Active Power Control Testing at the U.S. National Wind Technology Center

Erik Ela

Presented at the Wind Power Workshop, 27 January 2011, Boulder, Colorado

Erik.Ela@nrel.gov

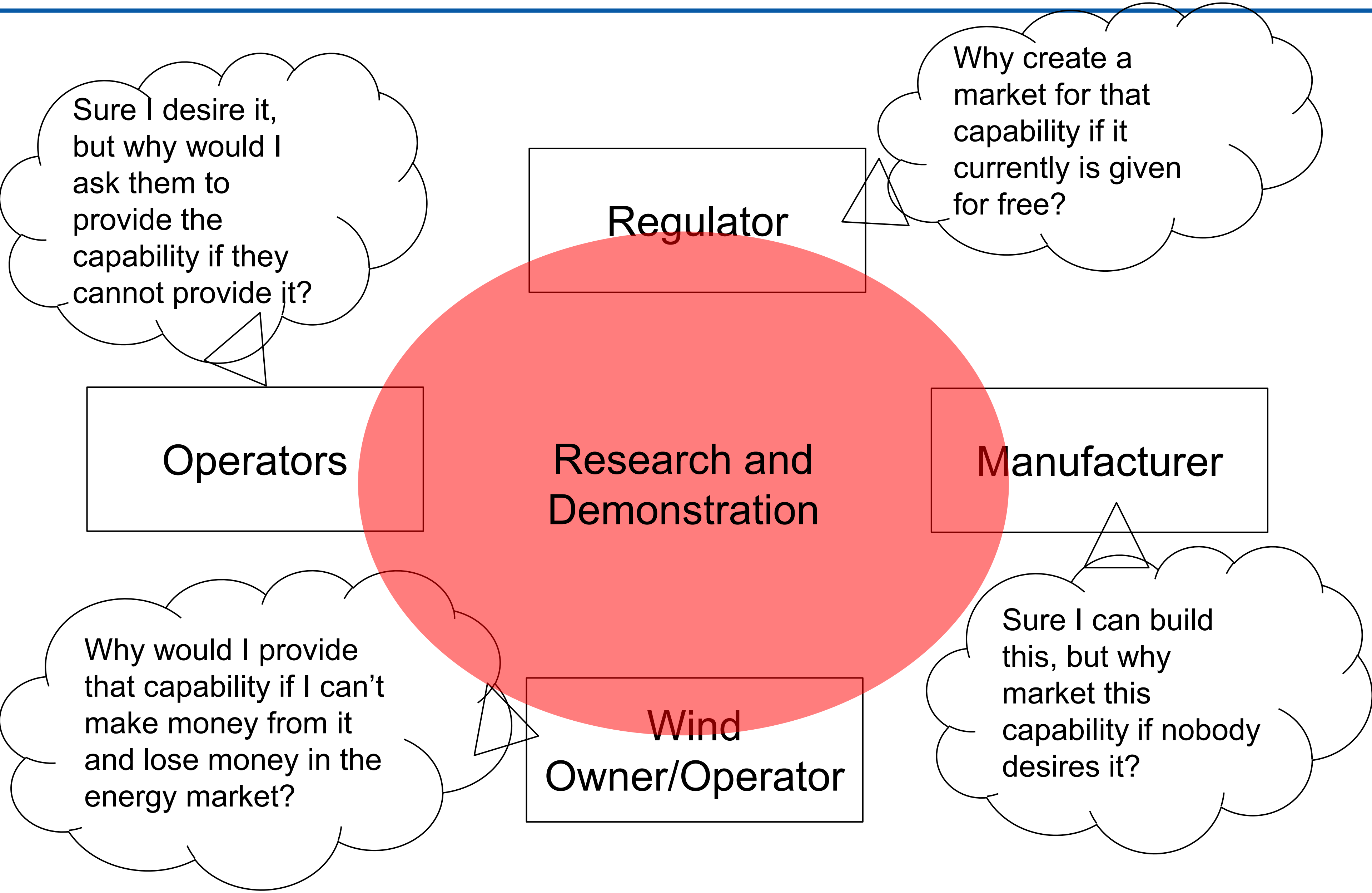
NREL/PR-5500-49785

PIX 16571

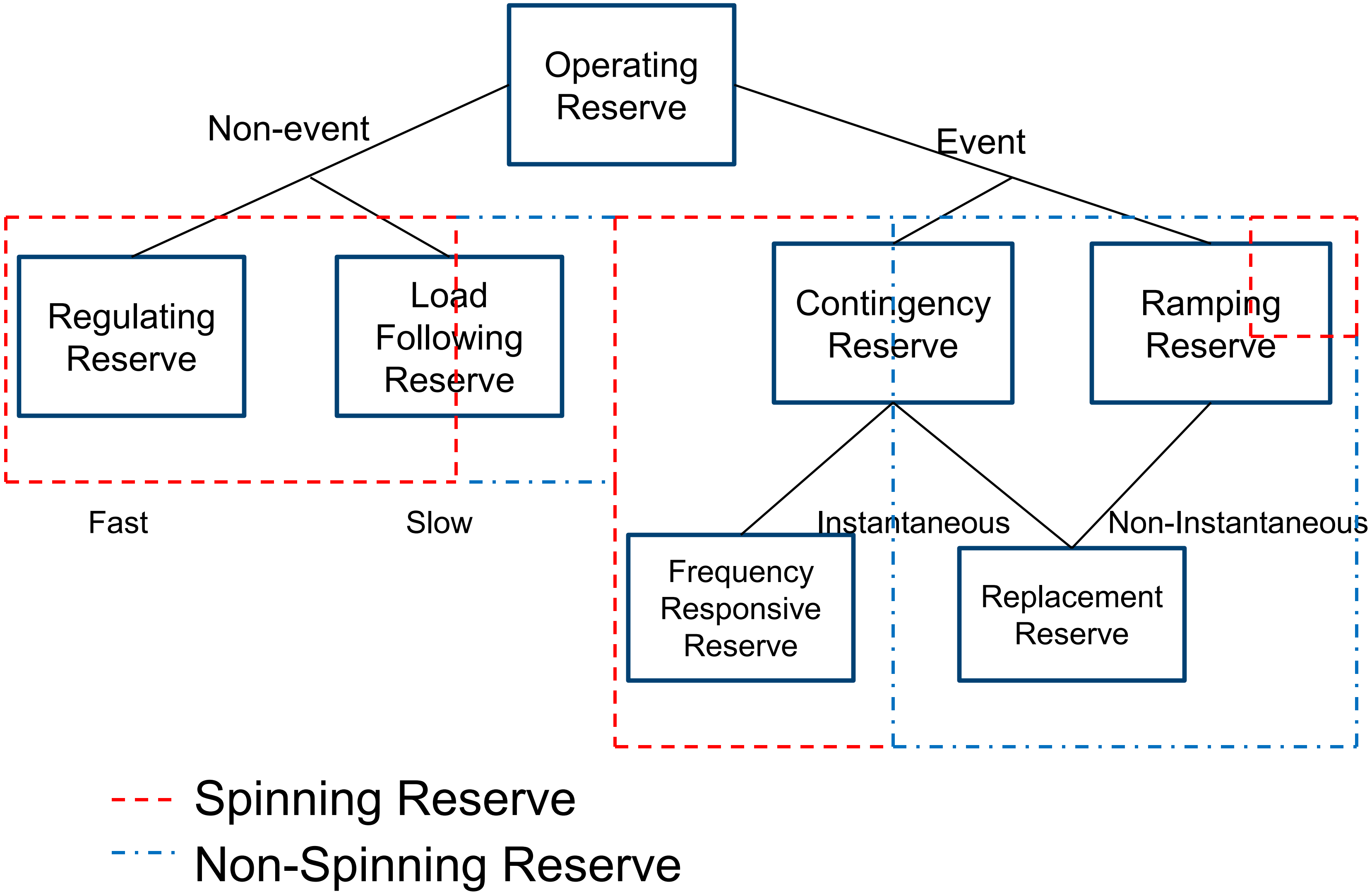
Current Mainstream Limitations of Wind

- What some of the papers and the anti-wind community say about wind…
- It costs too much
  - Only competitive when gas prices soar
  - Without RPS and PTC revenues would not be enough to justify high capital costs
  - Causes negative prices in areas where too much wind has been built before transmission
- It cannot behave as traditional generators
  - It is variable and is more of a detriment to power system stability than a benefit
  - The word “non-dispatchable” comes to mind

