

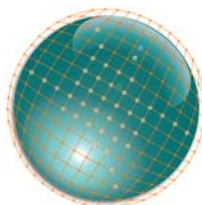


## Case Studies and Benchmarking: Canadian DER Integration Projects

*Tarek EL-Fouly, PhD*

Workshop: Smart Grid Demo Project Reviews

December 10, 2010



4th International Conference on  
**Integration of  
Renewable and Distributed  
Energy Resources**  
December 6 - 10, 2010  
Albuquerque, USA



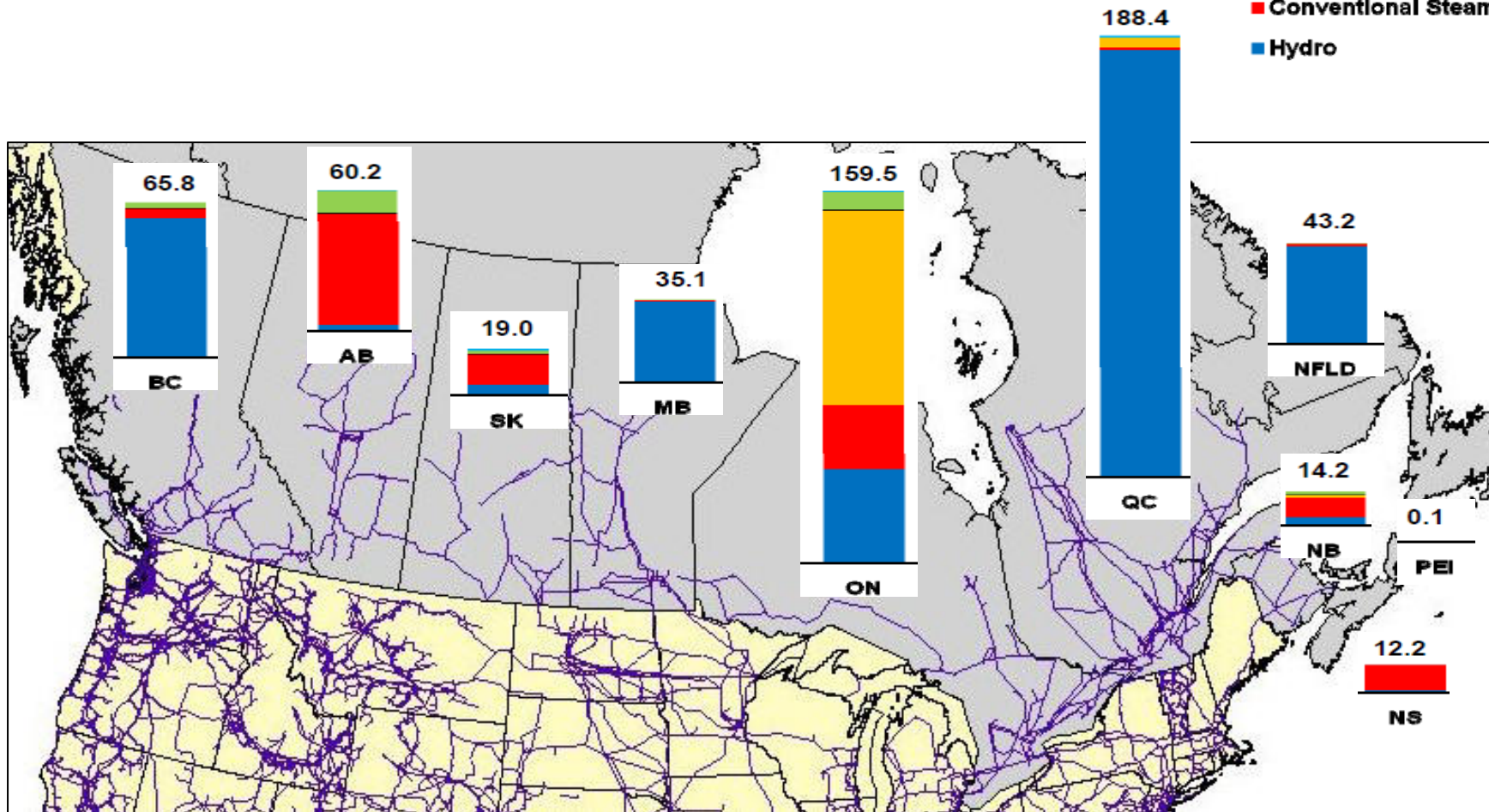
# Outline

- Introduction
- Modeling, Simulation and Benchmark Case Studies
- Demonstrations and Field Tests Case Studies
- Smart Grid Demonstration Projects

- **Introduction**
- Modeling, Simulation and Benchmark Case Studies
- Demonstrations and Field Tests Case Studies
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# Provincial Electricity Generation Mix

- Tidal
- Wind
- Combustion Turbine
- Internal Combustion
- Nuclear
- Conventional Steam
- Hydro

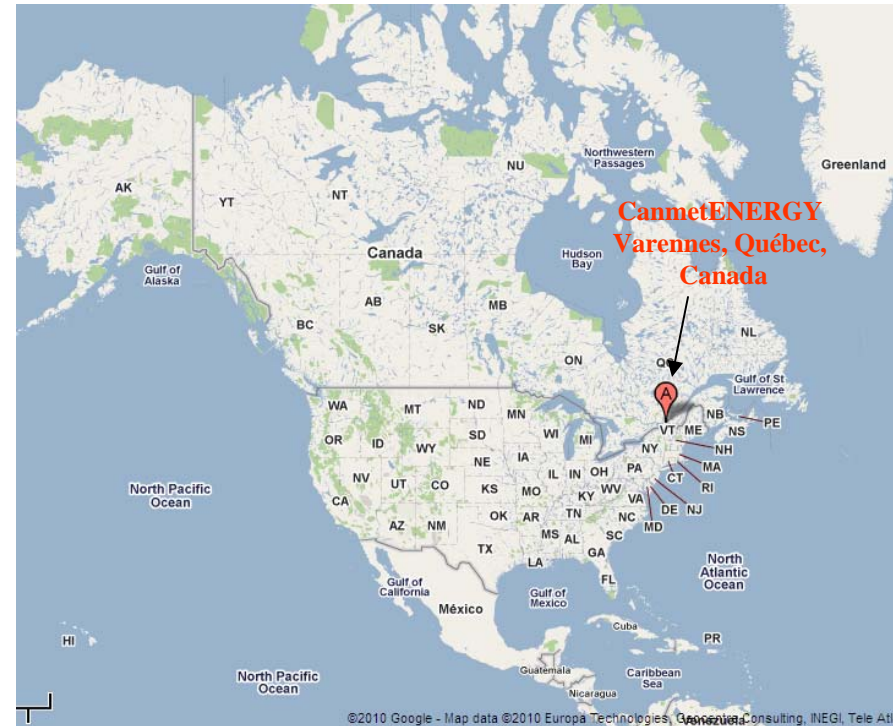


Statistical Source: North American Electric Reliability Council (NERC)  
 Map Source: Global Energy Network Institute (GENI)



# CanmetENERGY, NRCan

- National energy laboratories within the department of Natural Resources Canada
- CanmetENERGY manages science and technology programs and services and support the development of energy policies, codes and regulations.
- Canadian leader in clean energy research and technology development - 3 energy research centres : Ottawa, Devon and Varennes. Over 450 scientists, engineers and technicians.



