Impact of DGs on Voltage Profile and Protection
-EDIST 2012-

Steven Wong

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Natural Resources Canada
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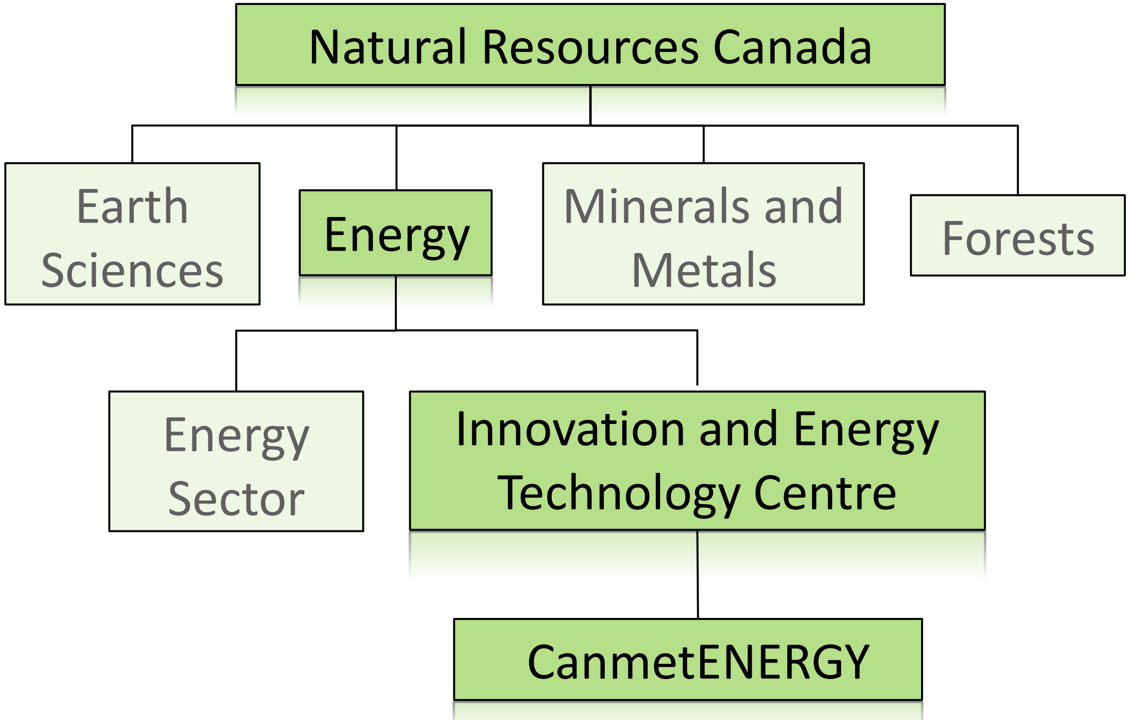
Order of Presentation

- Introduction to NRCan/CanmetENERGY
- Fault location detection with DG[1]
- Fault detection with multiple DG[2]
- IEEE 1547.8[3]
- Voltage profiles with high penetration PV[4]
- Questions and Answers

Work conducted by [1]Tarek EL-Fouly, [2]Ahmed Ozeer & Claude Bergeron, [3]Canadian writing group led by Dale Williston and [4]Reinaldo Tonkoski.

Introduction to CanmetENERGY

- Research and development arm of NRCan
- Over 450 scientists, engineers, and technicians spread over three research centres (Ottawa, Devon, and Varennes).



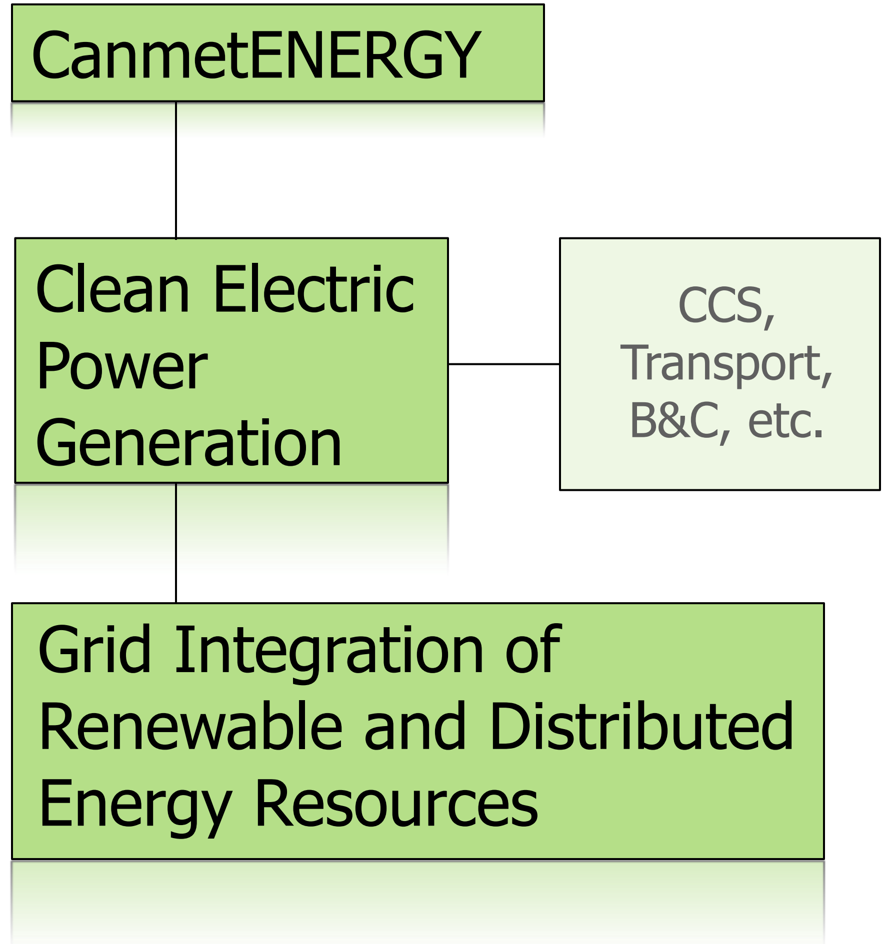
Goal: To ensure that Canada is at the leading edge of clean energy technologies to reduce air and greenhouse gas emissions and improve the health of Canadians.

CanmetENERGY: http://canmetenergy-canmetenergie.nrcan-rncan.gc.ca/

Introduction to CanmetENERGY

The CanmetENERGY Research Centre supports national S&T efforts that contribute to

- modernization of the electricity grid,
- improvement of resource diversity and system security, and
- increased adoption of clean and renewable energy resources.



Introduction to CanmetENERGY

CanmetENERGY Research Centre Roles

- Engage in discussions and consultations with partners to improve decision making and regulations in Canada.
- Participate in codes and standards bodies to address technical barriers.
- Conduct research with universities and other researchers home and abroad to strengthen Canadian knowledge and capacity.
- Work with regulators, utilities, and communities to lower risks to the integration of renewables and increase their acceptance.

Introduction to CanmetENERGY

Research Activities

- PV systems and integration
  - Arrays, inverters, and setup/output
- Smart grid, microgrids, and smart zones
  - Demand side management, renewables integration, and EVs
- Active distribution
  - Fault detection
- Remote communities

CanmetENERGY low voltage test facility: Inverter and interconnection testing

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Fault Location Detection with DG

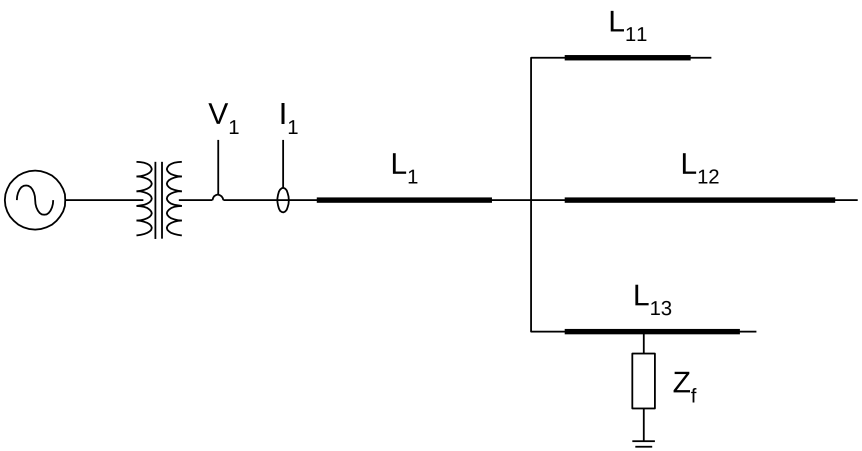
Locating faults on the distribution system is important to

- 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.

