Implementation of the Revised IEEE Standard 1547

Planning Advisory Committee

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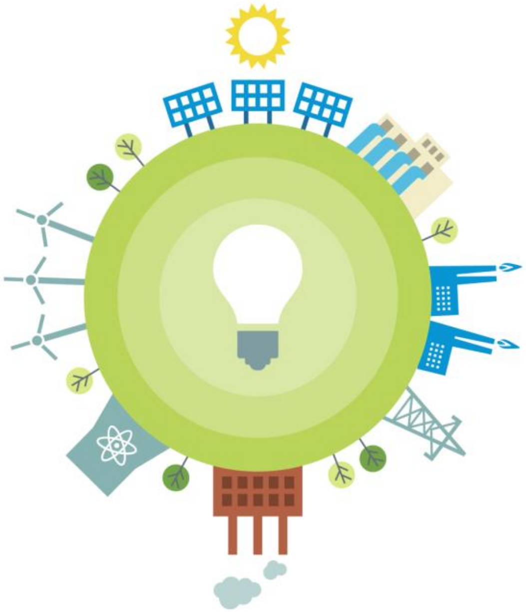
Purpose

- Provide an update on standards impacting interconnection of distributed energy resources (DER)
- Discuss the need for DER performance that supports the reliability of the Bulk Electric System
- Discuss interim steps that will improve DER performance

KEY POINTS OF PRESENTATION

Key Points



- As New England adds significant amounts of Distributed Energy Resources (DER), it is essential for these resources to be interconnected in a way that does not adversely impact the reliability of the Bulk Electric System (BES)
- The revision to IEEE Standard 1547 (*Standard for Interconnecting Distributed Resources with Electric Power Systems*) will not be <u>fully</u> implemented until 2020 or later
- In this presentation, ISO-NE identifies interim requirements for performance of solar PV DER that are required to ensure support of the reliability of the BES

BACKGROUND

The ISO Engaged Stakeholders on DER Standards

ISO-NE continues to be involved in discussions of the need for DER to support the reliability of the BES

ISO-NE has initiated ongoing discussions about the need for updating state interconnection requirements to include ride-through for voltage and frequency excursions

- May 16, 2012: Planning Advisory Committee (PAC) meeting
- June 20, 2013: PAC meeting
- September 30, 2013 Distributed Generation Forecast Working Group (DGFWG) meeting
- December 16, 2013: DGFWG meeting
- January 17, 2014: Comments on MA DPU 12-76-A (Grid Modernization)
- January 21, 2014: DGFWG meeting
- April 2, 2014: DGFWG meeting
- April 16, 2014: MA Technical Standard Review Group (TSRG) meeting
- July 11, 2014: PAC and DGFWG meeting
- May 16, 2017: TSRG meeting

