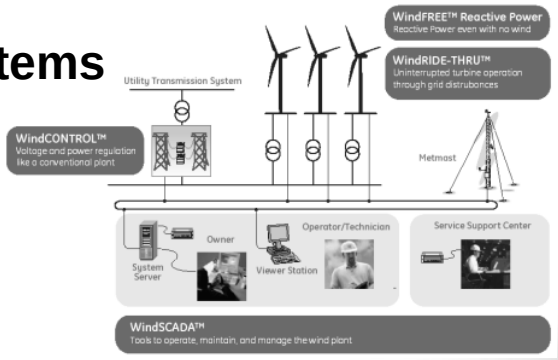
GE Energy

Wind Plant Systems

- **Grid Integration**
- **Plant and Turbine Controls**
- **SCADA**



Mahesh Morjaria
Manager, Wind Plant Systems Platform

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Adopted for
Wind Power Management class
http://www.icaen.uiowa.edu/~ie_155/
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Agenda

- ***Grid Friendly Wind Plant***
- ***Wind Plant Controls***
- ***SCADA System***

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*

Grid Fault Tolerance

Low Voltage Ride Through

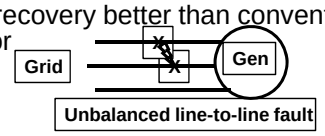
> Required by grid codes
> Improves gearbox life

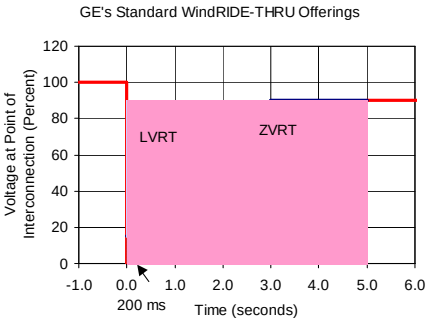
Zero Voltage Ride Through

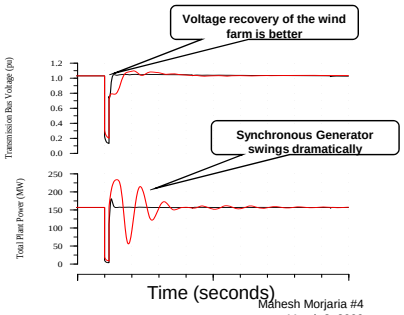
> Required by FERC after 12/31/07
> New controls for unbalanced faults
> GE 1.5 and 2.5 will comply

Fault Recovery

> Voltage recovery better than conventional generator







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Low Voltage Ride Through Capability

Low voltage ride through (**LVRT**) is a turbine capability
when the voltage in the grid drops due to a fault or load change in the grid.

The severity of the voltage dip is defined by the voltage level
during the dip (may go down to zero) and the duration of the dip.

Depending on the application the device may, during and after the dip,
be required to:
- ✓ Disconnect temporarily from the grid, but reconnect and continue operation after the dip
- ✓ Stay operational and not disconnect from the grid
- ✓ Stay connected and support the grid with reactive power

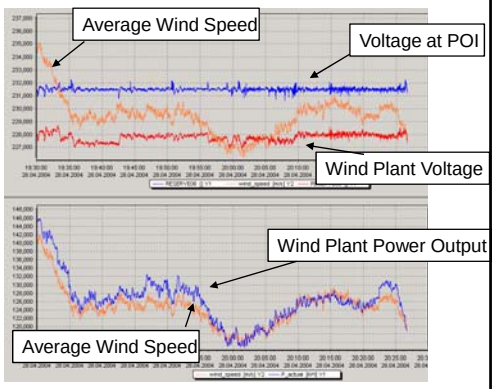
Power Droop

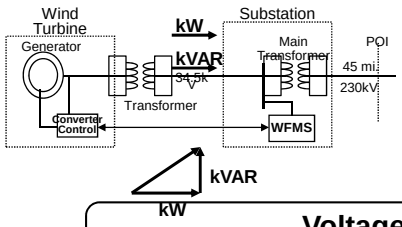
- ✓When circuit activity changes abruptly, it can cause a sudden drop or rise in power supply voltage.
- ✓This change is known as power droop and is an instance of power supply noise.
- ✓Power droop can cause an IC to fail.
- ✓Such failures should be screened during testing
- ✓Evaluation of the worst-case power drop by accumulating the high- and low-frequency effects.

