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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

U.S. DEPARTMENT OF ENERGY

NNSA National Nuclear Security Administration

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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

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.

About NERC Alerts >>

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.

RELIABILITY | ACCOUNTABILITY

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

Webinar Agenda

- Review timeline and logistics of NERC Alert responses
- Review modeling for
  - 2nd 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

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

Timeline and Logistics of NERC Alert Responses

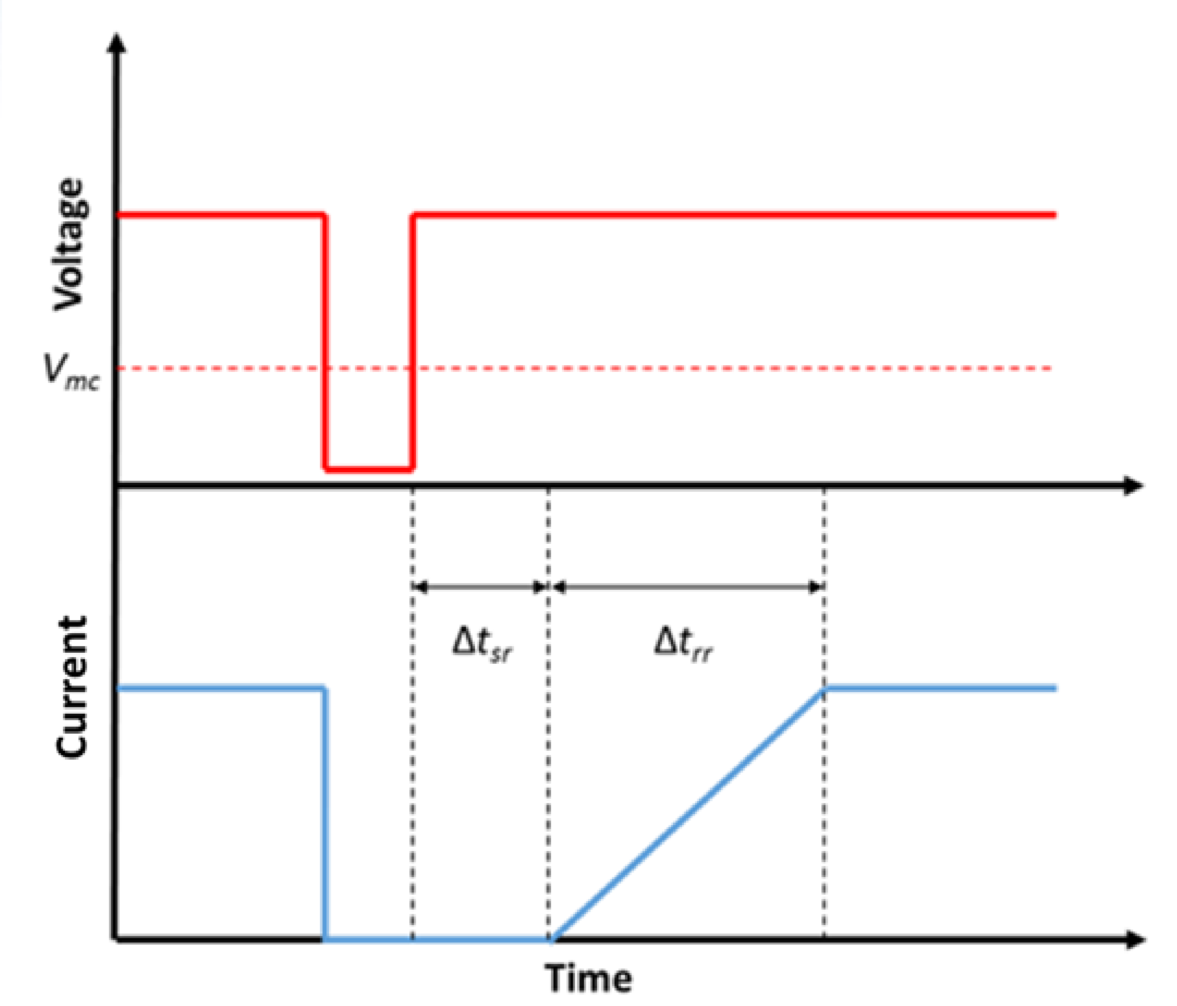
Rec. #	Description	Provided By	Provided To	Due Date
4	Implement DC reverse current protection setting changes, if applicable	GO	N/A	*
5	Complete Data Submission Workbook	GO	TP, PC, TOP, RC and BA	7/31/18
6A	Provide notification of completion of system studies with models provided by GO in Rec. #1A	TP,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

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.

