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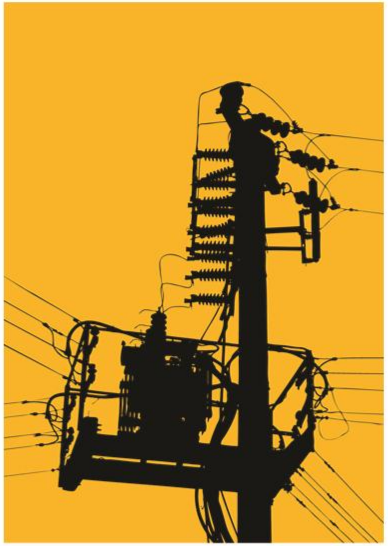

Impacts of DRGs on Distribution Network Protection

2014 GREEN Grid Conference

O5 November 2014, Christchurch

PSG Investigators : Momen Bahadornejad (Presenter), Rhett Calvert, Nicholas Carson, Minh Dinh, Mehdi Farzinfar, Jagadeesha Joish, Ankur Mishra, Nirmal Nair, Moonis Vegdani, Jake Zhang

Industry Contributors: Alpine Energy, Aurora Energy, Main Power, North Power, Orion, PowerCo, PowerNet, Unison Networks, Vector, Wellington Electricity, WEL Network

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Introduction

RA2.2: Impacts of different scales of DRG deployment on the LV network

- CS2.2.1 (2012-2013): New modelling methodology
- CS2.2.2 (2013-2014): Simulation platform

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Introduction

RA2.2: Impacts of different scales of DRG deployment on the LV network

- CS2
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RA2.3: Protection and automation in active distribution network

- CS2.3.1 (2012-2014): Leveraging of ICT infrastructure
- CS2.3.2 (2012-2013): Protection schemes used by NZ distribution network utilities
- CS2.3.3 (2013-2014): Fault analysis with bi-directional flows
- CS2.3.5 (2012-2015): Vector's PV trials

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Outline

RA2.2: Impacts of different scales of DRG deployment on the LV network

- CS2
- CS2

RA2.3: Protection and automation in active distribution network

- CS2.3.1 (2012-2014): Leveraging of ICT infrastructure
- CS2.3.2 (2012-2013): Protection schemes used by NZ distribution network utilities (Survey/Detailed report)
- CS2.3.3 (2013-2014): Fault analysis with bi-directional flows
- CS2.3.5 (2012-2015): Vector's PV trials

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New Zealand Distribution Network Protection Practices

- **Industry Survey**
  - Developed and Issued in 2013
  - First comprehensive survey of its kind for NZ
  - Based on previous international surveys

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New Zealand Distribution Network Protection Practices

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DISTRIBUTION LINE PROTECTION PRACTICES
INDUSTRY SURVEY RESULTS
IEEE POWER SYSTEM RELAYING COMMITTEE REPORT
December, 2002

Working Group on Distribution Protection: P.T. Carroll, Chairman, C. Fink, Vice Chairman
Contributing Members: J. Appleyard, J. R. Boyle, B. Jackson, J. Johnson, L. Kojovic, E. Krizauskas, L. P. Lawhead, P. J. Lerley, D. Miller, A. Napikoski, R.D. Pettigrew, W. M. Strang, C. R. Sufana, R.P. Taylor, J. T. Tengdin, J. T. Uchiyama, R. M. Westfall, J. B. Williams, P. Winston, J. A. Zipp

Key Words – Distribution Protection, Protective Relaying, Reclosers, Reclosing, Phase Protection, Ground Protection, High Impedance Ground Fault, Survey, Utility Practices

Abstract – This report presents the results of an extensive survey of utility practices for the protection of distribution lines at the substation. The survey was issued in 2000 and responses were received through 2001. Results of similar surveys were published in 1983 (Ref. 1), 1988 (Ref. 2), and in 1995 (Ref.3). In this survey, most of the sections were comparable to the earlier surveys. In addition, these sections were expanded to collect more data on the reasons behind a practice and on the methods used. Two new sections were added to address the impact of organizational considerations on distribution protection, and to summarize emerging technologies and applications relevant to distribution protection. The responses to this survey have been compared to the previous surveys in an attempt to detect any trends in the protection of distribution circuits.

Introduction – The IEEE Power Systems Relaying Committee (PSRC) has the responsibility of reviewing and reporting on current practices in protective relaying. In the distribution area, the "Effectiveness of Distribution Protection" Working Group of the Line Protection Subcommittee has the on-going role to survey the utility industry at periodic intervals. The data collected through this survey, when compared to the previous surveys, indicates that there are some trends emerging. The advantages of these changing practices are discussed within this report. Further surveys will be conducted to determine the extent of these and future trends.

New Zealand Distribution Network Protection Practices

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  - Based on previous international surveys
  - Distributed to all 29 companies directly and through EEA

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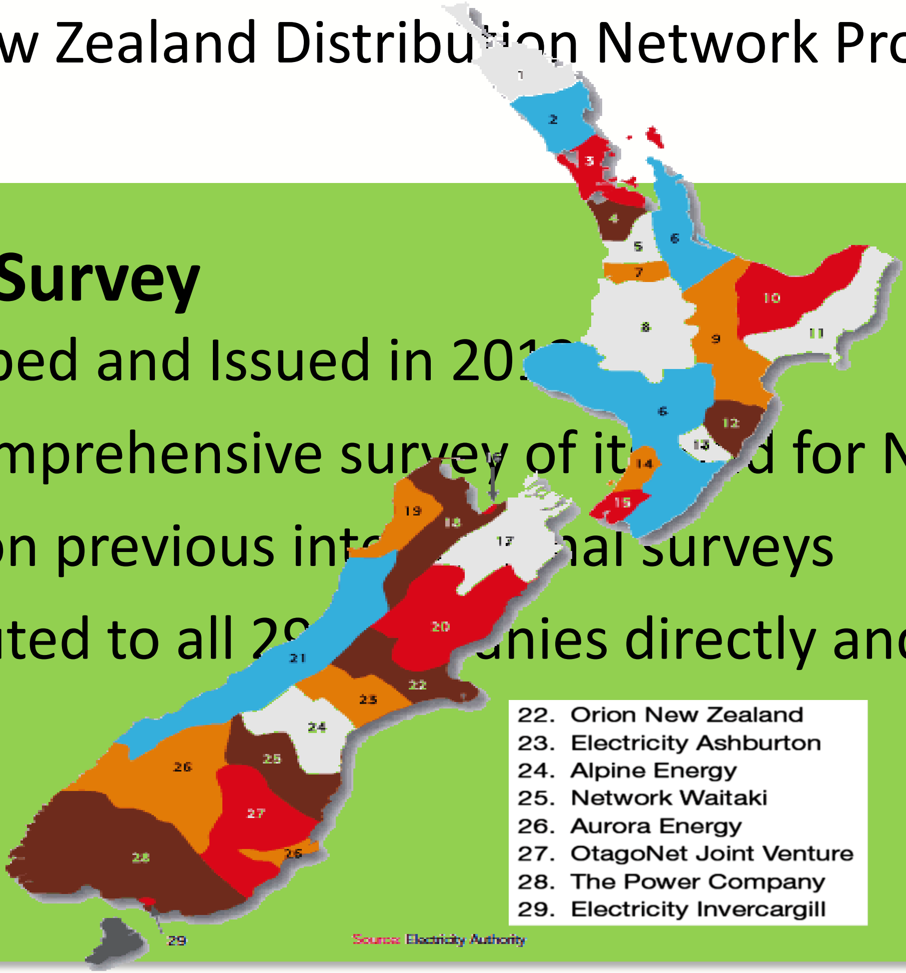

Source: Electricity Authority

1. Top Energy
2. Northpower
3. Vector
4. Counties Power
5. WEL Networks
6. Powerco
7. Waipa Networks
8. The Lines Company
9. Unison Networks
10. Horizon Energy Distribution
11. Eastland Network
12. Centralines
13. Scanpower
14. Electra
15. Wellington Electricity
16. Nelson Electricity
17. Malborough Lines
18. Network Tasman
19. Buller Electricity
20. Mainpower New Zealand
21. Westpower
22. Orion New Zealand
23. Electricity Ashburton
24. Alpine Energy
25. Network Waitaki
26. Aurora Energy
27. OtagoNet Joint Venture
28. The Power Company
29. Electricity Invercargill

New Zealand Distribution Network Protection Practices

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  - 11 responses received (Covering 80% of NZ consumers)
  - Report reviewed by Industry contributors
  - Planned for wider release through EEA

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POWER SYSTEMS GROUP

New Zealand Distribution Network Prote…

Industry Survey Resu…

Authors:
Momen Bahadornejad and Nirmal Nair … *Auckland)*

Industry Contributors: The following ind… and comments to this document:
Frank Arthur (*Alpine Energy*), Aaron Aa… (*Main Power*), Sujay Orpe (*North power*), … (*Orion*), Stephen Chiu (*PowerCo*), Dyson … *Networks*), Zhelyko Popovich (*Vector*), C… Nenad Pulijic (*WEL Network*)

Noti…

This work supported financially by the New Zealand … (MBIE) GREEN Grid project funding. The GREEN Grid … Canterbury with the University of Auckland's Power S… for Sustainability, Food, and Agriculture, and with a n… officially titled "Renewable Energy and the Smart G… greater renewable generation and improved energy … generation into the electricity network. The project … methods for managing and balancing supply and dem… distribution network in which intermittent renewable … New Zealand currently generates about 75 percent of … it a world-wide leader in this area.

September 2014

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  - 11 responses received (Covering 80% of NZ consumers)
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  - Planned for wider release through EEA
  - Some findings important to CS2.3.3 highlighted

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Survey Highlights

- Section 1- Utility General Information
  - Q 1.3 Available voltage classes and loads (MVA)

Voltage Class, kV	Load, MVA	% of TOTAL	UTILITIES
6.6 kV	10	0.13	1
11 kV	2418.875	31.86	9
22kV	229	3.02	2
33 kV	3447.875	45.41	9
66 kV	1049	13.82	5
Other	438	5.77	1

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Survey Highlights

- Section 2- Considerations
  - Q 2.3 How often distribution protection settings are reviewed?

Reviews	Utilities	%
When changes are known to have occurred	7	63%
When problems occur	8	72%
Annually	1	9%
Periodically (2-10 years)	5	45%
No policy	1	9%

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Survey Highlights

- Section 3- System Data
  - Q 3.2 What are the design practices on the high voltage side of transformers?

Practice	Utilities	%
No interrupting device between transformer and feeders	2	18%
Main Breaker	10	90%
Parallel with other transformer through closed tie breaker	3	27%
Parallel with other transformer through closed switch	2	18%
Parallel with other transformer through open tie breaker	-	0%
Parallel with other transformer through open switch	1	9%
Breaker and a half or ring bus	-	0%
HV fuse	1	9%

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Survey Highlights

- Section 3- System Data
  - Q 3.4 What types of breakers are used in the feeders?

Breaker Type	Utilities	%
Metalclad Switchgear	10	90%
Outdoor Breakers	5	45%
Electronic Reclosers	7	63%
Hydraulic Reclosers	2	18%
SF6 switch	1	9%

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Survey Highlights

- Section 3- System Data
  - Q 3.8 What is the typical relaying applied to your feeders?

Device	Utilities	%
Circuit reclosers	6	54%
Phase overcurrent relays	11	100%
Ground overcurrent relays	11	100%
high impedance fault detection devices	2	18%
Distance relaying	1	9%
Negative sequence relaying	2	18%
Directionalized overcurrent relays	-	0%
Automatic tie control schemes	1	9%
Under/Over voltage	1	9%
Frequency deviation trip	1	9%
Cable differential	1	9%

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Survey Highlights

- Section 3- System Data
  - Q 3.10 What are the methods used to limit fault current on your system?

Method	**Utilities**			
	Phase Fault	%	Ground Fault	%
Phase or neutral transformer reactors	2	18%	2	18%
Phase or neutral feeder reactors	-	0%	-	0%
Transformer impedance only	7	63%	4	36%
Source and transformer impedance	5	45%	1	9%
Resonance grounding	-	0%	5	45%
Neutral Earthing Resistor	-	0%	6	54%

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Survey Highlights

- Section 4- Phase Protection
  - Q4.1 Do you apply phase overcurrent protective devices with instantaneous trips for downstream fuse saving and other purposes (Q4.2)?

	Utilities	%
Fuse saving	3	27%
Limit duration of fault for personnel safety	8	72%
Limit equipment damage	9	81%
Minimize voltage dip duration	5	45%
Enhance coordination	8	72%
Enable grading margins	1	9%

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Survey Highlights

- Section 4- Phase Protection
  - Q 4.4 What criteria do you use to determine phase overcurrent pick-up?

Criterion	Utilities	%
A multiple of expected feeder load	7	63%
Conductor thermal limits	8	72%
Emergency loading	7	63%
Coordination considerations with downstream devices	9	81%
Coordination considerations with upstream devices	9	81%
Available tail end fault current	8	72%

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Survey Highlights

- Section 5- Ground Protection
  - Q 5.5 What is the basis for feeder Time-Delay Over-current pickup settings?

	Utilities	%
Percent of feeder maximum capacity	3	27%
Percent of feeder expected maximum load	1	9%
Percent of phase device pickup level	2	18%
Fixed current level	-	0%
Based on maximum downstream fuse size	2	18%
Available tail end fault current	3	27%

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Survey Highlights

- Section 5- Ground Protection
  - Q 5.6 What feeder time-over current characteristics do you use?

	Utilities	%
Inverse Time	7	63%
Ground Instantaneous	1	9%
Definite Time Delay	7	63%
Ground fault definite time	1	9%

Survey Highlights

- Section 6- Reclosing
  - Q 6.2 How many re-closing attempts are configured?

	Utilities	%
1 attempt	5	45%
2 attempt	4	36%
3 attempt	6	54%
4 attempt	2	18%

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Survey Highlights

- Section 7- System Faults
  - Q 7.6 Protective devices clearing time criteria for distribution line protection?

	Utilities	%
Less than or equal to 50 cycles	7	63%
Between 50+ and 75 cycles	1	9%

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Survey Highlights

- Section 8- Cold Load Pickup (CPLU)
  - Q 8.3 What did you do to reduce or eliminate the CPLU tripping?

	Utilities	%
Sectionalizing to pick up less load	-	0%
Blocking instantaneous or fast tripping	1	9%
Increasing the phase overcurrent relay pickup	2	18%
Increasing the ground overcurrent pickup	3	27%
Increasing the phase time overcurrent delay	1	9%

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Survey Highlights

- Section 9- System Operation
  - Q 9.2 What is your experience with sympathetic tripping?
    - Yes (6), No (3), Don't know (2)
  - Q9.3 Relays causing the sympathetic trip

	Utilities	%
Phase instantaneous over-current relay	0	0%
Ground instantaneous over-current relay	2	18%
Phase time over-current relay	2	18%
Ground time over-current relay	4	36%
Unknown	1	9%
AVR	1	9%

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Survey Highlights

- Section 9- System Operation
  - Q 9.29 Are there IEC 61850 compatible relays/ devices installed?

	Utilities	%
Yes (for parallel control of tap changers (1))	8	72%
No	2	18%
Planning in future	1	9%

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Survey Highlights

- Section 10- Single Wire Earth Return (SWER)
  - Q 10.5 What are the protection devices at each voltage level?

Voltage Class	Protection Device									
	Fuse		Recloser		Surge Arrester		Drop out fuse switch		Bypass switch	
	Utilities	%	Utilities	%	Utilities	%	Utilities	%	Utilities	%
19.1 kV	1	14%	1	14%	1	14%	-	0%	-	0%
11 kV	4	57%	4	57%	3	42%	2	28%	1	14%
6.6 kV	1	14%	1	14%	1	14%	1	14%	-	0%
230 V	1	14%	-	0%	1	14%	-	0%	-	0%

Note: Percentages in this table are based on the 7 respondent utilities who have SWER

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Survey Highlights

- Section 11- Distributed Renewable Generation (DRG)
  - Q11.2 What effects DRG (MV) has on your usual protection

	Utilities	%
Added voltage check supervision	1	9%
Extended first shot reclose time	3	27%
Added communication permission/control	1	9%
Eliminated all reclosing on the feeder	3	27%
Added synchronism supervision	-	0%
Reduced number of reclose attempts	-	0%

  - For domestic DRG there has been no effect on protection practice of NZ distribution utility yet

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Part 2

RA2.2: Impacts of different scales of DRG deployment on the LV network

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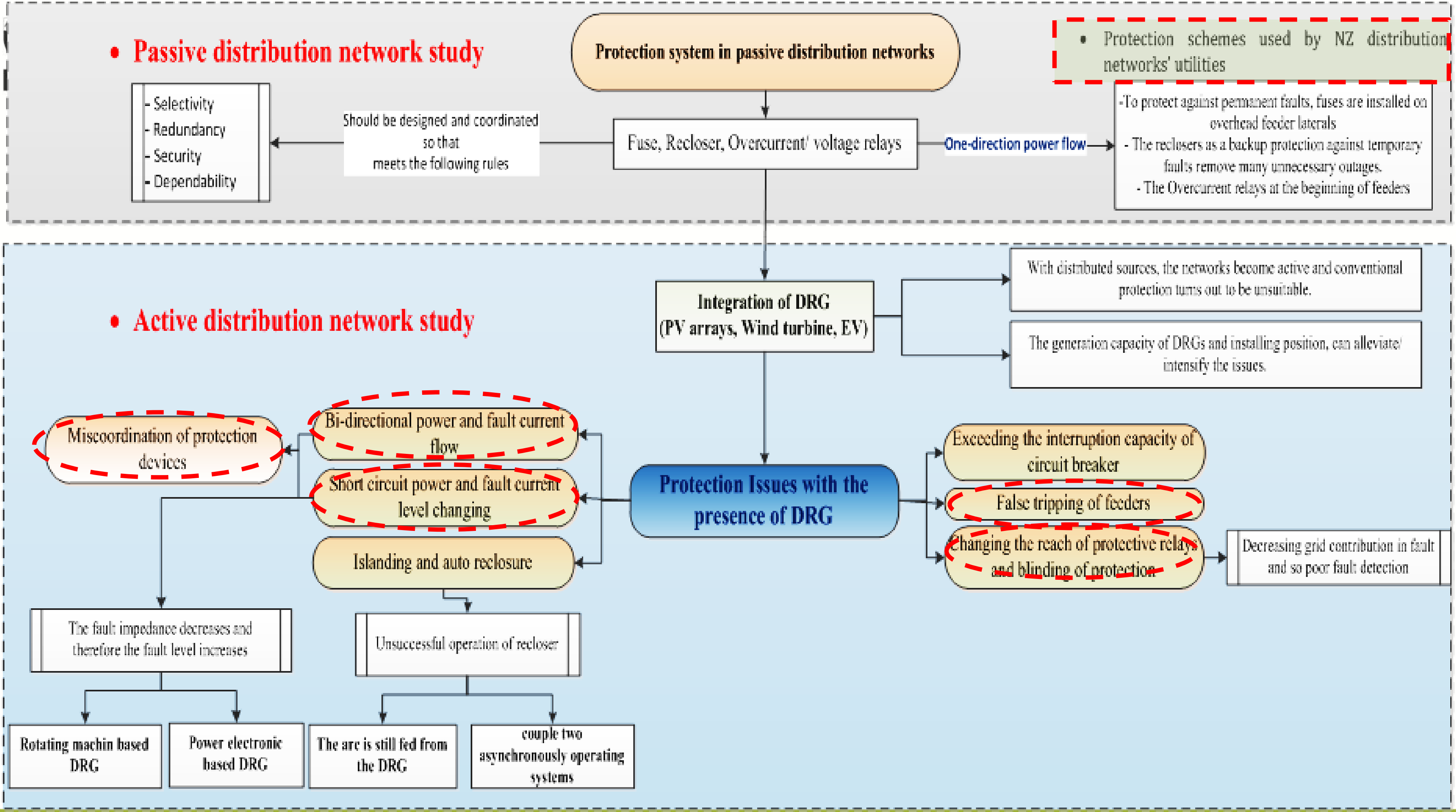

• Passive distribution network study
Protection system in passive distribution networks
• Protection schemes used by NZ distribution networks' utilities
- Selectivity
- Redundancy
- Security
- Dependability
Should be designed and coordinated so that meets the following rules
Fuse, Recloser, Overcurrent/ voltage relays
One-direction power flow
-To protect against permanent faults, fuses are installed on overhead feeder laterals
- The reclosers as a backup protection against temporary faults remove many unnecessary outages.
- The Overcurrent relays at the beginning of feeders
• Active distribution network study
Integration of DRG (PV arrays, Wind turbine, EV)
With distributed sources, the networks become active and conventional protection turns out to be unsuitable.
The generation capacity of DRGs and installing position, can alleviate/ intensify the issues.
Protection Issues with the presence of DRG
Miscoordination of protection devices
Bi-directional power and fault current flow
Short circuit power and fault current level changing
Islanding and auto reclosure
Exceeding the interruption capacity of circuit breaker
False tripping of feeders
Changing the reach of protective relays and blinding of protection
Decreasing grid contribution in fault and so poor fault detection
The fault impedance decreases and therefore the fault level increases
Unsuccessful operation of recloser
Rotating machin based DRG
Power electronic based DRG
The arc is still fed from the DRG
couple two asynchronously operating systems

