Active Distribution Management Workshop

CIGRE Canada 2009 Symposium

Mark McGranaghan - EPRI
Roger Dugan – EPRI
Chad Abbey - IREQ

October 4, 2009
Toronto
Agenda

• Active Distribution Management Overview
• Modeling Considerations and OpenDSS
• Examples of Active Distribution Management and CIGRE C6.11 Activities
• IEEE Distribution Automation Working Group
• Demonstrations
Active Distribution Management - Definition

• Distribution system operation and controls with the following characteristics

1. Active monitoring of distribution system conditions
2. Control of distribution system in real time
   • Protection functions
   • Reconfiguration after faults
   • Fault location
   • Voltage and var management
3. Integration of distributed generation, storage, and demand response
Developing a Roadmap for Active Distribution Management

- System Topologies (Configuration, protection, control)
- Communication architecture and information model development
- New technologies (power electronics, IUT, etc.)
- Sensors and monitoring systems (intelligent monitoring)
- Advanced distribution controls (coordinated distributed intelligence)

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System Design Considerations

• Distributed Controls vs Central Controls
  – Local controls
  – Substation control
  – Central control

• Communication Infrastructure Requirements
  – What happens when communications are out?

• Distribution management system
  – Basic functions
  – Integration requirements
  – Maintaining the model

• Integrating distributed resources
Before Distribution Automation (courtesy of Alabama Power)
Automation benefits and costs can be evaluated in stages but consider infrastructure requirements for each stage and joint benefits for the infrastructure.
More detailed flow of implementation - roadmap

Information System Infrastructure for Managing Data and Providing Basis for Applications

Communication Infrastructure to the Substations

Communication Infrastructure to the Feeders

Communication Infrastructure to the Customers

Substation Monitoring and Applications (SCADA, Fault Location, Equipment Diagnostics, etc.)

Feeder Monitoring and Automation (SCADA, Automatic Reconfiguration, Optimization)

Customer System Integration (AMI, Demand Response, DER, Energy Efficiency)
Substation Automation and Substation Integration

- Most significant implementation of automation today
- Many different communication technologies and protocols – migration to UCA/IEC 61850
- Significant improvement in operations and reliability is possible from substation automation alone.
Using substation monitoring for fault location

Single-Phase Fault Evolves into Two-Phase

Voltage (kV)

Current (kA)

Time (s)

EPR/Electrotek
Automating Distribution Feeder Circuits – Benefits

- More flexible operation of distribution system
- Automated system response to disturbances and outages
- Improved reliability with multiple options for supplying load
- Optimized asset management and system efficiency
- Integration of DER to improve system performance and allow integration with energy management systems
Line Monitoring for RTUs

- Detection per phase
- Voltage, current and power factor per phase
- Standard distribution line design
Fault Isolation & Restoration

• Primary Systems
  – Traditional utility first line of defense
  – Protective Relays & Reclosing Relays
  – Distribution Line Reclosers

• Secondary Systems
  – Operates after feeders have locked out
  – Gathers granular fault data from field devices
  – Determines fault location
  – Automatically isolate the faulted feeder section (if possible)
  – Automatically restore unfaulted feeder sections (i.e., customer load)
Automatic Sectionalizing & Restoration (ASR)

• ASR is a generic term for secondary fault isolation and service restoration

• Three types of ASR
  – Switch based
  – Distributed ASR (DASR)
  – Centralized ASR (CASR)
Automated reconfiguration opportunities

- Open Recloser
- Fault
- Automatic Closing device (recloser or switch)
- Shaded area is portion picked up by auto-loop
Example Operator View
S&C
Omni-Rupter flat-plane switch with Cleaveland/Price motor operator
Pole-Mounted Recloser

MAS remote antenna
SCADAMate Switch
Pulse closing
Sensors for Automation Applications

Piedmont Dielectric Line Sensors

Lindsey voltage and current sensors for OH and UG

Wireless communicating voltage and current sensors
Hydro Quebec – $188M 6 year plan for automation (3750 switches)

DATA
(Using what?)
Voltage
Fault Currents
Load Currents
Temperature
Number of Operations
Alarms

Applications
(How?)
Voltage Control
Optimised Load Flow
Fault Location
Faulty Equipment
Power Quality Evaluation
...
What Else?

