Gary Rackliffe – Vice President Smart Grids North America, ABB Inc.

Smart Grid Vision and Trends

How2Guide for Smart Grids in Distribution Networks
ISGAN, IEA, and SENER
Mexico City, March 26 – 28, 2012
ABB’s vision

As one of the world’s leading engineering companies, we help our customers to use electrical power efficiently, to increase industrial productivity, and to lower environmental impact in a sustainable way.
Global electric energy drivers

Helping the global grids work smarter not harder
Capacity – Electricity consumption to double by 2030 …but global climate concerns gathering momentum

Rise in electricity consumption by 2035 (under current policies)
Source: IEA, World Energy Outlook 2010

Electricity consumption in kWh per capita by country

<table>
<thead>
<tr>
<th>Country</th>
<th>2008</th>
<th>2020</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>Canada</td>
<td>16,800</td>
<td>23,700</td>
<td>32,900</td>
</tr>
<tr>
<td>USA</td>
<td>20,000</td>
<td>23,700</td>
<td>32,900</td>
</tr>
<tr>
<td>Japan</td>
<td>11,000</td>
<td>15,000</td>
<td>21,000</td>
</tr>
<tr>
<td>Russia</td>
<td>9,000</td>
<td>12,000</td>
<td>15,000</td>
</tr>
<tr>
<td>Germany</td>
<td>14,000</td>
<td>18,000</td>
<td>23,000</td>
</tr>
<tr>
<td>South Africa</td>
<td>7,000</td>
<td>10,000</td>
<td>13,000</td>
</tr>
<tr>
<td>Bulgaria</td>
<td>5,000</td>
<td>8,000</td>
<td>10,000</td>
</tr>
<tr>
<td>Malaysia</td>
<td>6,000</td>
<td>9,000</td>
<td>12,000</td>
</tr>
<tr>
<td>China</td>
<td>3,000</td>
<td>4,000</td>
<td>5,000</td>
</tr>
<tr>
<td>Brazil</td>
<td>1,000</td>
<td>1,500</td>
<td>2,000</td>
</tr>
<tr>
<td>Iraq</td>
<td>700</td>
<td>1,000</td>
<td>1,500</td>
</tr>
<tr>
<td>Algeria</td>
<td>1,000</td>
<td>1,500</td>
<td>2,000</td>
</tr>
<tr>
<td>India</td>
<td>400</td>
<td>600</td>
<td>800</td>
</tr>
</tbody>
</table>

World avg: 3,240 kWh/capita

Rise in electricity consumption by 2035 (under current policies)

<table>
<thead>
<tr>
<th>Year</th>
<th>2008</th>
<th>2020</th>
<th>2035</th>
</tr>
</thead>
<tbody>
<tr>
<td>TWh</td>
<td>16,800</td>
<td>23,700</td>
<td>32,900</td>
</tr>
</tbody>
</table>

+96%
Reliability – Ensuring reliable grid operations

- **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
  - Power oscillation monitoring
  - Integration of renewables
1. 80% of energy is lost along the value chain
2. Approximately 10% of electric energy produced by power plants is lost during transmission & distribution
4. Efficient distribution transformers and Volt/Var control improve efficiency.
Renewable generation – variable sources

Solar output over time

Wind output over time
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.
Technology solutions – how are we responding

1. Power electronics
   - HVDC and FACTS
   - Inverters for Solar PV
   - Drives for industrial automation
   - DC grids for data centers

2. Creating a more flexible, adaptive grid
   - Communications
   - Distribution grid management – FDIR, Volt/Var Efficiency
   - Demand Response
   - Energy Storage
   - Distributed Generation

3. OT/IT integration
   - Back office data processing – MDMS, WAMS, VPP
   - Business intelligence – Asset Health, Customer Preferences
   - Systems integration – Smart Grid Control Center
Smart grid pillars

- Transmission Grid Management
  - Energy Management System
  - Wide Area Management System
  - Flexible AC Transmission System
  - High Voltage DC Link

- Distribution Grid Management
  - Distribution Management System
  - Outage Management System
  - Volt/Var Efficiency
  - Self Healing Reliability

- Meter Management

- Asset Health Management
  - Monitoring & Diagnostics
  - Sensors & Monitors
  - Asset Analytics
  - Dashboards

Utility IT Management
- CIS and GIS
- Security
- Work and Asset Management
- Business Intelligence

Demand Management
- Demand Response
- Distributed Generation
- Energy Storage
- Electric Vehicle Charging
Smart grid pillars

