Inverter Ride through Functions

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Presentation Outline

- **Acknowledgements**
- **Background - Ride Through versus Trip Settings**
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  - Operating Regions
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Acknowledgments

- **This presentation is intended to give an overview of issues associated with inverter based ride through functions.**
- **The recommendations provided herein are based on the work done to date by the California Smart Inverter Working Group, and the UL 1741 / IEEE 1547 Working Groups for ride through**
- **These recommendations represent an evolving consensus of the active utility and inverter industry members of the Smart Inverter Working Group and those participating in the 1741 / IEEE 1547 revision process.**

Background - Ride Through vs Trip Settings

- Historically US regulations have been written around must disconnect requirements not around must remain connected requirements.
- Extended trip settings with large voltage and frequency windows DO NOT ensure that DER will stay online during abnormal frequency excursions.
- Additional specification of ride through needed to insure that DER remains online during these excursions.
- The issues are complex and the desired behavior varies depending on the direction, magnitude and duration of the excursions as well as utility specific operational considerations, e.g. coordination with load shedding and voltage regulation schemes.

Why is Ride Through Needed ?

- **Fundamentally, ride through is needed to avoid cascade failure of the utility grid during severe under frequency events, and to a lesser degree, severe under voltage events.**
- **Limit loss of generation to “an acceptable level”**
  - During severe under frequency events DER should remain online until local load shedding schemes have activated.
  - Local Load shedding schemes will shed load AND generation simultaneously thereby minimizing the net loss of generation during an event.
  - If DER is lost ahead of load, grid instability may quickly worsen and possibly lead to cascade failure.