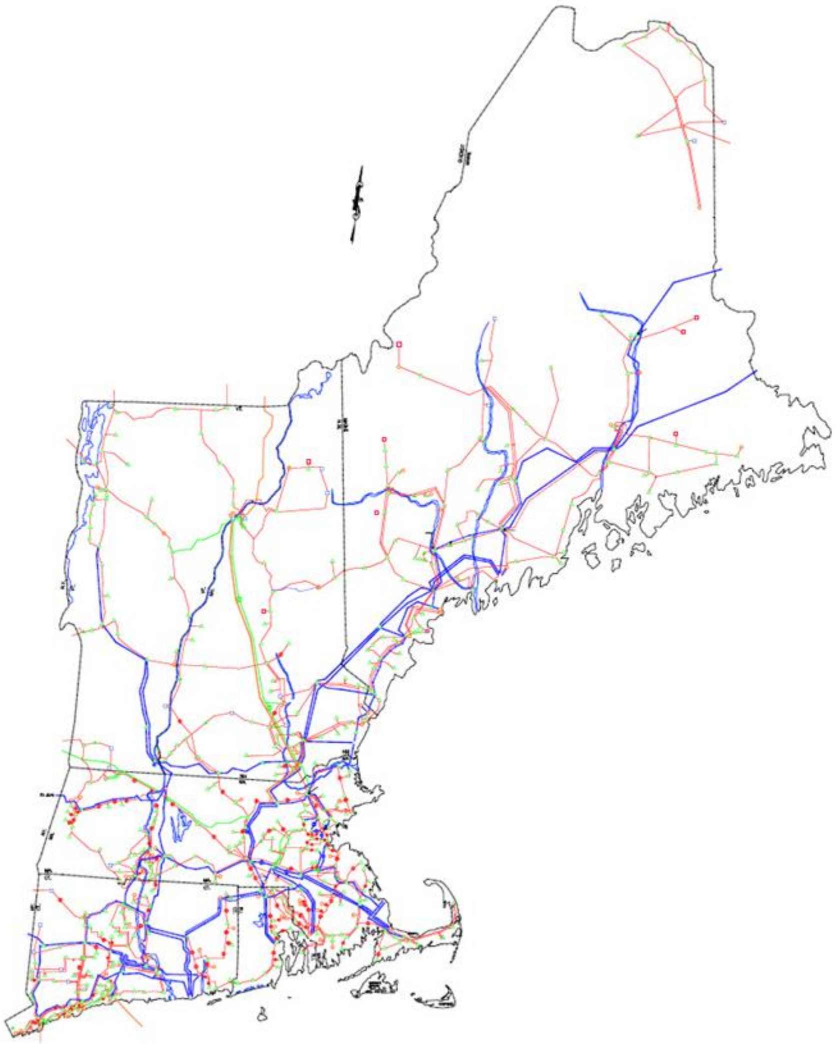
Role of IEEE in Setting Interconnection Standards

- The Energy Policy Act of 2005 requires electric utilities to provide interconnection services "based on standards developed by the Institute of Electrical and Electronics Engineers: IEEE Standard 1547 for Interconnecting Distributed Resources with Electric Power Systems, as they may be amended from time to time."
  – Public Law 109–58, August 8, 2005

Bulk Electric System Planning Criteria

- ISO-NE is required to plan for the contingency loss of resources (including DER) for conditions included in planning criteria mandated by NERC and NPCC
- Planning criteria require that the transmission system remain secure for a permanent three-phase fault with normal fault clearing
  - Normal clearing of a three-phase fault on the 345 kV system is approximately 0.1 seconds
  - Normal clearing of a three-phase fault on a the 115 kV system can range from 0.1 seconds to over 0.5 seconds depending on the protective relay scheme

Bulk Electric System Planning Criteria, cont.



- Planning criteria also require analysis of a three-phase fault with delayed clearing
  - Delayed clearing of a three-phase fault on the 345 kV system is approximately 0.1-0.2 seconds
  - Delayed clearing of a three-phase fault on a the 115 kV system can range from 0.3 seconds to over a second depending on the protective relay scheme

Limitations on the Loss of Source

- Planning criteria for stability analysis require limitations on the amount of sources that be lost for a contingency
- Historically, the concern has been large generators being disconnected or going unstable and tripping
- Tripping of DER for a transmission fault would add to source loss
- If total source loss exceeds the amount allowed by the planning criteria, a system upgrade would be required

Effect on the New England System

- In a 12/16/13 stakeholder presentation, ISO-NE described its reliability concern that New England may lose significant amounts of DER due to transmission faults*
  - This presentation shows how a fault on the transmission system can cause low voltage over a large portion of the New England system
- ISO-NE recommended the following capabilities for DER:
  - High/low frequency ride-through
  - High/low voltage ride-through
  - Default and emergency ramp rate limits
  - Reconnect by "soft start" methods
  - Voltage support
  - Communication capabilities

* *See: www.iso-ne.com/static-assets/documents/committees/comm_wkgrps/othr/distributed_generation_frcst/2013mtrls/dec162013/dg_transmission_impacts.pdf.*

Concern at the NERC Level

- The North American Electric Reliability Corporation (NERC) has expressed increasing concern with the impact of DERs on BES reliability
- In February 2017 NERC issued a report* "*Distributed Energy Resources, Connection Modeling and Reliability Considerations*"
- NERC's report supports the need for the DER capabilities identified by ISO-NE

* See: www.nerc.com/comm/other/essntlrlbltysrvcstskfrcdl/distributed_energy_resources_report.pdf

Concern at the NERC Level, cont.

