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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Accommodating High Levels of Distributed Energy Resources:

A Bulk Power System Reliability Perspective

John Moura, Director Reliability Assessment and System Analysis

EPRI Transmission & Distribution Coordination Workshop

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RELIABILITY | ACCOUNTABILITY




NERC : Mission & Purpose

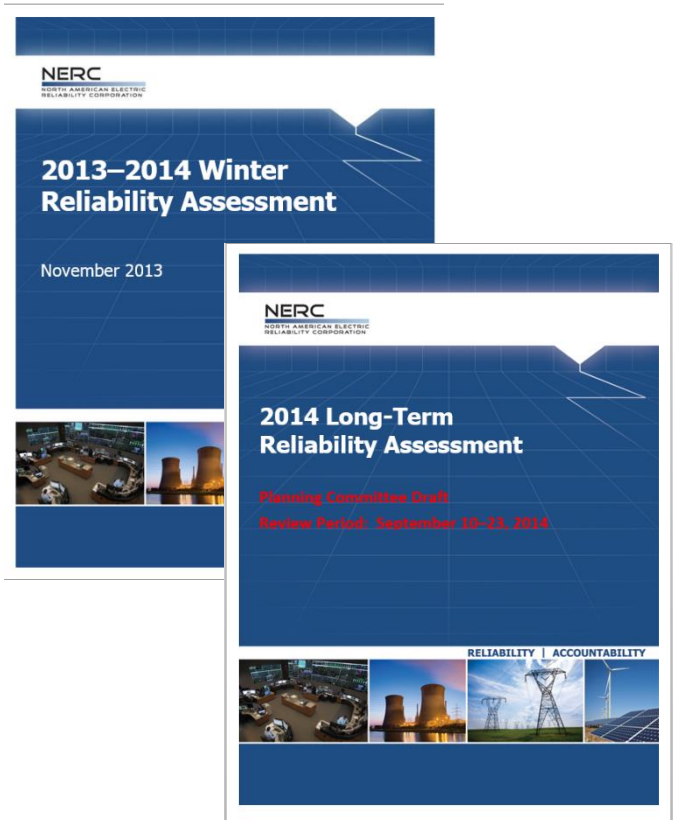
To assure North American bulk power system (BPS) reliability

Accountable as ERO to regulators in the United States (FERC) And Canada (CA NEB & provincial authorities) to:

- **Develop & enforce NERC Reliability Standards**
  - Over 100 mandatory standards (1,500 requirements) in place
  - Developed & voted on by technical experts
  - Approved & Enforced by NERC & FERC
- **Assess current & future reliability**
  - Develop reports to assess resource adequacy & identify reliability issues
  - Analyze system events & recommend improved practices
  - Manage technical committees & stakeholder groups

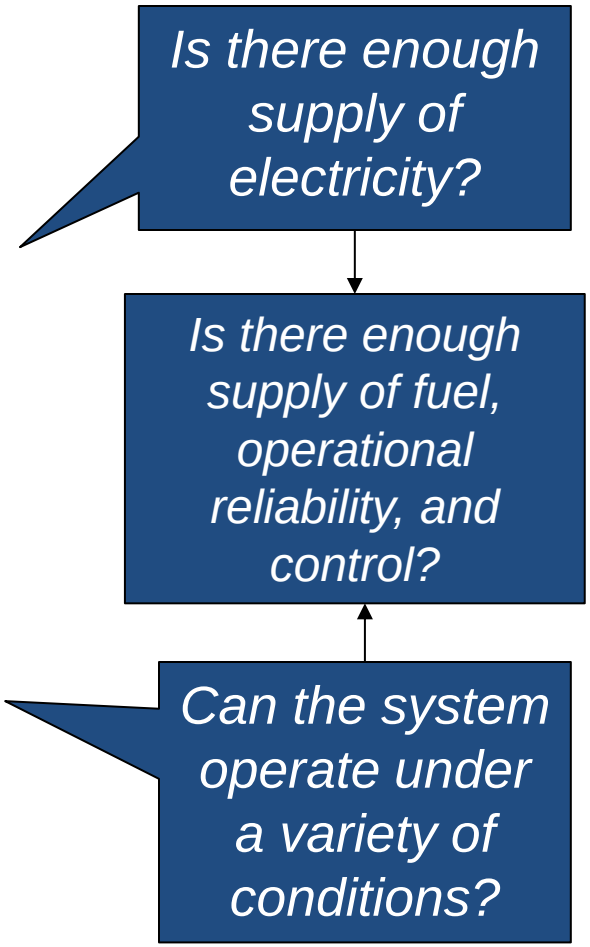
NERC Reliability Assessments

- Reliability
  - Resource Adequacy
  - Operating Reliability
- Transmission adequacy
- Demand and Generation forecasts
- Demand-Side Management
- Regional coordination
- Key issues - emerging trends
  - Technical challenges
  - Evolving market practices
  - System elements/dynamics
  - Potential legislation/regulation



What is BPS Reliability?

- The ability of the BPS to meet the electricity needs of end-use customers at all times.
  - **Adequacy** — The ability of the bulk power system to supply the aggregate electrical demand and energy requirements of the customers at all times.
  - **Operating Reliability** — The ability of the bulk power system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements.



What's Changing?

- **Resource mix shifting**
  - Variable Energy Resources (wind and solar) with very different generation characteristics and stochastic production profiles
  - Demand side resources (roof top solar and demand response) "invisible" to system operators
  - Coal and nuclear in decline
  - Electric storage becoming viable option
  - Heavy reliance on natural gas
- **BPS load growth flattening**
  - Pricing (rate) pressures
  - Business model challenges for utilities
  - Potential for significant rapid growth (i.e., electrification, transportation)
- **Reliability and security requirements increasing**
  - Electricity is "fundamental" to modern society
  - Persistent security threat with sophisticated actors

