Attachment #5.6.1
Return to Agenda

2023 Southwest Utah Disturbance

Southwestern Utah: April 10, 2023
Joint NERC and WECC Staff Report

August 2023

RELIABILITY | RESILIENCE | SECURITY




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Preface

Electricity is a key component of the fabric of modern society and the Electric Reliability Organization (ERO) Enterprise serves to strengthen that fabric. The vision for the ERO Enterprise, which is comprised of NERC and the six Regional Entities, is a highly reliable, resilient, and secure North American bulk power system (BPS). Our mission is to assure the effective and efficient reduction of risks to the reliability and security of the grid.

Reliability | Resilience | Security
Because nearly 400 million citizens in North America are counting on us

The North American BPS is made up of six Regional Entities as shown on the map and in the corresponding table below. The multicolored area denotes overlap as some load-serving entities participate in one Regional Entity while associated Transmission Owners/Operators participate in another.

MRO	Midwest Reliability Organization
NPCC	Northeast Power Coordinating Council
RF	ReliabilityFirst
SERC	SERC Reliability Corporation
Texas RE	Texas Reliability Entity
WECC	WECC

Executive Summary

The ERO Enterprise continues to analyze disturbances that involve the widespread abnormal performance of inverter-based resources to identify systemic reliability risk issues, support affected facility owners, and share key findings and recommendations broadly with industry for increased awareness and action. Refer to the *NERC Quick Reference Guide: Inverter-Based Resource Activities* and the *NERC Inverter-Based Resource Strategy* for more details regarding all aspects of risk mitigation activities in this area.[1,2] The ERO Enterprise continues to stress the need for proactive industry action to ensure a reliable, resilient, and secure BPS under the grid's rapid transformation. As reported in numerous past events,[3] the unexpected and unplanned loss[4] of multiple generating facilities during normally cleared grid faults poses a significant risk to BPS reliability.

This disturbance report documents the key findings and recommendations from analyzing the widespread loss of solar photovoltaic (PV) resources that occurred in Southwest Utah in the morning of April 10, 2023 (referred to herein as the "2023 Southwest Utah Disturbance"). This report is abbreviated relative to others since the causes of reduction have all been identified in past events; however, it is imperative to continue highlighting the systemic risk issues and unique observations from each event analysis.

This event is the first major widespread solar loss to occur in the Western Interconnection outside of California. Nine solar PV facilities (some with multiple phases) failed to ride through a normally cleared fault on a 345 kV transmission circuit. This resulted in an unexpected loss of 921 MW of generation, which is categorized as a Category 1i event in the NERC Event Analysis Process.[5]

Key Findings and Recommendations

The findings from this analysis and in the context of past disturbance reports for inverter performance issues highlight the following:

- **Reiterated Need for NERC Project 2023-02 to Ensure Proactive Risk Mitigation:** This report, along with past reports, illustrates and reiterates the strong need for inverter-based resource performance issues to be addressed by Generator Owners (GOs) in a timely manner. GOs are often not addressing performance issues that latently exist within the existing fleet. All of the causes of abnormal performance in this event have been previously documented by NERC in past reports; however, actions were not taken either by the GOs or by the inverter original equipment manufacturers (OEM) to mitigate these known risks. Project 2023-02[6] is addressing this reliability risk by "requiring analysis and mitigation of unexpected or unwarranted protection and control operations from inverter-based resources following the identification of such a performance issue." The goal is to minimize the number of large-scale widespread resource loss events through more proactive performance improvements at individual facilities.
- **Reiterated Need for Performance-Based Comprehensive Ride-Through Standard:** This report, along with past reports, further emphasizes the need for a comprehensive ride-through standard in lieu of NERC PRC-024-3. Project 2020-02[7] is currently addressing this risk issue by replacing PRC-024-3 "with a performance-based ride-through standard that ensures generators remain connected to the BPS during system disturbances." The standard authorization request specifically addresses the myriad of protection and controls beyond voltage and frequency protection that have affected ride-through performance in numerous large-scale events such as this. This project remains a top priority for NERC to address persistent inverter-

[1] https://www.nerc.com/pa/Documents/IBR_Quick%20Reference%20Guide.pdf
[2] https://www.nerc.com/comm/Documents/NERC_IBR_Strategy.pdf
[3] https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx
[4] As in, the failure to "ride through" and provide essential reliability services.
[5] NERC Event Analysis Program: https://www.nerc.com/pa/rrm/ea/Pages/EA-Program.aspx
[6] https://www.nerc.com/pa/Stand/Pages/Project-2023-02-Performance-of-IBRs.aspx
[7] https://www.nerc.com/pa/Stand/Pages/Project_2020-02_Transmission-connected_Resources.aspx

based resource performance issues and the elevated risk to BPS reliability posed with the rapidly changing resource mix.

- **Reiterated Need for Level 2 NERC Alert Regarding Inverter-Based Resource Performance Issues:** This event illustrates that equipment installed in the field for many years have latent performance issues that are not identified until certain grid conditions and disturbances result in a widespread resource loss event. With the rapidly growing inverter-based resource mix, it is imperative that newly connecting facilities not have these known performance deficiencies. NERC issued a Level 2 alert to industry to share key findings and recommendations regarding solar PV performance issues as well as to gather information regarding extent of condition of risk. The data submission deadline was extended to July 31, 2023, to provide entities with additional time to gather and submit high-quality data. NERC will be conducting an assessment of the data received and will report key findings and recommendations to industry based on the assessment of the data submitted.

Introduction

This *2023 Southwest Utah Disturbance* documents the key findings and recommendations from analyzing the widespread loss of solar PV resources that occurred in Southwest Utah in the morning of April 10, 2023. The **Introduction** provides a brief overview of the initiating event and overall system conditions. **Chapter 1** highlights the key findings from the analysis, which establish a technical basis for the recommendations listed below. **Appendix A** provides more details regarding the abnormal performance observed for each affected solar PV facility.

Description of Analysis Process

PacifiCorp-East (PACE) submitted a brief report to NERC and WECC because this event met the criteria for a Category 1i event per the NERC Event Analysis Program. NERC and WECC agreed to develop an ERO disturbance report to share the key findings and recommendations from the analysis with industry. WECC solicited requests for information to affected GOs. NERC and WECC held follow-up calls with any entities where additional information was needed to perform root cause analysis. The analysis focused specifically on facilities that reduced power output by more than 10 MW. NERC also engaged affected OEMs, where possible, to discuss mitigation actions and improve overall performance of the existing and future solar PV fleet.

Predisturbance Operating Conditions

Figure I.1 shows the total PACE solar PV profile for April 10. The disturbance occurred at 08:51 a.m. Pacific time, right about the time when aggregate solar PV output reached its peak for the day. Synchronous generation, wind, and solar PV resources comprised 42%, 31%, and 26% of total generation prior to the disturbance, respectively (see **Table I.1**).