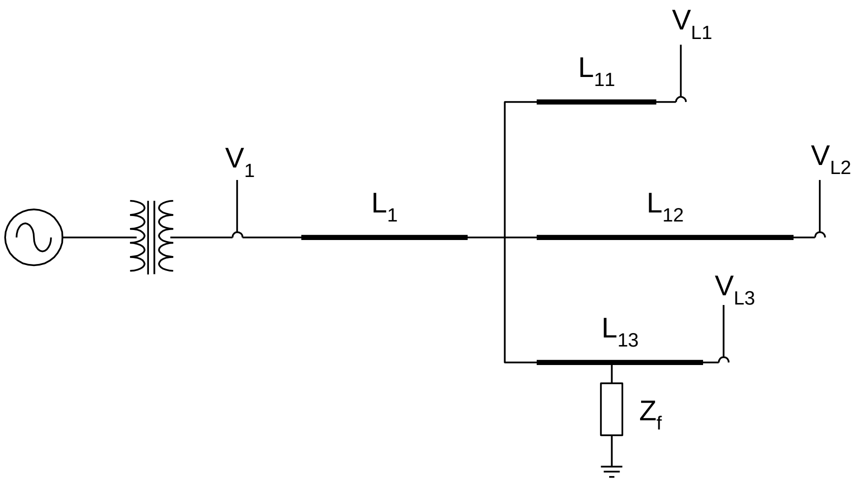
Fault Location Detection with DG

Automatic fault location detection approaches include

- 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

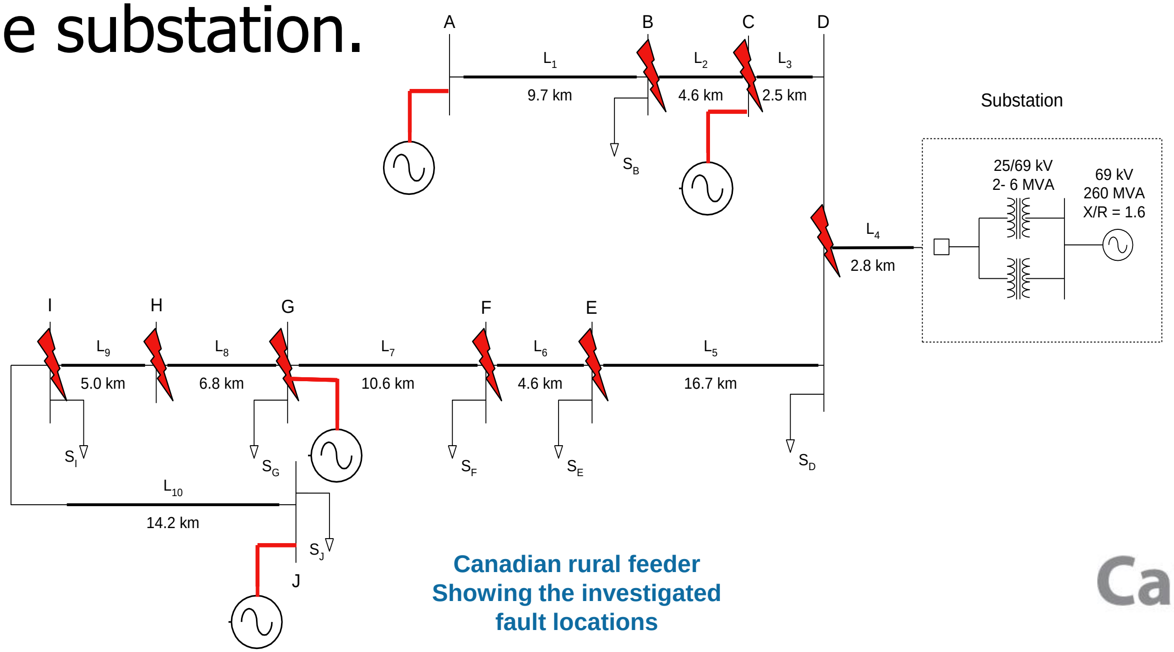


Approach using the voltage measurements from the substation and from AMI

Fault Location Detection with DG

Rural Feeder with DGs

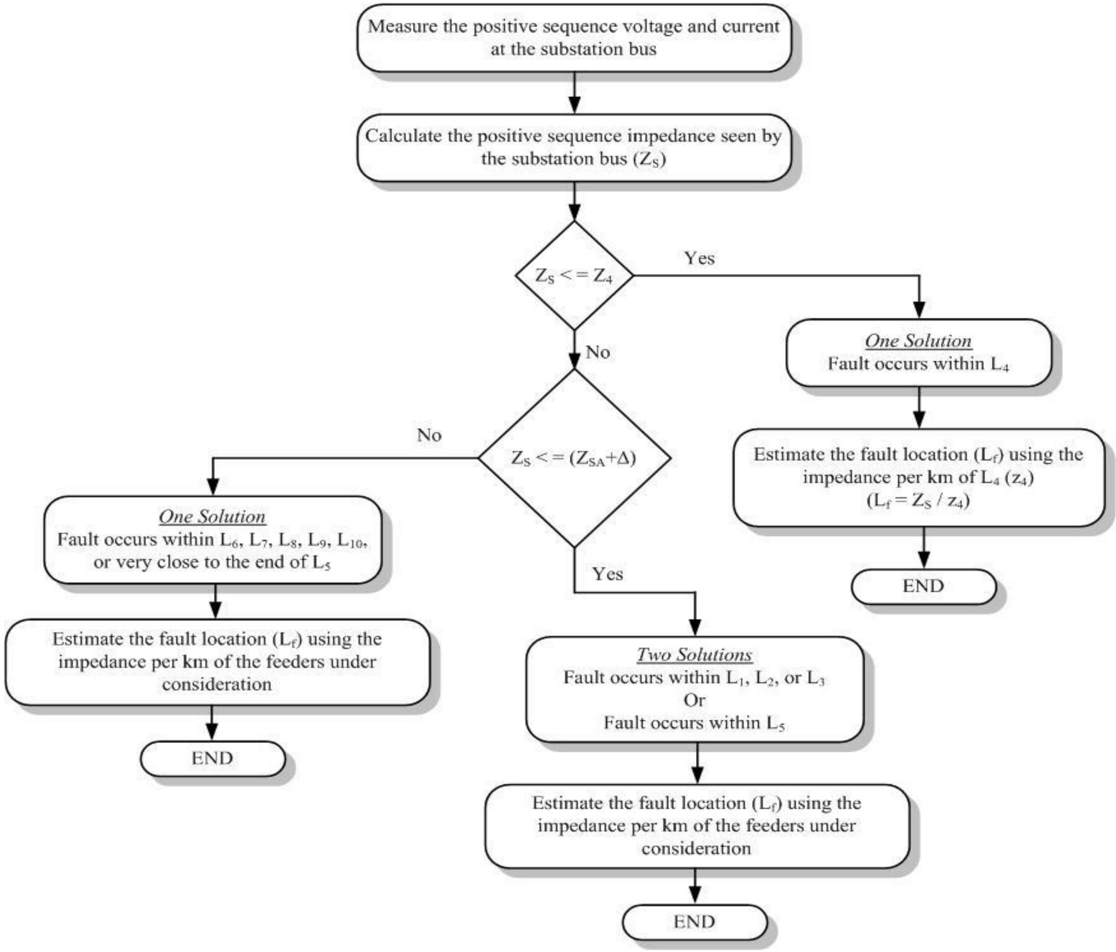
- However, DGs may impact existing detection systems.
- This study considers the impact of the DGs on the performance of an automatic fault location approach on rural feeders using the voltage and current measured at the substation.



Canadian rural feeder
Showing the investigated
fault locations

Fault Location Detection with DG

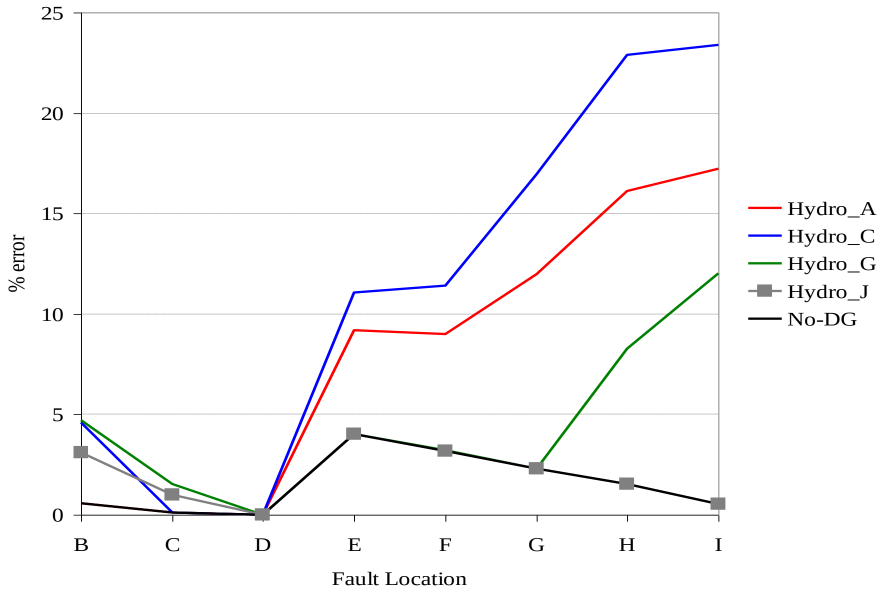
- The performance was assessed for cases with and without DG
- Both induction machine (Wind) and synchronous machine (Hydro) based DGs were considered.

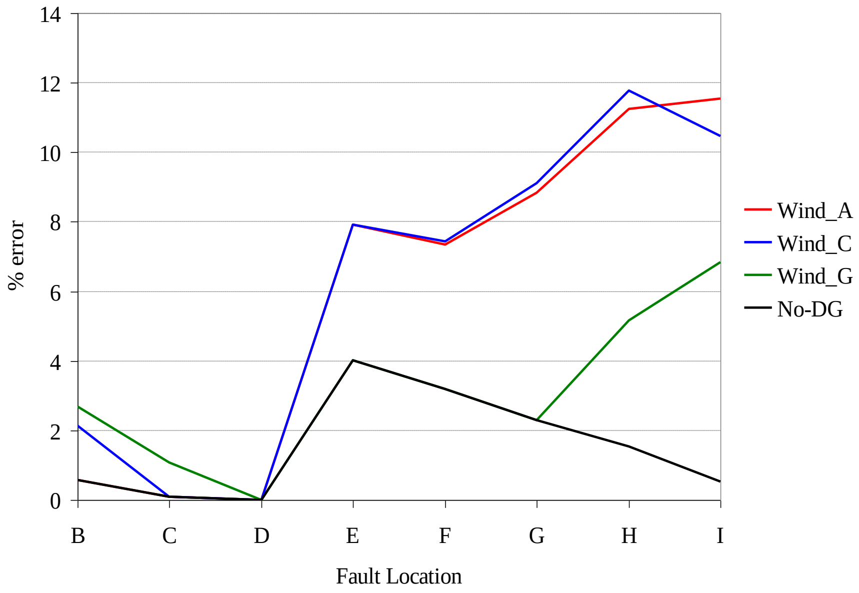


Automatic Fault Location Detection Algorithm

Fault Location Detection with DG

- 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.





