APRIL 16, 2014

Impact of Distributed Energy Resource Interconnections on Transmission in New England

Massachusetts TSRG Meeting

DAVID FORREST

MANAGER ENGINEERING AND STUDY COORDINATION

Background

- Distributed Energy Resources (DER) are now poised to reach significant levels in the region. Based on a review of current state policies and goals, a total of approximately 2,000 MW of DER is now anticipated in the region by 2023
- Most DER are anticipated to be solar PV that is inverter-interfaced
- ISO believes that revising the interconnection requirements for DER would enable their deployment without compromising the reliability of the New England transmission system
- ISO believes that interconnection requirements can be established that satisfy the goals of both Transmission and Distribution systems

Background

- There are several key issues associated with DER that ISO believes need to be addressed in the short term:
  - Voltage Ride-through
  - Frequency Ride-through
  - Voltage Support
  - Ramp rates
  - Soft-Start Capability
- All of these functionalities could be provided by existing inverter technology in an autonomous manner
- I will address the first two issues today
- Subsequent slides reference technical standards recommended by California's Smart Inverter Working Group (SIWG). The January 2014 draft of the SIWG document is available at:
  - http://docs.cpuc.ca.gov/PublishedDocs/Efile/G000/M087/K821/87821977.PDF

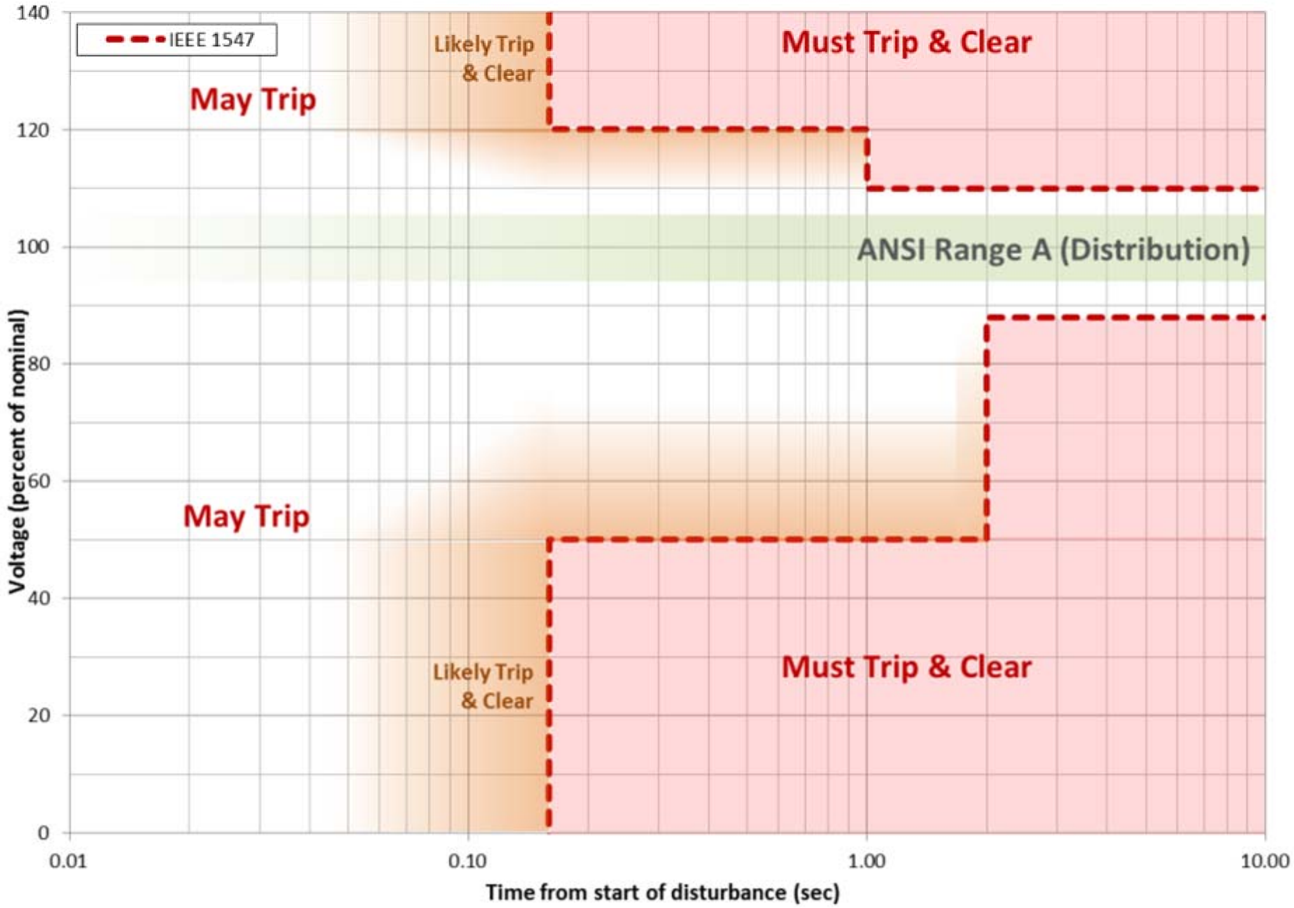
Voltage Ride-Through

- State jurisdictional interconnection standards for DER are generally consistent with IEEE Standard 1547-2003. IEEE 1547-2003 originally developed with the assumption that DER would not reach significant levels with regards to the regional power system
- IEEE 1547-2003 has a "don't ride through" requirement. New England may lose significant amounts of DER for a transmission fault unless the interconnection standards for DER are revised

Voltage Ride-Through IEEE 1547-2003

Voltage Range in percent	Maximum Clearing Times
V<50	0.16 seconds
50≤V≤88	2.00 seconds