Momentary Cessation (MC) Example



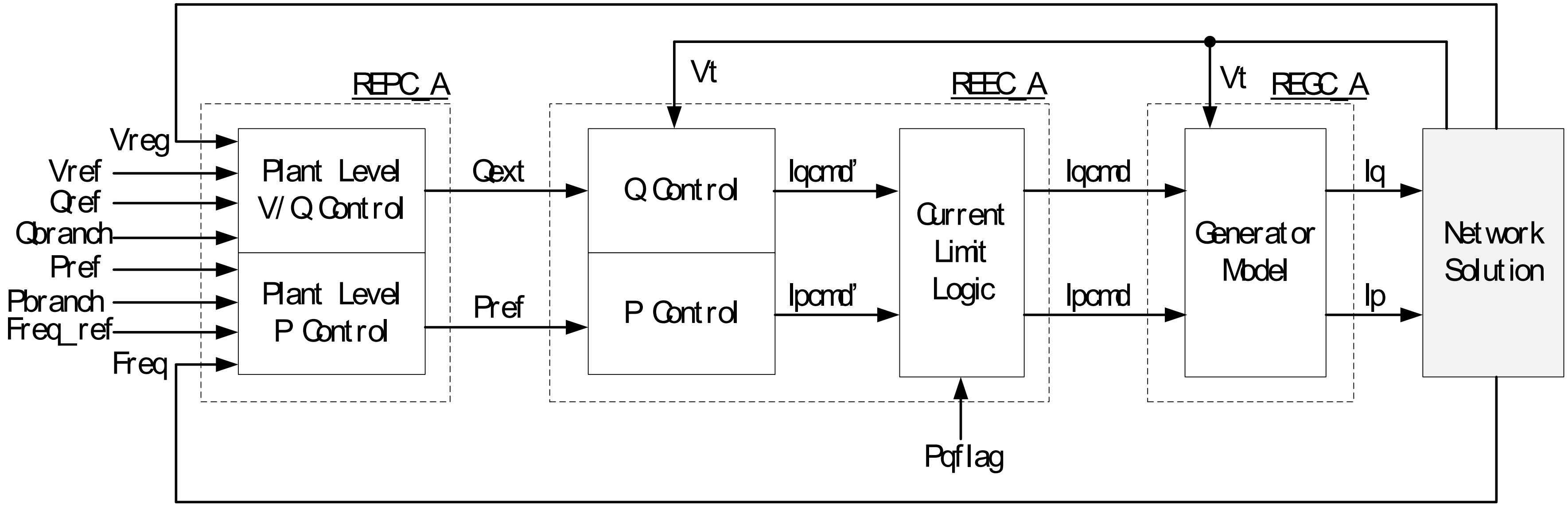
MC operation example in response to undervoltage disturbance

Review of 2nd Generation Generic Positive Sequence Dynamic Models for Solar Photovoltaic (PV) Resources

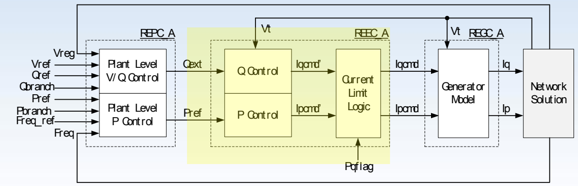
- ***REGC_A*** (Generator/Converter Model): Generates real and reactive current injections for network solution based on current commands and terminal voltage conditions
- ***REEC_A*** (Electrical Control Model): Generates real and reactive current commands based on real and reactive power references 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