T.H.M. EL-Fouly and C. Abbey, “On the Compatibility of Fault Location Approaches and Distributed Generation” Proceedings of the Joint CIGRE PES Integration of Wide-Scale Renewable Resources into the Power Delivery System Symposium, Calgary, Alberta, Canada. (**July 29 - 31, 2009**)

Fault Detection with Multiple DG

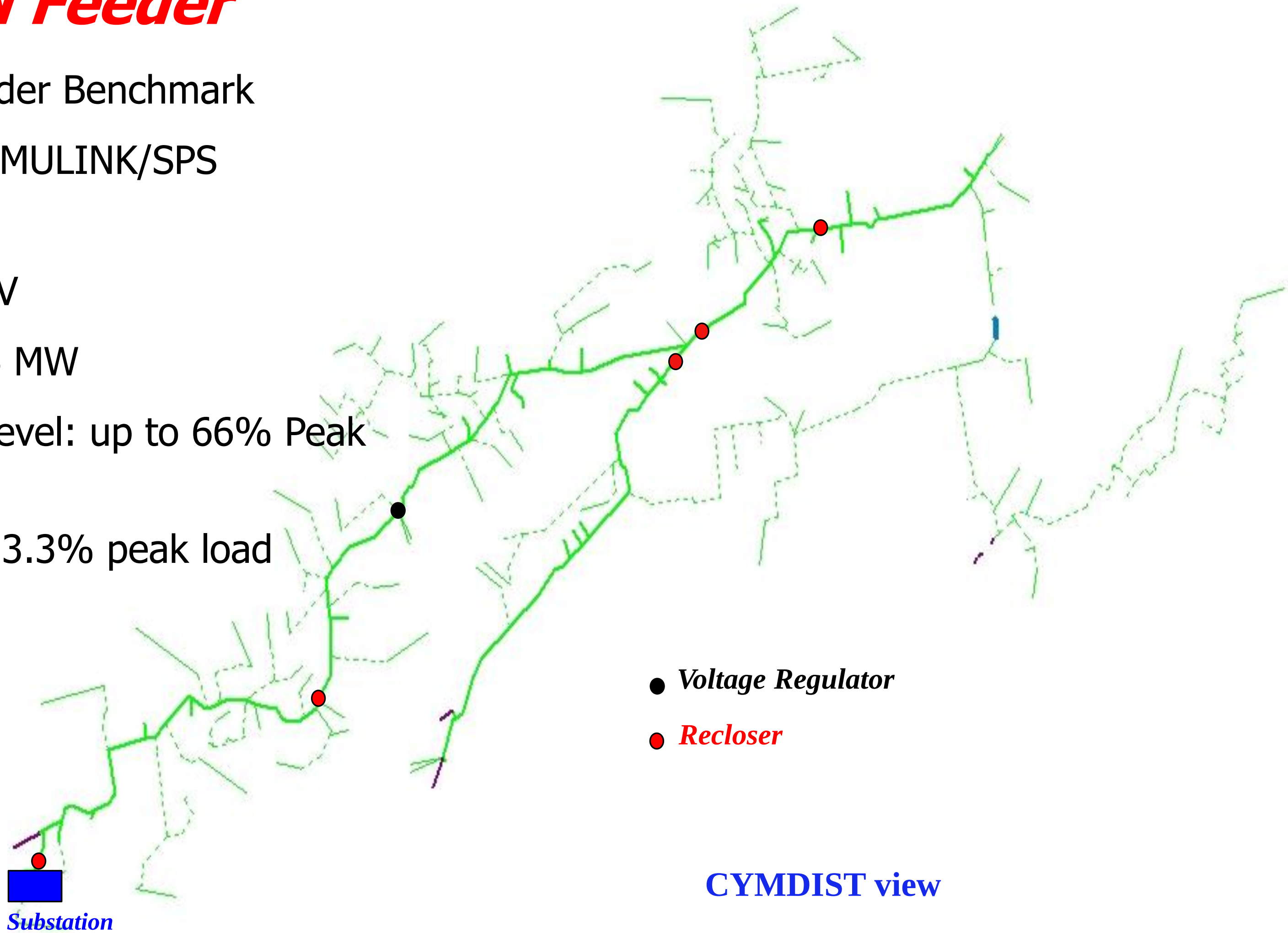
- Data from two actual Canadian feeders were used in the analysis.
- Four types of faults have been investigated
  - 3-phase faults
  - L-L faults
  - L-G faults
- Faults were simulated at various locations along the feeder and system currents and voltages were recorded:
  - with the generator off and only the system supplying the fault;
  - with the generator on and both the system and the generator supplying the fault; and,
  - when the system has tripped and only the generator is supplying the fault.

Feeder Protection Systems for Multiple Generation Sites on the Same Feeder, T. EL-Fouly A. Ozeer, C. Bergeron, CanmetENERGY, NRCan, Presentation at the DG Protection-Coordination Study Group Workshop, Toronto, January 18, 2011

Fault Detection with Multiple DG

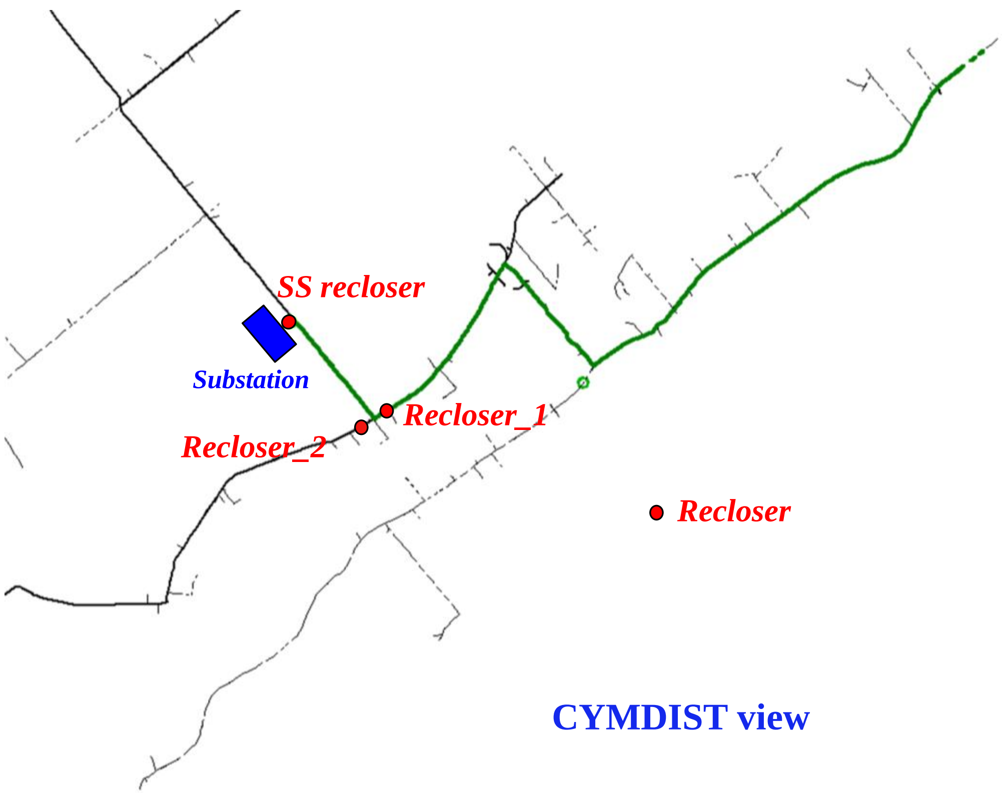
Study 1: ON Feeder

- Battersea F1 feeder Benchmark
- Tool: MATLAB/SIMULINK/SPS
- Length: 23.4 km
- Voltage: 12.47 kV
- Peak load: 2.266 MW
- DG penetration level: up to 66% Peak load
- Minimum load: 33.3% peak load



Fault Detection with Multiple DG

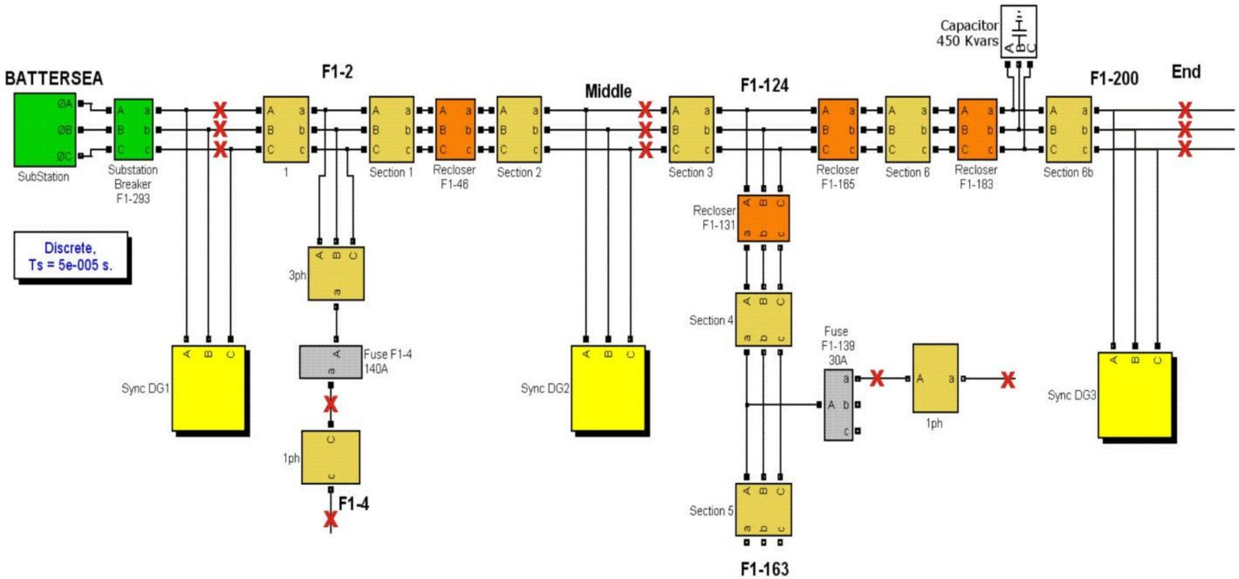
Study 2: NB Feeder



- Bouctouche in New Brunswick
- Tool: CYMDIST
- Length of 9.5 km
- Voltage: 12.47 kV
- Peak load: 4.1 MVA.
- DG penetration level: up to 88% peak load
- Minimum load: 25% peak load

