NREL
NATIONAL RENEWABLE ENERGY LABORATORY

Testing Active Power Control from Wind Power at the National Wind Technology Center

PIX 16562

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Current Mainstream Limitations of Wind

- Two of the most talked about limitations of wind…
  - It costs too much
  - It cannot behave as traditional generators (non-dispatchable)

APCFWP Team

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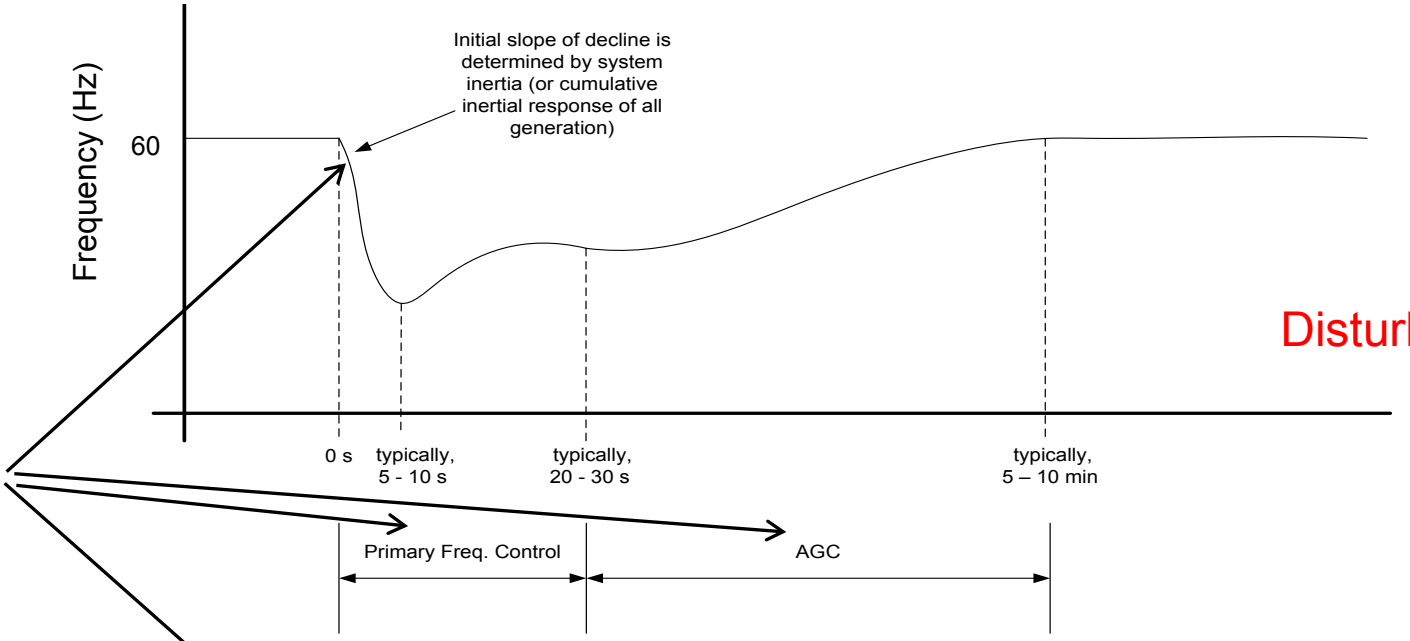
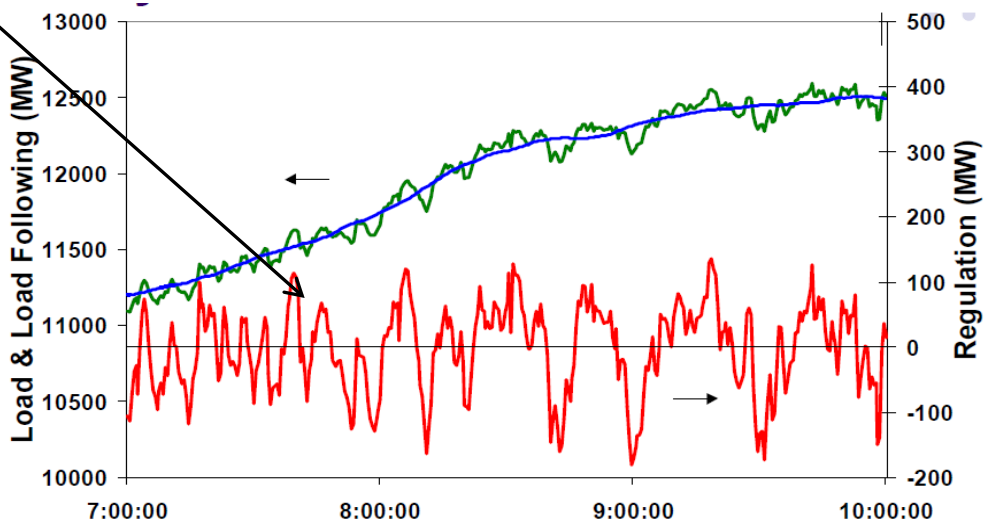
Active Power Control

Where can wind power fit in?

