7.2 Frequently Asked Questions (FAQ) Document

The PSMTSDT has also written a lengthy document of *Frequently Asked Questions – Practical Compliance and Implementation,* in which the drafting team members respond to technical and program implementation questions they have anticipated from industry practitioners who use the Standard. The FAQ guidance does not have the force of the Standard. However, it will help engineers, managers, and compliance auditors understand the intent of the Standard requirements, to develop effective and compliant maintenance solutions. Find the link to this document also at the project web page http://www.nerc.com/filez/standards/Protection_System_Maintenance_Project_2007-17.html.

8 Taking Advantage of Operating Experience

8.1 Recording Normal Operations

Some natural fault operations or normal operating events can be used to reset TBM maximum interval time clocks, eliminating the need for a separate overt or on-site test. However, note the following requirements:

1) Consider what records you need to have, and how they will be gathered and maintained. For each asset whose testing is documented this way, the owner needs to have a specific hard record (written or electronic) of the event that is used to reset the clock for that asset. Since many utilities do not analyze all operations today, this would call for extra work by the event analysis team. Knowing that the opportunity exists to save field work, some utilities might choose to set up an automatic or semi-automatic program at the control center to log these events, or make it easy for an operator to log them, and associate them with the protection system whose components were verified. This may require development of new applications in the system control and asset management software systems.

2) Be careful about exactly what a particular operation proves, and what remains unproven. Two examples:

    a) We already described the fact that with dual trip coils, and normal operation in which both are energized does not prove that both are working. One utility is addressing this by connecting a communications-based trip path (SCADA or local substation host computer HMI) separately through each of the trip coils. A remote or local manual trip can be performed through each coil to prove its operation.

    b) If an electromechanical Zone 1 distance relay trips correctly for a nearby fault and is observed in a DFR record, its trip circuit might be proven, but its calibration is not proven. Proving calibration this way would require an unlikely sequence of two faults, one just inside the set zone boundary, and the other just outside, with locations that demonstrate correct calibration. This virtually never happens and is not worth the trouble of tracking – the E/M relay will simply need a manual calibration test. However, if the relay is microprocessor based, it is possible for the user to compare its nonfault metered values (displayed or communicated to SCADA) with those of a redundant system or comparable measuring point. This nonfault check proves calibration, and extends the maintenance interval or eliminates other calibration checking.

8.2 Performance Based Maintenance (PBM) Provisions in Standard

Documented TBM may show that some families of similar protective devices are extremely reliable and that it is rare for a maintenance test to show a performance problem or meaningful calibration error. An example is the collection of electromechanical high impedance single phase bus differential relays. It is necessary to consider the populations of each type and manufacturer separately.

With that documentation of TBM, the PBM provisions of draft PRC-005-2 in Attachment A of the supplied Standard draft show the process for determining an extended maintenance interval for such a family of like devices.

First of all, the user needs data for a statistically valid sample of about 60 like products to begin applying an evaluation of extension. Multiple users can aggregate their populations of like devices operating in similar service conditions – for example, a group of generation owners can associate to develop data for a merged population of generator protection relays, where each individual owner does not have a statistically valid sample.

If the TBM results show a problem discovery rate of less than 4%, it is permissible to extend intervals beyond those in Table 1(a) or the other tables that apply to the population of devices. The intervals may be extended up to the point where only 5% of the population is tested every year, if this extension would not cause the testing problem discovery rate to exceed 4%. This is equivalent to a maintenance interval of 20 years! At least this low 5% level of TBM is always required to insure discovery of problems that arise with time, like deterioration failure of components within the population of devices.

Failures may be discovered during the periodic tests, but the counting also includes failures discovered via non-testing misoperations or other field events that show a degradation or failure of a device in the population, or a design problem.

The owner(s) of the population of devices must document their management process of this program. N They must review the results of field experience and maintenance results every year to insure that the extension criteria are still met. Maintenance data for at least 30 of the devices in the population must be available. If the failure or misoperation rate is seen to rise above the acceptable 4% threshold, the owners must start and document a mitigation program to achieve the failure rate threshold within 3 years.

9 Auditing Considerations

As the Standard becomes mandatory and enforceable, responsible managers and engineers must focus not only on how to comply, but how to document compliance for an auditor. Users need documentation of the program they have chosen and how they are carrying it out. Doing the right work is not enough – if there is no written or concrete proof of performance of all the details, the auditor may treat the implementation as noncompliant. This must trigger a lot of thought, planning, and software application design to keep track of the program *and the activities to carry out the program*.

1) The user needs a document that describes the details of the chosen maintenance program, including listing of covered equipment, eligibility of Protection System elements for the chosen approaches, and functional procedures for testing and documentation. The program must recognize the core requirement that no part of the NERC-defined Protection System is left unchecked.

2) For all time based testing, the owner needs written or electronic records that show details of which tests were performed, and when, by whom, on which components. The record must show that all required maintenance tests are performed, time gaps within the allowed intervals are managed, and test failures are corrected.

