VAR Communications

Voltage Regulation in Distribution Systems

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Conference Sponsors

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solar electric power association

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GE Renewable Energy Portfolio

1.5 XLE

- Lower wind speeds
- Performance ↑

2.5 60hz

- Expanding MMW reach
- Advanced load controls

Offshore

- ScanWind Acquisition
- Direct drive, simple design

Services

- Performance Upgrades
- Diagnostics & Life Extension

Solar

- Inverters & utility scale systems
- PrimeStar TF technology

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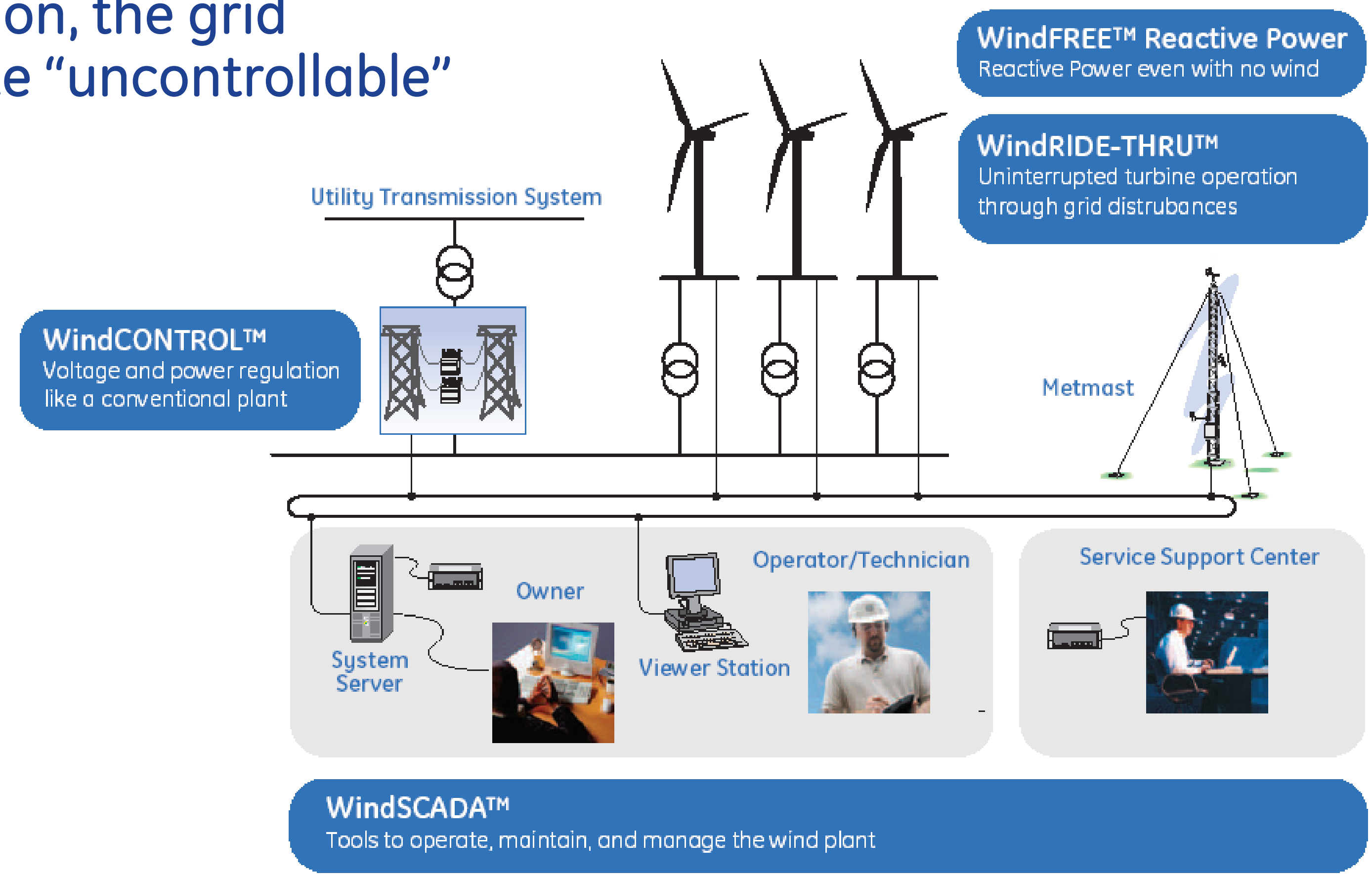
Grid Friendly Plant

- Intermittent variations lead to changes in electrical quantities
  - Active Power (MW)
  - Voltage
- High penetration, the grid cannot tolerate "uncontrollable" power plants
- Grid operators prefer (require?) plants that can actively help the power system
- Wind Plant Control Experience



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Mitigation of Voltage Variation

