NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Special Protection Systems (SPS) / Remedial Action Schemes (RAS): Assessment of Definition, Regional Practices, and Application of Related Standards

Draft for Planning Committee Review

RELIABILITY | ACCOUNTABILITY




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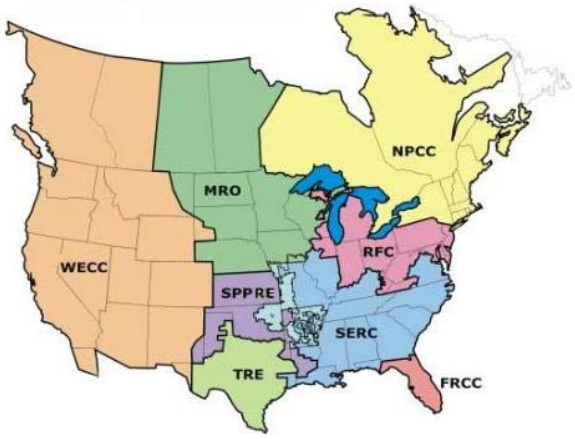
NERC's Mission

The North American Electric Reliability Corporation (NERC) is an international regulatory authority established to enhance the reliability of the bulk power system in North America. NERC develops and enforces Reliability Standards; assesses adequacy annually via a ten-year forecast and winter and summer forecasts; monitors the bulk power system; and educates, trains, and certifies industry personnel. NERC is the electric reliability organization for North America, subject to oversight by the U.S. Federal Energy Regulatory Commission (FERC) and governmental authorities in Canada.[1]

NERC assesses and reports on the reliability and adequacy of the North American bulk power system, which is divided into eight Regional areas, as shown on the map and table below. The users, owners, and operators of the bulk power system within these areas account for virtually all the electricity supplied in the U.S., Canada, and a portion of Baja California Norte, México.



Note: The highlighted area between SPP RE and SERC denotes overlapping Regional area boundaries. For example, some load serving entities participate in one Region and their associated transmission owner/operators in another.

NERC Regional Entities

FRCC Florida Reliability Coordinating Council	**SERC** SERC Reliability Corporation
MRO Midwest Reliability Organization	**SPP RE** Southwest Power Pool Regional Entity
NPCC Northeast Power Coordinating Council	**TRE** Texas Reliability Entity
RFC ReliabilityFirst Corporation	**WECC** Western Electricity Coordinating Council

[1] As of June 18, 2007, the U.S. Federal Energy Regulatory Commission (FERC) granted NERC the legal authority to enforce Reliability Standards with all U.S. users, owners, and operators of the bulk power system, and made compliance with those standards mandatory and enforceable. In Canada, NERC presently has memorandums of understanding in place with provincial authorities in Ontario, New Brunswick, Nova Scotia, Québec, and Saskatchewan, and with the Canadian National Energy Board. NERC standards are mandatory and enforceable in Ontario and New Brunswick as a matter of provincial law. NERC has an agreement with Manitoba Hydro making reliability standards mandatory for that entity, and Manitoba has recently adopted legislation setting out a framework for standards to become mandatory for users, owners, and operators in the province. In addition, NERC has been designated as the "electric reliability organization" under Alberta's Transportation Regulation, and certain reliability standards have been approved in that jurisdiction; others are pending. NERC and NPCC have been recognized as standards-setting bodies by the Régie de l'énergie of Québec, and Québec has the framework in place for reliability standards to become mandatory. NERC's reliability standards are also mandatory in Nova Scotia and British Columbia. NERC is working with the other governmental authorities in Canada to achieve equivalent recognition.

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This technical document was approved by the NERC Planning Committee on _____.

Executive Summary

This draft report is submitted for Planning Committee review of the strawman definition under development by SAMS and SPCS. The first two chapters, *Introduction* and *SPS Definition*, are substantially complete and comments are requested on these two chapters and the strawman definition. The strawman definition, in part, will form the basis for the remaining chapters of the report. The remaining chapters are under development by SAMS and SPCS and will be included in the next draft of the report.

