ISO New England Operating Procedure No. 22 - Disturbance Monitoring Requirements (OP-22)

Effective Date: July 31, 2025

Review By Date: July 31, 2027

References:

NERC Reliability Standard MOD-033 - Steady-State and Dynamic System Model Validation

NERC Reliability Standard PRC-002 - Disturbance Monitoring and Reporting Requirements

ISO New England Inc. Transmission, Markets, and Services Tariff (ISO Tariff), Attachment D - ISO New England Information Policy.

ISO New England Operating Procedure No. 2 - Maintenance of Communications, Computers, Metering, and Computer Support Equipment (OP-2)

IEEE Standard C37.111 IEEE/IEC Measuring relays and protection equipment - Part 24: Common format for transient data exchange (COMTRADE) for power systems

IEEE Standard C37.118.2-2011 Standard for Synchrophasor Data Transfer for Power Systems

IEEE Standard C37.232 Standard for Common Format for Naming Time Sequence Data Files (COMNAME)

IEEE C37.242-2013 Guide to the Synchronization, Calibration, Installation, and Testing of Phasor Measurement Units (PMUs) for Power System Protection and Control

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I. PURPOSE

Information about the power system responses during system disturbances is collected by transmission station equipment called Dynamic Disturbance Recorders (DDRs) or Phasor Measurement Units (PMUs). This information is necessary for disturbance analysis, and to compare in simulations using the planning dynamic model to actual system response as required for North American Electric Reliability Corporation (NERC) Reliability Standard MOD-033 - Steady-State and Dynamic System Model Validation (MOD-033).

- This OP-22 establishes:
    - the Transmission Owner (TO) requirement to install a DDR or PMU at the specific existing and new transmission stations that are identified by ISO New England Inc. (ISO), and
    - the DDR and PMU standards to ensure that Market Participant (MP) installed equipment provides the necessary information about power system response.
- This OP-22 describes the process to establish DDR and PMU requirements, and to share DDR and PMU data.
- This OP-22 specifies the maintenance procedures and schedules that each TO shall follow to ensure the required functionality and performance is realized.

II. DDR IMPLEMENTATION

MPs shall have in-service, or be progressing towards having in-service, all the DDR equipment necessary to meet the OP-22 requirements and NERC Reliability Standard PRC-002 – Disturbance Monitoring and Reporting Requirements (PRC-002) requirements.

III. PROCESS FOR DETERMINING, DOCUMENTING AND REPORTING DDR REQUIREMENTS

ISO shall determine and provide DDR location requirements to the DDR/PMU Working Group. The DDR/PMU Working Group shall meet as required to review and modify these requirements. Criteria for this review shall include additions or changes in transmission configuration, generation, load patterns, analytical needs and technological developments.

A. DDR Locations

DDR locations shall be established and reviewed by the DDR/PMU Working Group to provide a minimum of one DDR location per 3,000 MW of peak load and with consideration of the following facilities/locations:

1. Major load centers
2. Major generation clusters
3. Major voltage sensitive areas
4. Major transmission interfaces
5. Major transmission junctions

6. Elements associated with Interconnection Reliability Operating Limits (IROLs)
7. Major Extra-High Voltage (EHV) interconnections between operating areas
8. In accordance with PRC-002 Requirement R5

B. DDR Capabilities

The DDR/PMU Working Group shall establish and review capabilities for all New England DDRs. Each New England DDR shall have the following capabilities:

1. A minimum recording time of sixty (60) seconds per triggered event.
2. A minimum data sample rate of 960 samples per second, and a minimum data rate for Root Mean Square (RMS) quantities of six (6) data points per second.
3. Set to trigger for at least one of the following:
   a. Rate of change of frequency
   b. Rate of change of power
   c. Delta frequency
   d. Oscillation of frequency
   e. Voltage rate of change and voltage magnitude of change
4. Recorders installed after the enforceable date of PRC-002-2 shall function as continuous recorders. Recorders installed prior to that date shall meet PRC-002-2 triggering requirements.
5. Each recorder shall have the capability of monitoring all listed elements from Appendix A at a station. For example, all 345 kV listed elements shall be measured at a station.
6. Each DDR shall meet or exceed PRC-002 requirements.
7. By June 1, 2022, each DDR shall function as a PMU or a separate PMU shall be installed in addition to the DDR, with identical monitoring capabilities. PMUs shall stream data continuously to ISO for disturbance analysis, and meet the other requirements contained in Section VI of this OP-22.