- Located in Varennes, QC about 26 km from downtown Montreal.
- Web link: <http://canmetenergy-canmetenergie.nrcan-nrcan.gc.ca/eng/index.html>

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# Program Objectives and Key Activities

- Smart Grid R&D objective: To support national S&T efforts that will contribute to the modernization of the electricity grid network, enhance the benefits of renewable and clean distributed energy resources, increase diversity and reliability of supply, and facilitate recovery after disruptions.
- Key activities:
  - Modeling, Simulation and Benchmark Case Studies
  - Technology Assessment and Demonstrations
  - Standards, Codes and Regulatory Support
  - National and International Collaboration

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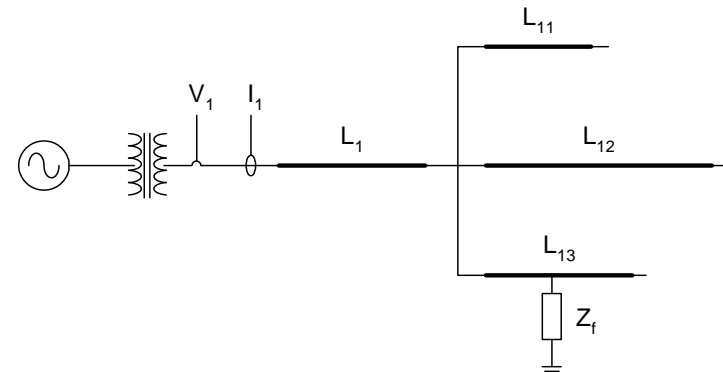
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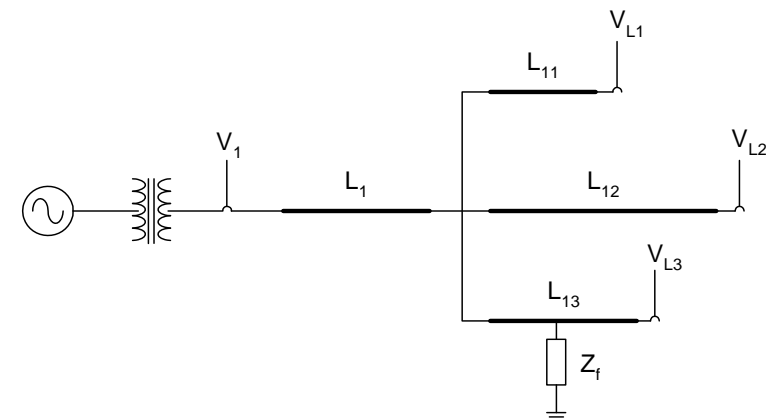
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# Automatic Fault Location Detection on Rural Feeders with DGs

- Locating faults on the distribution system is important to:
  - repair the faulted section and restore service as fast as possible in the case of permanent faults.
  - identify incipient problems and monitor equipment that may have been damaged during transient fault events.
- Automatic fault location detection approaches:
  - Using the voltage and current measured at the substation to estimate the impedance to the fault.
  - Using the voltage measured at the substation, in addition to voltages obtained from advanced meter infrastructure (AMI).



Approach using measurements at the substation



Approach using the voltage measurements from the substation and from AMI

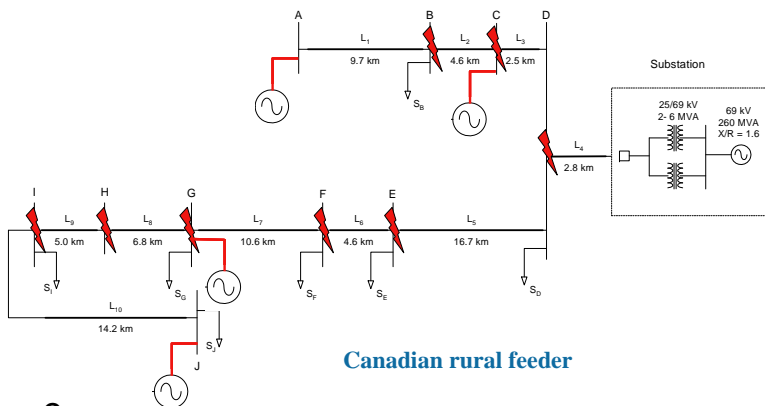
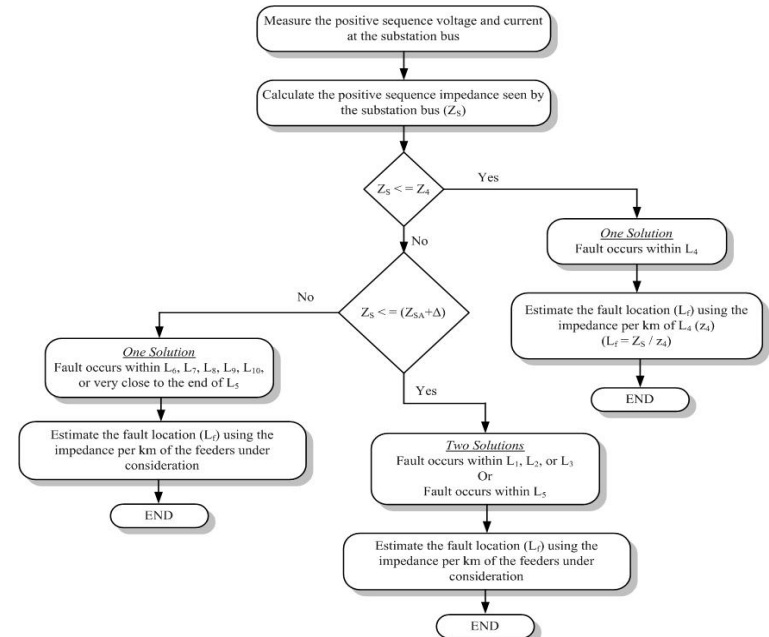
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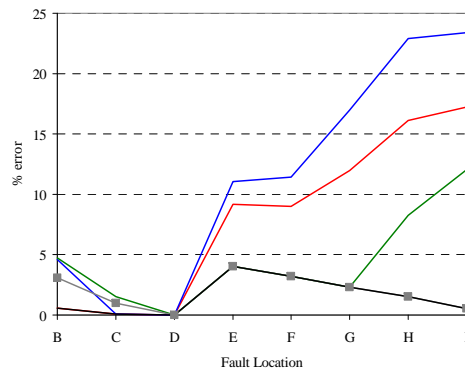
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# Automatic Fault Location Detection on Rural Feeders with DGs (Cont.)

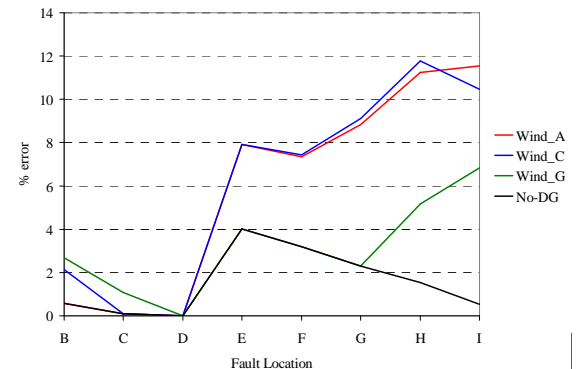
- This study considers the impact of DGs on the performance of an automatic fault location approach using the voltage and current measured at the substation.
- In general, when the DG is upstream of the fault section, the performance will be degraded, with the impact being more severe for synchronous machine based DG.