NERC Distributed Energy Resources Task Force

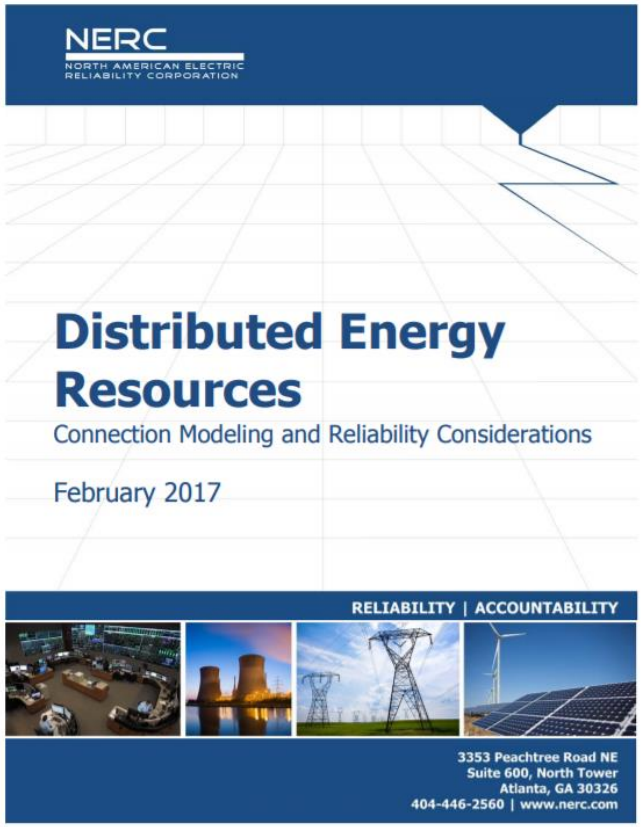
NERC DER Task Force 2017 Report: DER Connection, Modeling, and Reliability Considerations

DERTF working definition of DER:

- *A 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 (BES).*

Examples Include:

- *Residential rooftop solar*
- *Microgrids*
- *Cogeneration projects*
- *Any other distribution resource*



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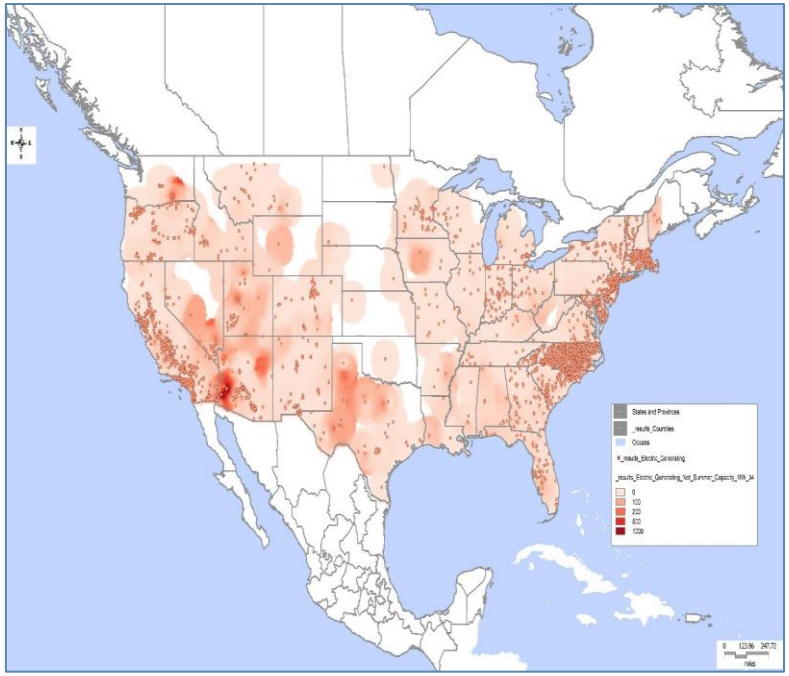
Distributed Energy Resources

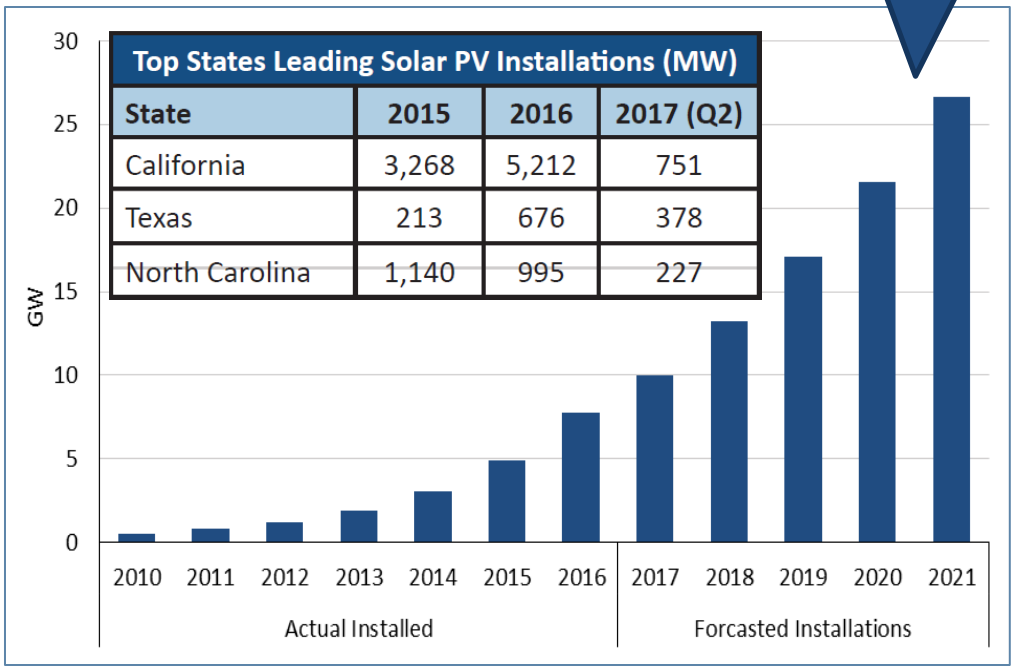
2017 Long-Term Reliability Assessment: Demand and Resources Outlook

- Solar PV continues to expand at a rapid pace
- Visibility is needed to plan and operate the bulk power system
- Coordination of protection and control

