NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Industry Recommendation

Loss of Solar Resources during Transmission Disturbances due to Inverter Settings - II

Initial Distribution: May 1, 2018

NERC has identified adverse characteristics of inverter-based resource performance during grid faults that could present potential risks to reliability of the BPS. As the penetration of inverter-based resources (particularly solar PV resources) continues to increase in North America, these adverse characteristics need to be widely communicated. This Level 2 Industry Recommendation alerts industry to these adverse characteristics observed with BPS-connected solar PV resources, and provides recommended actions to address fault ride-through and timely restoration of current injection by all inverter-based resources connected to the BPS.
(See Background section for more information.)

Although this NERC Alert pertains specifically to BES solar PV resources, the same characteristics may exist for non-BES[1] solar PV resources connected to the BPS regardless of installed generating capacity or interconnection voltage. Owners and operators of those facilities are encouraged to consult their inverter manufacturers, review inverter settings, and implement the recommendations described herein. While this NERC alert focuses on solar PV, we encourage similar activities for other inverter-based resources such as, but not limited to, battery energy storage and wind resources.

For more information, see the October 9, 2017 Canyon 2 Fire Disturbance Report.

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Status:	**Acknowledgement Required[2] by Midnight Eastern on May 8, 2018** **Reporting Required by Midnight Eastern on July 31, 2018**

PUBLIC: No Restrictions
More on handling >>

[1] These resources do not meet the Bulk Electric System definition, and are generally less than 75 MVA yet connected to transmission-level voltage.
[2] To the extent that Canadian jurisdictions have implemented laws or requirements that vary from Section 810 of the ROP, NERC requests entities in such jurisdictions voluntarily participate in response to this Alert.

Instructions:	This Level 2 Industry Recommendation provides specific actions that registered entities should consider taking to respond to a particular issue. Pursuant to Rule 810 of NERC's Rules of Procedure (ROP), NERC registered entities shall 1) acknowledge receipt of this Industry Recommendation within the NERC Alert System, and 2) report to NERC on the status of their activities in relation to this recommendation as provided below. For U.S. entities, NERC will compile the responses and report the results to the Federal Energy Regulatory Commission (FERC). Information supplied by Canadian registered entities will not be provided to FERC. This recommendation is not the same as a Reliability Standard and your organization will not be subject to penalties for a failure to implement. Issuance of this recommendation does not replace or modify the requirements of any approved Reliability Standard or excuse the prior failure to follow the practices discussed in the recommendation if such failure constitutes a violation of a Reliability Standard.
Distribution:	**Initial Distribution:** Balancing Authority, Generator Owner, Generator Operator, Planning Coordinator, Reliability Coordinator, Transmission Planner, Transmission Operator **Who else will get this alert? >>**
Primary Interest Groups:	Generation Engineering, Generation Operations, System Operations—Transmission Engineering, Transmission Planning

Recommendations:

As background, all recipients are advised to review the October 9, 2017, Canyon 2 Fire Disturbance Report for more technical information and a detailed description of the behavior (e.g., alternate modes of ride-through, momentary cessation, voltage tripping) of inverter-based resources during the type of event that led to the following recommendations.

Generator Owners

Generator Owners of solar photovoltaic (PV) resources who are receiving this Industry Recommendation should:

Recommendation 1a: Ensure that the dynamic model(s) being used accurately represent the dynamic performance of the solar facilities. Refer to the Modeling Notification published on this topic. If the inverters at the solar facility use momentary cessation, update the dynamic model(s) to accurately represent momentary cessation and provide the model(s) to the Transmission

Planner and Planning Coordinator (to support NERC Reliability Standard TPL-001-4 studies) and to the Reliability Coordinator, Transmission Operator, and Balancing Authority (in accordance with NERC Reliability Standards TOP-003-3 and IRO-010-2). If no change is required in the model(s), a written notification that the previously provided model(s) accurately captures the dynamic behavior of the solar PV facility should be provided. Provide the updated model(s) or written notification of no change to the Transmission Planner, Planning Coordinator, Reliability Coordinator, Transmission Operator, and Balancing Authority as soon as possible but no later than July 31, 2018.

Recommendation 1b: Work with their inverter manufacturer(s) to identify the changes that can be made to eliminate momentary cessation of current injection to the greatest extent possible, consistent with equipment capability. For inverters where momentary cessation cannot be eliminated entirely (i.e., by using another form of ride-through mode), identify the changes that can be made to momentary cessation settings that result in:

a. Reducing the momentary cessation low voltage threshold to the lowest value possible.
b. Increasing the momentary cessation high voltage threshold to the highest value possible, at least higher than the NERC Reliability Standard PRC-024-2 voltage ride-through curve levels.
c. Reducing the recovery delay (time between voltage recovery and start of current injection) to the smallest value possible (i.e., on the order of 1-3 electrical cycles).
d. Increasing the active power ramp rate upon return from momentary cessation to at least 100% per second, unless specific reliability studies have demonstrated otherwise.

