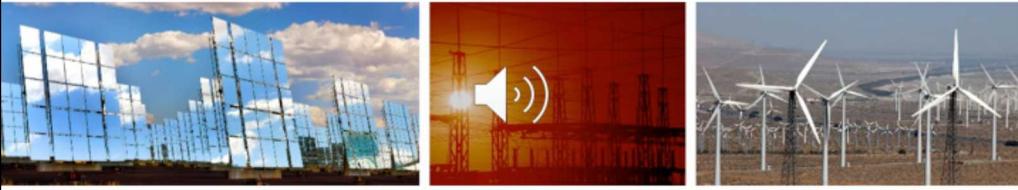


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# Modeling of Momentary Cessation and Voltage Ride-Through

Level 2 NERC Alert  
*Loss of Solar Resources during Transmission Disturbances due to Inverter Settings – II*  
Issued May 1, 2018

Webinar is provided in coordination NERC, DOE/EERE, and Sandia National Laboratories  
Sandia National Laboratories is a multi-program laboratory managed and operated by Sandia Corporation, a wholly owned subsidiary of Lockheed Martin Corporation, for the U.S. Department of Energy's National Nuclear Security Administration under contract DE-AC04-94AL85000



Narration:

Hello. Welcome to a webinar on the modeling of momentary cessation. This webinar is in response to a Level 2 NERC alert titled “Loss of Solar Resources During Transmission Disturbances due to Inverter Settings” issued on May 1, 2018.

# Introduction

- This webinar includes audio – push the audio button on each slide to hear the accompanying narration for that slide
- Webinar addresses situations where you need to accurately model MC and/or eliminate MC
- NERC held a webinar on this Alert. It's recommended to view that before viewing this webinar.
  - Webinar is technical in nature
  - Provides examples on how to fill out the data worksheet
  - Explains motivations behind the alert

[https://www.nerc.com/pa/rrm/Webinars%20DL/Inverter\\_Alert\\_2\\_Webinar\\_20180511.pdf](https://www.nerc.com/pa/rrm/Webinars%20DL/Inverter_Alert_2_Webinar_20180511.pdf)

Initial Distribution: May 1, 2018

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

NERC has identified adverse characteristics of inverter-based resources 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 and provides recommendations for BPS-connected solar PV resources, and other inverter-based resources, 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<sup>1</sup> solar PV resources connected to the BPS regardless of installed generating capacity or interconnection point. Once the industry has implemented the recommendations to address these 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 FME (Disturbance Report).

[About NERC Alerts >](#)

Status: **Acknowledgment Required<sup>2</sup> by Midnight Eastern on May 8, 2018**  
**Reporting Required by Midnight Eastern on July 31, 2018**

 PUBLIC: No Restrictions  
[More on handling...](#)

<sup>1</sup>These resources do not meet the Bulk Electric System definition, and are generally less than 75 MVA connected to transmission-level.  
<sup>2</sup>To the extent that Canadian jurisdictions have implemented laws or requirements that vary from Section 839 of the ROP, NERC requests action in such jurisdictions voluntarily participate in response to this Alert.

RELIABILITY | ACCOUNTABILITY



## Narration:

This webinar is technical in nature, provides examples on how to fill out the data worksheet, and explains motivations behind the alert issued May 1, 2018. This webinar addresses model parameters associated with the NERC alert shown. NERC has held a webinar on this alert previously. It's recommended to view that before viewing this webinar. Please note that this webinar includes audio narration which may be heard by pushing the audio button on each slide.



## Purpose

- This webinar will focus on technical modeling related to the recommendations in the NERC Alert
- Of concern is that dynamic model data used to represent existing solar PV resources connected to the Bulk Power System (BPS) do not always represent momentary cessation response to over/under voltage events
- This webinar introduces no new requirements
- Webinar focuses on BPS-connected solar PV resources with ratings >75 MW, and representing their dynamic response to BPS events
- What will not be addressed
  - Distribution-connected solar PV resources
  - Dynamic system study techniques



Narration:  
Read slide

At this point, we wish to draw a distinction between the models and the model data (or parameters). The 2<sup>nd</sup> generation RE dynamic models have the capability to model momentary current cessation, but in many cases inappropriate model parameters are being used in regional base cases.