3) For CBM, the owner needs a design document that shows how the products and their protection system application meet the requirements stated in Tables 1(b) or 1(c) that we reviewed above. For Table 1(c) compliance, monitoring map help from relay and product vendors will make the documentation task more practical for users. In general, this documentation will be massive unless the user designs new installations according to documented design-controlled standards whose site-specific variations are limited and also documented.

4) For PBM, the TBM records the owner needed in any case should be organized to show basis for time extensions described in Section 7 above, including annual evaluations of maintenance results showing continued good performance and/or action to mitigate problems.

10 Conclusions

The draft NERC PRC-005-2 Protection System Maintenance Standard may show changes as it passes through the industry comment and response process now taking place. However, it will later become mandatory and enforceable, as required by FERC. The deployment will include an implementation plan, giving protection system owners time to develop approaches and become compliant.

A time based maintenance program with prescribed activities and intervals is always allowed, with proper documentation. However, this may prove to be costly and inefficient over time. Owners may need to document a compliant TBM program, and to tighten the operation of data gathering systems in the organization that prove the program is being carried out without gaps. Once the data is compiled, the maintenance activities of reliable legacy (or newer) relays and components can be extended using a PBM program as described in Section 8.

New Protection System designs can take advantage of condition based maintenance approaches described in this paper to reduce future maintenance and data gathering work, or even eliminate most of it. Now is the time to evaluate the opportunity and to develop compliant design standards, as well to document those designs and to develop automated field data gathering systems.

The industry can follow the evolution and deployment of the new Standard via the links to the NERC web site in Section 7 of this paper.

11 Acknowledgement

The members of the Standards Drafting Team for PRC-005-2 are:

- Charles Rogers, Consumers Energy, Chairman
- John Anderson, Xcel Energy
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- Bob Bentert, Florida Power and Light
- Al Calafiore, NERC Staff
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- Sam Francis, Oncor Energy Delivery
- Carol Gerou, Midwest Reliability Organization
- Russell Hardison, TVA
- David Harper, NRG Texas Maintenance Services
- John Kruse, Exelon
- Mark Peterson, Great River Energy
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- Leonard Swanson, National Grid USA
- Eric Udren, Quanta Technology
- Philip Winston, Georgia Power Company
- John Zipp, ITC Holdings

In addition, twenty five others have attended at least one, and usually several, Standards Drafting Team meetings, and have all contributed significantly to the work of the Standards Drafting Team.

Eric A. Udren has a 40 year distinguished career in design and application of protective relaying, utility substation control, and communications systems. He programmed the world's first computer based transmission line relay, led software development of the world's first LAN-based substation protection and control system, and managed development and application at Westinghouse, ABB, and Eaton Electrical. He has worked with utilities to develop new substation protection and control designs as a consultant since 2004. He is now Executive Advisor with Quanta Technology and is based in Pittsburgh.

Eric is IEEE Fellow, and chairs multiple standards working groups at IEEE Power System Relaying Committee. He is US Technical Advisor for IEC relay standards; and is member of the IEC 61850 substation communications protocol WG. Eric serves on the North American Electric Reliability Corporation (NERC) System Protection and Control Task Force, and Protection System Maintenance Standard Drafting Team. He has written and presented over 50 technical papers and book chapters. He can be reached at eudren@quanta-technology.com.

Charles W. Rogers, a Principal Engineer at Consumers Energy, has worked there since 1978, primarily responsible for a broad spectrum of activities related to transmission system protection. In addition to general protection of transmission systems, he has been responsible for the interconnection protection of distributed generators (since 1980) and for all switching surge analysis activities at Consumers (since 1985). He is currently responsible for managing and coordinating all NERC compliance activities for the transmission and distribution functions at Consumers Energy.

A Senior Member of IEEE, Charles has been extremely active on the IEEE Standards Coordinating Committee 21 P1547 working group, developing national standards related to the interconnection of distributed generation since 1997.

Charles led the ECAR investigation into the August 14, 2003 blackout, and, from 2004 through mid-2008, was the Chairman of the NERC System Protection and Control Task Force. He was the Chairman of the NERC Standard Drafting Team that developed NERC Standard PRC-023-1 – Transmission Relay Loadability, and currently chairs the NERC Standard Drafting Team that is developing the emergent NERC Standard PRC-005-1 – Protection System Maintenance.

Standard Development Roadmap

This section is maintained by the drafting team during the development of the standard and will be removed when the standard becomes effective.

Development Steps Completed:

1. Standards Committee approves SAR for posting on June 5, 2007.
2. The SAR was posted for comment from June 11, 2007–July 10, 2007.
3. The SC approves development of the standard on August 13, 2007.
4. Drafting team posts first draft for comments (July 23, 2009).

