Overview of BCIT Smart Power Microgrid

Hassan Farhangi, PhD, PEng, SM-IEEE
Director, Smart Grid Research
British Columbia Institute of Technology, Vancouver, Canada

Saudi Arabia Smart Grid Conference & Exhibition
SASG 2012, Dec 2012
Jeddah, Saudi Arabia
Agenda

1. Background
2. Drivers for Smart Grid
3. Topology of Smart Microgrid
4. Smart Grid Evolution
5. BC-Hydro/BCIT Smart Microgrid
6. Smart Microgrid Building Blocks
7. Smart Microgrid Functions
8. Smart Microgrid Applications
9. BCIT Smart Microgrid Current Projects
10. Q&A
Background

Problems facing the Power Industry:
1. Rising cost of energy
2. Aging infrastructure
3. Mass Electrification
4. Climate Change

Solutions pursued by Utility companies:
1. Optimize use of expensive assets
2. Manage end-user demand
3. Facilitate Co-Generation
4. Use renewable sources of energy

These require modernization of the electricity grid!
The Existing Grid

- Centralized Grid
- Only 1/3 of fuel energy converted to electricity
- Waste heat is not recovered
- 8% is lost along transmission lines
- 20% gen capacity exists to meet peak demand only (i.e. 5% of time)
- Domino effect failures
The future Smart Grid

- Real-time Simulation and Contingency Analysis
- Distributed Generation and Alternate Energy Sources
- Self-Healing Wide-Area Protection and Islanding
- Asset Management and On-Line Equipment Monitoring
- Demand Response and Dynamic Pricing
- Participation in Energy Markets

Source: EPRI
Smart Grid Dev Roadmap

Technologies
- One-Way Comm
- Two-Way Communication
- CIM/IEC-61850 Compliant
- Distributed Command & Control
- Network Management
- Intelligent Applications
- Intelligent Agents

Investments
- Automated Billing
- Demand Response
- Outage Detection & Restoration
- Asset Management
- Customer Information System
- Distribution Automation
- Substation Automation
- Preventive/Self-Healing
- Load Management
- Emission Control
- Distributed/Co Gen
- Customer Portals
- Intelligent Appliances

Capabilities
- Smart Grid
- SG-AMI
- AMR

All Rights Reserved, Dr. Hassan Farhangi, BCIT, Vancouver, Canada, Nov 2010
Transition from Legacy Grid to Smart Grid

Through Islands of Intelligence in Grid-Tied or Off-Grid modes
The Future Grid

- Network of loosely integrated independent Smart Microgrids
- Harnesses Heat & Power (CHP)
- Allows Demand Response
- Avoids transmission losses
- Integrates renewables
- Resilient to Domino failures

- Empowers Consumers and Independent Power Producers to be proactive players and stakeholders in smart energy transactions
Path from Legacy to Smart
BC Hydro/BCIT’s Smart Microgrid

Canada’s first campus based Smart Microgrid at BCIT’s Burnaby Campus
BCIT’s Burnaby Campus
BC-Hydro/BCIT’s Smart Microgrid Topology

CO-Gen Plants
- Flywheel + Li-Ion Storage 150 KW
- Thermal Turbine 250KW
- PV Modules (Solar) 31KW
- Wind Turbine 2X5 KW

Meshed Network
- Distributed Command & Control

Core Intelligence
- Smart Grid Control Center

Campus Loads
- EV Charging Stations
- Industrial Loads
- Classrooms & Offices
- Residences

Microgrid Controller

Core Intelligence

Meshed Network

CO-Gen Plants
Smart Grid Research Objectives

- Development of a Smart Microgrid to enable:
  - Provisioning Methods for Smart Termination Points (Meters, Data Aggregators, Appliances, Sensors, Controls, etc)
  - Integration Solutions for Alternative Sources of Energy (Co-Generation thru Wind, Solar, Thermal, Bio-Mass, etc)
  - Innovative Network Architecture and Topology for Smart Grid

- Operational Analysis and Qualification of Grid’s:
  - Resilience, Reliability, Security and Scalability
  - Data Collection, Command & Control algorithms
  - Forward/backward compatibility with up & coming technologies