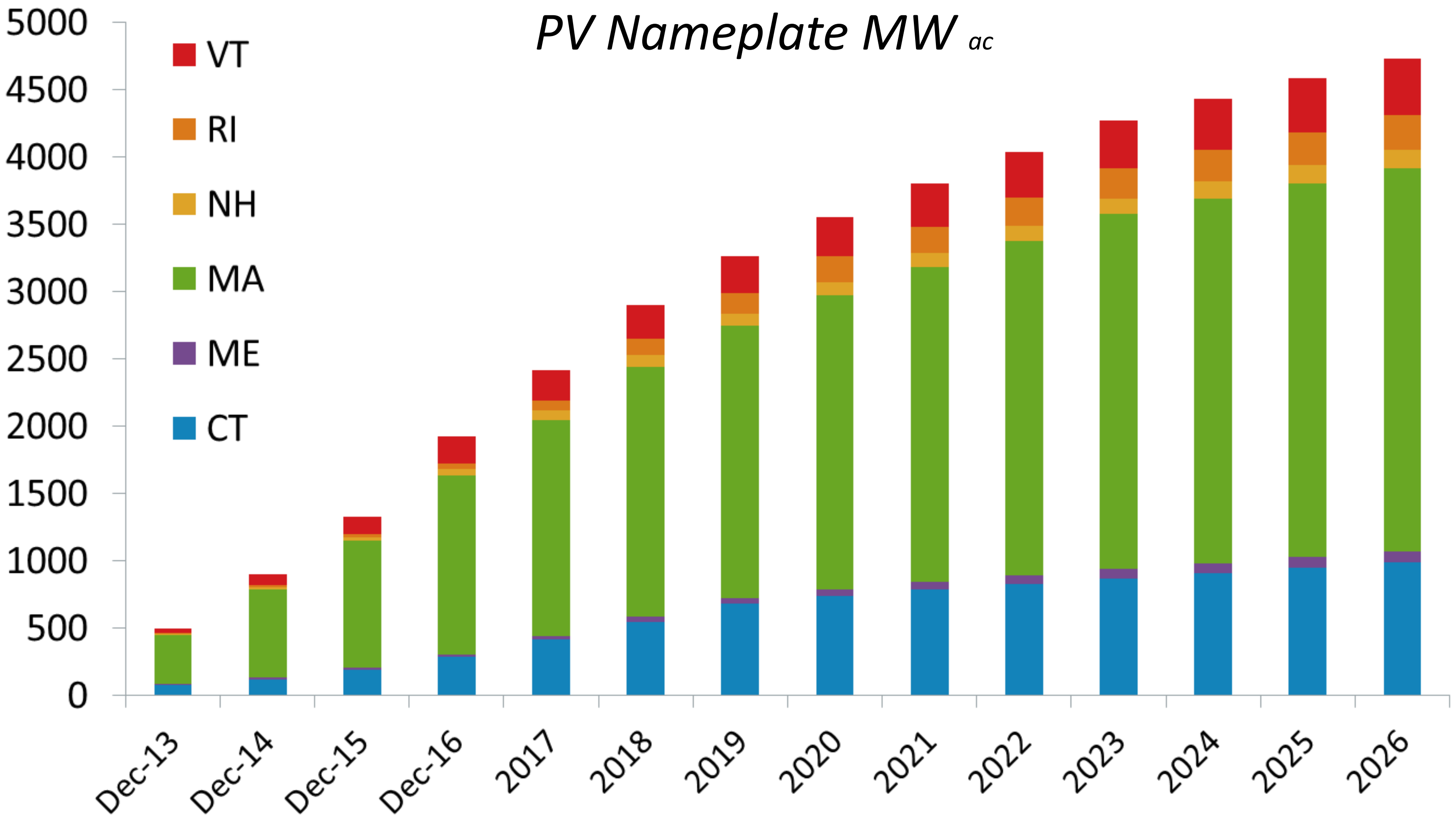
- NERC’s report also describes autonomous inverter functionalities that will be added to California’s technical operating standards in Rule 21 by the end of 2017
  – Support anti-islanding to trip off under extended anomalous conditions
  – Provide ride-through of low/high voltage excursions beyond normal limits
  – Provide ride-through of low/high frequency excursions beyond normal limits
  – Provide volt/VAR control through dynamic reactive power injection through autonomous responses to local voltage measurements
  – Define default and emergency ramp rates as well as high and low limits
  – Provide reactive power by a fixed power factor
  – Reconnect by “soft-start” methods

