NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

SPIDER Working Group

Dan Kopin

Utility Services, Inc.

VELCO Operating Committee

December 2019

RELIABILITY | ACCOUNTABILITY

Presentation Overview

1. SPIDER?
2. Work Plan (2019 – Q4)
3. DER → Bulk Power System
   a) MOD-032
   b) TPL-001
   c) PRC-006
4. → VT Generation Constraint Analysis

System Planning Impacts from Distributed Energy Resources (**SPIDER**) Working Group

- NERC stakeholder forum focusing on Distributed Energy Resources (DER) from transmission-level perspectives

- DER is defined as…"Any resource on the distribution system that **produces** electricity and is not otherwise included in the formal NERC definition of the Bulk Electric System [a subset of the Bulk Power System]"

- Subgroups: Modeling, Verification, Studies, Coordination

Work Plan 2019 – Q4

Subgroup	Reliability Guidelines	Target Date
Modeling	• DER Data Collection for Modeling • **DER_A Model Parameterization (link)**	• Q2 2020 • **Q3 2019**
Verification	• DER Performance and Model Verification • DER Forecasting Practices and Relationship to DER Modeling for Reliability Studies	• Q1 2020 • Q4 2020
Studies	• Bulk Power System Planning under Increasing Penetration of Distributed Energy Resources • Recommended Approaches for Developing Underfrequency Load Shedding Programs with Increasing DER Penetration	• Q2 2020 • Q1 2020
Coordination	• **Reliability Guideline: BPS Perspectives for Implementing IEEE 1547-2018 (to be posted for 45-day comment period)** • Communication and Coordination Strategies for Transmission Entities and Distribution Entities regarding Distributed Energy Resources	• **Q4 2019** • Q3 2020

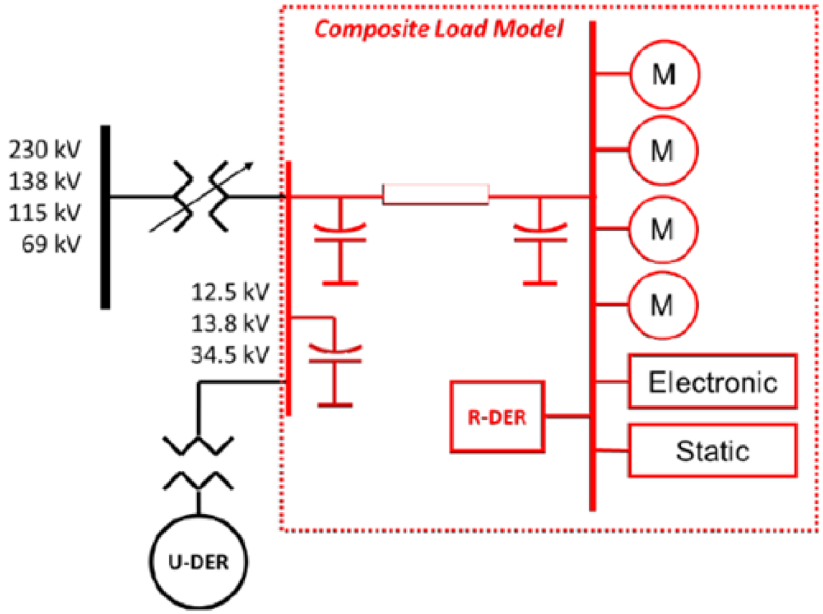
Work Plan 2019 – Q4

Subgroup	Other Tasks…	Target Date
Modeling	• Modeling Survey: DER Modeling Practices of SPIDER Members • **Modeling Notification: Dispatching DER off Pmax in Case Creation (link)**	• Q4 2019 • **Q3 2019**
Verification		
Studies	• White Paper: Review of TPL-001-5 for Incorporation of DER • White Paper: Recommended Simulation Improvements and Techniques • White Paper: DER Impacts to Undervoltage Load Shedding • White Paper: Beyond Positive Sequence RMS Simulations for High DER	• Q4 2019 • Q2 2020 • Q3 2020 • Q1 2020
Coordination	• Educational Material to Support Information Sharing between Industry Stakeholders • Coordination of DER Terminology • **NERC Reliability Standards Review** • Tracking and Reporting DER Growth	• Ongoing • Ongoing • **Q2 2020** • Ongoing

DER → Bulk Power System

MOD-032-1

Reliability Guideline: DER Modeling (2017)



Dynamic Load Model with R-DER and U-DER Represented

"As a growing component of the overall load characteristic, it is important the TPs and PCs are able to assess how DER performance impacts the BPS…"

https://www.nerc.com/comm/PC_Reliability_Guidelines_DL/Reliability_Guideline_-_DER_Modeling_Parameters_-_2017-08-18_-_FINAL.pdf

Angeles Forest Disturbance Report (1/22/2019)

- "Net load increases [of **~130 MW**] lasted on the order of five to seven minutes, correlating with the reset times for DER tripping as described in IEEE Std. 1547-2003"
- **Note:** Evidence is "anecdotal" and "method is time intensive and difficult to aggregate all individual T-D transformer banks to ascertain a total DER reduction value."