While the NERC Alert applies specifically to BPS-connected PV plants greater than 75MW nameplate, NERC encourages all BPS-connected PV to take these actions.

# Webinar Agenda

- Review timeline and logistics of NERC Alert responses
- Review modeling for
  - 2<sup>nd</sup> generation positive sequence dynamic models used to represent BPS-connected solar PV generation
  - Voltage ride-through 
- NERC Alert modeling recommendations
- Data sources for determining proper modeling parameters for both MC and voltage ride-through
- Useful reference documents



Narration:  
Read slide

# Timeline and Logistics of NERC Alert Responses

Rec. #	Description	Provided By	Provided To	Due Date
1A	Update dynamic models for existing configuration or notify of no changes	GO	TP, PC, TOP, RC and BA	7/31/18
1B	Identify feasible disturbance recovery performance changes, provide updated dynamic models	GO	TP, PC	7/31/18
2	Modify plant-level ramp rate controls in post-disturbance period, if necessary	GO	N/A	*
3	Identify feasible changes to inverter voltage trip settings, provide updated dynamic models	GO	TP, PC	7/31/18

\*Any modifications should be provided to applicable entity listed as soon as practical



## Narration:

The timeline and logistics of the required response to the NERC Alerts are provided in this slide and the following slide for convenience. This information was obtained from the NERC Alert itself. The modelling recommendations discussed in this webinar are relevant to all NERC recommendations except for #5.

GO: Generator Owner

TP: Transmission Planner

PC: Planning Coordinator

TOP: Transmission Operators

RC: Reliability Coordinator

BA: Balancing Authority

TBD's are unspecified in NERC alert

# Timeline and Logistics of NERC Alert Responses

Rec. #	Description	Provided By	Provided To	Due Date
4	Implement DC reverse current protection setting changes, if applicable	GO	N/A	*
5	Complete Data Submission Workbook	GO	TP, PC, TOP, RC and BA	7/31/18
6A	Provide notification of completion of system studies with models provided by GO in Rec. #1A	TP, PC, TOP, RC and BA	Regional Entity	12/7/18
6B	Approve or disapprove proposed changes from Rec. #1B, provide notification of completion of system studies with updated models	TP, PC	Regional Entity	12/7/18

\*Any modifications should be provided to applicable entity listed as soon as practical



## Narration:

There is no audio associated with this slide

GO: Generator Owner

TP: Transmission Planner

PC: Planning Coordinator

TOP: Transmission Operators

RC: Reliability Coordinator

BA: Balancing Authority

TBD's are unspecified in NERC alert

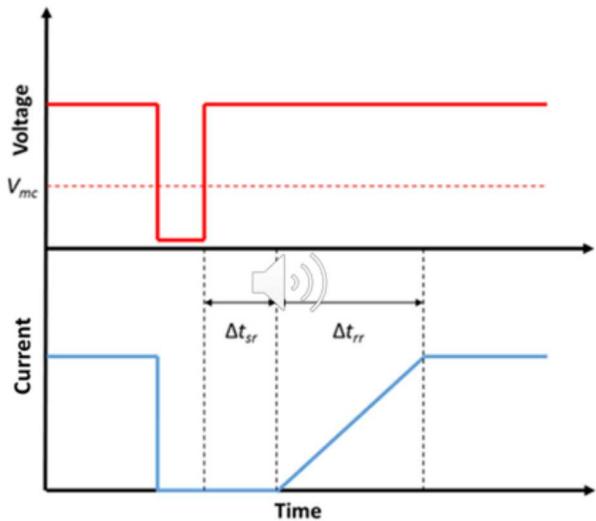
# Momentary Cessation (MC)

- Some inverter types are known to employ MC during under and/or overvoltage conditions at the inverter terminals
- During these events, real and/or reactive current is momentarily ceased for a fixed or programmable time delay
- When terminal voltage returns to its normal range, current injection resumes after the programmed or fixed delay
- Ramp rates on recovery may be limited by fixed or programmable setpoints in the inverter-level and/or plant-level controls
- MC is differs from “tripping” in that during a MC condition, the inverters are still connected to the BES, and power is restored automatically via the inverter control logic. Whereas in tripping, the inverter is electrically disconnected from the BES.



