Gary Rackliffe – Vice President Smart Grids North America

Generating Smart Grid Solutions

ABB Distinguished Lecture Series in Power Engineering
NCSU Electrical and Computer Engineering Department

Raleigh, September 2011
The smart grid is an integrated approach to transform utilities to a future state. It requires the coordination of advanced technologies, business processes and people.

It will be a gradual transformation of the systems that have served us for many years into a more intelligent, more effective and environmentally sensitive network to provide for our future needs.
Five ways Smart Grid technologies improve the grid
Helping the power grids work smarter not harder

Capacity

Reliability

Efficiency

Sustainability

Customer Enablement
Growing demand - Electricity demand rising twice as fast
Ensuring a reliable grid

- **Distribution Management Systems (DMS)**
  - Monitor status of the grid and manage grid disturbances to reduce in outage duration.
  - Automation for Fault Detection Isolation and Restoration (FDIR)

- **Asset Health Management**
  - Manage aging and capacity constrained assets to minimize disruptions and provide asset health decision support
  - Collect condition data of assets in the field.
  - Analyze the data to determine the health of the asset and recommended actions.
  - Manage the execution of preventative and predictive maintenance

- **Transmission Grid Management**
  - Wide area monitoring
  - Voltage stability support
  - Integration of renewables
Efficiency

Up to 80% of energy lost in energy value chain

Primary energy    Transport    Generation    T&D    Industry    Commercial Residential

Available energy

- Improved well efficiency
- Improved pipeline flows
- More efficient fuel combustion
- Lower line losses, higher substation efficiency
- Improved productivity
- Building management

80% losses
30% saving
6-10%

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September 23, 2011 | Slide 6
Sustainable development with renewable power generation

- Strong growth of renewable power generation
- In OECD countries wind power is dominating the growth
- Estimated global investment in renewables: $200 billion by 2030

Hydropower will remain the key global renewable energy source, followed by wind energy.
Engaging the end-use consumer

- Today residential consumers use energy without regard to the actual supply situation
- Power producers plan the supply and deliver without knowing the detailed projected consumption
- Effective information exchange and automation of appropriate actions of both parties can optimize the demand supply equation
- For US a 20% reduction potential in peak demand after full deployment of demand response is estimated – Source FERC 2009

**The future electrical system must facilitate an effective dialog**
Smart Grid Technologies
Utility Implementation Strategies

- Utility Information Technologies that enable smart grid applications
# Smart Grid Technologies

## Utility Implementation Strategies

### Core Smart Grid Applications/Solutions

<table>
<thead>
<tr>
<th>Advanced Metering Infrastructure (AMI)</th>
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<tr>
<td>Smart Meters</td>
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<td>Communications</td>
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<tr>
<th>Distribution Grid Management (DGM)</th>
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<tr>
<td>D-SCADA</td>
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<td>Dist. Auto.</td>
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<th>Asset Health Center (AHC)</th>
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<td>Sensors and Monitors</td>
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<th>Transmission Grid Management (TGM)</th>
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<tr>
<td>HVDC</td>
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<td>Wide Area Monitoring</td>
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- End-to-End Smart Grid Applications
- Operations and IT Integration
Distributed Energy Resource Management System

- Forecasts, aggregates, and manages resources
- Models distributed energy resources as a Virtual Power Plant
- End-to-end process integrating to:
  1. Grid Operations
  2. Generation Portfolio Management – Virtual Power Plant
  3. Ancillary Services – Energy Markets
- Manages commercial process of participating in demand response energy markets
- Manages customer registration and billing determinants
# Smart Grid Technologies

## Utility Implementation Strategies

<table>
<thead>
<tr>
<th>Information Technology</th>
<th>Core Smart Grid Applications/Solutions</th>
<th>Distribution Edge of Grid Technologies</th>
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<tr>
<td><strong>CIS</strong></td>
<td>Advanced Metering Infrastructure (AMI)</td>
<td>Electric Vehicles</td>
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<tr>
<td></td>
<td>Meter Data Management</td>
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<td></td>
<td>Work Management</td>
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<tr>
<td><strong>Communications</strong></td>
<td>Distribution Management</td>
<td>Energy Storage</td>
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<tr>
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<tr>
<td><strong>GIS</strong></td>
<td>Asset Health Center (AHC)</td>
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<tr>
<td><strong>Asset Management</strong></td>
<td>Analytics</td>
<td>Demand Response</td>
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<tr>
<td><strong>Work Management</strong></td>
<td>Dashboard</td>
<td></td>
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<tr>
<td><strong>Mobile Data</strong></td>
<td>Work Management</td>
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<tr>
<td><strong>Security</strong></td>
<td>Transformation</td>
<td></td>
</tr>
</tbody>
</table>

