NPCC, Inc.

NORTHEAST POWER COORDINATING COUNCIL, INC.
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September 14th, 2015

Subject:

Approval Ballot for NPCC Regional Reliability Directory #1 *Design and Operation of the Bulk Power System*.

Approval Ballot for NPCC Regional Reliability Directory #4 *System Protection Criteria*.

NPCC Full Member Representatives and Alternates:

Attached for your review are **two** revised NPCC Regional Reliability Directories which are presented to the NPCC Full Member Committee for ballot.

Directory #1 Design *and Operation of the BPS:*

The Task Force on Coordination of Planning (TFCP) and the Task Force on Coordination of Operation (TFCO) have completed a collaborative review of Directory#1 through their respective Working Groups.

The Task Force review of this document included:

- A review of the criteria pertaining to Reliability Coordinator operations and their impact on other RC Areas.
- The development of Planning and Operation criteria 'Tables' which now contain the relevant contingency events and fault types and present the performance expectations of the criteria with added precision.
- Revisions to the Objective section intended to clearly delineate where applicable performance requirements should be monitored.

Note: a separate Implementation Plan governing protection system upgrades in New England was approved by the NPCC Reliability Coordinating Committee (RCC) on September 10th, 2015 and is not subject to this ballot.

Directory#1 was posted to the NPCC Open Process review for three 45 day comment periods and the TFCP and TFCO have jointly reviewed and responded to all comments.

Finally, the draft of Directory#1 has undergone significant structural changes that would render a redline to the current approved version of the document unusable and a full record of the documents development history can be found at:

Directory#1 Development History

The NPCC Reliability Coordinating Committee (RCC) approved the attached clean version of the revised Directory#1 at its meeting on September 10th, 2015.

Directory#4 *System Protection Criteria*:

The Task Force on System Protection (TFSP) has completed a comprehensive review of Directory#4 *System Protection Criteria* and has revised the document in consideration of emerging protection technologies, industry lessons learned and the impact of retiring NPCC Directory#3 *Maintenance Criteria for BPS Protection.*

The revised document was posted to the NPCC Open Process review for two 45 day comment periods and the TFSP reviewed and responded to all comments.

The NPCC Reliability Coordinating Committee (RCC) approved these revisions at its meeting on September 10th, 2015.

In accordance with Section VIII of the NPCC Amended and Restated Bylaws dated April 15, 2011 these documents will be considered approved upon receipt of a two- thirds weighted affirmative vote of the Full Members for each of two separate ballots.

Your vote to approve Ballot #1 signifies acceptance of:

- Criteria revisions governing the planning and operation criteria as contained in Directory #1 *Design and Operation of the BPS.*

Your vote to approve Ballot #2 signifies acceptance of:

- Criteria revisions governing the protection criteria as contained in Directory #4 *System Protection Criteria.*

Please log in to the NPCC Website with your User ID and password and cast your vote electronically by September 28th, 2015.

Please contact me with any questions regarding Directory content or voting instructions.

Thank you.

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NPCC
Regional Reliability Reference Directory # 4
Bulk Power System Protection Criteria

Full Member Ballot

September 14th, 2015

Task Force on System Protection Revision Review Record:
December 1st, 2009

Clean
Approved by the RCC

Adopted by the Members of the Northeast Power Coordinating Council, Inc. December 01, 2009 based on recommendation by the Reliability Coordinating Committee, in accordance with Section VIII of the NPCC Amended and Restated Bylaws dated July 24, 2007 as amended to date.

Revision History

Version	Date	Action	Change Tracking (New, Errata or Revisions)
0	12/01/2009		New
1	3/31/2015	Inserted Applicability of NPCC Criteria	
	X/XX/2015	TFSP Revisions	Revisions

Table of Content

1.0 Introduction

1.1 Title Bulk Power System Protection Criteria

1.2 Directory Number 4

1.3 Objective

The purpose of this Directory is to provide the **protection** criteria for **protection** of the **Bulk Power System** in NPCC Inc. member **Areas**. It is not a design specification.

1.4 Effective Date December 1st, 2009.

Compliance Guidance Statement- **Protection system** designs submitted to the TFSP prior to Month, Day 2015 (date this revision is approved by the NPCC Full Members) are not subject to the submittal requirements described in Section 6, Compliance Requirements R1, R2, and R3.

1.5 Background

This Directory establishes the basic **protection system** design criteria and review process for **protection systems** for the **Bulk Power System**.

Guidance for consideration in the implementation of these criteria is provided in Appendix A, and the procedure for reviewing new and modified **protection systems** is provided in Appendix B.

1.6 Applicability

The requirements of an NPCC Directory apply only to those facilities defined as NPCC **bulk power system elements** as identified through the performance based methodology of NPCC Document A-10, *"Classification of Bulk Power System Elements*," the list of which is maintained by the NPCC Task Force on System Studies and approved by the NPCC Reliability Coordinating Committee.

Requirements to abide by an NPCC Directory may also reside in external tariff requirements, bilateral contracts and other agreements between facility owners and/or operators and their assigned Reliability Coordinator, Planning Coordinator, Transmission Operator, Balancing Authority and/or Transmission Owner as applicable and may be enforceable through those external tariff requirements, bilateral contracts and other agreements.

NPCC will not enforce compliance to the NPCC Directory requirements in this document on any entity that is not an NPCC Full Member.

1.6.1 Functional Entities

Transmission Owners
Generator Owners
Distribution Providers

1.6.2 Facilities

1.6.2.1 New Facilities

These criteria shall apply to all new **Bulk Power System** (BPS) facilities.

1.6.2.2 Existing Facilities

It is the responsibility of individual companies to assess the **protection systems** at existing facilities and to make modifications which are required to meet the intent of these criteria as follows.

1.6.2.2.1 Facilities found lacking two batteries or **elements** lacking two independent sets of **protective relays**

If an entity becomes aware of an existing facility that lacks an independent battery for each **protection group,** or an **element** that lacks two independent sets of **protective relays**, a mitigation plan to meet the requirements of this Directory must be submitted to TFSP within six months. The mitigation plan shall correct these deficiencies within three years. Justification for a longer timeframe must be approved by TFSP.[1]

1.6.2.2.2 Planned Renewal or Upgrade to Existing BPS

[1] A BPS Risk Mitigation Plan was put in place in 2010 based on a recommendation by the Task Force on System Protection following an extensive survey by NPCC member entities of their BPS protection system conformance to Directory No. 4 (Criteria A5 at the time). The purpose of this plan was to provide direction to separately mitigate the two attributes identified by TFSP as the highest risk to reliability namely the lack of two independent sets of protective relays or two batteries. At the time, members who owned protection systems that were subject to these high risk items were directed to provide a schedule to mitigate the identified deficiencies based on their original survey which occurred in 2009.

Facilities

It is recognized that there may be portions of the **bulk power system,** which existed prior to each member's adoption of the *Bulk Power System Protection Criteria* (Directory 4 and its predecessor Document A-5) that do not meet these criteria. If **protection systems** or sub-systems of these facilities are replaced as part of a planned renewal or upgrade to the facility and do not meet all of these criteria, then an assessment shall be conducted for those criteria that are not met. The result of this assessment shall be reported to TFSP. It is recommended this reporting be in accordance with the procedure stipulated in Appendix B of this Directory and using the appropriate portion of the "**Protection System** Review forms", for review and disposition by the TFSP, or in a form consistent with the intent of the procedure.

1.6.2.2.3 Facility Classification Upgraded to **Bulk Power System**.

These criteria apply to all existing facilities which become classified as **bulk power system**. A mitigation plan shall be submitted to TFSP for review to bring such a facility into compliance with these criteria.

Where the owner of the **protection system** has determined that the cost and risks involved to implement physical separation, as per Section 5.12, cannot be justified, the reason for this determination and an assessment shall be reported to the TFSP. It is recommended this reporting be in accordance with the procedure stipulated in Appendix B of this Directory and using the appropriate portion of the "**Protection System** Review forms", for review and disposition by the TFSP, or in a form consistent with the intent of the procedure.

1.6.2.2.4 Additions to **Bulk Power System** Facilities

If a **bulk power system element** is added to an existing **bulk power system** facility that is recognized under Section 1.6.2.2.1, Planned Renewal or Upgrade to Existing Facilities, these criteria apply to the **protection systems** for the new **element**.

1.6.2.2.5 Unplanned In-kind Replacement of **Bulk Power System** Equipment

If a **bulk power system element** (e.g., breaker, transformer, capacitor bank, reactor, etc.) or a **protective relay** is replaced "in kind" as a result of an unplanned event, then it is not required to upgrade the associated **protection system** to comply with these criteria.

1.6.2.2.6 Change in **Bulk Power System** Facility Status

When a facility was originally on the **BPS** list of April 2007 and has been shown to be non-**BPS** but later was determined to be **BPS** again, Section 1.6.2.2.1 would apply.

2.0 Terms Defined in this Directory

The definitions of terms found in this Directory appearing in bold typeface, can be found in NPCC *Glossary of Terms*.

DC Circuit: a set of **protection** and/or control equipment connected by wire under a common DC circuit breaker or fuse. This DC circuit breaker or fuse is the most immediate device to isolate the aforementioned set of **protection** and/or control equipment connected by wire from the DC power supply that does not also remove the DC power supply from other equipment.

Galvanic isolation: the separation of two or more items or components such that no electrical current can traverse between them under normal operating conditions. The components may be discrete devices such as: relays; wire/cables; relay panels, etc. or the separation can be on a single device such as that between traces on a circuit board. The electrical separation of components that prevents current flow between these components is, in essence, electrical (galvanic) isolation.

Merging Unit: An intelligent electronic device (IED) that collects multichannel signals output by current transformers and voltage transformers synchronously, along with device status, control, then exchanges these signals with the protocol of IEC 61850 to protective devices and measure-control devices.

IED - Intelligent Electronic Device: a microprocessor-based device equipped with digital communication abilities, some examples are **protective relays**, RTUs, SERs, DFRs, PLCs, data concentrators, telecommunications equipment, **merging units**, remote I/O units, and general monitoring equipment.

Process Bus - IEC 61850 addresses this need through the definition of Sampled Measured Values services and the implementation of a Process Bus. The Process layer of the substation is related to gathering information, such as Voltage, Current, and status information, from the transformers and transducers connected to the primary power system.

3.0 NERC ERO Reliability Standard Requirements

The NERC ERO Reliability Standards containing requirements that are associated with this Directory include, but may not be limited to:

3.1 PRC-001
3.2 PRC-002
3.3 PRC-005
3.4 PRC-006
3.5 PRC-012
3.6 PRC-018
3.7 PRC-023
3.8 PRC-024
3.9 PRC-025

4.0 NPCC Regional Reliability Standard, Directory, Criteria Requirements that are associated with this Directory include, but may not be limited to:

Document A-15 - Disturbance Monitoring Equipment Criteria or PRC-002-NPCC as approved by applicable Regulatory Authorities
PRC-006-NPCC-01 – Automatic Underfrequency Load Shedding
Directory #12 – Underfrequency Load Shedding Program Requirements

5.0 NPCC Full Member, More Stringent Criteria

These Criteria are in addition, more stringent or more specific than the NERC or any Regional Reliability standard requirements.

5.1 General Criteria

The intent of the criteria established in this Directory is to ensure dependable and secure operation of the **protection systems** for **bulk power system.** For those **protective relays** intended for removal of **faults** from the **bulk power system**, dependability is paramount, and the redundancy provisions of the criteria shall apply. For **protective relays** installed for reasons other than **fault** sensing such as overload, etc., security is paramount, and the redundancy provisions of the criteria do not apply. The relative effect on the **bulk power system** of a failure of a **protection system** to operate when desired versus an unintended operation shall be weighed carefully in selecting design parameters as follows.

5.2 Criteria for Dependability

5.2.1 Except as identified otherwise in these criteria, all **elements** of the **bulk power system** shall be protected by two **protection groups**, each of which is independently capable of performing the specified protective function for that **element.** This requirement also applies during energization of the **element.**

5.2.1.1 The failure of a **merging unit** shall not lead to the momentary or permanent loss of more than one **protection group** per **element**.

5.2.2 Except as identified otherwise in these criteria, the two **protection groups** shall not share the same **component.** If the two **protection groups** share a redundant **component** in order to achieve improved reliability, the **galvanic isolation** and physical separation of the two **protection groups** shall not be compromised. This is to ensure that a single **component** failure or malfunction will not prevent both **protection groups** from performing their **protective** functions.

5.2.2.1 Each **protection group** shall be supplied from its own DC circuit and that DC circuit shall not be used in any other **protection group** protecting the same **element**. Any non-**protection** control or monitoring circuits shall be supplied from a **separately protected DC circuit.** **Non-protection** control or monitoring circuits include but are not limited to closing, reclosing, SCADA, and **DME** functions**.**

5.2.3 Means shall be provided to trip all necessary local and remote breakers in the event that a breaker fails to clear a fault. This **protection** need not be duplicated. If **breaker failure protection** is duplicated, the exceptions as allowed in 5.12.3 and 5.15.1 for single **breaker failure protection** do not apply.

5.2.4 On installations where free-standing or column-type current transformers are provided on one side of the breaker only, resulting in a **protection** blind spot, **protection** shall be provided locally to detect **faults** to ground occurring in the **protections**' blind spot area..

5.2.5 When frame ground **protection** is used, then frame ground and **breaker failure protections** are two local independent **protections** for the blind spot between the current transformer and the circuit breaker. Neither of these **protections** need be duplicated. Both of these **protections** shall be designed so as to not be disabled by the same failure. The frame ground protection and breaker failure protection will in fact provide independent **protections** for the blind spot.

5.3 Criteria for Security

Protection systems shall be designed to isolate only the **faulted element**, except in those circumstances where additional **elements** are tripped intentionally to preserve system integrity, or where isolating additional **elements** has no impact outside the **local area**

5.4 Criteria for Dependability and Security

5.4.1 The thermal capability of all **protection system** components shall be adequate to withstand rated maximum short time and continuous loading of the associated **protected elements**.

5.4.2 Position or state of control devices that can disable **protections** shall be monitored and annunciated to allow prompt attention by appropriate operating authorities. These devices include but are not limited to communication cutoff switches, relay test mode switch, and protection scheme cutoff switches.

5.4.3 When a Local Area Network (LAN) is used as part of the **protection system, relay** hardware, network paths, network hardware and **merging unit** shall be continuously monitored and annunciated for software failure, hardware failure and/or communication failure in order to allow prompt attention by the appropriate operating authorities.

5.4.4 Short Circuit Models used to assess **protection** scheme design and to develop **protection** settings shall take into account minimum and maximum **fault** levels and mutual effects of parallel transmission lines. Details of neighboring systems shall be modeled wherever they can affect results significantly.

5.4.5 **Protection system components** with redundant power supplies shall be powered from the same DC battery system**.**

5.4.6 Contact outputs used for tripping interrupting devices shall be properly rated to make and carry the DC current for the tripping circuits that they are applied to.

5.5 Operating Time Criteria

Bulk power system protection shall take corrective action within times determined by studies in accordance with Directory No. 1, Design and Operation of the Bulk Power System.