Introduction

Problem Statement

The existing NERC *Glossary of Terms* definition for a Special Protection System (SPS or, as used in the Western Interconnection, a Remedial Action Scheme or RAS) lacks clarity and specificity necessary for consistent identification and classification of protection schemes as SPS or RAS across the eight NERC Regions, leading to inconsistent application of the related NERC Reliability Standards. In addition, three of the related standards (PRC-012, PRC-013, and PRC-014) were identified by FERC in Order No. 693 as fill-in-the-blank standards and consequently are not mandatory and enforceable.

NERC project 2010-05.2, Phase 2 of Protection Systems: SPS and RAS, will modify the current standards and definitions related to SPS and RAS. The NERC Standards Committee has identified that prior to initiating a project to address these issues, additional research is necessary to clearly define the problem and recommend solutions for consideration.

Background

NERC Definitions

The existing NERC *Glossary of Terms* defines an SPS and RAS as:

> *Special Protection System (Remedial Action Scheme):*
>
> An automatic protection system designed to detect abnormal or predetermined system conditions, and take corrective actions other than and/or in addition to the isolation of faulted components to maintain system reliability. Such action may include changes in demand, generation (MW and Mvar), or system configuration to maintain system stability, acceptable voltage, or power flows. An SPS does not include (a) underfrequency or undervoltage load shedding or (b) fault conditions that must be isolated or (c) out-of-step relaying (not designed as an integral part of an SPS). Also called Remedial Action Scheme.

In this document, use of the term SPS in general discussions and proposals for future definitions and standards apply to both SPS and RAS. Specific references to existing practices within Regions use the term SPS or RAS as appropriate for that Region.

The NERC *Glossary of Terms* defines a Protection System as:

> *Protection System:*
>
> - Protective relays which respond to electrical quantities,
> - Communications systems necessary for correct operation of protective functions

- Voltage and current sensing devices providing inputs to protective relays,
- Station dc supply associated with protective functions (including batteries, battery chargers, and non-battery-based dc supply), and
- Control circuitry associated with protective functions through the trip coil(s) of the circuit breakers or other interrupting devices.

Inclusion of the words "protection system" in the term Special Protection System has raised questions whether this is an intentional reference such that SPS are a subset of Protection Systems. Use of "protection system" (lower case) within the SPS definition identifies that SPS are not Protection Systems. While SPS may include the same types of components as Protection Systems, SPS are not limited to detecting faults or abnormal conditions and tripping affected equipment. SPS may, for example, effect a change to the operating state of power system elements to preserve system stability or to avoid unacceptable voltages or overloads in response to system events. There are many reasons for implementing an SPS; for example, an SPS can be implemented to ensure compliance with the TPL Reliability Standards, to mitigate temporary operating conditions or abnormal configurations (e.g., during construction or maintenance activities), or in instances where system operators would not be able to respond quickly enough to avoid adverse system conditions.

A second area in which the existing SPS definition lacks clarity is the actions that are characteristics of SPS. The actions listed in the definition are broad and may unintentionally include equipment whose purpose is not expressly related to preserving system reliability in response to an event. Inclusion of any system taking "corrective action other than … isolation of faulted components to maintain system reliability" could be deemed to include equipment such as voltage regulators and switching controls for shunt reactive devices. This inclusion would then make these elements subject to redundancy, coordination, reporting, testing and maintenance requirements that may be required in the NERC Reliability Standards related to SPS.

This report proposes a revised definition of SPS to address these issues. Development of the proposed definition considered other definitions, common applications, and existing practices regarding classification of SPS.

NERC Reliability Standards

The NERC Reliability Standards contain six standards in the protection and control (PRC) series that specifically pertain to SPS.