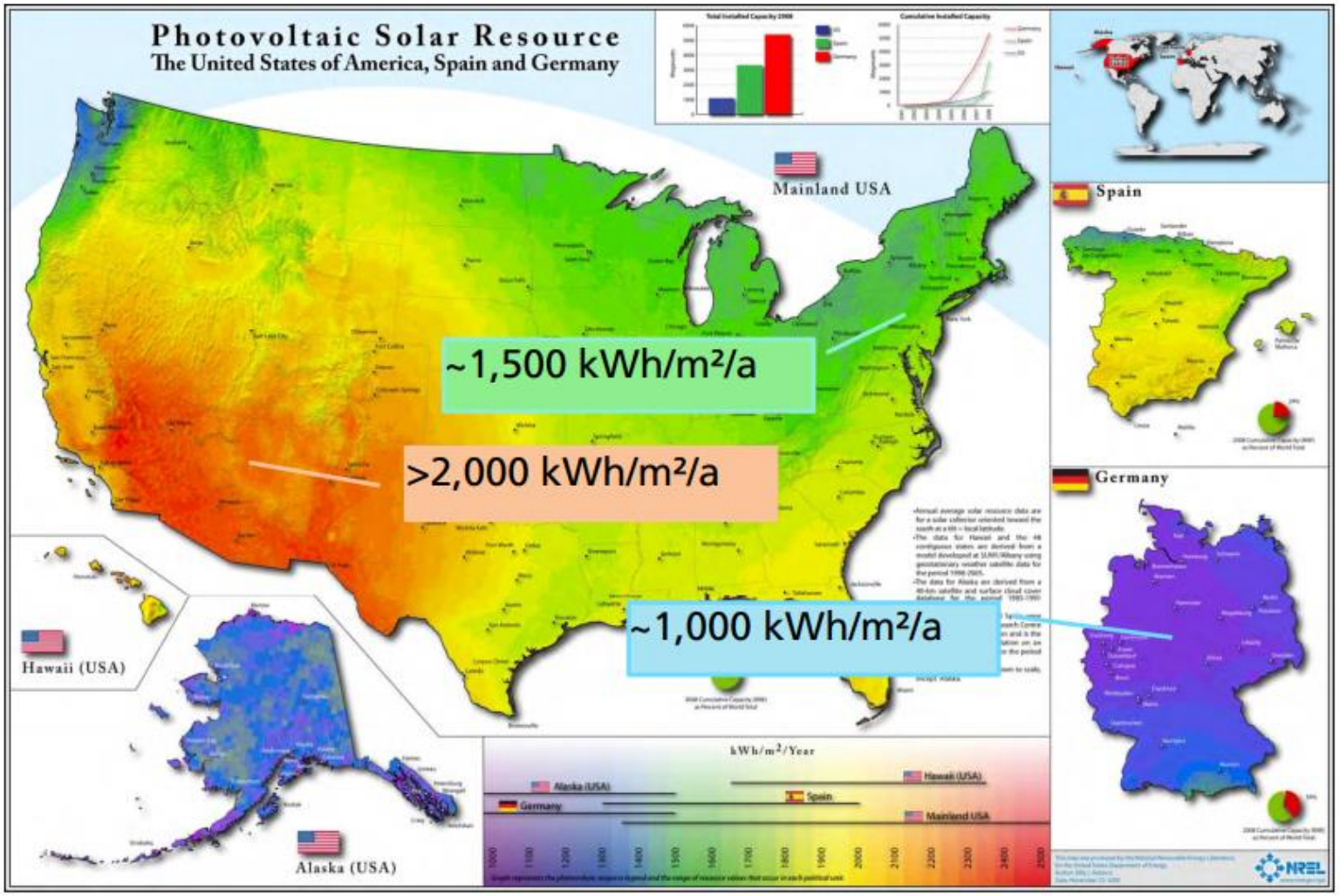
Over 100 GW by 2022 when considering utility-scale PV



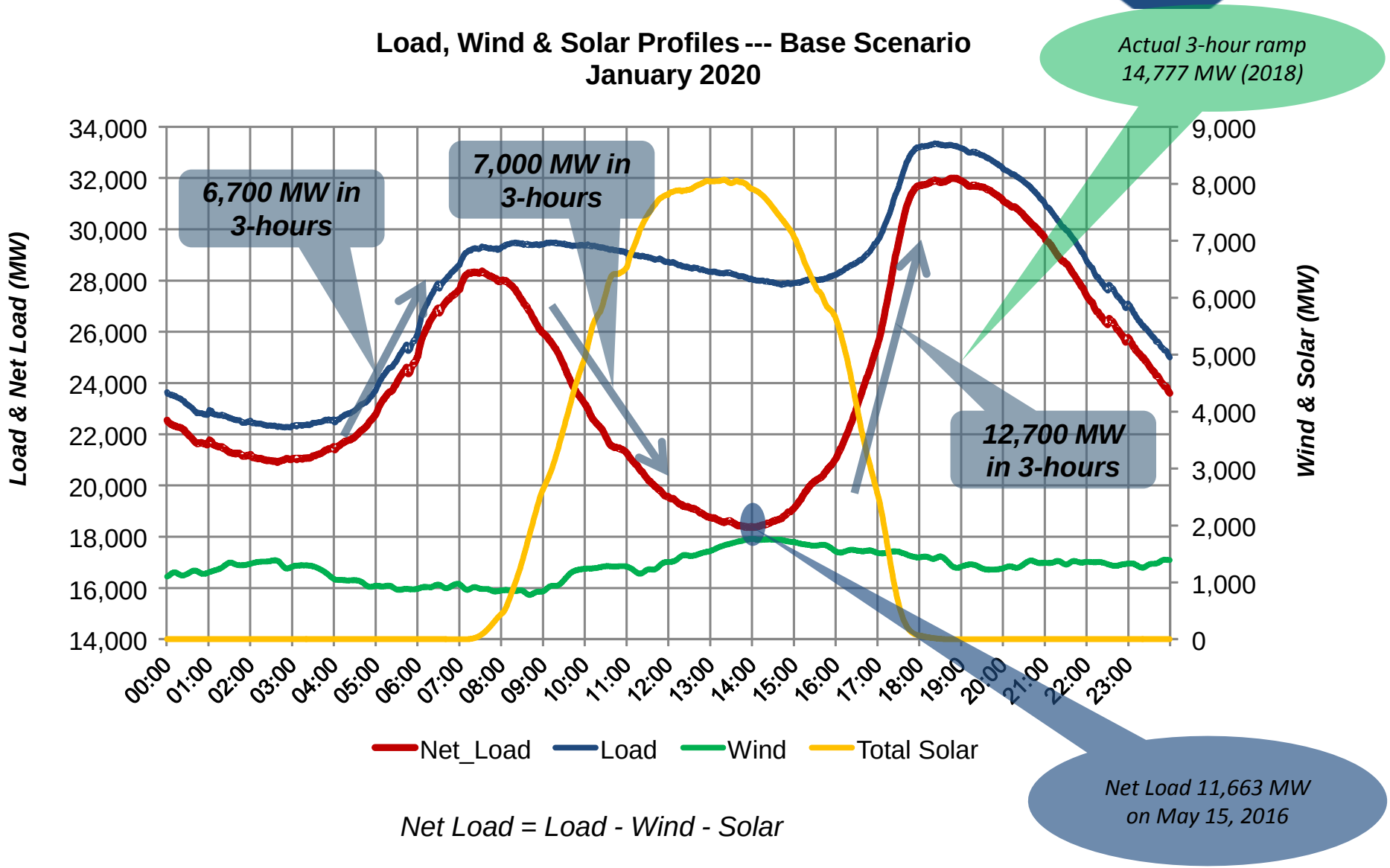
Top States Leading Solar PV Installations (MW)			
State	2015	2016	2017 (Q2)
California	3,268	5,212	751
Texas	213	676	378
North Carolina	1,140	995	227