Narration:  
Read slide

## Momentary Cessation (MC) Example



MC operation example in response to undervoltage disturbance



### Narration:

This diagram shows momentary cessation graphically. MC is defined as a decrease of inverter current to zero, while the inverter remains connected to the grid, as a result of inverter terminal voltage falling below a threshold, shown here as  $V_{mc}$ . The inverter current output remains zero after the terminal voltage recovers, for a duration  $\Delta t_{sr}$ . After  $\Delta t_{sr}$ , the inverter current recovers using a controlled ramp rate over period  $\Delta t_{rr}$ . The values  $\Delta t_{sr}$ ,  $\Delta t_{rr}$  and  $V_{mc}$  are parameters unique to individual inverters.

## Review of 2<sup>nd</sup> Generation Generic Positive Sequence Dynamic Models for Solar Photovoltaic (PV) Resources

- **REGC\_A** (Generator/Converter Model): Generates real and reactive current injections for network solution based on current commands and terminal voltage conditions
- **REEC\_A** (Electrical Control Model): Generates real and reactive current commands based on real and reactive power references and terminal voltage and current conditions. Use of REEC\_B model is not recommended.
- **REPC\_A** (Plant Controller Model): Generates real and reactive power references based on remote voltage and power flow setpoints. No changes to the REPC\_A model should be necessary in response to the NERC alert.

*All three models self-initialize state and algebraic variables from solved power flow case conditions*



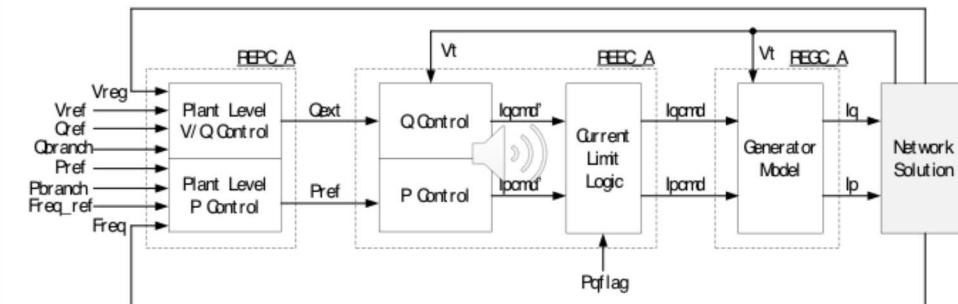
### Narration:

Proper modeling of MC requires the adjustment of specific parameters in the REEC\_A model and the the REGC\_A model. These models are the 2<sup>nd</sup> Generation Generic Positive Sequence Dynamic Models for Solar Photovoltaic (PV) Resources. Though local studies may utilize other models to represent solar PV systems, the 2<sup>nd</sup> generation generic models are required for interconnection-wide dynamics base cases. The generic models are identical across all major software platforms.

Read bullets 1,2,3

The physical plant controller could be configured to limit ramp rate recovery after a momentary cessation event. Such a limitation is not modeled within the REPC\_A model and will not be reflected if it does occur. GOs should ensure, per the NERC Alert, that plant controllers do not restrict recover ramp rate recovery after an MC event . The use of the REEC\_B electrical control model is not recommended for inverters that operate with momentary current cessation during BPS faults due to limitations in modeling MC behavior. We will review the relevant models associated with this Momentary Cessation.

