NATF Inverter-Based Resources Change Management and Event Analysis

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Approval

Date	Version	Notes
06/14/2026	1.0	Initial version
09/17/2026	2.0	Added reference to PRC-028; approved for Open Distribution

Review and Update Requirements

- Review: every 5 years
- Update: as necessary

Contents

1. Purpose

Power electronics and digital controls cause inverter-based resources (IBR) to interact with the grid differently than traditional synchronous generators. IBR performance can be greatly impacted if its parameters (settings, firmware, protection, etc.) are modified. Yet, parameter changes often occur throughout the operational life of IBR. These modifications can lead to unexpected IBR behavior and performance issues during grid Disturbances if not properly communicated and updated in planning, protection, and operations models and systems.

Transmission Owners (TO) and Transmission Operators (TOP) are responsible for compliance and reliability of the Bulk Power System (BPS). An IBR owner, operator, or representative failing to provide adequate updates can result in poor IBR performance during normal operations and grid emergencies. However, communicating with and receiving updates from the IBR representatives can be challenging due to multiple communication layers and different interconnection agreement requirements.

Operations personnel can address operational and communication challenges by establishing clear change management practices for the purpose of promoting helpful IBR participation on the grid. When unexpected behavior does occur, established event analysis processes for collecting data, modeling the event, and identifying the cause will lead to timely corrective actions and mitigate further grid issues.

This document is intended to help readers with creating, communicating, and maintaining defined policies and procedures to reinforce performance requirements through effective change management and event analysis processes over the operational life of the IBR.

This document does not create, replace, or change any requirements in the NERC Reliability Standards or other applicable criteria, nor does it create binding norms by which compliance with NERC Reliability Standards is monitored or enforced. Implementation of NATF practices does not ensure compliance with the NERC Reliability Standards. In addition, this document is not intended to take precedence over any company or regional procedure. It is recognized that individual companies may use alternative and/or more specific approaches that they deem more appropriate.

2. Scope

This practice applies to functions that are involved in supporting, monitoring, and operating the BPS that could be affected by IBR performance. That may include, but is not limited to, system protection, operations support, system operations, and IBR owners, operators, and representatives.

This document focuses on an important piece of the final step of the IBR interconnection lifecycle, Performance Monitoring and Design Validation (Figure 1). It provides guidance on change management, design validation, stakeholder engagement, and the event analysis process for grid Disturbances that involve an IBR. The practices in this document are intended for in-service IBR facilities and assume all necessary information from the commissioning phase of the resource's lifecycle is available to the TO/TOP.

North American Transmission Forum

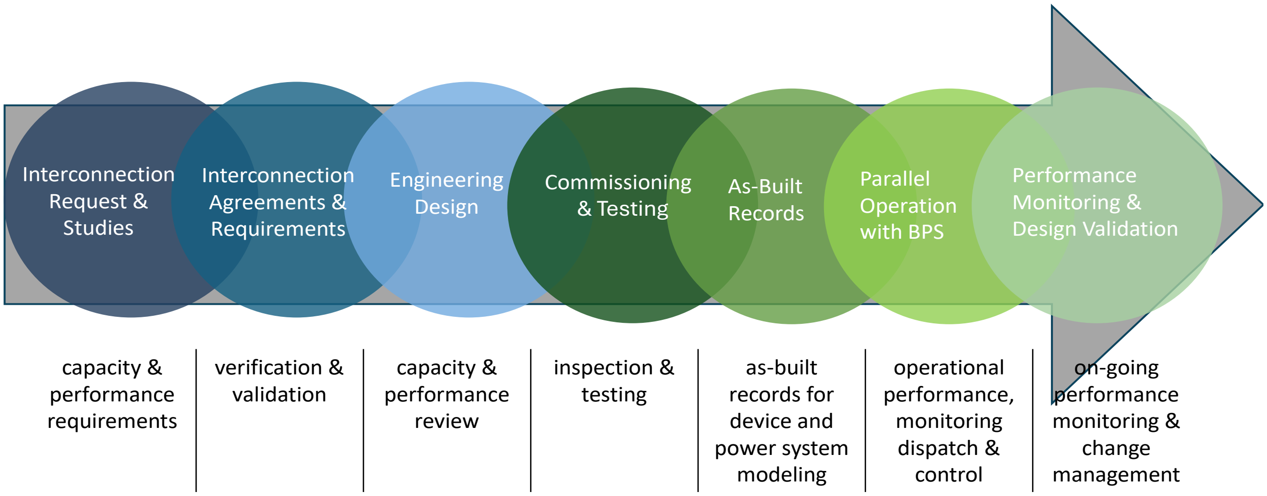

Figure 1. Inverter-based resource interconnection lifecycle

3. Definitions

NATF Practice

A documented method for performing a process, under the same or similar circumstances, in a safe, effective manner where the requisite skills, diligence, prudence, and foresight are those that are reasonably expected from skilled and experienced industry organizations.

NATF Superior Practice

A leading industry practice that can be consistently applied under a range of circumstances and that is a safe, effective, and efficient process or activity for achieving near-optimal industry results in terms of quality, reliability, and maintainability.

Co-located Plant

Two or more generation or storage resources that are operated and controlled as separate entities yet connected behind a single point of interconnection [1].

Control Center

One or more facilities hosting operating personnel that monitor and control the Bulk Electric System (BES) in real-time to perform the reliability tasks, including their associated data centers, of: 1) a Reliability Coordinator, 2) a Balancing Authority, 3) a Transmission Operator for transmission Facilities at two or more locations, or 4) a Generator Operator for generation Facilities at two or more locations [2].

Disturbance

An unplanned event that produces an abnormal system condition. Any perturbation to the electric system. The unexpected change in Reporting ACE that is caused by the sudden failure of generation or interruption of load [2].

Energy Management System (EMS)

A system used to monitor and control transmission systems and maintain wide-area situational awareness.

Inverter-Based Resource (IBR)

A plant/facility consisting of individual devices that are capable of exporting Real Power through a power electronic interface(s) such as an inverter or converter, and that are operated together as a single resource at a common point of interconnection to the electric system. Examples include, but are not limited to, plants/facilities with solar photovoltaic (PV), Type 3 and Type 4 wind, battery energy storage system (BESS), and fuel cell devices [2].