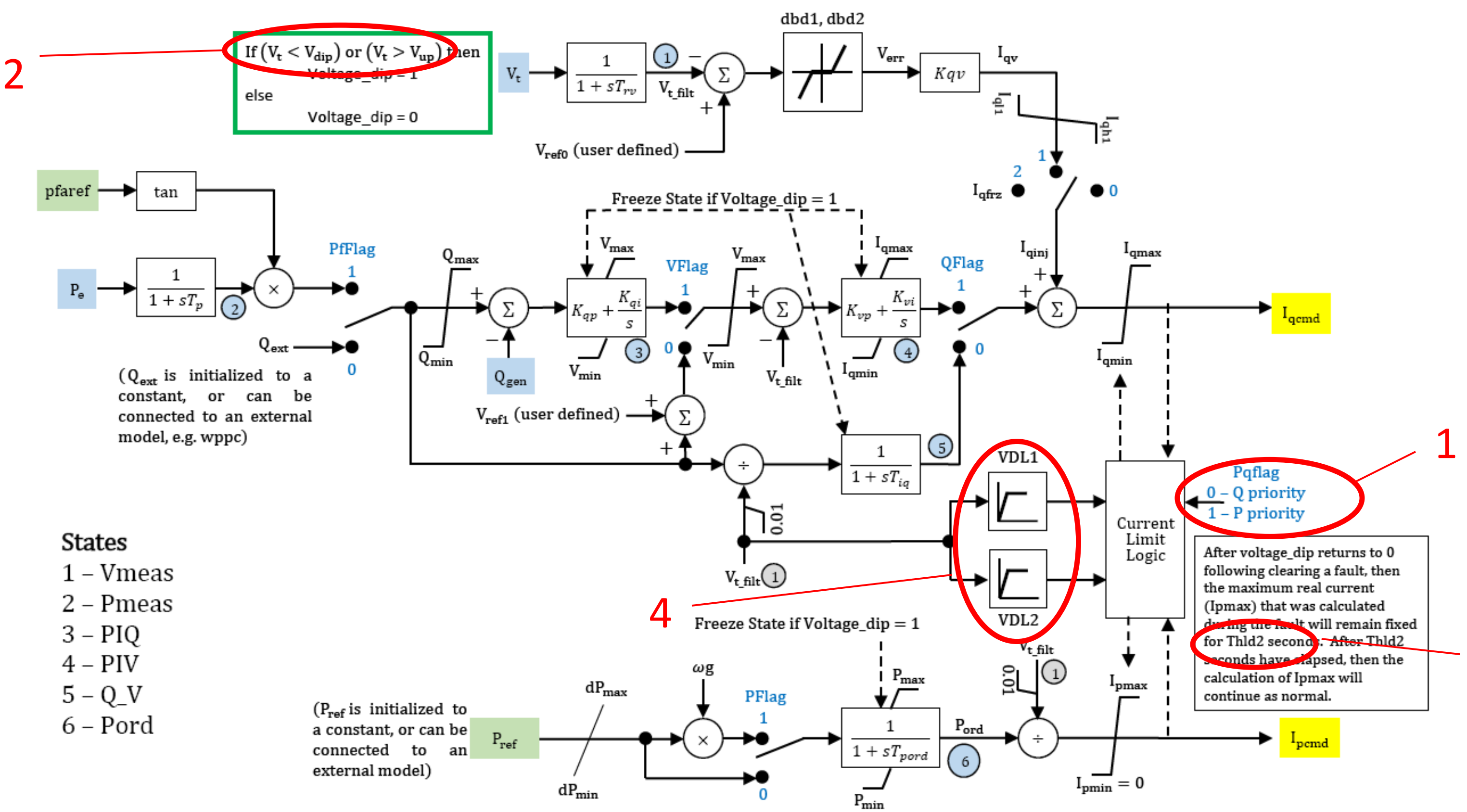
Model Connectivity



Modeling of MC in 2nd-Generation Generic Dynamic Models



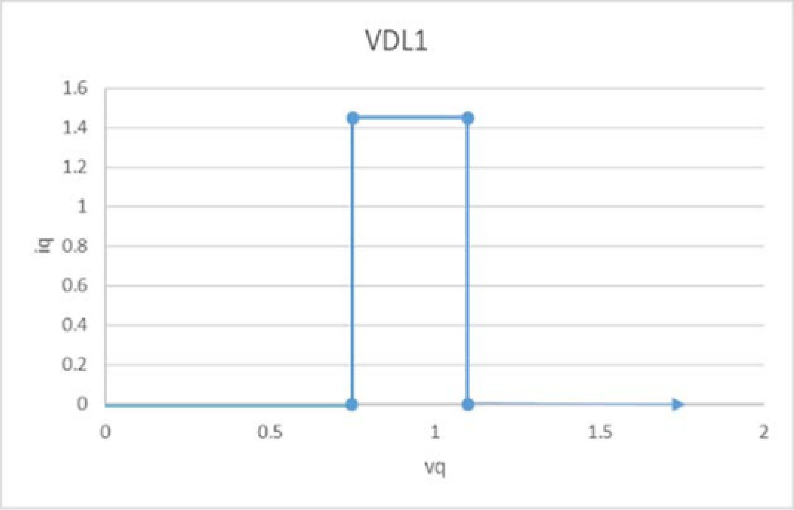
REEC_A Model (Source: PowerWorld)

