ("PSRPS Report"), which provided technical information and recommendations for a proposed Reliability Standard. The proposed Reliability Standard approach is consistent with those recommendations.

Below, NERC provides a technical overview of stable power swings, background information on the 2003 Blackout along with subsequent technical analysis, the regulatory history of Order No. 733, a summary of the PSRPS Report, and justification for the proposed Reliability Standard and its Requirements.

III. Technical Overview

Provided below is a high-level technical overview of the general characteristics of stable power swings and protection system attributes related to power swings to assist in understanding the technical issues that will be discussed in the background material and in NERC's presentation of the proposed Reliability Standard. This information was developed by the SPCS and adapted for this summary. The discussion is included in Appendices A and B of the PSRPS Report in Exhibit E.[14]

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13 *See* Ex. E, NERC SPCS, *Protection System Response to Power Swings*, August 2013.

14 Ex. E PSRPS Report, Appendix A at 25 and Appendix B at 29.

1. Stable Power Swings

The electric power grid, consisting of generators connected to loads via transmission lines, is constantly in a dynamic state as generators automatically adjust their output to satisfy real and reactive power demand. During steady-state operating conditions, a balance exists between the power generated and the power consumed. In the balanced system state, each generator in the system maintains its voltage at an appropriate level for conditions on the system and each machine's internal machine rotor angle in relation to the other generators is dictated by the dispatched power flows across the system.

Sudden changes in electrical power caused by power system faults, line switching, generator disconnection, or the loss or connection of large blocks of load, disturb the balance between the mechanical power into and the required electrical power output of generators. This causes acceleration or deceleration of the generating units because the mechanical power input responds more slowly than the generator electrical power. Such system disturbances cause the machine rotor angles of the generators to swing or oscillate with respect to one another in the search for a new equilibrium state. During this period, power system Elements will experience power swings. A power swing is "[a] variation in three phase power flow which occurs when the generator rotor angle differences are advancing or retarding relative to each other in response to changes in load magnitude and direction, line switching, loss of generation, faults, and other system disturbances."[15] Swings can be stable or unstable, depending of the severity of the disturbance.

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[15] *See* IEEE Power System Relaying Committee, Working Group D-6, *Power Swing and Out-of-Step Considerations on Transmission Lines*, at 6, *available at* http://www.pes-psrc.org/Reports/Power%20Swing%20and%20OOS%20Considerations%20on%20Transmission%20Lines%20F..pdf.

In a stable power swing, the power system will return to a new equilibrium state where the generator machine rotor angle differences are within stable operating range to generate power that is balanced with the load. In an unstable power swing, the generation and load do not find a balance and the machine rotor angles between generators or coherent groups of generators continue to increase, eventually leading to loss of synchronism between generators or coherent groups of generators. The location where loss of synchronism occurs is based on the physical attributes of the system, such as, what generation and transmission is in service and the nature of the disturbance. When synchronism is lost between areas, this is referred to as an out-of-step condition.

2. Protection System Attributes Related to Power Swings

To maintain the reliability of the Bulk-Power System, secure protective relay settings are necessary to avoid relay operation during stable power swings and provide dependable tripping for faults and unstable power swings. A Protection System is required to detect line faults and trip appropriately. During power swing conditions where generation, transformer, and transmission line protection should not operate, i.e., if the power swing is stable, the unnecessary loss of power system Elements could exacerbate the power swing to the extent that a stable swing becomes unstable. In this case, the relevant protective relays should be set to not operate in response to the stable power swing condition. This may be achievable by use of a Protection System immune to power swings, selection of the settings not susceptible to stable power swings, or use of dedicated logic to block operation during power swings.

IV. 2003 Blackout and Regulatory History

A. 2003 Blackout

In the 2003 Blackout, large portions of the Midwest and Northeast United States and Ontario, Canada, experienced an electric power blackout. Following the event, the Task Force investigated the causes and how to reduce the possibility of future outages. The Task Force's work was divided into two phases:

- Phase I: Investigate the outage to determine its causes and why it was not contained.
- Phase II: Develop recommendations to reduce the possibility of future outages and minimize the scope of any that occur.[16]

In November 2003, the Task Force issued the Interim Blackout Report, describing its investigation and findings and identifying the causes of the 2003 Blackout.[17] In the Final Blackout Report, the Task Force reaffirmed the findings stated in the Interim Blackout Report that the initiating causes of the 2003 Blackout were: 1) lost functionality of critical monitoring tools, resulting in loss of situational awareness of degraded conditions on the transmission system; 2) inadequate management of tree growth on transmission line rights-of-way; 3) inadequate diagnostic support for a reliability coordinator tools; and 4) that coordination between reliability coordinators was ineffective. The Final Blackout Report indicated that fourteen lines tripped by zone 2 and zone 3 relays "after each line overloaded."[18] The investigation team concluded that because these zone 2 and 3 relays tripped after each line overloaded, these relays

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16 *See* U.S.-Canada Power System Outage Task Force, *Interim Report: Causes of the August 14th Blackout in the United States and Canada* at 1 (Nov. 2003) ("Interim Blackout Report") (describing the work of the Task Force), *available at* http://emp.lbl.gov/sites/all/files/interim-rpt-Aug-14-blkout-03.pdf.

17 *Id.*

18 Final Blackout Report at 80.

were the common mode of failure that accelerated the geographic spread of the cascade.[19] The Task Force stated that "although the operation of zone 2 and 3 relays in Ohio and Michigan did not cause the blackout, it is certain that they greatly expanded and accelerated the spread of the cascade."[20]

B. Regulatory History

1. Order No. 733

On March 18, 2010, FERC issued Order No. 733, approving Reliability Standard PRC-023-1 (*Transmission Relay Loadability*) and directing NERC to develop a new Reliability Standard that requires the use of protective relay systems that can differentiate between faults and stable power swings and retirement, when necessary, of protective relay systems that cannot meet this requirement.[21] FERC found that undesirable relay operation due to stable power swings is a specific matter that must be addressed by NERC and that NERC's standard must address this concern.[22] In its determination, FERC reiterated the findings of the 2003 Blackout Task Force that the inability of zone 2 and zone 3 relays to distinguish between a dynamic, but stable power swing and an actual fault contributed to the cascade.[23]

Various entities submitted comments to the NOPR preceding Order No. 733.[24] In its comments, NERC stated that while it is possible to employ protection systems that are immune from stable power swings, use of these systems should not be favored at the expense of diminishing the ability of protective relays to dependably trip for faults or detect unstable power swings. Other commenters argued that stable power swings were not the root cause of the

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[19] *Id*.
[20] *Id*. at 82.
[21] Order No. 733 at P 150.
[22] *Id*. at P 152.
[23] *Id*.
[24] *See* Order No. 733 at PP 131-49.

cascading outages. Entities stated, among other things, that relay performance during stable power swings is outside the scope of relay loadability, that one company's stability studies have not identified any of its lines that would trip from stable power swings, and that PRC-023-1 indirectly addresses FERC's concern. One entity even argued that FERC's directive would harm reliability by phasing out certain relays, leaving the electric system without any reliable backup for transmission lines with failed communication or other equipment failures, thereby exposing the system to faults that cannot be cleared and potentially resulting in larger outages and/or equipment damage. Ultimately, FERC was not persuaded,[25] although FERC did agree with one commenter that argued that "islanding" strategies in conjunction with out-of-step[26] blocking (or tripping)[27] requirements should be considered in the proposed Reliability Standard.