5.6 Current Transformer Criteria

Current transformers (CTs) associated with **protection systems** shall have adequate steady-state and transient characteristics for their intended function as follows:

5.6.1 The output of each current transformer secondary winding shall be designed to remain within acceptable limits for the connected burdens under all anticipated **fault** currents to ensure correct operation of the **protection system**.

5.6.2 The thermal and mechanical capabilities of the CT at the operating tap shall be adequate to prevent damage under maximum **fault** conditions and normal or **emergency** system loading conditions.

5.6.3 For **protection groups** to be independent, they shall be supplied from separate current transformer secondary windings.

5.6.4 Interconnected current transformer secondary wiring shall be **grounded** at only one point.

5.6.5 Current transformers shall be connected so that adjacent **protection** zones overlap.

5.7 Voltage Transformer and Potential Devices Criteria

Voltage transformers and potential devices associated with **protection systems** shall have adequate steady-state and transient characteristics for their intended functions as follows:

5.7.1 Voltage transformers and potential devices shall have adequate volt-ampere capacity to supply the connected burden while maintaining their rated accuracy over their specified primary voltage range.

5.7.2 The two **protection groups** protecting an **element** shall be supplied from separate voltage sources. The two **protection groups** may be supplied from separate secondary windings on one transformer or potential device, provided all of the following requirements are met:

5.7.2.1 Complete loss of one or more phase voltages does not prevent all tripping of the protected **element**;

5.7.2.2 Each secondary winding has sufficient capacity to permit fuse **protection** of the circuit;

5.7.2.3 Each secondary winding circuit is adequately fuse protected.

5.7.3 The wiring from each voltage transformer secondary winding shall not be **grounded** at more than one point.

5.8 Batteries and Direct Current (DC) Supply Criteria

DC supplies associated with **protection** shall be designed to have a high degree of dependability as follows:

5.8.1 No single battery or DC power supply failure shall prevent both independent **protection groups** from performing the intended function. Each battery shall be provided with its own charger. Physical separation shall be maintained between the two station batteries or DC power supplies used to supply the independent **protection groups**.

5.8.2 Each station battery shall have sufficient capacity to permit operation of the station, in the event of a loss of its battery charger or the ac supply source, for the period of time necessary to transfer the **load** to the other station battery or re-establish the supply source. Each station battery and its associated charger shall have sufficient capacity to supply the total DC **load** of the station.

5.8.3 A transfer arrangement shall be provided to permit connecting the total **load** to either station battery without creating areas where, prior to failure of either a station battery or a charger, a single event can disable both DC supplies.

5.8.4 The battery chargers and all DC circuits shall be protected against short circuits. All protective devices shall be coordinated to minimize the number of DC circuits interrupted.

5.8.5 DC systems shall be continuously monitored and annunciated to detect abnormal voltage levels (both high and low), DC grounds, and loss of ac to the battery chargers, in order to allow prompt attention by the appropriate operating authorities.

5.8.6 **Protection group** DC sources shall be continuously monitored to detect loss of voltage in order to allow prompt attention by the appropriate operating authorities.

5.9 Station Service ac Supply Criteria

On **bulk power system** facilities there shall be two sources of station service ac supply, each capable of carrying at least all the critical **loads** associated with **protection systems**.

5.10 Circuit Breaker

5.10.1 No single trip coil failure shall prevent both independent **protection groups** from performing the intended function. The design of a breaker with two trip coils shall be such that the breaker will operate if both trip coils are energized simultaneously. The correct operation of this design shall be verified by tests.

5.10.2 Each trip coil shall be monitored in a fail-safe manner for continuity and presence of corresponding DC voltage and annunciated to allow prompt attention by appropriate operating authorities.

5.11 **Teleprotection** Criteria

5.11.1 Communication facilities required for **teleprotection** shall be designed to have a level of performance consistent with that required of the **protection system**, and shall meet the following:

5.11.1.1 Where each of the two **protection groups** protecting the same **bulk power system element** requires a communication channel:

5.11.1.1.1 The equipment for each **protection group** shall be separated physically on non-adjacent panels and designed to minimize the risk of both **protection groups** being disabled simultaneously by a single event or condition.

5.11.1.1.2 The communication medium outside the substation physical perimeter for each **protection group** shall be designed to minimize the risk of both **protection groups** being disabled simultaneously by a single event or condition. In addition, physical separation of the communication media shall be three feet at a minimum. In cases where constraints do not allow three feet separation, this distance may be reduced if a proposed alternative design can achieve comparable physical protection of the communication medium.

5.11.1.2 **Teleprotection** equipment shall be monitored to detect loss of equipment to allow prompt attention by the appropriate operating authorities.

5.11.1.3 **Teleprotection** communication channels shall be designed with continuous monitoring and alarming for loss of function to allow prompt attention by appropriate operating authorities. For **teleprotection** communication channels that utilize ON/OFF signaling that cannot be continuously monitored, the design shall provide daily automated testing for the presence of the channel health and alarming for loss of function to allow prompt attention by appropriate operating authorities.

5.11.1.4. **Teleprotection** equipment shall be provided with means to test for proper signal adequacy where provisions for automated testing are not provided.

5.11.1.5 **Teleprotection** equipment shall be powered by the substation batteries or other sources independent from the power system.

5.11.1.6 Except as identified otherwise in these criteria, the two **teleprotection** groups shall not share the same **component**.

5.11.1.6.1 The use of a single communication tower for the radio communication systems used by two

protection groups protecting a single **element** is permitted as long as directional diversity of the communication signals is achieved.

5.12 Environment

5.12.1 Each separate **protection group** and **teleprotection** protecting the same system **element** shall be on different non-adjacent vertical mounting assemblies or enclosures, except as noted in 5.12.7.

5.12.2 **Protection group** LAN devices for redundant **protection groups** shall be on different non-adjacent vertical mounting assemblies or enclosures, except as noted in 5.12.7.

5.12.3 Wiring for separate **protection groups** and **teleprotections** protecting the same system **element** shall not be in the same cable or terminated in the same panel. The sole exception is cable termination on single non-redundant **breaker failure** panels.

5.12.4 The use of fiber optics for separate **protection groups** and **teleprotections** protecting the same system **element** shall not result in a common mode failure.

5.12.5 Cabling for separate **protection groups** and **teleprotections** protecting the same system **element** shall be physically separated. This can be accomplished by being in different raceways, trays, trenches, etc. Cable separation shall be achieved up to the breaker control cabinet or equipment control cabinet.

5.12.6 In the event a common raceway is used, cabling for separate **protection groups** protecting the same **element** shall be separated by a non-flammable barrier.

5.12.7 Electronic devices physically located outdoor in the substation yard which serve as **components** of separate **protection groups**, protecting the same **element**, shall be physically separated. This can be accomplished by separate enclosures, or by a non-flammable barrier.

5.12.8 An electronic device, which serves as a **component** of a **protection group,** and is physically located near the primary equipment and outside of the control house, may be subject to more severe environmental conditions than if it was located inside of a building. These environmental conditions may include extreme temperatures, corrosive atmosphere, and electromagnetic interference (EMI). Electronic device selection and secondary enclosure design ("cabinets") shall ensure that environmental conditions do not reduce **protection group reliability** and availability and that the electronic devices contained therein are not subject to the environmental conditions above the accepted limits specified by the IEEE or IEC. Any outdoor enclosure shall have as a minimum a NEMA 4X rating for non-EMI related environmental conditions.

5.13 Grounding Criteria

An entity shall have established as part of its substation design procedures or specifications, a mandatory method of designing the substation ground grid, which:

5.13.1 Can be traced to a recognized calculation methodology
5.13.2 Considers cable shielding
5.13.3 Considers equipment grounding and its impact on the operation of the live tank frame ground protection.

5.14 Transmission Line **Protection** Criteria

5.14.1 **Protection system** settings shall not constitute a loading limitation as per NERC requirement/standard. In cases where NERC approved exceptions are used the limits thus imposed shall be adhered to as system operating constraints.

5.14.2 A **pilot protection** shall be so designed that its failure or misoperation will not affect the operation of any other **pilot protection** on that same **element**.

5.15 Breaker Failure **Protection** Criteria

Means shall be provided to trip all necessary local and remote breakers in the event that a breaker fails to clear a **fault**, as follows.

5.15.1 Non-redundant breaker failure **protection** shall be initiated by each of the **protection groups** which trip the breaker, with the optional exception of a breaker failure **protection** for an adjacent breaker.
5.15.2 For redundant breaker failure protection, each breaker failure protection shall be initiated only by its respective **protection groups** which trip the breaker (i.e.: System 1 line protection initiates System 1 breaker failure protection), with the optional exception of a breaker failure protection for an adjacent breaker.
5.15.3 For redundant breaker failure protections, system 1 breaker failure protection shall only operate system 1 trip coil of the associated

backup breakers needed to clear the fault and system 2 breaker failure protection shall only operate system 2 trip coil of the associated backup breakers needed to clear the fault.

5.15.4 **Fault** current detectors shall be used to determine if a breaker has failed to interrupt a **fault** current.

5.15.5 A series breaker can be an acceptable means of providing **fault** clearing for a failed circuit breaker, in lieu of breaker-failure **protection**. This requires both series breakers be in the same overlapping zones of relay **protection**, and both series breakers are tripped by these same **protection** zones.

5.16 Design to Facilitate Testing and Maintenance

5.16.1 The design of **protection systems** both in terms of circuitry and physical arrangement shall facilitate periodic testing and maintenance.

5.16.2 When a Local Area Network (LAN) is used as part of the **protection system**, the design shall provide the ability to isolate the operation of **protective relaying**, while maintaining a network communication path to give personnel the ability to view **relay** response while under test.

5.16.3 When a Local Area Network (LAN) is used as part of the **protection system**,the network architecture shall provide a dedicated and secure means for personnel to connect to the LAN for testing, troubleshooting and operational purposes.

5.16.4 Test facilities or test procedures shall be designed such that they do not compromise the independence of the redundant design aspects of the **protection systems**.

5.16.5 If a segmented testing approach is used, test procedures and test facilities shall be designed to ensure that related tests properly overlap. Proper overlap is ensured if each portion of circuitry is seen to perform its intended function, such as operating a relay from either a real or test stimulus, while observing some common reliable downstream indicator.

5.16.6 When a Local Area Network (LAN) is used as part of the **protection system**, network monitoring tools shall be deployed to facilitate troubleshooting/corrective maintenance.

5.17 Design to Facilitate Analysis of **Protection System** Performance

5.17.1 Event recording capability shall be provided to permit analysis of the **protection systems**' performance.

5.18 Commissioning Testing

5.18.1 Each **protection group** shall be functionally tested to verify the dependability and security aspects of the design, when initially placed in service and when modifications are made.

5.19 HVdc **System Protection** Criteria

5.19.1 The ac portion of an HVdc converter station, up to the valve-side terminals of the converter transformers, shall be protected in accordance with these criteria.

5.19.2 Multiple commutation failures, unordered power reversals, and **faults** in the converter bridges and the dc portion of the **HVdc link** which are severe enough to disturb the **bulk power system** shall be detected by more than one independent control or **protection group** and appropriate corrective action shall be taken, in accordance with the considerations in these criteria.

5.20 Criteria for **protection systems** utilizing IEC 61850 protocol

5.20.1 Loss of one **protection group's** sampled value data stream shall not momentarily or permanently compromise the redundant **protection group's** sampled value data stream, unless studies demonstrate that the total clearing time including momentary interruption is acceptable.

5.20.2 If process bus is employed for both **protection groups** protecting the same **element**, a single device failure shall not lead to momentary or permanent loss of time synchronization for both **protection groups**.

5.20.3 **Protection** related data shall take priority over other types of data that are transported over the same LAN. LANs used for **protection** shall be designed such that the **protection** response shall not be adversely impacted during stressed network conditions. Due to the possibilities for non-**protection** network traffic such as DME record retrieval, security video streaming, phasor measurements, etc., **protection** message response time shall meet the critical clearing time requirements in all network loading conditions.

5.20.4 The actual propagation times through LANs used for **protection** during stressed network conditions shall be included in the calculation of clearing times of protected **element**. Network congestion occurs when a link or node is carrying so much data that its quality of service deteriorates. Typical effects include queuing delay, packet loss or the blocking of new connections.

5.20.5 The failure of a single network device shall not momentarily or permanently disable both **protection groups**, unless studies demonstrate that the total clearing time including momentary interruption[2] is acceptable.

5.20.6 The network topology shall be designed in a way that will ensure that a single broken path does not momentarily or permanently disable both **protection groups**, unless studies demonstrate that the total clearing time including momentary interruption is acceptable.

5.20.7 Analog to digital conversion, processing and communication latency shall maintain a level of speed and accuracy that, at a minimum, meets current utility **protection** performance.

6.0 Compliance Requirements

R1. An entity, proposing to install a new **protection system** or a modification to an existing **protection system**, shall submit documentation to TFSP in accordance with Appendix B of this Directory.

R2. An entity, proposing to install a new **protection system** or a modification to an existing **protection system**, shall obtain a letter of acceptance by TFSP of the compliance statement accompanying the submittal in R1 prior to or within twelve months of placing the **protection system** in service.

R3. The entity shall provide within 30 days, upon request from the Regional Entity (Criteria Compliance Enforcement Program) documented evidence of the submittal and acceptance by TFSP, of any new or modified **protection system**.

7.0 Compliance Monitoring Process

Compliance with the requirements set forth in this Directory will be in accordance with the NPCC Criteria Compliance and Enforcement Program (CCEP). Measures and corresponding Levels of Non Compliance for these requirements are contained within the compliance templates associated with this Directory.

[2] Certain network protocols (RSTP, ERSTP, etc.), can expose a **protection system** to significant disruptions during the self-healing process known as re-convergence. During this period no traffic is passed by the network switches and results in a momentary loss of **protection**.

Prepared by:	Task Force on System Protection
Review and Approval:	Revision to any portion of this Directory will be posted by the lead Task Force in the NPCC Open Process for a 45 day review and comment period. Upon satisfactorily addressing all the comments in this forum, the Directory document will be sent to the remaining Task Forces for their recommendation to seek RCC approval. Upon approval of the RCC, this Directory will be sent to the Full Member Representatives for their final approval if sections pertaining to the Requirements and Criteria portion have been revised. All voting and approvals will be conducted according to the most current "NPCC. Bylaws" in effect at the time the ballots are cast. Revisions pertaining to the Appendices or any other portion of the document such as Links glossary terms, etc., only RCC Members will need to conduct the final approval ballot of the document. This Directory will be updated at least once every three years and as often as necessary to keep it current and consistent with NERC, Regional Reliability Standards and other NPCC documents.

Appendix A
Guideline for Bulk Power System Protection

1.0 Introduction

This Appendix provides the guidance for consideration in the implementation of the **bulk power system protection** criteria stipulated in this Directory.

2.0 Design Considerations

2.1 General Considerations

2.1.1 In general, the function of a **protection system** is to limit the severity and extent of **system disturbances** and possible damage to system equipment.

