Security and Reliability Council

Reliability-related matters from the GREEN Grid project

5 October 2016

Note: This paper has been prepared for the purpose of the Security and Reliability Council (SRC). Content should not be interpreted as representing the views or policy of the Electricity Authority.

Background

The Security and Reliability Council (SRC) functions under the Electricity Industry Act 2010 (Act) include providing advice to the Electricity Authority (Authority) on security and reliability of supply matters.

To this end, the SRC created an action for the secretariat to:

> "…request for a representative from the Green Grid project to attend and present to a future SRC meeting, by no later than the second SRC meeting of 2017"

In response to this, the secretariat invited the GREEN Grid project to send a representative at a time when there was appropriate material to present. Dr Allan Miller has accepted the invite for the GREEN Grid project and the secretariat anticipates the presentation will touch on:

- voltage quality issues associated with solar photovoltaic deployment
- the development of a connection guideline for solar photovoltaics
- frequency quality in light of increased wind penetration.

The presentation will be given by Dr Miller at the SRC's 19 October 2016 meeting. No slides or presentation material has been included with the papers sent to members.

Dr Miller is the Director of the Electric Power Engineering Centre at the University of Canterbury. Following a competitive tender process , the University of Canterbury was awarded the contract to conduct the GREEN Grid research by the Ministry of Business, Innovation and Employment (MBIE). MBIE is the primary funder, though the project is co-funded by Transpower and the Electricity Engineers' Association.

The SRC may wish to consider the following questions.

Q1.	What further information, if any, does the SRC wish to have provided to it by the secretariat?
Q2.	What advice, if any, does the SRC wish to provide to the Authority?

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ELECTRIC POWER ENGINEERING CENTRE

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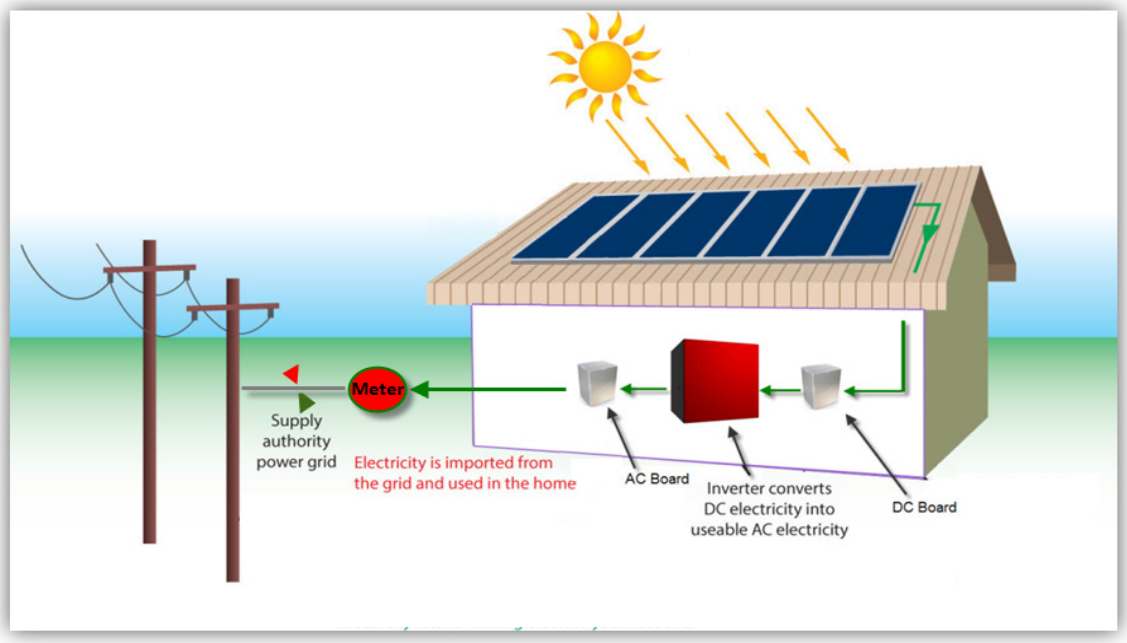
Guideline for the connection of solar PV to Manage Voltage Quality & Reliability and other GREEN Grid Research

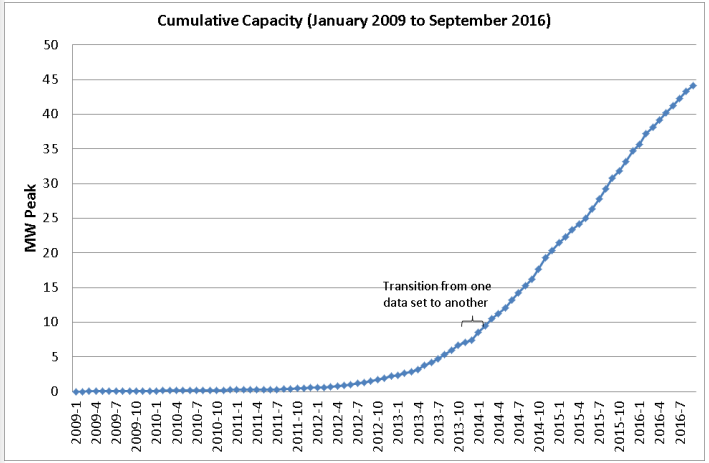
Security and Reliability Council, 19 October 2016

Dr Allan Miller, EPECentre & GREEN Grid Director

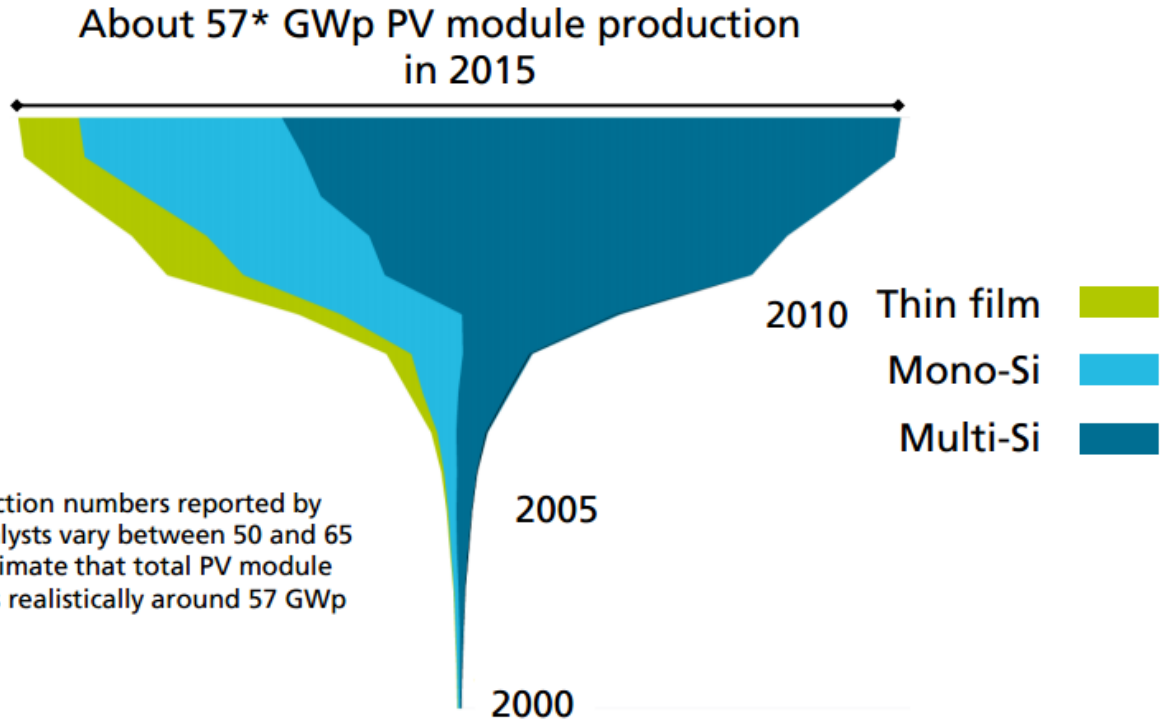
- Introduction: Global photovoltaic (PV) market & GREEN Grid
- Voltage quality issues associated with solar PV deployment
- The development of a connection guideline for solar PV
- Frequency quality in light of increased wind penetration

