NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

NERC Inverter-Based Resource (IBR) Webinar Series:

Session 2: NERC Disturbance Reports and Lessons Learned

June 8, 2023

RELIABILITY | RESILIENCE | SECURITY




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IBR Disturbance Event Analysis

Rich Bauer
NERC Event Analysis
NERC IBR Webinar Series
June 8, 2023

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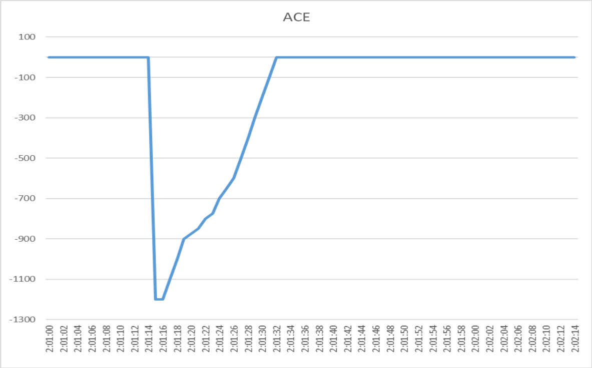
NERC Disturbance Reports

Planned Upcoming Reports:

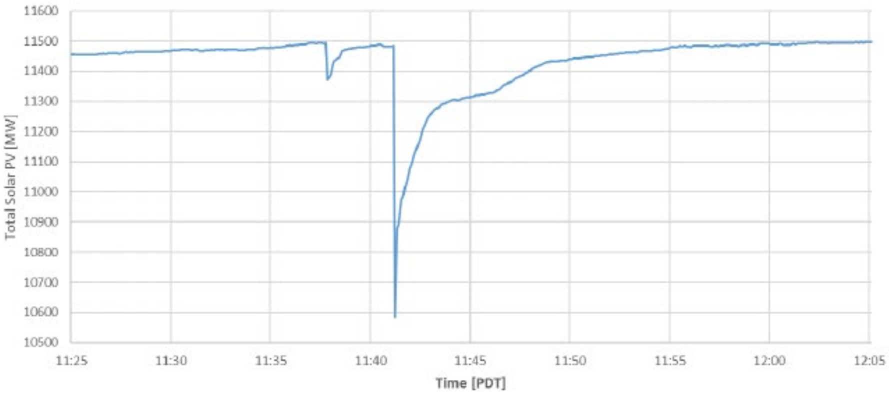
- BESS-Related Events in California in 2022