C. DDR Monitored or Derived Quantities

The monitored or derived quantities that a DDR provides shall be established and reviewed by the DDR/PMU Working Group so that the following information is provided:

1. Line currents for most lines such that normal line maintenance activities do **not** interfere with DDR functionality
2. Bus voltages such that normal bus maintenance activities do **not** interfere with DDR functionality
3. As a minimum, one phase current per monitored element, expressed in amps, and two phase-to-neutral voltages of different elements. One of the monitored voltages shall be of the same phase as the monitored element.
4. Frequency
5. Real and reactive power

D. Documenting And Reporting DDR/PMU Locations, Capabilities And Monitored Or Derived Quantities

The DDR/PMU Working Group shall develop and maintain a confidential DDR Status Document that lists the capabilities, and monitored or derived quantities of each DDR/PMU. The appendices to this OP-22 shall include the following information for each DDR/PMU:

1. Make and model of equipment
2. Installation location
3. Operational Status (planned, active, removed)
4. Date last tested
5. Monitored Elements (lines, transformers, SVCs, STATCOMs, HVDC terminals, etc.)
6. All identified channels
7. Monitored electrical quantities
8. Type and level of trigger settings
9. Rate at which primary quantities (voltage, current) is sampled by the device
10. For triggered events, rate at which data is stored
11. For triggered events, length of time of pre-event data
12. For triggered events, length of time data is recorded after event is detected
13. For continuous data, rate at which data is stored.
14. Transmission station engineering one-line drawings marking the location of PMU signals to the device shall be provided so that the location in relationship to substation and transmission equipment can be determined. The diagram markings shall have a clear connection to the signal names on the registration form. An example drawing is shown below in Figure 1. Figure 1 has nomenclature blurred for public release, documents provided to ISO will not have blurring. Other drawing formats than that shown in Figure 1 are permissible but for drawings that are not clear, it will be necessary to have discussions with Transmission Owners to detail PMU signal connections. For existing PMUs, it is not necessary to provide new updated one-line drawings.