Fault Detection with Multiple DG

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



MATLAB&SIMULINK Model for the ON feeder

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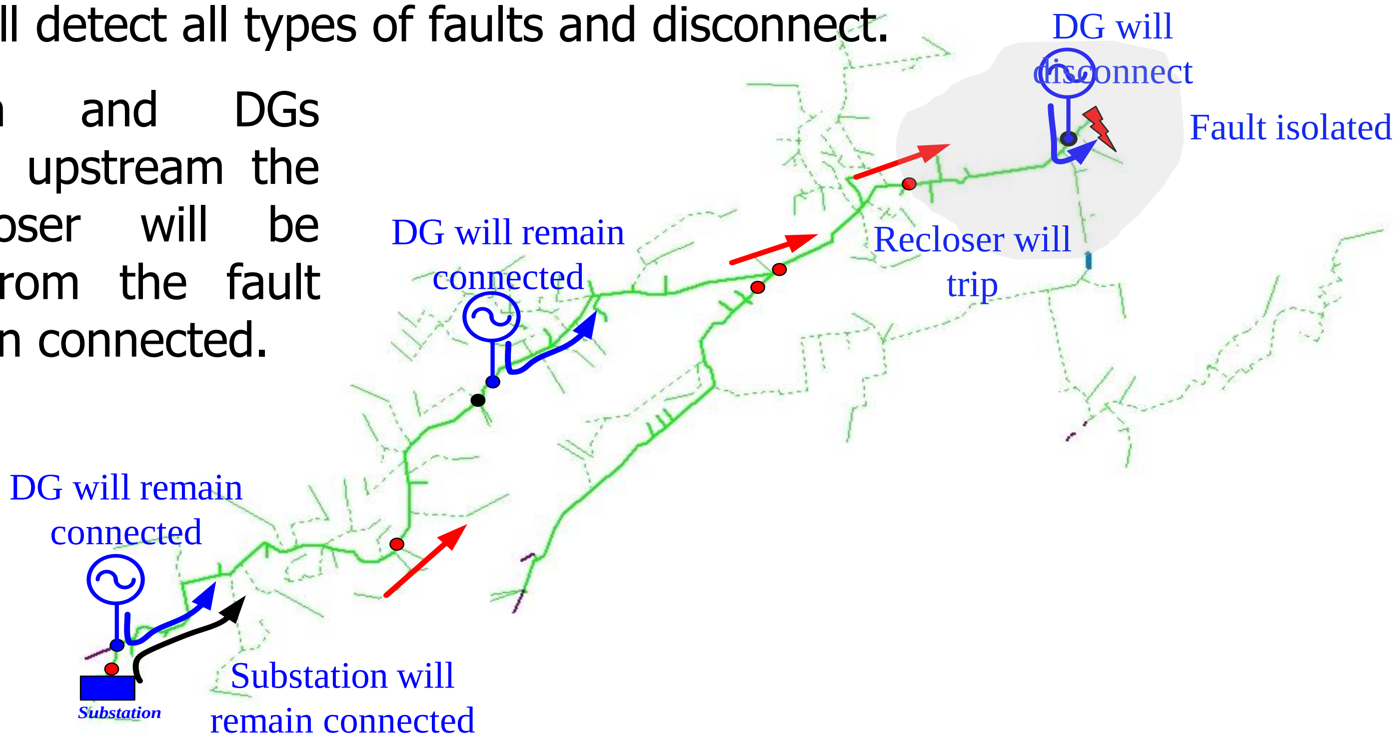
Fault Detection with Multiple DG

For faults at the end of the feeder:

- Last recloser on the feeder (nearest recloser to the end of the feeder) will detect all types of faults and trips.
- DG located at the end of the feeder (downstream the last recloser on the feeder) will detect all types of faults and disconnect.
- Substation and DGs connected upstream the last recloser will be isolated from the fault and remain connected.



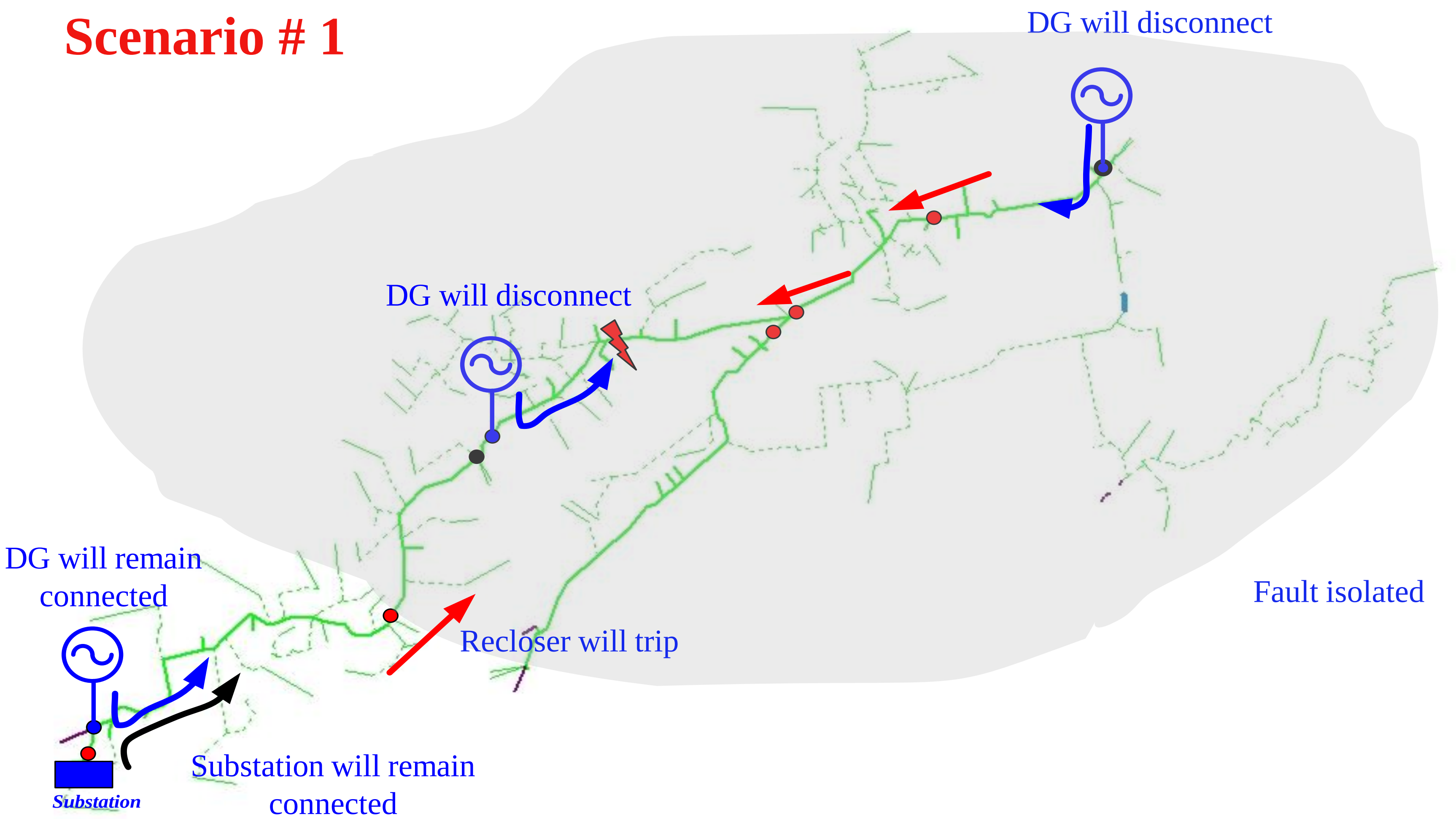
Fault Detection with Multiple DG

For faults at the middle of the feeder:

- First recloser upstream the fault will detect all types of faults and trips.
- DGs located downstream the tripped recloser will detect all types of faults and disconnect.
- Substation and DGs located upstream the tripped recloser will be isolated from the fault and remain connected.
- Reclosers located downstream the tripped recloser could detect L-L-L and L-L faults and might trip before the downstream DGs and create an unplanned island. Possible solutions to avoid the unplanned island formation:
- Using directional overcurrent relays
- Adjust downstream DGs' overcurrent protection setting to ensure DG disconnection before upstream recloser trips.