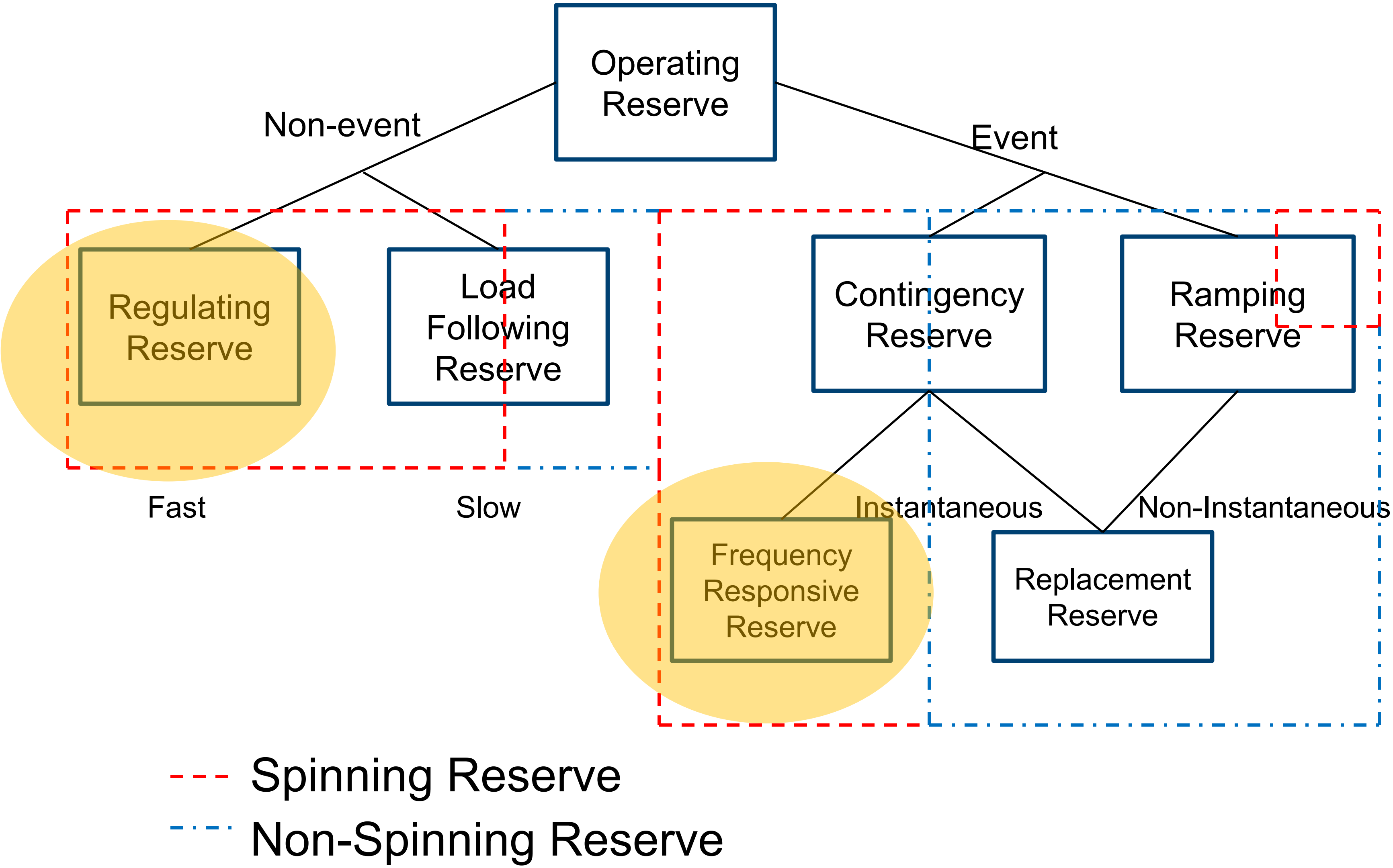
Differences in Perspective



Operating Reserves for Active Power Control



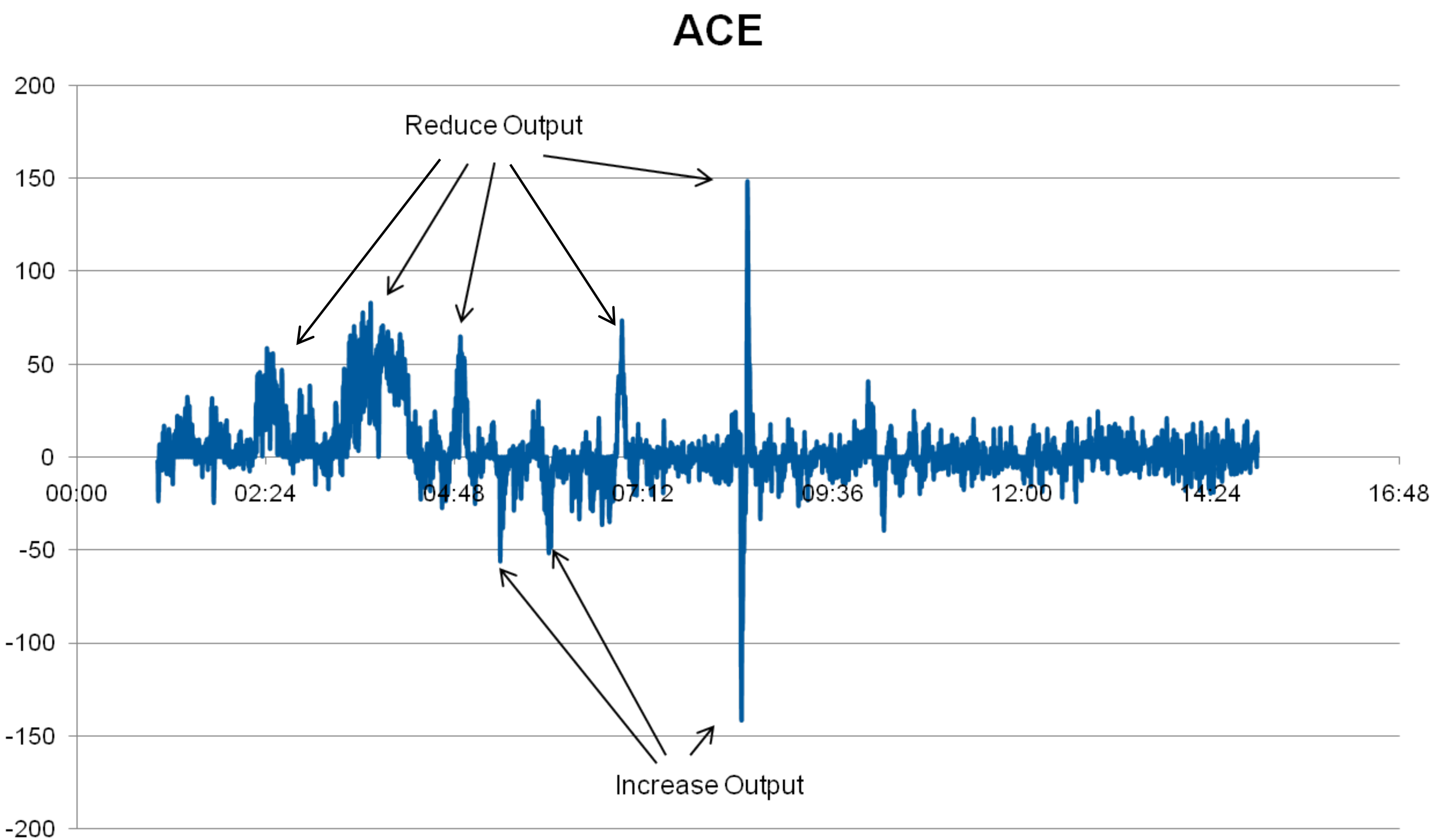
Operating Reserves for Active Power Control



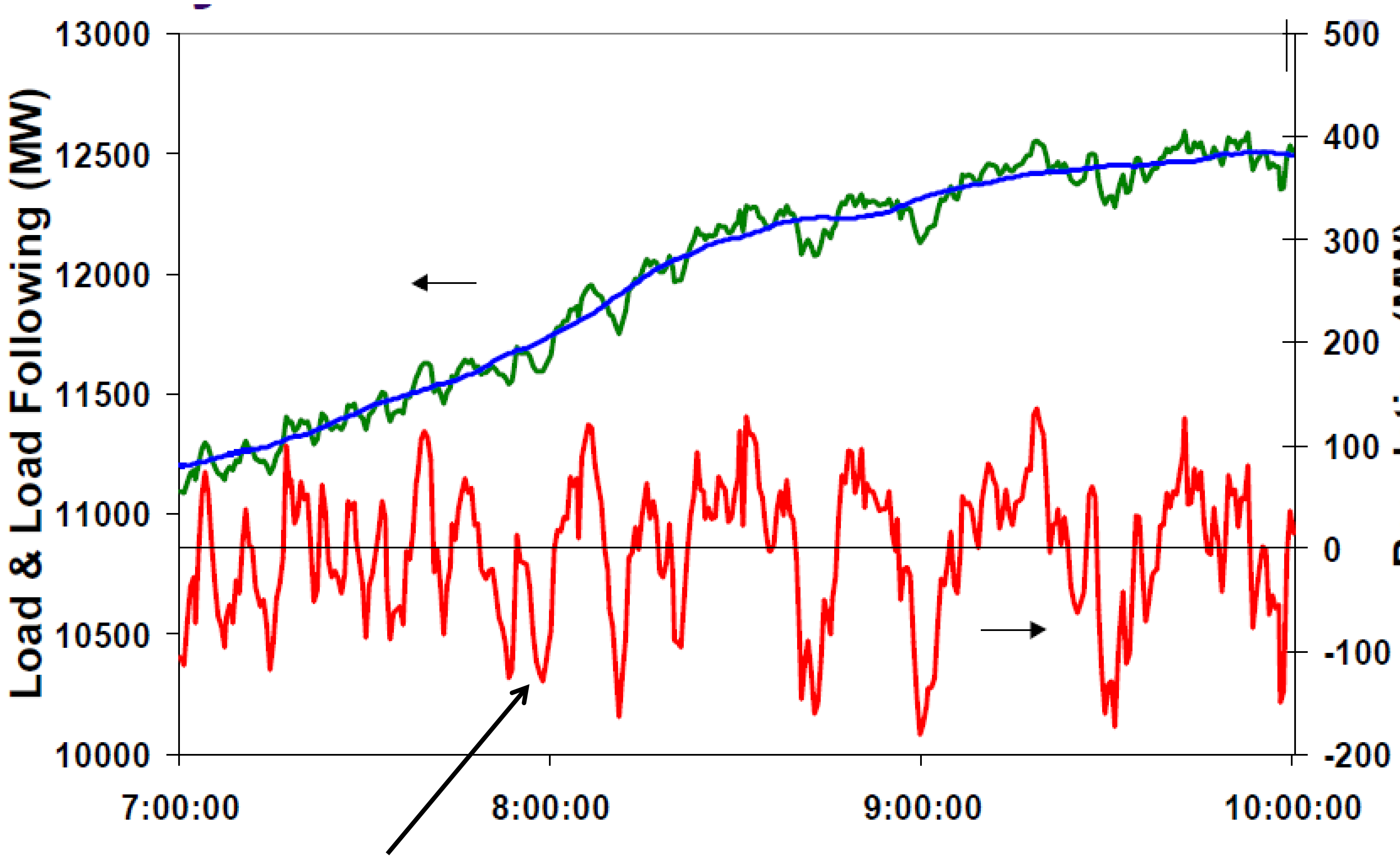
Regulation

- Regulation is provided by units that have automatic generation control (AGC)
- AGC signals are developed by the control area operator's energy management system and are sent directly to the generator (in some areas loads can also participate)
- In a stand-alone system (island) AGC signals are used to correct frequency back to its scheduled setting
- In large interconnected systems, AGC is used to correct area control error (ACE) for each area within the interconnection
- ACE is based on each individual areas' load balance and calculated based on tie-line schedule errors considering the area's frequency response
- Maintaining low ACE in all areas will in affect balance frequency while also minimizing accounting problems of inadvertent interchange between areas