- Proactive load management
- Adaptive Volt/VAR control
- Demand response Integration
- AMI Integration
- Distributed generation integration
Coordinated Volt/Var Control

• Voltage regulators
• Capacitor banks
• Future – integrated operation of power electronics for
  – Storage
  – PV
  – Static compensators
  – …
• **Volt-VAR flows managed by individual, independent, standalone volt-VAR regulating devices:**
  - Substation transformer load tap changers (LTCs)
  - Line voltage regulators
  - Fixed and switched capacitor banks
“SCADA” Controlled Volt-VAR

- Volt-VAR power apparatus monitored and controlled by SCADA

- Volt and VAR Control typically handled by **two separate** (independent) systems:
  - **VAR Dispatch** – controls capacitor banks to improve power factor, reduce electrical losses
  - **Voltage Control** – controls LTCs and/or voltage regulators to reduce demand and/or energy consumption (aka, *Conservation Voltage Reduction*)

- Operation of these systems is primarily based on a **stored set of predetermined rules** (e.g., “if power factor is less than 0.95, then switch capacitor bank #1 off”)
Develops a coordinated “optimal” switching plan for all voltage control devices and executes the plan.
Integrated communication network for distribution management
Integrated Volt VAR Control – DG Included

Voltage and VAR Regulation Coordination Algorithm

Manages tap changer settings, inverter and rotating machine VAR levels, and capacitors to regulate voltage, reduce losses, conserve energy, and system resources.
Integrating AMI Data with Distribution Operations

IEC 61970/61968 Common Information Model (CIM)
Enterprise Application Integration

CIS
EMS
OMS
Distribution Automation

“Middleware” “Integration Bus”

AM/FM/GIS
Work Management
Meter Data Management

Customer Communications

ANSI/IEC Metering “Field Operations”

Field Data Collection

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AMI Integration Options and Use Cases
Fault Location with Distributed Monitors

- Voltage Drop Fault Location (VDFL)
  - Distributed Monitors
  - Voltage waveforms
  - Most feeders require only 4 measurement sites
  - Easy measurement
    - Low voltage (customer side)
    - GPS not required (no precise synchronisation required)
    - Calibration not needed
New Distribution Models Open Up New Applications

- Fault Location
- Minimize Losses
- Volt/Var Control
- Transformer Load Management
- Integration of Distributed Resources

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Vision for Distribution Management System integration with Smart Grid

- Asset Management
- GIS
- Planning/Forecasting
- AMI/MDMS/CIS
- Outage Data
- Distribution Model
- OMS
- GIS
- SCADA
- DA
- VVC
- Efficiency
- DG
- DSM, PHEV

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Discussion of DMS Issues

- DMS Applications
  - Volt Var Control
  - Loss Management
  - Reliability/reconfiguration
  - Asset management
  - Fault location/fault management

- Important Interfaces
  - GIS
  - OMS
  - Asset Management
  - Distribution Models
  - MDMS
  - CIS

- Distributed vs Central processing considerations
- Model management and complexity
- State estimators
- Operator interface requirements
- Cost/benefit assessment approaches
- Integration of distributed resources
Questions?
Agenda

• Active Distribution Management Overview
• Modeling Considerations and OpenDSS
• Examples of Active Distribution Management and CIGRE C6.11 Activities
• IEEE Distribution Automation Working Group
• Demonstrations
Open Source Software for Simulating Active Distribution Systems

Roger Dugan
Sr. Technical Executive
rdugan@epri.com

Active Distribution Management Tutorial
Cigre Canada
Toronto, Ontario
October 4, 2009
OpenDSS

• EPRI released its Distribution System Simulator (DSS) program as *open source* in Sept 2008
  – Source code is available to public
  – BSD License – basically no limitations

• Called “OpenDSS”