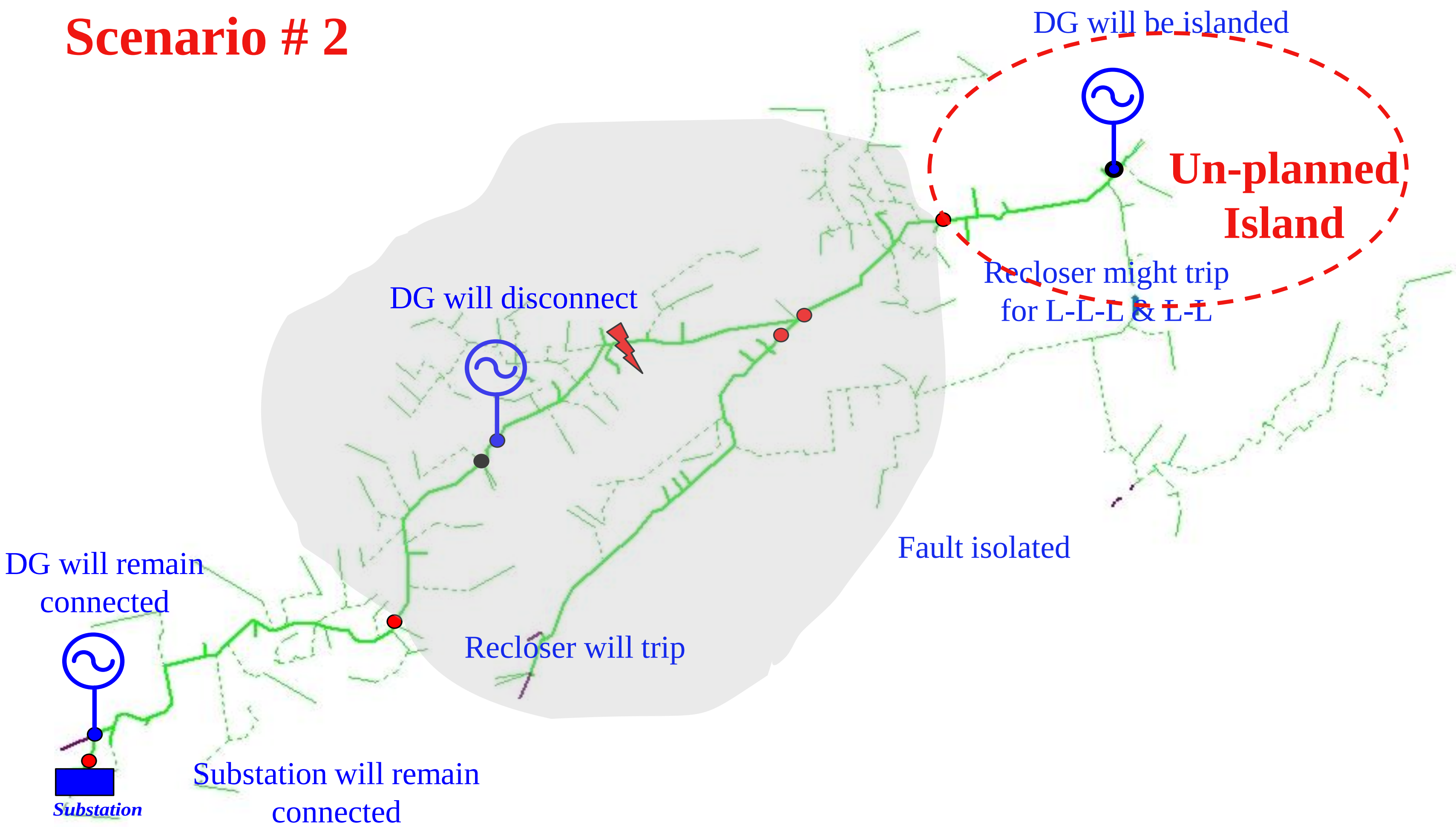
Fault Detection with Multiple DG

For faults at the middle of the feeder:



Fault Detection with Multiple DG

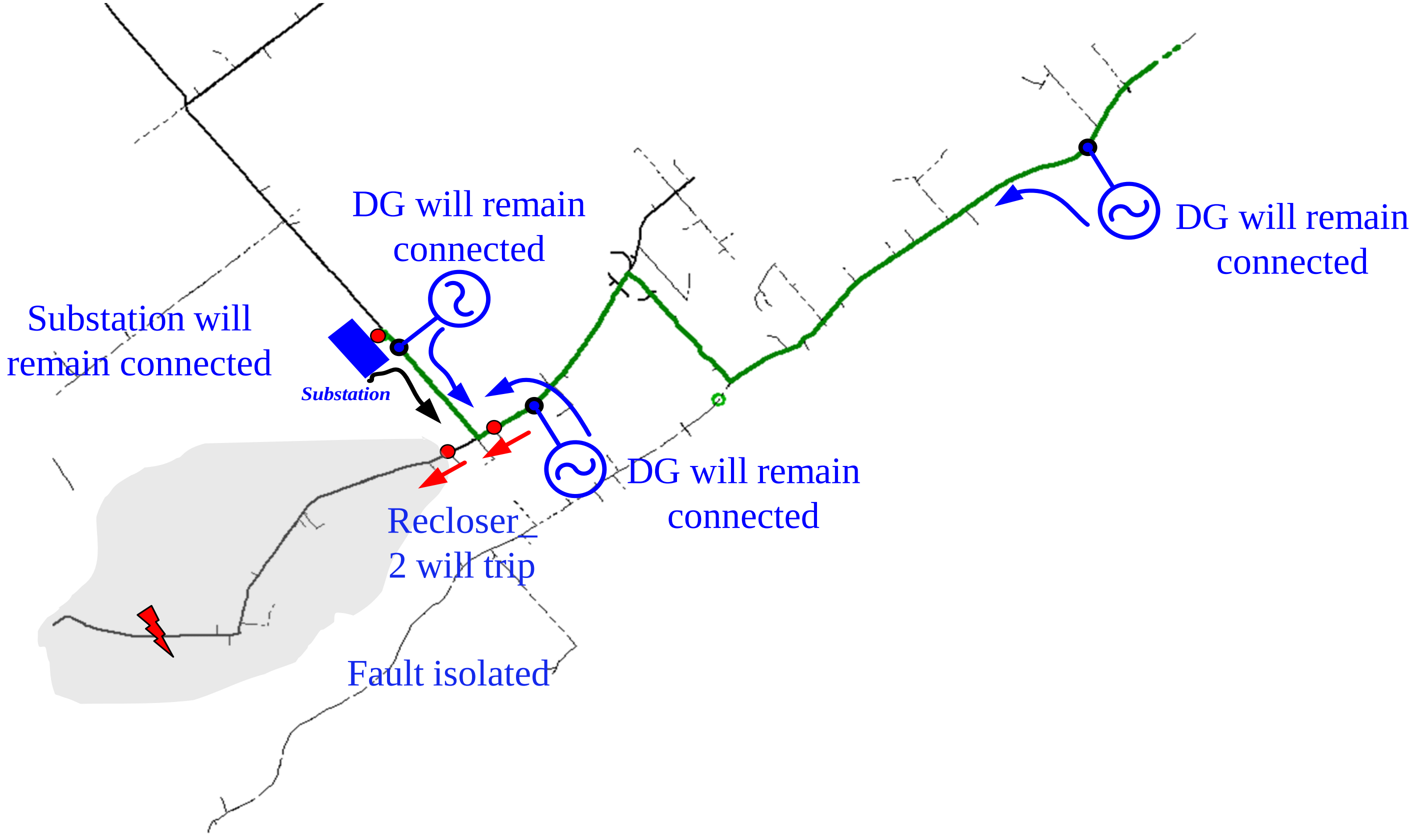
For faults at the middle of the feeder:



Fault Detection with Multiple DG

For faults at the branch:

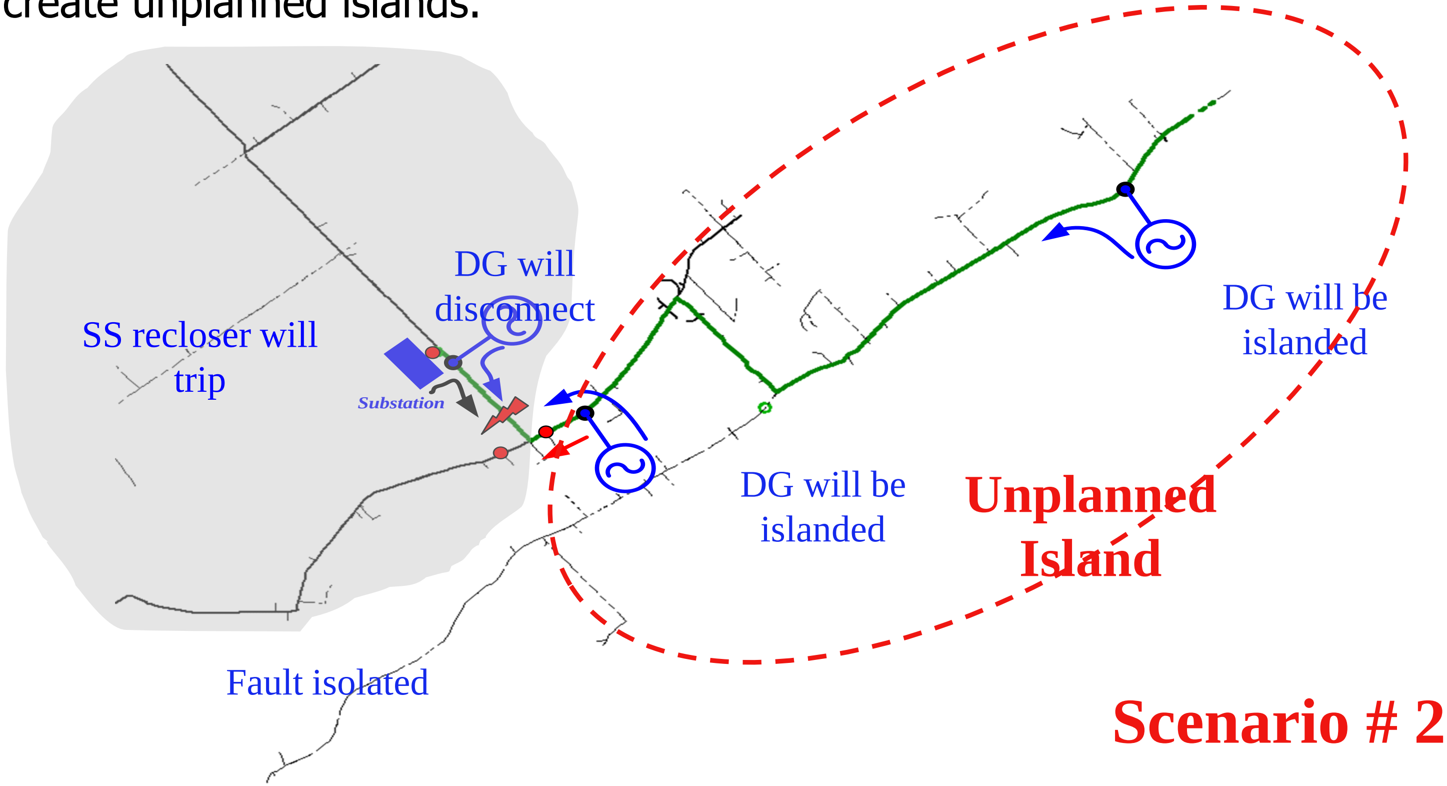
- Recloser at the beginning of the branch will detect all types of faults and trips.
- Substation and DGs will be isolated from the fault and remain connected.



Fault Detection with Multiple DG

For faults near the substation:

- Substation reclosers will detect all types of faults and trips.
- In most cases, DGs won't detect any faults. However, once the Substation recloser trips, all DGs will detect all types of faults and disconnect.
- Feeder reclosers could detect L-L-L and L-L faults and might trip before the downstream DGs and create unplanned islands.