2.1.2 The Directory's criteria objectives can be met only if **protection systems** have a high degree of dependability and security. In this context dependability relates to the degree of certainty that a **protection system** will operate correctly when required to operate. Security relates to the degree of certainty that a **protection system** will not operate when not required to operate.

2.1.3 Often increased security (fewer unintended operations) results in decreased dependability (more failures to operate), and vice versa. As an example, consideration is given to the consequence of applying permissive line protection schemes, which often are more secure, but less dependable, than blocking line protection schemes. The relative effect on the bulk power system of a failure of a protection system to operate when desired versus an unintended operation should be weighed carefully in selecting design parameters. Considerations for specific aspects of protection design are provided below.

2.1.4 Whenever changes are anticipated in generating sources, transmission facilities, or operating conditions, Generator Owners, Transmission Owners, and Distribution Providers should review those protection system applications (i.e., settings, ac and dc supplies) which can reasonably be expected to be impacted by those changes.

2.2 Issues Affecting Dependability

2.2.1 Some portions of **elements** may not in themselves be part of the **bulk power system**. Those portions do not require two **protection groups**.

2.2.2 Two identical measuring **relays** should not be used in independent **protection groups** due to the risk of simultaneous failure of both groups because of design deficiencies or equipment problems.

2.2.3 In addition to the separation requirements in the criteria, areas of common exposure should be kept to a minimum to reduce the possibility of both **protection groups** being disabled by a single event such as fire, excavation, water leakage, and other such incidents.

2.2.4 **Merging unit** design should consider the inherent reduction in **protection system reliability** and availability that the use of these devices presents. To mitigate the inherent reduction in **reliability**, more than one merging unit should be provided for each **protection group**.

2.3 Issues Affecting Security

2.3.1 For **faults** external to the protected zone, each **protection group** should be designed either to not operate, or to operate selectively with other **protection groups** and with breaker failure **protection**.

2.3.2 For planned system conditions, **protection systems** should not operate to trip for stable **power swings**.

2.3.3 If a **merging unit** failover scheme is used, the loss of sampled value data shall not result in any **protection** Misoperations.

2.4 Issues Affecting Dependability and Security

2.4.1 **Protection systems** should be no more complex than required for any given application.

2.4.2 The components and software used in **protection systems** should be of proven quality, as demonstrated either by actual experience or by stringent tests under simulated operating conditions.

2.4.3 **Protection systems** should be designed to minimize the possibility of component failure or malfunction due to electrical transients and interference or external effects such as vibration, shock and temperature.

2.4.3.1 Modern digital relaying and control systems may also be subjected to other signal or noise interference events which may cause transients to be detected as a full contact closure by the **protective relay** digital input boards and/or cause contact outputs to erroneously conduct. The digital inputs/outputs associated with the **protective relays** should be designed or modified as necessary to reduce their sensitivity to voltages from transients, signal noise or high resistance contact bridging.[3]

2.4.4 **Protection system** circuitry and physical arrangements should be designed so as to minimize the possibility of incorrect operations due to personnel error.

2.4.5 **Protection system** automatic self-checking facilities should be designed so as to not degrade the performance of the **protection system**.

2.4.6 Consideration should be given to the consequences of loss of instrument transformer voltage inputs to **protection systems**.

2.4.7 Inputs and Outputs necessary for correct **protection system** operation shall be conditioned for a communication loss or power failure such that upon restoration of communication or power the intended output state is restored.

2.4.8 The use of network redundancy protocol and network configuration should be considered to improve LAN availability.

2.4.9 **Protection systems**, including intelligent electronic devices (IEDs) and communication systems used for **protection**, should comply with applicable industry standards for utility grade **protection** service. Utility Grade **Protection System** Equipment are equipment that are suitable for protecting **bulk power system elements**, that are required to operate reliably, under harsh environments normally found at substations. Utility grade equipment should meet the applicable sections of all or some of the following types of industry standards, to ensure their suitability for such applications:

- IEEE C37.90.1-2002 (oscillatory surge and fast transient)
- IEEE C37.90.1-2002 (service conditions)

[3] Reference NERC Lessons Learned dated October 2, 2013 on loss of converter station due to initiation of a top oil temperature signal from the transformer A protection system.

- IEC 60255-22-1, 2005 (1 MHz burst, i.e. oscillatory)
- IEC 61000-4-12, 2001 (oscillatory surge)
- IEC 61000-4-4, 2004 (EFT)
- IEC 60255-22-4, 2002 (EFT)
- IEEE C37.90.2-2004 (narrow-band radiation)
- IEC 60255-22-3, 2000 (narrow-band radiation)
- IEC 61000-4-3, 2002 (narrow-band radiation)
- IEEE 1613 (communications networking devices in Electric power Substations)

2.5 Issues Affecting Performance

2.5.1 Control cables and wiring and ancillary control devices should be highly dependable and secure. Due consideration should be given to published codes and standards, fire hazards, current-carrying capacity, voltage drop, insulation level, mechanical strength, routing, shielding, grounding, and environment.

2.5.2 **Protection** performance should be evaluated under stressed network and failover conditions to ensure that protection coordination and performance is within the acceptable design limits.

2.5.3 Continuous streaming of sampled values may consume a large amount of LAN bandwidth. The network architecture should account for bandwidth-intensive applications and **protection system** response, as required by planning standards, should not be impacted by increased traffic during any scenario.

2.5.4 Redundant communications within a **protection group** can significantly increase **protection** availability and reliability.

2.5.5 Sampled values and Generic Object Oriented Substation Events (GOOSE) messages should have the highest priority among all traffic in the network and network interfaces of end-devices.

2.6 Operating Time

Adequate time margin should be provided taking into account study inaccuracies, differences in equipment, and **protection** operating times. In cases where clearing times are deliberately extended, consideration should be given to the following:

- Effect on system **stability** or reduction of **stability** margins.

- Possibility of causing or increasing damage to equipment and subsequent extended repair and/or outage time.

- Effect of **disturbances** on service to customers.

- Network configurations that impact the delivery or latency of GOOSE messages in one **protection group** should not momentarily or permanently affect the delivery or latency of GOOSE messages in the redundant **protection group** for the same **element**, unless studies demonstrate that the total clearing time including momentary interruption is acceptable**.**

- The reception and processing of a GOOSE message is time critical, specifically during events and relaying operations. The use of GOOSE messages for **protection** should be configured (dataset priority, how messages are published, VLANS, network configuration, etc.) such that the maximum clearing times as specified by Planning Studies are met.

2.6 Current Transformer

None.

2.7 Voltage Transformers and Potential Devices

2.7.1 Voltage transformer installations should be designed with due regard to ferroresonance.

2.7.2 Special attention should be given to the physical properties (e.g. resistance to corrosion, moisture, fatigue) of the fuses used in **protection** voltage circuits.

2.7.3 Relay systems utilizing capacitive voltage transformer should be designed with due regard for transient response

2.8 Batteries and Direct Current (dc) Supply

2.8.1 The circuitry between each battery and its first protective device cannot be protected and therefore should be designed so as to minimize the possibility of electrical **short circuit**.

2.8.2 The design for the regulation of the dc voltage should be such that, under all anticipated charging and loading conditions, voltage within acceptable limits will be supplied to all devices, while minimizing ac ripple and voltage transients.

2.9 Station Service ac Supply

None.

2.10 Circuit Breakers

2.10.1 The indication of the circuit breaker position in **protection systems** should be designed to reliably mimic the main contact position.

2.10.2 Consideration should be given to DC trip circuits monitoring in addition to trip coil monitoring.

2.11 **Teleprotection**

2.11.1 **Teleprotection** systems should be designed to prevent unwanted operations such as those caused by equipment or personnel.

2.11.2 Two identical **teleprotection** equipments should not be used in independent **protection groups**, due to the risk of simultaneous failure of both **protection groups** because of design deficiencies or equipment problems.

2.11.3 Areas of common exposure should be kept to a minimum to reduce the possibility of both **protection groups** being disabled by a single event such as fire, excavation, water leakage, and other such incidents.

2.11.4 For applications where each of the two protection groups protecting the same bulk power system element requires a communication channel, and telecommunication route diversity cannot be achieved, proper selection of protection scheme can be used to achieve required performance, for example, a DCB scheme and a POTT scheme could be used over the same communication medium.

2.11.5 **Teleprotection** systems should be designed to mitigate the effects of signal interference from other communication sources and to assure adequate signal transmission during **bulk power system disturbances**.

2.11.6 The directional diversity for microwave signals for the two independent **protection groups** protecting the same **element** should be designed to establish an angle difference of at least 60 degrees between the two communication paths. This is to minimize the possibility of a storm cell preventing transmission of both communication channels.

2.12 Environment

2.12.1 Means should be employed to maintain environmental conditions that are favorable to the correct performance of a **protection system.**

2.12.2 Non-flammable barrier used to separate the cabling of the two **protection groups** protecting the same **element** in a common raceway should be sufficiently rated to allow enough time to isolate the affected facility while maintaining operation of one **protection group**.

2.12.3 Raceways containing the cabling of the two **protection groups** protecting the same **element** should be sufficiently separated, in both horizontal and vertical planes, to allow enough time to isolate the affected facility subsequent to a failure in one raceway while maintaining operation of one **protection group**.

2.13 Grounding

2.13.1 Station grounding is critical to the correct operation of **protection systems**. The design of the ground grid directly impacts proper **protection system** operation and the probability of false operation from **fault** currents or transient voltages.

2.13.2 When frame ground **protection** is used, the design must ensure that the current passing through the frame ground CT will be adequate to operate for a primary equipment ground **fault** and that the scheme is secure enough to not operate for a **fault** external to the intended zone of **protection**.[4]

2.14 Transmission Lines **Protection**

2.14.1 For planned system conditions, line **protection systems** associated with transmission facilities should not operate to trip for stable **power swings**.

2.15 Transformer **Protection**

[4] Reference July 1, 2013 NERC Lesson Learned reviewed by TFSP at the May 2014 Meeting on Current Transformer Ground Relay.

2.15.1 Fault pressure or Buchholz **relays** used on transformers, phase shifters or regulators should be applied so as to minimize the likelihood of their misoperation due to through **faults**.

2.15.2 The transformer differential relays have the tendency to misoperate during energization of the transformer. The high inrush current flowing into the transformer from the energizing terminal may cause the **protective relay** to mistakenly sense an internal **fault**. This effect has traditionally been mitigated by utilizing the high harmonic content of the inrush current as a restraining quantity but this may be insufficient for modern transformers due to their low second harmonic inrush characteristic. Due regard should be given to the possibility of incorrect blocking for an internal transformer **fault** when mitigating the above issue.[5]

2.16 Breaker Failure **Protection**

2.16.1 It is not necessary to duplicate the breaker failure **protection** itself.

2.16.2 Auxiliary switches may also be required in instances where the **fault** currents are not large enough to operate the **fault** current detectors. In addition, auxiliary switches may be necessary for high-speed detection of a breaker failure condition.

2.17 Generating Station **Protection**

2.17.1 Each **protection system** should be designed to minimize the effects to **the bulk power system** of **faults** and **disturbances**, while itself experiencing a single failure.

2.17.2 Generators should be protected to limit possible damage to the equipment. The following are some of the abnormal (not necessarily **fault**) conditions that should be detected:

- Unbalanced phase currents, loss of excitation
- overexcitation, generator out of step, field ground
- inadvertent energization.

2.17.2.1 **Protections** for the above conditions, which are applied for equipment **protection**, need not be duplicated.

[5] Reference NERC Lesson Learned reviewed by TFSP dated July 15, 2014 on Power Transformer Differential Relay during Transformer Energization prepared by SP-7 Working Group.

2.17.2.2 When a directional overcurrent or distance **relay** is applied to remove the generator for slowly cleared **faults** on the external system, such **protection** is a backup and need not be duplicated.

2.17.2.3 The apparatus should be protected when the generator is starting up or shutting down as well as running at normal speed; this may require additional **relays** as the normal **relays** may not function satisfactorily at low frequencies.

2.17.2.4 Generator **protection systems** should not operate for stable **power swings** except when that particular generator is out of step with the remainder of the system. This does not apply to **Special Protection Systems** designed to trip the generator as part of an overall plan to maintain **stability** of the **power** system.

2.17.2.5 Loss of excitation and out of step **relays** should be set with due regard to the performance of the excitation system.

2.17.2.6 It is recognized that the overall **protection** of a generator involves non-electrical considerations that have not been included as a part of the criteria in this Directory.

2.17.2.7 All overfrequency, overvoltage and undervoltage **protection systems** designed to disconnect generators from the **power** system should be coordinated with automatic underfrequency **load shedding** programs.

2.18 Automatic Underfrequency Load Shedding **Protection Systems**

2.18.1 Automatic underfrequency **load shedding protection systems** are not generally located at **bulk power system** stations; however, they have a direct effect on the operation of the **bulk power system** during major **emergencies**.

2.18.2 Automatic underfrequency **load shedding protection** need not be duplicated.

2.18.3 Underfrequency **relays** which operate at a discrete frequency value are called “underfrequency threshold **relays**.” Selection of underfrequency sensing devices should be on a threshold basis. Alternatively, rate of change of frequency **load shedding** may be used when the requirements of the Balancing Authority indicate that this method will achieve the intent of the **load shedding** program. Appropriate studies are necessary to determine the application and settings of the rate of change of frequency **relays** for a particular Balancing Authority area.

2.18.4 In order for each Balancing Authority within NPCC to **shed** approximately the same proportion of **load**, given the same frequency condition, all styles and manufacture of underfrequency **relays** should trip at essentially the same time. For electromechanical **relays**, time delay depends on rate of frequency decline, and it is not possible to achieve uniform response for different rates of decline. The recommendations in this guideline are based on the goal of a uniform response at a rate of frequency decline of 0.2 Hz per second.

2.18.5 Additional Application Considerations

2.18.5.1 Where undesired underfrequency **relay** operation can be caused by decaying frequency due to isolated generation or motor load, additional supervising undercurrent or voltage **relays** may be used to prevent misoperation.

2.18.5.2 Where the AC voltage source for an underfrequency **relay** is derived from a potential device connected to a cable circuit, care should be taken to estimate the voltage present during deenergization of the circuit. The natural frequency of the decaying cable voltage may be less than 60 Hz, and thus cause an incorrect **relay** operation.

2.18.5.3 The AC Voltage Inhibit feature available on some relays may be useful as a security tool to restrain operation during cable deenergization, depending on the voltage decay time constant

2.18.5.4 Due regard should be given to the expected **power** system voltage during events for which the underfrequency **relays** are expected to operate. The **relay's** minimum AC voltage operating characteristic should not inhibit proper **relay** operation, nor should the Voltage Inhibit feature, where it exists, be set to prevent proper operation.

2.18.6 Settings and Maintenance Recommendations

2.18.6.1 Pickup Time Delay Settings

Pickup and time delay settings of underfrequency threshold

relays should be applied in accordance with the requirements specified in Section 5.2 and Section 5.4 of *Emergency Operation Criteria* (Directory #2).