Description of Current Draft:
This is the initial draft of the Standard. This standard merges previous standards PRC-005-0, PRC-008-0, PRC-011-0, and PRC-017-0. It also addresses FERC comments from Order 693, and addresses observations from the NERC System Protection and Control Task Force, as presented in *NERC SPCTF Assessment of Standards: PRC-005-1 — Transmission and Generation Protection System Maintenance and Testing, PRC-008-0 — Underfrequency Load Shedding Equipment Maintenance Programs, PRC-011-0 — UVLS System Maintenance and Testing, PRC-017-0 — Special Protection System Maintenance and Testing.*

Future Development Plan:

Anticipated Actions	Anticipated Date
1. Post response to comments and second draft of standard and associated documents.	To be determined.

Definitions of Terms Used in Standard

This section includes all newly defined or revised terms used in the proposed standard. Terms already defined in the Reliability Standards Glossary of Terms are not repeated here. New or revised definitions listed below become approved when the proposed standard is approved. When the standard becomes effective, these defined terms will be removed from the individual standard and added to the Glossary.

Protection System Maintenance Program (PSMP) — An ongoing program by which Protection System components are kept in working order and proper operation of malfunctioning components is restored. A maintenance program can include:

- Verification — A means of determining that the component is functioning correctly.
- Monitoring — Observation of the routine in-service operation of the component.
- Testing — Application of signals to a component to observe functional performance or output behavior, or to diagnose problems.
- Physical inspection — To detect visible signs of component failure, reduced performance and degradation.
- Calibration — Adjustment of the operating threshold or measurement accuracy of a measuring element to meet the intended performance requirement.
- Upkeep — Routine activities necessary to assure that the component remains in good working order and implementation of any manufacturer's hardware and software service advisories which are relevant to the application of the device.
- Restoration — The actions to restore proper operation of malfunctioning components.

Protection System (modification) — Protective relays, associated communication systems necessary for correct operation of protective devices, voltage and current sensing inputs to protective relays, station DC supply, and DC control circuitry from the station DC supply through the trip coil(s) of the circuit breakers or other interrupting devices.

A. Introduction

1. **Title:** **Protection System Maintenance**

2. **Number:** **PRC-005-2**

3. **Purpose:** To ensure all transmission and generation Protection Systems affecting the reliability of the Bulk Electric System (BES) are maintained.

4. **Applicability:**

   4.1. Functional Entities:

   4.1.1 Transmission Owners

   4.1.2 Generator Owners

   4.1.3 Distribution Providers

   4.2. Facilities:

   4.2.1 Protection Systems that are applied on, or are designed to provide protection for the BES.

   4.2.2 Protection System components used for underfrequency load-shedding systems which are installed per ERO underfrequency load-shedding requirements.

   4.2.3 Protection System components used for undervoltage load-shedding systems which are installed to prevent system voltage collapse or voltage instability for BES reliability.

   4.2.4 Protection System components which is installed as a Special Protection System for BES reliability.

   4.2.5 Protection Systems for Generator Facilities that are part of the BES, including:

   4.2.5.1 Protection system components that act to trip the generator either directly or via generator lockout or auxiliary tripping relays.

   4.2.5.2 Protection systems for generator step-up transformers for generators that are part of the BES.

   4.2.5.3 Protection systems for transformers connecting aggregated generation, where the aggregated generation is part of the BES (e.g., transformers connecting facilities such as wind-farms to the BES).

   4.2.5.4 Protection systems for generator-connected station service transformers for generators that are part of the BES.

   4.2.5.5 Protection systems for system-connected station service transformers for generators that are part of the BES.

5. **(Proposed) Effective Date:** **TBD**

B. Requirements

R1. Each Transmission Owner, Generator Owner, and Distribution Provider shall establish a Protection System Maintenance Program (PSMP) for its Protection Systems that use measurements of voltage, current, frequency and/or phase angle to determine anomalies and to trip a portion of the BES[1] and that are applied on, or are designed to provide protection for the BES. The PSMP shall meet the following criteria: *[Violation Risk Factor: TBD] [Time Horizon: Long Term Planning]*

1.1. For each component used in each Protection System, include all maintenance activities specified in Tables 1a, 1b, and 1c.

1.2. Identify whether each Protection System component is addressed through time-based, condition-based, performance-based, or a combination of these maintenance methods and identify the associated maintenance interval.

1.3. Include all batteries associated with a Protection System in a time-based program.

R2. Each Transmission Owner, Generator Owner, and Distribution Provider that uses condition-based maintenance intervals in its PSMP for partially or fully monitored Protection Systems shall ensure the components to which the condition-based criteria are applied (as specified in Tables 1b or 1c), possess the necessary monitoring attributes. *[Violation Risk Factor: TBD] [Time Horizon: Long Term Planning]*

R3. Each Transmission Owner, Generator Owner, and Distribution Provider that uses performance-based maintenance intervals in its PSMP shall follow the procedure established in PRC-005 Attachment A. *[Violation Risk Factor: TBD] [Time Horizon: Long Term Planning]*

R4. Each Transmission Owner, Generator Owner, and Distribution Provider shall implement its PSMP, including identification of the resolution of all maintenance correctible issues[2] as follows: *[Violation Risk Factor: TBD] [Time Horizon: Long Term Planning]*

4.1. For time-based or condition-based maintenance programs perform the Maintenance activities detailed in Table 1 (for the appropriate monitoring level(s)) for all Protection System components within maximum allowable intervals not to exceed those established in Tables 1a, 1b, and 1c.