Canadian rural feeder

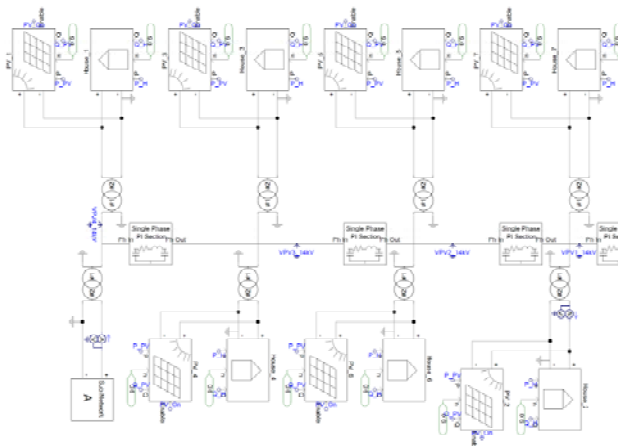


Automatic Fault Location Detection Algorithm

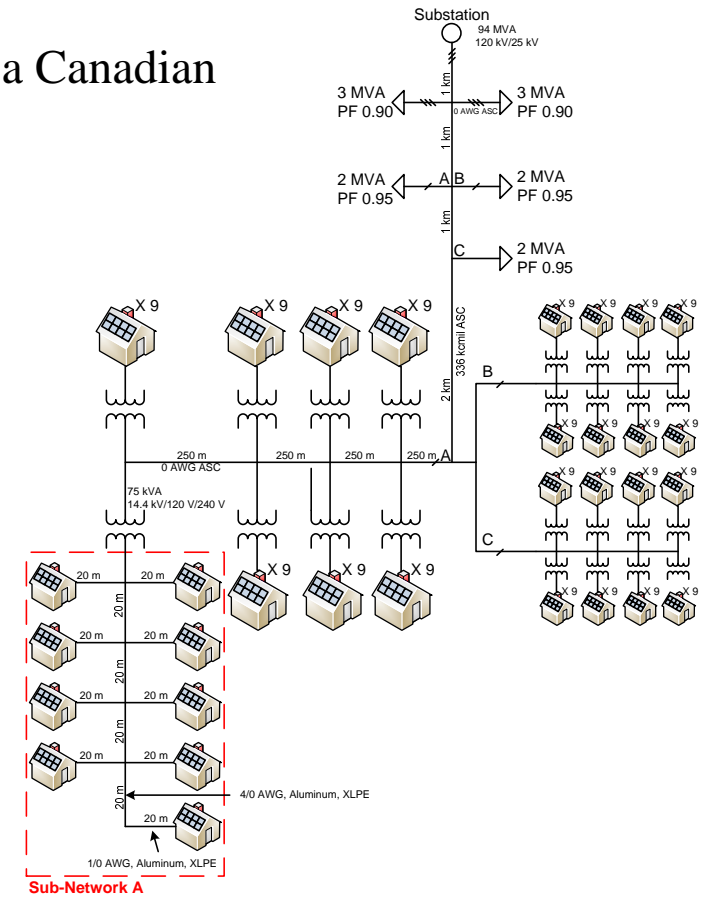


# Impact of High PV Penetration on Voltage Profiles in Residential Neighborhoods

- A model using PSCAD/EMTDC has been developed for a Canadian overhead residential feeder benchmark.
- Various case studies have been investigated:
  - Average load
  - Light load
  - Feeder length (impedance)
  - Feeder configuration
  - LV transformer impedance



PSCAD model



Canadian overhead residential feeder Benchmark

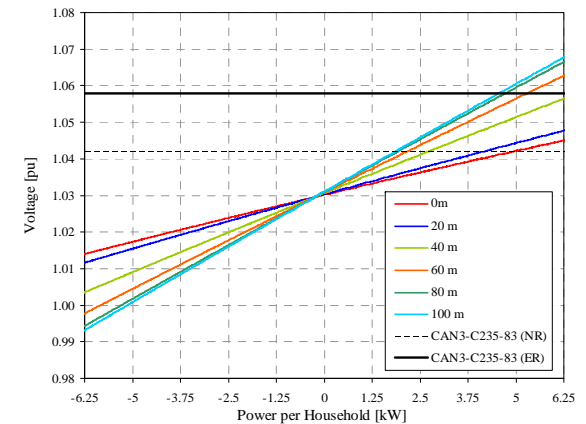
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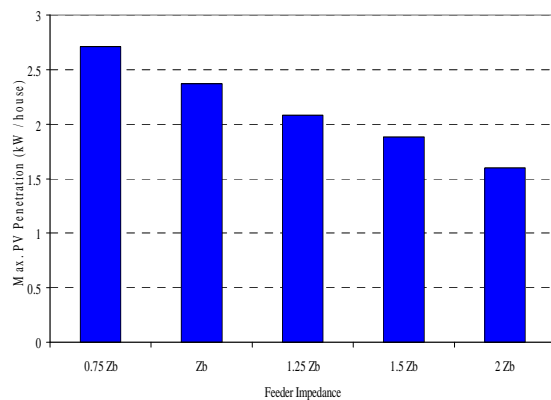


# Impact of High PV Penetration on Voltage Profiles in Residential Neighborhoods *(Cont.)*

- Feeder length and transformer impedance play important roles in determining the voltage rise level for residential feeders with high PV penetration levels (up to 75 % LV transformer capacity).
- An average PV penetration level of around 2.5 kW per household on a typical distribution grid would not cause the voltage to exceed the normal standard voltage threshold value.
- Improvements on the LV network efficiency, by reducing transformers and feeder impedances, would reduce the voltage rise

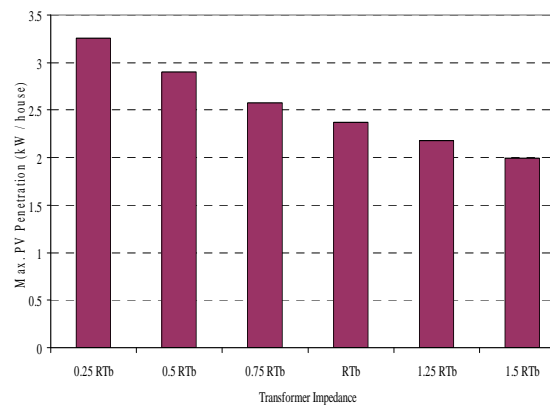


Voltage profile in the sub-network A (LV) considering average feeder load level



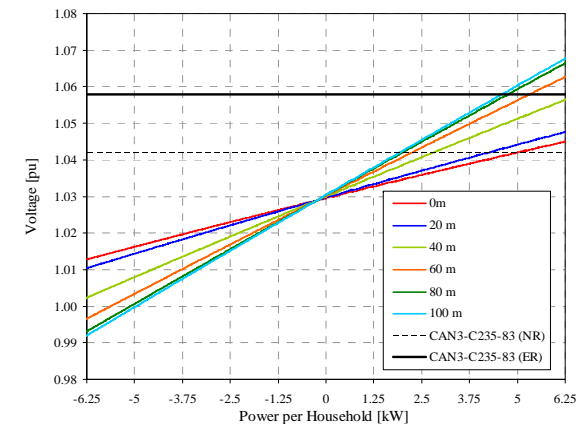
PV penetration levels for different absolute values of the feeder impedances

Drop Lines: R<sub>b</sub> = 0.55 Ω/km and L<sub>b</sub> = 0.29 mH/km  
 Pole-Pole Lines: R<sub>b</sub> = 0.27 Ω/km and L<sub>b</sub> = 0.24 mH/km