# Model Connectivity



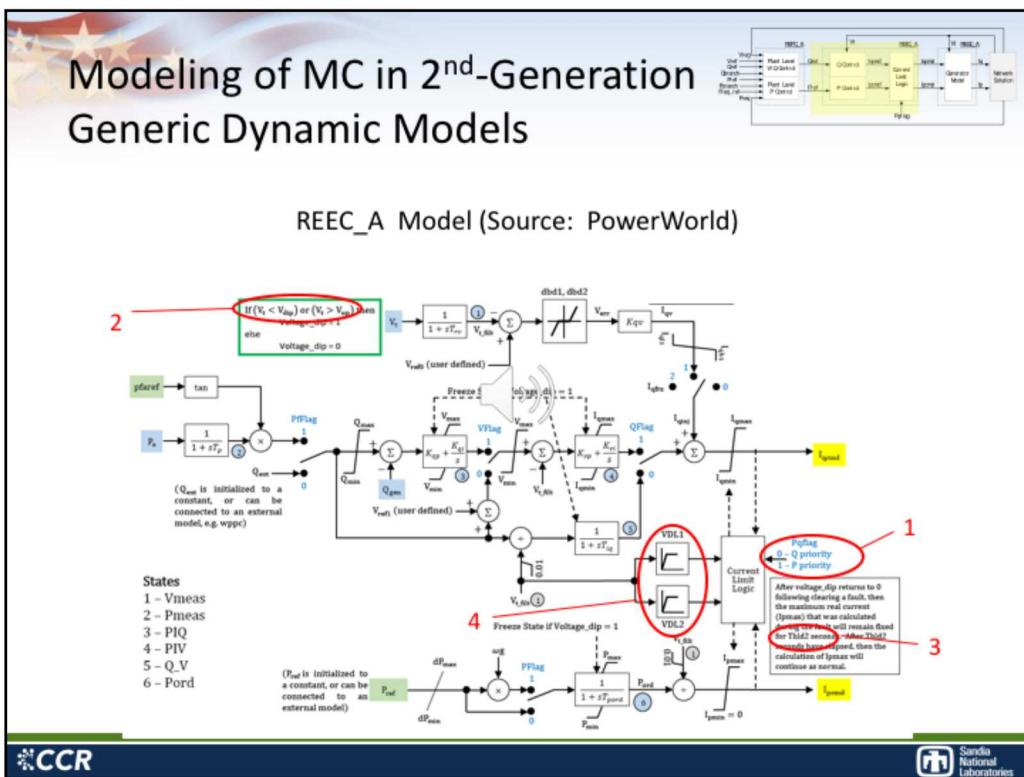
CCR

Sandia National Laboratories

## Narration:

The diagram shows the configuration of models used for PV plant modeling and the signals that are passed between the REPC\_A, REEC\_A and REGC\_A subsystem models. Our focus today will identify values for REEC\_A and REGC\_A that must be confirmed. There are NO changes needed to the plant controller model (REPC\_A), although it is shown here for context.

## Modeling of MC in 2<sup>nd</sup>-Generation Generic Dynamic Models



### Narration:

This diagram shows the 2<sup>nd</sup> generation REEC\_A model which should be checked and updated as necessary per Recommendation 1A. The source of this diagram is from PowerWorld modeling documentation, however, its important to note that the same model is available in other bulk power system simulation programs.

In this diagram we will review the relevant parameters that apply to momentary cessation and the NERC Alert.

1. Ensure the model parameter PQflag is set to reflect actual active or reactive current priority during and immediately following voltage disturbance.
2. Set model parameters vdip and vup to reflect the actual lower and upper thresholds of inverter terminal voltage at which momentary current cessation is triggered. Vdip is represented in the earlier slide (Slide #8) depicting momentary cessation as the parameter Vmc. Vup is not shown in that earlier slide.  
note that:
  - A) Some inverters may use a family of voltage versus time points to define the thresholds of momentary cessation, instead of a single value.
  - B) Since the REEC\_A model only allows a single value, we recommend selecting the most conservative value for grid modeling purposes. That means the thresholds closest to nominal voltage.
  - C) The NERC Modeling Notification recommends that the GO provide the voltage versus time curves in the Comments column of Data Submission Worksheet.
3. Set model parameter Thld2 to represent the actual delay in beginning active current recovery following terminal voltage recovery. Thld2 is represented in the earlier slide as the parameter delta tsr. Note that the 2<sup>nd</sup> generation models do not accommodate recovery delay for reactive current; if reactive recovery is delayed, note that in the Comments column of Data Submission Worksheet.
4. Set model parameters VDL1 and VDL2 tables to properly reflect the inverter's actual voltage-dependent active and reactive current limits. These parameters are used to drive appropriate current limits to zero during momentary cessation.

