10th March 2013

Mr Simon Bartlett
Chairperson
E.S. Cornwall Scholarship Advisory Committee
PO Box 1193
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Dear Simon

Final Report – E.S. Cornwall Memorial Scholarship – Alexandra Price

Please find enclosed my second and final E. S. Cornwall Scholarship report outlining my period of employment from the 7th November 2012 – 5th February 2013.

During my six month placement with UK Power Networks working on the Low Carbon London Programme I was involved in the design phase of a number of trials relating to smart meters, electric vehicles, distributed generation and demand response. In my final three months I spent the majority of my time helping finalise the design of smart metering time of use trials and preparing Hypothesis Analysis reports. This experience has provided valuable insight into the trial design and management process of large future network technology programmes and I have no doubt the skills I have obtained will be of benefit in my future career.

My placement also enabled me to compare and contrast the differences between the Australian and UK network planning and operation and regulatory landscape. I have included the network comparisons in my final report for interest. I have also provided commentary on what I believe are some potential opportunities for the Australian Power Industry as a result of what I learned during my placement.

I thank the committee for this exceptionally valuable opportunity and look forward to applying my knowledge and experience in contributing to the Australian power industry.

Yours sincerely,

Alexandra Price

E.S. Cornwall Scholarship Final Report

7th November 2012 – 5th February 2013

By Alexandra Price

Photo reference: Utility Week, "UK Power Networks buys three electric vehicles that will take part in Low Carbon London trial", 16 Nov 2012.

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Introduction

My E.S. Cornwall Memorial Scholarship supported work was aimed at gaining a valuable insight into the future of the electricity industry from the work completed as part of UK Power Networks (UKPN) lead Low Carbon London Programme. In particular, I focussed on the active network management of distributed generation, implementation of demand response and smart metering time of use trials.

My tenure of the E. S. Cornwall Memorial Scholarship was from the 6th August 2012 – 5th February 2013. My six month placement was with UK Power Networks on the Low Carbon London Programme. I was based in UKPN's head office in Elephant and Castle, London, where I was working as part of the solution design authority and trial implementation teams.

Low Carbon London Programme

The Low Carbon London Programme is a £30 million program which commenced in January 2011 and is funded through Ofgem's Low Carbon Network Fund. The programme covers a broad range of future technologies as illustrated below. There are 11 partners involved in the programme including universities, consultants, manufacturers, retailers, load aggregation companies, and industry and government. The programme is expected to conclude in December 2014.