Global PV Market & GREEN Grid



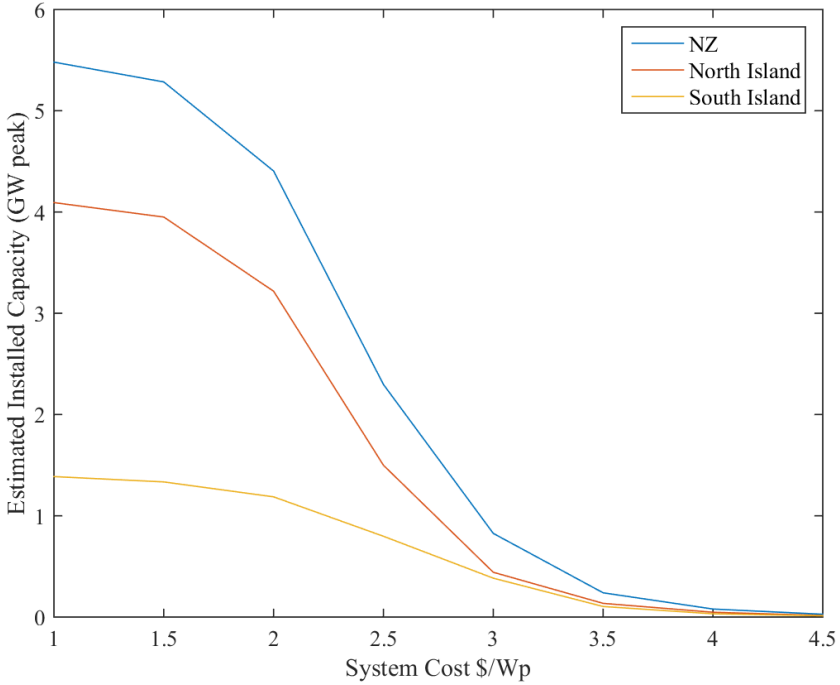


Global Photovoltaic Market



©Fraunhofer ISE: Photovoltaics Report, updated: 6 June 2016
Data: from 2000 to 2010: Navigant; from 2011: IHS. Graph: PSE AG 2016

Estimated Maximum PV Uptake

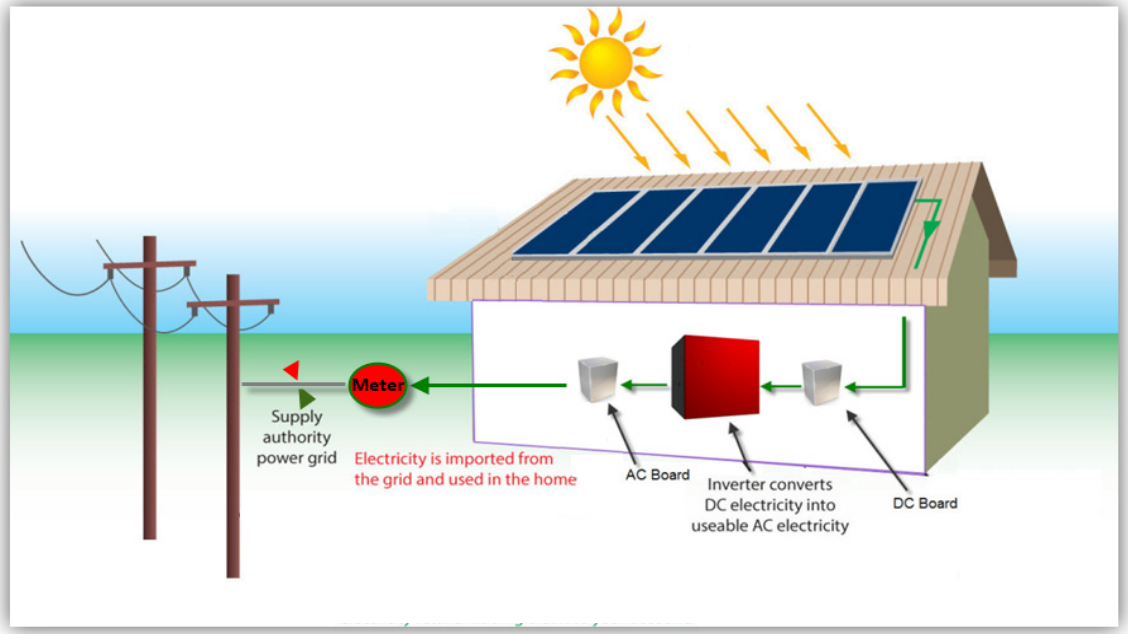


Consistent connection requirements and standardization across EDBs. Benefits EDBs, installers, inverter manufacturers, and electricity customers

From: The Economics and Potential Uptake of PV Solar Power by Region and PV System Cost, Dr Sharee McNab, Dr Allan Miller, Scott Lemon, Dr Alan Wood, 2016

GREEN Grid

- Investigate and Facilitate more renewables
- PV Solar Power



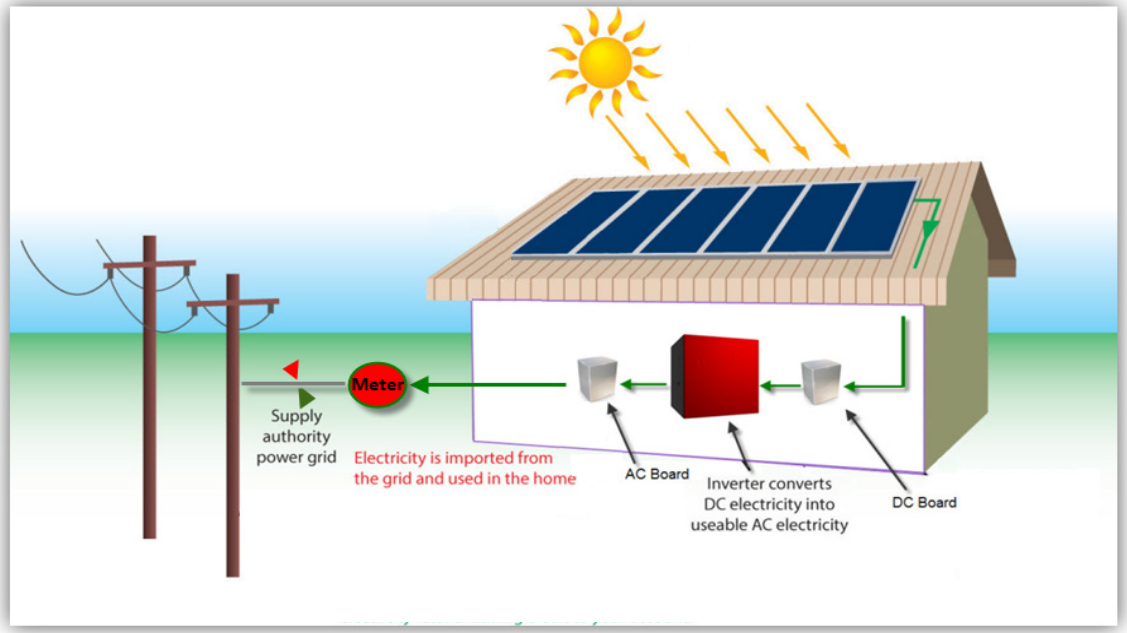
2016 GREEN Grid Achievements

energywise™ Solar Calculator

- Give householders impartial information to make decisions
- Educate the public about solar power
- Goes live 27th!

