Mr Donald McPhail
430 South 2nd Street
Phoenix Arizona 85003
United States of America

11th October 2012

Mr Simon Bartlett
Chairperson
ES Cornwall Scholarship Advisory Committee
P.O. Box 1193
Virginia QLD 4014
Australia

Dear Mr Bartlett,

ES Cornwall Memorial Scholar – Donald McPhail
Fourth Quarterly Report

Please find enclosed my fourth quarterly report for the ES Cornwall Memorial Industry Scholarship for the period 2nd July 2012 – 30th September 2012 during my employment with DNV KEMA in the Netherlands.

During the second three months of my placement with DNV KEMA, I have continued working as an Electrical Engineer as part of the New Energy Technologies team in the Clean Energy Services business unit based in Arnhem, the Netherlands. The New Energy Technologies team is made up of a number of professionals from various technical and business backgrounds and has a focus on projects related to energy storage, carbon capture, transition to sustainable energies, and industrial use of polymers, for governments, utilities and businesses.

The key work I have carried out during this quarter has included continuing on with the development of a grid modelling and optimisation tool for the European Commission supported NEMO project. I have also worked on a project to model the Dutch LV grid of 2050 to make predictions on the cost to network augmentation to support predicted penetration of EVs, PVs, heating technology (gas vs. electric booster), and 2h and 12h shiftable loads, as well as the predicted customer demand profiles.

Given the confidential nature of much of my work I have undertaken, I have had to omit certain details of some developments that are of commercial significance to DNV KEMA and their clients.

I would welcome any feedback and advice from the committee and all interested parties, regarding this report or my proposed goals for the next quarter.

Kind regards,

Donald McPhail

E.S. CORNWALL MEMORIAL INDUSTRY SCHOLARSHIP
FOURTH QUARTERLY REPORT

By

Donald McPhail

Reporting period: 2nd July 2012 – 30th September 2012

11th October 2012

Approved by Dr. Jos van der Burgt
(DNV KEMA)

Table of Contents

Introduction

My proposed program under the E.S. Cornwall Memorial Industry Scholarship is to gain international experience in the best practices regarding the application of distributed generation and electric vehicle infrastructure on global electricity networks. In particular, I hope to gain experience and an understanding of the associated current and future engineering challenges through working with a Distribution Network Operator (DNO), an energy consulting business, and an electric vehicle infrastructure business. It is anticipated that my scholarship period will run from September 2011 to May 2013, and will consist of the following placements:

- UK Power Networks (September 2011 to February 2012)
- DNV KEMA (April 2012 to September 2012)
- ECOtality North America (November 2012 to April 2013)

This report is the fourth of six quarterly reports required under the scholarship guidelines, and covers 2nd July 2012 – 30th September 2012. This three month period is the second half of my six month placement with DNV KEMA in Arnhem in the Netherlands, as part of the New Energy Technologies team. This period also concludes my six month full time tenure with DNV KEMA as part of the ES Cornwall Scholarship. I believe I have gained a lot of knowledge working along side a diverse group of technical professionals, and have thoroughly enjoyed my time here. I believe my exposure to other projects, related to my scholarship topic, being carried out in Europe within and outside of DNV KEMA, has been a major benefit. I have also been fortunate enough to develop a number of great professional and personal relationships with my colleagues and co-workers which I am sure I'll be able to make great use of in the future. I also want to make a point of thanking my supervisor, Dr Jos van der Burgt, whom I am particularly grateful for providing me throughout the duration of my tenure with the necessary assistance and guidance to complete my work.

Summary of Work Experience

In my role as an *Electrical Engineer* within the New Energy Technologies group, my work this quarter has allowed me to continue on with the development of a grid modelling and optimisation tool for the European Commission supported NEMO project. I have also worked on a project to model the Dutch LV grid of 2050 in order to make predictions on the cost to network augmentation to support predicted penetration of EVs, PVs, heating technology (gas vs. Electric booster), and 2h and 12h shiftable loads, as well as the predicted customer demand profiles. This work is discussed in what follows.