ISO New England is Forecasting Significant Solar Growth

- The following three slides are from the *Final 2017 PV Forecast**
  - Massachusetts accounts for more than 60% of of the projected PV MW
  - Massachusetts' forecast is projected to more than double in the next decade
- Each year the projections increase for the amount of DER in New England thus making DER impact on the BES reliability a larger concern

** See: www.iso-ne.com/system-planning/system-forecasting/distributed-generation-forecast*

ISO is Forecasting Continued Solar PV Growth Over the Next Decade



Source: Final PV Forecast (April 2017); * Note: MW values are AC nameplate

Final 2017 PV Forecast

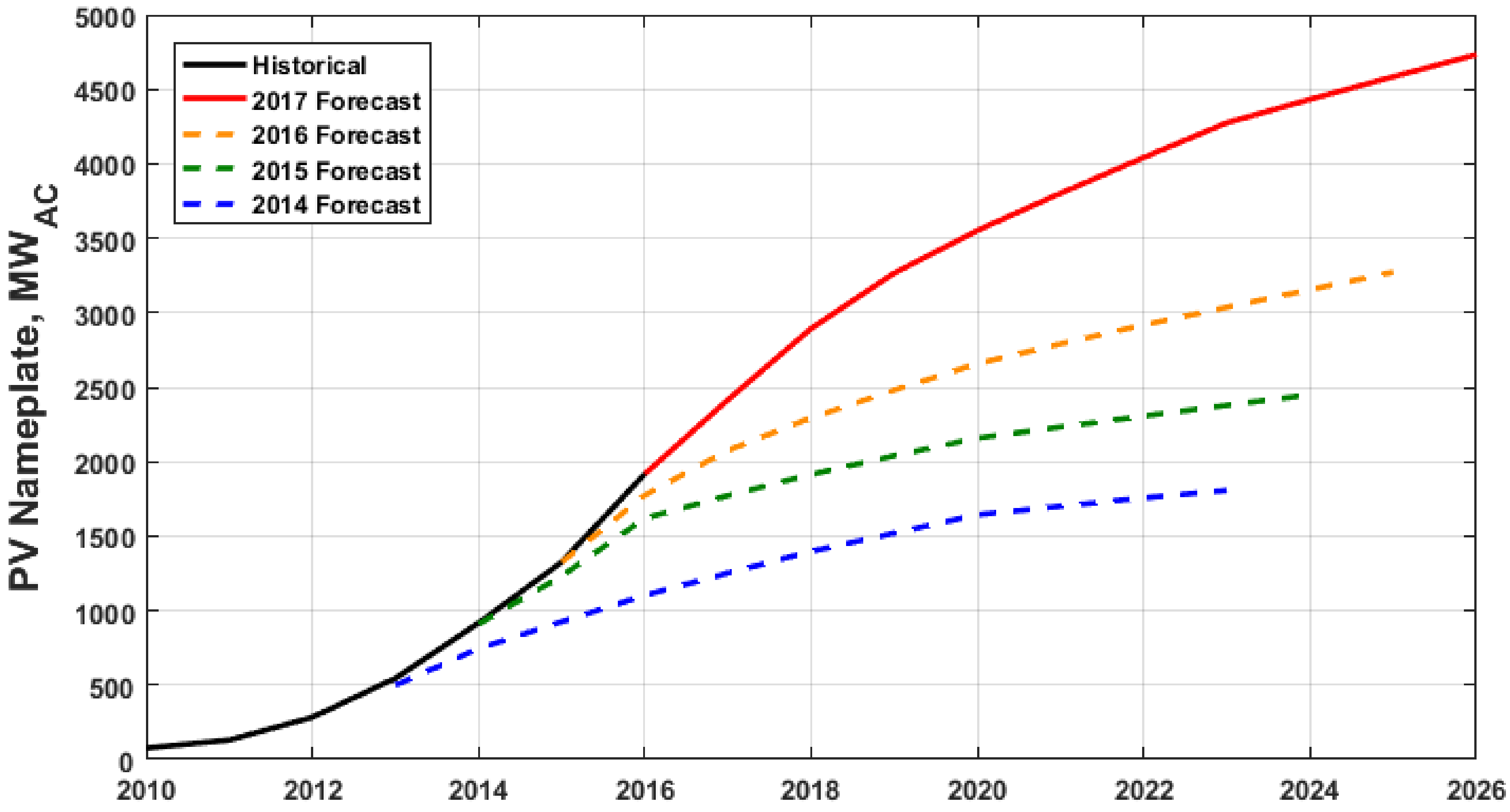
Nameplate Capacity, MW_{ac}

States	Cumulative Total MW (AC nameplate rating)										
	Thru 2016	2017	2018	2019	2020	2021	2022	2023	2024	2025	2026
CT	281.5	414.3	547.1	679.9	738.9	783.6	827.1	869.3	910.2	949.8	988.2
MA	1324.8	1598.7	1858.9	2023.3	2183.3	2338.9	2490.0	2636.7	2707.8	2776.7	2843.3
ME	22.1	29.0	35.8	42.7	48.8	54.6	60.4	66.3	72.1	77.9	83.7
NH	54.3	72.4	84.4	91.8	99.1	106.1	112.9	119.5	125.9	132.2	138.2
RI	36.8	78.1	119.5	154.8	186.6	201.8	213.1	224.1	235.0	245.6	255.9
VT	198.4	223.4	248.4	273.4	295.9	317.1	338.4	359.6	380.9	402.1	423.4
Regional - Cumulative (MW)	**1918.0**	**2415.9**	**2894.1**	**3265.9**	**3552.5**	**3802.1**	**4041.9**	**4275.5**	**4431.8**	**4584.2**	**4732.7**

Source: Final PV Forecast (April 2017); * Note: MW values are AC nameplate

