Integrating Wind into the Grid

Presented at NCSL

Midwestern Wind Policy Institute

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UWIG

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Utility Wind Integration Group

What is UWIG?

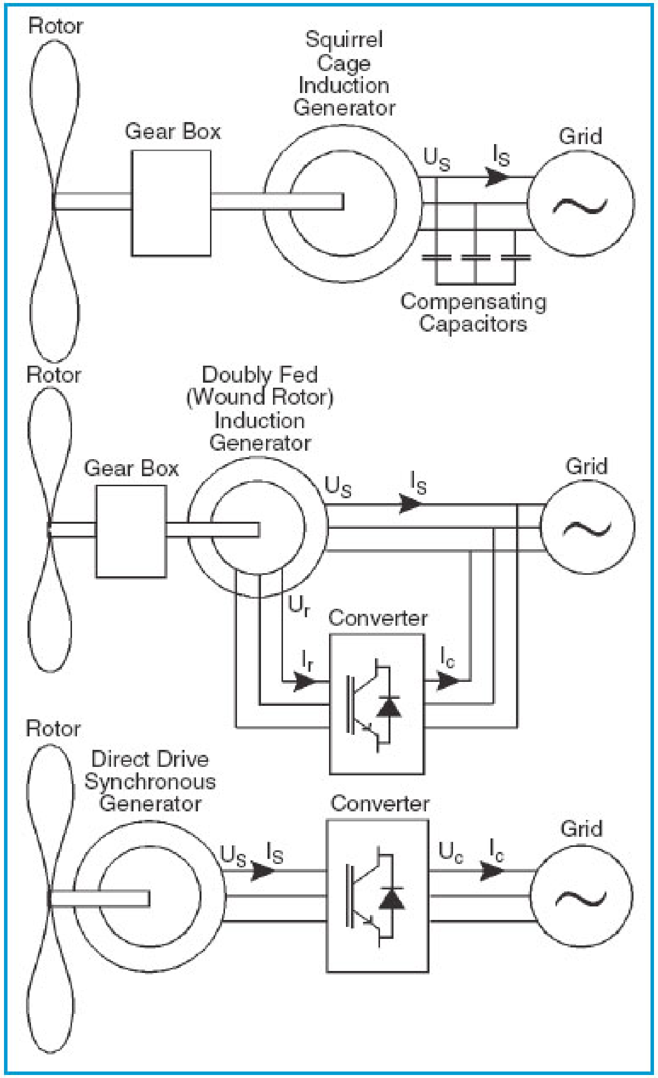
- Non-profit corporation established by 6 utilities in 1989 with support from EPRI and DOE/NREL
- Current membership totals 102, including Associate Members from wind development, equipment, and consulting community
- Focus on technical issues
- Mission: To accelerate the appropriate integration of wind power into the electric system

Evolution of Wind Turbine Technology

Past →

Present →

Future →



Source: IEEE Power & Energy Magazine

How Does Wind Plant Performance Compare?

	Past	Present	Future
Voltage Control	√-	√	√+
Short Circuit Contribution	√-	√	√+
Flicker	√-	√	√+
Low Voltage Ride-Through	√-	√	√+
Stability Behavior	√-	√	√+
AGC Participation	√-	√	√+

