Document A-5

NORTHEAST POWER COORDINATING COUNCIL

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Bulk Power System Protection Criteria

Adopted by the Members of the Northeast Power Coordinating Council August 31, 1970, based on recommendation by the Operating Procedure Coordinating Committee and the System Design Coordinating Committee, in accordance with paragraph IV, subheading (a), of NPCC's Memorandum of Agreement dated January 19, 1966 as amended to date.

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Note:

Terms in bold typeface are defined in the *NPCC Glossary of Terms* (Document A-7)

1.0 Introduction

1.0.1 This document establishes the **protection** criteria and recommends minimum design objectives and practices for **protection** of the NPCC **bulk power system**. It is not intended to be a design specification. It is a statement of **protection** objectives to be observed when developing design specifications.

1.0.2 These criteria apply to all new **protection systems**. 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* (Document A-5) that do not meet these criteria. It is the responsibility of individual companies to assess the **protection systems** at these locations and to make modifications which, in their judgment, are required to meet the intent of these criteria. Similar assessment and judgment shall be used with respect to **protection systems** existing at the time of revisions to these criteria, and to existing **protection systems** on **elements** which, because of system changes, become part of the **bulk power system**.

It is recognized that certain **Areas** or member systems may choose to apply more rigid criteria because of local considerations.

1.0.3 **Protection system** applications (i.e., settings, ac and dc supplies) should be reviewed whenever significant changes in generating sources, transmission facilities, or operating conditions are anticipated. Close coordination must be maintained among planning, design, operating, maintenance and **protection** functions to ensure that modifications or additions to the **bulk power system** will result in facilities that are adequately protected and can be operated and maintained reliably and safely.

2.0 General Criteria

In general, the function of a **protection system** is to limit the severity and extent of system disturbances and possible damage to system equipment. The intent of these criteria is to ensure that **protection systems** are designed to perform this function in accordance with the **protection** dependability and security levels implicit in the *Basic*

Criteria for Design and Operation of Interconnected Power Systems (Document A-2).

The above 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.

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

2.1 Considerations Affecting Dependability

2.1.1 Except as noted in Sections 2.1.4, 2.1.5, 4.5.2, 4.7, and 4.8.1 all **elements** of the **bulk power system** must 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**. Some portions of **elements** may not in themselves be part of the **bulk power system**. Those portions do not require two **protection groups**.

2.1.2 The use of two identical **protection groups** is not generally recommended, due to the risk of simultaneous failure of both groups because of design deficiencies or equipment problems.

2.1.3 The **protection system** design should avoid the use of components common to the two groups. Areas of common exposure should be kept to a minimum to reduce the possibility of both groups being disabled by a single event or condition.

2.1.4 Means must be provided to trip all necessary local and remote breakers in the event that a breaker fails to clear a **fault**. This provision need not be duplicated.

2.1.5 On installations where free-standing or column-type current transformers are provided on one side of the breaker only, **protection** must be provided to detect a **fault** to ground on the primaries of such current transformers. This **protection** need not be duplicated.

2.2 Considerations Affecting Security

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

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

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

2.2.3 **Protection system** settings should not normally constitute a loading limitation. In cases where they do, the limits thus imposed must be documented and adhered to as a system operating constraint.

2.3 Considerations Common to Dependability and Security

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

2.3.2 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.

2.3.3 The thermal capability of all **protection system** components must be adequate to withstand the maximum short time and continuous loading conditions to which the associated **protected elements** may be subjected.

2.3.4 **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.

2.3.5 Critical features associated with the operability of **protection systems,** e.g. guard signals, critical switch positions and trip circuit integrity, should be annunciated or monitored.

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

2.3.7 **Protection system** self-checking facilities should not degrade the performance of the **protection system**.

2.3.8 Consideration should be given to the consequences of loss of ac voltage inputs to **protection systems**.

2.3.9 When remote access to **protection systems** is possible, the design should consider the consequences of unauthorized access to the **protection systems** on their overall security and dependability.

2.3.10 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.