• Can be found at:
  – [WWW.SOURCEFORGE.NET](http://WWW.SOURCEFORGE.NET) (Search for OpenDSS)
History

• DSS development was started at Electrotek Concepts in 1997 to provide
  – a very flexible and expandable research platform
  – a foundation for special distribution analysis applications
    • In particular, DG analysis

• Fills many of the gaps left by more conventional distribution system analysis tools
• For developing new approaches to distribution system analysis
• Acquired by EPRI in 2004
Time- and Location-Specific Benefits

• The DSS was designed from the beginning to capture both **Time- and Location-specific benefits** of
  – DG or other proposed capacity enhancements

• Most traditional distribution system analysis programs:
  – Capture only some location-specific benefits
  – Ignores time; Assumes resource is available
  – *This gets the wrong answer* for many DG and energy efficiency analyses

• Must do **time sequence analysis**
  – Over distribution planning area
Original Overall Model Concept circa 1997

- Distribution Planning Area consisting of one or more substations
- Controllable power conversion elements (e.g. DG, Storage)
- Model transmission system connecting the substations

Control system overlay

Inf. Bus (Voltage, Angle)

Power Delivery System

Comm Msg Queue 1

Comm Msg Queue 2

Power Conversion Element ("Black Box")

Control Center

Control
Why Did We Make it Open Source?

• EPRI has made the DSS open source to:
  – Cooperate with other open source efforts in the USA in Smart Grid research
    • Gridlab-D at PNL, for example
  – To encourage new advancements in distribution system analysis
    • We’ve already seen proof of this
  – To provide Smart Grid researchers a tool for testing and developing distribution control algorithms
Example DSS Applications (the more exotic ones)

- Neutral-to-earth (stray) voltage simulations.
- Loss evaluations due to unbalanced loading.
- Development of DG models for the IEEE Radial Test Feeders.
- High-frequency harmonic and interharmonic interference.
- Losses, impedance, and circulating currents in unusual transformer bank configurations.
- Transformer frequency response analysis.

- Distribution automation control algorithm assessment.
- Impact of tankless water heaters on flicker and distribution transformers.
- Wind farm collector simulation.
- Wind farm impact on local transmission.
- Wind generation and other DG impact on switched capacitors and voltage regulators.
- Open-conductor fault conditions with a variety of single-phase and three-phase transformer connections.
What Can It Do?

Examples of Results
Current

```
 oh_pri_132118_i
  48.0524 /_ -62.53 →
  42.5858 /_ 177.11 →
  47.5882 /_ 57.29 →

line.2750_5011_sw

  48.0524 /_ 117.47 ←
  42.5859 /_ -2.89 ←
  47.5883 /_ -122.71 ←

  5.36637 /_ 175.26 →
  5.36637 /_ -4.74 ←
```
A Bit More Complicated …

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| U143046 / 159.6 / → | ← U1431/V / -20.38 |

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Annual Losses

Peak load losses are not necessarily indicative of annual losses
Power Distribution Efficiency (EPRI Green Circuits Project)

Light Load Week

Peak Load Week

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Solar PV Simulation

Difference

MW

Without PV  With PV

Difference

MW

2 Weeks

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Solar Ramp Simulation – Regulator Impacts
Using DSS to Determine Incremental Capacity of DG

"Needle" Peaking System

Capacity Gain for 2 MW CHP

"How much more power can be served at the same risk of unserved energy?"

Broad Summer Peaking System
Wind Plant 1-s Simulation

Active and Reactive Power

Feeder Voltage and Regulator Tap Changes

Electrotek Concepts® TOP, The Output Processor®
DG Dispatch

Power, kW

Reactive Power, kvar

Hour

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Areas with greatest change in fault current due to DG
Where Can I Find It?

http://sourceforge.net/projects/electricdss/develop

(Or go to Sourceforge.net and search for “OpenDSS”)

Download OpenDSS

What's happening?
- OpenDSS
  - rdugan committed revision 203 to the OpenDSS SVN repository, changing 5 files.
    - 2009-08-21 02:12:39 UTC by rdugan
  - OpenDSS
  - rdugan committed revision 202 to the OpenDSS SVN repository, changing 10 files.
    - 2009-08-20 22:05:53 UTC by rdugan
  - OpenDSS
  - rdugan committed revision 201 to the OpenDSS SVN repository, changing 1 files.
    - 2009-08-20 15:56:38 UTC by rdugan
  - OpenDSS
  - rdugan committed revision 200 to the OpenDSS SVN repository, changing 1 files.

