WIND AND WATER POWER PROGRAM

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Reliability Impacts of High Wind Penetrations

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What type of "Reliability" are we talking about???

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- The North-American Electric Reliability Corporation (NERC) defines the reliability of the interconnected bulk power system in terms of two basic and functional aspects:
  - **Adequacy —** The ability of the bulk power system to supply the aggregate electrical demand and energy requirements of the customers at all times, taking into account scheduled and reasonably expected unscheduled outages of system elements.
  - **Security —** The ability of the bulk power system to withstand sudden disturbances such as electric short circuits or unanticipated loss of system elements from credible contingencies.

System Adequacy

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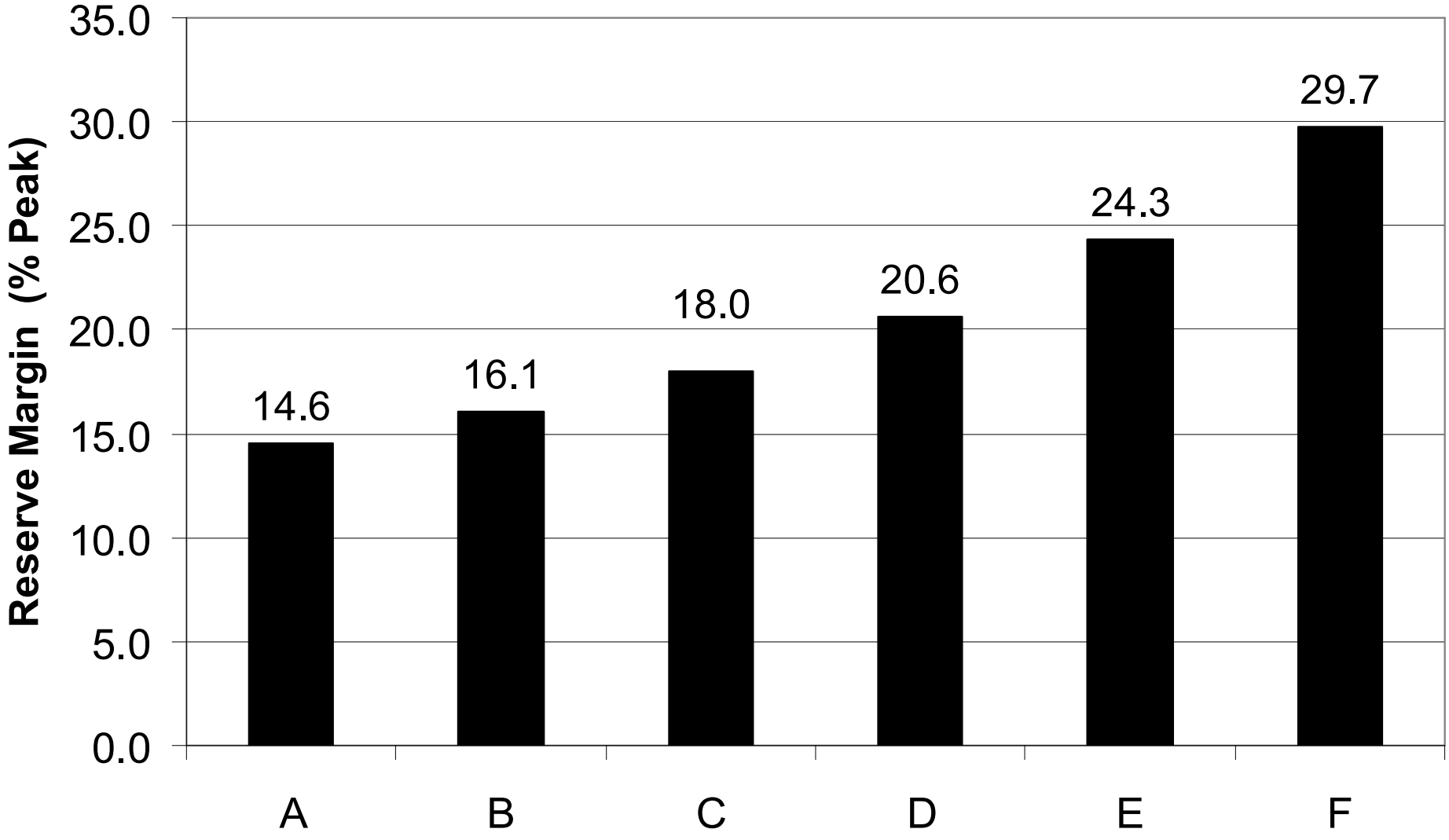
- Often measured based on installed capacity, peak load, and a planning reserve
- A fixed planning reserve margin (15%) does not in itself provide a measure of adequacy
- No system can be perfectly adequate
- How adequate is adequate enough?
- Quantify the number of times system will be inadequate – often measured as hours/year; days/year (1d/10y ≈ 99.97%)