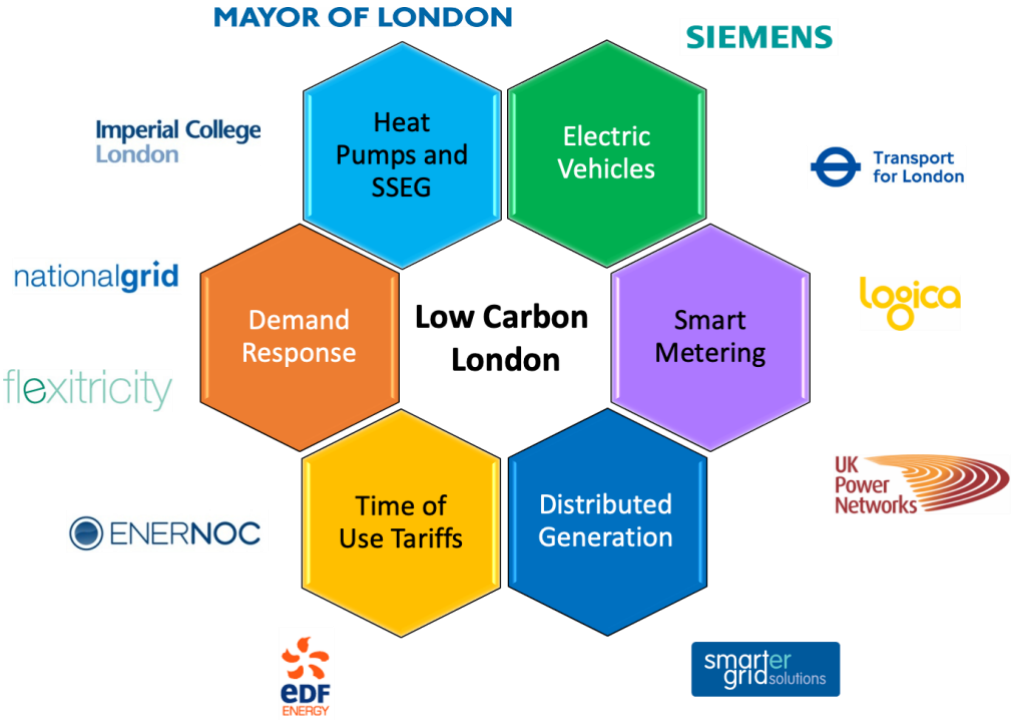

Figure 1 Low Carbon London Programme – Trial Groups and Partners

Work Placement

I completed a variety of tasks during my six month placement as a *Trials and Solution Design Authority Engineer* working within UK Power Networks with the aim of contributing to the development of the Low Carbon London Programme trials. In my final three months I spent the majority of my time helping finalise the design of smart metering time of use trials and preparing Hypothesis Analysis reports.

Demand Response

One of the aims of the LCL programme is to embed low carbon practices into UKPN's operations. Embedding demand response as a network management tool is seen as a priority for UKPN management. There is also strong support for demand response from Ofgem. As mentioned in my first report, I was asked to investigate and report on the barriers, issues and challenges to demand response within Distribution Network Operators (with a focus on UKPN). Following the completion of my report, we held an internal learning event in November with key stakeholders from all areas of UKPN. Using my report as a basis, we discussed what processes and systems need to change to embed the use of demand response capabilities within UKPN. Following the event, I updated my report and summarised several actions which the team will progress.

The key findings of my report (excluding UKPN specific) are summarised below.

For a Distribution Network Operator (DNO), there are three key potential benefits for demand side response (DSR):

- Reduction in capital expenditure (CAPEX) - by deferring or avoiding capital investment in network infrastructure.
- Better network management - during pre- and post-fault conditions reducing outage impacts, including reduction in Customer Interruptions (CIs) and Customer Minutes Lost (CMLs).
- Greater network control - through automated load management schemes.

However, there are several barriers to effective demand side response implementation as summarised below.

Internal DNO Barriers

The potential barriers to Demand Side Response (DSR) within a DNO may include:

- Operational visibility of DSR – the DNO's energy management system (EMS) may not be setup for displaying DSR resources and real time attributes to aid in the implementation of DSR from a network operations perspective
- Database of DSR Resources – no processes, procedures or resource may be in place to manage DSR resources in the network.
- DSR Contract Management – no structured process might exist for developing formal DSR contractual arrangements with DSR resources or the management of these contracts.

Regulatory and Financial Barriers

The UK's regulatory and fiscal barriers to DNO managed DSR have been identified as follows:

- DSR Participation in multiple markets - inability for DSR resources to participate in multiple DSR markets and initiatives during overlapping availability periods due to existing rules and potential conflicts (eg. between DNO and National Grid requirements).
- Reliability requirements – requirement that non network options must have equivalent reliability (or greater) than network infrastructure capital investments.
- Financing of DSR – no clear regulatory framework surrounding the financing of DSR

Societal and Participant Engagement Barriers

The societal barriers to DNO managed DSR have been identified as follows:

- Customer concerns – regarding DNO being able to control devices and fear of paying more for electricity.
- Residential Time of Use (ToU) could lead to increased bills

Future Opportunities and Challenges

In light of the above barriers, there are a number of upcoming changes that will impact on the way in which DNOs manage their network, including:

- Smart metering – opportunity to provide greater visibility and control of DSR
- Time of Use tariffs - customer choice and flexibility
- High penetration of potential DSR resources - managing high penetration of potential DSR resources along with increased penetration of renewable distributed generation.
- RIIO (Revenue = Incentives + Innovation + Outputs) – the UK's future regulatory environment and opportunities for DSR.