### Advanced Metering Infrastructure (AMI)
- Meter Data Management
- Work Management
- Communications
- Smart Meters

### Distribution Management (DGM)
- SCADA
- DMS
- OMS
- Advanced Applications
- Communications
- Distribution
- Automation
- Sensors

### OT/IT Integration
- Analytics
- Dashboard
- Work Management

### Transmission Management (TGM)
- HVDC
- FACTS
- HV Cables
- Energy Storage
- SCADA/EMS
- Wide Area Monitoring
- HV Optical Sensors
- PMUs
- Substation Automation
Intelligent Grid Improves Distribution Operations

Leverage energy information…
- advanced utility operations and management
- self-healing grid
- avoid disruptive events

…which modernizes the grid to support the competitive electric marketplace.

Source -- CenterPoint
Distribution Grid Management
Optimizing power for maximum efficiency

- Reactive power can account for a significant portion of distribution losses. Utilities need to manage the amount of reactive power on the grid to ensure maximum efficiency. A 1% improvement in efficiency is estimated to eliminate 100 million tons of CO2.

- Volt/VAr Optimization – Optimizing the balance between active and reactive power can allow for reduction of energy losses on distribution feeders of 4 – 5%.

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![Diagram showing voltage regulation and power/resource savings](image)

Upper bound: ~124v
Lower bound: ~118v

VVC & CVR

Power/resource savings

LTC

Voltage regulator / Capacitor
**Asset Management as a Process**

**Performance Models** are key to the process. The objective is to leverage data to:
- Define risk factors
- Quantify them
- Recommend mitigation options
- Optimize spend

**Apparatus** → **Sensors and Monitoring** → **Substation Gateway** → **Asset Database** → **Analytics & Decision Support** → **Work & Asset Management**

**Performance Models**

- Equipment specs
- Failure data
- Test results
- Service records

**Decision Support:***
1. Operations Impact
2. Optimized Maintenance
3. Lifecycle Management
4. Recommended Work Execution

**Work Management Inventory Crew Deployment**
Integrating renewable power
Challenging locations

- Wind farms are built where wind availability is highest
- For energy transport, AC technology with FACTS is often the optimum choice
- Often remote and deserted or off shore
- For offshore installations cables are the only option for energy transport
- For long subsea distances DC technology is the optimal choice
- For medium and short subsea distances AC technology with FACTS is the optimum choice

The future electrical system must offer economic and reliable solutions
Connecting renewable sources to the grid

Renewables will be a major source of new energy production in the future.

By their very nature, renewables are variable. Solutions are needed to store energy for peak demand or to supplement energy when renewable production is low.
Transmission Grid Management
Reducing line loss over long distances

**Challenges**
Line losses are especially great when transmitting energy over long distances making it more expensive to bring power from remote areas to populations centers that need it.

**Solutions**
**HVDC** – High Voltage Direct Current lines decrease line loss and connect remote sources. In China, UHVDC lines reduce transmission losses by 30% along a 2000 km connection.

**FACTS** – Flexible AC transmission systems (FACTS) for improved power transfer
The Dutch and German transmission company TenneT Offshore GmbH has awarded a contract to ABB to supply a transmission link with total capacity of 900 MW at ±320 kV that will connect offshore wind farms located in the cluster DolWin in the North Sea to the German grid.

- This is third offshore wind connection to be delivered by ABB.
- The system will help avoid more than three million tons of carbon dioxide emissions per year by replacing fossil-fuel based generation.
- The wind farms will be connected with AC cables to the HVDC converter station on a North Sea offshore platform and further through 45 km of DC sea cable and 90 km of land cable to the HVDC onshore station.
Wind application, Western Texas

- West Central Texas: plenty of wind power
  - McCamey area: 750 MW and growing;
  - Central area: 1.000 MW
- Very high wind power penetration (up to 80%).
- Induction generators lose synchronism at low voltages and thus increase their reactive power demand, further dragging down the system voltage until protection intervenes.
- Variations in import/export of active power due to rapid swings of wind farm output require continuous voltage regulation.
Horse Hollow is a very large wind farm in Texas, USA: 750 MW, and growing.

A 345 kV inter-tie is taking the wind power 300 km to the south, to Kendall in the San Antonio area.

A **Series Capacitor** has been installed at the northern end of the inter-tie, rated at 400 Mvar.