DGHost
(Support EDB decisions)

EEA SSDG Connection Guideline
(Power quality, reduce costs)



- Introduction: Global photovoltaic (PV) market & GREEN Grid
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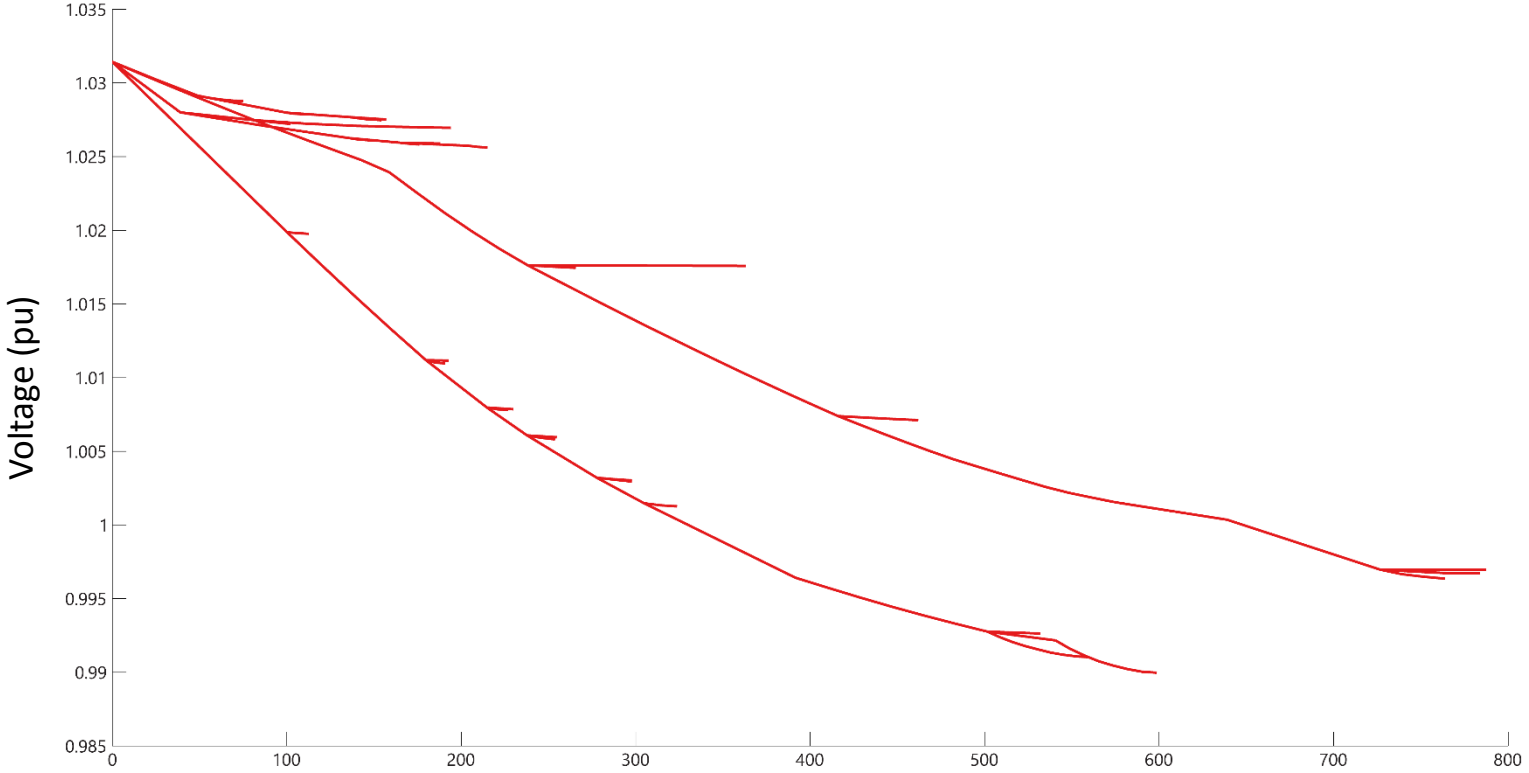
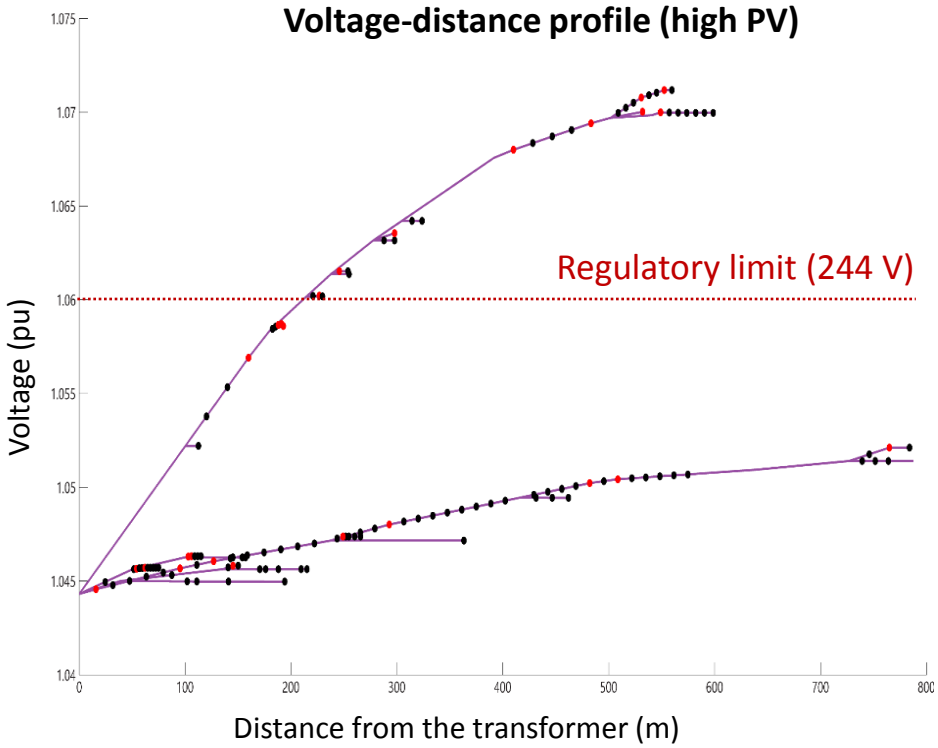
Voltage-distance profile for an LV network (moderately loaded, no gen)



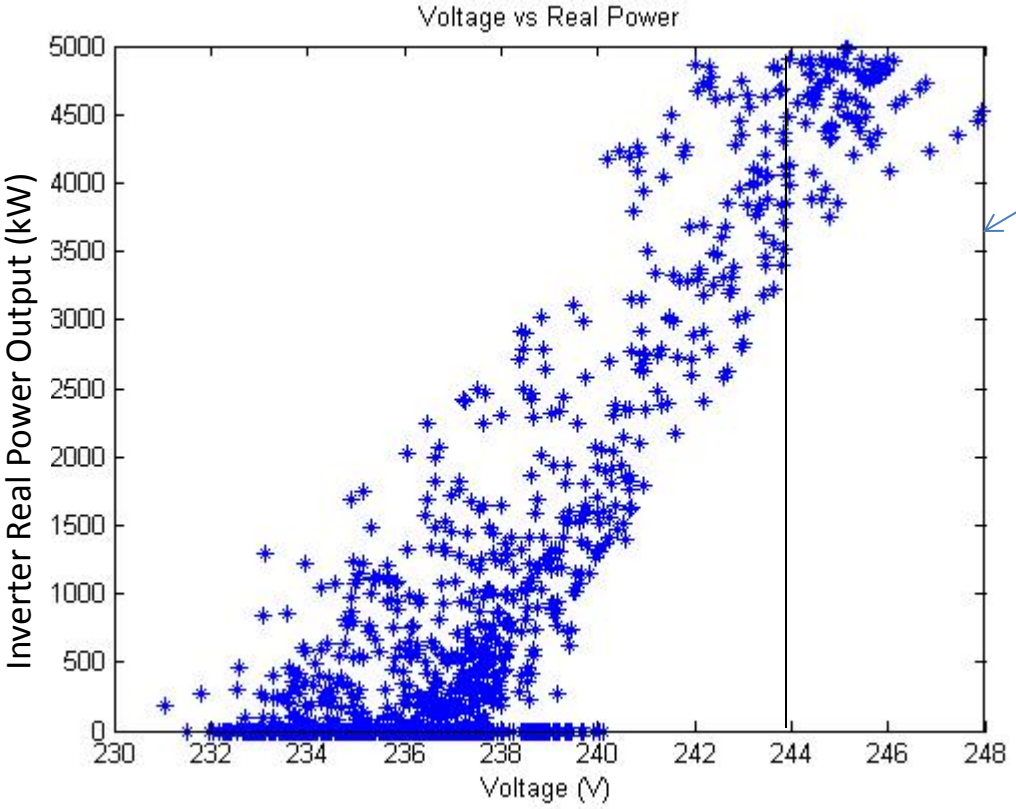
Voltage-distance profile for an LV network (lightly loaded, high PV)