https://www.nerc.com/pa/rrm/ea/Pages/Major-Event-Reports.aspx

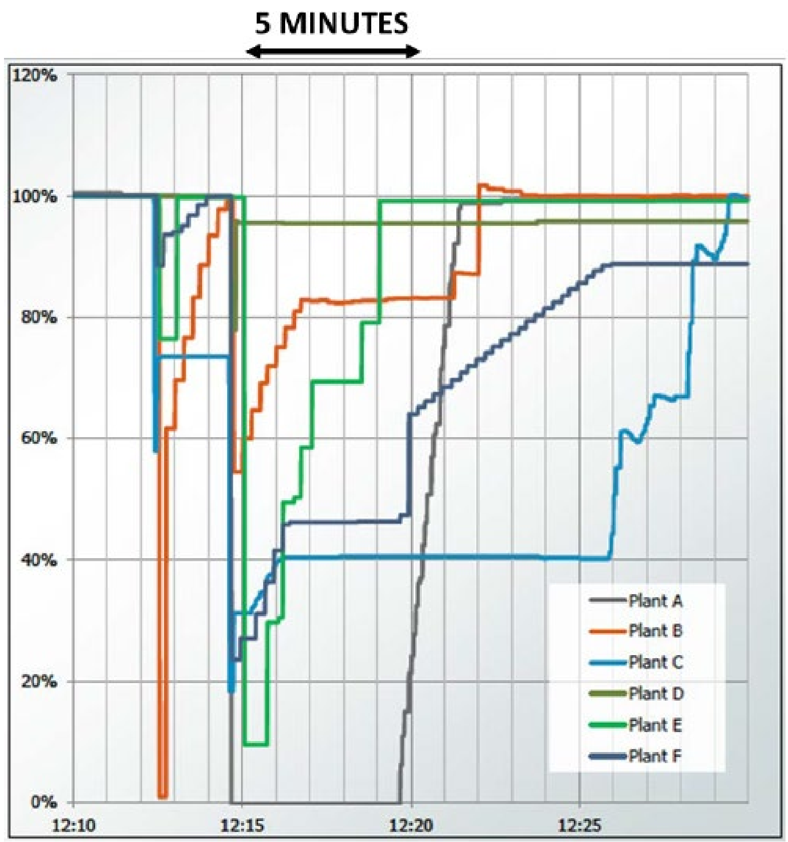
Aggregate Solar PV Response



- Change in ACE
- Change in Total Solar Output



Individual Solar PV Response



Data Requests

- Data recording for facility output during disturbance
  - Highest resolution data available
- Causes of reductions
- Settings for protection that operated during disturbance

Data Request Issues

- Data recording for facility output during disturbance
  - Highest resolution data available
- No high resolution data available – Point on wave data (relay event files, DFR) is the most beneficial data
- Causes of reductions
- SOE Log overwritten
- Settings for protection that operated during disturbance
- Don’t know what the settings are

Lessons Learned/SARS

- EOP-004 SAR
  - Standards Project 2023-01
- PRC-004 SAR
  - Standards Project 2023-06
- PRC-002 SAR
  - Standards Project 2021-04 Phase 2
- PRC-024 SAR
  - Project 2020-02

Questions and Answers After All Presentations

Feel free to reach out to us if interested in participating in the NERC IRPS or EMTTF!

IBR Event Analysis Process

Patrick Gravois
Operations Engineer – Operations Analysis

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IBR Event Analysis Overview

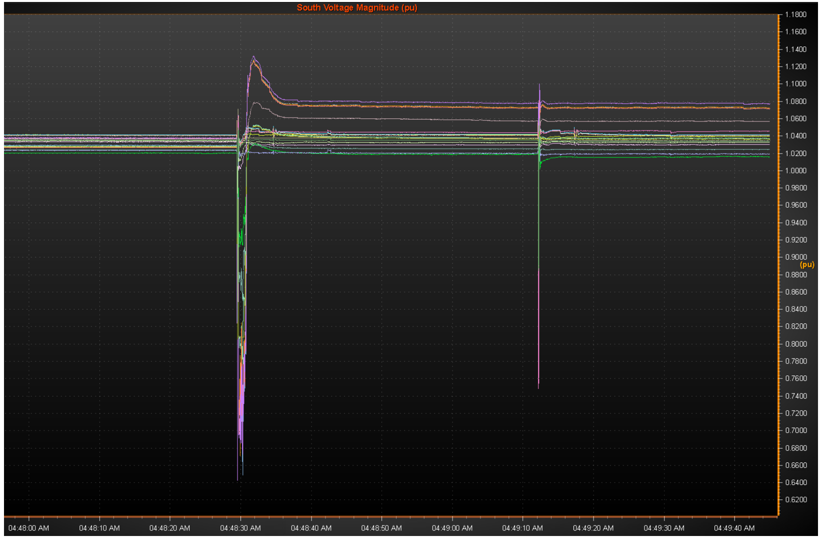
1. Event Detection – based on aggregate SCADA tags
2. Initial Analysis (1-2 days)
   - System Disturbance? SCADA Dropout? Frequency/ACE drop?
   - Find facilities/units that reduced > 10 MW
3. Data Collection – Send requests for PMU data and DFR data (1-2 days)
4. Send out RFIs (1 week)
5. Review high resolution data (2 weeks)
6. Review RFIs (2-3 weeks)
7. Create NERC Brief Report if threshold met (4 weeks)
8. Conduct follow up calls with GOs/OEMs to identify root causes and corrective actions (2 months)
9. Work with NERC/TRE for Final Report (6 months)
10. Follow up with GOs about mitigation plans and implementation (6 months – 1year)