PV Growth: Reported Historical vs. Forecast

ISO Updates the Forecast Annually to Capture Policy Changes



STATUS OF IEEE 1547 AND UL 1741

IEEE 1547

- IEEE 1547, IEEE Standard for Interconnecting Distributed Resources with Electric Power Systems, was originally issued in 2003 (1547-2003).
- In 2013, Amendment 1 was approved (IEEE 1547a) to allow ranges of settings for tripping distributed resources for abnormal voltage and frequency. Amendment 1 also allowed settings to regulate voltage with the agreement of the interconnecting utility.
- In December 2013, IEEE started the process to do a complete revision to IEEE 1547.
- In 2017, the revised IEEE 1547 was balloted and approved.
- The standard was then updated to address comments from the balloters, was re-balloted and approved by a greater margin.

IEEE 1547, cont.

- The approved revision to 1547 is undergoing final editing at IEEE and should be published by the second quarter of 2018
- Before DER can be certified as meeting the revised 1547, the testing standard 1547.1 must be revised
- Work on 1547.1 is ongoing and will optimistically be completed by the end of 2018
- Once 1547.1 is approved, UL 1741 will need to be updated to agree with the revised 1547.1
- Once UL 1741 is updated and approved, it will take a year or longer for all inverter manufacturers to have their inverters tested and certified
- Thus, it will be 2020 or possibly later before utilities will be able to use the revised IEEE 1547