DG can introduce reverse power flow into the LV network, which causes issues of:

- Over-voltage (>1.06 p.u.)
- Phase imbalance
- Over-loading of conductors
- Over-loading of transformer
- Safety and Protection



Voltage Measurements with PV



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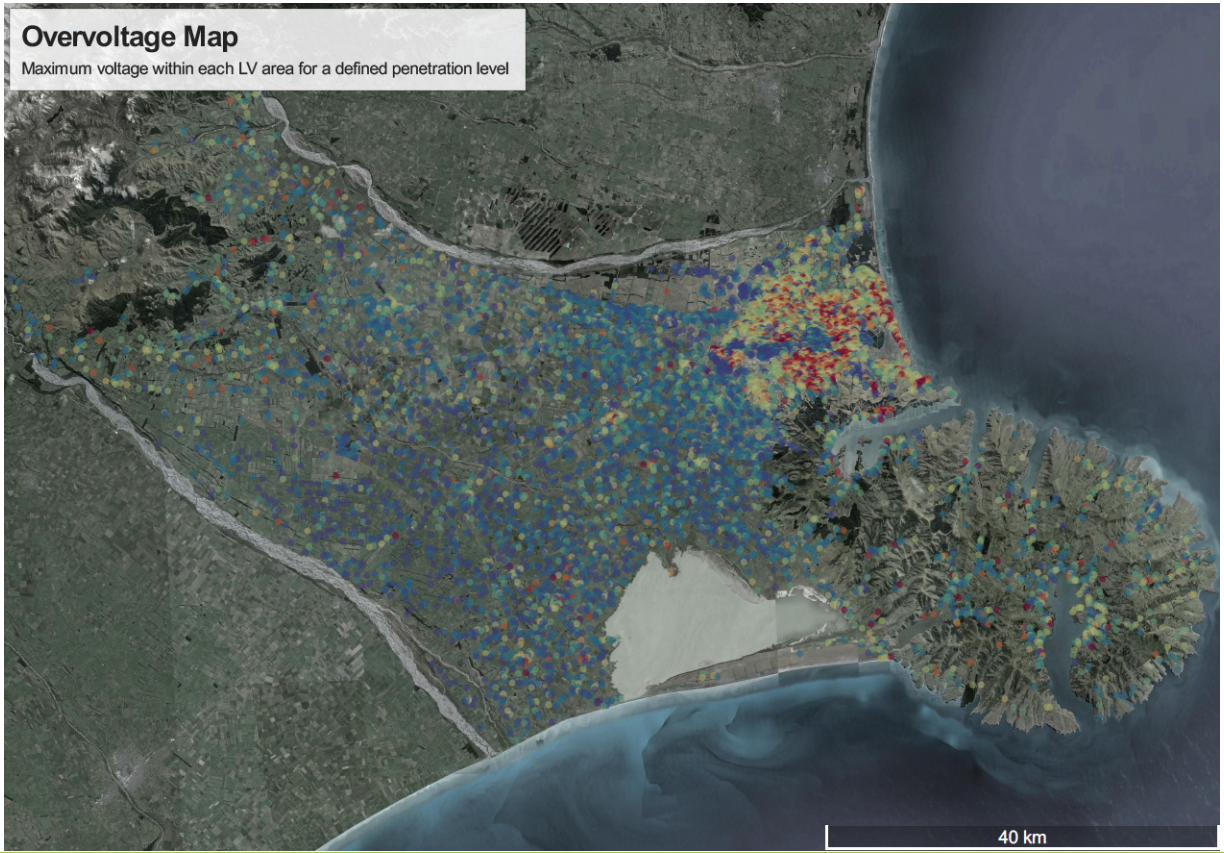
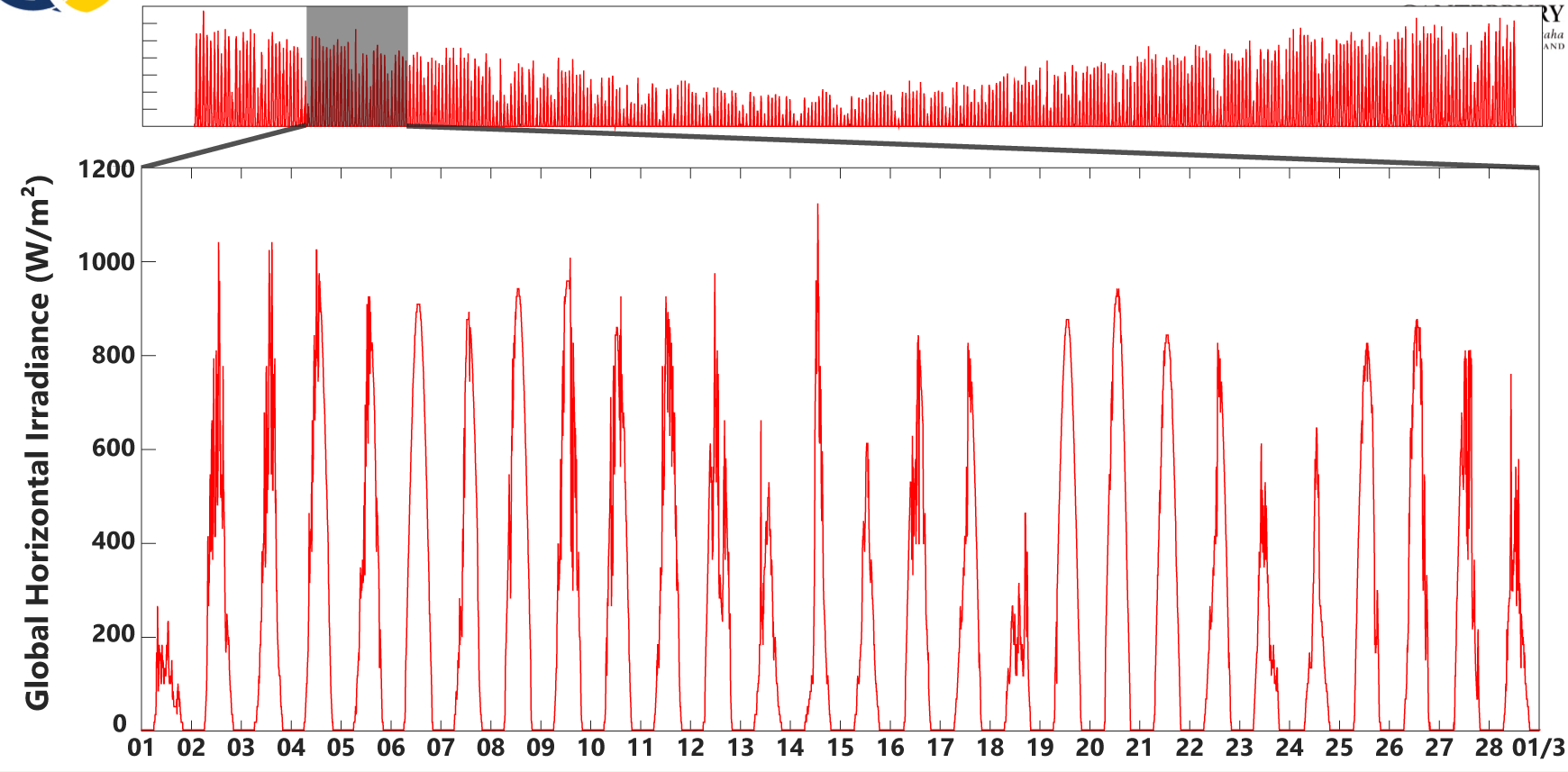
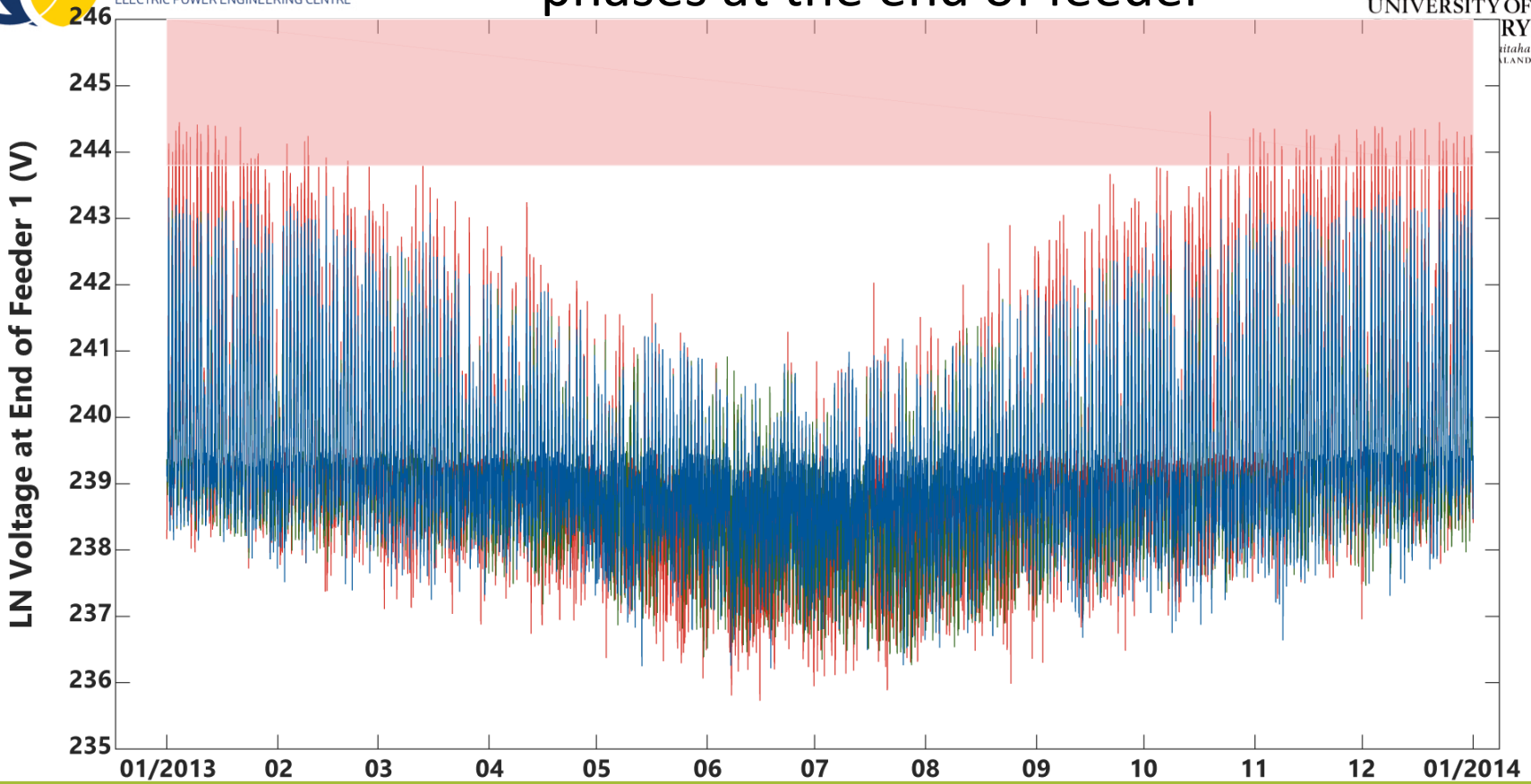