Area Control Error Signal



Regulation



Constant balancing of Area Control Error

Typical generator regulating

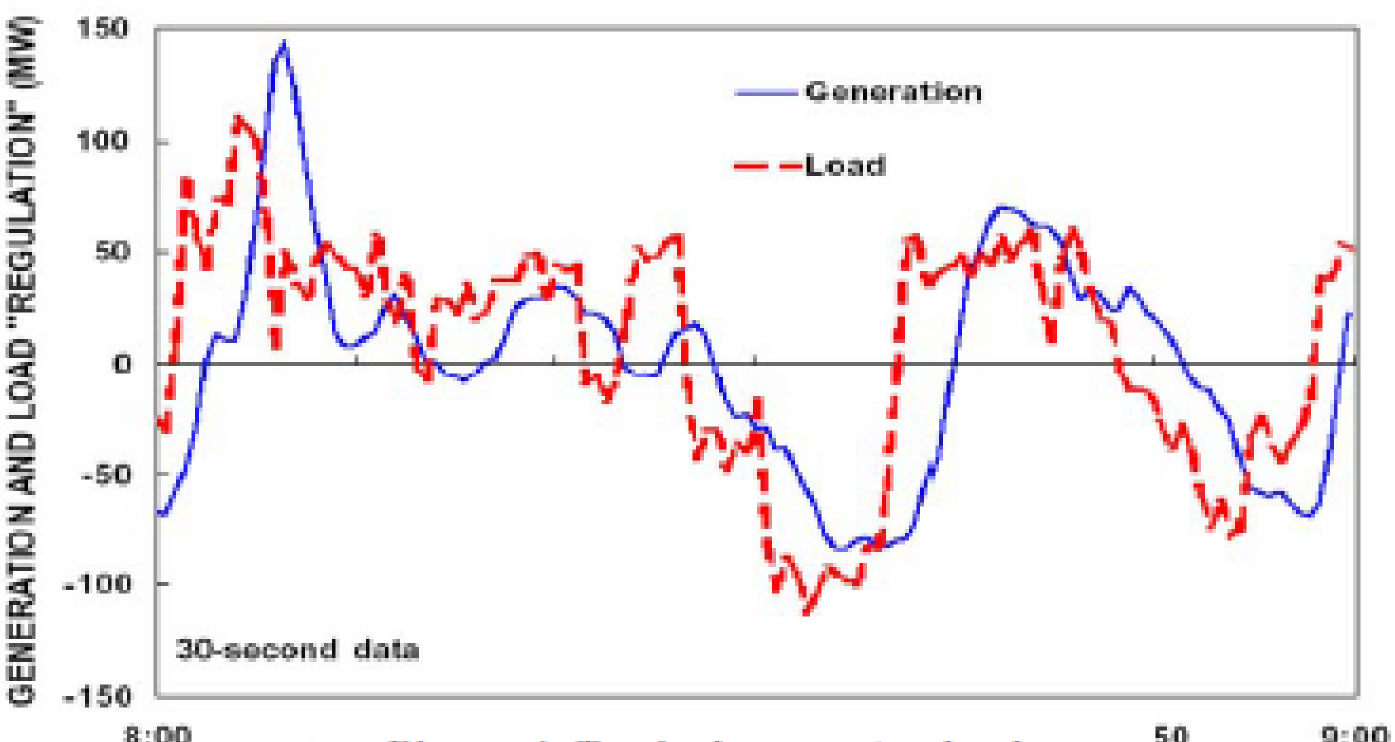
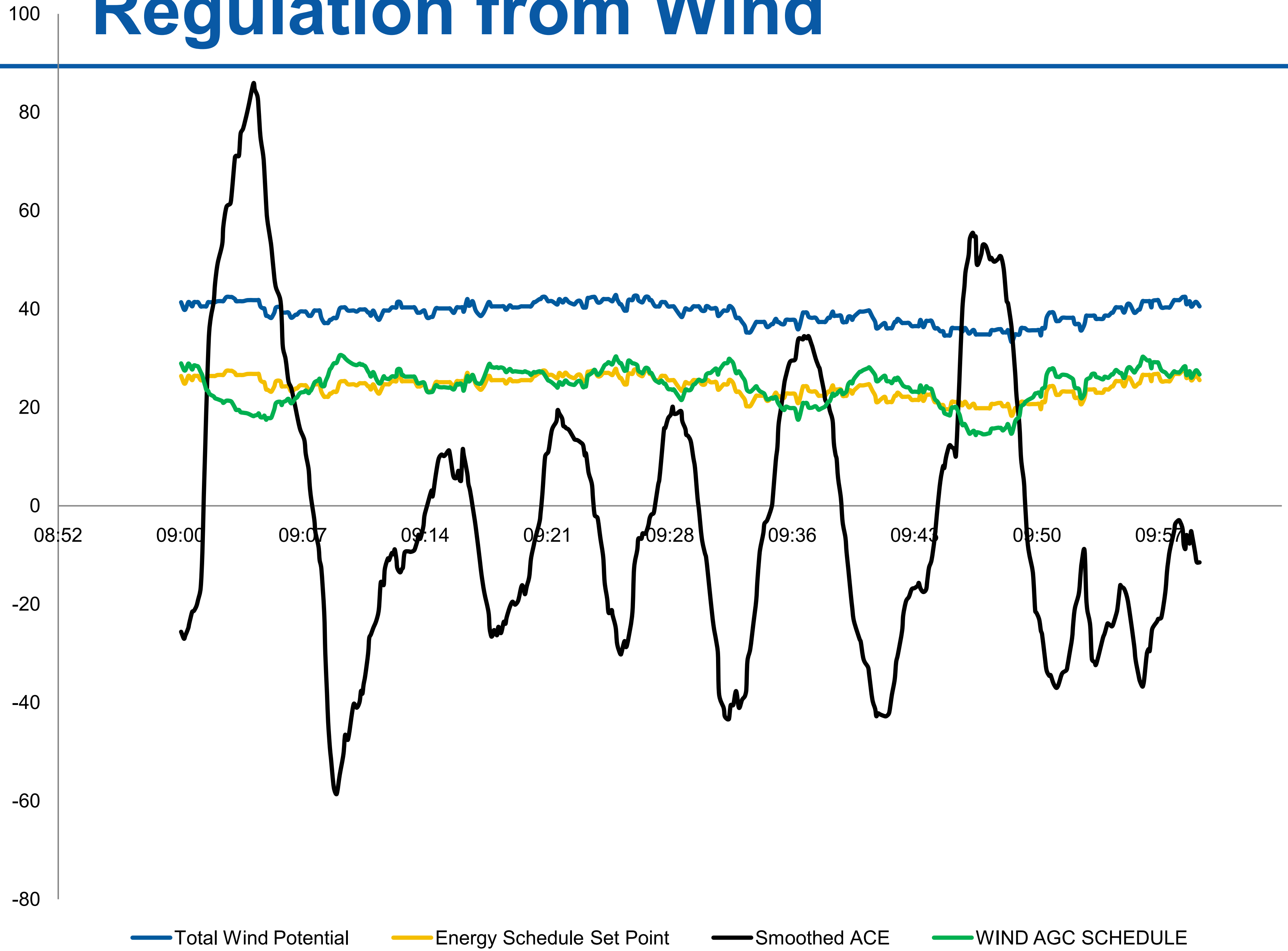