IEEE 1547.8 Recommended Practice for Establishing Methods and Procedures that Provide Supplemental Support for Implementation Strategies for Expanded Use of IEEE Standard 1547

Section on DR and Utility Protection Best Practices

- The *NRCan Protection and Safety Study Group* for Distributed Generation was established in 2009. Its goal is to remove technical obstacles for the interconnection of DG.
- In September 2010, the Study Group decided to participate in the international IEEE 1547.8 development
- Four members of the *NRCan Study Group* including Dave Turcotte from *CanmetENERGY* with two other individuals from the US are the writing group for the section on protection options for DG interconnection and the rest of the *NRCan Study Group* act as advisory committee members.
- Dale Williston, *Williston & Associates Inc.*, is the lead writer.

IEEE 1547.8

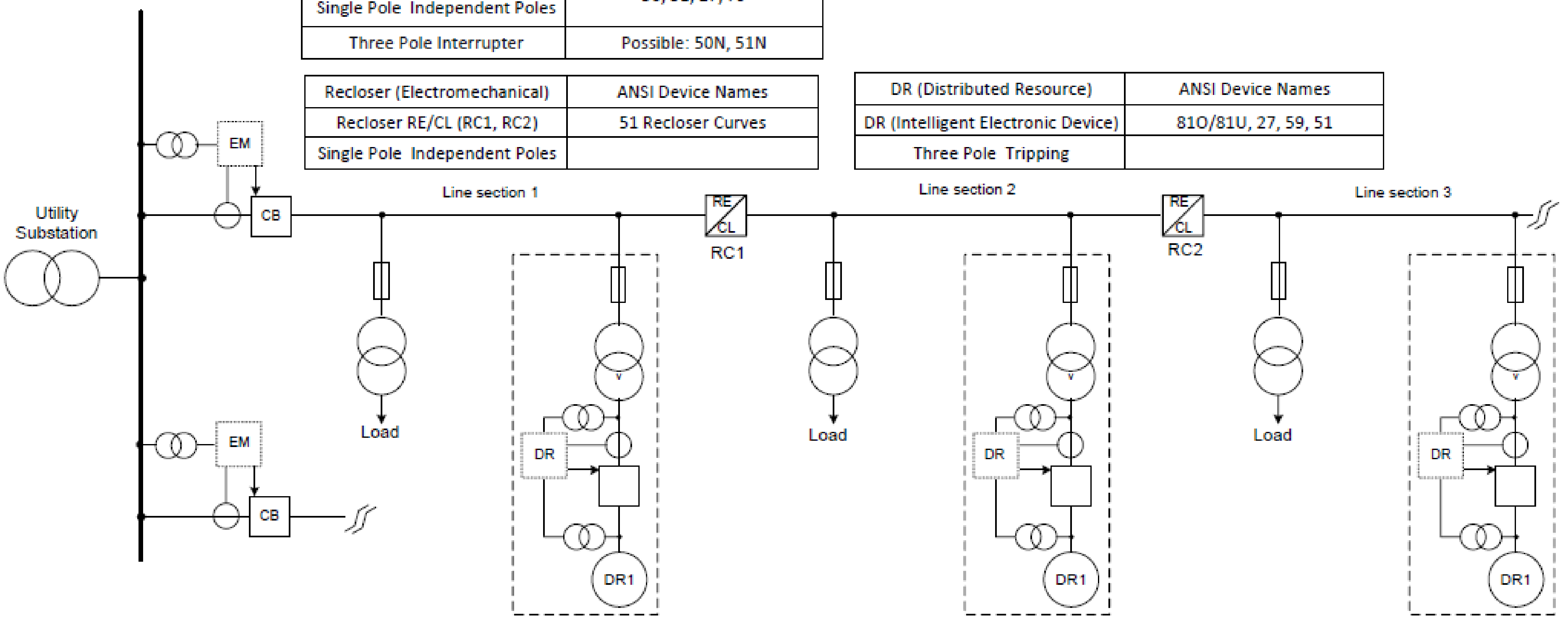
Section on DR and Utility Protection Best Practices

Option 1: Overcurrent Protection on the Area EPS and Anti-islanding Protection on the DR

Utility Substation	ANSI Device Names: EM
CB Relaying (Electromechanical) Single Pole Independent Poles	50, 51, 27, 79
Three Pole Interrupter	Possible: 50N, 51N

Recloser (Electromechanical)	ANSI Device Names
Recloser RE/CL (RC1, RC2)	51 Recloser Curves
Single Pole Independent Poles	

DR (Distributed Resource)	ANSI Device Names
DR (Intelligent Electronic Device)	81O/81U, 27, 59, 51
Three Pole Tripping	



IEEE 1547.8

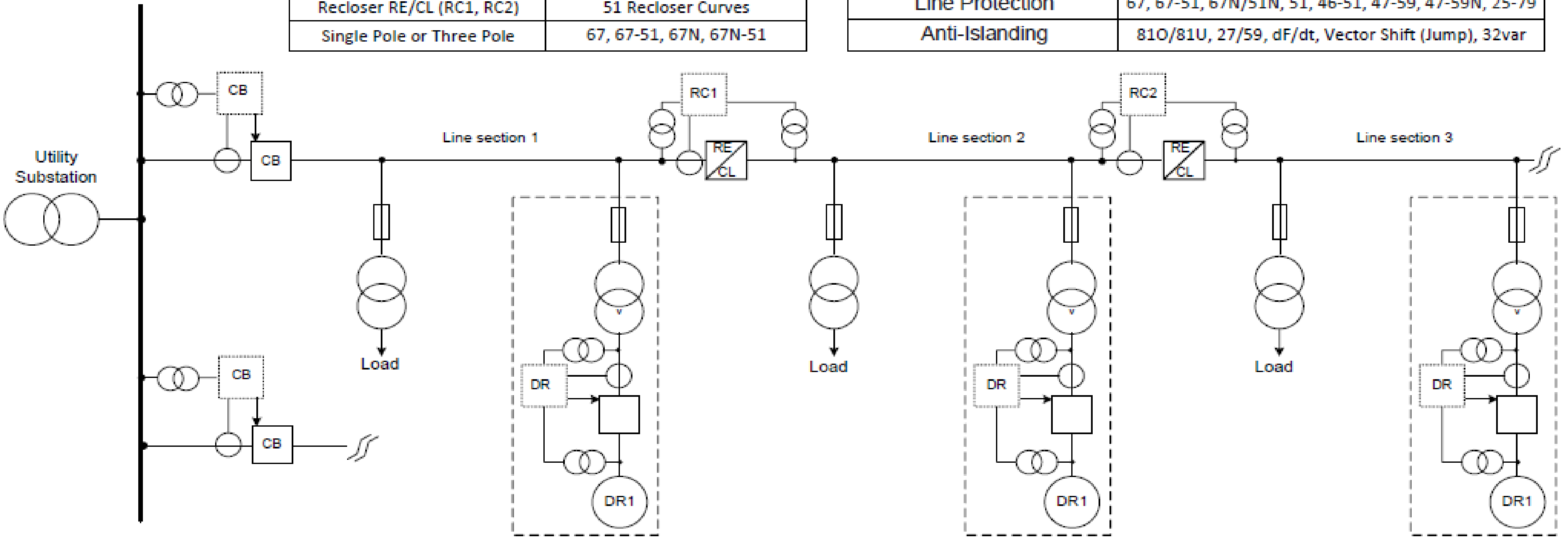
Section on DR and Utility Protection Best Practices

Option 2: Overcurrent Protection at the Area EPS, Directional Overcurrent at the DR

Utility Substation	ANSI Device Names: CB
CB Relaying (Electromechanical) Single Pole or Three Pole	50, 51, 27, 79
CB Relaying Intelligent Electronic Device	67, 67-51, 67N, 67N-51

Recloser with IED	ANSI Device Names
Recloser RE/CL (RC1, RC2)	51 Recloser Curves
Single Pole or Three Pole	67, 67-51, 67N, 67N-51

DR (Distributed Resource)	ANSI Device Names
DR (Intelligent Electronic Device)	Three Pole Tripping
Line Protection	67, 67-51, 67N/51N, 51, 46-51, 47-59, 47-59N, 25-79
Anti-Islanding	81O/81U, 27/59, dF/dt, Vector Shift (Jump), 32var



IEEE 1547.8

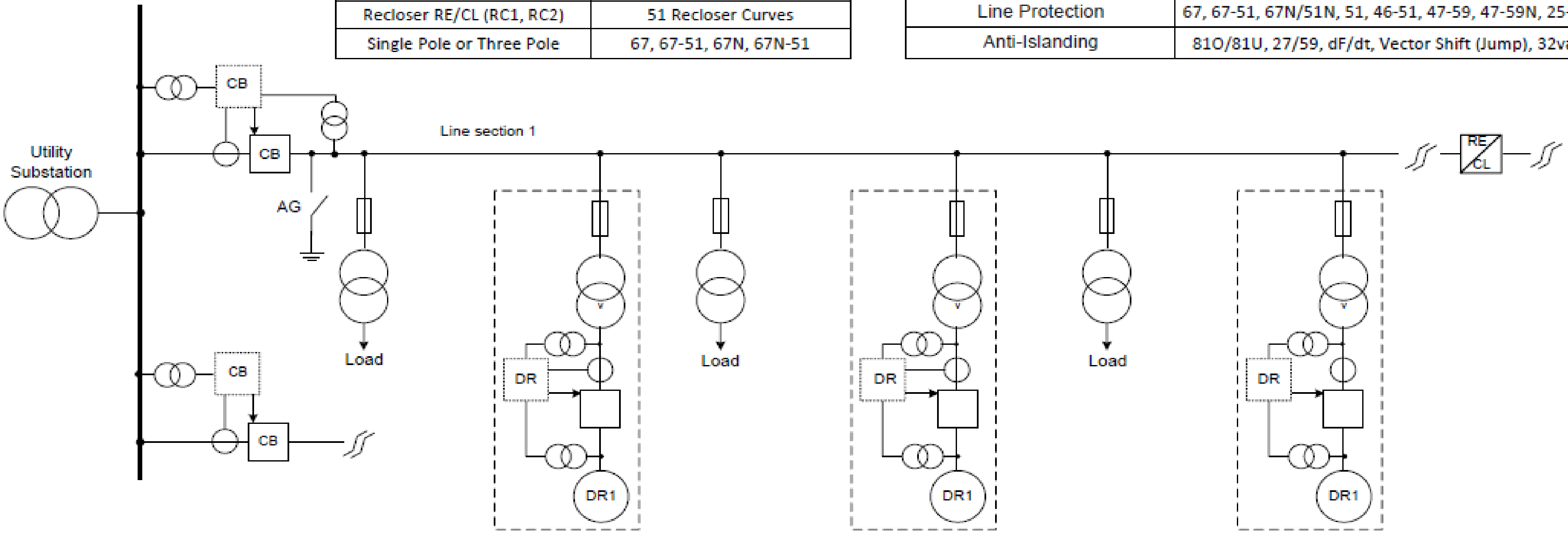
Section on DR and Utility Protection Best Practices