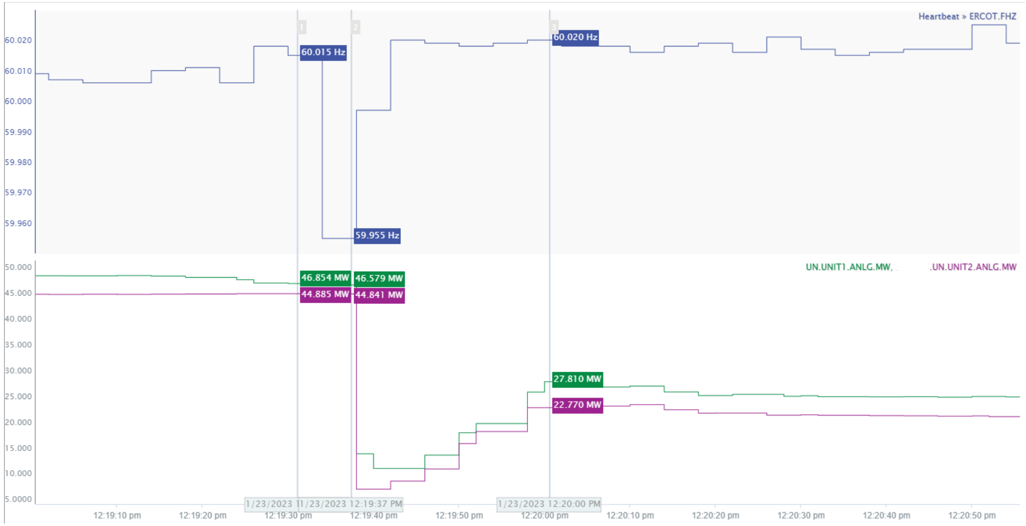
IBR Event Detection

- Three different event types/thresholds – currently manual/automated process performed weekly and working on event notifications
  - ➢ Combined IBR generation SCADA tag with loss > 400 MW within 30 sec period
  - ➢ Solar generation tag with loss and ACE drop > 150 MW
  - ➢ Wind generation tag with loss and ACE drop > 200 MW
- Control room will detect event in real time if large enough for freq. to drop to 59.85 Hz

IBR Event Initial Analysis

- Determine if event is real and due to system disturbance
  - ➢ Significant drop in ACE and frequency?
  - ➢ Real time PMU data and playback to look for voltage disturbance at time of the event
- Run tool to find all units with SCADA MW drop > 10 MW at time of event
- Aggregate losses of individual units



