An Update on Hydro-Québec Advanced Distribution Automation Program

Georges Simard
Orientations du réseau
Direction Gestion de l'actif - VPRD
1. General approach

2. Hydro-Québec's ADA projects
   1. Volt and VAR Control
   2. Fault location
   3. Underground Vault
   4. PQ Data from Distribution substation
   5. Data management – software analysis

3. Next steps

4. Hydro-Québec's Distribution roadmap

5. Conclusion
Intelligent Distribution Network

Flow of Information

Technologies

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

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

Business drivers
(Why?)
- Energy Efficiency
- Reliability
- Distributed Resources
- Power Quality
- Customer Satisfaction
Intelligent Distribution Network
Flow of Decision

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

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

Business drivers
(Why?)
- Energy Efficiency
- Reliability
- Distributed Resources
- Power Quality
- Customer Satisfaction

Technologies
**Distribution Network – DA Roadmap**

<table>
<thead>
<tr>
<th>Business Drivers</th>
<th>Projects</th>
<th>Years</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Reliability</td>
<td>Remote Control</td>
<td>2006-2012</td>
</tr>
<tr>
<td>• Energy Efficiency</td>
<td>DER HQ Programs</td>
<td>2006-2015</td>
</tr>
<tr>
<td>• Energy Efficiency</td>
<td>Voltage Control</td>
<td>2008-2015</td>
</tr>
<tr>
<td>• Reliability</td>
<td>Fault Location</td>
<td>2008-2015</td>
</tr>
<tr>
<td>• Reliability</td>
<td>Underground Vault</td>
<td>2008-2015</td>
</tr>
<tr>
<td>• Power Quality (PQ)</td>
<td>PQ Monitoring</td>
<td>2008-2015</td>
</tr>
<tr>
<td>• Energy Efficiency</td>
<td>Load side Management</td>
<td>2009-2015</td>
</tr>
<tr>
<td>• Customer Satisfaction</td>
<td>Predictive Maintenance</td>
<td>2009-2015</td>
</tr>
<tr>
<td>• Reliability</td>
<td>Automatic Reconfiguration</td>
<td>2010-2015</td>
</tr>
<tr>
<td>• Customer Satisfaction</td>
<td>Customer Portal</td>
<td>2010-2015</td>
</tr>
</tbody>
</table>
VOLT and Var Control
Project Objectives

- Improve energy efficiency by reducing the voltage
  - The amount of energy bought at marginal price (8.3¢/kWh) and delivered to customers (6.5¢/kWh)
  - Peak load of the system
  - Energy losses
Voltage control benefit

Voltage level at a customer installation at the remote end of a feeder

- Voltage (V)
- Time over one year

Normal voltage range as per (C.235)

With Voltage Control

Present (without VC)

Voltage control leads to energy saving.
Volt and VARS Control Project Concepts

Minimum CSA C235 = 115 V

123 V

Volt Control
Volt and VARS Control

Actual

Substation

End of feeders

Minimum CSA C235 = 115 V
Volt and VARS Control Intelligent System

The control logic must select the voltage level to use from all the voltage readings from the remote end sensors and capacitors.
Project Description

- **Phase 1: Volt Reduction**
  - Reducing voltage settings at the substation to reduce energy and peak load
    - Studies to be done to fix the voltage level (must consider type of load – constant impedance, power or current proportions)
    - Must keep a margin for dynamic operations and unbalanced loads
    - Power Quality monitoring may be needed to insure respect of C235

- **Phase 2: Volt and VARS Control**
  - Voltage and VARS controlled through remote sensors on the feeder
    - Intelligent system to optimise online capacitors management and volt control in a single system
Results and next steps

- Phase 1: Manual voltage reduction test at a typical distribution substation confirmed an average CVR of 0.4 over one year (1% of voltage reduction = 0.4% of energy conservation)
- Phase 2: Demonstration project – End 2008
- HQD aims to deploy a global Volt and VARS Control project by 2008-2015
Hydro-Québec's Distributed Approach