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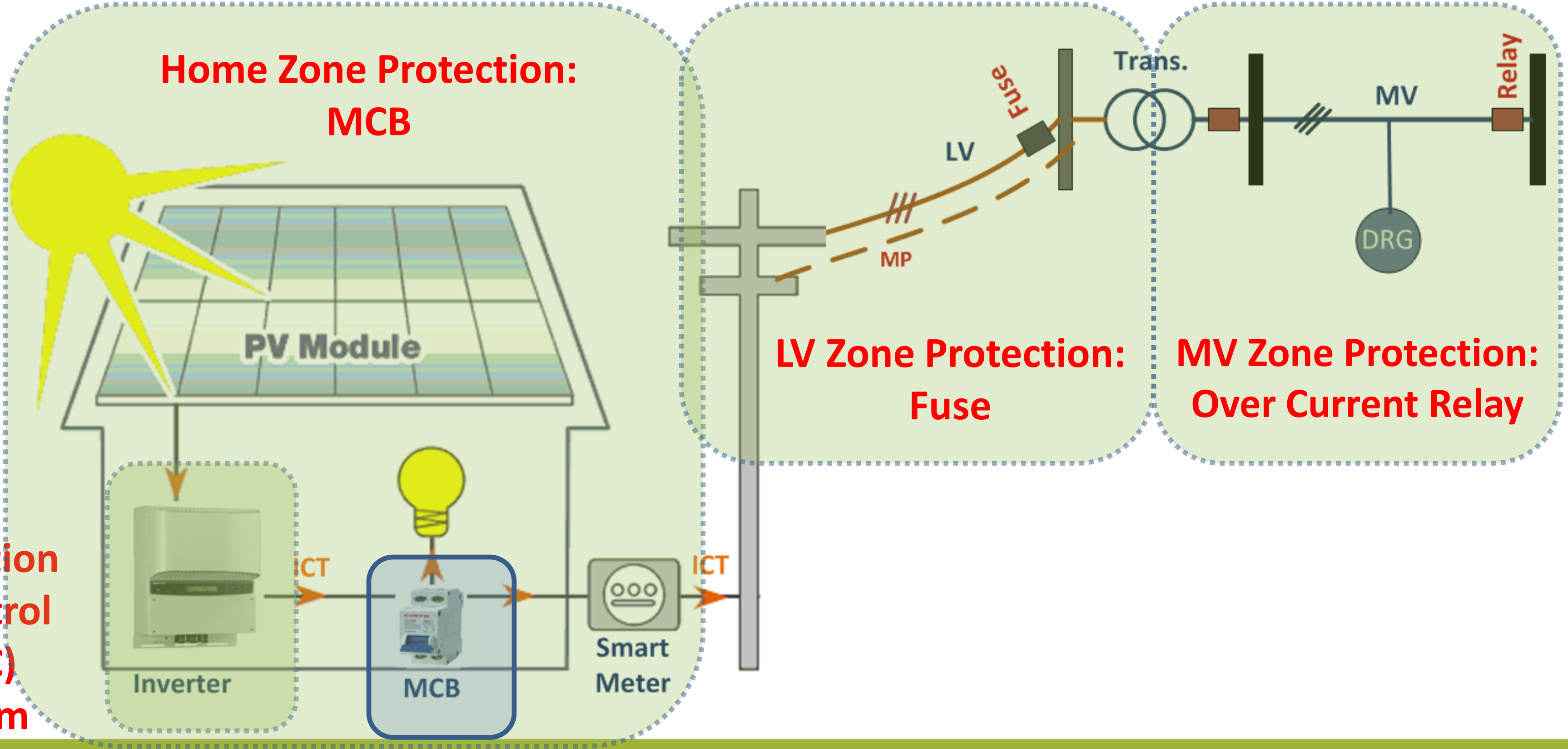
Part 2: Issues of Active Distribution Network Protection



PV Protection & Control (P&C) System

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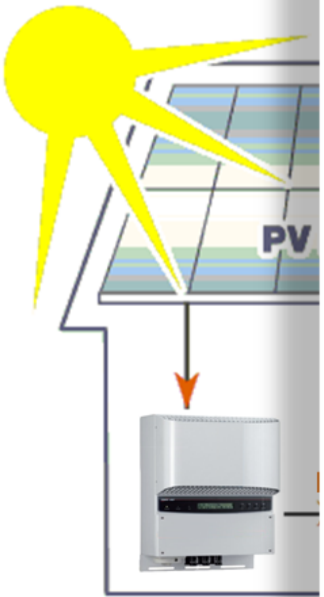

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Impacts of DRGs on Distribution Network Protection

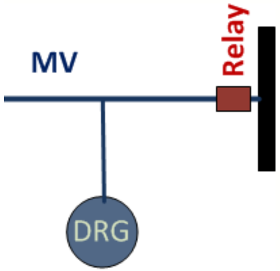
Mehdi Farzinfar, Momen Bahadornejad, Ankur Mishra, and Nirmal Nair

(Power Systems Group, University of Auckland)

Notice

This work supported financially by the New Zealand Ministry of Business, Innovation and Employment (MBIE) GREEN Grid project funding. The GREEN Grid project is a joint project led by the University of Canterbury with the University of Auckland's Power System Group and the University of Otago's Centre for Sustainability, Food, and Agriculture, and with a number of electricity industry partners. The project, officially titled "Renewable Energy and the Smart Grid" will contribute to a future New Zealand with greater renewable generation and improved energy security through new ways to integrate renewable generation into the electricity network. The project aims to provide government and industry with methods for managing and balancing supply and demand variability and delivering a functional and safe distribution network in which intermittent renewable generation is a growing part of the energy supply. New Zealand currently generates about 75 percent of its electricity from renewable generation, making it a world-wide leader in this area.

September 2014



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Short Circuit Analysis

- Protection system are designed to clear the faults/abnormalities
- Short circuit analysis aids in achieving this objective by:
  - Estimating the magnitude of fault current
  - Providing robust protection coordination (selectivity, sensitivity & speed)

- For PV/Inverter the fault current contribution depends on the control mode and Fault Ride Through (FRT) capability

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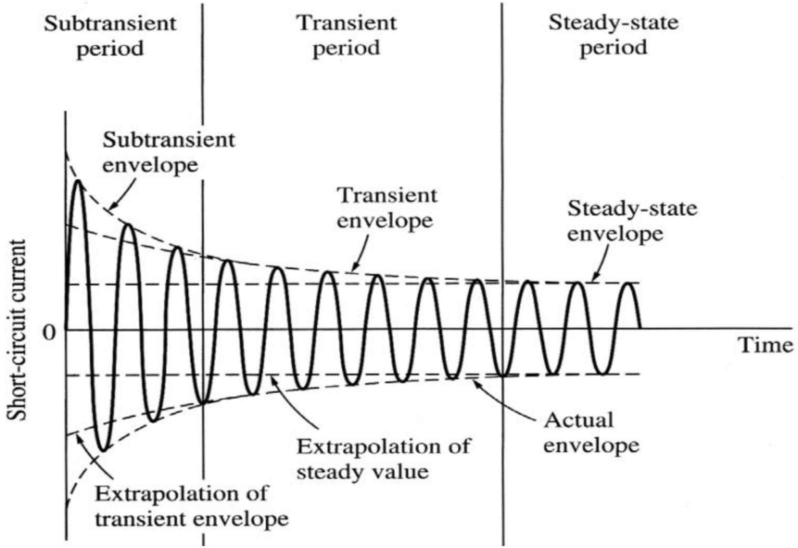
DRG Behaviour in Short Circuit Analysis

Rotating Machines

Synchronous DRGs contribute directly to the fault current.



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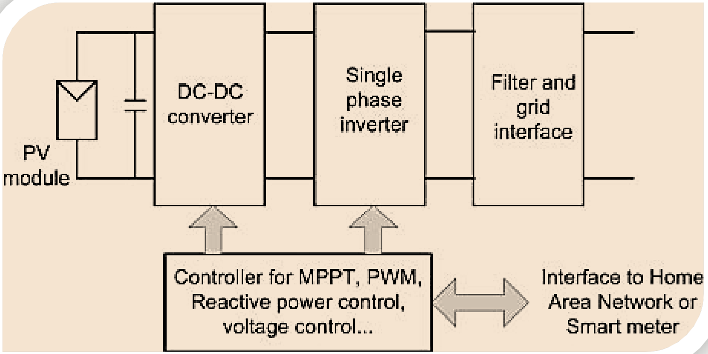
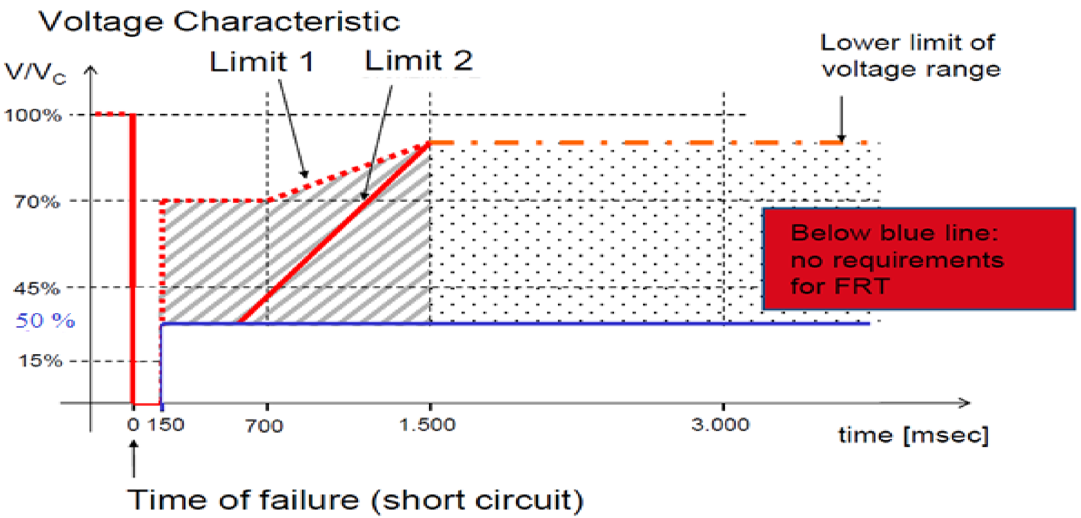
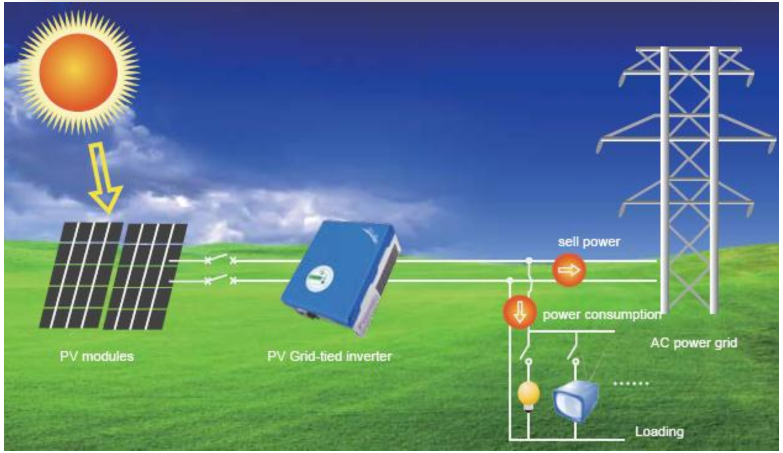
DRG Behaviour in Short Circuit Analysis

Inverter Based

PVs contribute through inverters to the fault







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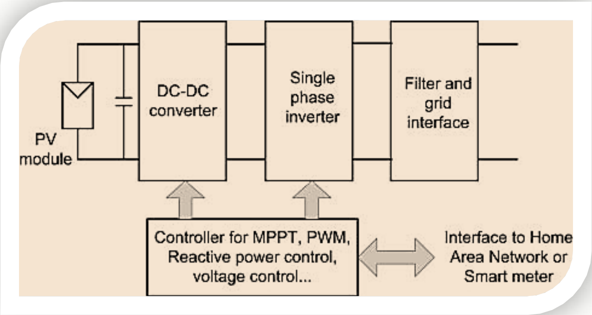
PV/Inverter Behaviour under Fault Condition

FRT capability:
PV plant should stay connected for cases of grid faults depending on the fault duration.

PV have also to provide support to the grid voltages by injecting reactive power



4 major issues which limit PV contribution

- Overcurrent at the AC side
- Excessive DC-link voltage
- Exceeds the reactive current injection
- Loss of grid voltage synchronization

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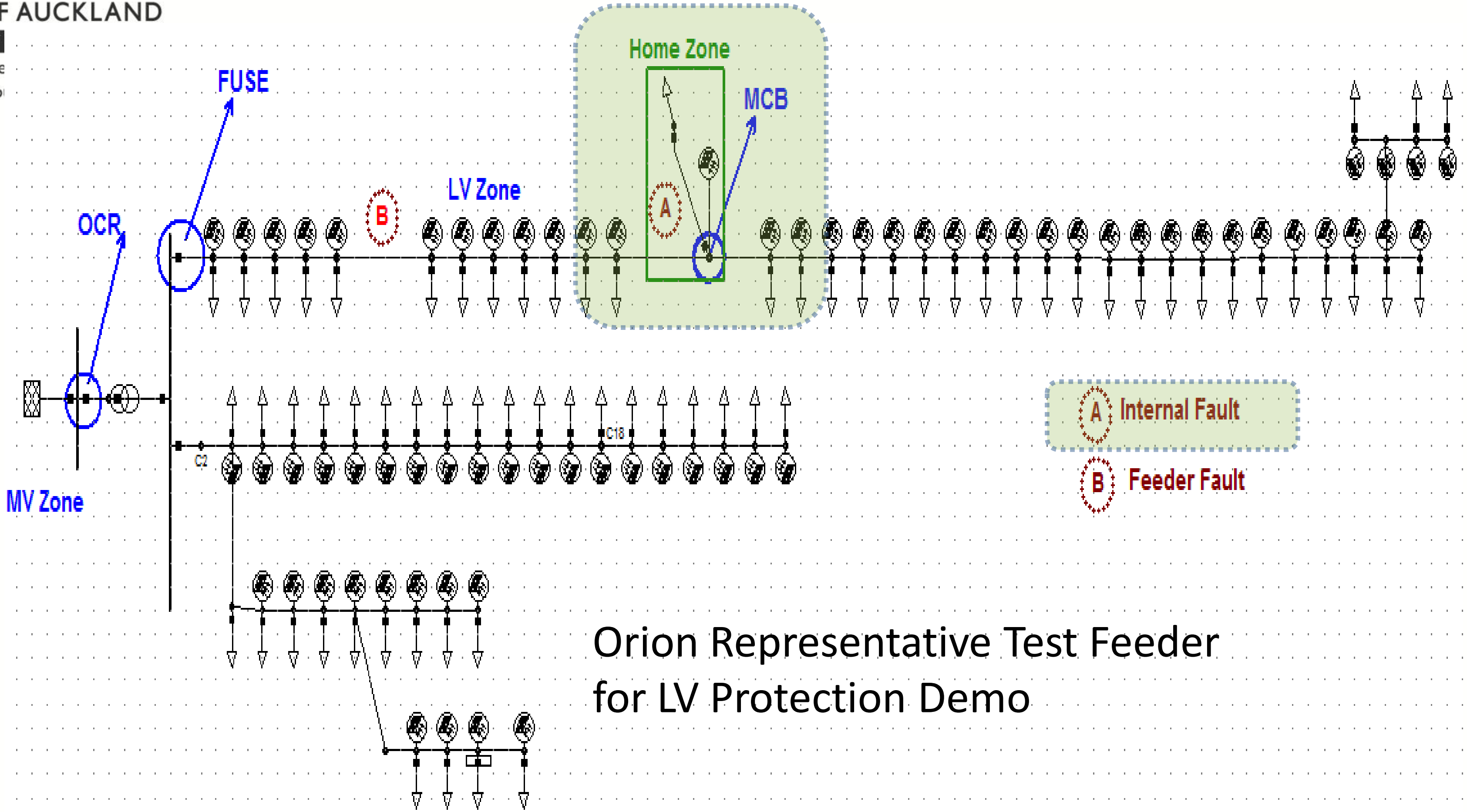
PV/Inverter behaviour under Fault Condition, Cont.

- Fault contribution of PV/Inverter is limited to maximum 2 per unit (as per literature review and industry practices)
- If the current exceeds the limit, the inverter is disconnected from the grid
- **Test being conducted in cooperation with UC/EPECentre to find the PV/Inverter model during the fault**



Orion Representative Test Feeder for LV Protection Demo

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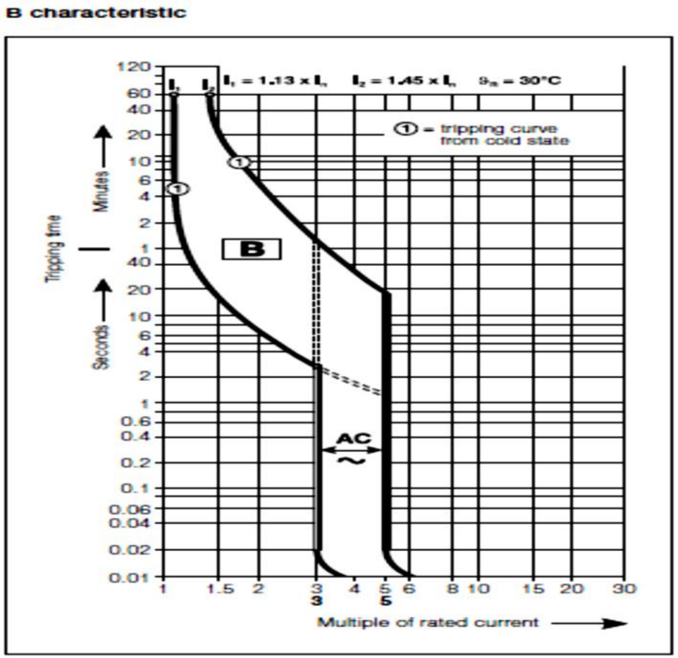
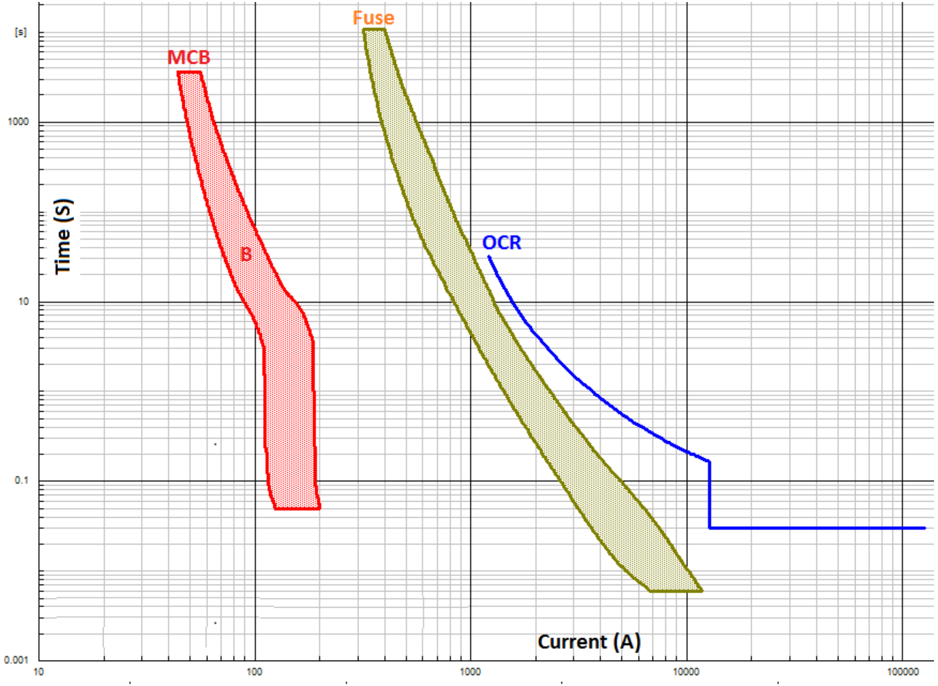
Impacts of PV on LV Protection



A type B MCB trips in less than 0.1 sec for the currents above 3 I_n up to and including 5 I_n



MCB, fuse, and over current relay (OCR) characteristics:
The min operation time of MCB has been set to 0.05 sec

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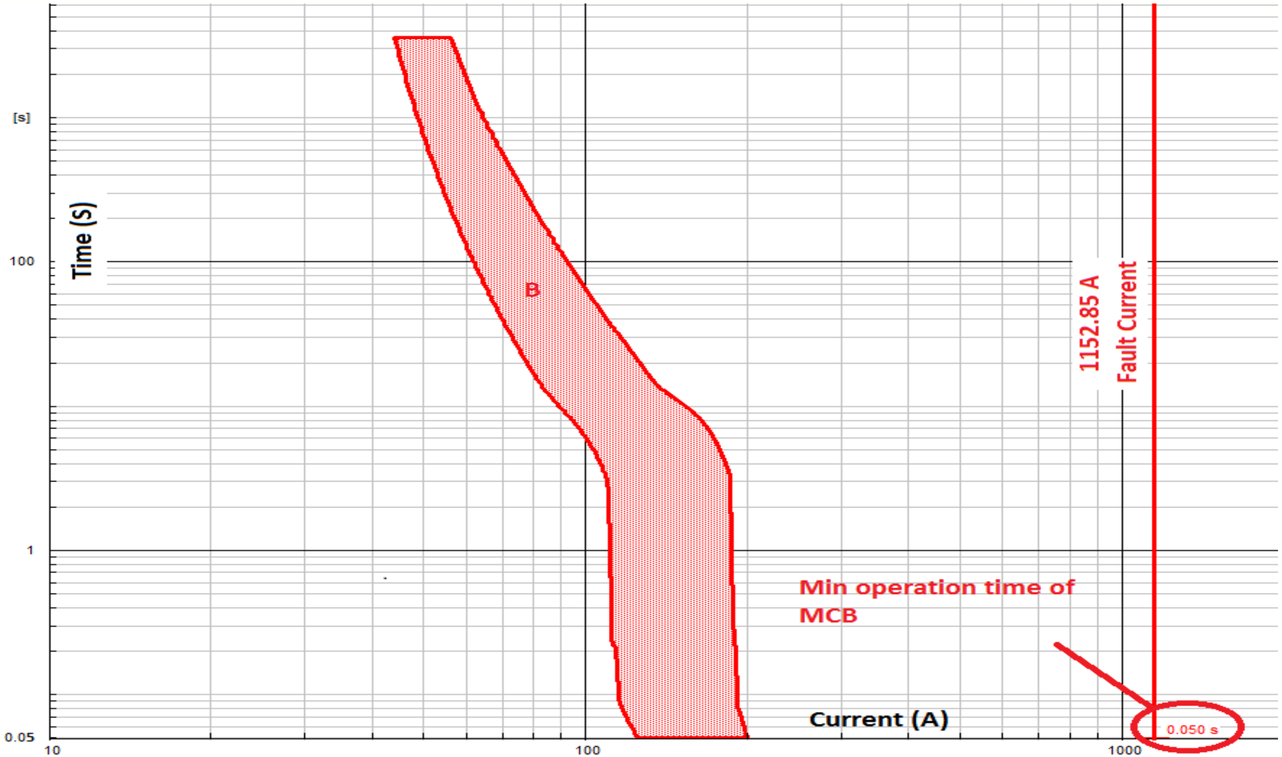
Impacts of PV on Home Zone