- PRC-012-0: Special Protection System Review Procedure
- PRC-013-0: Special Protection System Database
- PRC-014-0: Special Protection System Assessment
- PRC-015-0: Special Protection System Data and Documentation
- PRC-016-0.1: Special Protection System Misoperations

- PRC-017-0: Special Protection System Maintenance and Testing

Three of these standards are not mandatory and enforceable because FERC identified them as fill-in-the-blank standards in Order No. 693, *Mandatory Reliability Standards for the Bulk-Power System*. These standards assign the Regional Reliability Organizations responsibility to establish regional procedures and databases, and to assess and document the operation, coordination, and compliance of SPS. The deference to regional practices, coupled with lack of clarity in the definition of SPS, preclude consistent application of requirements pertaining to SPS. This report provides recommendations that may be implemented through the NERC Reliability Standards Development Process to consolidate the standards and provide greater consistency and clarity regarding requirements.

SPS Definition

Considerations for a Revised Definition

Other Definitions in Industry

Several IEEE papers[2] define a similar term to SPS: System Integrity Protection System (SIPS). Adopting the SIPS definition is not appropriate because it is more inclusive than NERC's definition:

> "The SIPS encompasses special protection system (SPS), remedial action schemes (RAS), as well as other system integrity schemes, such as underfrequency (UF), undervoltage (UV), out-of-step (OOS), etc."[3]

NERC applies special consideration to UF and UV load shedding schemes in the Reliability Standards and considers OOS relaying in the context of traditional protection systems. Thus, SIPS is not an appropriate term for use in the Reliability Standards, and a new definition of SPS is more appropriate.

Common Application of SPS in Industry

Most SPS are used to address a range of system issues including stability, voltage, and loading concerns. Less common applications include arresting sub-synchronous resonance and suppressing torsional oscillations. Actions taken by SPS may include (but are not limited to): system reconfiguration, generation rejection or runback, load rejection or shedding, reactive power or braking resistor insertion, and DC fast ramping.

SPS are often deployed because the operational solutions they facilitate are substantially quicker and less expensive to implement than construction of transmission infrastructure. Permanent SPS have been implemented in some cases where the cost associated with system expansion is prohibitive, construction is not possible due to physical constraints, or obtaining permits is not feasible. In other cases temporary SPS have been implemented to maintain system reliability until transmission infrastructure is constructed; or when a reliability risk is temporary (e.g., during equipment outages) and the expense associated with permanent transmission upgrades is not justified.

The deployment of SPS adds complexity to power system operation and planning:

> "Although SPS deployment usually represents a less costly alternative than building new infrastructure, it carries with it unique operational elements among which are: (1) risks

[2] One notable reference: Madani, et al, "IEEE PSRC Report on Global Industry Experiences with System Integrity Protection Schemes (SIPS)," IEEE Trans. on Power Delivery, Vol. 25, Oct. 2010.

[3] Ibid.

of failure on demand and of inadvertent activation; (2) risk of interacting with other SPS in unintended ways; (3) increased management, maintenance, coordination requirements, and analysis complexity." [4]

Subsequent sections of this report consider these three operational elements and provide recommendations regarding how they should be addressed in the NERC Reliability Standards.

A summary of the number of schemes identified as SPS or RAS by Region is provided below.

Table 1: Overview of SPS by Region[5]

Region	Total Number
FRCC	20
MRO	36
NPCC	117
RFC	47
SERC	20
SPP	6
TRE	24
WECC	192

Classification of SPS Types

Three regions classify SPS according to various criteria, including the type of event the SPS is designed to address as well as the ability of the SPS to impact on a local versus wide-area reliability. The following information describes how NPCC, WECC and TRE classify SPS. Please note that examples of regional practices are provided for illustration throughout this document, but are not necessarily best practices or applicable to all Regions. Also in this context, what constitutes local versus wide-area varies among Regions and is not based on the NERC glossary term Wide Area, which is specific to calculation of Interconnection Reliability Operating Limits (IROL).[6]

NPCC:

Type I – A Special Protection System which recognizes or anticipates abnormal system conditions resulting from design and operating criteria contingencies, and whose misoperation or failure to operate would have a significant adverse impact outside of the local area. The corrective action taken by the Special Protection System along with

[4] McCalley, et al, "System Protection Schemes: Limitations, Risks, and Management", PSERC Publication 10-19, Dec 2010.

