Integration Wind Energy into the Grid

GE Energy

Product Line 2.5
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Customer Value Manager

imagination at work

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

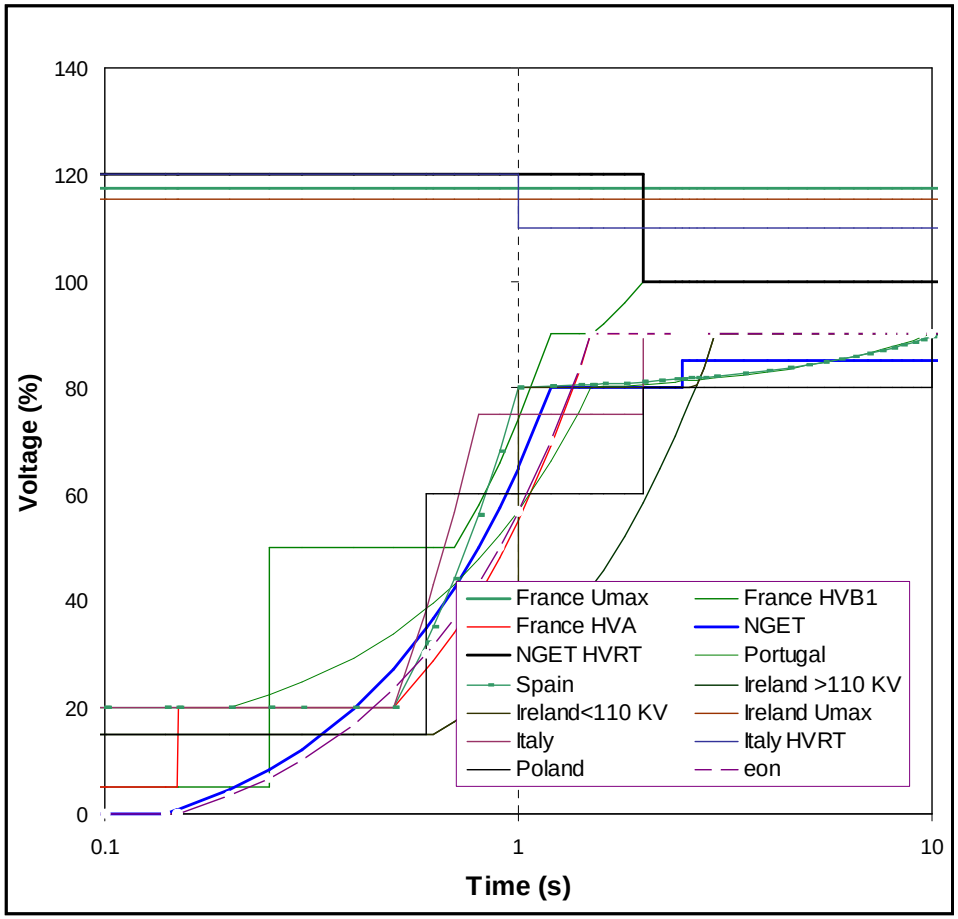
Good locations for wind plants often entail connection to relatively weak transmission systems

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



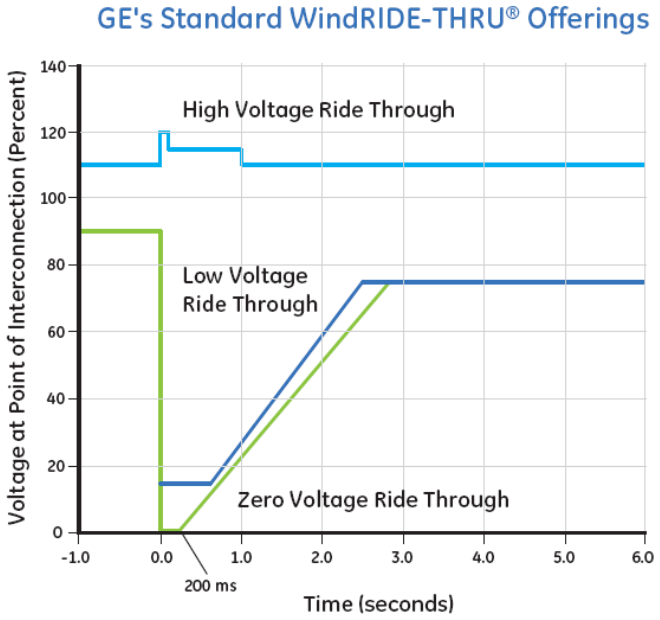
Challenge:

- 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

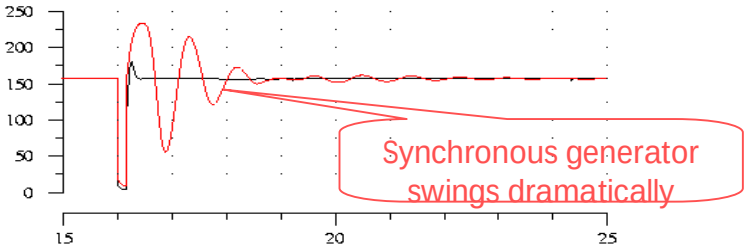
Ride-Thru Capabilities

- 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

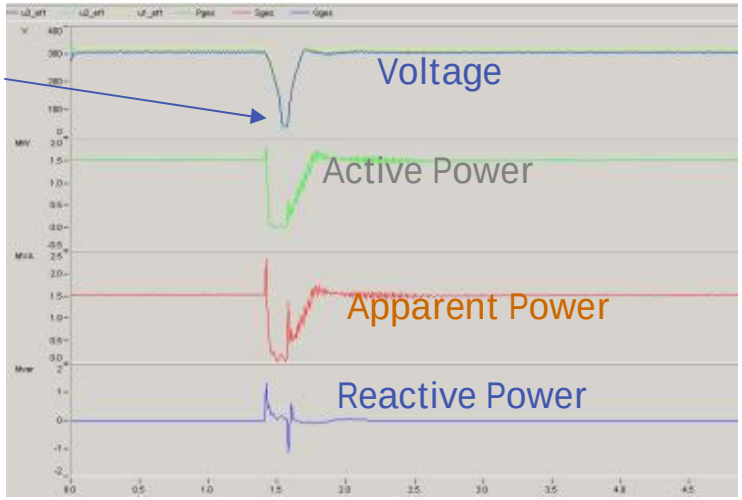


Fault Recovery

- Voltage recovery better than conventional generator

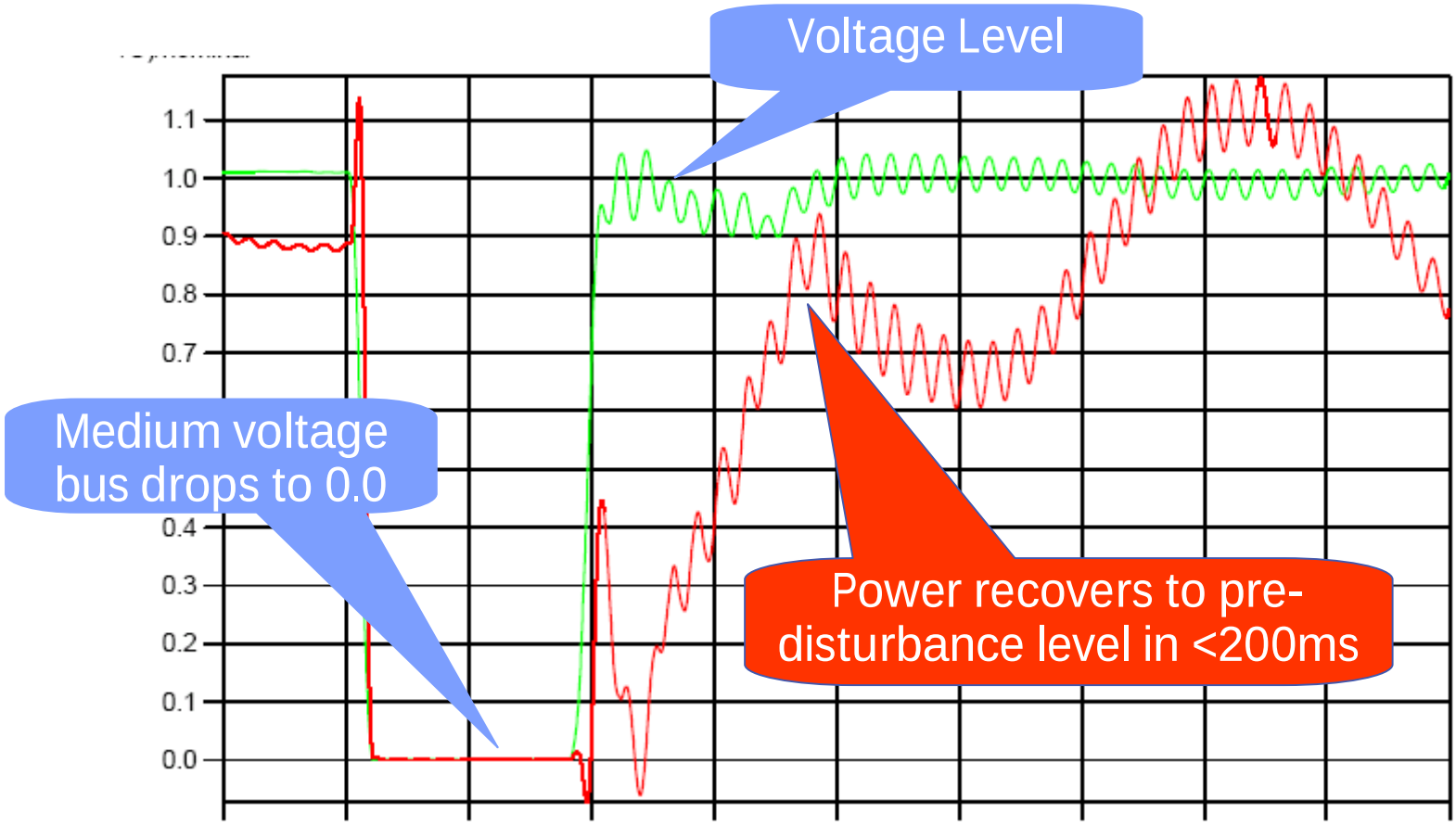


Zero Voltage Event



Testing & Validation Results