Development of a Grid Modelling and Optimisation Tool – The NEMO Project

Following on from my work in the previous quarter on working on the development of a grid modelling and optimisation tool for the European Commission supported NEMO project[1], my work

[1] Further information about the NEMO project can be found at: http://www.nemo-project.eu/

this quarter has again focussed on creating a clean working version of the PLATOS tool and working with project team to determine the requirements to integrate the tool into the complete NEMO suite. Specifically I created a clean working version of the bulk of the functionality of the PLATOS tool within DIgSILENT PowerFactory, as well as make it so it can be easily integrated into an external programming shell for the NEMO suite. The improvements in the clean version of PLATOS included the ability to:

- Accurately perform an automated forward time sweep load flow and identify network issues (i.e. overloads and voltage outside network limits) and their location in the grid, for a given simulation period based on the starting time/date, time step size, and the power flow profiles of loads and generators.
- Assess 'Business As Usual' (BAU) solutions ability to fix identified network issues, and calculate their associated capital costs. BAU solutions include changing the fixed tap setting of the distribution transformer, replacing conductors with those of higher current rating and lower impedance, and the installation of a capacitor bank.
- Translate the network issues into Energy Storage System (ESS) performance requirements for the purpose of performing the ESS optimisation calculation.
- Calculate the net present value of the cost of a solution and ability to compare solutions against performance criteria.
- Output results for each load flow time step, showing nodal voltages (importantly the upper and lower points and whether these or any other nodes were outside the limits), the current flowing through conductors (including the most loaded conductor and any that exceeded its rating), and graphical representation of result.

The only functionality missing from the clean version of PLATOS was the comprehensive ability to optimise the location, size and type of an ESS. Rather it was decided that by employing some simple rules/guidelines, the location of the ESS can be manually selected and the size and type would be automatically optimised. This process was selected as it was hoped that it would reduce the number of potential combinations and hence the run time of the modelling software. While working on incorporating this ESS optimisation methodology, the NEMO project team recommended that this optimisation may be quicker if performed outside PowerFactory (for example in a separate program shell), so as to get around a number of its computational limitations. Giving the timing of this recommendation, I altered my work so as to make it that the modelling tool was set so that optimisation calculation could easily be added internally or externally to PowerFactory at a later date.

The remainder of the time I spent working on this project, was focused on putting together a user manual including an example grid simulation with results, and passing on my knowledge about the tool to the DNV KEMA employees who would complete the development post my departure. The user manual outlined the process for setting up a model, performing the network simulation with the desired criteria, and understanding the results that are produced. In addition I also worked with the NEMO project team to develop a functionality, usability, technical requirements and constraints document for the NEMO tool suite. Given my knowledge of the Clean PLATOS tool, and my previous

distribution utility experience, I provided technical input regarding the modelling of LV networks and evaluation of potential solutions to allow for network optimisation.

Modelling of the Impact of Distributed Energy Resources on the 2050 LV Distribution Grid

The New Energy Technologies group of DNV KEMA had been contracted by a client to complete modelling of the anticipated Dutch, United Kingdom and German urban and rural energy networks in 2050, based on meeting the national emissions reduction targets. The models were to take into consideration the anticipated level of penetration of EVs, PVs, heating methods (gas vs. electric boosters), and 2h and 12h shiftable loads, as well as the predicted customer demand profiles. Fortunately, DNV KEMA already had a 2050 urban Dutch LV grid model that they had created with a Dutch distribution utility for studies in previous projects. I was therefore given the task to validate the existing model for the needs of this project, as well as create a rural model which essentially consists of longer lines, lower customer numbers and differences in the types of customers. The model consisted of a completely underground network (typical for the Netherlands) and the validation showed there was an effective mix of LV feeder spurs that included a shopping centre, school, apartments, row houses, pair (semi-detached) houses, and single (detached) houses. The conductors' (feeder and service cable) and transformer's types (and subsequent ratings and impedance) were also selected to reflect those that would be in place in a typical urban grid in 2050.

For analysis purposes, the model was created in DIgSILENT PowerFactory which allowed for time based load-flows. Thus by assigning desired generation and demand power profiles to customers, a simulation could be completed to commence on a desired date and run for a desired time with desired time steps, so as to identify network issues against moments in time. Using this method, a number of yearly events were to be modelled including an extreme winter week profile (-17°C), and sunny summer week profile (no clouds). Given the Netherlands experiences a winter peak in demand and the current reliance on gas for heating, the extreme winter case is an important one as comparing scenarios with different heating strategies in 2050 could see significant increase in peak load on the LV network. Likewise a sunny (no clouds) day typically results in high PV production and lower demand which can cause reverse power flows in the network. These events can then result in network issues such as overload and voltage outside of network constraints. For each yearly event, a number of scenarios were to be modelled to reflect the different likely customer behaviours in 2050 in order to meet the emissions targets. The designed scenarios also reflected the different house types that are anticipated to be in place by 2050, with 'existing', 'refurbished' and 'new', each reflecting the efficiency of the building and associated technologies and amount of shiftable loads (2h and 12h) available. It was assumed for this analysis that by 2050 an extensive ICT network would be in place and all EV charging would consist of smart charging (i.e. distributor manages EV charging to take place in troughs in the power flow curve). In total, 126 scenarios were determined, whose attributes included:

- Year 2050 profiles and grid
- Urban and Rural grids for the Netherlands, UK and Germany

- Three types of houses mixed according to building stock (Apartments, Row Houses, Detached), plus school and shopping centre
- Three environmental cases (Winter -17°C, Winter -12°C, and Summer Sunny day)
- Three grid cases (Electric + Gas, Future all Electric, Future Electric + Gas)
- Mix of house ages (Existing, Refurbished, New)
- Mix of Technologies all depending on grid and house age type (this affects amount of 2h and 12h shiftable load)
- Forecast EV penetration levels based on house type with smart charging (DSO controllable)

Unfortunately, a number of project delays occurred and this resulted in the load profiles not being available for me to complete the analysis before my last day at DNV KEMA. Rather I was able to simulate dummy cases using real sunny day PV profiles (adjusted per PV size) and 2011 load profiles (winter and summer), to gain results of how the 2050 grids operate with current demands and identify any existing network constraints. I presented this, along with a user manual for completing the analysis, to my colleague so that the work could be completed as soon as the remaining load profiles became available.

Additional Experiences and Opportunities

In order to further continue my professional development, I have also taken advantage of the opportunity to attend a number of engineering events, as well as some site visits. The highlight of this quarter was being able to attend the 2012 CIGRE Session in Paris, France. The CIGRE Sessions are held every 2nd year in Paris and allow an opportunity for members from around the world to come together, enhance their knowledge, discuss new developments and innovations, and to network. Following my attendance at CIGRE, I put together a report that summarised the key learning from papers and presentations regarding international developments that would be beneficial to the Queensland distribution electricity industry. I have previously circulated this report and it is also uploaded on the ES Cornwall Scholarship website[2]. Some notable points about the conference were:

- As part of the CIGRE Next Generation Network, I was able to go on a tour of the RTE Paris Seine 225/20KV GIS substation
- I was able to attend the Workgroup C6 technical session, private study committee session, and poster session on the topic of Distribution Systems and Dispersed Generation. This topic aligned with my scholarship objective.
- I attended general sessions on the role of electricity systems in reducing energy's environmental footprint, and responding to large network disturbance events around the world.

[2] http://escornwall.com.au/index.php/2012/09/lessons-learned-from-the-cigre-sessions-on-distribution-systems-and-dispersed-generation/

Outside of my work, I have also taken advantage of the opportunity the scholarship has provided me to be living in the Netherlands, to complete an introductory Dutch language course, and to travel throughout Europe. Over the past three months I have been able to see more of the Netherlands, Germany, Belgium, France, Switzerland, and Luxembourg, and throughout October I am embarking on a trip throughout Spain and Portugal while I make my way to the USA for my role with ECOtality North America.

Future Direction

As I have now finished my six month tenure with DNV KEMA, as I mentioned I am taking part of the month of October 2012 off to spend some time travelling in Europe. In this time I will also relocate to the USA where I will be commencing my final six month role, which will be as a Ground Energy Storage Engineer with ECOtality North America in Phoenix, Arizona from the 5th of November 2012. ECOtality North America is the operations centre and research and development unit of the ECOtality Inc. organisation. ECOtality is a leader in clean electric transportation and storage technologies, and provides products and services for Residential, Commercial and Industrial applications. My goal for this placement is to gain greater experience in the deployment of electric vehicle charging infrastructure, the impact it has on the energy network, and the best practices for managing these systems. My focus in this role will be on evaluating local grid conditions to determine the requirements for ground energy storage and estimating the optimum size of DC Fast Charge energy storage and make improvements in system efficiency; conducting research with utility companies to understand and resolve issues regarding the use of ground energy storage systems; exploring the US energy markets, comparing them to the Australian market and evaluating the revenue opportunity potentials in the EV infrastructure market. With respect to immigration, with the assistance of the staff at ECOtality North America, I have applied for and received an E3 visa to allow me to work in the USA, in this role with ECOtality North America for the duration of my placement. I am now very much looking forward to commencing this placement and the opportunities it presents to build off of my E.S. Cornwall scholarship.