Mr Donald McPhail
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Phoenix Arizona 85003
United States of America

3rd May 2013

Mr Simon Bartlett
Chairperson
ES Cornwall Scholarship Advisory Committee
Australia

Dear Mr Bartlett,

**ES Cornwall Memorial Scholar – Donald McPhail**
**Sixth Quarterly Report**

Please find enclosed my sixth and final quarterly report for the ES Cornwall Memorial Industry Scholarship for the period of 4th February 2013 – 3rd May 2013 during my employment with ECOtality North America in the United States of America.

During the final three months of my placement with ECOtality, I have continued working as a Ground Energy Storage Engineer as part of the Engineering team based in Phoenix, Arizona. ECOtality North America is a leader in clean electric transportation and storage technologies, and provides Electric Vehicle Supply Equipment and services for Residential, Commercial and Industrial applications. ECOtality has also designed and currently manages the world's largest EV infrastructure demonstration - The EV Project.

The key work I have carried out during this quarter has included producing a report that discusses the state of the USA electricity demand response programs, and proposes the technical/economic opportunities and challenges that exist for ECOtality to participate in these programs, as well as a roadmap and recommendations for doing so. I have also produced a white paper, to be published by ECOtality, on the opportunities to reduce utility demand charges incurred by DC fast charging units, by utilising demand diversity, energy storage system assisted recharging, and providing demand response to the electricity grid.

Given the confidential nature of much of the work I have undertaken, I have had to omit certain details of some developments that are of commercial significance to ECOtality.

I would welcome any feedback and advice from the committee and all interested parties regarding this or any of my previous reports for the ES Cornwall Memorial Industry Scholarship.

Kind regards,
Donald McPhail

# E.S. CORNWALL MEMORIAL INDUSTRY SCHOLARSHIP
# SIXTH QUARTERLY REPORT

*By*

*Donald McPhail*

**Reporting period: 4th February 2013 – 3rd May 2013**

**3rd May 2013**

***Approved by Garrett Beauregard***
***EVP and GM of ETEC Labs***
***(ECOtality North America)***

# Table of Contents

# Introduction

My proposed program under the E.S. Cornwall Memorial Industry Scholarship was 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 organised roles that allowed me to gain experience and an understanding of the associated current and future engineering challenges, through working with a distribution network operator, an energy consulting business, and an electric vehicle infrastructure business. As anticipated, my scholarship period ran from September 2011 to May 2013, and consisted 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 May 2013)

This report is my sixth and final quarterly report required under the scholarship guidelines, and covers 4th February 2013 to 3rd May 2013. This three month period is the second half of my six month role with ECOtality North America (ECOtality) in Phoenix, Arizona in the USA, as a Ground Energy Storage Engineer.

# Summary of Work Experience

In my role as a *Ground Energy Storage Engineer* my work during this quarter allowed me to gain a greater understanding of the USA electricity markets and Demand Response (DR) programs, the application ground energy storage with EVSE infrastructure, and the challenges and opportunities for the deployment of a network of EVSE infrastructure. Specifically my work included:

- Complete research and analysis on the USA DR programs and the opportunities for a network of aggregated EVSE units to participate. My deliverable from this work was a detailed report outlining my corresponding recommendations and a roadmap for participation.

- Write a white paper on the opportunity to reduce or mitigate utility demand charges incurred by DC Fast Charge (DCFC) EVSE units, through the use of: demand diversity, Ground Energy Storage system (GES) assisted recharging, and providing DR to the electricity grid.

## Report on the Opportunities for an Aggregated Network of EVSE Units to Provide DR

Following on from my work in the previous quarter where I investigated the structure and players of the USA electricity markets, and the state of the DR programs that are available for participation, I carried out the following analysis and work:

- Updated the previous USA Electricity Market catalogue I'd created to include details on the DR programs offered by each entity.

- Identified which DR programs suited an aggregated network of EVSE units, including what program rules were desirable, and what rules limited the opportunity to provide DR.

