High penetration solar PV experience

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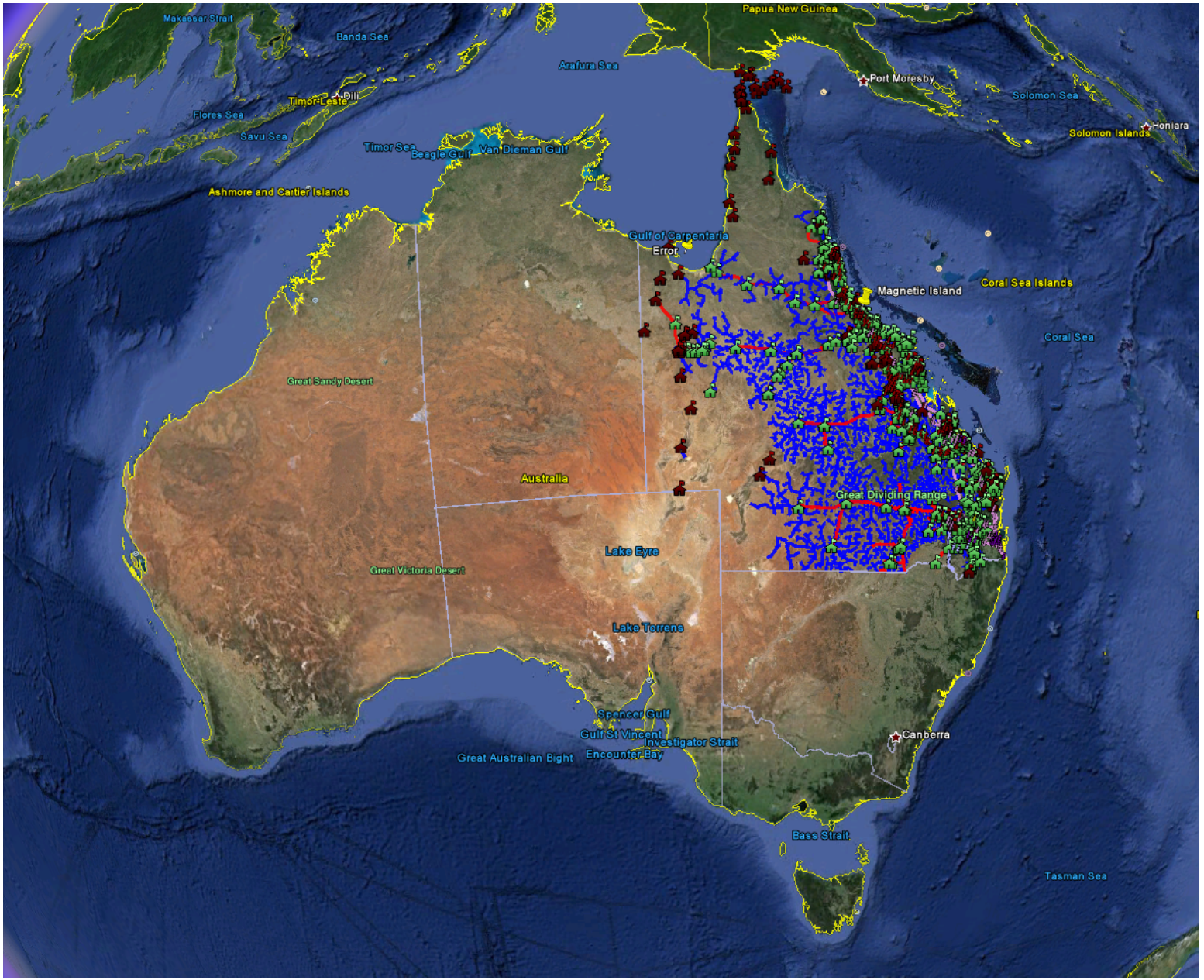
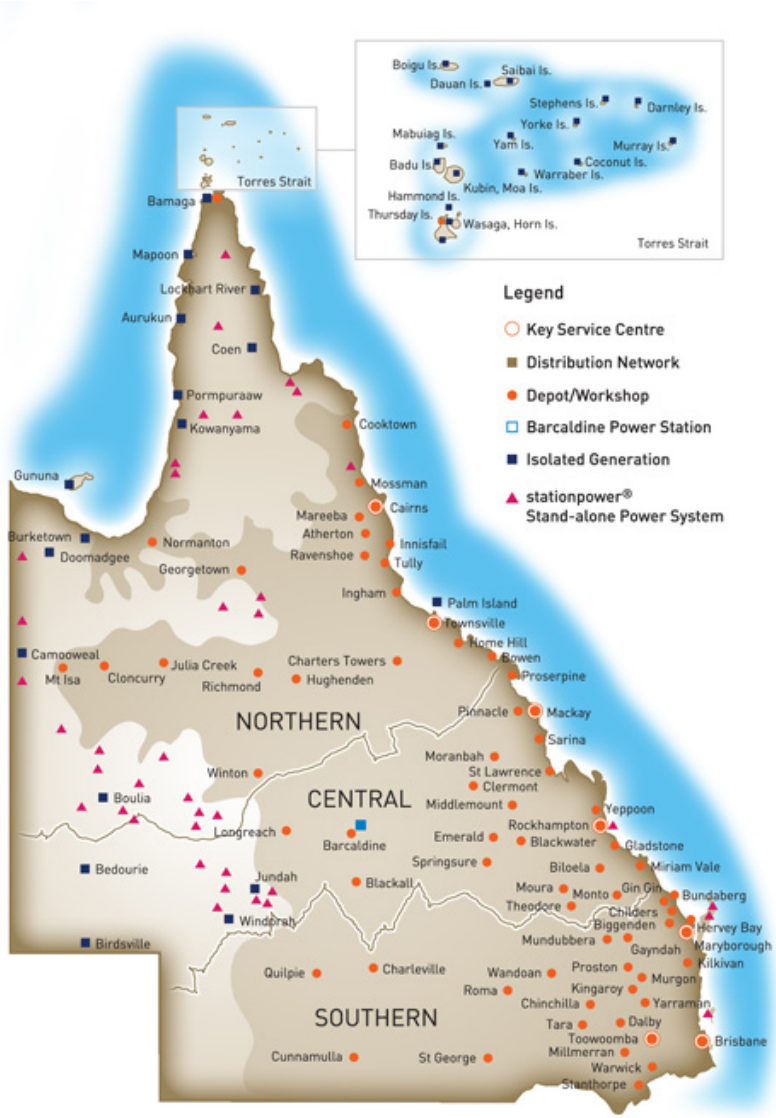
November 2013

Ergon Energy



Ergon Energy

- Distributer & Retailer
- 33 remote generators
- 1.7 million sq km area
- 97% of Queensland
- 150,000 km on line
- Small customer base – 700,000
- $2.7 B revenue
- $11 B asset value
- 4500 employees