2.4 Operating Time

Bulk power system protection shall take corrective action within times determined by studies with due regard to security, dependability and selectivity. 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 must 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.

2.5 Reserved for Future Application

2.6 **Protection System** Testing and Maintenance

2.6.1 **Protection systems** shall be maintained in accordance with the *Maintenance Criteria for Bulk Power System Protection* (Document A-4).

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

2.6.3 Test facilities and test procedures should be designed such that they do not compromise the independence of redundant **protection groups**. Test devices or switches should be used to eliminate the necessity for removing or disconnecting wires during testing.

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

2.7 Analysis of **Protection** Performance

2.7.1 **Bulk power system** automatic operations must be analyzed to determine proper **protection system** performance. Corrective measures must be taken promptly if a **protection group** fails to operate or operates incorrectly.

2.7.2 Event and fault recording capability should be provided to the maximum practical extent to permit analysis of system disturbances and **protection system** performance. It is recommended that these devices be time synchronized.

3.0 Equipment and Design Considerations

3.1 Current Transformers

Current transformers (CTs) associated with **protection systems** must have adequate steady-state and transient characteristics for their intended function.

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

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

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

3.1.4 Interconnected current transformer secondary wiring must be grounded at only one point.

3.1.5 Current transformers must be connected so that adjacent protection zones overlap.

3.2 <u>Voltage Transformers and Potential Devices</u>

Voltage transformers and potential devices associated with **protection systems** must have adequate steady-state and transient characteristics for their intended functions.

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

3.2.2 The two **protection groups** protecting an **element** must 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:

- Complete loss of voltage does not prevent all tripping of the protected element;
- Each secondary winding has sufficient capacity to permit fuse protection of the circuit;
- Each secondary winding circuit is adequately fuse protected.

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

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

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

3.3 Logic Systems

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

3.3.2 It should be recognized that timing is often critical in logic schemes. Operating times of different devices vary. Timing differences shall be recognized and accounted for in overall design.

3.4 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 care should be taken in the design of the software and the interface so that the support of the other functions does not degrade the **protection system**.

3.5 Batteries and Direct Current (dc) Supply

DC supplies associated with **protection** must have a high degree of dependability.

3.5.1 No single battery or dc power supply failure shall prevent both independent **protection groups** from performing the intended function. Each battery must be provided with its own charger.

3.5.2 Each station battery should 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 should have sufficient capacity to supply the total dc load of the station.

A transfer arrangement should 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.

3.5.3 The circuitry between each battery and its first protective device cannot be protected and therefore must possess a high degree of integrity.

3.5.4 The battery chargers and all dc circuits must be protected against short circuits. All protective devices should be coordinated to minimize the number of dc circuits interrupted.

3.5.5 The regulation of the dc voltage should be such that, under all possible charging and loading conditions, voltage within acceptable limits will be supplied to all devices.

3.5.6 Dc systems shall be monitored to detect abnormal voltage levels (both high and low), dc grounds, and loss of ac to the battery chargers. **Protection systems** should be monitored to detect abnormal power supply.

3.5.7 Dc systems should be designed to minimize ac ripple and voltage transients.

3.6 Station Service ac Supply

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**.

3.7 Circuit Breakers

3.7.1 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 must be such that the breaker will operate if both trip coils are energized simultaneously. The correct operation of this design must be verified by tests.

3.7.2 The indication of the circuit breaker position in **protection systems** should reliably mimic the main contact position.

3.8 **Teleprotection**

Communication facilities required for **teleprotection** must have a level of performance consistent with that required of the **protection system**, such as:

3.8.1 Where each of the two **protection groups** protecting the same bulk power system **element** requires a communication channel, the equipment and channel for each group should be separated physically and designed to minimize the risk of both **protection groups** being disabled simultaneously by a single event or condition.

3.8.2 **Teleprotection** equipment should be monitored in order to assess equipment and channel readiness.

3.8.3 **Teleprotection** systems should be designed to assure adequate signal transmission during **bulk power system** disturbances, and should be provided with means to verify proper signal performance.