Which System is Most Reliable?



Are There Metrics For System Adequacy?

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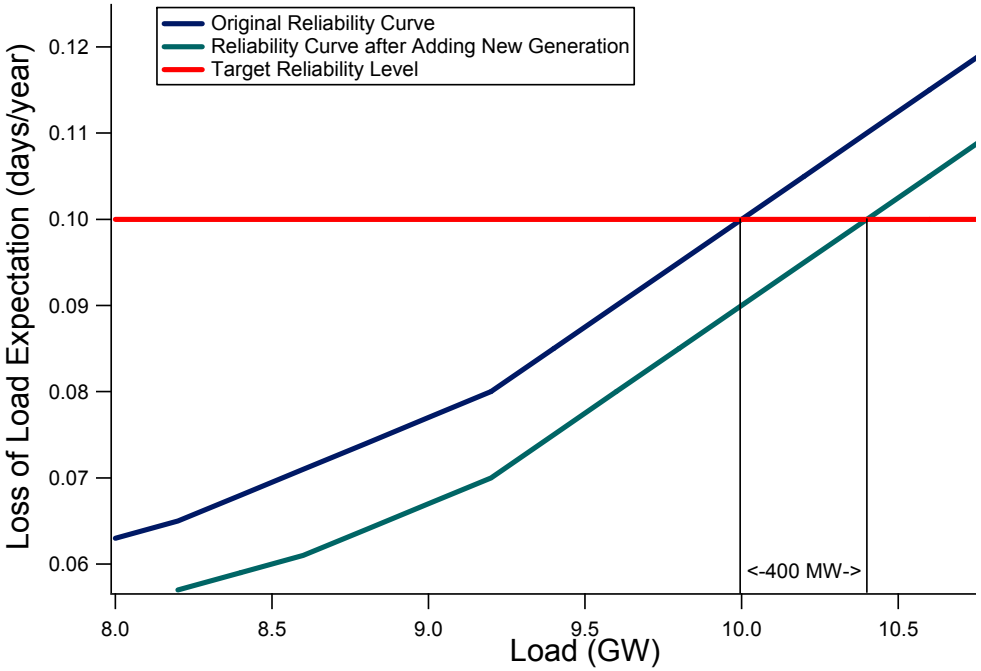
- Loss of load probability
  - Probability of insufficient generation to cover load
  - Not necessarily load shedding; covers the probability of unforeseen/spot imports
- Loss of load expectation = probability x time
- Expected unserved energy
  - Measures the *amount* of potential shortfall, not just the likelihood
- All of these measures capture varying levels of risk – something that is missing from fixed planning reserve margin approaches (15%) unless they have been 'trued up' with reliability results

Individual Generators' Contribution to Adequacy can be Measured

- Effective load carrying capability (ELCC)
- Applies to all generators, not just wind
- De-composes each individual generator's contribution to system adequacy



Capacity Credit (ELCC) Properties

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- Not unique to wind, and can be adapted to wind generators
- Wind capacity credit depends on output profile (hourly for *at least* one year):
  - Low when wind contributes small amount to reliability
  - High when wind contributes large amount to reliability
  - Depends on system and wind characteristics
  - Values can range from approximately 10%-40%, depending on system and wind characteristics
  - Capacity credit outside this range are possible
  - *Use multiple years of data if available*

Is ELCC the Same as Capacity Factor? (No)