Voltage Drop Fault Location (VDFL)
- Distributed PQ analyzers
- Voltage Sags waveforms
- Most feeders require only 4 measurement sites
- Easy measurement
  - Low voltage (customer side)
  - GPS not required (no precise synchronisation required)
  - Calibration not needed

Patent Pending
VDFL Basics (1)

Distance to faulty lateral
VDFL Basics (2)

VDFL deduce:
- Fault current
- Position of faulty lateral
- Distance to fault
- Arcing voltage
MILE - Voltage drop on phase C
MILE – Fault Probable Locations
Fault located

Burning traces located on conductor at mid distance between poles.
Fault Location Accuracy

Average absolute error: 188 m
Error spread: -315m to 619 m

95% of the distribution faults located are within 332m
Advantages

The main advantages are:

- PRECISION: faults are located within an average absolute error of 188 meters (617 ft). Independent of fault contact impedance.

- INTEGRATION: with existing distributed advanced systems such as AMI or ADA: The same sensors used for VDFL can be used for PQ qualification of the system and possibly voltage and VAR control. This system needs only software and computers to treat the data that will lead to fault location.

- TIME STAMP NOT NEEDED: waveshape synchronization is done through the software.

- ABSOLUTE PRECISION NOT NEEDED: The VDFL technique automatically compensates for lack of monitoring accuracy.
Approaches for fault location

- Fault location based on voltage monitoring at distribution system locations (Hydro Quebec)
- Fault location based on voltage and current monitoring at substation (EPRI PQView)
- Fault location with fault current indicators (communicating)
Example of waveforms used for fault location

Single-Phase Fault Evolves into Two-Phase

Voltage (kV) Current (kA)

EPRI/Electrotek
Key Application – Fault Location

Probable fault locations

Known fault location

Measurements
Collaboration between EPRI and Hydro-Québec (2 mirror projects):

- Hydro-Quebec will expand its actual fault location project by implementing fault current measurement in a HQ substation and using EPRI's concept through PQView.
- EPRI will find a partner among US utilities to implement Hydro-Québec's fault location system as a demonstration project.

Hydro-Québec continues to improve its fault location system (Cost of sensors and telecommunication, MILE predictive capabilities...).
Underground Vault
Underground DA program

Justification: improve downtown Montreal SAIDI

Completed in 2006 (~100 remote controlled underground switches)

Optical fiber is used for telecommunication

Project to extend data acquisition for the underground system (system of the future)
3ph Transformers

1Ph Transformer

Underground transformer vault

Sectionnalizing
Teaching installation, 1st prototype

- RTU
- Connexion box
- Optical fibers
- Water level indicator
- Underground remote control switch
Underground Vault of the future

- First stage of the project (defining the needs)
- From 8 potential benefits, 2 were selected
  - Transformers and underground cable overload
  - Teledetection of thermal anomalies
Underground Vault - Today

Underground vault Today (Year 2000)

Components

- **Medium voltage cables**: 3Ø, 500 or 750 MCM Al, 25 kV, XLPE, cn Cu
- **1Ø, 3/0 Al, XLPE, Nc Cu**

**MV connections**:

**Transformers**:
Underground Vault of the future

Telemonitoring

Underground vault Tomorrow

Medium voltage lines and Sectionnalizer:
- Fault detection
- Feeders currents
- Overload

MV connections:
- Detection et teleindication of thermal anomaly

Transformers:
- Overload
- Water level
- MV voltage
- LV Protection opération

Data acquisition system
Load profile
- Follow-up of thermal evolution
- Water presence
- Waterpump monitoring
PQ data from Distribution substations
PQ data from Distribution substations

- Hydro-Québec's substations belong to the transmission company (TransÉnergie)
- Substations PQ monitoring equipment selected in 2006: ION 8600 / 8800 from Schneider-PML
  - One PQ meter per MV busbar or Power Transformer
- More than 50 meters installed by the end of this year, (57 planned for 2008)
- Joint working group (HQ Distribution / TransÉnergie) to optimize the data management (Secure Data access, Data architecture and software, standard reports, specific PQ analysis...)
Data management software analysis
DATA Management – Software analysis

The goals are:

- Analyze the Software available to manage the distribution equipment (Reclosers, Remote Controlled Switches, Voltage Regulators, Meters…) installed on Hydro-Québec's distribution system:
  - Precision and accuracy
  - Compatibility, file format
  - Ease of use
- Gather information to optimize the data management for Hydro-Québec's technical staff
## RESULTS - Control, relay & meter software interface characteristics

### Interface Software

<table>
<thead>
<tr>
<th>Control</th>
<th>Software</th>
<th>Alarm</th>
<th>Data format supported</th>
<th>Clock synch</th>
<th>Polling</th>
<th>PQ functionality</th>
<th>Comm Ports</th>
<th>Associated Graphical Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>SEL 351R</td>
<td></td>
<td>Yes</td>
<td>t.txt, log(t.txt), txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, RS-485</td>
<td></td>
</tr>
<tr>
<td>SEL 351J</td>
<td></td>
<td>Yes</td>
<td>t.txt, log(t.txt), txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, RS-485</td>
<td></td>
</tr>
<tr>
<td>SEL 651R</td>
<td></td>
<td>Yes</td>
<td>t.txt, log(t.txt), txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, RS-485</td>
<td></td>
</tr>
<tr>
<td>Cooper Form 6</td>
<td></td>
<td>Yes</td>
<td>t.txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, etc</td>
<td>RS-232, RS-485</td>
<td></td>
</tr>
<tr>
<td>ABB PCD-2000</td>
<td>ABB Asuite</td>
<td>Yes</td>
<td>t.txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells</td>
<td>RS-232, RS-485, FO</td>
<td></td>
</tr>
<tr>
<td>ABB SCD</td>
<td>ABB Asuite</td>
<td>Yes</td>
<td>t.txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells</td>
<td>RS-232, RS-485, FO</td>
<td></td>
</tr>
<tr>
<td>S&amp;C M Series</td>
<td>Intellink</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>Yes</td>
<td>+</td>
<td>RS-232</td>
<td></td>
</tr>
<tr>
<td>Cooper CL-6A</td>
<td>(CCD)</td>
<td>*</td>
<td>*</td>
<td>*</td>
<td>YES</td>
<td>Harmonics, etc</td>
<td>RS-232, RS-485, FO</td>
<td></td>
</tr>
</tbody>
</table>

* Test on IED and corresponding software not performed yet
## RESULTS - Control, relay & meter software interface characteristics

<table>
<thead>
<tr>
<th>Control</th>
<th>Software</th>
<th>Alarm</th>
<th>Data format supported</th>
<th>Clock synchro</th>
<th>Polling</th>
<th>PQ functionality</th>
<th>Comm Ports</th>
<th>Associated Graphical Software</th>
</tr>
</thead>
<tbody>
<tr>
<td>PML ION 8600</td>
<td></td>
<td>Yes</td>
<td>SQL</td>
<td>Auto</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, FO, RS-485, 10BaseT</td>
<td><img src="image" alt="Vista" /></td>
</tr>
<tr>
<td>PML ION 8800</td>
<td></td>
<td>Yes</td>
<td>SQL</td>
<td>Auto</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, FO, RS-485, 10BaseT</td>
<td><img src="image" alt="Vista" /></td>
</tr>
<tr>
<td>EI NEXUS 1252</td>
<td></td>
<td>Yes</td>
<td>SQL, PQDIF, COMTRADE</td>
<td>Auto</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-485, IR, 10/100BaseT</td>
<td><img src="image" alt="Power Graphs" /></td>
</tr>
<tr>
<td>EI NEXUS 1270</td>
<td></td>
<td>Yes</td>
<td>SQL, PQDIF, COMTRADE</td>
<td>Auto</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-485, IR, 10/100BaseT</td>
<td><img src="image" alt="Power Graphs" /></td>
</tr>
<tr>
<td>FUTURA+</td>
<td></td>
<td>Yes</td>
<td>.txt</td>
<td>Manual</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-485</td>
<td><img src="image" alt="Power Graphs" /></td>
</tr>
<tr>
<td>GE KV2c+</td>
<td>MaterMate</td>
<td>Yes</td>
<td>* (HTML)</td>
<td>*</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, FO</td>
<td></td>
</tr>
<tr>
<td>AREVA BITRONICS M571</td>
<td></td>
<td>Yes</td>
<td>.dat, .cfg, .ini, .txt</td>
<td>Auto</td>
<td>Yes</td>
<td>Waveform Capture, Sags, Swells, Harmonics, Flicker, etc</td>
<td>RS-232, RJ11, IRIGB, RS-485, 10BaseT</td>
<td><img src="image" alt="WaveWin" /></td>
</tr>
</tbody>
</table>