IEEE 1547-2003 Standard Voltage Sensitivity



Source: ~~Draft~~ NERC IVGTF Task 1-7 report

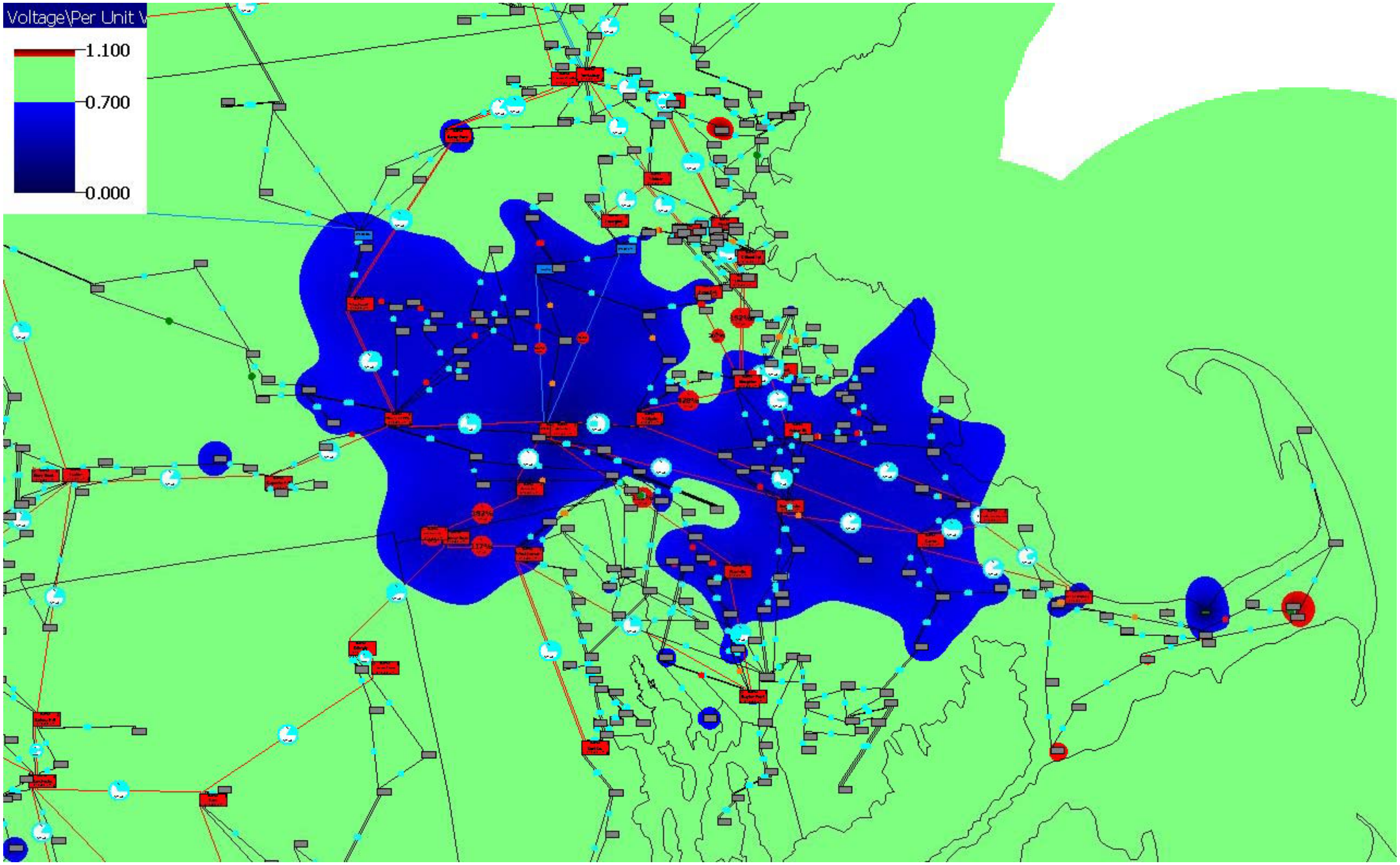
Short Circuit Analysis

- To understand how transmission faults might impact DER in New England, the ISO had a consultant and a transmission owner test several three-phase short circuits on the transmission system
- Testing was done with a model of the existing transmission system and with all existing generation on line
- A sensitivity test was done with a number of generators off line to simulate a light load period (a spring day with high levels of solar and wind generation)

Short Circuit Analysis

- Limited testing indicates that three-phase short circuit on the 345 kV transmission system with all generators in service can result in low voltages over a significant area
- The following plot show the extent of low voltages that could occur for a fault on the 345 kV system in western Norfolk county in Massachusetts

Low Voltage for 345 kV Fault in Massachusetts With All Generators On



Low Voltage for 345 kV Fault in MA With Min Gen

- Sensitivity testing indicates that low voltages can be more severe and extend to a wider area during light load periods when local generation is off line
- ISO's consultant tested the same three-phase fault on the 345 kV system in western Norfolk county simulating a light load scenario
- The following table illustrates how the low voltages caused by a short circuit can vary significantly based on generation dispatch

Low Voltage for 345 kV Fault in MA With Min Gen

Location	Miles From Fault	Voltage-Min Generation	Voltage-Max Generation
Palmer	50 (west)	.53	>.75
Ashburnham	50(northwest)	.41	>.75
Bourne	60(southeast)	.24	.56
Chatham	90(southeast)	.29	.48
Scituate	40(east)	.19	.45
Hyde Park	20(east)	.13	.19
Sterling	40(northeast)	.35	.58

Transmission Planning Criteria

- NERC and/or NPCC require that the transmission system remain secure for a permanent three-phase fault with normal fault clearing or for a single-line to ground fault with delayed clearing
- Planning criteria also requires analyzing a three-phase fault with delayed clearing
- Delayed clearing of a three-phase fault on the 345 kV system is approximately 0.15-0.3 seconds
- Delayed clearing of a three-phase fault on a the 115 kV system can range from 0.3 seconds to over 0.6 depending on the protective relay scheme