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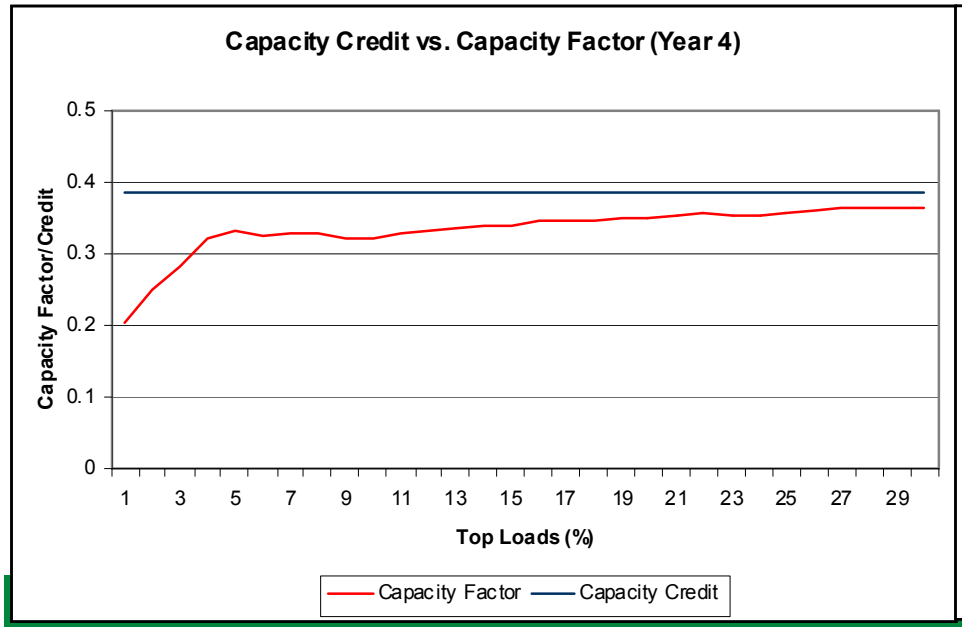
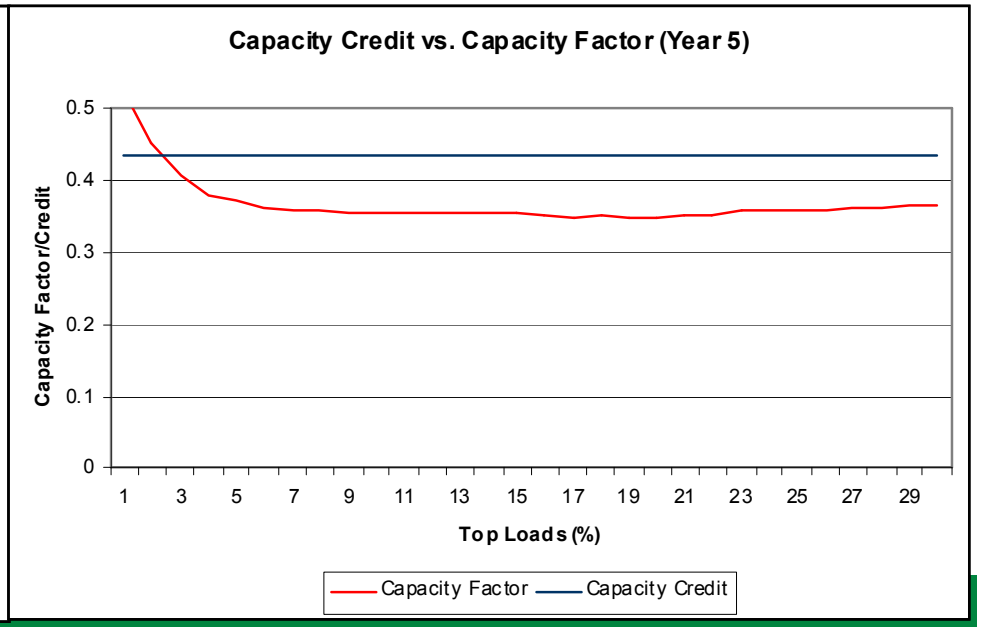
- Wind-load relationship is only part of the equation
- Capacity factor, even during peak periods, won't necessarily match ELCC