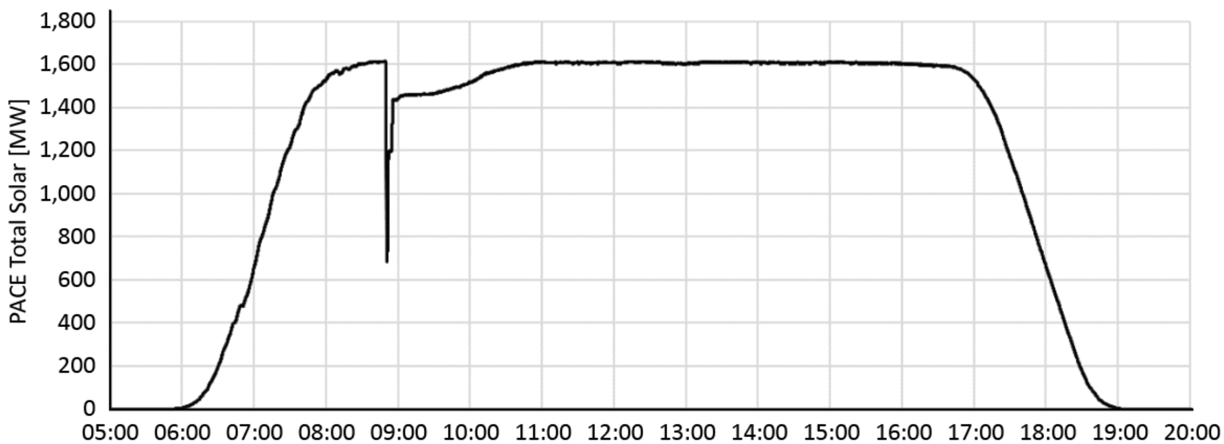


Figure I.1: PACE Solar PV Profile for April 10, 2023

Table I.1: Predisturbance Resource Mix		
BPS Operating Characteristic	**MW**	**%***
Internal Net Demand	5,636	-
Exports	477	-
Solar PV Output	1,615	26.4%
Wind Output	1,914	31.3%
Synchronous Generation	2,577	42.3%

* % of internal net demand plus exports

Disturbance Overview

At 08:51 Pacific time, a single-line-to-ground fault occurred on a 345 kV transmission circuit in the Southern Nevada/Southwest Utah area. Protective relaying cleared the fault normally in 3.5 cycles.[8] While no generation tripped consequentially due to the transmission line outage, PACE supervisory control and data acquisition (SCADA) data[9] shows that aggregate solar PV output in the PACE footprint dropped significantly (see **Figure I.2**). All affected solar PV facilities are located in the Southwest Utah area (see **Figure I.3**). The abnormal response from multiple facilities was caused by the protection and controls within each facility responding to the BPS fault in an unreliable manner. The loss of generation caused system frequency to fall from around 60.01 Hz to 59.89 Hz (see **Figure I.4**).

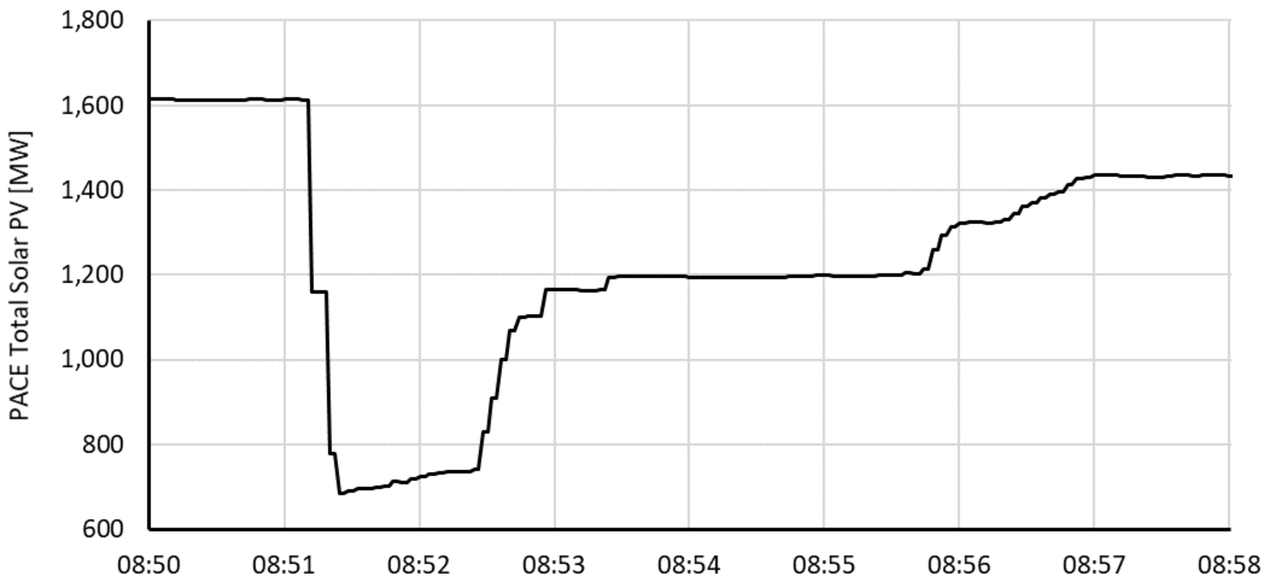


Figure I.2: PACE BPS-Connected Solar PV during Disturbance

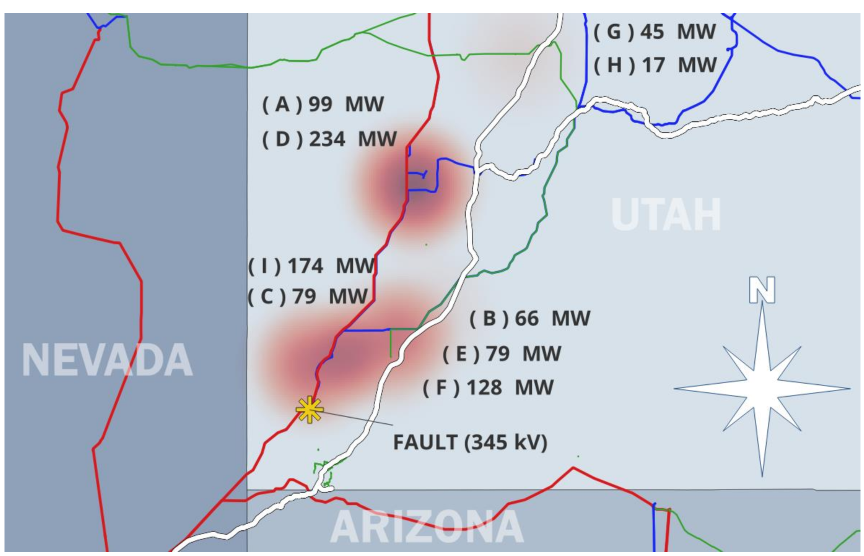


Figure I.3: Map of Fault Location and Affected Solar PV Facilities

8 3 cycles and 3.5 cycles on the near- and far-end of the line, respectively.