2.18.6.2 Relay Performance Considerations

Any underfrequency **relay** which has been found to have drifted more than ±0.2 Hz from its set point or ±0.1 seconds from its time delay should be recalibrated and then retested in six months. If, at that time, the **relay** has drifted ±0.2 Hz or more from its set point or ±0.1 seconds or more from its fixed time delay, the cause of the drift should be corrected or the **relay** should be replaced.

2.19 Commissioning Testing

2.19.1 Firmware upgrades, automation software updates shall be tested and documented in a controlled, off-line environment prior to being placed into service to determine if there are any adverse impacts which could prevent proper **protection system** operation. Reference IEEE C37.231-2012

2.19.2 Pre-commissioning testing specific to the entity's design shall be performed to ensure interoperability of IEC 61850 devices. The fact that an Intelligent Electronic Device (IED) has a conformance certificate will not guarantee it will inter-operate with other conformance certified IEDs in the same substations.

2.20 HVdc Systems Protection

2.20.1 Converter terminals should be protected to avoid excessive equipment stresses and to minimize equipment damage and outage time. These **protections** are usually specific to the design of the converter station(s) and are determined by the manufacturer to comply with availability guarantees. The followings are some conditions which should be detected:

- ac and dc undervoltage,
- ac and dc overvoltage,
- valve misfire,
- excessive **harmonics** on the dc,
- dc ground **faults** and open circuits,
- dc switching device failures,
- thyristor failures,
- valve, and snubber circuit overloads.

2.20.2 The overall **protection** and control of an **HVdc link** may also involve the initiation of actions in response to abnormal conditions on the ac interconnected system. The control and **protection systems** associated with such conditions are not considered part of the HVdc systems **protection**.

2.21 **Protection System** Testing and Maintenance

2.21.1 Test facilities and test procedures should be designed such that they do not compromise the independence of **protection groups** protecting the same **bulk power system element**. Test devices or switches should be used to eliminate the necessity for removing or disconnecting wires during testing.

2.21.2 The configuration of IEC 61850 **protection system** should remain as simple as possible to minimize the risks associated with test and maintenance.

2.21.3 All GOOSE messages should contain information to uniquely identify its publishing device. GOOSE message identifiers should provide descriptive nomenclature to aid maintenance and troubleshooting activities.

2.21.4 While isolated testing of a device is acceptable for some commissioning tests, end-to-end secondary injection testing should be conducted to ensure that all interfacing protections perform as designed under dynamic/fault conditions.

2.22 Analysis of **Protection System**

2.22.1 Insofar as possible, each active protective function within a **protective relay** should provide separate target information.

2.23 Transmission Station **Protection**

2.23.1 The **protection systems** should operate properly for the anticipated range of currents.

2.23.2 For planned system conditions, all station **protection systems** should not operate for **load** current or stable **power swings.**

2.23.3 **Load** responsive **protection relays** applied to transmission autotransformers should allow all possible loadability, consistent with equipment **protection** requirements.

2.24 Capacitor Banks

2.24.1 Each **protection system** should be designed to minimize the effects to the **bulk power system** of **faults** and **disturbances**, while itself experiencing a single failure.

2.24.2 Capacitor bank **protection** should be applied with due consideration for capacitor bank transients, **power** system voltage unbalance, and system **harmonics**.

2.24.3 **Protection** may be provided to minimize the impact of failures of individual capacitor units on the remaining capacitor units, however, these types of **protections** do not need to be duplicated:

a. Overvoltage **Protection**
b. Individual fuses for each capacitor unit
c. Overvoltage **Protection** for each capacitor units

2.25 Static Var Compensation (SVC) **Protection**

2.25.1 The low voltage branch circuits contain the reactive controlling equipment, filters, etc. These may include all or some of the following:

a. Thyristor Controlled Reactors (TCR)
b. Thyristor Switched Capacitors (TSC)
c. Switched or Fixed Capacitors
d. **Harmonic** Filters

2.25.2 **Protection** for the branch circuits that are not part of the **bulk power system** need not be duplicated. **Protection** for these branch circuits should be applied with due consideration for capacitor bank transients, power system voltage unbalance, and system **harmonics**.

2.25.3 **Protection** against abnormal non-**fault** conditions within the SVC via control of the TSC and TCR valves should be designed so as to not interfere with the proper operation of the SVC.

2.26 Logic System

2.26.1 The design should recognize the effects of contact races, spurious operation due to battery grounds, dc transients, radio frequency interference or other such influences.

2.26.2 It is recognized that timing is often critical in logic schemes. Operating times of different devices vary. Known timing differences should be accounted for in the overall design.

2.27 Microprocessor-Based Equipment and Software

A **protection system** may incorporate microprocessor-based equipment. Information from this equipment may support other functions such as **power** system operations. In such cases, the software and the interface should be designed so as to not degrade the **protection system** functions.

2.28 Control Cable, Wiring and Ancillary Control Devices

Control cables and wiring and ancillary control devices should be highly dependable and secure. Due consideration should be given to published codes and standards, fire hazards, current-carrying capacity, voltage drop, insulation level, mechanical strength, routing, shielding, grounding and environment.

Appendix B
Procedure for Reporting to TFSP New and Modified Protection Systems

1.0 Introduction

As stated in Section 6.0 of this Directory, **"**an entity, proposing to install a new **protection system** or a modification to an existing **protection system**, shall submit documentation to TFSP" in accordance with this Appendix. Presentation should be made to the TFSP early in the engineering design stage.

2.0 Additional Requirements for Presentation and Review

2.1 As stated in NPCC Document A-10, Classification of **Bulk Power System Elements**, Paragraph 4.1, "within three months of an **element** being added to the **Bulk Power System** List, a plan and schedule for achieving compliance shall be provided to TFSP for review and acceptance. TFSP may require modifications to the proposed plan and schedule."

2.2 A presentation will be made to the TFSP on new facilities or a modification to an existing facility when requested by either a member entity or the TFSP.

2.3 A presentation will be made to the TFSP when the design of the **protection** facility deviates from the criteria set forth in this Directory.

2.4 A presentation will be made to the TFSP when a member entity is in doubt as to whether a design meets the **protection** criteria set forth in this Directory.

2.5 For specific relay replacement programs that largely follow the same design, a presentation will be made to the TFSP for the initial installation in full as described in Section 4.2. For subsequent installations in the program, only a Protection System Review Form and a cover letter referencing the program and initial presentation will be required.

3.0 Data Required for Presentation and Review of Proposed Protection Facilities

3.1 The **protection system** owner will advise the TFSP of the basic design of the proposed system. The data will be supplied on the "Protection System Review Forms" (formerly C-22 forms) as listed below, accompanied by a geographical map, a one-line diagram of all affected areas, and the associated **protection** and control function diagrams as well as network architecture drawings if applicable. A physical layout of **protection** panels and batteries for the purpose of illustrating physical separation will also be included. Physical layout drawings of cabinets located in the substation yard housing protection system IED components will also be included if applicable.

- Protection System Details
- Line Relaying (Phase)
- Line Relaying (Ground)
- Transformer/Reactor Relaying
- Generator Relaying
- Bus Relaying
- Shunt Capacitors and Filters Relaying
- HVdc Converter Relaying
- Special Protection Systems
- Communication links
- Equipment Details
- Current Transformers
- Voltage Transformers
- Station Battery
- Physical Separation
- Breakers
- Disturbance Monitoring Equipment
- Exception Request

The proposed **protection system** will be explained with due emphasis on any special conditions or design restrictions existing on the particular **power** system.

4.0 Procedure for Presentation

4.1 The **protection system** owner will arrange to have a technical presentation made to the TFSP

4.2 To facilitate scheduling, the chairman of the TFSP will be notified approximately four months prior to the desired date of presentation.

4.3 Copies of materials to be presented will be distributed to TFSP members 30 days prior to the date of the presentation.

5.0 TFSP Procedures

5.1 The TFSP will review the material presented and develop a position statement concerning the proposed **protection system**. This statement will indicate one of the following:

5.1.1 The need for additional information to enable the TFSP to reach a decision.

5.1.2 Acceptance of the member statement of conformance to the **Protection** Criteria.

5.1.3 Acceptance of the submitted proposal

5.1.4 Conditional acceptance of the submitted proposal*.

5.1.5 Rejection of the submitted proposal*.

* Position Statements 4.1.4 and 4.1.5 which will include an indication of areas of departure from the intent of the **protection** criteria and suggestions for modifications to bring the **protection system** into conformance with the NPCC criteria.

5.2 The results of the TFSP review will be documented in the following manner in a letter:

5.2.1 A position statement, which will also be included in the minutes of the meeting at which the proposed **protection system** was reviewed.

5.2.2 If necessary, a letter will outline areas of nonconformance with the **protection** criteria stipulated in this Directory and recommendations for correction will be submitted to the **protection system** owner. If necessary, the matter will be brought to the attention of the RCC.

The Task Force will maintain a record of all the reviews it has conducted.

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Full Member Ballot

September 14th, 2015

NPCC
Regional Reliability Reference Directory # 4
Bulk Power System Protection Criteria

Task Force on System Protection Revision Review Record:
December 1st, 2009

TFSP Redlined Revisions
Approved by the RCC

Adopted by the Members of the Northeast Power Coordinating Council, Inc. December 01, 2009 based on recommendation by the Reliability Coordinating Committee, in accordance with Section VIII of the NPCC Amended and Restated Bylaws dated July 24, 2007 as amended to date.

Revision History

Version	Date	Action	Change Tracking (New, Errata or Revisions)
0	12/01/2009		New
1	3/31/2015	Inserted Applicability of NPCC Criteria	

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Table of Content

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1.0 Introduction

1.1 Title Bulk Power System Protection Criteria

1.2 Directory Number 4

1.3 Objective

The purpose of this Directory is to provide the **protection** criteria, for **protection** of the **Bulk Power System** in NPCC **bulk power system**Inc. member **Areas**. It is not a design specification.

1.4 Effective Date December 01, 2009

Compliance Guidance Statement- **Protection system** designs submitted to the TFSP prior to Month,Day 2015 the (date Full Members approve of this revision) are not subject to the submittal requirements described in Section 6, Compliance Requirements R1, R2, and R3.

1.5 Background

This Directory was developed fromdirectory establishes the draft NPCC A-05 basic **protection system** design criteria and review process for **protection systems** for the Bulk Power Protection Criteria document dated December 4, 2008 and approved B-05, B-07, B-24 and C-22 documents. Guidelines and procedures**System**.

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Guidance for consideration in the implementation of this Directory arethese criteria is provided in Appendix A, and the procedure for reviewing new and modified **protection systems** is provided in Appendix B.

1.6 Applicability

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The requirements of an NPCC Directory apply only to those facilities defined as NPCC **bulk power system elements** as identified through the performance based methodology of NPCC Document A-10, "*Classification of Bulk Power System Elements*," the list of which is maintained by the NPCC Task Force on System Studies and approved by the NPCC Reliability Coordinating Committee.

Requirements to abide by an NPCC Directory may also reside in external tariff requirements, bilateral contracts and other agreements between facility owners and/or operators and their assigned Reliability Coordinator, Planning Coordinator, Transmission Operator, Balancing Authority and/or Transmission Owner as applicable and may be enforceable through those external tariff requirements, bilateral contracts and other agreements. NPCC will not enforce compliance to the NPCC Directory requirements in this document on any entity that is not an NPCC Full Member.

1.6.1 Functional Entities

Transmission Owners
Generator Owners
Distribution Providers

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1.6.2 Facilities

1.6.2.1 New Facilities

These criteria shall apply to all new Bulk Power System (BPS) facilities.

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1.6.2.2 Existing Facilities

It is the responsibility of individual companies to assess the **protection systems** at existing facilities and to make modifications which are required to meet the intent of these criteria as follows.

1.6.2.2.1 Facilities found lacking two batteries or **elements** lacking two independent sets of **protective relays**

If an entity becomes aware of an existing facility that lacks an independent battery for each **protection group,** or an **element** that lacks two independent sets of **protective relays**, a mitigation plan to meet the requirements of this Directory must be submitted to TFSP within six months. The mitigation plan shall correct these deficiencies within three years. Justification for a longer timeframe must be approved by TFSP.[1]

1.6.2.2.11.6.2.2.2 Planned Renewal or Upgrade to Existing BPS Facilities

It is recognized that there may be portions of the **bulk power system,** which existed prior to each member's adoption of the *Bulk Power System Protection Criteria* (Directory 4 and its predecessor Document A-5) that do not meet these criteria. However, ifIf **protection systems** or sub-systems of these facilities are replaced as part of a planned renewal or upgrade to the facility and do not meet all of these criteria, then an assessment shall be conducted for those criteria that are not met.

The result of this assessment shall be reported, to TFSP. It is recommended this reporting be in accordance with the procedure stipulated in Section 4.0 of Appendix AB of this Directory and using the appropriate portion of the "Protection System Review forms" (formerly C-22 forms),", for review and disposition by the TFSP, or in a form consistent with the intent of the procedure.

1.6.2.2.21.6.2.2.3 Facility Classification Upgraded to **Bulk Power System**.

These criteria apply to all existing facilities which become classified as **bulk power system**. A mitigation plan shall be requiredsubmitted to TFSP for review to bring such a facility into compliance with these criteria.

[1] A BPS Risk Mitigation Plan was put in place in 2010 based on a recommendation by the Task Force on System Protection following an extensive survey by NPCC member entities of their BPS protection system conformance to Directory No. 4 (Criteria A5 at the time). The purpose of this plan was to provide direction to separately mitigate the two attributes identified by TFSP as the highest risk to reliability namely the lack of two independent sets of protective relays or two batteries. At the time, members who owned protection systems that were subject to these high risk items were directed to provide a schedule to mitigate the identified deficiencies based on their original survey which occurred in 2009.

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Where the owner of the **protection system** has determined that the cost and risks involved to implement physical separation, as per Section 5.12, cannot be justified, the reason for this determination and an assessment shall be reported to the TFSP.

_It is recommended this reporting be in accordance with the procedure stipulated in Section 4.0 of Appendix AB of this Directory and using the appropriate portion of the "Protection System Review forms" (formerly C-22 forms),", for review and disposition by the TFSP, or in a form consistent with the intent of the procedure.

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1.6.2.2.31.6.2.2.4 Additions to **Bulk Power System** Facilities

If a **bulk power system element** is added to an existing **bulk power system** facility that is recognized under Section 1.6.2.2.1, Planned Renewal or Upgrade to Existing Facilities, these criteria apply to the **protection systems** for the new **element**.

1.6.2.2.41.6.2.2.5 "Unplanned In-Kind"kind Replacement of **Bulk Power System** Equipment

If a **bulk power system element** (e.g., breaker, transformer, capacitor bank, reactor, etc.) or a **protective relay** is replaced "in kind" as a result of an unplanned event, then it is not required to upgrade the associated **protection system** to comply with these criteria.

1.6.2.2.51.6.2.2.6 Change in **Bulk Power System** Facility Status

When a facility was originally on the BPS list of April 2007 and has been shown to be non-BPS but later was determined to be BPS again, Section 1.6.2.2.1 would apply. When the facility returns to BPS status, it shall be maintained in accordance with Directory #3 within two years timeframe._

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1.6.31.6.1 Responsibility

Whenever changes are anticipated in generating sources, transmission facilities, or operating conditions, Generator Owners and Transmission Owners shall review those **protection system** applications (i.e., settings, ac and dc supplies) which can reasonably be expected to be impacted by those changes.