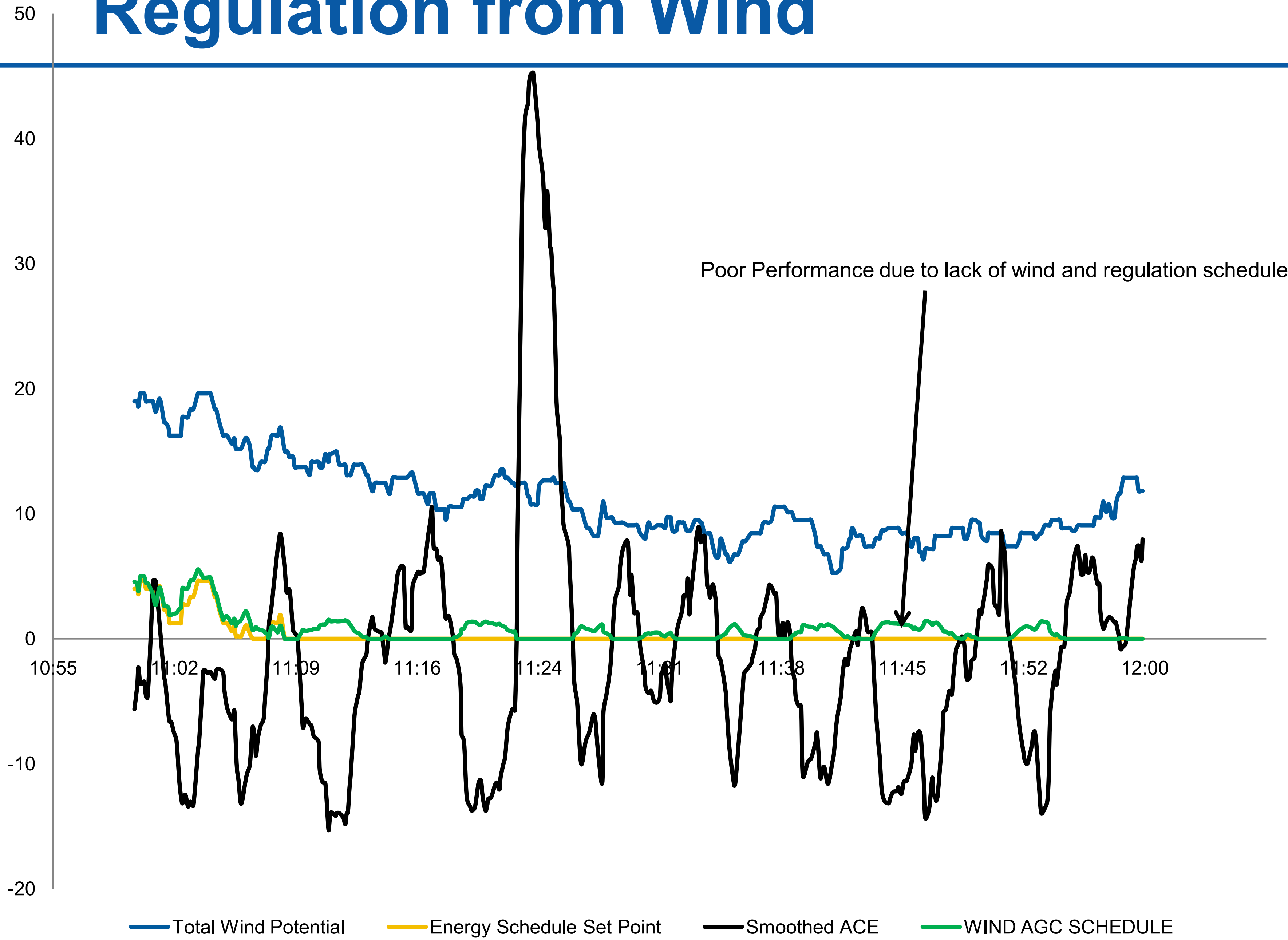
Figure 4. Typical generator load following characteristics [5]