Links You May Need
- Download OpenDSS
- Get Support for OpenDSS
- Send a request to join this project

Project Admins
- rdugan
- robertkenny
- temcdi
- treno1

Our Numbers
- Bugs (0 open / 0 total)
- Support Requests (0 open / 0 total)
- Patches (0 open / 0 total)
- Feature Requests (0 open / 0 total)
- Public Forums (2 messages in 2 forums)
- Mailing Lists (0 total)
- SVN Repository (199 commits, 269 reads)

Newest Members
- dfinn
- shizhenhant
- taniel
- leeking337
### Installation files on SourceForge.Net

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**Number of Downloads Since May Release**

- Training_6_3_1.zip: 125 downloads
- OpenDSS_6_3_1.zip: 218 downloads
- Training_6_3_1.zip: 125 downloads
Known Active* Users Outside EPRI

• Strathclyde University
• University of Tennessee
• Tennessee Tech / NES
• GE
• KEMA
• (Student in Poland)
• PNNL
• Arizona State Univ

• Cal Tech
• EnerNex
• IEEE Test Feeders WG

* - Active includes those using OpenDSS to benchmark their own tools
EPRI Usage

- Green Circuits
- PHEV Impacts
- Wind plant and solar power simulations
- DG interconnection studies
- Harmonics studies
- Stray voltage/NEV
- As basis for renewable DG screening apps (e.g., P174)
- Support for Smart Grid Demos (P124)
- Distribution State Estimator development (w/ EDF)
- Lab support
- General studies
  - Distribution power flow, Loss evaluation, etc.
  - Atypical faults, transformer connections, etc.
OpenDSS Strengths

• Arbitrarily detailed n-phase circuit model - Few limitations
• Extensible
  – Can add new models or drive from another program
• Can solve large problems
  – Upper limit? (We don’t know yet)
• Solution speed is competitive with commercial programs (does some things better than many)
• Designed to do time series simulations:
  – Annual simulations (15 min – 1 hr steps)
  – Daily simulations (15 min – 1 hr steps)
  – Duty cycle simulations (1 s – 1 min steps)
  – Dynamics simulations (step size in ms)
OpenDSS Limitations

• Frequency domain only
  – Does not currently do electromagnetic transients
    • There have been several requests to add it
  – Sufficient for >90% of its intended purpose supporting distribution planning

• Is a solution engine, not a complete distribution planning support system
  – Sufficient for research and consulting environment
    • Or a commercial software developer
  – Lacks graphical circuit data editor and database
    • Relies on commercial vendors for that function
DSS Structure

Scripts

COM Interface

Main Simulation Engine

User-Written DLLs

Scripts, Results

Written DLLs

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DSS Object Structure

DSS Executive

Commands | Options
---|---

Circuit

Solution

PDElement
- Line
- Transformer
- Capacitor
- Reactor

PCElement
- Load
- Generator
- Vsource
- Isource
- Storage

Controls
- RegControl
- CapControl
- Relay
- Reclose
- Fuse
- StoreControl

Meters
- Monitor
- EnergyMeter
- Sensor

General
- LineCode
- LineGeometry
- WireData
- LoadShape
- GrowthShape
- Spectrum
- Spectrum
- TCCurve

NEW 11/09
Power Delivery (PD) Elements

\[ I_{\text{term}} = [Y_{\text{prim}}] V_{\text{term}} \]
\[ I_{\text{Term}}(t) = F(V_{\text{Term}}, \text{State}, t) \]

Power Conversion Element
Load (a PC Element)

(One-Line Diagram)
Putting it All Together

ALL Elements

Yprim 1
Yprim 2
Yprim 3
Yprim n

PC Elements

Compensation
Currents

I1
I2
Im

(non-Linear Part)

I_{inj} = Y

(Linear Part)

V

Node Voltages

Iteration Loop
Questions I Get ...
What Kind of Power Flow does OpenDSS Use?