Solar Irradiation in Germany Similar to that of Alaska



The Need For Flexibility

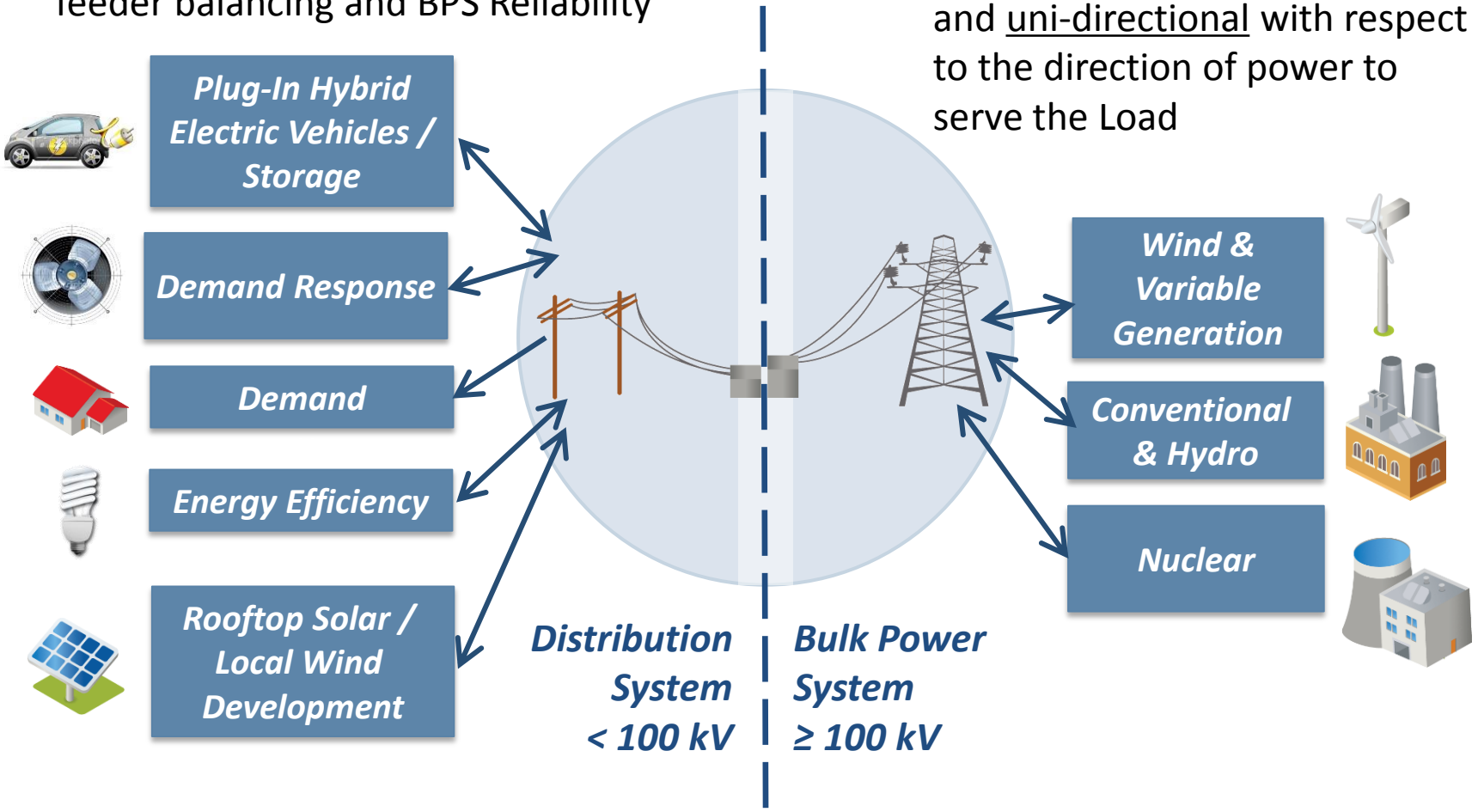


Net Load = Load - Wind - Solar

DER & BPS Power Flow Changes

- DER enable bi-directional power flows from the Distribution System which effects feeder balancing and BPS Reliability

- BPS previously considered the Distribution System as balanced and uni-directional with respect to the direction of power to serve the Load



The Control Shift (1 of 3)

