Wind Energy Development in the US

Presented at Joint NERC

OC/PC Meeting

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UWIG
Utility Wind
Integration Group

J. Charles Smith
Executive Director
UWIG

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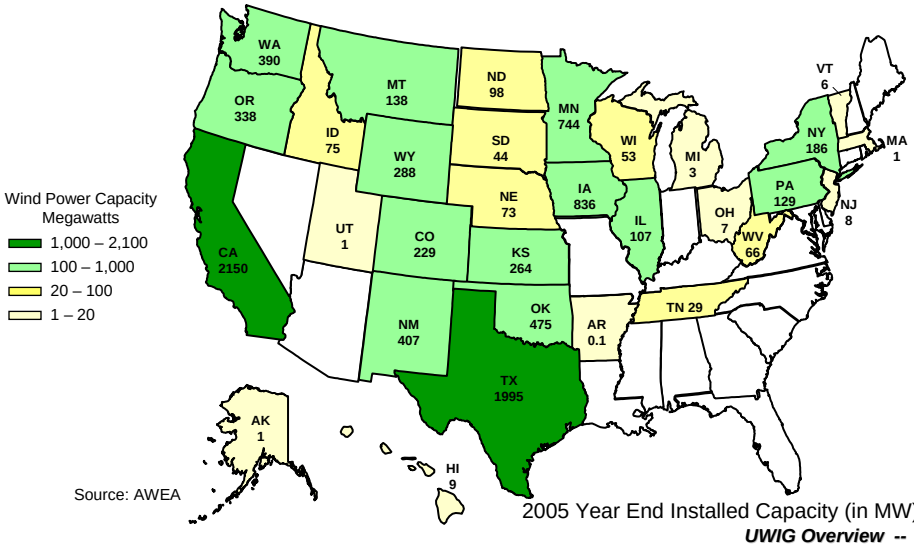
US Wind Capacity by State



Source: AWEA

2005 Year End Installed Capacity (in MW)

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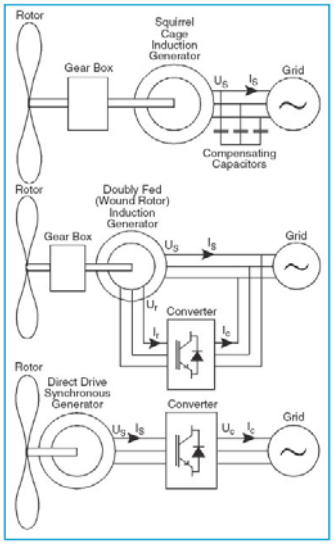
Evolution of Wind Turbine Technology

Past →

Present →

Future →



Source: IEEE Power & Energy Magazine

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How Does Wind Plant Performance Compare?

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

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

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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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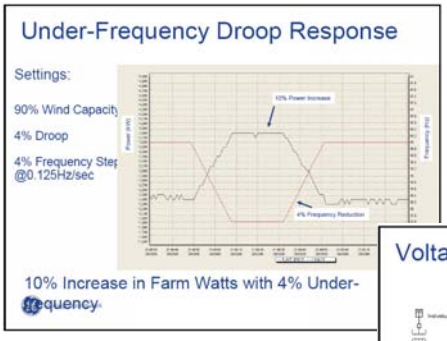
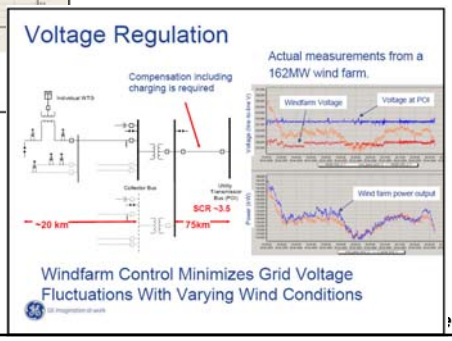
Wind Plant Control Capability