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

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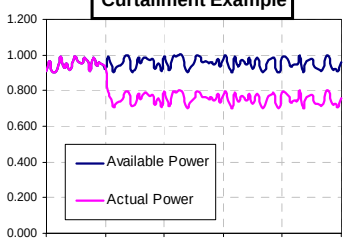
Active Power Controls

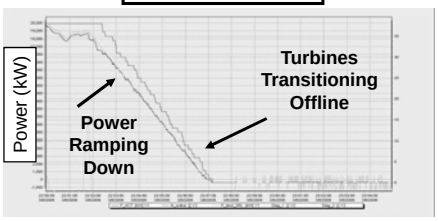
Typical Grid Requirements

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

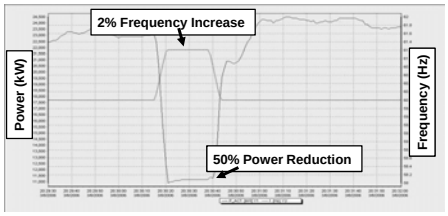
Curtailment Example



Shutdown Ramp Test



Power Droop Test



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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

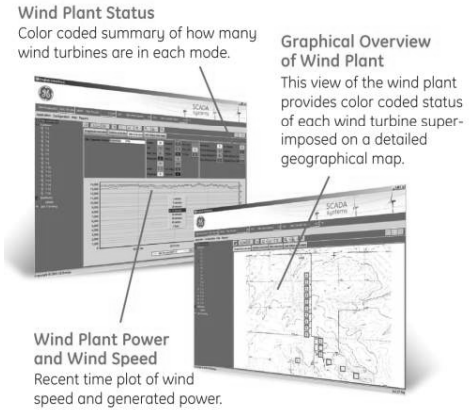
Reactive Power - *even without wind*

Agenda

- ***Grid Friendly Wind Plant***
- ***Wind Plant Controls***
- ***SCADA System***

Wind Plant SCADA System

- Real-time operational control of each turbine & complete Wind Plant
- Historical data base with comprehensive reporting system including Production and Wind reports
- Secure User-Access, intuitive Operation & Maintenance tool



Tools to operate, maintain and manage the wind plant

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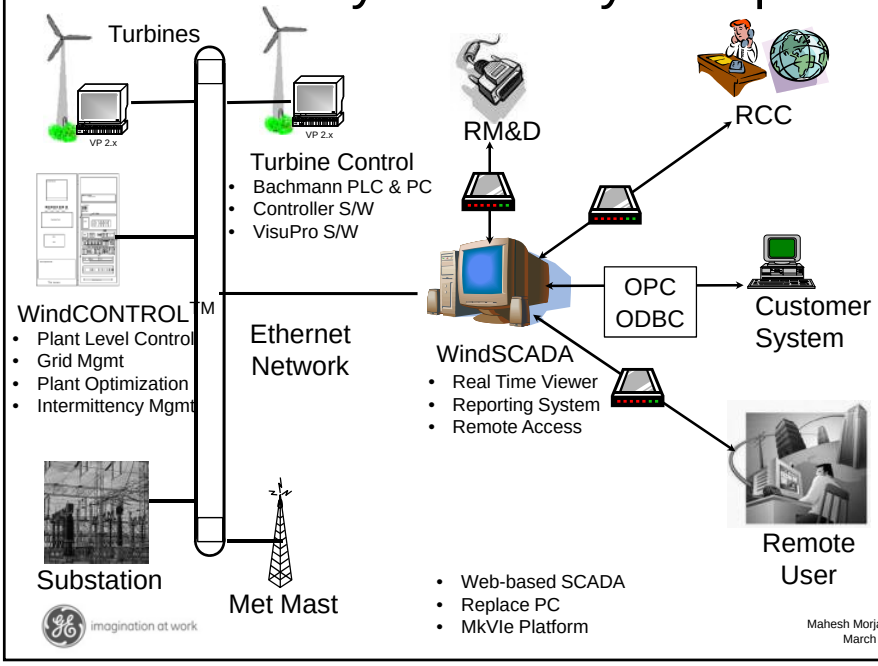
Wind Plant Systems Key Components