3-Phase, 200ms, Zero Voltage Fault



Active Power (delivered to Medium Voltage bus)

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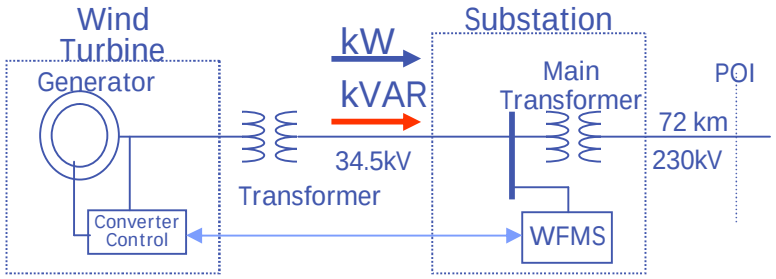
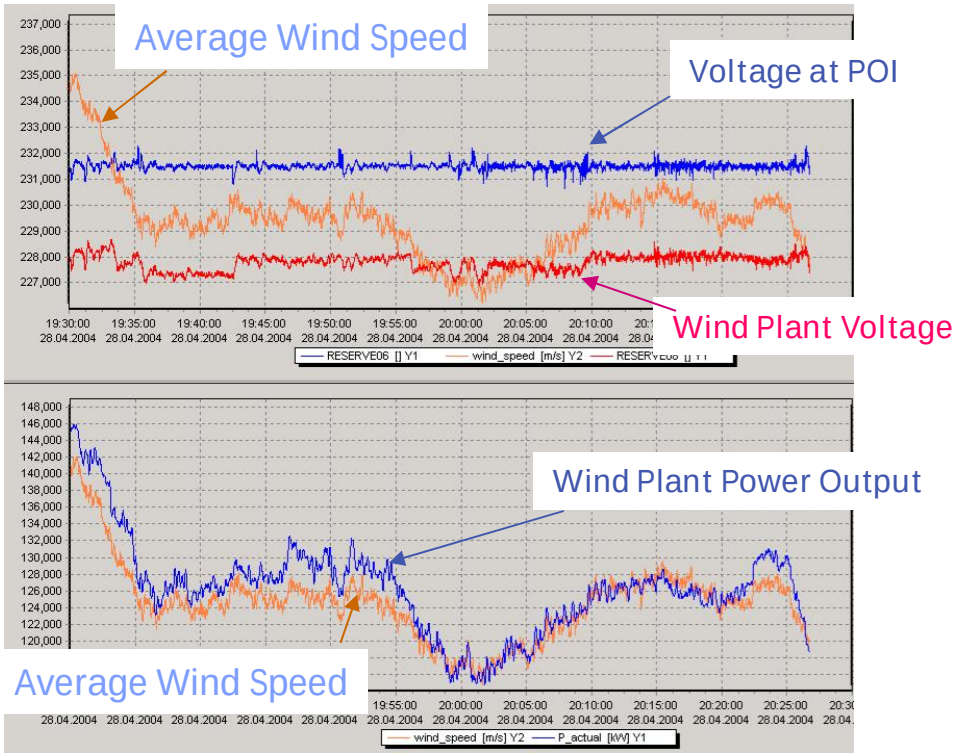
- Regulates Plant Voltage and Power
- Limits the Rate of Change of Power from Variations in Wind Speed … *Ramp Rate Control*
- Reacts to Changes in Grid Frequency … *Frequency Droop Control*