Solar City Project: overview

- Reduce peak by 27%
- Reduce energy use by 25%
- Around 2500 smart meters
- 1700 energy audits
- About 1MW of solar PV
- Demand management
- Tariff trials
- Community Engagement

Australian Government
Solar Cities

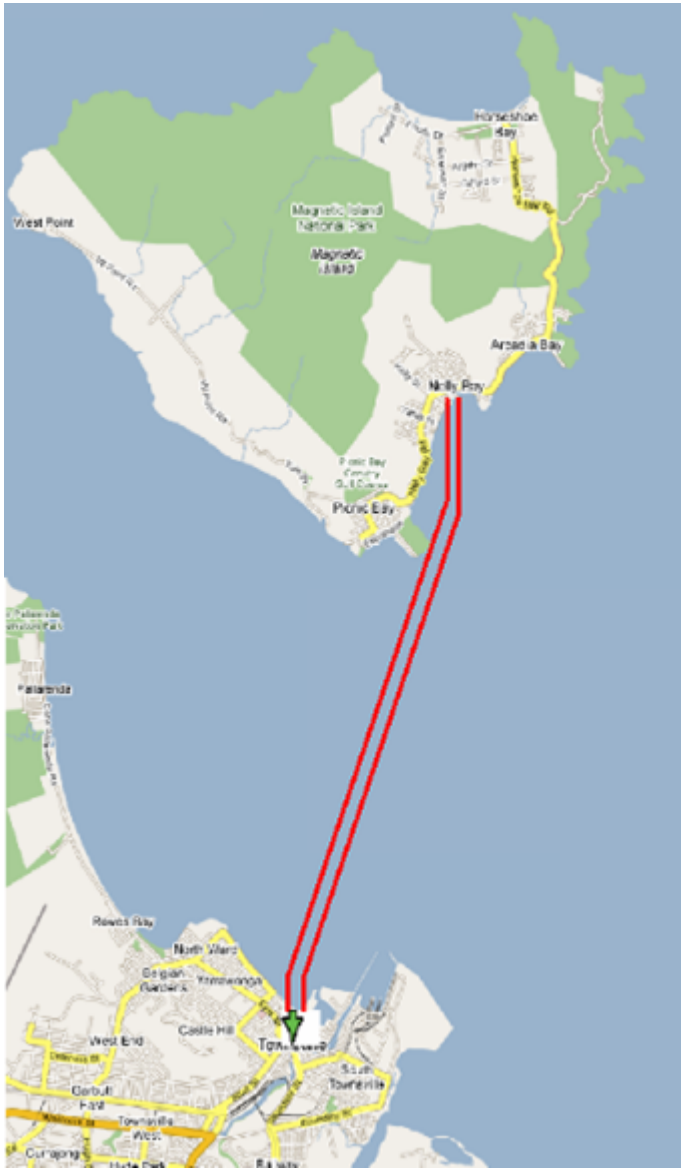
Queensland Government

City of Townsville

One word, Delfin

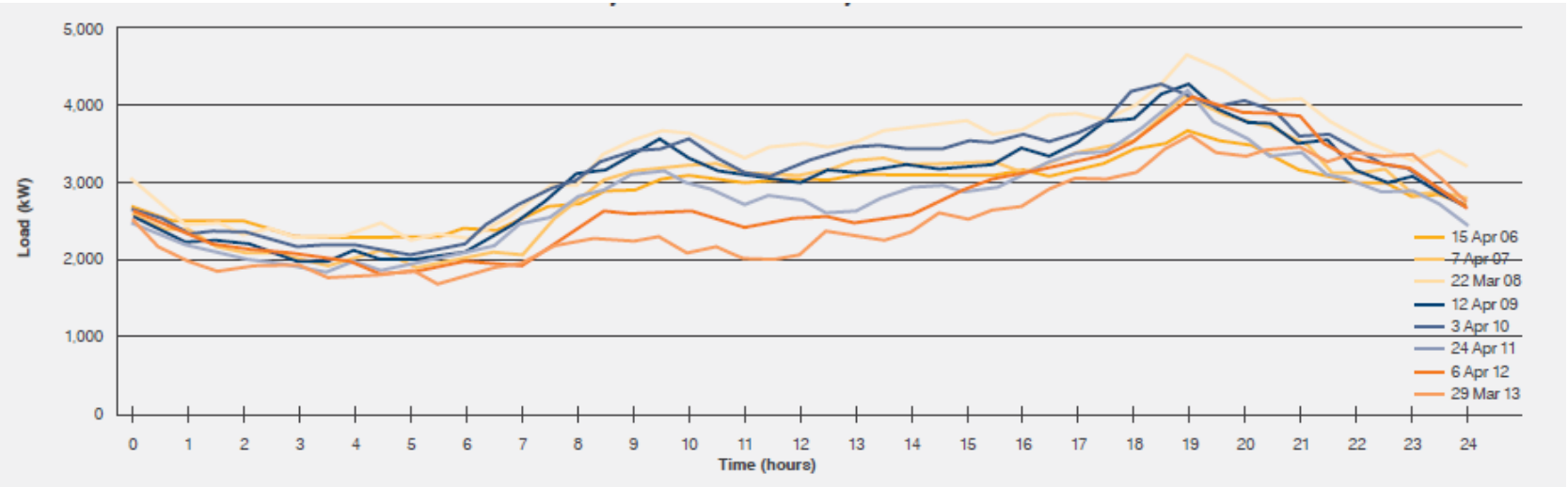
HONEYCOMBES PROPERTY GROUP

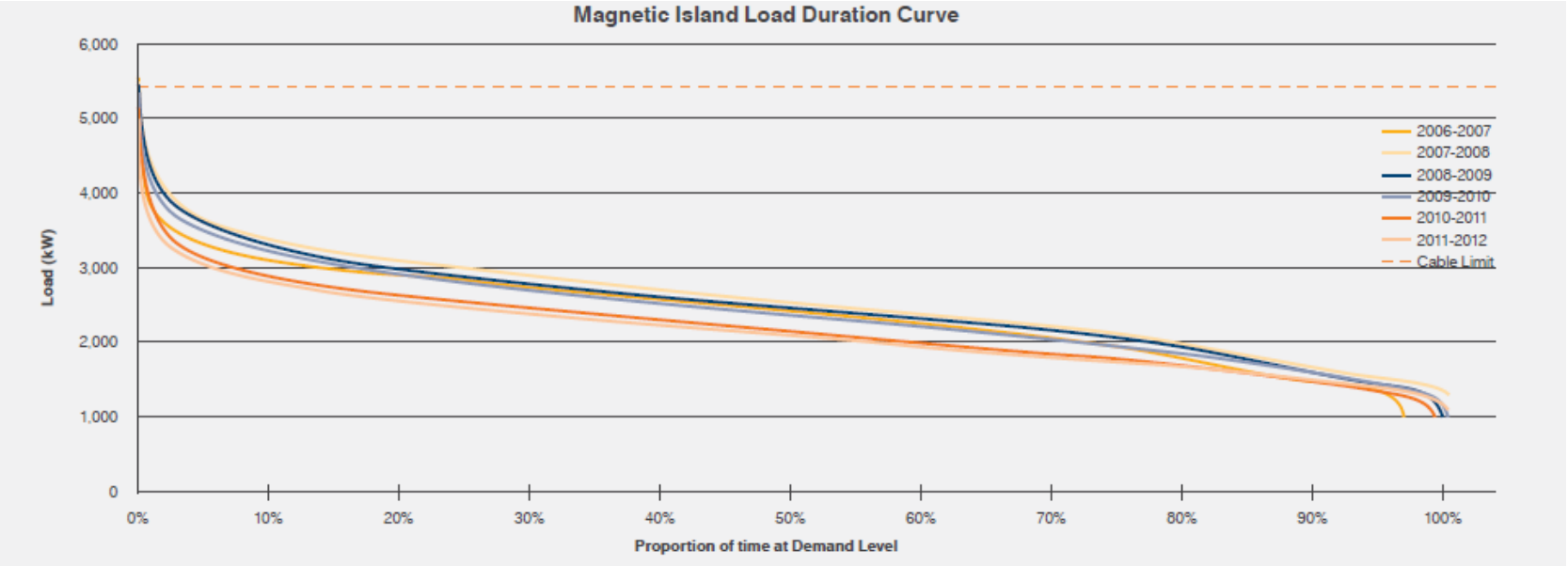
cafalo pty ltd



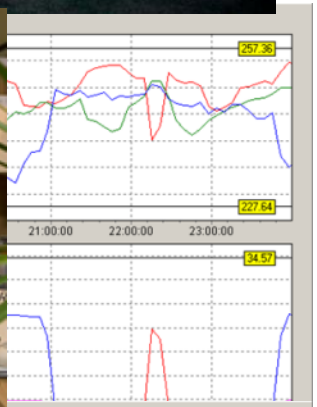
Solar City Project: problem identification