[5] Numbers for 2011 obtained from data reported in the NERC Reliability Metric ALR6-1.

[6] The NERC Glossary defines Wide Area as "The entire Reliability Coordinator Area as well as the critical flow and status information from adjacent Reliability Coordinator Areas as determined by detailed system studies to allow the calculation of Interconnected Reliability Operating Limits."

the actions taken by other protection systems are intended to return power system parameters to a stable and recoverable state.

Type II – A Special Protection System which recognizes or anticipates abnormal system conditions resulting from extreme contingencies or other extreme causes, and whose misoperation or failure to operate would have a significant adverse impact outside of the local area.

Type III – A Special Protection System whose misoperation or failure to operate results in no significant adverse impact outside the local area.

The following terms are also defined by NPCC to assess the impact of the SPS for their classification:

Significant adverse impact – With due regard for the maximum operating capability of the affected systems, one or more of the following conditions arising from faults or disturbances, shall be deemed as having significant adverse impact:

a. system instability;
b. unacceptable system dynamic response or equipment tripping;
c. voltage levels in violation of applicable emergency limits;
d. loadings on transmission facilities in violation of applicable emergency limits;
e. unacceptable loss of load.

Local area – An electrically confined or radial portion of the system. The geographic size and number of system elements contained will vary based on system characteristics. A local area may be relatively large geographically with relatively few buses in a sparse system, or be relatively small geographically with a relatively large number of buses in a densely networked system.

WECC:

Local Area Protection Scheme (LAPS): A Remedial Action Scheme (RAS) whose failure to operate would NOT result in any of the following:

- Violations of TPL-(001 thru 004)-WECC-1-CR – System Performance Criteria,
- Maximum load loss ≥ 300 MW,
- Maximum generation loss ≥ 1000 MW.

Wide Area Protection Scheme (WAPS): A Remedial Action Scheme (RAS) whose failure to operate WOULD result in any of the following:

- Violations of TPL-(001 thru 004)-WECC-1-CR – System Performance Criteria,
- Maximum load loss ≥ 300 MW,

- Maximum generation loss ≥ 1000 MW.

Safety Net: A type of Remedial Action Scheme designed to remediate TPL-004-0 (System Performance Following Extreme Events Resulting in the Loss of Two or More Bulk Electric System Elements (Category D)), or other extreme events.

TRE:

(a) A "Type 1 SPS" is any SPS that has wide-area impact and specifically includes any SPS that:

(i) Is designed to alter generation output or otherwise constrain generation or imports over DC Ties; or

(ii) Is designed to open 345 kV transmission lines or other lines that interconnect Transmission Service Providers (TSPs) and impact transfer limits.

(b) A "Type 2 SPS" is any SPS that has only local-area impact and involves only the facilities of the owner-TSP.

These three regional classifications can be roughly mapped:

- NPCC Type I = WECC WAPS = TRE Type 1
- NPCC Type III = WECC LAPS = TRE Type 2
- NPCC Type II = WECC Safety Net

SPS classification differentiates the reliability risk associated with SPS and provides a means to establish more or less stringent requirements consistent with the reliability risk. For example, it may be appropriate to establish less stringent requirements pertaining to monitoring or redundancy of SPS that present a lower reliability risk. A recommendation for classification of SPS is included with the proposed definition and subsequent discussion of standard requirements includes recommendations where different requirements based on classification are deemed appropriate.

