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Dear Simon,

E.S. Cornwall Memorial Scholarship – Sixth Quarterly Report – Reena Kwong

Please find enclosed my sixth and final quarterly report as part of the E.S. Cornwall Memorial Scholarship.

As well as outlining my work during the second half of my year at the Ontario Power Authority (OPA), this report also provides a summary of my scholarship tenure whilst working at National Grid and in Ontario with the OPA in terms of renewable energy integration.

I welcome any constructive feedback from all interested parties in relation to this report.

Kind Regards,
Reena

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Executive Summary

My proposed program under the E.S. Cornwall Memorial Scholarship was aimed at gaining international experience in the integration of renewable energy into an electricity market. Specifically, exposure is sought on the network planning and operational requirements to be considered in order to cater for large amounts of renewable energy due to climate change policies in place, as well as investigating the issues, and solutions to such issues, which may arise in the integration of renewable generation in a market.

The period of my placement overseas commenced in March 2009 and ended in March 2011. My first placement was with National Grid, the system operator of Great Britain (GB), from March 2009 to March 2010. During my 12 month term with National Grid I was part of the System Strategy department where I was involved in power system studies to assess the impact of certain transmission reinforcements to accommodate wind generation. My placement between March 2010 and March 2011 was with the Ontario Power Authority (OPA); the transmission planner and generation procurer for the province of Ontario, Canada.

This report is the final of six reports for my scholarship tenure.

Work Experience to Date

Similarly to my Q5 Report, my work experience during 2010 and early 2011 at the OPA has included the transmission availability tests on Post-Launch period applications in Eastern and Central Ontario as well as work leading up to the ECT assessment for renewable projects which did not pass the transmission availability tests from the Launch and Post-Launch periods due to transmission and/or distribution capability limitations.

I was involved in a pre-transmission availability testing for the Korean Consortium renewable phases, as well as the implications of these connections on current FIT program applicants. Due to the confidentiality of this work I am not at liberty to provide further details, however this type of work has not only enhanced my experience with both wind and solar renewable integration, but has also exposed me to the delicate situations involving planning jurisdictions, private developers, the government and the energy board.

Work on integrated regional area planning was also a focus during my time at the OPA due to the announcement of the Long Term Energy Plan being released by the government. In addition to the bulk transmission planning, the OPA addresses specific regional supply

adequacy issues, either current or foreseen that may affect the reliable delivery of electricity to customers; areas of focus were detailed in the Long Term Energy Plan published at the end of 2010. The regional area studies are becoming more complex due to the recent introduction of the FIT program where a large number of distributed renewable generation have successfully applied, and therefore the impact of these now need to be considered within the integrated plan. The integrated plans include reviewing options of conservation measures, distributed generation, and transmission and distribution system reinforcements against near-term, mid-term and long-term needs. These options are evaluated based on economic, environmental and technical considerations so that an integrated plan can be recommended to ensure distribution and transmission expansion plans are coordinated. Whilst at the OPA, I was leading the working group for a regional area study in southwest Ontario which consisted of representatives from four southwest Ontario LDCs, Hydro One Distribution and Transmission groups as well as the IESO. I was also providing technical support for other regional planning working groups for northern and eastern Ontario areas.

Other work also included system studies for part of the bulk transmission network in northern Ontario which is mainly supplied by large coal plants and hydro generation. Many of the hydro plants in the northern Ontario area are classed as Non-Utility Generators (NUGs) or contracted generators, whose contracts are coming to an end in the near future. Consequently, with the Government's clean energy initiative of ceasing the operation of all coal plants in the province by 2015, renewal of the NUG contracts under consideration, and with the intermittent nature of renewable generation applied to connect to the area through the FIT Program, the supply to certain areas of northern Ontario in particular is of concern, especially during low-water periods which can occur in the north when there is insufficient melted ice from the lakes due to mild winters. These studies being completed in collaboration with the IESO, are considering potential transmission and distribution reinforcements, load rejection schemes, the extent of reliance on the northern demand response program, as well the possibility of negotiating extended generation contracts for both some coal generators and hydro NUGs in order to alleviate supply adequacy concerns post-2015. The latter scenario is very sensitive due to the Government's clean energy policy and cost implications of extending contracts of non-utility generators which were not expected to be relied on for supply adequacy. As a result, this type of work further exposed me to the coordination required between the Ministry and its policies, transmission planning as well as generation company priorities for supply reliability.