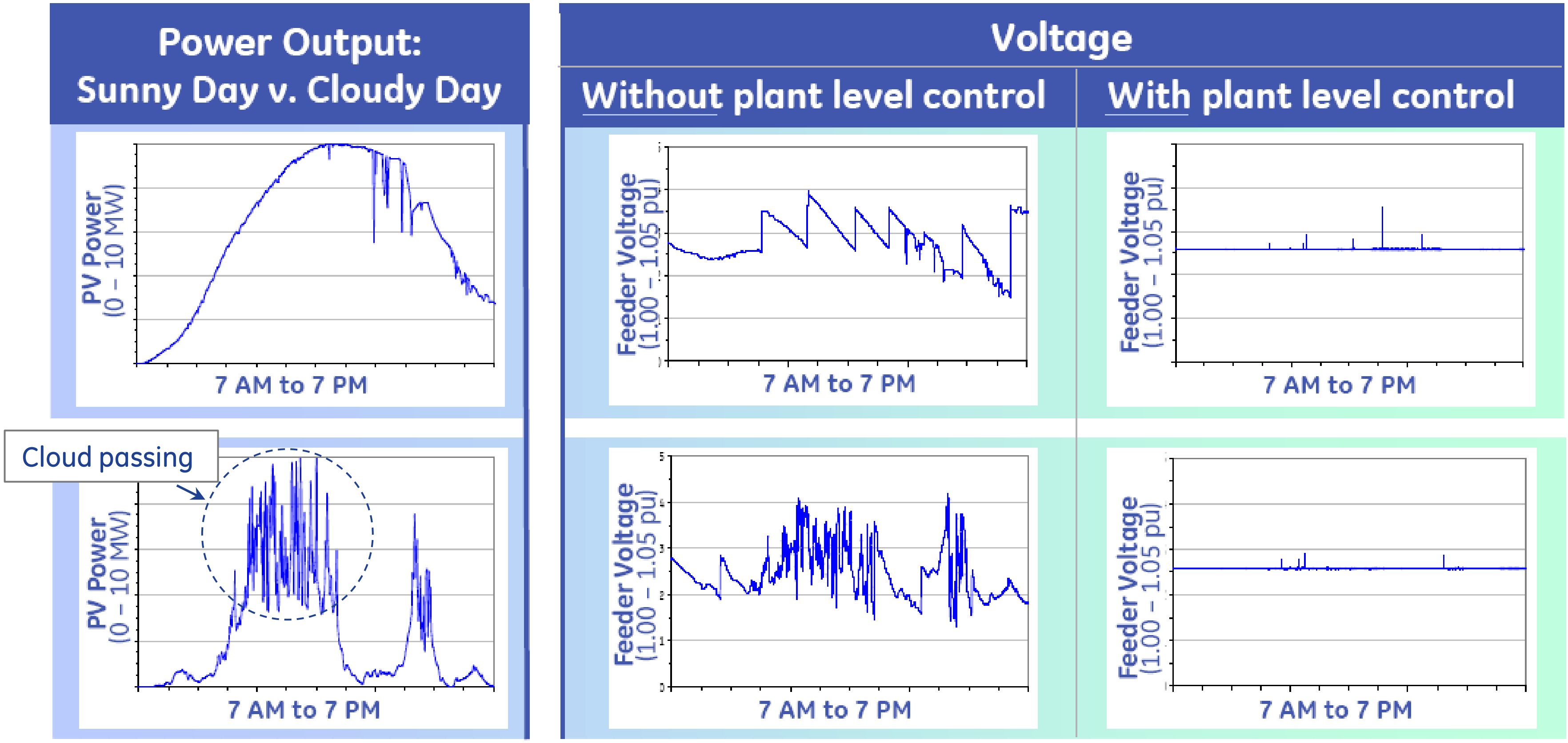
$$\Delta V \approx \frac{\Delta P}{V} \cdot R - \frac{\Delta Q}{V} \cdot X$$

V = Voltage
P = Active Power (Watts)
Q = Reactive Power (Vars)
R = Resistance (between inverter and POI)
X = Reactance (between inverter and POI)

- Control of inverter reactive output allows for full compensation of voltage change caused by power output change
- Reactive power change offsets effects of real power variation
- Accomplished through a closed-loop regulator

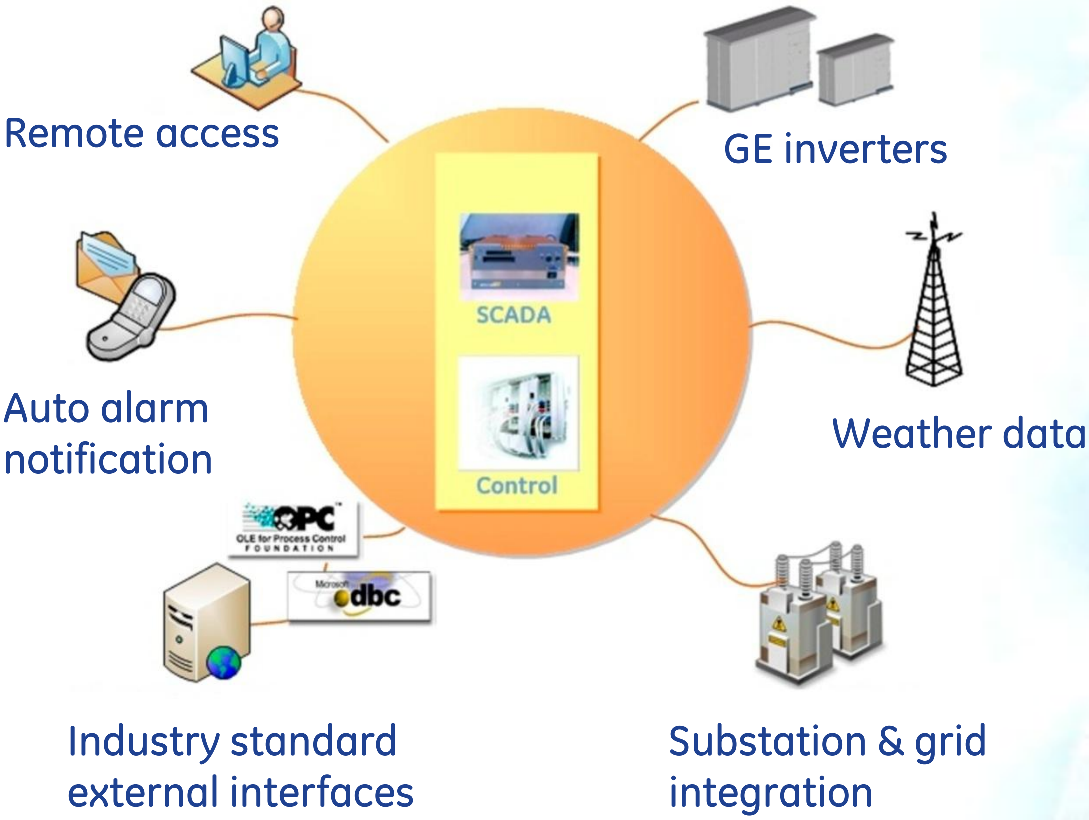
Voltage Regulation Example (Solar)

