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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

Accommodating High Levels of Distributed Energy Resources

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2017 NARUC Winter Committee Meetings
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RELIABILITY | ACCOUNTABILITY



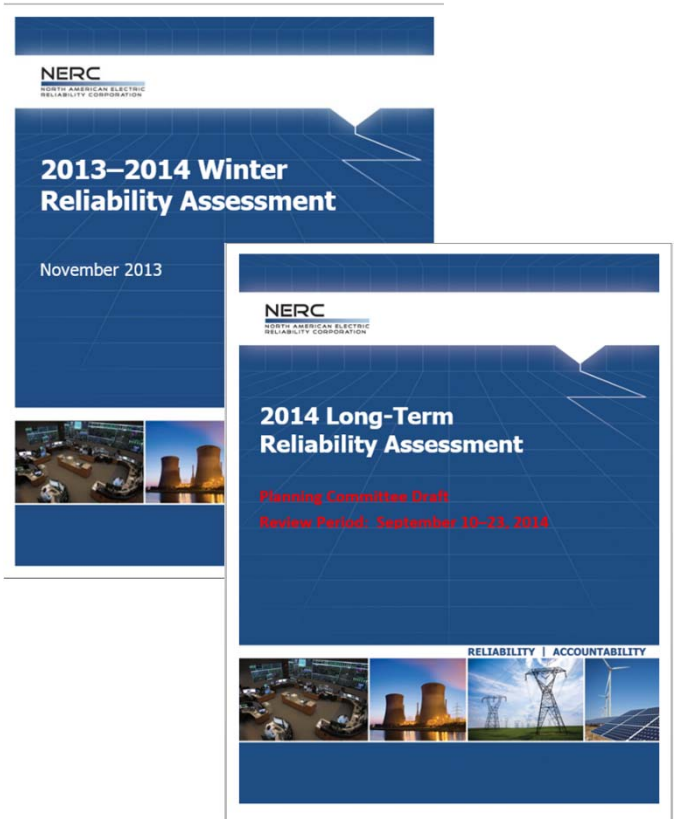

About NERC: Mission

To ensure the reliability of the North American bulk power system

- Develop and enforce reliability standards
- Assess current and future reliability
- Analyze system events and recommend improved practices
- Encourage active participation by all stakeholders
- Accountable as ERO to regulators in the United States (FERC) and Canada (NEB and provincial governments)

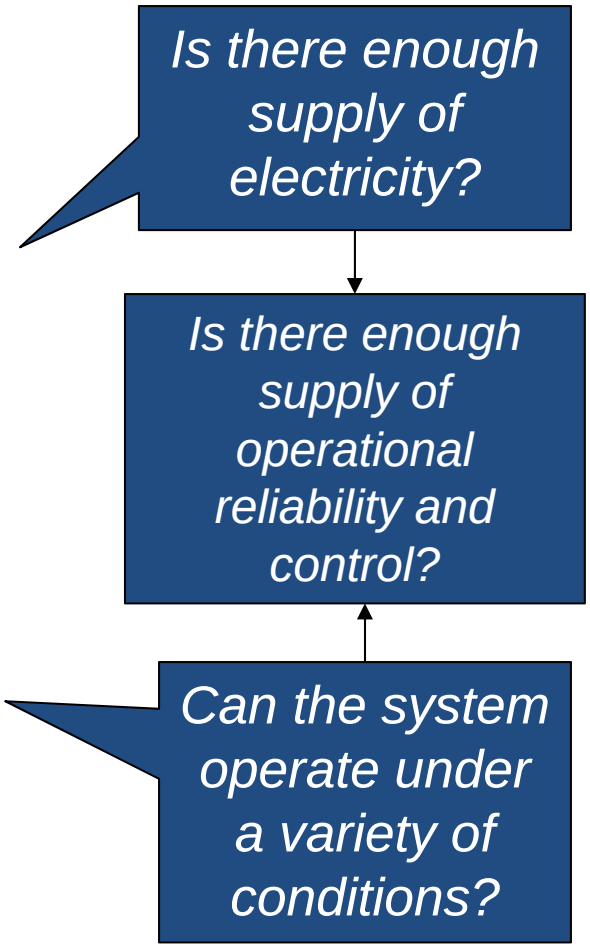
NERC Reliability Assessments

- 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.



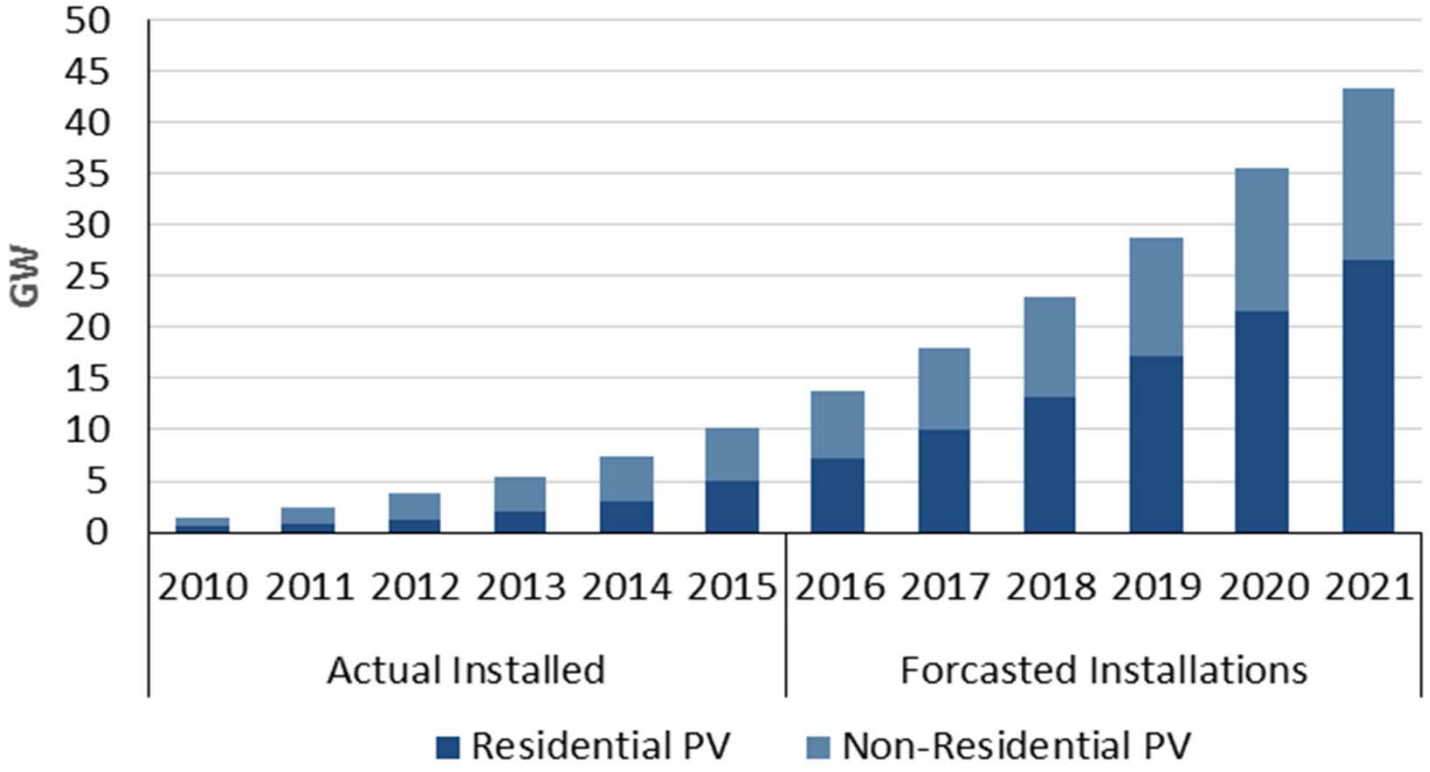
System Dynamic Character is Changing

- Retirement/displacement of conventional generation
  - Variable energy resources
  - Rapid penetration of electronically-coupled resources
- Essential Reliability Services
  - Reduced inertia
  - Frequency Reponses
  - Voltage Support
  - Ramping and flexibility needs
- Rapid penetration of new loads
- System controls and protection coordination
- Modeling and simulation constraints
- Increasing interface with distribution-centric resources

Trend of Distribution Photovoltaic (PV) Systems

Trending and Forecasting DER:

U.S. Cumulative Installations of Non-Utility PV Generation



[4] *GTM Research: Solar Market Insight Report 2016 Q2*

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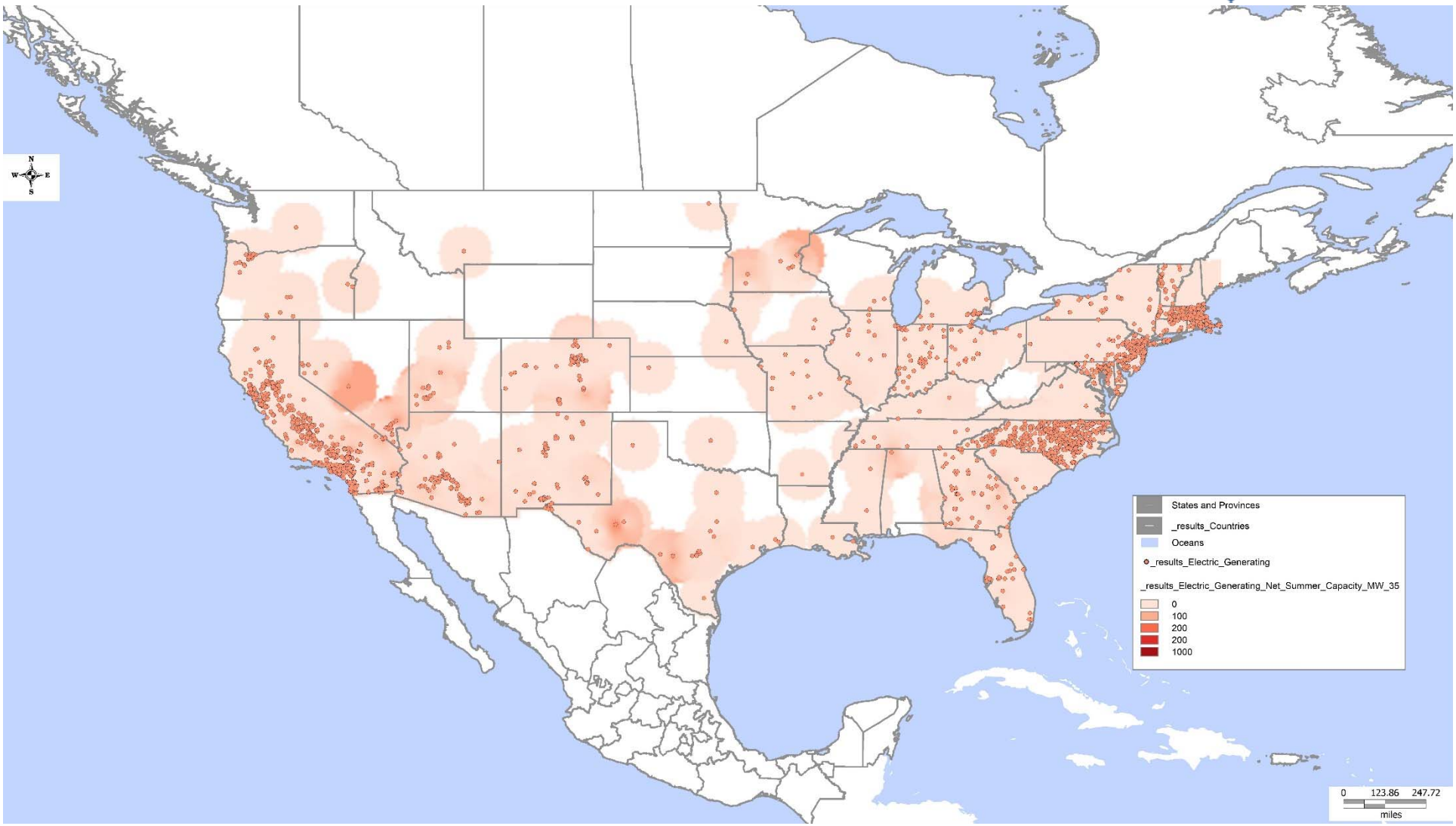
Current Solar Production



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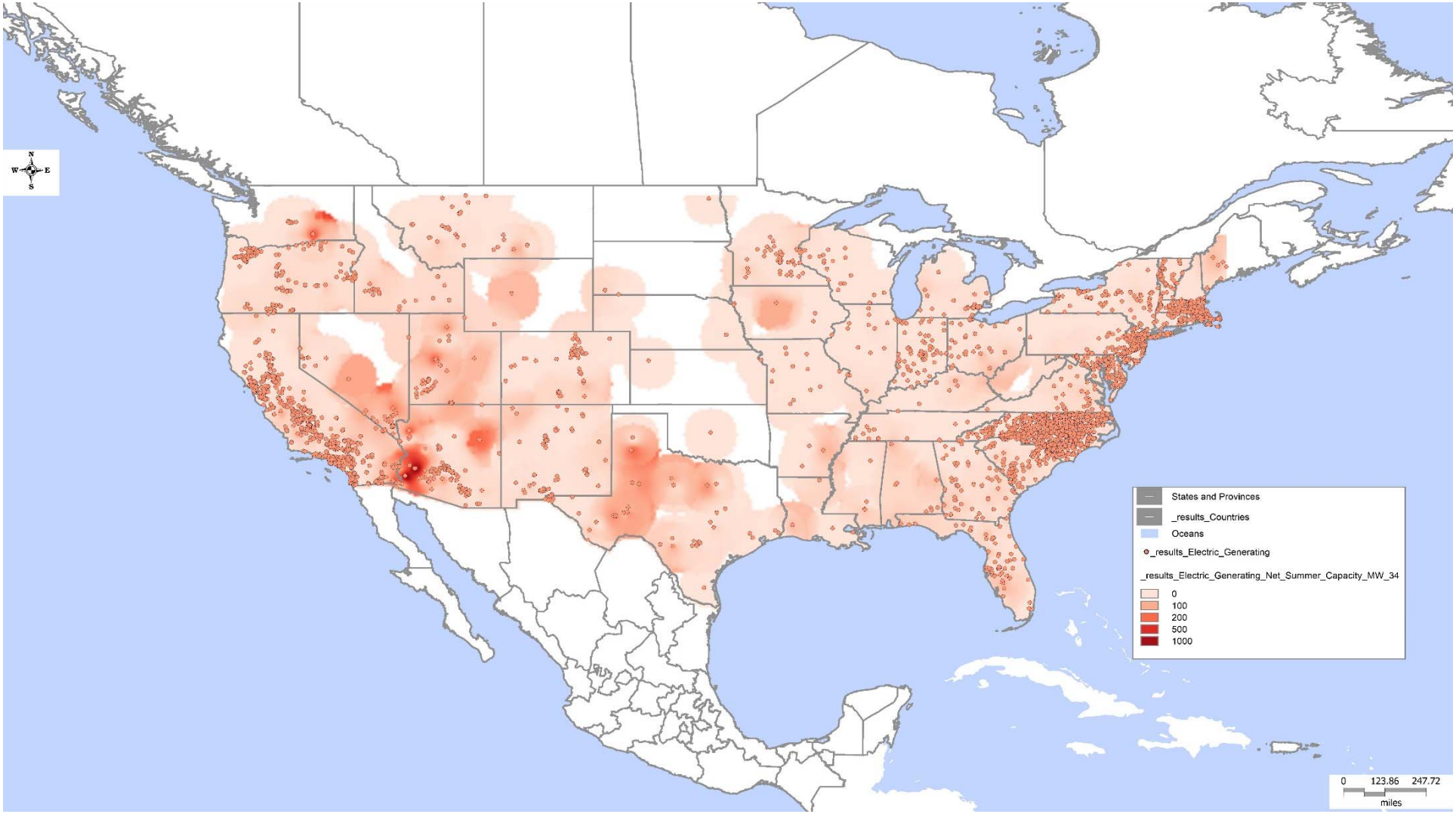
Current and Planned Production (Based on 2-3 Year Commitments)



Distributed Energy Resources Task Force: Background and Status

- Task Force formed December 2015
- Membership: representatives from
  - Transmission planning and operations
  - Renewable developers
  - Regulatory organizations
  - Distribution utility
  - Researchers, equipment and control vendors
- Final report to NERC Technical Committees in December 2016
  - Recommendations to NERC, industry, and regulators
- NERC Board of Trustees approved report February 9, 2017

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Key Findings

- The impact of DER on the BPS is not a simple issue
  - At lower penetration levels, the overall impact of DER is minor and can be managed by existing BPS resources
  - At higher penetration levels, issues may develop in transmission line loading, grid voltage, system control and protection, and system frequency during normal or disturbed operation
- DER penetration is rapidly increasing and altering the load mix
- DERs will increasingly have capabilities for active power control and reliability services
- Fundamental changes to modeling, planning and operations, and conventional assumptions
- Increased coordination needed between distribution and transmission planners

Distributed Energy Resources Defined

Distributed Energy Resource (DER) *is 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).*

Types of DER :

- Distributed Generation
- Behind the Meter Generation
- Energy Storage Facility
- DER Aggregation
- Micro-Grid
- Cogeneration
- Emergency, Stand-By or Back-Up Generation