9 As with past inverter-based resource disturbances analyzed, reductions captured by SCADA likely differ from information captured with higher resolution monitoring equipment. Discrepancies may exist between this value and others reported in this disturbance report. However, the reduction in solar PV output captured by SCADA provides a relative indicator of the impact of each disturbance.

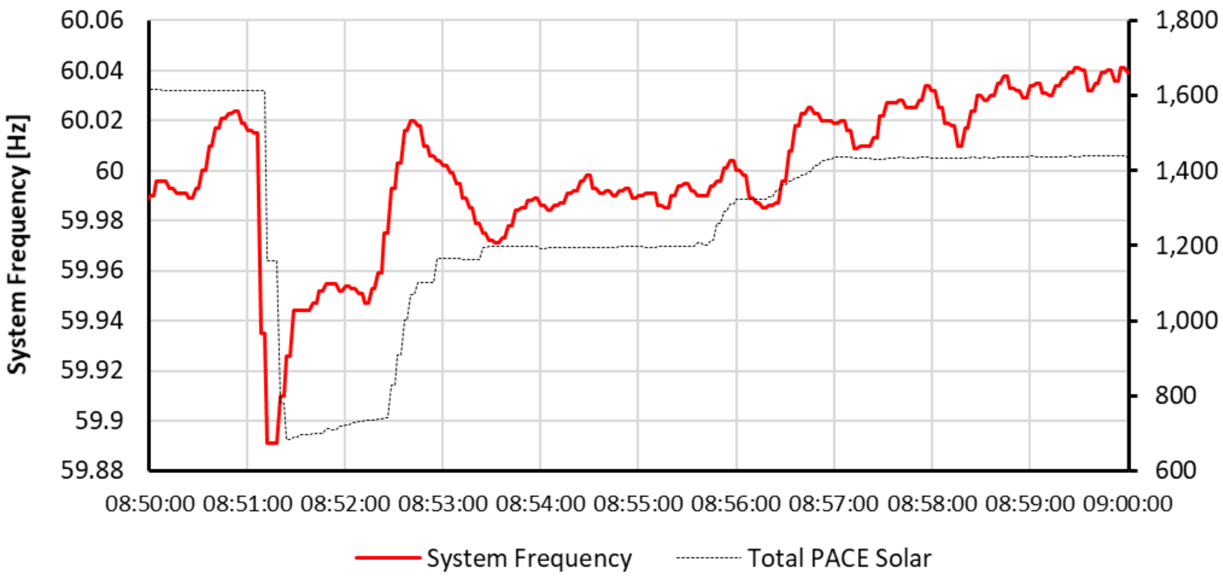


Figure I.4: WECC System Frequency

The magnitude of the solar PV reduction (> 900 MW) is significant; however, the large percentage of aggregate generation unexpectedly lost (over 57% of the PACE solar PV fleet output) is the most concerning attribute of this event, particularly with growing levels of solar PV in the PACE footprint and neighboring areas. PACE received about 45 GW of interconnection requests for its 2022 cluster studies (PACE peak load is about 13 GW) and is planning to connect an additional 3.8 GW of generation (1.6 GW of solar) in the next three years. These projects are in the advanced stages of the interconnection process (i.e., signed interconnection agreement, design, construction).

No notable changes in net load quantities attributable to distributed energy resource tripping were observed nor were there any abnormal performance issues identified with the wind and synchronous generation fleet in the PACE area.

Chapter 1: Detailed Findings from Disturbance Analysis

This chapter briefly describes the key findings from this analysis. Refer to **Appendix A** for details regarding each affected facility.

Overview of Causes of Solar PV Reduction

The causes of abnormal active power reduction for each facility is listed in **Table 1.1**, and **Figure 1.1** shows the inverter OEMs involved in this event. Multiple facilities tripped for several reasons, making attribution of active power reductions to specific causes difficult. Technical details are omitted in this report since the causes of reduction have been well-documented in past disturbance reports.[10] The following are brief descriptions of the causes of tripping:

- One facility tripped on inverter instantaneous ac overcurrent protection; this is indicative of inverter inner current control issues. This issue has been previously reported in past NERC reports.
- Two facilities tripped for unknown causes due to poor data retention and/or quality. Data quality problems continue to be an issue and have been previously reported in past NERC reports.
- Multiple facilities tripped on a combination of inverter phase lock loop (PLL) loss of synchronism, instantaneous ac overvoltage, and dc reverse current protection within the inverters. These issues have been previously reported in past NERC reports.
- One facility tripped on passive anti-islanding and instantaneous ac overcurrent protection from an inverter OEM that has not been widely involved in past events. Therefore, this appears to be a new issue for this specific inverter OEM; however, NERC has previously reported on problems with anti-islanding protection in past events.

Table 1.1: Causes of Solar PV Abnormal Performance

Plant	Loss	OEM	Passive Anti-Islanding	ACOC[11]	PLL Loss of Sync	ACOV[12]	DC Reverse Current	Unknown
A	99	TMEIC		X				
B	66	AE[13]						X
C	79	TMEIC			X	X	X	
D	234	TMEIC			X	X	X	
E	79	TMEIC			X	X		
F	128	TMEIC			X	X		
G	45	TMEIC						X
H	17	TMEIC			X			
I	174	Sungrow	X	X				

[10] https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx
[11] AC overcurrent
[12] AC overvoltage
[13] Advanced Energy

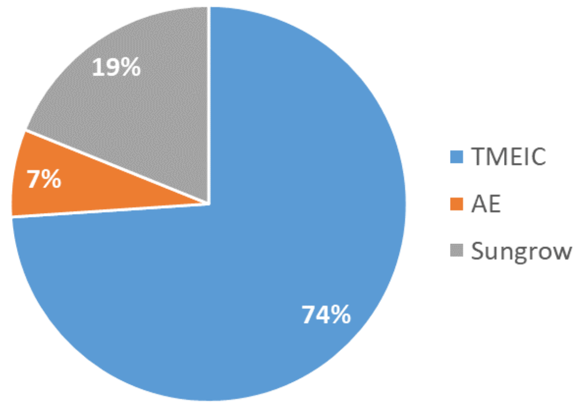


Figure 1.1: Share of Inverter OEMs at Affected Solar PV Facilities

Anti-Islanding Protection

Most, if not all, inverter OEMs have some form of anti-islanding protection that can be configured in the inverters. This stems from distribution-centric requirements and standards where islanding is a concern for reliability and safety. However, anti-islanding protection should generally not be used for BPS-connected inverter-based resources and should be coordinated with the interconnecting transmission service provider (i.e., the Transmission Owner (TO)) to determine appropriate settings. NERC has previously highlighted that anti-islanding protection has unexpectedly tripped inverters during normal BPS grid faults; however, this issue continues to persist in industry. One reason for this is that TO interconnection requirements usually do not address anti-islanding protection, so the default distribution-centric settings are applied at these facilities during commissioning and left unchecked.

