Wind Integration Study Overview

Inverter-based Generation Power System Performance Needs Workshop
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No rigorous definitions
- Unique characteristics of wind generation don’t fit conventional “slots” very well
- General meanings:
  What does it take to make it work?
  What does that cost?

Interconnection relates generally to “volts and VArS”
Integration is primarily focused on operations and economics, within technical and reliability constraints

Bulk electric system focus
General Components

- Grid impacts
  - Voltage regulation and reactive power management
  - Short-circuit behavior
  - Dynamic performance
  - Grid codes and interconnection requirements

- Operating impacts
  - Unit commitment & scheduling
  - Real-time operation
  - Operational overlays – market structures, approaches for dealing with uncertainty, etc.

- Planning
  - Capacity contribution from wind plants
  - Overall portfolio considerations
IEA Task 25 Conclusions – “State of the Art” for Wind Integration Assessment

- Wind power production time series for the geographic diversity assumed
- Utilizing wind forecasting best practice for the uncertainty of wind power production
- Examining wind variation in combination with load variations, coupled with actual historic utility load and load forecasts
- Capturing system characteristics and response through operational simulations and modeling
- Examining actual costs independent of tariff design structure.
## EnerNex Wind Integration Studies

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Large scale renewable studies by GE

These studies were commissioned by the Energy Commissions and ISOs of each region...

- Examining the Feasibility of 100+ GW of new wind and other renewable resource additions
- Considering Operability, Costs, Emissions, Transmission Constraints, Forecasting

Each successive study has raised the threshold for acceptable penetration of wind and solar

2004 New York:
- 3 GW Wind
- 10% of Peak Load
- 4% of Energy

2005 Ontario:
- 15 GW Wind
- 50% Peak Load
- ~30% Energy

2006 California:
- 13 GW Wind
- 3 GW Solar
- 5 GW Bio & Geo
- 26% Peak Load
- 15% Energy (33% Total)

2007 Texas:
- 15 GW Wind
- 25% Peak Load
- 17% Energy

2008-9 Western Wind & Solar:
- (all of Western US)
- 72 GW Wind
- 15 GW Solar
- 50% Peak Load
- 27% Energy
Major Study Results

Large interconnected power systems can accommodate \textit{variable} renewable generation (Wind + Solar) penetration levels exceeding 25% of peak loads; \textit{total} renewables (including Wind, Solar, Geothermal, Bio) exceeding 30% of total energy

But not by doing more of the same.....

To reach higher levels of wind generation and other renewables:

- Reinvest in infrastructure
- Implement balanced market rules
- Incentivize owners and operators to better utilize technology and assets

The debate has changed:
No longer:  “Is it possible?”
Now:  “How do we get there?”
Lessons learned

Higher levels of wind generation penetration increase need for:

- **Transmission reinforcement**
- Wind forecasting
- **Operational flexibility of the balance of the generation portfolio**
  (Quick Start + Faster Ramp Up/Down + Lower Turn Down + Load Following)
- New operating strategies during light load hours & other high risk periods
- New ancillary services rules & incentives for ALL technologies
- Coordination across neighboring control areas
- Deployment of modern grid-friendly Wind and Solar Power Plants

**Policy and market structures ... key to successful integration of wind and other renewables**
U.S. Wind Integration Studies Summary

- Primary focus on operational issues
  - Unit commitment and economic dispatch
  - Impacts of additional variability and uncertainty in net demand
  - Costs related to integration
  - Effects of transmission constraints

- “Standard” SOA wind plant operational capabilities
  - Sufficient reactive capability to support power delivery
  - LVRT; wind plants do no re-define largest contingency
  - Excess wind generation is curtailed ("dump energy")
U.S. Wind Integration Studies Summary (cont)

- Assess impacts of additional variability and uncertainty on secondary and tertiary frequency responsive reserves
  - Regulation
  - Load following
  - “Normal” operating conditions
  - Severe wind ramp events