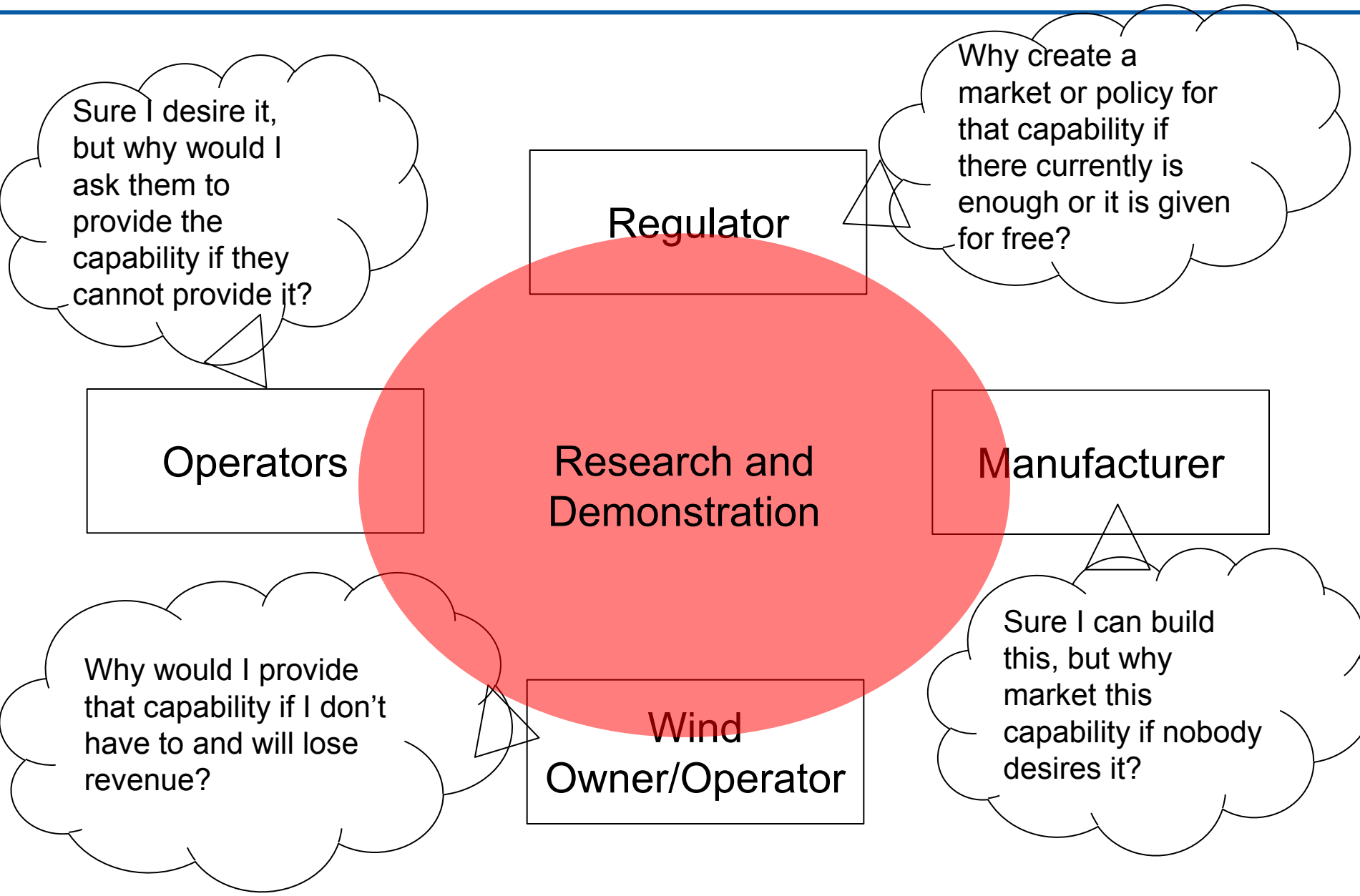


Disturbance



Normal conditions

Differences in Perspective



Making the Case

- 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

Regulation: A Lucrative Business

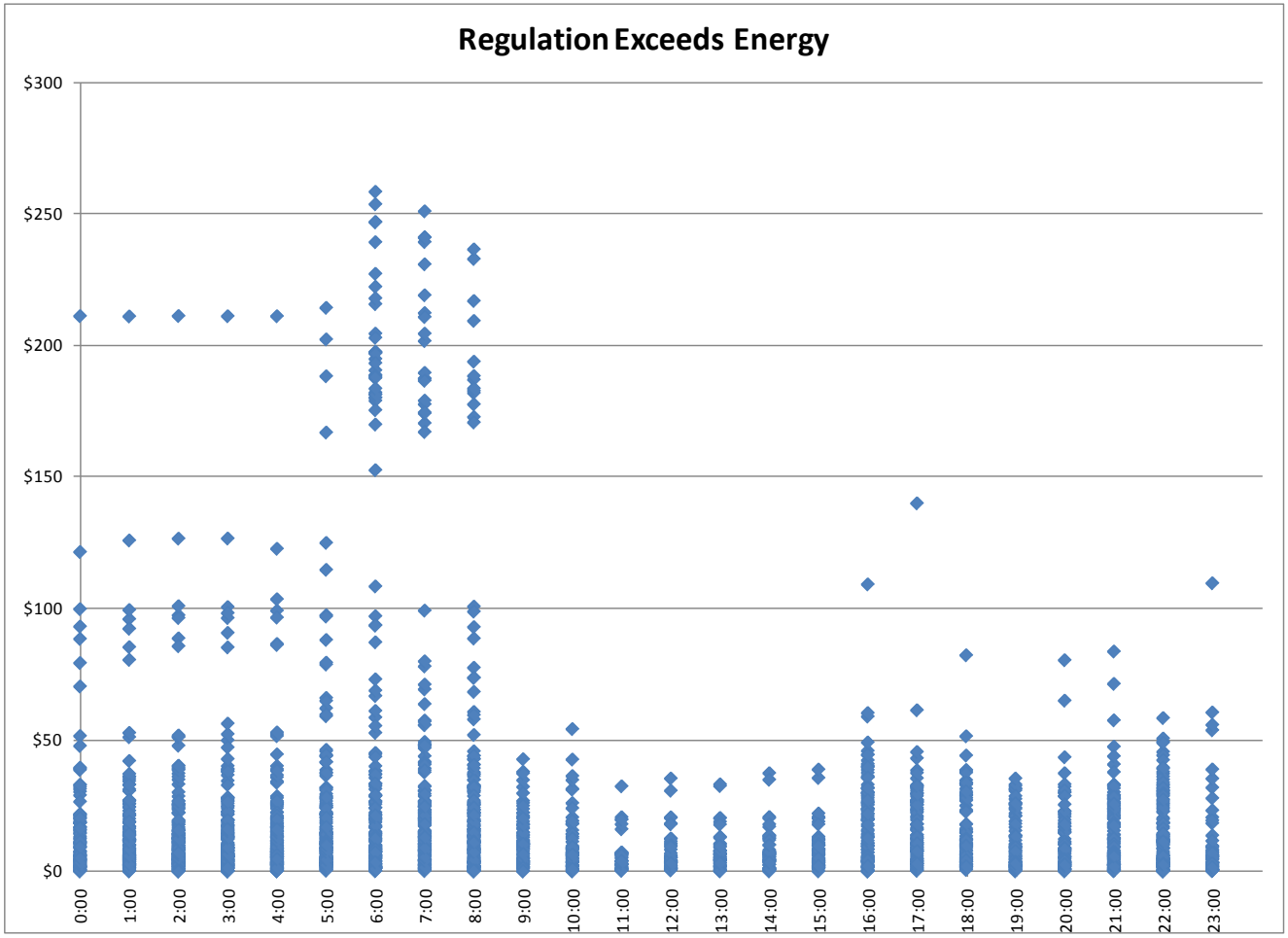
- Regulating is essential to an area; since "deregulation" markets have been formed to pay for this service along with other ancillary services
- Many units take wear and tear hits on their machine and turn this into high offer costs to provide the service that lead to high prices (also efficiency loss costs)
- These prices are in $/MWh of capacity, the unit will be paid the energy price based on where it actually produced in addition
- Resource is ONLY asked to provide regulation if it is economic
- 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 regulating 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



Primary Response Status

- Europe: UCTE (ENTSO-E requires 3000 MW of primary response throughout interconnection, distributed based on load/generation ratio.
- NERC: No quantifiable requirement for primary response.
- Current decline (Ingleson research).
- Eastern Interconnection currently has no “C” point.