Distribution

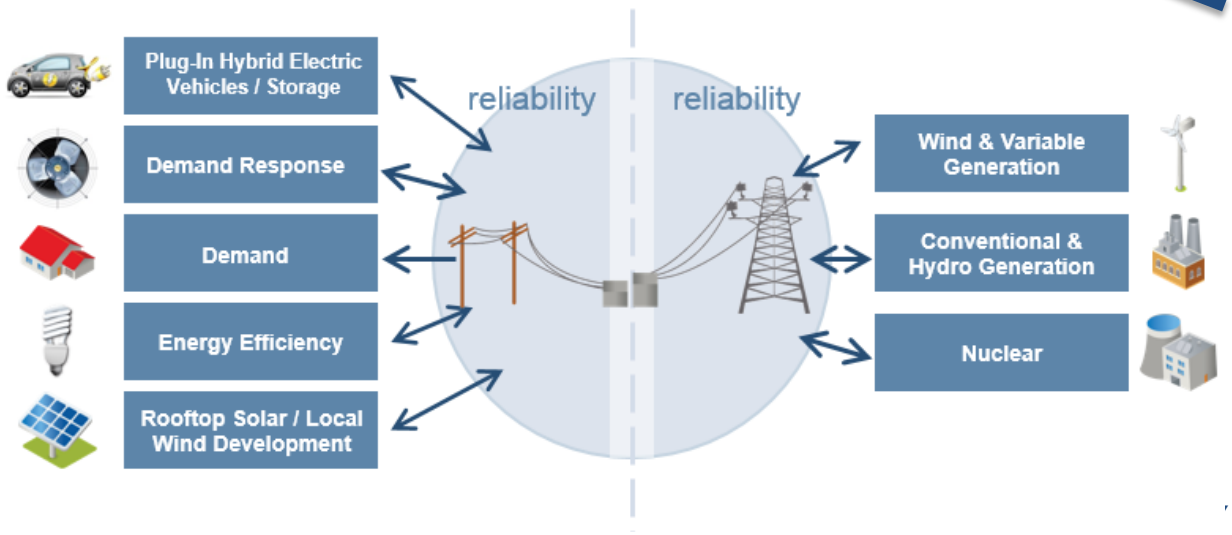
- Variability absorbed by load variability
- Operational characteristics do not permeate to BPS

10%

90%

Bulk-Power System

- Supports system inertia and recovery modes
- Dispatchable based on demand
- Centralized to System Operator



The Control Shift (2 of 3)

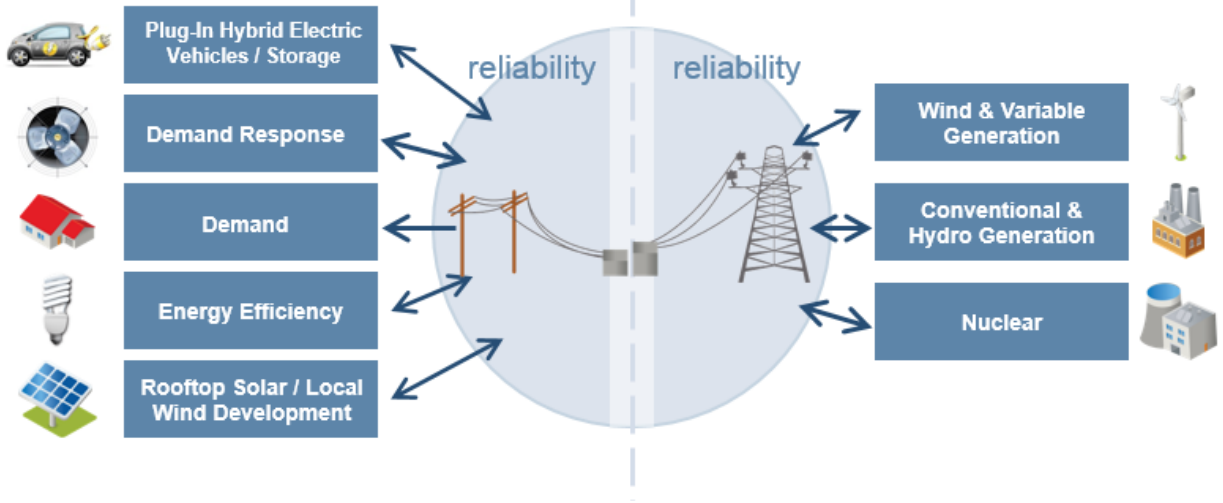
Bulk-Power System

- More rigorous generator control and dispatch ability
- Increased reliance on BPS generation
- Additional equipment to control local voltages

70%

Distribution 30%

- Disturbances permeate to BPS (common-mode)
- Dynamic and fast demand response
- Potential for over generation



The Control Shift (3 of 3)