Simulated 10 MW PV plant



Allows tight Voltage control … despite large MW fluctuations

Solar plant monitoring & control



Enhance plant performance

- Real-time plant data visualization
- Real-time coordinated control of inverters to improve grid integration
- Data analysis and improved troubleshooting

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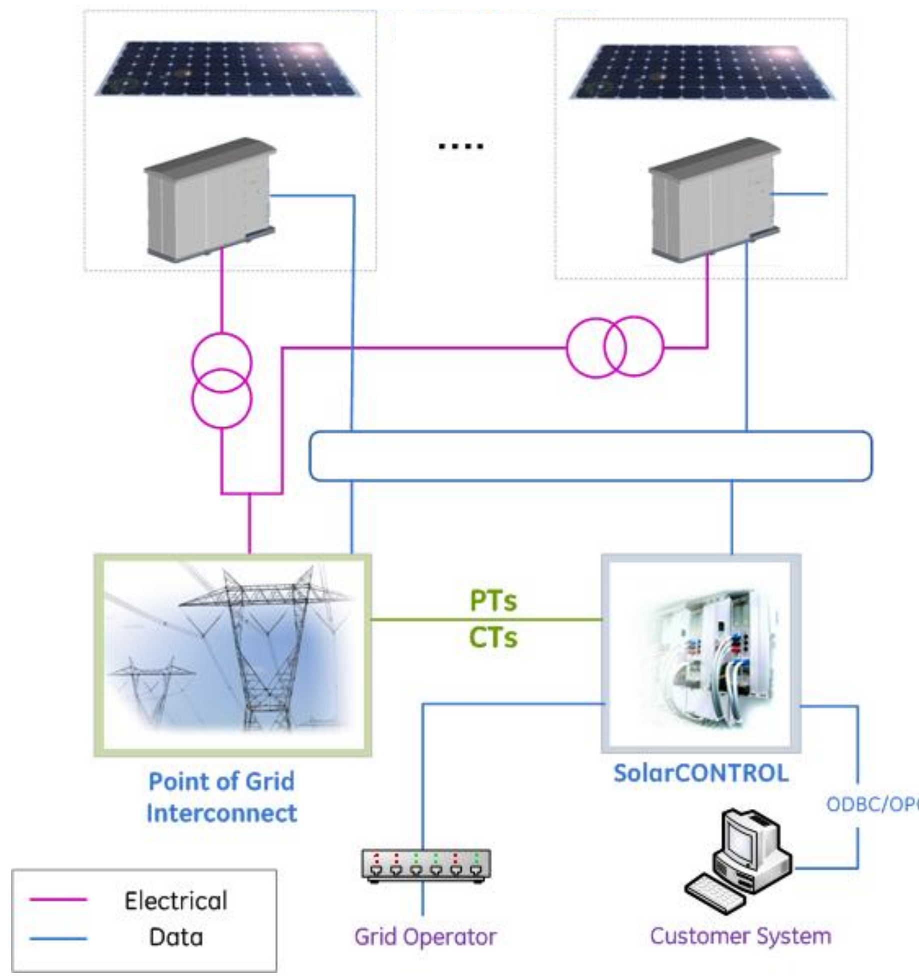
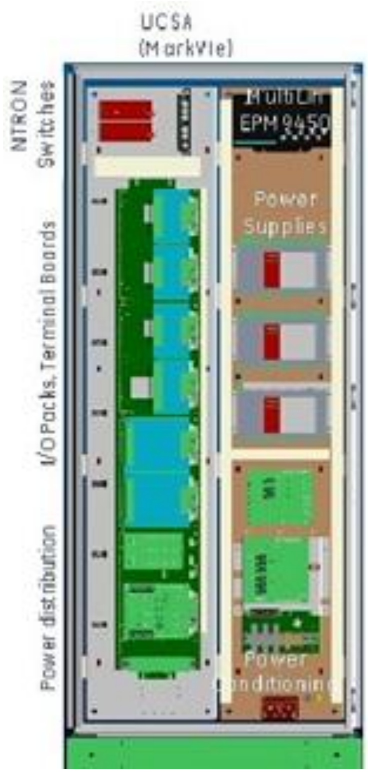
Control capability

- Inverters…fast, self-protecting regulation of terminal voltage
- Plant control…coordinated control of inverters to meet requirements at point of interconnection
- Measures conditions at the POI, compares actual vs. set points, commands individual inverters
- Closed loop control to achieve desired behavior at the POI
- Multiple paths to set plant control features - Remotely via SCADA, Interfaces with utility SCADA, Analog & digital I/O
- Broad range of functions… Reactive & Active Power controls