- Development of Interface Protocols & Models to ensure:
  - Interface with Utility Back-office tools (Billing, Load Management, Service Provisioning, Asset Management, Outage Restoration, etc)
  - Seamless end-to-end deployment, operation & maintenance
  - Easy & Intuitive human interface for operators & customers
Phase 1: Construction of Smart Microgrid (2008-2010)
- Completion of Smart Metering on designated loads
- Development of Load Control Devices for Afresh/Dorms
- Integration of Comm Network (Zigbee, WiMax and Fiber backhaul)
- Integration of Co-Gen, Solar Modules and Wind Turbine
- Completion of protection/islanding of BCIT Campus
- Retrofitting and Integration of AFRESH with Microgrid
- Dev of BCIT EMS system (target 10% annual saving)

Phase 2: Smart Grid Research and Development (2010-2015)
- Research thru NSERC Strategic Network (UoNB, McGill, UoT, UoWO, UoA, UBC, SFU, UVIC and BCIT)

- Setup of Industry Canada’s NCE (Network of Centers of Excellence) in pan-Canadian Smart Grid technology
Thermal Co-Gen

- Fed by Nebraska Boiler
- New advanced multi-fuel boiler in Building SE8
- Combined Heat and Power (CHP)
- Planned Flywheel (75 KW) and Li-Ion Storage pack (75 KW)
- Rated at ~ 250 kW
Thermal Co-Gen
Thermal Co-Gen
PV Co-Gen

- First Generation Solar Tower (2kw on each side, 8kw nominal capacity)
- Various PV installations on the campus with total capacity of 14 kw
- High efficiency PV cells are installed on Gateway building with a nominal “installed” capacity of 17 Kw
- The output is fed into campus grid
- Purpose of PV Co-Gen is to study its integration issues with the Microgrid
PV Co-Gen
Wind Turbines

- 5Kw vertical axis wind turbine installed next to Smart Home
- Installation of 5Kw horizontal axis wind turbine is planned
- Number of windy days are limited in the lower mainland
- Wind speed is not high
- Purpose is to study wind resource integration issues
Wind Co-Gen
Net-zero Nanogrid

- Known as Smart Home
- Integrated Smart Metering Technologies
- Solar panels
- Geo-thermal
- Fuel cell
- EV charging station
- Smart Appliances
- Residential EMS
Smart Home (Nanogrid)
Load Control Thru Scheduling
Core Intelligence: BCIT’s SGCS
BCH/BCIT Smart Microgrid AMI

- Smart Meters are installed in various buildings and on some target loads to be monitored
- Technologies chosen based on challenging environments (e.g. PLC in Welding shop, etc)
- Different MDMS need to be integrated under utility EMS
- Issues were discovered (e.g. reliability of technologies)
BC Hydro/BCIT Smart Microgrid Communication System Topology

Home Area Network
- Appliances
- Load Control
- Residential EMS
- Residential Grade Meter

Local Area Network
- LAN Interface Unit
- Substation Field Components
- Substation Data and Control Servers

Wide Area Network
- Enterprise Clients
- Revenue Management
- Asset Management
- Operational Management

Applications:
- Home Area Network: DR, EMS
- Local Area Network: Substation Automation & Feeder Management
- Wide Area Network: Billing, Asset Management, Outage Management

Communication Technology:
- Home Area: Zigbee, HomePlug
- Local Area: NB PLC, HomePlug, ISM RF
- Wide Area: WiMax 16D/E, Fibre

Protocol:
- Home Area: Smart Energy Profile 2.0
- Local Area: ANSI C12.22 (for metering), IEC-61850 (for Substation)
- Wide Area: TCP/IP
Frequency & Network Planning

Network Status as of October 2010
BCH/BCIT Smart Microgrid WAN
Smart Microgrid Subprojects

1. Energy Management System
2. Maquinna Residence AMI
3. North Campus AMI
4. Smart Home Appliances
5. Wind Co-Gen Integration
6. Solar Co-Gen at Gateway
7. Full Islanding of EVCS
8. Smart Grid Control Center
9. Microgrid Controller
10. Substation Automation
Load Control Thru Scheduling

- User Specified Scheduling
- Targets baseboard heaters, hot water tanks, lighting, etc.
- EMS directly communicates with load control boxes
Load Control thru Pricing Signals
Maquinna Residence