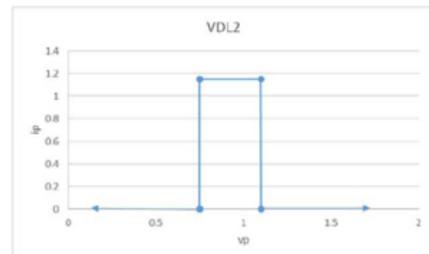
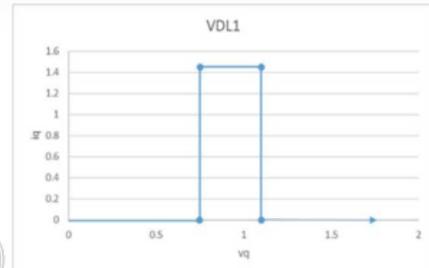
The GO should consult with the inverter manufacturer to find the existing setpoints for each of these parameters.

# VDL Tables: Example

- Low voltage threshold: 0.75 pu
- High voltage threshold: 1.1 pu

Table 2: VDL1 and VDL2 Settings

VDL1		VDL2	
vq	iq	vp	ip
0.74	0	0.74	0
0.75	1.45	0.75	1.15
1.1	1.45	1.1	1.15
1.11	0	1.11	0



## Narration:

This slide shows an example of how the VDL1 and VDL2 tables are populated to represent momentary cessation in a particular inverter. For this inverter, its real and reactive current limits are momentarily reduced from 1.15 pu and 1.45 pu, respectively, to zero when the inverter terminal voltage is less than 0.75 pu or greater than 1.1 pu.

# Modeling of MC in 2<sup>nd</sup>-Generation REEC\_A Model

1. **Pqflag** Active or Reactive Priority Flag
2. **Vdip** MC low voltage threshold (or curve<sup>1</sup>)  
**Vup** MC high voltage threshold (or curve<sup>1</sup>)
3. **thld2** Active current recovery delay<sup>2</sup>
4. **VDL1** Voltage dependent reactive current limit table  
**VDL2** Voltage dependent active current limit table

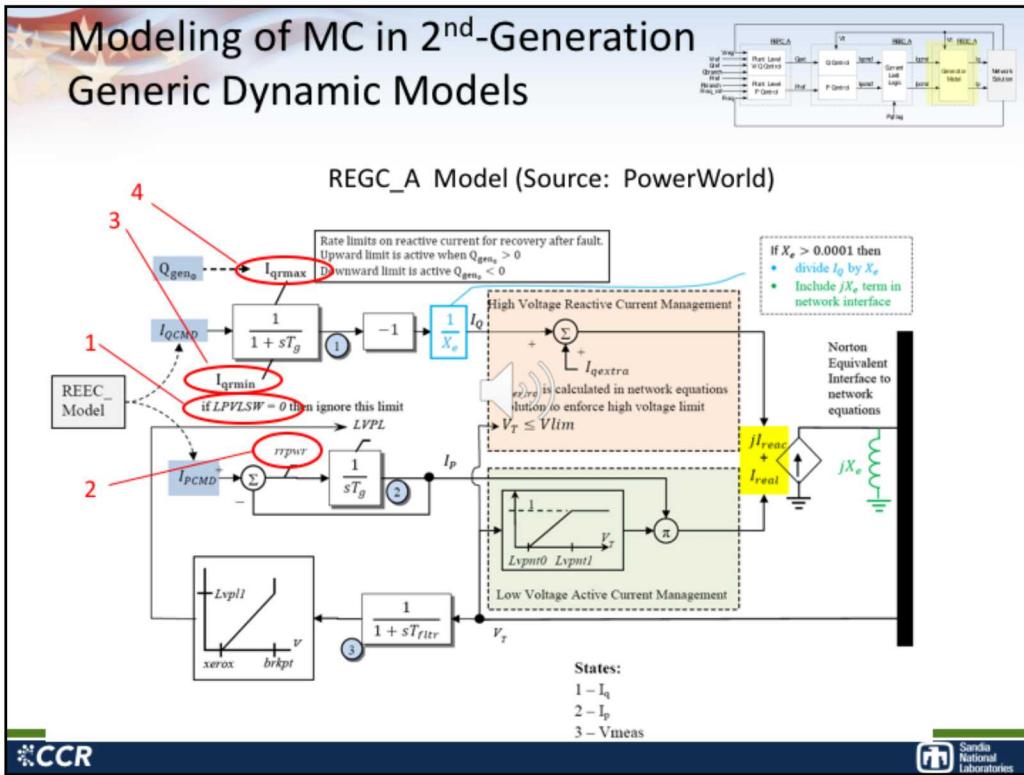
<sup>1</sup>If the limit is based on a time duration, then a curve should be provided

<sup>2</sup>Existing generation of models do not accommodate recovery delay on reactive current; if recovery is delayed, note in Comments column of Data Submission Worksheet



## Narration:

To summarize, this slide lists the model parameters for the REEC\_A model which need to be reviewed and updated. The GO should consult with the inverter manufacturer to find the existing setpoints for each of these parameters. Note that VDL1 and VDL2 are not individual parameters, but tables of 8 parameters each.