PV penetration levels for different LV transformer impedances

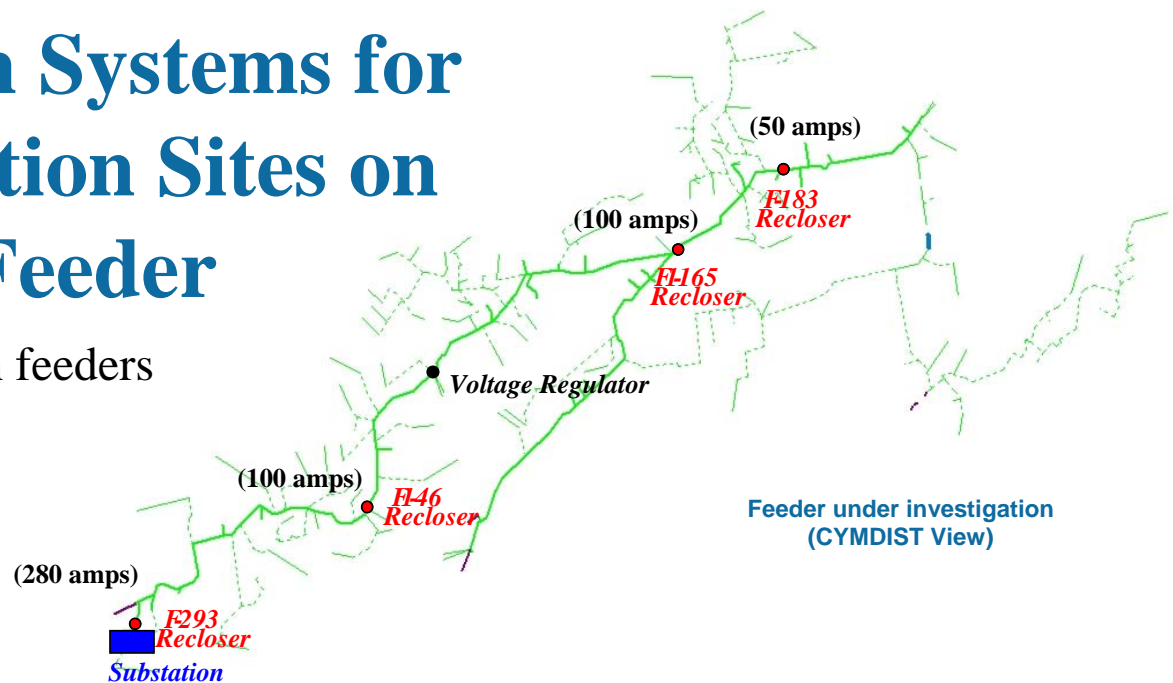
R<sub>1b</sub> = 0.06 pu  
 R<sub>2b</sub> = R<sub>3b</sub> = 0.012 pu



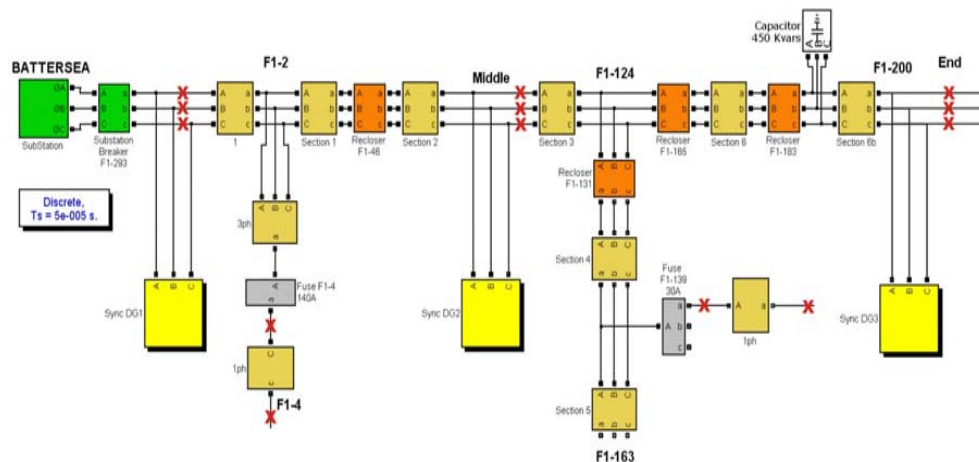
Voltage profile in the sub-network A (LV) considering light feeder load level

# Feeder Protection Systems for Multiple Generation Sites on the Same Feeder

- Data from two actual Canadian feeders are used in the analysis.
- Four types of faults have been investigated:
  - 3-phase faults
  - L-L faults
  - L-G faults
  - High impedance L-G faults



- System has been analyzed at various operating conditions/configurations:
  - DG size, location and technology
  - Peak and minimum load
  - Different load model
  - Transformer impedance



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MATLAB&SIMULINK model

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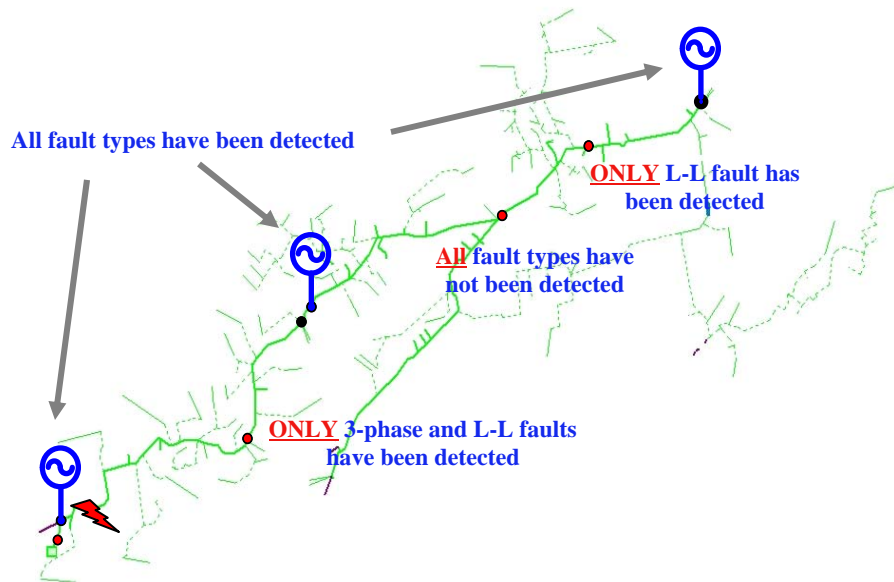
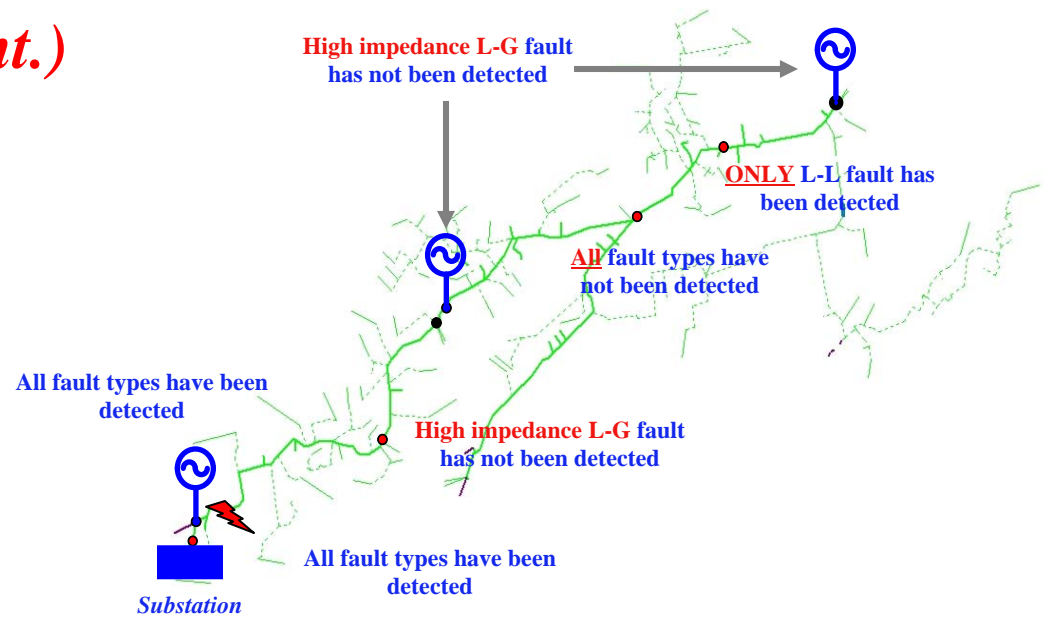
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# Feeder Protection (Cont.)