- Calculated what the revenue potential for ECOtality would be if it entered into providing DR from its aggregated EVSE network, based on aggregated EVSE demand profiles, the rules and incentives of suitable DR programs, and EVSE technology capabilities in providing DR.

- Developed a high-level roadmap that shows how electricity markets and their DR programs are predicted to evolve (or need to evolve) over the short-to-medium term (approximately 10 years). In addition, I included as part of the roadmap, how ECOtality needs to develop going forward in order to be able to participate in the most appropriately aligned programs and leverage the maximum benefit for the business.

- Produced a detailed report that provided an overview of the current state of DR programs on offer throughout the USA, and discussed opportunities for ECOtality's aggregated EVSE network to be involved. As part of this report I discussed the challenges associated with participation, including recruitment and management of EVSE users, participating directly through a utility or via a third-party aggregator, addressing the conflicts that arise between providing DR and providing reliable charging stations, and addressing the technical capabilities of ECOtality's EVSE network. Upon completion, I presented this report, and my findings and recommendations to a group of key internal stakeholders that consisted of management, engineers and project managers.

While the purpose of this work was to guide a number of related internal decisions, the quality of the content was well received and I was also asked to create a detailed report and a technical paper to be published and made available to the industry. At time of writing this quarterly scholarship report, these papers were going through internal development and review stages and are envisaged to be made publicly available in Q3 2013.

## White Paper on Methods to Reduce Utility Demand Charges Incurred by DC Fast Charge EVSE Units

The other main piece of work I completed this quarter was to write an industry white paper on methods to reduce utility demand charges incurred by DC Fast Charge EVSE units (DCFCs), with the paper to be released as part of the lessons learned component of 'The EV Project', and published on the project's website[1]. This report followed on from a previous industry white paper produced by The EV Project on demand charge reduction, which proposed the following six methods and addressed the first three[2]:

1. Never allow the overall site power demand to exceed a specified value.
2. Attempt to ensure that the average power over the interval is less than or equal to a

[1] More information on The EV Project, including all of the lessons learned reports, can be found at: http://www.theevproject.com/

[2] The EV Project lessons learned white paper produced in May 2012 on demand charge reduction using methods 1 to 3 can be found at: http://www.theevproject.com/downloads/documents/2.%20DC%20Fast%20Charge-Demand%20Charge%20Reduction%20V1.0%20Revised%20(2).pdf

specified value.

3. Attempt to recoup the demand charge cost through structured pricing for EVSE charging.
4. Add a GES that buffers the EVSE unit from high power demands during charging.
5. Aggregate demand among multiple EVSE installations into one demand charge calculation, taking advantage of the diversity that may exist in individual unit usage.
6. Provide DR capability to the utility to either offset or circumvent demand charges.

My project therefore was to investigate methods four, five and six, and cover the application of these methods in the subsequent white paper. While complete details of this work will be available in the white paper once it is published on The EV Project website[1] by late Q2 2013, the following is an overview of several points covered in the paper.

- Regarding Method 4 - GES Coupled with EVSE to Buffer High Power Demands
    - As discussed in my fifth quarterly report, this method involves using a GES to assist an EVSE unit during a recharge, so as to buffer the high power demands. As shown in Figure 1, the arrangement allows for the GES to supply some or all of the power and energy needs of the EVSE during charging. The GES can then be recharged at or below the power demand threshold to minimize or eliminate power demand charges, and/or during off-peak time periods when energy prices are lower.