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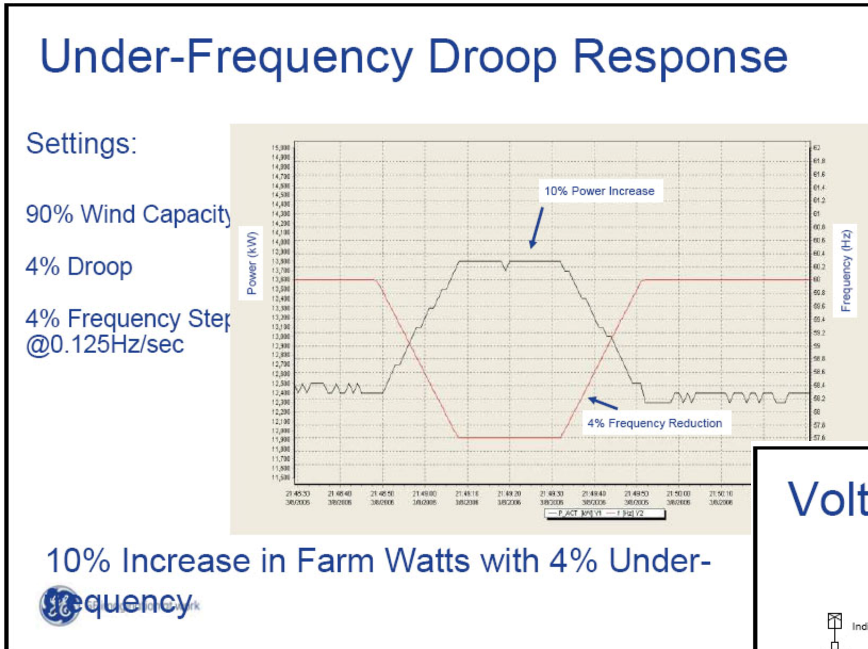
Order 661–A Provisions

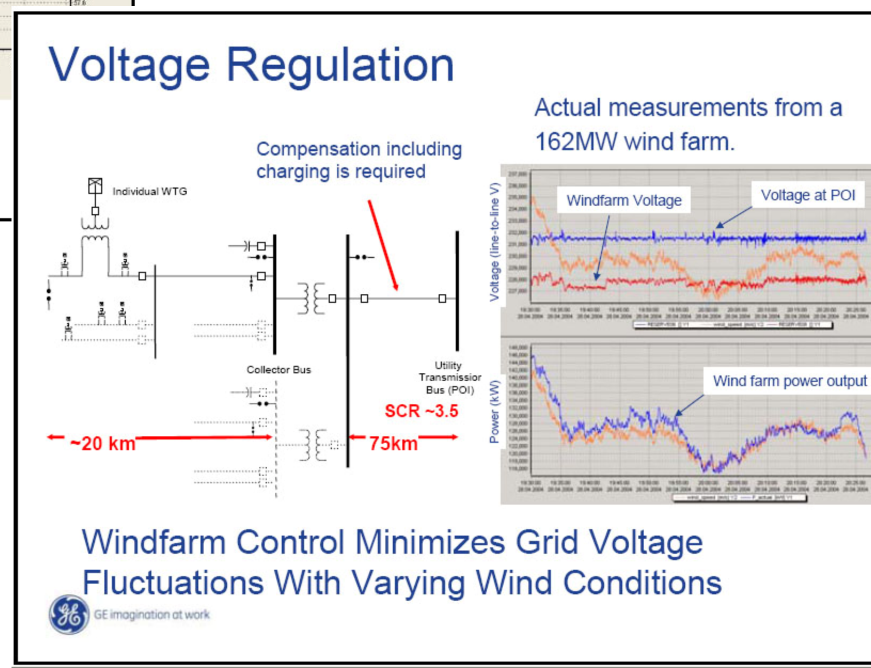
- LVRT
  - Generator stays on line during a 3 phase fault for normal fault clearing time up to 9 cycles and SLG faults with delayed clearing during a voltage dip as low as .15 pu at the high side of the GSU for units in service before 2008
  - Voltage dip requirement extends to 0.0 pu in 2008
- Reactive Power
  - Provide power factor of +/- .95, including dynamic voltage support, if needed for safety and reliability
  - Partial dissent by Chairman Kelliher over lack of mandatory requirement, ie placing burden of proof on transmission provider
- SCADA
  - Provide necessary information, as agreed with transmission provider

Wind Turbine Modeling

- WECC Wind Generator Modeling Group
- Mission
  - Develop a set of generic (non-vendor specific), non-proprietary, positive-sequence power flow and dynamic models suitable for representation of the major commercial, utility-scale WTG technologies
  - Develop a set of best practices to represent wind plants using generic models as basic building blocks
- Model types based on characteristics of grid interface
  - Type A – conventional induction generator
  - Type B – wound rotor induction generator with variable rotor resistance
  - Type C – doubly-fed induction generator
  - Type D – full converter interface
- Model validation important requirement
- Working with IEEE, AWEA, UWIG, and industry