Primary Response Status

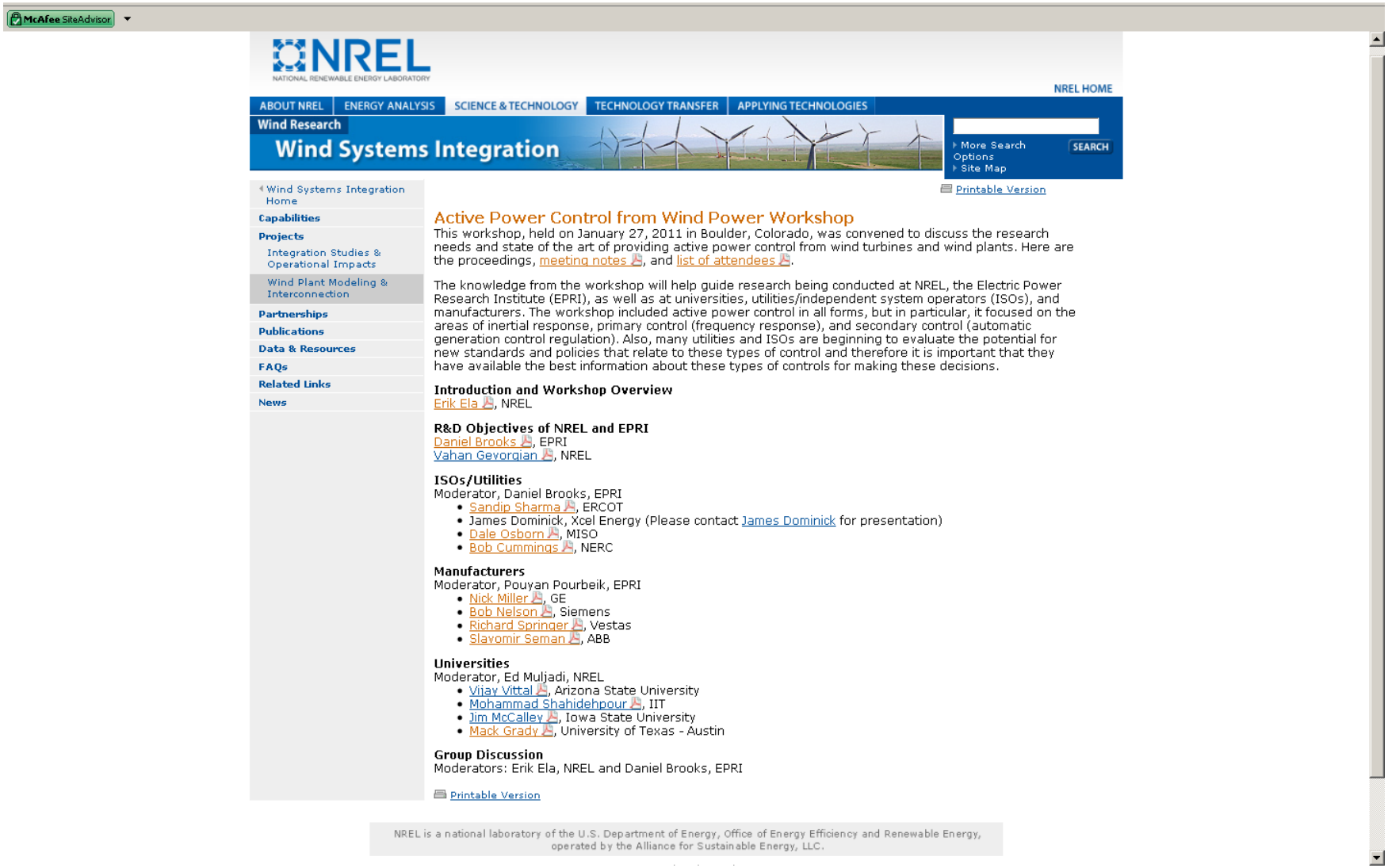
- Reasons for decline:
  - Governor dead bands;
  - Stepped droop vs. proportional droop;
  - Blocked governors;
  - Market issues;
  - Generator modes (sliding pressure, exhaust temperature control mode).
- Neither Europe nor North America have designated ancillary services market for primary response —
  - 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