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

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

3.9 Control Cables and 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.

3.10 Environment

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

3.10.2 Physical separation should be maintained between the **protection groups** protecting an element in order to minimize the risk of both groups being simultaneously disabled by fire or accidents.

3.11 Grounding

Station grounding is critical to the correct operation of **protection systems**. Consideration must be given to station ground grid design, cable shielding and equipment grounding to ensure proper **protection system** operation and to minimize the risk of false operation from **fault** currents or transient voltages.

4.0 Specific Application Considerations

4.1 Transmission Line Protection

The **protection system** must be designed to limit the effects of **faults** and disturbances, while itself experiencing a single failure. For **faults** external to the protected zone, each **protection group** must be designed either to not operate, or to operate selectively with other groups and with breaker failure protection.

For planned system conditions, line **protection systems** associated with transmission facilities should not operate to trip for stable power swings. **Protection system** settings should not normally constitute a loading limitation. In cases where they do, the limits thus imposed must be documented and adhered to as a system operating constraint.

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.

4.2 Transmission Station Protection

Each **protection system** must be designed to limit the effects of **faults** and disturbances, while itself experiencing a single failure. The **protection systems** should operate properly for the anticipated range of currents.

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

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

4.3 Breaker Failure Protection

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

4.3.1 Breaker failure **protection** must be initiated by each of the **protection groups** which trip the breaker, with the optional exception of a breaker failure **protection** in an adjacent zone. It is not necessary to duplicate the breaker failure **protection** itself.

4.3.2 Fault current detectors must be used to determine if a breaker has failed to interrupt. 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.

4.4 Generating Station Protection

4.4.1 Each **protection system** must be designed to limit the effects of **faults** and disturbances, while itself experiencing a single failure.

4.4.2 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, and inadvertent energization.

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.

4.4.3 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.

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

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

4.4.6 All underfrequency **protection systems** designed to disconnect generators from the power system shall be coordinated with automatic underfrequency **load shedding** programs, in accordance with the *Emergency Operation Criteria* (Document A-3). All overfrequency, overvoltage and undervoltage **protection systems** designed to disconnect generators from the power system should be coordinated with automatic underfrequency **load shedding** programs.

4.5 <u>Automatic Underfrequency **Load Shedding Protection Systems**</u>

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**.

4.5.1 The criteria for the operation of these Protection Systems are detailed in the *Emergency Operation Criteria* (Document A-3) and the *Automatic Underfrequency Load Shedding Program Relaying Guide* (Document B-7).

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

4.6 <u>HVdc Systems Protection</u>

4.6.1 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.

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

4.6.3 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 following 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.

4.6.4 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**.

4.7 Capacitor Bank Protection

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

Protection may be provided to minimize the impact of failures of individual capacitor units on the remaining capacitor units.

This **protection**, which need not be duplicated, includes:

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

4.8 **Static Var Compensator (SVC) Protection**

4.8.1 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

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.

4.8.2 **Protection** against abnormal non-**fault** conditions within the SVC via control of the TSC and TCR valves must not interfere with the proper operation of the SVC.

5.0 Reporting of Protection Systems

Each new or revised **protection system** shall be reported to the Task Force on System Protection in accordance with the *Procedure for Reporting and Reviewing Proposed Protection Systems for the Bulk Power System* (Document C-22).

Prepared by: Task Force on System Protection

Review frequency: 3 years

References: *Basic Criteria for the Design and Operation of the Interconnected Power Systems* (Document A-2)

Emergency Operation Criteria (Document A-3)

Maintenance Criteria for Bulk Power System Protection (Document A-4)

NPCC Glossary of Terms (Document A-7)

Automatic Underfrequency Load Shedding Program Relaying Guide (Document B-7)

	Procedure for Reporting and Reviewing Proposed Protection Systems for the Bulk Power System (Document C-22)
For Information:	NPCC Working Group Report entitled, “Telecommunications for Bulk Power System Protection" dated March 1992