Wind Plant Control Capability





Source: GE Energy

Interconnection Summary

- Wind plant terminal behavior is different from conventional machines, but compatible and improving
- Better dynamic models of wind turbines required for system studies
- Increased demands will be placed on wind plant performance (LVRT, reactive control, output and ramp rate control, inertial and governor response)
- System reliability can be enhanced by wind plants

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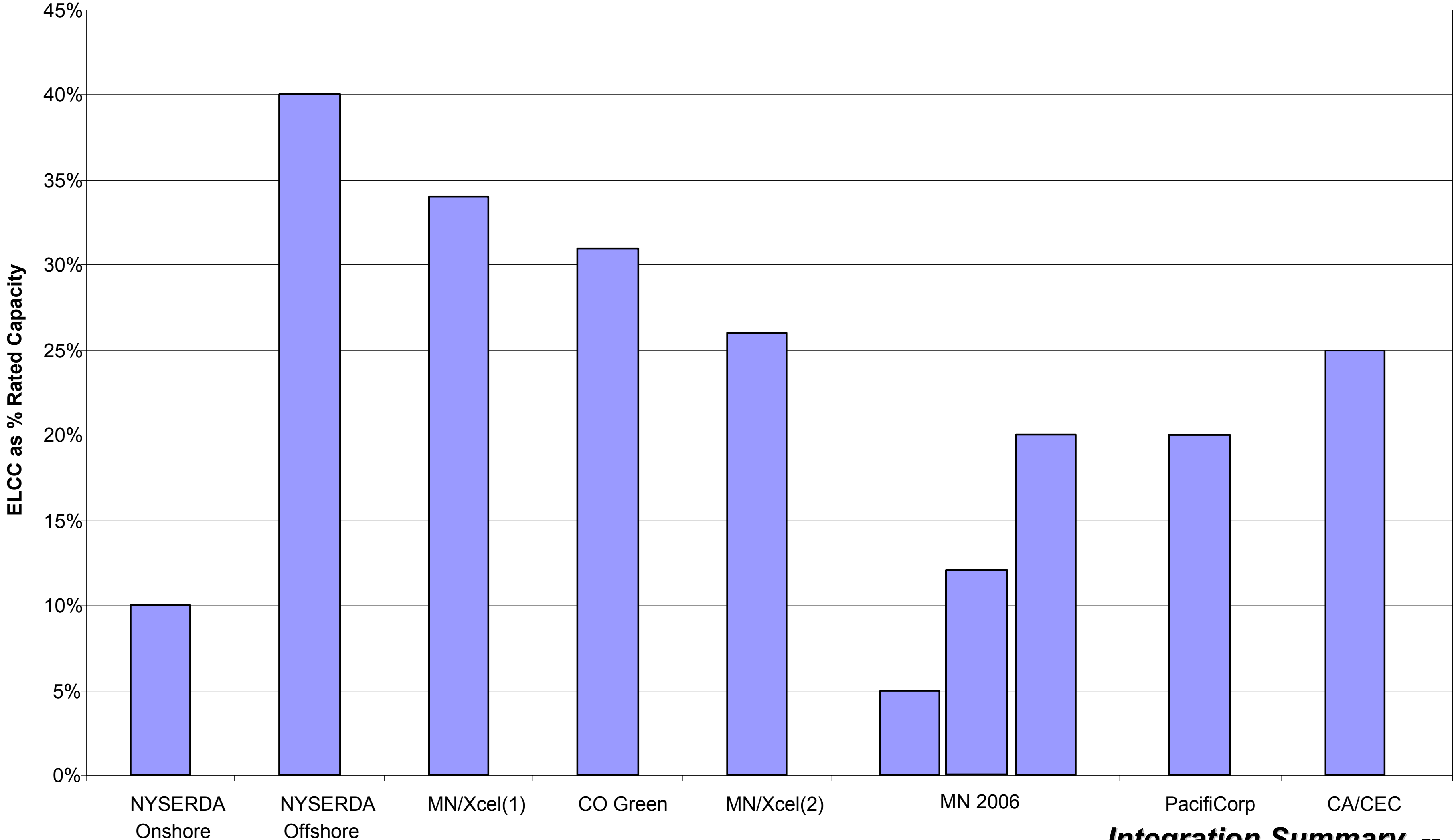
What To Do When the Wind Doesn't Blow