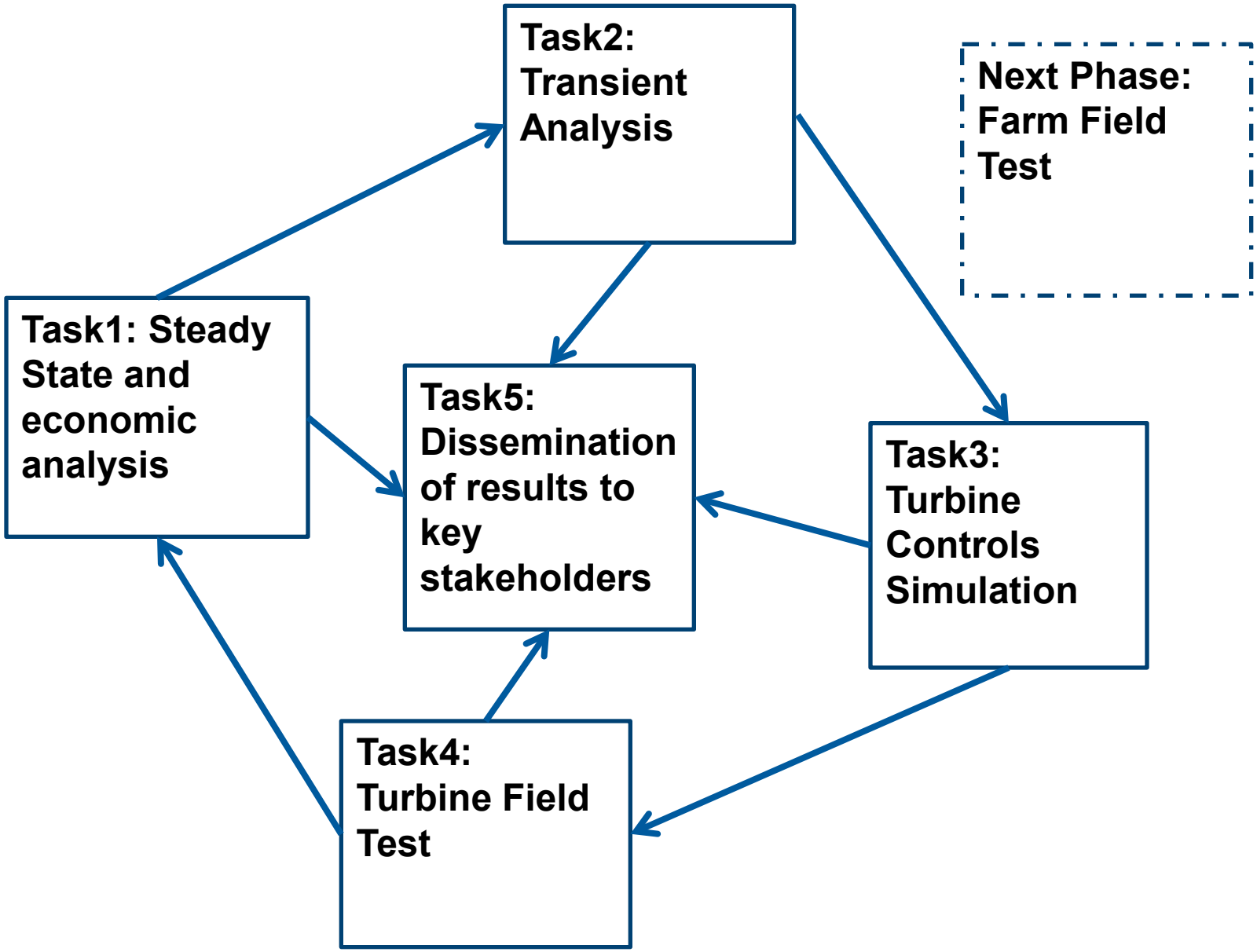
- NREL and EPRI joint project, to test at NWTC facilities.
- Economic and power system analysis and simulations.
- Computer simulations of control capabilities.
- CART machine field-test.
- Utility scale wind turbine test and demonstration.
- Push the boundaries, more in-depth testing
- Parameter adjustments (dead bands, ramp rates, droop characteristic, etc.).
- Different wind speeds, upward and downward, high varying wind.
- All responses together.
- Publish results and demonstrate to regulators, operators, wind owner/operators, and manufacturers.

Active Power Control from Wind Power Workshop

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



Project Tasks



Project Objectives

- Task 1: Economic and Steady State Analysis:
  - What is the priority?
  - What is the business case?
- Task 2: Transient Analysis:
  - What is the needed system response?
  - How does wind power impact the system response?
- Task 3-4: Turbine simulation and field tests
  - What does the response look like?
  - How does the response compare to current providers?
  - How does the response affect the machine/component life, etc.?
- Task 5: Dissemination
  - How can these capabilities be adopted?
  - Will industry endorse these capabilities?

Steady-State Modeling Results

120-MW Wind Plant:

Wind plant supplied regulation 2800 of the 3282 hrs regulation price exceeded energy.

Wind plant earned an additional $3.5 million or $9.96/MWH spread over the plants production –

- 4% reduction if the plant had to flatten production before selling regulation.