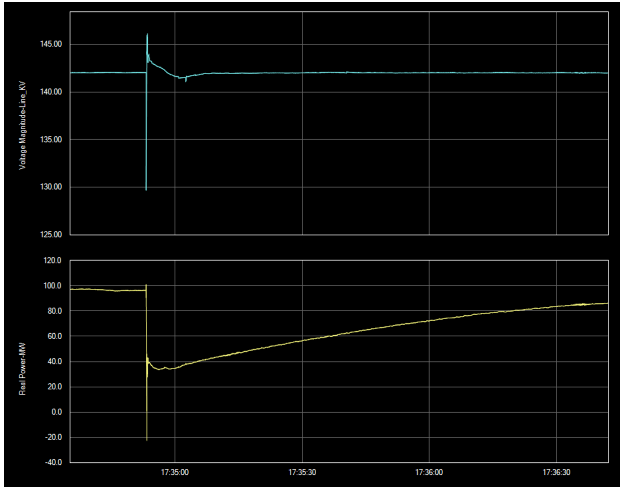


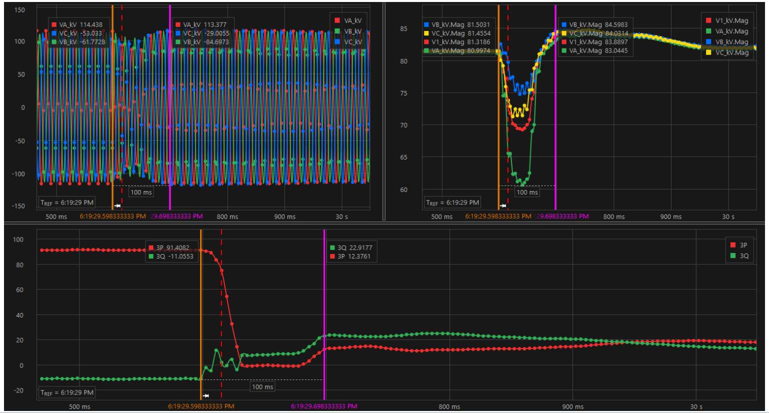
Send Requests for Data and RFIs

- Requests for PMU and DFR data need to go out to GOs ASAP
  - All facilities with loss >10 MW and other facilities in area
  - Data retention requirement is currently 10 days – in process of extending
  - GOs given 1 week to provide data
- RFIs sent out within 1 week
  - TOs and GOs given 2 week deadline
  - Fault and disturbance details
  - Inverter and turbine tripping or slow recovery
  - Fault codes and root cause analysis
  - Protection settings

Review Data and RFI Responses – Create NERC Brief Report

- Calculate active and reactive power in PMU and DFR data
  - ➢ Verify calculated power matches SCADA
  - ➢ Often data incomplete or wrong time – need to request again
- Units that recover to pre-disturbance output within 1 second not included in aggregate loss total
- Determine aggregate loss based on high resolution data
- Determine if there were potential ride-through failures
  - ➢ POI voltage and frequency within "No trip Zone?"
- Verify number of inverter or turbines that tripped
  - ➢ SCADA tags unreliable – verify with RFI response
- Create event summary, narrative, sequence of events, and rest of NERC Brief Report





Corrective Actions and Mitigation Plans

- Schedule follow-up calls with GOs and OEMs to discuss root cause analysis and potential corrective actions
  - NERC/TRE often on calls to gather information for final ERO report
  - Review data and unit performance
  - Identify potential settings that may have caused inverter/turbine tripping
  - Determine potential settings changes that can improve ride-through performance without risking equipment damage
  - Work with OEMs to develop potential updates to improve performance
- If ERCOT deems there was a ride-through failure, GOs must submit mitigation plan and timeline
  - GOs given 3-4 weeks to submit plan
- ERCOT continues follow-up with GO until corrective actions have been implemented
  - Continues work with NERC for final ERO report providing latest information and verification
  - Notifies Electric Reliability Monitor of potential Operating Guide violations
  - Requests model updates during process and validates models

Questions and Answers After All Presentations

Feel free to reach out to us if interested in participating in the NERC IRPS or EMTTF!

Business Segment Large Scale

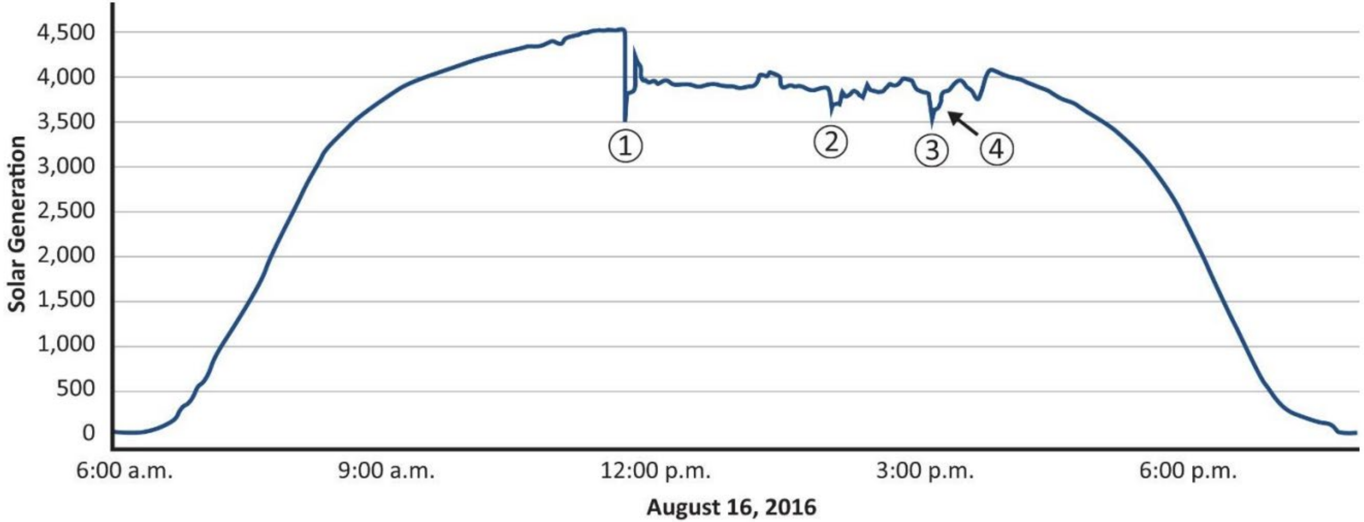
Lessons SMA Learned from the NERC Disturbances Reports

