WECC

Inverter-Based Resource Disturbances in the Western Interconnection

CAISO, NERC, and WECC Staff Report

October 2025

Executive Summary

NERC and Regional Entities continue to analyze disturbances involving widespread reduction of inverter-based resources (IBR) to identify any systemic reliability issues to support affected facilities as they develop mitigating measures, and to share key findings and recommendations with industry for increased awareness and action. The events identified in this report confirm that the ongoing widespread reduction of IBR resources is a notable reliability risk to the bulk power system (BPS).

This report contains four BPS disturbances involving widespread reduction of IBR output that occurred in WECC's footprint between March and June 2024.

Each disturbance was categorized as a Category 1i event per the NERC Event Analysis Process and involved widespread reduction of active power output from solar photovoltaic (PV), wind, and battery energy storage system (BESS) / hybrid resources in the entity area (specifically in areas of high penetrations of solar PV and wind resources). One of the events occurred at a time when most of the solar PV resources were not producing power and involved generation loss at both wind and BESS IBR facilities.

All initiating faults were normally cleared with proper protection system operation. These four disturbances further show the need to ensure all BPS-connected IBRs operate reliably to support the BPS.

Table 1 is an overview of the four disturbances analyzed by NERC and WECC.

Table 1: Overview of Disturbances

Disturbance	Initiating Fault Event	Description of Resource Loss*
March 25, 2024 "Vincent Disturbance"	Phase-to-Ground Fault on 500 kV bus	Loss of 1046 MW of solar PV and wind resources (28 units)
May 12, 2024 "Red Butte Disturbance"	Phase-to-Ground Fault on 345 kV Line	Loss of 532 MW of solar PV resources (8 units)
May 20, 2024 "Windhub Disturbance"	Differential trip on 500/220 kV Transformer	Loss of 698 MW of solar PV, wind, and BESS resources (22 units)
June 15, 2024 "Post fire Disturbance"	Phase-to-Phase Fault on 500 kV Line	Loss of 934 MW of solar PV, wind, and BESS resources (37 units)

Recommended Actions

Based on the findings of this work, WECC recommends the following actions for entities to take.

1. During updates to the firmware or software of IBR control equipment, IBR owners/operators should understand what changes are being made and why. All changes should be approved by the owners/operators.
2. Transmission Service Providers may consider what changes, if any, are required in their interconnection agreements to establish an appropriate framework to ensure that IBR-based generation resources perform safely and reliably while interconnected to the BES.
3. IBR owners/operators should identify the user-level inverter grid protection settings for their equipment and adjust these settings utilizing the maximum capability of the equipment. IBR owners/operators should work with the OEM for their equipment to adjust the OEM inverter settings utilizing the maximum capability of the equipment. Making these changes will allow your equipment to better support the reliability of the BES.

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Introduction

IBRs continue to trip for non-consequential faults on the Bulk Power System (BPS). The four events in this report that exceeded the threshold of a NERC Categorized 1i event due to loss of more than 500 MW of IBR generation show that there is still a need for Reliability Standards. This section describes the initiating fault and gives an overview of the affected IBR facilities for each of the four disturbances analyzed.

Predisturbance Operating Conditions

Figure 1 shows solar PV power profiles for the California Independent System Operator (CAISO) each day that disturbances occurred, and **Figure 2** shows the solar PV power profile for PacifiCorp East (PACE) for that disturbance. **Table 2** shows predisturbance operating conditions for each fault. BPS-connected IBR (wind, solar PV, and BESS) output ranged from 30% to 81% of the CAISO internal net demand and 38% of the PACE internal net demand at the time of each fault, with solar PV providing less than 1% for the May 20 event due to the event time. These predisturbance operating conditions illustrate the significant amount of IBR capacity in the CAISO and PACE footprints and highlight the importance of ensuring that all BPS-connected IBRs are operating in a manner that supports reliable operation of the BPS.