Passive network- low impedance fault



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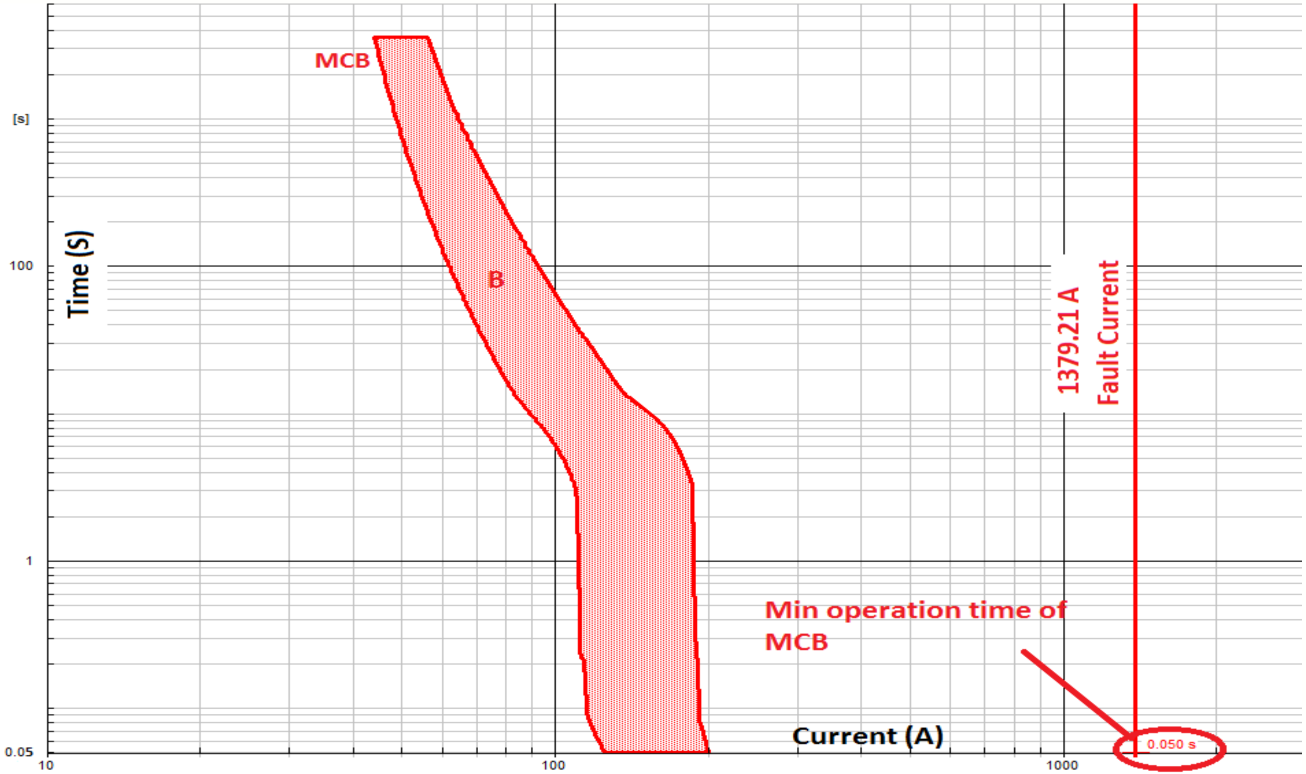
Impacts of PV on Home Zone

90% PV penetration- low impedance fault



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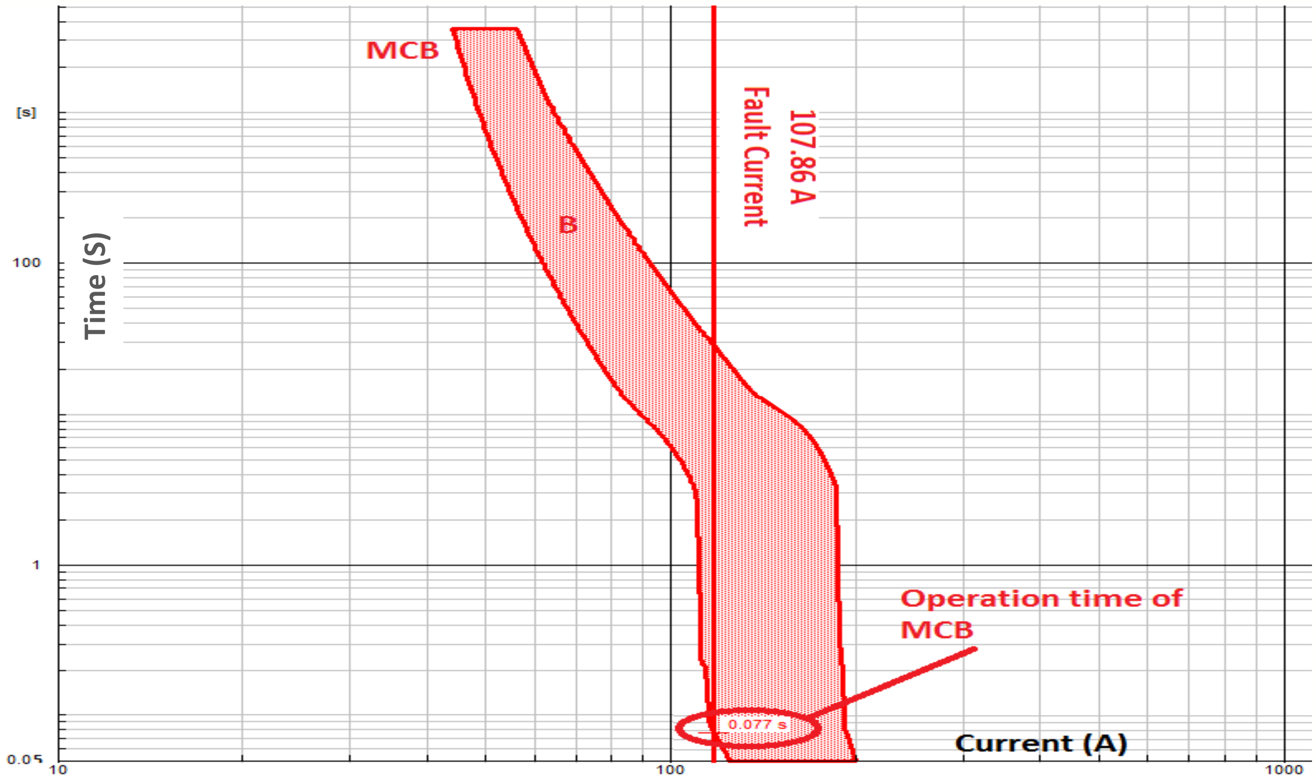
Impacts of PV on Home Zone

Passive network- high impedance fault



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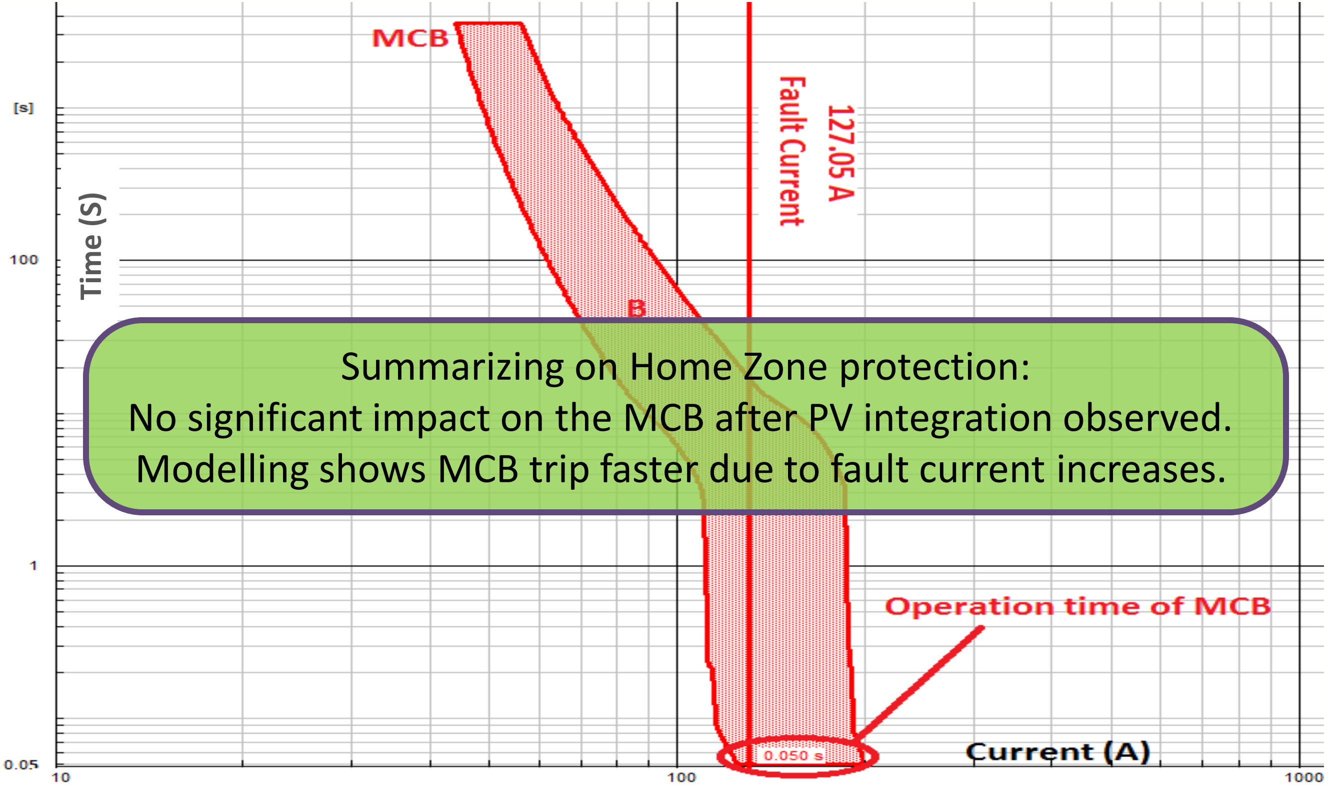
Impacts of PV on Home Zone

90% PV penetration- high impedance fault



Summarizing on Home Zone protection:
No significant impact on the MCB after PV integration observed.
Modelling shows MCB trip faster due to fault current increases.

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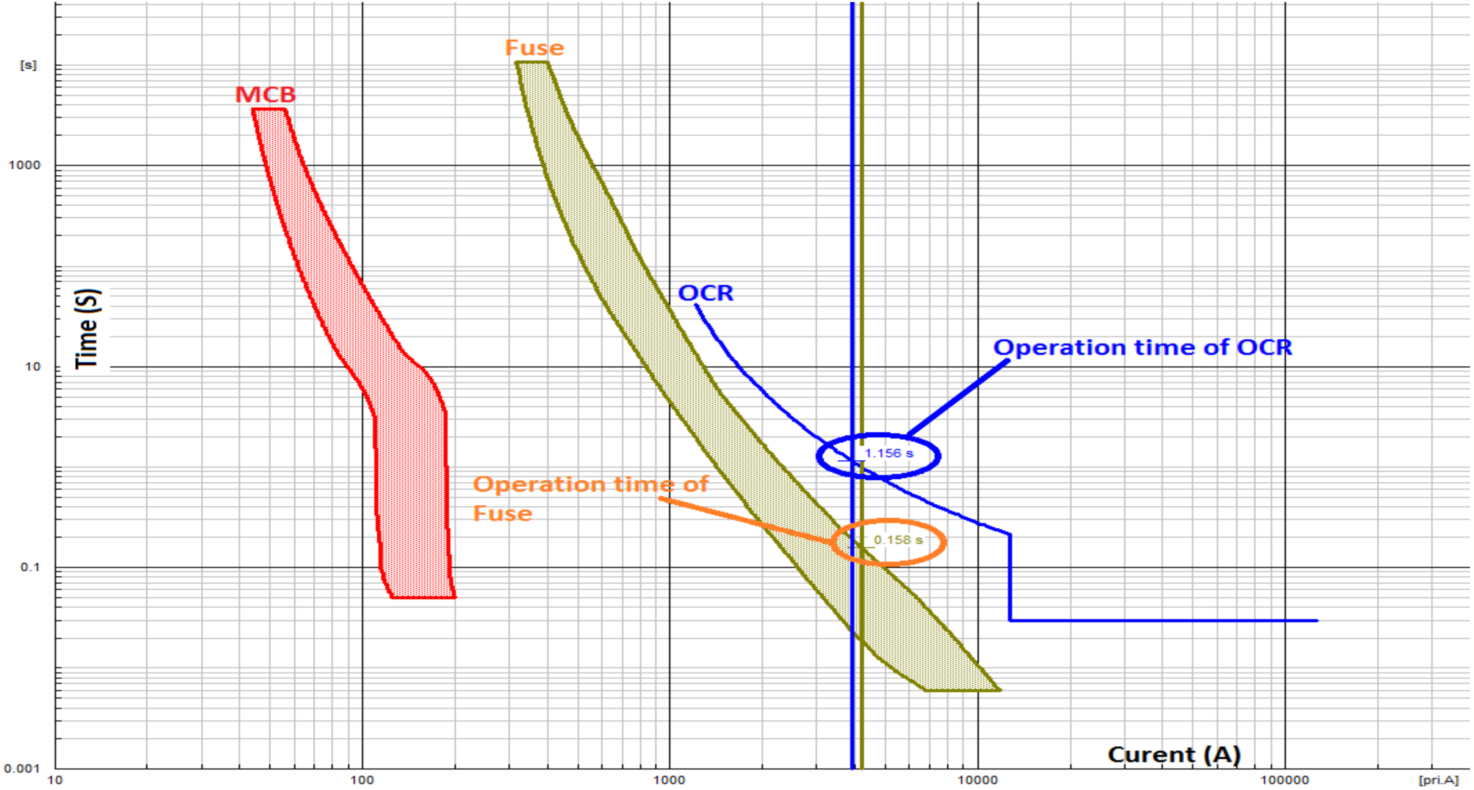
Impacts of PV on LV Zone

Passive network- low impedance fault



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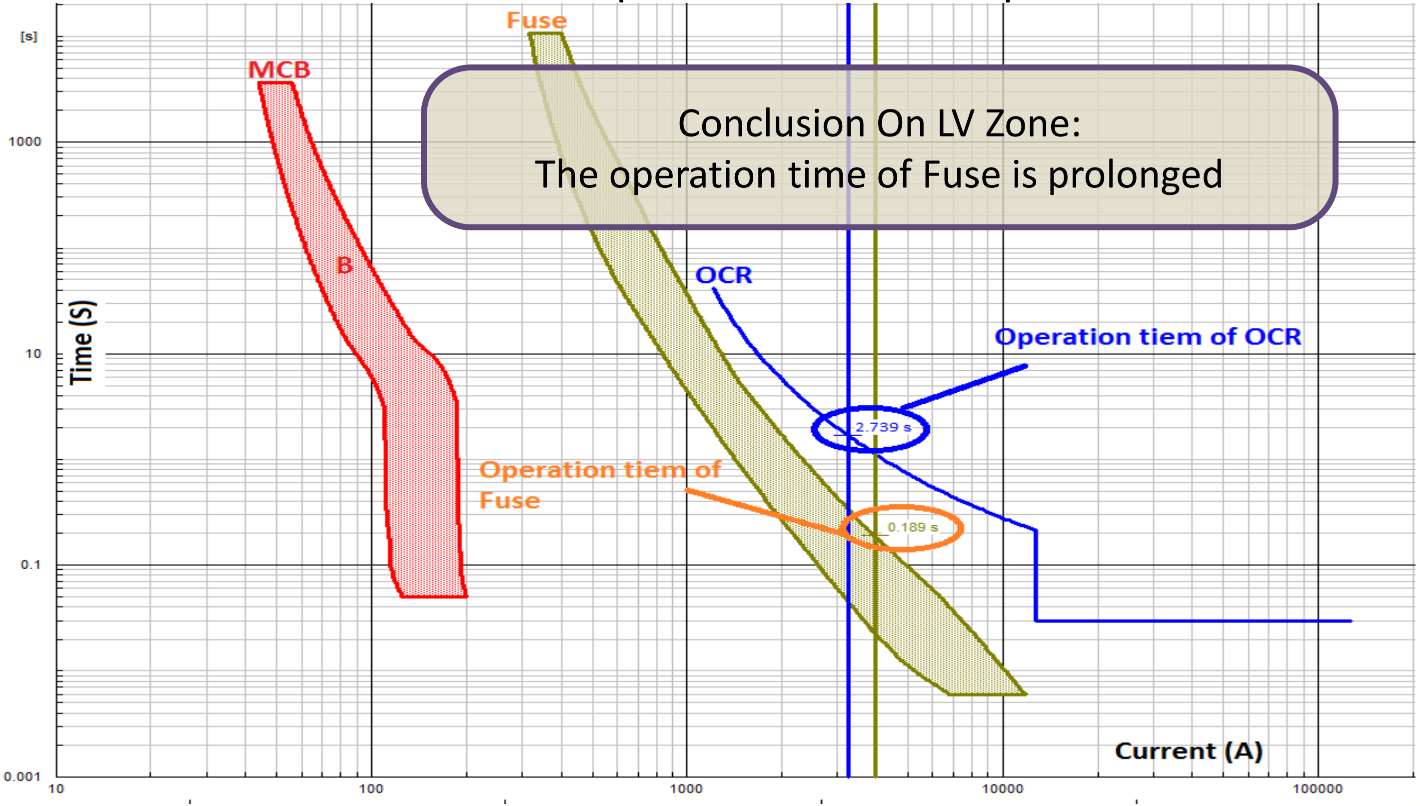
Impacts of PV on LV Zone

90% PV penetration- low impedance fault



Conclusion On LV Zone:
The operation time of Fuse is prolonged

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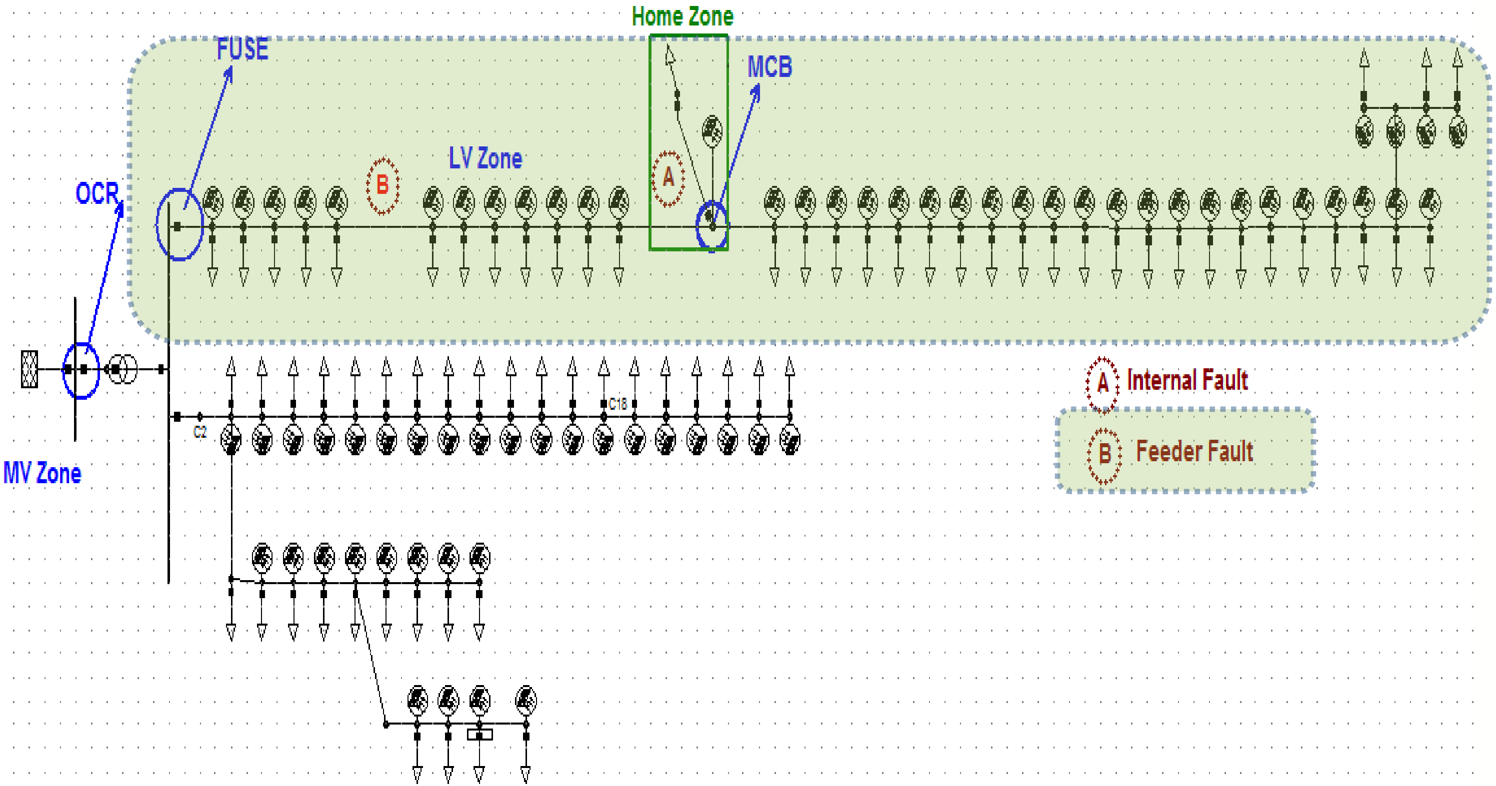
Impacts of PV on LV Zone