Irradiance time series for simulation in the network



Phase-to-neutral voltage across all phases at the end of feeder



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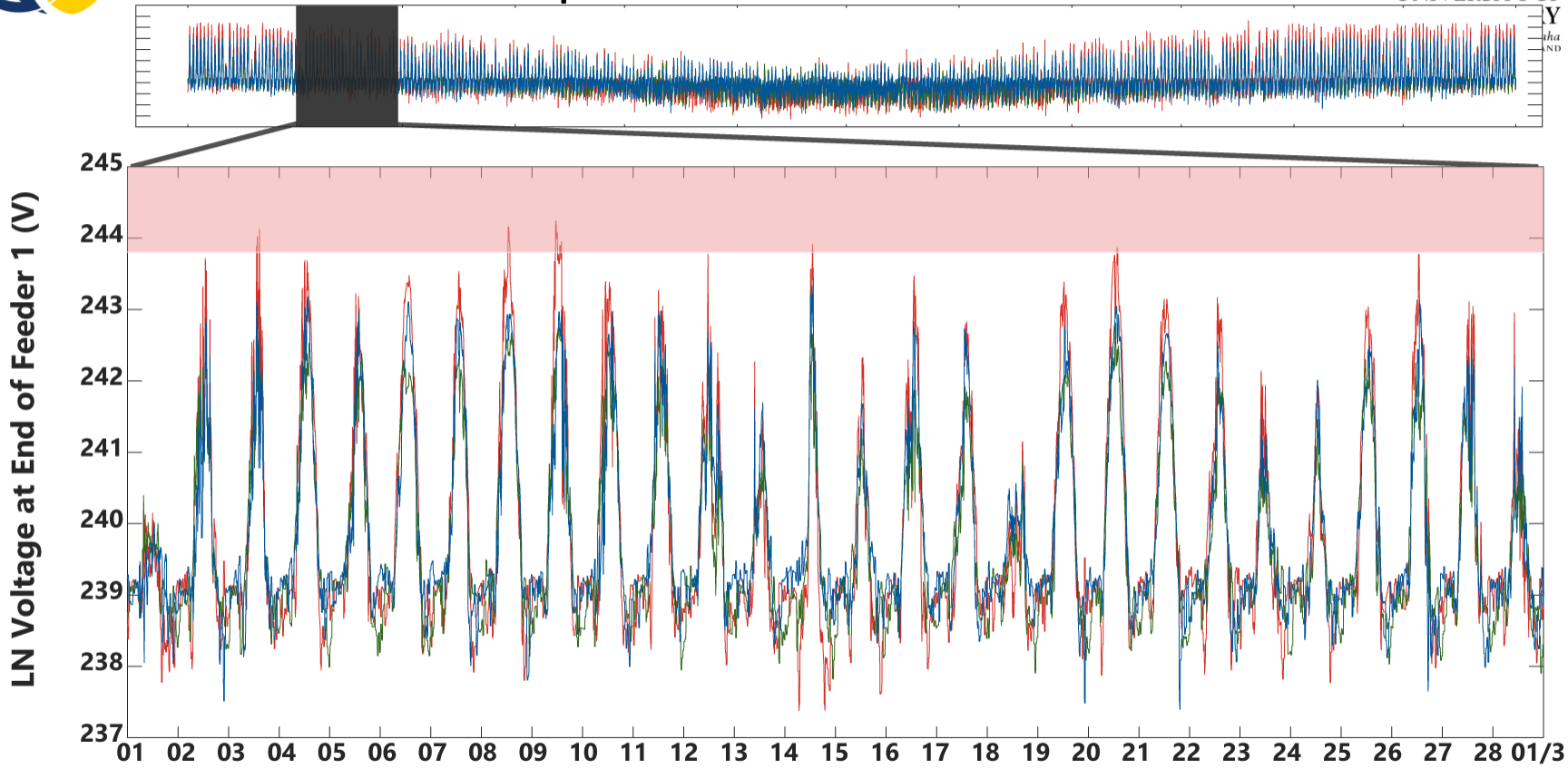