During my at the OPA, I have also attended site visits to the Sir Adam Beck hydro generation plant (located at Niagara Falls) as well as the Thorold co-generation plant. I have also been

fortunate to attend seminars including the Wind Power Standing Committee which is coordinated by the IESO, discussing wind generation issues in Ontario, as well as the annual Ontario Power Summit which provided me with an insight on the issues of the different sources of energy mix within the province as well a financial perspective on investing in renewable energy projects.

Update on Ontario's FIT Program

My previous report provided background information on Ontario's Feed-In Tariff (FIT) Program which was launched in October 2009. As mentioned in that report, the FIT Program gave renewable energy developers incentives to build their renewable generation in the province under the Green Energy and Green Economy Act (GEGEA). Over 9,000 MW of applications were submitted during the two-month launch program, with only 2,500 MW able to be accommodated on the existing Ontario network. The remainder MW are subject to the Economic Connection Test (ECT) process, which is stage two of the FIT Program.

Since my previous report, the OPA accepted "Post-Launch" applications under the FIT Program from 1 December 2009 until 4 June 2010. These applications are subject to similar Transmission and Distribution Availability Tests (TATs/DATs) that the Launch Period applications underwent and according to their time of submission (priority timestamp).

During the Post-Launch period, just over 3,500 MW of applications were received for the province; a figure indicating the large amount of continued interest in the renewable energy sector.

As mentioned previously, the initial schedule of the FIT Program was aiming to start the ECT Process by September 2010. However, due to the large volume of applications received in the Post-Launch period requiring more time to process these applications and then perform Transmission and Distribution Availability assessments, the ECT Process is not expected to begin until the second half of 2011. An IPA stage (Individual Project Assessment) where additional capacity allocation is awarded to applications due to rescinding contracts and/or new transmission facilities expected to come into service, is to be completed before commencement of the ECT.

Observations from the FIT Program

Over the last six months whilst employed by the OPA, I have witnessed both positive and negative implications resulting from Ontario's FIT program which I will express below.

Favourable Implications

Ontario's approach to encouraging more development of green energy through the two-month Launch Period FIT application window was a very aggressive method in terms of achieving a fast response from the energy sector. An advantage to this is that Ontario will be incorporating close to 12 GW of renewable/clean energy in the near future due to the success of the Launch and Post-Launch FIT program.

Another advantage that stems from the FIT Program is the opportunity of creating many green energy jobs in Ontario. The FIT Program's Rules require that a project's domestic content portion, that is, the portion of the project's development which must be sourced from Ontario, including manufacturing or labour etc, is between 50-60% (depending on type and size of the project) if the project's commercial operating date (COD) is on or after 1 January 2011.

An advantage of the Post-Launch period is that applications that applied within this period may enable applications from the Launch Period which did not receive contracts due to transmission contraints, to obtain a contract by now enabling the requirement of transmission expansion in a particular location through the ECT Process, as cumulative benefits of the projects are deemed 'economic'.

Unfavourable Implications

Such affects are perhaps due to the fact that parts of the FIT Program Rules were not as well developed as initially thought in the following areas:

- High price for developers; as a result of the very attracive price set for renewable energy developers, there was a larger than expected influx of applications, which caused the program to be delayed in terms of announcing contracts to be awarded and as such, developers have had to wait patiently for the outcome.
- Also resulting from the high price offered for FIT contracts, majority of the Launch Period applications showed that developers were not necessarily considering the most beneficial project location according to resource availability, as some of the proposed points of connection, when considering the size or type of renewable technology, do not seem physically viable. For example, I mentioned in my previous report that the

OPA did engage a consultant to provide an indication on potential high-wind sites, however the locations of wind applications recevied did not reflect results from the consultant's study.