2. Order No. 733-A

In response to the directive in Order No. 733 related to stable power swings, several organizations sought rehearing. Requesters contended that FERC's directive is ambiguous and that the record did not support issuance of the directive. Others, including NERC, cautioned that the use of protection that differentiates between faults and stable swings might result in less stability because of a decreased ability to identify unstable swings. NERC also sought clarification that it can use its industry technical experts to appropriately address the issue of stable power swings and that the directive was not intended to create an absolute requirement to highlight a concern that other approaches might satisfy.

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[25] *See generally id*. at PP 150-73.

[26] An out-of-step condition is the same as an unstable power swing. *See* IEEE Power System Relaying Committee, Working Group D-6, *Power Swing and Out-of-Step Considerations on Transmission Lines*, at 4, *available at* http://www.pes-psrc.org/Reports/Power%20Swing%20and%20OOS%20Considerations%20on%20Transmission%20Lines%20F..pdf.

[27] Out-of-step tripping schemes are designed to protect the power system during unstable conditions, isolating generators or larger power system areas from each other with the formation of system islands, in order to maintain stability within each island by balancing the generation resources with the area load. *Id*. at 24.

FERC issued Order No. 733-A on February 17, 2011, denying these requests for rehearing and maintaining its position that a Reliability Standard to address stable power swings is necessary for reliability of the Bulk-Power System.[28] In that Order, FERC emphasized that it "did not intend to prohibit NERC from exercising its technical expertise to develop a solution to an identified reliability concern that is equally effective and efficient as the one proposed in Order No. 733."[29] FERC also clarified that it did not require an across-the-board elimination of all zone 3 relays, but only the creation of a Reliability Standard that addresses Protection Systems vulnerable to stable power swings (resulting from Category B and Category C contingencies from the NERC Planning Standards in place at that time) that will result in inappropriate tripping.[30]

3. Order No. 733-B

Various trade organizations requested rehearing on Order 733-A, again reemphasizing their concern with FERC's directives related to the creation of a Reliability Standard to address stable power swings. The requestors reiterated their concerns with the actions of FERC and asserted that the directives were based on either a faulty understanding of the Final Blackout Report or an incorrect characterization of relay engineering. The requestors also repeated arguments made in the proceeding.

FERC issued Order No. 733-B on September 15, 2011. In that Order, FERC ruled that the issues raised had been addressed in both Order Nos. 733 and 733-A, and that further clarification was not necessary.[31]

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28 *Transmission Relay Loadability Reliability Standard*, Order No. 733, 130 FERC ¶ 61,221 (2010); *order on reh'g and clarification*, Order No. 733-A, 134 FERC ¶ 61,127 (2011).

29 *Id*. at P 11.

30 Order No. 733-A at P 107.

31 Order No. 733-B at P 12.

4. NERC Informational Filing

After the issuance of Order No. 733-A, NERC submitted an Informational Filing to FERC addressing certain aspects of 2003 Blackout investigation relative to operation of protective relays in response to stable power swings. Some of the clarifications in the NERC Informational Filing were documented in the Final Blackout Report, while other clarifications were based on unpublished findings of the blackout investigation team derived from detailed analyses that occurred subsequent to the issuance of the Final Blackout Report.

Order 733-A discussed tripping of fourteen transmission lines to support the directive pertaining to conditions in which relays misoperate due to stable power swings that were identified as propagating the cascade during the 2003 Blackout. The NERC Informational Filing clarified that all of these fourteen lines did not trip due to stable power swings. Ten of these lines tripped by zone 2 and zone 3 relays after each line overloaded in response to the steady-state loadability issue addressed by Reliability Standard PRC-023, while the last four lines tripped in response to dynamic instability of the power system.

That detailed subsequent analysis confirmed that ten of the line trips occurring up to and including the time of the initial trips of the Argenta – Battle Creek and the Argenta – Tompkins 345 kV lines occurred as a result of increasingly heavy line loading. NERC stated that the relays on those lines reacted as though there was a fault in their protective zone when there was no fault. Such behavior is related to the steady-state loadability issue addressed by Reliability Standard PRC-023. Line trips following the initial trips of Argenta – Battle Creek and Argenta – Tompkins lines were verified by those simulations and analysis of relay performance to be associated with high-speed dynamic instability during the system collapse.

Although the fourteen line trips by zone 2 and zone 3 relays discussed in the Final Blackout Report did not occur because of stable power swings, the Task Force did identify two other transmission lines that tripped on zone 1 relays due to protective relay operation in response to power swings.[32] The Task Force identified these lines as the Homer City – Watercure 345 kV line and the Homer City – Stolle Road 345 kV line. NERC explained in its Informational Filing that as the dynamic instability propagated across the system, a system separation occurred along the border between New York and the PJM Interconnection. Two swings occurred between the two systems. The first swing occurred at approximately 16:10:39.5 corresponding with tripping of the Homer City – Watercure and Homer City – Stolle Road 345 kV transmission lines. The second swing occurred approximately four seconds later corresponding with the New York-PJM separation completed by the Branchburg – Ramapo 500 kV trip. The Task Force performed a sensitivity analysis without tripping of the Homer City lines to identify how the system performance might have been different if the line trips had not occurred. The simulation demonstrates the two swings associated with the Homer City line trips occurred on a stable power swing.

However, the simulations also indicated that the second swing between New York and PJM would have resulted in a loss of synchronism between the two systems regardless of whether the Homer City lines had tripped on the first swing. The simulation also indicated that the sequence of events following separation of the New York and PJM systems would have essentially the same end result, including the subsequent separations between New York and New England, western and eastern New York, and Ontario and western New York.

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[32] Final Blackout Report at 89. Although NERC noted in its Informational Filing that these trips were due to stable power swings, the Final Blackout Report does not use the term “stable” to describe the type of power swing.

Since the New York and PJM separation and subsequent system separations would have occurred regardless of whether the Homer City – Watercure and Homer City – Stolle Road lines tripped on the stable swing, NERC concluded that the Protection System operations on these lines did not contribute significantly to the overall outcome of the 2003 Blackout.

However, NERC reiterated in the Informational Filing that Protection System operation during stable power swings could negatively impact system reliability under different operating conditions and that NERC supports the reliability objective associated with developing a standard to address operation of protective relays in response to stable power swings.

V. NERC Activity to Address the Directive

A. Project 2010-13.3 Phase 3 of Relay Loadability: Stable Power Swings

To respond to the directives in Order No. 733, NERC initiated a three-phased Project 2010-13. Phase I focused on making specific modifications to PRC-023-1 identified in Order No. 733. In Phase I, NERC developed Reliability Standard PRC-023-2, which was submitted on April 13, 2011. In Phase II, NERC developed new Reliability Standard PRC-025-1, which was submitted on October 4, 2013, to address generator relay loadability and aligning changes to the transmission loadability standard resulting in PRC-023-3, which was submitted on August 1, 2014. Phase III of the Project focused on developing proposed Reliability Standard PRC-026-1 to address FERC's concerns regarding undesirable protective relay operations due to stable power swings.

B. PSRPS Report

To support Project 2010-13.3, the SPCS, with support from the SAMS, developed the PSRPS Report to promote understanding of the overall concepts related to the nature of power swings; the effects of power swings on protection system operation; techniques for detecting power swings and the limitations of those techniques; and methods for assessing the impact of power swings on protection system operation. Based on its review of historical events,[33] consideration of the trade-offs between dependability and security, and recognizing the indirect benefits of implementing the transmission relay loadability standard (PRC-023), the SPCS concluded that a NERC Reliability Standard to address relay performance during stable power swings was not needed, and could result in unintended adverse impacts to Bulk-Power System reliability.