- Introduction: Global photovoltaic (PV) market & GREEN Grid
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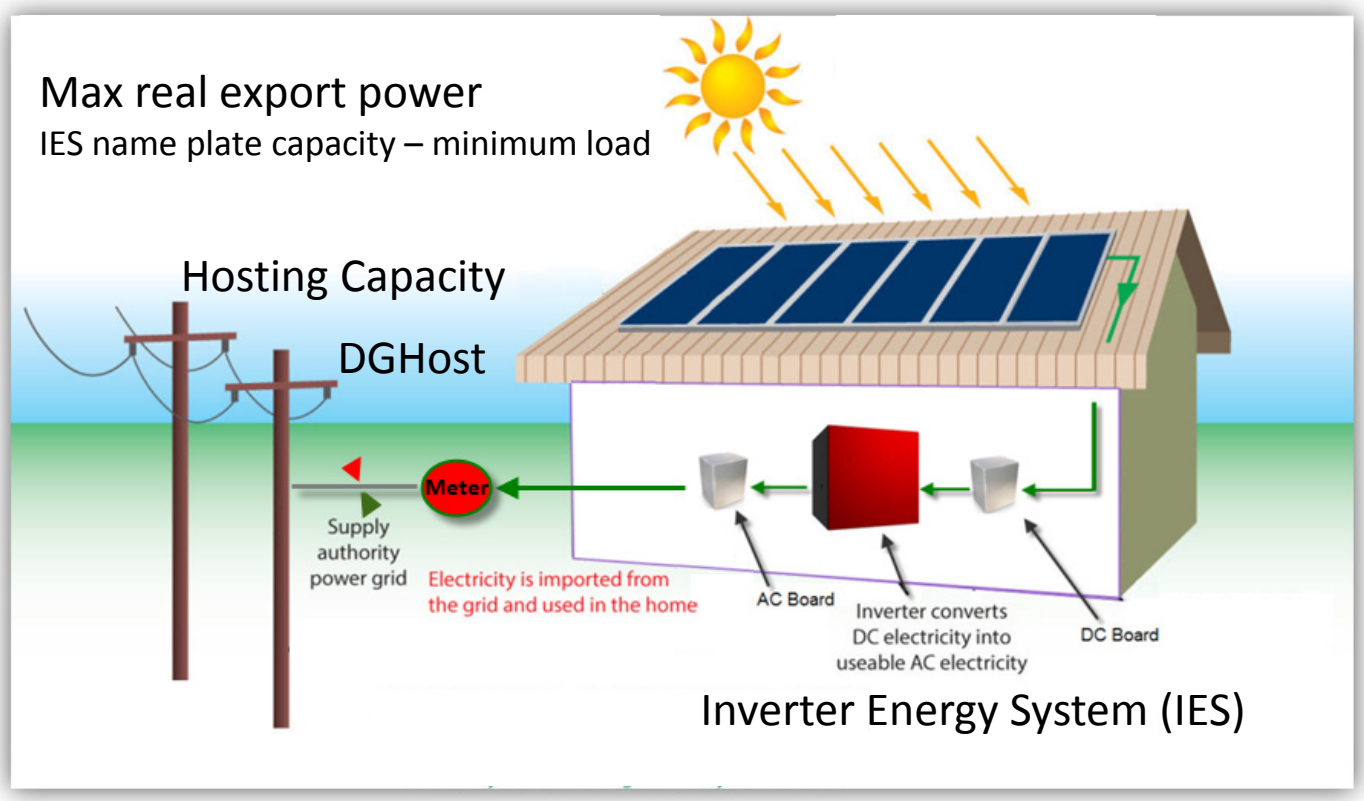
Guideline Mission

- Reduce PV application processing time and cost for EDBs
- Make PV application easier for the customer
- Avoid additional network costs in the future

Important Terms
Rooftop Photovoltaic (PV) Solar

LV Network



Introduction and Issues to Address:

DG Connection Application Assessment

The Situation

- Assessment of connection applications is typically a manual procedure
- No consistent approach to assessing applications and connection requirements across EDB's
- Technical complexity of assessment compounded by introduction of advanced inverter technology – as captured in the new *AS/NZS 4777.2 (2015) – Grid connection of energy systems via inverters – Part 2: Inverter Requirements*

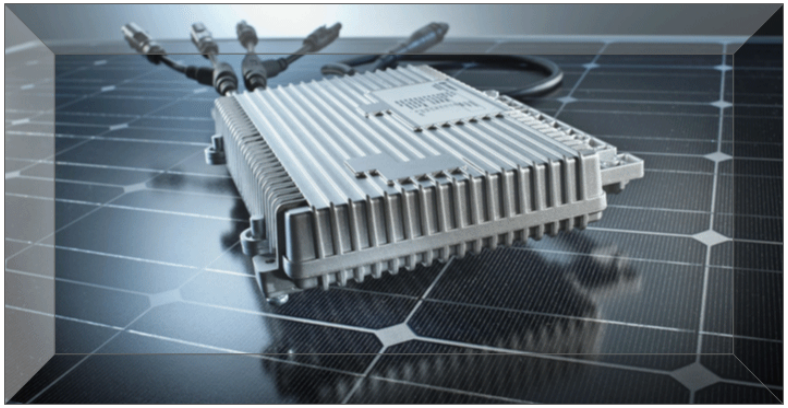
Some Questions

- What criteria should an EDB use to assess a connection application under the EIPC Schedule 6.1, Part 1A up to 10 kW export power?
- What information does the EDB need from the applicant on the DG application form?
- Can an application be auto-assessed, and if so, when should an application be manually assessed?
- Are there circumstances when an applicant can use low cost inverter technology (e.g. which does not have power quality response modes)?

Providing consistent connection requirements and standardization across EDBs would be of major benefit to installers, inverter manufacturers, and consumers

Introduction and Issues to Address:

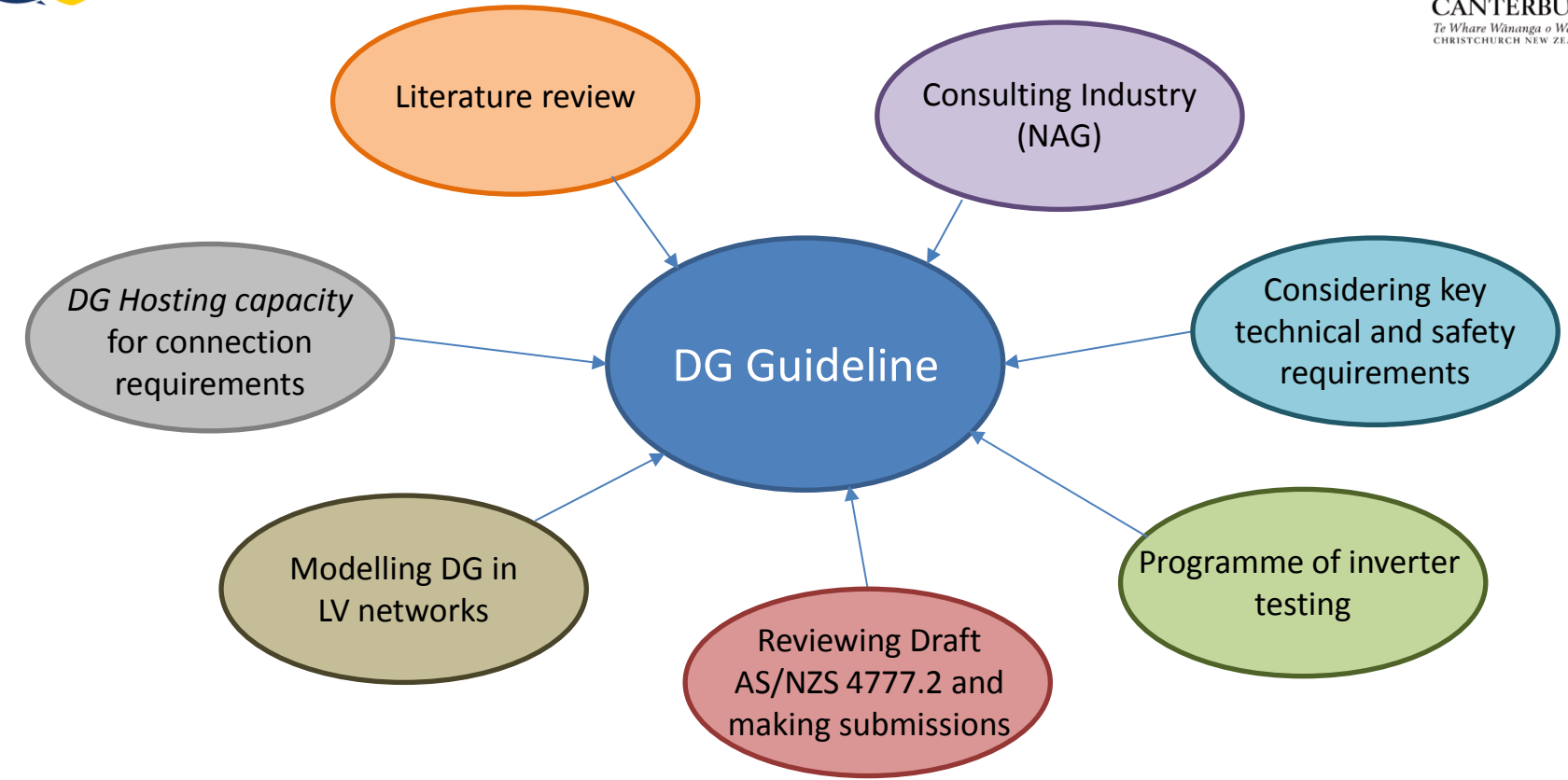
AS/NZS 4777.2 (2015) – Grid connection of energy systems via inverters – Part 2: Inverter Requirements