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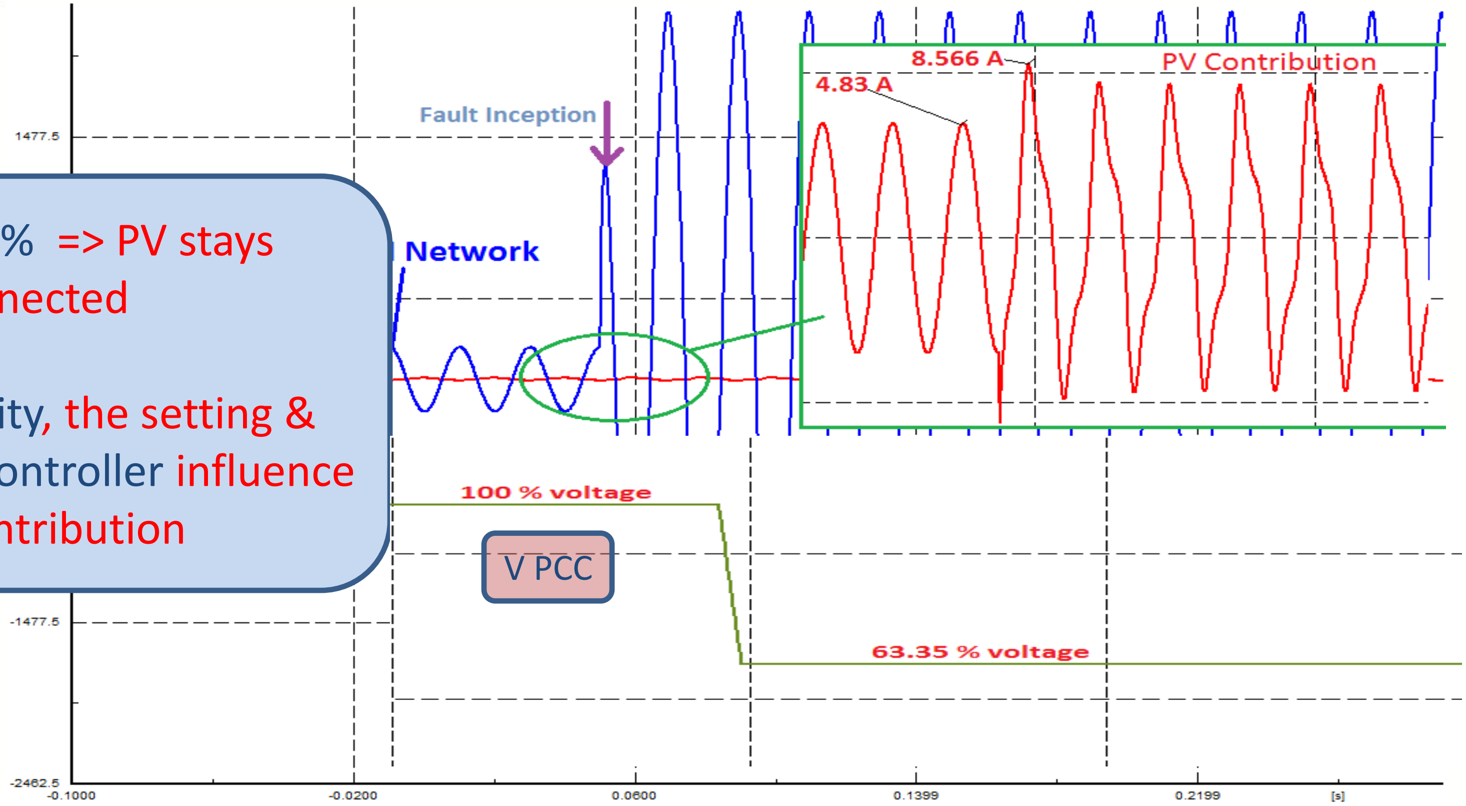
Fault Contribution of PV

B: Feeder fault (AG- with R_f)

V PCC > 50 % => PV stays connected

The PV capacity, the setting & robustness of controller influence the contribution



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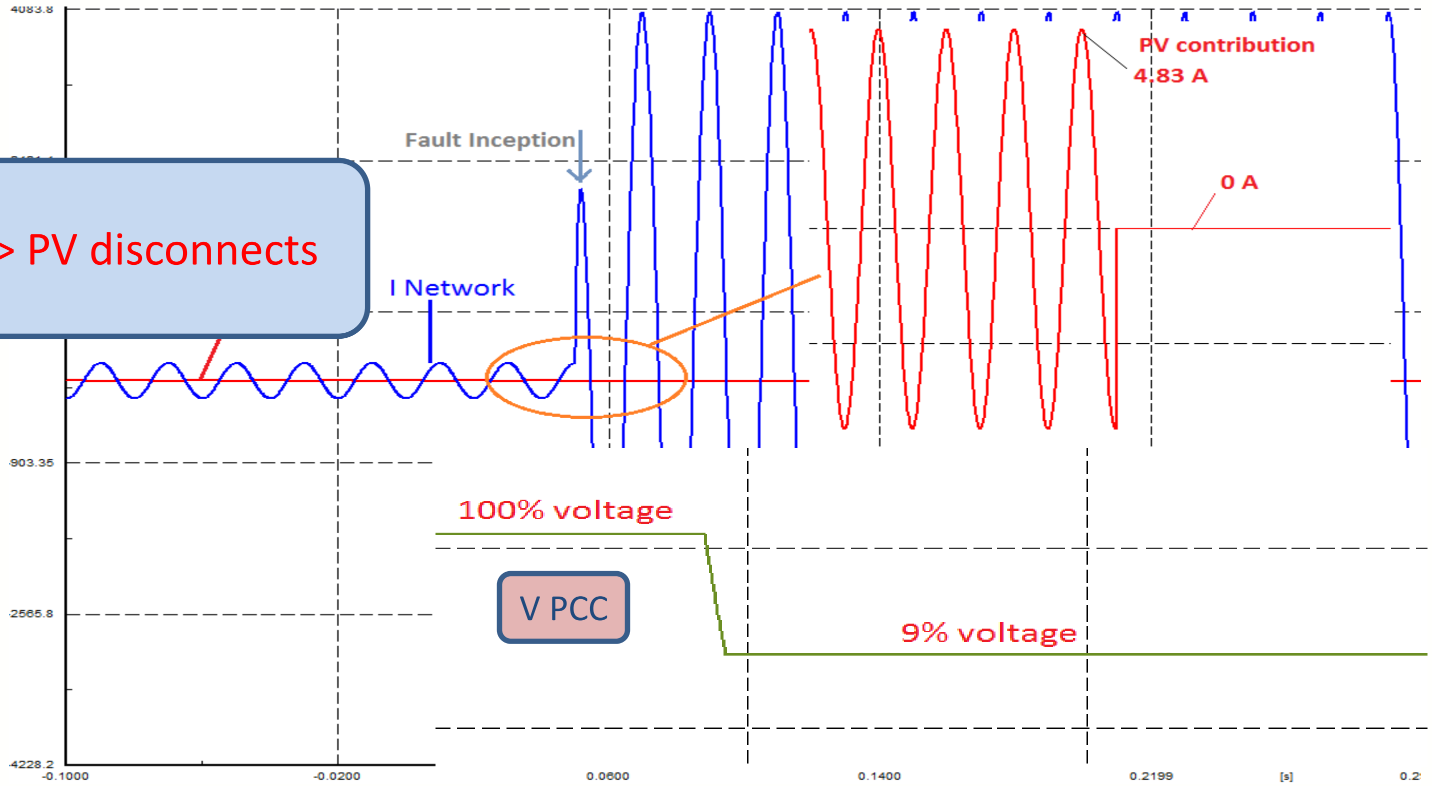
Fault Contribution of PV

B: Feeder fault (AG- solid)

V PCC < 50 % => PV disconnects



Impacts of PV on LV Zone

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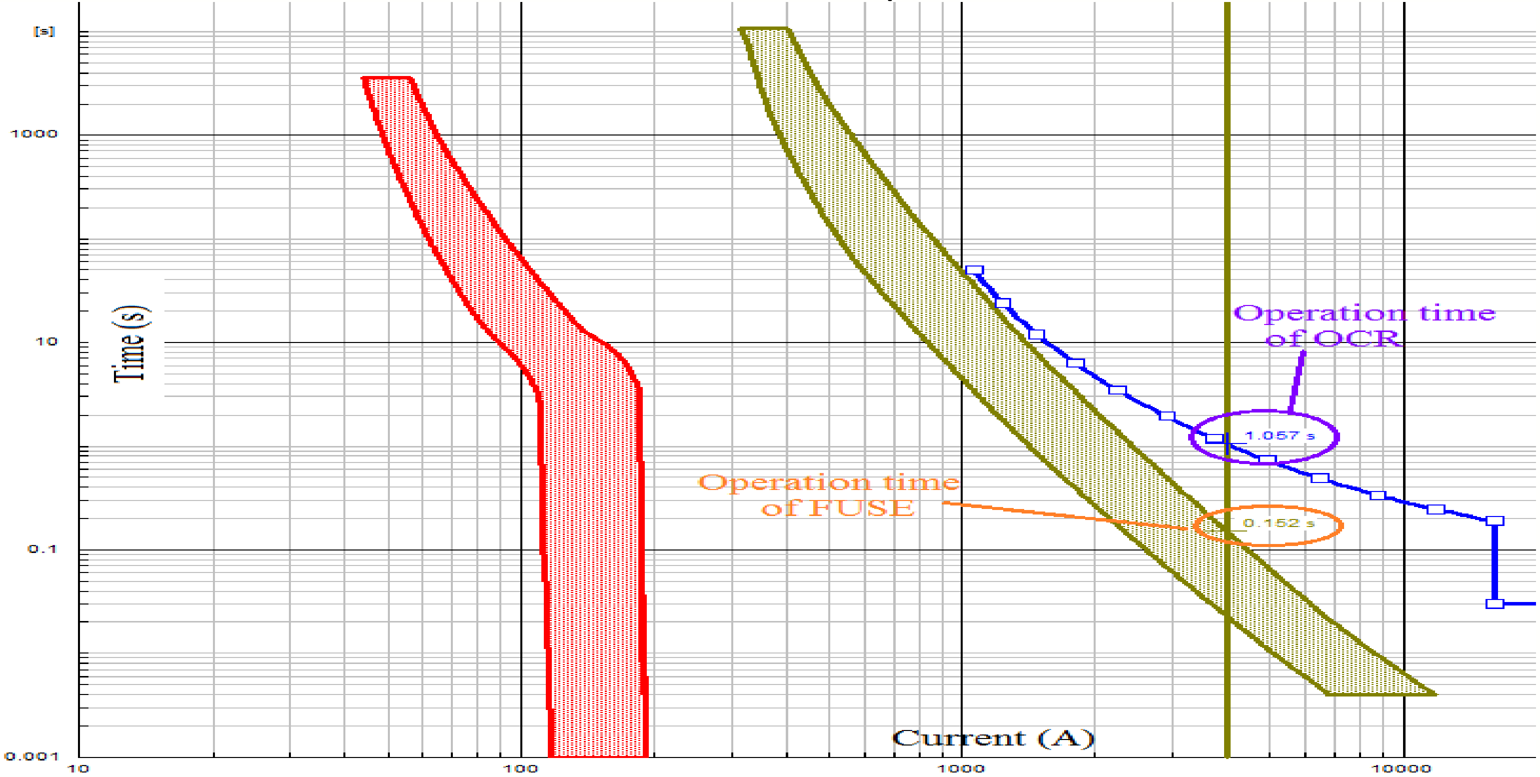
Passive network- low impedance fault



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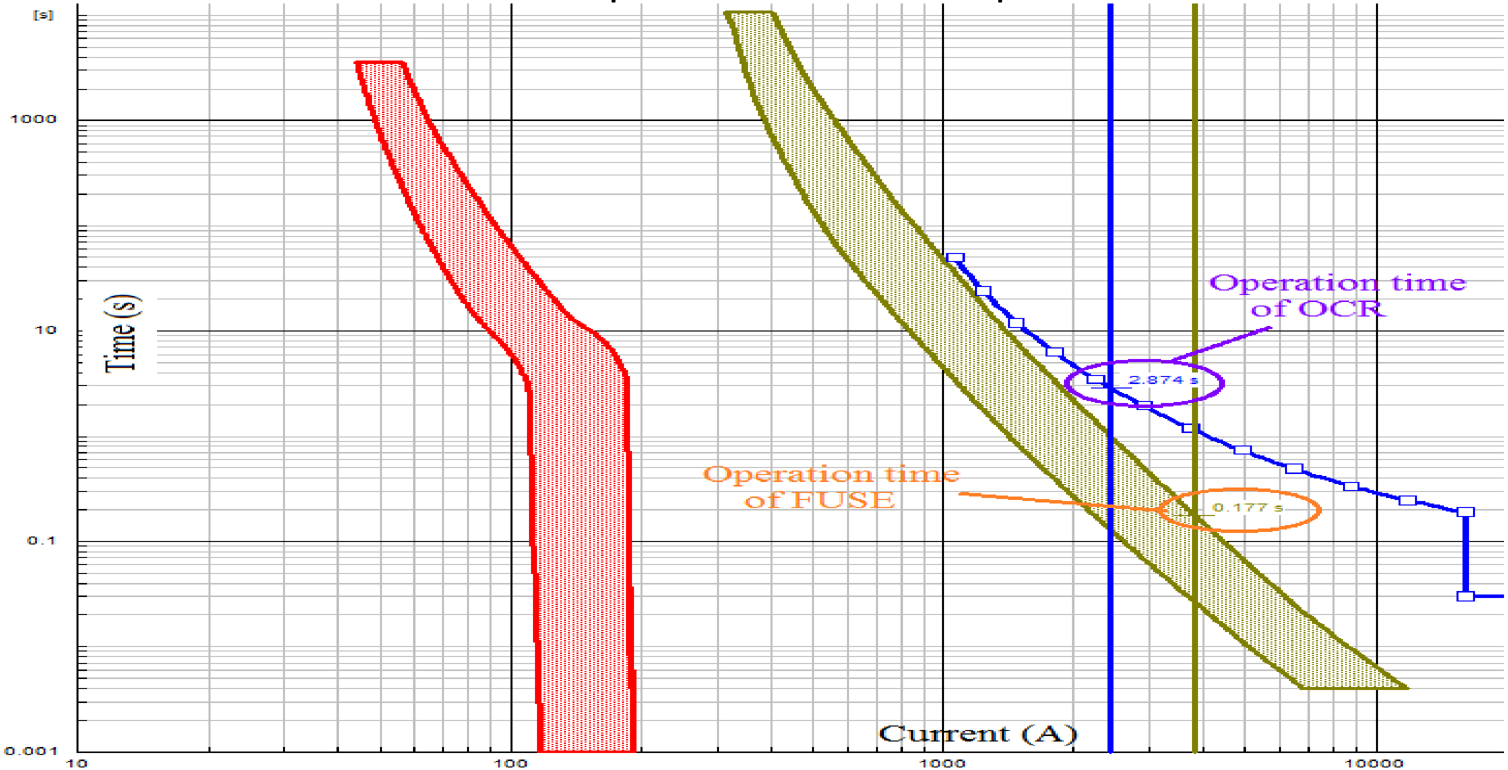
Impacts of PV on LV Zone

90% PV penetration- low impedance fault



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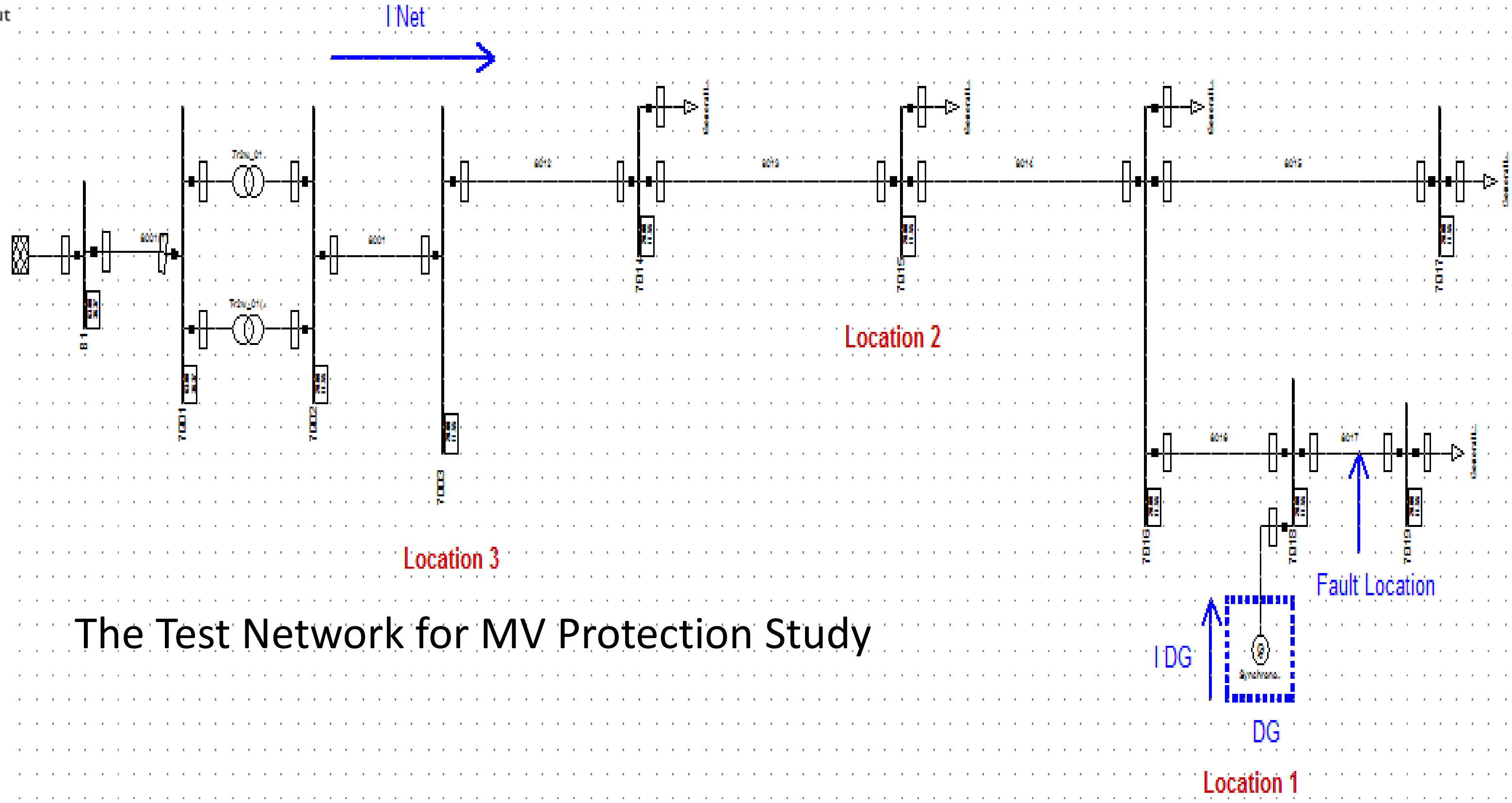
Impacts of PV on MV Zone



The Test Network for MV Protection Study

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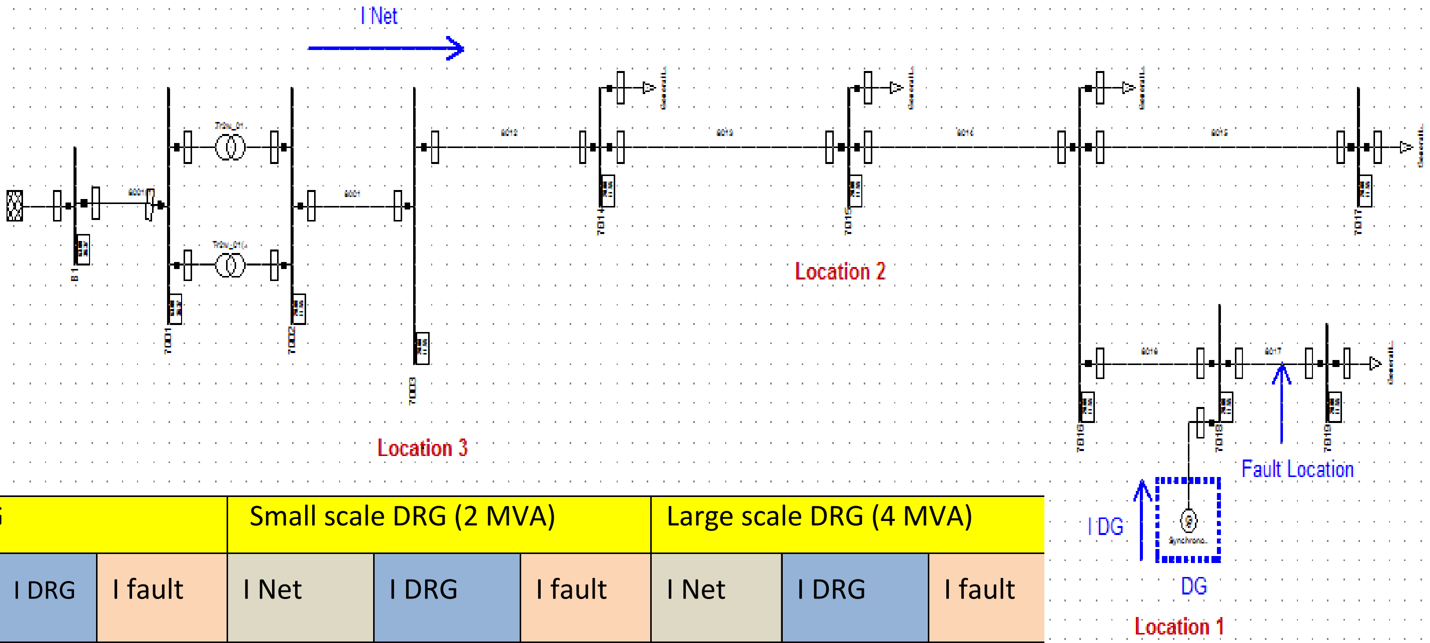
Impacts of PV on MV Zone