- At peak load, all fault types will be detected by the line and/or the DG protection and/or the substation breaker.
- In some cases, DGs protection will not detect the fault but as soon as the line protection and/or the substation breaker protection trips, the DGs protection will detect the fault.



- Report on the findings with conclusions and recommendations will be produced



# Impact of Integration of Storage on Distribution Systems *(Cont.)*

- Three different options for DS capacity are considered:
- A DS without power and storage capacity constraints,
- A DS is a typical 1 MW NaS battery with 7.2 MWh storage capacity and 100% DOD; and,
- A DS is a typical 1 MW NaS battery with 7.2 MWh storage capacity and 90% DOD.

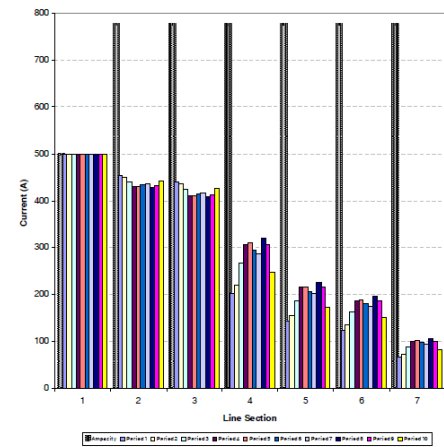
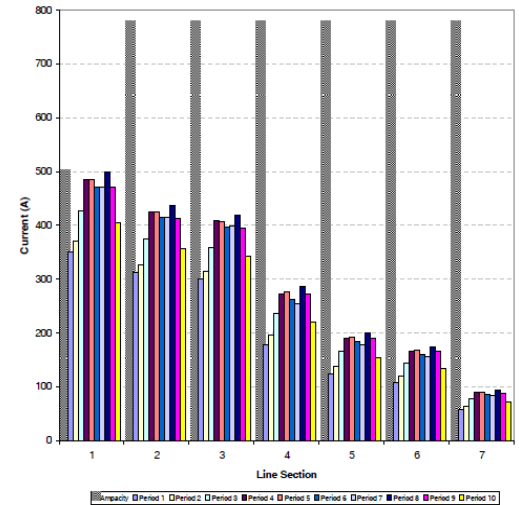
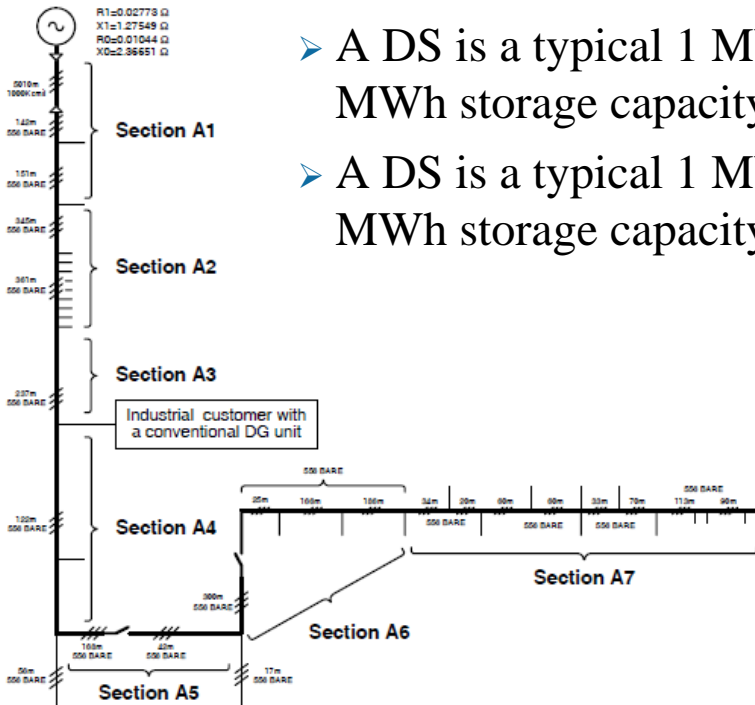


Figure 2.9 Feeder loading per section for cable ampacity; loading with one DS unit (70% efficiency and no power/energy limits), located after section A3 and no DG in the system

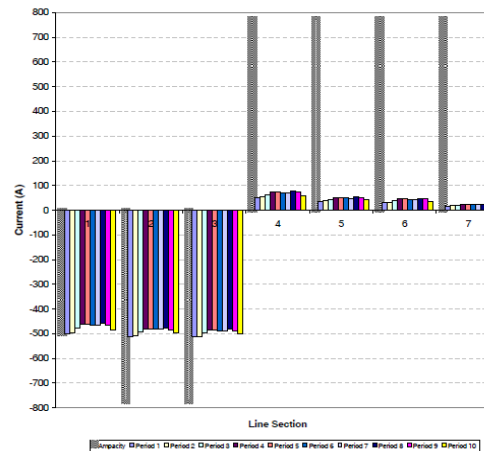
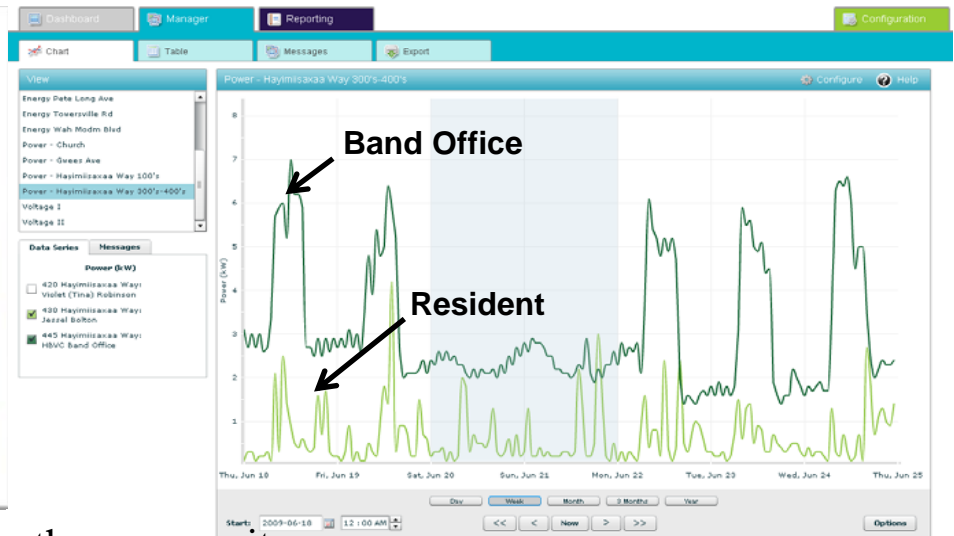