4.2. For performance-based maintenance programs perform the maintenance activities detailed in Table 1 (for the appropriate monitoring level(s)) for all Protection System components in accordance within the maximum allowable intervals established per Requirement R3.

C. Measures (TBD)

[1] Devices that sense non-electrical conditions, such as thermal or transformer sudden pressure relays, are not included within the scope of this standard**.**

[2] A maintenance correctable issue is a failure of a device to operate within design parameters that can be restored to functional order by calibration, repair or replacement.

D. Compliance

1. Compliance Monitoring Process

1.1. Compliance Monitoring Responsibility

Regional Entity

1.2. Compliance Monitoring Period and Reset Time Frame

Not Applicable.

1.3. Compliance Monitoring and Enforcement Processes:

Compliance Audits

Self-Certifications

Spot Checking

Compliance Violation Investigations

Self-Reporting

Complaints

1.4. Data Retention

The Transmission Owner, Generator Owner, and Distribution Provider shall each retain documentation for two maintenance intervals for the Protection System components.

The Compliance Enforcement Authority shall keep the last periodic audit report and all requested and submitted subsequent compliance records.

1.5. Additional Compliance Information

2. Violation Severity Levels — TBD

E. Regional Differences

None

F. Supplemental Reference Documents

The following documents present a detailed discussion about determination of maintenance intervals and other useful information regarding establishment of a maintenance program.

1. PRC-005-2 Protection System Maintenance Supplementary Reference — July 2009.
2. NERC Protection System Maintenance Standard PRC-005-2 FREQUENTLY ASKED QUESTIONS — Practical Compliance and Implementation DRAFT 1.0 — June 2009

Version History

Version	Date	Action	Change Tracking

Table 1a — Level 1 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Unmonitored Protection Systems **General Description:** Protection System components which do not have self-monitoring alarms, or if self-monitoring alarms are available, the alarms are not transmitted to a location where action can be taken for alarmed failures.		
Type of Component	**Maximum Maintenance Interval**	**Maintenance Activities**
Protective Relays	6 Calendar Years	Test and calibrate the relays (other than microprocessor relays) with simulated electrical inputs. (Note 1) Verify proper functioning of the relay trip outputs. For microprocessor relays verify proper functioning of the A/D converters (Note 2) Verify that settings are as specified.
Voltage and Current Sensing Devices Inputs to Protective Relays	12 Calendar Years	Verify proper functioning of the current and voltage circuit inputs from the voltage and current sensing devices to the protective relays
Protection System Control Circuitry (Breaker Trip Coil Only) (except for UFLS or UVLS)	3 Months	Verify the continuity of the breaker trip circuit including trip coil (except for protection system control circuitry associated with breakers that remain open for the entire “maintenance interval” period”)
Protection System Control Circuitry (Trip Circuits) (except for UFLS or UVLS)	6 Calendar Years	Perform a complete functional trip test that includes all sections of the Protection System trip circuit, including all auxiliary contacts essential to proper functioning of the Protection System.
Protection System Control Circuitry (Trip Circuits) (UFLS/UVLS Systems Only)	(when the associated UVLS or UFLS system is maintained)	Perform a complete functional trip test that includes all sections of the Protection System trip circuit, including all auxiliary contacts essential to proper functioning of the Protection System.

Table 1a — Level 1 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Unmonitored Protection Systems

General Description: Protection System components which do not have self-monitoring alarms, or if self-monitoring alarms are available, the alarms are not transmitted to a location where action can be taken for alarmed failures.

Type of Component	Maximum Maintenance Interval	Maintenance Activities
Station dc supply (that has as a component any type of battery)	3 Months	Verify proper electrolyte level (excluding valve-regulated lead acid batteries). Verify proper voltage of the station battery. Verify that no dc supply grounds are present.
Station dc supply (that has as a component any type of battery)	18 Months	Verify proper voltage of each individual cell or unit in the station battery. Verify that station battery charger provides the correct float and equalize voltages. Verify continuity and cell integrity of entire battery. Perform a visual cell inspection of all cells for “cell condition” (where cells are visible) or measurement of cell/unit internal ohmic values (where cells are not visible). Measure that specific gravity and temperature of each cell is within tolerance(where applicable) Verify cell to cell and terminal connection resistance is within tolerance Inspect the structural integrity of the battery rack.
Station dc supply (that has as a component Valve Regulated Lead-Acid batteries)	3 Calendar Years - or - 3 Months	Verify that the station battery can perform as designed by conducting a performance or service capacity test of the entire battery bank. (3 calendar years) - or - Verify that the station battery can perform as designed by evaluating the measured cell/unit internal ohmic values to station battery baseline. (3 months)

Table 1a — Level 1 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Unmonitored Protection Systems

General Description: Protection System components which do not have self-monitoring alarms, or if self-monitoring alarms are available, the alarms are not transmitted to a location where action can be taken for alarmed failures.