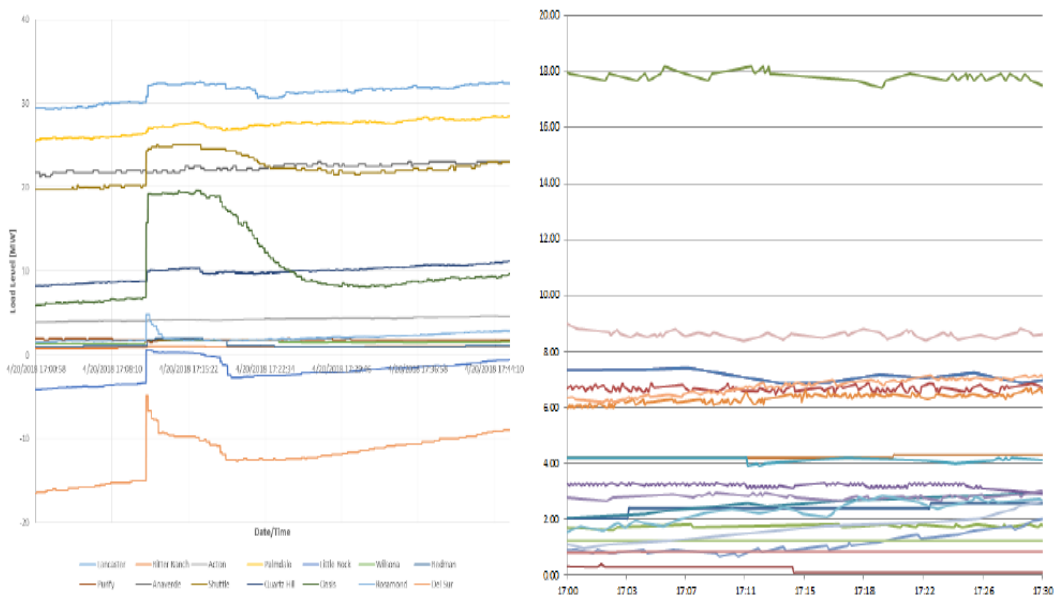


Figure 2.13: SCE (left) and PG&E (right) Individual Load SCADA Points

https://www.nerc.com/pa/rrm/ea/April_May_2018_Fault_Induced_Solar_PV_Resource_Int/April_May_2018_Solar_PV_Disturbance_Report.pdf

DER_A Model (2018)

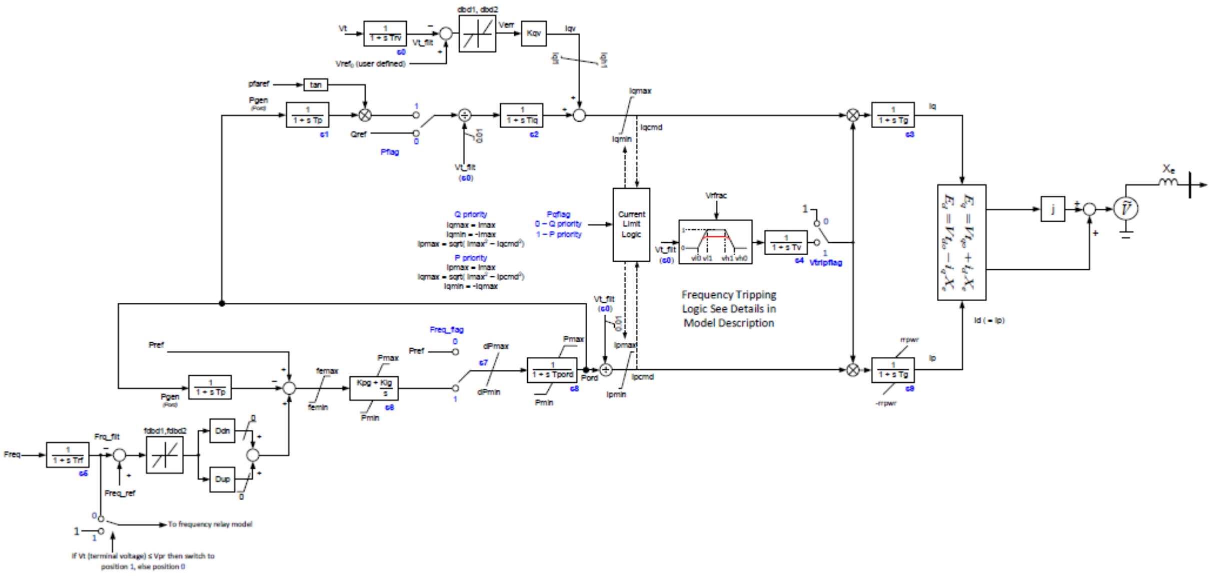


Figure 2: Proposed distributed energy resource model version A (*DER_A*).

Table 1: Model parameter list

Parameter	Description
Trv	transducer time constant (s) for voltage measurement
Trf	transducer time constant (s) for frequency measurment (must be ≥ 0.02 s)
dbd1	lower voltage deadband ≤ 0 (pu)
dbd2	upper voltage deadband ≥ 0 (pu)
Kqv	proportional voltage control gain (pu/pu)
Vref0	voltage reference set-point > 0 (pu)
Tp	transducer time constant (s)
Tiq	Q control time constant (s)
Ddn	frequency control droop gain ≥ 0 (down-side)
Dup	frequency control droop gain ≥ 0 (up-side)
fdbd1	lower frequency control deadband ≤ 0 (pu)
fdbd2	upper frequency control deadband ≥ 0 (pu)
femax	frequency control maximum error ≥ 0 (pu)
femin	frequency control minimum error ≤ 0 (pu)
Pmax	Maximum power (pu)
Pmin	Minimum power (pu)
dPmax	Power ramp rate up > 0 (pu/s)
dPmin	Power ramp rate down < 0 (pu/s)
Tpord	Power order time constant (s)
Kpg	active power control proportional gain
Kig	active power control integral gain
Imax	Maximum converter current (pu)
vl0	voltage break-point for low voltage cut-out of inverters
vl1	voltage break-point for low voltage cut-out of inverters
vh0	voltage break-point for high voltage cut-out of inverters
vh1	voltage break-point for high voltage cut-out of inverters
tvl0	timer for vl0 point
tvl1	timer for vl1 point
tvh0	timer for vh0 point
tvh1	timer for vh1 point
Vrfrac	fraction of device that recovers after voltage comes back to within vl1 < V < vh1
fl	frequency break-point for low frequency cut-out of inverters
fh	frequency break-point for high frequency cut-out of inverters
tfl	timer for fl (Tfl > Trf)
tfh	timer for fh
Tg	Current control time constant
rrpwr	Power rise ramp rate following a fault > 0 (pu/s)
Tv	time constant on the output of the voltage/frequency cut-out
Vpr	voltage below which frequency tripping is disabled
Pflag	0 - for constant Q control, and 1 - constant power factor control
Pqflag	0 - Q priority, 1 - P priority for current limit
Freq_flag	0 - frequency control disabled, and 1 - frequency control enabled
Ftripflag	0 - frequency tripping disabled; 1 - frequency tripping enabled
Vtripflag	0 - voltage tripping disabled; 1 - voltage tripping enabled
typeflag	0 - the unit is a generator Ipmin = 0; 1 - the unit is a storage device and Ipmin = - Ipmax
Xe	Source impedance reactive > 0 (pu)
Iqh1	Maximum limit of reactive current injection, p.u.
Iql1	Maximum limit of reactive current injection, p.u.