I thoroughly enjoyed investigating and preparing my report on demand side response barriers, challenges and opportunities as it allowed me to deep dive into UKPN's operations and the UK's current and future regulatory environment. The UK is currently undergoing significant changes in its regulatory framework with the introduction of RIIO-ED1 and it will be interesting to watch how it is implemented and whether the Australian Energy Regulator decides to implement similar components of this scheme. I found my experience with Energex's demand response allowed me to assist in normalising demand side participation during discussions with internal UKPN stakeholders. I also realised that, although somewhat antiquated, Energex's audio frequency load control system has the potential to be of incredible value in the future.

Smart Meter Trials

A significant portion of my last three months was spent working with partners on the specifics of trial design, data collection and analysis for the smart meter time of use (ToU) tariff trial which formally commenced in January 2013. There are several dimensions to this trial which influenced both participant recruitment and the analysis framework including:

- Technology (different smart meter manufacturers with varying data collection capabilities; presence of in-home display head unit; presence of home energy management system; communications issues with some proposed participants)
- Type of customer who opt-in to ToU trial (electricity vs gas, customer demographics as determined using ACORN profile)
- Time of use tariff trial design (frequency of events, duration, price signal, communication)

From the discussions and preliminary analysis conducted, I developed a draft hypothesis analysis framework and network impact report. The development of the hypothesis analysis framework was quite challenging at first as I needed to consider what data we were able to collect and how we were going to use this data to evaluate our hypothesis. My colleagues at Imperial College London were particularly useful to chat to about the approach and how we could ensure the analysis was robust statistically.

Although the trial has commenced there are still a few key Acorn demographic groupings we are missing sufficient participants in which we are hoping to fill. We are also hoping to obtain smart meter data from another retailer for standard tariff arrangements which will be useful in our comparison analysis.

ToU Tariff Trials

Due to confidentiality, I am unable to provide detailed information on the ToU tariff design. However, there are some key aspects of the trial we have agreed upon which I am able to mention:

- The dynamic "Energy Alert" tariff has three levels – high, medium and low
- No customers will be worse off on the ToU tariff (customers will be reimbursed at the end of the trial period for any additional costs incurred as a result of the ToU tariff above their standard tariff rate).
- Customers can leave the trial at any time but will not receive the trial completion financial incentive.
- Customers receive a text message the day before upcoming tariff periods and where available, this information will also be displayed on the in-home display (see Figure 2).
- Customers will be provided with a monthly summary of their usage and indicative bill. They also receive a comparison to what their bill would have looked like on their pre-trial tariff.

Figure 2 Text Message and In-Home Display Tariff Notifications

During the second half of my placement, I conducted some preliminary analysis on de-identified historical billing data for trial customers to help inform the hypothesis analysis framework. However, as many had only had their meters installed relatively recently, I also had to rely on pre-smart meter data. In the UK, non-smart electricity meters are only read once a year with bills being created on forecasted usage based on customer demographics. In my own experience, this overestimated my usage, but I did spend a several weekends travelling which would have reduced my overall consumption. However, customers are able to input their own meter reading (into their retailers' website to get an accurate bill. The result is that pre-smart meter data does not yield particularly useful outputs for comparison to more granular time of use data.

SMETS compliant meters

Smart Meter Equipment Technical Specifications (SMETS) compliant smart meters are currently being roll out across the UK. This rollout is being led by energy retailers. There are different generations of SMETS-1 compliant meters; "Gen 2" meters only measure consumption and "Gen 3" meters also measure voltage and some power quality parameters. Although SMETS is an industry standard framework, consumers appear largely locked into their energy retailer once they have a smart meter. If a customer wants to change retailer their meter will need to be replaced by one owned by their new retailer. This results in a wasteful churn of metering infrastructure and from my

perspective, I believe a distribution network operator or third-party rollout (e.g. Victoria's rollout) would be of greater customer benefit. The meters being rolled out are typically read using a 2G modem however, in trials we found there were some communication signal issues in high density living arrangements (apartments in high rise buildings).