Transmission Planning Criteria

- New England is limited by loss of source contingencies because of transmission system limitations in both NYISO and PJM
- As significant DER is added in New England, ISO is concerned that the loss of source for normally cleared three-phase short circuits and three-phase short circuits with delayed clearing could increase substantially and result in the requirement for additional transmission
- ISO is also concerned with the additional complexity of modeling DER in stability studies

Transmission Planning Criteria

- The following response can be considered acceptable to an extreme contingency involving a three phase short circuit with delayed clearing:
  - A net loss of source above 1400 MW and up to 2200 MW, resulting from any combination of the loss of synchronism of one or more generating units, generation rejection initiated by a Special Protection System, or any other defined system separation, if supported by studies, on the basis of acceptable likelihood of occurrence, limited exposure to the pre-contingent operating conditions required to create the scenario, or efforts to minimize the likelihood of occurrence or to mitigate against the consequence of the contingency. The loss of source is net of any load that is interrupted as a result of the contingency.

Voltage Ride-Through

- The IEEE has a proposed amendment to its voltage ride through requirements
- Also the California Smart Inverter Working Group has proposed voltage ride through requirements
- ISO has reviewed both and has a proposal for voltage ride through for DER

Voltage Ride-Through - IEEE 1547a

Voltage Range in percent	Default Clearing Time in seconds	Clearing Time Range in seconds
V<45	0.16	0.16
45≤V≤60	1	1-11
60≤V≤88	2	2-21

Under mutual agreement between the EPS and DR operators, other static or dynamic voltage and clearing time trip settings shall be permitted

Voltage Ride-Through - California SIWG

Voltage Level in Percent	Stay Connected Until(in seconds)	Voltage Level in Percent	Disconnect By (in seconds)
		>120	<0.16
109-117	12	110-120	13
92-109	Indefinite	88-110	Do not Disconnect
70-92	20	60-88	21
50-70	10	45-60	11
0-50	1.0 (range of 0.16-2.0)	0-45	2.5

Voltage Ride-ISO Recommendation

Voltage Range in percent	Stay Connected Until (in seconds)
$V<45$	1
$45 \le V \le 60$	1
$60 \le V \le 88$	2

Voltage Ride-ISO Recommendation

- What concerns do the distribution engineers or manufactures have with ISO's proposal?

Under Frequency Tripping

- The IEEE has an existing standard and a proposed amendment addressing under frequency ride-through requirements
- Also the California Smart Inverter Working Group has proposed under frequency ride-through requirements
- ISO proposes that the NPCC frequency ride-through requirements be used for DER in New England

Under Frequency Tripping - IEEE 1547-2003

DR Size	Frequency Range (Hz)	Clearing Time in Seconds
≤ 30 kW	>60.5	0.16
≤ 30 kW	<59.3	0.16
> 30 kW	>60.5	0.16
> 30 kW	<(59.8-57.0)	0.16 to 300
> 30 kW	<57	0.16

Under Frequency Tripping - IEEE 1547a

Function	Frequency (Hz)	Clearing Time in Seconds	Frequency Range (Hz)	Clearing Time up adjustable up to and including (in Seconds)
UF1	57	0.16	56-60	10
UF2	59.5	0.16	56-60	300
OF1	60.5	2	60-64	300
OF2	62	0.16	60-64	10