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2.0 Terms Defined in this Directory

The definitions of terms found in this Directory appearing in bold typeface, can be found in Document A-07, NPCC *Glossary of Terms*.

DC Circuit: a set of **protection** and/or control equipment connected by wire under a common DC circuit breaker or fuse. This DC circuit breaker or fuse is the most immediate device to isolate the aforementioned set of **protection** and/or control equipment connected by wire from the DC power supply that does not also remove the DC power supply from other equipment.

Galvanic isolation: the separation of two or more items or components such that no electrical current can traverse between them under normal operating conditions. The components may be discrete devices such as: relays; wire/cables; relay panels, etc. or the separation can be on a single device such as that between traces on a circuit board. The electrical separation of components that prevents current flow between these components is, in essence, electrical (galvanic) isolation.

Merging Unit: An intelligent electronic device (IED) that collects multichannel signals output by current transformers and voltage transformers synchronously, along with device status, control, then exchanges these signals with the protocol of IEC 61850 to protective devices and measure-control devices.

IED - Intelligent Electronic Device: a microprocessor-based device equipped with digital communication abilities, some examples are **protective relays**, RTUs, SERs, DFRs, PLCs, data concentrators, telecommunications equipment, **merging units**, remote I/O units, and general monitoring equipment.

Process Bus - IEC 61850 addresses this need through the definition of Sampled Measured Values services and the implementation of a Process Bus. The Process layer of the substation is related to gathering information, such as Voltage, Current, and status information, from the transformers and transducers connected to the primary power system.

The following revisions to NPCC definition for "**protection system**" are also proposed:

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Comment [GJD1]: Proposed revision to the NPCC defined term for 'protection system' withdrawn pending TFCP evaluation of the impact on other aspects of the NPCC criteria.

See letter from TFSP Chair to TFCP Chair dated 7/23/2015.

Protection System is as defined in NERC's Glossary of Terms as follows:
- 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 station 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.

Protection System – Element Basis
One or more **protection groups**; including all equipment such as instrument transformers, station wiring, circuit breakers and associated trip/close modules, and communication facilities; installed at all terminals of a power system **element** to provide the complete **protection** of that **element**.

Protection System – Terminal Basis
One or more **protection groups**, as above, installed at one terminal of a power system **element**, typically a transmission line.

3.0 NERC ERO Reliability Standard Requirements

The NERC ERO Reliability Standards containing requirements that are associated with this Directory include, but may not be limited to:

3.1 PRC-001
3.22.1 PRC-002
3.32.1 PRC-012

3.2 PRC-002
3.3 PRC-005
3.4 PRC-006
3.5 PRC-012
3.6 PRC-018
3.7 PRC-023
3.8 PRC-024
3.9 PRC-025

4.0 NPCC Regional Reliability Standard, Directory, Criteria Requirements that are associated with this Directory include, but may not be limited to:

None.
Document A-15 - Disturbance Monitoring Equipment Criteria or PRC-002-NPCC as approved by applicable Regulatory Authorities
PRC-006-NPCC-01 – Automatic Underfrequency Load Shedding
Directory #12 – Underfrequency Load Shedding Program Requirements

5.0 NPCC Full Member, More Stringent Criteria

These Criteria are in addition, more stringent or more specific than the NERC or any Regional Reliability standard requirements.

5.1 General Criteria

The intent of the criteria established in this Directory is to ensure dependable and secure operation of the **protection systems** for ~~**Bulk Power System**~~ ~~facilities.~~**bulk power system.** For those **protective relays** intended for removal of **faults** from the **bulk power system**, dependability is paramount, and the redundancy provisions of the criteria shall apply. For ~~**Protective**~~**protective relays** installed for reasons other than **fault** sensing such as overload, etc., security is paramount, and the redundancy provisions of the criteria do not apply. The relative effect on the **bulk power system** of a failure of a **protection system** to operate when desired versus an unintended operation shall be weighed carefully in selecting design parameters as follows.

5.2 Criteria for Dependability

5.2.1 Except as identified otherwise in these criteria, all elements of the **bulk power system** shall be protected by two protection **groups**, each of which is independently capable of performing the specified protective function for that **element.** This requirement also applies during energization of the **element.**

5.2.1.1 The failure of a **merging unit** shall not lead to the momentary or permanent loss of more than one **protection group** per **element**.

5.2.2 Except as identified otherwise in these criteria, the two **protection groups** shall not share the same component**.** If the two **protection groups** share a redundant **component** in order to achieve improved reliability, the **galvanic isolation** and physical separation of the two **protection groups** shall not be compromised. This is to ensure that a single **component** failure or malfunction will not prevent both **protection groups** from performing their **protective** functions.

5.2.2.1 Each **protection group** shall be supplied from its own DC circuit and that DC circuit shall not be used in any other **protection group** protecting the same **element**. Any non-**protection** control or monitoring circuits shall be supplied from a **separately protected DC circuit.** **Non-protection** control or monitoring circuits include but are not limited to

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closing, reclosing, SCADA, and **DME** functions.

5.2.3 Means shall be provided to trip all necessary local and remote breakers in the event that a breaker fails to clear a fault. This **protection** need not be duplicated. If **breaker failure protection** is duplicated, the exceptions as allowed in 5.12.3 and 5.15.1 for single **breaker failure protection** do not apply.

5.2.4 On installations where free-standing or column-type current transformers are provided on one side of the breaker only, resulting in a **protection** blind spot, **protection** shall be provided locally to detect **faults** to ground occurring in the **protections**' blind spot area..

~~2.1.1~~5.2.5 **When frame ground protection is used, then frame ground and breaker failure protections are** two local independent protections **for the blind spot between the current transformer and the circuit breaker. Neither of these** protections **need be duplicated. Both of these protections shall be designed so as to not be disabled by the same failure. The frame ground protection and breaker failure protection will in fact provide independent** protections **for the blind spot.**

5.3 Criteria for Security

Protection systems shall be designed to isolate only the faulted **element**, except in those circumstances where additional **elements** are tripped intentionally to preserve system integrity, or where isolating additional **elements** has no impact outside the local area~~.~~

5.4 Criteria for Dependability and Security

5.4.1 The thermal capability of all **protection system** components shall be adequate to withstand rated maximum short time and continuous loading of the associated **protected elements**.

~~5.4.2~~2.1.1 ~~Communication link availability, critical switch positions, and trip circuit integrity,~~Position or state of control devices that can disable **protections** shall be monitored and annunciated to allow prompt attention by appropriate operating authorities.

~~5.4.3~~5.4.2 ~~When remote access to~~ These devices include but are not limited to communication cutoff switches, relay test mode switch, and **protection** ~~**systems** is possible, the design shall include security measures to minimize the probability of unauthorized access to the **protection systems**~~scheme cutoff switches.

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5.4.3 When a Local Area Network (LAN) is used as part of the **protection system, relay** hardware, network paths, network hardware and **merging unit** shall be continuously monitored and annunciated for software failure, hardware failure and/or communication failure in order to allow prompt attention by the appropriate operating authorities.

5.4.4 Short Circuit Models used to assess **protection** scheme design and to develop **protection** settings shall take into account minimum and maximum fault levels and mutual effects of parallel transmission lines. Details of neighboring systems shall be modeled wherever they can affect results significantly.

5.4.5 **Protection system components** with redundant power supplies shall be powered from the same DC battery system**.**

5.4.6 Contact outputs used for tripping interrupting devices shall be properly rated to make and carry the DC current for the tripping circuits that they are applied to.

5.5 Operating Time Criteria

Bulk power system protection shall take corrective action within times determined by studies ~~with due regard to security, dependability and selectivity~~in accordance with Directory No. 1, Design and Operation of the Bulk Power System.

5.6 Current Transformer Criteria

Current transformers (CTs) associated with **protection systems** shall have adequate steady-state and transient characteristics for their intended function as follows:

5.6.1 The output of each current transformer secondary winding shall be designed to remain within acceptable limits for the connected burdens under all anticipated **fault** currents to ensure correct operation of the **protection system**.

5.6.2 The thermal and mechanical capabilities of the CT at the operating tap shall be adequate to prevent damage under maximum **fault** conditions and normal or **emergency** system loading conditions.

5.6.3 For **protection groups** to be independent, they shall be supplied from separate current transformer secondary windings.

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5.6.4 Interconnected current transformer secondary wiring shall be grounded at only one point.

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5.6.5 Current transformers shall be connected so that adjacent **protection** zones overlap.

5.7 Voltage Transformer and Potential Devices Criteria

Voltage transformers and potential devices associated with **protection systems** shall have adequate steady-state and transient characteristics for their intended functions as follows:

5.7.1 Voltage transformers and potential devices shall have adequate volt-ampere capacity to supply the connected burden while maintaining their ~~**relay**~~rated accuracy over their specified primary voltage range.

5.7.2 The two **protection groups** protecting an element shall be supplied from separate voltage sources. The two protection groups may be supplied from separate secondary windings on one transformer or potential device, provided all of the following requirements are met:

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5.7.2.1 Complete loss of one or more phase voltages does not prevent all tripping of the protected **element**;

5.7.2.2 Each secondary winding has sufficient capacity to permit fuse **protection** of the circuit;

5.7.2.3 Each secondary winding circuit is adequately fuse protected.

5.7.3 The wiring from each voltage transformer secondary winding shall not be grounded at more than one point.

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5.8 Batteries and Direct Current (DC) Supply Criteria

DC supplies associated with **protection** shall be designed to have a high degree of dependability as follows:

5.8.1 No single battery or ~~dc~~DC power supply failure shall prevent both independent **protection groups** from performing the intended function. Each battery shall be provided with its own charger. Physical separation shall be maintained between the two station batteries or ~~dc~~DC power supplies used to supply the independent **protection groups**.

5.8.2 Each station battery shall have sufficient capacity to permit operation of the station, in the event of a loss of its battery charger or the ac supply source, for the period of time necessary to transfer the **load** to the other station battery or re-establish the supply source. Each station battery and its associated charger shall have sufficient capacity to supply the total ~~dc~~DC **load** of the station.

5.8.3 A transfer arrangement shall be provided to permit connecting the total **load** to either station battery without creating areas where, prior to failure of either a station battery or a charger, a single event can disable both ~~dc~~DC supplies.

5.8.4 The battery chargers and all ~~dc~~DC circuits shall be protected against short circuits. All protective devices shall be coordinated to minimize the number of ~~dc~~DC circuits interrupted.

~~Dc~~

5.8.5 DC systems shall be continuously monitored ~~or~~and annunciated to detect abnormal voltage levels (both high and low), ~~dc~~DC grounds, and loss of ac to the battery chargers, in order to allow prompt attention by the appropriate operating authorities.

5.8.6 **Protection group** ~~dc~~DC sources shall be continuously monitored to detect loss of voltage in order to allow prompt attention by the appropriate operating authorities.

5.9 Station Service ac Supply Criteria

On **bulk power system** facilities there shall be two sources of station service ac supply, each capable of carrying at least all the critical **loads** associated with **protection systems**.

5.10 Circuit Breaker

5.10.1 No single trip coil failure shall prevent both independent **protection groups** from performing the intended function. The design of a breaker with two trip coils shall be such that the breaker will operate if both trip coils are energized simultaneously. The correct operation of this design shall be verified by tests.

5.10.2 Each trip coil shall be monitored in a fail-safe manner for continuity and presence of corresponding DC voltage and annunciated to allow prompt attention by appropriate operating authorities.

5.11 Teleprotection Criteria

5.11.1 Communication facilities required for **teleprotection** shall be designed

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to have a level of performance consistent with that required of the **protection system**, and shall meet the following:

5.11.1.1 Where each of the two **protection groups** protecting the same **bulk power system element** requires a communication channel~~, the~~:

~~5.11.1.1~~5.11.1.1.1 The equipment ~~and channel~~ for each **protection group** shall be separated physically on non-adjacent panels and designed to minimize the risk of both **protection groups** being disabled simultaneously by a single event or condition.

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5.11.1.1.2 The communication medium outside the substation physical perimeter for each **protection group** shall be designed to minimize the risk of both **protection groups** being disabled simultaneously by a single event or condition. In addition, physical separation of the communication media shall be three feet at a minimum. In cases where constraints do not allow three feet separation, this distance may be reduced if a proposed alternative design can achieve comparable physical protection of the communication medium.

5.11.1.2 **Teleprotection** equipment shall be monitored to detect loss of equipment ~~and/or channels~~ to allow prompt attention by the appropriate operating authorities.

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5.11.1.3 **Teleprotection** communication channels shall be designed with continuous monitoring and alarming for loss of function to allow prompt attention by appropriate operating authorities. For **teleprotection** communication channels that utilize ON/OFF signaling that cannot be continuously monitored, the design shall provide daily automated testing for the presence of the channel health and alarming for loss of function to allow prompt attention by appropriate operating authorities.

~~5.11.1.3~~ 5.11.1.4. **Teleprotection** equipment shall be provided with means to test for proper signal adequacy~~.~~ where provisions for automated testing are not provided.

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~~5.11.1.4~~ 5.11.1.5 **Teleprotection** equipment shall be powered by the substation batteries or other sources independent from the

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5.11.1.5 5.11.1.6 Except as identified otherwise in these criteria, the two **teleprotection** groups shall not share the same component.

5.11.1.5.15.11.1.6.1 The use of a single communication tower for the radio communication systems used by two **protection groups** protecting a single **element** is permitted as long as directional diversity of the communication signals is achieved.

5.12 Environment

5.12.1 Each separate **protection group** and **teleprotection** protecting the same system **element** shall be on different non-adjacent vertical mounting assemblies or enclosures, except as noted in 5.12.7.

5.12.2 **Protection group** LAN devices for redundant **protection groups** shall be on different non-adjacent vertical mounting assemblies or enclosures, except as noted in 5.12.7.

5.12.25.12.3 Wiring for separate **protection groups** and **teleprotections** protecting the same system **element** shall not be in the same cable or terminated in the same panel. The sole exception is cable termination on single non-redundant **breaker failure** panels.

5.12.4 The use of fiber optics for separate **protection groups** and **teleprotections** protecting the same system **element** shall not result in a common mode failure.

5.12.35.12.5 Cabling for separate **protection groups** and **teleprotections** protecting the same system **element** shall be physically separated. This can be accomplished by being in different raceways, trays, trenches, etc. Cable separation shall be achieved up to the breaker control cabinet or equipment control cabinet.

5.12.45.12.6 In the event a common raceway is used, cabling for separate **protection groups** protecting the same system **element** shall be separated by a firenon-flammable barrier.

5.12.7 Electronic devices physically located outdoor in the substation yard which serve as **components** of separate **protection groups**, protecting the same **element**, shall be physically separated. This can be accomplished by separate enclosures, or by a non-flammable barrier.