Type of Component	Maximum Maintenance Interval	Maintenance Activities
Station dc supply (that has as a component Vented Lead-Acid Batteries)	6 Calendar Years - or - 18 Months	Verify that the station battery can perform as designed by conducting a performance, service, or modified performance capacity test of the entire battery bank. (6 calendar years) - or - Verify that the station battery can perform as designed by evaluating the measured cell/unit internal ohmic values to station battery baseline. (18 Months)
Station dc supply (that has as a component Nickel-Cadmium batteries)	6 Calendar Years	Verify that the substation battery can perform as designed by conducting a performance service, or modified performance capacity test of the entire battery bank.
Station dc supply (that uses a battery and charger)	6 Calendar Years	Verify that the battery charger can perform as designed by testing that the charger will provide full rated current and will properly current-limit.
Station dc Supply (battery is not used)	18 Months	Verify proper voltage of the station dc supply Verify that no dc supply grounds are present. Perform a visual inspection, of all components of the station dc supply to verify that the physical condition of the station dc supply is as desired and any visual inspection if required by the manufacturer on the condition of the dc supply that is the source of dc power when ac power is unavailable. Verify where applicable the proper voltage level of each component of the station dc supply. Verify the correct operation of ac powered dc power supplies. Verify the continuity of all circuit connections that can be affected by wear or corrosion.
Station dc Supply (used only for UVLS or UFLS)	(when the associated UVLS or UFLS system is maintained)	Verify proper voltage of the dc supply.

Table 1a — Level 1 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Unmonitored Protection Systems

General Description: Protection System components which do not have self-monitoring alarms, or if self-monitoring alarms are available, the alarms are not transmitted to a location where action can be taken for alarmed failures.

Type of Component	Maximum Maintenance Interval	Maintenance Activities
Protection system communications equipment and channels.	3 Months	Verify that the Protection System communications monitoring and alarms reflect the intended communications system condition by means of a substation inspection.
Protection system communications equipment and channels.	6 Calendar Years	Verify that the performance of the channel and the quality of the channel meets performance criteria, such as via measurement of signal level, reflected power, or data error rate. Verify proper functioning of communications equipment outputs.
UVLS and UFLS relays that comprise a protection scheme distributed over the power system	6 Calendar Years	Test and calibrate the relays (other than microprocessor relays) with simulated electrical inputs. (Note 1) Verify proper functioning of the relay trip outputs. For microprocessor relays verify the proper functioning of the A/D converters (Note 2) Verify that settings are as specified.
Relay sensing for Centralized UFLS or UVLS systems	See Maintenance Activities	Perform all of the Maintenance activities listed above as established for components of the UFLS or UVLS systems at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the UFLS or UVLS components whose operation leads to that control action must each be verified.
SPS	See Maintenance Activities	Perform all of the Maintenance activities listed above as established for components of the SPS at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the SPS components whose operation leads to that control action must each be verified.

Table 1b — Condition-Based Maintenance - Level 2 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Partially Monitored Protection System Components

General Description: Protection System components whose alarms are automatically provided daily (or more frequently) to a location where action can be taken for alarmed failures. Monitoring includes all elements of level 1 monitoring with additional monitoring attributes as listed below for the individual type of component.

Type of Component	Level 2 Monitoring Attributes for Component	Maximum Maintenance Interval	Maintenance Activities
Protective Relays	Includes internal self diagnosis and alarm capability, which must assert for power supply failures. Includes input voltage or current waveform sampling three or more times per power cycle, and conversion of samples to numeric values for measurement calculations by microprocessor electronics that are also performing self diagnosis and alarming.	12 Calendar Years	Verify the status of relays is normal with no alarms indicated. Verify the proper functioning of the A/D converters within the relay by testing or comparing values against other devices. Verify proper functioning of the relay trip outputs. Verify that settings are as specified. Verify that the relay alarms will be received at the location where action can be taken. See Note 2.
Voltage and Current Sensing Devices - Inputs to Protective Relays	No Level 2 monitoring attributes are defined – use Level 1 Maintenance Activities	12 Calendar Years	Verify the proper functioning of current and voltage circuit inputs from the voltage and current sensing devices to the protective relays
Protection System Control Circuitry (Trip Coils and Auxiliary Relays)	No Level 2 monitoring attributes are defined – use Level 1 Maintenance Activities and intervals	6 Calendar Years	Verify that each breaker trip coil, each auxiliary relay, and each lockout relay is electrically operated within this time interval.
Protection System Control Circuitry (Trip Circuits) (except for UFLS/UVLS)	Monitoring and alarming of continuity of trip coil(s)	12 Calendar Years	Perform a complete functional trip test that includes all sections of the Protection System trip circuit, including all auxiliary contacts essential to proper functioning of the Protection System. Verify that the relay alarms will be received at the location where action can be taken.

Table 1b — Condition-Based Maintenance - Level 2 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Partially Monitored Protection System Components

General Description: Protection System components whose alarms are automatically provided daily (or more frequently) to a location where action can be taken for alarmed failures. Monitoring includes all elements of level 1 monitoring with additional monitoring attributes as listed below for the individual type of component.