- Load Profile and Asset utilisation

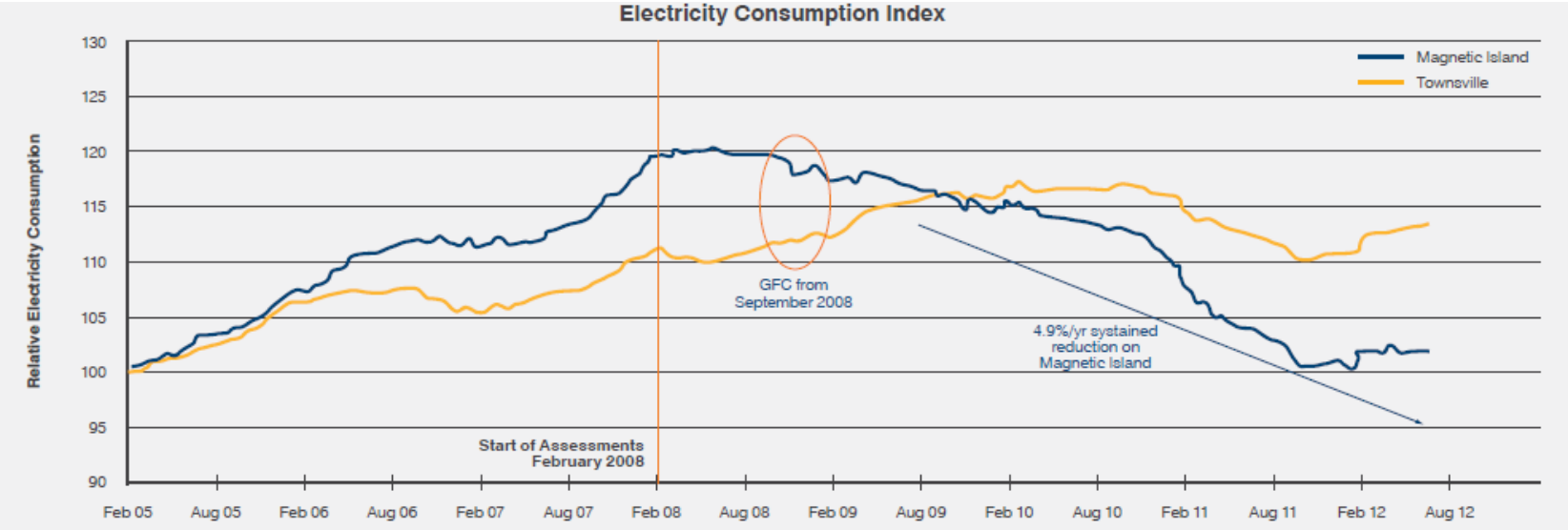


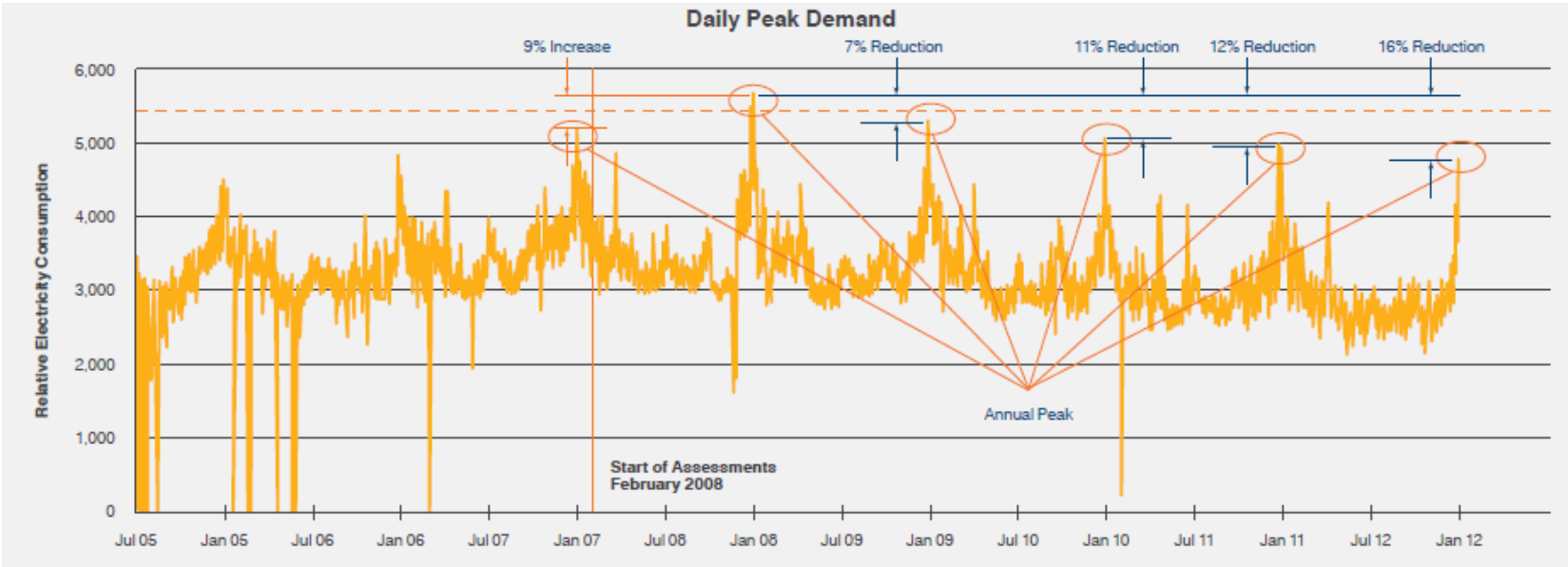


Solar City Project: trials



Solar City Project: results



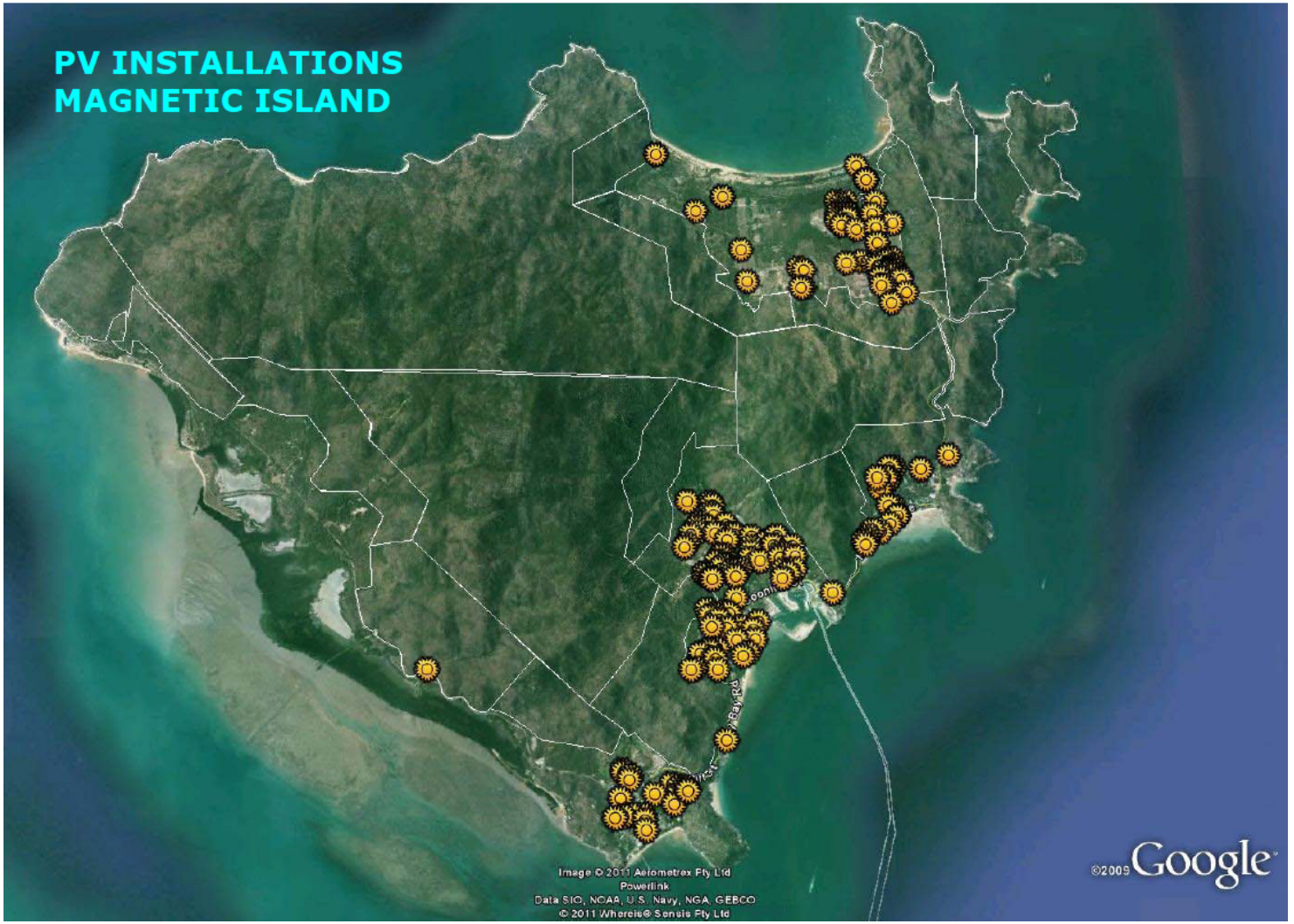


Solar City Project: results

Objective	Target	Achievement	
Reduce Maximum Demand	27% against business as usual	46%	✓
Reduce Electricity Consumption	25% against business as usual	46%	✓
Defer undersea cable	By 6 years	Now at least 8 years	✓
Reduce greenhouse gas emissions	50,000 tonnes	54,000 tonnes to June 2012	✓
Increase take up of renewable energy	Install 1 MW of hosted photovoltaic systems	1.084MW installed in 212 systems	✓
Reduce costs to consumers	$1,000,000	$1,784,000 to June 2012	✓
Build capability in the community for sustainable living	Develop campaigns for the community, schools, and businesses using the Citysolar program	Eco-electricity tours, Cool Roofs, Centre of Excellence, Smart Lifestyle Expo	✓
Demonstrate energy efficient housing	Develop continuous improvement in residential and medium density housing	Three efficient apartment complexes completed	✓
Energy Efficient Office accommodation	Investigate best practice for energy efficient office accommodation	Wide research, workshops, report produced	✓
Energy efficient refurbishment of heritage office building	Reduce the energy demand in a 140 year old office building	25% reduction in demand from the grid	✓

Solar City Project: solar PV

- 1MW of Solar PV, project wide
- 180 systems for 726kW, and RSL Stadium at 348kW



Solar City Project: solar PV