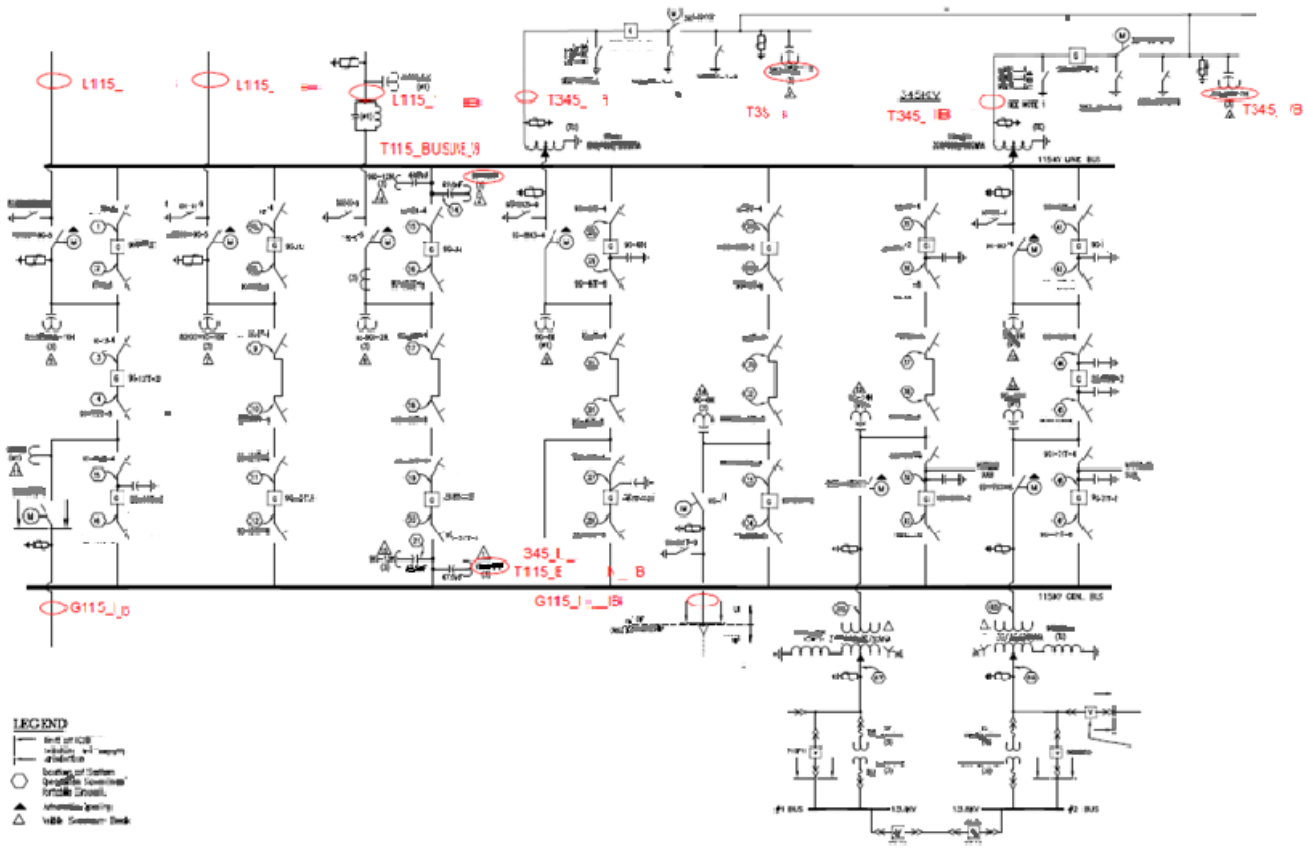

Figure 1 – Sample One-Line Drawing with PMU Inputs (intentionally blurred nomenclature for public release)

IV. PROCESS FOR SHARING DDR DATA

PRC-002 requires Reliability Coordinators (RCs), and TOs to provide DDR data upon request. DDR data may contain information about specific generators and about the critical energy infrastructure of New England. For these reasons, all DDR data, including the list of DDR locations, must be protected under the ISO New England Inc. Transmission, Markets, and Services Tariff (ISO Tariff), Attachment D - ISO New England Information Policy. TOs shall submit DDR data to ISO when requested using the method described in the request.

A. Entities That May Request DDR Data

NOTE

DDR data shall be made available in accordance with the ISO Tariff Attachment D - ISO New England Information Policy

External entities which can request data are:

a. Federal Energy Regulatory Commission (FERC),

b. NERC

c. Northeast Power Coordinating Council Inc. (NPCC).

d. TOs and Generation Owners (GOs) within NPCC

B. Entities That Must Provide DDR Data

In all cases as applicable, TOs shall provide DDR data to the requesting entity as they are defined in Section IV.A. ISO shall **not** provide data to any requesting entity on behalf of a TO.

C. Time Frame Within Which DDR Data Must Be Provided

Data shall be provided to the requesting entity within thirty (30) days from receipt of a request.

D. Information That The Requesting Entity Must Provide To The TO Or GO

The requesting entity must provide the following data:

1. Time of the event, to the nearest second.
2. Specific area for which DDR data is requested.

E. Format In Which The TO Must Provide DDR Data

The format in which DDR data is provided shall have the following attributes:

1. The data files shall be capable of being viewed, read, and analyzed with a generic COMTRADE analysis tool as per the latest revision of IEEE Standard C37.111.
2. Disturbance Data files shall be named in conformance with the latest revision of IEEE Standard C37.232.
3. DDR Files shall contain all fields established in Section III.C.