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



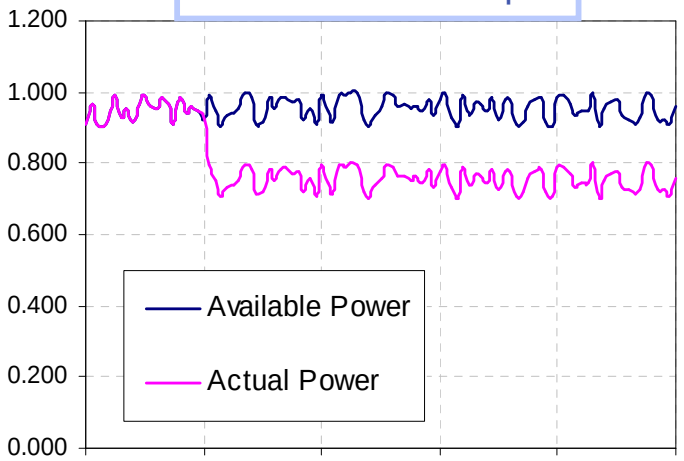
Voltage Regulation
Like A Conventional Power Plant

Active Power Controls

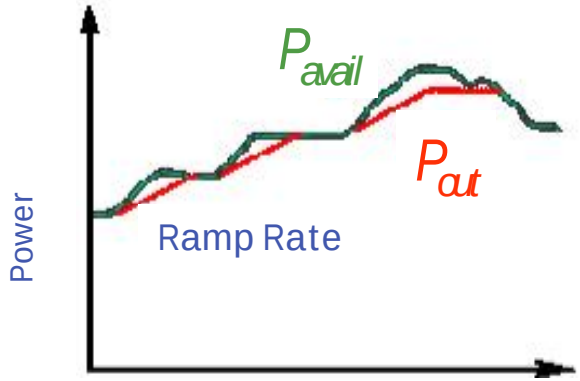
Typical Grid Requirements

- Ramp rates
- Power curtailment
- Power droop w/ frequency