• The DSS is not a traditional power flow as power engineers tend to think of power flows
  – It is a Simulator
• Its heritage is harmonics analysis and dynamics analysis
  – It is a power flow in the sense that you can model loads connected to buses and get a solution that matches traditional power flow programs
• The “Normal” solution mode is a fixed point iterative solution that works fine for >90% of distribution systems
• There is a “Newton” solution method for circuits that are difficult to converge with the Normal method.
  – Not to be confused with the traditional Newton-Raphson method in power flow programs
The Fixed Point Solution Algorithm …

ALL Elements

Yprim 1  Yprim 2  Yprim 3  ...  Yprim n

PC Elements Compensation Currents

I1  I2  ...  Im

(non-Linear Part)

I_{inj}  =  Y

(Linear Part)

Node Voltages

V

Iteration Loop
Solution Speed

• Distribution systems generally converge quite rapidly with this method.

• The OpenDSS program seems to be on par with the faster commercial programs – or faster

• It is set up to run annual simulations easily
  – Our recommendation:
    • *Err on the side of running more power flow simulations*
    • That is, don’t worry about the solution time until it proves to be a constraint
    • This reveals more information about the problem.
How Do You Get Currents and Power If You Only Solve for Node Voltages?

• One thing that troubles some users who are accustomed to other ways of solving power flows is how the branch currents (and powers) are determined when only the Node voltages and “Compensation” currents are known.

• If the Y matrix is properly formed, and convergence is achieved, the currents will be correct
  – Trust Kirchoff’s Current Law at nodes!!
Where Does OpenDSS include Mutual Coupling?

• It Always Includes mutual coupling!
  – All circuit element models provide the DSS executive with an Admittance **MATRIX**
    • That is, every model may have coupled phases
  – Units on admittance matrix are actual siemens (S)
    • OpenDSS may report values in per unit, but internally works in actual volts, amps, siemens
  • A necessity to model unbalances, e.g,
    – 120/240V split-phase distribution transformer
    – Fault where 69 kV falls on 12.47 kV
Can it solve network systems as well as radial?

• The use of the word “Distribution” in the name of the program conjures up ideas of radial circuit solvers in North America
  – (but not necessarily in Europe)

• The DSS circuit solver is completely general
  – It has no idea whether the circuit is radial or not.
    • Stemming from its harmonics analysis heritage

• The EnergyMeter class is presently the only class that cares about radiality.
Load and Buses

• There is a subtle difference in the way the DSS treats loads that is confusing to many power engineers:
• Traditional power flow programs
  – “A Bus has load”
• OpenDSS
  – “A Load has a bus”
• This allows connection of a multitude of different loads and load types to the same bus
• Much more flexible and powerful
Load Models (Present version)

1: Standard constant $P + jQ$ load. (Default)
2: Constant impedance load.
3: Const $P$, Quadratic $Q$ (like a motor).
4: Nominal Linear $P$, Quadratic $Q$ (feeder mix).
   (Use this with CVR factor)
5: Constant Current Magnitude
6: Const $P$, Fixed $Q$
7: Const $P$, Fixed Impedance $Q$
Standard P + jQ Load Model  (Model=1)

DSS P,Q Load Characteristic

$|I| = |S/V|$  

Const Z

105%  
(Defaults*)

95%

* Change by setting $V_{minpu}$ and $V_{maxpu}$ Properties
Why Do I Need This Kind of Load Model?

• So annual simulations can be executed with less concern for lack of convergence

• What happens when the DG trips off and the voltage drops really low because the regulators are bucking?
  – Solution does not break
  – Solution may not be correct, but will be when the regulators bring the voltage back to normal

• Faults can be simulated during a run and the solution will still converge
  – Gives the DSS the ability to solve difficult problems
Where is the P-V bus type?