One of the challenges with the original smart meter rollout in the UK has been the lack of availability of Gen 3 smart meters. This has delayed some of Low Carbon London's trials as we have had no way of obtaining suitable voltage and power quality data. I was involved in discussions with a different meter manufacturer which, although not deemed complaint for the provision of billing consumption data, is able to provide a Gen 3 meter which we can install at some sites (in addition to the billing meter) to provide the voltage and power quality information we require.

Data provision to DNO

One of the aims of the Low Carbon London programme is to improve UKPN's operational efficiency with the goal of reducing its carbon footprint. The timely access of smart meter data has the potential to improve UKPN's outage restoration efforts, asset utilisation and load forecasting activities. Currently the transfer of smart meter data between the retailer and UKPN is via a manual download and transfer process. This data is also de-identified before transfer in compliance with data privacy protections. It is hoped that an automatic data provision method will be available in the future which will allow the DNO to leverage near real-time access to data collected on the low voltage network.

Fuel poverty

I was involved in a Technology Strategy Board project investigating the potential for time of use tariffs for vulnerable customers. Energy poverty is a big issue in many parts of the UK and one of the ways energy retailers limit their exposure is through the use of pre-paid electricity/gas meters. However, the pence/kWh tariffs for these meters are typically higher than a non-pre-paid meter, which is a further burden on those who are unable to pay. The introduction of time of use tariffs for these customers may result in them being able take advantage of cheaper off-peak pricing if they choose to heat their homes outside of peak times. Interestingly 50% of those in fuel poverty are single person residences (25% of all homes in England are single person). Furthermore, 50% of households in fuel poverty are not in the bottom quintile of income so the factors contributing to fuel poverty are broader than just income. There are challenges relating to meter capabilities and communication with vulnerable customers that need to be addressed before this strategy can be trialled.

Community solar

I attended meetings where I learned about community solar projects happening in the London area. Community solar projects allow people living in high rise residential buildings, with no opportunity to install solar panels on their property, the opportunity to contribute to the UK's low carbon future by investing in renewable generation technologies. The community solar organisers negotiate to lease roof space from large commercial property owners like warehouses. The financial contributions from the community are pooled and invested in solar infrastructure on commercial and industrial buildings. Unlike residential solar, where many people are not at home during the day when the solar is generating, the electricity produced by community solar is able to de readily used locally. The community also receives a proportion of the generation income.

Additional smart meter data

I was also involved in discussions with another large energy retailer about the potential to use their smart meter roll out data for analysis and comparison with our time of use trials. I am optimistic an agreement will be reached in the near future. This data will assist in providing statistically significant outputs from the analysis framework.

Programme Management and Other Tasks

During the second half of my placement, as we worked with partners, explored data capture techniques and recruited participants I continued to regularly review and update the trial description and hypothesis test approach documents to reflect the current state of the trials. I also maintained the LCL Programme Dependency Management Tool and hypothesis breakdown spreadsheet. Further detail on the description of these documents can be found in my first quarter report and in Donald McPhail's (2011 E.S. Cornwall Scholar) first quarter report.

In addition to developing drafts of the hypothesis analysis framework and network impact report for the smart metering time of use trials I was also involved in developing similar draft documents for the demand response, distributed generation and electric vehicle trials.

Due to some scope changes as a result of primarily external factors (e.g. unable to recruit participants for certain trials), we were required to submit a programme change request to Ofgem. This document outlined changes to scope and funding and provided justification for these changes. I assisted in the preparation of the change request which was submitted to Ofgem in December.

Network Comparisons

During my placement I have taken the opportunity to learn about the electricity industry in the UK and compare and contrast the methodologies used with my knowledge of the Australian electricity industry (in particular South East Queensland). I found it fascinating to compare the two networks and company practices. The network voltages used in UKPN are fairly similar to Energex; 132kV, 66kV, 33kV, 11kV, some 6.6kV in the London area and some 3.5kV three phase networks in the Southern Power Network area.

London, being very densely populated, and having a significantly colder winter than Queensland, has a number of key network topology differences to Energex's South East Queensland network. The most notable difference is that London Power Network (LPN) covers a mere 655km^2 yet has a peak load of 5.4GW and caters for 2.27 million customers. In contrast, Energex has 1 million fewer customers, covers an area over 35 times that of LPN and has peak load is 4.6GW, 85% of the peak load of LPN (see table below).