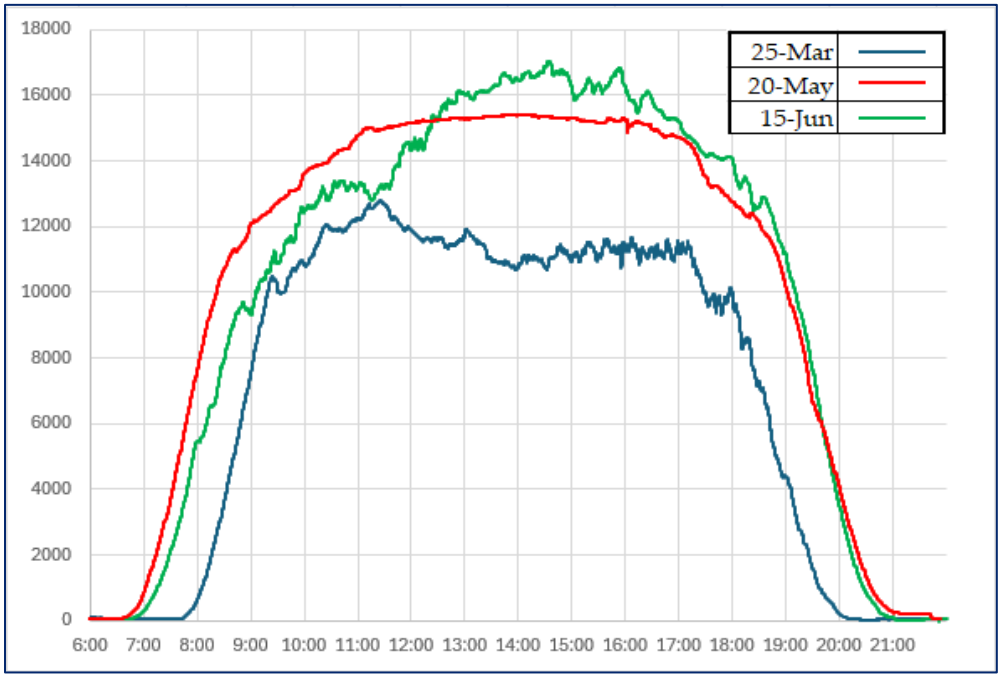

Figure 1: CAISO total solar PV profiles for each day events occurred.

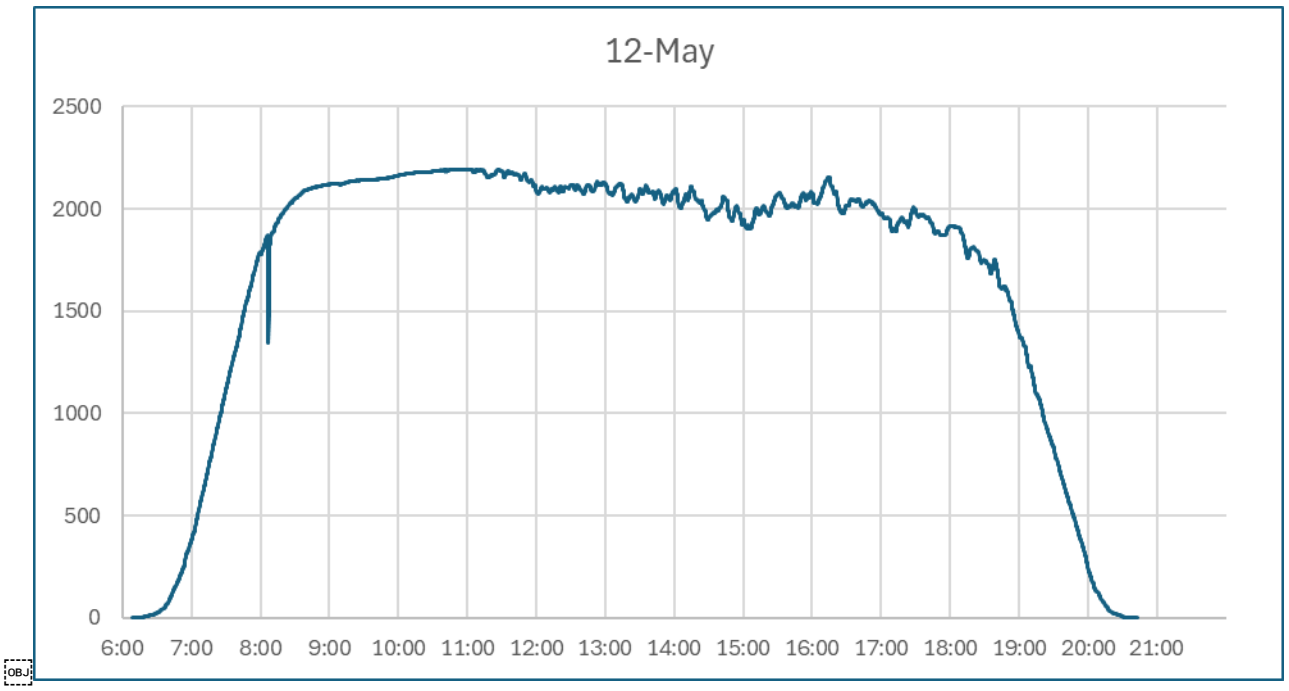

Figure 2: PACE total solar PV profile for the day event occurred.