Questions

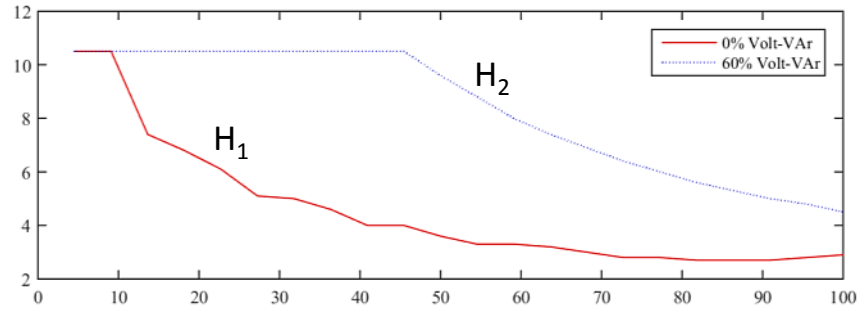
- What inverter protection settings are appropriate for NZ?
- How should inverter power quality response modes be applied here?
- Does AS/NZS 4777.2 provide all the appropriate information and suitable requirements for the NZ context?
- Can inverters actually perform as required?
- What are the technical requirements for the installation?

Methodology to develop the DG Guideline

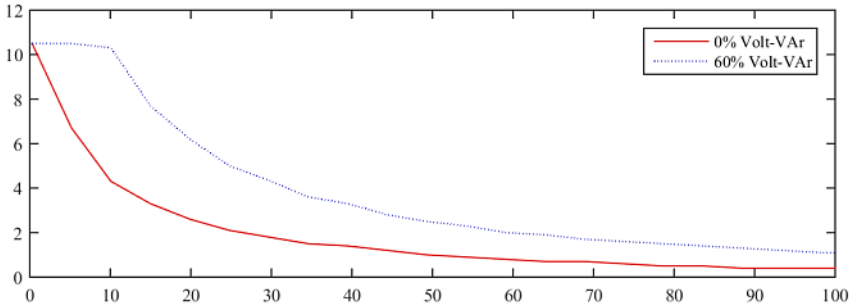


Hosting Capacity Network Examples (Max export power before congestion)

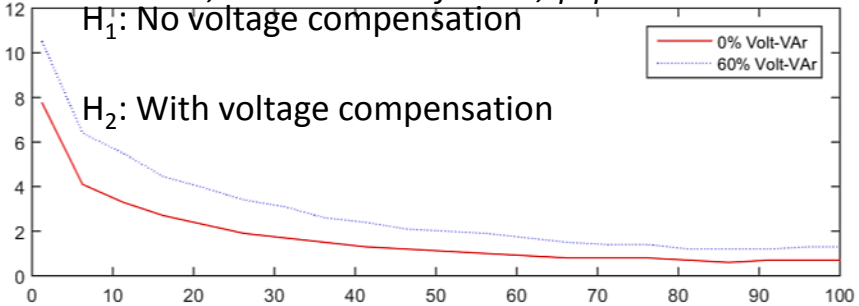
22 ICPs, 100 kVA transformer, |Z| = 0.2026 Ω



347 ICPs, 750 kVA transformer, |Z| = 0.1582 Ω



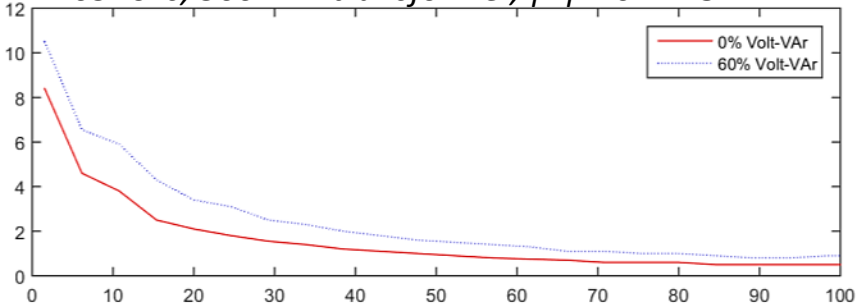
80 ICPs, 300 kVA transformer, |Z| = 0.2849 Ω



H_1: No voltage compensation

H_2: With voltage compensation

65 ICPs, 500 kVA transformer, |Z| = 0.2723 Ω

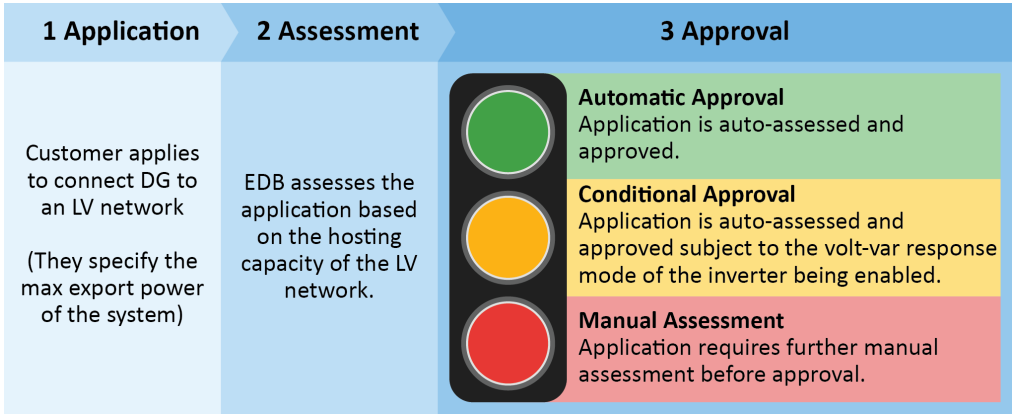


DG hosting capacity (kW)

DG penetration level (%)

DG Connection Application Assessment Process:

Traffic light system



Customer DG Application	LV Network Hosting Capacity Outputs	
Max real export power [kW]	Connection threshold H_1 [kW] (upper limit for no mitigation)	Connection threshold H_2 [kW] (upper limit with mitigation – Volt-VAr response)
4.5	2.7	7.2

Guideline: What it Provides

- Reduce PV application processing time and cost for EDBs
  - National guidelines, developed across EDBs
  - Models to support decision making when assessing applications
- Make PV application easier for the customer
  - National guidelines that all EDBs could adopt, thereby providing a uniform method to all installers, with training
- Avoid additional network costs in the future & improve reliability
  - Orderly allocation of PV
  - Ensure compliance with standards and safety
  - Make use of in-built inverter voltage control – smart grid
  - More fully realises the hosting capacity of a network
  - Ensure appropriate frequency settings
  - Ensures voltage limits are not exceeded