Provide these proposed changes, and an accompanying proposed dynamic model, to their Transmission Planner and Planning Coordinator. GOs should provide these proposed models, according to their Transmission Planners'/Planning Coordinators' procedures for modifying existing facilities, as soon as possible but no later than July 31, 2018. Make the proposed changes to equipment settings once the Transmission Planner/Planning Coordinator approves or disapproves the changes (based on Recommendation 6b).

Recommendation 2: Ensure that inverter restoration from momentary cessation is not impeded by plant-level control ramp rates. This could involve adding a short delay before the plant-level controller resumes sending power commands to the individual inverters after voltage recovers and the inverters re-enter continuous operation range.

Recommendation 3: Coordinate with their inverter manufacturer(s) to set inverter voltage trip settings using the following principles:

a. The region outside the "No Trip Zone" of the voltage (and frequency) ride-through curves of NERC Reliability Standard PRC-024-2 does not state that it is a "Must Trip Zone".[3]

b. Inverter voltage trip settings should be based on physical equipment limitations to protect the inverter, as necessary. The PRC-024-2 voltage ride-through curve defines the baseline level of voltage trip settings rather than specifying required trip settings.[4]

c. Refer to Figure 2.4, Pg. 15 of the Canyon 2 Fire Disturbance Report for additional guidance on recommended transient overvoltage ride-through. It is preferable to avoid instantaneous tripping coupled with an unfiltered voltage measurement that could cause inverters to trip for transient (sub-cycle) overvoltages the inverter could withstand without tripping.

Recommendation 4: Consult with their inverter manufacturer(s) and their PV panel manufacturer(s) to implement inverter DC reverse current protection settings based on equipment limitations, such that the resource will not trip unnecessarily during high voltage transients on the BPS.

Recommendation 5: Provide responses to the questions in this NERC Alert to their Reliability Coordinator, Balancing Authority, Transmission Operator, Planning Coordinator, and Transmission Planner as soon as possible but no later than July 31, 2018.

Transmission Planners, Planning Coordinators, Transmission Operators, and Reliability Coordinators

Transmission Planners, Planning Coordinators, Transmission Operators, and Reliability Coordinators who are receiving this Industry Recommendation should:

Recommendation 6a: Track, retain, and use the updated dynamic model(s) (and any other pertinent information gathered from this NERC Alert) of existing resource performance that are supplied by the Generator Owners to perform assessments and system analyses to identify any potential reliability

[3] See NERC Standards Committee meeting package for July 19, 2017 meeting, agenda item 15. https://www.nerc.com/comm/SC/Agenda%20Highlights%20and%20Minutes/SC%20Agenda%20Package_July192017.pdf

[4] *Id*.

risks related to instability, cascading, or uncontrolled separation as soon as possible but no later than December 7, 2018, with notification to their Regional Entity that these studies are complete. For updated models received after July 31, 2018, assessments and system analyses should be performed within 120 calendar days.

Recommendation 6b: Track, retain, and analyze the proposed dynamic model(s) supplied by the Generator Owners that indicate their proposed changes (based on Recommendation 1b) to eliminate momentary cessation to the extent possible. Based on the analysis, approve or disapprove the potential changes based on reliability risks related to instability, cascading, or uncontrolled separation as soon as possible but no later than December 7, 2018, with notification to their Regional Entity that these studies are complete. For updated models received after July 31, 2018, assessments and system analyses should be performed within 120 calendar days.

Reporting Instructions:

Initial acknowledgement of receipt is required[2] by **May 8, 2018 Midnight Eastern** via the NERC Alert System. Responses to the questions below are required[2] to be submitted via the NERC Alert System by **July 31, 2018 Midnight Eastern**. Once a response has been submitted, follow-up or update responses will not be required.

The questions below seek data pursuant to Section 800 of the ROP to support NERC's evaluation of actions taken in response to this Alert and of risks to reliability presented by the identified issues.[5] Plant and inverter information, for example, will enable NERC to track responses, including actions taken in response to this NERC Alert, and to evaluate the extent of conditions associated with the identified issues. Confidential Information should be labeled appropriately per the dropdown option in the **Data Submission Worksheet**.[6] Confidential Information shall be protected in accordance with the provisions of Section 1500 of the ROP. As emphasized in Section 810, for example, NERC's report to FERC regarding actions taken in response to this Alert will include "appropriate protection for Confidential Information or Critical Energy Infrastructure Information."[7]

[5] *See*, Section 810 of the ROP stating, "Members of NERC and Bulk Power System owners, operators, and users shall provide NERC with detailed and timely operating experience information and data."; *see also*, Section 804 of the ROP stating, "To carry out the reviews and assessments of the overall reliability of the interconnected Bulk Power Systems, the Regional Entities and other entities shall provide sufficient data and other information requested by NERC in support of the annual long-term and seasonal assessments and any special reliability assessments."

