MAY 16, 2017 | WORCESTER, MASSACHUSETTS

Implementation of Revised IEEE Standard 1547

Presentation to Massachusetts Technical Standards Review Group (TSRG)

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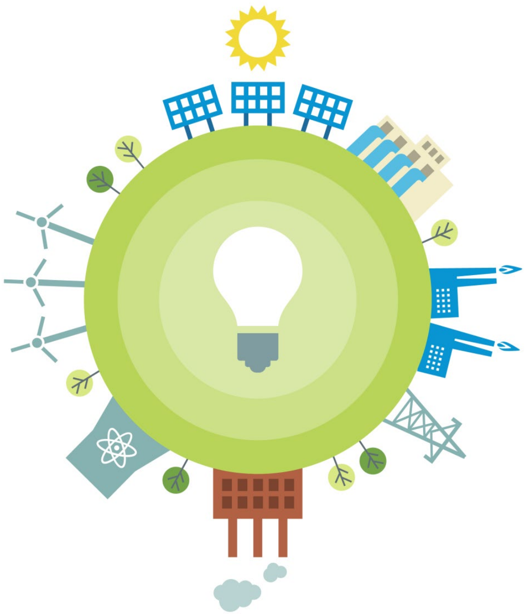
KEY POINTS OF PRESENTATION

Key Points



- As New England adds significant amounts of Distributed Energy Resources (DERs), 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)
- ISO-NE identifies, in this presentation, settings in the proposed revision to IEEE Standard 1547 (*Standard for Interconnecting Distributed Resources with Electric Power Systems*) that are required to ensure this support
- Distribution engineers and planners will identify the issues that need to be addressed to allow implementation of settings proposed by ISO-NE
- ISO-NE looks forward to working with the TSRG to resolve any issues by the end of 2017

BACKGROUND

ISO New England Has Been Engaged

ISO-NE will continue to be involved in TSRG discussions and in the development of the update to IEEE 1547

ISO-NE has initiated on-going 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: TSRG meeting
- July 11, 2014: PAC and DGFWG meeting

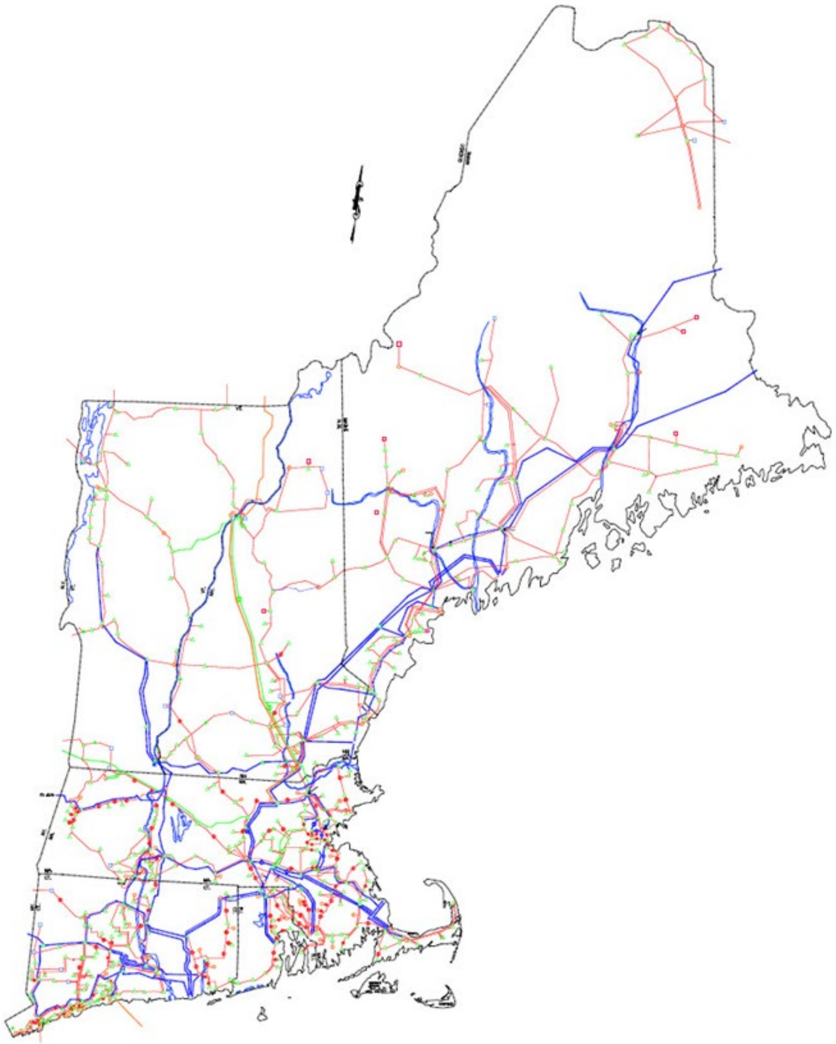
Role of IEEE In Setting Interconnection Standards