Scenario	W/O DRG			Small scale DRG (2 MVA)			Large scale DRG (4 MVA)		
Location	I Net	I DRG	I fault	I Net	I DRG	I fault	I Net	I DRG	I fault
1	4375.82	0	4272.16	4357.167	**314.3289**	4533.93	4343.86	**605.9193**	4773.05
2	4375.82	0	4272.16	4298.887	**201.6524**	4379.68	4238.71	**375.7525**	4470.25
3	4375.82	0	4272.16	4306.342	**90.67103**	4290.43	4262.32	**155.5094**	4303.21

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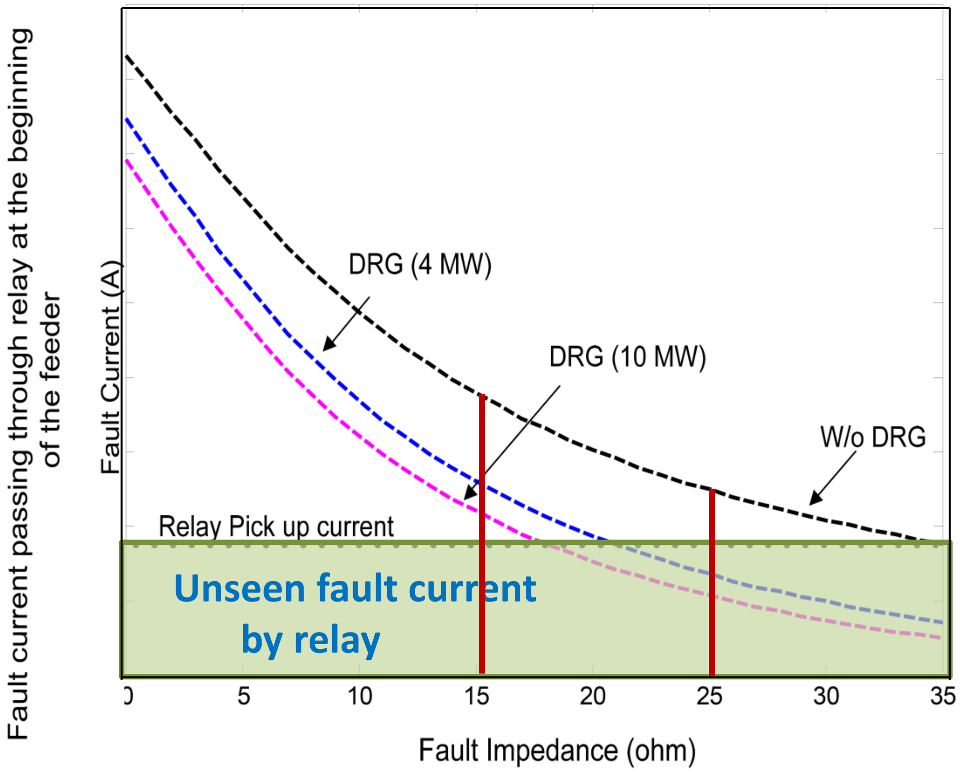
Impacts of DRG on MV Zone

Protection blinding

The relay could be blinded for high impedance faults



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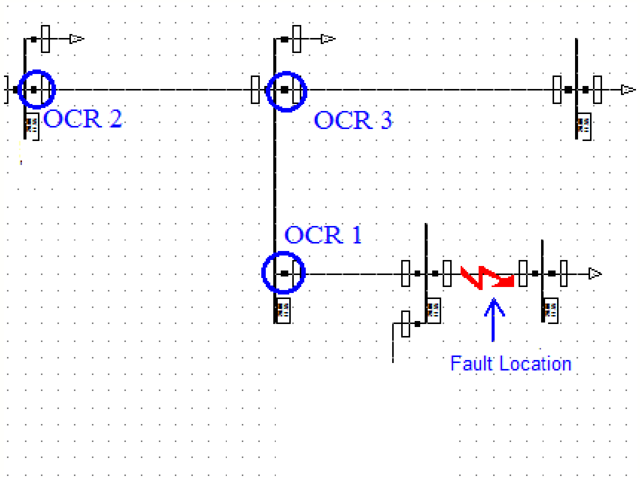
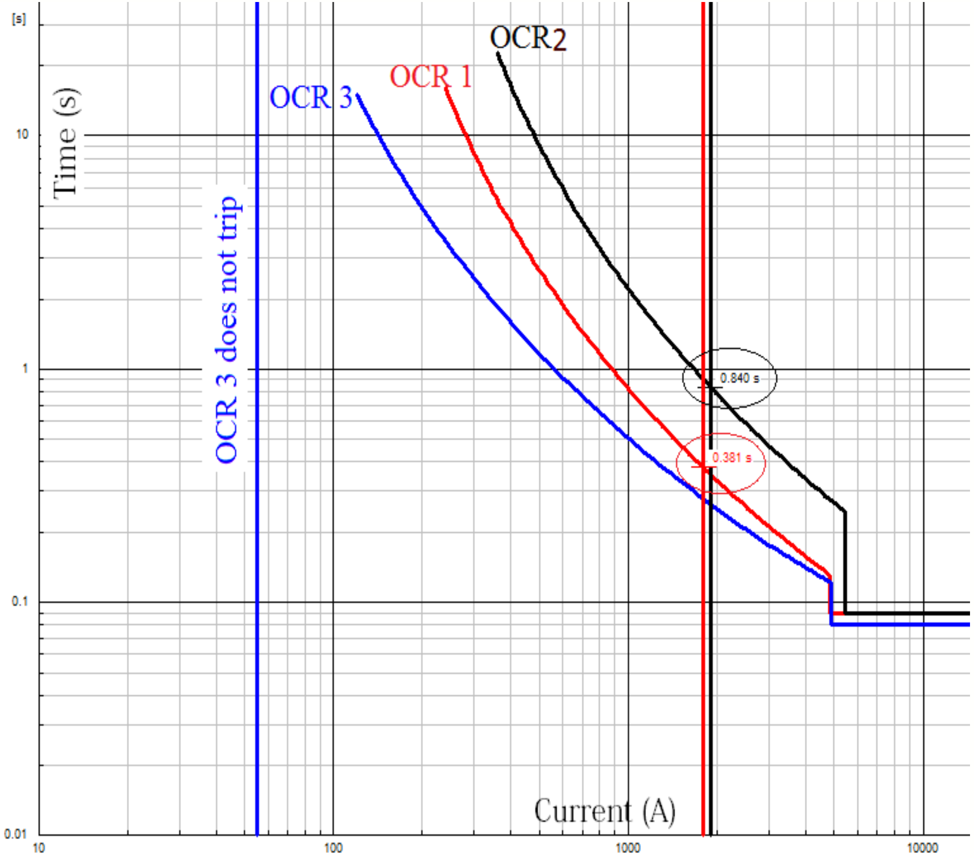
Impacts of PV on MV Zone

Protection blinding

Time-current characteristic of the relays **(Without DRG)**





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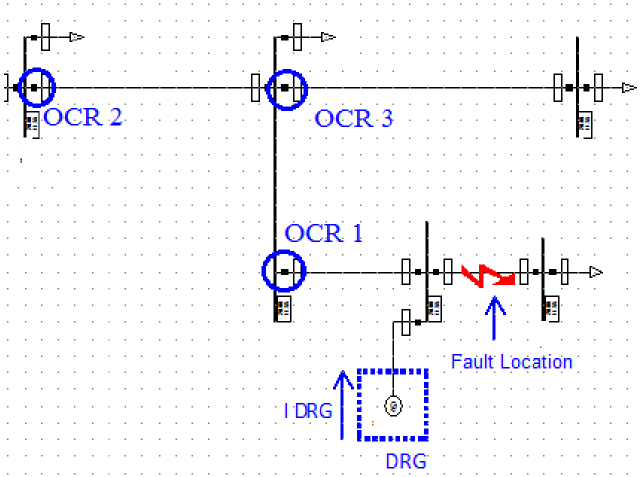
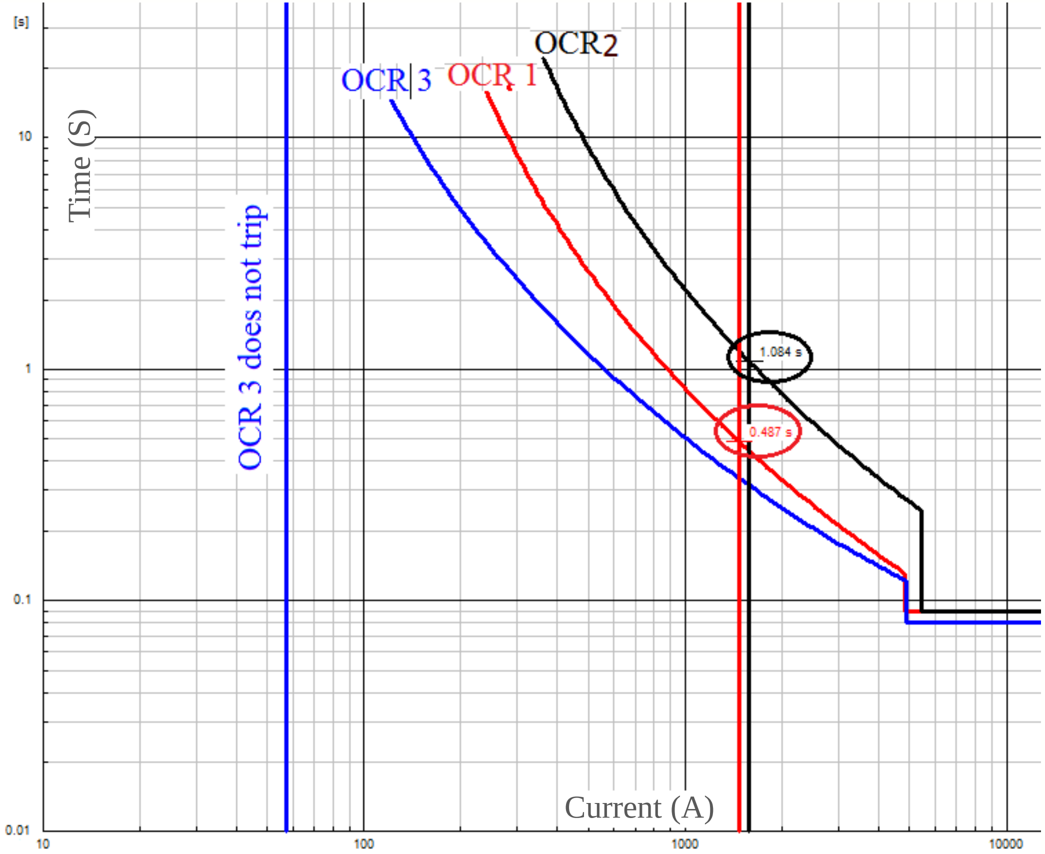
Impacts of PV on MV Zone

Protection blinding

Time-current characteristic of the relays **(With DRG)**





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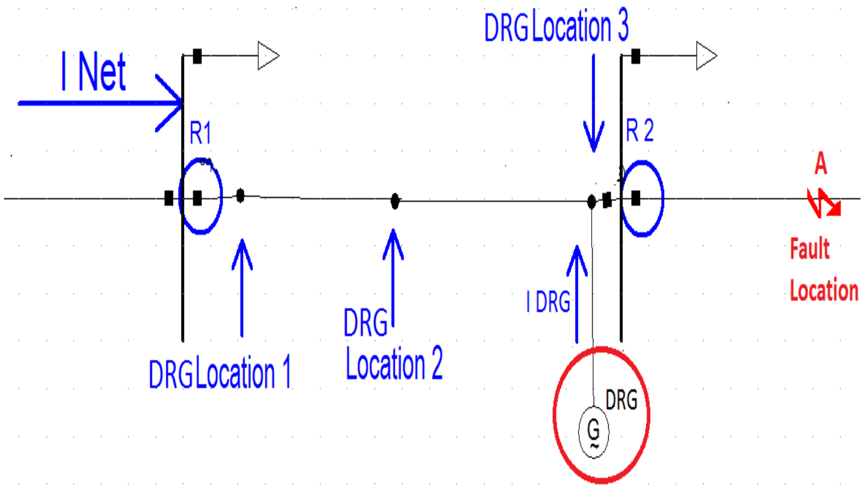
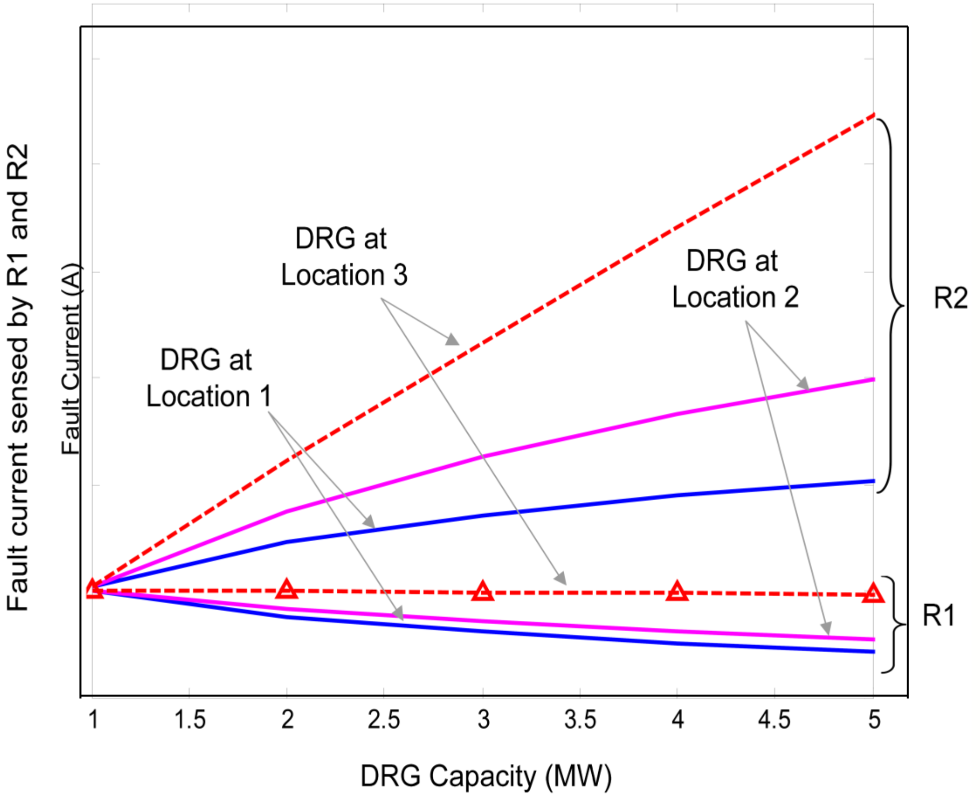
Impacts of DRG on MV Zone

Miscoordination between protective devices

Increase and decrease in fault current level of DRG upstream and downstream relays





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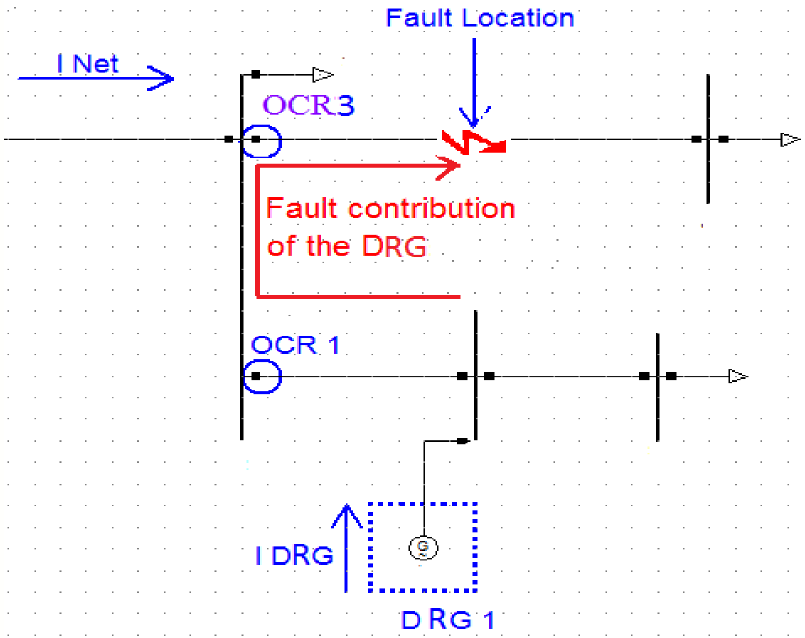
Impacts of PV on MV Zone

Sympathetic tripping (False tripping of feeders)



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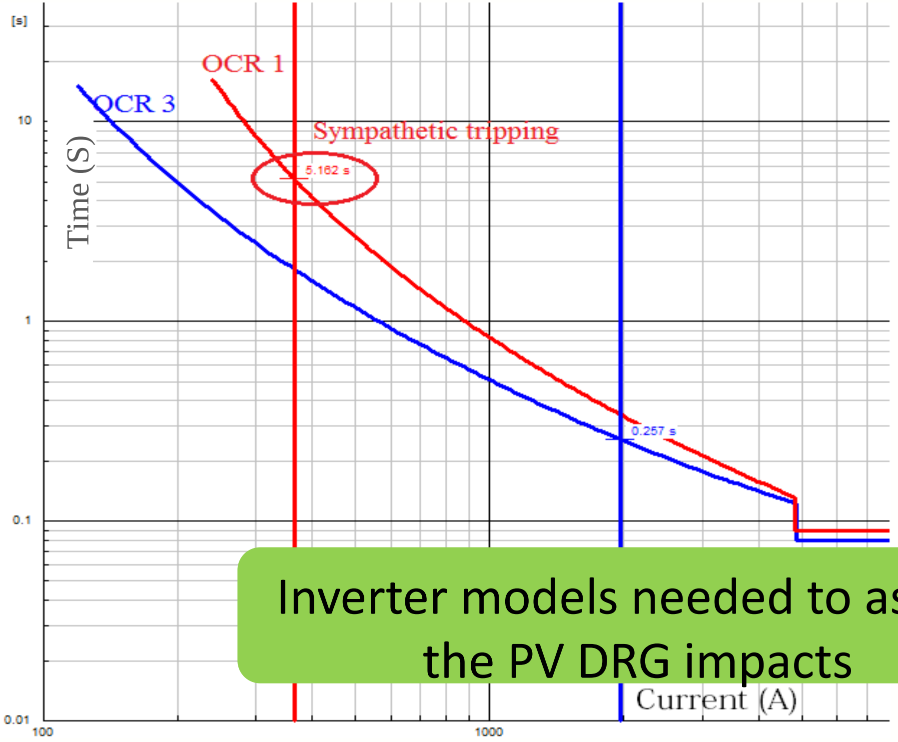