[6] *See*, Section 810 of the ROP; *and* Section 804 of the ROP stating, "Some of the data provided for these reviews and assessment may be considered confidential from a competitive marketing perspective, a Critical Energy Infrastructure Information perspective, or for other purposes. Such data shall be treated in accordance with the provisions of Section 1500 – Confidential Information."

[7] Section 810(5) of the ROP.

A valid response in the NERC Alert System consists of the following three steps by the submitting entity:

1) Acknowledgement of Alert
2) Submission of Response
3) Approval of Response

The NERC Alert System contains menu options for each of the above commands that are available to authorized individuals upon login. **A response will not be considered valid until all three steps have been completed.**

All Generator Owners, Generator Operators, Reliability Coordinators, Balancing Authorities, Transmission Operators, Planning Coordinators, and Transmission Planners are required to acknowledge receipt of this Alert and respond as applicable.

Contact information for each Region, necessary for the status updates detailed in Recommendations 6a and 6b, is listed below:

- **WECC: alerts@wecc.biz**
- **TRE: rapa@texasre.org**
- **SPP: spprecompliance@spp.org**
- **SERC: Solar_Inverter_Alert@serc1.org**
- **RF: NERCInverterAlert@rfirst.org**
- **NPCC: SolarAlertII@npcc.org**
- **MRO: alerts@midwestreliability.org**
- **FRCC: ea@frcc.com**

If your entity is currently transitioning, or has transitioned, from SPP to a different NERC Region, respond to the Alert in the system using the SPP as your Region.

All Generator Owners (GOs) are required to respond to the following questions:

For GOs: Do you own or operate any solar photovoltaic (PV) generating facilities that are registered in the Bulk Electric System (BES)? (Yes, No)

For GOs that answered "Yes" to the question above, answer the following questions in the attached Data Submission Worksheet. Use the "Add Additional Document" link on the NERC Alert System response web page to submit the completed worksheet. Each row in the worksheet should represent a make and model of inverter at each solar PV facility identified.

Q1: Enter the EIA-860 Solar PV Plant Name.[8]

Q2: Enter the EIA-860 Solar PV Plant Code.[8]

Q3: Enter the EIA-860 Solar PV Plant Nameplate Capacity [MW].[9]

Q4: Enter the inverter manufacturer name (use a different row for each manufacturer in plant).

Q5: Enter the inverter model number (use a different row for each model of inverter for each manufacturer in plant).

Q6: Enter the quantity of inverters for each make and model of inverter.

Q7a: Enter the individual inverter nameplate MW rating for each make and model of inverter [MW].

Q7b: Enter the individual inverter nameplate MVA rating for each make and model of inverter [MVA].

Q8: Do the existing inverter settings use momentary cessation when voltage fall outside the continuous operating range? (Dropdown options)

Q9a: If you answered "Yes" to (8), what is the existing low voltage momentary cessation voltage threshold? (Dropdown options - p.u. voltage)

Q9b: If you answered "Yes" to (8), what is the existing high voltage momentary cessation voltage threshold? (Dropdown options - p.u. voltage)

Q9c: If you answered "Yes" to (8), what is the existing time delay before the inverter begins injecting current after momentary cessation, once voltage has returned to within the momentary cessation voltage threshold(s)? (milliseconds)

Q9d: If you answered "Yes" to (8), what is the existing active current ramp rate when recovering from momentary cessation? (% of nameplate rating/sec)

Q10: Can the inverters be updated to COMPLETELY ELIMINATE the use of momentary cessation for these? (Dropdown options)

Q11: If you answered "No" to (10), can you MAKE CHANGES TO the momentary cessation settings (see Recommendation #1b of this NERC Alert)? (Dropdown options)

Q11a: If you answered "No" to (11), explain the rationale. (Open-ended response)

Q12a: If you answered "Yes" to (11), what is the proposed low voltage momentary cessation threshold? (Dropdown options - p.u. voltage)

Q12b: If you answered "Yes" to (11), what is the proposed high voltage momentary cessation threshold? Dropdown options - p.u. voltage)

Q12c: If you answered "Yes" to (11), what is the proposed time delay before the inverter begins injecting current after momentary cessation, once voltage

[8] If no EIA-860 data exists, use a unique plant name and plant code for each distinct solar PV facility.