Table 2: Predisturbance Operating Conditions

Operating Condition	March 25, 2024		May 12, 2024		May 20, 2024		June 15, 2024	
	Value	%	Value	%	Value	%	Value	%
Internal Net Demand	18,945	N/A	5,440	N/A	26,747	N/A	24,077	N/A
Solar PV Output [MW]	11,427	60.3%	1,888	92%	107	0.4%	16,070	66.7%
Wind Output [MW]	2,326	12.3%	165	5%	3,760	14.1%	3,363	14%
BESS Output [MW]	-1,268	-6.7%	0	0%	4,135	15.5%	-781	-3.2%

Description of Disturbances

March 25, 2024 "Vincent Disturbance": At 14:55:52, the Vincent 500kV South bus, along with 3AA and 4AA banks, relayed during restoration of a power circuit breaker after scheduled maintenance at Vincent. CAISO observed a 1,046 MW reduction in solar PV and wind resources across the area. CAISO identified 28 facilities that reduced output due to the fault.

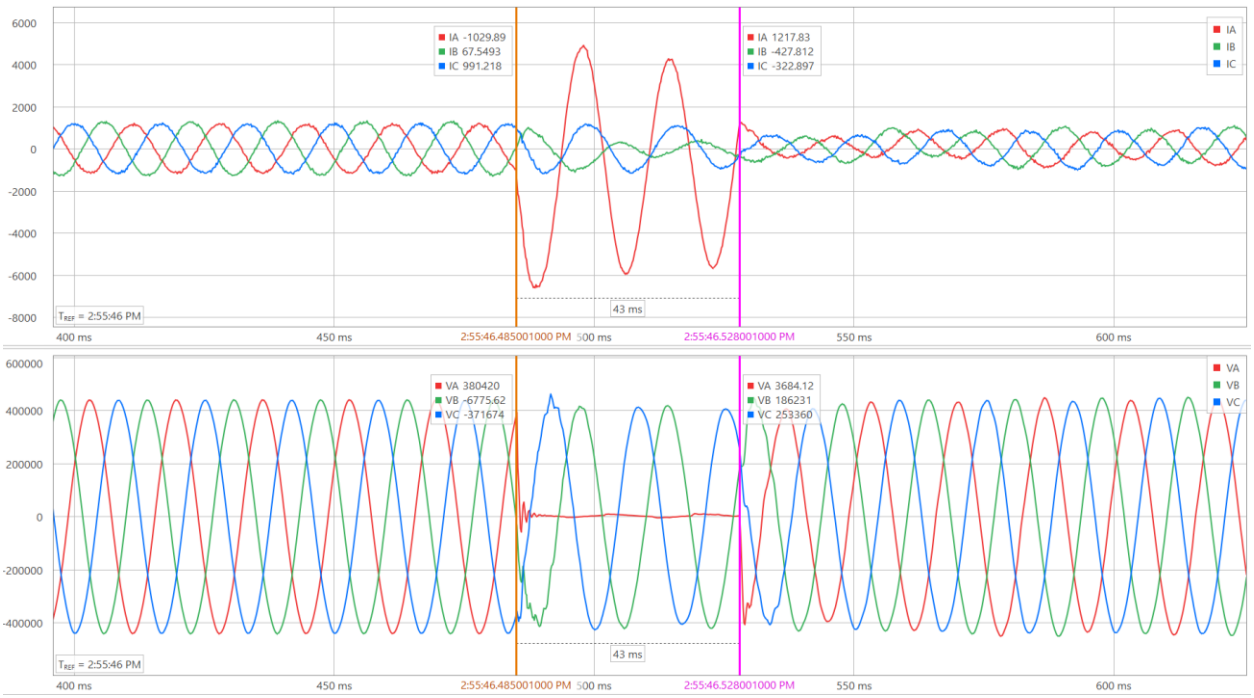

Figure 3: Fault clearing for March 25 disturbance.

May 12, 2024 "Red Butte Disturbance": At 07:06 the Hickory-Red Butte 345kV line relayed out on a phase-to-phase fault. PACE observed a 532 MW reduction in solar PV resources across the area. PACE identified eight solar PV facilities that reduced output due to the fault.