Transmission Grid Management

Distribution Grid Management

Asset Health Management

Monitoring & Diagnostics
Sensors & Monitors

Asset Analytics
Dashboards

OT/IT Integration

Utility IT Management

CIS and GIS
Security

Work and Asset Management
Business Intelligence

Demand Management

Demand Response
Distributed Generation

Energy Storage
Electric Vehicle Charging

Flexible AC Transmission System
Wide Area Management
High Voltage DC Link
FACTS – wind applications in West Texas

- West Central Texas: plenty of wind power
  - McCain area: 750 MW and growing;
  - Central area: 1,000 MW
- Very high wind power penetration (up to 80%) and variations in import/export of active power due to rapid swings of wind farm output require continuous voltage regulation.
- Induction generators lose synchronism at low voltages and thus increase their reactive power demand, further dragging down the system voltage. **SVCs provide voltage support.**
- A **Series Capacitor**, rated 400 Mvar, has been installed at the Horse Hollow end of a 345-kV inter-tie. Horse Hollow is a very large wind farm in Texas with 750 MW. The line takes the power 300 km to the south, to Kendall in the San Antonio area.
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. Savings of 4 – 5% can be achieved.
Distribution grid management
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
Control – None of the Technologies

Programmable Communicating Thermostat

In-Home Display

Web Portal

All 3 Technologies

Source – OG&E
EV Charging infrastructure

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

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

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

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

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

- Balancing power is a major issue for utilities and especially critical with large amounts of variable 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

minutes
- Spinning reserve (for voltage and frequency regulation)
- Uninterruptible power supply
- Blackstart

Energy Management Applications: “production can be decoupled from demand”

hours
- Load leveling
- Peak shaving
- Energy trading
- Integration of renewables
- Island operation
Solar PV

PV Grid Tied Solar Smoothing
1,000 Watt PV Array

Battery size = ~2 kWh
For a 1 KW PV System
~41 Ah @ 48V Total Battery Size
Assumes ±10 Ah or ±480 Wh Cycle

Power / Irradiance (W/m²) / Energy (Wh)

Solar Irradiance
Inverter Output (Running Average)
Energy Required (Wh)

0:00 2:24 4:48 7:12 9:36 12:00 14:24 16:48 19:12 21:36
-348 Wh

-200.0 -100.0 0.0 100.0 200.0 300.0 400.0 500.0 600.0 700.0 800.0 900.0

Sandia National Laboratories
Integrating OT/IT with virtual power plants
Integrated Operations Center for Smart Grid

ABB Network Manager

SCADA and DMS
Outage management
Advanced applications

SCADA/EMS
Integration

AMI/MDM
GIS
MWM
CIS
WMS
VR

Communication

Unbalanced load flow

Substation computer / gateway
Voltage regulator

Feeder protection

Line recloser

Capacitor control

Backfed tie switch

Distributed generation and energy storage

Fault location
automatic switching
and restoration

Plug-in hybrid electric vehicles

AMI integration and demand response

Field crews

Substation

Feeder

Customer
End-to-End Solution to Drive Asset Performance

Asset Health Management End-to-End Process

Operations Technology (OT)
Information Technology (IT)

Apparatus & Service
- Transformers
- Breakers
- Batteries
- HVDC & FACTS
- Switches
- Reclosers
- Switchgear

Sensors and Monitoring
- Transformer monitors
- Circuit Breaker monitors
- Battery Monitors
- Relays (IED’s)
- Instrumentation/sensors

Substation Gateway
- Substation Automation
- Data Concentration
- Communications

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

Analytics & Performance Models
- Decision Support:
  1. Operations Impact
  2. Optimized Maintenance
  3. Lifecycle Management
  4. Recommended Work Execution

Performance models based on embedded T&D equipment intelligence

Work & Asset Management
- Work Management
- Inventory
- Crew Deployment

ABB T&D products, systems, service & expertise

Asset Health Center
## Smart Grid Value

<table>
<thead>
<tr>
<th></th>
<th>20-Year Total ($billion)</th>
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<tr>
<td>Net Investment Required</td>
<td>338 – 476</td>
</tr>
<tr>
<td>Net Benefit</td>
<td>1,294 – 2,028</td>
</tr>
<tr>
<td>Benefit-to-Cost Ratio</td>
<td>2.8 – 6.0</td>
</tr>
</tbody>
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(Provided by EPRI Report 1022519: *Estimating the Cost and Benefits of the Smart Grid*)
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.
Power and productivity for a better world™
Contact Information:

gary.racklifffe@us.abb.com