• Buses do not have special types in OpenDSS
  – Buses are simply connection points for circuit elements

• A Generator can control (or attempt to) power and voltage

• This question usually arises with regard to modeling DG on distribution systems
  – Fortunately, one seldom needs this model unless the DG is quite large with respect to system capacity
  – Most DG is controlled by Power and Power Factor while interconnected
How Do I Make One of Those 3-D Plots?

Maximum of value for each hour over the month.

We call this an “E-3” plot after the San Francisco economics firm who taught us how to do it (see http://ethree.com)

This is done in MS Excel by post-processing CSV files from annual simulations.
OpenDSS Application Workshop - Nov 2-3

OpenDSS Introduction and Basics
Setting up the model
Modeling control systems
Example Applications - Case Studies

- Distribution Loss Studies - Green Circuits, Program 172B
- Modeling distribution automation and distribution controls - Program 124C
- Integration of Plug-In Hybrid Electric Vehicles
- Distributed Energy Resources Integration with the Smart Grid - Smart Grid Demonstration Initiative
- Evaluation of PV and other renewables integration with the distribution system - Program 174
- Energy storage integration - e.g. community energy storage
- Using OpenDSS for Harmonic Analysis
- CIM Interface for OpenDSS

Ongoing development plans
- Coordination with other development efforts

Bring your own Windows laptops for hands-on experience
Webcast of workshop for those that cannot attend (attendance limited to 25)

Nov 2-3, Knoxville, TN
Half day Monday
Full day Tuesday
New Project – Develop Industry Library of Load Models with Voltage Dependency Characteristics

Equipment Response to Voltage Changes (laboratory testing and selected field testing)

Preliminary Customer Response Models

Customer Classification Development based on important characteristics

Assessment and refinement based on field deployments (AMI, etc.)

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Questions?
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• Active Distribution Management Overview
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Summary of CIGRE and Canadian Activities

EPRI Active Distribution Network Network Workshop

Chad Abbey
October 4, 2009
Overview

> **CIGRE activities**

> **Canadian Initiatives**
  - Utility projects
  - Industry collaborations
  - NRCan activities
  - Testing facilities

> **Summary**
C6.11 Development and operation of active distribution networks

Overview of activities
C6.11 Achievements

> Preparation of a survey on active distribution networks
  • Define *Active distribution network* concept and main features
  • Review actual status of implementation and barriers
  • Review actual operational rules for DG

> Definition of 5 sub-WG and review of questionnaire responses

> Published survey result in Electra and at CIRED
Active Distribution Network Definition

Active networks are distribution networks with Distributed Energy Resources *(generators and storage)* and flexible loads *subject to* control.

DERs and participating loads take some degree of responsibility for system support, which will depend on a suitable regulatory environment and connection agreements. The DSO may also have the possibility to manage electricity flows using a flexible network topology.
Future Activities

> Summarize results from EPRI events
> Document innovative pilot projects using standard template
> Classify active distribution network projects
  - Objectives and drivers
  - Distribution system operator, private producer, and societal benefits
  - Enabling technologies
  - Barriers, catalysts / triggers
  - Research needs
> Help update EPRI distribution roadmap
Sources of Information

> International events – EPRI Workshops, conferences
> EU projects - More Microgrids, ADDRESS, ADINE
> Smart Grid Demos
> Other National Programs
  • Australia, Canada, Korea, Japan
> Active Network Management database
  • http://cimphony.org/cimphony/anm/
Introduction

Survey results and definition

Present level of development of ADN
  - Methodology
  - Pilot project results

The way to the future
  - Conclusions
  - Recommendations
Active Distribution Networks in Canada

Overview
Smart Grid and DG Drivers

> Distribution System Automation
  - Reliability
  - Ageing infrastructure – grid modernization
  - Smart meter initiatives
  - Energy efficiency

> Distributed Energy Resources
  - Predominantly policy push
  - Secondary drivers: reliability, capacity
Distributed Generation in Canada