UL 1741

- UL 1741 is the UL Standard for Safety for Inverters, Converters, Controllers and Interconnection System Equipment for Use With Distributed Energy Resources
- The second edition was dated January 28, 2010
- UL 1741 was revised as of September 7, 2016 to incorporate the new supplement SA
- UL 1741 SA defines the requirements for "Grid Support Utility Interactive Inverters"
- These inverters have the capabilities required by California Rule 21 (see slide 13) and that meet ISO-NE needs
- As of September 9, 2017 inverter-based generation in California is required to be certified as meeting UL 1741 SA

INTERIM SOLUTION

Interim Solution

- Because of the rapid growth of solar PV in New England and the timeline for full implementation of the revision to IEEE 1547, ISO-NE sought out an interim solution for obtaining ride-through for voltage and frequency variations
- Inverters meeting the requirements of UL 1741 SA have the capabilities required by ISO-NE
- Choosing performance requirements for these inverters required the input from distribution engineers, solar PV developers and inverter manufacturers
- ISO-NE worked with the Massachusetts Technical Standards Review Group (TSRG) to get input from these entities

Interim Solution, cont.

- The TSRG is an existing group tasked with addressing distribution interconnection issues
- The TSRG includes representatives from utilities, developers, manufacturers and Massachusetts regulators
- Over 60% of solar PV in New England is/will be installed in Massachusetts
- The TSRG includes representatives from Eversource, which also has subsidiaries in Connecticut and New Hampshire
- The TSRG includes representatives from National Grid, which also has a subsidiary in Rhode Island

Interim Solution, cont.

- Development of inverter performance requirements and an implementation plan required addressing multiple issues
  - Transmission reliability
  - Distribution protection
  - Retaining maximum trip time
  - Anti-islanding protection
  - Conformance with the revised IEEE 1547
  - Allowing time for manufacturers to develop software to implement ISO-NE settings
- Balancing these and other issues, ISO-NE and the TSRG developed a Source Requirements Document and an implementation plan
  - A summary follows

Interim Solution (developed with the MA TSRG)

- The Inverter Source Requirements Document of ISO-NE (ISO-NE SRD) contains additional details on the application of "Grid Support Utility Interactive Inverters"
  - Also posted with this PAC meeting's materials
  - A Source Requirements Document can be used by to certify that equipment meets a specific set of requirements
  - The ISO-NE SRD can be used with the existing UL 1741 SA
- All inverter-based solar PV projects 100 kW or less with applications submitted on or after June 1, 2018 are subject to the ISO-NE SRD

Interim Solution (developed with the MA TSRG), cont.

- All inverter-based solar PV projects greater than 100 kW, with applications submitted on or after March 1, 2018, are subject to the ISO-NE SRD
- Inverter-based solar PV projects with applications submitted prior to the above dates are encouraged to comply with the ISO-NE SRD with the approval of the interconnecting utility

Interim Solution (developed with the MA TSRG), cont.

- ISO-NE will require the following frequency trip settings which are consistent with the allowable ranges of the revised 1547 and with NPCC requirements:

Shall Trip Function	Default Settings (b)	
	Frequency (Hz)	Clearing Time(s)
OF2	62	0.16
OF1	61	300
UF1	58.5	300
UF2	56.5	0.16

Interim Solution (developed with the MA TSRG), cont.

- The frequency trip settings will result in the following ride-through capability

Frequency Range (Hz)	Operating Mode	Minimum Time(s) (design criteria)
f > 62.0	No ride-through requirements apply to this range	
61.2 < f ≤ 61.8	Mandatory Operation	297-300
58.8 ≤ f ≤ 61.2	Continuous Operation	Infinite
57.0 ≤ f < 58.8	Mandatory Operation	297-300
f < 57.0	No ride-through requirements apply to this range	

Interim Solution (developed with the MA TSRG), cont.

- ISO-NE will require the following voltage trip settings which are consistent with the allowable ranges in Category II of the revised 1547

Shall Trip		
Shall Trip Function (OV = Overvoltage UV = Undervoltage)	Voltage (per unit of nominal voltage)	Clearing Time(s)
OV2	1.20	0.16
OV1	1.10	2.0
UV1	0.88	2.0
UV2	0.50	1.1

Interim Solution (developed with the MA TSRG), cont.