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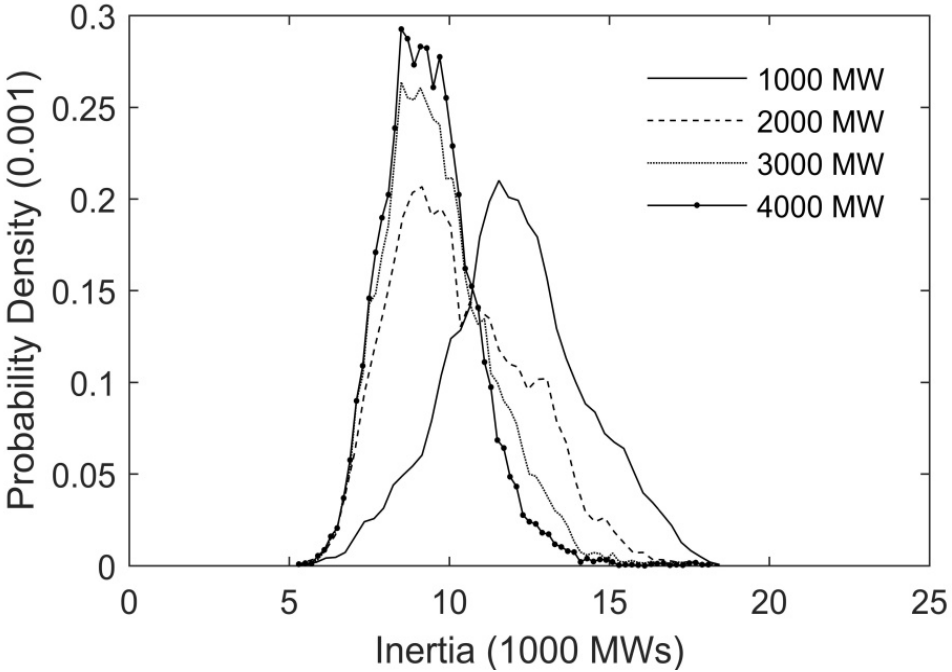
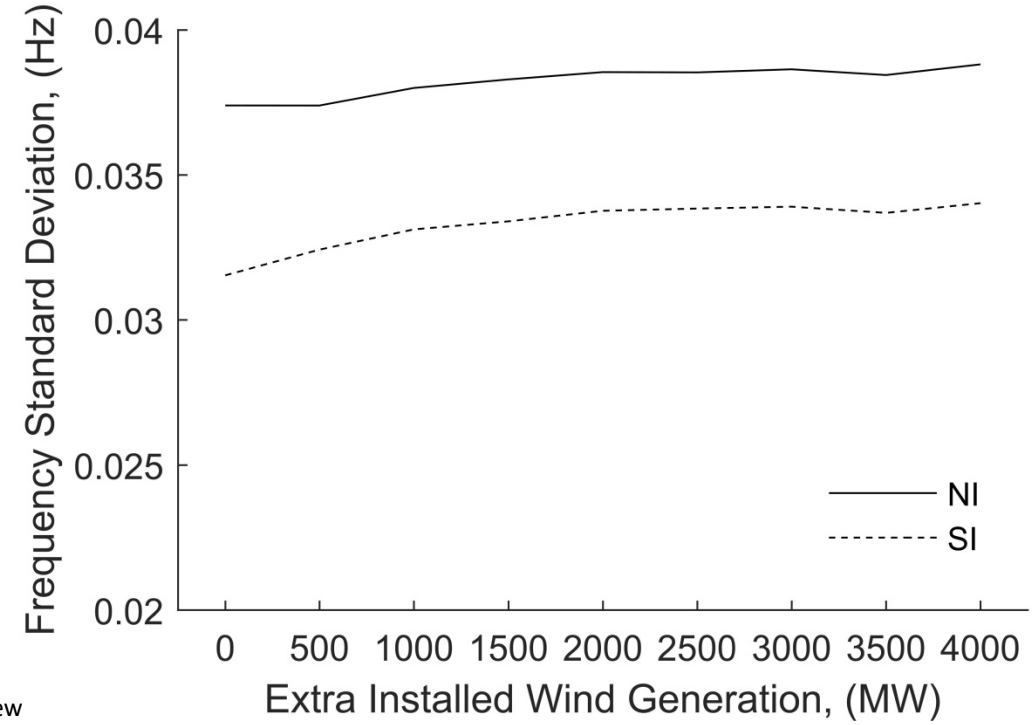
North Island Inertia with Increasing Wind Capacity



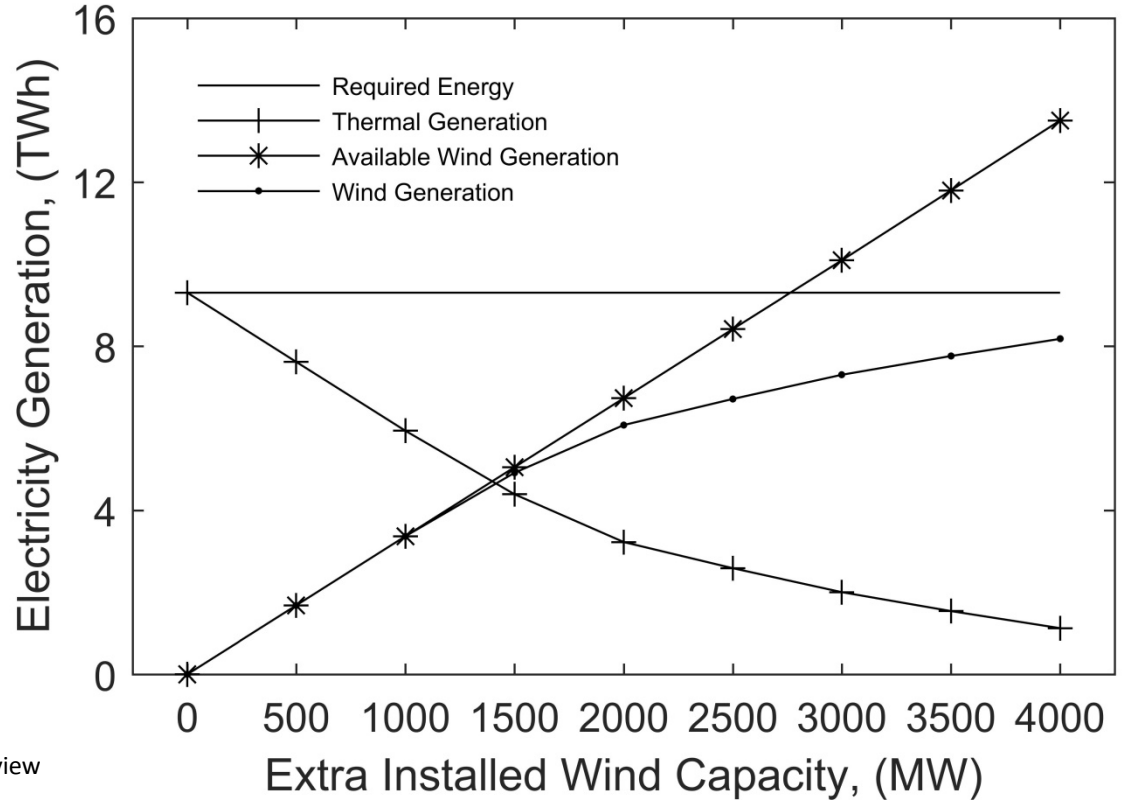
Preliminary results, under review

Frequency Quality with Increasing Wind Capacity



Preliminary results, under review

Generation Dispatch with Increasing Wind Capacity



Preliminary results, under review

Discussion

- Introduction: Global photovoltaic (PV) market & GREEN Grid
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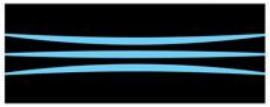

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Further Reading

www.epecentre.ac.nz/research/papers.shtml

- The EECA energywise™ PV Solar Calculator, Dr Alan Wood, Dr Allan Miller, Dr Sharee McNab, Scott Lemon
- Guideline for the connection of small-scale inverter based distributed generation: an introduction and summary, Dr Allan Miller, Dr Richard Strahan, Dr Sharee McNab, Tim Crownshaw, Shreejan Pandey, Prof. Neville Watson, Scott Lemon, Dr Alan Wood
- The Value of Frequency Keeping and Governor Response to New Zealand, Josh Shipper, Dr Alan Wood, Conrad Edwards, Dr Allan Miller
- The Economics and Potential Uptake of PV Solar Power by Region and PV System Cost, Dr Sharee McNab, Dr Allan Miller, Scott Lemon, Dr Alan Wood
- Small-scale PV inverters - New equipment standards versus actual performance, Dr Bill Heffernan, Patrick Chen, Ankur Mishra
- Determination of Distributed Generation Hosting Capacity in Low-voltage Networks and Industry Applications, Tim Crownshaw, Dr Allan Miller, Scott Lemon, Dr Sharee McNab, Dr Richard Strahan
- Impact of Solar Photovoltaics on the Low-voltage Distribution Network in New Zealand, Jeremy Watson, Professor Neville Watson, David Santos-Martin, Alan Wood, Scott Lemon, Dr Allan Miller
- Economics of Photovoltaic Solar Power and Uptake in New Zealand, Dr Allan Miller, Dr Michael Hwang, Scott Lemon, Dr E. Grant Read and Dr Alan Wood
- Environmental Aspects of Photovoltaic Solar Power: The New Zealand Context, Luke Schwartfeger and Dr Allan Miller