Improving grid integration of solar plants

Control Hardware



Environmental

- NEMA 4 enclosure
- Operating temp. –20C to +50C*
- Storage temp. –20C to +70C*

*Outside ambient

Main components

- GE MarkVIe controller
- GE Multilin transducer
- SCADA PC
- Fiber optic switch
- CT / PT terminations
- Input / Output packs
- UPS/battery powered backup for 60 minutes

Communication

- OPC / ODBC remote connectivity
- Analog / Digital I/O
- Interface to Inverters via Fiber optic
- Substation RTU interface

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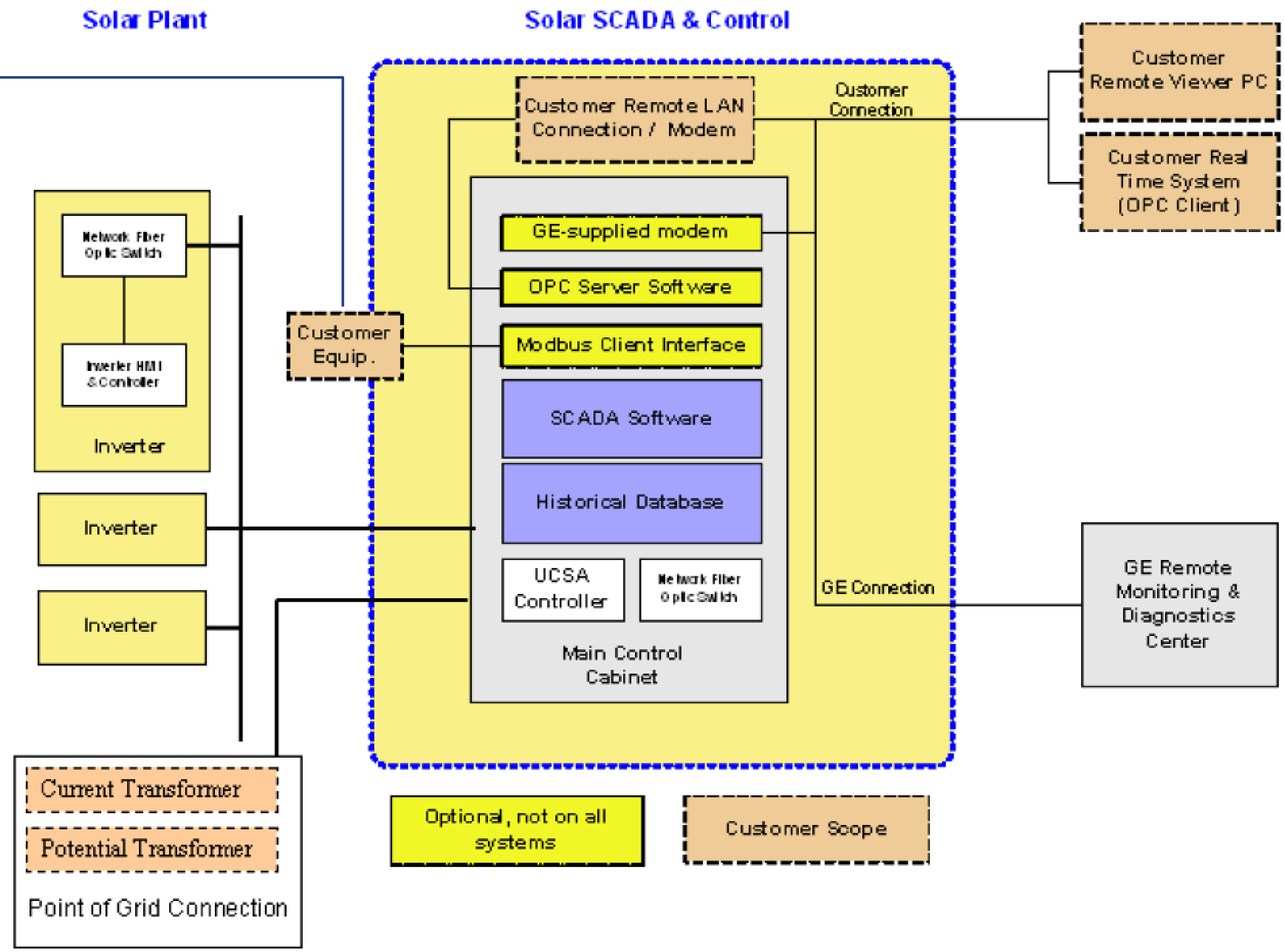
Integrated monitoring and control solution

Solar plant communications



3rd Party Devices:

- Alarms
- DC Input Power
- AC Output real Power
- VAR set-point
- VAR output
- Status Codes
- Fault Codes

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SCADA plant monitoring

Features:

- Web based for easy access
- Both plant-wide and inverter specific displays with drill down capabilities
- Real-time status of inverters and auxiliary devices
- High level cumulative performance metrics
  - Energy produced
  - Performance ratio
  - Availability
  - Capacity factor
  - Efficiency
- User-configurable views

Real-time visibility and analysis of plant performance

SCADA inverter monitoring

Features:

- Remote inverter control functions
- Remote inverter troubleshooting
- Current active alarms prioritized based on criticality
- Configurable trending of variables
- Inverter-specific metrics (status, DC & AC power, etc.)
- Counters to track operational states – uptime, service, repair, grid outage, etc.
- String parameter trending
- Weather data (irradiance, temp. and wind speed)