Source: GE Energy

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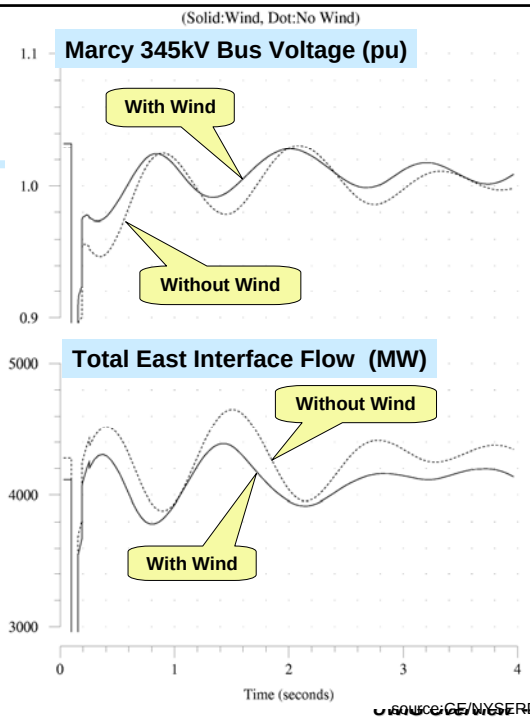
Impact of Wind Generation on System Dynamic Performance

- 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

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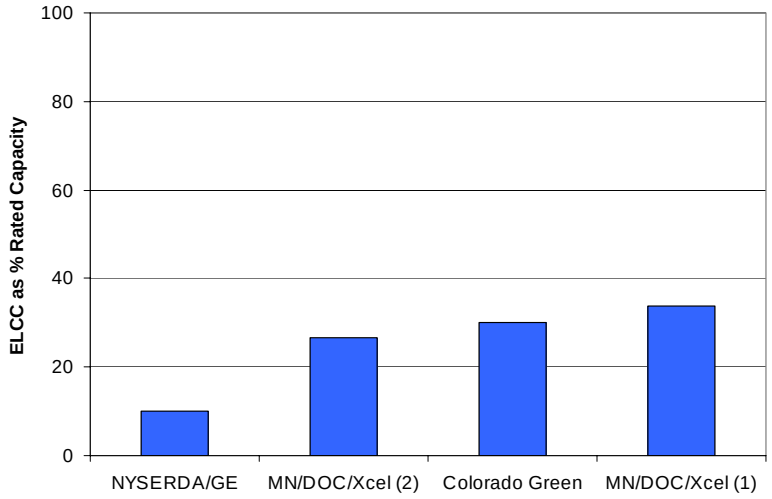
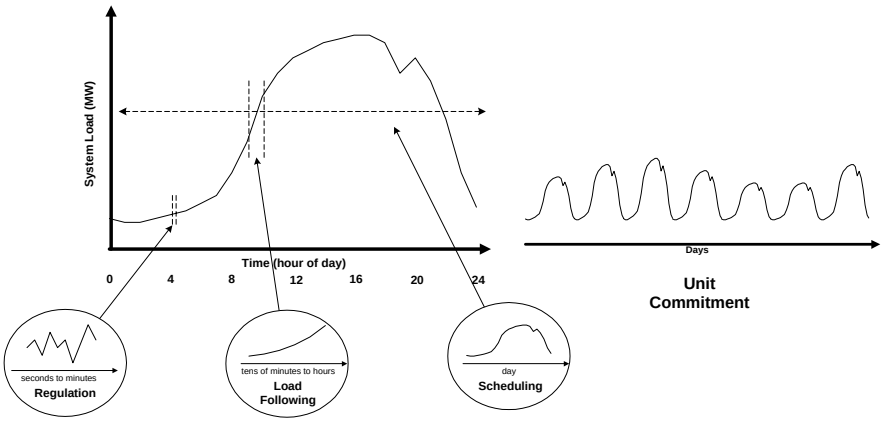
What To Do When the Wind Doesn't Blow

- 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 Wind Capacity Values



Time Scales of Interest



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

Integrating More Wind in the Future

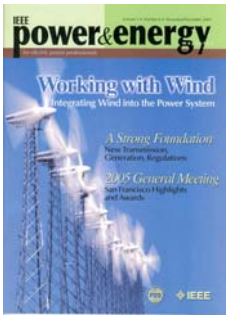
- Improvements in wind-turbine and wind-plant models
- Improvements in wind-plant operating characteristics
- Improvements in the flexibility of operation of the balance of the system generating mix
- Carefully evaluating wind-integration operating impacts
- Incorporating wind-plant output forecasting into utility control-room operations

Integrating More Wind in the Future (con't)

- Making better use of physically (in contrast with contractually) available transmission capacity
- Upgrading and expanding transmission systems
- 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

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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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)

Utility Wind Integration Group
P.O. Box 2787 Reston, VA 20195
703-860-5160
www.uwig.org

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