### Narration:

This diagram shows the 2<sup>nd</sup> generation REGC\_A model which should be checked and updated as necessary per Recommendation 1A. The source of this diagram is from PowerWorld modeling documentation.

1. Set the model parameter LVPLSW to zero to prevent override of VLD1 and VLD2 settings in REEC\_A model.
2. Set the model parameter rrpwr to the active current recovery rate following an event that invokes momentary cessation.
3. Set the model parameter lqrmax to limit the upward reactive current ramp rate.
4. Set the model parameter lqrmin to limit the downward reactive current rate limit.

For iqrmax and iqrmin, any of the following should be reported: Ramp rate limits, reduced current limit for a specified period of time, or no limit is imposed.

The proper setpoint for each of these parameters should be provided by your inverter manufacturer.

# Key Parameters for Modeling Momentary Cessation: Example

```
regc_a
"lvplsw" 0 "rrpwr" 1.0

reec_a
"vdip" 0.88 "vup" 1.2 "dbd1" -0.12 "dbd2" 0.2
"iqfrz" 0.0 "thld" 0.0 "thld2" 0.5
"vq1" 0.87 "iq1" 0.0
"vq2" 0.88 "iq2" 1.45
"vq3" 1.20 "iq3" 1.45
"vq4" 1.21 "iq4" 0.00

"vp1" 0.87 "ip1" 0.00
"vp2" 0.88 "ip2" 1.45
"vp3" 1.20 "ip3" 1.45
"vp4" 1.21 "ip4" 0.00
```



## Narration:

This slide shows an example of the REGC\_A and REEC\_A parameters used to represent momentary cessation in a particular inverter.

Parameter “rrpwr” in REGC\_A allows for a 1.0 pu per second active current ramp-up return of nominal terminal voltage.

The inverter enters the momentary cessation mode of operation for terminal voltages outside a range of 0.88 to 1.2 pu by driving the real and reactive current limits to zero.

Real current then begins ramping from zero after 0.5 seconds following the return of terminal voltage within the 0.88 to 1.2 pu range.

# Modeling of MC in 2<sup>nd</sup>-Generation REGC\_A Model

1. **LVPSW** Set to zero to prevent override of VLD1 and VLD2 settings in REEC\_A model
2. **rrpwr** Real current recovery ramp rate<sup>1</sup>
3. **Iqrmax** Upward reactive current ramp rate limit<sup>2</sup>
4. **Iqrmin** Downward reactive current ramp rate limit<sup>2</sup>

<sup>1</sup> Active power ramp rate recovery should equal 100% per second per the NERC Alert