However, the SPCS provided recommendations for the creation of a Reliability Standard in recognition of the FERC directive in the event NERC proceeded with development. The proposed Reliability Standard developed by the standard drafting team is based on and is consistent with the recommendations found in the PSRPS Report. The following summary of the PSRPS Report provides the SPCS's position on the role of stable power swings in the 2003 Blackout. NERC also provides an explanation by SPCS of the trade-off between dependability and security, and a summary of the SPCS's recommendations related to the creation of a proposed Reliability Standard related to stable power swings.

1. <u>2003 Blackout Comments</u>

With respect to the 2003 Blackout, the PSRPS Report stated that although it might be reasonable, based on the Final Blackout Report, to conclude stable power swings was a causal factor on August 14, 2003, subsequent analysis clarified the line trips that occurred prior to the system becoming dynamically unstable were a result of steady-state relay loadability. The SPCS explained that the causal factors in these disturbances included weather, equipment failure, relay

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[33] As part of this assessment, the SPCS reviewed six of the most significant system disturbances that have occurred since 1965 and concluded that operation of transmission line Protection Systems during stable power swings was not causal or contributory to any of these disturbances. *See* PSRPS Report at 7-17.

failure, steady-state relay loadability, vegetation management, situational awareness, and operator training. However, the SPCS noted that while tripping on stable swings was not a causal factor, unstable swings caused system separation during several of these disturbances. Therefore, it is possible, according to the SPCS, that the scope of some events may have been greater without dependable tripping on unstable swings to physically separate portions of the system that lost synchronism.

2. Dependability vs. Security

The PSRPS Report explained that secure and dependable operation of protection systems are both important to power system reliability. A summary of the SPCS discussion of the trade-offs between dependability and security is provided to explain why the SPCS recommended an approach in a draft standard that favors dependability over security. The SPCS stated that to support power system reliability, it is desirable that protection systems are secure to prevent unnecessary operation during stable power swings. It also is desirable to provide dependable means to separate the system in the event of an unstable power swing. The PSRPS Report continued that while methods for discriminating between stable and unstable power swings have improved over time, ensuring both secure and dependable operation for all possible system events remains a challenge.

The SPCS cautioned that the directive in Order No. 733 is focused on protective relays operating unnecessarily due to stable power swings and that it is important, in the process of achieving this goal, not to decrease the ability to dependably identify unstable power swings and separate portions of the system that have lost synchronism. The SPCS continued that application of protection systems that can discriminate between fault and power swing conditions at locations where the system may be prone to unstable power swings does not provide a dependable means of separating portions of the system that lose synchronism. Where this occurs, it would be necessary to install out-of-step protection to initiate system separation, which reintroduces the need to discriminate between stable and unstable power swings. The SPCS stated that a lack of dependability is more likely to result in an undesirable outcome. For example, with an unstable power swing, a failure to trip will result in portions of the system slipping poles[34] against each other and resultant increased equipment stress and an increased probability of system collapse.

3. Recommendations for the Design of a Reliability Standard

While the SPCS recommended that a Reliability Standard is not needed, the SPCS recognized the directive in FERC Order No. 733 and the NERC Standards Committee request for research to support Project 2010-13.3. The SPCS explained that two options exist for developing requirements for secure operation of protection systems during power swings: (i) develop requirements applicable to protection systems on all circuits, or (ii) identify the circuits on which a power swing may affect protection system operation and develop requirements applicable to protection systems on those specific circuits, similar to the approach used in standard PRC-023. The SPCS stated that an approach covering each circuit would be a significant effort with varying results that are dependent on the system topology and the assumptions specified for the analysis.

As a result, the SPCS recommended that if a standard is developed, the most effective and efficient use of industry resources would be to limit applicability to protection systems on

[34] A pole slip is a condition whereby a generator, or group of generators, terminal voltage angles (or phases) go past 180 degrees with respect to the rest of the connected power system. IEEE Power System Relaying Committee, Working Group D-6, *Power Swing and Out-of-Step Considerations on Transmission Lines*, July 2005, *available at* http://www.pes-psrc.org/Reports/Power%20Swing%20and%20OOS%20Considerations%20on%20Transmission%20Lines%20F..pdf.

circuits where the potential for observing power swings has been demonstrated through system operating studies, transmission planning assessments, event analyses, and other studies that have identified locations at which a system separation may occur. The SPCS also proposed, as a starting point for a standard drafting team, criteria to determine the circuits to which the standard should be applicable, as well as methods that entities could use to demonstrate that protection systems on applicable circuits are set appropriately to mitigate the potential for operation during stable power swings.

VI. <u>Justification</u>

Proposed Reliability Standard PRC-026-1 is responsive to FERC's directive in Order No. 733 and is just, reasonable, not unduly discriminatory or preferential, and in the public interest. As discussed below and specifically in Exhibit C, the proposed Reliability Standard satisfies the Reliability Standrds criteria. The following section explains NERC's development of its alternative[35] approach to FERC's suggested direction for the proposed Reliability Standard. It also explains the purpose and benefit of proposed Reliability Standard PRC-026-1 to reliability and provides a description of and the technical basis for the proposed Requirements. Finally, this section includes a discussion of the enforceability of the proposed Reliability Standard.

A. NERC's Approach to Meet the Directive

As noted above, the fourteen lines associated with the 2003 Blackout discussed in Order No. 733 did not trip due to stable power swings. NERC explained in its Informational Filing that ten of these lines tripped in response to the steady-state loadability issue addressed by Reliability

[35] As clarified in Order No. 733-A, FERC states that its directive is for the creation of a Reliability Standard that addresses Protection Systems vulnerable to stable power swings that will result in inappropriate tripping. Order No. 733-A at P 107. NERC's proposed Reliability Standard is directly responsive to FERC's directive, as clarified. As a result, NERC is not necessarily proposing its Reliability Standard as an "equally effective and efficient alternative" to FERC's suggested approach to employ specific relays that can differentiate between faults and stable power swings to meet FERC's concern.

Standard PRC-023, while the last four lines tripped in response to dynamic instability of the power system. However, as noted in NERC's Informational Filing, two other transmission lines tripped due to protective relay operation in response to stable power swings. Analysis showed that had these relays not tripped on the initial stable power swings, the next power swings would have been unstable and tripped the relays. As a result, not tripping in response to the stable power swings, which is the focus of FERC's directive, would not have arrested the collapse of the Bulk-Power System during the 2003 Blackout.

In Order No. 733-B, which came after NERC's Informational Filing, FERC again reaffirmed its prior directive when challenged on the technical justification for the directive related to stable power swings. In its determination, FERC cited the tripping of the Homer City – Watercure and Homer City – Stolle Road 345 kV transmission lines due to protective relay operation in response to stable power swings as justification for reaffirming its original Order No. 733 directive in response to technical challenges by trade associations.[36] While the technical justification for the directive has been questioned by the follow-up analysis to the Final Blackout Report, in its filings in the Order No. 733 proceeding, NERC did acknowledge FERC's concern that protection system operation during stable power swings could negatively impact system reliability under different operating conditions. NERC continues to hold that it remains important for power system reliability that protection systems are secure to prevent undesired operation during stable power swings and to provide dependable means to separate the system in the event of an unstable power swing.

In response to FERC's directive, this proposed Reliability Standard improves reliability by ensuring that relays are expected to not trip in response to stable powers swing during non-

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[36] Order No. 733-B at P 72, n.108.

Fault conditions in the future. The standard drafting team based the development of the proposed Reliability Standard on the recommended approach provided in the PSRPS Report to meet the directive.

