Attachment 2 - DMIS

Essential Energy response to Regulatory Information Notice Under Division 4 of Part 3 of the National Electricity (NSW) Law

1.5 In respect of the DMIS:

(a) provide an explanation of each demand management project or program for which approval is sought;

GRID INTERACTIVE INVERTER PROJECT

An electricity network has real and reactive characteristics that interact with real and reactive power flows to determine the levels of voltage, current, and losses around the network. The network's capacity to deliver load or absorb generation at any point can be constrained either by current rating of elements in the supply path, or unacceptable voltage conditions for customers. Traditional network solutions involve augmentation to increase the supply capacity through upgrading existing infrastructure or providing additional infrastructure to reduce the impedance of the supply path.

The grid interactive inverter project involves the development and field testing of four quadrant inverters, which, through the use of energy storage or reactive compensation can be utilised to avoid or defer network augmentation in the low and medium voltage distribution networks.

A four quadrant inverter is capable of providing a combination of bidirectional (either into or out of the network), real, and reactive power. This capability can be used to adjust power flows, significantly improve both high voltages (caused by the proliferation of PV solar systems) and low voltages, decrease voltage transients or flicker, and reduce peak currents and losses on the existing infrastructure, all as an alternative to network augmentation.

The outcome of the successful implementation of the grid interactive inverter project will be improved utilisation of existing infrastructure with increased capacity for both generation and transmission of electricity, and, therefore avoidance or deferral of network augmentation, not just within Essential Energy but industry wide.

(b) explain, for each demand management project or program identified in the response to paragraph 1.5(a), how it complies with the DMIA criteria detailed at section 3.1.3 of the DMIS, with particular reference to:

(i) the nature and scope of each demand management project or program;

Four quadrant power electronics technology is currently used extensively in high power, high voltage, network applications for static VAr compensation, and large energy storage applications. There is, however, no low cost commercially available equivalent for low power, low voltage or single phase systems. Commercially available low voltage inverters are widely used for the connection of small scale renewable energy generation but their control methodology and design is not suited to full four quadrant grid interaction to facilitate network support.

The grid interactive inverter project is a non-tariff based project aimed at developing an innovative enabling technology to address a multitude of network constraints (such as high/low voltages, oversupply of distributed generation, voltage flicker, thermal capacity constraints) and shortfall in existing low voltage inverters (no control methodology or grid interaction facility) to be used as a non-network alternative. These constraints being

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overcome through the inverters ability to shift or reduce peak demand on the network, through the near instantaneous rectification of power quality issues, or by providing reactive support to the network at the time and location of the constraint.

The outcomes of this project will provide input to the strategy of the use of such technologies (i.e. whether there is a case for broad based usage of the technology, or whether the technology is project or constraint specific).

(ii) the aims and expectations of each demand management project or program;

Aims and expectations

The aim of the project is to develop a cost effective, flexible, low voltage, four quadrant inverter which can be used in a variety of applications (refer Appendix A) to address a range of supply quality issues for use as a non-network alternative.

The capabilities of such technology (including but not limited to)

Provide a combination of real and reactive power either into or out of the network. This capability can be used to adjust power flows and significantly improve voltages, currents and losses:

- **Providing real power support on long rural feeders -** on high resistance circuits store energy at light load periods and release it at peak times to reduce voltage drop on the feeder.
- **Power factor correction -** providing reactive power to adjust the power factor of the load on the network reducing network loads and losses.
- **Generation capacity enhancement -** use lagging reactive power to compensate for voltage rises caused by embedded generation or use energy storage to reduce the power sent back to the network. Higher concentrations of embedded generation such as rooftop photovoltaic systems can create problems with voltage rise on the network.
- **Handle short term fluctuations**

It is expected that final production cost for a single phase inverter will be in the order of $500 per kVA which compares favourably to commercially available small scale photovoltaic units offering substantially less functionality.