The purpose of the SC is to allow the generated wind power to be transferred under steady-state and dynamically stable conditions.
Virtual Power Plants Aggregate Distributed Energy Resources

VPP WEST: Critical Peak Pricing
VPP NORTH: Pricing Program

VPP SOUTH: Direct Load Control
VPP EAST: DG & Storage
Integrating OT/IT with Virtual Power Plants
**Dynamic Pricing**

- Peak demand
- Hours: 2 - 7 PM
- Monday - Friday
- June - September
- Customers receive day-ahead price via in-home display, web, text, email, etc.

*All electricity is not created equally – as demand increases, the cost to generate and deliver electricity increases*

Source – OG&E
Demand Response – VPP/CP High Weekday

Source – OG&E
Energy Storage

- Balancing power is a major issue for utilities and especially critical with large amounts of intermittent wind and solar energy in the supply mix.

- Storage of electrical energy helps to bridge the time of reduced or missing power to activate reserves.

1990-2000
  - Technical feasibility

2001-2010
  - Commercial feasibility

2011-2015
  - Grid integration
Energy Storage

Electricity Storage Spectrum in Utility Grids

High Power  High Energy

Power Quality Applications: “increase of power grid reliability”
- Seconds or less
  - Flicker compensation
  - Voltage sag correction
  - Reactive power control

Energy Management Applications: “production can be decoupled from demand”
- Minutes
  - Spinning reserve (for voltage and frequency regulation)
  - Uninterruptible power supply
  - Blackstart

- Hours
  - Load leveling
  - Peak shaving
  - Energy trading
  - Integration of renewables
  - Island operation
ABB/GM Collaboration on Electric Car Battery R&D

R&D project to examine the potential of reusing spent lithium-ion battery packs from GM’s Chevrolet Volt to provide cost-effective energy storage capacity, improving the efficiency of electrical systems as they evolve into smart grids.
ABB Understands the System Behind the Charging

**Substation**
- Substation Automation System
- High Voltage Products
- Power Transformers
- Medium Voltage Switchgear
- Distribution Transformers
- Protection & Control
- Grid communication
- Measurement Devices

**Network Management**
- Energy Management System
- Generation Management System
- Distribution Management System

**Renewable energy sources**
- DC/DC Converters
- Grid communication
- Measurement Devices

**Public fast charging station 100kW DC**
- MV Switchgear
- Transformer
- AC/DC converter
- DC/DC Converter & Charging controller
- DC Circuit Breaker
- Grid communication
- Measurement Devices
- Remote Terminal Unit
- User Interface & Billing System
- LV Plugs and Cables
- Residual Current Protection Device

**Domestic Wallbox 3-4kW**
- Circuit Breaker
- Over Current Protection
- Grid communication
- Measurement Devices
- Grid Communication
- Charging Control Pilot
- Low Voltage Connectors

**Energy storage for grid peak leveling**
- Grid communication
- Measurement Devices
- Charging Controller

**Public slow and semi-fast charging pole 22-50kW AC**
- Circuit Breaker
- Over Current Protection
- Grid communication
- Measurement Devices
- Residual Current Protection Device
- Low Voltage Connectors
- User Interface & Billing System
- Charging Control Pilot
EPRI Study on Influencing PEV Charging Behavior

Source: EPRI
Impact of electric cars on the local distribution grid
Why charging is more then plug-and-play

Scenario:
- 10 houses at one 50kVA transformer, 6 households own an electric car,
- 5 of them start recharging at 3.7kW at 6pm

➢ EV charging must be smart to prevent possible damage to the local grid infrastructure.
Stockholm Royal Seaport – An emerging environmental profile area and international showcase

Vision

- Royal Seaport – A sustainable urban city performing world class

Objectives

- Year 2030 the Royal Seaport is fossil free
- Year 2020 CO2-emissions below 1,5 ton per person

Focus areas

- Effective energy end-usage
- Environmental effective transports
- Local re-cycling
- Life style
Development and demonstration of a large scale Smart Grid in Stockholm Royal Seaport

1. **Smart homes/Buildings and Demand Response**
   - Reduced peak load and increased energy efficiency by demand side participation and home/building automation

2. **Distributed Energy Systems**
   - Integration of production for local generation PV and Wind in Home/Building Automation Solution

3. **Integration and Use of electric vehicles**
   - Integration of PHEV Charging Infrastructure

4. **Energy Storage for Network Support and DES**
   - Increased stability and power quality

5. **Harbor Control Solution**
   - Reduced CO2 emission based High voltage shore connection

6. **Smart Primary Substations**
   - Increased efficiency and reliability with higher automation level