NERC recommends all solar PV GOs conduct an assessment of their facility's anti-islanding settings and identify any potential performance issues that could arise from enabling these functions. As stated, this should be coordinated with the TO per their interconnection requirements and/or protection practices; however, these settings should be disabled for BPS-connected solar PV facilities in most cases.

Unexpected Field Settings

Multiple facilities had inverters configured with protection and/or control settings that did not match the expectations of the GO, including:

- In one case, all but two inverters at a facility were configured with low- and high-voltage ride-through (LVRT/HVRT) parameters disabled. NERC was unable to get clarity as to what the inverter injected (active or reactive current) during the fault; however, all of these inverters abnormally tripped during the event on ac overcurrent protection. The remaining two inverters were unexpectedly configured with momentary cessation settings (they rode through but with an undesirable performance).
- At another facility, inverter protections reported by the GO's were not the same as those documented by the inverter OEM as the "as left" settings during the commissioning process. These are not owner-configurable protections, so neither GO's nor the OEM knew which settings were "correct."

Systemic Performance Issues Persist

Systemic performance issues with BPS-connected solar PV facilities continue to pose a risk to BPS reliability. All causes of tripping in **Table 1.1** have been reported in past events; however, industry is not taking proactive steps to mitigate these performance issues. Many of the plants involved in this event went into commercial operation in the 2016 time frame, meaning they likely have similar performance issues that have been previously reported in NERC reports.

However, little to no action has occurred to mitigate these possible performance issues until a large-scale disturbance occurs, where the ERO Enterprise is involved in analysis to initiate changes.

The ERO Enterprise continues to highlight that lack of proactive industry action is a key contributor to these types of widespread inverter-based resource events. For example, the systemic performance issues at many of the affected facilities have been discussed in depth with the inverter OEMs during past event analyses. Inverter OEMs have developed corrective actions to eliminate the performance issues for these inverters; however, corrective actions are not being deployed proactively in the field. NERC strongly recommends that inverter OEMs proactively reach out to all affected asset owners for existing facilities to address identified performance issues. GOs and OEMs should be working together to proactively eliminate these risks to their equipment performance. The aggregate effects of abnormal performance across multiple inverter-based resources poses a risk to BPS reliability.

This issue has been reported in past NERC reports and reiterates the need for Project 2023-02 Performance of IBRs[14] to ensure GOs are analyzing and mitigating abnormal performance issues when they occur. It is imperative that industry proactively mitigates performance risks before they result in systemic issues that can remain latent in the existing equipment until a large-scale disturbance occurs. Risk mitigations are being developed and deployed to minimize the number of latent and systemic risks that could exist on the BPS through projects such as this.

Lastly, this finding also reiterates the need for the Level 2 NERC alert[15] that was issued March 2023 to provide industry with recommendations regarding known inverter-based resource performance issues and to gather information regarding existing facility protection and control settings. The deadline for GOs of solar PV facilities to submit responses was extended to July 31; NERC is currently analyzing results obtained and will be publishing key findings and recommendations in Q3 or Q4 of 2023. The alerts help ensure that GOs are aware of potential risk issues so they can develop corrective actions at their facilities where applicable.

Need for Comprehensive Ride-Through Standard

As documented in past disturbance reports, this report further highlights the need for a comprehensive ride-through standard to replace NERC PRC-024-3. The existing PRC-024-3 focuses only on voltage and frequency protection settings; and therefore, it does not address nearly all the causes of tripping in this event. Furthermore, PRC-024-3 has limitations regarding root-mean-square versus instantaneous peak measurements that relate to its applicability to inverter protection for ac overvoltage protection settings. All of this has been previously documented, and this report further supports the need for Project 2020-02 Modifications to PRC-024 (Generator Ride-through).[16] It is important to note that PRC-024-3 specifically pertains to POI voltages.

PacifiCorp Modeling Requirements

NERC did not conduct a comprehensive model quality review as part of this analysis; however, NERC did request details from PACE regarding their interconnection and modeling requirements for newly connecting facilities. PACE implemented Business Practice 84, which requires all interconnecting customers to submit electromagnetic transient (EMT) data and models for their projects. The Business Practice 84 is new and was not effective for any of the affected facilities in this event, so PACE does not have EMT models for any of these facilities (which reiterates NERC's previous findings that TOs, TPs, and Planning Coordinators) should implement modeling requirements enhancements as early as possible to gather high-quality and accurate models for newly connecting facilities.

The Business Practice 84 requires dynamics data and EMT data for "individual generator units with capacity of 10 MMVA or larger or aggregated generator unit capacity of 20 MVA or larger, connecting at 60 kV or higher."[17] It also

[14] https://www.nerc.com/pa/Stand/Pages/Project-2023-02-Performance-of-IBRs.aspx
[15] https://www.nerc.com/pa/rrm/bpsa/Alerts%20DL/Alert%20Level%202%20-%20Inverter-Based%20Resource%20Performance%20Issues%20-%20EXTENDED%20DEADLINE.pdf
[16] https://www.nerc.com/pa/Stand/Pages/Project_2020-02_Transmission-connected_Resources.aspx
[17] https://www.pacificorp.com/transmission/transmission-services.html

clearly defines model quality requirements, which is a critical component of model submissions from entities. NERC reiterates that the requirements explicitly state that these models must be submitted at the earlier of the return of the executed cluster study agreement or written request from PACE. Furthermore, once the interconnection study reports are issued, any changes to settings, output, plant topology, or any other change that affects the electrical characteristics or response of the facility will trigger a material modification assessment or permissible technological change evaluation.

NERC would like to recognize the work of PACE in this area and the recent enhancements made to their modeling requirements. NERC continues to emphasize the need for improvements to both interconnection requirements per NERC FAC-001 as well as improvements to interconnection studies and modeling requirements per NERC FAC-002.

Appendix A: Detailed Review of Affected Facilities

Table A.1 provides an overview of the affected solar PV facilities that reduced output by more than 10 MW. Details regarding abnormal performance for each facility are described in the subsections below.

