Technologies for Managing Utility Scale PV

Erik Bakke
GE Solar Technologies
West Region Solar Sales Manager
October 2011
GE Power & Water

Part of GE’s $38B energy business

Renewables – building on power generation technology & expertise
Leading Renewable Energy portfolio

**Wind**
- Leading N. American wind turbine supplier
- 5x unit growth since ‘02
- Product leadership in efficiency & customer value

**Solar**
- Leading thin-film technology
- System solutions for lowest LCOE
- Most widely deployed power electronics

**Renewable Services**
- Flexible portfolio of solutions
- Full service agreements
- Upgrades drive technology into existing fleet
- Focus on increasing performance & profitability

**Energy Financial Services**
- Developing creative financial solutions
- 25+ years in Energy Finance
- $20B assets

- 125+ global sites
- 4,500 global employees
- Installed base: 25GW
- Projects in 65+ countries
- 10,000 sub-supplier jobs created
GE positions for solar growth

- Set record thin film solar efficiency
- 400MW U.S. solar factory announced
- New commercial agreements for 100MW+ of solar thin film products
- Announced acquisition of PrimeStar & Converteam

Solidifying GE’s position of excellence in the Renewable Energy Industry
GE brings 1-stop shop to utility scale solar

- Renewable feasibility & interconnect studies
- Reliable power conversion
- Advanced grid-friendly features
- Plant level monitoring & control
- Remote monitoring & diagnostics
- Extensive service network
- Robust module technology
- 700kW & 1MW power plant blocks available

© 2011 General Electric Company.

www.ISETC.org
GE's large-scale solar portfolio...

**Thin Film Modules**
- Advanced technology for winning LCOE
- CIGS: 12% efficiency, available today
- CdTe: 14% efficiency, production by '13

**Solar Power Plants**
- Cost optimized design for lowest LCOE
- Designed for BOS cost savings and optimized installation
- 700kW and 1MW scalable blocks
- Commercial rooftop option in development

**Plant control & Inverters**
- High reliability, low cost ... based on 17,000 1.5MW wind units in the field
- UL & CE certification
- Grid integration leader ... 40+ wind patents to PV
- 700kW & 1MW units available

**Services**
- Supported by 900 technicians and 115 service office locations globally
- 20yr module power guarantee included with all modules
- 24/7 remote monitoring included with all inverters

High-tech solutions drive down cost of solar electric power
Utility Scale PV Challenges
These studies were commissioned by the Energy Commissions, ISOs, & IOUs...

- Examining the Feasibility of 100+ GW of new wind, solar & other renewable resources
- Considering Operability, Costs, Emissions, Transmission Constraints, Forecasting

- **2004 New York:**
  - 3 GW Wind
  - 10% of Peak Load
  - 4% of Energy

- **2005 Ontario:**
  - 15 GW Wind
  - 50% Peak Load
  - 30% Energy

- **2006 California:**
  - 13 GW Wind & 5GW Bio/Geo
  - 3 GW Solar
  - 26% Peak Load
  - 15% Energy (33% total)

- **2007 Texas:**
  - 15 GW Wind
  - 25% Peak Load
  - 17% Energy

- **2009 Western region:**
  - 72 GW Wind
  - 15 GW Solar
  - 50% Peak Load
  - 27% Energy

- **2010 Oahu:**
  - 500 MW Wind
  - 100 MW Solar
  - 50% Peak Load
  - 25% Energy
Increasing renewables advances customer grid requirements

Early stages
- Trip offline w/ grid disturbance
- No reactive power
- Individual operation

Increasing GW online
- Ride-thru grid disturbances
- Dynamic voltage control
- Coordinated plant level control

GE meets wind customer needs ... ready for solar

GE Solar

© 2011 General Electric Company.
www.ISETC.org
Different fuel source variability...

... similar grid considerations

Stochastic: many timescales
(season, day, hour, minute)

Power output dominated by
day-night cycle, cloud cover

System challenges:
- Unit commitment
- Load following

Local challenges:
- Voltage regulation
- Disturbance response
Increasing requirements necessary

Wind interconnection requirements

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

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

Solar today (N. America)

EU leading w/ solar requirements

www.ISETC.org
Why plant level voltage control
Simulated PV output variation over 12 hour period (10MW plant)

Plant level control addresses interactions
Active power controls

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

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

www.ISETC.org
GE Brilliance™ Inverter/SunIQ™ ... complete utility scale solution

Two components ... one solution
GE SunIQ™ ... beyond data capture

- Plant level controls
- SCADA
- Remote Oper. Center
- Outdoor rated
- Standard comm.: OPC, Ethernet, Modbus TCP/IP, ODBC, Analog/Digital
- Wind heritage

© 2011 General Electric Company.
Advanced plant level controls

Robust plant level control
- Voltage control
- Line drop compensation
- Power factor control, VAR control
- Power curtailment & ramp rate control
- Power frequency droop control
- Park shut-down/start-up

Integrated SCADA
- SQL database & standard comm. (OPC)
- Real-time data visualization
- Remote inverter control
- Metmast & substation interface
- Historical data analysis
- Automated reporting

Based on GE Mark VIe controls platform
- Heart of GE's wind & thermal power plant fleet
- 250+ utility scale projects controlled
- 100+ GW renewables feasibility studies
- 40+ grid integration patents

Based on GE’s proven grid integration expertise

© 2011 General Electric Company.
GE Brilliance™ PV Inverter ... beyond kW

Units Available:
1. 700kW, 600V, 60Hz
2. 1MW, 1000V, 50/60Hz

Certified: UL1741, CE, UL508C,