Source: Lazerwicz et al

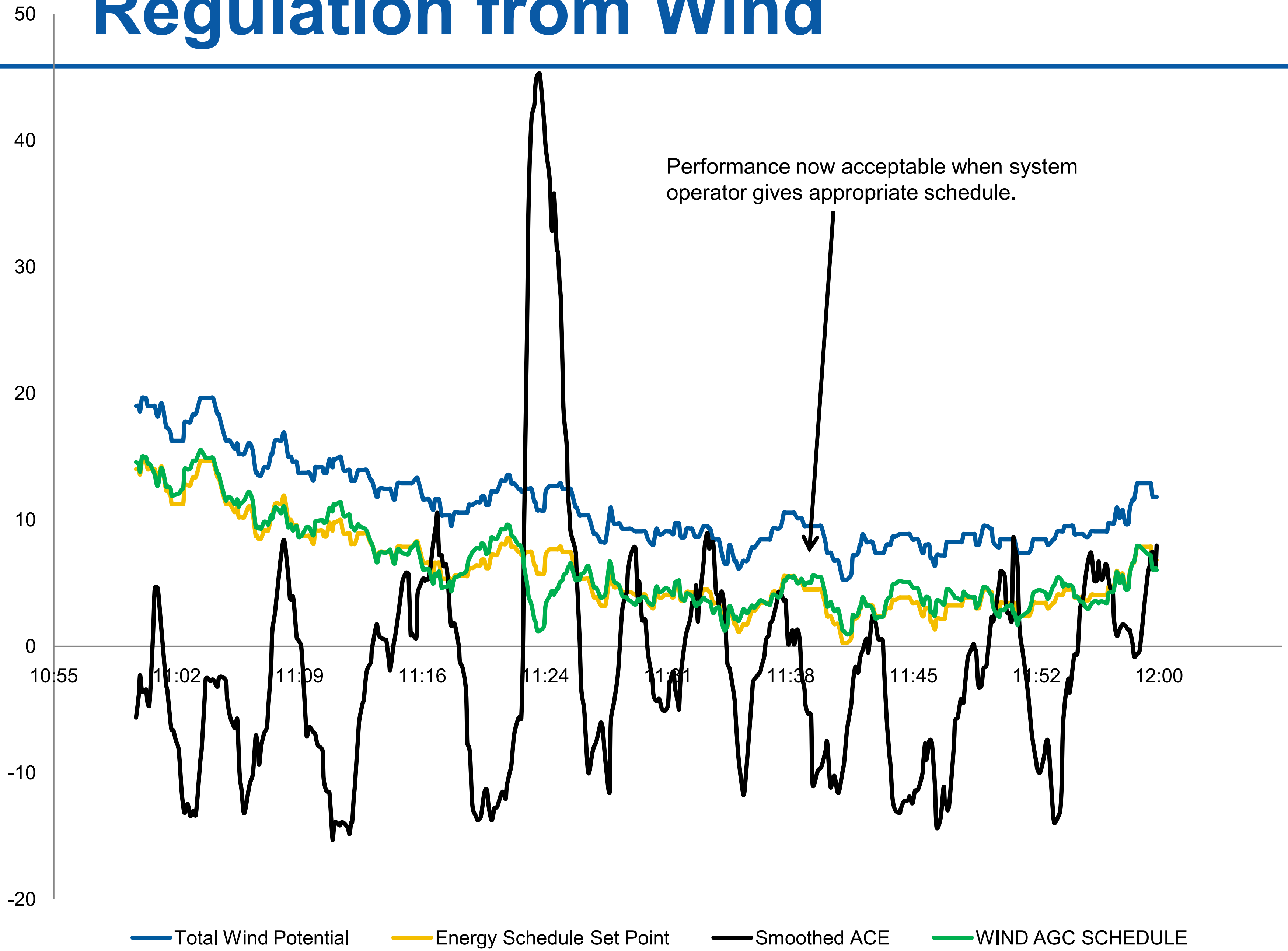
Regulation from Wind



Regulation from Wind



Regulation from Wind



A Lucrative Business

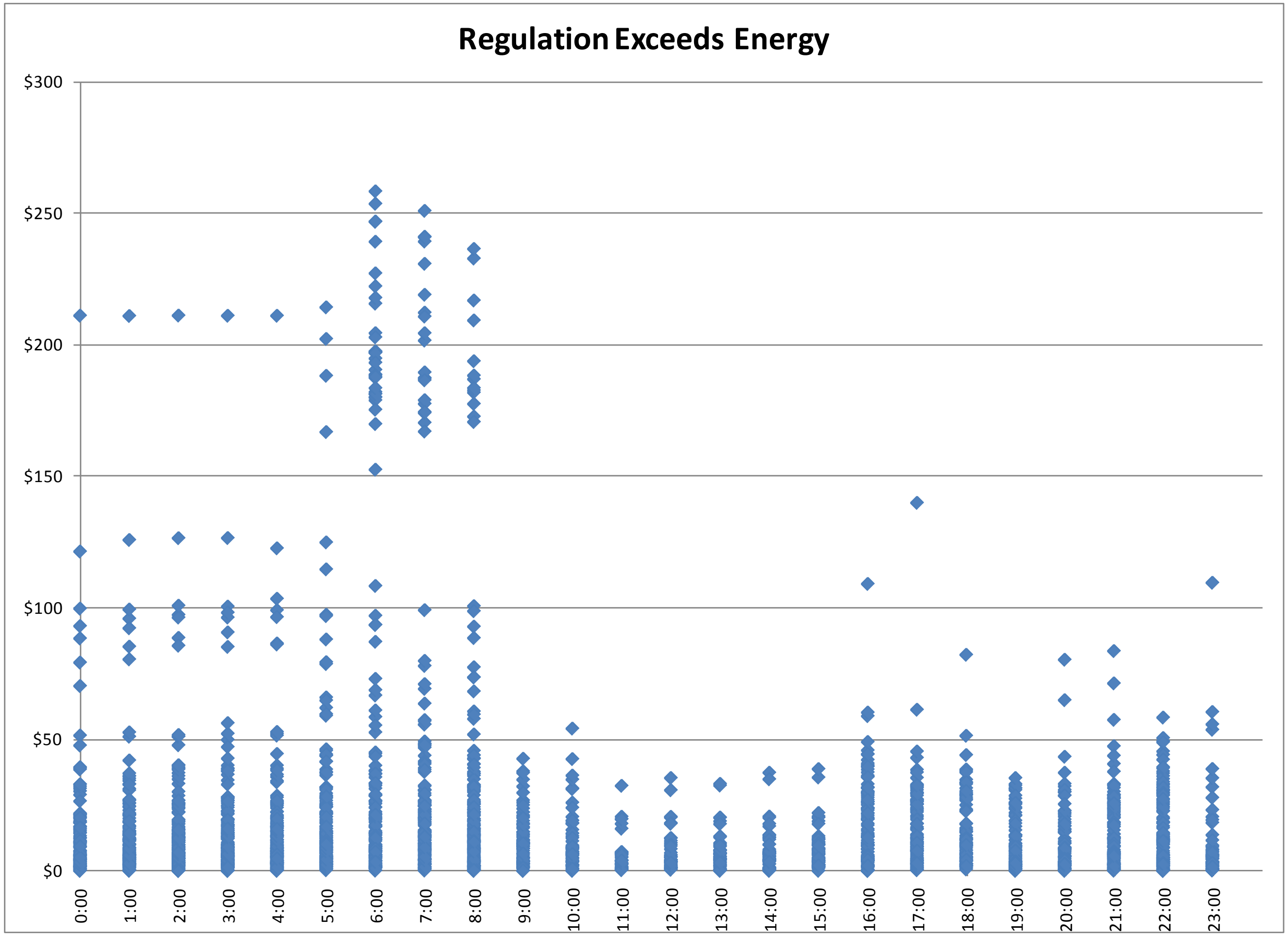
- Regulating is essential to an area; since “deregulation” markets have been formed to pay for this service along with other ancillary services
- Many units take wear and tear hits on their machine and turn this into high offer costs to provide the service that lead to high prices (also efficiency loss costs)
- These prices are in $/MWh of capacity, the unit will be paid the energy price based on where it actually produced in addition
- These prices will be paid as long as the unit follows the AGC directions in a reasonable manner
- The prices can often be higher than energy prices and will increasingly be so as more low-variable-cost resources enter the energy market

21 cents per kWh just to provide capacity!