- Good question!
- Must deal with energy resource in a capacity world
- Dealt with through probabilistic reliability methods used to calculate Effective Load Carrying Capability (ELCC)
- Contribution may be large (40%) or small (<5%)
- Once the ELCC is determined, get on with the job of designing a reliable system

Selected Capacity Values



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Won't Too Much Wind Power Cause the System to Collapse?

- Often comes up as a question after a system disturbance resulting in a blackout
- Related questions about system stability are driving world-wide wind turbine and wind plant model development and verification efforts (IEEE, UWIG, WECC, manufacturers, TSOs, utilities)
- Detailed simulations of DFIGs shows that wind plants can actually aid system stability by providing LVRT and dynamic var support to reduce voltage excursions and dampen swings

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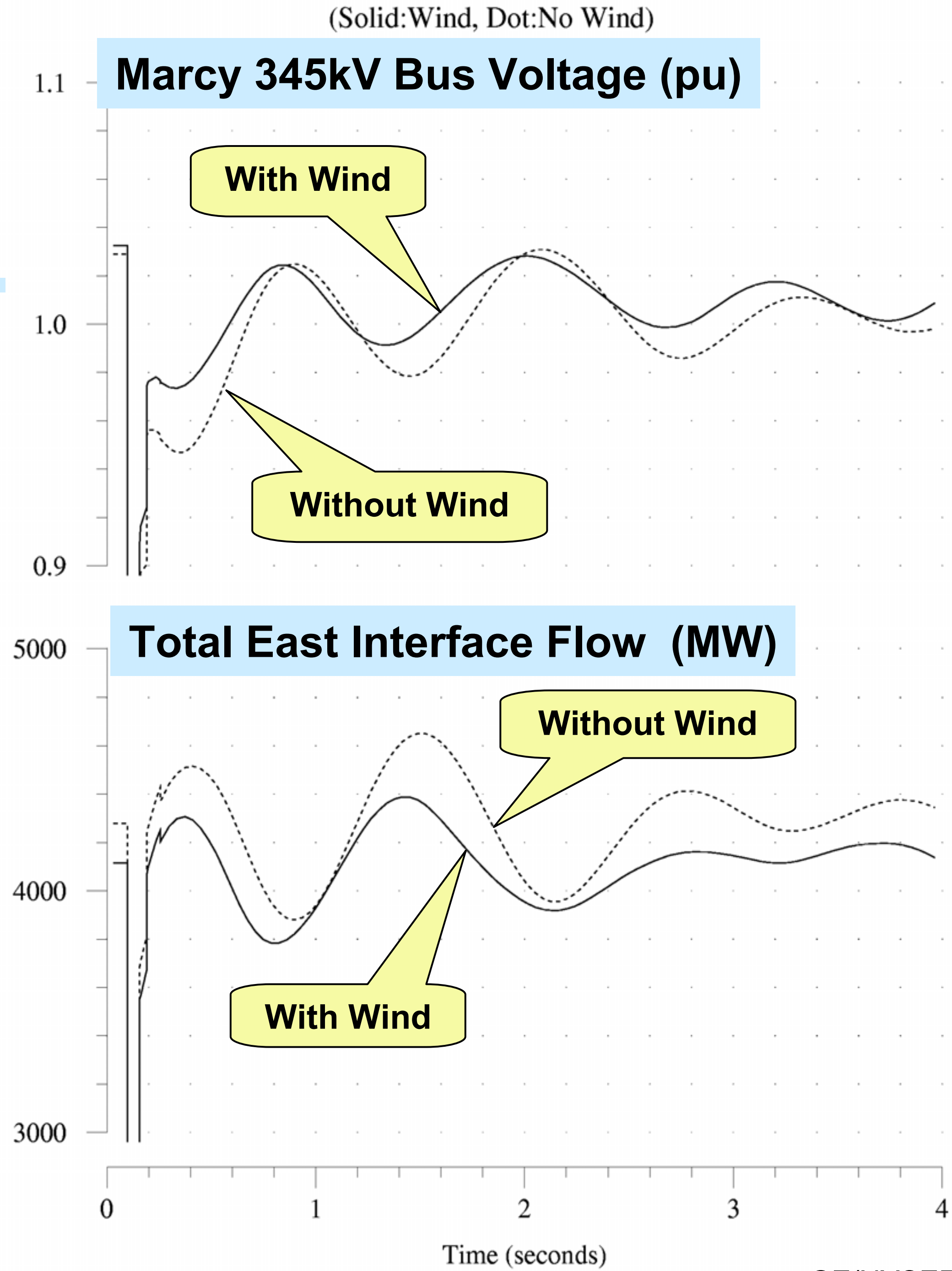
Impact of Wind Generation on System Dynamic Performance