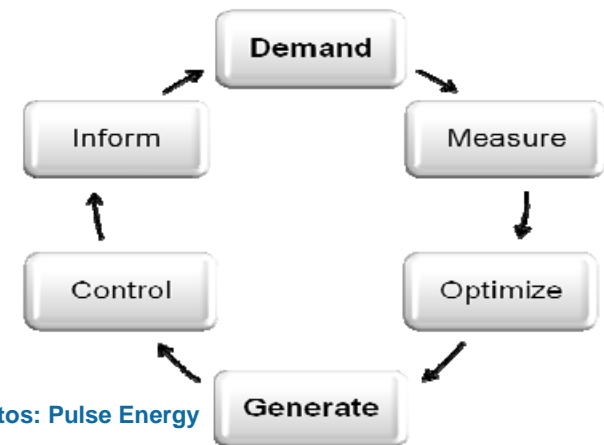
Figure 2.6 Feeder loading per section when 29.6 MW DG is installed after Section A3 and no DS is connected to the feeder

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# Smart Remote Microgrid



- “Rural electricity cooperative” - saving remain in the community
- First year research results 2010 – Modify transformer loading; Monitoring 3 diesel generators; research “dispatch strategy” with DR;
- 2010-11 - Research on demand responsive load and validate optimal smart grid operation;
- Knowledge base will improve our understanding of cost-benefit of advanced metering infrastructure
- Target fuel cost reduction: \$50,000-100,000 per year
- Optimal smart microgrid performance tool



Photos: Pulse Energy

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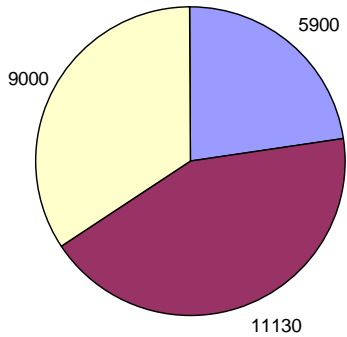
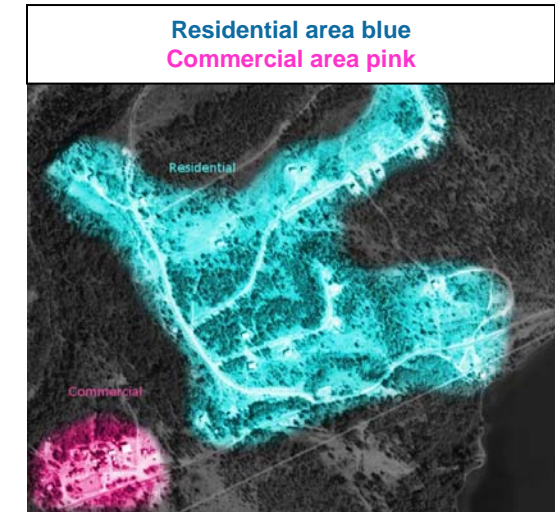
# PV-Microgrid Nemiah, BC

## AMI infrastructure – pay-as-you go meter

- Research on medium penetration Solar PV, whereby the PV generation exceeded the load
- Alternative system design and grid topology options
- Research combination with diesel gensets and low-load operation with PV
- Three measures in the Nemiah grid
  - Introducing 6 distributed rooftop PV - 27kW,
  - Replacing a 95 kW genset by a 30 kW genset,
  - Reducing commercial loads on weekday evenings and weekends by introducing a contactor to switch these off.

- Validation of fuel saving with 25% reduction in diesel fuel compared to baseline

- Local employment \$ and rural electricity cooperative \$



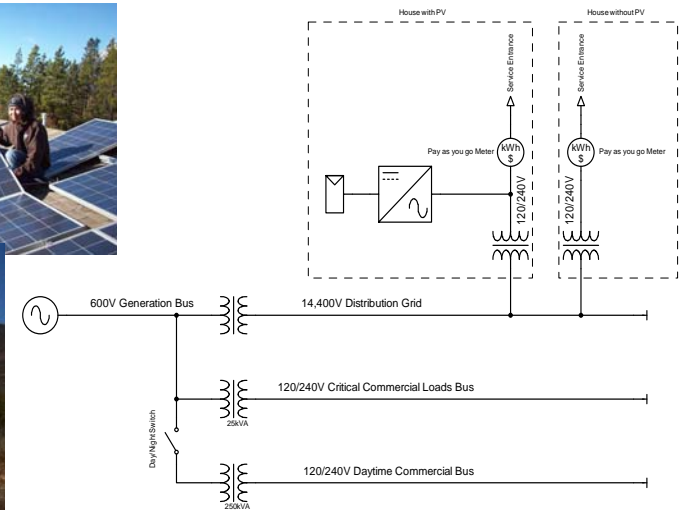
■ PV ■ Commercial load control □ 30 kW genset

Fuel savings (in litres) from each of the three measures .



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Source: Dave Turcotte, Sophie Pelland



General Diagram of the mini-grid.



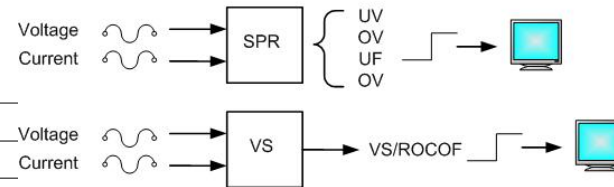
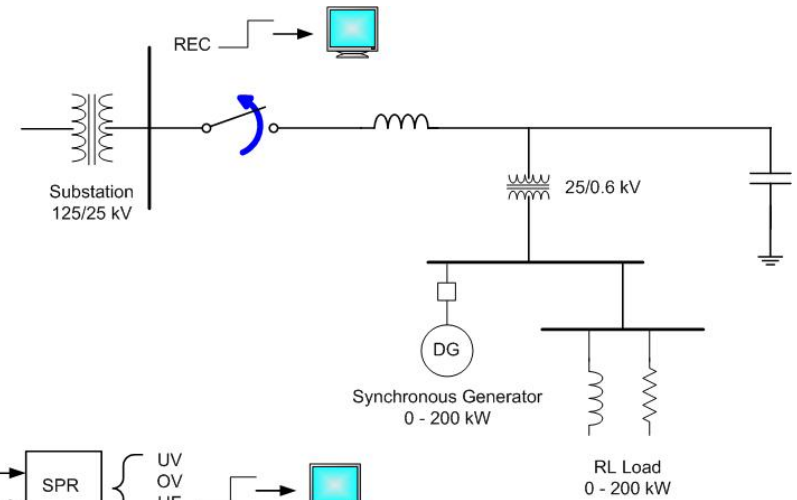
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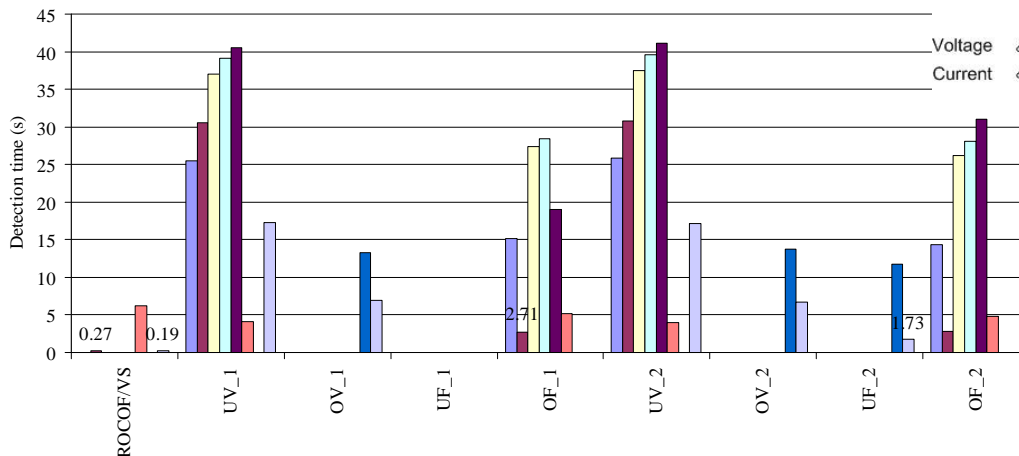
# Commercial Relays Field Tests for Passive Anti-Islanding Protection

- Synchronous based DGs
- 3 commercial (off-the-shelf) protection relays.
- In collaboration with Hydro Quebec Research Centre (IREQ)



Test Line Single Line Diagram

- A combination of ROCOF and VS schemes could detect islanding of a synchronous DGs for power mismatches above 10%.