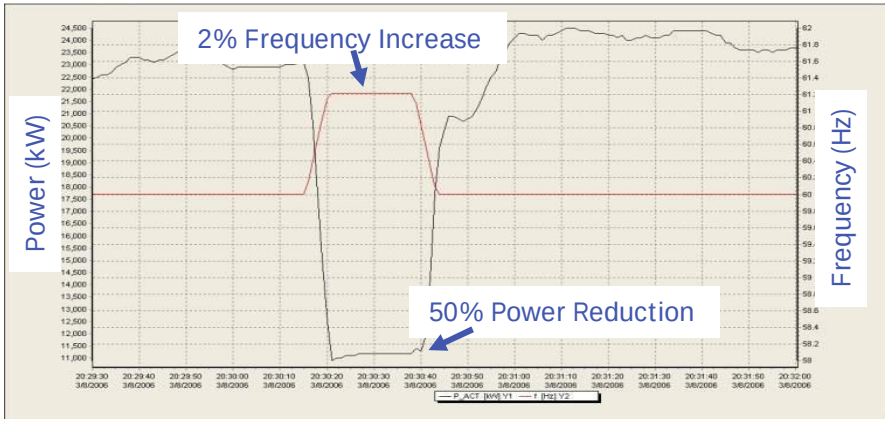
Curtailment Example



Power Ramp Rates



Power Droop Test



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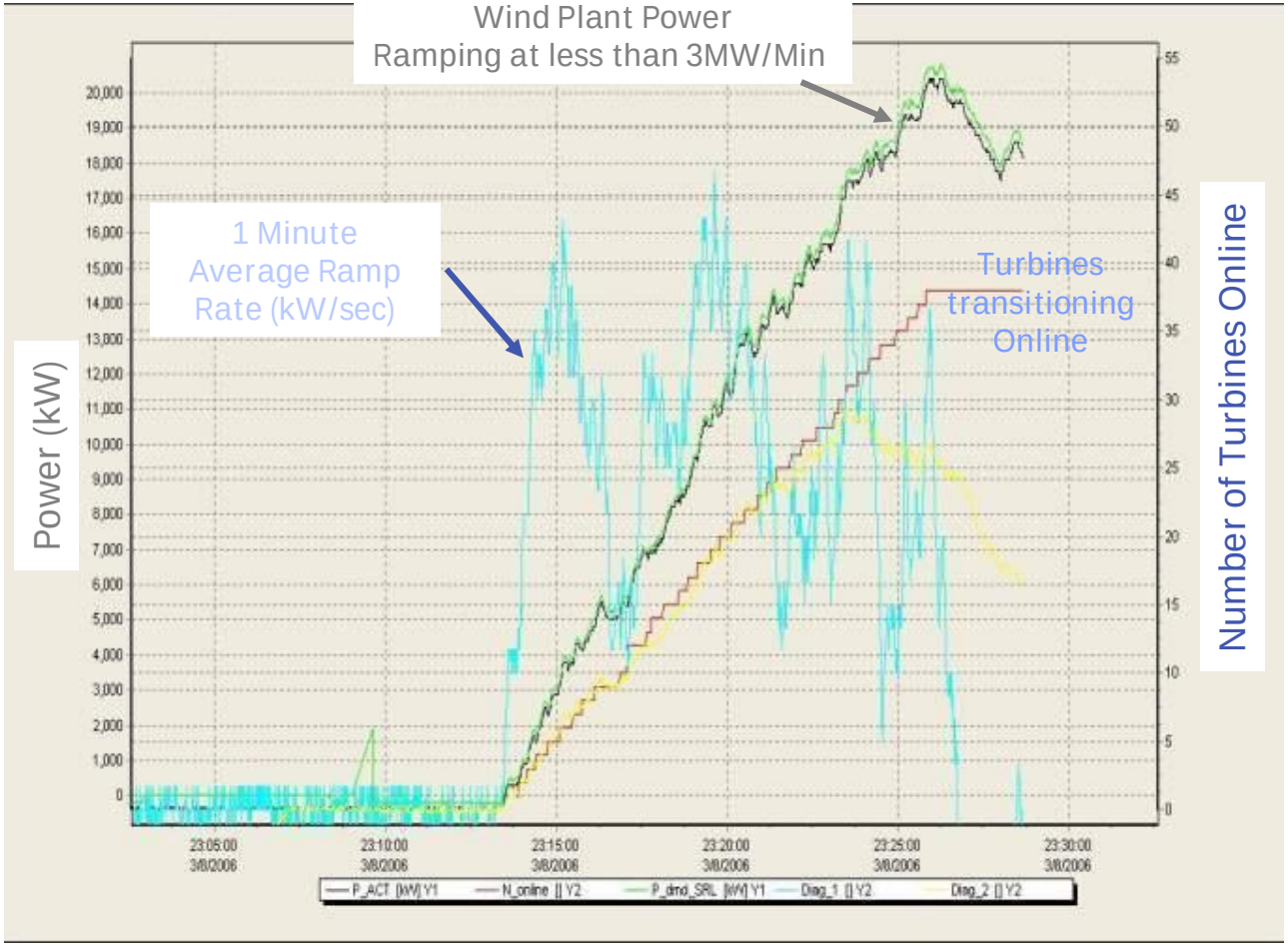
- Controls the Insertion and Removal of Large Power Blocks … *Startup and Shutdown Control*