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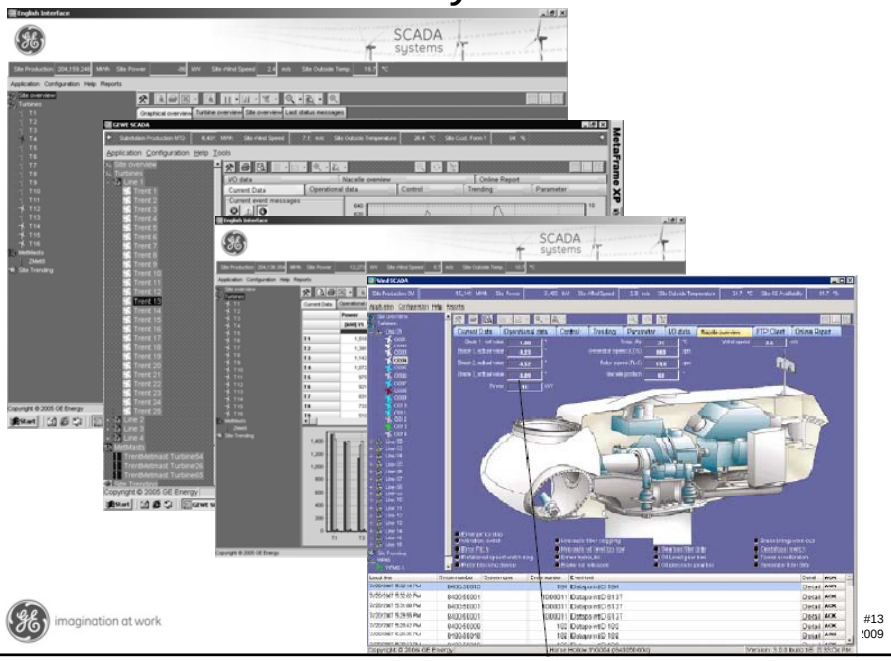
Plant Level SCADA System



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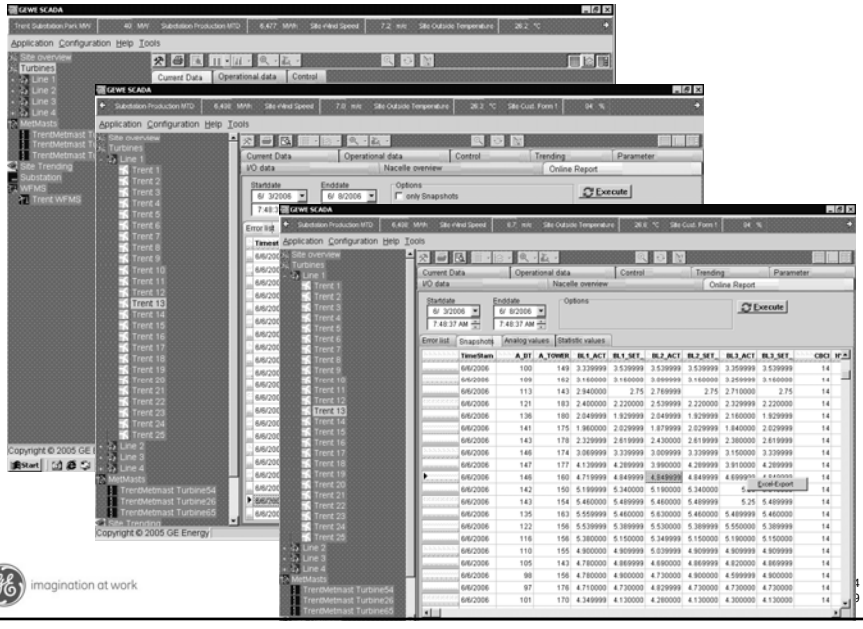
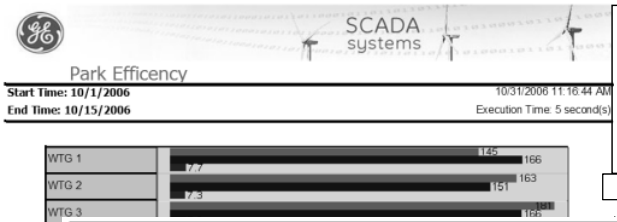
Plant Level SCADA System