Allan Montanari

Lessons SMA Learned from the Blue Cut Fire Event

Blue Cut Fire Event (13 faults at 500 kV lines, 2 faults at 287 kV lines):

- 4 faults led to **1178 MW of PV generation reduction**
- SMA inverters were impacted with **underfrequency tripping** and entering **momentary c**



Lessons SMA Learned from the Blue Cut Fire Event

Causes of MW Reduction applicable to SMA inverters

- **Erroneous frequency measurements during faults** (inverters measured under 57 Hz; FNET at WECC measured 59.87 Hz):
  - voltage transients with **distortion** (not a sinewave)

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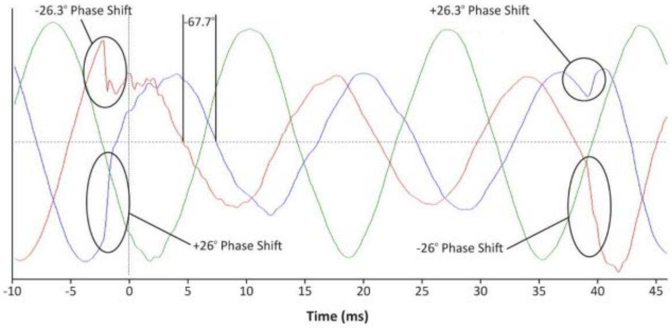


Distorted voltage from the disturbance

SMA Solutions Implemented

- **PLL (Phase Lock Loop) is used for frequency measurements** feeding the protection settings algorithms
- **Improved PLL filtering** to increase frequency measurement accuracy during distorted voltage waveforms
-

Parameter	Value	Unit
Pll.Inv.DmpRto	2	
Pll.Inv.SetTm	0.045	s
Pll.Inv.HzGraLim	300	Hz/s
Pll.Inv.On2Srch.NomSum	320	
Pll.Inv.HzFilOn2Off.NomSum	300	
Pll.Inv.HzFilOn2Wt.Vol	0.75	pu
Pll.Inv.HzFilWt2On.Vol	0.65	pu
Pll.Inv.HzFilOff2On.Vol	0.6	pu

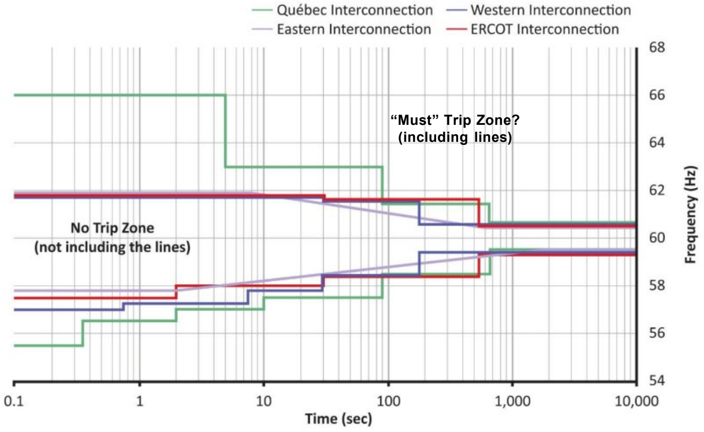
Recommended PLL settings (prevention of loss of synchronization)

- **Detailed SMA Benchmarking Reports** available under NDA

Lessons SMA Learned from the Blue Cut Fire Event

Causes of MW Reduction applicable to SMA inverters

- **Near Instantaneous Underfrequency Tripping** (PRC-024-2 Standard and misleading interpretation of "must trip" zones)
  - Inverters configured to **trip in 10 ms under 57 Hz**



PRC-024-2 Frequency Ride-Through Curves

SMA Solutions Implemented

- SMA worked with CAISO/NERC to **add a time delay to inverter frequency tripping** to ride through transient/distorted voltage waveforms without tripping
- **Inverters freeze the PLL frequency measurements during that time delay** exclusively for frequency protection purposes immediately after leaving the no trip zones
- SMA worked with CAISO/N ... **and high frequency trip param...**

Revised Parameters	Value
HzCtlMin	57.0 Hz
HzCtlMinTm	5 Sec.
HzCtlMax	61.7 Hz
HzCtlMaxTm	2 Sec.
GdErrTm	30 Sec.