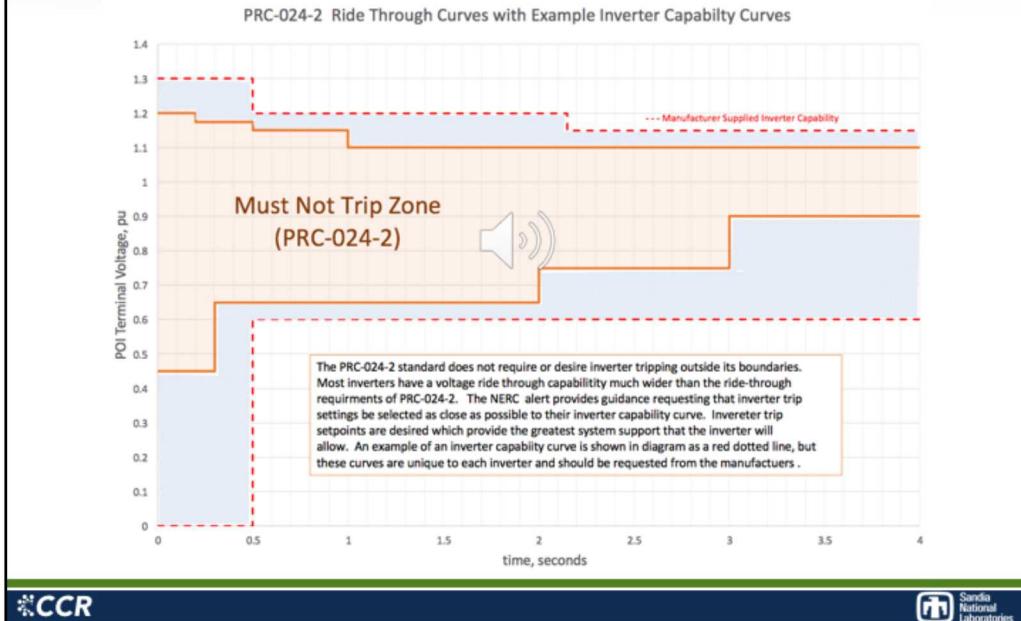
<sup>2</sup> Any of the following should be reported: ramp rate limits, reduced current limit for a specified period of time, or no limit imposed



## Narration:

In summary, this slide lists the model parameters for the REGC\_A model which need to be reviewed and updated. The GO should consult with the inverter manufacturer to find the existing setpoint for each of these parameters.

# Voltage- and Frequency-Related Protection



Narration:

In some cases models are used to represent low/high voltage or frequency tripping, typically using the Low/High Voltage Ride Through Generation Protection (LHVRT) model. There is a similar model used for frequency (LHFRT). Voltage or frequency related Tripping is not modeled using either the REEC\_A or REGC\_A Models

## Desired Solar PV Resource Response to BPS Voltage Disturbances

- Resource must ride through No Trip Zone
- Voltage outside the No Trip Zone does not mean must trip!
- Voltage setpoints and time delays should be as wide as physical inverter limitations allow
- Transient (subcycle) overvoltage during disturbance recovery should not trip resource



Narration: The PRC-024-2 Performance ride-through curves apply to plant protection modeling, but not to MC modeling

1. Resource must ride through No Trip Zone
2. Voltage outside the No Trip Zone does not mean must trip! It is favorable for the inverter to remain online if it can safely do so.
3. Voltage setpoints and time delays should be as wide as physical inverter limitations allow
4. Operation outside the orange boundary is preferred to have resource ride-through, if the resource can safely accomplish it
5. Transient (subcycle) overvoltage during disturbance recovery should not trip the resource- The data may need to be collected from the PV Manufacturer

May 1, 2018 NERC Alert

## Industry Recommendations 1A and 1B

Rec. #	Description	Objectives
1A	GO's: Update dynamic models for existing configuration or notify of no changes	<ul style="list-style-type: none"> <li>Ensure dynamic model parameters accurately represent existing resources <u>as currently configured</u></li> <li>Proper modeling of momentary cessation of power injection and its recovery</li> </ul>
1B	GO's: Identify feasible disturbance recovery performance changes, provide updated dynamic models	 <ul style="list-style-type: none"> <li>Identify feasible changes to inverter and plant controller settings that: <ul style="list-style-type: none"> <li>Eliminate (or reduce the impact of) momentary cessation</li> <li>Reduce, to maximum extent feasible, any post-recovery active power ramp rate limitations</li> </ul> </li> <li>Ensure that dynamic model parameters accurately represent the resources <u>following the implementation of these setting changes</u></li> </ul>