An Energy Resource in an Capacity World

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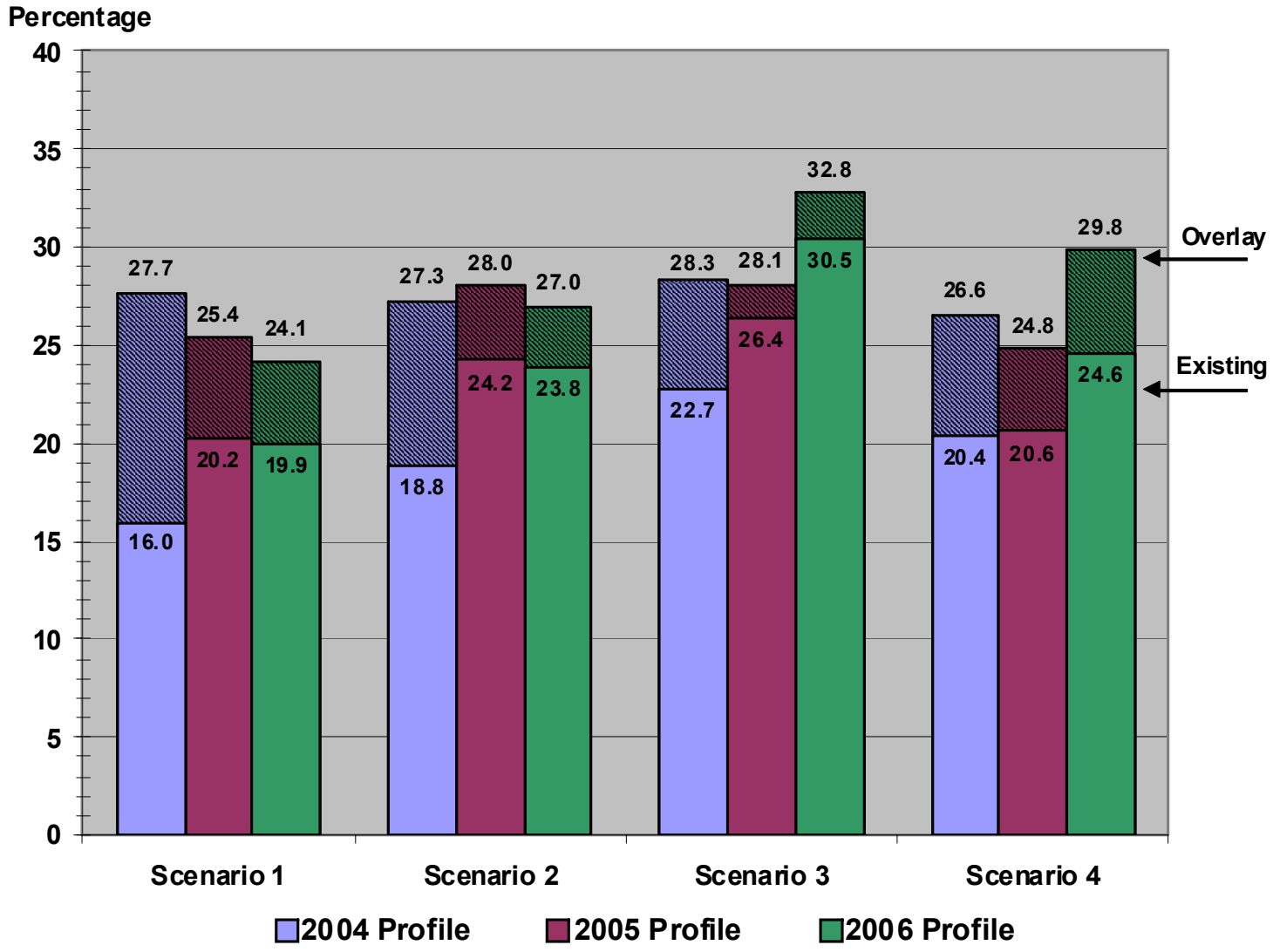
LOLE/ELCC results for high penetration scenarios, with and without transmission overlays