Eastern Date Hour	Pricing Region	10 Min Sync	10 Min Non Sync	30 Min Non Sync	Regulation
10/1/2009 0:00	EAST	3.34	3.34	0.25	28
10/1/2009 1:00	EAST	3.35	3.35	0.25	28
10/1/2009 2:00	EAST	3.35	3.35	0.25	28
10/1/2009 3:00	EAST	3.35	3.35	0.25	28
10/1/2009 4:00	EAST	3.35	3.35	0.25	28
10/1/2009 5:00	EAST	3.35	3.35	0.25	45
10/1/2009 6:00	EAST	3.36	3.36	0.25	**209.02**
10/1/2009 7:00	EAST	7	3.4	0.5	39.5
10/1/2009 8:00	EAST	5	3.38	0.5	43
10/1/2009 9:00	EAST	6.11	3.38	0.5	41.5
10/1/2009 10:00	EAST	6.2	3.36	0.5	41.5
10/1/2009 11:00	EAST	7	3.37	0.5	28
10/1/2009 12:00	EAST	6.11	3.35	0.5	28
10/1/2009 13:00	EAST	6.14	3.35	0.5	28
10/1/2009 14:00	EAST	6.11	3.35	0.5	28
10/1/2009 15:00	EAST	6.1	3.35	0.5	28
10/1/2009 16:00	EAST	6.11	3.32	0.5	41.5
10/1/2009 17:00	EAST	6.1	3.32	0.5	41.5
10/1/2009 18:00	EAST	6.89	3.32	0.69	41.5
10/1/2009 19:00	EAST	9.84	3.34	2	41.5
10/1/2009 20:00	EAST	5	3.32	0.5	41.5
10/1/2009 21:00	EAST	5	3.34	0.5	41.5
10/1/2009 22:00	EAST	5	3.36	0.5	41.5
10/1/2009 23:00	EAST	0.25	0.25	0.25	28

NYISO pricing data www.nyiso.com

NYISO Regulation Prices



Example

Steam Generators: 5 with minimum gen = 100 MW, maximum = 300 MW, 2 MW/min ramp rate; all must stay on at night due to commitment constraints
Wind: blowing at 300 MW
Load: 800 MW
Regulation Requirement: 50 MW/5min up and down,

Current Solution: Steam generators all operate at 110 MW, wind is curtailed to 250 MW. (Energy price = $0, regulation price >> $0)

Wind on Regulation: Steam generators all operate at 100 MW, Wind is not curtailed.