The PSRPS Report recommended the following criteria in establishing the applicability of the Reliability Standard to limit applicability to only those transmission lines on which protective relays are most likely to be challenged during stable power swings: (i) lines terminating at a generating plant, where a generating plant stability constraint is addressed by an operating limit or Special Protection System (SPS) (including line-out conditions), (ii) lines that are associated with a System Operating Limit (SOL) that has been established based on stability constraints identified in system planning or operating studies (including line-out conditions), (iii) lines that have tripped due to power swings during system disturbances, (iv) lines that form a boundary of the Bulk Electric System that may form an island, and (v) lines identified through other studies, including but not limited to, event analyses and transmission planning or operational planning assessments.[37] The standard substantively adopted the five criteria above as recommended by the PSRPS Report, adding generator and transformer Elements in addition to transmission lines and limited the fifth criteria to transmission Planning Assessments.

Operational planning assessments were not included as a criteria for identifying Elements because addressing at-risk Elements should be performed in the planning horizon through Planning Assessments by the Planning Coordinator which has a wide-area view of the system, and where corrective actions can be identified and implemented before entering the operating timeframe. Operations planning assessments are generally performed in the operations horizon by the Reliability Coordinator. In addition, event analyses were not included because actual

[37] PSRPS Report at 21.

disturbances and the event analyses are typically addressed by the owners of the applicable Elements, not the Planning Coordinator.

The standard drafting team agreed with the PSRPS Report that focusing the applicability of the standard to Elements meeting a select set of criteria provides a number of benefits. For example, the efforts of the applicable entities is more focused on the Elements having the greatest risk of being challenged by power swings. The PSRPS Report further suggested that certain entities could use the focused criteria in creating the possibility to include dynamic simulations assessing a greater number of fault types and system configurations; however, the standard drafting team implemented the following alternative approach.

The PSRPS Report acknowledged that it may be possible, subject to relay model availability, to model specific relay settings in the dynamic simulation software, to more precisely identify the likelihood of a stable swing entering the relay characteristic. Although precise for the contingency under study, the standard drafting team determined that performing such dynamic simulations would be burdensome, highly variable and dependent on the contingency selected by the planner. As an alternative approach to dynamic simulations to produce the apparent impedance for relay owners, the standard requires that the owners of load-responsive protective relays to evaluate their relay characteristics to specific criteria provided in Attachment B of the proposed Reliability Standard. This method provides a consistent approach for determining whether the relay for an identified Element is at-risk to tripping in response to a stable power swing. If the relay is at-risk, the relay owner is required to develop and implement a Corrective Action Plan to modify the Protection System so that the relays meet the criteria and, therefore, are expected to not trip in response to stable power swings during non-Fault conditions.

The SPSC Report further recommended that each facility owner to document its basis for applying protection to each of its applicable Elements (as identified above), and provide this information to its Reliability Coordinator, Planning Coordinator, and Transmission Planner. Furthermore, subsequent requirements should include all entities responsible for assessing dynamic performance of the Bulk-Power System.[38] The Reliability Coordinator has responsibility for operating studies and the Planning Coordinator and Transmission Planner have responsibility for transmission Planning Assessments. Although this approach increases communication among entities, it adds unnecessary requirements to achieve the purpose of the proposed Reliability Standard. The proposed Reliability Standard's approach of notifying the owners of protective relays for Elements meeting specific criteria is the most efficient and effective manner to ensure at-risk protective relays are evaluated, and where necessary, modified such that the relays are expected to not trip in response to stable power swings during non-Fault conditions.

Islanding strategies, as directed by Order No. 733,[39] were considered during the development of the proposed standard. The standard drafting team determined that islanding strategies are not an appropriate method to meet the purpose and intent of the proposed standard. For example, islanding strategies are developed to isolate the system from unstable power swings, which is not prohibited under the proposed standard. The proposed standard's intent is to ensure that load-responsive protective relays are expected to not trip in response to stable power swings during non-Fault conditions, while maintaining dependable fault detection and dependable out-of-step tripping (if out-of-step tripping is applied at the terminal of the BES Element).

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[38] PSRPS Report at 22.

[39] Order No. 733 at P 162.

NERC's proposed Reliability Standard is directly responsive to the specific matter FERCdirected NERC to address in Order No. 733 — to develop a Reliability Standard addressing undesirable relay operation due to stable power swings.[40] However, the proposed Reliability Standard includes an alternative to FERC's approach to require "the use of protective relay systems that can differentiate between faults and stable power swings and, when necessary, phases out protective relay systems that cannot meet this requirement."[41]

The proposed Reliability Standard appropriately narrows the applicable Facilities to generator, transformer, and transmission line Bulk Electric System Elements identified by the Planning Coordinator using specific criteria for determining which Bulk Electric System Elements could be at-risk to power swings, similar to the criteria used determine the applicability of PRC-023, and by the Generator Owner and Transmission Owner upon becoming aware of Bulk Electric System Elements that actually trip in response to power swings. Additionally, the Applicability section of the proposed Standard only includes those protective systems that are not immune to operating in response to power swings. This includes load-responsive protective relays associated with backup protection for the applicable Element meeting the proposed Reliability Standard's criteria, without regard to the various zones of protection, when the relay has an intentional time delay of less than 15 cycles or no time delay (i.e., instantaneous).

The standard drafting team did not adopt FERC's approach requiring the use of protective relay systems that can differentiate between faults and stable power swings and, when necessary, phasing out protective relay systems that cannot meet this requirement. Given the relative risks associated with a lack of dependable operation for unstable power swings and the lack of secure operation for stable swings, it is generally preferable to emphasize dependability

[40] *Id.* P 153.
[41] *Id*. P 150.

over security when it is not possible to ensure both for all possible system conditions. Prohibiting use of certain types of relays, such as those protective relay systems that cannot differentiate between faults and stable power swings, may have unintended negative outcomes for Bulk-Power System reliability. It is important to note that NERC's proposed Reliability Standard does not restrict or discourage entities from employing any technically viable solutions. This is evident in development of a Corrective Action Plan in Requirement R3 that allows the protective relay owner to either modify the existing Protection System to meet the Attachment B criteria or to exclude the existing Protection System under Attachment A by applying power swing blocking supervision to relay functions. The protective relay owner has the option to replace the protection system with protective functions that are immune to power swings. This approach also addresses the comment, summarized above, in the Order No. 733 proceeding that stated phasing out certain relays would leave the electric system without any reliable backup for transmission lines, thereby exposing the system to faults that cannot be cleared and potentially result in larger outages and/or equipment damage.

B. Proposed Reliability Standard PRC-026-1

1. Purpose and Reliability Benefit of Proposed PRC-026-1

The purpose of proposed Reliability Standard PRC-026-1 is "[t]o ensure that load-responsive protective relays are expected to not trip in response to stable power swings during non-Fault conditions." The reliability goal of the proposed Reliability Standard is to reduce or eliminate unnecessary tripping of Bulk Electric System Elements in response to stable power swings. The proposed Reliability Standard requires at-risk Elements to be identified using specific criteria by the Planning Coordinator and the respective Generator Owners and Transmission Owners to be notified of the Elements. Generator Owners and Transmission

Owners that apply load-responsive protective relays (identified in Attachment A of proposed PRC-026-1) must determine whether their relays meet certain criteria (Attachment B of proposed PRC-026-1), if the relays had not been evaluated according to the Attachment B criteria in the last five calendar years. This ensures that relays will continue to be secure for stable power swings if any changes in system impedance occur. Additionally, if a Generator Owner or Transmission Owner identifies an Element as having tripped in response to a power swing, it must determine whether the relays meet the Attachment B criteria regardless of any previous evaluation using the criteria.