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5.12.8 An electronic device, which serves as a **component** of a **protection group,** and is physically located near the primary equipment and outside of the control house, may be subject to more severe environmental conditions than if it was located inside of a building. These environmental conditions may include extreme temperatures, corrosive atmosphere, and electromagnetic interference (EMI). Electronic device selection and secondary enclosure design ("cabinets") shall ensure that environmental conditions do not reduce **protection group reliability** and availability and that the electronic devices contained therein are not subject to the environmental conditions above the accepted limits specified by the IEEE or IEC. Any outdoor enclosure shall have as a minimum a NEMA 4X rating for non-EMI related environmental conditions.

5.13 Grounding Criteria

Station grounding is critical to the correct operation of **protection systems**.An entity The design of the ground grid directly impacts proper **protection system** operation and the probability of false operation from **fault** currents or transient voltages. Each member shall have established as part of its substation design procedures or specifications, a mandatory method of designing the substation ground grid, which:

5.13.1 Can be traced to a recognized calculation methodology

5.13.2 Considers cable shielding

5.13.3 Considers equipment grounding and its impact on the operation of the live tank frame ground protection.

5.14 Transmission Line Protection Criteria

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5.14.1 **Protection system** settings shall not constitute a loading limitation as per NERC requirement/standard. In cases where NERC approved exceptions are used the limits thus imposed shall be adhered to as system operating constraints.

5.14.2 A **pilot protection** shall be so designed that its failure or misoperation will not affect the operation of any other **pilot protection** on that same **element**.

5.15 Breaker Failure Protection Criteria

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Means shall be provided to trip all necessary local and remote breakers in the event that a breaker fails to clear a **fault**, as follows.

5.15.1 BreakerNon-redundant breaker failure **protection** shall be initiated by each of the **protection groups** which trip the breaker, with the optional exception of a breaker failure **protection** infor an adjacent zone.breaker.

5.15.2 For redundant breaker failure protection, each breaker failure protection shall be initiated only by its respective **protection groups** which trip the breaker (i.e.: System 1 line protection initiates System 1 breaker failure protection), with the optional exception of a breaker failure protection for an adjacent breaker.

5.15.3 For redundant breaker failure protections, system 1 breaker failure protection shall only operate system 1 trip coil of the associated backup breakers needed to clear the fault and system 2 breaker failure protection shall only operate system 2 trip coil of the associated backup breakers needed to clear the fault.

5.15.25.15.4 Fault current detectors shall be used to determine if a breaker has failed to interrupt a **fault** current.

5.15.5 A series breaker can be an acceptable means of providing **fault** clearing for a failed circuit breaker, in lieu of breaker-failure **protection**. This requires both series breakers be in the same overlapping zones of relay **protection**, and both series breakers are tripped by these same **protection** zones.

5.16 Design to Facilitate Testing and Maintenance

5.15.35.16.1 The design of **protection systems** both in terms of circuitry and physical arrangement shall facilitate periodic testing and maintenance.

5.162.1 Generating Station Protection Criteria

When a Local Area Network (LAN) is used as part of the protection system, the design shall provide the ability to isolate

All under- and over-frequency **protection systems** designed to disconnect generators from the power system shall be coordinated with automatic under frequency **load shedding** programs, in accordance with the *Emergency Operation Criteria* (Directory #2).

5.172.1Automatic Under frequency Load Shedding Protection System Criteria

5.16.2 **The requirements and guides for** the operation of **these** Protection Systems **are detailed in the *Emergency Operation Criteria* (Directory #2). The**

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guideline for automatic under frequency load shedding protective relaying, while maintaining a network communication path to give personnel the ability to view **relay** response while under test.

5.16.3 When a Local Area Network (LAN) is used as part of the **protection system**,the network architecture shall provide a dedicated and secure means for personnel to connect to the LAN for testing, troubleshooting and operational purposes.

5.16.4 Test facilities or test procedures shall be designed such that they do not compromise the independence of the redundant design aspects of the **protection systems**.

5.16.5 If a segmented testing approach is used, test procedures and test facilities shall be designed to ensure that related tests properly overlap. Proper overlap is ensured if each portion of circuitry is seen to perform its intended function, such as operating a relay from either a real or test stimulus, while observing some common reliable downstream indicator.

5.16.6 When a Local Area Network (LAN) is used as part of the **protection system**, network monitoring tools shall be deployed to facilitate troubleshooting/corrective maintenance.

5.17 Design to Facilitate Analysis of **Protection System** Performance

5.17.1 Event design is recording capability shall be provided in Appendix A of this Directoryto permit analysis of the **protection systems'** performance.

5.18 Commissioning Testing

5.17.25.18.1 Each **protection group** shall be functionally tested to verify the dependability and security aspects of the design, when initially placed in service and when modifications are made.

5.185.19 HVdc System Protection Criteria

5.18.15.19.1 The ac portion of an HVdc converter station, up to the valve-side terminals of the converter transformers, shall be protected in accordance with these criteria.

5.18.25.19.2 Multiple commutation failures, unordered power reversals, and **faults** in the converter bridges and the dc portion of the HVdc link which are severe enough to disturb the **bulk power system**

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shall be detected by more than one independent control or **protection group** and appropriate corrective action shall be taken, in accordance with the considerations in these criteria.

5.192.1Protection System Testing and Maintenance Criteria

5.20 **Protection** for **protection** **systems** shall be maintainedutilizing IEC 61850 protocol

5.20.1 Loss of one **protection group's** sampled value data stream shall not momentarily or permanently compromise the redundant **protection group's** sampled value data stream, unless studies demonstrate that the total clearing time including momentary interruption is acceptable.

5.20.2 If process bus is employed for both **protection groups** protecting the same **element**, a single device failure shall not lead to momentary or permanent loss of time synchronization for both **protection groups**.

5.20.3 **Protection** related data shall take priority over other types of data that are transported over the same LAN. LANs used for **protection** shall be designed such that the **protection** response shall not be adversely impacted during stressed network conditions. Due to the possibilities for non-**protection** network traffic such as DME record retrieval, security video streaming, phasor measurements, etc., **protection** message response time shall meet the critical clearing time requirements in all network loading conditions.

5.20.4 The actual propagation times through LANs used for **protection** during stressed network conditions shall be included in the calculation of clearing times of protected **element**. Network congestion occurs when a link or node is carrying so much data that its quality of service deteriorates. Typical effects include queuing delay, packet loss or the blocking of new connections.

5.20.5 The failure of a single network device shall not momentarily or permanently disable both **protection groups**, unless studies demonstrate that the total clearing time including momentary interruption[2] is acceptable.

5.20.6 The network topology shall be designed in a way that will ensure that a single broken path does not momentarily or permanently disable both

[2] Certain network protocols (RSTP, ERSTP, etc.), can expose a **protection system** to significant disruptions during the self-healing process known as re-convergence. During this period no traffic is passed by the network switches and results in a momentary loss of **protection**.

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protection groups, unless studies demonstrate that the total clearing time including momentary interruption is acceptable.

5.20.7 Analog to digital conversion, processing and communication latency shall maintain a level of speed and accuracy that, at a minimum, meets current utility **protection** performance.

6.0 Compliance Requirements

5.19.1 **R1. An entity, proposing to install a new protection system or a modification to an existing protection system, shall submit documentation to TFSP in accordance with the *Maintenance Criteria for Bulk Power System Protection* (Appendix B of this Directory #3)..**

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5.19.26.1.1 The design of **protection systems** both in terms of circuitry and physical arrangement shall facilitate periodic testing and maintenance.

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5.19.36.1.2 Each **protection group** shall be functionally tested to verify the dependability and security aspects of the design, when initially placed in service and when modifications are made.

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5.202.1 Analysis of Protection Performance Requirements

5.20.12.1.1 **Bulk power system** automatic operations shall be analyzed**R2. An entity, proposing** to determine proper**install a new protection system** performance. Corrective measures shall be taken promptly if a **protection group** fails**or a modification to** operate or operates incorrectly.

an existing protection system, shall obtain a letter of acceptance by TFSP of

5.20.2 **Event and fault recording capability shall be provided to the extent required to permit analysis of system disturbances andcompliance statement accompanying the submittal in R1 prior to or within twelve months of placing the** protection system **performancein service.**

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5.20.32.1.1 Internal clocks in event and **fault** recording equipment shall be time synchronized to within 2 milliseconds or less of Universal Coordinated Time scale. The time zone shall be clearly identified as either universal time zone or local time zone.

5.20.42.1.1 Each **protective relay** which trips **Bulk Power System** equipment shall provide separate target indication.

6.02.0 Measures and Assessments

None developed at this time.

R3. The entity shall provide within 30 days, upon request from the Regional Entity (Criteria Compliance Enforcement Program) documented evidence of the submittal and acceptance by TFSP, of any new or modified **protection system**.

7.0 Compliance Monitoring Process

7.12.1 Each member shall provide the Task Force on System Protection (TFSP)Compliance **with** advance notification of any of the member's new **bulk power system protection systems**, or significant changes in the member's existing **bulk power system protection systems**.

7.22.1 Each member shall also provide the TFSP with advance notification of non-member **protection** facilities as required per *NPCC Bylaws*.

7.32.1 Each new or revised **protection system** shall be reported to the TFSP. It is recommended this reportingthe requirements set forth in this Directory will be in accordance with the procedure detailed in Section 4.0 of Appendix A of NPCC Criteria Compliance and Enforcement Program (CCEP). Measures and corresponding Levels of Non Compliance for these requirements are contained within the compliance templates associated with this Directory, or in a form consistent with the intent of the procedure.

7.4 Adherence to these Criteria shall be reported by the responsible entity in a manner and form designated by the Compliance Committee.

Prepared by: Task Force on System Protection

Review and Approval: Revision to any portion of this Directory will be posted by the lead Task Force in the NPCC Open Process for a 45 day review and comment period. Upon satisfactorily addressing all the comments in this forum, the Directory document will be sent to the remaining Task Forces for their recommendation to seek RCC approval.

Upon approval of the RCC, this Directory will be sent to the Full Member Representatives for their final approval if sections pertaining to the Requirements and Criteria portion have been revised. All voting and approvals will be conducted according to the most current "NPCC. Bylaws" in effect at the time the ballots

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are cast.

Revisions pertaining to the Appendices or any other portion of the document such as Links glossary terms, etc., only RCC Members will need to conduct the final approval ballot of the document.

This Directory will be updated at least once every three years and as often as necessary to keep it current and consistent with NERC, Regional Reliability Standards and other NPCC documents.

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~~**Appendix A**~~

Appendix A
Guideline ~~and Procedure~~ for Bulk Power System Protection

1.0 Introduction

This Appendix provides the guidance for consideration in the implementation of the **bulk power system** ~~**Protection**~~**protection** criteria stipulated in this Directory~~, and the procedure on reporting new and revised~~ ~~**bulks power system protection facilities**~~.

~~3.0~~2.0 Design Considerations

~~3.1~~2.1 General Considerations

2.1.1 In general, the function of a **protection system** is to limit the severity and extent of **system disturbances** and possible damage to system equipment.

2.1.2 The Directory's criteria objectives can be met only if **protection systems** have a high degree of dependability and security. In this context dependability relates to the degree of certainty that a **protection system** will operate correctly when required to operate. Security relates to the degree of certainty that a **protection system** will not operate when not required to operate.

2.1.3 Often increased security (fewer unintended operations) results in decreased dependability (more failures to operate), and vice versa. As an example, consideration is given to the consequence of applying permissive line protection schemes, which often are more secure, but less dependable, than blocking line protection schemes. The relative effect on the bulk power system of a failure of a protection system to operate when desired versus an unintended operation should be weighed carefully in selecting design parameters. Considerations for specific aspects of protection design are provided below.

2.1.4 Whenever changes are anticipated in generating sources, transmission facilities, or operating conditions, Generator Owners, Transmission Owners, and Distribution Providers should review those **protection system** applications (i.e., settings, ac and dc supplies) which can reasonably be expected to be impacted by those changes.

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~~3.2~~2.2 Issues Affecting Dependability

~~3.2.1~~2.2.1 Some portions of **elements** may not in themselves be part of the **bulk power system**. Those portions do not require two **protection groups**.

~~3.2.2~~2.2.2 Two identical measuring **relays** should not be used in independent **protection groups** due to the risk of simultaneous failure of both groups because of design deficiencies or equipment problems.

~~3.2.3~~2.2.3 In addition to the separation requirements in the criteria, areas of common exposure should be kept to a minimum to reduce the possibility of both **protection groups** being disabled by a single event such as fire, excavation, water leakage, and other such incidents.

~~**On installations where free-standing or column-type current transformers are provided on one side of the breaker only, resulting in a** protection **blind spot,** protection **should be provided to detect a** fault **to ground on the primaries of such current transformers. When frame ground** protection **is used, then frame ground and breaker failure** protections **are the**~~2.2.4 **Merging unit** design should consider the inherent reduction in **protection system reliability** and availability that the use of these devices presents. To mitigate the inherent reduction in **reliability**, more than one merging unit should be provided for each **protection group**.

~~3.2.4~~7.1.1 ~~**two local independent** protections **for the blind spot between the current transformer and the circuit breaker. Neither of these** protections **need be duplicated. Both of these protections should be designed so as to not be disabled by the same failure. The frame ground protection and breaker failure protection will in fact provide independent** protections **for the blind spot.**~~

~~3.3~~2.3 Issues Affecting Security

~~3.3.1~~2.3.1 For **faults** external to the protected zone, each **protection group** should be designed either to not operate, or to operate selectively with other **protection** groups and with breaker failure **protection**.

~~3.3.2~~2.3.2 For planned system conditions, **protection systems** should not operate to trip for stable power swings.

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2.3.3 If a **merging unit** failover scheme is used, the loss of sampled value data shall not result in any **protection** Misoperations.

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~~3.4~~2.4 Issues Affecting Dependability and Security

~~3.4.1~~2.4.1 **Protection systems** should be no more complex than required for any given application.

~~3.4.2~~2.4.2 The components and software used in **protection systems** should be of proven quality, as demonstrated either by actual experience or by stringent tests under simulated operating conditions.

~~3.4.3~~2.4.3 **Protection systems** should be designed to minimize the possibility of component failure or malfunction due to electrical transients and interference or external effects such as vibration, shock and temperature.

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2.4.3.1 Modern digital relaying and control systems may also be subjected to other signal or noise interference events which may cause transients to be detected as a full contact closure by the **protective relay** digital input boards and/or cause contact outputs to erroneously conduct. The digital inputs/outputs associated with the **protective relays** should be designed or modified as necessary to reduce their sensitivity to voltages from transients, signal noise or high resistance contact bridging.[3]

~~3.4.4~~2.4.4 **Protection system** circuitry and physical arrangements should be designed so as to minimize the possibility of incorrect operations due to personnel error.

~~3.4.5~~2.4.5 **Protection system** automatic self-checking facilities should be designed so as to not degrade the performance of the **protection system**.

~~3.4.6~~2.4.6 Consideration should be given to the consequences of loss of instrument transformer voltage inputs to **protection systems**.

2.4.7 Inputs and Outputs necessary for correct **protection system** operation shall be conditioned for a communication loss or power failure such

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[3] Reference NERC Lessons Learned dated October 2, 2013 on loss of converter station due to initiation of a top oil temperature signal from the transformer A protection system.