Point of Interconnection (POI)

A point where the interconnection system connects an IBR to the transmission system [1].

Transmission Operator (TOP)

The entity responsible for the reliability of its "local" transmission system, and that operates or directs the operations of the transmission facilities [2].

Transmission Owner (TO)

The entity that owns and maintains transmission facilities [2].

4. Monitoring and Assessing Performance

Operators and operations support personnel have the responsibility of ensuring IBR performance in real-time and near-term operations. Dispatch capabilities and operating performance requirements need to be clearly stated and agreed upon in the interconnection agreement prior to the IBR connecting to the transmission system. Operations personnel can use visual displays, setpoints/bands in energy management system (EMS) and supervisory control and data acquisition (SCADA), and alerts for the operators, are ways to ensure the IBR operates in accordance with the agreements. Monitoring performance establishes the reference needed to identify when IBR behavior changes and assess when an IBR event occurs.

See *NATF IBR Operating Practices* [3] for proper monitoring and control practices to assist system operators in the operation of IBR.

See *NATF EMS Modeling of Inverter-Based Resources* [4] for a complete list of IBR modeling parameters and EMS modeling practices to create operator displays and indications.

See *NATF Inverter-Based Resource Interconnection Lifecycle: Interconnection Agreements and Requirements Practices* [5] for more information on interconnection procedures and agreements.

5. Change Management

When a new IBR comes into service, the TO/TOP testing and commissioning process validates if the generation side of the facility can provide and maintain its specified requirements. The IBR operation is studied under expected conditions using the parameters provided, and approved baseline data is collected and used to reflect what is in-service in the field. Operations personnel must ensure the IBR is properly characterized in both EMS and load-flow software models if any changes to the IBR (e.g., inverter or power plant controller [PPC] settings) occur after it is in-service.

Change management helps ensure any modifications that could affect that behavior are communicated, documented, and reflected in operations models and tools. The TO/TOP should clearly set expectations that the IBR owner, operator, and representatives will communicate parameter changes (e.g. inverter settings, inverter firmware, RTU points, and PPC programming) in a timely manner. However, what information is needed, when the information is communicated, to whom the information is communicated, and in what form, can vary greatly depending on the situation.

This section describes the change management process for communicating, documenting, and authorizing requests to change the inverter or the PPC parameters, settings, firmware, models, etc. after the IBR is in-service.

NATF Practices

5.1 Establish a procedure that clearly states what, when, and how the IBR representative is to contact the appropriate operations personnel (e.g., real-time operator, operations planner, operations engineer, etc.,) when changing inverter settings, PPC settings, RTU, status, taking an outage, etc.

  5.1.1 Establish a timeframe for the IBR representative to contact the appropriate operations personnel with future planning information that affects the IBR. For example, the IBR representative sends a message with 30 days’ notice to the operations support email to inform the operations planner that the IBR will be offline for a maintenance outage.

5.1.2 Develop criteria defining the timeframe within which the IBR representative is required to contact operations personnel when the resource will be in an abnormal operating state or status, such as when the IBR:

- will be offline for an outage;
- automatic generator control (AGC) is on/off or not following AGC;
- will be in derated condition due to maintenance; and/or
- plans to change operating modes

5.1.3 Require notification when changing IBR parameters that affect interaction with the grid, such as:

- PPC logic
- firmware updates
- inverter parameters (ride through settings)

> The requirements for notification (when, what, and how) are typically identified in the interconnection agreement. However, if the requirements are not established in the agreement, procedures of the Control Center will fundamentally set the expectations for communication between the IBR representatives and system operations personnel.
>
> For more information on interconnection agreements see *NATF Inverter-Based Resource Interconnection Lifecycle: Interconnection Agreements and Requirements Practices* [5].

5.2 Ensure the IBR representative communicates planned changes through an outage planning process, which gives operations personnel time to implement and test any IBR parameter changes in EMS prior to implementation in the field.

> As IBR technology is being deployed, especially in areas without previous IBR, many issues are going to be found in real-time, requiring communication with the real-time operators. This becomes especially important if an IBR that is being used to alleviate a system constraint or as a reserve unit must come offline and require additional generation to be brought online.
>
> See *NATF Inverter-Based Resources Operating Practices* [5] for information on real-time operations communication between TO/TOP, IBR, and RTO/ISO.

5.3 Log IBR change requests and parameter updates in a centralized database. Keep the record in a system (e.g., outage management system) that is available for operators, outage planners, and operations engineers to view, edit, and save notes.

5.4 Schedule periodic meetings with IBR personnel to compare actual IBR performance to contractually required performance and discuss planned outages [5].

5.5 Establish a process for the TO/TOP to reach out periodically to the IBR representative for confirmation that the IBR parameters haven’t changed. This ensures no changes in the field were missed or mis-communicated. This request can also be used to support reiteration of the communication expectations and to verify pertinent information, such as IBR representative contact information, MW/MVAR schedule, and future outage schedule.

> It may be necessary to scan all grid-interacting parameters of each inverter regularly (e.g., once a quarter or at a minimum once a year). Regular scanning and reporting ensure the inverter parameters are returned to the commissioned settings after performing maintenance. This is especially important during the original equipment manufacturer (OEM) warranty period (typically 5 years).

6. IBR Event Data Collection

When abnormal behavior is detected, event data collection processes are necessary to gather the detailed information needed to evaluate the IBR response during an event and perform an event analysis. Furthermore, collecting high-resolution data supports model validation, real-time performance monitoring, and analyzing Disturbance data. Devices like phasor measurement units (PMU), digital fault recorders (DFR), and data/dynamic disturbance recorders (DDR) capture synchronized, high frequency data at rates of 30 samples per second or greater. Non-synchronized data from EMS/SCADA is slow to capture dynamic IBR information (e.g., 2-4 second updates), making it essential to have devices on the system that can capture high-resolution IBR data.

This section outlines IBR data collection practices that support event analysis practices.

See *NATF IBR Operating Practices* [3] for proper communication practices with IBR operators to assist system operations personnel with the collection of IBR event data.