DER_A Model Reliability Guideline (2019)

- **Vrfrac:** “the fraction of DER that recovers after voltage returns to within acceptable limits after dropping below or above the threshold values.”
- “Based on the expected [IEEE 1547] vintage of DER and the distribution circuit characteristic.”
- “TPs should coordinate with their DPs to attempt to track the proportion of DERs that could be expected to fall within each category."

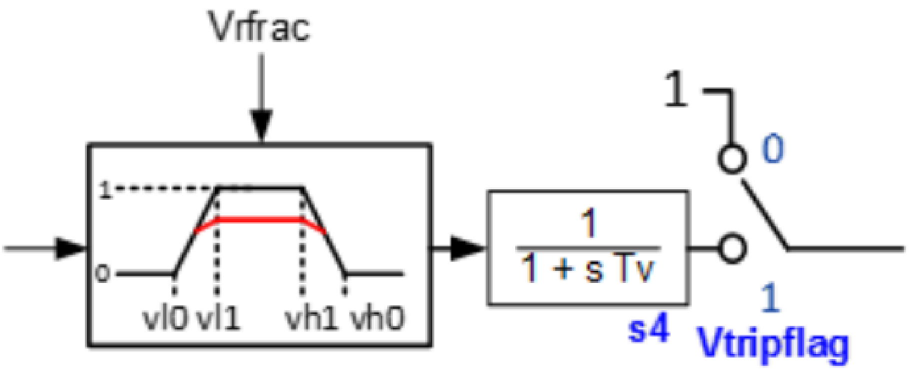


Figure 1.5: Fractional Tripping Controls

MOD-032-1: Data for Power System Modeling and Analysis

"Each Balancing Authority, Generator Owner, Load Serving Entity, Resource Planner, Transmission Owner, and Transmission Service Provider shall provide steady-state, dynamics, and short circuit modeling data [listed in Attachment 1] to its Transmission Planner(s) and Planning Coordinator(s) according to the data requirements and reporting procedures developed by its Planning Coordinator and Transmission Planner in Requirement R1"

MOD-032-1: Attachment 1

"Other (steady-state, dynamics, and short circuit) information requested by the Planning Coordinator or Transmission Planner necessary for modeling purposes. [BA, GO, LSE, TO, TSP]"

MOD-032-1: Standard Authorization Request (12/10/2019)

"LSE should be removed and replaced by DP as the applicable entity in Section 4.1.3 and all instances in the standard requirements and attachments. The SDT should review any potential gaps regarding data collection for aggregate DER data with the de-registration of LSE."

Endorsed by Planning Committee → Standards Committee

MOD-032-1 Standard Authorization Request (12/10/2019)

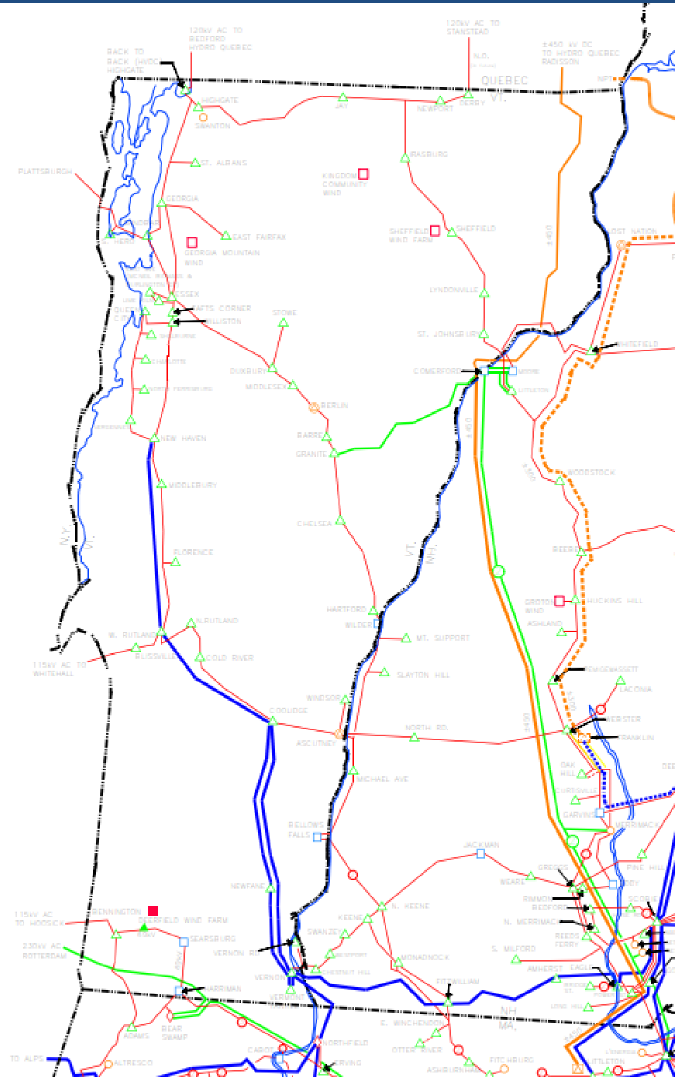
Requested information
• The table in Attachment 1 should include references to aggregate DER in the steady-state and dynamics columns. The drafting team should consider the data needed for modeling aggregate DER for the purposes of BPS reliability studies. However, the NERC SPIDERWG proposes that the SDT consider including, at a minimum, the following information in the table: o Steady-State: ▪ Aggregate Distributed Energy Resources • Aggregate maximum and minimum active power capacity • Location (correlated to BPS bus location) • Breakdown by type of DER (e.g., by fuel type or technology) o Dynamics: ▪ Aggregate Distributed Energy Resources