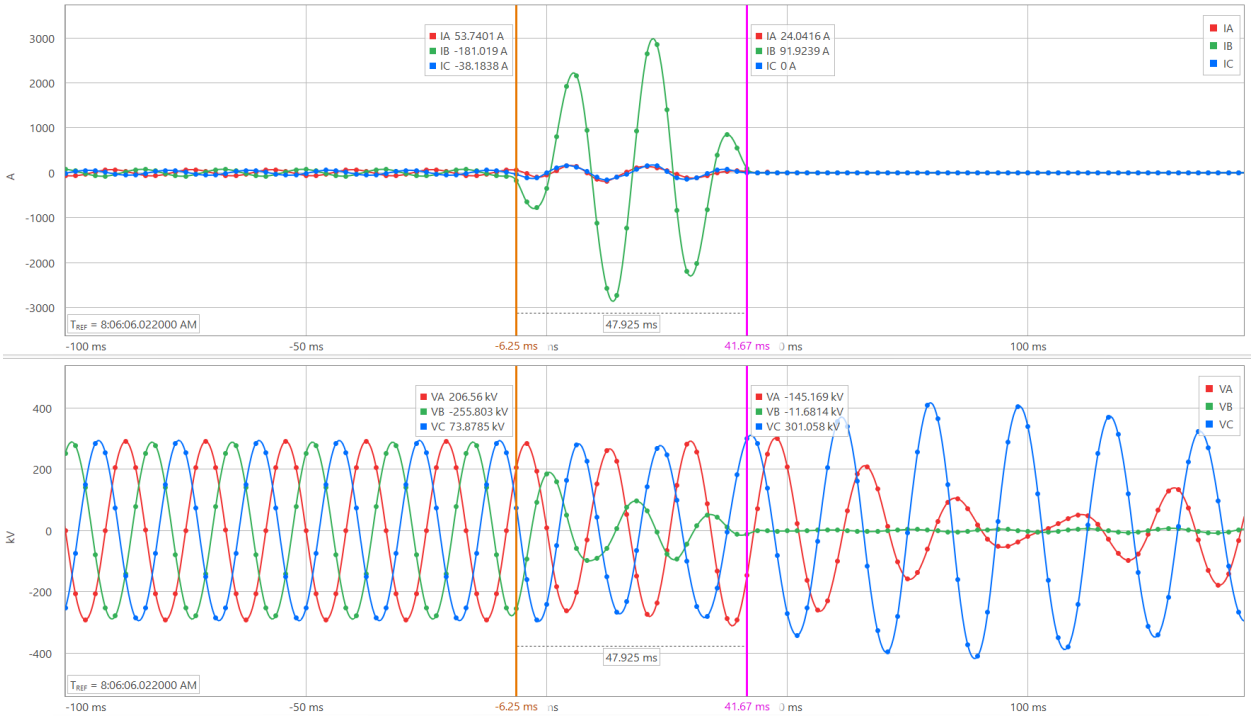

Figure 4: Fault clearing for May 12 disturbance.

May 20, 2024 "Windhub Disturbance": At 21:10:04, the Windhub 500/230 kV 3AA transformer bank tripped on differential protection when a riser lead became separated. CAISO observed a 698 MW reduction in solar PV, wind, and BESS resources. Due to the event time, the majority loss was wind and BESS for this incident. CAISO identified 22 facilities that reduced output due to the fault.