Energy storage costs are estimated to be $500 per kWh based on currently available lead acid technology, however, it is expected that battery development for electric vehicles will ultimately provide a more cost effective alternative.

(iii) the process by which each demand management project or program was selected, including the business case for the demand management project and consideration of any alternatives;

Project justification

Essential Energy has a substantial rural distribution network, much of which was installed in the 1950s, 1960s and 1970s under various Rural Electrification Schemes using small section conductor on single phase and SWER construction in order to minimise cost to the customer. The capacity of these lines to supply load or absorb generation is limited (refer Appendix B).

Subsequent changes to system loads through "infilling", and increased demands of individual installations due to changes in lifestyle and price accessibility of electrical appliances, has created many situations throughout Essential Energy where general voltage levels cannot be satisfactorily maintained within the allowable voltage range, and short term fluctuations create increasing annoyance for customers.

Traditional network solutions include the installation of voltage regulators to address general voltage levels, or conductor upgrades in situations where voltage regulation is not an effective option. Current costing for conductor upgrades is in the order of $5,000 per km for SWER and $6,000 for single phase lines and significant distances are involved, if an effective improvement in voltage conditions is to be achieved.

While the initial focus of the project was on a modular 20 kVA unit to address feeder level issues, the initial prototype installation demonstrated that the four quadrant capability can also be utilised for power quality improvement on low voltage systems. This is to mitigate voltage drops due to increased circuit loading or voltage rises due to increasing levels of small scale embedded generation. The scope of the program was subsequently extended to facilitate PV connection, VAr support, and energy storage at residential level, through the development of a smaller 5 kVA four quadrant inverter using the same basic design plus associated DC/DC converters, with the hope of creating a possible broad based DM solution.

Low voltage network solutions include conductor upgrades or additional distribution substations. Depending on the circumstances this could typically cost between $20,000 and $200,000 to address a single constraint.

Options considered

- **Traditional generation -** an alternative is to use an embedded generator at the end of the affected feeder to reduce the load the feeder needs to supply but traditional generators are often difficult to implement as they have issues with noise, pollution, security and maintenance.

- **Adaptation of commercially available inverter equipment -** the use of commercially available inverters as used for the connection of small scale wind and photovoltaic generation has previously been considered. A trial installation at Lake Mungo included Xantrex 4.5 kVA inverters at a unit cost of $6,300. Significant problems were experienced in adapting the inverter operation for interactive grid support with the final configuration and the units were not considered to be suited to further development due to the lack of a suitable grid interface.

- **High Voltage large scale equipment -** high voltage inverters with grid interactivity are available from established companies such as ABB and Siemens, however, they are very expensive and not cost effective for low power applications required on weak rural feeders. Previous contact with these companies indicated that development of a suitable unit was not a high priority and any development costs would need to be recovered.

- **Develop a single phase, modular system (preferred option) -** identify a suitable partner and work with them to develop a specification and produce a prototype, modular power electronics system to provide real and reactive four quadrant operation for voltage support when used in conjunction with a suitable direct current source such as battery storage or renewable generation:

The proposed benefits of a grid interactive inverter over other existing technologies for this application

- The lower cost and physical sizing associated with the voltage level and current capacity.

- That the output is continuously variable and independent of voltage so there are no "step changes". The inverter response is instantaneous so the power factor can be constantly adjusted.

- An appropriately sized grid interactive inverter can enhance the network's capacity to absorb generation by providing inductive reactive power to reduce voltage levels, whilst also providing the primary function of renewables generation.

While the steady state operation of the inverter is limited by thermal ratings the production unit will have significantly higher short term capability to provide ride through support for dips and surges from sudden connection or disconnection of large loads.

(iv) how each demand management project or program was/is to be implemented;

Project implementation

The project is broken into three stages:

- **Knowledge acquisition phase -** prototype units were developed and installed in an environment where they can be closely monitored and design improvements checked for inclusion in a production version.