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that upon restoration of communication or power the intended output state is restored.

2.4.8 The use of network redundancy protocol and network configuration should be considered to improve LAN availability.

3.4.72.4.9 **Protection systems**, including intelligent electronic devices (IEDs) and communication systems used for **protection**, should comply with applicable industry standards for utility grade **protection** service. Utility Grade **Protection System** Equipment are equipment that are suitable for protecting transmission**bulk** power system elements, that are required to operate reliably, under harsh environments normally found at substations. Utility grade equipment should meet the applicable sections of all or some of the following types of industry standards, to ensure their suitability for such applications:

- IEEE C37.90.1-2002 (oscillatory surge and fast transient)
- IEEE C37.90.1-2002 (service conditions)
- IEC 60255-22-1, 2005 (1 MHz burst, i.e. oscillatory)
- IEC 61000-4-12, 2001 (oscillatory surge)
- IEC 61000-4-4, 2004 (EFT)
- IEC 60255-22-4, 2002 (EFT)
- IEEE C37.90.2-2004 (narrow-band radiation)
- IEC 60255-22-3, 2000 (narrow-band radiation)
- IEC 61000-4-3, 2002 (narrow-band radiation)
- IEEE 1613 (communications networking devices in Electric power Substations)

2.5 Issues Affecting Performance

2.5.1 Control cables and wiring and ancillary control devices should be highly dependable and secure. Due consideration should be given to published codes and standards, fire hazards, current-carrying capacity, voltage drop, insulation level, mechanical strength, routing, shielding, grounding, and environment.

2.5.2 **Protection** performance should be evaluated under stressed network and failover conditions to ensure that protection coordination and performance is within the acceptable design limits.

2.5.3 Continuous streaming of sampled values may consume a large amount of LAN bandwidth. The network architecture should account for

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bandwidth-intensive applications and **protection system** response, as required by planning standards, should not be impacted by increased traffic during any scenario.

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2.5.4 Redundant communications within a **protection group** can significantly increase **protection** availability and reliability.

2.5.5 Sampled values and Generic Object Oriented Substation Events (GOOSE) messages should have the highest priority among all traffic in the network and network interfaces of end-devices.

~~3.5~~ 2.6 Operating Time

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Adequate time margin should be provided taking into account study inaccuracies, differences in equipment, and **protection** operating times. In cases where clearing times are deliberately extended, consideration should be given to the following:

- Effect on system **stability** or reduction of **stability** margins.
- Possibility of causing or increasing damage to equipment and subsequent extended repair and/or outage time.
- Effect of **disturbances** on service to customers.
- Network configurations that impact the delivery or latency of GOOSE messages in one **protection group** should not momentarily or permanently affect the delivery or latency of GOOSE messages in the redundant **protection group** for the same **element**, unless studies demonstrate that the total clearing time including momentary interruption is acceptable**.**
- The reception and processing of a GOOSE message is time critical, specifically during events and relaying operations. The use of GOOSE messages for **protection** should be configured (dataset priority, how messages are published, VLANS, network configuration, etc.) such that the maximum clearing times as specified by Planning Studies are met.

~~3.6~~2.6 Current Transformer

None.

~~3.7~~2.7 Voltage Transformers and Potential Devices

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2.7.1 **Voltage transformer installations should be designed with due regard to ferroresonance.**

~~3.7.1~~2.7.2 Special attention should be given to the physical properties (e.g. resistance to corrosion, moisture, fatigue) of the fuses used in **protection** voltage circuits.

2.7.3 Relay systems utilizing capacitive voltage transformer should be designed with due regard for transient response

~~3.8~~2.8 Batteries and Direct Current (dc) Supply

~~3.8.1~~2.8.1 The circuitry between each battery and its first protective device cannot be protected and therefore should be designed so as to minimize the possibility of electrical short circuit.

~~3.8.2~~2.8.2 The design for the regulation of the dc voltage should be such that, under all anticipated charging and loading conditions, voltage within acceptable limits will be supplied to all devices, while minimizing ac ripple and voltage transients.

~~3.9~~2.9 Station Service ac Supply

None.

~~3.10~~2.10 Circuit Breakers

2.10.1 The indication of the circuit breaker position in **protection systems** should be designed to reliably mimic the main contact position.

2.10.2 Consideration should be given to DC trip circuits monitoring in addition to trip coil monitoring.

~~3.11~~2.11 Teleprotection

~~3.11.1~~2.11.1 **Teleprotection** systems should be designed to prevent unwanted operations such as those caused by equipment or personnel.

~~3.11.2~~2.11.2 Two identical **teleprotection** equipments should not be used in independent **protection groups**, due to the risk of simultaneous failure of both **protection** groups because of design deficiencies or equipment problems.

~~3.11.3~~2.11.3 Areas of common exposure should be kept to a minimum to reduce the possibility of both **protection** groups being disabled by a

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single event such as fire, excavation, water leakage, and other such incidents.

2.11.4 For applications where each of the two protection groups protecting the same bulk power system element requires a communication channel, and telecommunication route diversity cannot be achieved, proper selection of protection scheme can be used to achieve required performance, for example, a DCB scheme and a POTT scheme could be used over the same communication medium.

3.11.42.11.5 **Teleprotection** systems should be designed to mitigate the effects of signal interference from other communication sources and to assure adequate signal transmission during **bulk power system disturbances**.

2.11.6 The directional diversity for microwave signals for the two independent **protection groups** protecting the same **element** should be designed to establish an angle difference of at least 60 degrees between the two communication paths. This is to minimize the possibility of a storm cell preventing transmission of both communication channels.

3.122.12 Environment

2.12.1 Means should be employed to maintain environmental conditions that are favorable to the correct performance of a **protection system.**

2.12.2 Non-flammable barrier used to separate the cabling of the two **protection groups** protecting the same **element** in a common raceway should be sufficiently rated to allow enough time to isolate the affected facility while maintaining operation of one **protection group**.

2.12.3 Raceways containing the cabling of the two **protection groups** protecting the same **element** should be sufficiently separated, in both horizontal and vertical planes, to allow enough time to isolate the affected facility subsequent to a failure in one raceway while maintaining operation of one **protection group**.

3.132.13 Grounding

2.13.1 Station grounding is critical to the correct operation of **protection systems**. The design of the ground grid directly impacts proper **protection system** operation and the probability of false operation from **fault** currents or

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transient voltages.

3.142.14 Grounding

None.

2.13.2 When frame ground **protection** is used, the design must ensure that the current passing through the frame ground CT will be adequate to operate for a primary equipment ground **fault** and that the scheme is secure enough to not operate for a **fault** external to the intended zone of **protection**.[4]

3.152.15 Transmission Lines Protection

2.14.1 For planned system conditions, line **protection systems** associated with transmission facilities should not operate to trip for stable **power swings**.

2.16 Transformer **Protection**

3.15.12.16.1 Fault pressure or Buchholz **relays** used on transformers, phase shifters or regulators should be applied so as to minimize the likelihood of their misoperation due to through **faults**.

2.16.2 The transformer differential relays have the tendency to misoperate during energization of the transformer. The high inrush current flowing into the transformer from the energizing terminal may cause the **protective relay** to mistakenly sense an internal **fault**. This effect has traditionally been mitigated by utilizing the high harmonic content of the inrush current as a restraining quantity but this may be insufficient for modern transformers due to their low second harmonic inrush characteristic. Due regard should be given to the possibility of incorrect blocking for an internal transformer **fault** when mitigating the above issue.[5]

3.162.17 Breaker Failure Protection

[4] Reference July 1, 2013 NERC Lesson Learned reviewed by TFSP at the May 2014 Meeting on Current Transformer Ground Relay.
[5] Reference NERC Lesson Learned reviewed by TFSP dated July 15, 2014 on Power Transformer Differential Relay during Transformer Energization prepared by SP-7 Working Group.

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~~3.16.1~~2.17.1 It is not necessary to duplicate the breaker failure **protection** itself.

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~~3.16.2~~2.17.2 Auxiliary switches may also be required in instances where the **fault** currents are not large enough to operate the **fault** current detectors. In addition, auxiliary switches may be necessary for high-speed detection of a breaker failure condition.

~~3.17~~2.18 Generating Station Protection

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~~3.17.1~~2.18.1 Each **protection system** should be designed to minimize the effects to **the bulk power system** of **faults** and **disturbances**, while itself experiencing a single failure.

~~3.17.2~~2.18.2 Generators should be protected to limit possible damage to the equipment. The following are some of the abnormal (not necessarily **fault**) conditions that should be detected:

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- Unbalanced phase currents, loss of excitation
- ~~Overexcitation~~overexcitation, generator out of step, field ground
- inadvertent energization.

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~~3.17.2.1~~2.18.2.1 **Protections** for the above conditions, which are applied for equipment **protection**, need not be duplicated.

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~~3.17.2.2~~2.18.2.2 When a directional ~~over current~~overcurrent or distance **relay** is applied to remove the generator for slowly cleared **faults** on the external system, such **protection** is a backup and need not be duplicated.

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~~3.17.2.3~~2.18.2.3 The apparatus should be protected when the generator is starting up or shutting down as well as running at normal speed; this may require additional **relays** as the normal **relays** may not function satisfactorily at low frequencies.

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~~3.17.2.4~~2.18.2.4 Generator **protection systems** should not operate for stable **power swings** except when that particular generator is out of step with the remainder of the system. This does not apply to **Special Protection Systems** designed to trip the generator as part of an overall plan to maintain **stability** of the power system.

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3.17.2.52.18.2.5 Loss of excitation and out of step **relays** should be set with due regard to the performance of the excitation system.

3.17.2.62.18.2.6 It is recognized that the overall **protection** of a generator involves non-electrical considerations that have not been included as a part of the criteria in this Directory.

3.17.2.72.18.2.7 All over frequencyoverfrequency, overvoltage and under voltageundervoltage **protection systems** designed to disconnect generators from the power system should be coordinated with automatic under frequencyunderfrequency **load shedding** programs.

3.182.19 Automatic Under frequencyUnderfrequency Load Shedding Protection Systems

3.18.12.19.1 Automatic under frequencyunderfrequency **load shedding protection systems** are not generally located at **bulk power system** stations; however, they have a direct effect on the operation of the **bulk power system** during major **emergencies**.

3.18.22.19.2 Automatic under frequencyunderfrequency **load shedding protection** need not be duplicated.

3.18.32.19.3 Under frequencyUnderfrequency **relays** which operate at a discrete frequency value are called "under frequencyunderfrequency threshold **relays**." Selection of under frequencyunderfrequency sensing devices should be on a threshold basis. Alternatively, rate of change of frequency **load shedding** may be used when the requirements of the Balancing Authority indicate that this method will achieve the intent of the **load shedding** program. Appropriate studies are necessary to determine the application and settings of the rate of change of frequency **relays** for a particular Balancing Authority area.

3.18.42.19.4 In order for each Balancing Authority within NPCC to **shed** approximately the same proportion of **load**, given the same frequency condition, all styles and manufacture of under-frequencyunderfrequency **relays** should trip at essentially the same time. For electromechanical **relays**, time delay depends on rate of frequency decline, and it is not possible to achieve uniform response for different rates of decline. The recommendations in this

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guideline are based on the goal of a uniform response at a rate of frequency decline of 0.2 Hz per second.

3.18.52.19.5 Additional Application Considerations

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3.18.5.12.19.5.1 Where undesired under-frequencyunderfrequency **relay** operation can be caused by decaying frequency due to isolated generation or motor load, additional supervising undercurrent or voltage **relays** may be used to prevent misoperation.

3.18.5.22.19.5.2 Where the AC voltage source for an under-frequencyunderfrequency **relay** is derived from a potential device connected to a cable circuit, care should be taken to estimate the voltage present during deenergization of the circuit. The natural frequency of the decaying cable voltage may be less than 60 Hz, and thus cause an incorrect **relay** operation.

3.18.5.32.19.5.3 The AC Voltage Inhibit feature available on some relays may be useful as a security tool to restrain operation during cable deenergization, depending on the voltage decay time constant

3.18.5.42.19.5.4 Due regard should be given to the expected power system voltage during events for which the underfrequency **relays** are expected to operate. The **relay's** minimum AC voltage operating characteristic should not inhibit proper **relay** operation, nor should the Voltage Inhibit feature, where it exists, be set to prevent proper operation.

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3.18.62.19.6 Settings and Maintenance Recommendations

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3.18.6.12.19.6.1 Pickup Time Delay Settings

Pickup and time delay settings of underfrequency threshold **relays** should be applied in accordance with the requirements specified in Section 5.2 and Section 5.4 of *Emergency Operation Criteria* (Directory #2).

3.18.6.22.19.6.2 Relay Performance Considerations

Any underfrequency **relay** which has been found to have drifted more than ±0.2 Hz from its set point or ±0.1 seconds from its time delay should be recalibrated and then retested in

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six months. If, at that time, the **relay** has drifted ±0.2 Hz or more from its set point or ±0.1 seconds or more from its fixed time delay, the cause of the drift should be corrected or the **relay** should be replaced.

3.18.6.32.1.1.1 Maintenance

Underfrequency **load shedding relays** have a direct effect on the operation of the **bulk power system** during major **emergencies**. These **relays** should be maintained in accordance with requirements stipulated in *Maintenance Criteria for Bulk Power System Protection* (Directory 3), even though they are usually located in non-**bulk power system** stations.

2.20 Commissioning Testing

2.20.1 Firmware upgrades, automation software updates shall be tested and documented in a controlled, off-line environment prior to being placed into service to determine if there are any adverse impacts which could prevent proper **protection system** operation. Reference IEEE C37.231-2012

2.20.2 Pre-commissioning testing specific to the entity's design shall be performed to ensure interoperability of IEC 61850 devices. The fact that an Intelligent Electronic Device (IED) has a conformance certificate will not guarantee it will inter-operate with other conformance certified IEDs in the same substations.

3.192.21 HVdc Systems Protection

3.19.12.21.1 Converter terminals should be protected to avoid excessive equipment stresses and to minimize equipment damage and outage time. These **protections** are usually specific to the design of the converter station(s) and are determined by the manufacturer to comply with availability guarantees. The followings are some conditions which should be detected:

- ac and dc undervoltage,
- ac and dc overvoltage,
- valve misfire,
- excessive harmonics on the dc,
- dc ground **faults** and open circuits,
- dc switching device failures,
- thyristor failures,

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- valve, and snubber circuit overloads.

~~3.19.2~~2.21.2 The overall **protection** and control of an HVdc link may also involve the initiation of actions in response to abnormal conditions on the ac interconnected system. The control and **protection systems** associated with such conditions are not considered part of the HVdc systems **protection**.

~~3.20~~2.22 Protection System Testing and Maintenance

2.22.1 Test facilities and test procedures should be designed such that they do not compromise the independence of **protection groups** protecting the same **bulk power system element**. Test devices or switches should be used to eliminate the necessity for removing or disconnecting wires during testing.

2.22.2 The configuration of IEC 61850 **protection system** should remain as simple as possible to minimize the risks associated with test and maintenance.