Type of Component	Level 2 Monitoring Attributes for Component	Maximum Maintenance Interval	Maintenance Activities
Protection System Control Circuitry (Trip Circuits) (UFLS/UVLS Systems Only)	Monitoring and alarming of continuity of trip coil(s)	(when the associated UVLS or UFLS system is maintained)	Perform a complete functional trip test that includes all sections of the Protection System trip circuit, including all auxiliary contacts essential to proper functioning of the Protection System. (Verification does not require actual tripping of circuit breakers or interrupting devices.) Verify that the relay alarms will be received at the location where action can be taken.
Station dc supply (that has as a component any type of battery)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	3 Months	Verify proper electrolyte level (excluding Valve-Regulated Lead Acid batteries).
Station dc supply (that has as a component any type of battery)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	18 Months	Verify proper voltage of each individual cell or unit in the station battery. Verify that station battery charger provides the correct float and equalize voltages. Verify electrical continuity of the entire battery. Perform a visual cell inspection of all cells for “cell condition” (where cells are visible) or measurement of cell/unit internal ohmic values. (where cells are not visible) Measure that specific gravity and temperature of each cell is within tolerance. (where applicable) Verify cell to cell and terminal connection resistance is within tolerance. Inspect the structural integrity of the battery rack. Verify that the battery voltage and dc supply ground alarms will be received at the location where action can be taken.

Table 1b — Condition-Based Maintenance - Level 2 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Partially Monitored Protection System Components

General Description: Protection System components whose alarms are automatically provided daily (or more frequently) to a location where action can be taken for alarmed failures. Monitoring includes all elements of level 1 monitoring with additional monitoring attributes as listed below for the individual type of component.

Type of Component	Level 2 Monitoring Attributes for Component	Maximum Maintenance Interval	Maintenance Activities
Station dc supply (that has as a component Valve Regulated Lead-Acid batteries)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	3 Calendar Years - or - 3 Months	Verify that the station battery can perform as designed by conducting a performance or service capacity test of the entire battery bank. (3 calendar years) - or - Verify that the station battery can perform as designed by evaluating the measured cell/unit internal ohmic values to station battery baseline. (3 months)
Station dc supply (that has as a component Vented Lead-Acid batteries)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	6 Calendar Years - or - 18 Months	Verify that the substation battery can perform as designed by conducting a performance service, or modified performance capacity test of the entire battery bank. (6 calendar years) - or - Verify that the station battery can perform as designed by evaluating the measured cell/unit internal ohmic values to station battery baseline. (18 Months)
Station dc supply (that has as a component Nickel-Cadmium batteries)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	6 Calendar Years	Verify that the substation battery can perform as designed by conducting a performance service, or modified performance capacity test of the entire battery bank.
Station dc supply (that uses a battery and charger)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	6 Calendar Years	Verify that the battery charger can perform as designed by testing that the charger will provide full rated current and will properly current-limit.

Table 1b — Condition-Based Maintenance - Level 2 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Partially Monitored Protection System Components **General Description:** Protection System components whose alarms are automatically provided daily (or more frequently) to a location where action can be taken for alarmed failures. Monitoring includes all elements of level 1 monitoring with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 2 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Station dc Supply (battery is not used)	Monitoring and alarming of the station dc supply voltage. Detection and alarming of dc grounds.	18 Months	Verify proper voltage of the station dc supply, and where applicable, of each component of the station dc supply. Verify the proper operation of ac powered dc power supplies. Verify the continuity of all circuit connections that can be affected by wear or corrosion. Perform a visual inspection, of all components of the station dc supply to verify that the physical condition of the station dc supply is as desired and any visual inspection if required by the manufacturer on the condition of the dc supply that is the source of dc power when ac power is unavailable. Verify that the station dc supply voltage and dc supply ground alarms will be received at a location where action can be taken.
Station dc Supply (used only for UVLS or UFLS)	No Level 2 monitoring attributes are defined – use Level 1 Maintenance Activities and intervals	(when the associated UVLS or UFLS system is maintained)	Verify proper voltage of the dc supply
Protection system communications equipment and channels.	Monitoring and alarming of protection communications system by mechanisms that check for presence of the communications channel.	12 Calendar Years	Verify that the performance of the channel and the quality of the channel meets performance criteria, such as via measurement of signal level, reflected power, or data error rate. Verify proper functioning of communications equipment outputs. Verify proper functioning of alarm notification.

Table 1b — Condition-Based Maintenance - Level 2 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Partially Monitored Protection System Components

General Description: Protection System components whose alarms are automatically provided daily (or more frequently) to a location where action can be taken for alarmed failures. Monitoring includes all elements of level 1 monitoring with additional monitoring attributes as listed below for the individual type of component.