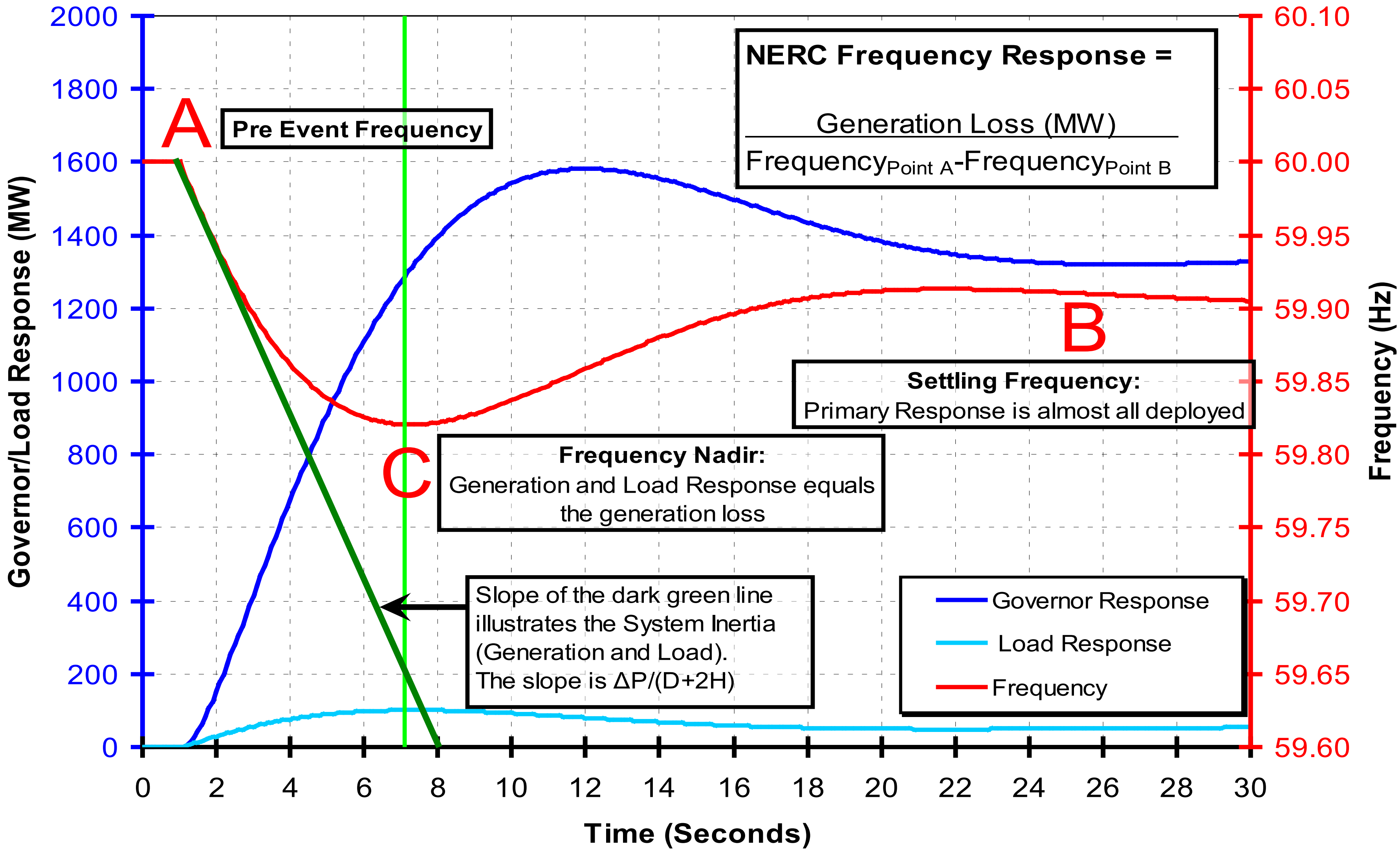
Thus reducing costs and emissions

Primary Response and Inertia

- Inertia of synchronous machines provide initial response to disturbances of supply-demand balance
- More inertia on the system will decrease the rate of change of frequency decline during disturbances
- Primary response (e.g., frequency response, governor control) adjusts mechanical input after sensing frequency deviations
- Primary response used to stabilize frequency to some level
- Primary response based on governor control of traditional hydro-thermal generating units
- Response based on droop ($\Delta f/\Delta P$ in pu), frequency dead band, and MW capacity head room (Pmax – Pgen)
- Both services essential to reduce the impact of frequency decline (or increase) and avoiding the need to shed load based on under-frequency load shedding relays

Frequency Response Basics

(Using a 1400 MW generation loss event as an example)

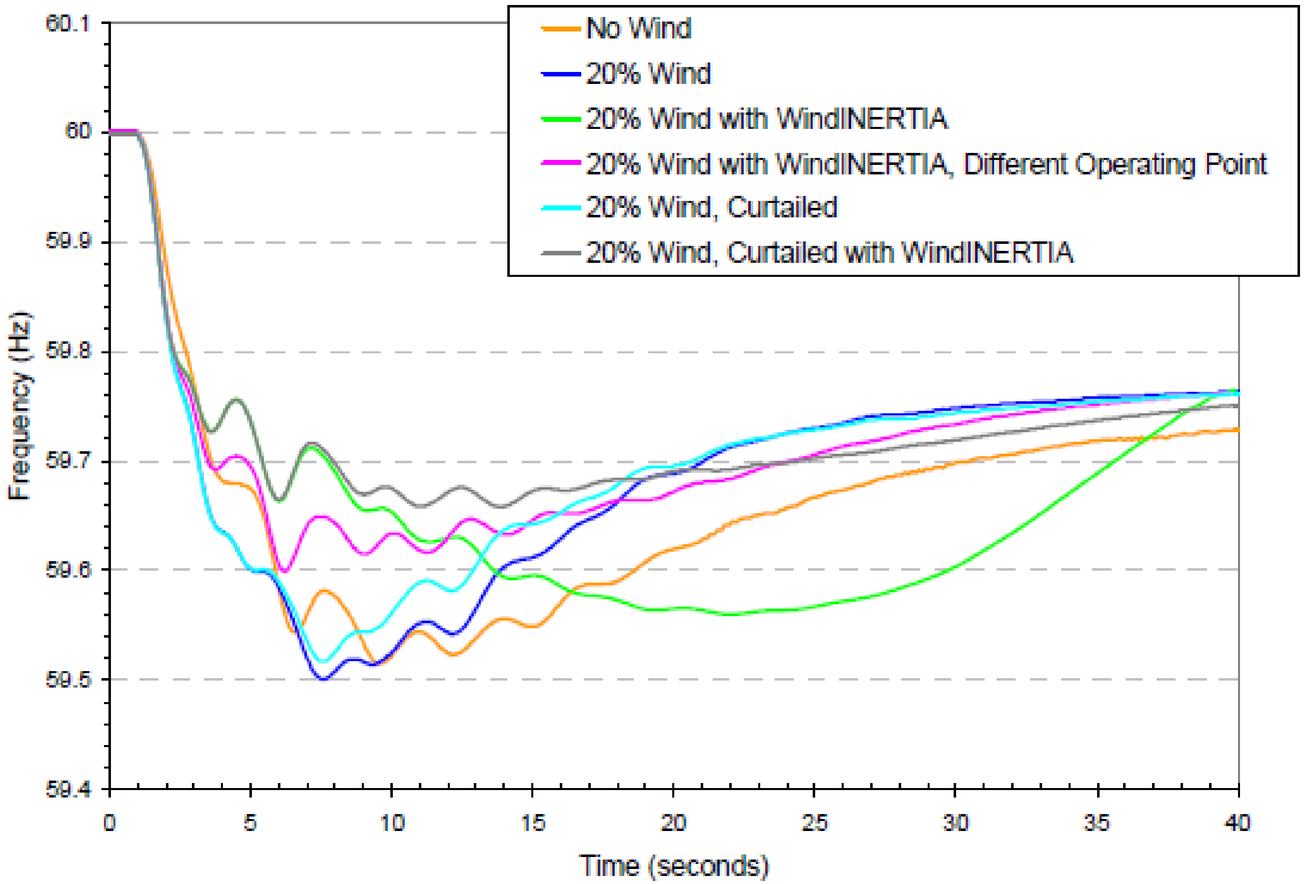


Taken from FERC Technical Conference on Frequency Response, Sept, 2010

Current Status

- Europe: UCTE requires 3000 MW of primary response throughout interconnection, distributed based on load/gen ratio
- N.America: No requirement for primary response, only a requirement for frequency bias as part of ACE equation (1%peak load/0.1Hz)
- Current decline of the North American Eastern Interconnection of about 60-70 MW/0.1 Hz per year (Ingleson and Nagle 98, Ingleson and Ellis 2004)
- 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)
- If enough wind displaces and de-commits units providing this, and wind does not provide these capabilities, this can cause a further decline

Response with Wind contribution



Miller et. al, "Impact of Frequency Responsive Wind Plant Controls on Grid Performance," 9th International Conference on transmission networks and offshore wind. Quebec, Canada, October 2010.

NREL project

- NREL and EPRI joint project, to test at NWTC facilities
- Computer simulations
- CART machine field test
- DOE wind turbine test and demonstration (1.5 MW)

- Regulation signal with actual ACE input
- Inertial response with synthetic/real frequency input
- Primary response with synthetic/real frequency input
- 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

Schedule

Currently setting up project roles, literature reviews.

Early 2011: Simulations for different procedures

September 2011: Interim project report

September 2012: Final project report, demonstrations

And the result

- If tested, and reports show wind turbine providing capability satisfactorily…
- It costs too much?
  - Additional revenues per wind plant would possibly be in the millions should they choose to participate and market rules are correctly designed
  - Help wind compete with other generation when subsidies are no longer given
- 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
- Obviously, more questions and issues will arise once it is shown to be a feasible option, but this would be a very good starting point

Questions

Erik.Ela@nrel.gov