Wind generators

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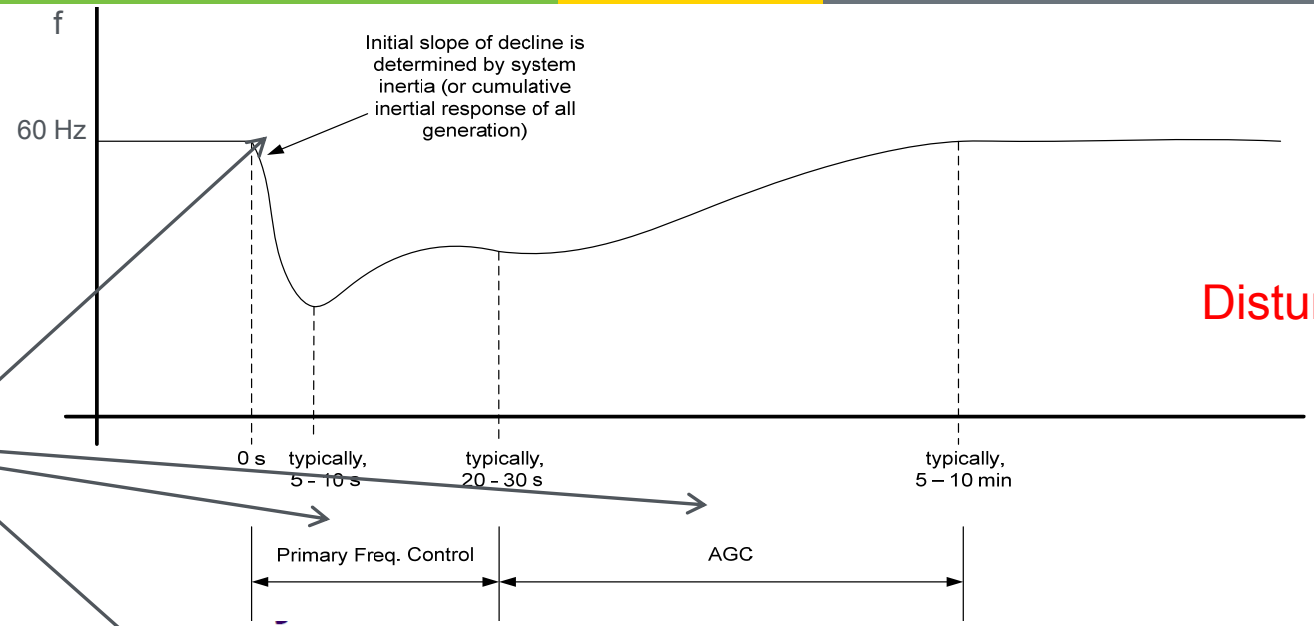
- We don't usually have enough long-term data
- Must be synchronized to load data
- Site-specific (not like thermal units)
- ELCC usually calculated one year at a time
- Should be multiyear
- Wind may deliver higher or lower than its ELCC estimate (just like thermal units)

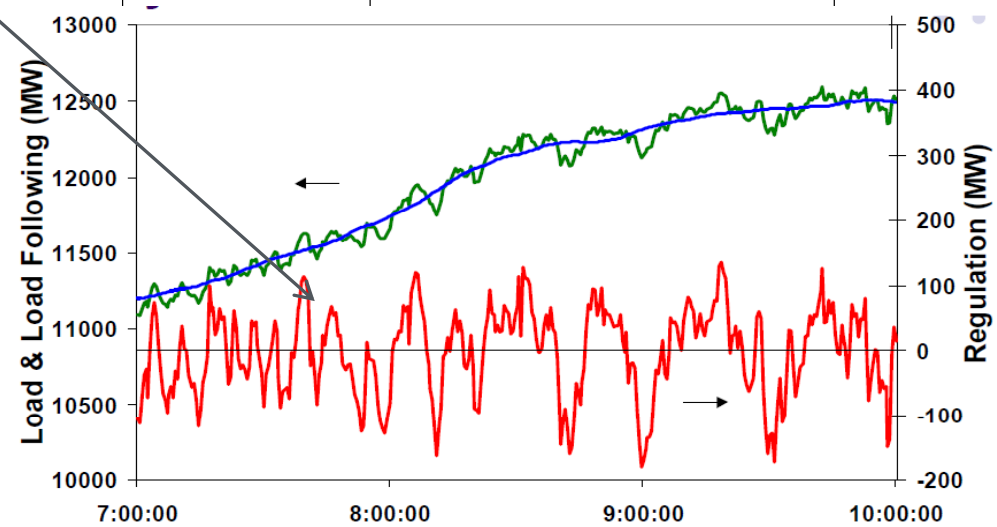
Wind 101 Tutorial – Wind Power Coordinating Committee – IEEE – T&D, 10

Security => Active Power Control

Where can wind power fit in?