- Ergon owned
- Hosted arrangement, grid side connection
- Size and location strategy changed during project
- Early on did not follow Ergon connection standard

- Minor PV rise issues, limited monitoring- as generation was not linked to customer FiT
- Adjusted Vmax set point to 255 V as per Ergon standard

ARENA

Australian Government

Australian Renewable Energy Agency

UNSW AUSTRALIA

Never Stand Still

Magnetic Island

A Case Study of Increasing PV Penetration in Electricity Networks

Anna Bruce, Simon Heslop, Iain MacGill & Muriel Watt, UNSW

Centre for Energy and Environmental Markets

Australian PV Association

Overview

- **A key objective of the research project is to facilitate the integration of higher PV penetrations in Australia.**
  - **Improve understanding of technical, economic and regulatory requirements**
  - **Share knowledge and experiences**
  - **Utility engagement**

- Previous case studies on isolated grids
  - Alice Springs:
    - 3 MW of PV on a grid with 4pm summer peak demand of 55 MW
    - max PV:load 8.5%
  - Canarvon 23 MW capacity diesel/gas gen:
    - 1.1 MW PV on a grid with 11.5 MW peak load
    - Max PV:load 13%
    - Up to 70% PV:transformer cap on DTxs

Case Study Process

- Case study aims:
  - Document the technical experiences, concerns and actions being taken by Ergon Energy in relation to integrating high levels of PV on the island and more broadly across their networks.
  - Investigate whether the existing levels of PV penetration on Magnetic Island's LV networks are causing power quality issues.