If relays do not meet the Attachment B criteria, the applicable Generator Owner and Transmission Owner must develop and implement a Corrective Action Plan to modify the Protection System so that the relays meet the criteria. Actions could include changes in relay settings, modification of the Protection System to meet the criteria, replacement of the Protection System to meet the criteria, or modification of the Protection System to exclude the relay from the coverage of the proposed Reliability Standard according to exclusions in the proposed Attachment A. Below, NERC provides an in-depth discussion the proposed Reliability Standard. NERC notes that while some information is included below, the standard drafting team has included extensive Application Guidelines within the proposed Reliability Standard, which provide additional detail and examples to assist applicable governmental authorities in their evaluation of the proposed Reliability Standard (*see* Exhibit A).

2. Applicable Entities

4.1. Functional Entities:

4.1.1 Generator Owner that applies load-responsive protective relays as described in PRC-026-1 – Attachment A at the terminals of the Elements listed in Section 4.2, Facilities.

4.1.2 Planning Coordinator.

4.1.3 Transmission Owner that applies load-responsive protective relays as described in PRC-026-1 – Attachment A at the terminals of the Elements listed in Section 4.2, Facilities.

4.2. Facilities: The following Elements that are part of the Bulk Electric System (BES):

4.2.1 Generators.

4.2.2 Transformers.

4.2.3 Transmission lines.

The proposed PRC-026-1 is applicable to Planning Coordinators. This inclusion is consistent with the recommendations in the PSRPS Report. The PSRPS Report also suggested inclusion of the Reliability Coordinator and Transmission Planner. The standard drafting team did not include these entities in the proposed Reliability Standard's Applicability. The standard drafting team determined that a single entity, the Planning Coordinator, should be the source for identifying Elements according to Requirement R1. A single source will insure that multiple entities will not identify Elements in duplicate, nor will one entity fail to provide an Element because it believes the Element is being provided by another entity. The Planning Coordinator has, or has access to, the wide-area model(s), which may be used to identify Elements according to the criteria in Requirement R1.

Use of the Planning Coordinator as the single identifying entity is also consistent with the NERC Functional Model.[42] Under the NERC Functional Model, Planning Coordinators work

42 *See* NERC Reliability Functional Model: Function Definitions and Functional Entities, Version 5, *available at* http://www.nerc.com/pa/Stand/Functional%20Model%20Archive%201/Functional_Model_V5_Final_2009Dec1.pdf.

through a variety of mechanisms to conduct facilitated, coordinated, joint, centralized, or regional planning activities to the extent that all network areas with little or no ties to others' areas, such as interconnections, are completely coordinated for planning activities. The Planning Coordinator coordinates and collects data for system modeling from Transmission Planners and other Planning Coordinators, and coordinates plans with Reliability Coordinators and other Planning Coordinators on reliability issues. Additionally, the Planning Coordinator collects information including Transmission facility characteristics and ratings from the Transmission Owners and Transmission Planner in addition to performance characteristics and capabilities of generator units from Generator Owners. Planning Coordinators submit and coordinate the plans for the interconnection of facilities to the Bulk Electric System, which are under the purview of the proposed Requirement R1 criteria, within its Planning Coordinator area with Transmission Planners and adjacent Planning Coordinator areas. The proposed Requirement R1 criteria include conditions related to identified System Operating Limits determined by the Planning Coordinator pursuant to Requirement R3 in Reliability Standard FAC-014-2 (*Establish and Communicate System Operating Limits*).

The Transmission Planner develops a long-term (generally one year and beyond) plan for the reliability (adequacy) of the Bulk Electric System within a Transmission Planner area and coordinate their plans with the adjoining Transmission Planners to assess impact on or by those plans at a localized level whereas the Planning Coordinator coordinates at a regional level. Although the Transmission Planner generally maintains transmission system models (steady state, dynamics, and short circuit) to evaluate Bulk Electric System performance, which would be used to identify Elements under the proposed Requirement R1 criteria, the Planning

Coordinator also has this ability or has the access to obtain the necessary information to perform the identification of Elements according to the proposed Requirement R1 criteria.

The Reliability Coordinator maintains the Real-time operating reliability of its Reliability Coordinator Area and includes situational awareness of its neighboring Reliability Coordinator Areas. Because of the Real-time operating nature of the Reliability Coordinator function, it receives operational plans from Balancing Authorities and transmission and generation maintenance plans from Transmission Owners and Generator Owners, respectively, for reliability analysis. Although the PSRPS Report recommended the inclusion of operating studies (e.g., Operational Planning Analysis) in connection with its recommendation to include the Reliability Coordinator in the approach to the standard, the standard drafting team determined that operating studies are not necessary because the Planning Coordinator is in the best position to identify at-risk Elements.

The proposed Reliability Standard is also applicable to Generator Owners and Transmission Owners that apply load-responsive protective relays as described in PRC-026-1 – Attachment A at the terminals of Bulk Electric System generators, transformers, and transmission lines, as listed in Section 4.2, Facilities. The standard drafting team also considered the Distribution Provider for inclusion in the proposed Reliability Standard as an applicable entity; however, this entity, by functional registration, would not own generators, transmission lines, or transformers other than load serving. Under the Functional Model, the Distribution Provider would be registered as a Generator Owner when it owns Bulk Electric System generators or generator step-up (GSU) transformers or registered as a Transmission Owner when it owns Bulk Electric System transformers (i.e., related to transmission operation) or transmission lines.

According to Attachment A, proposed PRC-026-1 applies to any protective functions that could trip instantaneously or with a time delay of less than 15 cycles on load current (i.e., "load-responsive") including, but not limited to: (1) phase distance; (2) phase overcurrent; (3) out-of-step tripping; and (4) loss-of-field. The proposed Reliability Standard addresses relays that trip instantaneously (without an intentional time delay) regardless of the zone of protection and those relays with a time delay less than 15 cycles.

Load-responsive protective relays that are set to trip instantaneously (without an intentional time delay) are applicable to the Standard and any relay where an entity may have a slight time delay which would not eliminate the susceptibility to power swings. In order to address this additional susceptibility, the standard drafting team developed a conservative time delay threshold value of 15 cycles (0.25 seconds) so that any applicable load-responsive protective relay set with a time delay of 15 cycles or greater may be excluded from the Applicability of the standard.

The 15 cycle or 0.25 second time delay is representative of an expected power swing having a slow slip rate of 0.67 Hertz (Hz) and is the average time that a stable power swing with that slip rate would enter the relay's characteristic, reverse direction, and then exit the characteristic before the time delay expired. The standard drafting team recognizes that the trajectory of a stable power swing is not constant (e.g., must slow when reversing direction). In consideration of this effect, a constant slip rate of 0.67 Hz as proposed by the standard assumes that the angle of the power swing begins at 90 degrees (see e.g., Equation 1 of the proposed Reliability Standard's Application Guidelines) as a determination of the time delay (i.e., zone timer).

A power swing having a slower slip rate of 0.25 Hz (e.g., slower than 0.67 Hz) would increase the risk to tripping, the following is an example of a transmission relay set according to the transmission relay loadability standard using maximum power transfer (e.g., 90 degree system angle). A relay set to comply with the transmission loadability standard (i.e., PRC-023-3, Requirement R1, Criteria 3, Bullet 2) using maximum power transfer would have a system angle beginning at 108.8 degrees (due to the 115% multiplier) and a calculated zone timer of 14.9 cycles based upon Equation 1 (zone timer) of the proposed standard's Application Guidelines. Therefore, in this example, a relay that is set 15 cycles or greater (i.e., not applicable to the standard), when challenged by a power swing with a constant slip rate of 0.67 Hz (i.e., the basis for 15 cycles) or a slower power swing with a slip rate of 0.25 Hz (not the constant 0.67 Hz), would achieve the reliability goal of the standard and be expected to not trip in response to the stable power swing. However, any relay with a time delay of less than 15 cycles, which is based on a power swing with a constant 0.67 Hz slip rate, is subject to the standard, and the entity would be required to evaluate its load-responsive protective relays to determine whether the relay meets the proposed Attachment B criteria.