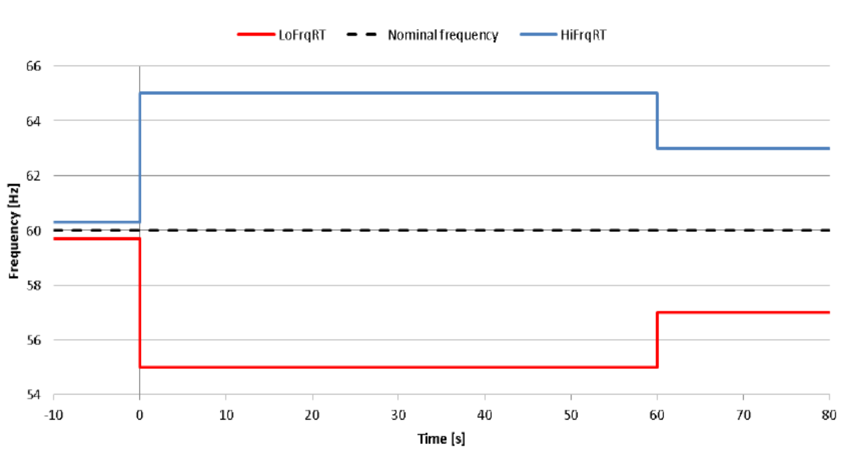
- SM...

Inverter Series	# Inverters	# PV Plants in CAISO	Capacity
Sunny Central CP	3965	35	2907 MW
Sunny Central UP	426	14	935 MW
TOTAL	4391	49	3842

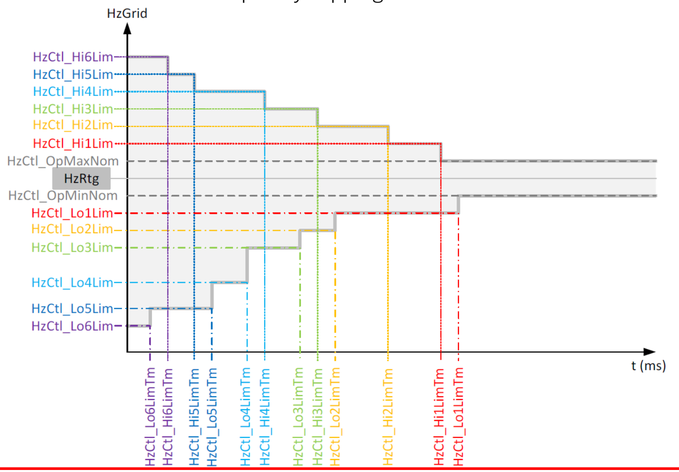
SMA Frequency Ride-Through Capabilities and Customizable Frequency Protection Envelopes

- **Ride through frequency curves** with the capability of reducing the output power at high frequency scenarios
  - +/- **3Hz** of the nominal frequency the inverter can **operate permanently**
  - +/- **5Hz** of the nominal frequency the inverter can **operate for 60 seconds**
- Offers **6 overfrequency** and **6 underfrequency** customizable **trip limits** with associated **time delays**

SMA Maximum Inverter Frequency Ride Through Capability



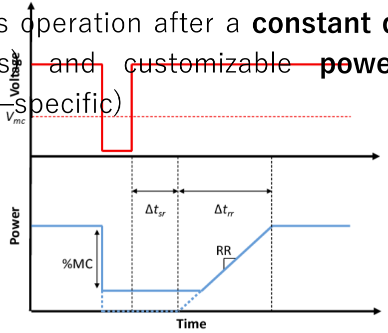
Parameters for user-defined frequency tripping thresholds and associated time delays