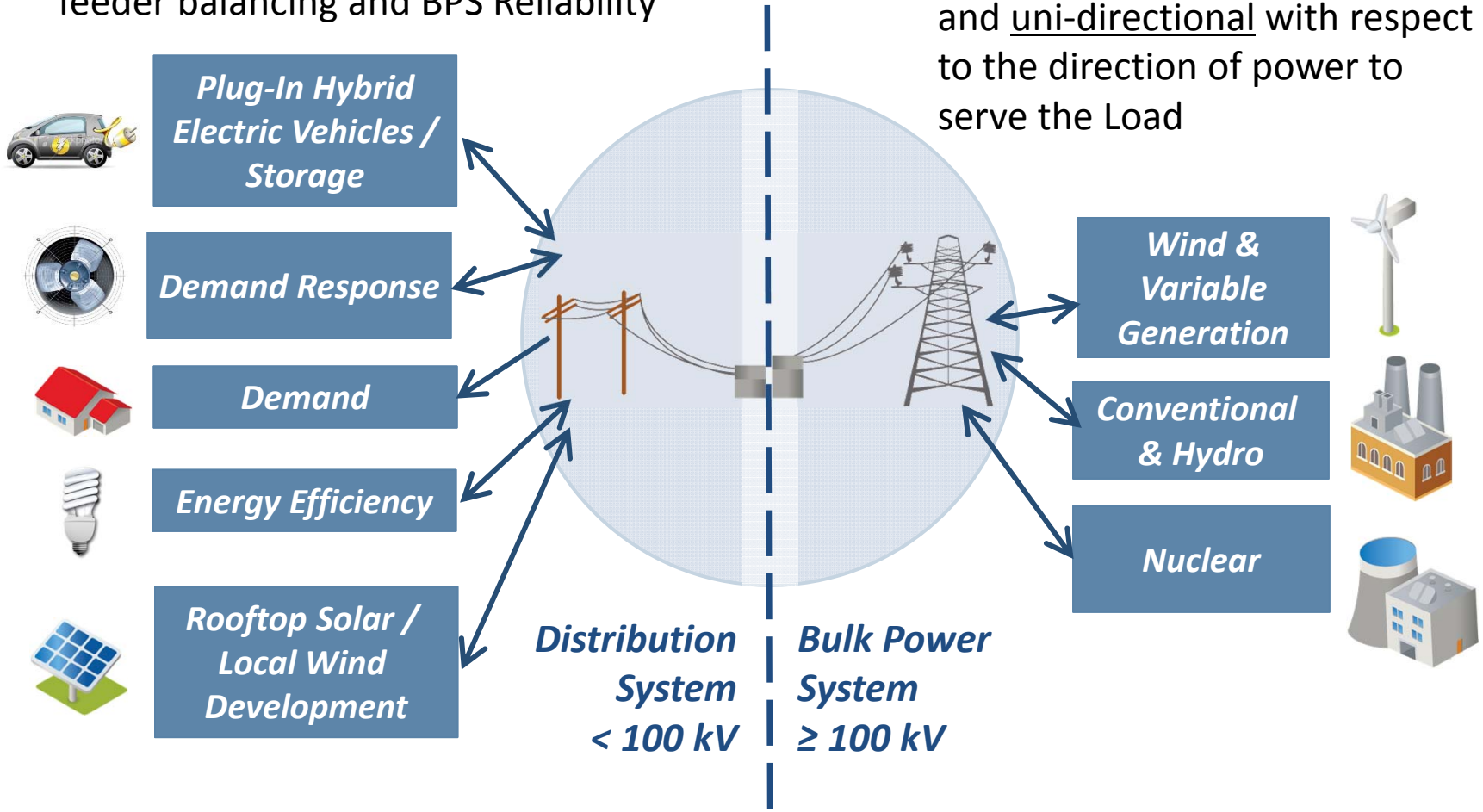
Some Problem Complexities:

- Various technologies, unit sizes, ages, customer types
- Physical and Virtual Aggregation
- Variable output of units which can be dependent on weather (uncontrollable factor)
- Protection coordination

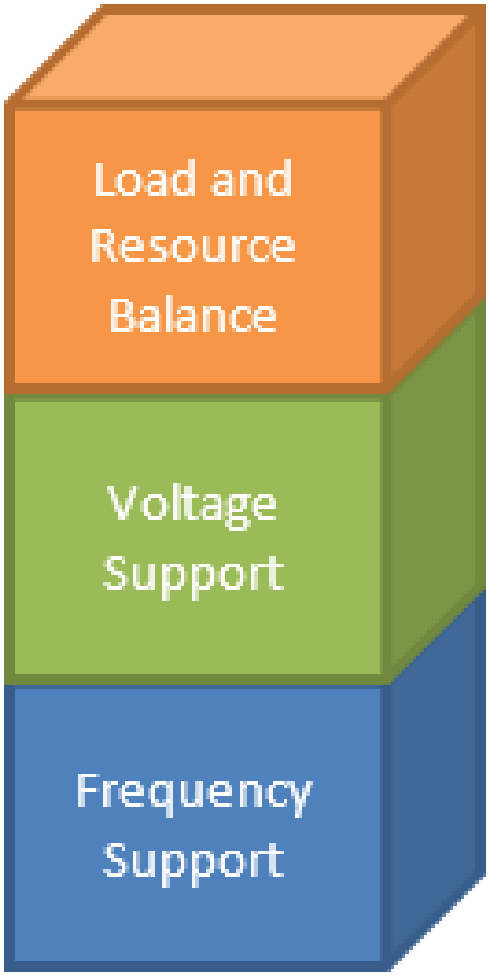
DER & BPS Power Flow Changes

- 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

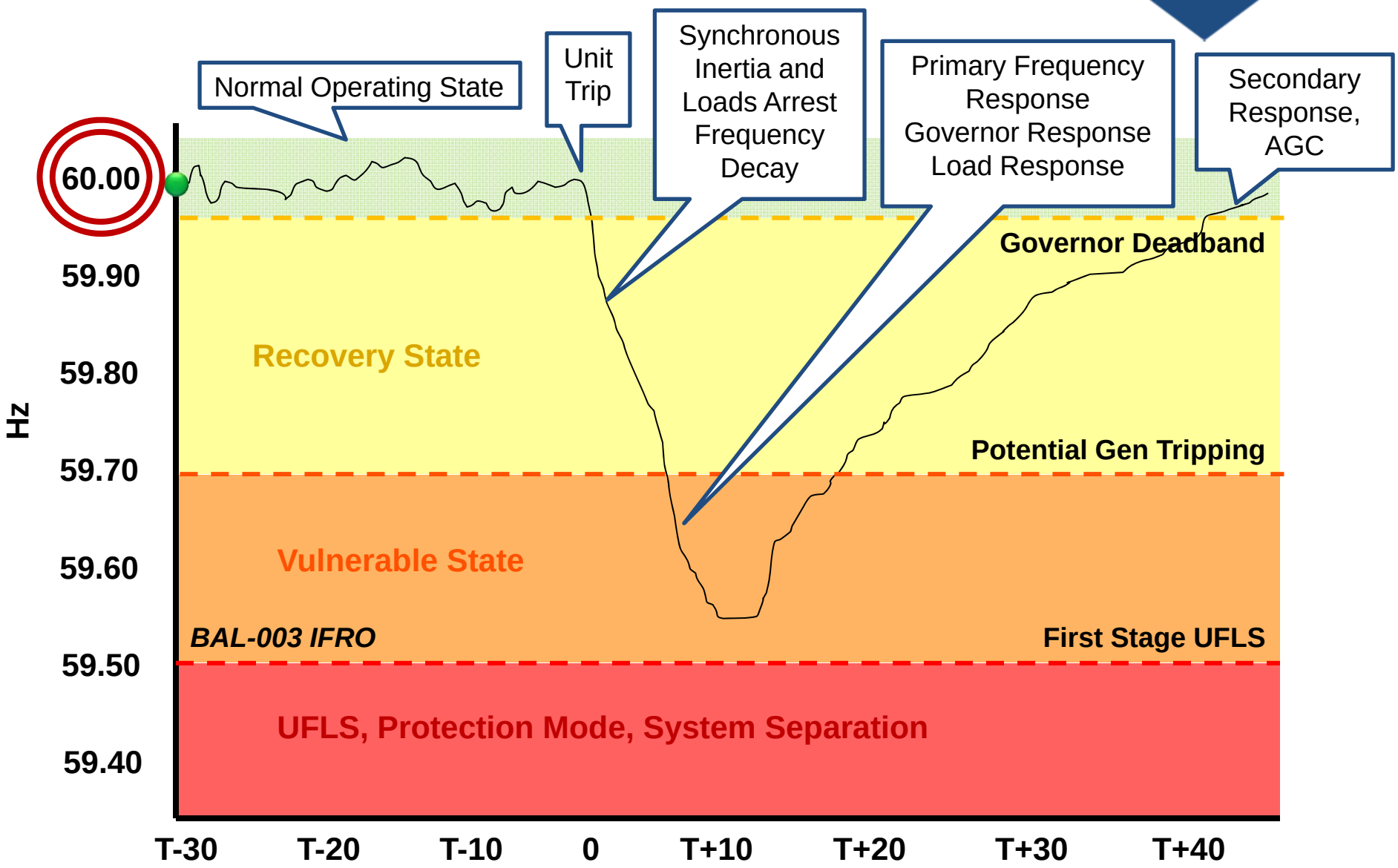


ERS Fundamentals



- "Building blocks" of physical capabilities
- Accentuated by resource changes
- Not all MWs are equal
- Some partly covered through ancillary services
- Accommodate local/regional needs

Anatomy of a Frequency Excursion with Recovery



For illustrative purposes only. This is not real data. Actual trip settings and operational modes are different for each interconnection and not fixed at the levels shown.