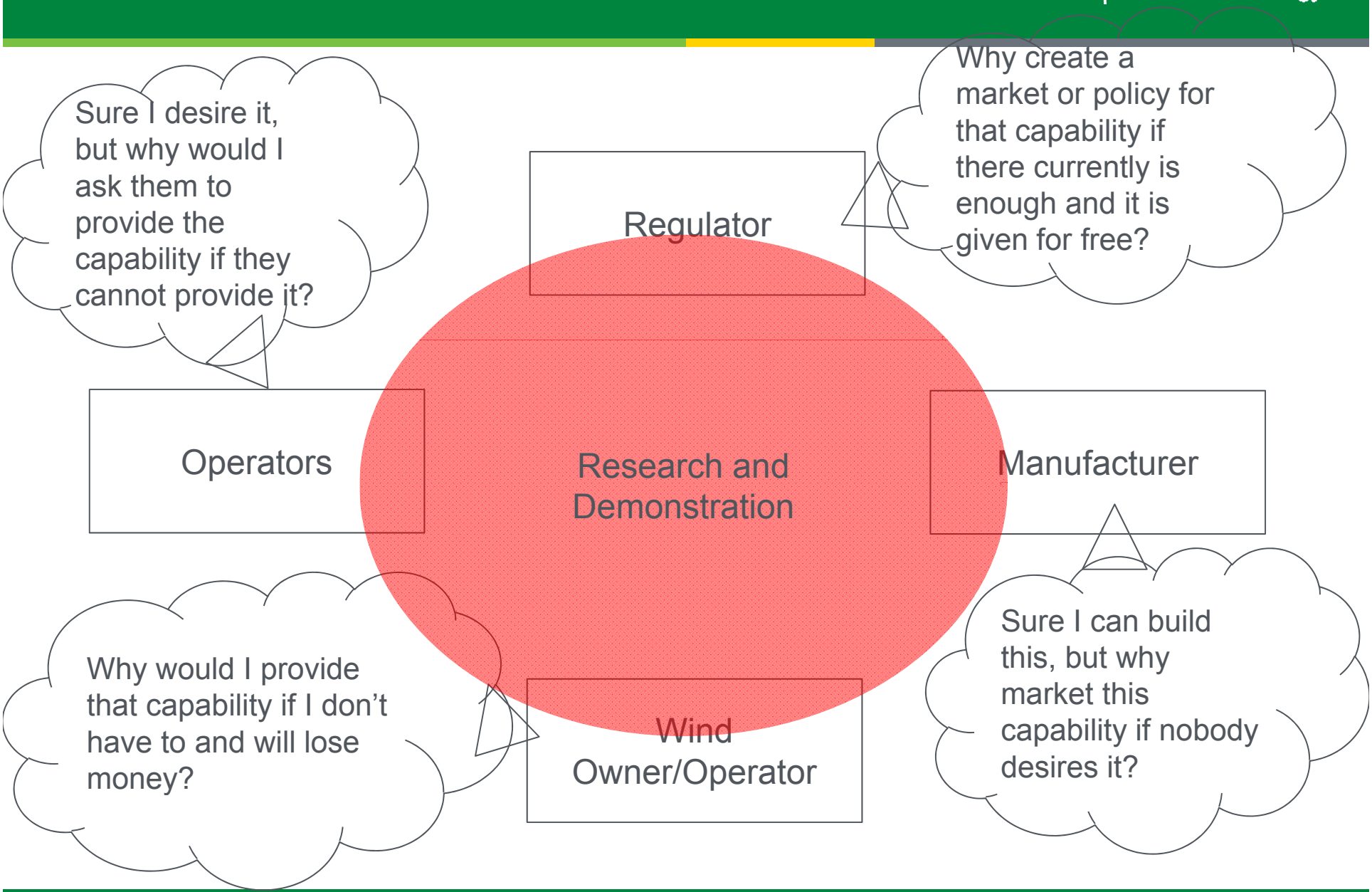


Disturbance



Normal conditions

Differences in Perspective



Making the Case

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- Current decline of the North American Eastern Interconnection frequency response of about 60-70 MW/0.1 Hz per year
  - Ingleson and Allan 2010, Ingleson and Ellis 2004, etc.
- 2011 FERC/LBNL study on Frequency Response Metrics to assess requirements for reliable integration of VG:
  - Though states wind not being the cause to frequency decline, recommends "expanded use of frequency control capabilities that could be provided by variable renewable generation technologies (primary frequency control, etc.)"
- Kirby et al "Providing minute to minute regulation from wind plants"
  - "The analysis has shown that there is a potential for wind plants to aid power system reliability and increase their own profits by providing regulation."
- Wind power integration studies (e.g. EWITS, WWSIS, etc.) have recommended use of wind power providing secondary and tertiary reserve power during min load periods

Primary Response Status

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- Europe: UCTE (ENTSO-E requires 3000 MW of primary response throughout interconnection, distributed based on load/gen ratio
- NERC: No quantifiable requirement for primary response
- Current decline (Ingleson research)
- Eastern Interconnection currently has no “C” point
- Reasons for decline
  - Governor dead bands
  - Stepped droop rather than proportional curve
  - Blocked governors
  - Generator modes (sliding pressure, exhaust temperature control mode)
- Neither Europe nor North America have designated ancillary services market for primary response
  - E.g., Spinning reserve market does not necessarily mean governors are enabled
- If enough wind displaces and de-commits conventional units providing this service, and wind does not provide these capabilities, this can cause a further decline

Active Power Control Project

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- NREL and EPRI joint project, to test at NWTC facilities
- Economic and power system analysis and simulations
- Computer simulations of control capabilities
- CART machine field test
- Utility scale wind turbine test and demonstration
- Push the boundaries, more in-depth testing

- Parameter adjustments (dead bands, ramp rates, droop characteristic, etc.)
- Different wind speeds, upward and downward, high varying wind
- All three responses together

- Publish results and demonstrate to regulators, operators, wind owner/operators, and manufacturers

Active Power Control from Wind Power Workshop

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www.nrel.gov/wind/systemsintegration/active_power_control_workshop.html