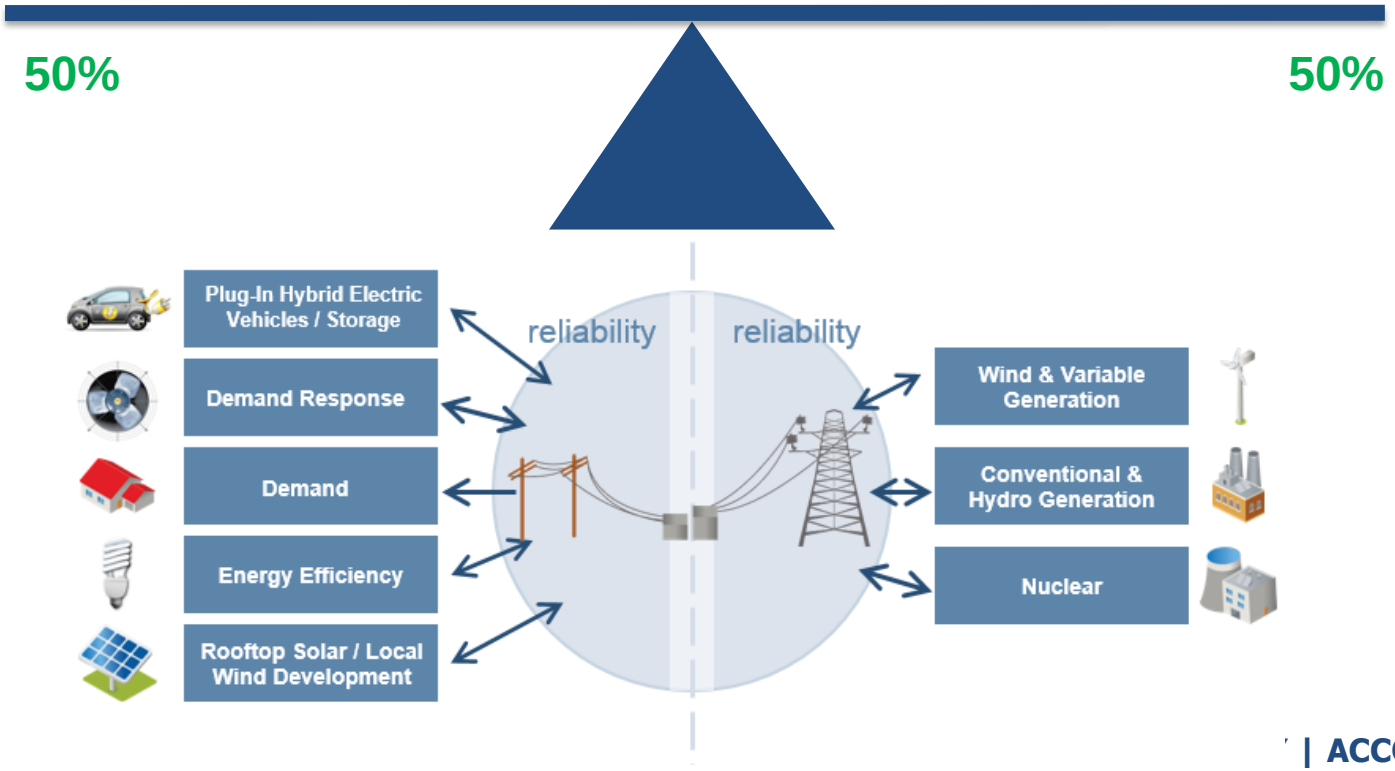
Integrated Power System

Distribution

- DER must act as a system resource
- Storage, curtailment, coordination, grid support, and control
- Operator or aggregator function is needed

Bulk-Power System

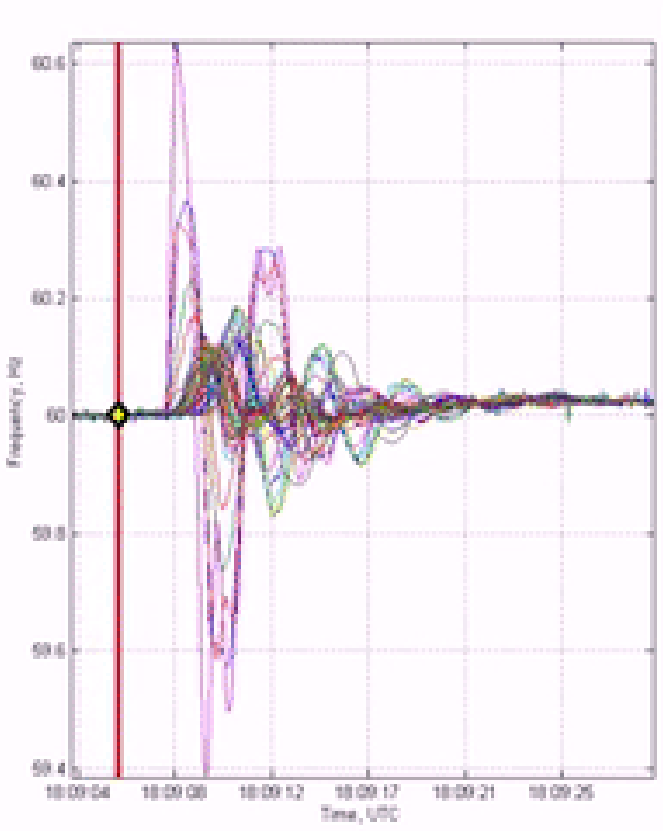
- Supports electricity services
- Long-haul power transfers provider
- Reliability backbone

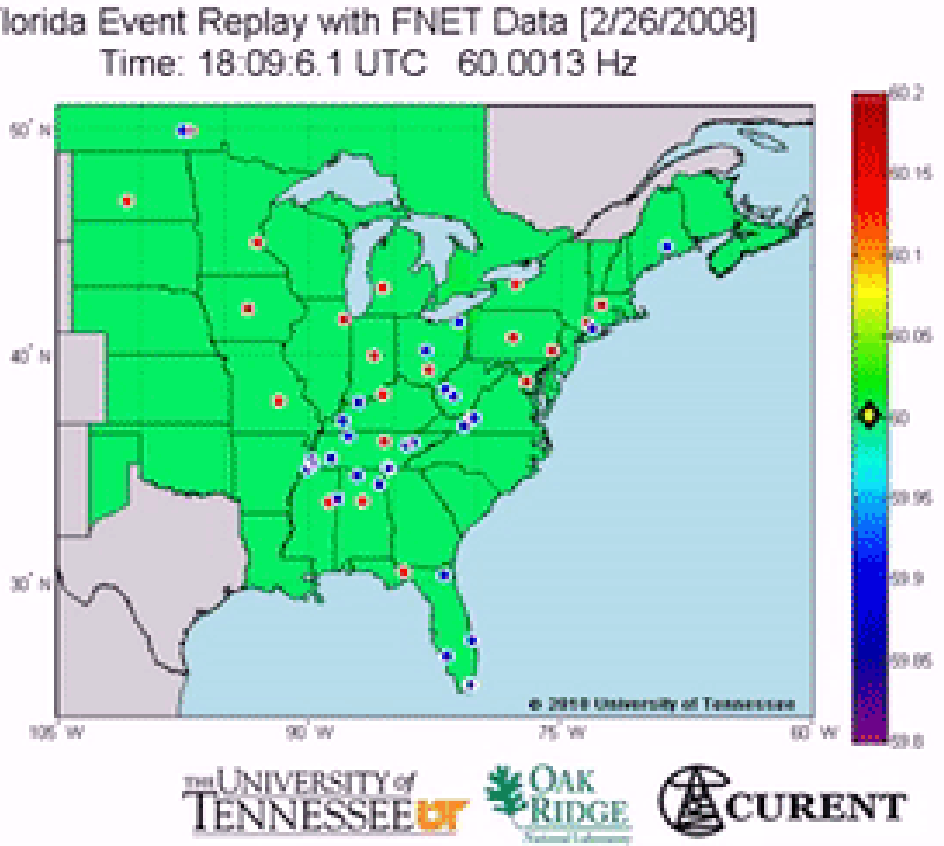


Disturbance Performance

- Large-scale deployment of DER without **adequate voltage and frequency tolerance** will negatively affect bulk system reliability and performance ("RIDE-THROUGH")
- **Disconnections** during a frequency event propels frequency decay
- Disturbances on the transmission grid can cause a wide-spread, automatic, and simultaneous shutdown of distributed resources
- **IEEE 1547** – inverter manufacturing standard for DER
  - NEW VERSION APPROVED IN 2018!