The Control Shift (1 of 3)

Bulk-Power System

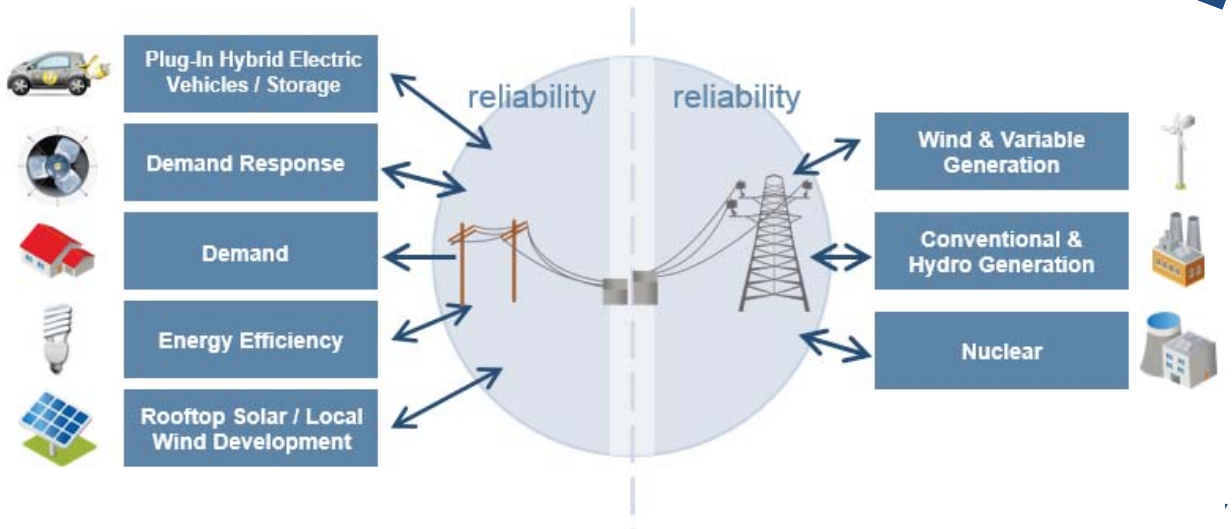
- Supports system inertia and recovery modes
- Dispatchable based on demand
- Centralized to System Operator

10%

90%

Distribution

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



The Control Shift (2 of 3)

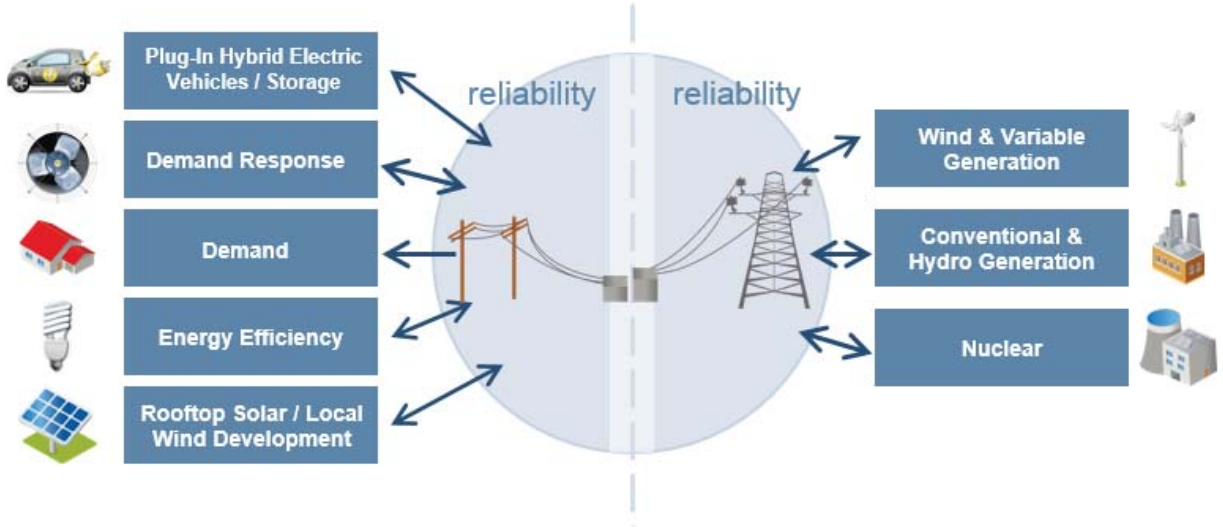
Bulk-Power System

- 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)