- 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
- IEEE seeks to revise Standard 1547 by 2018

Bulk Electric System Planning Criteria

- ISO-NE is required to plan for the contingency loss of resources (including DERs) 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, *continued*



- 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 transmission 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 Bulk Electric System 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

NERC
NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

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

Concern at the NERC Level, *continued*

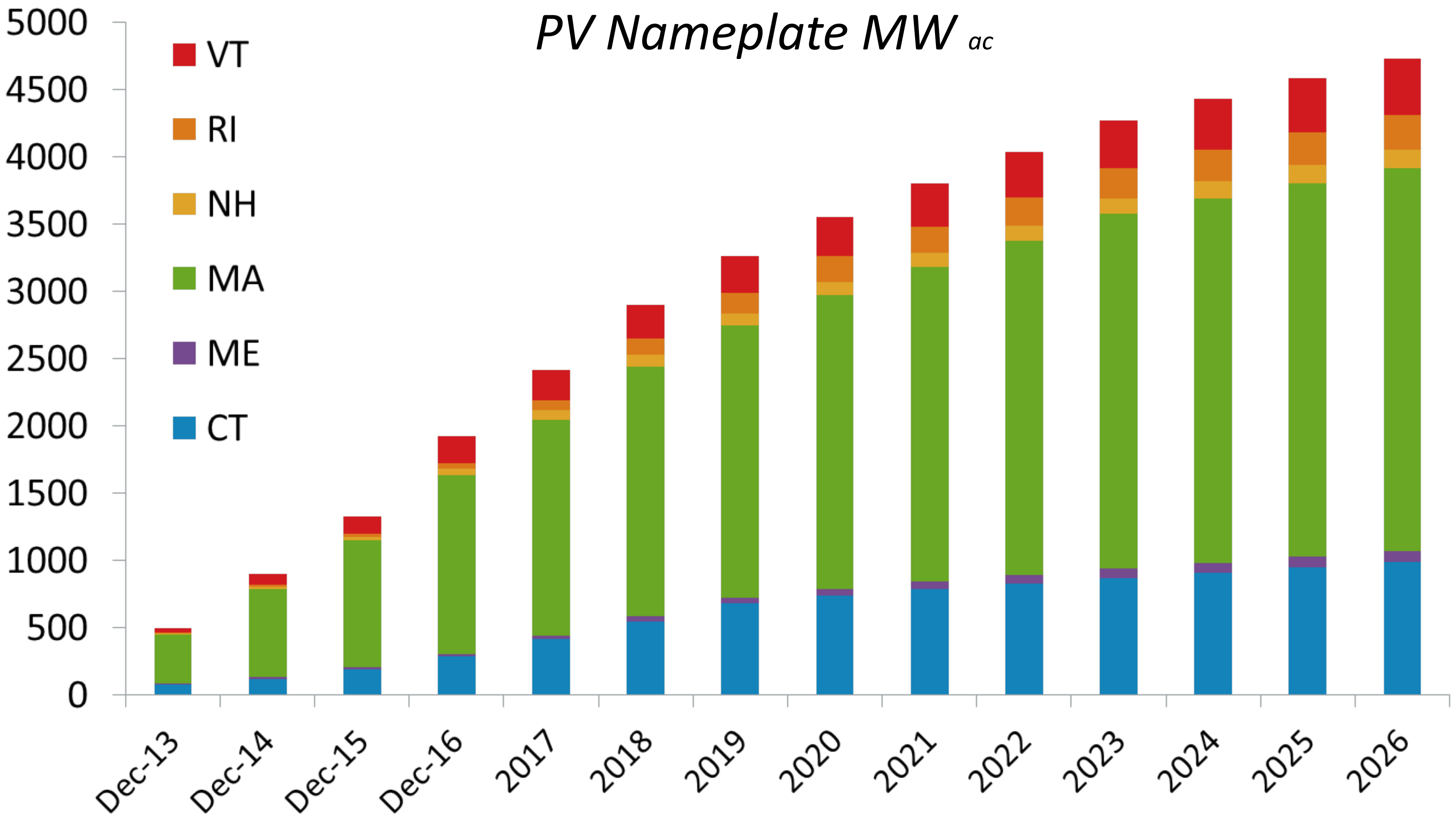
- NERC's report also describes autonomous inverter functionalities that will be added to California's technical operating standards in Rule 21 by the end of 2017
  - Support anti-islanding to trip off under extended anomalous conditions
  - Provide ride-through of low/high voltage excursions beyond normal 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**
  - PV capacity is projected to continue to grow
  - Massachusetts accounts for more that half of the projected PV MW
  - Massachusetts' forecast is projected to more than double in the next decade
  - PV MW have grown even faster than projected
- 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