Table A.1: Review of Solar PV Facilities

Facility ID	Capacity [MW]	Reduction [MW]	POI Voltage [kV]	In-Service Date	Cause of Reduction
Plant A	99	99	345	October 2019	All inverters tripped on instantaneous ac overcurrent protection.
Plant B	80	66	138	September 2019	Unknown. GO unable to identify cause of tripping.
Plant C	80	79	138	July 2016	All inverters tripped on instantaneous ac overvoltage, and also had fault codes attributed to PLL loss of synchronism and dc reverse current.
Plant D	240	234	345	July 2016	All inverters tripped on instantaneous ac overvoltage, and also had fault codes attributed to PLL loss of synchronism and dc reverse current.
Plant E	80	79	138	August 2016	All inverters tripped on instantaneous ac overvoltage and also had fault codes attributed to PLL loss of synchronism.
Plant F	130	128	138	September 2016	All inverters tripped on instantaneous ac overvoltage and also had fault codes attributed to PLL loss of synchronism.
Plant G	50	45	48	November 2016	Unknown. GO unable to identify cause of tripping.
Plant H	22	17	48	December 2016	All inverters tripped on PLL loss of synchronism.
Plant I	180	174	138	October/ November 2020	Nearly all inverters tripped on passive anti-islanding and ac overcurrent protection.
Total		**921**			

Plant A

Plant A reduced output by 99 MW during the event (see **Figure A.1**). All inverters at the facility tripped on instantaneous ac overcurrent protection. The plant had no high resolution data available and did not capture any inverter-level oscillography data to analyze the tripping further.

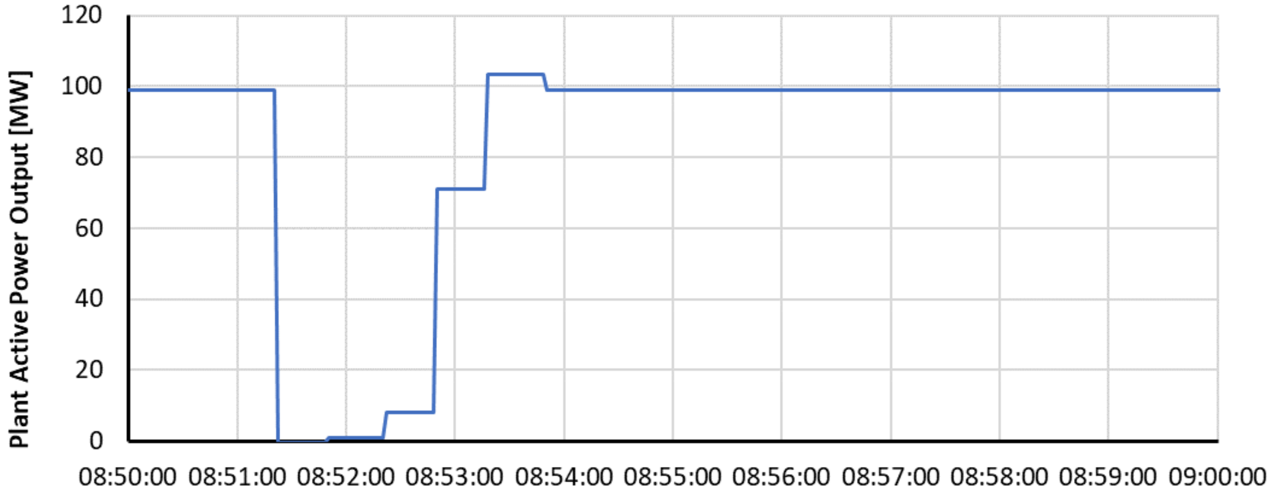


Figure A.1: Plant Active Power at POI

Plant B

Plant B reduced output by 66 MW during the event (see **Figure A.2**). The facility owner was unable to identify the cause of reduction. The plant owner was able to identify that two inverters tripped (cause undetermined) but could not determine the cause of the other abnormal reduction and delayed recovery.

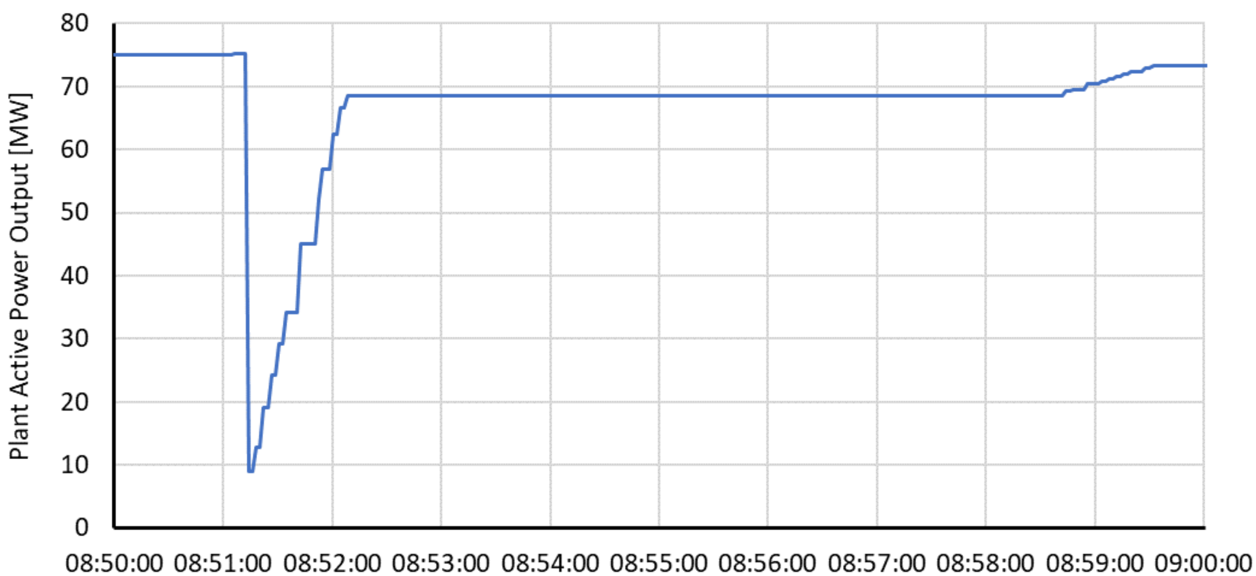


Figure A.2: Plant Active Power at POI

Plant C

Plant C reduced output by 79 MW during the event (see **Figure A.3**). All inverters at the facility tripped. The inverters recorded fault codes involving instantaneous ac overvoltage above 125%, phase lock loop loss of synchronism, and dc reverse current tripping. The plant had no high resolution data available and did not capture any inverter-level oscillography data to analyze the tripping further.