Option 3: Overcurrent Protection and Auto Ground on the Area EPS, Directional Overcurrent on the DR, Single Line Section

Utility Substation	ANSI Device Names: CB
CB Relaying (Electromechanical) Single Pole or Three Pole	50, 51, 27, 79
CB Relaying Intelligent Electronic Device	67, 67-51, 67N, 67N-51

Recloser with IED	ANSI Device Names
Recloser RE/CL (RC1, RC2)	51 Recloser Curves
Single Pole or Three Pole	67, 67-51, 67N, 67N-51

DR (Distributed Resource)	ANSI Device Names
DR (Intelligent Electronic Device)	Three Pole Tripping
Line Protection	67, 67-51, 67N/51N, 51, 46-51, 47-59, 47-59N, 25-79
Anti-Islanding	81O/81U, 27/59, dF/dt, Vector Shift (Jump), 32var



IEEE 1547.8

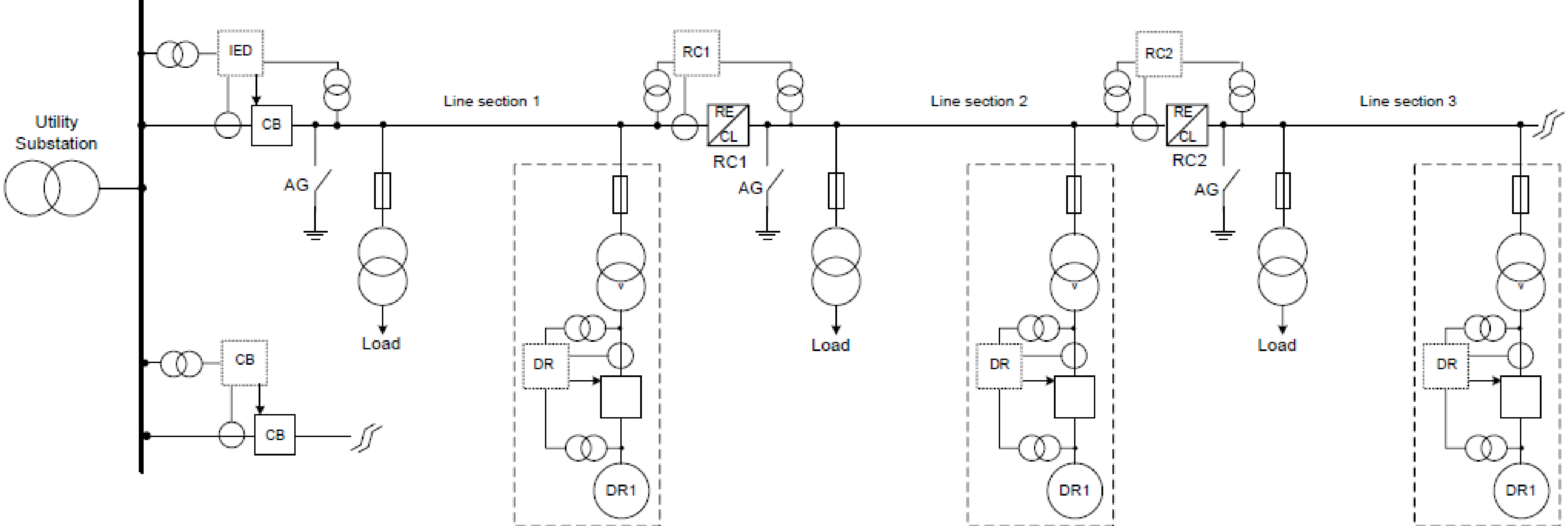
Section on DR and Utility Protection Best Practices

Option 4: Distance Protection, Auto Grounds, Multiple Line Sections

Utility Substation	ANSI Device Names
CB Relaying IED	21-Z1, 21-Z2, 21-Z3, 32-1, 32-2, 27-79
Intelligent Electronic Device IED	27-25, 67, 67-51, 67N, 67N-51

Recloser with IED	ANSI Device Names
Recloser RE/CL (RC1, RC2)	21-Z1, 21-Z2, 21-Z3, 32-1, 32-2, 27-79
Single Pole or Three Pole	27-25, 67, 67-51, 67N, 67N-51

DR (Distributed Resource)	ANSI Device Names
Line Protection DR (Intelligent Electronic Device)	21-Z1, 21-Z2, 21-Z3, 67, 67-51, 67N, 67N-51, 51, 46-51, 47-59, 47-59N, 25-79
Anti-Islanding	81O/81U, 27/59, dF/dt, Vector Shift (Jump), 32var



IEEE 1547.8

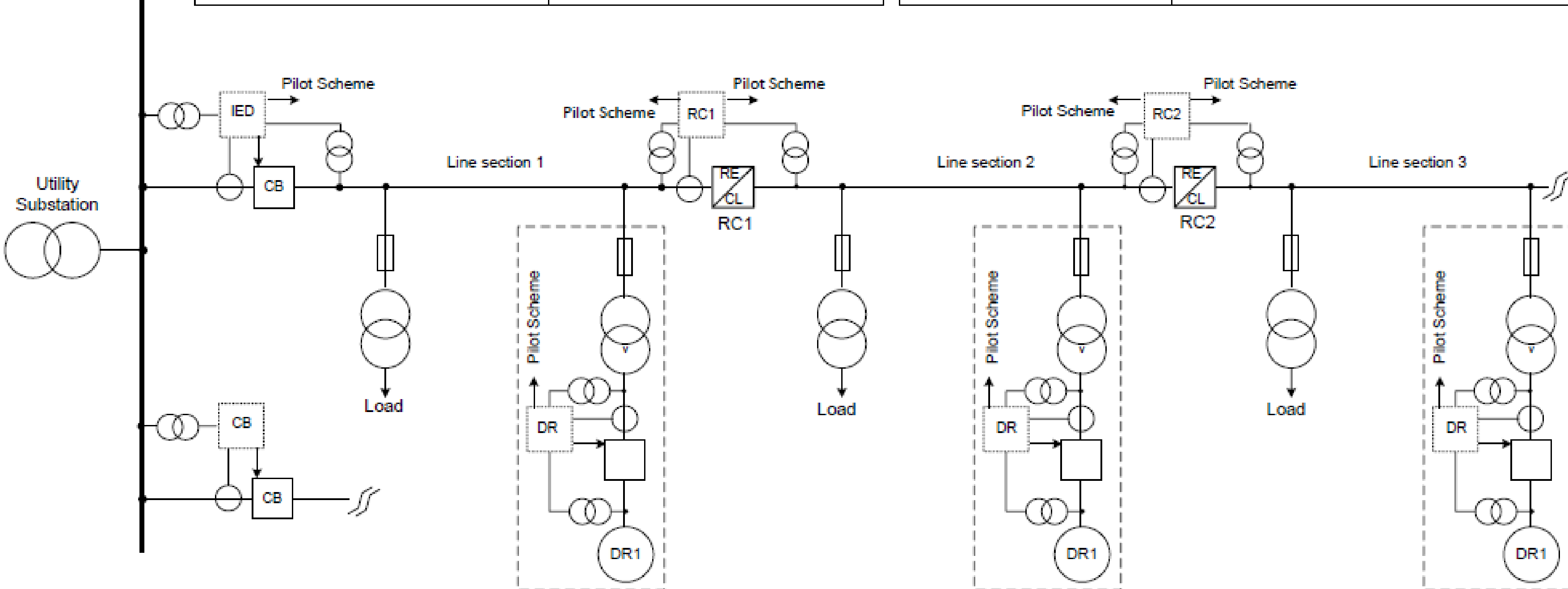
Section on DR and Utility Protection Best Practices

Option 5: Distance Protection, Teleprotection, Multiple Line Sections

Utility Substation	ANSI Device Names
CB Relaying IED	21-Z1, 21-Z2, 21-Z3, 32-1, 32-2, 27-79
Intelligent Electronic Device IED	27-25, 67, 67-51, 67N, 67N-51

Recloser with IED	ANSI Device Names
Recloser RE/CL (RC1, RC2)	21-Z1, 21-Z2, 21-Z3, 32-1, 32-2, 27-79
Single Pole or Three Pole	27-25, 67, 67-51, 67N, 67N-51

DR (Distributed Resource)	ANSI Device Names
Line Protection DR (Intelligent Electronic Device)	21-Z1, 21-Z2, 21-Z3, 67, 67-51, 67N, 67N-51, 51, 46-51, 47-59, 47-59N, 25-79
Anti-Islanding	81O/81U, 27/59, dF/dt, Vector Shift (Jump), 32var