Field-testing APC

- Research assumes a single turbine can actively control its power within different time frames
- Need to test methods to implement this on a real turbine to learn:
  - What is possible controller performance?
    - Bandwidth, settling time, steady-state error
  - What are potential upper-bound setting constraints?
    - Added structural loading
    - Interactions with existing control loops, resonances
- Compare strengths/weaknesses of various APC designs

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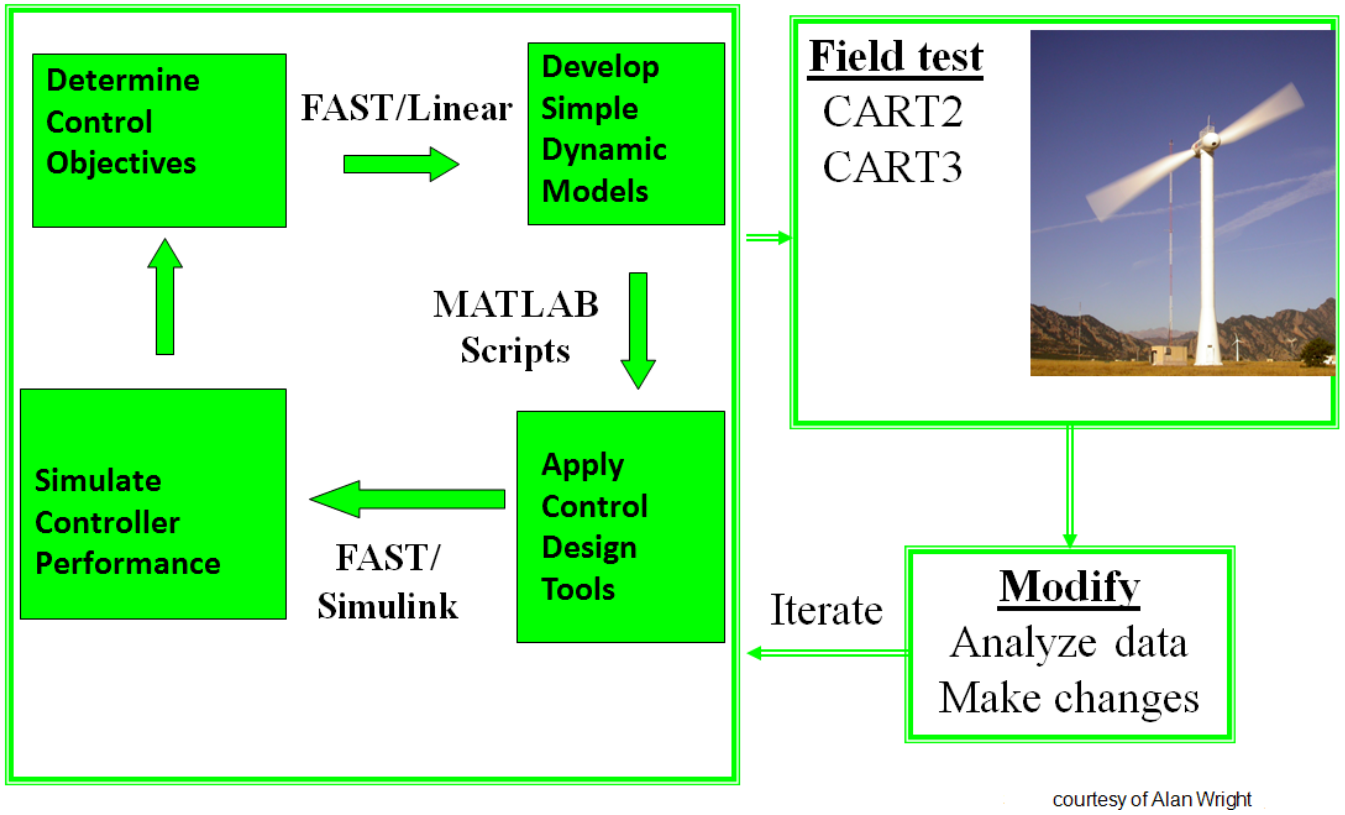
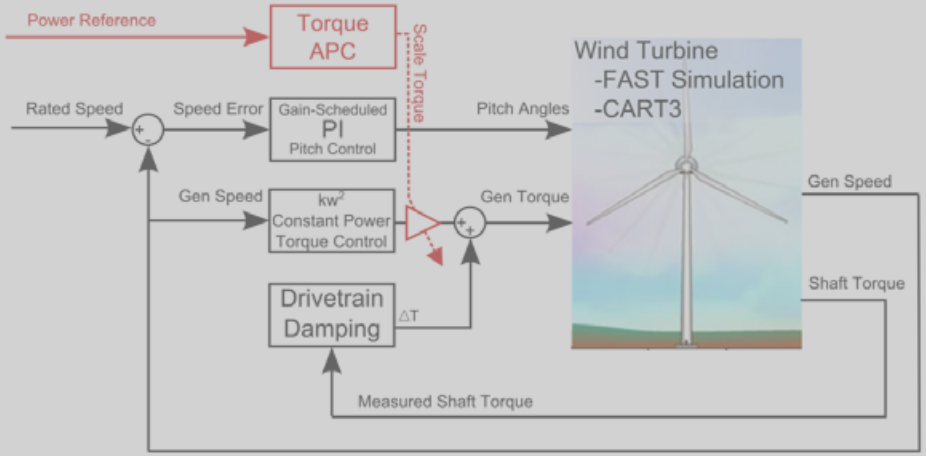
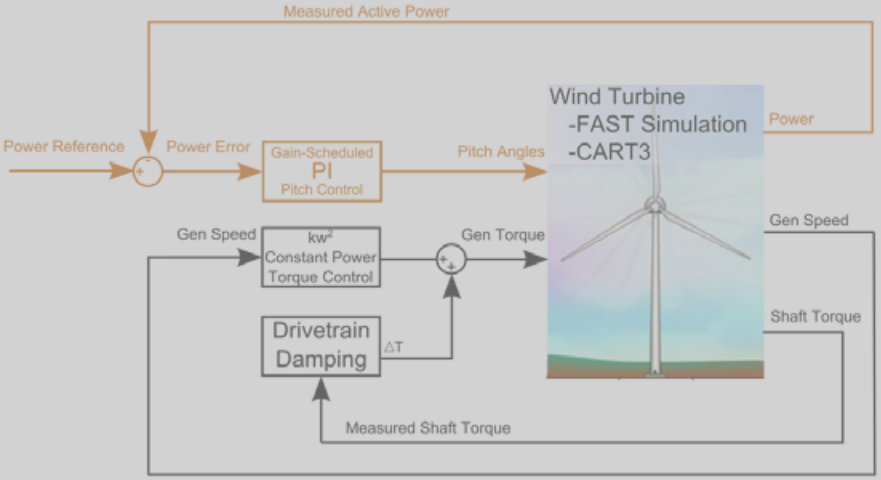
Simulation and Field-Testing Plan