> **Technologies**
  - Wind, small hydro, PV, biogas

> **Regions**
  - BC – small hydro, request for proposals
  - Alberta – Distributed wind, biogas
  - Manitoba – Distributed wind
  - **Ontario** – Green Energy Act
  - Québec – small hydro, wind, programs coming
Example - Impact of SOP West of Toronto (2005)

Source: M. Dang, Hydro One
Example - Impact of SOP West of Toronto (2007)

Source: M. Dang, Hydro One
## Smart Canadian Utility Projects

<table>
<thead>
<tr>
<th>Smart Grid Technology</th>
<th>Utilities/Region</th>
</tr>
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<tbody>
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<td>AMR/AMI</td>
<td>BC Hydro, Ontario, Hydro-Quebec</td>
</tr>
<tr>
<td>Automatic Fault Location</td>
<td>Hydro-Quebec</td>
</tr>
<tr>
<td>Fast Reconfiguration</td>
<td>BC Hydro, ENMAX, Burlington, Toronto Hydro</td>
</tr>
<tr>
<td>Voltage Reduction Schemes</td>
<td>BC Hydro, Hydro-Quebec</td>
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<tr>
<td>Remote Monitoring</td>
<td>Milton Hydro, Hydro-Quebec</td>
</tr>
<tr>
<td>Planned Islanding</td>
<td>BC Hydro, Hydro-Quebec</td>
</tr>
</tbody>
</table>
CEATI Smart Grid Working Group

Centre for Energy Advancement through Technological Innovation (CEATI) International

Objectives

• Definition of Smart Grid
• Action plan for development of the Smart Grid
• Identify technology gaps
• Share successful strategies for implementation of the Smart Grid

Initiated in 2008
Ontario Smart Grid Forum

- Participation
  - Led by IESO
  - Utilities, suppliers, government

- Objectives
  - Develop a high level vision of Ontario Smart Grid
  - Educate industry leaders on drivers, technologies
  - Identify enablers and barriers

- Outputs
  - Report on findings and recommendations
  - Website: www.theimo.com/imoweb/marketsandprograms/smart_grid.asp
Ontario – Encouraging Smart Grid and Renewables

- Smart Grid Forum releases its finding – February 2009
- Ontario Energy Board (OEB) - draft guidelines on planning for smart grid architecture - June 16, 2009

Important elements:
- Creation of new deferral accounts for capital investments incurred related to the development of a smart grid or the accommodation of new renewables.
- Introduction of a mechanism to provide advance funding for expenditures to accommodate new renewables or develop a smart grid.
- Initial guidance to distributors on planning to accommodate new renewables and a smart grid.
NRCan DG Study Group

> Membership
  - Utilities: BC Hydro, Hydro Quebec, NB Power
  - Manufacturers: GE Multilink, SEL
  - Private producers

> Activities
  - Review of utility interconnection guidelines (Hydro One)
  - Provide advice on cost effective DG interconnection technology
  - Linking Smart Grid with DG
    - Remote monitoring and control, advanced protection
NRCan Clean Energy Fund

> **Renewable Energy and Clean Energy Systems Demonstration Projects**
  - Deadline – September 14, 2009
  - Project selection - mid-November

> **Large Scale CCS Demonstration Projects**

> **Research and Development Projects**
  - Integration of renewable energy
  - Multi-stakeholder and Canada-US collaborations encouraged
Canadian Test Facilities

> **Low voltage test facility (CanmetENERGY):**
  - Multiple inverters and interconnection testing

  > 120-kVA, 3ph Grid simulator
  > 5kW/15kW Solar Simulator
  > Adjustable RLC loads

> **Medium voltage test facility (IREQ-HQ):**
  - Distribution automation network testing

  > A radial 25-kV feeder (35 poles, 370m)
  > 300-kW, 600 V, resistive, inductive and motor loads
  > Induction and synchronous generators
IREQ Feeder Layout