- **Field trial phase -** first run production units are installed and their performance evaluated in a number of situations and for a variety of network constraints prior to approval for general use.

- **General deployment phase -** utilisation as a generic supply quality improvement technology on Essential Energy's distribution network and construction of the business strategy regarding the use of such technology, which may include development of incentive schemes to leverage spare network support capacity from suitable renewable energy connection equipment.

At the close of the 2010/2011 financial year, proof of concept had been achieved with the prototype units installed at Queanbeyan. Design modifications required for the production unit were agreed and development work was in progress.

(v) the implementation costs of the demand management project or program, and;

Implementation costs

The estimated cost for the first stage (proof of concept) of the project is $400,000 including product development, test site installation and Essential Energy project management costs.

Development of production units and field testing of network compatibility with verification of support functionality at both network and customer level will continue into 2011/2012 at a total expected cost of $800,000.

(vi) any identifiable benefits that have arisen from the demand management project or program, including any off peak or peak demand reductions;

Identifiable benefits arising

Stage 1 of the project involved development and testing of prototype units and this was ongoing through 2009/2010. This was essentially a knowledge acquisition phase to observe the interaction of the prototype units under real network conditions and provide the basis for specification of a production unit.

Proof of concept was attained in 2010/2011 and design enhancements agreed for Stage 2 field trials. Network models have been built, and field projects designed to verify equipment functionality and provide the basis for development of the wider deployment strategy. The first two field trials are expected to commence in early 2012.

Benefits will accrue when the technology is field proven and deployed as an enabler for peak reduction and reactive power support applications to avoid or defer network augmentation.

(c) provide an overview of developments in relation to the demand management projects or programs completed in previous years, and any results to date;

Project overview

A development agreement was signed with an Australian electronics design and manufacturing company in December 2008 for the production of four prototype units, one for bench testing at their premises and three for a test installation on the Essential Energy network. Some of the preliminary development costs were incurred in the 2008/2009 financial year.

During 2009/2010 a test site was established at Queanbeyan, adjacent to the Essential Energy Research and Demonstration Centre and an existing solar array and the prototype four quadrant inverters installed in February 2010. There were significant network compatibility issues observed and the units were returned to the supplier for hardware and firmware upgrades to address them.

The units were reinstalled in June 2010 and firmware adjustments continued through to 2 September 2010 when network stability was achieved and proof of concept demonstrated (refer Appendix C). A workshop was held with the supplier in late September 2010 and design modifications agreed for a more robust unit and additional functionality for further field evaluation on the Essential Energy distribution network.

Proposed field testing for the upgraded 20 kVA units comprises the replacement of the original prototype units at Queanbeyan to check functionality followed by two separate field application trials:

i. An energy storage installation on a single phase 11,000 volt feeder at Pappinbarra, near Port Macquarie, comprising a single 20 kVA inverter and a lithium battery with 40 kWh of useable energy storage.

ii. Reactive power support installations on three phase, low voltage, mains at Tathra, near Bega, at two locations – one in a residential area and another near a commercial load. Each of these installations comprises three single phase, 20 kVAr inverters configured in statcom mode where the units provide coordinated reactive power support only and do not require a battery.

Testing of the first production 20 kVA units was intended to commence in June 2011 but due to delays in development this is now expected to occur in early 2012.

While trial sites have been nominated for assessment of energy storage, reactive support and renewables connection for the 5 kVA units at residential level these are not expected to be ready for deployment until 2012.

(d) State whether the costs associated with each demand management project or program identified in the response to paragraph 1.5(a) is:

(i) recoverable under any jurisdictional incentive scheme, and if so, which scheme;

(ii) recoverable under any other Commonwealth or State Government scheme, and if so, which scheme; and

(iii) included in the forecast capex or forecast opex allowances or any other incentive scheme (such as the D-factor scheme for NSW) approved in the AER's 2009-14 distribution determination.