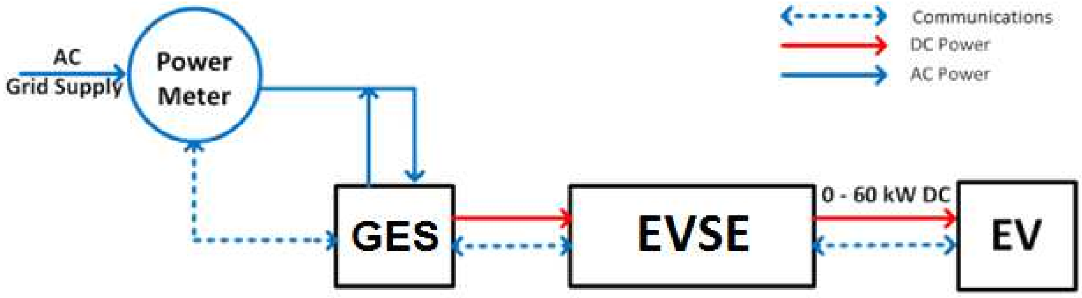


**Figure 1 - GES assisted recharging of an EVSE**

    - To aid in evaluating this method, I developed a GES-DCFC simulator that models the performance of a user proposed GES against any EVSE demand curve. An example of the power flow curves of a GES coupled DCFC is shown in Figure 2 over the course of 12 hours. In this example, the GES has a usable capacity of 20 kWh and a discharge rate of 30 kW, in order to keep the instantaneous demand on the AC grid supply less than or equal to 20 kW.
    - In the arrangement shown in Figure 1, there is a direct communications link between the EVSE and the GES. This communication link is necessary so that when a charge event begins, the GES can determine whether there is sufficient stored energy to complete the charge. If, however, the GES was being installed to support an existing EVSE and a direct communication link could not be established, the GES would have to be appropriately sized so as to ensure that it would never be fully discharged. In the event that there were a sufficient number of back-to-back charge events to cause the GES to be fully discharged, the GES would not be able to change

the charging current of the EVSE and the AC grid will be expected to supply the full, unconstrained demand of the EVSE. For this reason, as part of my simulation tool, I also included the functionality to identify whether or not this communication link was present for more effective evaluation.

