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NORTH AMERICAN ELECTRIC RELIABILITY CORPORATION

BPS Reliability Perspectives for 2050

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New England Power Pool
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RELIABILITY | RESILIENCE | SECURITY




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About NERC

Mission: To assure the effective and efficient reduction of risks to the reliability and security of the North American bulk power system

- Develop and enforce reliability standards for users, owners, and operators of the bulk power system
- Assess current and future reliability
- Analyze system events and recommend improved practices
- Encourage active participation by all stakeholders
- Facilitate information sharing on security matters
- Accountable to FERC and Canadian government entities

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Electric Reliability is Complicated

Grid 1.0
Isolated Systems

Late 1800s - 1940s

- Urban area focus
- Largely self-contained utilities

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Electric Reliability is Complicated

Grid 1.0 Isolated Systems

Late 1800s - 1940s

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Grid 2.0 Interconnected Systems

Post World War II

- Large, central station generation
- Long lines to support interconnected flows/ resource sharing
- Instantaneous load/resource balancing
- Significant coordination needs (incidents at speed of light)

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And Getting More So …

Grid 1.0 Isolated Systems	*Grid 2.0 Interconnected Systems*	***Grid 3.0 Integrated Systems***
Late 1800s - 1940s	***Post World War II***	***Now - Future***

• Urban area focus
• Largely self-contained utilities
	• Large central station generation
	• Long lines to support interconnected flows/ resource sharing
	• Instantaneous load/resource balancing
	• Significant coordination needs (incidents at speed of light)
		• More load variability
		• Shift in fuel mix
		  ▪ Just in time gas
		  ▪ Variable wind /solar
		  ▪ Solid fuel retirement
		• Expansion of digital controls/ “behind meter devices”
		• Future:
		  ▪ Battery deployment
		  ▪ Deep electrification

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Where Could We Be In 30 Years?

In 30 years, technology issues can be assumed away

- Battery storage could be economical **and** scaleable
  - Grid scale
  - Distributed/end use
- Off shore wind could be a major generation source in New England
- Small/modular nuclear reactors could be deployable
- Hydrogen and fuel cells?

That said, a reliable electric system will have a number of "physics-based" characteristics

- Maintain frequency and voltage within narrow parameters
- Adequate flexibility to follow loads and minimize system disturbances
- Adequate capacity and *adequate fuel* to serve load

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Key Technology Bets – Next 30 years

Smart Inverters

- As we replace MWs from conventional generation, we also need to replace the essential reliability services needed to maintain system reliability
- Inverters and new electronic controllers can:
  - Mimic physical inertial properties
  - Provide near instantaneous response to support grid stability
  - Optimize and manage charging cycles on batteries based on grid needs
  - Work in aggregate to achieve the same objectives as conventional generation
- But …
  - They are not “plug and play”
  - Much more difficult to model
  - Less reliance on physics, and more reliance on software code
  - Need performance incentives/rules to support reliable behavior