- The voltage trip settings will result in the following ride-through capability

Voltage Range (p.u.)	Operating Mode/Response	Range of Ride-through Time(s) (min – max)
V > 1.20	Cease to Energize	N/A
1.175 < V ≤ 1.20	Permissive Operation	0.2 – 2.0
1.15 < V ≤ 1.175	Permissive Operation	0.50 – 2.0
1.10 < V ≤ 1.15	Permissive Operation	1.00 – 2.0
0.88 ≤ V ≤ 1.10	Continuous Operation	Infinite
0.65 ≤ V < 0.88	Mandatory Operation	1.84 – 2.0
0.50 ≤ V < 0.65	Mandatory Operation	0.32 – 2.0
V < 0.50	Momentary Cessation (with a maximum response time of 0.083 seconds)	0.16 – 1.1

NEXT STEPS

Next Steps

- ISO-NE will work with utilities and regulators in each state to implement the ISO-NE SRD
  - Having one SRD for all of New England will minimize developer's costs
  - Having one SDR will simplify modeling DER in planning studies
- ISO-NE will work with utilities to optimize the utilization of advanced inverter functions that will be available under the revised IEEE 1547
- ISO-NE will work with utilities and regulators to specify the IEEE 1547 category that will be assigned to each type of DER (these categories are described in the Appendix)
- ISO-NE will work with Municipal Utilities and Co-ops to implement the ISO-NE SRD on their systems
- Utilities should evaluate joining EPRI's project "Navigating DER Interconnection Standards and Practices"

Questions

APPENDIX

IEEE 1547 Categories For Response to Abnormal Conditions

IEEE 1547 Categories

- IEEE 1547 is technology neutral and thus does not establish performance requirements for specific DER technologies
- Instead, it defines three categories related to the response of DER to abnormal conditions that have different performance requirements
- IEEE 1547 suggests that “Authorities Governing Interconnection Requirements” define the performance requirement (the category) for each type of DER and provides guidance on how to do this in Annex B
- A significant factor in determining performance requirements is the level of penetration of the DER technology
- DER technology that has a high level of penetration will have the largest impact on reliability and should have the highest performance requirements

IEEE 1547 Category I

- Category I is based on minimal bulk electric system reliability needs and is reasonably attainable by all DER technologies that are in common usage today
- The disturbance ride-through requirements for Category I are derived from the German standard for medium voltage synchronous generators and is one of the most widely applied standards in Europe
- Many synchronous generator manufacturers are currently designing products to meet the requirements of this standard

IEEE 1547 Category II

- Category II covers all BES reliability needs and is coordinated with existing reliability standards to avoid widespread DER tripping for disturbances for which the bulk system generators are expected to remain connected
- It is based on NERC Standard PRC-024 (generator frequency and voltage protective relay settings), with additional allowance for the fact that voltage levels in distribution systems may have delayed recovery after disturbances due to load effects, and is harmonized with NERC Standard PRC-006 (under frequency load shedding standard) with regard to frequency ride-through requirements

IEEE 1547 Category III

- Category III provides the highest disturbance ride-through capabilities, intended to address integration issues such as power quality and system overloads caused by DER tripping in local Area EPS having very high levels of DER penetration
- This category also provides increased bulk power system security by further reducing the potential loss of DER during bulk system events
- These requirements are based on the California Rule 21 Smart Inverter requirements

Sample Application of IEEE 1547 Categories

DER Type	Example of Applications	Sample Category
Engine	land fill gas	Category I
Synchronous Generators	small hydro	Category I
Synchronous Generators	combined heat and power	Category I
Synchronous Generators	self-generation	Category I
Inverters Sourced by Solar PV		Category II
Inverters Sourced by Fuel Cells		Category II
Inverters Sourced by Energy Storage	batteries either stand alone or associated with solar PV	Category II
Wind Turbines		Category II