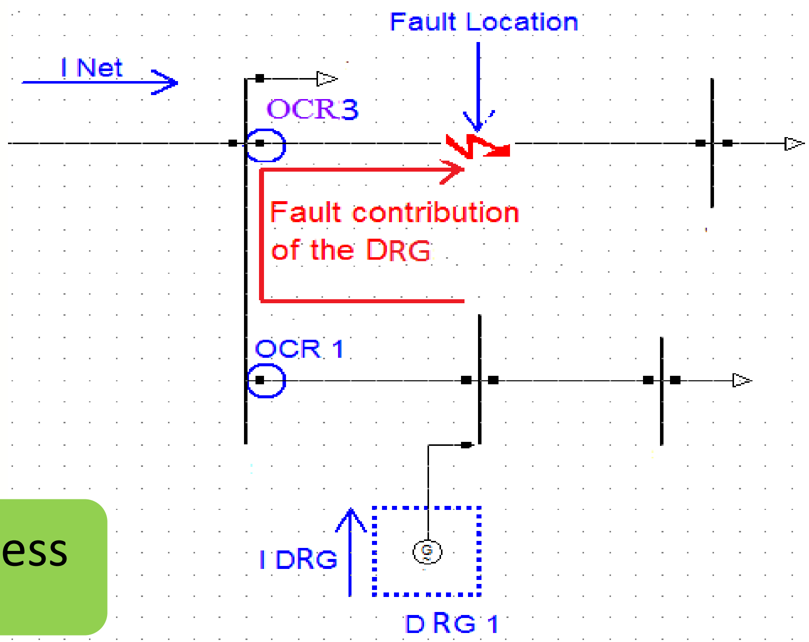

Inverter models needed to assess the PV DRG impacts

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International Approaches

Country	neutral treatment	grid operation	MV busbar protection	MV feeder protection	MV DER overcurrent protection	MV DER decoupling protection	LV DER decoupling protection	treatment of islanded grid
Australia	solid earthed	non-meshed	I> *with reverse interlocking*	I>, Ie> AR	I>, Ie>	U>, U<, f>, f<, *ROCOF, voltage vector shift, neutral displacement*		*Transfer trip where load matching is possible and other LoM protections may be unreliable.*
Austria	comp.	*meshed* or non-meshed	Z< *with reverse interlocking*	*Z<*	I>	U>, U<, f>, f<, *Q-U*		
China	isolated / compensated / low impedance	non-meshed	I>, Ie> arc protection	I>>, I>, Ie>	I>	U>, U<, f>, f<, *ROCOF*	U>, U<, f>, f<, *ROCOF*	*transfer trip*
Denmark	comp.	non-meshed	I>directional	I>directional	I>	*U>>>*, U>, U<, f>, f<, *ROCOF*		
Finland	comp./isolated	non-meshed	I> *with reverse interlocking, Ie>, arc protection*	I>, Ie>directional	I>, Ie>, fuse	*U>>*, U>, *U<<*, U<, f>, f<, *LoM*	U>, U<, f>, f<, *LoM*	
France	low imp. or comp.	non-meshed	I>, Ie>	I>, Ie>, *P0>*, I>directional	I>, Ie>	U0>, U>, U<, f>, f<, U< + FRT requirements + teleprotection	U>, U<, f>, f<, LoM (DIN VDE 0126-1-1/A1)	*tele decoupling (MV), impedance measurement (LV)*
Germany	low imp. or comp.	*meshed* or non-meshed	Z<, *f< & P> directional*	*Z<, I> (backup) or* I>directional, *I> (backup)*	*I>directional*	U>, U<, *Q-U*	U>, U<, f>, f<	
Italy	comp.	non-meshed	I>, *U>*	I>, I>directional,	I>, Ie>	U>, U<, Uen>, f>*, f<*, f>, f< **with voltmetric release: U0>, Ud>, Ui>*		*transfer trip*
Nether-lands	Low imp./ isolated	non-meshed	I>> I>, Ie> , some cases with reverse interlocking	I>>, I>, Ie>	I>, Ie>	U>, U<, f>, f<		
Norway	comp. *(solid earthed for earth fault detection)*	non-meshed	I> *with reverse interlocking*	Z< or I>	I>	U>, U<, f>, f<,		
Portugal	low imp.	non meshed	I>, Ie> and arc monitor	I>, Ie>	I>	U>, U<, U0>, f>, f<	U>, U<, f>, f<	*inform dispatch center*
Romania	low imp., comp. or isolated	non-meshed	I>	I> or I>directional, Ie> or I>directional	I>	U>, U<, f>, f<, *df/dt*		
South Africa	solid earthed	non-meshed	I>, Ie>, *sensitive earth fault prot.*	I>, Ie>, *sensitive earth fault prot.*	I>, Ie> or fuse	U>, U<, f>, f<, *df/dt*		

*with several levels and delay times

Joint CIGRE&CIRED Working Group B5/C6.26, "Protection of Distribution Systems with Distributed Energy Resources", Working Draft, August 2014

International Approaches

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Country	neutral treatment	grid operation	MV busbar protection	MV feeder protection
Australia	solid earthed	non-meshed	I> *with reverse interlocking*	I>, Ie> AR
Austria	comp.	*meshed* or non-meshed	Z< *with reverse interlocking*	Z<
China	isolated / compensated / low impedance	non-meshed	I>, Ie> arc protection	I>>, I>, Ie>
Denmark	comp.	non-meshed	I>directional	I>directional
Finland	comp./isolated	non-meshed	I> *with reverse interlocking, Ie>, arc protection*	I>, Ie>directional
France	low imp. or comp.	non-meshed	I>, Ie>	I>, Ie>, P0>, I>directional
Germany	low imp. or comp.	*meshed* or non-meshed	Z<, f< & P> *directional*	Z<, I> (backup) or I>directional, I> (backup)
Italy	comp.	non-meshed	I>, U>	I>, I>directional,
Nether-lands	Low imp./ isolated	non-meshed	I>> I>, Ie> , some cases with reverse interlocking	I>>, I>, Ie>
Norway	comp. *(solid earthed for earth fault detection)*	non-meshed	I> *with reverse interlocking*	Z< or I>
Portugal	low imp.	non meshed	I>, Ie> and arc monitor	I>, Ie>
Romania	low imp., comp. or isolated	non-meshed	I>	I> or I>directional, Ie> or I>directional
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*with several levels and delay times

Joint CIGRE&CIRED Working Group B5/C6.26, "Protection of Distribution Systems with Distributed Energy Resources", Working Draft, August 2014

EEA Annual Conference, 2010 'Black Box' For Simple Cost-Effective Grid Connection ofDG

'BLACK BOX' FOR SIMPLE COST-EFFECTIVE GRID CONNECTION OF DISTRIBUTED GENERATION

Authors:
Andrew Wells
Matthew Shanks
Chris Turney
Nirmal-Kumar C Nair

Affiliations:
1. Andrew Wells, B.E. (Hons.) recently graduated from Electrical and Computer Engineering at The University of Auckland, New Zealand and currently serving as an officer in the New Zealand Navy.

2. Matthew Shanks B.E. (Hons.) recently graduated from Electrical and Computer Engineering at The University of Auckland, New Zealand and currently working for AECOM Sydney.

4. Chris Turney, B.E. (University of Auckland, New Zealand), is currently CEO, Ergo Consulting, Auckland, New Zealand.

3. Nirmal-Kumar Nair, B.E. (M.S. University, Baroda, India), M.E. (IISc., Bangalore, India), Ph.D. (Texas A&M University, College Station, USA), is currently a Senior Lecturer in the Electrical and Computer Engineering Department, The University of Auckland, New Zealand.

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Fax +64 9 373 7461
Email: N.Nair@auckland.ac.nz

Presenters:
Chris Turney, Nirmal Nair

EEA Conference & Exhibition 2010, 17-18 June 2010, Christchurch

International Approaches

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Germany	low imp. or comp.	*meshed* or non-meshed	Z<, *f< & P> directional*	Z<, *I> (backup)* or I>directional, *I> (backup)*
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*with several levels and delay times

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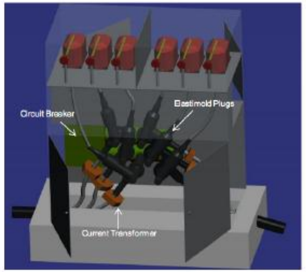
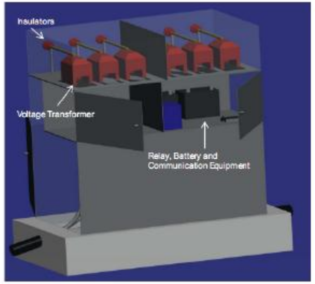
Tel: +64 9 373 7599 ext 89523
Fax +64 9 373 7461
Email: N.Nair@auckland.ac.n

Presenters:
Chris Turney, Nirmal Nair

Appendix C: 3-D Computer Aided Design Visualization of the 'Black Box'





EEA Conference & Exhibition 2010, 17-18 June 2010, Christchurch

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Utility Active LV Network Protection Assessment (CS2.3.4)

- Analysis of representative feeders
  - PV/Inverter realistic modelling
    - Being carried out in cooperation with EPECentre (will add value to CS2.2.1 & CS2.3.3)
  - Clustering
    - Has been carried out in the context of CS2.2.1
    - Is adjusted to be used for RA2.3

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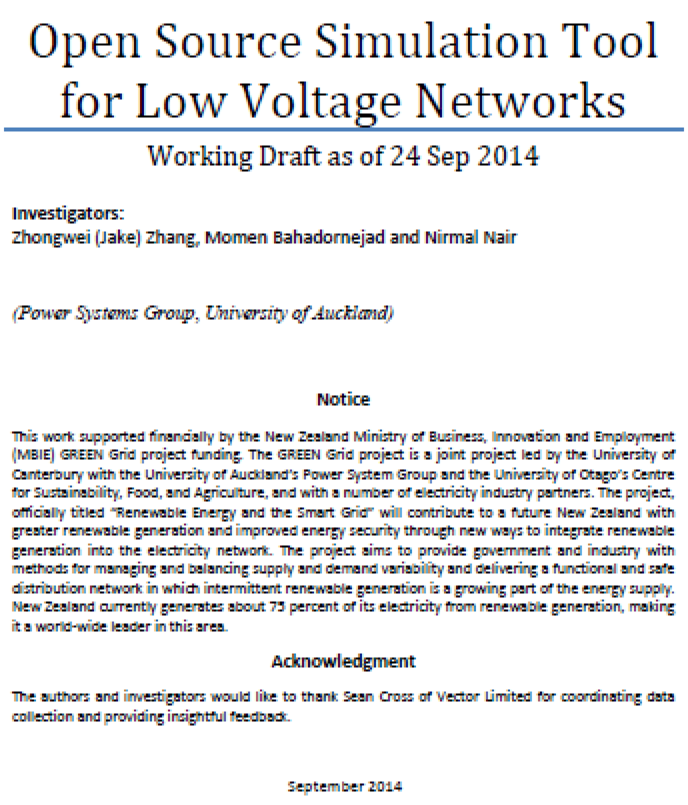
Utility A… Assessment

- Analysis of repr…
  - PV/Inverter rea…
    - Being carried c… entre (will add value to C…
  - Clustering
    - Has been carri… 2.1
    - Is adjusted to be used for RA2.3



Open Source Simulation Tool for Low Voltage Networks

Working Draft as of 24 Sep 2014

Investigators:
Zhongwei (Jake) Zhang, Momen Bahadornejad and Nirmal Nair

(Power Systems Group, University of Auckland)

Notice

This work supported financially by the New Zealand Ministry of Business, Innovation and Employment (MBIE) GREEN Grid project funding. The GREEN Grid project is a joint project led by the University of Canterbury with the University of Auckland's Power System Group and the University of Otago's Centre for Sustainability, Food, and Agriculture, and with a number of electricity industry partners. The project, officially titled "Renewable Energy and the Smart Grid" will contribute to a future New Zealand with greater renewable generation and improved energy security through new ways to integrate renewable generation into the electricity network. The project aims to provide government and industry with methods for managing and balancing supply and demand variability and delivering a functional and safe distribution network in which intermittent renewable generation is a growing part of the energy supply. New Zealand currently generates about 73 percent of its electricity from renewable generation, making it a world-wide leader in this area.

Acknowledgment

The authors and investigators would like to thank Sean Cross of Vector Limited for coordinating data collection and providing insightful feedback.

September 2014

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Utility Ac ... Assessment

- Analysis of repre
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(Power Systems Group, University of A

This work supported financially by the New Zea (MBIE) GREEN Grid project funding. The GREEN Canterbury with the University of Auckland's Po for Sustainability, Food, and Agriculture, and wit officially titled "Renewable Energy and the Sma greater renewable generation and improved ene generation into the electricity network. The pr methods for managing and balancing supply and distribution network in which intermittent renew New Zealand currently generates about 73 perce it a world-wide leader in this area.

Ackno

The authors and investigators would like to tha collection and providing insightful feedback.

Sept

Table of Contents

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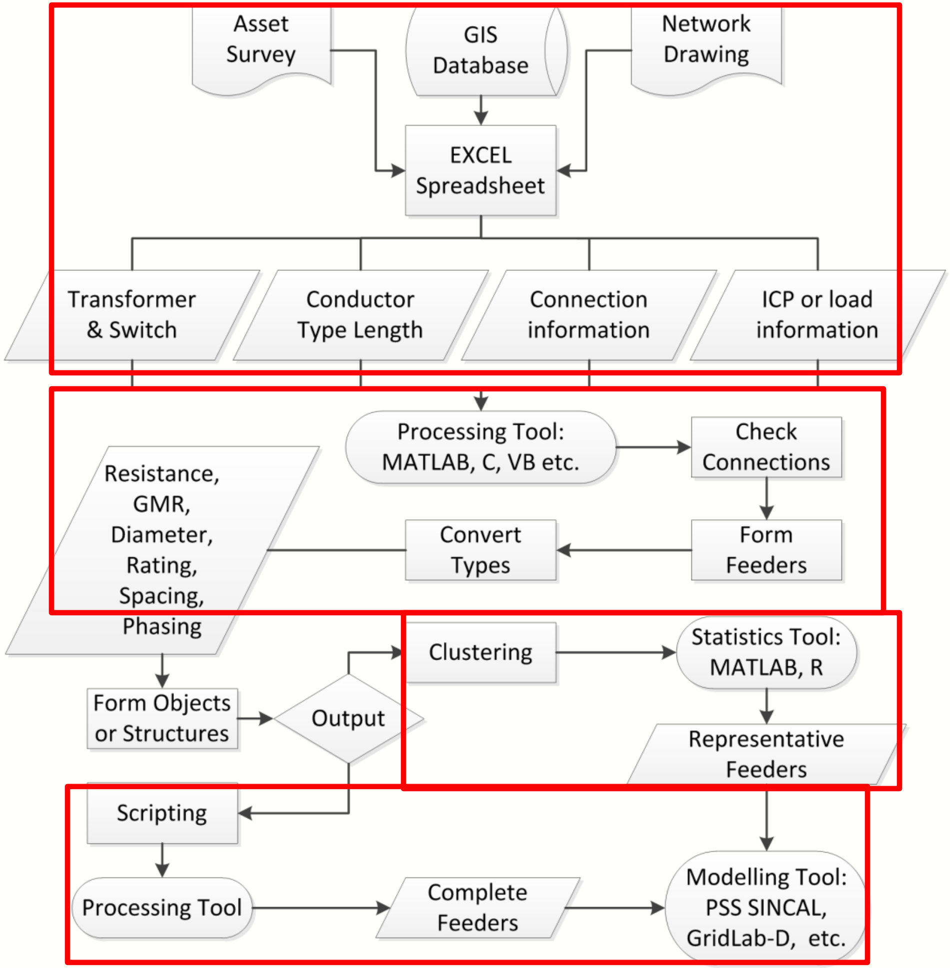
- LV network modelling
  - Data preparation
  - Data processing
  - Open software simulation (Gridlab-D)
  - Feeder clustering



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Choice of Clustering Variables

(Methodology: weighted k-means)

Ref: J. D. Watson, N. R. Watson, D. Santos-Martin, S. Lemon, A. Wood, and A. Miller, "Low voltage network modelling", in 2014 Electricity Engineers' Association Conf., Auckland, New Zealand, June 2014.

Orion representative feeders

- Overall feeder No.: 10558
- Main study purpose
  - Power quality, load flow
- Chosen clustering variables
  - No. of residential ICPs
  - No. of non-residential ICPs
  - Ave. distance between loads
  - kW rating

Vector representative feeders

- Feeder No.: 23661 (40000+)
- Main study purpose
  - Protection & fault analysis
- Variables choice reasons:
  - To reflect different fault levels
  - To reflect different cable sheath locations for zero sequence impedance models

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Choice of Clustering Variables

For Vector representative feeders

To calculate earth potential rise (EPR):

- To reflect different fault levels
- To reflect different cable sheath locations for zero sequence impedance models

8 chosen variables:

- Feeder maximum rating
- Circuit rating (mean & std)
- Circuit impedance (mean & std)
- Overhead circuit length
- Underground circuit length
- 'Neutral screen' circuit length*

Ref: A. K. Parsotam "Fundamentals of calculation of earth potential rise in the underground power distribution cable network", in Power & Telecommunications Systems Coordination Conf. , Melbourne, March 1997.

*Neutral screen cable is emphasised by Vector on its importance as its neutral/earth screen provides protection against the hazards of electric shock and has 60% to 80% coverage to protect the phase conductor.

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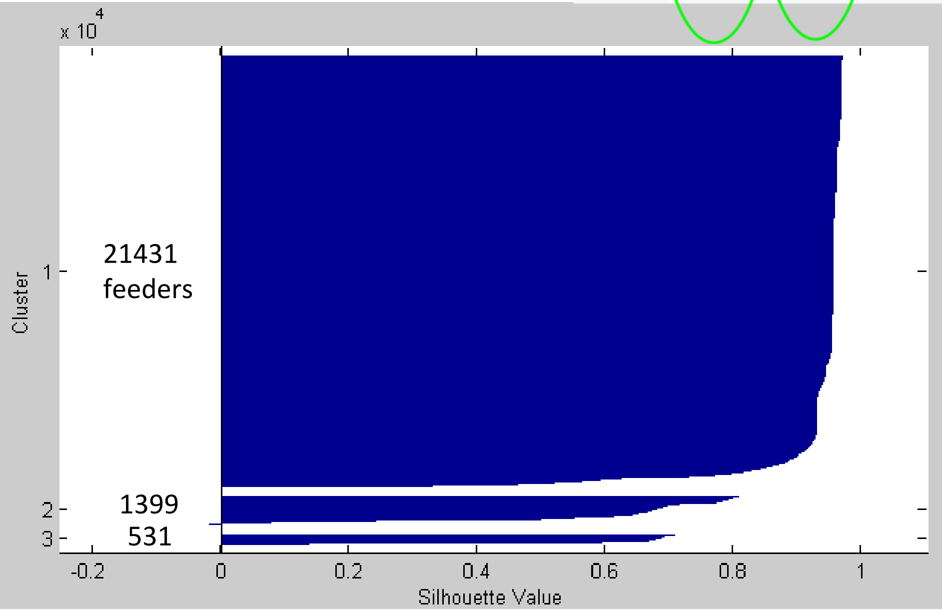
Vector Representative Feeders

K-means: silhouette plot

k=3 Values >0.5 representative
Value <0.2 not so good

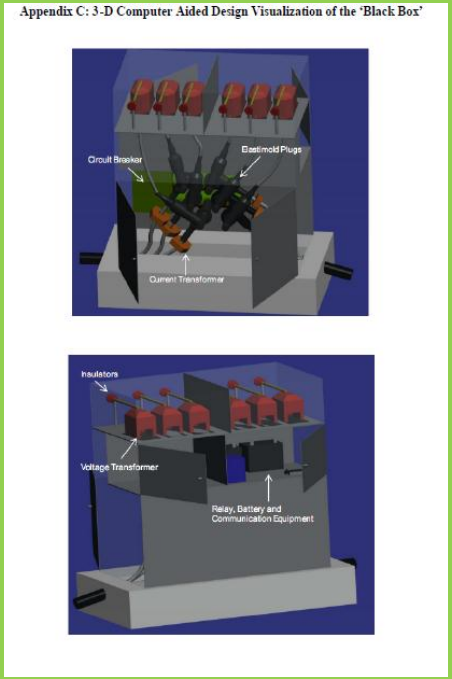
k	2	3	4
Mean	0.915	0.908	0.503
Std	0.217	0.128	0.208
Max	0.983	0.967	0.771
Min	-.487	-.254	-.374



Cluster	ID	Length	Cable / Line	Max Rating
1 Centre	55759842	Short	Cable	Low
1 Median	2197044	Short	Cable	Low
1 Extreme	47051941	Short	Cable	Low
2 Centre	3401607	Short	Cable +Line	Median
2 Median	46721145	Median	Cable +Line	Median
2 Extreme	6373894	Long	Cable +Line	Median
3 Centre	45970805	Median	Cable +Line	High
3 Median	47372234	Short	Line	High
3 Extreme	540826	Very Long	Cable +Line	High

Solution to MV Protection Issues

- Adaptive Protection
  - On-line network modelling
  - PV/Inverter modelling
  - Fault Current Estimation
  - Relays setting and coordination
  - Assess ICT aided options



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Part 3

RA2.2: Impacts of different scales of DRG deployment on the LV network

- CS2
- CS2

RA2.3: Protection and automation in active distribution network

- CS2.3.1 (2012-2014): Leveraging of ICT infrastructure
- CS2.3.2 (2012-2013): Protection schemes used by NZ distribution networks' utilities
- CS2.3.3 (2013-2014): Fault analysis with bi-directional flows
- CS2.3.5 (2012-2015): Vector's PV trials

Vector's PV Trials

- 2013:
  - Involved in Vector PV/Battery trial (SunGenie) by carrying out detailed literature review resulting in a report.

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- 2013:
  - Involved in Vector PV/Battery trial (SunGenie) by carrying out detailed literature review resulting in a report.
  - The report was released as a white paper.

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Vector's PV Trials

- 2013:
  - Involved in Vector PV/Battery trial (SunGenie) by carrying out detailed literature review resulting in a report.
  - The report was released as a white paper.
- 2014: Involved in Vector new grid connected PV/Inverter trial by providing them the inverter testing services in three stages:
  1. Basic tests: For Vector's business plan
  2. Advanced tests: Inverter behaviour in different control modes was assessed
  3. Inverter settings: Based on the grid codes

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Vector’s PV Trials

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Vector's PV Trials

Standards based testing of solar PV Inverters

Nicholas Carson

Department of Electrical and Computer Engineering
University of Auckland, Auckland, New Zealand

Abstract

Solar photovoltaic (PV) systems are becoming more prevalent in residential neighbourhoods both here in New Zealand and abroad. As distribution utilities face a future of increasing levels of distributed generation (DG) they have to contend with power being exported back into the Low Voltage (LV) network. In this respect it is important the associated inverter technology is well understood and can be set up in a manner which supports the local grid codes. The aim of this project was the development of a universal test bench for single phase residential scale PV inverters that is cost effective and adheres to international best practices. A solution is presented consisting of a programmable DC source – acting as the PV panels, a programmable current sink – for the residential load, a programmable AC source – representing the LV grid and a power quality analyser for data capture and analysis. It is shown that by subjecting the inverter to a range of basic and advanced tests the inverter behaviour can be characterised and appropriate settings can be determined. The acceptance by industry of the results and real world test comparison helps cement the validity of the test bench solution.

1. Introduction

Distributed generation (DG) is an increasing topical issue in the field of electrical power systems. This can be viewed not only in terms of the role it plays in system stability but also in the disruptive nature of this technology on the well-established radial power generation model. In particular photovoltaic (PV) systems are increasingly more prevalent around the world [1] and New Zealand [2] is no exception. An essential element of a PV system is the inverter whose primary purpose is the conversion of direct current (DC) power from solar panels to

characteristics under simulated conditions for normal, abnormal and grid fault scenarios. Understanding the inverter's behaviour and capabilities makes it possible to provide guidance to distribution companies about the potential impact of adopting PV onto their networks and the suitability of the inverter under test to support their grid codes. This report is structured by briefly discussing PV inverters in section 2, how inverters can be affected by the LV grid in section 3, the test bench itself is explained in section 4, what tests were conducted and how is detailed in section 5, section 6 looks back at some of the issues encountered during the project, while section 7 provides some reasoning for why the test bench has been validated, future work is explored in section 8 and the report is concluded in section 9.