- Fault at Marcy 345 kV bus
- Severe contingency for overall system stability
- Simulation assumes vector-controlled wind turbines
- Wind generation improves post-fault response of interconnected power grid



source:GE/NYSERDA

What If the Wind Stops Blowing Everywhere at the Same Time?

- Meso-scale wind forecasting techniques provide the answer
- Significant benefit to geographical dispersion
  - Dispersion provides smoothing in the long term
  - Aggregation provides smoothing in the short term
- Extensive modeling studies have shown no credible single contingency leading to simultaneous loss of capacity in a broad geographical region

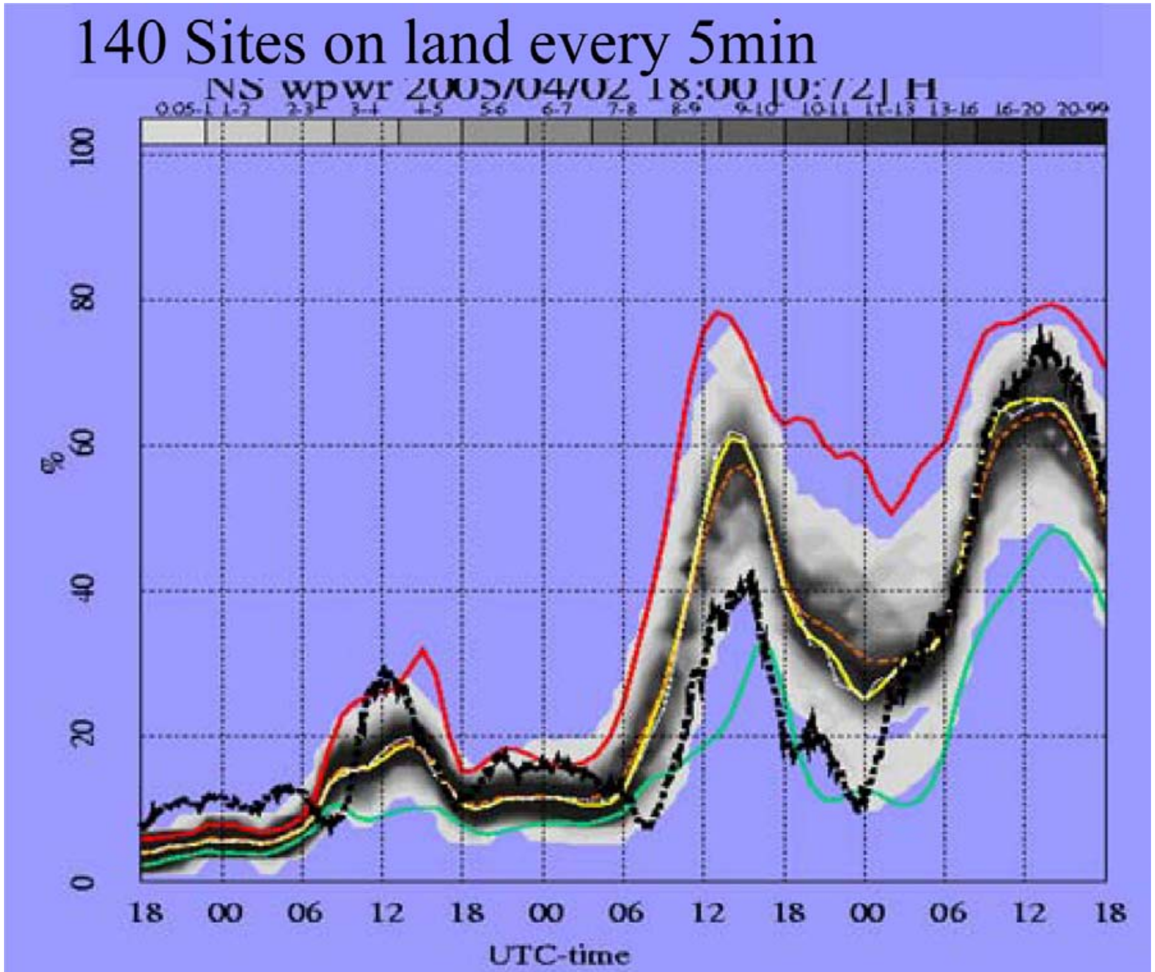
How Do You Deal with the Unpredictable Nature of the Wind?