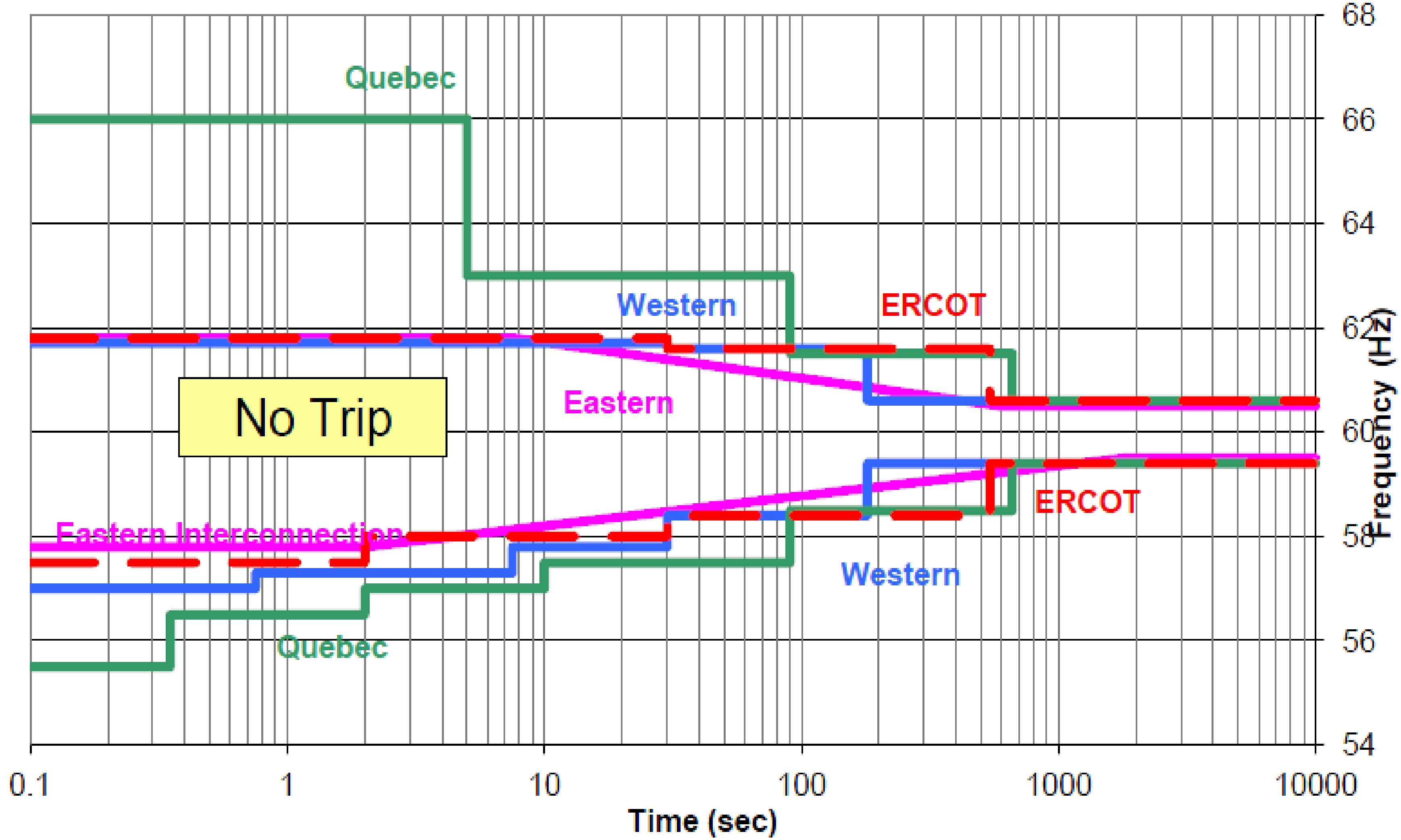
Abnormal Excursions

- **Abnormal excursions can be divided into four basic types.**
  - Under frequency – below 59 Hz
  - Over frequency – above 61.5 Hz
  - Under voltage – below ANSI Range B. < 88% PU
  - Over voltage – above ANSI Range B, >110% PU
- **During under frequency events it is essential for the DER assets to remain connected primarily to support the bulk system.**
  - Support of distribution system is important but secondary
- **In contrast during over voltage and over frequency events the DER should self regulate and attempt to reduce the Voltage or frequency**

Objectives – Low Frequency Ride Through

- **Low frequency ride through (LFRT):**
  - Reduce chances of cascade failures of bulk system by minimizing sudden loss of DER during low frequency event
  - Coordinate frequency trip behavior of DER with utility frequency load shedding schemes
- **Benefit:**
  - By shedding generation with load shedding schemes, i.e. in a predictable manner, grid stability is enhanced.
  - Load shedding schemes can be designed to shed load faster than generation
    - Shed feeders with low levels of generation first.
    - Shed feeders with high levels of generation later.

NERC Off-Nominal Frequency Curves



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Objectives – High Frequency Ride Through

- **High frequency ride through (HFRT):**
  - Reduce generation quickly to limit magnitude and duration of high frequency excursions.
  - Bring DER back online quickly following short duration high frequency events to minimize disruptions.
- **Benefit:**
  - System frequency stability is enhanced
  - Avoids mandatory time delays and ramp rates associated with tripping
- **Note:**
  - HFRT is a crude (on/off) form of a frequency/Watt function and is likely not needed if f/W is enabled.

Objectives – Low Voltage Ride Through

- **Low voltage ride through (LVRT):**
  - Improve system stability by minimizing sudden loss of DER during short duration low voltage events.
  - Minimize voltage disturbances on distribution system.
  - Avoid desensitization of overcurrent protection during feeder faults.
- **Benefit:**
  - Minimizes current disruptions during brief faults.
  - Reduces tap changer / voltage regulator operations following brief faults.
  - Allows DER to momentarily cease-to-export thereby limiting fault current and avoiding desensitization of overcurrent devices,

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Objectives – High Voltage Ride Through

- **High voltage ride through (HVRT):**
  - Reduce generation quickly to limit magnitude and duration of high voltage excursions without tripping.
  - Bring DER back online quickly following short duration high voltage events to minimize grid disruptions.
- **Benefit:**
  - System voltage stability is enhanced
  - Avoids mandatory time delays and ramp rates associated with reconnection after tripping
- **Note:**
  - HVRT is a crude (on/off) form of a Volt/Watt function and is likely not needed if V/W is enabled.