Endorsed by Planning Committee → Standards Committee

SPIDER Working Group

NERC ID	Entity	Functional Registration
NCR07024	Burlington Electric Department	Distribution Provider*
NCR07103	Green Mountain Power Corporation	Distribution Provider Generation Owner/Operator
NCR07224	Vermont Electric Cooperative	Distribution Provider
NCR07227	Vermont Public Power Supply Authority	Generator Owner/Operator
NCR07228	Vermont Transco, LLC	Transmission Owner Transmission Operator Transmission Planner Transmission Service Provider

**Underfrequency Load Shed Only*



DER → Bulk Power System

TPL-001-5

TPL-001-5: Transmission System Planning Performance Requirements

"Establish Transmission system planning performance requirements within the planning horizon to develop a Bulk Electric System (BES) that will operate reliably over a broad spectrum of System conditions and following a wide range of probable Contingencies."

- Do "System conditions" and "probable Contingencies" include consideration of aggregate DER?

TPL-001-5 White Paper (Highlight Reel)

"SPIDERWG recommends a SAR be developed that includes each of the following issues and that a future SDT assess the extent to which changes or implementation guidance are needed for each of these issues"

- Clarify Requirements R2.1 and R2.2 regarding use of phrase "System peak Load". This should be updated to consider "System net or gross peak demand", and sensitivity studies should consider "System net or gross peak demand" if the two conditions are significantly different from one another in either magnitude or locational spread.[1] The SDT should consider whether terms should be added to the NERC Glossary of Terms for "Gross Demand" and "Net Demand" so there is no misinterpretation of what these terms refer to.

[1] As the penetration of DER increases, the peak demand seen at the transmission-distribution interface can become significantly different at different locations.

TPL-001-5 White Paper (Highlight Reel)

"SPIDERWG recommends a SAR be developed that includes each of the following issues and that a future SDT assess the extent to which changes or implementation guidance are needed for each of these issues"

- Clarify Requirement R3.1 and R3.4 in regards to whether and how DER should be considered as a potential contingency.
- Clarify Requirement R3.3 in regards to the extent to which DER are considered in contingency definitions. While requirement R1.1.5 uses the term "resource" (which includes demand side resources[2]), Requirement R3.3 uses the term "generator" which is not a defined term in the NERC Glossary and typically does not include DERs. Therefore, it is unclear whether aggregate amounts of DER tripping should be considered in this assessment.

TPL-001-5 White Paper (Highlight Reel)

"SPIDERWG recommends a SAR be developed that includes each of the following issues and that a future SDT assess the extent to which changes or implementation guidance are needed for each of these issues"

- Clarify Requirement R4.3.2 regarding representation of the dynamic behavior of aggregate DER (e.g., aggregate DER tripping, dynamic voltage and frequency controls, momentary cessation, etc.) should be considered in stability analyses.

DER → Bulk Power System

PRC-006

PRC-006: Automatic Underfrequency Load Shedding

"**R3** Each Planning Coordinator shall develop a UFLS program, including notification of and a schedule for implementation by UFLS entities within its area, that meets the following performance characteristics in simulations of underfrequency conditions resulting from an imbalance scenario, where an imbalance = [(load — actual generation output) / (load)], of up to 25 percent within the identified island(s)."

Load = Net Load or Gross Load?

DER → PRC-006

ISO Perspective

"Take a system with 100 MW of load and 25 MW of DER. [There's] a net load of 75 MW. The deficiency created for analyzing this 'net load' scenario would be 25% of 75 MW, versus 25% of 100 MW. If the deficiency is modeled at a less-than-realistic deficiency, the frequency will not drop to the realistic level, modeled only at a higher deficiency. The system would thus be under-designed."

PRC-006-NPCC-1: Net Load Shed Requirements

	Peak ≥ 100 MW		*50 MW ≤ Peak < 100 MW*		*25 MW ≤ Peak < 50 MW*	
Trip Setting	Load Shed	Cumulative Load Shed	Load Shed	Cumulative Load Shed	Load Shed	Cumulative Load Shed
59.5	6.5-7.5%	6.5-7.5%	14-25%	14-25%	28-50%	**28-50%**
59.3	6.5-7.5%	13.5-14.5%				
59.1	6.5-7.5%	20.5-21.5%	14-25%	**28-50%**		
58.9	6.5-7.5%	27.5-28.5%				
59.5 (10s)	2-3%	**29.5-31.5%**				

PRC-006-NPCC-1: Net Load

Entity Name:	Projected DP 2025 Peak Load (MW)	UFLS Feeder ID	Trip Setting	Feeder Load Tripped (MW)	% of Peak
"Friendly Neighborhood Utility"	100	1	59.5	3.5	3.5
		2	59.5	3.5	3.5
		3	59.3	3.5	3.5
		4	59.3	3.5	3.5
		5	59.1	3.5	3.5
		6	59.1	3.5	3.5
		7	58.9	3.5	3.5
		8	58.9	3.5	3.5
		9	59.5 (10s)	1	1
		10	59.5 (10s)	1	1
				30	30

PRC-006-NPCC-1: Net Load

Entity Name:	Projected DP 2025 Peak Load (MW)	UFLS Feeder ID	Trip Setting	Feeder Load Tripped (MW)	% of Peak	DER (MW)
"Friendly Neighborhood Utility"	100	1	59.5	3.5	3.5	0
		2	59.5	3.5	3.5	0
		3	59.3	3.5	3.5	0
		4	59.3	3.5	3.5	0
		5	59.1	3.5	3.5	0
		6	59.1	3.5	3.5	0
		7	58.9	3.5	3.5	0
		8	58.9	3.5	3.5	0
		9	59.5 (10s)	1	1	0
		10	59.5 (10s)	1	1	0
				30	30	0