V. COMPLIANCE

Periodically, NPCC may conduct an audit survey of metering, recording devices and telemetering criteria to determine the degree of MP compliance with all NERC Reliability Standard Requirements.

The Chair of the DDR/PMU Working Group shall review the program annually to verify ongoing compliance with the NERC Reliability Standard Requirements.

VI. PMU REQUIREMENTS

A PMU provides data that is used in analyzing power system response. This section provides the requirements for PMUs as established by the DDR/PMU Working Group. A stand-alone PMU is **not** subject to the PRC-002 requirements for a DDR unless it is also used as a DDR. Each PMU shall meet the following requirements:

1. Each PMU shall provide a stream of synchrophasors for each required current and voltage in IEEE Standard C37.118-2005 format. The data stream channel names shall adhere to the submitted and approved Registry form. A template for the Registry form is provided in Appendix C. All synchrophasor data shall be reported in Coordinated Universal Time ("UTC time") with zero offset.
2. The timing device providing the clock signal shall be accurate to at least one microsecond. Equipment shall also support correct leap second insertion. The timing signal shall be of sufficient strength for each PMU device.
3. The PMU shall develop and transmit a synchrophasor at least once every one-thirtieth of a second with the capability of increasing the rate to once every one-sixtieth of a second.
4. Synchrophasors shall be derived from all three phases or from a single phase measurement:
    a. If three phase measurements are used, only one synchrophasor shall be provided (i.e., the positive sequence synchrophasor).
    b. If single phase measurements are used, the voltage synchrophasor shall be derived from the same phase as the current synchrophasor, and both shall originate from phase B if possible.
    c. For the ISO calculated MW and MVAR derived from the voltage and current signals, the TO must follow the polarity convention designated in OP-18 Appendix D, Figure 1.
5. Voltage synchrophasors for each station bus shall be provided from each specified voltage level or if measurements are based on equipment connected to only one bus, then two or more independent voltage synchrophasors shall be provided. If an independent source voltage is not available, then line voltage measurements are acceptable. Bus voltage measurements are preferred but multiple line voltage measurements are acceptable if bus measurements are **not** readily available.
6. Voltage and current measurements shall be provided on all specified facilities per Appendix B as indicated in the column "Monitored Electrical Quantities"
7. PMUs shall be powered by the station DC supply.

8. PMUs shall stream data continuously to ISO through a SCADA Center or LCC Phasor Data Concentrator (PDC). Compliance for PMU data streaming remains the responsibility of the PMU owner.
9. Each PDC shall have at least thirty (30) days of local storage capability.
10. The PMU shall continuously stream all current (I) and voltage (V) channel data to ISO throughout power system events. If a PMU or an associated PDC does not continuously stream during a power system event, then the TO responsible for the PMU and PDC shall respond to an ISO request for information by providing:
    a. All available disturbance monitoring equipment information and records within ten (10) Business Days. Under special circumstances (e.g. storm restoration) the ten Business Day response may be extended by agreement between ISO-NE and the responsible TO.
    b. A detailed description of why the PMU or PDC failed, within sixty (60) calendar days.
    c. A Corrective Action Plan provided within ninety (90) calendar days of the ISO request for information.
11. If PMU communications are lost during an event, the ISO shall notify the TO when continuous streaming is discontinued during a power system event, so that troubleshooting can be facilitated by the TO. ISO shall notify the TO that the continuous streaming was lost, within ten (10) Business Days or less when data is required for ISO event analysis.
12. For PMU installations only, average Latency shall be equal to or less than 0.5 seconds. Maximum Latency shall be equal to or less than 1.5 seconds. Latency is defined as arrival time at the ISO PDC minus the PMU time stamp.