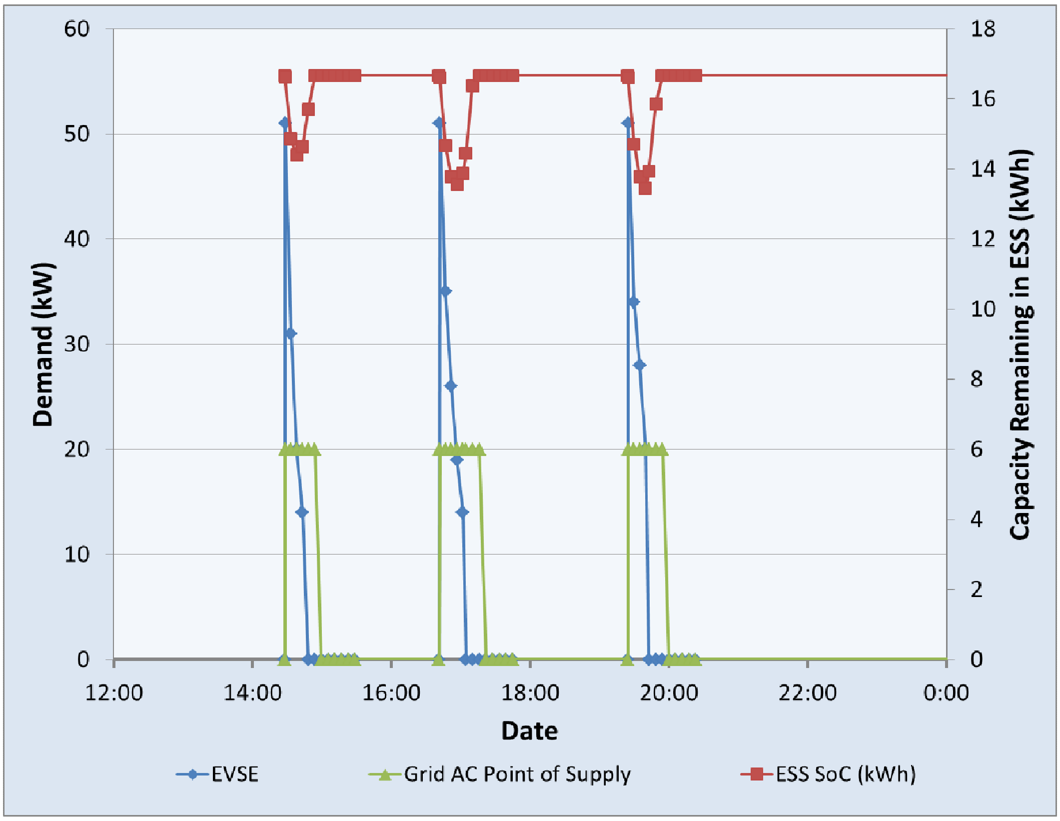


**Figure 2 – Charging and discharging a GES to support DCFC demand over a 12-hour period**

- Regarding Method 5 - Aggregation of Multiple EVSE Installations into one Demand Charge to Benefit from Diversity
    - In a site with multiple EVSE units, assuming that there is always one or more EVSE units that is not in use at any time, the owner benefits from demand diversity and rather than have a demand charge that corresponds to the summed total of peak demand of each unit (which would be the case when individually supplying the units), the owner only pays a single demand charge for the aggregated peak (which would be expected to be less). An example of this arrangement is shown in Figure 3.

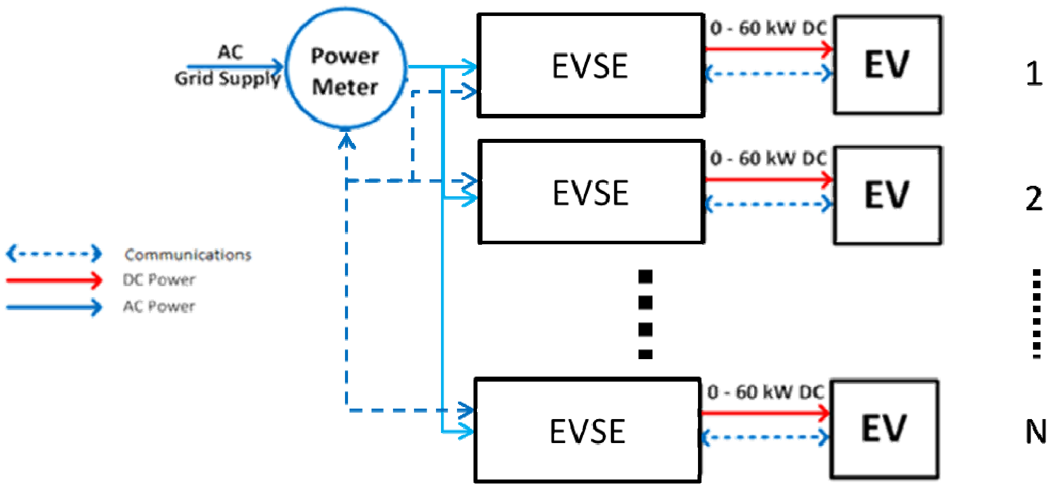


**Figure 3 – Aggregation of multiple EVSE units supplied via a single grid connection**

- In evaluating this method I created a number of weekly demand curves of aggregated EVSE units installed in similar locations, including both AC Level 2 EVSE units and DCFCs. From this analysis I could see that, while this method could result in some minor savings, it was hard to predict from one month to the next what the maximum site demand would actually be. There was also the high risk that all EVSE units would be in use at full capacity at once. This subsequently lead me to propose and evaluate three different demand diversity control strategies, which include:

  1. *'Delayed Start'* - Once the maximum demand threshold is reached, each subsequent PEV connected to an EVSE is delayed until another PEV is finished charging and there is sufficient demand capacity available.

  2. *'Demand Rationing'* - Once the maximum demand threshold is reached, any additional PEVs that are connected to an EVSE unit will result in the maximum total demand being rationed between all EVSE units.

  3. *'Complete-by'* - When a PEV is connected, the user can stipulate a delayed charged completion time. The system would then prioritize EVSE demand based on completion times in order to stay under the demand threshold. This strategy would also utilize either a 'delayed start' or a 'rationing' strategy for managing PEV charging to ensure completion by the desired time.

- Regarding Method 6 - Provide DR Capability to the Utility

  - This method involves providing DR to the electricity utility either directly or through a third-party aggregator, and in return avoiding some or all of the demand charges or having them offset by DR payments.