Furthermore, the proposed Reliability Standard requires that relays set with a time delay of less than 15 cycles meet the proposed Standard's criteria for a system separation angle of at least 120 degrees. Any relay applicable to the standard that meets the 120 degree criteria, which is the industry-accepted maximum system separation angle from which a stable power swing would be recoverable, along with the conditions and additional criteria listed in Attachment B, would be expected to not trip in response to a stable power swing. Any power swing subject to a system separation angle greater than 120 degrees is presumably unstable and beyond the scope of the proposed standard.

A time delay threshold of 15 cycles is not intended to characterize the slip rate of all power swings, but to address potential issues with limiting only instantaneous relays and relays with short time delays to the Applicability of the proposed standard while remaining cognizant of concerns raised in the PSRPS Report about potential trade-offs between dependability and security, and recognizing the indirect benefits of implementing the transmission relay loadability standard (PRC-023).

As noted above, proposed Attachment A provides clarity on which load-responsive protective relay functions are applicable. Attachment A also includes a list of those protective relay functions that are not applicable. Non-applicable relay functions include those functions that are either immune to power swings, block power swings, or prevent non-immune protective function operation due to supervision of the function.

3. Requirement R1

> *R1. Each Planning Coordinator shall, at least once each calendar year, provide notification of each generator, transformer, and transmission line BES Element in its area that meets one or more of the following criteria, if any, to the respective Generator Owner and Transmission Owner: [Violation Risk Factor: Medium] [Time Horizon: Long-term Planning]*
>
> *Criteria:*
>
> > *1. Generator(s) where an angular stability constraint exists that is addressed by a System Operating Limit (SOL) or a Remedial Action Scheme (RAS) and those Elements terminating at the Transmission station associated with the generator(s).*
> >
> > *2. An Element that is monitored as part of an SOL identified by the Planning Coordinator's methodology1 based on an angular stability constraint.*
> >
> > *3. An Element that forms the boundary of an island in the most recent underfrequency load shedding (UFLS) design assessment based on application of the Planning*

> *Coordinator's criteria for identifying islands, only if the island is formed by tripping the Element due to angular instability.*
>
> *4. An Element identified in the most recent annual Planning Assessment where relay tripping occurs due to a stable or unstable2 power swing during a simulated disturbance.*

Proposed Requirement R1 requires the Planning Coordinator to provide notification to the Generator Owner or Transmission Owner of each Bulk Electric System generator, transformer, and transmission line Element in its area that meets one or more of the four criteria listed in Requirement R1. These criteria along with examples are discussed in the Application Guidelines in the proposed Reliability Standard and are consistent with the recommendations in the PSRPS Report. The identification of Elements is derived from annual Planning Assessments pursuant to the transmission planning (i.e., "TPL") and other NERC Reliability Standards (e.g., PRC-006). The proposed Reliability Standard does not mandate any other assessments to be performed by the Planning Coordinator. The required notification is cycled on a calendar year basis to the respective Generator Owner and Transmission Owner to align with the completion of the annual Planning Assessments. The Planning Coordinator will continue to provide notification of Elements on a calendar year basis even if a study is performed less frequently (e.g., PRC-006 – Automatic Underfrequency Load Shedding, which is five years) and has not changed. The proposed Reliability Standard would also allow for the use of studies from a prior year in determining the necessary notifications pursuant to Requirement R1.

The first criterion identifies generator(s) where an angular stability constraint exists that is addressed by a System Operating Limit or a Remedial Action Scheme and those Elements terminating at the Transmission station associated with the generator(s).

The second criterion identifies Elements that are monitored as a part of an established System Operating Limit based on an angular stability limit regardless of the outage conditions that result in the enforcement of the System Operating Limit.

The third criterion identifies Elements that form the boundary of an island within an underfrequency load shedding ("UFLS") design assessment. The criterion applies to islands identified based on application of the Planning Coordinator's criteria for identifying islands, where the island is formed by tripping the Elements based on angular instability. The criterion applies if the angular instability is modeled in the UFLS design assessment, or if the boundary is identified "off-line" (i.e., the Elements are selected based on angular instability considerations, but the Elements are tripped in the UFLS design assessment without modeling the initiating angular instability). In cases where an out-of-step condition is detected and tripping is initiated at an alternate location, the criterion applies to the Element on which the power swing is detected. The criterion does not apply to islands identified based on other considerations that do not involve angular instability, such as excessive loading, Planning Coordinator area boundary tie lines, or Balancing Authority boundary tie lines.

The fourth criterion identifies Elements in the most recent annual Planning Assessment where relay tripping occurs due to a stable or unstable power swing during a simulated disturbance. The intent is for the Planning Coordinator to include any Element(s) where relay tripping was observed during simulations performed for the most recent annual Planning Assessment associated with the transmission planning TPL-001-4 Reliability Standard. Elements where relay tripping occurs due to an *unstable* power swing have been included in this criterion as a method of determining which Elements are susceptible and should be identified. An Element that trips on an unstable power swing is most likely subjected to other stable power swings that may challenge the Protection System. By identifying these Elements, an entity can then evaluate its load-responsive protective relays applied on these Elements according to the Attachment B criteria. If those relays do not meet the criteria, the entity would develop a Corrective Action Plan to modify the Protection System so that the relays meet the criteria and therefore, expected to not trip in response to stable power swings during non-Fault conditions.

4. Requirement R2

R2. Each Generator Owner and Transmission Owner shall: [Violation Risk Factor: High] [Time Horizon: Operations Planning]

> *2.1 Within 12 full calendar months of notification of a BES Element pursuant to Requirement R1, determine whether its load-responsive protective relay(s) applied to that BES Element meets the criteria in PRC-026-1 – Attachment B where an evaluation of that Element's load-responsive protective relay(s) based on PRC-026-1 – Attachment B criteria has not been performed in the last five calendar years.*
>
> *2.2 Within 12 full calendar months of becoming aware[FN4] of a generator, transformer, or transmission line BES Element that tripped in response to a stable or unstable[FN5] power swing due to the operation of its protective relay(s), determine whether its load-responsive protective relay(s) applied to that BES Element meets the criteria in PRC-026-1 – Attachment B.*

[FN4] Some examples of the ways an entity may become aware of a power swing are provided in the Guidelines and Technical Basis section, "Becoming Aware of an Element That Tripped in Response to a Power Swing."

[FN5] An example of an unstable power swing is provided in the Guidelines and Technical Basis section, "Justification for Including Unstable Power Swings in the Requirements section of the Guidelines and Technical Basis."

Proposed Requirement R2 requires the Generator Owner and Transmission Owner to evaluate its load-responsive protective relays, that are within the scope of the proposed Reliability Standard (*see* Section VI.B.2 above) and meet the conditions in Part 2.1 and 2.2, to ensure that they are expected to not trip in response to stable power swings during non-Fault conditions. The Generator Owner or Transmission Owner must evaluate the relay to determine whether it meets the criteria provided in Attachment B. The Generator Owner or Transmission Owner, as the protective relay owner, is in the best position to determine whether its load-responsive protective relays meet the PRC-026-1 – Attachment B criteria. Proposed PRC-026-1, Attachment B establishes two criteria, A and B, to measure whether each load-responsive protective relay is set so that protective relays are expected to not trip in response to stable power swings during non-Fault conditions.