VII. PMU INSTALLATIONS FOR EXISTING FACILITIES

If existing monitoring equipment in a Pool Transmission Facility (PTF) transmission station is **not** capable of providing power system response information, PMU installations shall be required.

1. All PTF transmission stations listed in Appendix B shall include a PMU installation.
2. PMUs shall develop the synchrophasors for all transmission elements at identified voltage levels at stations as listed in Appendix B.
3. PMUs shall monitor all station elements associated with STATCOMs, Synchronous Condensers, SVCs and load where specified.
4. PMUs shall be installed in accordance with the dates listed in Appendix B.

VIII. PMU ADDITIONS WITH NEW CONSTRUCTION OR MODIFICATIONS

PMUs at PTF transmission stations provide needed information on system performance for modeling calibration, transfer and operating limit validation and optimization, and post-event re-creation, all of which are needed to reliably operate the transmission system. Any PMUs required by the below criteria will monitor the PTF transmission station and all line and transformer terminals. For purposes of this

section, the term generation means any resource connected to the PTF, non-PTF transmission or distribution systems (including any subsystem thereof or behind a customer meter) that is capable of providing energy injection or energy withdrawal (this includes, but is not limited to, inverter-based generation, electric storage resources, and distributed generation).

Transmission Owners shall install PMUs based on the following criteria:

1. All new 345 kV PTF stations and any other PTF locations as specified by ISO shall include a PMU installation. ISO shall specify new locations for PMU installations for system observability. Such locations include, but are **not** limited to, PTF transmission stations that connect significant load, transmission, HVDC or generation to the transmission system. PMUs for new 345 kV PTF stations shall be in-service when the new station goes into service. PMU in-service dates for ISO identified PTF stations will be agreed upon by ISO and the Transmission Owner.
2. When new elements are added to a station with an existing PMU, PMU monitoring shall be added and made active for the new elements on the PTF side prior to energization. Each new element requiring PMU channels shall include lines (AC and AC side of DC), transformers (high and low side for PTF transformers) and dynamic reactive devices.
3. At new or existing TO PTF stations that are at a voltage of 100 kV or greater where new generation or new dynamic reactive devices (such as synchronous condensers, statcoms or SVCs) interconnect directly to the transmission system. PMUs monitoring new generation additions and dynamic VAR devices should be monitoring and in-service when the generation begins performing non-commercial testing with initial sync.

4. At new Transmission Owner PTF stations with planned generation totaling at least 20 MVA or 20 MW nameplate, including distribution connected generation. For new PTF stations built for generator interconnection, PMUs monitoring the new generation interconnection shall be monitoring and in-service when the generation begins performing non-commercial testing.

5. For existing PTF stations that will connect at least 20 MVA or 20 MW nameplate of generation as described in this Section VIII of this OP-22, the PMUs monitoring new generation additions shall be monitoring and in-service when aggregated generation of at least 20 MVA or 20 MW nameplate begins performing non-commercial testing If commencing monitoring at the time the generation begins performing non-commercial testing is not possible, then the TO shall coordinate with ISO to determine the schedule for PMU installation.

   This threshold is met when the next generator preceding commercial status will cause the sum of the DER to equal or exceed 20 MVA or 20 MW.

6. For existing PTF stations that already connect at least 20 MVA or 20 MW nameplate of generation as described herein, the TO shall coordinate with ISO to determine the schedule for PMU installation. The TO shall determine when stations meet these criterion. For existing stations the TO shall identify the stations that meet this criteria by December 1, 2023. TOs shall

coordinate with ISO to develop a PMU installation plan using this list by February 1, 2024.

7. For stations that are non-PTF that connect 20 MVA or 20 MW of generation as described herein, PMUs shall be installed at the nearest PTF stations to capture these non-PTF station flows.

8. Distribution entity Market Participants that do not own the stations supplying them shall annually provide amounts of DER and synchronous generation installed within their service territory by station to their interconnecting Transmission Owner(s)

The ISO shall include each identified station under these criteria in Appendix B to this OP prior to the PMU being required to be in service.