See *NATF EMS Modeling of Inverter-Based Resources* [4] for dynamic modeling of IBR which includes additional practices for specifying IBR instrumentation, data resolution, measurements, data retention and collecting Disturbance data.

NATF Practices

6.1 Collect as much high-resolution IBR data (e.g., 30 samples/second or higher) as feasible from supporting field devices (e.g., PMUs, DFRs, and DDRs). Individual inverters may also have fast data collection methods, which is helpful for individual IBR analysis. However, each entity should determine if the data that is collected at the individual inverter is collected from all inverters or only from a sample of inverters (figure 2), while considering the individual inverter's data collection and storage capabilities. Data collection parameters include:

- three phase voltage magnitude and phase angle
- three phase current magnitude and phase angle
- positive sequence voltage and current
- frequency and frequency rate-of-change
- alarm/status change (may be available from individual inverter)

From a TO/TOP perspective, it is useful to receive IBR status data, specifically automatic voltage regulation (AVR) status and whether the facility is operating in constant voltage mode or constant VAR mode. When the IBR operates in constant voltage mode, it provides more real-time responsiveness/voltage support to the surrounding grid. This information helps the TO/TOP to determine if the IBR is actively supporting voltage and allows the TO/TOP to set up alerts when a facility is in constant VAR mode.

Interconnection requirements may need to be updated to specify necessary data collection requirements. See *Inverter-Based Resource Interconnection Lifecycle: Interconnection Agreements and Requirements Practices* [5] for additonal information.

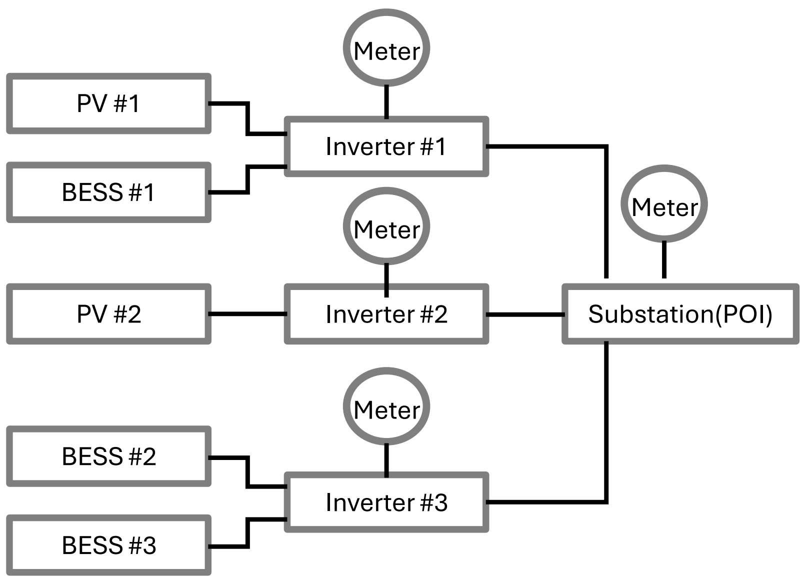

Figure 2. Illustrates how a co-located plant of individual inverters may either be measured at the individual inverter or at the point of interconnection (POI).

6.2 Establish a method to acquire high-resolution event data remotely from the IBR and/or inverters. Ensure the method accounts for data collection and storage capabilities for each type of collection device and location.

Manual data collection methods create challenges and are to be avoided if possible. When remote data collection is not possible, ensure off-site data storage locations are identified and easily accessible to facilitate timely data collection.

6.3 If not continuously saving/collecting data, set data collection to record directly before and after a triggering event.[1] This ensures the relevant data needed to conduct an event analysis is captured. For

[1] PRC-002 and PRC-028 require fault recorder data to be collected for a minimum specified time period both before and after triggering events [7].

example, a Disturbance occurs that prompts data collection, tripping the DFR to capture data five seconds before the event and 30 seconds after the event.

Some inverters take longer to reconnect to the grid; therefore, collecting data for at least 30 seconds post-event can capture the IBR coming back online.

6.4 Collect data from before, during, and after events (e.g., Disturbances, abnormal operations, etc.). IBR behaviors to prompt data collection include:

- unexpected IBR trip[2];
- unexpected "significant" reduction in IBR output reflecting a "significant" number of inverters coming offline without a related facility feeder breaker trip;
- sustained IBR MW or MVAR oscillations.

6.5 Create IBR behavior thresholds for data collection requirements. Some events, like a single inverter tripping offline, may not substantially affect the system or warrant data collection. Set thresholds for parameters including:

- MW transients (not weather dependent)
- voltage reduction/sag
- frequency transients

IBR output may not be enough to affect the system in a way that requires the same data collection as a larger unit. However, generator market requirements and NERC standards dictate Disturbance monitoring and reporting requirements for specific IBR output.[3] Therefore, the thresholds may need to be lower than market requirements and NERC Standards, but high enough to effectively capture system events for TO/TOP needs.

6.6 Capture event data from nearby buses, such as one bus away from a Disturbance. This data is useful when identifying if inverters responded appropriately (e.g., inverters tripped offline when they should not have tripped offline).

6.7 Collect the data as soon as possible following the event. Local storage is typically limited, and delaying collection could risk the data being overwritten.

6.8 Set expectations with IBR representatives to save data following an event.[4] Ensure expectations consider saving data for an extended period in instances where remote data collection is not available.

[2] See 2022 Odessa Disturbance report for a detailed list of inverter tripping causes [8].

[3] PRC-028 requirements apply to Generator Owners with BES IBR and non-BES IBR that have or contribute to an aggregate nameplate capacity of greater than or equal to 20MVA [7].

[4] PRC-028 requirements specify that each Generator Owner shall provide all requested sequence of event recording (SER), FR, and DDR data to applicable entities and shall be retrievable for the period of 20 calendar days, inclusive of the day the data was recorded [7].

6.9 Store data collected for event analyses in a location that is accessible to operations personnel to reference.

6.10 A centralized database is used to store IBR model data for operations and other personnel to view, reference, and analyze.

6.11 Evaluate the use of automated tools to retrieve event data, such as fault recording, sequence of events recording, and/or PMU recordings, for post-event analyses and assessments.