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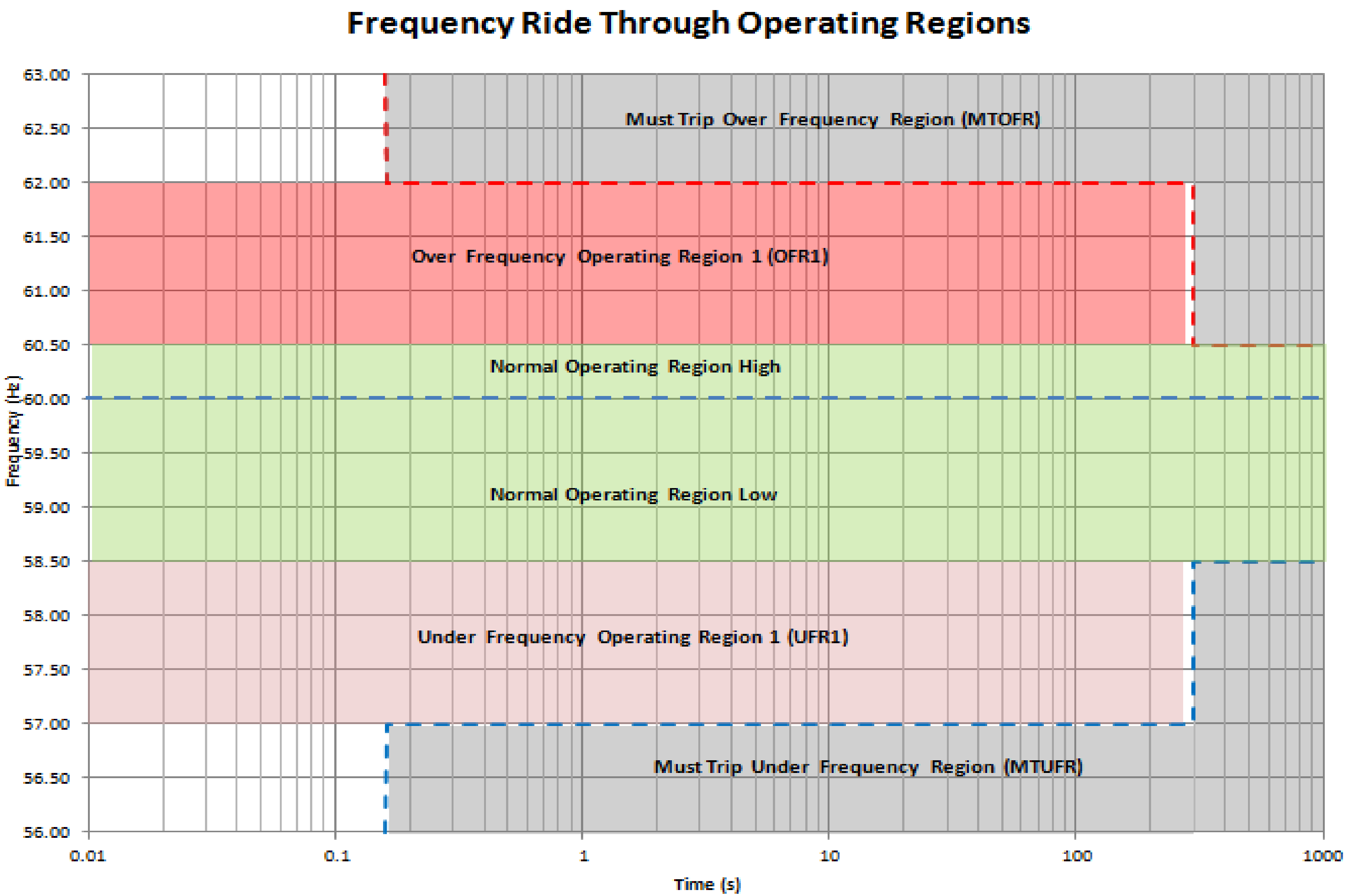