> 3 feeders (common source)
> Dedicated 47-MVA 25-kV transformer at the substation
Completely independent from the distribution network
> 2 x 3 167-kVA transformers - 14.4 kV/347 V
> Internet and phone lines to all equipment
> Auxiliary power 3 x 120 V
3 Small buildings:
Load
Control and acquisition
Distributed generation

IREQ’s test line
Distribution Automation Equipment

- 25 kV reclosers, breakers
- Automation equipment
  - Remote monitoring
  - Smart meters
- Switchable capacitor banks
- 25 kV in-line voltage regulator
Voltage regulator – 3 phases

CL-6A regulator control

25 kV measuring station (voltage and current)

Cooper VWVE recloser

Schweitzer SEL-351R for Recloser

Map of line
Acquisition computer

25-kV voltage and current transformers

DC measurements
Voltage and current

Acquisition and storage unit

600-V current measurements
Load Banks

> 3-phase resistive/inductive loads
  • (DELTA or/and STAR)
  • (Independently controllable phases, distortion, PF adjustment)
  • Total of 400 kW resistive

> Induction motor
  • AC drive, variable load of 150 kW
  • Drives DC alternator
Resistive and inductive loads

Load for motor

AC Drive for induction motor

AC induction motor and DC generator

Load and acquisition control room
**Distributed Energy Resources**

> **DG technologies**
  - Induction machine
  - Synchronous machine
    - Diesel generator
    - Motor driven synchronous generator

> **Future considerations**
  - Inverter interfaced
  - Wind turbine nacelle
Contactors and breakers

Speed relay

DC power supplies

Soft Start for induction generator and Beckwith relay

Other protection relays under tests

measurements and aux. power

Induction generator

Coupling of machines

DC motor
500-kW Cummins DIESEL Synchronous generator with synchronizing control (Power Rent - Onan)

Remote control

Diesel-generator controller

Breaker and contactor for diesel interconnection
Testing Capabilities

- Capacitor switching
- Reverse power flow characteristics of distribution transformers
- Evaluation of protection relays for anti-islanding
  - Diesel synchronous generator
  - Asynchronous machine to emulate a Wind generator
- Behavior of DG in a remote grid
- Testing of reclosers during faults
- Operation of in-line voltage regulator in the presence of distributed generation
Feeder Configurations

> Radial or meshed
> Adjustable line impedance
> Multiple feeders
Abnormal Events

> Feeder faults
> Islanding
> LVRT
Emulation of Distribution System Load

- **Controllable loads for basic tests**
- **Phase-shifter to emulate larger loads (future)**
Summary

> CIGRE C6.11 - collaboration on active distribution networks

> Investments in Canada’s power systems
  - Maintain / improve reliability
  - Improve energy efficiency
  - Integration of renewable energy

> Coordinated research and demonstration projects
  - Test facilities – CanmetENERGY, IREQ test line
  - Demonstration projects
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Agenda

• Active Distribution Management Overview
• Modeling Considerations and OpenDSS
• Examples of Active Distribution Management and CIGRE C6.11 Activities
• IEEE Distribution Automation Working Group
• Demonstrations
Application Guide for Smart Distribution

- Joint development with IEEE Distribution Automation Working Group
- Wiki.powerdistributionresearch.com
Roadmap for Smart Distribution

2004

Technical and System Requirements for Advanced Distribution Automation

2008

Update to Strategic Plan for ADA®/Smarter Distribution Systems

2010
Other developments with IEEE Distribution Automation Working Group

• Volt and Var Control Task Force formed in 2009, 1st meeting in January 2010

• Other groups in discussion
  – Task Force on Distribution Communications for Smart Distribution Systems
  – DMS Interest Group

• DAWG Web site
  http://grouper.ieee.org/groups/td/dist/da/
EPRI Smart Grid Demonstrations

• Integration of Distributed Energy Resources (DER)

• Deploying the Virtual Power Plant

• Several regional demonstrations
  – Multiple Levels of Integration
  – Multiple Types of Distributed Energy Resources & Storage

• Leverages Information & Communication Technologies

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EPRI Smart Grid Resource Center launched: www.smartgrid.epri.com
Questions and Discussion