PRC-006-NPCC-1: Net Load

Entity Name:	Projected DP 2025 Peak Load (MW)	UFLS Feeder ID	Trip Setting	Feeder Load Tripped (MW)	% of Peak	DER (MW)
"Friendly Neighborhood Utility"	95	1	59.5	2.5	2.6	1
		2	59.5	2.5	2.6	1
		3	59.3	2.5	2.6	1
		4	59.3	3.5	3.7	0
		5	59.1	2.5	2.6	1
		6	59.1	3.5	3.7	0
		7	58.9	3.5	3.7	0
		8	58.9	2.5	2.6	1
		9	59.5 (10s)	1	1.1	0
		10	59.5 (10s)	1	1.1	0
				25	26.3	5

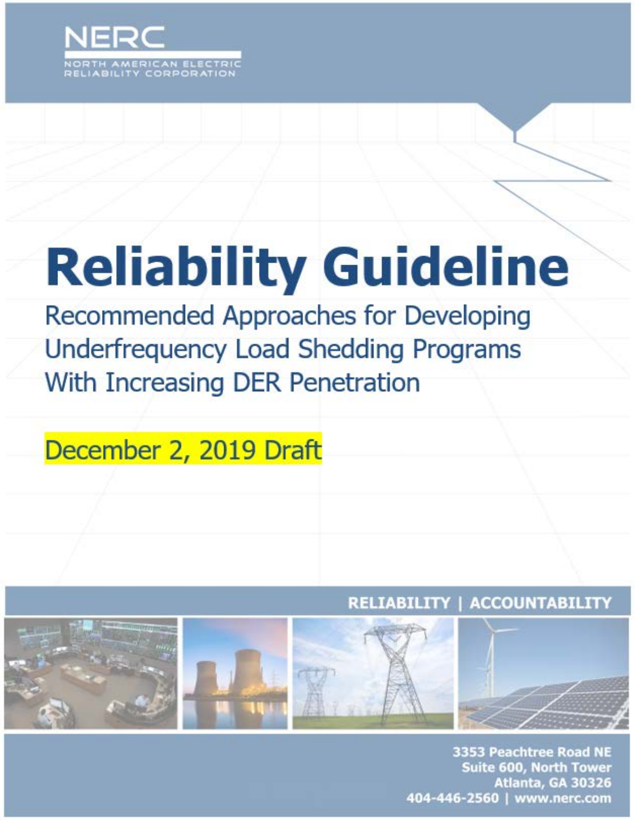
PRC-006-NPCC-1: Net Load

Entity Name:	Projected DP 2025 Peak Load (MW)	UFLS Feeder ID	Trip Setting	Feeder Load Tripped (MW)	% of Peak	DER (MW)
"Friendly Neighborhood Utility"	90	1	59.5	1.5	1.7	2
		2	59.5	1.5	1.7	2
		3	59.3	1.5	1.7	2
		4	59.3	3.5	3.9	0
		5	59.1	1.5	1.7	2
		6	59.1	3.5	3.9	0
		7	58.9	3.5	3.9	0
		8	58.9	1.5	1.7	2
		9	59.5 (10s)	1	1.1	0
		10	59.5 (10s)	1	1.1	0
				20	22.2	10

Reliability Guideline: Recommended Approaches for Developing UFLS Programs with Increasing DER Penetration

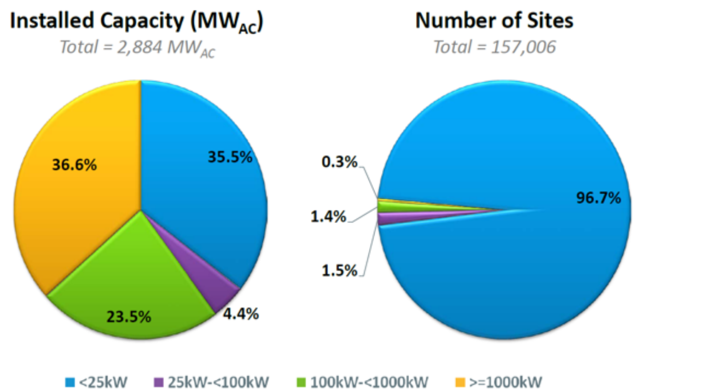
Guidance on how to study UFLS programs and ensure their effectiveness with increasing penetration of DER represented.

- Background
- Impacts of DER on Island-Level Frequency
- Impacts of DER on UFLS Program Design
- Recommendations