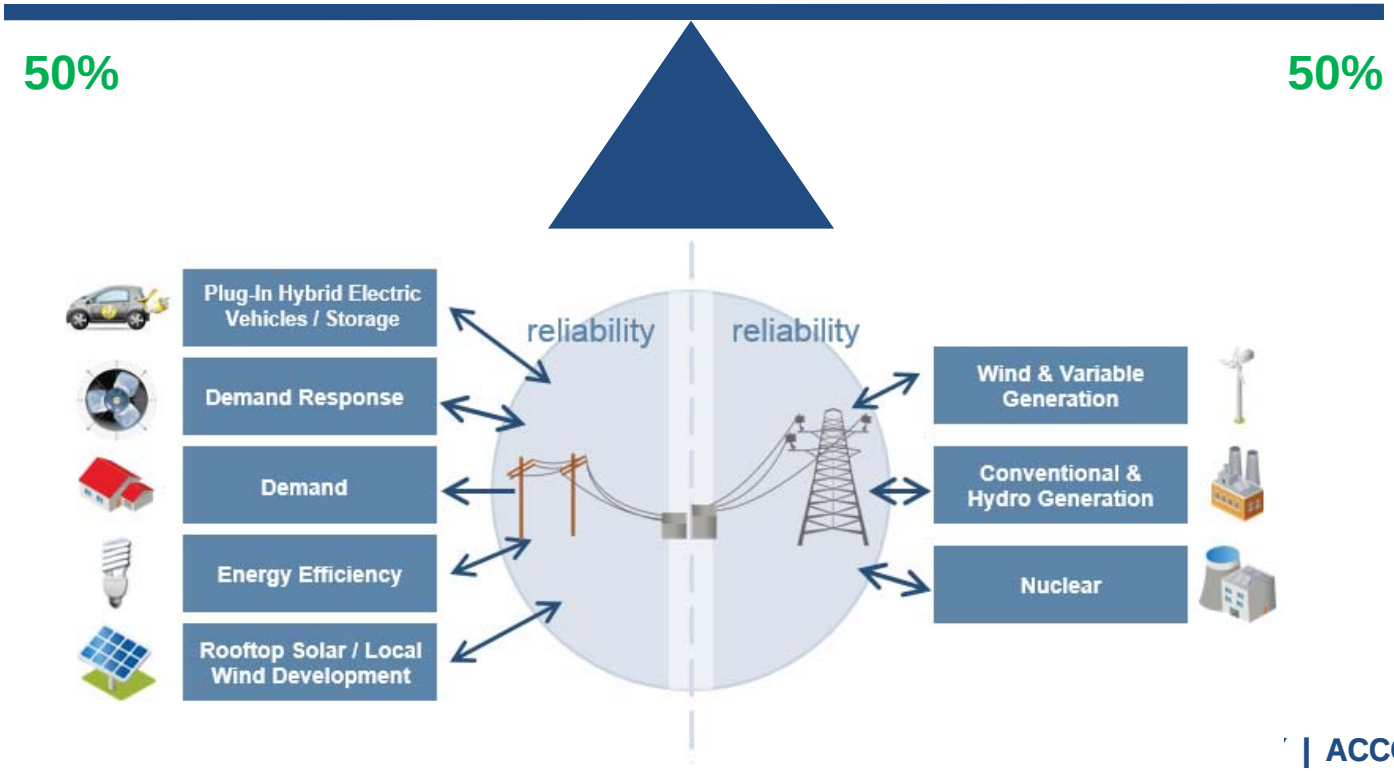
Integrated Power System

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



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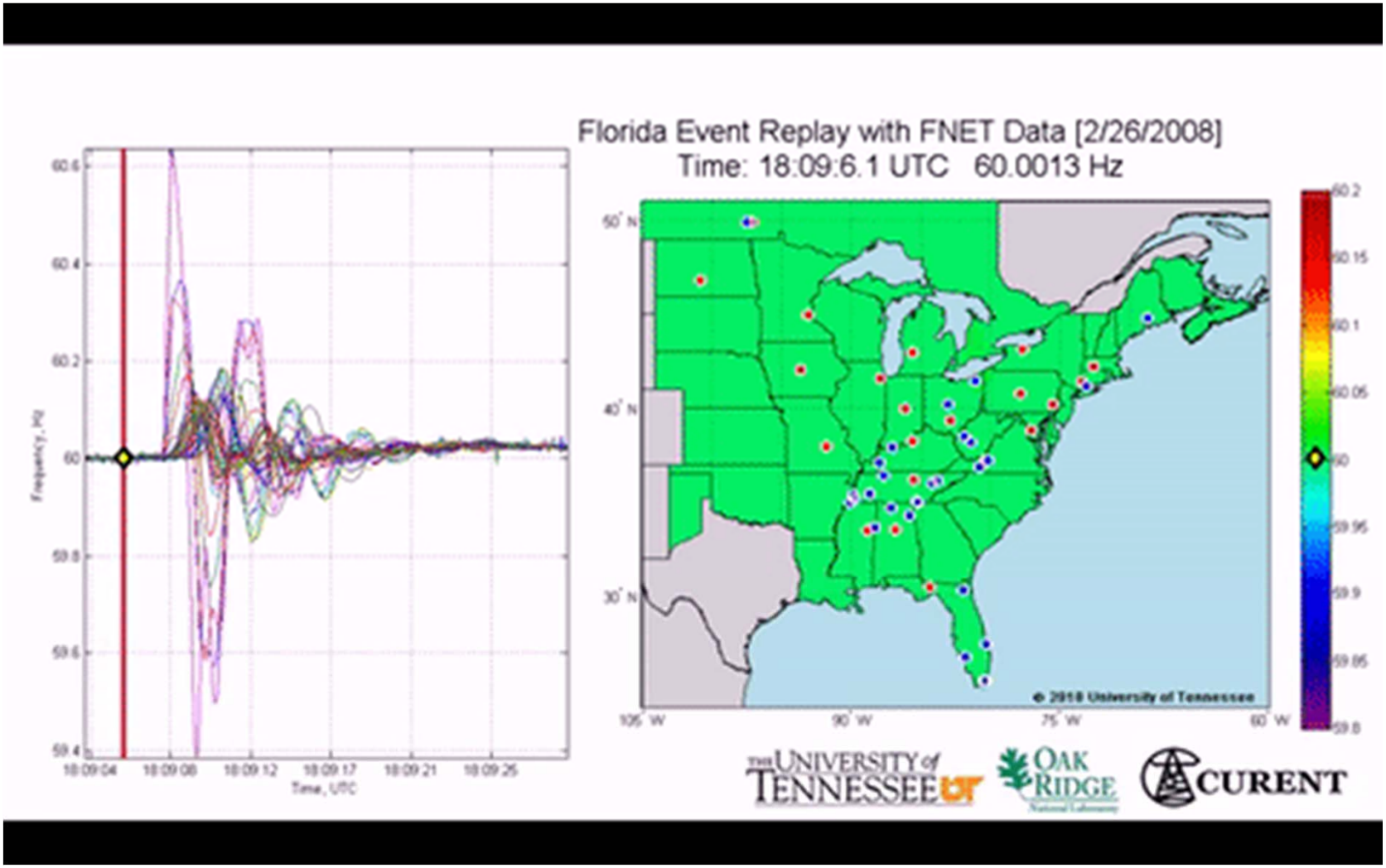
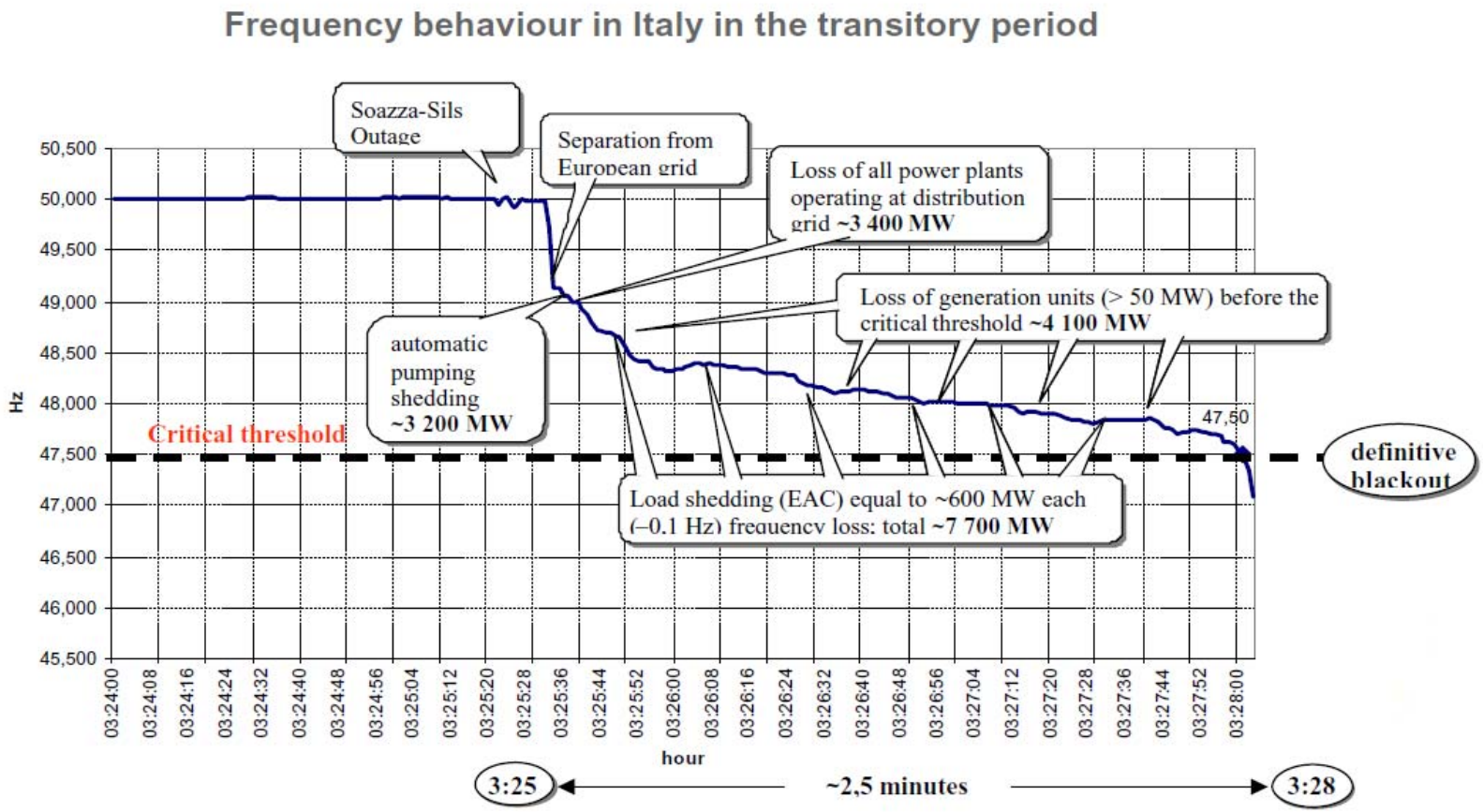
Frequency Excursion – Interconnection-wide Phenomena



Learning from Others – Italy 2003



On the 28th September 2003, a blackout affected more than 56 million people across Italy and areas of Switzerland. The disruption lasted for more than 48 hours as crews struggled to reconnect areas across the Italian peninsula. The reason for the blackout was that during this phase the under-voltage load shedding (UVLS) could not compensate the additional loss of generation, when approximately 7.5 GW of distributed power plants tripped during under-frequency operation.
https://www.entsoe.eu/fileadmin/user_upload/_library/publications/ce/otherreports/20040427_UCTE_IC_Final_report.pdf

NERC's Concern
DERTF Final Report Focus Points

As the CONTROL paradigm shifts, 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 standards
- Identifying actions for the Electric Reliability Organization (ERO) needed to adapt?