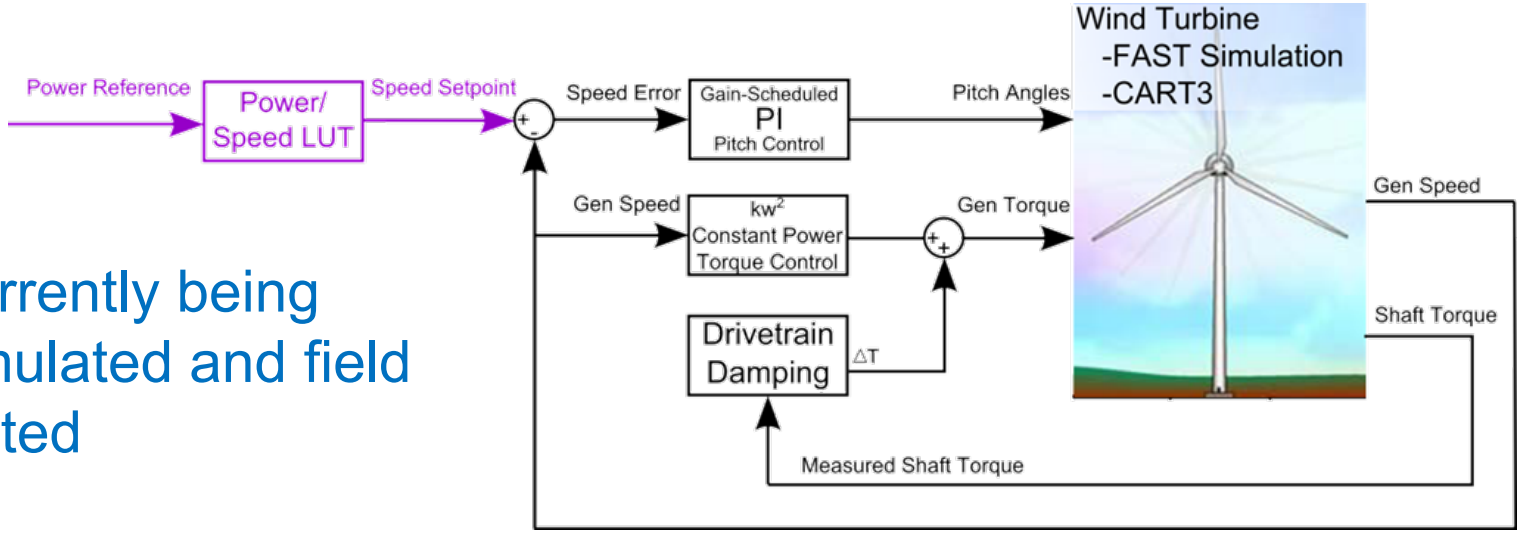


Design and Tune Control Strategies

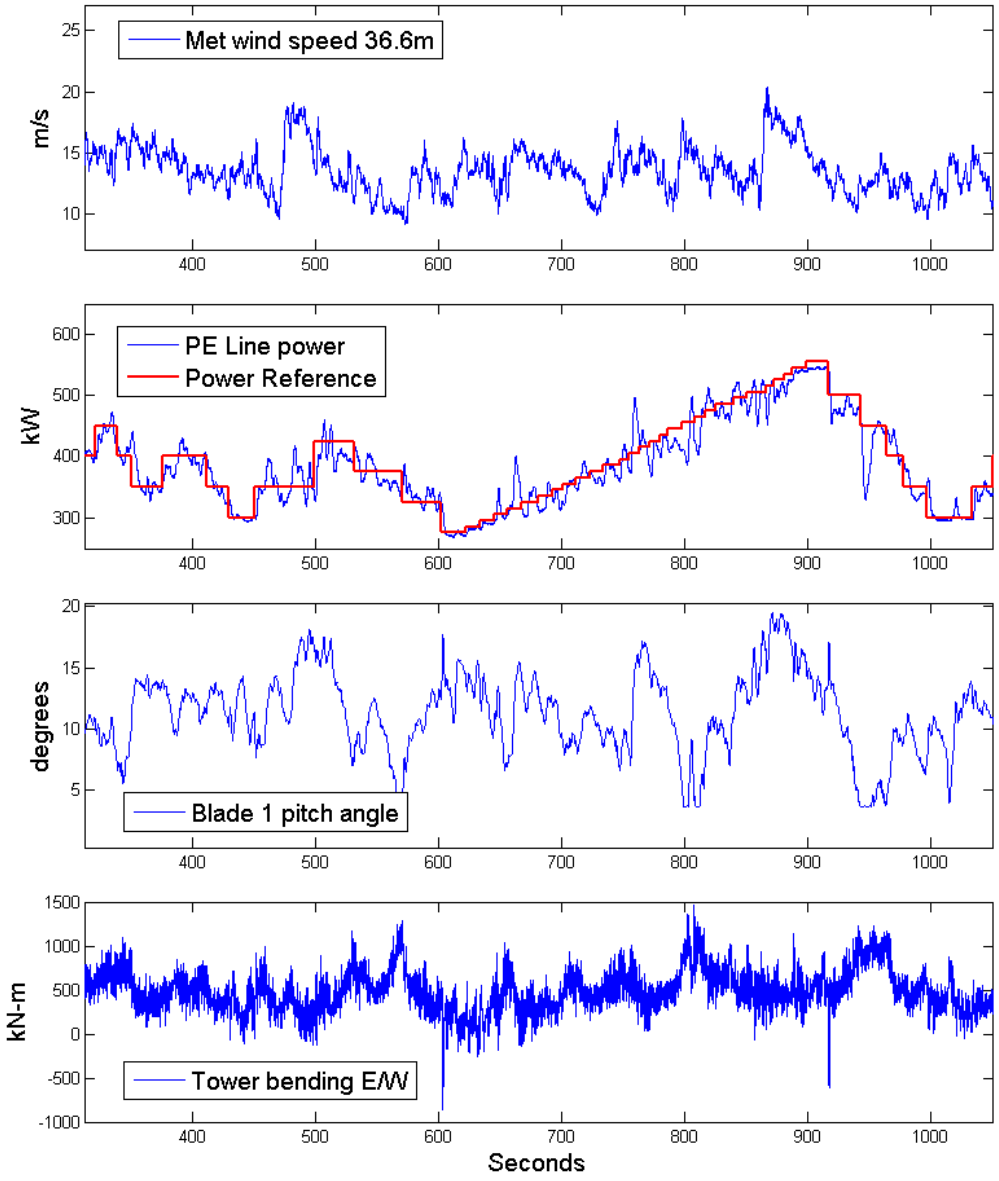




Currently being simulated and field tested



Field-testing results



Evaluate captured power against theoretically available

Investigate performance: RMS error, settling time, overshoot

Determine resultant additional actuation usage

Look at effects of APC on structural loads

Schedule

- September-December 2010: Project initiation, cooperative research and development agreement.
- January 2011: Active Power Control from Wind Power Workshop in Boulder, CO.
- February-March 2011: Project technical kickoff, scope breakdown.
- Late 2011: Interim project report.
- October 2010 – April 2011: Next wind season field tests.
- Late 2012: Final project report, demonstrations.

The End Goal

- 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 market rules are correctly designed.
- 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.