- Again, wind forecasting provides the answer
- Wind plant output can be forecast within some margin of error, and forecasts are getting better

Wind Plant Output Forecast Accuracy

	Currently	5-10 Years
Hour Ahead	4-6%	3-5%
Day Ahead	15-20%	10-15%

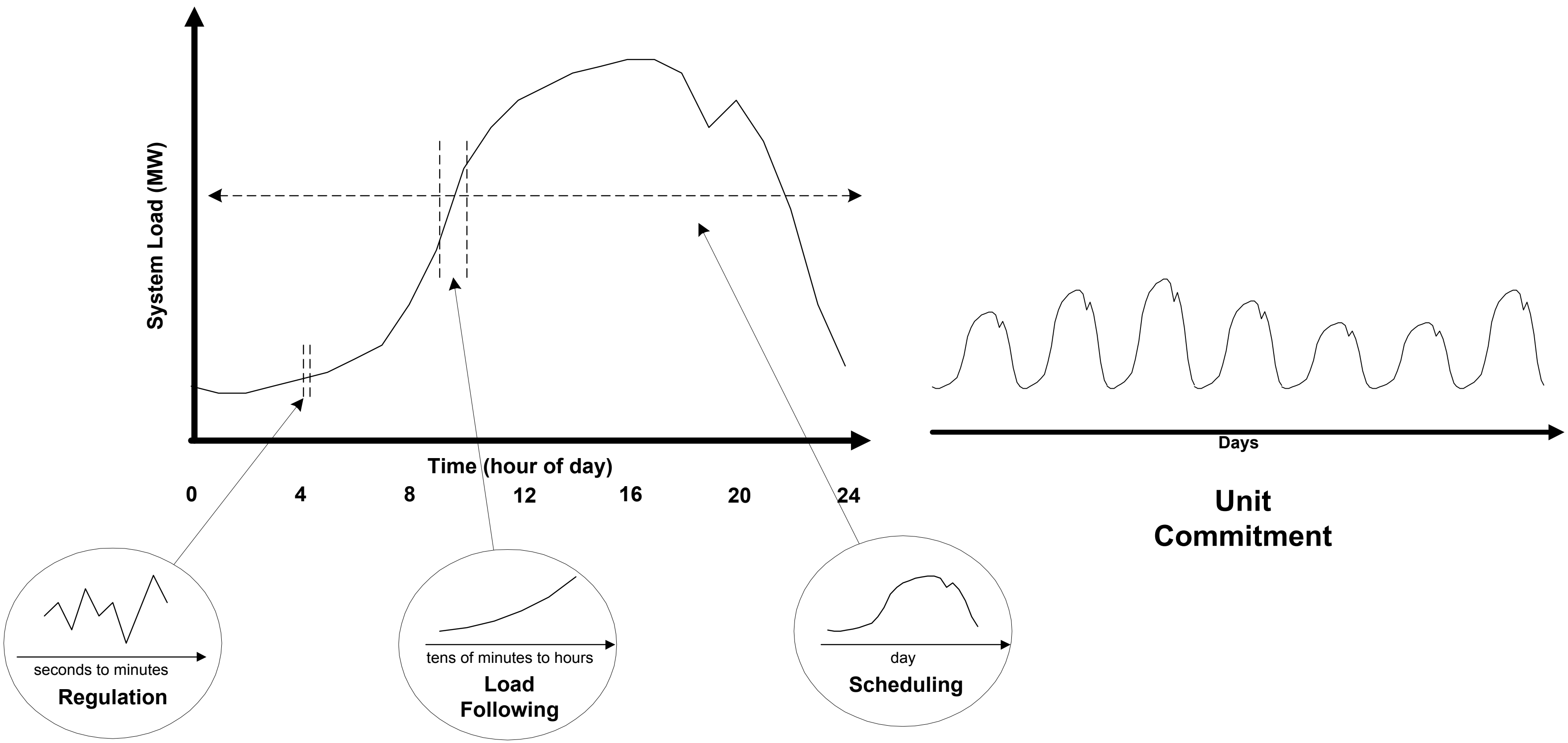
Forecasting and Balancing Markets Reduce Impacts