Insight into performance… enhanced troubleshooting

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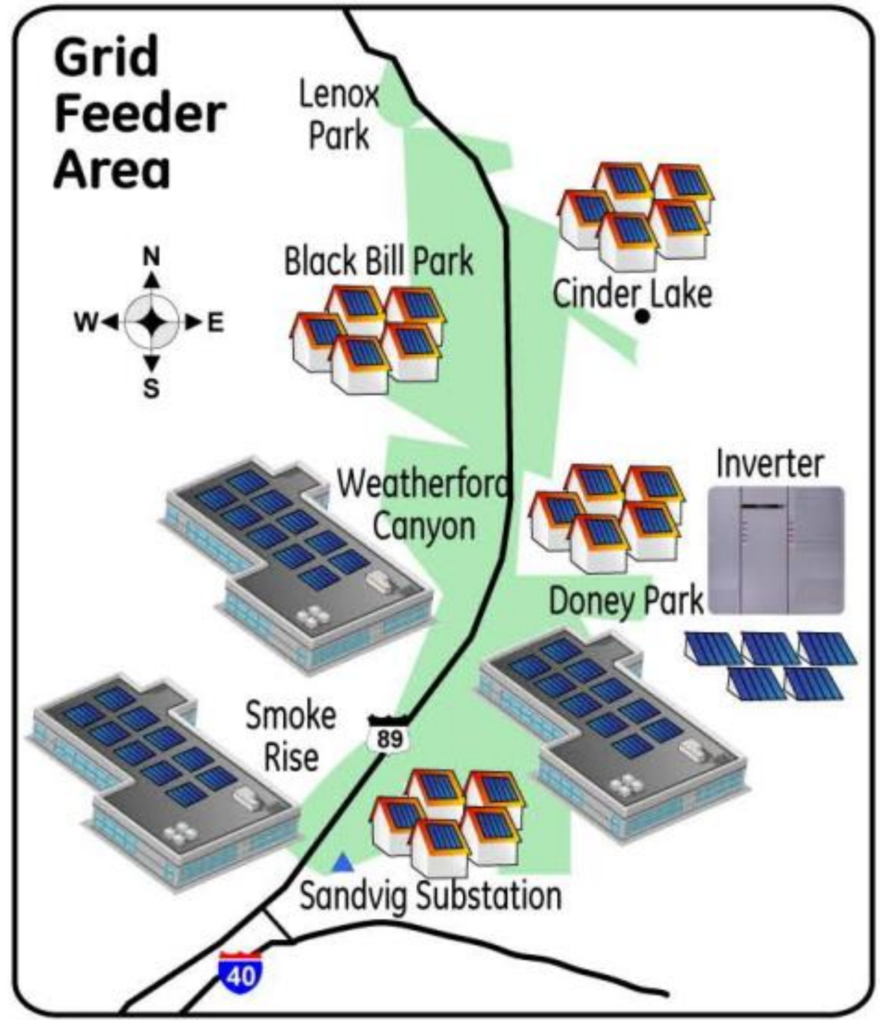
High Solar Penetration Study

Evaluating effects of high levels of PV on a distribution feeder

- Phase 1 started March 1st 2010
- 4 year program



Thank you

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December 6^{th}, 2010

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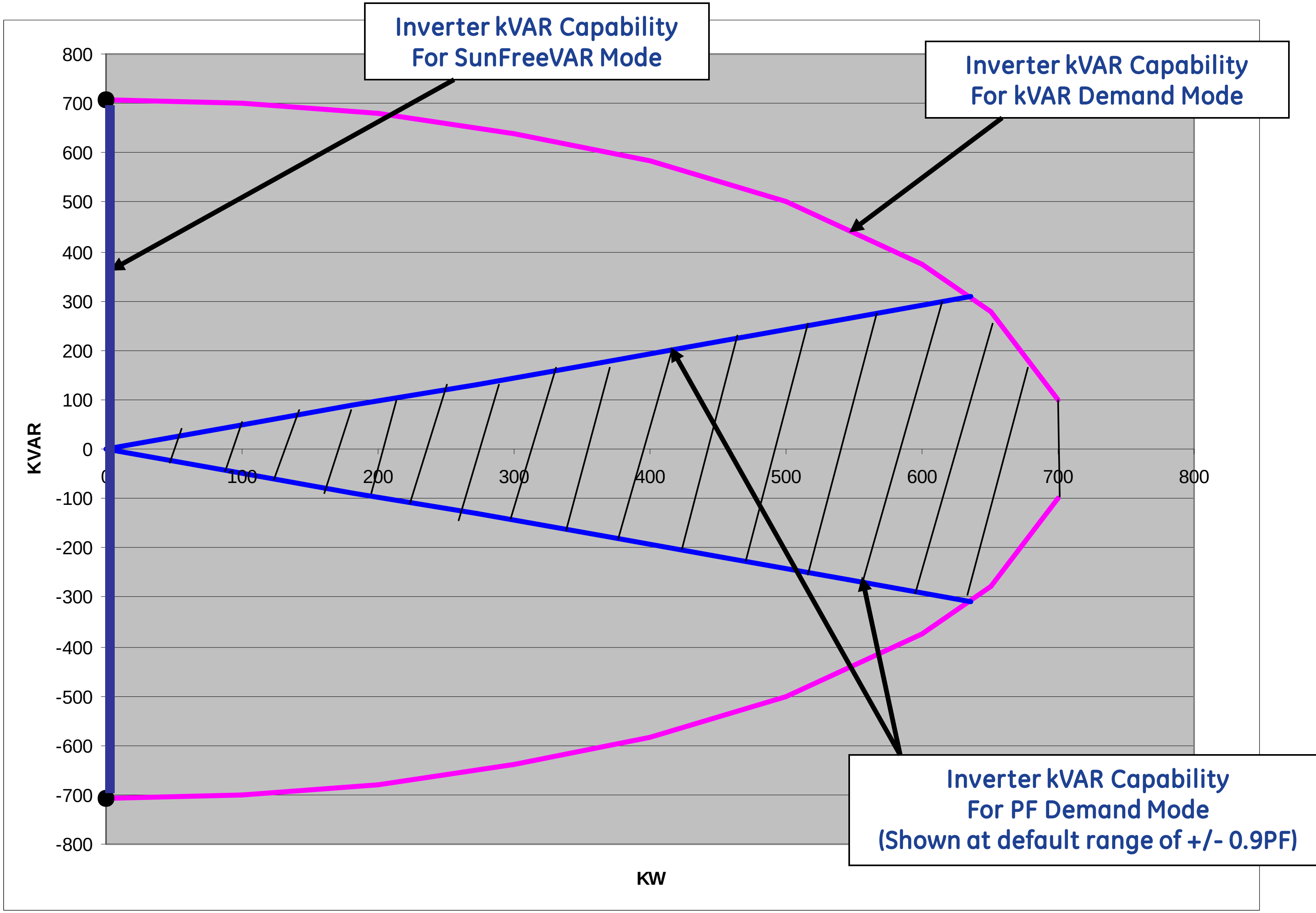