2.22.3 All GOOSE messages should contain information to uniquely identify its publishing device. GOOSE message identifiers should provide descriptive nomenclature to aid maintenance and troubleshooting activities.

2.22.4 While isolated testing of a device is acceptable for some commissioning tests, end-to-end secondary injection testing should be conducted to ensure that all interfacing protections perform as designed under dynamic/fault conditions.

~~3.21~~2.23 Analysis of Protection System

2.22.1 Insofar as possible, each active protective function within a **protective relay** should provide separate target information.

~~3.22~~2.24 Transmission Station Protection

~~3.22.1~~2.24.1 The **protection systems** should operate properly for the anticipated range of currents.

~~3.22.2~~2.24.2 For planned system conditions, all station **protection systems** should not operate for **load** current or stable **power swings.**

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~~3.22.3~~2.24.3 **Load** responsive **protection relays** applied to transmission autotransformers should allow all possible ~~load ability~~loadability, consistent with equipment **protection** requirements.

~~3.22.4~~2.24.4 ~~Fault pressure or Buchholz **relays** used on transformers, phase-shifters or regulators should be applied so as to minimize the likelihood of their misoperation due to through **faults**.~~

~~3.23~~2.25 Capacitor Banks

~~3.23.1~~2.25.1 Each **protection system** should be designed to minimize the effects to the **bulk power system** of **faults** and **disturbances**, while itself experiencing a single failure.

~~3.23.2~~2.25.2 Capacitor bank **protection** should be applied with due consideration for capacitor bank transients, power system voltage unbalance, and system harmonics.

~~3.23.3~~2.25.3 Protection may be provided to minimize the impact of failures of individual capacitor units on the remaining capacitor units, however, these types of **protections** do not need to be duplicated:

a. Overvoltage Protection
b. Individual fuses for each capacitor unit
c. Overvoltage Protection for each capacitor units

~~3.24~~2.26 Static Var Compensation (SVC) Protection

~~3.24.1~~2.26.1 The low voltage branch circuits contain the reactive controlling equipment, filters, etc. These may include all or some of the following:

a. Thyristor Controlled Reactors (TCR)
b. Thyristor Switched Capacitors (TSC)
c. Switched or Fixed Capacitors
d. Harmonic Filters

~~3.24.2~~2.26.2 **Protection** for the branch circuits that are not part of the **bulk power system** need not be duplicated. **Protection** for these branch circuits should be applied with due consideration for capacitor bank transients, power system voltage unbalance, and system harmonics.

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3.24.32.26.3 **Protection** against abnormal non-**fault** conditions within the SVC via control of the TSC and TCR valves should be designed so as to not interfere with the proper operation of the SVC.

3.252.27 Logic System

2.26.1 The design should recognize the effects of contact races, spurious operation due to battery grounds, dc transients, radio frequency interference or other such influences.

2.26.2 It is recognized that timing is often critical in logic schemes. Operating times of different devices vary. Known timing differences should be accounted for in the overall design.

3.262.28 Microprocessor-Based Equipment and Software

A **protection system** may incorporate microprocessor-based equipment. Information from this equipment may support other functions such as power system operations. In such cases, the software and the interface should be designed so as to not degrade the **protection system** functions.

3.272.29 Control Cable, Wiring and Ancillary Control Devices

Control cables and wiring and ancillary control devices should be highly dependable and secure. Due consideration should be given to published codes and standards, fire hazards, current-carrying capacity, voltage drop, insulation level, mechanical strength, routing, shielding, grounding and environment.

3.282.1 Environment

Means should be employed to maintain environmental conditions that are favorable to the correct performance of **protection systems**.

4.02.0 Guideline for Application of Remote Access to Protection System

Appendix B

The following guideline is established for the application of remote access to **protection system** Intelligent Electronic Devices (IEDs), such as relays, programmable logic controllers (PLC), and teleprotection equipment that have remote access capabilities, and are designed and configured for remote access applications. It is intended to assist in meeting the requirement stipulated in Section 5.1.3.3 of this Directory, and Section 3.3.1.6 of the *Special Protection System Criteria* (Directory 7).

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This guideline assumes that appropriate physical measures are in place, and that they meet all applicable standards.

4.12.1 Definitions for Use in this Guideline Only

The flowing defined terms are used for illustration of the guideline presented in this Section only. These terms are not defined in Appendix A of this Directory, or any other NPCC documents.

IED - Intelligent Electronic Device, normally computer based, equipped with digital communication abilities, some examples are **protective relays**, RTUs, SERs, DFRs, PLCs, data concentrators, telecommunications equipment, and general monitoring equipment.

PLC - Programmable Logic Controller, used to create and implement logical actions and automation.

Remote Access - accessing a device from a remote geographical area via a communications link; once accessed, provides similar local device functionality, at a distance.

Authenticate - to prove to be genuine or is an approved user.

Intrusion - An unauthorized electronic entry into an IED. Access normally provides user access to the functionality of the device.

Cryptography – is the study and application of codes and ciphers. Codes or encryption is used to transform data into a form that is not directly usable. Decryption transforms encrypted data using a decryption key back into the original useful form.

VPN – Virtual Private Network. It uses encryption to provide a private channel between private networks using a public network as its carrier i.e., two users using the Internet to provide confidentiality, integrity, and authentication.

4.22.1 Governing Principles

The industry has become more reliant on computer technology for power **system protection**, control, communications, and automation of its power system. Electromechanical and solid-state technologies are being replaced with microprocessor devices, offering, among other functions, local and remote communications access. **Protection system** IEDs are employed to protect, and or operate power system elements. Unauthorized access to an IED could result in interruption of electric service, damage to the power system equipment, major **disturbances**, or a danger to life and property.

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Protection system IEDs also contain a large amount of information that utility personnel have come to rely on, including telemetry, power system **disturbance** analysis, fault location, preventive maintenance information, as well as asset condition and optimization data. However, this technology has also created vulnerabilities that are similar to those seen in traditional computer networks. Therefore, the following should be the governing principles of any cyber security program:

- Prevent penetration from cyber attacks.
- Prevent local and remote access to critical cyber assets by non-authorized personnel.
- Monitor cyber assets to detect unauthorized access or attempts to access.
- Limit exposure.

4.32.1 Guideline

4.3.12.1.1 Authentication

One of the foundations of the cyber security program is controlled, or secure, access. This dictates that some form of user authentication be used. Three common means of authenticating a user's identity are:

4.3.1.12.1.1.1 Something the user knows, such as passwords, or IP addresses.

4.3.1.22.1.1.1 Something the user has, such as a key, or cryptographic token.

4.3.1.32.1.1.1 Something the user is, such as fingerprints and voiceprints

At minimum, at least two factors of authentication should be used, e.g., passwords, and a destination – telephone number, or an IP address. The use of more factors such as encryption, etc. will result in providing more secure authentication. However, most present day and legacy **protection system** IEDs do not yet support this technology. Existing equipment often contains some level of security features. At a minimum, they usually provide multi-level passwords. These features should be activated as a first step in security implementation

4.3.22.1.1 Substation IED Access Point

Appendix A

A list of all substation IEDs that have remote electronic access configured should be compiled and maintained. This list should also include the access method(s) (e.g., dial-in, WAN, etc), the associated phone numbers and/or IP address, passwords, and other pertinent data.

4.3.32.1.1 Approved Remote Access Authorization List

A list of approved users, and the station IEDs they are authorized to access, should be established and maintained. It is vital that all such access information be classified as confidential, and managed as such.

4.3.42.1.1 Remote Access Configuration

Protection system IEDs should be configured to afford remote access only where needed and approved, and then, only when proper authentication is provided.

4.3.52.1.1 Password

Most **protection system** IEDs offer multiple access levels, each with separate passwords. Normally, a "view" only level is provided which allows a user to extract and or view information only. An alternate access level is provided to allow trained and authorized users to "make" settings and configuration changes, and initiate breaker operations. It is this level of access that is susceptible to an intrusion which could cause the most damage to the power system. Only limited users should have access to this level by considering the followings:

4.3.5.12.1.1.1 Establish multi-tiered passwords with different privileges for different classes of users.

4.3.5.22.1.1.1 Default passwords should be changed when remote access is configured.

4.3.5.32.1.1.1 Make sure that all IEDs have "strong" passwords, i.e., passwords that are not dictionary words, not easily guessable, not blank, or have no password at all. It is recommended that all passwords contain a combination of letters and numbers, and should be at least six characters long.

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4.3.62.1.1 Logging/Alarming

When remote connections are used to access the relay beyond "view-only" mode, this should be alarmed and/or logged where possible.

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4.3.72.1.1 Controlling Authority Approval

For both local and remote communications, excluding viewing, notification and approval of the Controlling Authority should be required to access in-service **protection system** IEDs. Only authorized users, as per Sections 3.3.3 and 3.3.5 above, should have remote access capabilities.

4.3.82.1.1 Disable User Function

Often, **protection system** IEDs are put into service with functions that are not used. These functions can create vulnerabilities, and therefore, should be disabled if possible.

4.42.1 Other Available Higher Level Authentication Factors and Some General Good Practices

As stated in Section 3.3.1, a minimum of two factors of authentication should be used. However, the use of more factors will result in providing more secure authentication. This Section is intended to provide additional factors and practices that could be implemented where warranted, and where the technology allows.

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4.4.12.1.1 For WAN based access systems, implement Virtual Private Network (VPN) technology. VPN technology is also applicable when using ISDN, DSL, and cable.

4.4.22.1.1 Limit, as far as possible, dependence on the public telephone network for substation communications to IEDs. Instead, use secure communications facilities whenever possible.

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4.4.32.1.1 Call back (where the IED device or modem hangs up on the original caller and calls back on a second line to a preconfigured phone number) may be utilized as a portion of an IED's security to prevent unauthorized access. This security measure added to other security measures will improve the IEDs security. Security can be further enhanced by using a different telephone line for the return call.

4.4.42.1.1 For dial-up modem access, use a hardware lock and key dongle on the analog phone line at each modem and the lock and key combination will act as a gatekeeper. When a call is initiated, the lock at the called modem will verify the existence of a valid key at the calling modem Time.

4.4.52.1.1 Isolation from the Business/Corporate Network

Isolation of the substation **protection system** IEDs from the Corporate Network should be provided where possible. Data can be transferred from the substation IEDs to a server connected to a Corporate Network via appropriate firewalls. This practice is warranted because most Corporate Networks are Internet connected and therefore are exposed to external users.

5.0 **Procedure for Reporting to TFSP New and RevisedModified Protection Systems**

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1.0 Introduction

As stated in Section Paragraph 7.1 of this criteria states that **Protection system** owners shall provide the Task Force on System Protection (TFSP) with advance notification of any of their new **bulk power system protection** facilities, or significant changes in their existing **bulk power system protection** facilities. Paragraph 7.2 of this criteria states that **Protection system** owners shall also provide the TFSP with advance notification of non-member **protection** facilities as required per NPCC Bylaws . Notification will6.0 of this Directory, "an entity, proposing to install a new **protection system** or a modification to an existing **protection system**, shall submit documentation to TFSP" in accordance with this Appendix. Presentation should be made to the TFSP early in the engineering design stage.

5.12.0 Additional Requirements for Presentation and Review

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2.1 As stated in NPCC Document A-10, Classification of **Bulk Power System Elements**, Paragraph 4.1, "within three months of an **element** being added to the **Bulk Power System** List, a plan and schedule for achieving

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compliance shall be provided to TFSP for review and acceptance. TFSP may require modifications to the proposed plan and schedule."

5.1.12.2 A presentation will be made to the TFSP on new facilities or a modification to an existing facility when requested by either a member entity or the TFSP.

5.1.22.3 A presentation will be made to the TFSP when the design of the **protection** facility deviates from the criteria set forth in this Directory.

5.1.32.4 A presentation will be made to the TFSP when a member entity is in doubt as to whether a design meets the **protection** criteria set forth in this Directory.

2.5 For specific relay replacement programs that largely follow the same design, a presentation will be made to the TFSP for the initial installation in full as described in Section 4.2. For subsequent installations in the program, only a Protection System Review Form and a cover letter referencing the program and initial presentation will be required.

5.23.0 Data Required for Presentation and Review of Proposed Protection Facilities

5.2.13.1 The **protection system** owner will advise the TFSP of the basic design of the proposed system. The data will be supplied on the "Protection System Review Forms" (formerly C-22 formsC-22 forms) as listed below, accompanied by a geographical map, a one-line diagram of all affected areas, and the associated **protection** and control function diagrams. as well as network architecture drawings if applicable. A physical layout of **protection** panels and batteries for the purpose of illustrating physical separation will also be included. Physical layout drawings of cabinets located in the substation yard housing protection system IED components will also be included if applicable.

- Protection System Details
- Line Relaying (Phase)
- Line Relaying (Ground)
- Transformer/Reactor Relaying
- Generator Relaying
- Bus Relaying
- Shunt Capacitors and Filters Relaying

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- HVdc Converter Relaying
- Special Protection Systems
- Communication links
- Equipment Details
- Current Transformers
- Voltage Transformers
- Station Battery
- Physical Separation
- Breakers
- Disturbance Monitoring Equipment

~~Transmission Relay Loadability~~

- Exception Request

~~5.2.2~~ The proposed **protection system** will be explained with due emphasis on any special conditions or design restrictions existing on the particular power system.

~~5.3~~4.0 Procedure for Presentation

~~5.3.1~~4.1 The **protection system** owner will arrange to have a technical presentation made to the TFSP

~~5.3.2~~4.2 To facilitate scheduling, the chairman of the TFSP will be notified approximately four months prior to the desired date of presentation.

~~5.3.3~~4.3 Copies of materials to be presented will be distributed to TFSP members 30 days prior to the date of the presentation.

~~5.4~~5.0 TFSP Procedures

~~5.4.1~~5.1 The TFSP will review the material presented and develop a position statement concerning the proposed **protection system**. This statement will indicate one of the following:

~~5.4.1.1~~5.1.1 The need for additional information to enable the TFSP to reach a decision.

~~5.4.1.2~~5.1.2 Acceptance of the member statement of conformance to the Protection Criteria.

~~5.4.1.3~~5.1.3 Acceptance of the submitted proposal

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~~Appendix A~~

~~5.4.1.4~~5.1.4 Conditional acceptance of the submitted proposal*.

~~5.4.1.5~~5.1.5 Rejection of the submitted proposal*.

* Position Statements 4.~~4.~~1.4 and 4.~~4.~~1.5 which will include an indication of areas of departure from the intent of the **protection** criteria and suggestions for modifications to bring the **protection system** into conformance with the NPCC criteria.

~~5.4.2~~5.2 The results of the TFSP review will be documented in the following manner in a letter:

~~5.4.2.1~~5.2.1 A position statement, which will also be included in the minutes of the meeting at which the proposed **protection system** was reviewed.

~~5.4.2.2~~5.2.2 If necessary, a letter ~~outlining~~will outline areas of nonconformance with the **protection** criteria stipulated in this Directory and recommendations for correction will be submitted to the **protection system** owner. If necessary, the matter will be brought to the attention of the RCC.

~~5.4.2.3~~ The Task Force will maintain a record of all the reviews it has conducted.

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