6.12 Consider collecting synchrophasor data and, as applicable, stream it to interface tools that can create displays for operations personnel to view. See "Appendix 1: Displays from PMU and Synchrophasor Data" for display examples.

6.12.1 Displays are created from the collected data to allow the operators to visualize the response of the IBR during events, and for operations personnel to retrieve data and compare the IBR response to the model during the event analysis process.

6.12.2 Alerts are created from the data collected to notify the operators of issues involving IBR facilities, such as MW transients, voltage sag, and frequency transients.

6.13 Where needed, TO/TOPs collaborate with IBR owners to retrofit the instrumentation of existing IBR facilities to enable the collection and analysis of event data such that the response to grid Disturbances can be indisputably determined.

7. IBR Event Analysis

Post-event reviews allow personnel to review data, find fixes, and drive continuous improvement to mitigate future events. It is necessary for operations personnel to have proper analysis processes, and procedures to ensure evidence is gathered for actionable results.

Identifying processes and actions in advance is critical to the overall success of an event analysis. Event analysis processes become especially important when IBR are involved. Unconventional operation and the ability for IBR to change settings remotely makes the review and reconciliation that occur during an event analysis important to the safe and reliable operation of the transmission grid.

This section covers the analysis of the IBR's ability to respond to atypical changing grid conditions (e.g., Disturbances) including the comparison of the in-service event response to the model used in commissioning the unit.

NATF Practices

7.1 Ensure there are IBR-related event identification and reporting processes that include the types of reportable events, reporting responsibilities, reporting timelines, and the entities that receive notification [3]. See section 6 for examples of events to prompt data collection and "Appendix 2: IBR Event Analysis Process Example" for an example of reporting and action processes and timelines.

7.1.1 Specify reportable events with specific thresholds to prompt data collection and review actions. For example, if the threshold was set to 10MW, and a 10MW reduction occurred, an event analysis is initiated. See section 6 for IBR behavior thresholds for data collection requirements.

7.1.2 Create clear guidance for initiating an analysis for events without specific thresholds. For example, if the system operator notices the IBR responding abnormally or customers report irregular oscillations.

7.2 Retrieve inverter grid-interaction settings (low voltage ride-through [LVRT], high voltage ride-through [HVRT or OVRT], frequency regulation system [FRS], frequency ride-through [FRT], etc.) at the time of the event and compare to the values set at the time of IBR commissioning [4].

7.3 Retrieve inter-plant logs or plant-side data for the event analysis/replication. This information will give details and insight into the event by providing information such as number of inverters lost, status of equipment at the time of the event, position of the on-load tap changer (OLTC), if the internal cap bank was in-service, etc. Having this information will make event analysis work much easier and ideally, the facility's own records would indicate the issue.

7.4 Collect and store event data using a data historian program.

7.5 A standard event data collection template is created for system operations personnel to collect the required information for each reportable IBR event [3].

7.6 Reportable events are logged in the system operator logs and frequently reviewed. For example, operator logs from the previous day are reviewed by an operations engineer for a potential reportable event and then evaluated if the IBR was involved to prompt an event analysis.

7.7 Establish procedures for the IBR representative to contact the appropriate operations personnel with preliminary event information and data following a grid event. Ensure the procedures include:

- when the preliminary event details must be sent (e.g., within 24 hours of the event or next business day);
- what preliminary information and data must be sent (e.g., inter-plant logs, fault codes); and
- to whom the information must be sent (e.g., real-time operator, operations planner, operations engineer, etc.).

> After initial contact, the IBR representative and operations representative can schedule follow-up meetings or communication according to the processes and procedures. See "Appendix 2: IBR Event Analysis Process Example" for an example of communication between TOP and IBR representative during the event analysis process.
>
> Procedures may or may not include information that is in the interconnection agreements but restate the expectations of communication between the IBR representatives and system operations personnel.

7.8 Use an event tracking process to maintain communications, meeting notes, information requested and exchanged, observations, action items, and resolution.

7.9 Use the data collected to benchmark IBR performance against model data and/or assumptions provided to the TOP during the interconnection request process and/or IBR commissioning [4].

7.9.1 Build a model of the IBR using the commissioning model of the resource in a software tool that can simulate IBR behavior.

7.9.2 Adjust the model/test case to replicate initial system conditions at the time of the event. State estimator cases and digital fault recorder data can be used to verify system conditions and topology (e.g., cap bank statuses).

7.9.3 Collect PMU data from the time of the event and overlay with the model's simulation data to evaluate the behavior of the IBR. See "Appendix 3: Event Data Visualization and Capture Examples" for examples.

7.9.4 Recreate the event and run the simulation by inputting the event data into the model.

7.9.5 Use the software tool's diagnostic features to help identify the issue/cause of the event (i.e., inverter or PPC).

7.10 Develop a process to define how a corrective action plan is developed and the timeline within which the corrective action plan must be implemented and resolved.

> Establishing and maintaining relationships with the IBR stakeholders (e.g., Generator Owner [GO], Generator Operator [GOP], or the original project development team and their vendors) is important for ensuring resolution of performance deficiencies identified by the corrective action plan [4].

7.11 Create simulations for operator training from IBR events that affected operations. Include scenarios that include prompts (e.g., alarms) and operator actions to understand how to recognize, mitigate, and recover from events.

7.12 For events requiring detailed transient analysis, consider building a model of the IBR using the commissioning model of the resource in a software tool that can simulate electromagnetic transients (EMT) (i.e., the IBR's precise behavior over time).

> It may be necessary to use a tool with EMT capability to properly replicate an event, even though such tools have limitations (e.g., not being able to identify partial inverter plant tripping or not having a full model of the IBR collector system). Tools without EMT capability (i.e., phasor domain tools) may not be able to capture all the properties necessary for IBR event replication.

7.13 Event analysis meetings are scheduled to jointly perform post-incident reviews, analyze performance, and identify areas for improvement [3].

7.14 Establish an internal event review team to analyze reportable events, as appropriate.

7.14.1 Set expectations for the team to review the analysis and results of IBR outages, frequency excursions, protection anomalies, etc.