GE Brilliance 700kw Inverter kW/kVAR Capability

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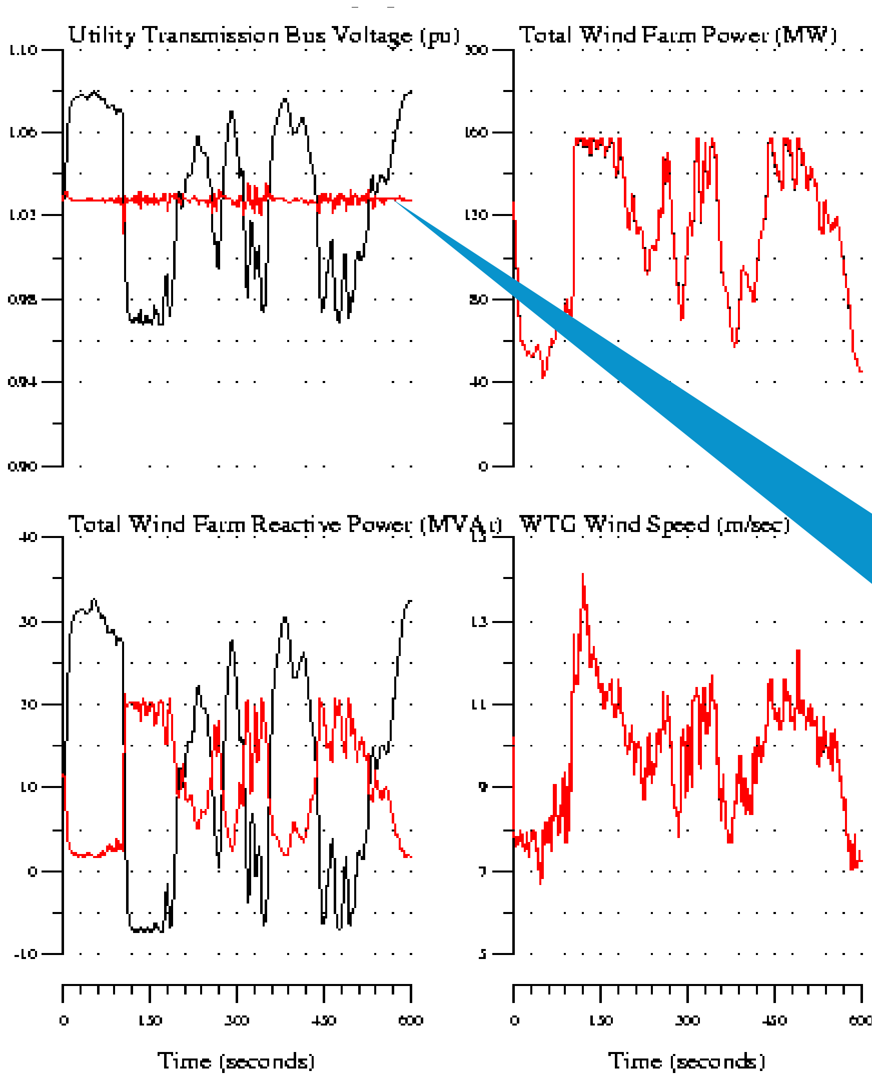
Voltage Regulation Example (Wind)



Voltages and Flows at Utility Point-of-Interconnection

Comparison: with WindCONTROL (red) vs. without (black)

Very clean voltage on the host utility grid bus

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SCADA data analytics and reporting