Network Parameter	Energex	LPN	UKPN
Customers (Millions)	1.33	2.27	8.05
Length of OH and UG Lines (km)	51,500	36,600	185,000
HV/EHV transformers	276	460	2288
Distribution transformers	46,800	15,000	116,600
Area (km^2)	25,000	665	29,000
Peak Load (GW)	4.6	5.4	16.2

A rough calculation of peak load per customer using the figures in the table above yields some interesting results.

Network Parameter	Energex	LPN	UKPN
Peak Load (kW)/customer	3.46	2.38	2.01
customers/distribution transformer	28	151	69
customers/km of line	26	62	44
Peak Load (kW)/km^2	184	8120	559

The significant number of customers per distribution transformer in LPN is understandable as the majority of LPN transformers (at least those replaced/installed in the last few years) are 1MVA transformers. In contrast, Energex distribution transformers typically range from <100kVA for rural sparsely populated areas to 500kVA for urban populated areas. It is also not unexpected that LPN would have a larger number of customers per kilometre of line due to the fact that LPN is a very densely populated network. The peak load (kW) per square kilometre calculated above is deceiving as it represents an average across the entire network area. However, as illustrated below, the load density of the City of London (also known as the 'square mile') is very large in specific areas.

I believe the significantly higher peak load (kW) per customer within the Energex network is a combination of both the differences in living (typically higher density living with smaller footprint per customer in London than in South East Queensland), and the difference in climate and air conditioning use on peak days.

Potential Opportunities for Australia

From my experience at UKPN, I have identified some potential opportunities for the Australian Power Industry:

Increase the allowable momentary interruption duration

In the UK, Ofgem defines a sustained interruption as an outage that lasts for three minutes or longer for the purposes of customer interruption and reliability calculations. Any outage which is restored within three minutes is considered a momentary interruption and does not count toward reliability indicators such as customers interrupted, or customer minutes lost. In Australia, a sustained outage is greater than one minute duration for reliability and the Service Target Performance Incentive Scheme (STPIS) calculations. For the vast majority of customers, an additional two minutes of outage would not be a significant impost. However, from an operational perspective, I believe an additional two minutes would allow a network controller to respond if an automatic control scheme was not available or failed to operate correctly. This would not adversely impact customer experience but would allow network operators an appropriate period of time to respond before accruing an outage penalty.

Community solar for low carbon equity

One of the challenges in the Energex network is the ever-reducing midday load in residential areas with heavy solar penetration while the evening peak load has remained relatively unchanged. The suburbs are arguably where generation is least needed during the day as people are typically at work. In addition, the 44c/kWh feed-in tariff is available to Queensland homeowners who can install solar panels on their roof but is arguably subsidised by electricity customers who do not have access

to a roof such as renters and those living in apartments. The provision of community solar, deployed in partnership with large commercial and industrial loads (those that typically peak around midday) would improve network utilisation, help voltage regulation whilst also allowing those without access to solar panels to contribute to Australia's low carbon energy future.

DNSP involvement in Power of Choice

Currently the National Electricity Rules (NER) in Australia specifies that residential customer metering be provided by the local network service provider (e.g. Energex) as opposed to the retailer. However, in March 2012, the Australian Energy Market Commission (AEMC) published a directions paper titled "Power of Choice" outlining potential revisions to existing electricity rules and regulations with a view to improving the opportunities for demand side participation (DSP). This paper indicated that the AEMC wanted to opt for a competition based residential metering sector.

DNSPs have historically had very little visibility of the low voltage network. However, the data collected from smart metering infrastructure has the ability to provide significant value to the distribution network operators (e.g. quicker fault locating and restoration of supply, better asset utilisation and improved load forecasting), providing the appropriate data is gathered and made available to the network operator in a timely manner. DNSPs must ensure that they are actively involved in Power of Choice discussions to ensure distributors can get maximum operational benefit by utilising the low voltage network data captured.