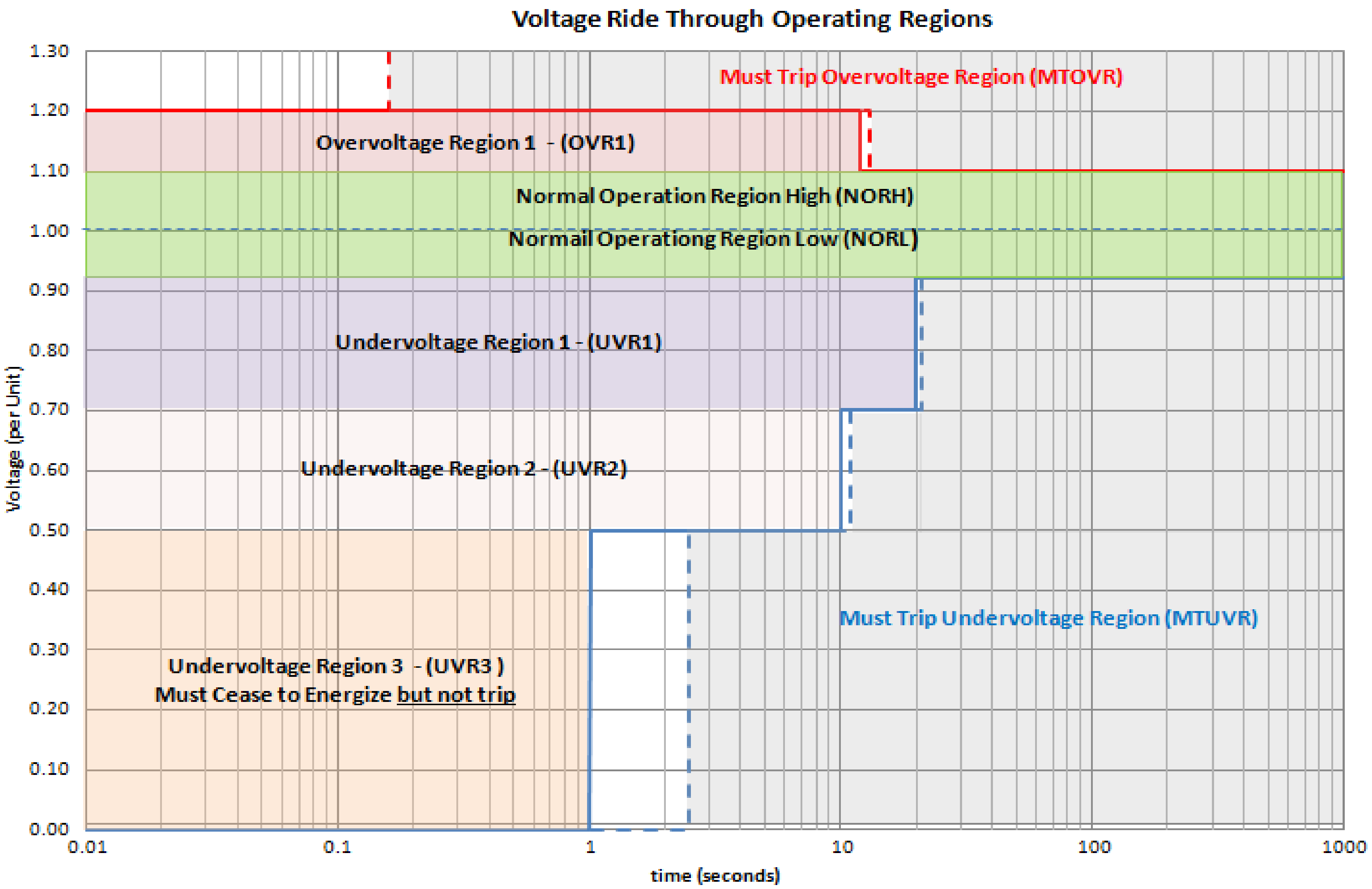
Operating Regions

