**Document A-5**

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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

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, but a statement of **protection** objectives to be observed when developing design specifications.

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

## 1.1 Applicability

### 1.1.1 New Facilities

These criteria apply to all new **Bulk Power System** facilities.

### 1.1.2 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.

#### 1.1.2.1 Planned Renewal or Upgrade to Existing 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* (Document A-5) that do not meet these criteria. However, if **protection systems** or sub-systems of these facilities are replaced as part of a planned renewal or upgrade to the facility, then these criteria apply to the extent practical.

#### 1.1.2.2 Facility Classification Upgraded to **Bulk Power System**

These criteria apply to all existing facilities which become classified as **bulk power system** due to system changes. A mitigation plan is required to bring such a facility into compliance with these criteria.

1.1.2.3 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 1.1.2.1, Planned Renewal or Upgrade to Existing Facilities, these criteria apply to the **protection systems** for the new **element**.

1.1.2.4 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 in-service failure, then it is not required to upgrade the associated **protection system** to comply with these criteria.

If a **bulk power system element** (e.g., breaker, transformer, capacitor bank, reactor, etc.) or a **protective relay** is replaced as a result of a planned upgrade, then these criteria apply to the extent practical.

1.1.2.5 Revisions to These Criteria

As these criteria are revised, it is the responsibility of members to assess the **protection systems** at their facilities and to make modifications which, in their judgment, are required to meet the intent of these criteria.

1.2 Responsibility

Whenever significant changes are anticipated in generating sources, transmission facilities, or operating conditions, members shall review those **protection system** applications (i.e., settings, ac and dc supplies) which can reasonably be expected to be impacted by those changes. Close coordination shall be maintained among planning, design, operating, maintenance and **protection** functions with the intent 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 shall 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 is given to the consequence of applying permissive line **protection** schemes, which often are more secure, but less dependable, than blocking line **protection** schemes.

For those **protective relays** responsible for removal of **faults** from the **bulk power system**, dependability is paramount, and the redundancy provisions of these criteria apply. For **Protective relays** installed for reasons other than **fault** sensing such as overload, etc., security is paramount, and the redundancy provisions of these criteria do not apply.

### 2.1 Issues Affecting Dependability

2.1.1 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**. 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 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.

2.1.3 Except as identified otherwise in these criteria, the **protection system** design shall not use components shared by the two **protection groups**.

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

2.1.5 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.

2.1.6 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 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 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.

2.2 Issues Affecting Security

2.2.1 **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.

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

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

2.3 Issues Affecting 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 shall be adequate to withstand rated maximum short time and continuous loading of the associated **protected elements**.

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 **Protection systems**, including intelligent electronic devices (IEDs) and communication systems used for **protection**, shall comply with applicable industry standards for utility grade **protection** service.

2.3.6 Communication link availability, critical switch positions, and trip circuit integrity, shall be annunciated or monitored.

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

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

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

2.3.10 When remote access to **protection systems** is possible, the design shall include security measures to minimize the probability of unauthorized access to the **protection systems**.

2.3.11 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

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

2.4.2 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 shall 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 This section is intentionally left blank.

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 shall 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 **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.

2.6.4 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.

2.7 Analysis of **Protection** Performance

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

2.7.2 Event and fault recording capability shall be provided to the extent required to permit analysis of system disturbances and **protection system** performance.

2.7.3 Event and **fault** recording equipment shall be time synchronized to Universal Coordinated Time with a time source accurate to within one millisecond. The time zone shall be clearly identified as either universal time zone or local time zone.

2.7.4 Each **protective relay** which trips **Bulk Power System** equipment shall provide separate target indication. Insofar as possible, each active protective function within a **protective relay** shall provide separate target information.

## 3.0 Equipment and Design Considerations

3.1 Current Transformers

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

3.1.1 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**.

3.1.2 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.