3.X Reporting System – Advanced Reports



Next Gen Reporting
- ✓ **Higher level processing …** *actionable information*
- ✓ **Web based Reporting**
- ✓ **Scheduled Reports**
- ✓ **Multiple Language Capable**

Park Efficiency Report

System	Windspeed (m/s)	Power (kW)	Capacity Factor (%)	Delivered Energy (MWh)	Expected Energy (MWh)	Performance Ratio (%)	System OK Time (hrs)	Availability (%)
WTG 1	7.7	458	28	145.2	166.0	87	318	96.4
WTG 2	7.3	508	32	163.4	150.9	108	321	97.7
WTG 3	7.6	566	35	181.3	165.8	109	321	97.5
WTG 4	7.8	513	32	163.3	174.3	94	322	97.5
WTG 5	7.9	552	34	175.8	184.8	95	321	97.6
Summary	7.6	519	32	828.9	841.9	98	1605	97.4

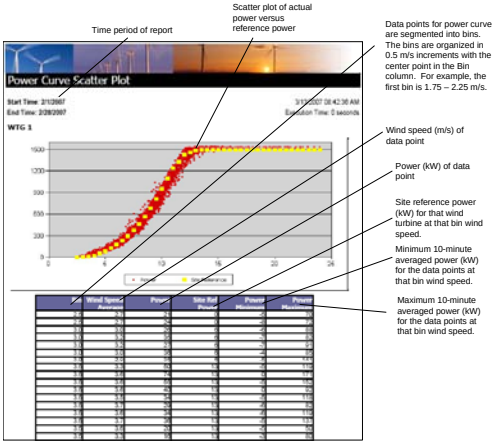
Pareto chart of trip events

Provides trip counts, outage duration and lost energy

Web Based Reporting System – Available Reports

Operational Reports
- Operational Data
- Meter Reading
- Plant Efficiency
- UPE Due to Curtailment
- Performance
- Grid
- Power Curve Line Plot
- Power Curve Line Plot Comparison
- Power Curve Scatter Plot
- Power Curve Scatter Plot (Min/Max)
- Wind Speed Distribution

Maintenance Reports
- Historian Data Coverage
- Event Log
- Event Pareto
- Fault Analysis
- Command Log
- Parameter Change
- Inverted Input
- VP/Bachmann PLC Comm Loss
- Parameter Values



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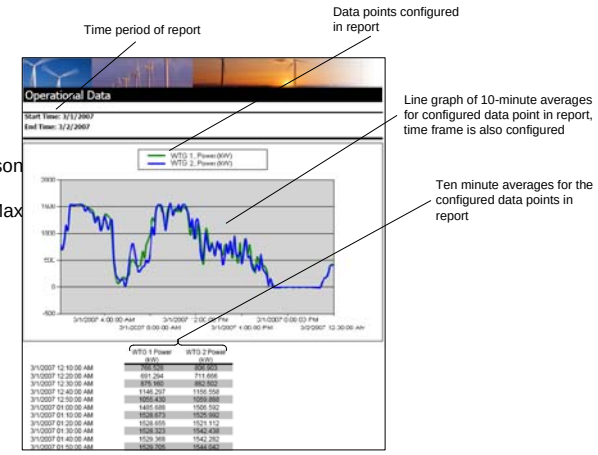

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March 3, 2009

Backup Material

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March 3, 2009

First SCADA Users' Group Mtg at AWEA Conference

Participants
- 14 users from FP&L, AEP, Brookfield Power, Horizon Energy, enXco, AES

Agenda
- SCADA development plans
- Test drive of web-based reporting and ESS operational web pages with user surveys
- Feedback Sessions

Customer Feedback:
- Browser based tools preferred, FPL has nine different SCADA packages across fleet … *migration to Web-based tools*
- Connectivity to third party systems (OSI-PI, Second Wind, customer systems) a plus relative to other vendors … *open architecture*
- Increased user configurability & flexibility
- Reports get customized at each site … *Excel export capability key*
- Users appreciated opportunity to provide inputs, look forward to next year's event
- ***Need upgrade for their existing SCADA s/w***