- **Operating regions are defined by pair points of voltage and time or frequency and time.**
- **The desired behavior of the DER in each operating region is different and should be tailored to solve a specific problem on the grid. Examples:**
  - Over frequency events, under frequency events
  - Over voltage events, under voltage events
    - Bulk system faults, close in feeder faults, far feeder faults, adjacent feeder faults
- **The behavior of the DER must be defined in terms of:**
  - What happens as the grid condition enters the region
  - What happens as the grid condition exits the region
  - Will be different depending on time duration of the excursion

Operating Regions – Frequency



Operating Regions - Voltage



Operating Modes

- **Historically inverter based DER has operated only in one of two modes.**
  - Normal Operation – full available current
  - Tripped – offline
- **Ride through requirements have introduced a new mode - "Momentary Cessation" (placeholder term)**
  - The mode in which the DER has ceased to energize the grid BUT has not tripped.
- **The difference between momentary cessation and tripped is determined by:**
  - Duration of the excursion
  - Criteria for "Return to Service"
  - Ramp rates limitations during "Return to Service"

Return To Service Behaviors

- **On initial startup, following manual restart or following a trip event.**
  - Frequency between 59 and 61.5 Hz
  - Voltage within ANSI Range B, 88% > V > 110% PU
  - Time delay of (15 seconds, formerly 300 seconds)
  - Slow Ramp Rate (2% /second)
- **Following a momentary cessation" event, Example: Voltage < 50% PU for < 1 second (UVR2)**
  - Frequency between 59 and 61.5 Hz
  - Voltage above 50% PU
  - No intentional time delay
  - Fast Ramp Rate (100% / second)

CA Rule 21 Proposed Settings

- ## Voltage Settings

Operating Region	Range (%/PU)	Operating Mode	Duration (s)		Return to Service - Ride through			Return To Service - Trip		
			Ride Through	Trip	Criteria (%/PU)	Time Delay (s)	Ramp (%/s)	Criteria (%/PU)	Time Delay (s)	Ramp (%/s)
OVR2	V > 120	Cease to Energize	-	<= 0.160	-	-	-	110 > V > 88	15	2
OVR1	120 <= V < 110	Momentary Cessation or Volt/Watt	12	13	V < 110	none	100	110 > V > 88	15	2
NORH	110 <= V < 100	Normal Operation	Indefinate	Indefinate	-	-	100	-	-	-
NORL	100 < V <= 88	Normal Operation	Indefinate	Indefinate	-	-	100	-	-	-
UVR1	88 < V <= 70	Mandatory Operation	20	21	-	-	100	110 > V > 88	15	2
UVR2	70 < V <= 50	Mandatory Operation	10	11	-	-	100	110 > V > 88	15	2
UVR3	V < 50	Momentary Cessation	1	2.5	V > 50	none	100	110 > V > 88	15	2

- ## Frequency Settings

Operating Region	Range (%/PU)	Operating Mode	Duration (s)		Return to Service - Ride through			Return To Service - Trip		
			Ride Through	Trip	Criteria (f)	Time Delay (s)	Ramp (%/s)	Criteria (f)	Time Delay (s)	Ramp (%/s)
OFR2	f > 62	Cease to Energize	-	< = 0.160	-	-	-	60.5 > f > 58.5	15	2
OFR1	62 <= f < 60.5	Momentary Cessation or freq./Watt	300	301	f < 62	none	100	60.5 > f > 58.5	15	2
NORH	60.5 <= f < 60	Normal Operation	Indefinate	Indefinate	-	-	100	-	-	-
NORL	58.5 < f < = 60	Normal Operation	Indefinate	Indefinate	-	-	100	-	-	-
UFR1	57 < f <= 58.5	Mandatory Operation	300	301	-	-	100	60.5 > f > 58.5	15	2
UFR2	f < 57	Trip	N/A	0.16	-	-	-	60.5 > f > 58.5	15	2

Regulatory Issues

- **IEEE 1547 / 1547.1 does not yet consider ride through**
  - 1547 is currently under revision and will add ride through requirements.
  - Once 1547 revision is complete 1547.1 test procedures can be developed.
- **UL 1741 will address ride through, real / reactive power functions, and new advanced anti-islanding as optional tests.**
  - Publication likely in Q1 2015
- **Suggested adoption schedule**
  - Permissive upon publication of revised 1741
  - Mandatory on expiration of adoption interval, typically 18 months

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Real and Reactive Power Control Functions

- **Real Power Control**
  - Commanded Max Power
  - Volt/Watt
  - Frequency/Watt
- **Reactive Power Control**
  - Commanded VAr
  - Fixed PF
  - ~~Volt/VAr (Watt Priority), Volt/VAr (VAr Priority)~~
- **Recommended Reading**
  - EPRI *"Common Functions for Smart Inverters, Version 3"*

Questions

Thank you for your attention

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