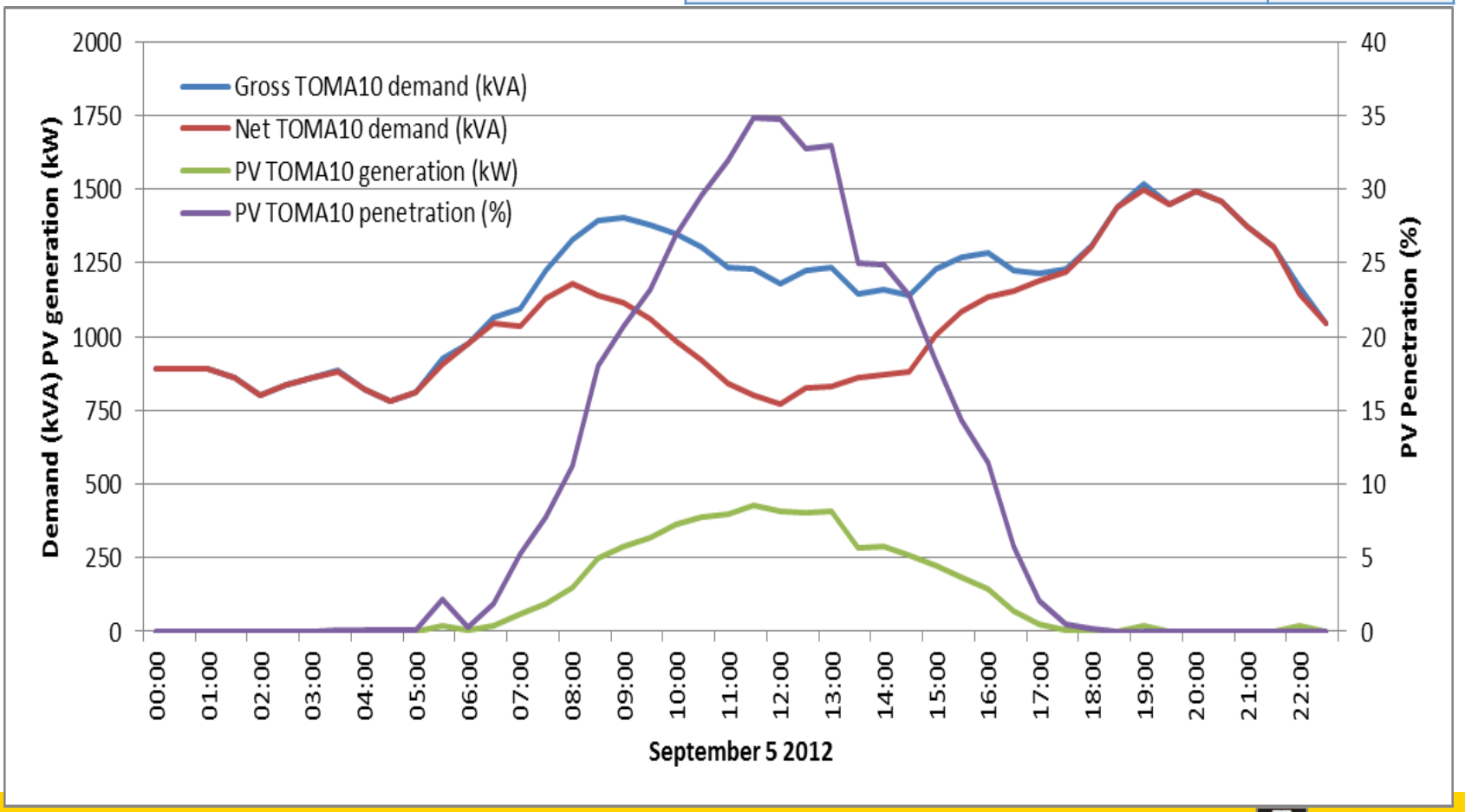
- Case study process:
  - Interviews conducted with Ergon Energy employees
  - Data collected

PV Penetration Levels on Magnetic Island

PV Penetration Measure	PV Measure	Estimated Value	System Measure	Value	% PV Pen.
PV Capacity Penetration	Installed Nominal PV Capacity	1102 kW	Annual Peak Load	5050 kW	22%
PV Peak Power Penetration – Summer	Est. Summer Midday PV Peak Power	583 kW	Ave. Summer Midday Load	2914 kW	20%
PV Peak Power Penetration – Winter	Est. Winter Midday PV Peak Power	497 kW	Ave. Winter Midday Load	1984 kW	25%
PV Peak Power Penetration – Average	Est. Average Midday PV Peak Power	392 kW	Average Midday Load	2372 kW	16.5%
PV Annual Energy Penetration	Est. Annual PV Energy	2 GWh	Annual Gross System Load	39 GWh	5%
Maximum instantaneous PV penetration	PV Generation at time of max. PV penetration	698 kW	Load at time of max. PV generation	2158 kVA	32%

TOMA10 highest PV generation day for period Nov 2011 – Oct 2012

Feeder rating	5.4 MVA
Nominal PV system capacity on feeder	676 kWp
Nominal PV capacity penetration	12.5 %
Estimated PV Peak Output	430 kW
Annual PV peak power:load penetration	35 %