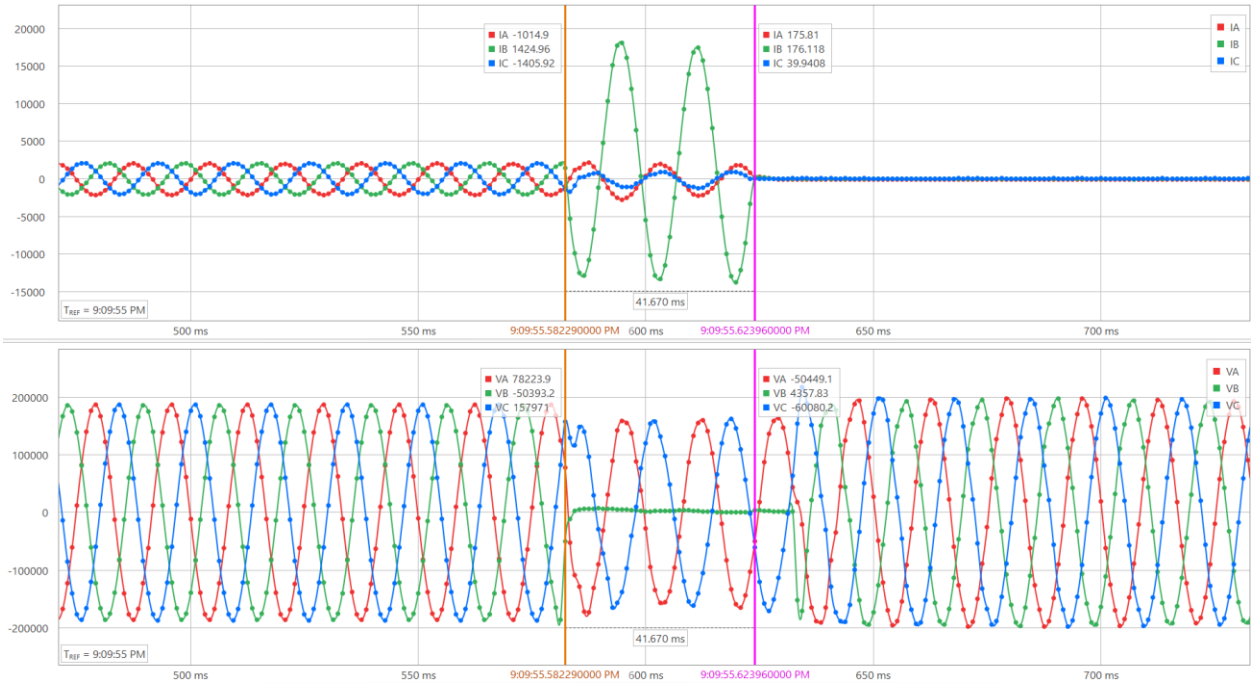

Figure 5: Fault clearing for May 20 disturbance.

June 15, 2024 "Post Fire Disturbance": At 15:06:40, the Post fire burning near the Midway-Vincent corridor resulted in the trip of the Midway-Vincent #1 500kV line. CAISO observed a 934 MW reduction in solar PV, wind, and BESS resources. At 15:07, the Midway-Vincent #2 500kV line also tripped. The lines remained out of service until the fire burned clear of the corridor. CAISO identified 37 facilities that reduced output due to the fault.

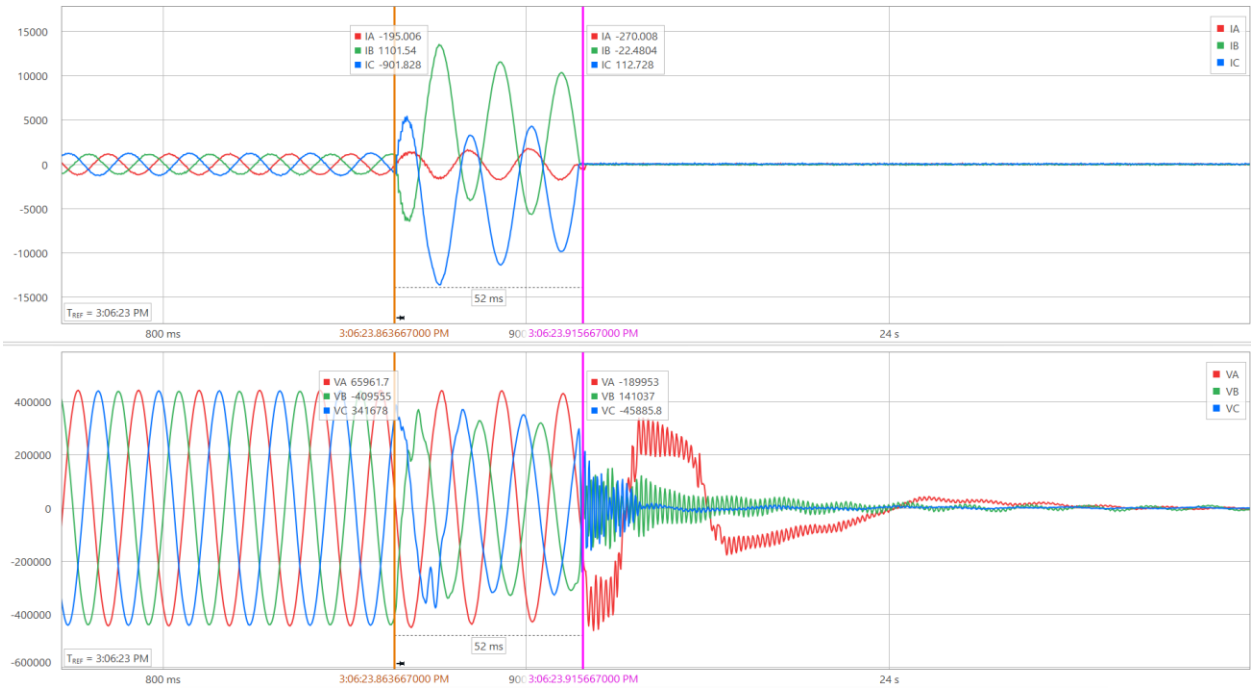

Figure 6: Fault clearing for June 15 disturbance

Findings and Recommended Actions

- **Finding:** In one of the events, it was found that IBRs that had made changes in settings to improve their performance due to faults, had reverted to the previous settings during a firmware update. These previous settings allowed tripping of the facility due to the fault during this event.