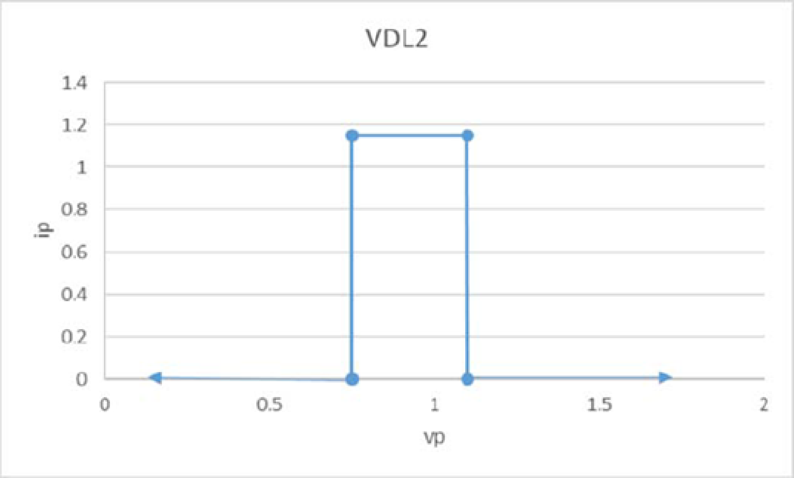


VDL Tables: Example

- 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



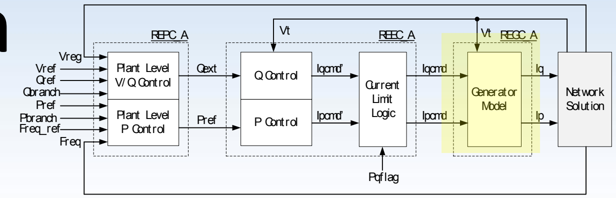


Modeling of MC in 2nd-Generation REEC_A Model

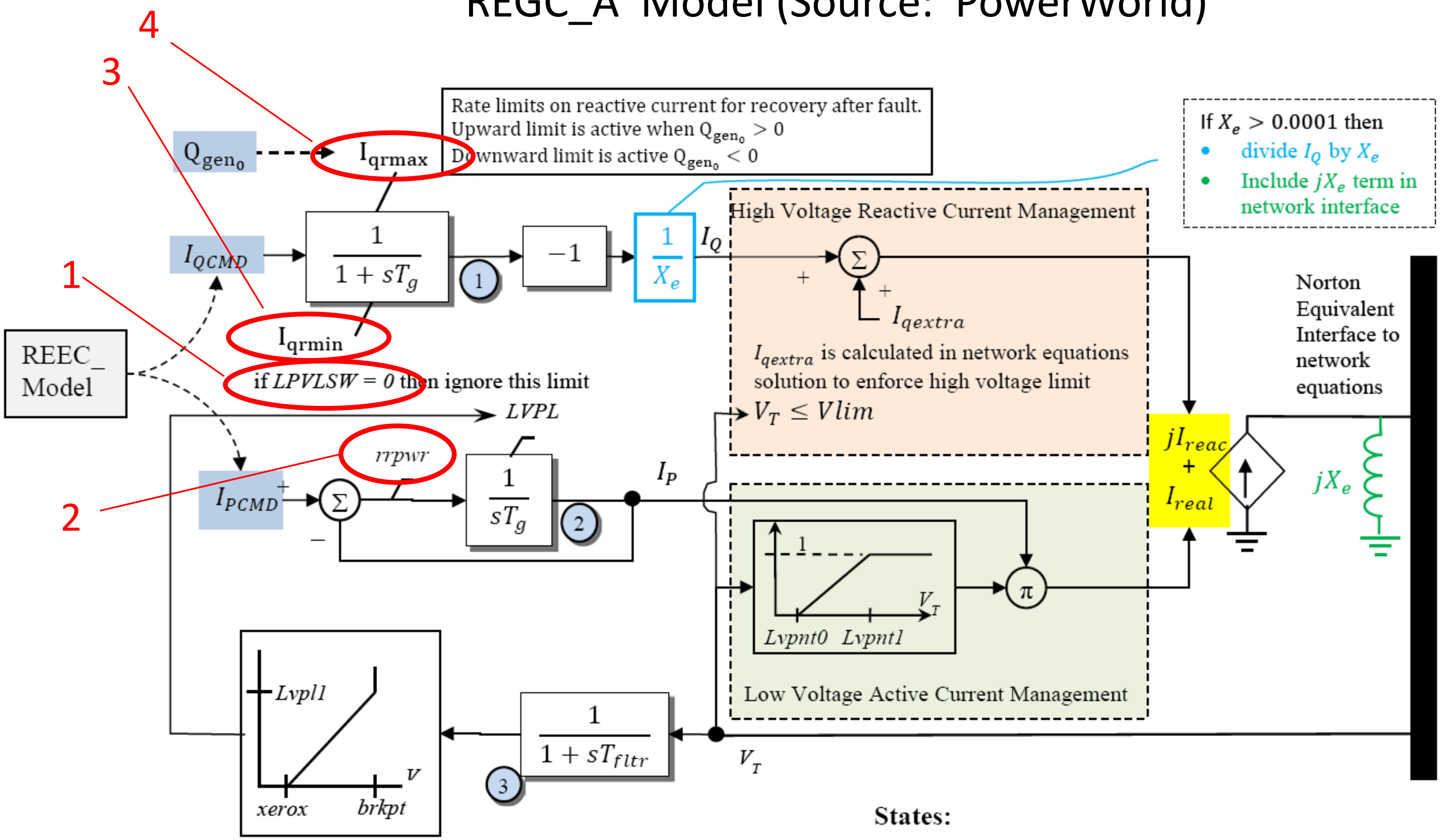
1. Pqflag — Active or Reactive Priority Flag
2. Vdip — MC low voltage threshold (or curve[1])
   Vup — MC high voltage threshold (or curve[1])
3. thld2 — Active current recovery delay[2]
4. VDL1 — Voltage dependent reactive current limit table
   VDL2 — Voltage dependent active current limit table

[1] If the limit is based on a time duration, then a curve should be provided
[2] Existing generation of models do not accommodate recovery delay on reactive current; if recovery is delayed, note in Comments column of Data Submission Worksheet

Modeling of MC in 2nd-Generation Generic Dynamic Models



REGC_A Model (Source: PowerWorld)



States:

1 – I_q

2 – I_p

3 – Vmeas

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"  0.00
 "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
```

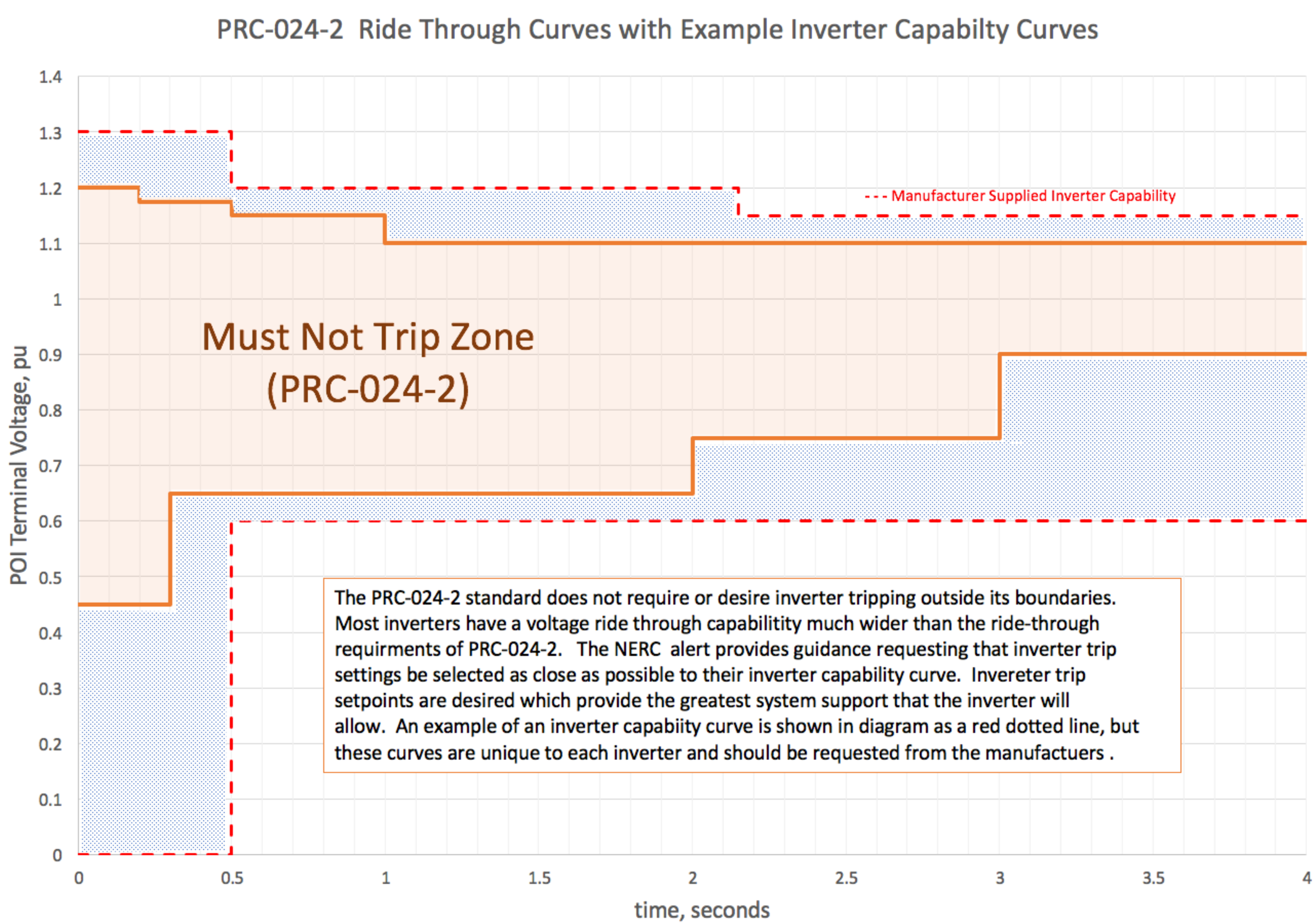
Modeling of MC in 2nd-Generation REGC_A Model

1. LVPSW — Set to zero to prevent override of VLD1 and VLD2 settings in REEC_A model
2. rrpwr — Real current recovery ramp rate[1]
3. Iqrmax — Upward reactive current ramp rate limit[2]
4. Iqrmin — Downward reactive current ramp rate limit[2]

[1] Active power ramp rate recovery should equal 100% per second per the NERC Alert

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

Voltage- and Frequency-Related Protection



Desired Solar PV Resource Response to BPS Voltage Disturbances

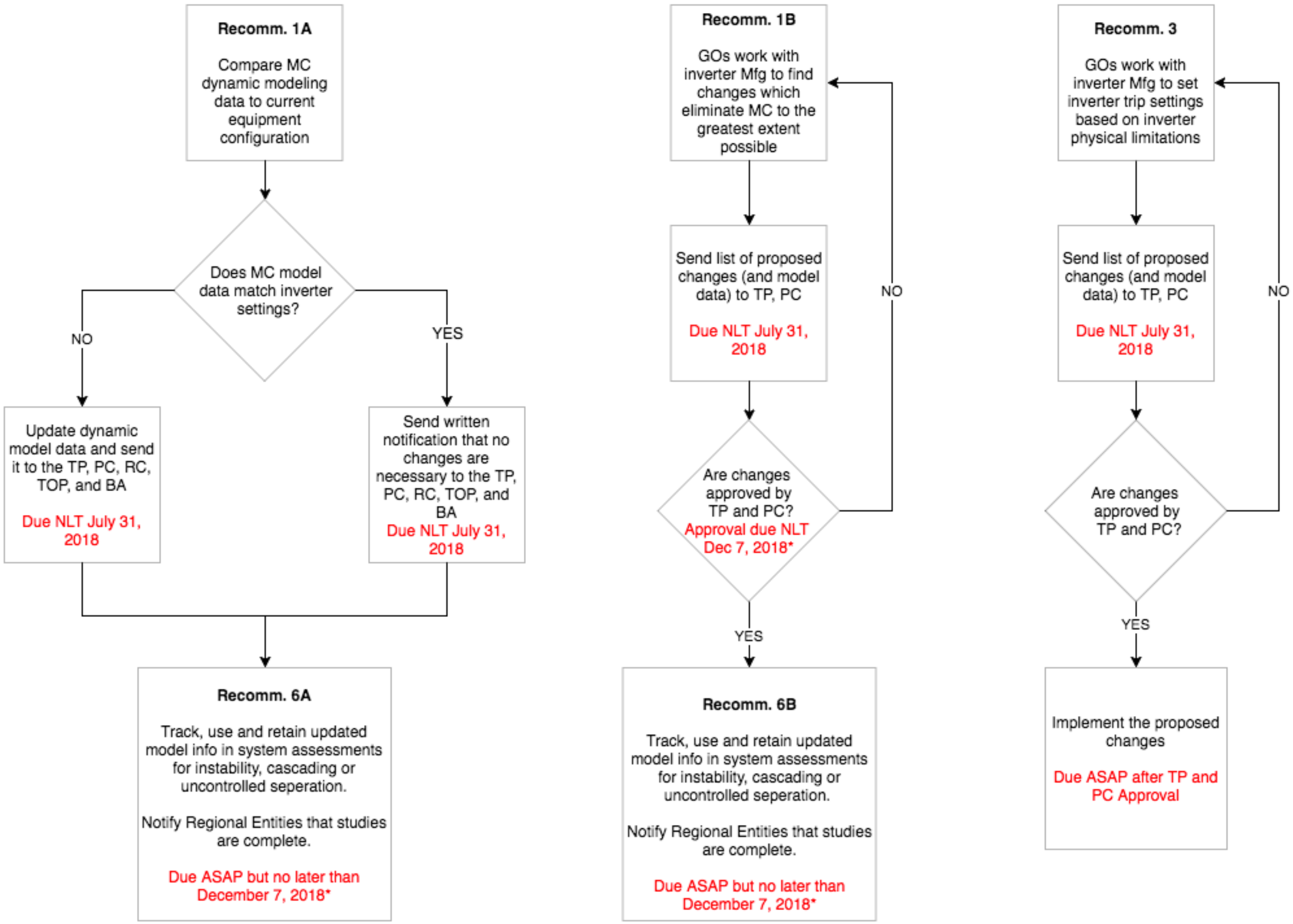
- Resource must ride through No Trip Zone
- Voltage outside the No Trip Zone does not mean must trip!
- Voltage setpoints and time delays should be as wide as physical inverter limitations allow
- Transient (subcycle) overvoltage during disturbance recovery should not trip resource

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	• Ensure dynamic model parameters accurately represent existing resources as currently configured • Proper modeling of momentary cessation of power injection and its recovery

1B	GO's: Identify feasible disturbance recovery performance changes, provide updated dynamic models	• Identify feasible changes to inverter and plant controller settings that:
		    • Eliminate (or reduce the impact of) momentary cessation
		    • Reduce, to maximum extent feasible, any post-recovery active power ramp rate limitations
		• Ensure that dynamic model parameters accurately represent the resources following the implementation of these setting changes

May 1, 2018 NERC Alert
Industry Recommendations 1A, 1B, 3, 6A, 6B



* For updated models received after July 31, 2018, assesesments and system analysis should be performed within 120 days

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-024-2 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 ≥ 100% per second
  - Eliminate plant controller-induced ramp rate limitations following MC

Modeling Data Sources

Rec. #	Description	Data Sources
1A	Update dynamic models for existing configuration or notify of no changes	•Inverter settings •Inverter test reports •Inverter manufacturer simulation results •Digital fault recorder data •PMU data
1B	Identify feasible disturbance recovery performance changes, provide updated dynamic models	•Inverter manufacturer

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

Contacts

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

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