IX. SIGNIFICANT MODIFICATIONS

A TO shall notify ISO of any station where PMU installation would necessitate significant modifications, such as, but **not** limited, to:

1. New cable tray or cable trench installation
2. Extensive rerouting of existing cables or other facilities
3. Additions or modifications to building structure

When notified of significant modifications per this requirement, ISO shall consider other stations for PMU installations, review those considerations with the respective TO and revise Appendix B, as needed.

X. TESTING, VERIFICATION, MAINTENANCE AND OUTAGE REPORTING

A. Overall Requirements

Each TO shall properly maintain its DDR and PMU equipment in accordance with applicable ANSI/IEEE and NERC Reliability Standards, as amended from time-to-time. The specific standards for testing, verification and maintenance are put forth in this Section X.

B. DDR/PMU Overall System Testing

To ensure the accuracy of DDR or PMU data, each TO shall perform the following tests using manual or computerized routines as specified below:

1. Initial Reasonability Tests (New or Modified Installation Prior to Streaming Data

   During commissioning or reconfiguring of PMUs, under steady-state conditions, i.e., without system events, for a period of ten (10) seconds, all timestamps must be correct up to one millisecond, and there must be **no** bad Status Flags, **no** out-of-normal range values, and **no** flat-lined values. Voltage angle must **not** have repeated consecutive values when the system frequency is **not** exactly at nominal (60 Hz). Frequency calculated from a voltage angle shall be consistent with that reported by the same PMU. Any necessary reconfiguring that is found as a result of reasonability testing shall be performed within fifteen (15) days.

2. Bench Testing

   Bench Testing shall be performed with normal field inputs to PMUs removed. The TO associated with the PMU shall install equipment to provide measured test signals for voltage and current input into the PMU in order to provide a known scaled reference output throughout the operating range.

   The TO shall calibrate or test the accuracy of systems according to manufacturer's procedures and with bench testing, at least every twelve (12) years or at ISO request due to suspected PMU data quality issues. In addition, when ISO requests PMU bench testing due to irregular PMU data quality, the TO associated with the PMU shall perform the bench testing within thirty (30) days and correct any issue found within sixty (60) days of the notification of the suspected data quality issues.

   Errors should **not** exceed an error of +/- 0.25 % of full scale. If during the test, errors exceed this value, the device shall be recalibrated, repaired or replaced as necessary within ninety (90) days to attain that accuracy.

C. Record Keeping and Auditing

Each TO shall maintain records of the testing and verification of all DDR and PMU equipment that is required to be installed in accordance with the provisions of this OP-22. The records shall include:

- Entity name
- Element (line, bus, transformer, etc.) name covered by telemetry
- Name of telemetering device (or system)
- The dates of testing or verification
- % error of as-found (and as-left if recalibrated or replaced)
- A note, if as-found is **not** within accuracy tolerance
- Action(s) taken (if applicable) including date(s) of action(s)

These records shall be retained for a minimum of the two (2) most current testing (or verification) cycles or since the last audit (whichever is greater) and shall be available to ISO and the LCC upon request.

D. PDC Software Updates

To obtain reliable data, the PDC shall use a reliable version of software or firmware in agreement with ISO. Prior to installation, any new software updates shall be assessed by the TO and tested prior to production use to ensure software has been verified for the upgrade.

E. Clock Out-of-Synch

If the time source is out-of-service or out of synchronization, then a Real-Time notification to TO personnel shall indicate clock out-of-synch.

F. Testing and Outage Notifications

Maintenance testing and outage requests shall be in accordance with ISO Operating Procedure OP-2 Maintenance of Communications, Computers, Metering, and Computer Support Equipment.

1. Planned Testing

   Prior to performing DDR, PDC or PMU testing, or testing of input signals (i.e. CT or VT inputs), the TO shall either take the DDR, PDC or PMU out-of-service or stop output from the tested device to prevent erroneous signals from being sent.