  Recommended action: During updates to the firmware or software of IBR control equipment, IBR owners/operators should understand what changes are being made and why. All changes should be approved by the owners/operators.

- **Finding:** Due to the current time frame required for developing and implementing Reliability Standards, some entities have made modifications to their interconnection agreements to allow better ability to manage the implementation of IBRs within their area and allow for effective corrective actions to be taken if misoperations occur.

  Recommended action: Transmission Service Providers may consider what changes, if any, are required in their interconnection agreements to establish an appropriate framework to ensure that IBR-based generation resources perform safely and reliably while interconnected to the BES.

- **Finding:** One of the IBR owner/operators reported identifying and modifying user-level inverter grid protection settings to improve the performance of their IBR facilities during BES fault events.

  Recommended action: IBR owners/operators should identify the user-level inverter grid protection settings for their equipment and adjust these settings utilizing the maximum capability of the equipment. IBR owners/operators should work with the OEM for their equipment to adjust the OEM inverter settings utilizing the maximum capability of the

equipment. Making these changes will allow your equipment to better support the reliability of the BES.

Appendix A: Industry Efforts

Industry is working to address this risk in a variety of ways.

FERC

On October 30, 2023, FERC issued Order No. 901 Reliability Standards to Address Inverter-Based Resources, directing NERC to develop new or modified standards to address reliability gaps identified through the performance of IBRs since 2016.

The four areas identified to be addressed are:

- IBR Data Sharing,
- IBR Model Validation,
- IBR Planning and Operational studies, and
- IBR Performance Requirements.

NERC

In response to FERC Order 901, NERC developed an implementation plan composed of four milestones:

1. Order No. 901 Work Plan submission,
2. Standards development and filing to address performance requirements and post-performance requirements and post-performance validations for Registered IBRs,
3. Development and filing of Reliability Standards to address data sharing and model validation for all IBRs, and
4. Development and filing of Reliability Standards to address use of performance data in Operational and Planning studies.

At the time of this report, Milestones 1 and 2 have been completed.

As part of the Milestone 2, on February 20, 2025, FERC approved PRC-028-1, Disturbance Monitoring and Reporting Requirements for Inverter-Based Resources and PRC-030-1, Unexpected Inverter-Based Resource Event Mitigation and on July 25, 2025 FERC approved PRC-029-1, Frequency and Voltage Ride-through Requirements for Inverter-Based Resources.

This also includes the addition of a definition for the term “Ride-through” to the Glossary of Terms Used in NERC Reliability Standards.

Milestone 3 is underway, with a projected due date for the standards of November 4, 2025.

This effort is working toward updates to NERC Standards:

- MOD-026, Verification of Models and Data for Generator Excitation Control System or Plant Volt/Var Control Functions.
- MOD-032, Data for Power System Modeling and Analysis.
- MOD-033, Steady-State and Dynamic System Model Validation.

Milestone 4 has a projected due date of November 4, 2026, with Standard Authorization Requests expected to be published around August.

WECC

On March 14, 2023, NERC issued a Level 2 NERC Alert on IBR performance issues. As part of this alert, NERC asked entities whether the inverter voltage and frequency protection settings were based on the maximum capability of the equipment.

In its November 2023 Inverter-Based Resource Performance Issues Report, NERC reported that results show less than one-third of the inverter settings reported are set based on equipment capability, meaning there is significant underused ride-through capability across the BPS. NERC also reported that this finding raises concerns regarding ride-through performance, the provision of essential reliability services, and BPS reliability, especially now, as the grid is undergoing retirements of substantial amounts of synchronous machines.

In the June 2022 Odessa Disturbance Report, NERC reported that for some of the causes of tripping "The inverter manufacturer stated that they plan to only make changes to facilities that request the update and do not have any plans to proactively update or mitigate this risk on their end."

In the report, NERC strongly recommended that all GOs with these inverters seek immediate updates (when available) to their in-service inverters to mitigate the possibility of unexpected and abnormal tripping for BPS faults.

WECC, using the Level 2 NERC alert data and disturbance report recommendation, identified 77 IBR facilities within the Western Interconnection that indicated their IBR inverters were not optimized for performance based on equipment limitations.

Building on previous outreach efforts, in April 2024, WECC began contacting these facilities requesting they voluntarily work with their OEM for the equipment and adjust the inverter settings using the maximum capability of the equipment.