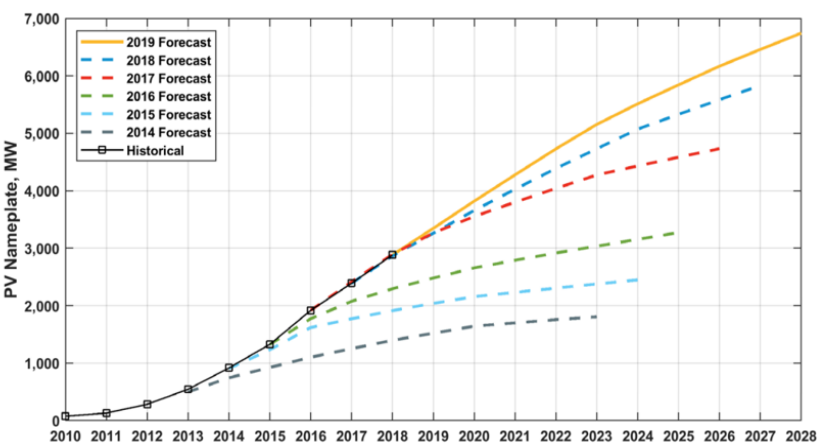


Impact of DER on Island-Level Frequency: Available Load Shed

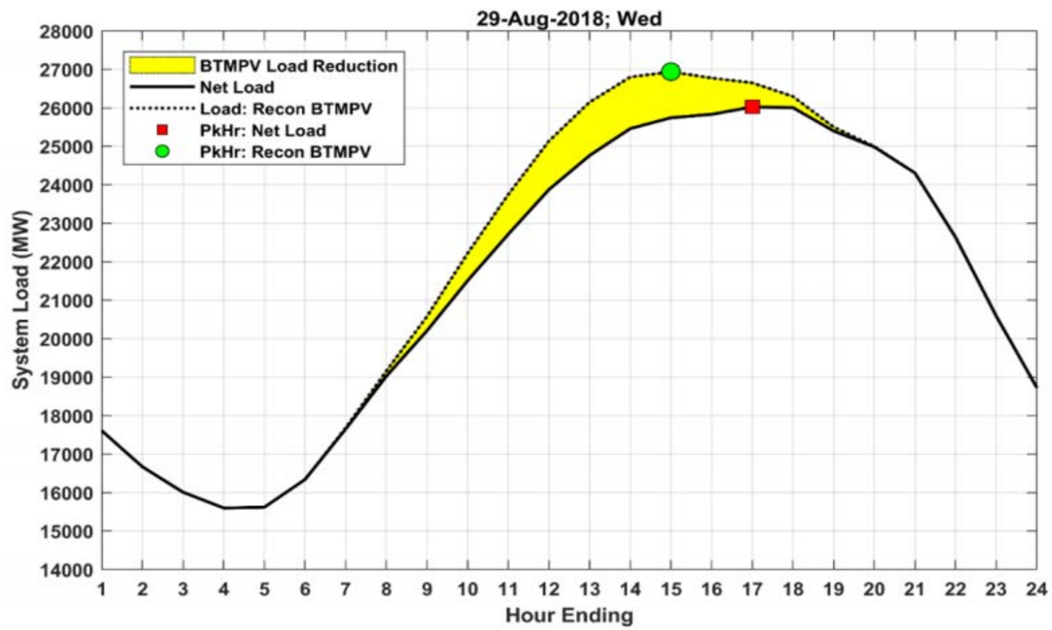
ISO New England's Islanding Study – Impact of DER



Installed PV Capacity as of December 2018 – ISO New England by Size Class



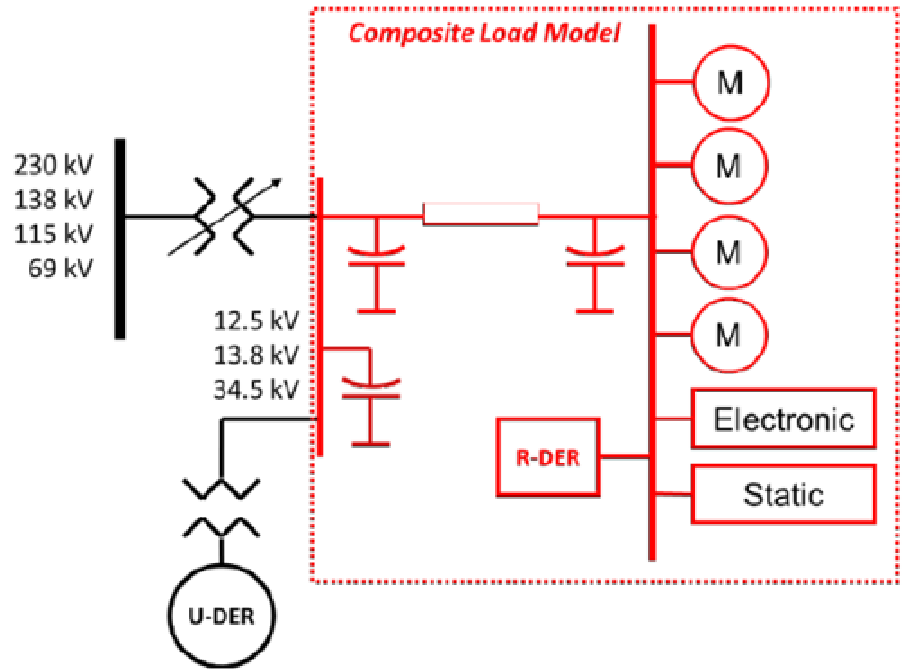
PV Growth: Reported Historical vs. Forecast