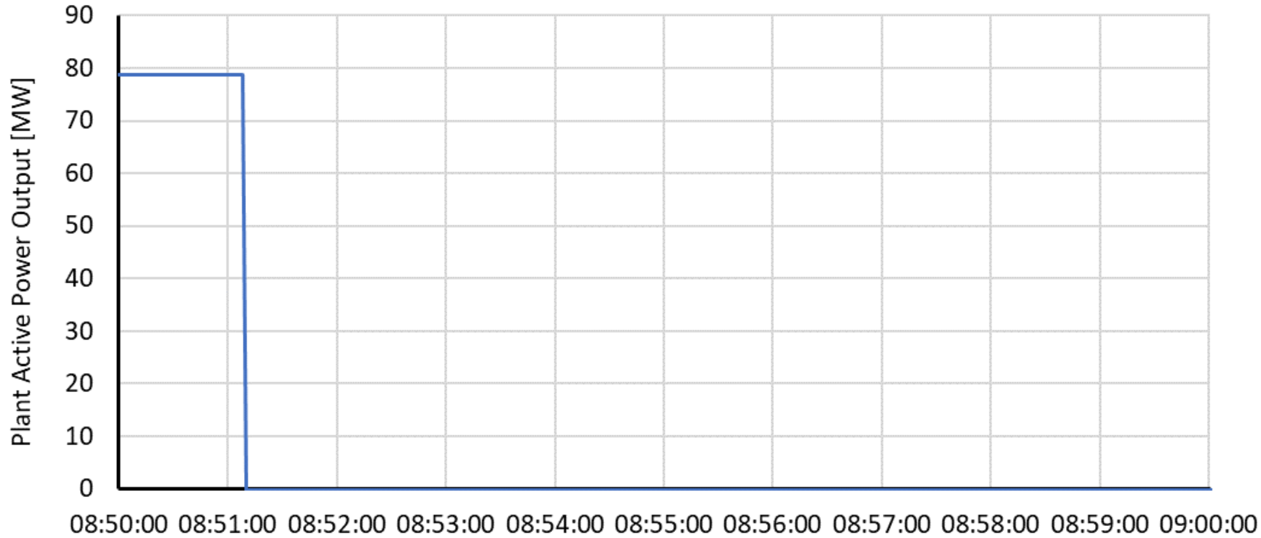


Figure A.3: Plant Active Power at POI

Plant D

Plant D reduced output by 234 MW during the event (see **Figure A.4**). All inverters at the facility tripped. The inverters recorded fault codes involving instantaneous ac overvoltage above 125%, phase lock loop loss of synchronism, and dc reverse current tripping. The plant had no high resolution data available and did not capture any inverter-level oscillography data to analyze the tripping further.

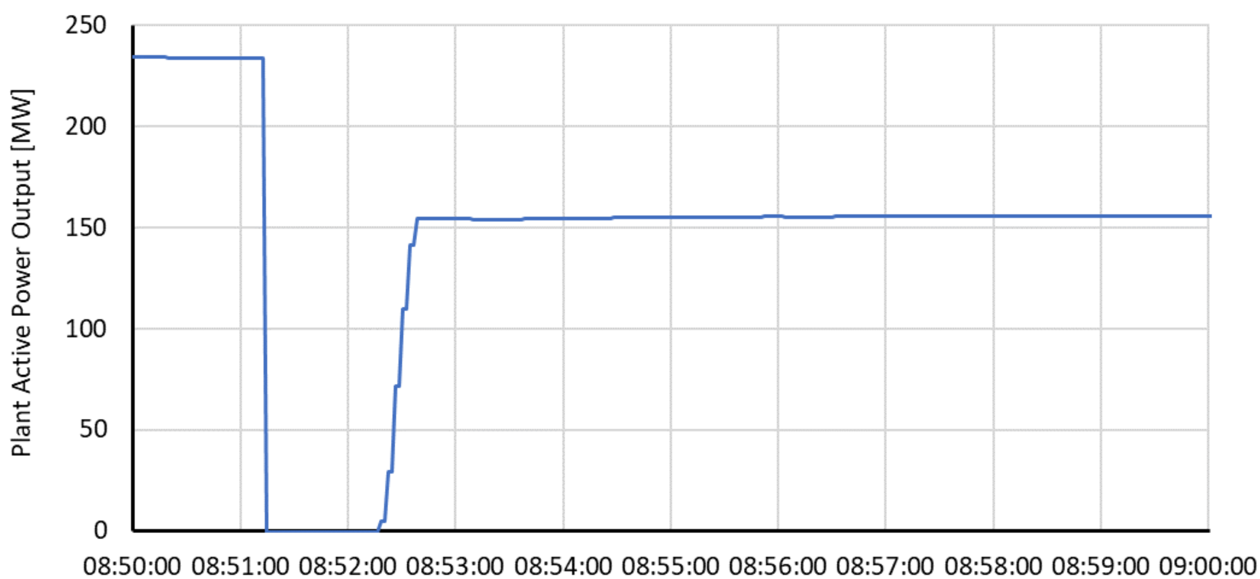


Figure A.4: Plant Active Power at POI

Plant E

Plant E reduced output by 79 MW during the event (see **Figure A.5**). All inverters at the facility tripped. The inverters recorded fault codes for instantaneous ac overvoltage above 125% and phase lock loop loss of synchronism. The plant had no high resolution data available and did not capture any inverter-level oscillography data to analyze the tripping further.

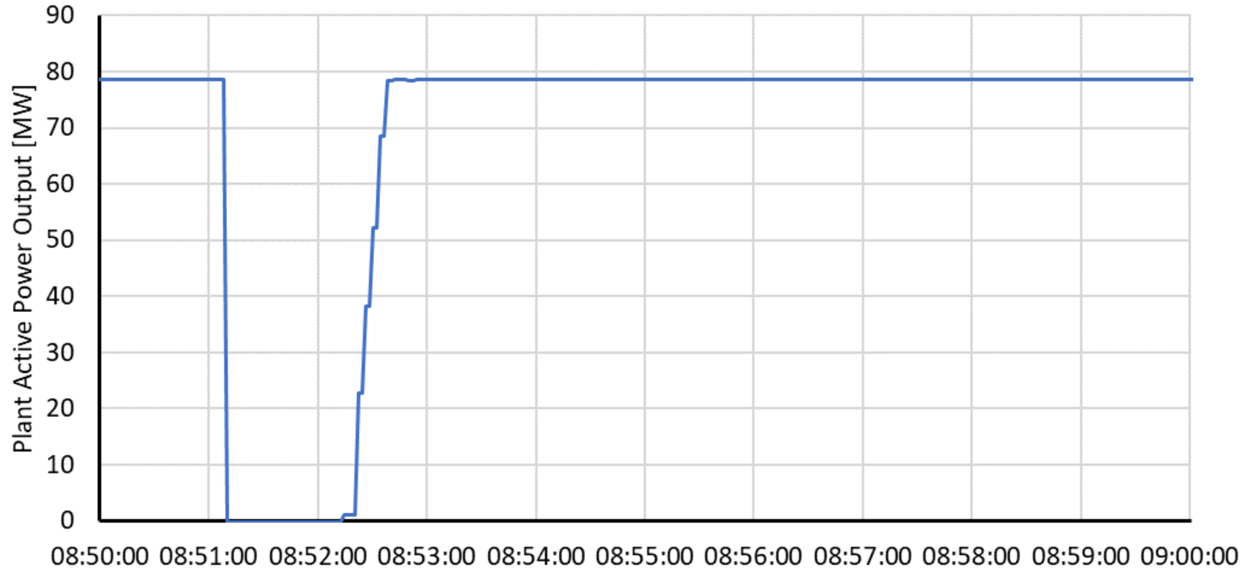


Figure A.5: Plant Active Power at POI

Plant F

Plant F reduced output by 128 MW during the event (see **Figure A.6**). All inverters at the facility tripped. The inverters recorded fault codes involving instantaneous ac overvoltage above 125% and phase lock loop loss of synchronism. The plant had no high resolution data available and did not capture any inverter-level oscillography data to analyze the tripping further.