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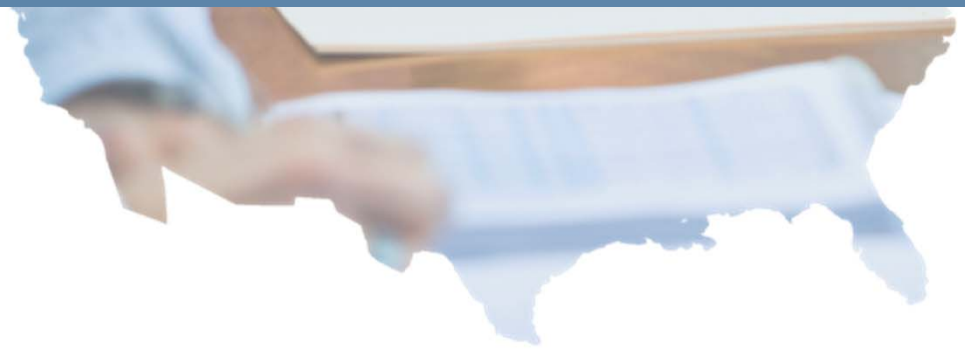
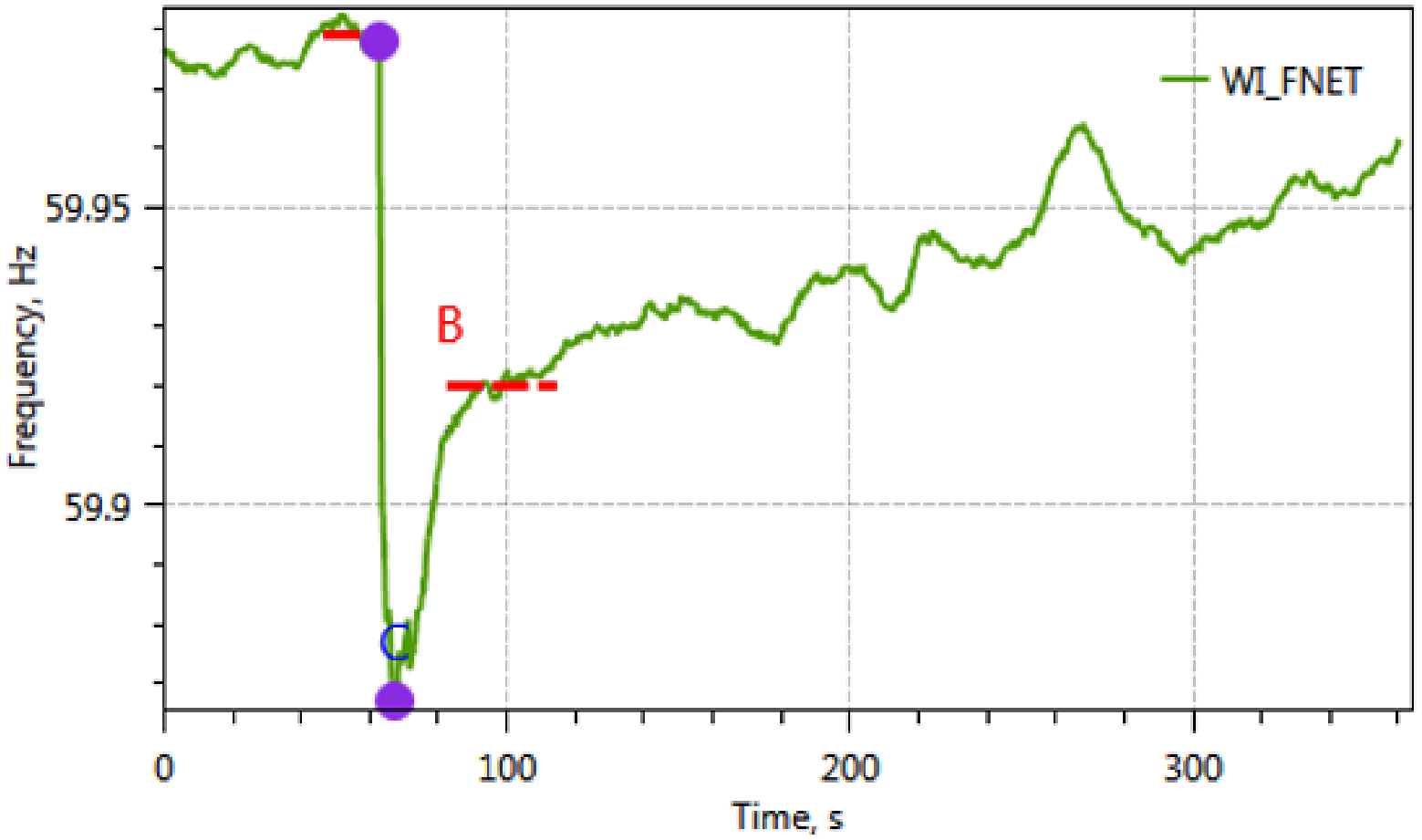
Recent Event