7. **Smart Grid Lab (part of Royal Seaport Lab)**
   - Research, development, simulation and implementation of smart grid application
### NAM Smart Grid

**Total Market: 2010 - 2015**

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<tr>
<th></th>
<th>2010</th>
<th>2011</th>
<th>2012</th>
<th>2013</th>
<th>2014</th>
<th>2015</th>
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<tbody>
<tr>
<td>Distribution Automation</td>
<td>$974</td>
<td>$1,635</td>
<td>$2,593</td>
<td>$2,598</td>
<td>$2,657</td>
<td>$2,232</td>
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<tr>
<td>Demand Response</td>
<td>$1,680</td>
<td>$2,049</td>
<td>$2,500</td>
<td>$3,325</td>
<td>$4,423</td>
<td>$5,882</td>
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<tr>
<td>Asset Management (Excluding service)</td>
<td>$4,054</td>
<td>$4,454</td>
<td>$4,882</td>
<td>$5,339</td>
<td>$5,828</td>
<td>$6,351</td>
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<tr>
<td>Metering/AMI</td>
<td>$1,258</td>
<td>$1,470</td>
<td>$1,738</td>
<td>$1,555</td>
<td>$1,362</td>
<td>$1,253</td>
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<tr>
<td>Smart Grid Transmission Upgrades</td>
<td>$2,244</td>
<td>$2,574</td>
<td>$3,281</td>
<td>$3,921</td>
<td>$4,498</td>
<td>$5,016</td>
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<tr>
<td></td>
<td>$10,210</td>
<td>$12,182</td>
<td>$14,994</td>
<td>$16,738</td>
<td>$18,768</td>
<td>$20,734</td>
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</tbody>
</table>

Source – Pike Research
U.S. Smart Grid Value

Exhibit 1
The $130 billion question

The U.S. smart grid value at stake is over $130 billion annually.

Smart grid benefits by 2019

<table>
<thead>
<tr>
<th>Customer applications</th>
<th>Description of benefits</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shift peak</td>
<td>Shifting demand away from the peak lowers peak prices</td>
</tr>
<tr>
<td>Energy conservation</td>
<td>Demand-side management programs aim to reduce energy consumption by customers and the number of KWh that need to be generated</td>
</tr>
<tr>
<td>Avoided cost of capacity</td>
<td>Decrease in peak and energy consumption reduces need for new power plants in the future, resulting in an avoided cost of capacity</td>
</tr>
<tr>
<td>Total</td>
<td>59</td>
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<thead>
<tr>
<th>AMI</th>
<th>Description of benefits</th>
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</thead>
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<tr>
<td>Meter data over network</td>
<td>Automated meters eliminate the need for manual meter reading and meter reading equipment</td>
</tr>
<tr>
<td>Advanced meter functions</td>
<td>Operational and billing benefits from remote disconnection/connection</td>
</tr>
<tr>
<td>Total</td>
<td>9</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Grid applications</th>
<th>Description of benefits</th>
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</thead>
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<tr>
<td>Volt-VAR</td>
<td>Volt-VAR increases energy efficiency through conservation voltage reduction (CVR)</td>
</tr>
<tr>
<td>FDIR</td>
<td>Fault detection, isolation and restoration (FDIR) reduces outage time through automated switching</td>
</tr>
<tr>
<td>M&amp;D</td>
<td>Monitoring and diagnostics (M&amp;D) reduces inspection and maintenance costs; provides early warning of potential failures</td>
</tr>
<tr>
<td>WAM</td>
<td>Wide area measurement (WAM) increases transmission throughput</td>
</tr>
<tr>
<td>Total</td>
<td>63</td>
</tr>
</tbody>
</table>

Source: McKinsey on whether the US smart grid value is at stake
Smart Grid Jobs

Total Smart Grid Jobs Created and Transitioned: 2009-2018

(KEMA, Inc. 2009)
Smart Grid Leadership

Accolades

1. Most Sustainable Mid-Size Community (Raleigh, NC)
   - U.S. Chamber of Commerce
2. Top City for Smart Grid
   - U.S. Headquarters (Raleigh, NC)
   - Duke University
3. Top City for Smart Grid Software Development
   - Raleigh, NC
   - Duke University
4. State for Smart Grid Vendors (North Carolina)
   - Duke University

“The combination of cutting edge research, manufacturing expertise, active utility involvement, and public sector support in establishing Raleigh as the world headquarters for smart grid development.”

Alex G. Huang, PhD, Director
NSF FREEDM Systems Center
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