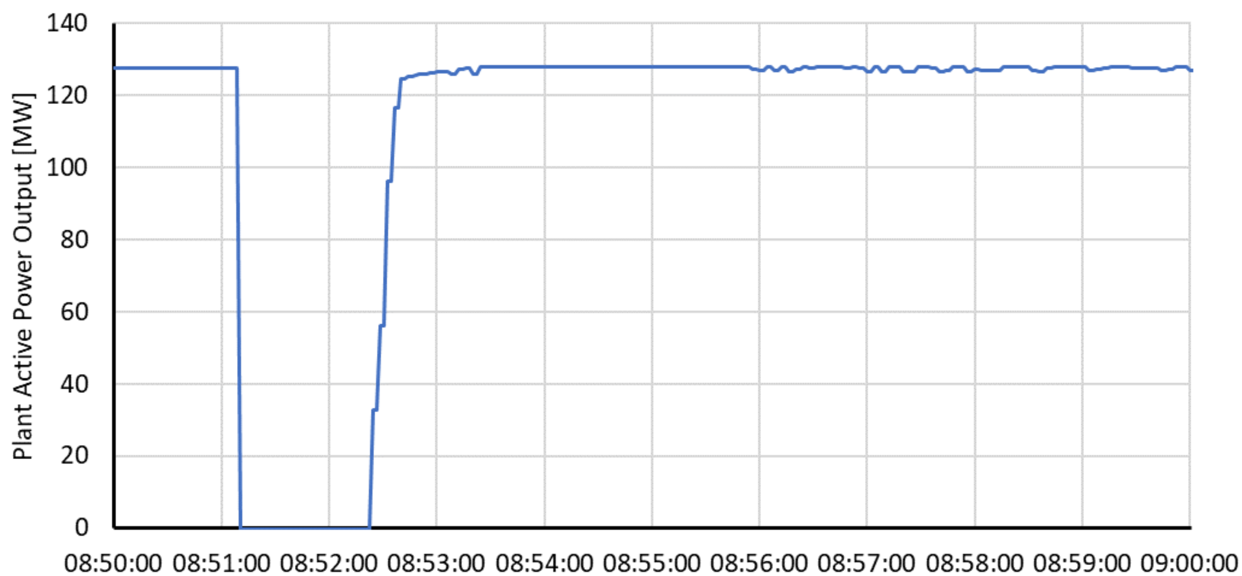


Figure A.6: Plant Active Power at POI

Plant G

Plant G reduced output by 45 MW during the event (see **Figure A.7**). The GO was unable to identify the cause of reduction.

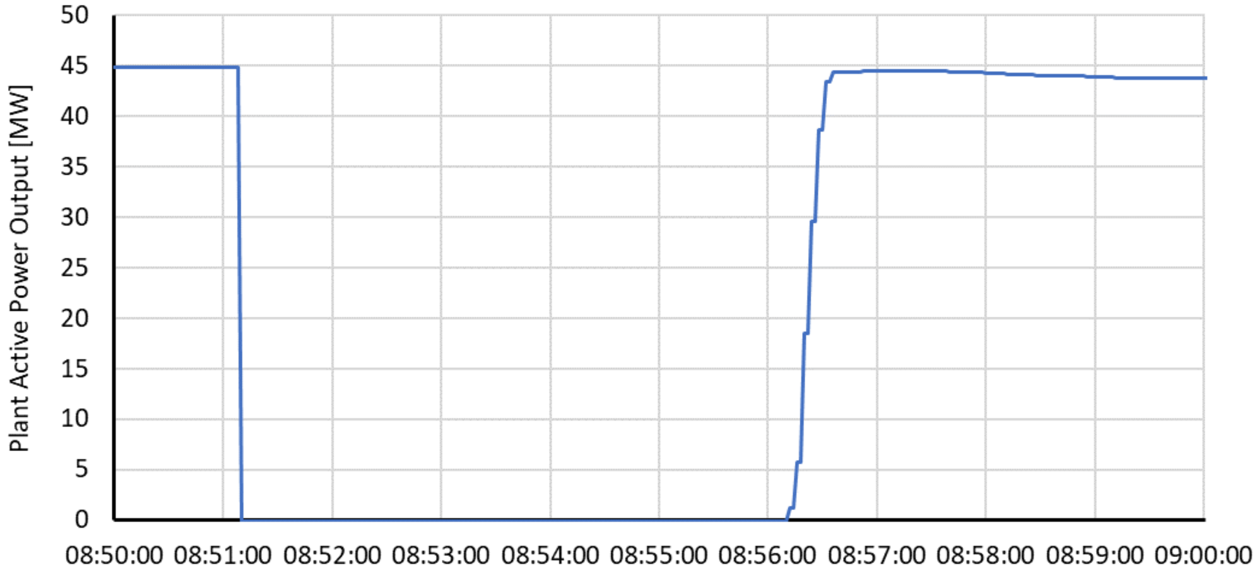
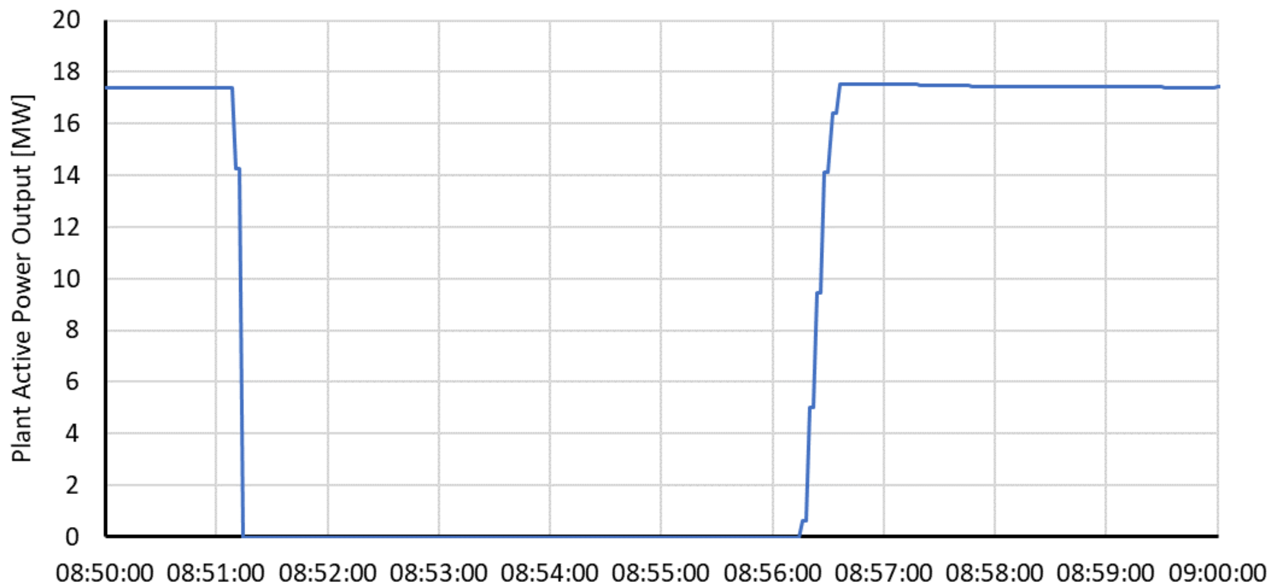


Figure A.7: Plant Active Power at POI

Plant H

Plant H reduced output by 17 MW during the event (see **Figure A.8**). All inverters at the facility tripped on phase lock loop loss of synchronism. The protection was set with a voltage phase jump anti-islanding detection of 15 degrees within 500 ms.