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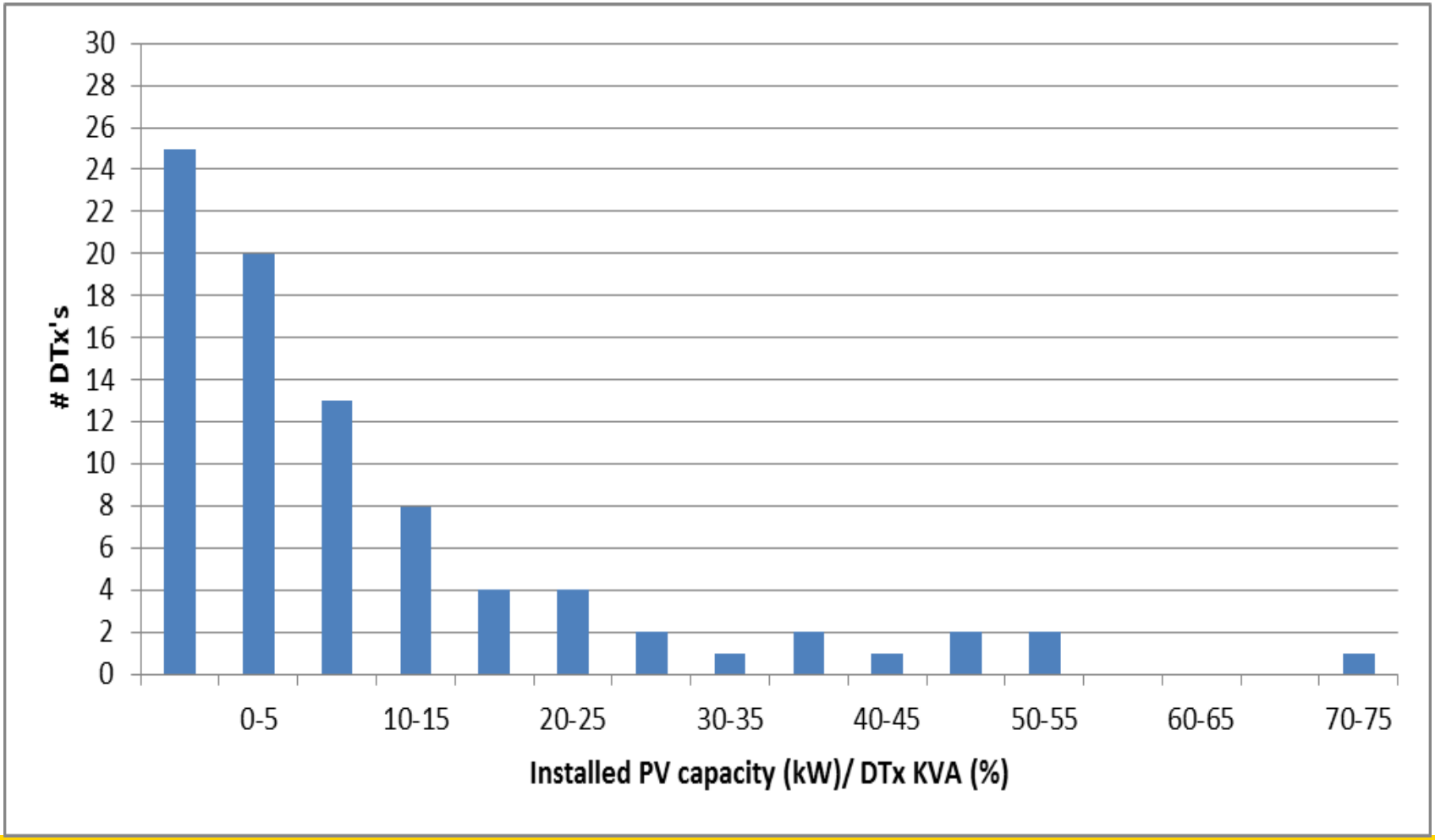
No of DTxs with different PV Penetrations

(ratio of PV capacity (kW): DTx rating (kVA))



Experiences with Increasing PV Penetration

- **LV Voltage Management**
  - Magnetic Island includes high impedance, overhead feeders, with high V to accommodate significant AC loads – V rise problems pre-existing
  - The majority of voltage complaints arise near PV systems, as PV systems are measuring voltages, which are not otherwise generally being monitored, and remove their contribution to high V.
  - Ergon has successfully addressed all voltage excursion issues to date, through standard upgrading of cabling or changing phase of connection
  - All Solar cities inverters HV disconnect 255V (QLD max V = 254.4), but Ergon is concerned that, more broadly across the network, installers are continuing to use wide voltage settings to prevent the inverter from disconnecting due to high voltages
    - Development of a test using a Variac to check voltage at a PV customer's premises
  - Upcoming changes to AS4777 will provide for more sophisticated operation of inverters under high voltage conditions, which will allow inverters to ride through short-term voltage non-compliance
  - STATCOMs and reactive power injection being trialled

Experiences with Increasing PV Penetration

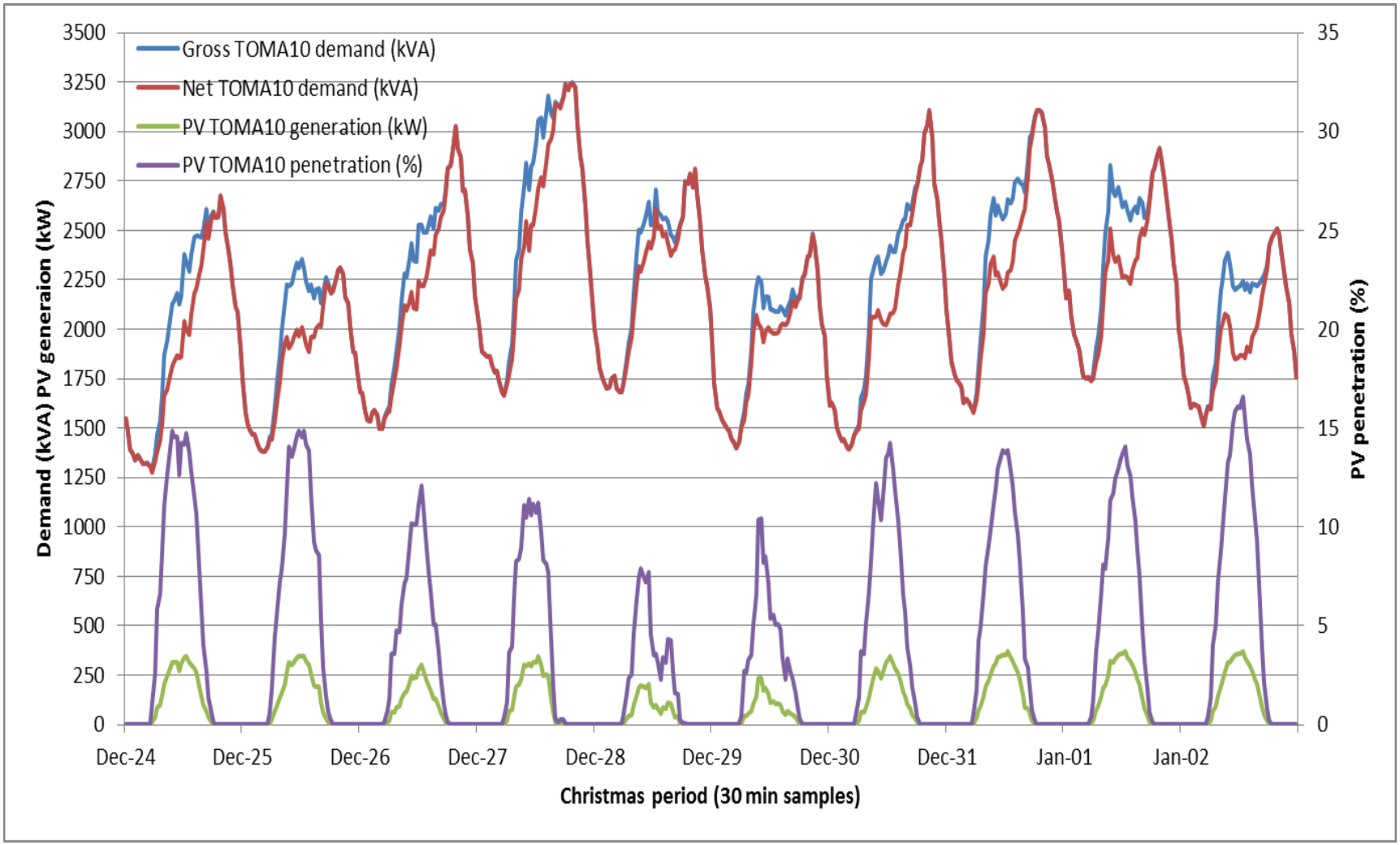
- **Reverse Power Flow**
  - Main concern is protection impacts
  - Isolated instances on Magnetic Island, but with no resultant issues
  - No measured data to confirm reverse power flow, except where trials are underway that include recording data at a Tx
- **PV Output Fluctuations**
  - Main concern is protection impacts and possible voltage fluctuations
  - Not a current concern on Magnetic Island
  - Ergon has not seen any switching or disconnection issues due to PV, even in urban areas with high PV penetrations