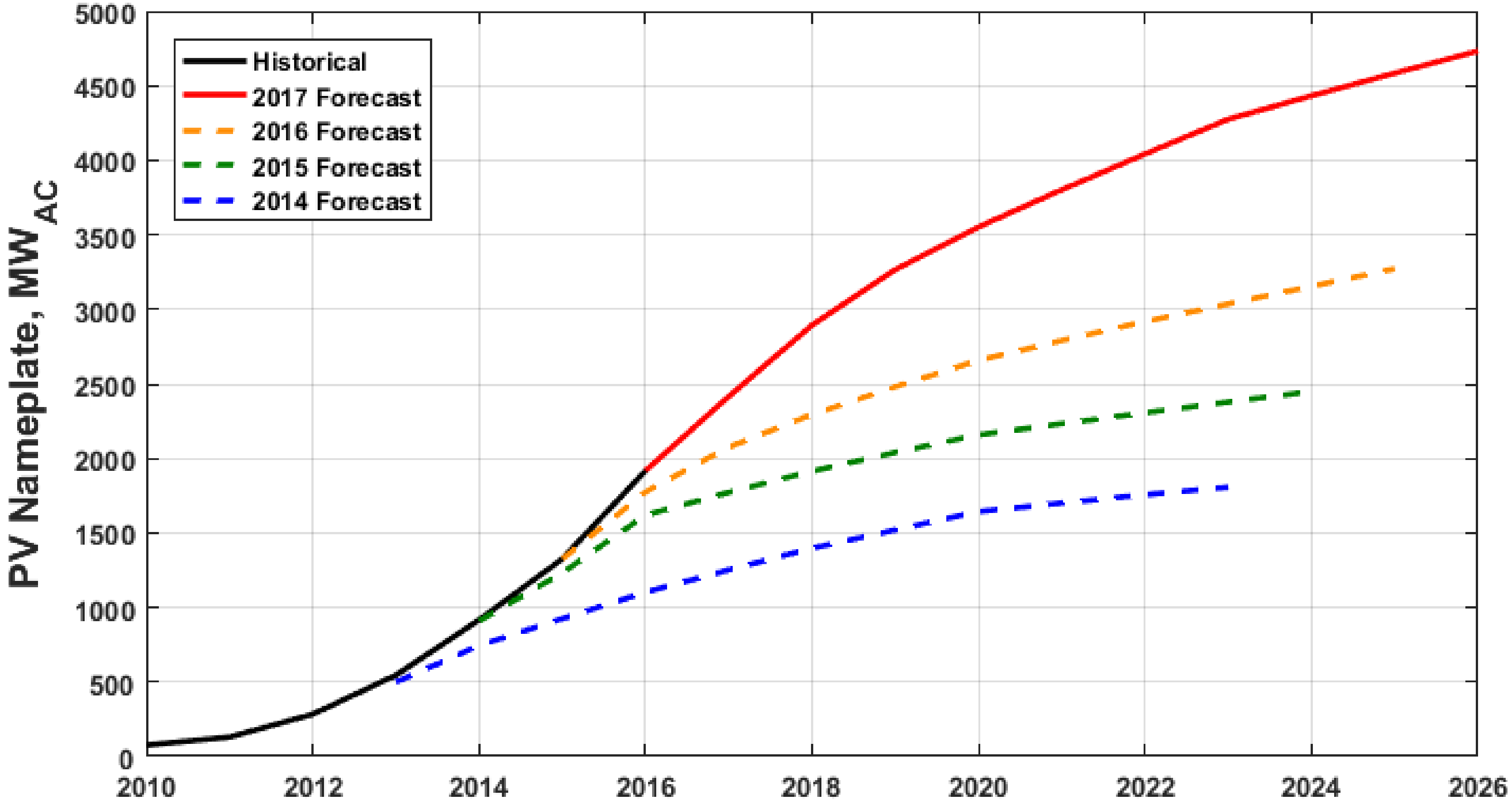
Nameplate Capacity, MW_{ac}

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



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

ISO-NE Recommendation: IEEE 1547 Categories

- ISO-NE recommends that new DERs that are synchronous generators be required to meet the performance requirements of Category I since this category is based on a synchronous generator standard
- ISO-NE recommends that inverter type DERs be required to meet the performance requirements of Category III since inverter-based generation designed for California will meet Category III requirements

ISO-NE Recommendation: IEEE 1547 Categories

DER Type	Example of Applications	Proposed 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 III
Inverters sourced by fuel cells		Category III
Inverters sourced by energy storage	Batteries either stand alone or associated with solar PV	Category III
Wind Turbines		Category III

Voltage Ride-Through Settings

- IEEE 1547 has ride-through requirements for Categories I, II, and III
- The chart to the right includes the requirements for Category II

Voltage range (% of nominal voltage)	Operating Mode / Response	Minimum ride-through time (s) (design criteria)	Maximum response time (s) (design criteria)
V > 120	Cease to Energize (a)	N/A	0.16
117.5 < V ≤ 120	Permissive Operation	0.2	N/A
115 < V ≤ 117.5	Permissive Operation	0.5	N/A
110 < V ≤ 115	Permissive Operation	1	N/A
88 ≤ V ≤ 110	Continuous Operation	infinite	N/A
65 ≤ V < 88	Mandatory Operation	Linear slope of 8.7 s/1 p.u. voltage starting at 3 s @ 0.65 p.u.: $T_{VRT} = 3\text{ s} + \frac{8.7\text{ s}}{1\text{ p.u.}}(V - 0.65\text{ p.u.})$	N/A
45 ≤ V < 65	Permissive Operation	0.32	N/A
30 ≤ V < 45	Permissive Operation	0.16	N/A
V < 30	Cease to Energize a	N/A	0.16

Voltage Ride-Through Settings

- ISO-NE will require the following voltage ride-through settings:

Voltage range (% of Nominal)	Minimum Ride-through Time in seconds
V > 120	N/A
110 < V ≤ 120	12 seconds *
5 ≤ V < 88	3+ seconds **