The proposed Attachment B, Criterion A requires that impedance-based relays used for tripping be expected to not trip for a stable power swing, when the relay characteristic is completely contained within the unstable power swing region (*see* proposed Reliability Standard, Figures 1 and 2). The unstable power swing region is formed by the union of three shapes in the impedance (R-X) plane. These shapes include:

(1) a lower loss-of-synchronism circle based on a ratio of the sending-end to receiving-end voltages of 0.7;

(2) an upper loss-of-synchronism circle based on a ratio of the sending-end to receiving-end voltages of 1.43;

(3) a lens that connects the endpoints of the total system impedance (with the parallel transfer impedance removed) bounded by varying the sending-end and receiving-end voltages from 0.0 to 1.0 per unit.

This must occur while maintaining a constant system separation angle across the total system impedance where:

(i) the evaluation is based on a system separation angle of at least 120 degrees, or an angle less than 120 degrees where a documented transient stability analysis demonstrates that the expected maximum stable separation angle is less than 120 degrees;

(ii) all generation is in service and all transmission BES Elements are in their normal operating state when calculating the system impedance; and

(iii) the saturated (transient or sub-transient) reactance is used for all machines.

The sending-end and receiving-end source voltages are varied from 0.7 to 1.0 per unit to form the lower and upper loss-of-synchronism circles. The ratio of these two voltages is used in the calculation of the loss-of-synchronism circles, and result in a ratio range from 0.7 to 1.43 as shown in Equations 2 and 3 of the proposed standard's Application Guidelines. The internal generator voltage during severe power swings or transmission system fault conditions will be greater than zero due to voltage regulator support. The voltage ratio of 0.7 to 1.43 is more conservative than the lower bound voltage of 0.85 per unit voltage used in the PRC-023-3 and PRC-025-1 relay loadability NERC Reliability Standards. A ±15% internal generator voltage range is a conservative voltage range for calculation of the voltage ratio used to calculate the loss-of-synchronism circles. For example, the voltage ratio using these voltages would result in a ratio range from 0.739 to 1.353 as shown in Equations 4 and 5 of the proposed standard's Application Guidelines. The lower ratio of 0.739 rounded down to 0.7 to be more conservative.

Similarly, Criterion B is used for overcurrent-based relays when the pickup of an overcurrent relay element used for tripping is above the calculated current value (with the parallel transfer impedance removed) for the conditions where the relay is:

(i) evaluated based on a system separation angle of at least 120 degrees, or an angle less than 120 degrees, where a documented transient stability analysis demonstrates that the expected maximum stable separation angle is less than 120 degrees;

(ii) all generation must be in service and all transmission BES Elements in their normal operating state when calculating the system impedance;

(iii) the saturated (transient or sub-transient) reactance is used for all machines; and

(iv) the sending-end and receiving-end voltages at 1.05 per unit.

The 1.05 per unit generator voltage is used to establish a minimum pickup current value for overcurrent relays that are set below 15 cycle time delay for both the sending and receiving end using the 120 degree system separation angle criteria.

Generator Owners and Transmission Owners must evaluate applicable relays that meet either of the two conditions in Part 2.1 and 2.2. Under Part 2.1, once a Generator Owner or Transmission Owner is notified of Elements pursuant to Requirement R1, it has 12 full calendar months to determine if each Element's load-responsive protective relays meet the PRC-026-1 – Attachment B criteria, if the determination according to Attachment B criteria has not been performed in the last five calendar years. Additionally, under Part 2.2, each Generator Owner and Transmission Owner, that becomes aware of a generator, transformer, or transmission line BES Element that tripped in response to a stable or unstable power swing due to the operation of its protective relay(s) must perform the same evaluation according to the PRC-026-1 – Attachment B criteria within 12 full calendar months. There is no re-evaluation interval for actual tripping in response to a stable or unstable power swing because each occurrence must be evaluated to ensure that system impedance has not changed or that some other issue is not present. The purpose of Part 2.2 is to initiate action by the Generator Owner and Transmission

Owner when it becomes aware of a *known* stable or unstable power swing and it resulted in the entity's Element tripping.

The phrase "becoming aware" is used in the proposed Requirement R2, Part 2.2 to not overburden entities by requiring a determination of whether a power swing was present for every Element trip. The identification of power swings will generally be associated with large events and revealed during an analysis of the event. This event analysis could include internal analysis conducted by the entity, the entity's Protection System review following a trip, or a larger scale analysis by other entities. Event analysis could include involvement by the entity's Regional Entity, and in some cases NERC. Given the expected infrequency of Elements tripping in response to a stable power swing afforded by the benefits of the application of PRC-023, the standard drafting team determined that requiring an evaluation following a known power swing trip, in addition to the evaluation of Elements identified in proposed Requirement R1, provides the requisite coverage recommended by the PSRPS Report to meet the reliability purpose of the proposed Reliability Standard and directive in an efficient manner without significant burden to applicable entities.

5. <u>Requirements R3 and R4</u>

> *R3. Each Generator Owner and Transmission Owner shall, within six full calendar months of determining a load-responsive protective relay does not meet the PRC-026-1 – Attachment B criteria pursuant to Requirement R2, develop a Corrective Action Plan (CAP) to meet one of the following: [Violation Risk Factor: Medium] [Time Horizon: Operations Planning]*
>
> > *• The Protection System meets the PRC-026-1 – Attachment B criteria, while maintaining dependable fault detection and dependable out-of-step tripping (if out-of-step tripping is applied at the terminal of the BES Element); or*
> >
> > *• The Protection System is excluded under the PRC-026-1 – Attachment A criteria (e.g., modifying the Protection*

> *System so that relay functions are supervised by power swing blocking or using relay systems that are immune to power swings), while maintaining dependable fault detection and dependable out-of-step tripping (if out-of-step tripping is applied at the terminal of the BES Element).*

> *R4. Each Generator Owner and Transmission Owner shall implement each CAP developed pursuant to Requirement R3 and update each CAP if actions or timetables change until all actions are complete. [Violation Risk Factor: Medium][Time Horizon: Long-Term Planning]*

To achieve the stated purpose of this standard, which is to ensure that load-responsive protective relays are expected to not trip in response to stable power swings during non-Fault conditions, the applicable entity is required to implement any CAP developed pursuant to Requirement R3 such that the Protection System will meet PRC-026-1 – Attachment B criteria or can be excluded under the PRC-026-1 – Attachment A criteria (e.g., modifying the Protection System so that relay functions are supervised by power swing blocking or using relay systems that are immune to power swings), while maintaining dependable fault detection and dependable out-of-step tripping (if out-of-step tripping is applied at the terminal of the Bulk Electric System Element). Protection System owners are required in the implementation of a CAP to update it when actions or timetable change, until all actions are complete. Accomplishing this objective is intended to reduce the occurrence of Protection System tripping during a stable power swing, thereby improving reliability and minimizing risk to the Bulk Electric System.

C. Enforceability of Proposed Reliability Standards

The proposed Reliability Standard PRC-026-1 includes Measures that support each Requirement to help ensure that the Requirements will be enforced in a clear, consistent, non-preferential manner and without prejudice to any party. The proposed Reliability Standard also includes VRFs and VSLs for each Requirement. The VRFs and VSLs for the proposed Reliability Standard comport with NERC and FERC guidelines related to their assignment. A detailed analysis of the assignment of VRFs and the VSLs for proposed PRC-026-1 is included as Exhibit E.