Type of Component	Level 2 Monitoring Attributes for Component	Maximum Maintenance Interval	Maintenance Activities
UVLS and UFLS relays that comprise a protection scheme distributed over the power system.	Includes internal self diagnosis and alarm capability, which must assert for power supply failures. Includes input voltage or current waveform sampling three or more times per power cycle, and conversion of samples to numeric values for measurement calculations by microprocessor electronics that are also performing self diagnosis and alarming.	12 Calendar Years	Verify the status of relays as in service with no alarms. Verify the proper function of the A/D converters (if included in relay). Verify proper functioning of the relay trip outputs. Verify that settings are as specified. Verify that the relay alarms will be received at the location where action can be taken.
Relay sensing for centralized UFLS or UVLS systems.	See the attributes of Level 1 Monitoring for the individual components of the SPS	See Maintenance Intervals for the individual components of the UFLS/UVLS	Perform all of the Maintenance activities listed above as established for components of the UFLS or UVLS systems at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the UFLS or UVLS components whose operation leads to that control action must each be verified.
SPS	See the attributes of Level 1 Monitoring for the individual components of the SPS	See Maintenance Intervals for the individual components of the SPS	Perform all of the Maintenance activities listed above as established for components of the SPS, at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the SPS components whose operation leads to that control action must each be verified.

Table 1c — Condition-based Maintenance — Level 3 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems **General Description:** Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 3 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Protective Relays	The relay A/D converters are continuously monitored and alarmed.	Continuous	Continuous verification of the status of the relays. (Note 2) Alarm on change of settings.
Protective Relays with trip contacts	All Level attributes, except relay possesses mechanical output contacts.	12 Calendar Years	Verify proper functioning of the relay trip contacts.
Voltage and Current Sensing Devices Inputs to Protective Relays	Verification of the ac analog values (magnitude and phase angle) measured by the microprocessor relay or comparable device, by comparing against other measurements using other instrument transformers.	Continuous	Continuous verification and comparison of the current and voltage signals from the voltage and current sensing devices of the Protection System.
Protection System Control Circuitry (Trip Coils and Auxiliary Relays)	No Level 3 monitoring attributes are defined – use Level 2 Maintenance Activities and intervals	6 Calendar Years	Each breaker trip coil, each auxiliary relay, and each lockout relay must be electrically operated within this time interval.

Table 1c — Condition-based Maintenance — Level 3 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems			
General Description: Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 3 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Protection System Control Circuitry (Trip Circuits)	Monitoring of the continuity of breaker trip circuits (with alarming for non-continuity), along with the presence of tripping voltage supply all the way from relay terminals (or from inside the relay) through to the trip coil, including any auxiliary contacts essential to proper Protection System operation. If a trip circuit comprises multiple paths, each of the paths must be monitored, including monitoring of the operating coil circuit(s) and the tripping circuits of auxiliary tripping relays and lockout relays.	Continuous	Continuous monitoring of trip voltage and trip path integrity of entire trip circuit is provided with alarming to remote terminal unit upon any failure of the trip path.

Table 1c — Condition-based Maintenance — Level 3 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems **General Description:** Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 3 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Station dc Supply (any battery technology)	Monitoring and alarming the station dc supply status, including, for station dc supplies that have as a component a battery, the voltage, specific gravity, electrolyte level, temperature and connectivity (cell to cell and terminal connection resistance) of each cell as well as the battery system terminal voltage and electrical continuity of the overall battery system. Monitoring and alarming if the performance capability of the battery is degraded. Monitoring and alarming the ac powered dc power supply status including low and high voltage and charge rate for station dc supplies that have battery systems. Detection and alarming of dc grounds.	18 Months	Verify that station battery charger operation provides the correct float and equalize voltages Perform a visual inspection of the station battery and charger, individual cells (including electrolyte level), connections, and racks to verify that the physical condition of the battery is as desired, and that no associated alarm lamps are illuminated.

Table 1c — Condition-based Maintenance — Level 3 Monitoring

Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems

General Description: Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.

Type of Component	Level 3 Monitoring Attributes for Component	Maximum Maintenance Interval	Maintenance Activities
Station dc supply (that uses a battery and charger)	Monitoring and alarming the station dc supply status, including, for station dc supplies that have as a component a battery, the voltage, specific gravity, electrolyte level, temperature and connectivity (cell to cell and terminal connection resistance) of each cell as well as the battery system terminal voltage and electrical continuity of the overall battery system. Monitoring and alarming if the performance capability of the battery is degraded. Monitoring and alarming the ac powered dc power supply status including low and high voltage and charge rate for station dc supplies that have battery systems. Detection and alarming of dc grounds.	6 Calendar Years	Verify that the battery charger can perform as designed by testing that the charger will provide full rated current and will properly current-limit.