50 ≤ V < 70	1 second ***
V < 50	1 second *

Notes

* *This is the minimum setting for Category III DER*

** *This is the minimum setting for Category II DER and is below the minimum setting for a Category III DER*

*** *This is below the minimum setting for Category III, a longer ride-through time would be desirable*

Voltage Tripping Settings

- ISO-NE will require that the following voltage trip settings coordinate with its voltage ride-through settings and proposes to utilize the default settings for Category III DER:

Shall Trip		
Shall Trip Function (OV = Overvoltage UV = Undervoltage)	Voltage (% of nominal voltage)	Clearing time(s)
OV2	120	0.16
OV1	110	13
UV1	88	21
UV2	50	2

Frequency Ride-Through Settings

- IEEE 1547 establishes the same ride-through requirements for frequency variations for DER in Categories I, II and III
- ISO-NE supports these frequency ride-through minimum settings because they coordinate with NPCC requirements

Frequency range (Hz)	Operating Mode	Minimum time(s) (design criteria)
f > 62.0	N/A	N/A
60.6 < f ≤ 62.0	Mandatory Operation a	299
58.5 ≤ f ≤ 60.6	Continuous Operation	Infinite (c)
57.0 ≤ f < 58.5	Mandatory Operation b	299
f < 57.0	N/A	N/A

Frequency Trip Settings

- IEEE 1547 establishes the frequency trip requirements for frequency variations for DER in Categories I, II and III
- ISO-NE supports these frequency trip settings because they coordinate 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

NEXT STEPS

Next Steps

- ISO-NE requests that the TSRG identify any issues that need to be resolved prior to distribution company implementation of ISO-NE's proposed settings
- ISO New England requests that the TSRG work to resolve any issues identified
- ISO-NE will continue to work with state regulators to urge the adoption of interconnection standards that achieve the objectives of IEEE 1547

January 2018

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	1	2	3	4	5	6
7	8	9	10	11	12	13
14	15	16	17	18	19	20
21	22	23	24	25	26	27
28	29	30	31			