Statement

The costs associated with the four quadrant inverter project are not:

(i) recoverable under any other jurisdictional incentive scheme, and if so, which scheme;

(ii) recoverable under any other Commonwealth or State Government scheme, and if so, which scheme; and

(iii) included in the forecast capex or forecast opex allowances or any other incentive scheme (such as the D—factor scheme for NSW) approved in the AER's 2009—14 distribution determination.

Appendix A -
Potential applications for the four quadrant inverter

Voltage pacification
Providing combinations of real and reactive power to keep voltages within a given range

Real power support on long rural feeders
On high resistance circuits store energy at light load periods and release it at peak times to reduce voltage drop on the feeder

Reactive power support
On high reactance circuits use either leading or lagging reactive power to raise or lower voltages as required.

Generation capacity enhancement
Use lagging reactive power to compensate for voltage rises caused by embedded generation

Motor starting compensation
The fast (sub-cycle) response and short term rating of the inverter enables it to provide reactive power to balance the fluctuations due to starting of large motors

Power factor correction
Providing reactive power to correct power factor - minimising line currents and losses

Load and voltage balancing
Transferring real and reactive power between phases to ensure balanced supply conditions

Conservation voltage reduction (CVR)
Controlling voltage levels to optimise energy usage and efficiency

Loss reduction
Managing loading patterns to optimise network current flows for loss minimisation

Energy storage (community, household, PV)
Balancing load and generation at local level to optimise network utilisation

Microgrid operation
Operation as a fast response balance between generation and load to stabilise microgrid operation

Peak price generation
Potential to store energy for release over peak price periods on the energy market to enhance asset value

Peak lopping
Provide real power at peak periods to ensure network ratings are not exceeded.

Reliability improvement
Ability to operate in uninterruptible power supply (UPS) mode to improve voltage quality and sustain critical loads during power outages

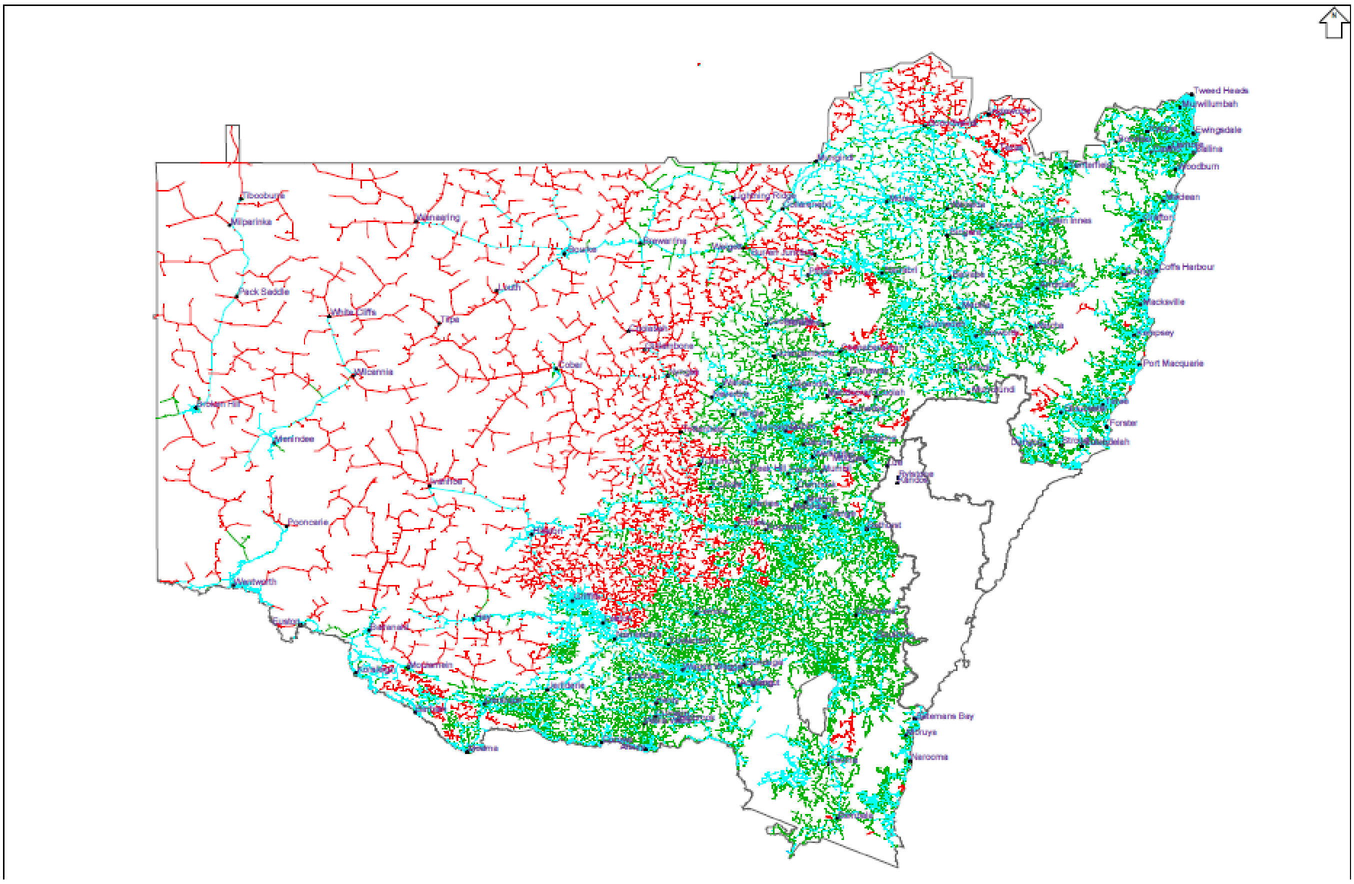
Local load control
Potential to act as a signal generator for local control applications