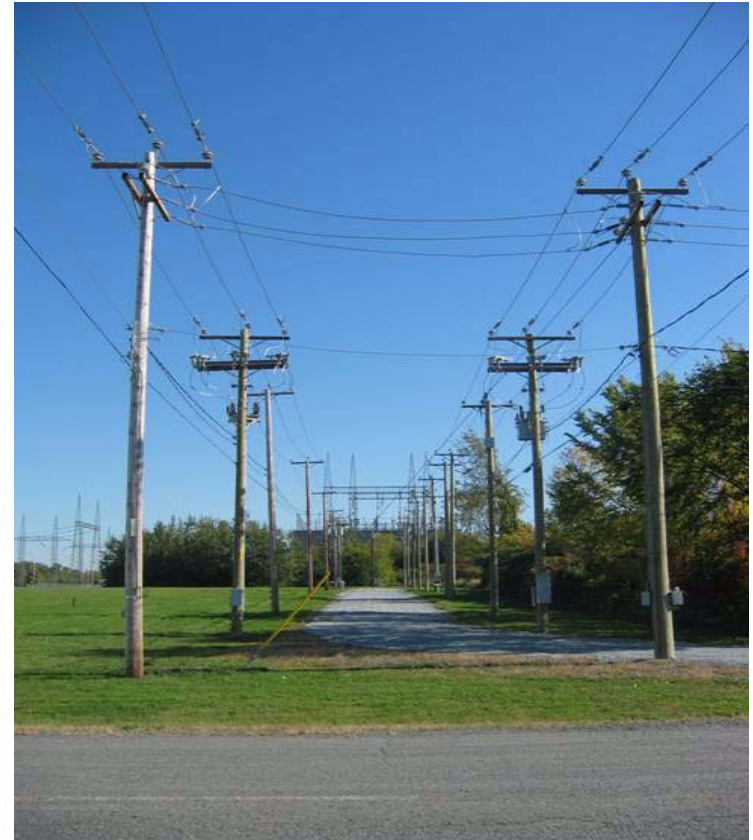
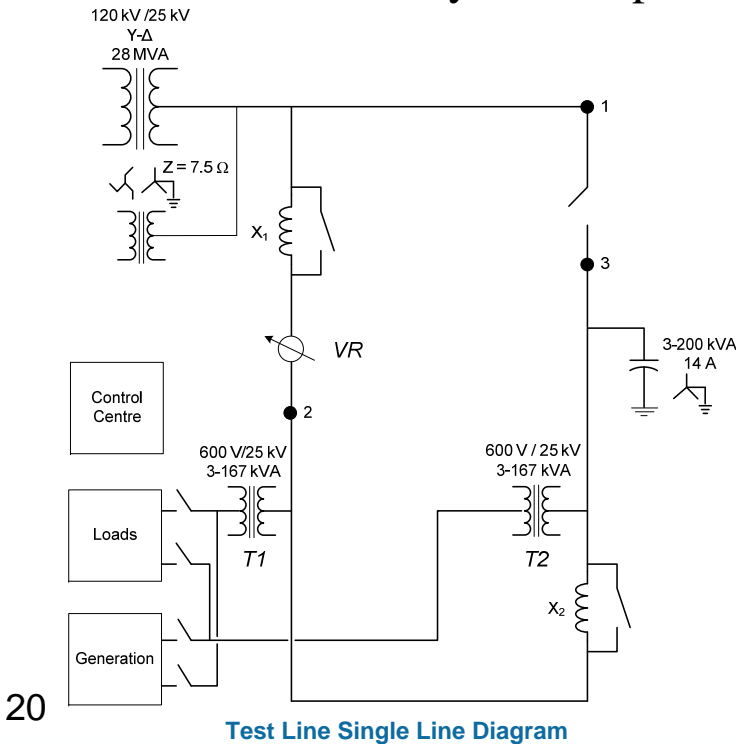


0% mismatch resistive	12.5% mismatch resistive
9.1% mismatch resistive	0% mismatch light resistive load
11.1% mismatch light resistive load	4.4 mismatch resistive-inductive
4.4 mismatch resistive-Capacitive	10.6% mismatch resistive-non-unity generation

Relays' Operating Time

# Voltage Regulator Testing with Distributed Generation

- In collaboration with Hydro Quebec Research Centre (IREQ).
- Test Line to be modeled using EMTP-RV to validate the field test results.
- Results will be analyzed and presented in a paper.



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- **Smart Grid Demonstration Projects**

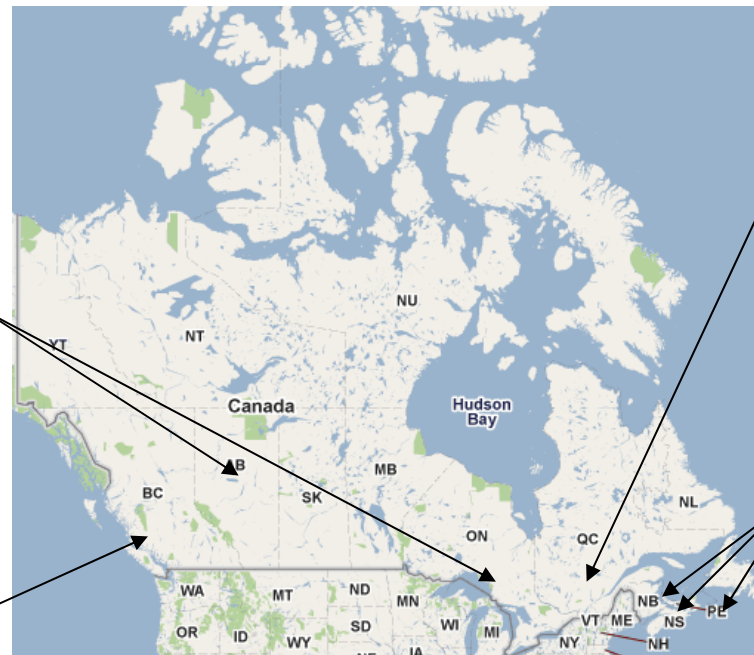
# CanmetENERGY provides technical and administration support for Clean Energy Fund (CEF) demonstration projects

## Power Measurement Ltd

- Load curtailment and peak shaving in large commercial buildings
- Partners include Brookfield Properties, ENMAX
- \$10M project

## BC Hydro

- Installation of two 1MW storage systems at two locations to support remote and weak grid systems
- \$13.4M project