Wind Plant Startup

Settings:

Turbines Sequenced On at 20 second Intervals

Desired Ramp Rate Limit 3MW/Min

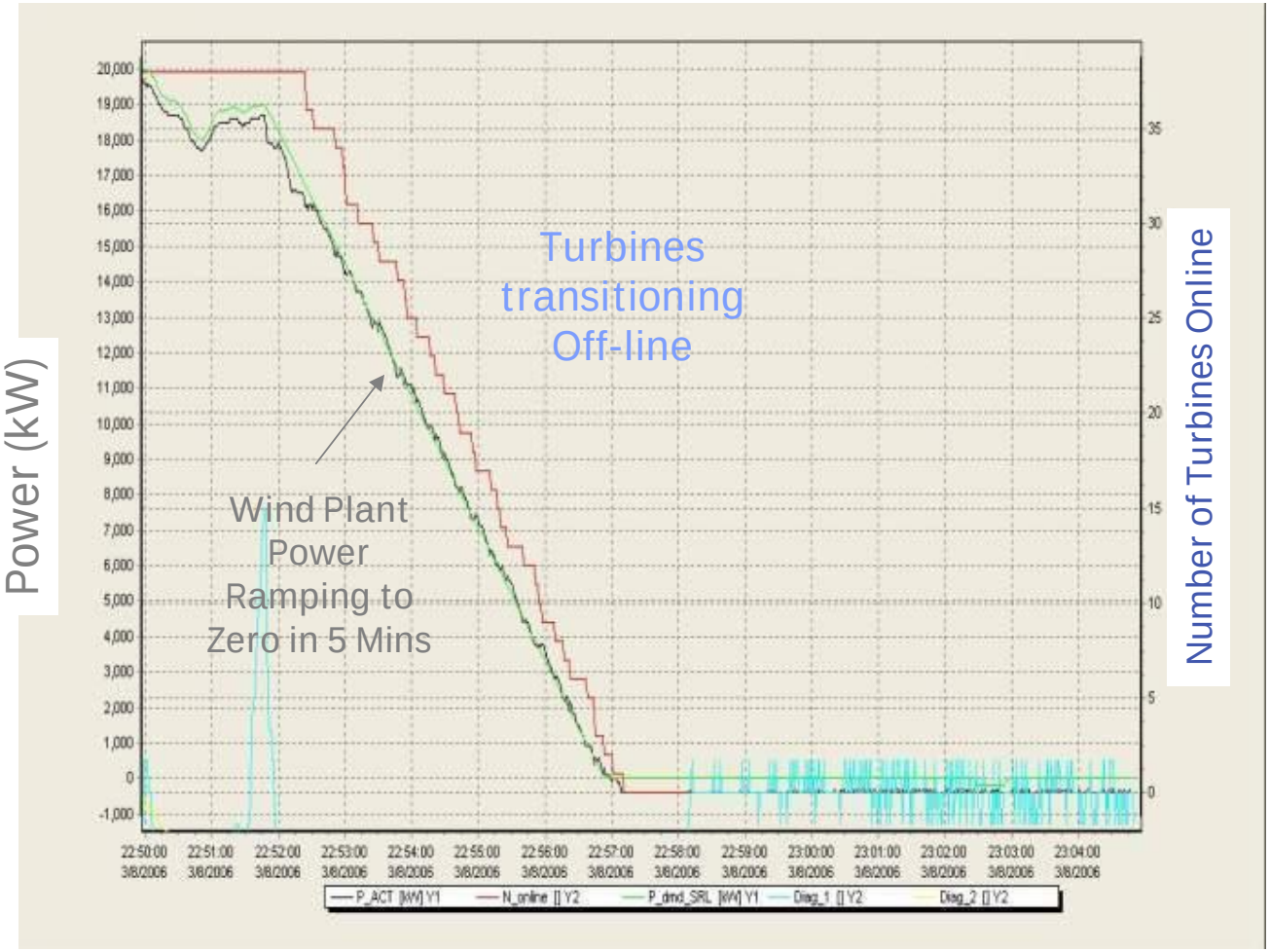


Wind Plant Output Controlled During Startup Conditions

Wind Plant Shutdown

Settings:

Shutdown Interval Set to 5 Minutes



Wind Plant Output Controlled During Shutdown Conditions

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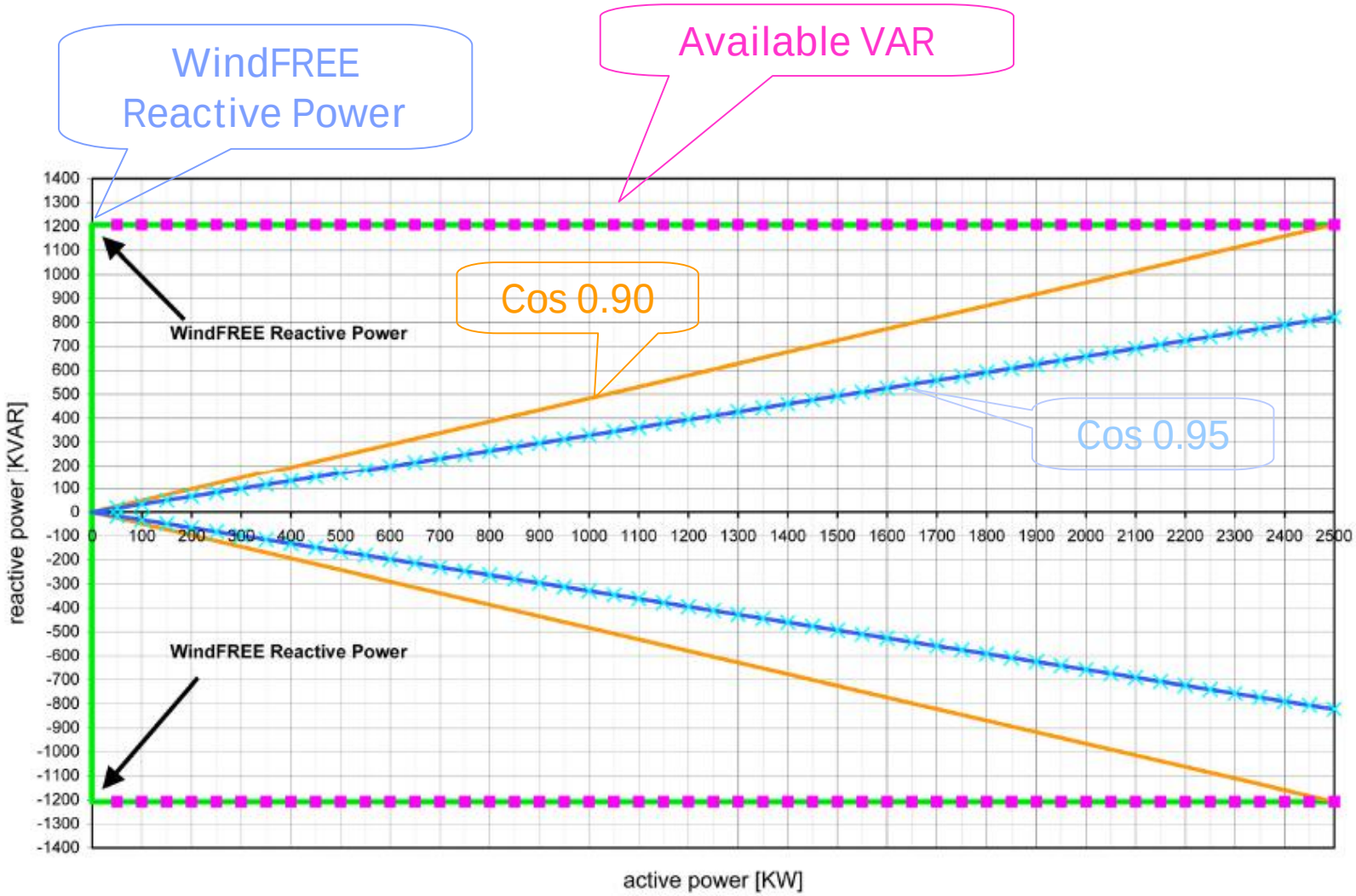
- Provides Reactive Power When Needed … *Wind Free Reactive Power*