Harmonic suppression
Acts as a “sink” for lower order harmonics through inductive coupling to the network

Network monitoring
Current and voltage measurement at the point of application

Appendix B

Essential Energy HV circuits
SWER – red, HV1 – green, HV3 – blue

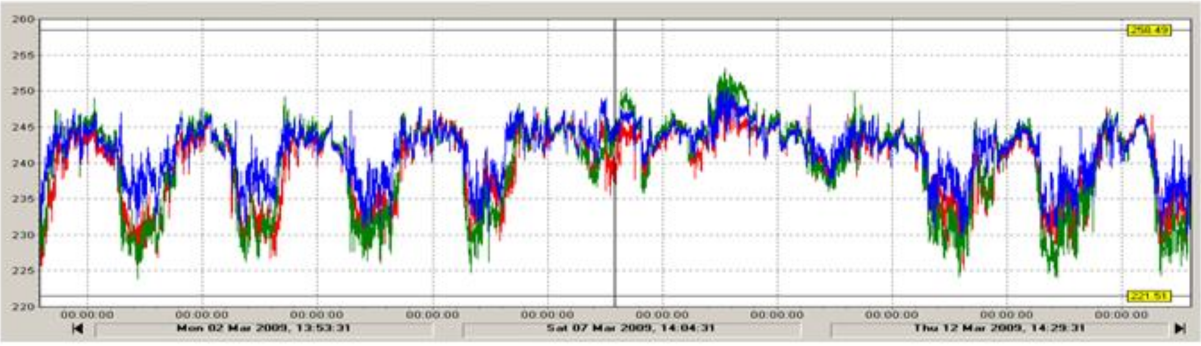


Appendix C

PROOF OF CONCEPT
Influence of four quadrant inverter on voltage levels

WEEKLY VOLTAGE CHART

BEFORE – voltage range 253 to 224, Voltage unbalance 10V



AFTER – voltage range 248V to 234V, unbalance 5V
Normal voltage fluctuations still apparent away from 245V and 239V reactive power support levels