What is a Wind Plant?
As Wind Power Plants increase in size and number ...

- Wind plants have a greater impact on the grid
- Displace other generation, so wind needs to provide its share of system support
- Continuity of wind generation contribution becomes essential to grid reliability
- Behavior during disturbances needs to be predictable

“Grid friendliness” is essential to wind energy’s continued growth
Grid Friendly Wind Power Plant

WindCONTROL™
Voltage and power regulation like a conventional plant

WindFREE™ Reactive Power
Reactive Power even with no wind

WindRIDE-THRU™
Uninterrupted turbine operation through grid disturbances

Utility Transmission System

WindSCADA™
Tools to operate, maintain, and manage the wind plant
What makes a Wind Plant “Grid Friendly”?

- Not trip during faults and other system disturbances ...
  
  *ride through capability:* WindRIDE-THROUGH™
Ride-Thru Capabilities
3-phase zero retained voltage, 200ms fault:
(GE Standard ZVRT offering)  P, Q (Mw,Mvar)

Power recovers to pre-disturbance level in <200ms

Medium voltage bus drops to 0.0

Field Test Results (2.5 unit)
3-phase 18.5% retained voltage, 700ms fault:
P, Q (Mw,Mvar)

Reactive Power well behaved: supports grid during voltage depression
What makes a Wind Plant “Grid Friendly”? 

- Not trip during faults and other system disturbances ... *ride through capability*

- Regulate plant voltage & reactive power: WindCONTROL™
Voltage & Reactive Power Controls

- Regulates Grid Voltage at Point of Interconnection
- Minimizes Grid Voltage Fluctuations Even Under Varying Wind Conditions
- Regulates Total Wind Plant Reactive Power through Control of Individual Turbines

Actual measurements from a 162MW wind plant

Voltage and Reactive Power Regulation Like A Conventional Power Plant
What makes a Wind Plant “Grid Friendly”?

- Not trip during faults and other system disturbances ... *ride through capability*
- Regulate plant voltage and reactive power
- Limits the amount and/or rate of change of power from variations in wind speed ... *Ramp Rate Control : WindCONTROL™*
Curtailment example (30 MW plant)
What makes a Wind Plant “Grid Friendly”?

- Not trip during faults and other system disturbances ... *ride through capability*
- Regulate plant voltage and power
- Limits the rate of change of power from variations in wind speed ... *Ramp Rate Control*
- React to changes in grid frequency ... *Frequency Droop: WindCONTROL™*
Under-Frequency Droop Response

Initial Steady-State Conditions:

- Power curtailed to 90% of available wind
- 2.5% power increase for 1% frequency drop

Test:

- 4% frequency ramp-down @ 0.125 Hz/sec
- 10% increase in plant power with 4% under-frequency

Function has High Opportunity Cost: To Be Used Sparingly
What makes a Wind Plant “Grid Friendly”?

- Not trip during Faults and other System Disturbances ... *ride through capability*
- Regulate Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ... *Ramp Rate Control*
- React to Changes in Grid Frequency ... *Frequency Droop*
- Provide reactive power all the time: WindFREE™ 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: A valuable option – An unreasonable requirement

Field Test Results (2.5 unit)
What makes a Wind Plant “Grid Friendly”? 

- Not trip during Faults and other System Disturbances ... *ride through capability*
- Regulate Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed ... *Ramp Rate Control*
- React to Changes in Grid Frequency ... *Frequency Droop*
- Provide reactive power all the time ...
- Provide inertial response to large under-frequency events: WindINERTIA™
Field Tests Results:

Test count:
- 8 m/s - 19 tests
- 10 m/s - 19 tests
- 14 m/s - 52 tests
Conclusions

- Wind Turbines can stabilize the grid voltage by rapid, smooth bidirectional control of reactive power
- GE’s Wind Turbines can participate in system frequency control through active power control
- GE now offers a suite of grid friendly features to meet these system needs
- Need and demand for inertial response from WTGs has been growing
- The latest feature (WindINERTIA™):
  - has been field tested and a dynamic model created
  - behavior is not identical to synchronous machines
  - grid codes must recognize physical reality & constraints

Grid Friendly Wind Plants - key to the continued successful large scale integration of wind power
Thank you

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