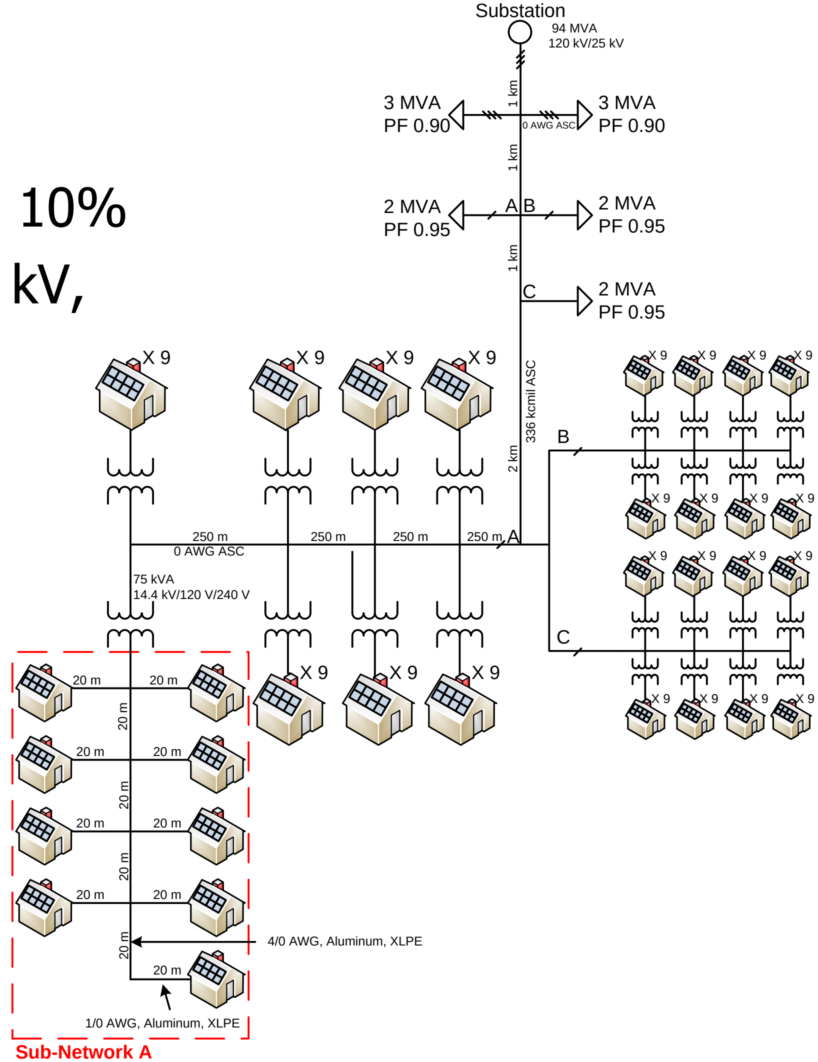
Voltage Profiles with High Penetration PV

Feeder

- 60 MVA @ 0.95 lagging p.f.
- On load tap changer, 1.03 pu, +/- 10%
- Neighbourhood at end of 5km, 25 kV, 336 ASC feeder

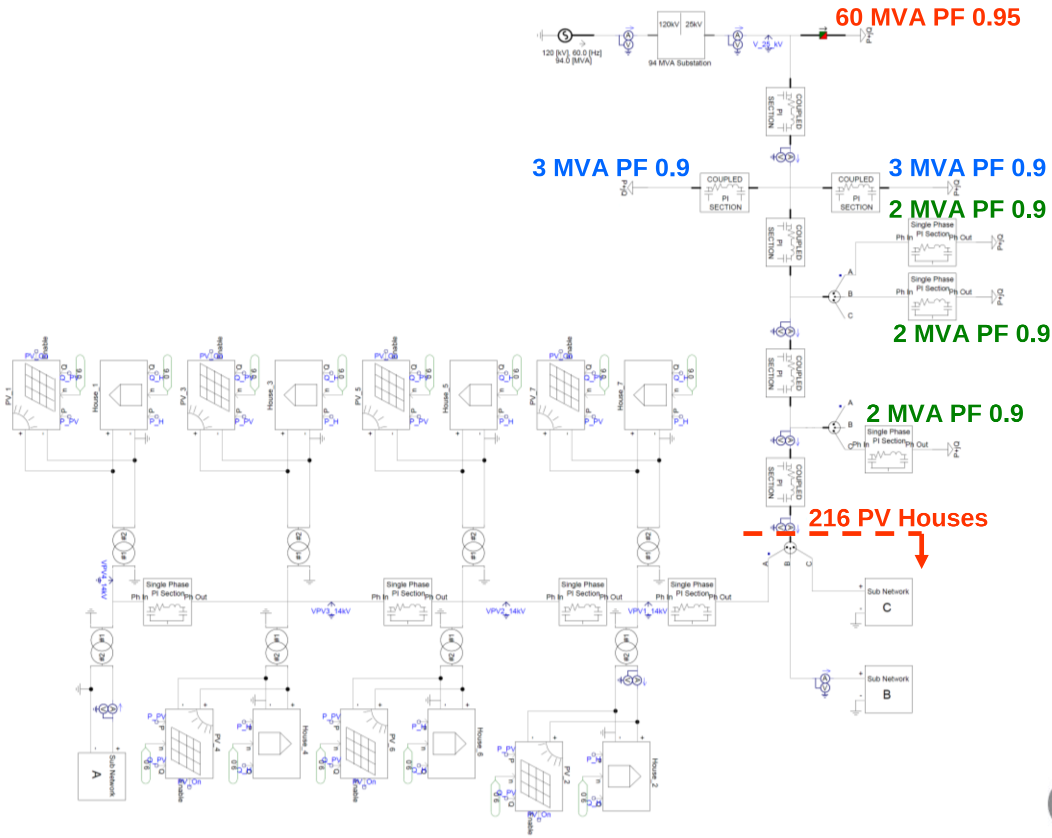
Various case studies have been investigated

- Average load
- Light load
- Feeder length (impedance)
- Feeder configuration
- LV transformer impedance



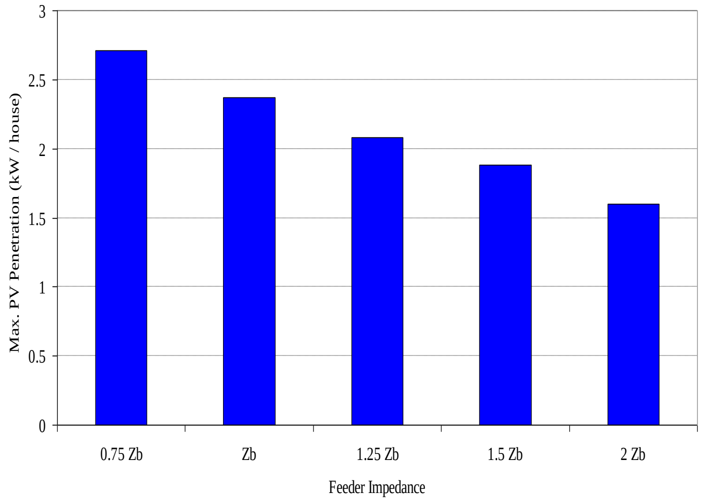
Voltage Profiles with High Penetration PV

- Model using PSCAD/EMTDC has been developed for a Canadian overhead residential feeder benchmark

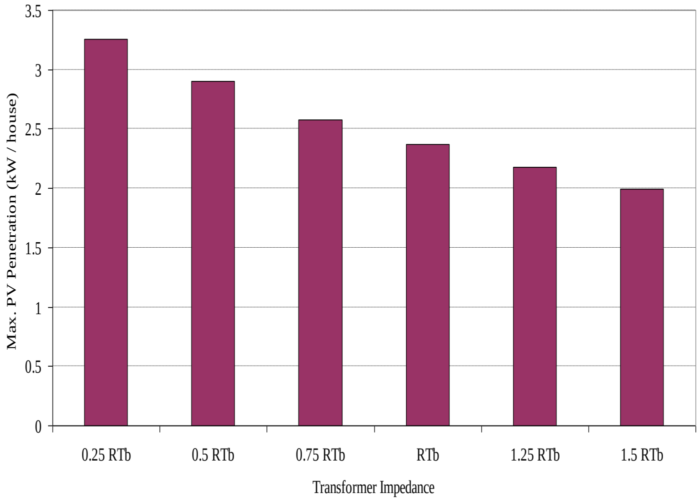


Voltage Profiles with High Penetration PV

- Feeder length and feeder 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).



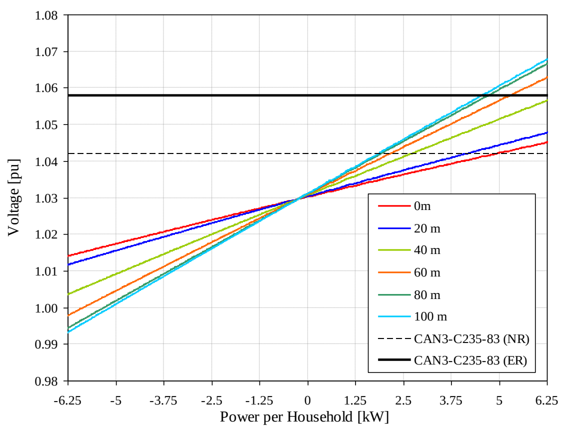
PV penetration levels for different absolute values of the feeder impedances
Drop Lines: Rb = 0.55 Ω/km and Lb = 0.29 mH/km
Pole-Pole Lines: Rb = 0.27 Ω/km and Lb = 0.24 mH/km



PV penetration levels for different LV transformer impedances
R1b = 0.06 pu
R2b = R3b = 0.012 pu

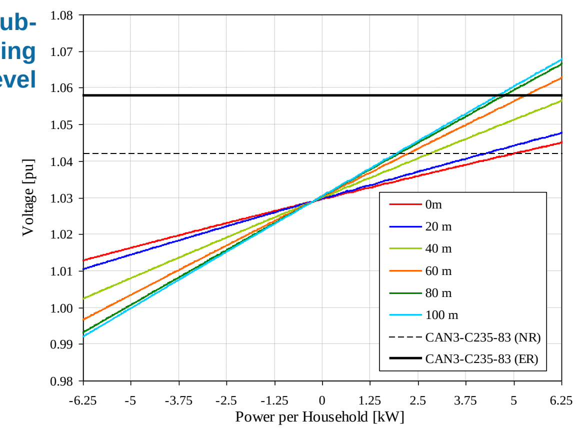
Voltage Profiles with High Penetration PV

- 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 transformer and feeder impedances, would reduce the voltage rise



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

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



Thank you – Questions and Answers

CanmetENERGY-Varennes, Natural Resources Canada

Steven Wong

CanmetENERGY, Natural Resources Canada,

1615 Lionel-Boulet Blvd., PO Box 4800,

Varennes, Quebec, CANADA J3X 1S6

steven.wong@nrcan.gc.ca

http://canmetenergy.nrcan.gc.ca/eng/renewables/integration_der.html

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