Professional and Personal Development

While in the UK, I have had the opportunity to attend several seminars, conferences and networking functions organised by the Institution of Engineering Technology (IET), the Royal Society, Royal Institution, and other professional engineering and science bodies.

Highlight events included:

- *IET Solar Time Keeping* – the history of time keeping
- *IET Raspberry Pi* – learned about several new Raspberry Pi applications
- *IET Smart Grid 2012 Poster Evening* – some excellent student posters on Smart Grid topics
- *IET Women Engineer of the Year Awards* – an inspiring event
- *The Fuellers' Annual Energy Lecture* – provided very interesting commentary on the future of Energy policy in the UK.

I also attended presentations and exhibitions by a number of energy related companies and groups including:

- *Energy Solutions Expo* – a variety of future energy displays which included an interesting demonstration of how hydrogen energy could be used in the future for zero carbon emission household heating
- *Smart Demand by Moixa* – demonstrated how household wiring could be converted to DC powered direct from solar with a battery using LED lighting and USB wall sockets
- *EDMI multidrive demonstration* – how to obtain live smart meter data direct from meters

- *OSIsoft Pi data logging software demonstration* – interactive data visualisation tool using Microsoft Silverlight
- *Vietnamese electricity industry* –representatives presented on the Vietnamese electricity industry challenges and opportunities

By far the most enjoyable was the IET Woman Engineer of the Year Awards held at Savoy Place in December. Over 350 people attended, from high school students through to retirees, including a number of professional female engineers. I spoke to female engineers from a variety of different countries including Germany, France, Sweden, and a number from the Asian and African subcontinents. It was inspiring to see so many people attending an event to recognise the outstanding achievements of female engineers.

Conclusion

My placement on the Low Carbon London programme has been an incredible learning experience. As a result of my placement, I feel I have gained technical expertise in a number of key smart grid related areas which I can apply in Australia in my career. I also feel I have also matured as an engineer, developing project management and communication skills in addition to technical knowledge.

I am greatly in debt to my colleagues on the Low Carbon London programme who made me feel part of the team and were happy to assist me whenever I asked for help. I would also like to thank the Network Engineering team at Energex for keeping in touch and providing encouragement via emails, Christmas cards and Skype. Finally, I would like to thank the ES Cornwall Scholarship Committee for providing me with this incredible opportunity.

References

Australian Energy Market Commission (AEMC), “Power of Choice - giving consumers options in the way they use electricity,” 2012. [Online]. Available: http://www.aemc.gov.au/Media/docs/EPR-0022-Power-of-choice-review---Directions-Paper-FINAL-for-publication-pdf-92ab8df4-d019-4e39-9d77-c0fb0c7407de-3.PDF

Energex. “Network Managemnt Plan”, 2012. [Online]. Available: http://www.energex.com.au/657A77C0-EA47-43B3-BCF9-830D2350D1BA/FinalDownload/DownloadId-E81D084C6C1FEF5B5D21458B23BB98E5/657A77C0-EA47-43B3-BCF9-830D2350D1BA/__data/assets/pdf_file/0003/117039/NMP2012-13-to-2016-17-Final-Ver16s.pdf

Garrone, V. (2012, May). EESA Presentation: Solar PV on the Energex Distribution Network.

Ofgem (n.d.). RIIO ED-1 glossary of terms. Retrieved from https://www.ofgem.gov.uk/ofgem-publications/47151/riioed1sconglossary.pdf

UKPN. “Introduction to London Power Networks”. UK Power Networks, 2012. [Online]. Available: http://www.ukpowernetworks.co.uk/internet/en/about-us/documents/london_power_networks_introduction.pdf

UKPN. “Introduction to Eastern Power Networks”. UK Power Networks, 2012. [Online]. Available: http://www.ukpowernetworks.co.uk/internet/en/about-us/documents/eastern_power_networks_introduction.pdf

UKPN. “Introduction to South Eastern Power Networks”. UK Power Networks, 2012. [Online]. Available: http://www.ukpowernetworks.co.uk/internet/en/about-us/documents/south_eastern_power_networks_introduction.pdf