2. Photovoltaic inverters

The following provides a brief overview of PV inverter functionality and the current standards for testing them.

2.1. Inverter functionality

PV inverters are solid state devices which provide control, protection and filtering functionality and are the interface between the electrical energy source - the PV cells or array - and the electricity distribution system [4]. Specifically inverters convert the DC created by the PV panels to an AC - via a Pulse Width Modulation (PWM) to sine wave transformation - for use at the local load or injection into the grid. Inverter topologies include transformer and transformer-less design, with differing types of building blocks of DC and AC stages. These stages handle various responsibilities such as MPPT, grid interface, balancing the input voltage and power decoupling at the output of the PV module [5]. Modern PV inverters provide four-quadrant functionality allowing

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Vector's PV Trials

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smart meter for a power analyser / data logger and the power grid for a programmable AC source as shown in Figure 3.3.

Figure 3.3: The inverter test bench, a simplified representation of a grid tied residential PV installation.

4.2. What equipment was needed?

The test bench consists of a programmable DC supply, programmable AC source, digital power meter, programmable AC load and the inverter under test.

The IEEE 1547.1 standards under section 4.3 'Measurement accuracy and calibration of the testing equipment' [5] and the test protocol [18] provided more specific guidance under section 5.2 'Test Equipment Requirements', Table 5-1, regarding the maximum uncertainty of the test equipment. The following test bench devices adhere to these guidelines.

4.2.1. *Programmable DC supply*

A *Sorensen SGI800-6.2 DC Supply* was utilised as the source for the inverter under test. This particular device is capable of outputting 800V at 6A and is suitable for emulating a residential scale PV panel installation of up to 4.8kW. The device is programmable either by way of the front panel or for more complex inputs via the rear RS232 port and a serial terminal programme (such as MS HyperTerminal). This latter functionality would allow for various stochastic irradiance patterns to be simulated.

4.2.2. *Programmable AC source*

The intention of this device is to simulate the LV grid network and the various operating conditions the inverter could experience. The ability to program ramp and step functions is introduced systematically so to simulate load changes within the home.

4.2.4. *Digital power meter*

To evaluate an inverter after each run of tests it is necessary to accurately capture the electrical quantities such as voltage, current, power – both real and reactive, current harmonics and waveform distortions. A *Fluke 434 Power Quality Analyser* was initially used but due to limited resolution of one second intervals we moved onto a more capable *ELSPEC G4500 BLACKBOX PQA*. The *ELSPEC* device samples at 1024 times per cycle for voltage and 256 times per cycle for current resulting in high resolution waveforms that aided characterising the inverter behaviour in response to the simulated fault conditions. Reviewing of captured data was viewed using the relevant device's proprietary software.

4.2.5. *Inverters tested*

Two inverters - referred to as Inverter A and Inverter B in this report - were tested during the course of this project. Both were rated at a max output of 3kW. By harnessing their proprietary software the advanced functionality was explored and tested.

5. Tests undertaken

The testing regime was sectioned into two categories; basic and advanced tests.

5.1. Basic tests

The following describes the types of tests as carried out in accordance with the applicable standard. Where appropriate both the magnitude and time response was investigated. The procedures and results are contained in the following subsection (5.3).

5.1.1. *Over/ under voltage*

The IEEE 1547.1 standards for Over/ Under Voltage are summarised in Table 1 and closely follows the accepted levels in New Zealand of >1.1p.u for over voltage and <0.88p.u for under voltage, as indicated by Vector grid codes (insert ref) and are considered as such when the event persists for greater than one minute.

Table 1: Over and Under Voltage Settings

IEEE 1547		VECTOR	
Voltage Range (p.u.)	Max Disc. Time (secs.)	Voltage Range (p.u.)	Max Disc. Time (secs.)
< 0.50	0.16	-	-

Testing

Basic

- OV/UV also Sags and Swells
- OF/UF
- Efficiency rating
- Harmonics and THD
- LVRT
- Disconnection and Reconnection

New Zealand voltage levels	Volts (V)	Per Unit (P.U.)
Nominal	230	1.00
Overvoltage	> 253	>1.10
Undervoltage	< 202	< 0.88

IEEE Standards based


IEEE Std 1547.1™-2005

IEEE Standards

1547.1™

IEEE Standard Conformance Test Procedures for Equipment Interconnecting Distributed Resources with Electric Power Systems

IEEE Standards Coordinating Committee 21

Sponsored by the IEEE Standards Coordinating Committee 21 on Fuel Cells, Photovoltaics, Dispersed Generation, and Energy Storage

New Zealand frequency levels	Frequency (Hz)
Nominal	50
Over-frequency	> 51.5
Under-frequency	< 47.5

TESTING

Advanced

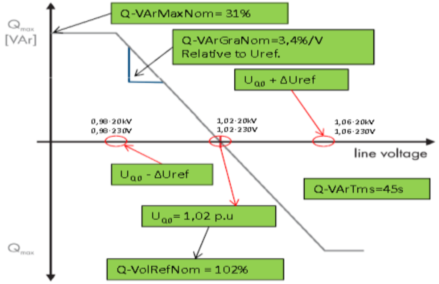
- Volt / Reactive Power (VAr)
- Power (W) / Frequency (Hz)
- Cos(phi) – fixed and variable

Set up as Reactive Power Q

SMA MPS Inverters Designed for Supply Reactive Power Q-VArMod=VArCtlVol

- Reactive Power is set according to the power line voltage. **Q-VArMod=VArCtlVol**

Parameter	Setting
Q-VArGraMod	xxxx
Q-VArMaxNom	31%
Q-VolRefNom	102%
Q-VolWidNom	0%
Q-VArGraNom	3,4%/V
Q-VArTms	45 s



- **Sign Criteria = Power Plant**

Q>0 Feed in reactive Power

Q<0 Consume reactive Power

Manufacturer's documentation

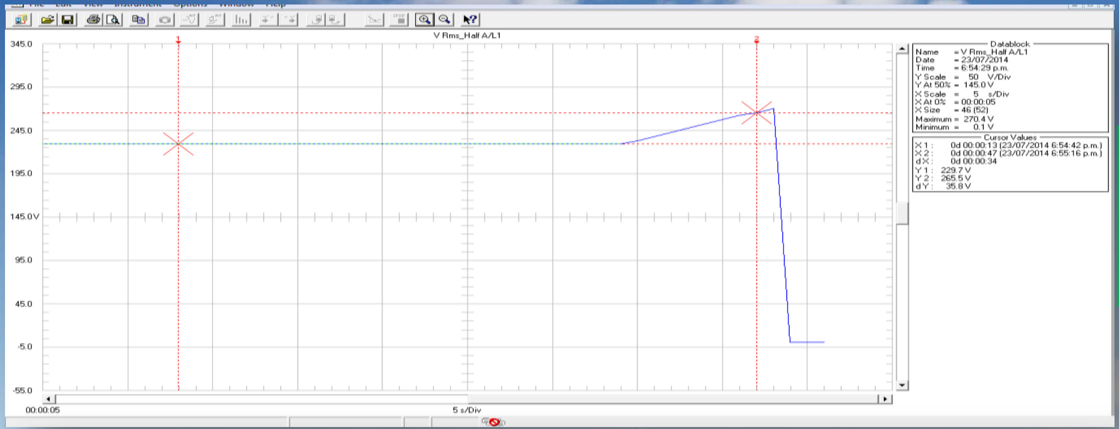
e 1. Advanced DER Inverter Functions contained in IEC TR 61850-90-7

Function	Description	Type
Connect/Disconnect	Physically connect or disconnect from grid	Command
Adjust Maximum Generation Level	Set maximum generation level at Electrical Coupling Point (ECP)	Command
Adjust Power Factor	Issues a power factor angle value	Command
Request Active Power	Request charging or discharging of the storage system	Request
PV/Storage Functions	Change the signal parameters for the storage system	Request
Volt-Var mode	Provide vars with no effect on watts	Set Parameter
Volt-Var mode	Provide maximum vars constrained by WMax	Set Parameter
Volt-Var mode	Establish fixed var settings	Set Parameter
Volt-Var mode	No var support	Set Parameter
Set maximum power output	Active power reduction due to high frequency	Set Parameter
Set maximum power output	Modify frequency-watts-delivered or watts-received curve according to time of day or other parameters	Set Parameter
Dynamic reactive power support	Provide var support at times of abnormally high or low voltage	Set Parameter
Connect/disconnect settings	Set voltage ride-through or disconnect requirements	Set Parameter
Power factor settings	Set power factor in response to feed-in power	Set Parameter
Power factor settings	Modify power factor-watts curve according to other parameters	Set Parameter
Set output to smooth voltage deviations	Voltage-watt curve of generator output based on various parameters	Set Parameter
Set output to smooth voltage deviations	Voltage-watt curve of storage charge/discharge output	Set Parameter
Temperature mode behavior	Temperature-based curves	Set Parameter
Signal mode behavior	Mode curves based on utility signal	Set Parameter
Modify DER Inverter Settings	Set default ramp rate, min. storage level, max. storage charge/discharge rate	Command
Event/History Logging	Request event logs	Command
Status Reporting	Request inverter status	Command
Time Synchronization	Set inverter time	Command
Connect/disconnect settings	Set frequency ride-through or disconnect requirements	Set Parameter

*function required under CPUC/CEC Rule 21, not part of IEC TR 61850-90-7

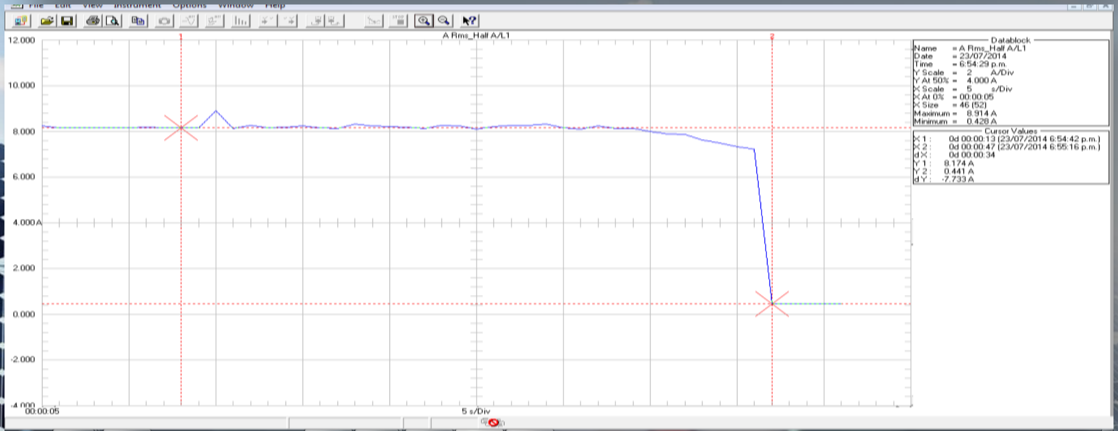
Over Voltage Test

Voltage



Inverter disconnects when the maximum voltage setting is exceeded.

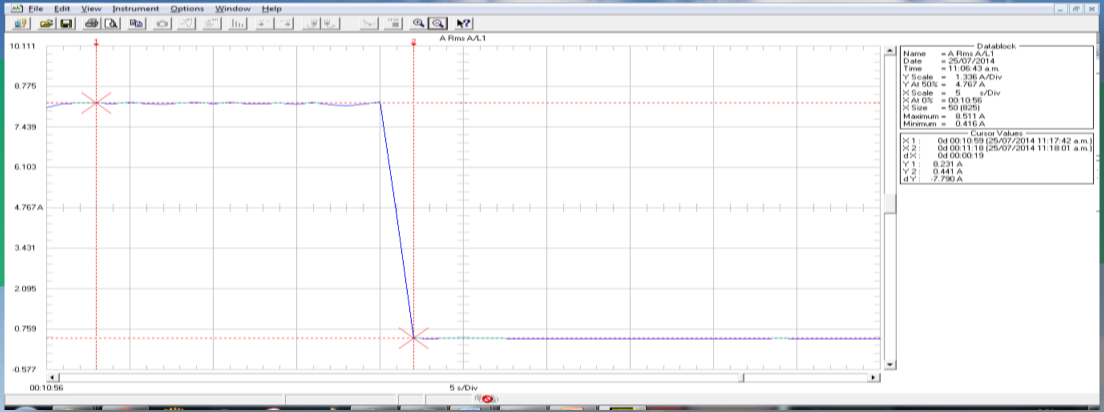
Current



Current ceases to be passed by the inverter confirming disconnection

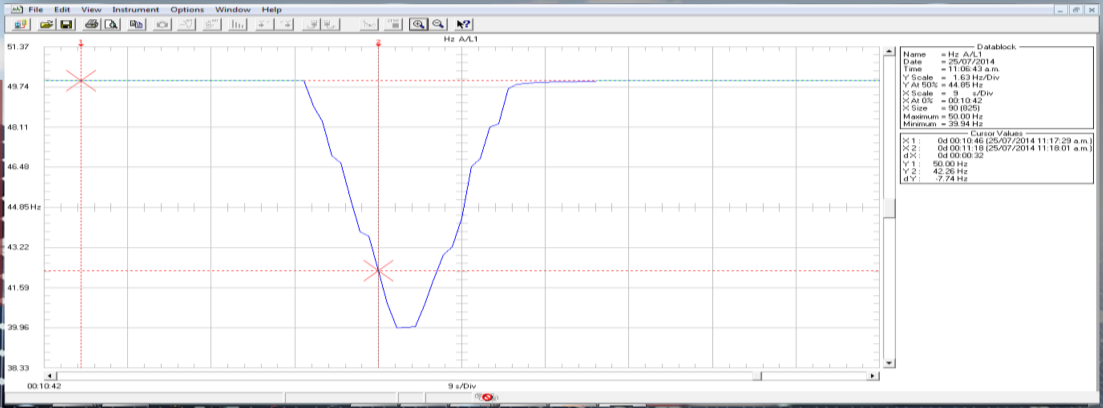
Under Frequency Test

Current



Current ceases to be passed by the inverter confirming disconnection

Freq.

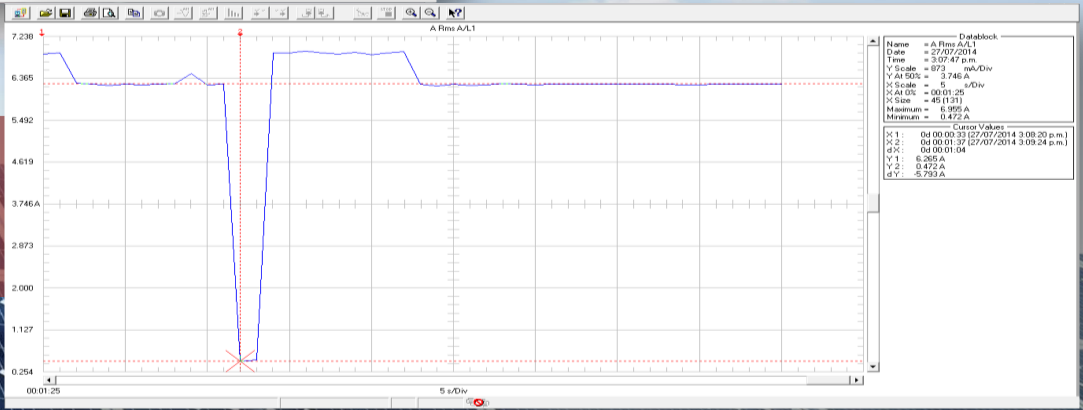


Frequency is decreased until inverter disconnects

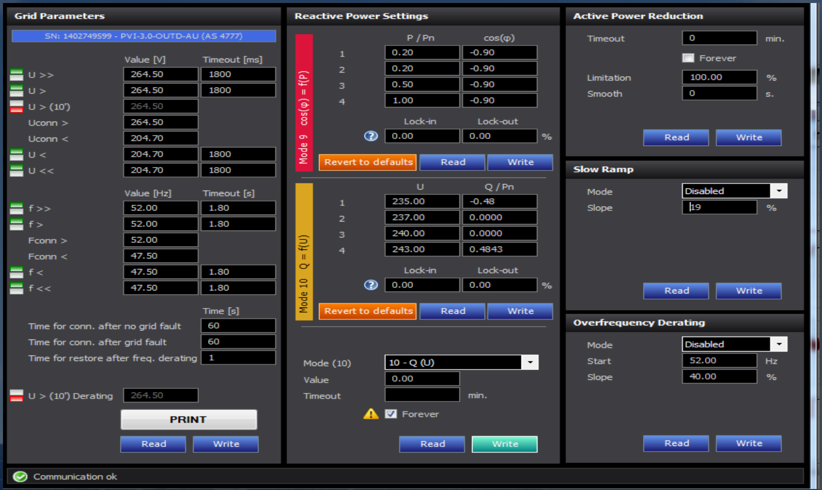
Low Voltage Ride Through (LVRT)

A LVRT voltage profile going down to 0.5 (p.u.)

The resultant current profile



Advanced Tests

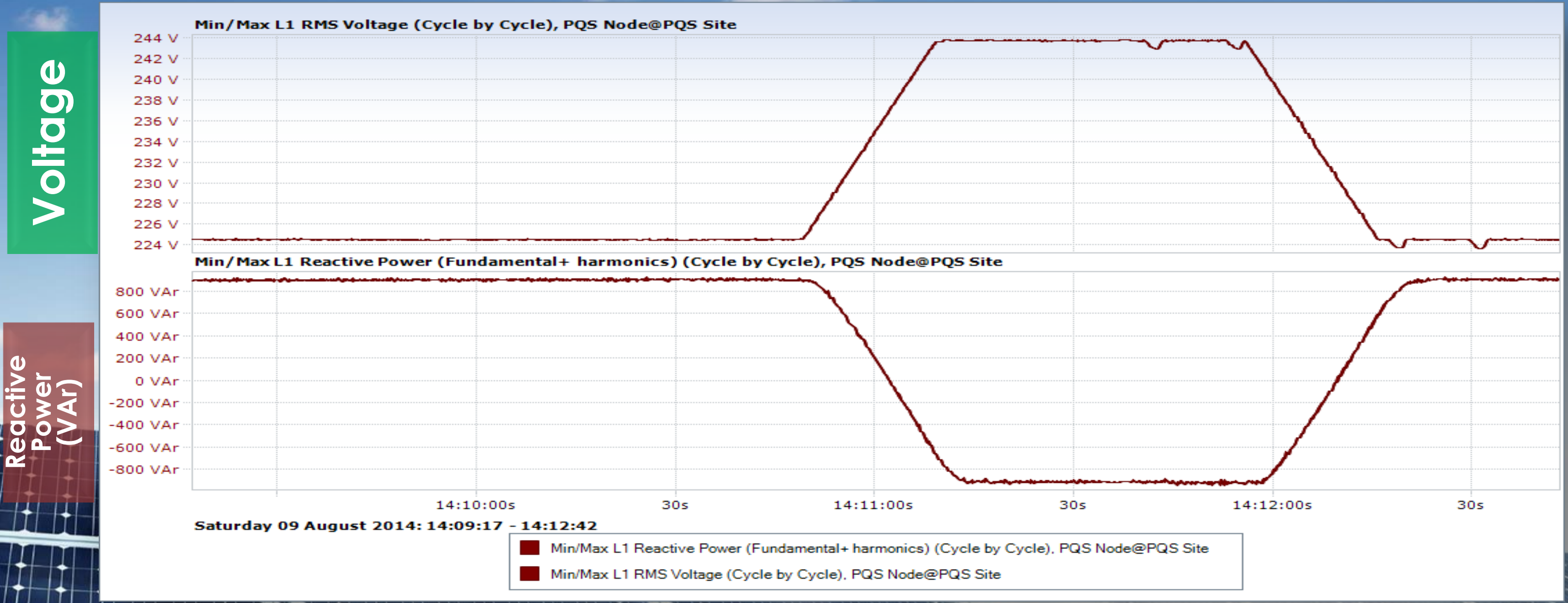


Software interface for accessing advanced features

Advanced

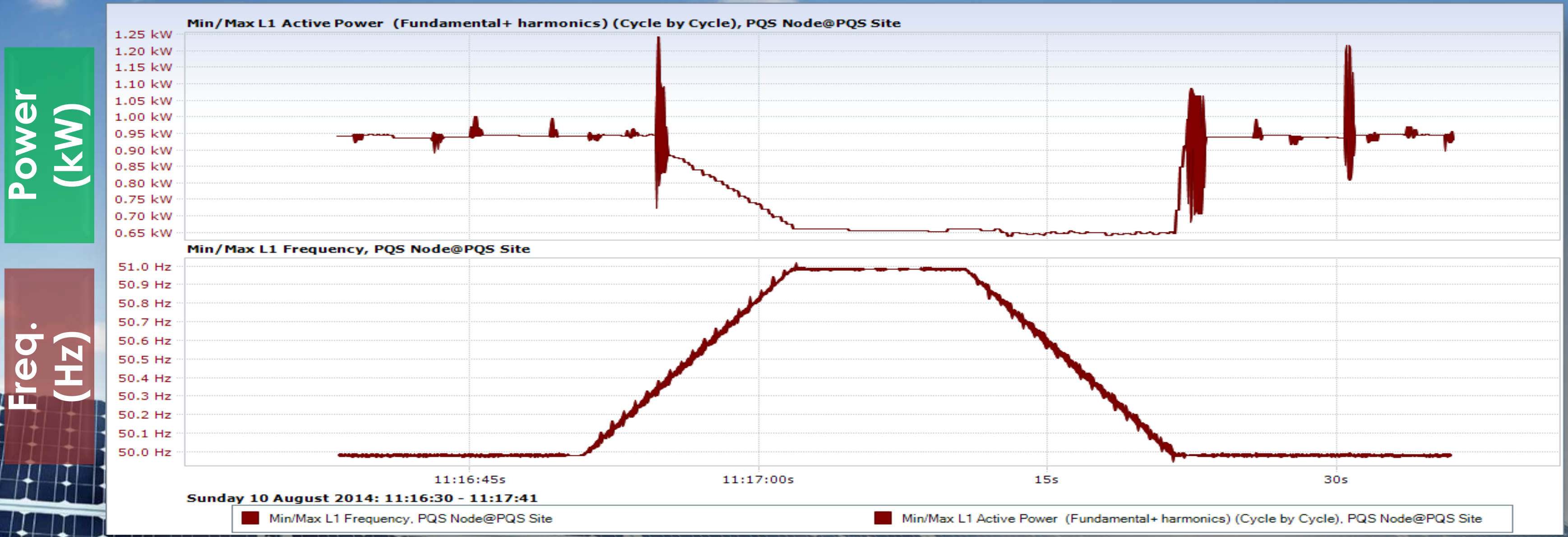
- Volt / Reactive Power (VAr)
- Power (W)/ Frequency (Hz)
- Power Factor or Cos(phi)