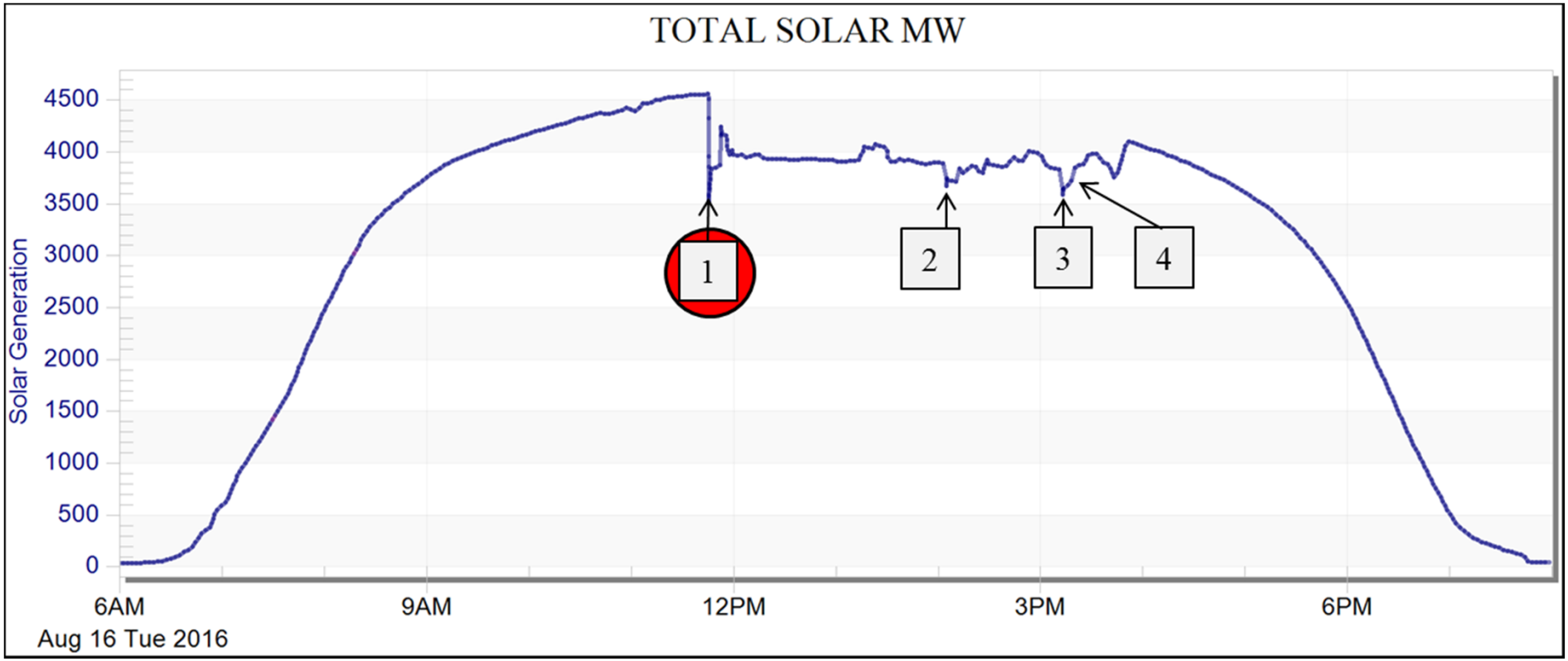


1,200 MW Fault Induced Solar PV Interruption
Blue Cut Fire Analysis

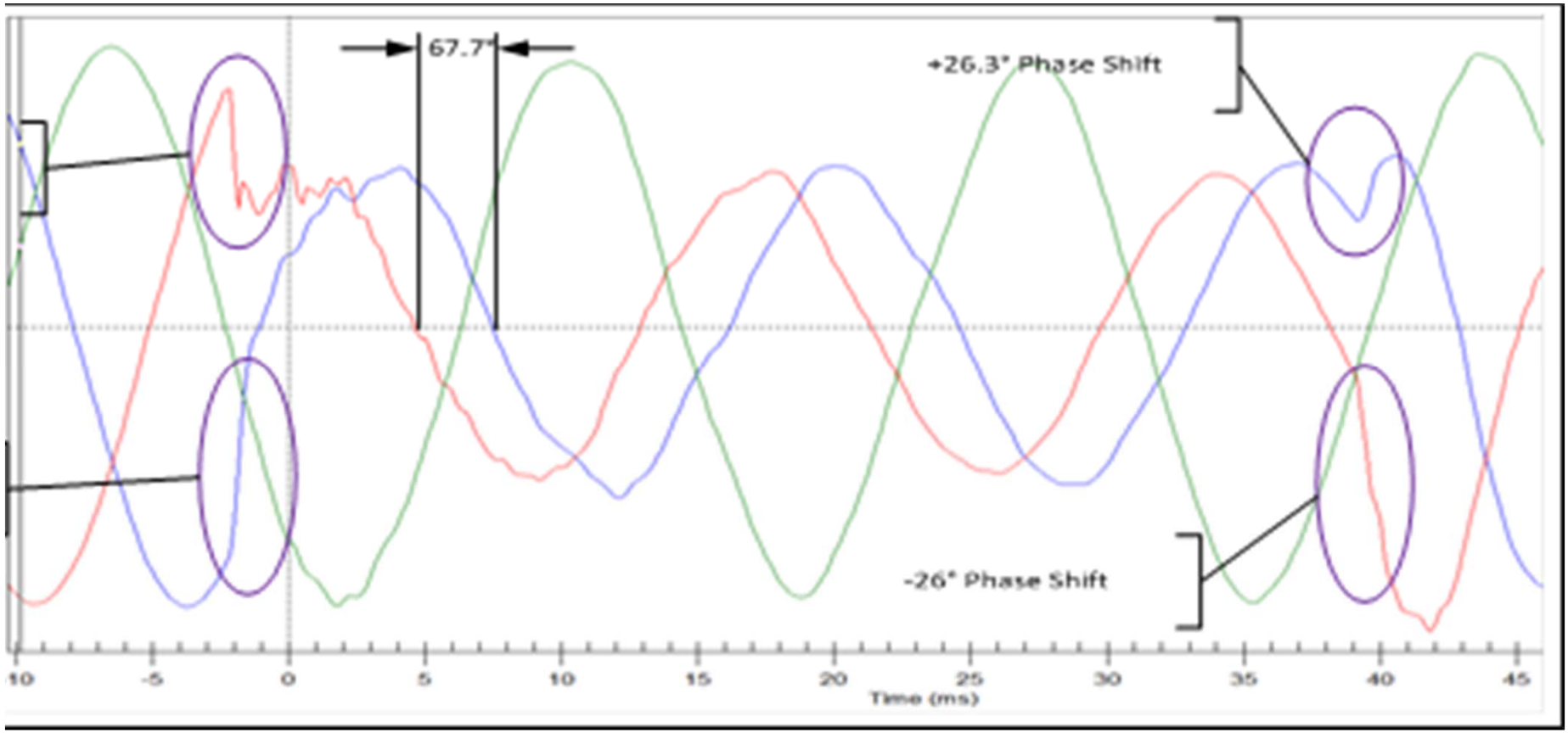
Blue Cut Fire Disturbance



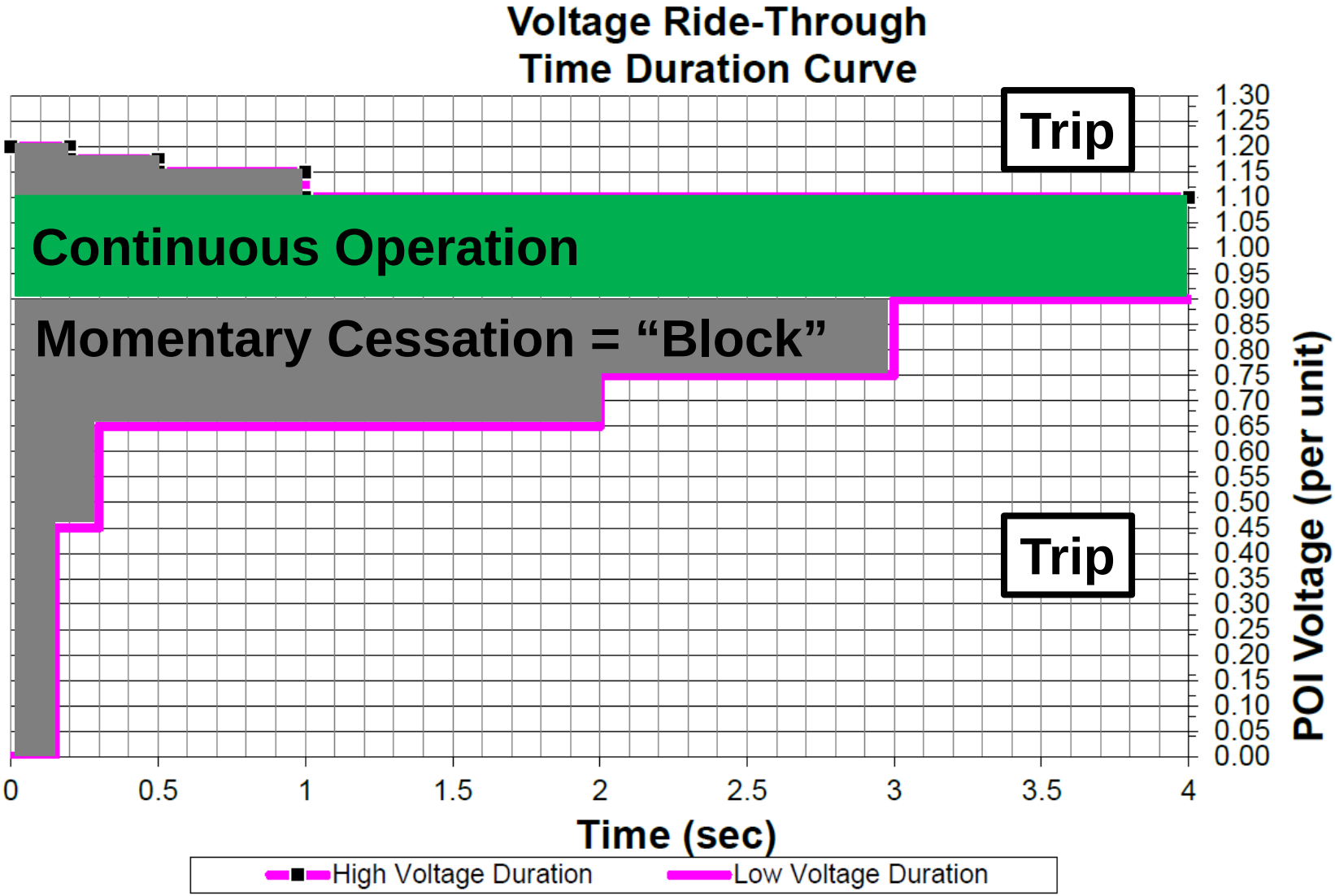
Blue Cut Fire Disturbance



Primary Issue #1: Frequency Calculation

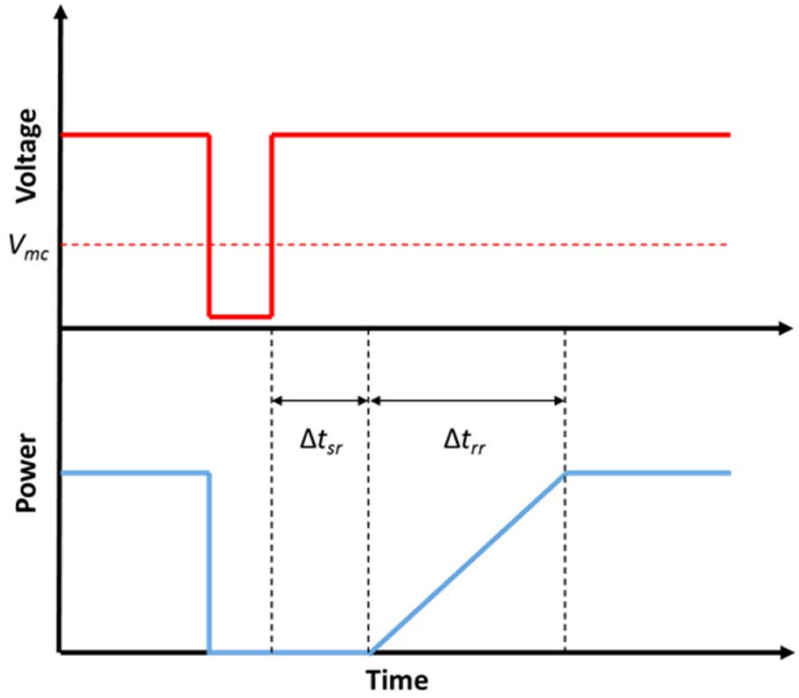


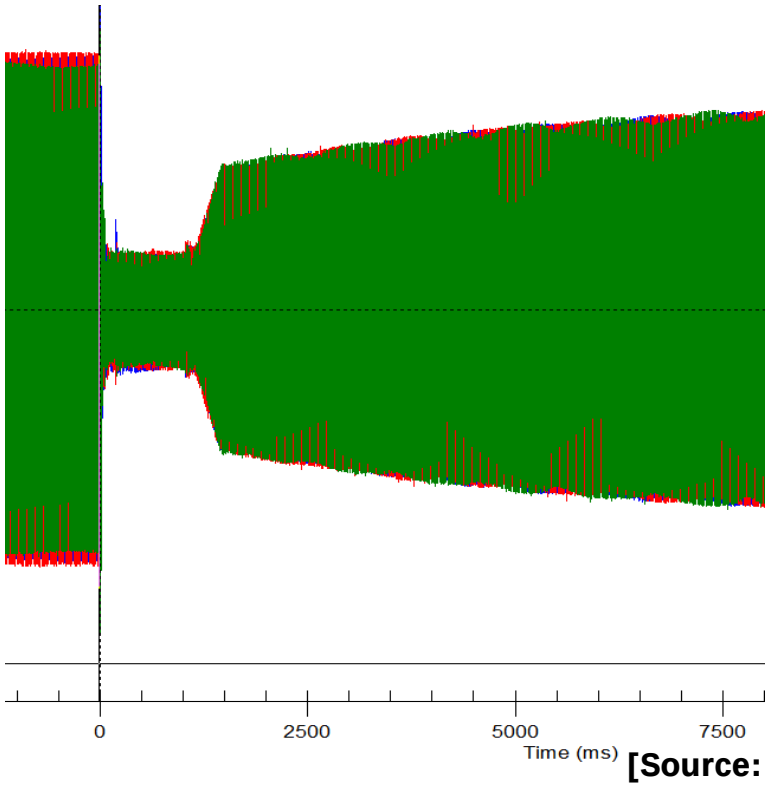
Primary Issue #2: Voltage Response of Inverters