Under Frequency Tripping - California SIWG

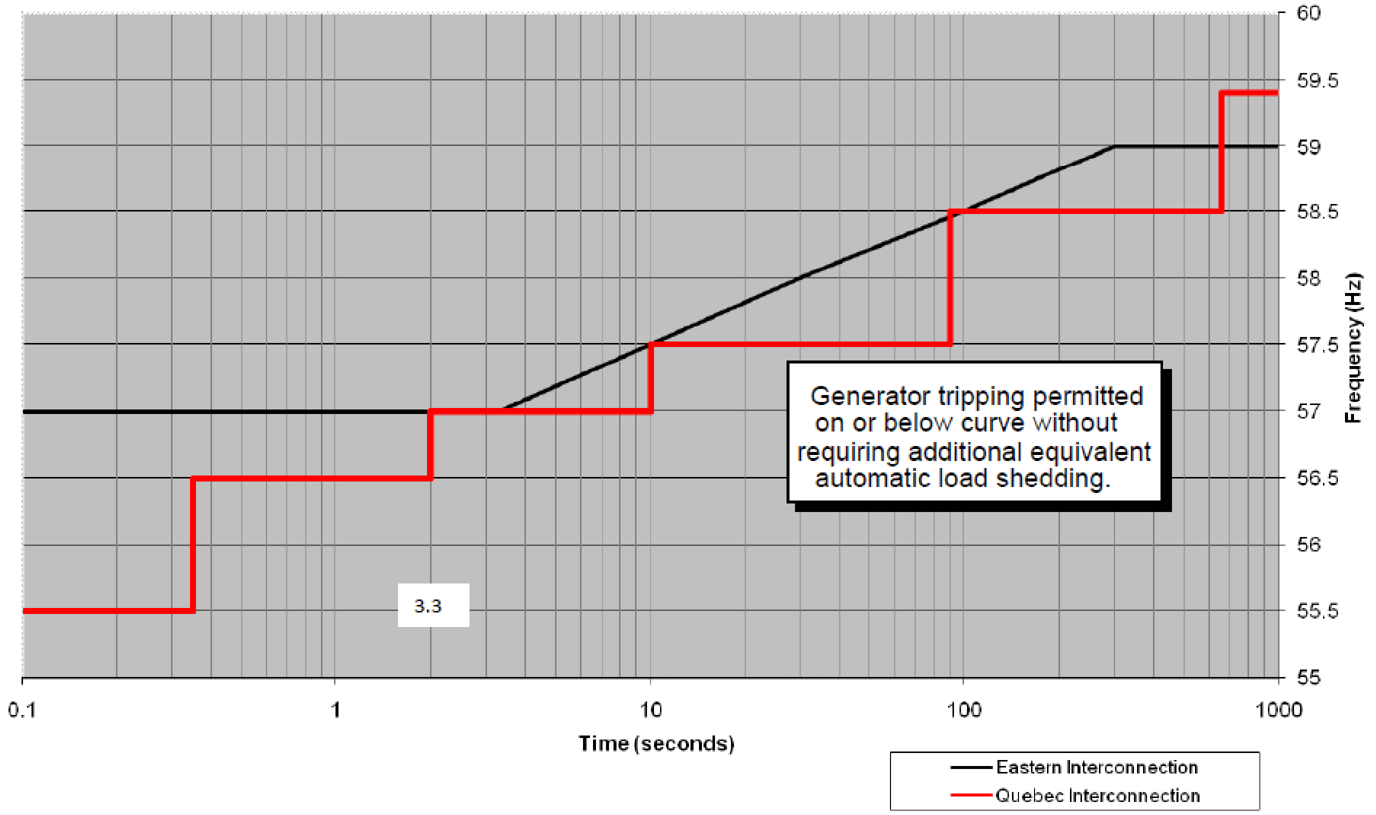
System Frequency	Default Frequency Setting	Default Clearing Time	Frequency Range (Hz)	Clearing Time up adjustable up to and including (in Seconds)
f>62	>62	0.16	62-64	0-300
60<f≤62	60.5	300	60-62	0-300
57<f≤58.5	58.5	300	57-60	0-600
F≤57	57	0.16	53-57	0-5

Under Frequency Tripping - NPCC

- NPCC includes the requirements for generators to ride through frequency excursions in its document entitled "NPCC Regional Reliability Reference Directory # 12 Under frequency Load Shedding Program Requirements "
- NPCC requires a generator to stay connected for frequencies as low as 57 hertz for up to 3.3 seconds. This coordinates with under frequency load shedding requirements
- ISO recommends that DER have under frequency tripping settings that satisfy NPCC requirements

Under Frequency Tripping - NPCC

Figure 1
Standards for setting underfrequency trip protection for generators



Under Frequency Tripping-ISO Recommendation

- What concerns do the distribution engineers or manufactures have with ISO's proposal?

Questions