7.14.2 Include representatives from across the organization that can support and provide input and feedback to the analysis, such as representatives from transmission lines, substations, protection engineering, compliance, operations, etc.

7.14.3 Ensure the team can affect change within the organization by taking feedback from the event analysis and updating processes, procedures, design, and/or parameters to prevent the event from recurring.

8. References

[1] Institute of Electrical and Electronics Engineers, "IEEE 2800-2022, Interconnection and Interoperability of Inverter-Based Resources Interconnecting with Associated Transmission Electric Power Systems," [Online]. Available: https://standards.ieee.org/ieee/2800/10453/.

[2] North American Electric Reliability Corporation, "Glossary of Terms Used in NERC Reliability Standards," 2026. [Online]. Available: https://www.nerc.com/globalassets/standards/reliability-standards/glossary_of_terms.pdf.

[3] North American Transmission Forum, "NATF Inverter-Based Resources Operating Practices," 9 December 2025. [Online]. Available: https://portal.natf.net/document-viewer?id={a3e23848-a3f2-6307-be03-ff00005e4fde}.

[4] North American Transmission Forum., "NATF EMS Modeling of Inverter-Based Resources Practices," 27 January 2024. [Online]. Available: https://portal.natf.net/document-viewer?id={fb0d1f48-a3f2-6307-be03-ff00005e4fde}..

[5] North American Transmission Forum, "NATF Inverter-Based Resource Interconnection Lifecycle: Interconnection Agreements and Requirements Practices," 24 September 2025. [Online]. Available: https://portal.natf.net/document-viewer?id={69c23448-a3f2-6307-be03-ff00005e4fde}.

[6] Federal Energy Regulatory Commission, "Notice of Proposed Rulemaking: Reliability Standards to Address Inverter-Based Resources," 17 November 2022. [Online]. Available: https://www.ferc.gov/media/e-2-rm22-12-000.

[7] North American Electric Reliability Corporation, "Reliability Standards," [Online]. Available: https://www.nerc.com/pa/Stand/Pages/ReliabilityStandards.aspx.

[8] North American Electric Reliability Corporation, "2022 Odessa Disturbance," [Online]. Available: https://www.nerc.com/comm/RSTC_Reliability_Guidelines/NERC_2022_Odessa_Disturbance_Report%20(1).pdf.

Appendix 1: Displays from PMU and Synchrophasor Data

These displays are examples of what can be created in a synchrophasor data interface tool using PMU data streams. The graphs and displays can be used by operators, operations support personnel, and other personnel for functions like real-time commissioning, situational awareness, current/historic trends, and event analysis.

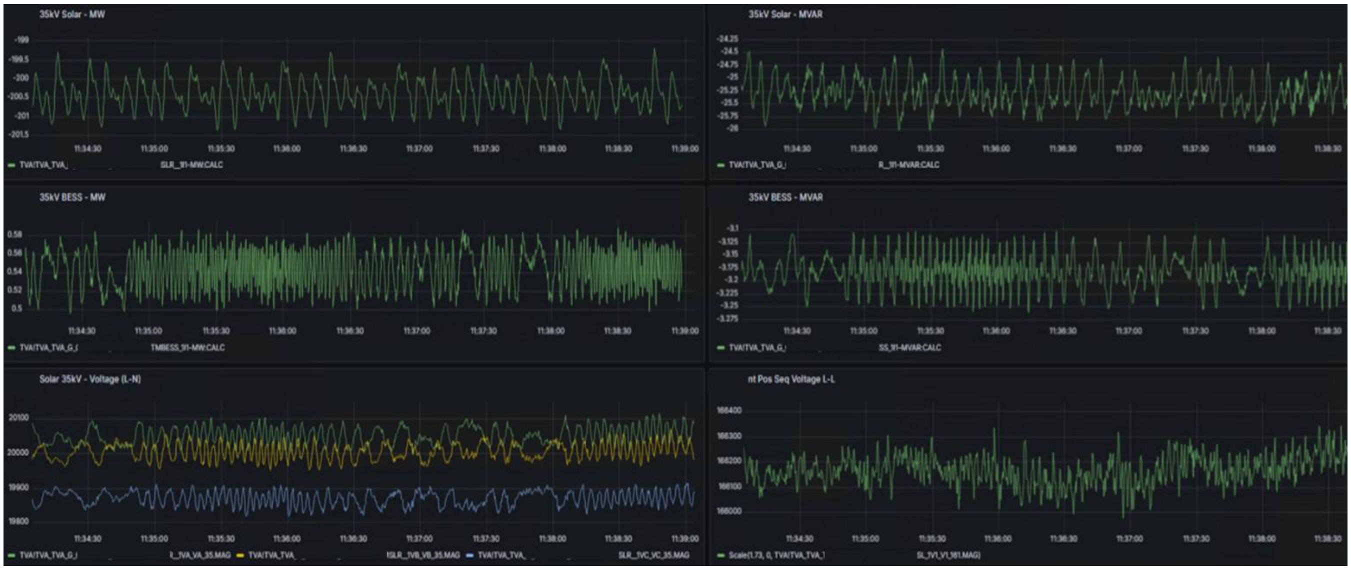

Figure 3. View of current and historic trends at solar sites.