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



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- Provides inertial response to address under-frequency events … WindINERTIA

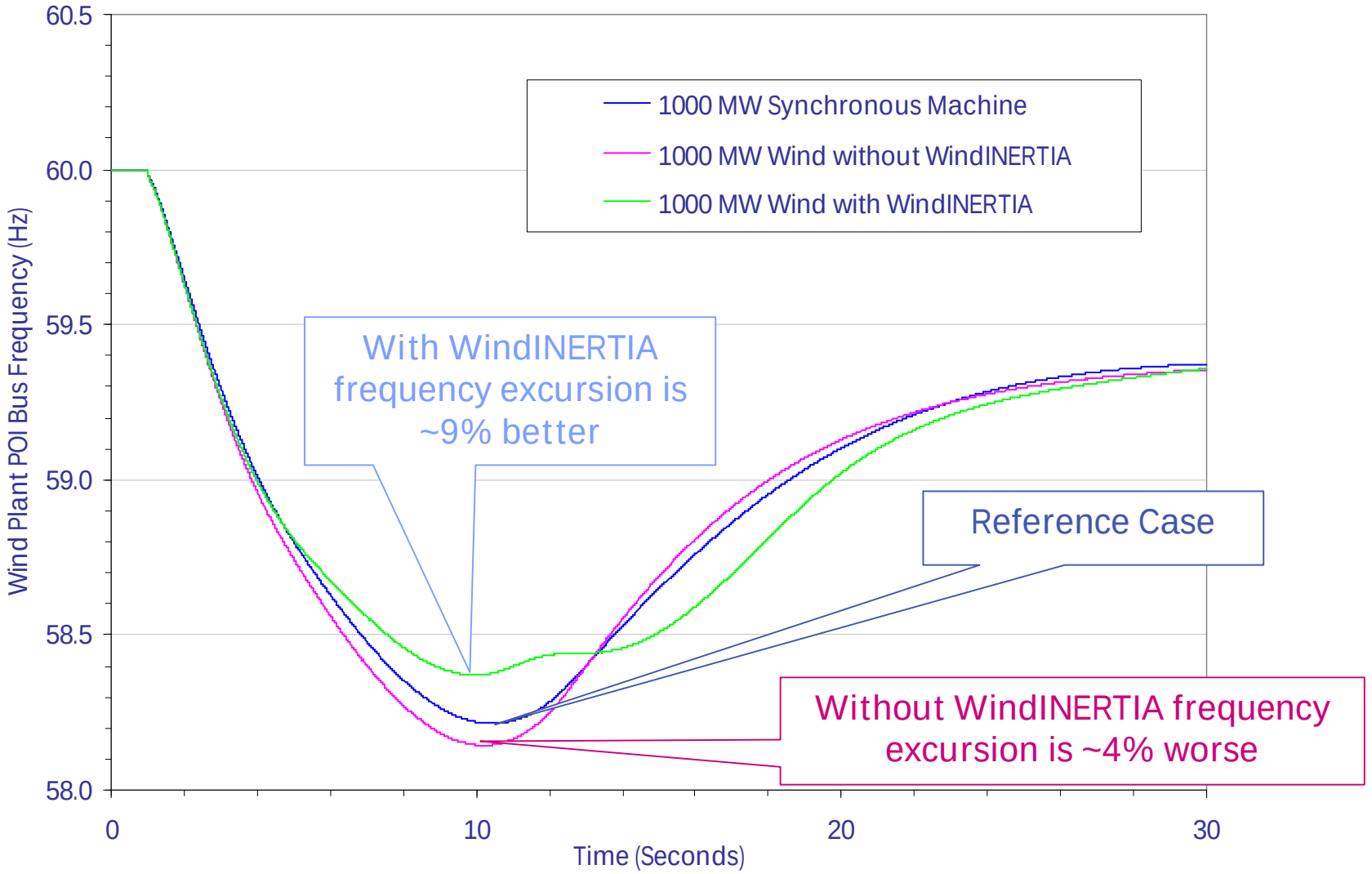
Why Inertial Response: System Needs

- 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



Making a Wind Plant "Grid Friendly"

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

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GE's 2.5xl

imagination at work