* Test on IED and corresponding software not performed yet
The analysis of the software results in the following conclusions:

- **Software Interface:**
  - All the different equipments present on the distribution system have their own proprietary software not compatible to each other, making very difficult for distribution engineers and technicians to communicate with the equipments, retrieve and interpret the data.
  - Most of the software interfaces were found to be user friendly.
  - Some interfaces are more complex and difficult to use (Versatility).
  - PQVIEW is the most versatile software so far.

- **Data file format:**
  - Several file formats are used: text, PQDIF, COMTRADE, SQL, etc.
  - So far, an SQL database has shown great advantages.
CONCLUSIONS - Control, relay & meter precision and accuracy

- Controls Measurement Accuracy and Linearity
  - The accuracy of controls measurement is acceptable, but the measurements do not fully comply with international standards.

- Meter Accuracy and Sampling Rate
  - The accuracy of meters is higher than that of controls. The meters comply with some of the international standards. Their sampling rate ranges from 128 to 1024. Some of them qualify for class A as defined by IEC 61000-4-30.
Data management Software analysis - General conclusion

Data management from today's equipment is possible but it is surely not optimal

- There is a need for data integration to reduce cost and improve data acquisition efficiency

This project brought knowledge about present distribution equipment performance and improvements to do in the future (technologies, sensors, standards…) to integrate data acquisition
Collaboration is needed between utilities and manufacturers to define distribution data integration standards based on IEC 61850 and CIM standards.

Distribution system technologies (sensors, control cabinet, meters...) development and software must be coordinated through standards to reduce cost and reach a "plug and play" design.

Distribution Network of the future

Architecture IEC 61850
Next steps
Next steps in Hydro-Québec's ADA program

1. Volt and VAR Control
   • Demonstration project – End 2008
2. Fault location
   • 2 mirror demonstration projects (one in Québec, one in the US) – Collaboration with EPRI
3. Underground Vault
   • Beginning of stage 1
4. PQ Data from Distribution substation
   • Joint working group (HQ Distribution / TransÉnergie) to optimize the data management from the PQ monitoring equipment
5. Data management
   • Software analysis – completed
   • Sensors analysis - 2008
Hydro-Québec's DA/DER test line

The test line has been used for
- DA equipment performances
- Broadband on Power Line tests
- Power Quality Benchmark
- Data management software

In 2008, it will be used for
- Sensors analysis
- Capacitors testing
- DER testing
Hydro-Québec's Distribution roadmap
Global Roadmap Process

Phase 1
December 2006

Collection of information

Elaboration of a vision

Validation

Elaboration of a shared vision

Elaboration of a development plan

Integrated development plan

Work plans

Phase 2
June 2007

Benchmarking

Studies, Analyses

Phase 3
December 2007

Current development plans

Business drivers
Guiding principles

Cohesion

R&D Development
Equipment certification
Publication of standards

Convergence

Global Roadmap Process

Studies,
Analyses

Work plans
Hydro-Québec's Distribution roadmap

In 2007 Hydro-Québec started a global roadmap exercise

- Technology: a contribution to efficiency

- Up to now the roadmap confirms that telecommunication technology will impact operation, maintenance and metering for the next 15 years

- The general design of both overhead and underground systems should remain the same for the next 15 years
Conclusion

Hydro-Québec has started several projects related to Advanced Distribution Automation

- Demonstration projects will be launched on Volt and Var Control and Fault location projects in 2008
- Data management studies will continue in 2008 (PQ data coming from substations and Sensors installed on feeders)

Collaboration is needed between utilities and manufacturers to define distribution data integration standards