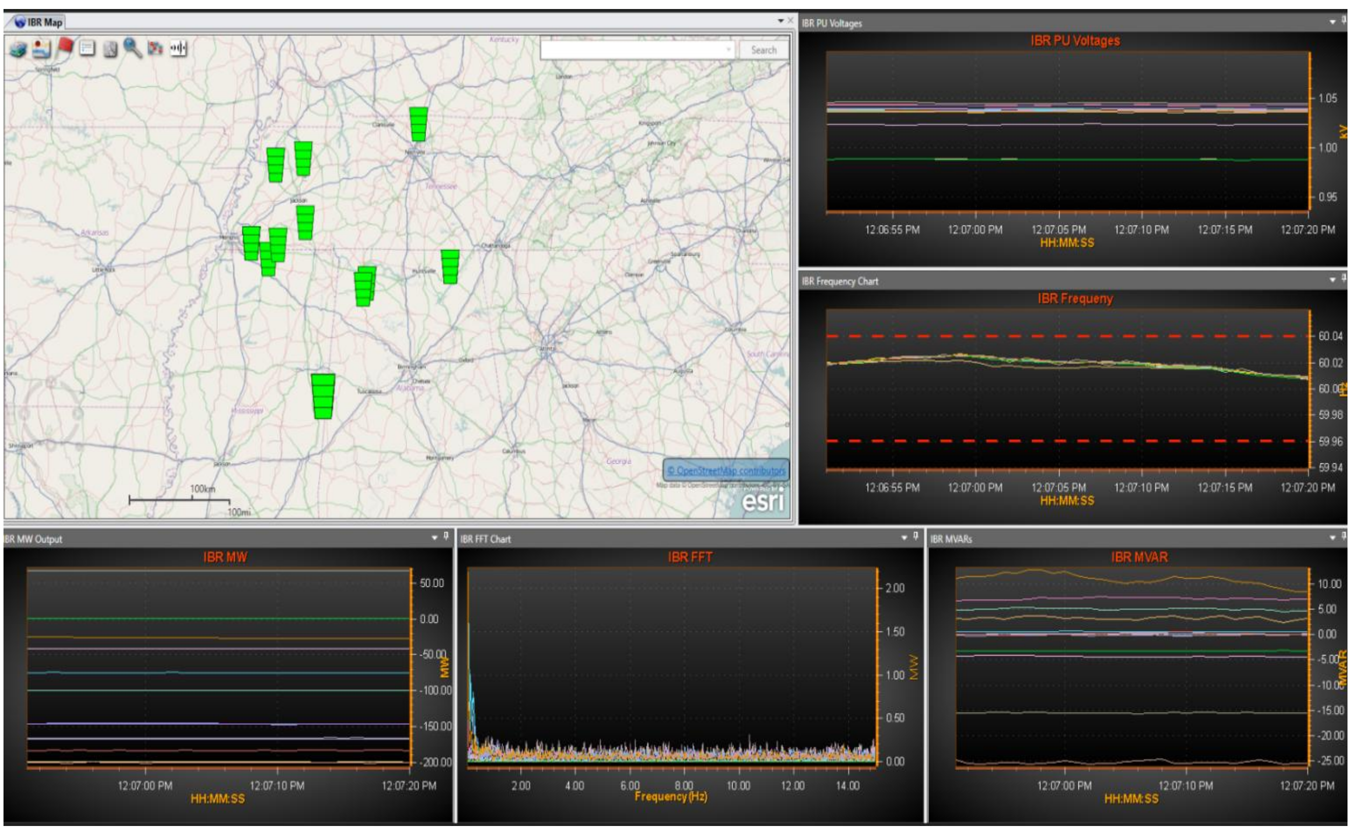

Figure 4. Oscillation monitoring display.

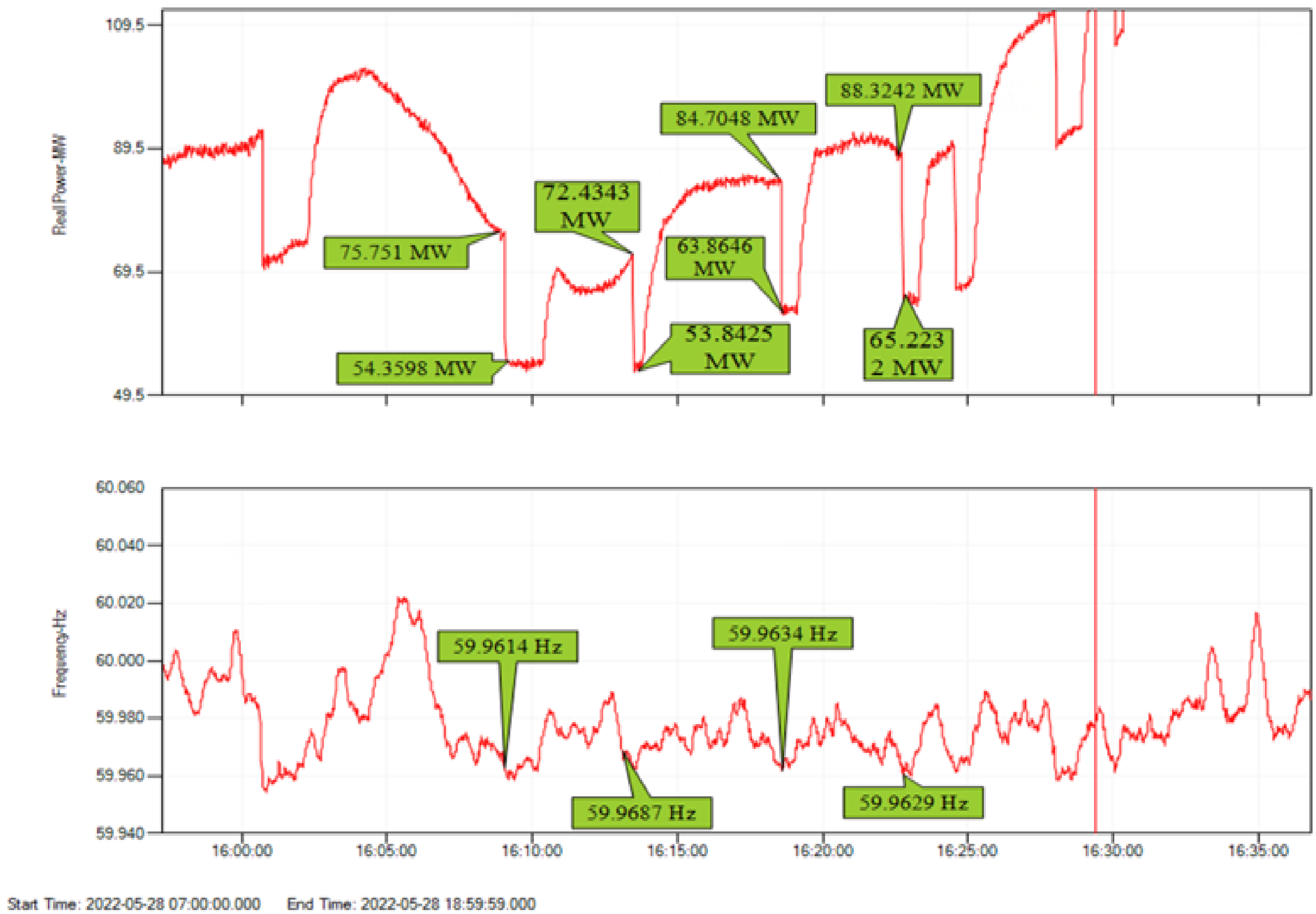

Figure 5. Display for MW and frequency excursions.