VOLT-VAR



Constant P, changing Q

Frequency-Power

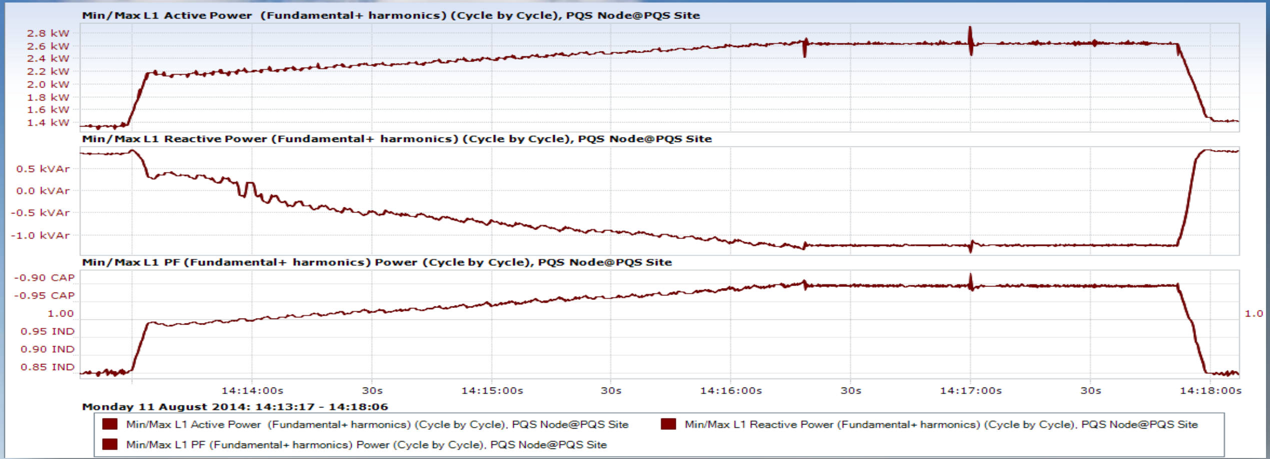


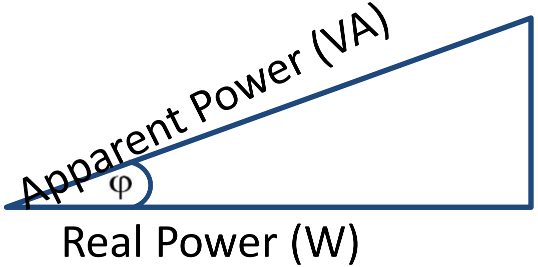
COS(PHI) -PQ

Power (kW)

Reactive Power (kVAr)

Power Factor





Reactive Power (VAr)

$$PF = \frac{Real\ Power\ (W)}{Apparent\ Power\ (VA)}$$

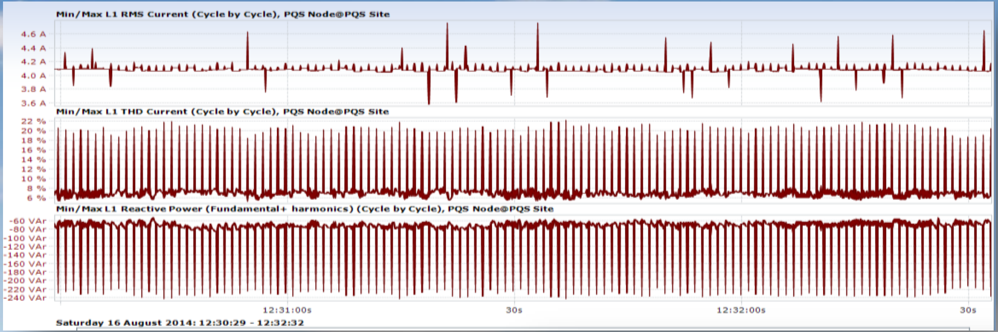
Validation of Test Bench

Lab test bench

Current (A)

THD %

Reactive Power (VAr)

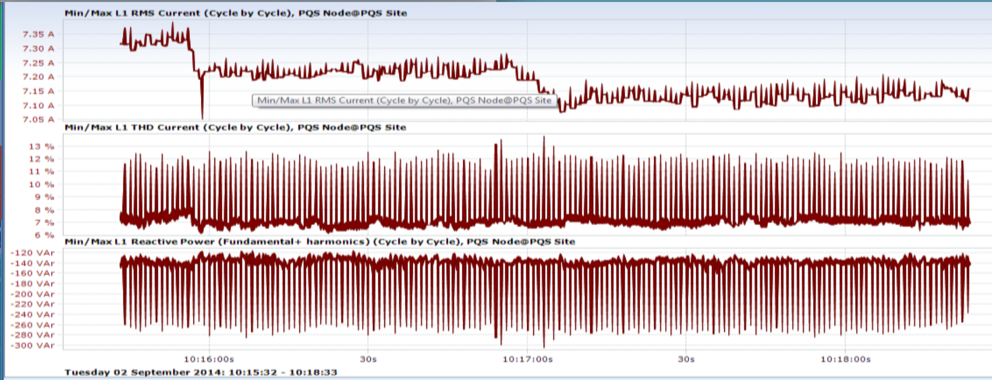


Substation

Current (A)

THD %

Reactive Power (VAr)



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Part 4

RA2.2: Impacts of different scales of DRG deployment on the LV netw...

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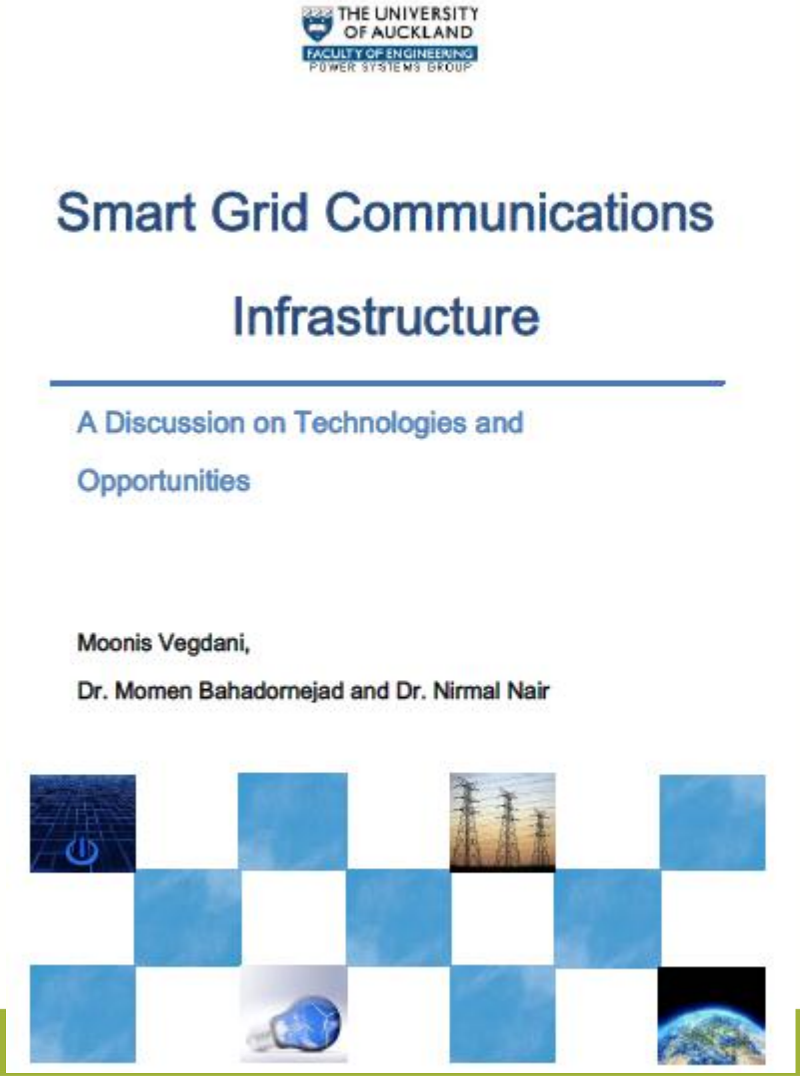
NZ ICT Practices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POWER SYSTEMS GROUP

Smart Grid Communications Infrastructure

A Discussion on Technologies and Opportunities

Moonis Vegdani,
Dr. Momen Bahadornejad and Dr. Nirmal Nair

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ICT Practices in New Zealand Distribution Utilities

Discussion paper on Smart meters, Communication technologies & Ripple control

Jagadeesha Joish, Momen Bahadornejad and Nirmal Nair
(Power Systems Group, University of Auckland)

Notice

This work supported financially by the New Zealand Ministry of Business, Innovation and Employment (MBIE) GREEN Grid project funding. The GREEN Grid project is a joint project led by the University of Canterbury with the University of Auckland's Power System Group and the University of Otago's Centre for Sustainability, Food, and Agriculture, and with a number of electricity industry partners. The project, officially titled "Renewable Energy and the Smart Grid" will contribute to a future New Zealand with greater renewable generation and improved energy security through new ways to integrate renewable generation into the electricity network. The project aims to provide government and industry with methods for managing and balancing supply and demand variability and delivering a functional and safe distribution network in which intermittent renewable generation is a growing part of the energy supply. New Zealand currently generates about 75 percent of its electricity from renewable generation, making it a world-wide leader in this area.

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Standards Based Household Load Control Prototype

Kaium Uz Zaman Mollah, Momen Bahadornejad and Nirmal-Kumar C. Nair
Department of Electrical and Computer Engineering
The University of Auckland
Auckland, New Zealand

***Abstract*—In this paper a platform is developed to facilitate the control of household loads using communication protocols relevant to home automation and substation automation systems. Protection IEDs that support IEC 61850 standard based protocol, universal secondary test gear for relays and a protocol converter are used to realize the protection/automation aspects for substation automation. The retrofitting of the latest relay IEDs with the existing control center software has also been demonstrated. In the home automation space, the available commercial Programmable Logic Controller (PLC) and IEDs are used to develop the platform. The automation load control scheme is programmed based on IEC 61131 standards using structural language and is implemented through EtherCAT protocol. The PLC uses the IEC 61850 server to communicate and gather raw data form the power measurement terminal. The developed platform establishes different aspects of automation and standard based communication system identified the Smart Grid framework. This prototype integrates two different vendors' intelligent electronic devices and implements a smart load shedding algorithm which controls load in real time.**

Keywords*— *Automation, smart grid, load shedding, Programmable Logic Control, Intelligent Electronic Devices (IED).

I. Introduction

The conventional power system is shifting onto smart grid (SG) to meet the various automation and integration needs. The SG consists of the latest technologies and is capable of bidirectional communication between utilities and consumers. Advanced Metering Infrastructure (AMI) comes along with SGs [1]-[2]. AMI is a system that measures and analyzes the energy usage and communicates through a range of media with smart meters. This interconnected advanced network will improve the system reliability and security [3].

In the era of rapid popularity of SG, Intelligent Electronics Devices (IED) and AMI has led to a diverse building/ home automation systems and substation automation to be evolved [4]-[6]. With the increased growth of SG infrastructure and automation systems, there is a need of interoperability between various devices and networks which are provided by a wide range of vendors. Therefore, there has been a development of diverse standards. The abbreviation of SG Friendly Devices defines the devices that can be automatically controlled via SG network [7].

At present the load tripping during under voltage/frequency events is done by triggering the feeders as depicted in Fig. 1. In near future the power consumer premises will be equipped

or an under frequency/voltage event, then they will control electrical appliances in an individual house or a building. Thus, the under voltage issue will be mitigated locally. This helps in relieving the increased stress on the power grid before the issue has any major effect on the main grid system. Thus it ensures the power grid to maintain a stable and healthy condition in the long term [8]-[9]. Therefore this is a smarter way to control loads, balance the power generation to the power consumption and to protect the power grid. The SG automation load control and priority load shedding (LS) are still on a research stage and there is a need to new algorithms to improve the system reliability and security.

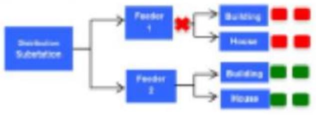

Fig. 1 Conventional load control method

In this paper an intelligent automation platform is developed to facilitate the control of household loads. The substation automation (SA) part of the laboratory test bench presented in this paper is a combination of virtual transmission system with real IEDs and other equipment [2]-[3][5]. The standards communication protocol IEC 61850 has been used for this implementation using GOOSE messaging and the Continuous Function Chart (CFC) programs which is a proprietary device specific programming option. The data collected by IEDs can be broadly categorized as operational data, which are in the form of analog and digital values, and non-operational data which are essentially waveform data.

In the home area (HA) part of the test bench, PLC along with IEC 61850 standards are used to implement the load control algorithm. TwinCAT software was used to write the LS algorithm. The power measurement terminal of PLC samples the relevant dynamic electrical data [10, 11]. This measured data is then compared against the set values in the algorithm (TwinCAT software) to recognize under voltage (UV) events. A load shedding algorithm is implemented using the real time data [12]. The preferences for LS are set by assigning each load with a specific priority number. The load with the lowest priority is shed first. When the controller

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Standards Based Household

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The conventional power system is shifting onto smart grid (SG) to meet the various automation and integration needs. The SG consists of the latest technologies and is capable of bidirectional communication between utilities and consumers. Advanced Metering Infrastructure (AMI) comes along with SGs [1]-[2]. AMI is a system that measures and analyzes the energy usage and communicates through a range of media with smart meters. This interconnected advanced network will improve the system reliability and security [3].

In the era of rapid popularity of SG, Intelligent Electronics Devices (IED) and AMI has led to a diverse building/ home automation systems and substation automation to be evolved [4]-[6]. With the increased growth of SG infrastructure and automation systems, there is a need of interoperability between various devices and networks which are provided by a wide range of vendors. Therefore, there has been a development of diverse standards. The abbreviation of SG Friendly Devices defines the devices that can be automatically controlled via SG network [7].

At present the load tripping during under voltage/frequency events is done by triggering the feeders as depicted in Fig. 1. In near future the power consumer premises will be equipped

SMART METER ENABLED CONTROL OF EXISTING AND FUTURE HOUSEHOLD LOADS

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Abstract

People all over the world are consuming more and more electrical energy each day. As a result there is a greater need for smarter and more adaptable power systems. Through smarter electrical technology, consumers will be able to have a greater understanding of their daily power consumption and control of their home appliances. Utility companies will be able to have a greater understanding of consumers power consumption activities which would help in making the network more efficient. This paper describes the implementation of a Smart Meter enabled control of existing and future household loads. A prototype was developed, simulated as a Smart Home to show the behaviour of a typical home during times of peak demand. A load control priority algorithm is presented. This algorithm looks into a hypothetical setting for a consumer with a range of loads and differing importance of each load during a 24 hour cycle.

1. Introduction

We are living in a world where we are consuming more electrical energy than ever before. As a result a need for smarter technology is required to ensure the stability of our power systems network. Smart Grid technologies are paving the way for the future for the power systems industry. A Smart Grid incorporates both digital and analogue technology for two-way communication between the utility company and the consumer. Embedded within the Smart Grid is a Smart Meter. The Smart Meter is a device installed in a customers' home. The Smart Meter is more advanced than the conventional meter installed in homes. Smart Meters are able to measure real-time energy consumption which include a vast amount of information that is beneficial to the utility. This includes power, voltage, phase angle and frequency which can then be relayed back to the utility for proper billing for customers. The Smart Meter

Automated Meter Reading (AMR) Systems, Automated Meter Management (AMM) and Advanced Metering Infrastructure (AMI). In the past most metering systems (AMR) were only capable of one-way communication, meaning directly from the meter to the utility. Over time newer technologies were being made available. AMM allows two-way communication between the customer and the utility. The two-way communication allows for commands to be uploaded to the meter and data downloaded from the meter[1]. AMI systems which are now referred to as "Smart Meters" also use two-way communication. However the AMI system measures, collects and analyses energy usage, and communicates either on request or on a schedule where the communication is either wireless or wired[2].

The electrical power that is supplied should always equal the electrical power that is in demand. As demand keeps increasing electrical companies will need to make use of inefficient backup generators which in turn create extra costs for customers. Construction of new generators and transmission networks will be required to cope with increased electrical demand. Demand Side Management (DSM) is a very important concept when it comes to load management for the customer of a household. Utilities usually have an agreement with the customer in regards to their total power consumption. When the utility experiences a problem in the network, customers who have opted into a certain demand side management plan will have some of their loads curtailed so that the total energy consumption is reduced and the impact on the utility network is reduced [3]. This way the customer and the utility are benefiting, the customer gets a lower power bill while the utility experiences less demand.

This report presents a method of smart load control using a Smart Meter to control common household devices. The report will be organised as follows, Section

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Contents

Question	Response
Q1: What is the technology used for Advanced Metering Infrastructure?	
Q2: Are Smart meters roll-out and establishment of communication medium going on simultaneously? If the answer is 'No', then what is the anticipated time for the establishment of communication medium?	
Q3: Do you agree that peak consumption timing for consumers will change after arming smart meter with dynamic pricing?	
Q4: To achieve discussion point (item a), it may be necessary to	

Smart Metering in NZ

- Most of the distribution companies in NZ are actively involved in replacing the old meters with smart meters
- Over **60% (1.2 Million)** of electricity meters in NZ would be smart meters after April 2015

Status of Smart meter implementation	No. of Companies	% of Consumer connections under this status
Initiated / will be initiated shortly	10	15.80%
Installing	9	40.57%
Installed in most part of the network	4	38.67%
Planning and deployment in coming years	6	4.95%

Communication

- More than 80% of the distribution companies in NZ use VHF and UHF radio links
- Microwave radio links have been used by 6 distribution companies (around 21% of total companies)
- 9 distribution companies are using copper cables (around 31% of total companies)
- 21 distribution companies are using optical fibre infrastructure (around 72% of total companies)
- A few distribution companies are also using Cellular data modems

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Ripple Control

- Ripple control has been used in NZ since many decades
- Different frequencies used by distribution companies are 175 Hz, 216⅔ Hz, 217 Hz, 233 Hz, 283 Hz, 297 Hz, 315 Hz, 317 Hz, 475 Hz, 492 Hz, 500 Hz, 725 Hz, 750 Hz, 1050 Hz and 1250 Hz

Questions

- To differentiate the practices followed by the line companies, it is necessary to cluster them on some basis.
  - **Q1: What is the technology used for Advanced Metering Infrastructure?**
- the establishment of communication medium is also important to enable the information exchange between the utility and the consumer.
  - **Q2: Are Smart meter roll-out and establishment of communication medium, going on simultaneously?**
- The Advanced Metering Infrastructure coupled with dynamic pricing may help in shifting the timing of certain activities of the consumers .
  - **Q3: Do you agree that the peak consumption timing of consumers will change with smart meter enabled dynamic pricing?**

Questions

- The Advanced Metering Infrastructure coupled with dynamic pricing may help in shifting the timing of certain activities of the consumers .
  - **Q4: To achieve the above point, it may be necessary to integrate the smart meters with Home Energy Management Systems (HEMS). Do you have any plans in this regard?**
  - **Q5: Do you have any plans to install In-Home Displays OR similar arrangements at consumer locations?**
- The distribution companies are using different communication technologies for reliable operation of the system.
  - **Q6: If the existing communication links are old and needs replacement, then what is the alternative technology planned for implementation?**

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Questions

- Gathering the information from distribution transformer sites would help in understanding and improving the quality of the power being supplied.
  - **Q7: What types of meters are installed at distribution transformer sites?**
- Ripple control has been used in New Zealand for many decades and still it is effectively being used.
  - **Q8: Are you planning to use smart meters as an alternative to ripple control? What is timeline?**
  - **Q9: It is anticipated that the smart meter roll out would lead to significant adoption of price based DR. What is your view on this?**

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Questions

- The Electricity Authority guidelines for the use of smart meters are not mandatory
- From 1 April 2015, for those customers who refuse a smart meter, electricity distributors will be able to recover the costs of a separate meter reading (like Victorian Government (Australia))
  - **Q10: What is your opinion on having a common platform for the AMI implementation?**
  - **Q11: What if the regulations similar to Victorian government is implemented in New Zealand? What is your view?**

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Conclusions

- Some exemplars of the 2014 NZ protection survey report highlighted
- Issues for active distribution network protection in 3 zones presented
    - Impacts assessed and some solutions introduced which need further implementation details developed , tested and assessed
- VECTOR's PV trials during 2013-14 addressed
    - Basic and Advanced tests of inverters are required before implementing PV business plans of other line companies
- NZ ICT technologies for 29 utilities summarized & submissions sought
    - Good to have a consensus driven and consistent platform for advanced metering infrastructure in New Zealand
- Experience/progress so far will help develop effective and consistent methods for NZ distribution networks protection in CS 2.3.4 phase

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