2. Planned Outage Notifications

   Planned DDR, PDC or PMU maintenance outage notifications shall be made to the ISO Manager, Real-Time Studies. Outage requests shall be made at least two (2) Business Days prior to the outage.

3. DDR, PDC or PMU Out-of-Service Notification

   When a DDR listed in Appendix A or PMU listed in Appendix B receives an "Out of Service" alarm, the TO associated with the DDR or PMU shall, within two (2) Business Days of the initial discovery, either resolve the issue or notify the ISO Manager, Real-Time Studies via email, of the outage.

   When a TO associated with the PDC receives an "Out of Service" alarm, the TO shall notify the ISO Manager, Real-Time Studies.

4. Clock Out-of-Synch or Service Notification

   When a Clock associated with a DDR or PMU receives an "Out of Sync" or "Out of Service" alarm, the TO associated with the Clock shall, within two (2) Business Days of the initial discovery, either resolve the issue or notify the ISO Manager, Real-Time Studies with a time estimate of when the Clock will be returned to service.

G. Restoration of PDC Equipment to Service

The PDC shall be restored to service within five (5) Business Days. Under special circumstances (e.g. storm restoration or failure of primary and back-up systems), the five Business Day response may be extended by agreement between ISO-NE and the responsible TO.

H. Restoration of DDR, and PMU Equipment to Service

The TO associated with a DDR or PMU shall make all reasonable efforts to restore equipment to service that is forced out-of-service or if the quality of data is inadequate. Restoration should be within 90 days. If an outage lasts longer than fifteen days, then the TO associated with the DDR or PMU shall provide a monthly update regarding equipment status to the ISO Manager, Real-Time Studies. The update shall include the reason for the extended outage; a repair progress update; purchase order numbers for parts and technical services; hours that have been expended on equipment repair; and, updates to the corrective action plan.

XI. OP-22 REVISION HISTORY

Rev. No.	Date	Reason
0	05/04/12	Initial Issue
0.1	02/25/14	Periodic review performed requiring no changes; Made administrative changes required to publish a Minor Revision;
1	01/22/15	Periodic review completed by procedure owner; Section III; identified new DDR Owner responsibilities; Section VIII, added new Appendix A - DDR Information (Confidential)
2	06/06/16	Updated for retirement of PRC-002-NPCC and enforcement of PRC-002; Added Section VII (PMU Requirements); Section IX. added Appendix B to Appendices list:
2.1	11/08/16	Periodic review performed requiring no changes; Made administrative changes required to publish a Minor Revision (including adding required corporate document identity to all page footers;
3	02/08/18	Periodic review completed by procedure owner; Editorial changes made to be consistent with current conditions, practices and management expectations; Changes to incorporate the following requirements: • Describe the criteria for determining where PMUs will be installed; • Additional PMU/PDC Maintenance Requirements;
4	02/07/20	Biennial review completed by procedure owner; Globally made editorial changes to be consistent with current conditions, practices and management expectations; Deleted Local Control Center Instructions from coverpage;
5	04/08/21	Periodic review completed by procedure owner; Section III.D; modified acronym from “DDR” to read “DDR/PMU"; Section VI.9: identified responsible party for maintaining streaming data compliance; VI.11.d and e; add new criteria notification and data latency standard Section VIII.3: added new criteria to determine when PMU is required at a new substation
6	07/01/22	Periodic review completed by procedure owner; Updated Section VI to add registry format information; Added Appendix C – New England PMU Registration.
7	08/21/23	Periodic review completed by procedure owner; Changes to language to make it more clear when PMUs need to be in-service; Changes to language to adjust when we want PMUs for generation; Changed threshold for PMU installation from 100 MVA or MW generation to 20 MVA or MW generation.
7.1	07/31/25	Biennial review completed by procedure owner with no changes required; Made administrative changes required to publish a Minor Revision.

XII. APPENDICES

Appendix A - DDR Information (Confidential)

Appendix B - PMU Information (Confidential)

Appendix C – New England PMU Registration