Appendix 2: IBR Event Analysis Process Example

The following example illustrates timeline, process, and the need for communication between operations and key accounts. In this example, key accounts is a group within the operations department that handles communication with external parties, such as IBR owners and operators, and manages system operations process improvement initiatives.

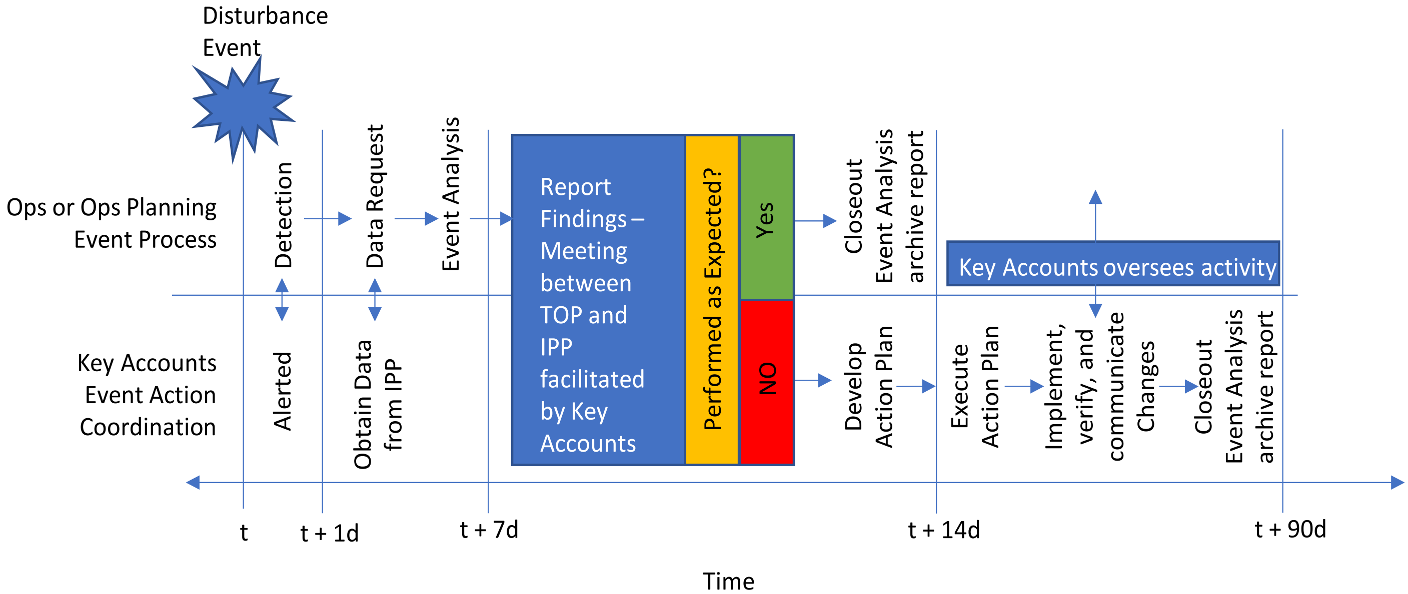

Figure 6. IBR event analysis process

Appendix 3: Event Data Visualization and Capture Examples

Tools/applications need to be implemented to allow monitoring of IBR performance under normal operating conditions and when events occur. Ideally, the implementation generates alerts when the IBR is operating differently than expected. Visualization tools can plot the data in one location so that abnormal behaviors can be easily identified. The following is a screen capture of a real-time display using high speed PMU data as an input to capture the dynamic phenomenon.