Experiences with Increasing PV Penetration

- **Network Fault Protection and PV System Islanding**
  - Protection staff concerned about (i) PV systems feeding a fault (ii) inverter anti-islanding failure
    - View is that if the PV output could potentially be equal to or greater than the minimum load, a risk of islanding exists
    - Concern about lack of standardisation amongst inverter active anti islanding protection mechanisms
  - Other staff within Ergon Energy were of the view that network protection is unlikely to be a major issue, and that international experience has been that islanding of PV inverters has not been an issue.
- **Harmonics**
  - Air-conditioning was shown to be a much more significant source of harmonics than PV inverters at high penetrations.
  - Low levels of harmonics recorded on a high penetration PV feeded on Magnetic Island in 2011
- **Power Factor**
  - Not an issue, but may become more significant as Ergon Energy begins using STATCOM devices to manage voltage issues.
  - Ergon Energy noted that inverters can potentially be used to supply reactive power.

- **Network Planning & PV System Approval**
  - Ergon Energy allows any inverter less than 5 kW to be connected to the majority of the network without a full desktop technical assessment
  - Applications to connect systems above 30 kW are assessed by Ergon Energy as major connections.
    - Significant network study to determine the suitability of the system and proposed network connection point.
    - Ergon Energy has been receiving several enquiries per week from investors wishing to install PV systems >30 kW
    - A major customer connection is categorised as >1.5MVA of load or 10kW of generation on a single phase, 30kW on 3 phases.
    - Options of export, controlled export (with limit), no export (alternative PoC may be offered.
    - If augmentation required, costs passed on to customer
  - Additional inverter functionality, protection or monitoring may be required (on top of AS4777)
  - Guideline for approval of large systems under development

PV de-loading on TOMA10 on peak day



Conclusion

- Some challenges associated with PV on Magnetic Island and in Ergon's network more broadly
  - A rapid change to a new technology with uncertain impacts
  - Administrative burden
  - Revenue impacts
  - In context of ageing assets and changes to demand patterns
- Technical challenges at current penetration levels have been minor and manageable
  - Lack of data to characterise technical impacts – need better methods of quantifying impacts of large numbers of small systems
  - Limited to voltage impacts, which have been resolved within standard operating procedures, minor costs
  - PV alerts operators to pre-existing issues
- PV-related issues are often difficult to separate from other distribution network issues
  - E.g. peak demand growth impacts on voltage management
- There are opportunities for PV penetrations to increase
  - DNSPs have tools to manage impacts as they arise
  - Limitations that have been introduced in some network areas are not evidence based

Current Projects on LV regulation

- **Large Statcom:** 300kvar unit, connected via a step up . Currently installed, showing good regulation of MV (3% +- of MV). Holding voltage in a narrower band and allows for more head room. Still a need for LV regulation

- **Customer Inverters:** 32kW of PV using inverters with reactive power functionality. Inverters installed, testing to commence in December

- **Series Regulators:** two manufacturers, operate as electronic series voltage regulators

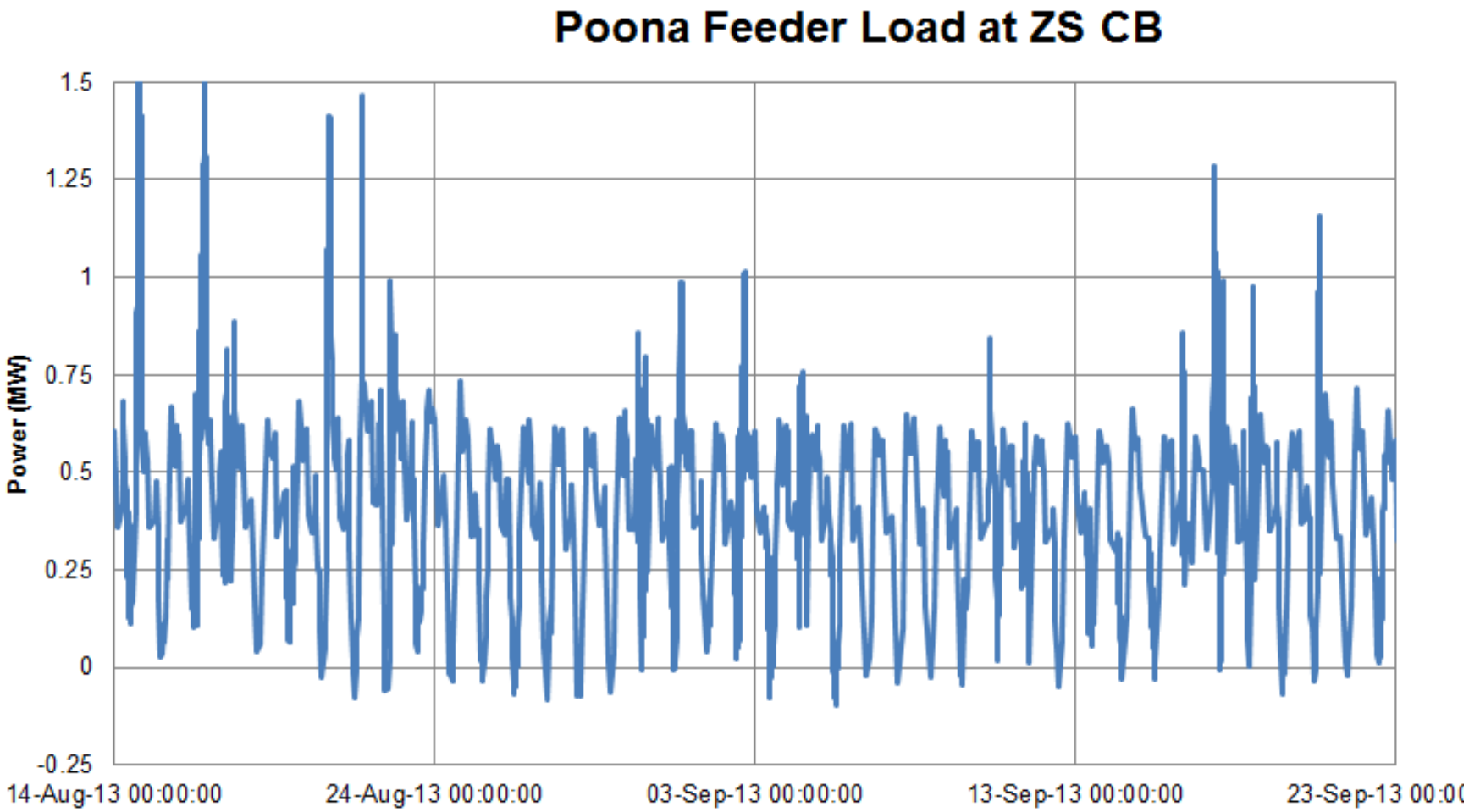
- **Urban LV Statcom:** trialling Statcom type products from 2 USA based suppliers
    - Varentec: Small capacitor only system, 10kvar, single phase
    - ZBB Energy Corporation: capacitive/inductive system, 3 phase, 20kvar – balanced output only and hence does not reduce out of balance issues