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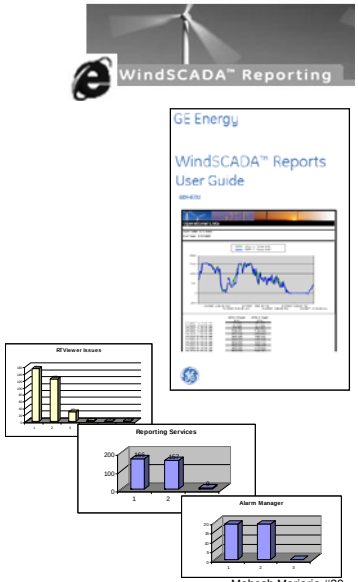
WindSCADA Version 3.0 Released (June 2007)

Key Features:
- Web-based Reporting with improved performance
- Built-in export capability (Excel, PDF, XML etc)
- Improved Product Documentation
- Fixed major software bugs of previous version



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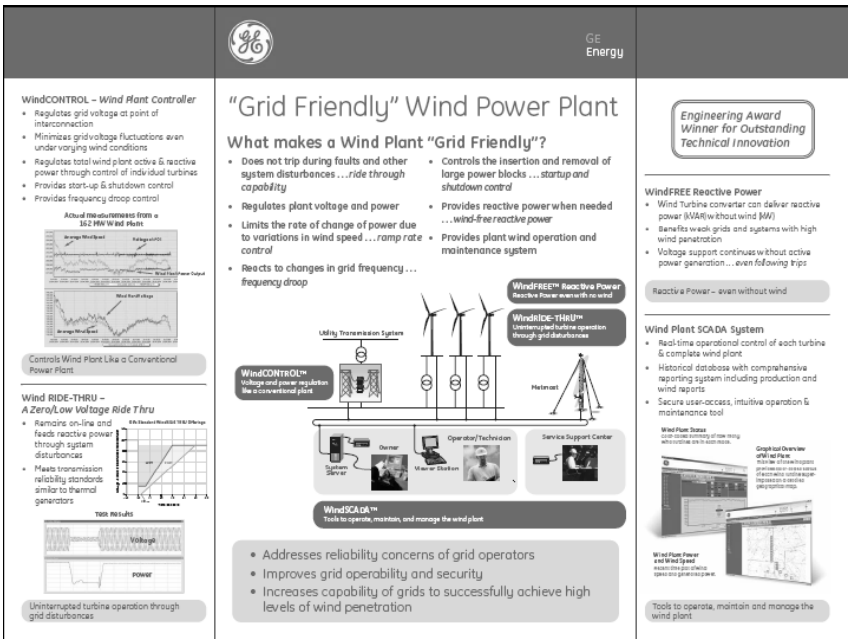
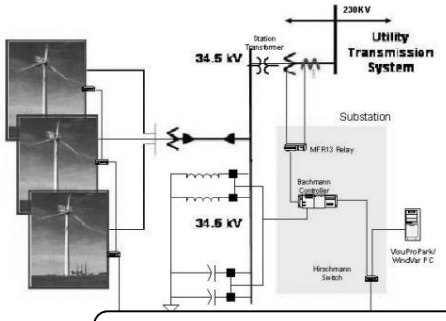
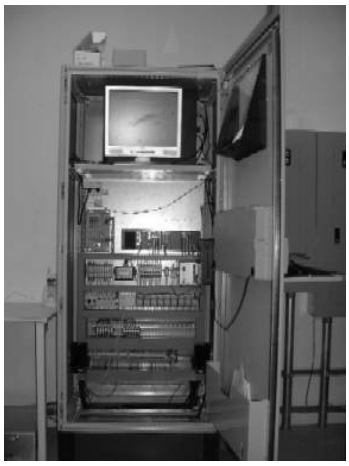


WindCONTROL

Hardware Overview

- Substation Mounted Cabinet
  PT&CT Interface to Substation
- SCADA HMI
  Operates on Wind Plant LAN





Plant Level Controller Orchestrates Operation of Individual Turbines

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