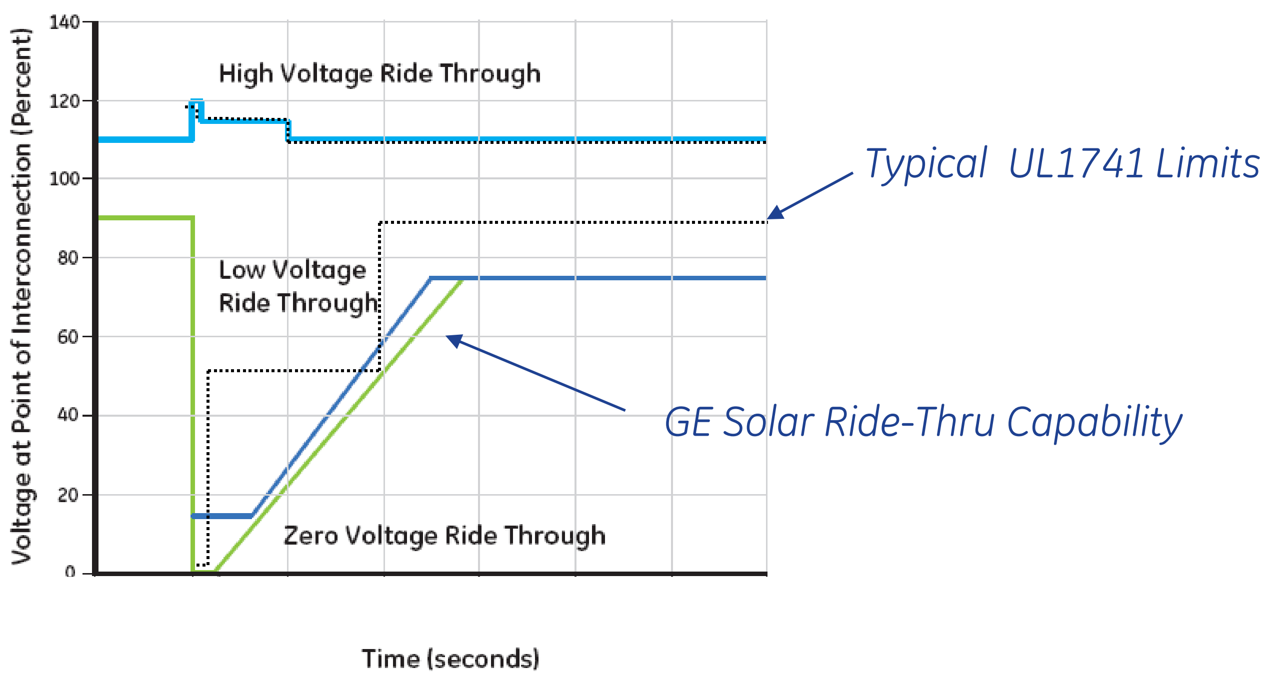
Features:

- 5 minute averaged data stored in SQL
- 1 year data storage for historical reporting
- Many pre-configured reports:
  - Performance evaluation
  - Operational reports
  - Maintenance / fault reports
- Report scheduling
- Export reports to standard formats (CSV, XLS, PDF)
- Interactive data analysis

Reporting tools for continuous optimization

SolarRIDE-THRU

- Features Mandated for Wind and Solar in EU, Required for Wind in US
  - Consistent with U.S. Federal Energy Regulatory Commission (FERC) Order 661-A
- Provides Capability beyond UL1741 requirement
  - Low Voltage Ride Through (LVRT)
  - High Voltage Ride Through (HVRT)
  - Optional Zero Voltage Ride Through (ZVRT)
- Proven Performance in over 10,000+ WTG's Worldwide



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Requirements increase with penetration

Wind interconnection requirements

	Prior to 2003	Today	Current evolution
Disturbance Response	Disconnect from grid	LVRT ZVRT HVRT	Broader LVRT, ZVRT envelopes Higher over-voltages
Voltage	Turbines at constant power factor	Plant level voltage control	Reactive power requirements Integration into weaker grids
Active Power	No MW control	Curtailment Ramp rate	Over-frequency droop Inertial response

↑ **Solar today (N. America)** (Prior to 2003 column)

↑ **EU leading w/ solar requirements** (Current evolution column)

Increased penetration drives advanced requirements

Voltage Response

None / Fixed Power factor → Dynamic voltage control

Fault Response

No ride thru (UL 1741) → Zero Voltage Ride thru (FERC661a)