Momentary Cessation

- Past uses for momentary cessation
- Limitations with existing inverters
- Recommendations for momentary cessation moving forward





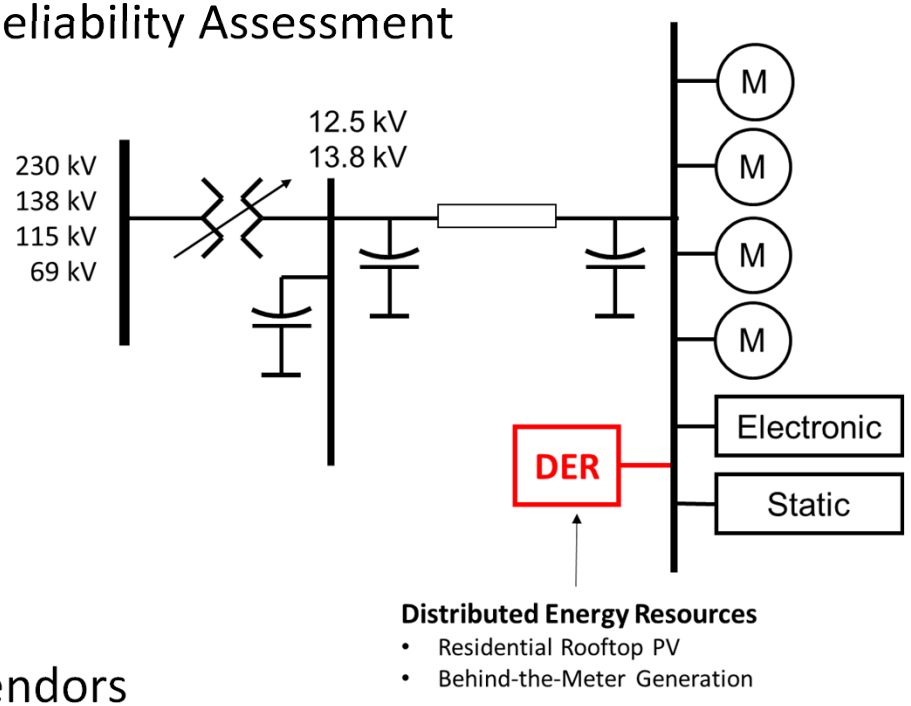
[Source: SCE]

Inverter-Based Resource Performance Task Force (IRPTF)

- Continuation of ad hoc Blue Cut Fire analysis team
- For on more complex inverter-based resource performance issues
  - Frequency-Related Inverter Performance
  - Momentary Cessation
  - Inverter-Based Resource Ride-Through
  - UL1741 and IEEE 1547 Interactions
  - Monitoring Data and Analyzing Performance
  - Modeling Inverter-Based Resources
  - Simulation of BPS Performance

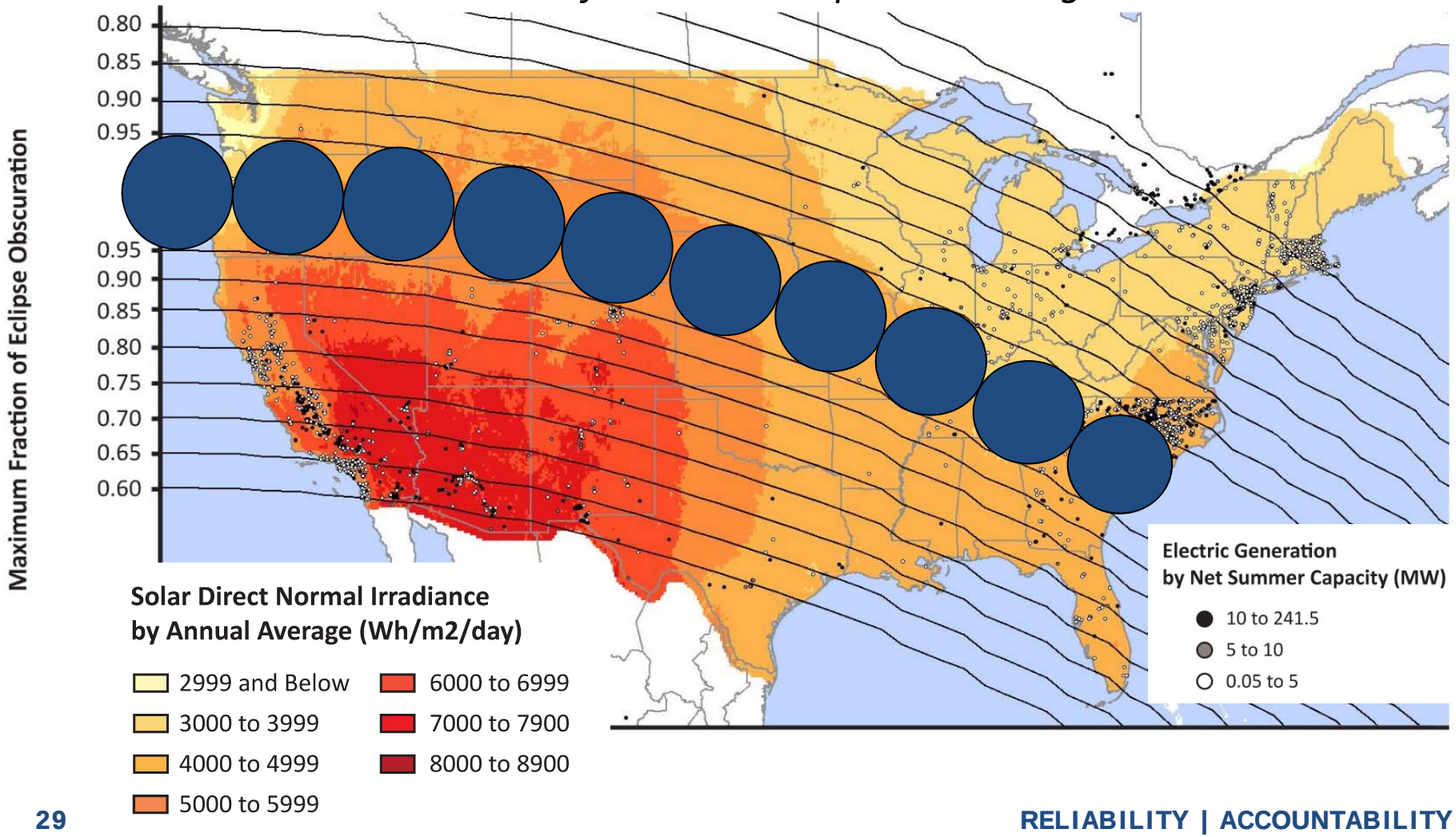
Recommendations for Next Steps

- Reliability Guidelines
  - Technical committee actions for load modeling, operations
- Data Sharing
  - Potential enhancement to NERC Reliability Standards
  - Continue to monitor in Long-Term Reliability Assessment
- System Modeling
  - Consistency and best practices
  - Annual assessment
- DER Component Models
- Definitions
- Industry Collaboration
  - IEEE, national laboratories, inverter manufacturers, software vendors



Eclipse Path and Eclipse Bands (Aug 2017) …but get ready for 2024

U.S. Map showing direct normal irradiance by annual average (Wh/m²/day), eclipse bands and locations of transmission photovoltaic generators



Key Messages for State Regulators

- Inverter-based, asynchronous resources (e.g., solar PV) have different characteristics than conventional generation
- Similar to the Bulk Power System and federally interconnected generation, resources must be "grid-friendly" and support the needs of the local Transmission Planner (e.g., ISO/RTO)
  - Maintain "ride-through" capability through implementation of new interconnection standard IEEE 1547 (updated version, NOT 2003 VERSION)
  - Supported by California's Rule 21 (review for best practices)
- NERC Reliability Standards exist to address BPS reliability needs, but do not impose requirements to any specific DER
- Rapid deployment means closer coordination with electric industry transmission planners and operators
  - Wide-area and interconnection reliability versus local reliability

Closing Remarks

- Lots of uncertainty in the future
  - Nuclear generation, increasing dependency on natural gas, climate change initiatives, transmission expansion
- Maintaining a diverse resource mix increases resilience, flexibility, and reliability
- New system behaviors and characteristics require new measurements for reliability and planning
- NERC Reliability Standards must be maintained
- Time needed to engineer the solutions!

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Questions and Answers

Technical Background, Guidelines & Group Webpages

- Reliability Guideline: Modeling DER in Dynamic Load Models
- Reliability Guideline: DER Modeling
- Disturbance Report: 1200 MW Solar PV Loss Blue Cut Fire
- NERC Inverter Based Resource Performance Task Force (IRPTF)
- NERC System Analysis and Modeling Subcommittee (SAMS)
- NERC Load Modeling Task Force (LMTF)
- NERC Power Plant Modeling & Verification Task Force (PPMVTF)
- NERC Essential Reliability Services Working Group (ERSWG)
- NERC Distributed Energy Resource Task Force (DERTF)
- DERTF Report: Distributed Energy Resources
- ERSTF Report: ERS Measures Framework