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Active Power Control from Wind Power Workshop

This workshop, held on January 27, 2011 in Boulder, Colorado, was convened to discuss the research needs and state of the art of providing active power control from wind turbines and wind plants. Here are the proceedings, meeting notes, and list of attendees.

The knowledge from the workshop will help guide research being conducted at NREL, the Electric Power Research Institute (EPRI), as well as at universities, utilities/independent system operators (ISOs), and manufacturers. The workshop included active power control in all forms, but in particular, it focused on the areas of inertial response, primary control (frequency response), and secondary control (automatic generation control regulation). Also, many utilities and ISOs are beginning to evaluate the potential for new standards and policies that relate to these types of control and therefore it is important that they have available the best information about these types of controls for making these decisions.

Introduction and Workshop Overview
Erik Ela, NREL

R&D Objectives of NREL and EPRI
Daniel Brooks, EPRI
Vahan Gevorgian, NREL

ISOs/Utilities
Moderator, Daniel Brooks, EPRI
- Sandip Sharma, ERCOT
- James Dominick, Xcel Energy (Please contact James Dominick for presentation)
- Dale Osborn, MISO
- Bob Cummings, NERC

Manufacturers
Moderator, Pouyan Pourbeik, EPRI
- Nick Miller, GE
- Bob Nelson, Siemens
- Richard Springer, Vestas
- Slavomir Seman, ABB

Universities
Moderator, Ed Muljadi, NREL
- Vijay Vittal, Arizona State University
- Mohammad Shahidehpour, IIT
- Jim McCalley, Iowa State University
- Mack Grady, University of Texas - Austin

Group Discussion
Moderators: Erik Ela, NREL and Daniel Brooks, EPRI

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NREL is a national laboratory of the U.S. Department of Energy, Office of Energy Efficiency and Renewable Energy, operated by the Alliance for Sustainable Energy, LLC.

The end goal

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- When tested, and reports show wind turbine providing capability satisfactorily…
- It costs too much?
  - Additional revenues per wind plant could possibly be very high should they choose to participate and <u>market rules are correctly designed</u>
  - Help wind compete with other generation
- It cannot behave as other generators?
  - Studies may show it providing the finest scale of active power control capability on a better quality than other generation

Contact

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Questions, Comments, and Feedback

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