Lessons SMA Learned from the Blue Cut Fire Event

Causes of MW Reduction applicable to SMA inverters

- **Momentary Cessation** (default below 0.9 pu & above 1.1 pu)
  - **inverters cease to inject current** (block IGBT firing pulses)
  - resumes operation after a **constant delay** (typically 500 ms) and customizable **power ramp rate** (project-specific)



Momentary Cessation Characteristics

- Some SMA inverters with **FRT-partial** mode enabled **stopped injecting current during fault**

SMA Solutions Implemented

- **Eliminated momentary cessation** mode in IBRs connected to the Bulk Power System (BPS) to the greatest extent possible
- **Enabled Full Dynamic Grid Support**: most common and preferred FRT mode for inverters connected to the BPS:
  - reactive/active current injection (reactive current priority at current limit)

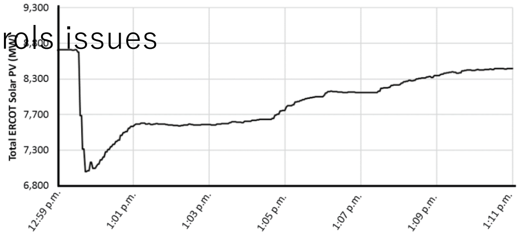
Dynamic Grid Mode (FRT)	Description
DISABLE	Dynamic grid support is deactivated
FULL	**Complete dynamic grid support is activated**
~~PARTIAL~~	~~Limited dynamic grid support~~
MOMENTARY CESSATION	Limited dynamic grid support activated while the apparent current is reduced simultaneously
ACTIVE CURRENT CONSTANT	Inverter supplies reactive power without reducing the active current fed in and without exceeding the nominal current
MAXIMUM ACTIVE CURRENT	Inverter increases the active power to the maximum regardless of the pre-fault condition, without limiting the reactive current for full dynamic grid support

- It ... from 5 minutes (UL1741) to 30 seconds

Fast forward: from 2017 Blue Cut Fire to 2022 Odessa Report

2022 Odessa Report (B-phase-to-ground fault cleared in 3 cycles on the 345 kV system in Odessa, Texas)

- **1711 MW of PV generation reduction** due to protection and controls issues



ERCOT Solar PV Profile for June 4, 2022

Main Causes of MW Reduction

- PLL loss of synchronism (phase angle jump trip)
- AC overvoltage trip (1.25 pu)
- Instantaneous AC overcurrent protection (1.4 pu, 1.5pu)
- Momentary cessation
- DC voltage imbalance trip
- Incorrect inverter ride-through configuration:
  - FRT support disabled (zero active power during faults)
- Instantaneous underfrequency trip (57.5 hz–feeder protection)

Lessons Learned by SMA

- NERC disclosed inverter OEMs of the facilities involved with generation loss
- There were **no inverters in operation manufactured by SMA involved** with the PV generation reduction
- **Confirmed that SMA has a very robust inverter technology contributing to the Bulk Power System increased reliability**

Other Lessons SMA Learned from the NERC Disturbance Reports

1

EMT models are needed (ride-through performance cannot be fully investigated using positive sequence simulations):

- Detailed **PSCAD/EMTDC models** available (”**Digital Twin**”): real firmware from inverter boards also runs in PSCAD
- **RTDS/RSCAD/GTSOC** models available for HIL (Hardware-In-the-Loop) simulations
- Challenges:
  - Plant-level models needs to be customized for each project to address grid code requirements

2

Proper selection of hardware options:

- **Transient High Voltage Ride Through Hardware Option** (in addition to our standard HVRT):
  - 2.0 pu for 1.66ms, 1.7 pu for 3ms, 1.4 pu for 20ms
- **Extended Low Voltage Ride Through Hardware Option** (16 kJ buffer):
  - Consecutive low voltage ride through events for 60s

3

Proper selection of parameters settings:

- **SMA benchmarking validation report** (under NDA) with recommended parametrization settings for challenging scenarios

Business Segment Large Scale

Thank you

Allan Montanari
Principal Engineer
allan.montanari@sma-america.com
SMA Solar Technology
3925 Atherton Road
Rocklin, CA 95765, USA
www.sma-america.com

Questions and Answers

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