Urban LV Statcom

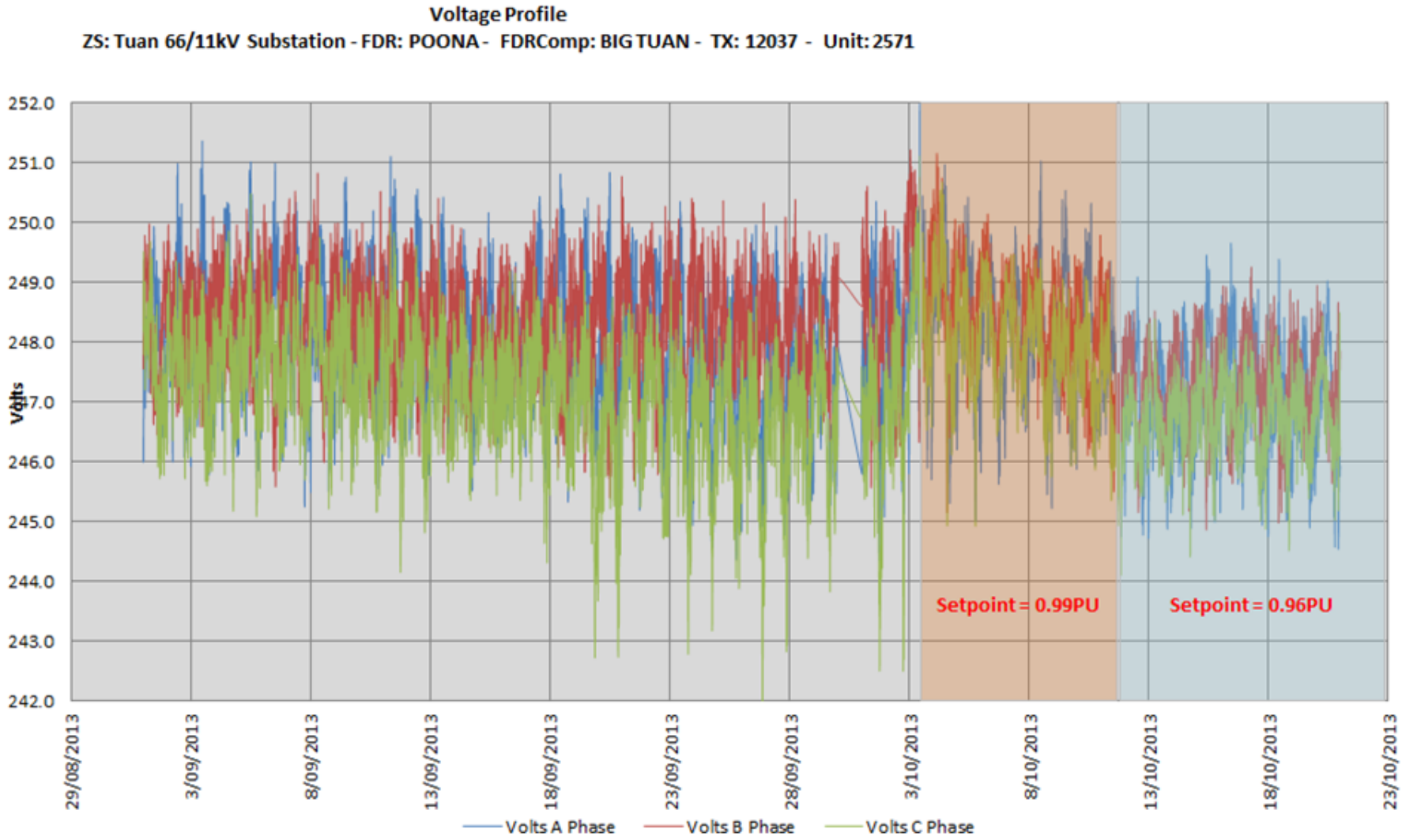
Variable	Varentec	ZBB
Quantities on order	6	2
Rating	10kvar	20kvar
Mode	Capacitive only	Capacitive and Inductive
Phases	Single Phase	Three Phase
Installation	Pole Mounted	Pole Mounted
Connection	LV fuses	LV Fuses
Communications	Suppliers software and blue tooth connection to collect data and adjust voltage set point	Ergon Cybertech modems and connection into OCN – not yet tested
Monitoring	LV feeder to have PM45 power quality analysers installed with remote comms	LV feeder to have PM45 power quality analysers installed with remote comms
Enclosure	Metal enclosure, individual mass is 15.5kg	Metal enclosure, individual mass is 91kg

Large Statcom

Large Statcom



Large Statcom



Summary

- As of Sep 2013 Solar Bonus, 86,354 PV systems (91% 44c, 9% 8c)
- PV connected 296,492 kW

- Application process, continuous improvement,, paper -> online
- Parallel generator connection standard >30kW available
- IES connection standard <30kW, draft due Feb 14
- Measuring PV caused QOS complaints

- Cost Pressures
- Tariff changes
- Market Enabler

End

Thank You

Questions ?