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

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

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

3.2 Voltage Transformers and Potential Devices

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

3.2.1 Voltage transformers and potential devices shall 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** 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:

- Complete loss of one or more phase voltages 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 shall 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 is recognized that timing is often critical in logic schemes. Operating times of different devices vary. Known timing differences shall be accounted for in the 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, the software and the interface shall be designed so as to not degrade the **protection system** functions.

3.5 Batteries and Direct Current (dc) Supply

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

3.5.1 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.

3.5.2 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.

3.5.3 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.

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

3.5.5 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.

3.5.6 The design for the regulation of the dc voltage shall 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,

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

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 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.

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

3.8 **Teleprotection**

3.8.1 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:

3.8.1.1 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 shall be separated physically and designed to minimize the risk of both **protection**

**groups** being disabled simultaneously by a single event or condition.

3.8.1.2 **Teleprotection** equipment shall be monitored in order to assess equipment and channel readiness.

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

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

3.8.1.5 Except as identified otherwise in these criteria, the **teleprotection** system design shall not use **teleprotection** components shared by the two **protection groups** protecting the same **bulk power system element**.

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

3.8.3 Two identical **teleprotection** equipments 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.

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

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 In addition to the physical separation as referenced in sections 2.1.4 and 3.8.8, each separate **protection group** protecting the same system **element** shall be on different non-adjacent vertical mounting assemblies or enclosures. In the event a common raceway is used, cabling for separate groups protecting the same system **element** shall be separated by a fire barrier.

3.11 Grounding

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

- Can be traced to a recognized calculation methodology
- Considers cable shielding
- Considers equipment grounding

## 4.0 Specific Application Considerations

4.1 Transmission Line **Protection**

4.1.1 The **protection system** shall 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** shall be designed either to not operate, or to operate selectively with other groups and with breaker failure **protection**.

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

4.1.3 **Protection system** settings should not normally constitute a loading limitation.

4.1.3.1 In the normal case, the tripping **relay**(s) should not operate at or below $I_{Load}$, assuming a 0.85 per unit voltage and a current phase angle of 30 degrees lagging.

4.1.3.2 $I_{Load}$ equals the highest seasonal ampere line or series **elements rating**, that most closely approximates a 4-hour **rating** (typically the winter seasonal rating), multiplied by a factor of 1.5, or; 1.15 times the 15-minute winter **emergency** ampere **rating** of the line.

4.1.3.3 In cases where the above criterion cannot be met, the limits thus imposed shall be documented and adhered to as a system operating constraint.

4.1.4 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**

4.2.1 Each **protection system** shall 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.

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

4.2.3 In particular, **load** responsive **protective relays** applied to transmission autotransformers should allow all possible loadability, consistent with equipment **protection** requirements. Any such **relays** settings that are identified in studies to be a possible limitation during normal or **emergency** conditions shall be documented and adhered to as a system operating constraint.

4.2.4 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**.

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** shall 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 shall be used to determine if a breaker has failed to interrupt a fault. 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** shall be designed to minimize the effects to the **bulk power system** 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.

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

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.

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).

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

4.5 Automatic Underfrequency **Load Shedding Protection Systems**

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 HVdc Systems **Protection**

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** 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.

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 <u>Capacitor Bank **Protection**</u>

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

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

4.7.3 **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 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 shall be designed so as to not interfere with the proper operation of the SVC.

## 5.0 Reporting of Protection Systems

Each member shall provide the Task Force on System Protection (TFSP) with advance notification of any of the member's new **bulk power system protection** facilities, or significant changes in the member's existing **bulk power system protection** facilities. Each member shall also provide the TFSP with advance notification of non-member **protection** facilities as required per NPCC *Membership Agreement* Article V A(2) (c). Each new or revised **protection system** shall be reported to the TFSP in accordance with the

*Procedure for Reporting and Reviewing Proposed Protection Systems for the Bulk Power System* (Document C-22).

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| 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) |
| | *Special Protection Systems Criteria* (Document A-11) |
| | *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) |
| | *Security Guidelines for Protection Systems IEDs* (Document B-24) |

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| For Information: | NPCC Working Group Report entitled, “Telecommunications for Bulk Power System Protection" dated March 1992 |