Example of BTM PV Impact on Summer Peak Day – August 29, 2018

Impact of DER on Island-Level Frequency: Available Load Shed

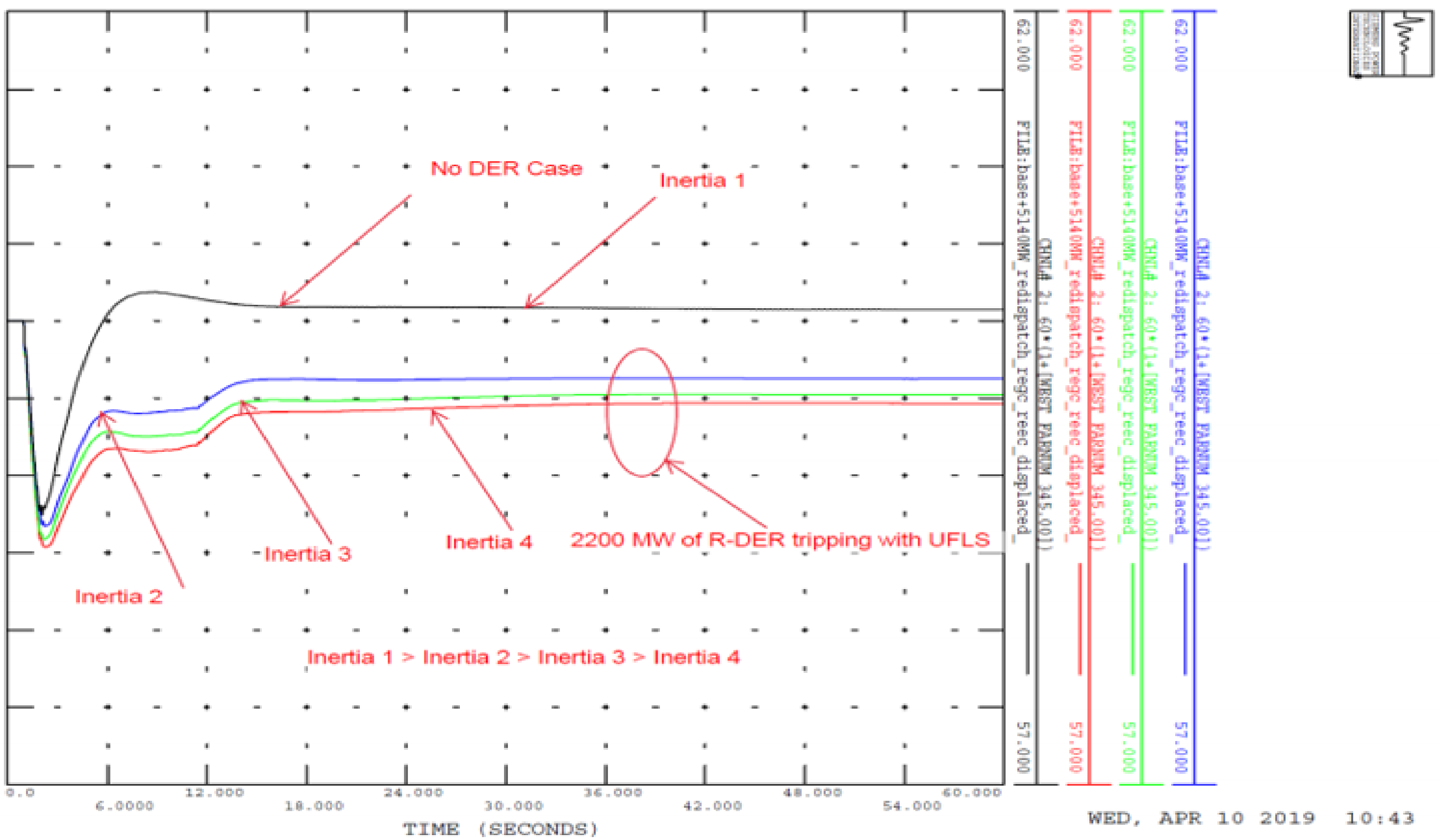
ISO New England's Islanding Study – Impact of DER



Dynamic Load Model with R-DER and U-DER Represented

Impact of DER on Island-Level Frequency: Available Load Shed

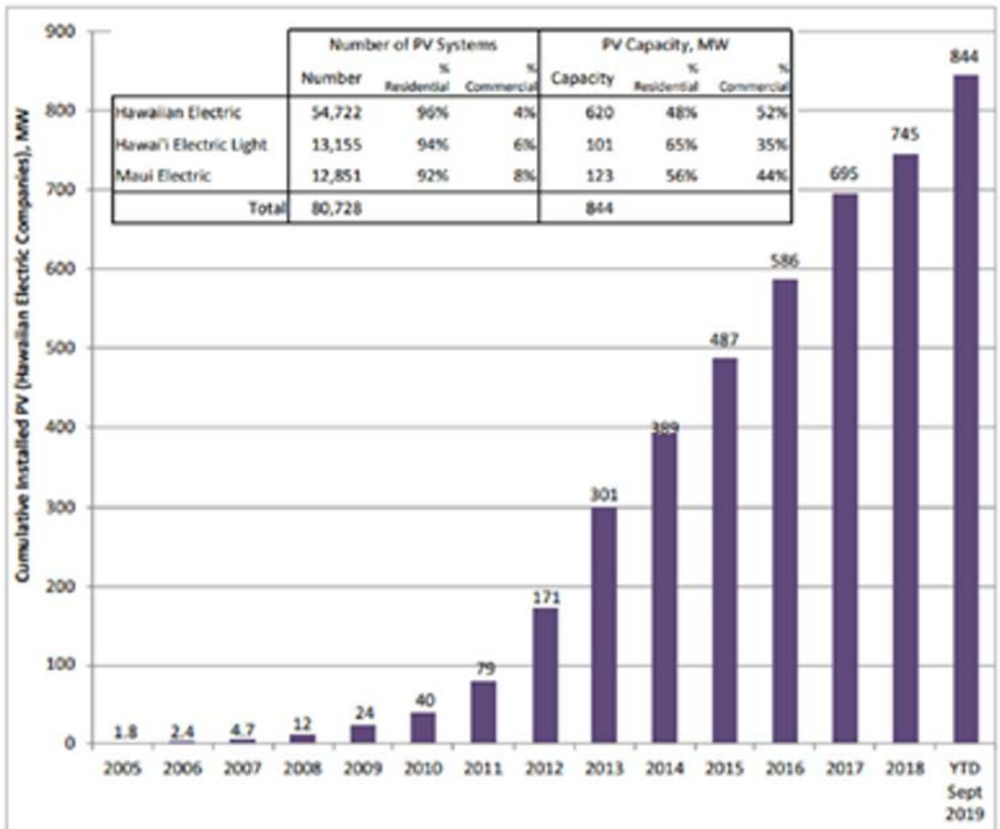
ISO New England's Islanding Study – Impact of DER