Frequency Excursion – Interconnection-wide Phenomena





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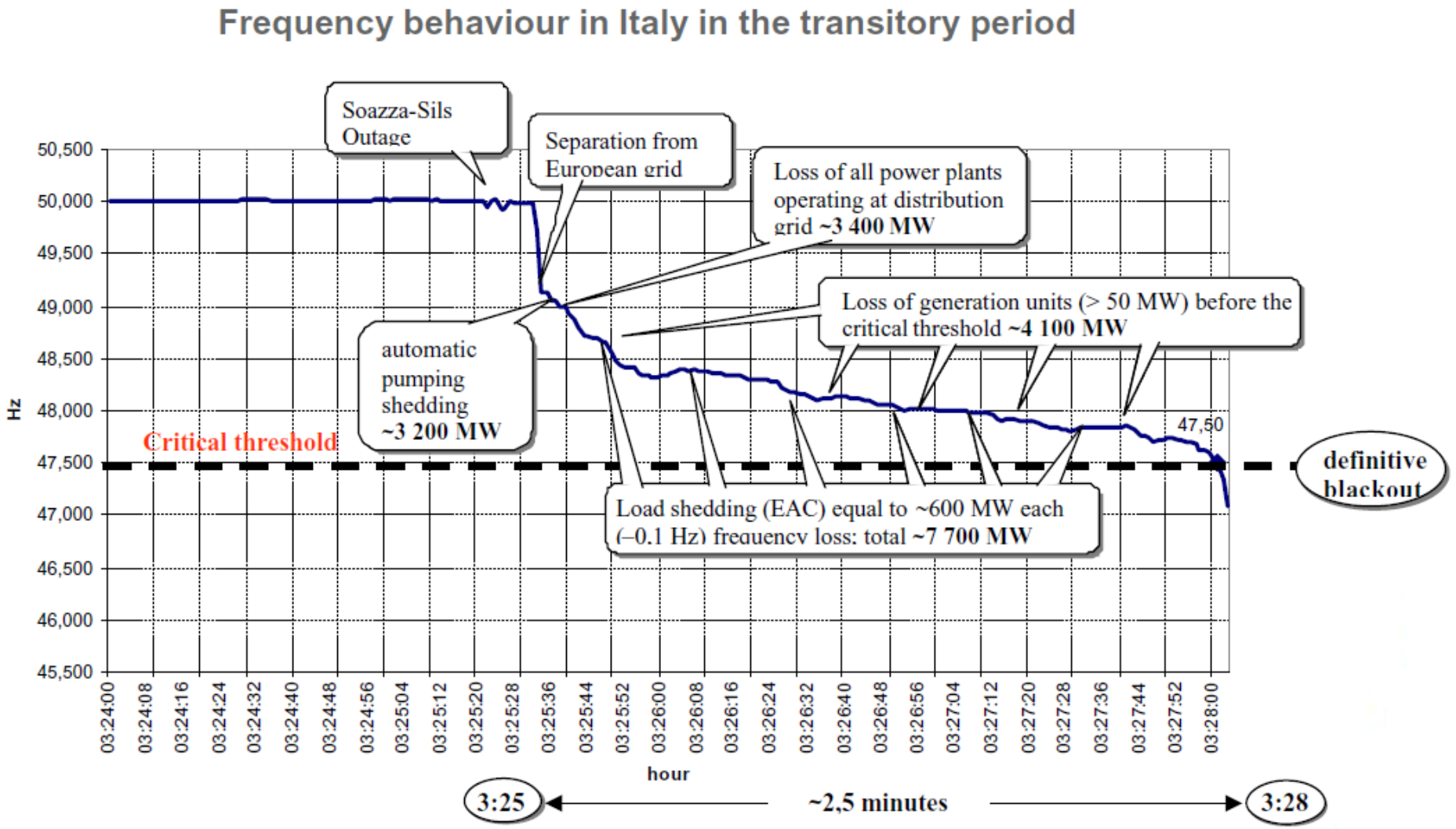
European Experience with DER (2003)



NERC's Concern
DERTF Final Report Focus Points

As the Operations and Control paradigms shift, the following questions arise:

- **How should DER be included in planning and operating models?**
  - How many are there, can DER be aggregated and where should they be modeled?
  - What level of detail of each type of DER model is needed for reliability?
  - What level of control is needed for reliable system operations?
  - What level of visibility do system operators require?

