Integration Wind Energy into the Grid

GE Energy

Product Line 2.5
Stefan Hartge
Customer Value Manager
As Wind Power Plants increase in size and contribution ...

Network systems require that wind power plants:

› Provide Controlled and Predictable Power Response From Variations in Wind, Turbine and Grid Frequency

› Must remain connected to the grid following disturbances – in short, they must remain stable

Good locations for wind plants often entail connection to relatively weak transmission systems

Wind plants must perform like a conventional power plant
What makes a Wind Plant “Grid Friendly”?

- Does not trip during Faults and other System Disturbances ...ride through capability
Grid Fault Ride-Through Requirements

Challenge:

- Requirements vary considerably by country/utility/voltage level
- Does not often distinguish between single phase vs three phase faults
- Voltage level specified at Point of Interconnection (POI) ... levels at each at turbine terminals is different depending upon plant design
- Assumes single fault events followed by recovery

OEM Response: Standard Ride-Through Requirement That Covers Most Cases
Ride-Thru Capabilities

- Remain on-line and feed reactive power through system disturbances
- Meets present and emerging grid requirement with Low/Zero Voltage Ride Through (LVRT/ZVRT) capability
- Meets transmission reliability standards similar to thermal generators

Fault Recovery
- Voltage recovery better than conventional generator
Testing & Validation Results
3-Phase, 200ms, Zero Voltage Fault

Active Power (delivered to Medium Voltage bus)

Voltage Level

Medium voltage bus drops to 0.0

Power recovers to pre-disturbance level in <200ms
What makes a Wind Plant “Grid Friendly”?  

- Does not trip during Faults and other System Disturbances ... ride through capability
- Regulates Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ... Ramp Rate Control
- Reacts to Changes in Grid Frequency ... Frequency Droop Control
Voltage Regulation

- Regulates Grid Voltage at Point of Interconnection
- Minimizes Grid Voltage Fluctuations Even Under Varying Wind Conditions

Actual measurements from a 162MW wind plant

Voltage at POI
Wind Plant Voltage
Wind Plant Power Output
Average Wind Speed

Voltage Regulation
Like A Conventional Power Plant
Active Power Controls

Typical Grid Requirements
- Ramp rates
- Power curtailment
- Power droop w/ frequency

Power Ramp Rates
- $P_{ad}$ - Available Power
- $P_{at}$ - Actual Power

Power Droop Test
- 2% Frequency Increase
- 50% Power Reduction

Curtailment Example
What makes a Wind Plant “Grid Friendly”? 

- Does not trip during Faults and other System Disturbances ...ride through capability
- Regulates Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ...Ramp Rate Control
- Reacts to Changes in Grid Frequency ...Frequency Droop
- Controls the Insertion and Removal of Large Power Blocks ...Startup and Shutdown Control
Wind Plant Startup

Settings:

- Turbines Sequenced On at 20 second Intervals
- Desired Ramp Rate Limit 3MW/Min

Wind Plant Power Ramping at less than 3MW/Min

1 Minute Average Ramp Rate (kW/sec)

Turbines transitioning Online

Wind Plant Output Controlled During Startup Conditions
Wind Plant Shutdown

Settings:

Shutdown Interval Set to 5 Minutes

Wind Plant Power Ramping to Zero in 5 Mins

Turbines transitioning Off-line

Wind Plant Output Controlled During Shutdown Conditions
What makes a Wind Plant “Grid Friendly”?

- Does not trip during Faults and other System Disturbances ...ride through capability
- Regulates Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ...Ramp Rate Control
- Reacts to Changes in Grid Frequency ...Frequency Droop
- Controls the Insertion and Removal of Large Power Blocks ...Startup and Shutdown Control
- Provides Reactive Power When Needed ...Wind Free Reactive Power
WindFREE Reactive Power

- Wind Turbine converter can deliver reactive power (kVAR) without wind (kW).
- Benefits weak grids and systems with high wind penetration.
- Voltage support continues without active power generation...even following trips.

Reactive Power - even without wind.
2.5 WTG Reactive Power Capability

WindFREE Reactive Power

Available VAR

Cos 0.90

Cos 0.95
What makes a Wind Plant “Grid Friendly”? 

- Does not trip during Faults and other System Disturbances ... ride through capability
- Regulates Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ...Ramp Rate Control
- Reacts to Changes in Grid Frequency ...Frequency Droop
- Controls the Insertion and Removal of Large Power Blocks ...Startup and Shutdown Control
- Provides Reactive Power When Needed ...Wind Free Reactive Power
- Provides inertial response to address under-frequency events ...WindINERTIA
Why Inertial Response: System Needs

- Increasing Dependence on Wind Power
  - Large Grids with Significant Penetration of Wind Power
- Modern variable speed wind turbine-generators do not contribute to system inertia
- System inertia declines as wind generation displaces synchronous generators (which are de-committed)
- Result is deeper frequency excursions for system disturbances
- Increased risk of
  - Under-frequency load shedding (UFLS)
  - Cascading outages

Inertial response will increase system security and aid large scale integration of wind power
An Example:
14GW, mostly hydro system, for trip of a large generator

- Reference Case: Without WindINERTIA frequency excursion is ~4% worse.
- With WindINERTIA: frequency excursion is ~9% better.
Making a Wind Plant “Grid Friendly”

- Regulates Plant Voltage and Power
- Reactive power regulation to meet grid needs ... Dynamic VAR Control
- Limits the Rate of Change of Power from Variations in Wind Speed ... Ramp Rate Control
- Reacts to Changes in Grid Frequency ... Frequency Droop, Inertial Response
- Controls the Insertion and Removal of Large Power Blocks ... Startup and Shutdown Control
Integration Wind Energy into the Grid

GE’s 2.5xl