- **Problems**
  - Lots of waste
  - little incentive to conserve
  - no real-time metering
  - awareness of issues low

- **Solution**
  - Smart meters
  - EMS Residence Portal
  - Create Awareness
EMS Residence Portal

- Designed to increase awareness of electrical consumption
- Targets to reduce consumption by modifying consumer behavior
- Portal design was based on Social science research
- Consumers sensitive to how they’re doing versus their neighbours
- Focus on empowering consumers to make the right energy choices
EMS Residence Portal

energy consumption: SW14 - Kootenay

848.0 kWh consumed in this period could power for the same period:

65,231 compact fluorescent bulbs (CFLs)

or

26,092 laptops

Carbon Dioxide Emissions CO₂ eq for BC Hydro

Outdoor Temperature Degrees Celsius Average

Kootenay Footprint
Total kWh 848.0 kWh
$$ $ 110.88
CO₂ 22.0 kg

House Comparison

<table>
<thead>
<tr>
<th>kWh</th>
<th>CO₂</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nootka</td>
<td></td>
</tr>
<tr>
<td>Salish</td>
<td></td>
</tr>
<tr>
<td>Chilcotin</td>
<td></td>
</tr>
<tr>
<td>Carrier</td>
<td></td>
</tr>
<tr>
<td>Kootenay</td>
<td></td>
</tr>
<tr>
<td>Nisga’a</td>
<td></td>
</tr>
<tr>
<td>Haida</td>
<td></td>
</tr>
</tbody>
</table>
DR Competition Results

- 21% overall reduction in consumption
- Over 30% reduction in winning house
- GREAT response from students!
  - Level of interest very high
  - Many were studying by flashlight
  - Motivated by competition
Impact of DR Field Tests on Student Residence Demand Curve
Current Smart Grid Projects

- Adaptive Real-Time VVO/CVR using AMI Data
- Virtual Substation using IEC 61850 Architecture
- Mitigating impact of EV Charging Station on utility distribution network using Renewable Sources and EMS
Real-time Adaptive VVO/CVR
Virtual Substation (61850 based)
Mitigation of EV Charging Impact
Mitigation of EV Charging Impact
Mitigation of EV Charging Impact

[Diagram showing the integration of EV charging stations with renewable energy sources and storage systems.]

- Transformer
- Voltage Regulator
- Feeder Breaker
- Cap Bank
- Wi-Max Base Station
- Solar Co-Gen
- Wind Co-Gen
- MultiFuel Co-Gen
- Battery Storage
- EV Level 3 Charging Station #1
- EV Level 3 Charging Station #2
- EV Level 3 Charging Station #n
- Substation Automation Server (IEC 61850)
Mitigation of EV Charging Impact
Mitigation of EV Charging Impact

Welcome to BCIT OASIS
EV Fast-Charge Station

A charger is available for the next 59 minutes.

Solar powered EV charge.

Identify your EV to begin charging:

Province / State: British Columbia (BC)
License Plate #: 000 AAA
Mitigation of EV Charging Impact

Welcome to BCIT OASIS
EV Fast-Charge Station

Remaining charge in EV battery?

I need to charge up to at least

OR

I know where my next destination is

Earn a free charge. Learn how!
Mitigation of EV Charging Impact

Welcome to BCIT OASIS
EV Fast-Charge Station

To: 29447 Matheson Ave, Mission, BC V4S 1B5, Canada

Use zoom if needed, then touch map to indicate your next destination where charging is available.

Estimated
Distance: 52.0 km
Highway: 13 km
Mitigation of EV Charging Impact

Battery Charge Cumulative Energy
- 12.24 kWh

Charger Input Cumulative Energy
- 177.31 kWh

1.62 kWh

154.20 kWh
Questions?

Dr. Hassan Farhangi, PhD, PEng, SM-IEEE
Director, GAIT, BCIT Technology Centre
BCIT CARI Bldg Wing B, 4355 Mathissi Place
Vancouver, BC, V5G 4S8, CANADA.

Tel: +1-604-456-8074

e-mail: Hassan_Farhangi@bcit.ca

http://www.bcit.ca/microgrid/
http://www.smart-microgrid.ca/