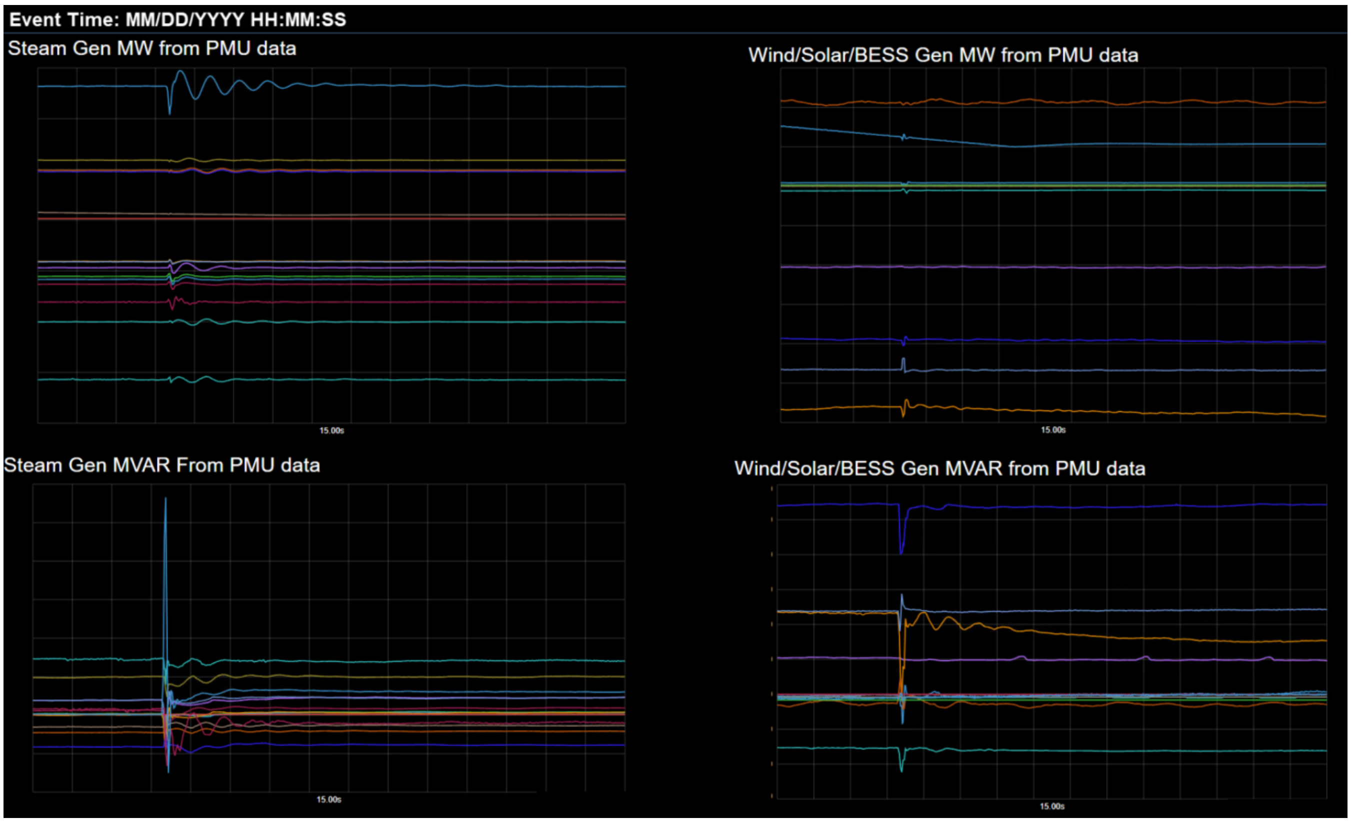

Figure 7. Real-time visualization of IBR output to enable identification of abnormal operations

The following is part of a spreadsheet used to analyze events. When an event/operating issue has been identified, the data is extracted for later analysis and sharing with the IBR owner. Plots are generated with five seconds pre-event and 40 seconds post-event data used for playback into modeling analysis tools. The spreadsheet includes data for all types of dynamic resources on the system, including STATCOMs, HVDC, SVCs, loads with significant IBR penetration, etc.

Event Time: MM/DD/YYYY HH:MM:SS
Event Description: Line close with relatively large angle difference

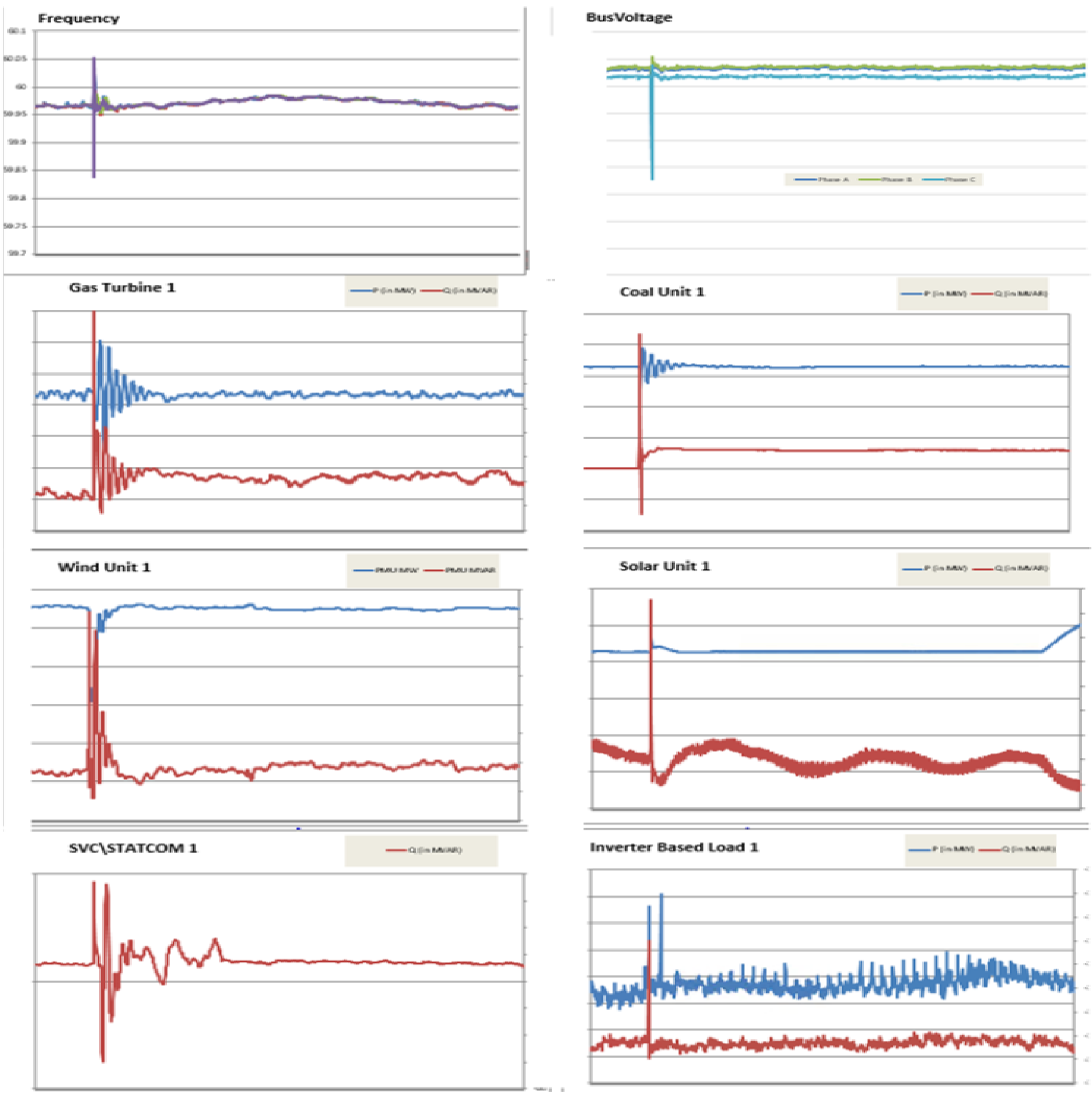

Figure 8. Post-event analysis spreadsheet data capture to allow visualization and creation of files for analysis.