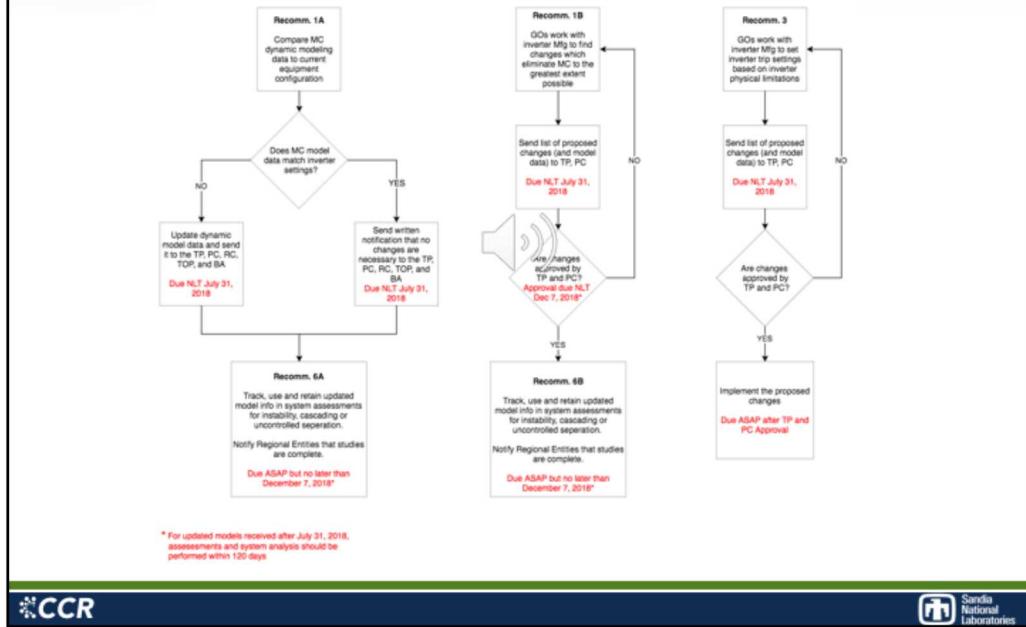
### Narration

This slide summarizes the objectives of NERC Alert recommendations 1A and 1B.

Read slide

# May 1, 2018 NERC Alert

## Industry Recommendations 1A, 1B, 3, 6A, 6B



### Narration:

The flow chart on this slide indicates the relationship between Recommendations 1A and 1B, which are targeted to the Generator Owners, and Recommendations 6A and 6B, which are targeted at the Transmission Planners and Planning Coordinators. Note that any changes proposed in response to Recommendation 1B require approval by the TP/PC before implementation in the field.

# Desired Solar PV Resource Response to BPS Disturbances

- Momentary Cessation
  - Preferred: Eliminate MC where possible (within equipment capabilities)
  - Where MC cannot be eliminated:
    - Reduce MC low voltage threshold to lowest feasible level
    - Increase MC high voltage threshold to highest feasible level (but not lower than NERC PRC-024-7 ride-through levels)
    - Reduce MC recovery delay to shortest feasible time, ideally 1-3 cycles
- Active Power Recovery (Post-Disturbance)
  - Active power ramp rate should  $\geq$  100% per second
  - Eliminate plant controller-induced ramp rate limitations following MC



## Narration

This slide describes the Desired Solar PV Resource Response to BPS Disturbances  
Read slide

# Modeling Data Sources

Rec. #	Description	Data Sources
1A	Update dynamic models for existing configuration or notify of no changes	 <ul style="list-style-type: none"><li>•Inverter settings</li><li>•Inverter test reports</li><li>•Inverter manufacturer simulation results</li><li>•Digital fault recorder data</li><li>•PMU data</li></ul>
1B	Identify feasible disturbance recovery performance changes, provide updated dynamic models	<ul style="list-style-type: none"><li>•Inverter manufacturer</li></ul>



## Narration

This slide discusses the sources of data for response to NERC Alert recommendations 1A and 1B.

Read slide

## Useful References

- [Blue Cut Fire Disturbance Report \(August 16, 2016\)](#)
- [Canyon 2 Fire Disturbance Report \(October 9, 2017\)](#)
- [NERC Alert I](#)
- [NERC Alert II](#)
- [Modeling Notification: Modeling Momentary Cessation](#)
- [NERC Webinar on NERC Alert](#)
- [Resource Loss Protection Criteria Assessment NERC Inverter-Based Resource Performance Task Force \(IRPTF\) White Paper – February 2018](#)
- [NERC Reliability Guideline, BPS-Connected Inverter-Based Resource Performance, April 2018 Draft](#)



### Narration:

The references, all available on the NERC website, may be helpful in providing a deeper understanding of the issues addressed in this webinar.

## Contacts

Technical questions regarding modeling issues addressed in this webinar may be directed to Sandia National Laboratories:

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All other questions regarding responses to the NERC alert may be directed to NERC:

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Narration:  
Read slide