  - Utilising the research I had conducted as part of the report investigating opportunities for ECOtality from providing DR, I was able to investigate where a single DCFC could participate in established DR programs. My finding was that typically, DR programs require loads to be at least 100 kW in size, which prevents a single DCFC from being able to participate. There are some exceptions to this rule, with the best opportunity being for the DCFC to either enrol through a third-party aggregator, or as part of an aggregated EVSE network. The added benefit with aggregation is that it can protect the DCFC from penalties for not reducing its demand by the required amount during a DR event, if for example a priority charge was taking place, or no vehicle was connected to the DCFC at the time of the DR event, and so it physically had no demand to reduce.

  - Evaluating this method highlighted to me that while there is a great opportunity available to utilise EVSE units for DR, ultimately this can have a negative impact on the core function of the EVSE, which is to provide reliable charging infrastructure. Mishandling on the EVSE owner's part could result in user backlash due to extended charge times and uncertainty on whether an EVSE will be available for use.

- In order to demonstrate the application of these methods, I applied each of them to a real life case study of a DCFC installed near San Diego in California, which is subject to some of the highest utility demand charges in the U.S. for 50 kW connections, at $30.68 per kW per month in summer, and $21.90 per kW per month in winter. As a 20 kW connection would be subject to no demand charges under the utility's rate structure, one notable finding in this case study was that an appropriately sized GES (30 kW instantaneous rate of discharge rating and 10 kWh usable (12 kWh total) Li-Ion battery) would have a payback period of approximately 3.25 years, and over a seven year lifespan, would save the owner an additional $48,500 USD in avoided demand charges.

## 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. This quarter I have:

- Been awarded my CPEng and NPER following my professional interview with Engineers Australia in March 2013.
- Continued in my role chairing the organising committee for the 2013 IEEE Global Humanitarian Technology Conference Young Professional Project contest.
- Written a paper that has been accepted to be presented at the Australian World Renewable Energy Congress conference in Perth in July 2013 (*Paper Title: "Evaluation of Ground Energy Storage Assisted Electric Vehicle DC Fast Charger for Demand Charge Reduction and Providing Demand Response*")
- Written an abstract for a presentation that has been accepted for the All-Energy Australia conference in Melbourne in October 2013 (*Presentation Title: "Utilising an Aggregated Electric Vehicle Charging Station Network to Provide Demand Response to the Electricity Grid"*)

- Co-authored an article for the Electric Vehicles Magazine *CHARGED* on methods for utility demand charge reduction for EVSE units.
- Co-authored a paper for submission to IEEE-PES Great Lakes Symposium on Smart Grid and the New Energy Economy in Chicago in September 2013.

In addition, I have also had the opportunity to meet and work with professionals from a variety of backgrounds. Being a part of the engineering team and working alongside automobile professionals, mechanical engineers, electronics and control system engineers, chemical engineers, and project managers, has allowed me to gain a greater understanding of the challenges faced with EVs and EVSEs from the user and vehicle perspective. This in turn has improved my thinking of how best to manage the effects of EVs from the electricity supply side. One of the great benefits has also been the opportunity to test drive a number of EVs new to the USA market, and gain insight into the results of their performance testing throughout their life.

Outside of my work, I have also taken advantage of the opportunity the scholarship has provided me in being able to travel internationally. Over the past three months while living in the USA I have been able to attend a number of events and see even more of Arizona and California. I am now spending a couple of weeks travelling in the USA before returning to Australia to re-enter the Australian electricity supply industry. Upon my return I am more than happy to make myself available for any industry or ES Cornwall scholarship events as required.

I would like to conclude my final quarterly scholarship by thanking the scholarship committee for providing me the opportunity to gain this invaluable global industry experience that will define my professional and personal life for years to come. I would also like to thank the teams at UK Power Networks, DNV KEMA, and ECOtality North America who have allowed me to come and work with them for six months each, and gain a wealth of knowledge and experience. I know I have developed some valuable professional and personal connections that I am truly grateful for.