## Hydro-Québec-Institut de recherche

- Development of a smart zone in Boucherville including PHEV charging infrastructure
- \$20M project

## New Brunswick Power Corporation

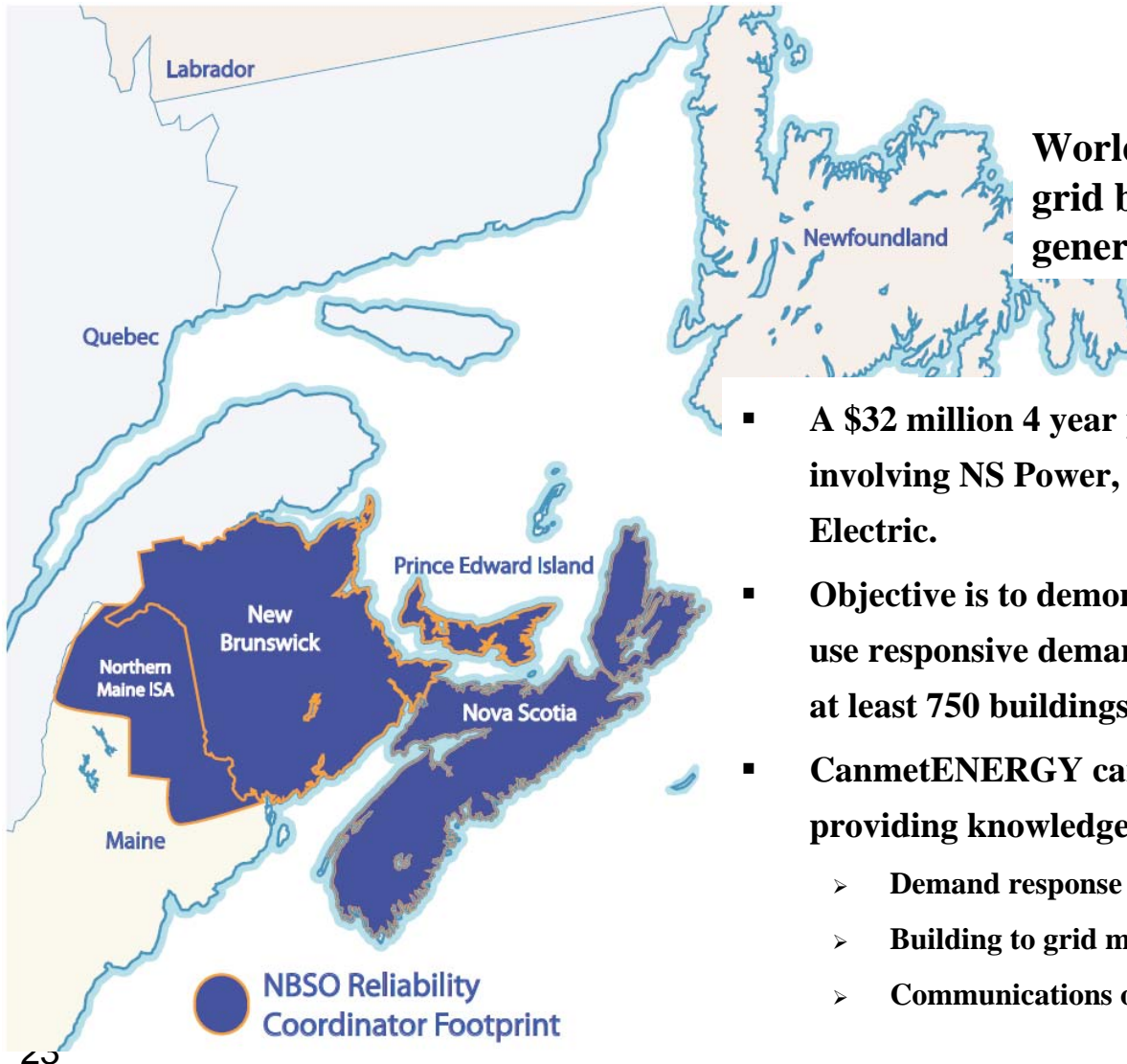
- Project will install monitoring and control systems in 750 buildings in PEI, NB and NS. Load control will be driven by availability of regional wind power
- 4 utilities involved
- \$32M project

**Total \$75.4 Million (4 projects)**

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# CEF Fund: The Atlantic Power Shift Project



## The Maritimes:

**World class wind regime but limited grid balancing resources. Current generation is mainly fossil fuel based.**

- A \$32 million 4 year project led by NB Power and involving NS Power, St John Energy and Maritime Electric.
- Objective is to demonstrate smart grid technologies to use responsive demand to balance wind generation with at least 750 buildings involved.
- CanmetENERGY can provide technical support by providing knowledge on:
  - Demand response in commercial building
  - Building to grid models
  - Communications options for demand response

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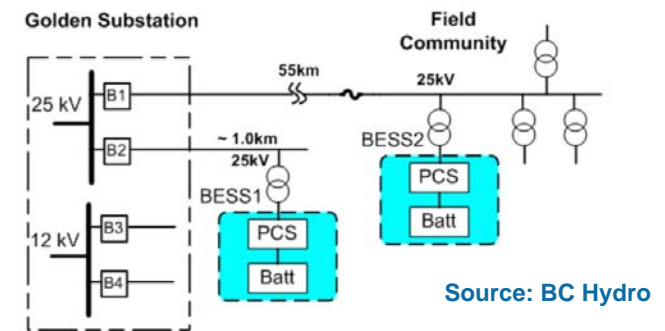
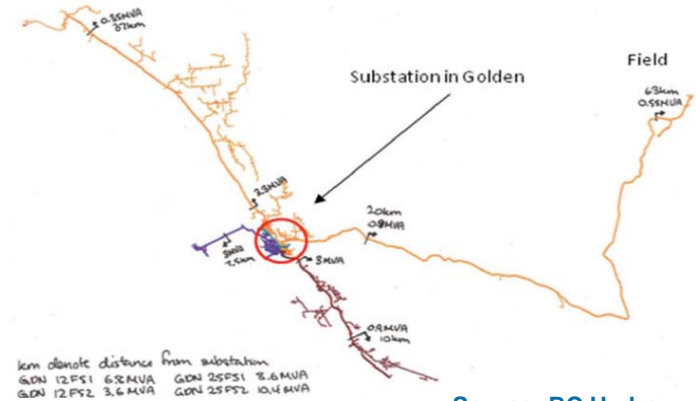
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# CEF Fund: BC Hydro

## Energy Storage and Demand Response for Near-Capacity Substation

- This project demonstrates the integration of energy storage as a mechanism for mitigating risk of exceeding capacity at near-peak capacity substations.
- This type of solution has the ability to be used in other remote communities where the grid reliability is low and the cost of the transmission line upgrade is uneconomical.
- Solution to near-capacity substation at Golden
  - Proposed use of 2 x 1 MW battery storage (at Golden and Field) to bridge capacity gap prior to transmission upgrade (peak shaving)
- Solution to poor reliability indices for Field
  - Proposed use of 1 MW battery storage at Field and demand response to provide back-up energy source (islanding)
- Use knowledge for future initiatives
  - Defer capacity (transmission or generation) in other locations
  - Support for intermittent generation from renewable sources
  - Energy management of distributed energy resources
  - Alternative energy source to diesel generation as back-up



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# Questions

## CanmetENERGY research centre in Varennes (Quebec)



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[http://canmetenergy.nrcan.gc.ca/eng/renewables/integration\\_der.html](http://canmetenergy.nrcan.gc.ca/eng/renewables/integration_der.html)

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