Common Exclusions from the SPS Definition in Industry

Exclusions provide a means to assure that specific protection or control systems are not unintentionally included as SPS. The NERC glossary definition of SPS states that "An SPS does not include (a) underfrequency or undervoltage load shedding or (b) fault conditions that must be isolated or (c) out-of-step relaying (not designed as an integral part of an SPS)."

Even with the exclusions in the NERC definition, other commonly applied protection and control systems meet the general language in the SPS definition. Considerable effort has been expended by industry discussing what systems are SPS. NPCC and SERC have documented examples of exclusions to the SPS definition in their regional guidelines. NPCC explicitly

excludes "Automatic underfrequency load shedding; Automatic undervoltage load shedding and manual or automatic locally controlled shunt devices." [7] SERC's SPS guideline calls out specific exclusions as follows:

a. UFLS and/or UVLS,
b. Fault conditions that must be isolated including bus breakup / backup / breaker failure protection,
c. Relays that protect for specific equipment damage (such as overload, overcurrent, hotspot, reclose blocking, etc.),
d. Out of step relaying,
e. Capacitor bank / reactor controls,
f. Load Tap Changer (LTC) controls,
g. Automated actions that could be performed by an operator in a reasonable amount of time, including alternate source schemes, and
h. Scheme that trips generation to prevent islanding

A recommended list of protection and control systems that should be excluded from classification as SPS is included with the proposed definition.

Exclusion for Operator Aides

Some Regions have received inquiries as to whether automated actions that could be performed by an operator in a reasonable amount of time or schemes installed for operator convenience are SPS. Since the action could be performed by an operator in sufficient time to avoid violation of a reliability standard, the scheme is not necessary for reliability; however, the fact the scheme is automated means it could cause adverse interaction with other automated systems during system events.

SAMS and SPCS considered a number of factors in discussing this subject including:

1) whether the actions are required to be completed with such urgency that it would be difficult for an operator to react and execute in the necessary time, and

2) whether the required actions are of such complexity or across such a large area that it would be difficult for an operator to perform the actions in the necessary time.

It is difficult to address these questions with concise and measurable terms, making it difficult to explicitly exclude them in the definition without introducing ambiguous terms counter to the objective of providing needed clarity in the SPS definition. Whether its existence is based upon convenience or not, any automated system with the potential to impact bulk power system reliability should be defined and expressed to the appropriate authority (e.g., Planning Coordinator, Reliability Coordinator) for the purposes of system modeling and coordination studies, to ensure that these systems are properly coordinated with other protection and

[7] NPCC *Glossary of Terms Used by Directories*

control systems, and to ensure that inadvertent operations do not result in adverse system impacts.

On these bases, SAMS and SPCS decided not to provide an exclusion for schemes based on a general criterion as to whether the scheme automates actions that an operator could perform in a reasonable amount of time or schemes installed for operator convenience. However, SAMS and SPCS do recommend exclusions for specific applications that meet these criteria such as bus reconfiguration schemes and automatic sequences that are initiated manually by an operator. Also excluded, by definition, are schemes installed to assist an operator if they are not installed to meet system performance requirements identified in the NERC Reliability Standards, or to limit the impact of two or more elements removed, an extreme event, or Cascading.

Voltage Threshold

All elements, at any voltage level, of an SPS intended to remediate performance issues on the BES, or of an SPS that acts upon BES elements, should be subject to the NERC requirements.

Proposed Definition

The proposed definition clarifies the areas that have been interpreted differently between individual entities and within Regions, in some cases leading to differing regional definitions of SPS. The proposed definition provides a framework for differentiating among SPS with differing levels of reliability risk and will support the drafting of new or revised SPS standards.

Special Protection System (SPS):

A scheme designed to detect predetermined system conditions and automatically take corrective actions, other than the isolation of faulted components, to meet system performance requirements identified in the NERC Reliability Standards, or to limit the impact of: two or more elements removed, an extreme event, or Cascading.