[9] If no EIA-860 data exists, provide the equivalent plant nameplate capacity.

has returned to within the momentary cessation voltage threshold(s)? (milliseconds)

Q12d: If you answered "Yes" to (11), what is the proposed active current ramp rate when recovering from momentary cessation? (% of nameplate rating/sec)

Q13: Which models were provided to the Transmission Planner, Planning Coordinator, Reliability Coordinator, and Transmission Operator based on Recommendations 1a and 1b? (Dropdown options)

Q14: Complete the tables in the "Voltage Protection" tab for each inverter model specified for each plant. If no changes were made to voltage protection settings, provide existing settings only. (Complete "Voltage Protection" tab)

Q15: Have you provided your response to the questions in this NERC Alert to your Reliability Coordinator, Balancing Authority, Transmission Operator, Planning Coordinator, and Transmission Planner? (Dropdown options)

Q15a: If you answered "Planned" to (15), provide an expected date for submitting this information to the RC, BA, and TOP. (Enter date)

Q16: Provide any additional comments or clarifications, as necessary. (Open-ended response)

Background:

This Level 2 Industry Recommendation (NERC Alert) is a continuation of the Level 2 Industry Recommendation titled "Loss of Solar Resources during Transmission Disturbances due to Inverter Settings" issued on June, 20, 2017. That Level 2 Industry Recommendation explained that NERC had identified adverse characteristics exhibited by some inverter-based resources, particularly BPS-connected solar PV facilities. These resources were erroneously tripping based on instantaneously calculated frequency and also using an operating mode called momentary cessation (zero current injection) during fault events.

NERC continues to analyze disturbances on the BPS that involve faults that result in the loss of solar PV generating resources. On October 9, 2017, the Canyon 2 Fire caused two transmission system faults that subsequently resulted in a reduction of solar PV generation of over 900 MW. Analysis of this event, and other BPS disturbances, has identified additional inverter characteristics that could potentially present a risk to BPS reliability. For more information on these recommendations, see the 900 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report.

Analyses of recent solar resource loss events have revealed that many inverters have overvoltage trip settings that are based solely on the NERC Reliability Standard PRC-024-2 overvoltage ride-through curve. While the

curve allows for instantaneous tripping at 1.2 per unit voltage, some inverters may not be using filtering for the voltage sensing on their voltage protective trip functions. Instantaneous tripping coupled with an unfiltered voltage measurement can cause inverters to trip for transient (sub-cycle) overvoltage that the inverter could actually withstand without tripping. This unnecessary tripping presents a potential risk of widespread loss of inverter-based resources for a normally-cleared transmission fault. Generator Owners should work with their inverter manufacturers to ensure inverter overvoltage trip settings are set to avoid erroneously tripping for transient overvoltage conditions that the inverters can withstand without tripping. A suggested overvoltage tripping curve is included in the referenced report.

Analysis of these events has also revealed that many inverters are continuing to use momentary cessation. Stability studies have shown that widespread use of momentary cessation could pose a stability risk to the BPS. Generator Owners should eliminate the use of momentary cessation to the greatest extent possible for those inverters where it can be eliminated. Generator Owners whose inverters can be configured to inject current during low voltages should configure those inverters to do so. Generator Owners should consult with their Transmission Planner about prioritizing real or reactive current injection during low voltages. For those that that cannot eliminate the use of momentary cessation, Generator Owners should configure those inverters as per the recommendations outlined in this NERC Alert.

Inverters that must use momentary cessation should quickly return to their pre-disturbance current injection levels (restore output) once voltage has recovered. Guidance is provided in this Industry Recommendation as to how that recovery should occur to support BPS reliability. No intentional delay should be used upon recovery of current following momentary cessation. Analysis of the events has shown that some inverters are impeded from restoring output quickly after momentary cessation by the plant-level controller. Restoring output from momentary cessation is very different than the needs when normally dispatching a resource. System stability is dependent on post-fault response of inverter-based resources, and those resources should restore output very quickly following momentary cessation. Generator Owners with inverters that must use momentary cessation should review their inverter settings to ensure that current injection recovery following momentary cessation has no intentional, programmed delay. All controls, including plant-level ramp rate controls, should be coordinated so as not to impede the inverters from restoring output.

Some inverters were susceptible to tripping on measured DC reverse current. When the inverter has ceased to inject current and a transient overvoltage occurs, the inverter trips on DC reverse current. The inverters that tripped were set with a low tripping threshold for the DC reverse current. This tripping action, in many instances, requires a manual reset of the inverter to resume operation. Generator Owners should consult with their inverter and solar panel manufacturers to address DC reverse current trip settings to protect the equipment yet not trip on transient overvoltage conditions.

Contact:

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