By October 2024, WECC had received responses from 87% of the identified facilities.

CAISO

CAISO IBR Operational Performance Investigations

Technical requirements for IBRs are set out in the ISO's Large Generator Interconnection Agreement (LGIA).

These changes were made due to several factors, including:

- Between the months of August and February 2017 there were eight transmission system faults in ISO's BA that resulted in the unanticipated loss of approximately 1200 MW of inverter-based generation per event.
- After seeking to enlist support for adding requirements to NERC Standards, the ISO conducted a stakeholder process and revised its pro forma LGIA and SGIA agreements to include specific technical IBR requirements. FERC adopted the changes in April 2019.

The requirements were performance-based and set specific conditions for all non-synchronous generation sources interconnecting to the ISO transmission system. The ISO monitors and investigates non-compliance with the performance requirements

The ISO follows a process similar to this:

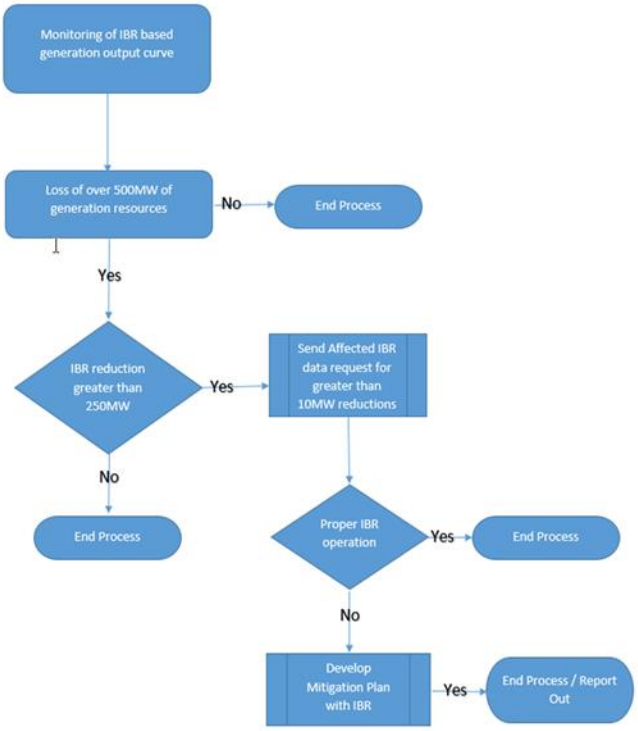

Figure 7: Desktop procedure overview

The ISO follows these review steps:

1. Our staff uses CAISO's operating logs, frequency deviations, and SCADA to monitor the CAISO total generation curve. If we observe a total generation reduction of greater than 500 MW that is predicated by a transmission event, ISO staff will analyze the event to determine whether there was an aggregate reduction of 250 MW or more of IBR resources.
2. Operations staff then requests data from the affected TOP, including PMU, SCADA, and any associated relay records. Resources with reductions of 2 MW or more are identified, but the threshold for further analysis is 10 MW.
3. Our transmission team will review the data and use contact information to issue an IBR data request. We also review past event analysis to determine whether the facility has been involved in previous events, is currently working to mitigate any improper operations, or whether it is a legacy facility not subject to revised LGIA requirements. After reviewing the submitted data, we will coordinate with the associated generator to review the facility response. This meeting will be used to develop action items and next steps to correct or mitigate operational concerns or improper inverter response.

4. Members of our team also request data from the affected TOP, including PMU, SCADA, and any relay records to assist in the investigation including:
    - Electrical quantities for the total plant at POI and inverter-level signals.
    - DFR or protective relaying data, if available, in Comtrade format.
    - Summary of inverters that tripped or entered momentary cessation including the associated fault codes.
    - Detailed accounting of the duration of cessation or fault for all affected inverters.
    - Plant single lines identifying affected inverters.
    - Power Plant Controller (PPC) type and response/control data during the event.
    - Facility information including inverter manufacturer and model.
    - Inverter control settings.
    - Most current EMT and Planning Study Model.
5. If an escalation is required to enforce the operational requirements of the LGIA, our staff will issue a contract breach letter.
6. All mitigation plans, meeting minutes, analysis, and associated documentation for each event will be archived by the CAISO.
7. LGIA requirements
    a. LGIA Appendix HH: "An Asynchronous Generating Facility shall remain online for the voltage disturbance caused by any fault on the transmission grid … having a duration equal to the lesser of the normal three-phase fault clearing time (4–9 cycles) or one-hundred fifty (150) milliseconds."