ISO New England Island Frequency Performance – 60 Seconds

Impact of DER on UFLS Program Design: Load Selection

Hawai'i Electric Light's Adaptive UFLS

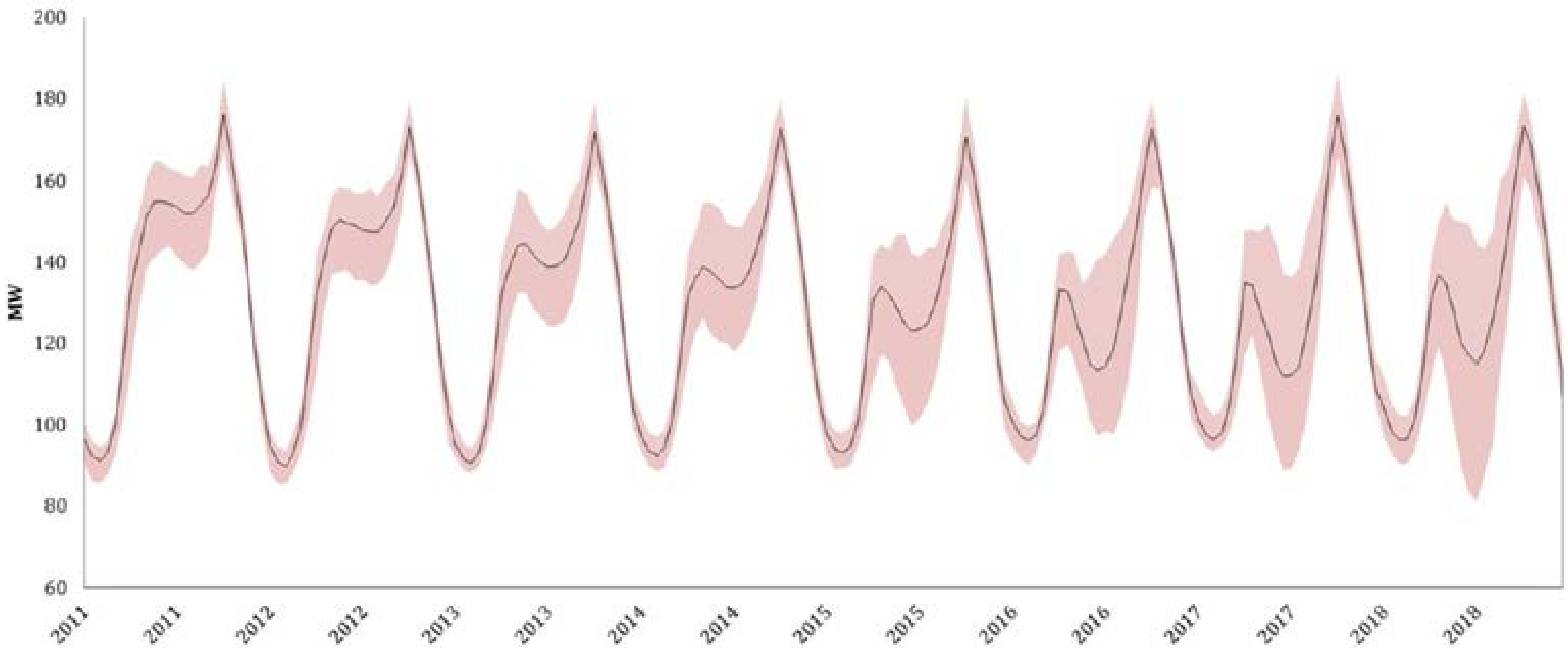


	Number of PV Systems			PV Capacity, MW		
	Number	% Residential	% Commercial	Capacity	% Residential	% Commercial
Hawaiian Electric	54,722	96%	4%	620	48%	52%
Hawai'i Electric Light	13,155	94%	6%	101	65%	35%
Maui Electric	12,851	92%	8%	123	56%	44%
Total	80,728			844		

Hawaiian Electric Consolidated Distributed Solar Growth

Impact of DER on UFLS Program Design: Load Selection

Hawai‘i Electric Light’s Adaptive UFLS



Impact of DER on Hawaii Island’s February Average Daily (Net) Load

Impact of DER on UFLS Program Design: Load Selection

Hawai'i Electric Light's Adaptive UFLS

Table 2: Hawai'i Electric Light Adaptive UFLS Load Shedding Scheme

Stage	Setting (Hz)	% of Net System Load (MW)	Time
df/dt*	*0.5/sec*	15%	9 cycle relay plus breaker time
1	*59.1*	5%	8 cycle relay plus breaker time
2	*58.8*	10%	8 cycle relay plus breaker time
3	*58.5*	10%	8 cycle relay plus breaker time
4	*58.2*	15%	8 cycle relay plus breaker time
5	*57.9*	10%	8 cycle relay plus breaker time
6	*57.6*	20%	8 cycle relay plus breaker time
Kicker 1a	*59.3*	5%	10 seconds
Kicker 1b	*59.5*		30 seconds
Kicker 2	*59.5*	5%	20 seconds

Stage 1 and stage 2 should sum to 15% of the system net load.
- Maximum allowed load shedding for N-1 unit trips.

Stage 1 through stage 4 should sum to 40% of the system net load.
- Maximum allowed load shedding for N-1-1 unit contingencies.

*Not currently active.

Impact of DER on UFLS Program Design: Load Selection

Hawai'i Electric Light's Adaptive UFLS

UFLS STAGE DATA

System Load:	141.853
Total Target:	112.185
Total Available:	114.292

Stage	Frequency	Percent	Target MW	Avail MW	Tol %	Tolerance	Delta MW
STAGE1	59.100	5.00	7.01154	6.82032	5.000	0.351	0.191
STAGE2	58.800	10.00	14.02308	13.83560	5.000	0.701	0.187
STAGE3	58.500	10.00	14.02308	13.34422	5.000	0.701	0.679
STAGE4	58.200	15.00	21.03462	22.24468	8.000	1.683	-1.210
STAGE5	57.900	10.00	14.02308	14.21575	8.000	1.122	-0.193
STAGE6	57.600	20.00	28.04617	25.46988	25.000	7.012	2.576
KICKER1	59.500	5.00	7.01154	6.79824	8.000	0.561	0.213
KICKER2	59.300	5.00	7.01154	6.54598	8.000	0.561	0.466

Summary Display of Hawaii Electric Light Adaptative UFLS Scheme EMS

→ Generation Constraint Analysis

MOD-032/TPL-001

- Unlocking generation constrained areas or increasing hosting capacity of substations for distribution-level DER may require unanticipated upgrades, monitoring equipment, model validations, and studies for aggregate DER

PRC-006

- Distribution Providers in Vermont require flexibility to meet PRC-006-NPCC-1 load shed requirements as distribution-level DER increases
- Violations of PRC-006-NPCC-1 have the highest severity level among all NERC standards

Questions and Answers

NERC ID	Entity	Functional Registrations
NCR07124	ISO-NE	Balancing Authority Planning Coordinator Reliability Coordinator Resource Planner Reserve Sharing Group Transmission Operator Transmission Planner Transmission Service Provider