How To Deal With the Continually Changing Output of the Wind Plant

- Wind plant output and net load variations are well characterized in sec, min, and hr time frames
- Best handled through deep, liquid real-time energy markets to financially settle schedule deviations
- At increasing (10-20%) penetration levels, small but measurable increase in regulating or ramping requirement can generally be met by existing generation with some modest cost increase
- At higher (30%+) levels, minimum load problems may appear
  - More flexible generation
  - Price responsive load or energy storage
  - Larger control areas and stronger interconnections
  - Curtailment

Time Scales of Interest



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Summary of Wind Plant Ancillary Service Costs

Ancillary Services Cost Comparison

Date	Study	Wind Capacity Penetration (%)	Regulation Cost ($/MWh)	Load Following Cost ($/MWh)	Unit Commitment Cost ($/MWh)	Gas Supply Cost ($/MWh)	Total Operating Cost Impact ($/MWh)
2002	BPA	7	.19	.28	1.00-1.80	na	1.47-2.27
2003	GRE	16.6	na	na	na	na	4.53
May ‘03	Xcel-UWIG	3.5	0	0.41	1.44	na	1.85
Sep ‘04	Xcel-MNDOC	15	0.23	na	4.37	na	4.60
July ‘04	CA RPS Phase III	4	0.36	na	na	na	na
June ‘03	We Energies	4	1.12	0.09	0.69	na	1.90
June ‘03	We Energies	29	1.02	0.15	1.75	na	2.92
2005	PacifiCorp	20	0	1.6	3.0	na	4.6
April ‘06	Xcel-PSCo	10	0.20	na	2.26	1.26	3.72
April ‘06	Xcel-PSCo	15	0.20	na	3.32	1.45	4.97

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Integrating More Wind in the Future

- Interconnection Options
  - Improvements in wind-turbine and wind-plant models
  - Improvements in wind-plant operating characteristics
- Integration Options
  - Carefully evaluating wind-integration operating impacts
  - Integration of wind plant output over large geographical regions
  - Improvements in the flexibility of operation of the balance of the system generating mix
  - Incorporating wind-plant output forecasting into utility operations