- Exception is ISO-NE:
  - “Task 2” report
  - Consultants’ recommendations for interconnection, interoperability, and forecasting requirements
  - To be considered in market rules updates
  - Technology neutral; “plant” focus
RECOMMENDATIONS FOR WIND PLANTS
Voltage and Reactive Power Recommendations

- Comply with FERC and NERC
- Pursue 0.95 Power Factor at POI
- Specify a minimum level of dynamic reactive power capability
- Enforce prescriptive interpretation of the rules
- Schedule voltages
- Avoid power factor control
- Be careful of control of multiple plants
- Adopt permissive rules for low power
- Consider no-wind VArS
Performance During and After System Disturbances

- Comply with FERC and NERC
- Avoid divergent fault-ride through specifications
- Frequency ride-through as per NPCC rules
- Don’t bother with explicit dF/dt requirements
- Allow, or even encourage, reduced power output for deep voltage events
- Allow or encourage increase in reactive power for deep voltage events.
- Avoid over prescribing fault performance
- Prohibit islanding
- Specify recovery and re-start rules after system and wind disturbances
- Substation and station service design
Active Power Control Recommendations

- Engage with FERC and NERC
- Require curtailment capability, but avoid requirements for excessively fast response
- Require capability to limit rate of increase of power output
- Require capability to accept AGC signals
- Encourage or mandate reduction of active power in response to high frequencies
- Consider requiring the capability to provide increase of active power for low frequencies
- Consider requiring inertial response in near future
Harmonics

- Wind turbines not significant sources of harmonic distortion, but
- IEEE-519 is recommended standard
- Guidance on medium voltage capacitor applications/background distortion
Modeling

- Follow forthcoming NERC guidance regarding model requirements
- Use open structure models, when possible
- Always make sure data is up-to-date
- Short-Circuit Behavior
- Avoid Point-on-Wave modeling
Communications between Wind Plants and ISO-NE Operations

- Wind Plant Operator
- Monitoring signals from wind plant to ISO
- Control signals from ISO to wind plant
- Communication standards
Distribution Connected Wind Generation

- Reduced interconnection requirements for 100kW < rating, 10 MW
- Default to No LVRT or voltage regulation
- No islanding, ever
- No recloser action with turbines running
- Communicate: status (on/off), power, anemometry
- Accept shut-down commands for ISO
RECOMMENDATIONS FOR WIND GENERATION FORECASTING
Forecast System Type and Components

- Centralized (ISO-administered)
- Ramp forecasting
- Severe Weather
- Type of Forecast
Selection of a Forecast Provider

- Trial Period
- Provider Evaluation
- Multiple Providers
- Forecast Methods
- Offshore Forecasting
Forecast Performance Evaluation Issues

- Methods and Metrics
- Data Requirements
- Production Data
- Meteorological Data
Operator Considerations

- Control Room Integration
- Education and Training
- Provider/User Communication
RECOMMENDATIONS FOR GRID OPERATIONS WITH WIND GENERATION
Applying Results from Wind Integration Studies

- Curtailment Policies
- Enabling Ramp Rate Controls
- Enabling Under-frequency controls
- Use of AGC and dispatch to wind plants
- Start-up and Shut Down
Wind Plant Scheduling and Congestion

- Turbine availability/maximum possible production to be known by Operator
- Also must be communicated to forecaster
Communications Infrastructure for Managing Wind Generation

- Consider adopting IEC 61400-25 series of standards
- Relatively new, but gaining some traction
- Adoption would support development of future tools and applications not anticipated at this time
- Would assist with distribution-connected turbine operation
Operations with Distribution Connected Wind Generation

- Distribution-connected turbines are not as “visible” to system operators

- Installations should be tracked
  - Incorporation into forecasts when significant
  - Allows assessment of loss-of-generation due to distribution, bulk system events
Best Practice for Determination of Wind Generation and Wind Plant Capacity Value

- Recommended Method for Aggregate Wind Generation Capacity Valuation
- Allocating Aggregate Capacity to Individual Plants