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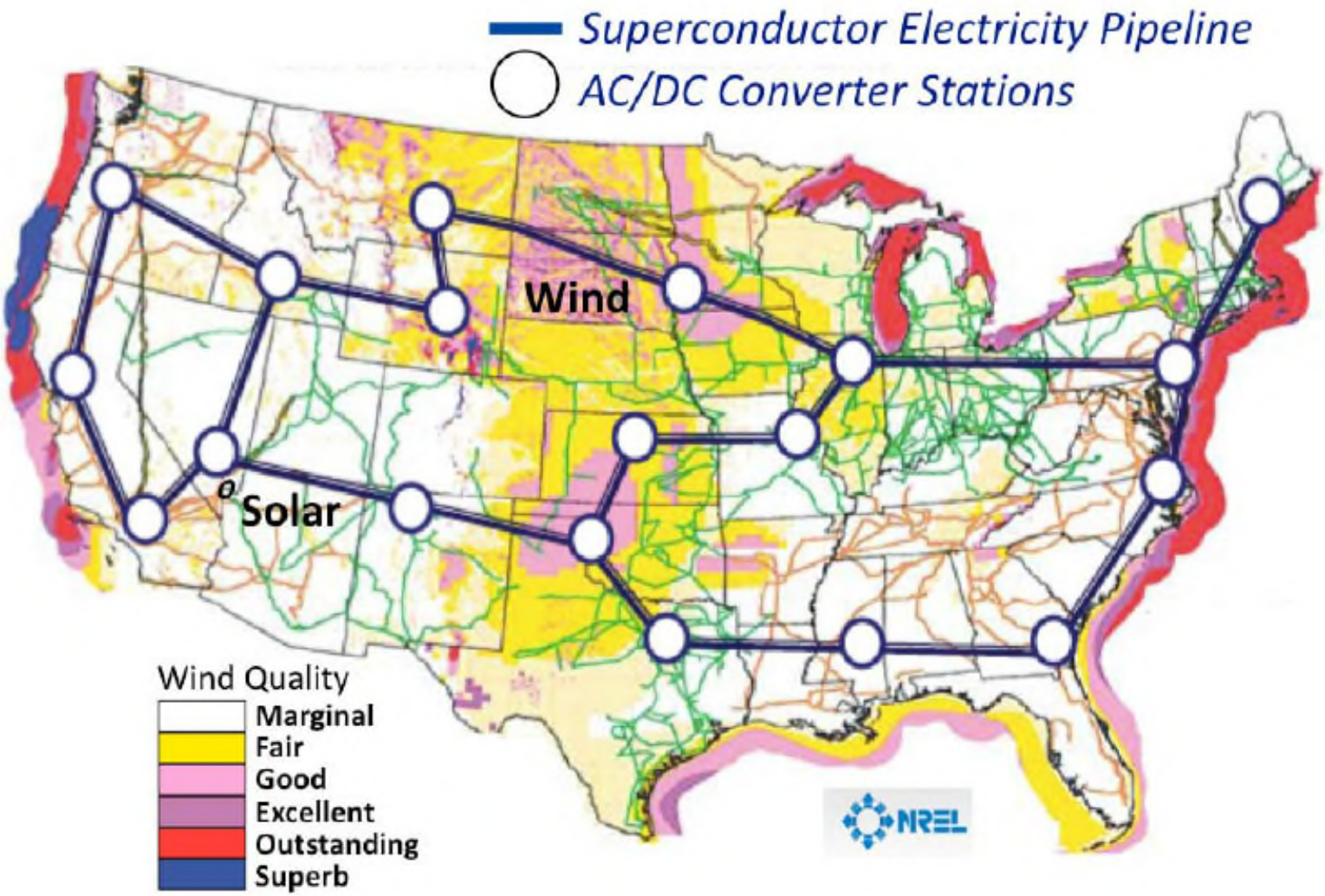
Role of Transmission System:
Bulk Power System as a Super Highway



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Until Then – Gas Remains a Critical Fuel

1980s

An Economic Choice

- Easy to modify steam plants to burn gas
- Gas prices often favorable to bunker fuel
- Utilities developed switching capabilities
- Gas and electric customers benefit

1990s-2000s

An Environmental/ Efficiency Opportunity

- Gas emissions substantially lower than fuel oil
- Combined cycle technology substantially reduced heat rates
- "Dual fuel" capability eliminated in many jurisdictions

Foreseeable Future

A Reliability Requirement

- Public policy focus on clean resources, especially solar
- Key dispatchable and flexible resource to balance variable generation
- Substantial changes to BPS power plant operations profiles due to "duck curve" and ramp rate impact
- Declining volumes but substantial peak needs result in an economic/pricing problem and create a key vulnerability

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Transitional Reliability and Energy Policy:
Bridging the Gap on an Evolving System

Key Issues

- Timing of technology development and deployment, especially batteries
- Pace of “deep” electrification
- Gas ratemaking/ regulatory treatment

Getting to the "End State"

- **Substantial investment in technology (especially batteries) and transmission**
- **New planning and operating tools**
  - Much more dynamic and stochastic – opportunity for AI?
  - Focus on fuel and energy adequacy, not just capacity/resource adequacy
  - Less centralized resource planning; more focus on enabling resource access
- **Improved situation awareness and visibility**
  - Real underlying loads
  - Real generation capability
- **Integrated cyber defenses**
  - "Design in" vs. "bolt on"
  - Understanding and securing new attack vectors and attack surfaces across a more distributed system

Questions and Answers