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Integrating More Wind (con't)

- Market Operation and Transmission Policy Options
  - Upgrading and expanding transmission systems
  - Making better use of physically (in contrast with contractually) available transmission capacity
  - Developing well-functioning hour-ahead and day-ahead markets and expanding access to those markets
  - Adopting market rules and tariff provisions that are more appropriate to weather-driven resources
  - Consolidating balancing areas into larger entities or accessing a larger resource base through the use of dynamic scheduling or some form of ACE sharing

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Utility Wind Integration State of the Art

Prepared by

Utility Wind Integration Group

in cooperation with

American Public Power Association (APPA)
Edison Electric Institute (EEI)
National Rural Electric Cooperative Association (NRECA)

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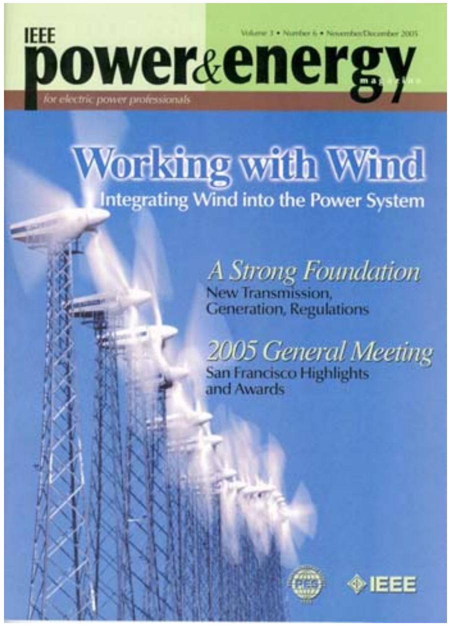
Wind Power Coming of Age

- IEEE PES Wind Power Coordinating Committee established 2005
- IEEE PES *Power & Energy* magazine special issue on wind integration:
  Nov-Dec 2005
- IEEE/NERC/AWEA/UWIG
  Wind Policy Symposium:
  April 2006
- AWEA Transmission Task Force
- UWIG User Groups



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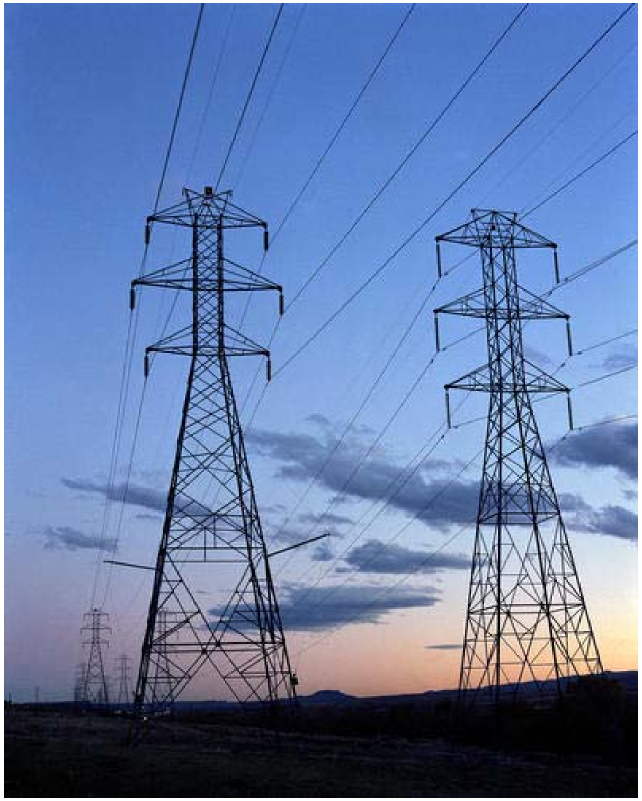
UWIG User Groups

- Wind Plant Modeling and Interconnection
- Operating Impact and Integration Study
- Market Operation and Transmission Planning
- Turbine Operation and Maintenance
- Distributed Wind Applications



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