Such schemes are designed to maintain system stability, acceptable system voltages, acceptable power flows, or to address other reliability concerns. They may execute actions that include but are not limited to: changes in MW and Mvar output, tripping of generators and other sources, load curtailment or tripping, or system reconfiguration.

SPS are categorized into four distinct types. These types may be subject to different requirements within the NERC Reliability Standards.

- **Type PS** (planning-significant): A scheme designed to meet system performance requirements identified in the NERC Reliability Standards, where misoperation of the scheme can have a significant impact on the BES.
- **Type PL** (planning-limited): A scheme designed to meet system

performance requirements identified in the NERC Reliability Standards, where misoperation of the scheme can have only a limited impact on the BES.

- **Type ES** (extreme-significant): A scheme designed to limit the impact of two or more elements removed, an extreme event, or Cascading, where misoperation of the scheme can have a significant impact on the BES.
- **Type EL** (extreme-limited): A scheme designed to limit the impact of two or more elements removed, an extreme event, or Cascading, where misoperation of the scheme can have only a limited impact on the BES.

An SPS is classified as having a significant impact on the BES if failure or inadvertent operation of the scheme results in any of the following:

- Non-Consequential Load Loss ≥ 300 MW
- Generation loss > the largest unit within the interconnection[8]
- Loss of synchronism between two portions of the system
- Negatively damped oscillations

If none of these criteria are met, the SPS is classified as having a limited impact on the BES.

The schemes below do not constitute an SPS in and of themselves:

a) Underfrequency or undervoltage load shedding

b) Locally sensing devices designed to protect against equipment damage by tripping or modifying the operation of the affected equipment

c) Autoreclosing schemes

d) Locally sensed and locally operated series and shunt reactive devices, FACTS devices, phase-shifting transformers, variable frequency transformers, and tap-changing transformers

e) Bus reconfiguration based on locally sensed system conditions

f) Schemes that prevent high line voltage by automatically switching the affected line

g) Out-of-step relaying

h) Schemes that provide anti-islanding protection

[8] I.e., Eastern, Western, ERCOT, or Quebec Interconnection.

i) Back up protection schemes that operate local breakers other than those on the faulted circuit such as bus sectionalizing schemes (also known as bus splitting or bus break-up schemes)

j) Automatic sequences manually initiated by an operator

k) Sub-synchronous resonance (SSR) protection schemes

Definition of Significant and Limited Impact

The parameters used to define the bright line between "significant" and "limited" impacts are proposed to consider only the electrical scale of the event. Defining the bright line in this way eliminates the difficulty in distinguishing the geographic impact of an SPS as either "wide" or "local."

NERC Standard EOP-004-1, DOE Form OE-417 "Electric Emergency Incident and Disturbance Report" establishes the criteria by which an event is categorized as a Disturbance and requires a disturbance report. In terms of SPS, the proposed criteria for significant impact mirrors EOP-004-1 by including a non-consequential load loss value of 300 MW.

NERC Reliability Standards require consideration of loss of any generating unit; therefore, generating unit loss would not impact reliability of the bulk power system unless the combined capacity loss exceeds the largest unit within the interconnection. The generation loss level was selected as a loss greater than the largest unit within an interconnection on this basis.

Tripping multiple generating units exceeding the capacity of the largest unit within an interconnection, system separation (loss of synchronism) that results in isolation of a portion of an interconnection, or system oscillations that increase in magnitude (negatively-damped) are indicators of adverse impact to the reliability of an interconnection. These criteria identify system performance indicative of the potential for instability, uncontrolled separation, or cascading outages, without requiring detailed analyses to confirm the extent to which instability, uncontrolled separation, or cascading outages may occur. These indicators, combined with the loss of load criterion, are proposed to identify the potential reliability risk associated with failure of a SPS. Subsequent sections of this report recommend requirements for assessment and design of SPS based on whether the potential reliability risk associated with the SPS are significant versus limited impacts.

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