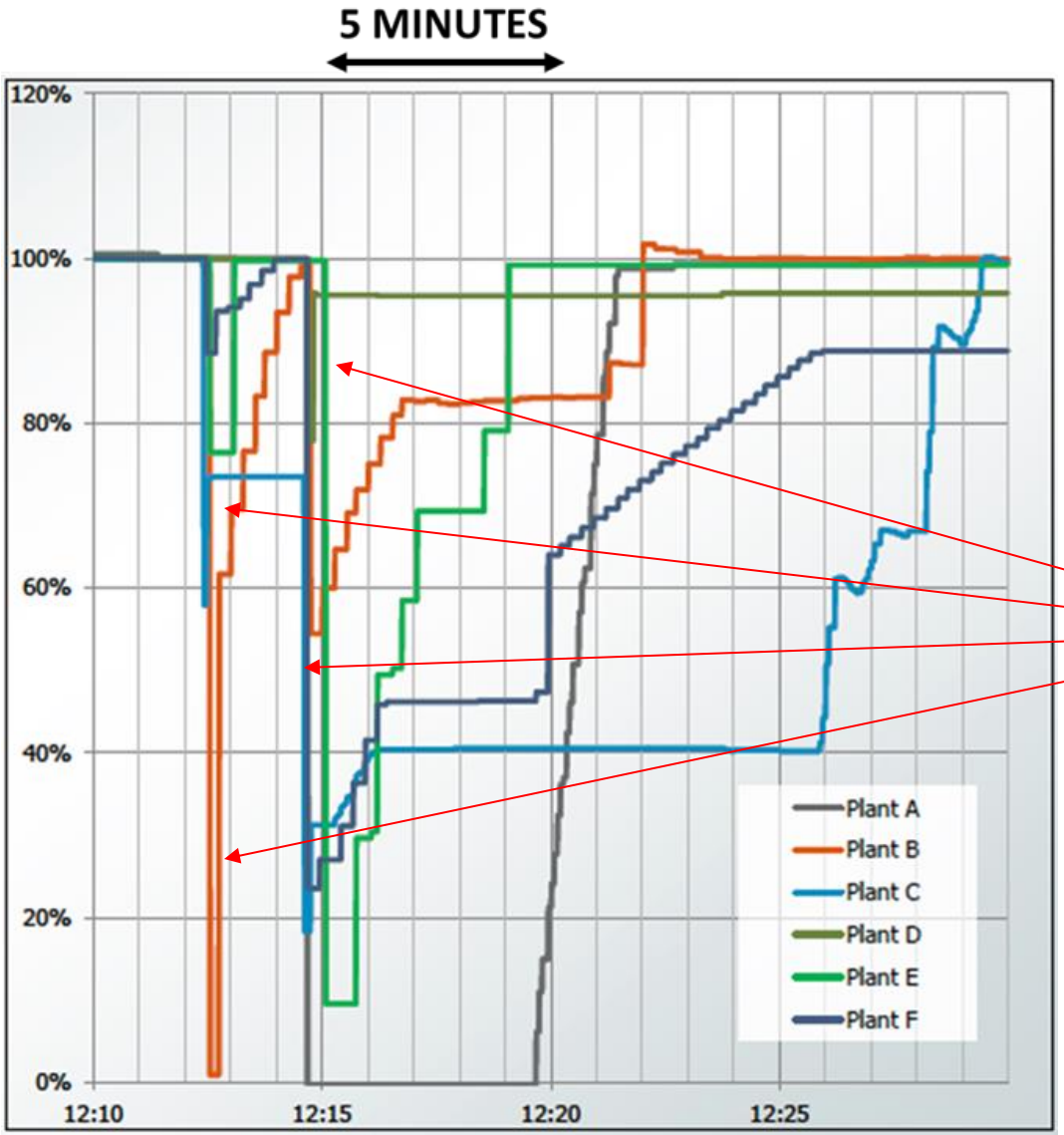
NERC and the Industry are collaborating in order to:

- Determine how DER characteristics contribute to and/or impact BPS reliability
- Quantify the DER characteristics and effects to steady state and dynamic analysis
- Investigate DER modeling, develop guidelines, revise and/or create Reliability Standards

Case Study: Blue Cut Fire

- On August 16, 2016, the Blue Cut Fire caused thirteen 500 kV line faults
- All of these faults cleared normally
- Four of the faults caused a loss of photovoltaic (PV) generation
- PV resources impacted – 1,178 MW
  - Tripped faster than 500 kV system protection operated
  - 26 different solar developments
  - All utility scale – connected at 500kV or 230kV
  - 10 different inverter manufacturers
  - No PV site system protection relays/breakers operated
  - All action was by on-board inverter controls

Solar PV Outputs



Momentary Cessation

Blue Cut Fire Disturbance Report & Alert

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1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

Southern California 8/16/2016 Event

June 2017

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3353 Peachtree Road NE
Suite 600, North Tower
Atlanta, GA 30326
404-446-2560 | www.nerc.com

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Industry Recommendation

Loss of Solar Resources during Transmission Disturbances due to Inverter Settings

Initial Distribution: June 20, 2017

NERC identified a potential characteristic exhibited by some inverter-based resources, particularly utility-scale solar photovoltaic (PV) generation, which reduces power output during fault conditions on the transmission system. An example of this behavior has been observed during recent BPS disturbances, highlighting potential risks to BPS reliability. With the recent and expected increases of utility-scale solar resources, the causes of this reduction in power output from utility-scale power inverters needs to be widely communicated and addressed by the industry. The industry should identify reliability preserving actions in the areas of power system planning and operations to reduce the system reliability impact in the event of widespread loss of solar-resources during faults on the power system.

For more information, see the 1,200 MW Fault Induced Solar Photovoltaic Resource Interruption Disturbance Report

About NERC Alerts >>

Status:	**Acknowledgement Required by Midnight Eastern on June 27, 2017** **Reporting Required by Midnight Eastern on August 31, 2017**
	PUBLIC: No Restrictions More on handling >>
Instructions:	This recommendation provides specific actions NERC registered entities should consider taking to respond to a particular issue. Pursuant to Rule 810 of NERC's Rules of Procedure, NERC registered entities shall 1) acknowledge receipt of this advisory within the NERC Alert System, and 2) report to NERC on the status of their activities in relation to this recommendation as provided below. For U.S. entities, NERC will compile the responses and report the results to the Federal Energy Regulatory Commission.

RELIABILITY | ACCOUNTABILITY

Keeping Reliability in Balance

- Bulk power system reliability must be maintained, regardless of the generation mix;
- Maintaining a diverse resource mix increases resilience, flexibility, and reliability
- All generation must contribute to system reliability within their physical capabilities; and
- Industry standards and criteria must be fair, transparent and performance-based.
- Reliability challenges are bigger than any one organization and time is needed to engineer the solutions

Questions & Answers

NERC Industry Efforts

- **DER Subgroup of Essential Reliability Services Working Group**
  - 2017 Report: DER Connection, Modeling, and Reliability Considerations
  - 2018 Technical brief: DER Data Collection for Transmission System Entities
    - Anticipated Approval Spring 2018, Please see ERS Website for final posting
  - 2018 DER Educational Video
- **Load Modeling Task Force**
  - 2016 Report: Dynamic Load Modeling Technical Reference Document
  - 2016 Reliability Guideline : Modeling DER in Dynamic Load Models
  - 2017 Reliability Guideline : Developing Load Model Composition Data
- **Industry and Research Partnerships**
  - IEEE Standards Participation and NERC - IEEE Joint Task Force
  - Argonne National Laboratory : **Impact of DERs on the Bulk Electric System – Combined Modeling of T&D Systems & Benchmark Case Studies**