Respectfully submitted,

/s/ William H. Edwards

Charles A. Berardesco
Senior Vice President and General Counsel
Holly A. Hawkins
Associate General Counsel
William H. Edwards
Counsel
North American Electric Reliability Corporation
1325 G Street, N.W., Suite 600
Washington, D.C. 20005
(202) 400-3000
(202) 644-8099 – facsimile
charles.berardesco@nerc.net
holly.hawkins@nerc.net
william.edwards@nerc.net

Counsel for the North American Electric Reliability Corporation

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EXHIBITS A—B and D – H

(Available on the NERC Website at

http://www.nerc.com/FilingsOrders/ca/Canadian%20Filings%20and%20Orders%20DL/PRC-026-1%20exhibits.pdf)

Exhibit C
<u>Reliability Standards Criteria</u>

The discussion below explains how the proposed Reliability Standard has met or exceeded the Reliability Standards criteria:

1. **Proposed Reliability Standards must be designed to achieve a specified reliability goal and must contain a technically sound means to achieve that goal.**

Please refer to Section VI.A and VI.B of NERC's petition.

2. **Proposed Reliability Standards must be applicable only to users, owners and operators of the bulk power system, and must be clear and unambiguous as to what is required and who is required to comply.**

Please refer to Section VI.B.2 of NERC's petition.

3. **A proposed Reliability Standard must include clear and understandable consequences and a range of penalties (monetary and/or non-monetary) for a violation.**

The Violation Risk Factors ("VRFs") and Violation Severity Levels ("VSLs") for the proposed Reliability Standard comport with NERC and FERC guidelines related to their assignment. The assignments of the severity levels for the VSLs are consistent with the corresponding Requirement and will ensure uniformity and consistency in the determination of penalties. The VSLs do not use any ambiguous terminology, and support uniformity and consistency in the determination of similar penalties for similar violations. For these reasons, the proposed Reliability Standard includes clear and understandable consequences. Justification and explanation of the VRFs and VSLs is included in Exhibit F.

4. **A proposed Reliability Standard must identify clear and objective criterion or measure for compliance, so that it can be enforced in a consistent and non-preferential manner.**

The proposed Reliability Standard contains Measures that support the Requirements by clearly identifying what is required and how the Requirements will be measured for compliance.

The Measures are listed after each of the Requirements of the proposed PRC-026-1 Reliability Standard. The Measures provide clarity on the types of evidence to support each Requirement and will allow the Requirements to be enforced in a consistent and non-preferential manner.

5. Proposed Reliability Standards should achieve a reliability goal effectively and efficiently — but do not necessarily have to reflect "best practices" without regard to implementation cost or historical regional infrastructure design.

The proposed Reliability Standard achieves its reliability goal effectively and efficiently. The proposed Reliability Standard appropriately narrows the applicable Facilities to generator, transformer, and transmission line Bulk Electric System Elements identified by the Planning Coordinator using specific criteria for which Bulk Electric System Elements would be at-risk to power swings, similar to the criteria used determine the applicability of PRC-023, and by the Generator Owner and Transmission Owner upon becoming aware of Bulk Electric System Elements that actually trip in response to power swings. Additionally, the Applicability section of the proposed Standard only includes those protective systems that are not immune to operating in response to power swings. This also includes load-responsive protective relays associated with backup protection for the applicable Element meeting the proposed Reliability Standard's criteria, without regard to the various zones of protection, when the relay has an intentional time delay of less than 15 cycles or no time delay (i.e., instantaneous). As a result, the standard drafting team has taken the most efficient approach to addressing FERC's concern in Order No. 733.

The standard drafting team did not adopt FERC's approach requiring the use of protective relay systems that can differentiate between faults and stable power swings and, when necessary, phasing out protective relay systems that cannot meet this requirement. Given the relative risks associated with a lack of dependable operation for unstable power swings and the lack of secure operation for stable swings, it is generally preferable to emphasize dependability over security when it is not possible to ensure both for all possible system conditions. Prohibiting use of certain types of relays, such as those protective relay systems that cannot differentiate between faults and stable power swings, may have unintended negative outcomes for Bulk-Power System reliability. It is important to note that NERC's proposed Reliability Standard does not restrict or discourage entities from employing any technically viable solutions.

6. **Proposed Reliability Standards cannot be "lowest common denominator," *i.e.*, cannot reflect a compromise that does not adequately protect Bulk-Power System reliability. Proposed Reliability Standards can consider costs to implement for smaller entities, but not at consequences of less than excellence in operating system reliability.**

The proposed Reliability Standard does not reflect a "lowest common denominator" approach. The standard drafting team continuously sought to meet industry concerns and continue to maintain essential elements in the proposed Reliability Standard to effectively meet the purpose statement of the proposed Reliability Standard. The proposed Reliability Standard is consistent with the technical input received from the SPCS in the SPCS Report. In all drafts of the proposed Reliability Standard balloted by industry, the standard drafting team determined that the proposed Reliability Standard was tailored to meet the reliability purpose of the proposed Reliability Standard. Each draft supported the goal of making certain that Protection Systems are secure to prevent unnecessary operation during stable power swings and provide dependable means to separate the system in the event of an unstable power swing.

7. **Proposed Reliability Standards must be designed to apply throughout North America to the maximum extent achievable with a single Reliability Standard while not favoring one geographic area or regional model. It should take into account regional variations in the organization and corporate structures of transmission owners and operators, variations in generation fuel type and ownership patterns,**

and regional variations in market design if these affect the proposed Reliability Standard.

The proposed Reliability Standard applies throughout North America and does not favor one geographic area or regional model.

8. Proposed Reliability Standards should cause no undue negative effect on competition or restriction of the grid beyond any restriction necessary for reliability.

Proposed Reliability Standard PRC-026-1 has no undue negative effect on competition and does not unreasonably restrict transmission or generation operation on the Bulk-Power System.

9. The implementation time for the proposed Reliability Standard is reasonable.

The time for transition in the Implementation Plan is reasonable. As noted in the Implementation Plan, there are a number of factors that influenced the determination of an implementation period for the proposed Reliability Standard. The additional time for implementation is necessary to account for the effort and resources for all applicable entities to develop or modify internal processes and procedures to comply with the proposed Reliability Standard. Planning Coordinators will need time to begin identifying Element(s) according to the criteria in Requirement R1 based on existing information (e.g., the most recent Planning Assessment). Time is also needed for the Generator Owner or Transmission Owner to plan for and secure resources (e.g., availability of consultants, if needed) to address the initial influx of Element notifications from the Planning Coordinator during the implementation period of Requirement R2. Additional explanation of the timeframes for implementation is included in Exhibit B in the "Justification" section of the Implementation Plan. Specifically, the Implementation Plan contains discussion of the implementation timeframes of each Requirement relative to the other Requirements.

10. The Reliability Standard was developed in an open and fair manner and in accordance with the Reliability Standard development process.

The proposed Reliability Standard was developed in accordance with NERC's Commission-approved, ANSI- accredited processes for developing and approving Reliability Standards. Exhibit G includes a summary of the standard development proceedings, and details the processes followed to develop the proposed Reliability Standard. These processes included, among other things, multiple comment periods, pre-ballot review periods, and balloting periods. Additionally, all meetings of the standard drafting team were properly noticed and open to the public.

11. NERC must explain any balancing of vital public interests in the development of proposed Reliability Standards.

NERC has not identified competing public interests regarding the request for approval of the proposed Reliability Standard. No comments were received that indicated the proposed Reliability Standard conflicts with other vital public interests.

12. Proposed Reliability Standards must consider any other appropriate factors.

No other factors relevant to whether the proposed Reliability Standard is just and reasonable were identified.