Plant I

Plant I reduced output by 174 MW during the event (see **Figure A.9** and **Figure A.10**). Nearly all inverters at the facility tripped with fault codes indicating passive anti-islanding and ac overcurrent protection operating.

The plant provided high resolution point-on-wave oscillography data at the point of interconnection as well as at the inverter terminals.

The GO identified that the low and high voltage ride-through "switch" parameters were disabled in all but two of their inverters, ultimately resulting in the unexpected tripping. The inverters with the setting enabled rode through the disturbance although they did enter momentary cessation due to these settings.

The GO also shared that they had proactively reached out to the inverter manufacturer for corrective actions. The inverter manufacturer focused primarily on IEEE 1547 standard requirements (particularly for disabling anti-islanding), which is an incorrect application of a distribution-centric standard to the bulk power system. The GO stated that they will be enabling LVRT with a "K-factor" of 2 to support ride-through performance.

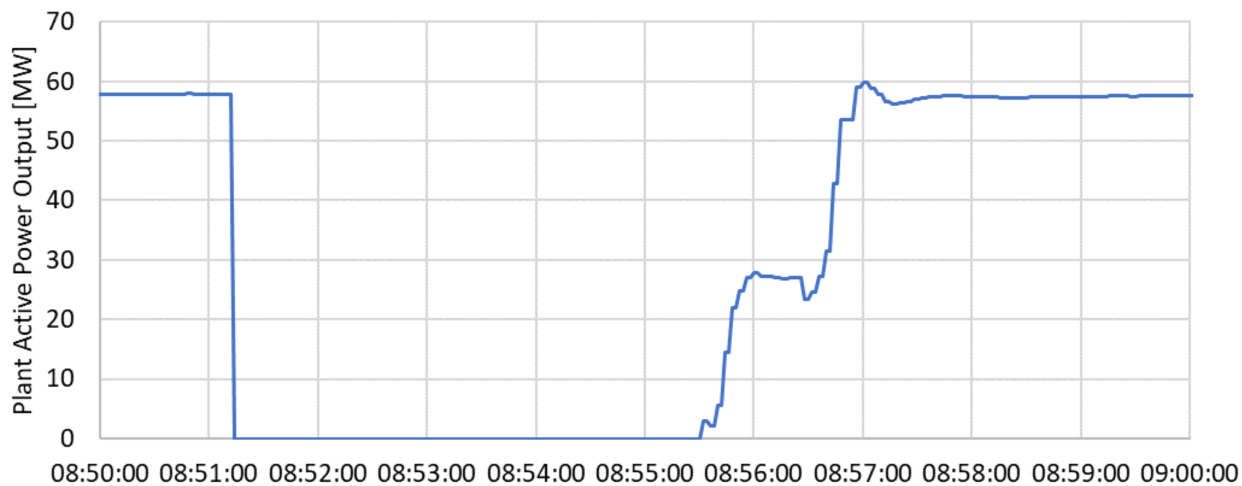


Figure A.9: Plant Unit 1 Active Power at POI

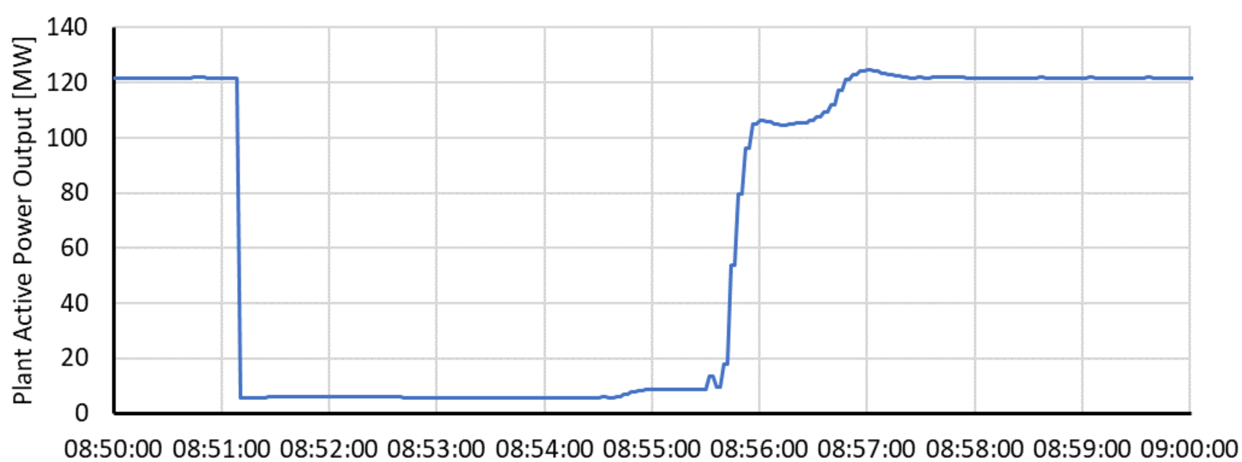


Figure A.10: Plant Unit 2 Active Power at POI

Appendix B: List of Contributors

This disturbance report was published with the contributions of the following individuals. NERC gratefully acknowledges WECC, PacifiCorp, and the affected GOs and Generator Operators. Coordination between all affected entities was crucial for the successful analysis of this disturbance and publication of this report. NERC would also like to acknowledge the continued engagement and support of the inverter manufacturers to ensure that the mitigating measures being developed are pragmatic and implemented in a timely manner. Lastly, members of the NERC Inverter-Based Resource Performance Subcommittee continue to support NERC in its mission to ensure reliable operation of the BPS with rapidly increasing levels of inverter-based resources.

Name	Company
Rich Bauer	North American Electric Reliability Corporation
Ryan Quint	North American Electric Reliability Corporation
Alex Shattuck	North American Electric Reliability Corporation
Aung Thant	North American Electric Reliability Corporation
James Hanson	WECC
Curtis Holland	WECC
William Ruthruff	PacifiCorp
Daniel Koppes	PacifiCorp