Plant Controls

Autonomous operation → Coordinated Controls

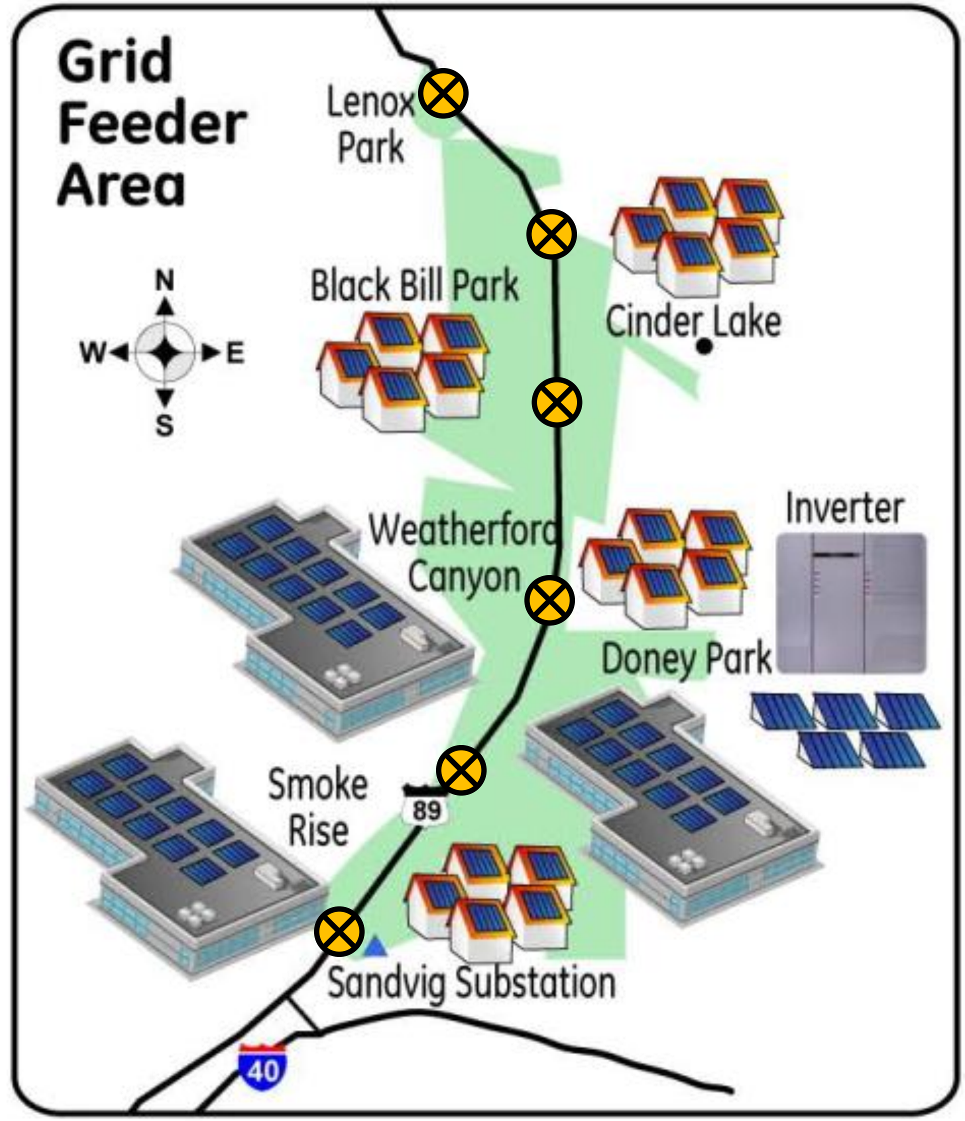
Power System Data Acquisition

NI Compact RIO

Garmin GPS Receiver

Features:

- High Event Sample Rate
- Lower Statistical Sample Rate
- GPS Synchronized Data
- Event Based Data Capture
- Wireless Network Trigger and Data Download

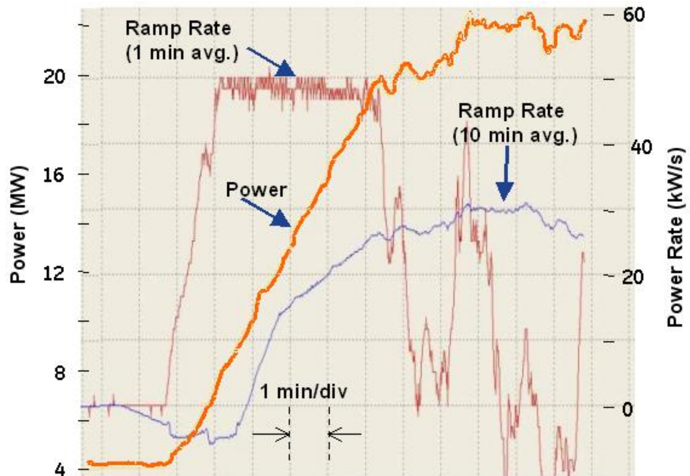


Data Acquisition Box Location

Active Power Controls

Power Ramp Rate control

- Limits the rate of change of MW to a defined value
- Reduces requirement on other generation to change output rapidly



Wind Farm example - Ramp rate controlled to 50kW/sec

Power Curtailment

- Caps the farm output at a certain max MW
- Helps respect system MW limits (eg: Transmission line Power transfer limit)

MW Control in addition to VAR control

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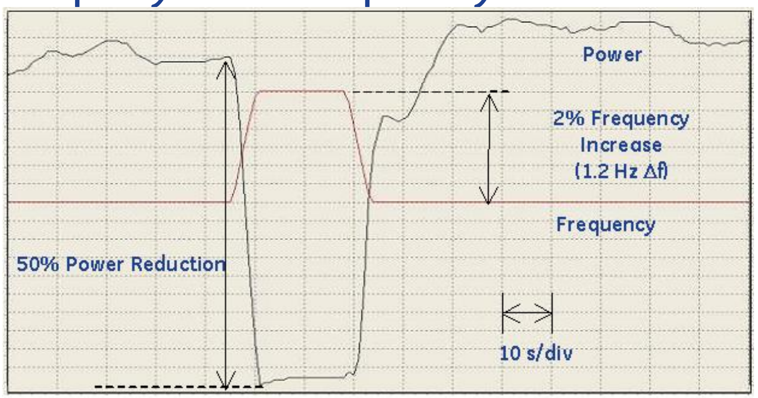
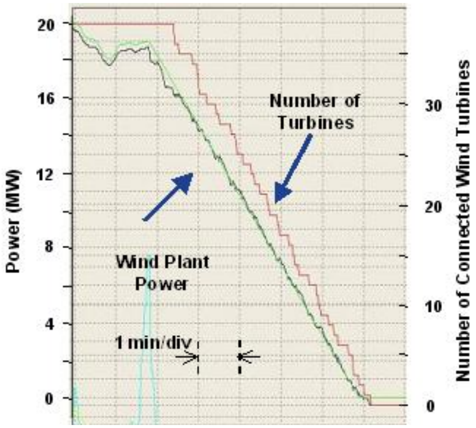
Active Power Controls

Over Frequency Droop control

- MW output reduced in response to grid frequency
- Helps system frequency recover



Wind Farm example – 50% MW reduction for 2% freq increase



Wind Farm example – controlled shut down

Startup / Shut down control

- Uncontrolled startup/ shutdown results in insertion/removal of large MW blocks at once
- Ensures gradual startup / shut down

MW Control in addition to VAR control

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