Table 1c — Condition-based Maintenance — Level 3 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems **General Description:** Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 3 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Station dc Supply (battery is not used)	Monitoring and alarming the station dc supply status, including output voltage of the dc supply. Monitoring and alarming if the performance capability of the dc supply is degraded. Detection and alarming of dc grounds.	Continuous	Continuous verification of the status of the station dc supply and its ability to deliver dc power when required, is provided.
Station dc Supply (used only for UVLS or UFLS)	No Level 3 monitoring attributes are defined – use Level 2 Maintenance Activities and intervals	(when the associated UVLS or UFLS system is maintained)	Verify proper voltage of the dc supply
Protection system telecommunications equipment and channels.	Evaluating the performance of the channel and its interface to protective relays to determine the quality of the channel and alarming if the channel does not meet performance criteria	Continuous	Continuous verification that the performance and quality of the channel meets performance criteria is provided. Continuous verification of the communications equipment alarm system is provided.
UVLS and UFLS relays that comprise a protection scheme distributed over the power system.	The relay A/D converters are continuously monitored and alarmed.	Continuous	Continuous verification of the status of the relays. (Note 2) Alarm on change of settings. Verification does not require actual tripping of circuit breakers or interrupting devices.

Table 1c — Condition-based Maintenance — Level 3 Monitoring Maximum Allowable Testing Intervals and Maintenance Activities for Fully Monitored Protection Systems			
General Description: Protection System components in which every function required for correct operation of that component is continuously monitored and verified, and detected maintenance-correctable issues reported. Level 3 Monitored Protection Systems also includes verification of the means by which alarms and monitored values are transmitted to a location where action can be taken. Detected maintenance correctable issues for Level 3 Monitored Protection Systems must be reported within 1 hour or less of the maintenance-correctable issue occurring, to a location where action can be taken. Level 3 Monitoring includes all elements of Level 2 Monitoring, with additional monitoring attributes as listed below for the individual type of component.			
Type of Component	**Level 3 Monitoring Attributes for Component**	**Maximum Maintenance Interval**	**Maintenance Activities**
Relay sensing for centralized UFLS or UVLS systems.	See the attributes of Level 3 Monitoring for the individual components of the UFLS/UVLS	See Maintenance Activities	Perform all of the Maintenance activities listed above as established for components of the UFLS or UVLS systems at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the UFLS or UVLS components whose operation leads to that control action must each be verified.
SPS	See the attributes of Level 3 Monitoring for the individual components of the SPS	See Maintenance Activities	Perform all of the Maintenance activities listed above as established for components of the SPS at the intervals established for those individual components. The output action may be breaker tripping, or other control action that must be verified, but may be verified in overlapping segments. A grouped output control action need be verified only once within the specified time interval, but all of the SPS components whose operation leads to that control action must each be verified.

Notes for Table 1a, Table 1b, and Table 1c

1. For some Protection System components, adjustment is required to bring measurement accuracy within parameters established by the asset owner based on the specific application of the component. A calibration failure is the result if testing finds the specified parameters to be out of tolerance.
2. Microprocessor relays typically are specified by manufacturers as not requiring calibration, but power system input values must be verified as correct within the Table intervals. The integrity of the digital inputs and outputs will be verified with the Protection System Control Circuitry.

PRC-005 — Attachment A

Criteria for a Performance-Based Protection System Maintenance Program

Purpose: To establish a technical basis for initial and continued use of a performance-based Protection System Maintenance Program (PSMP).

Segment: In this procedure, the term, "segment" is a grouping of Protection Systems or component devices from a single manufacturer, with common factors such that consistent performance is expected across the entire population of the segment, and shall only be defined for a population of 60 or more individual components.[3]

To establish the technical justification for the initial use of a performance-based PSMP:

1. Develop a list with a description of components included in each designated segment of the Protection System component population.
2. Maintain the components in each segment according to the time-based maximum allowable intervals established in Table 1 until results of maintenance activities for the segment are available for a minimum of 30 individual components of the segment.
3. Document the maintenance program activities and results for each segment, including maintenance dates and countable events[4] for each included component.
4. Analyze the maintenance program activities and results for each segment to determine the overall performance of the segment and develop maintenance intervals.
5. Determine the maximum allowable maintenance interval for each segment such that the segment experiences countable events on no more than 4% of the components within the segment, for the greater of either the last 30 components maintained or all components maintained in the previous year.

To maintain the technical justification for the ongoing use of a performance-based PSMP:

1. At least annually, update the list of Protection System components and segments and/or description if any changes occur within the segment.
2. Perform maintenance on the greater of 5% of the components (addressed in the performance based PSMP) in each segment or 3 individual components within the segment in each year.
3. For the prior year, analyze the maintenance program activities and results for each segment to determine the overall performance of the segment.
4. If the components in a Protection System segment maintained through a performance-based PSMP experience 4% or more countable events, develop, document, and

[3] Entities with smaller populations of component devices may aggregate their populations to define a segment and shall share all attributes of a single performance-based program for that segment.
[4] Countable events include any failure of a component requiring repair or replacement, any condition discovered during the verification activities in Table 1a through Table 1c which requires corrective action, or a Misoperation attributed to hardware failure or calibration failure.

implement an action plan to reduce the countable events to less than 4% of the segment population within 3 years.

5. Using the prior year's data, determine the maximum allowable maintenance interval for each segment such that the segment experiences countable events on no more than 4% of the components within the segment, for the greater of either the last 30 components maintained or all components maintained in the previous year.