Sample Data:

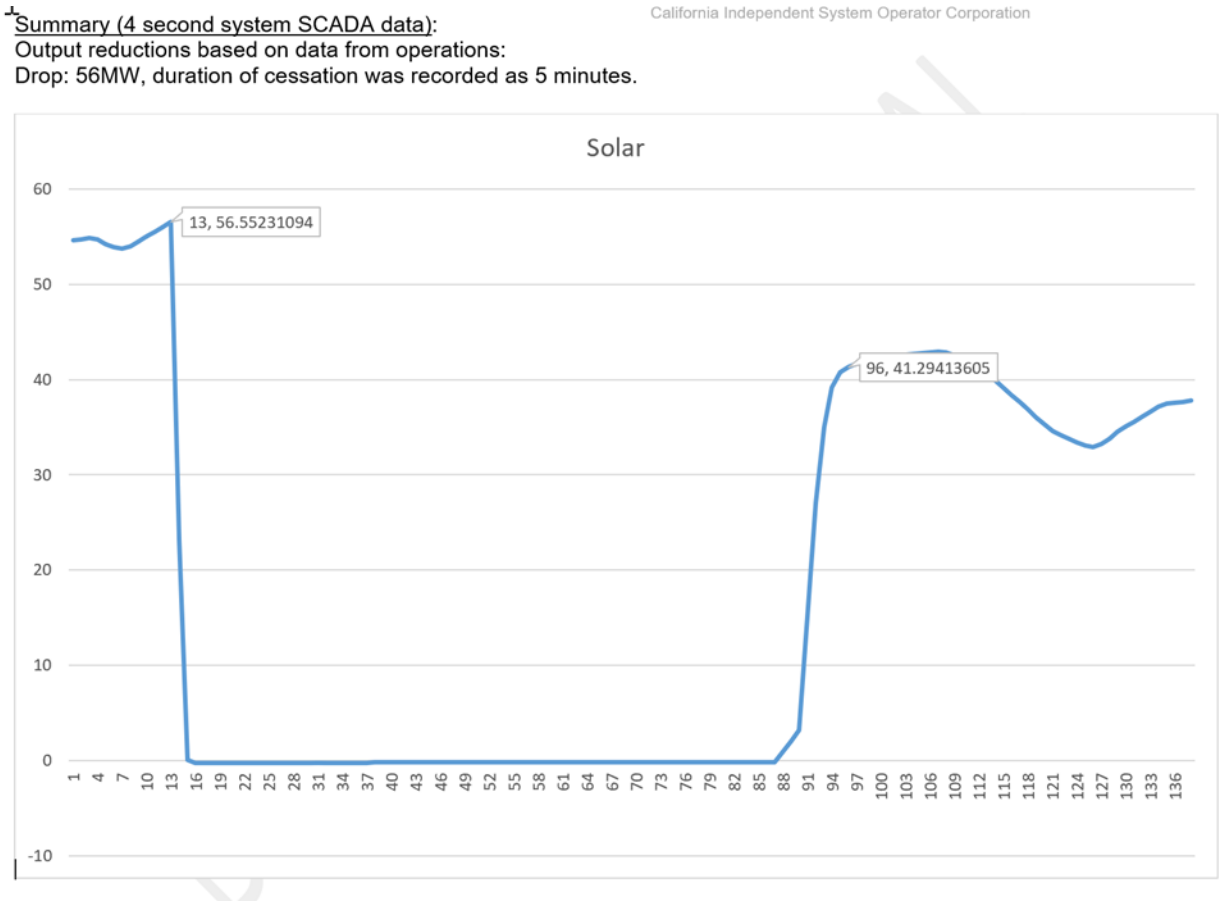

Figure 8: Sample reduction data

An example of the findings could look like this:

- Faulted units: DC overvoltage, over/under frequency, AC overcurrent, Module Fault, Unbalanced Voltage AC or DC.

Resolutions:

- Typical resolutions involve firmware upgrades, setting changes, or both.

Challenges:

- More events that are not predicated by a transmission event due to better tools and operator training/familiarity such as oscillations and loss of generation.
- Date granularity and synchronization of data records are an ongoing challenge to accurately diagnosing events.

Appendix B: List of Contributors

This disturbance report was published with the contributions of the following individuals. WECC gratefully acknowledges NERC and CAISO for the successful analysis of these disturbances and publication of this report.

Name	Company
Curtis Holland	WECC
Dave Grover	WECC
Rich Bauer	NERC
Aung Thant	NERC
Wei Qiu	NERC
Scott Vaughan	CAISO

Approving Committee, Entity, or Person	Approval Date

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