- The FIT Rules do not outline a requirement for a project's land size to match up accordingly to project MW size; it has been noticed that when a successful applicant moves forward in acquiring land or sizing up turbines or solar panels for that location, the OPA are receiving information that the project's installed capacity is to be reduced due to land restrictions. There are no penalties for a reduction in project capacity. This can be seen as 'unfair' to other applicants where transmission capability was taken up by oversized applications purely because the project was higher on the program's priority order list.
- The effect of even small generators as part of the microFIT or CAE categories contributing to short circuit issues at stations has caused unexpected concern. It was found through the process that such applications were contributing to short circuit due to the extremely high number of applications received for these categories. Since microFIT and CAE applications are awarded a contract without network assessments, the larger sized FIT applicants were being pushed to the FIT Reserve until short circuit issues at the station they would likely connect to are fixed. This also caused delays to in-service dates of other microFIT and CAE applicants until the short circuit issue is managed.
- The fact that there was no specified renewable energy target set by the Government has caused a large number of applications to be submitted, and as such, the OPA had to deal with tens of thousands of applications within a small timeframe and are now obligated to identify transmission expansions for all applications through the ECT process. The waiting-time that developers must face due to this has now caused some negativity towards the program.

I have noticed that public messaging is essential throughout a new program such as Ontario's Feed-In Tariff. This is in order for applicants to understand and be aware of the status their application is at and also for potential applicants to be aware of areas that are and/or are not encroaching capacity to allow for better planning of their projects.

Observations from National Grid

Over my time with National Grid, I gained an insight into the planning and operational approaches that the GB system operator is interested in applying in order to accommodate larger volumes of renewable energy, wind in particular. I have outlined below the areas which

I feel National Grid is paying particular attention to in attempting to achieve the renewable energy targets that have been set by the UK government.

Review of the Security and Quality of Supply Standard (SQSS)

The GB Security and Quality of Supply Standard (SQSS) describes the transmission planning standards for investment and standards for planning and operating the system in real-time. The standards were established for a system predominately supplied by conventional generation, however with the increase in renewable generation proposed in order to meet the EU target in the near future, it has been found that the existing standards are not relevant. Therefore in November 2008, the GB SQSS Fundamental Review was proposed with an aim of developing solutions to integrate new generation technologies such as wind and other renewable generation into the electricity networks. In addition to the Fundamental Review, a separate 'Review of Infeed Loss Limits' is also in progress which considers the accommodation of infrequent infeed losses from 1320 MW to 1800 MW.

The main objective of the review is to develop a new methodology that will consider numerous elements of renewable technology. These include intermittency, variability of output, in particular, generally lower output during peak demand periods compared to conventional generation and higher value on transmission capacity access during windy periods. In addition to accommodating the above characteristics of wind generation, the current standard also needs to be modified to incorporate high wind penetration throughout all of the GB transmission system; it was initially established based on limited geographical data as the large wind farm project applications were for developments in Scotland only.

Subsequently with increasing amounts of renewable generation more geographically spread out and also larger single generating units due to connect to the system, National Grid have been required to amend their planning and operational standards in order to maintain security and reliability of the transmission system.

Transmission Access Review

Due to the current GB regime of generation access to the transmission system being quite slow, and with the increase in renewable generation required to meet the UK energy targets in a relatively short time span, a joint review of transmission access was initiated by Ofgem and DECC. There is a lack of flexibility to the short-term access regime as the optimisation of costs is more long-term focussed and the current GB generation access queue stretches out to 2020; therefore new renewables must wait for new capacity.

It has been identified that the provision of economic signals in the short-term would allow network investment requirements to be determined by the users and would also offer a choice between waiting for new capacity, at the investment cost, or to connect and use existing capacity at the operational cost; investing in additional capacity faster when required and making better use of the existing transmission capacity.

As a result, five transmission access models have been proposed and are still currently being investigated. These options are listed below:

(i) Connect and Manage with socialised costs which provides early access for renewables at stable long-term prices;

(ii) Connect and Manage with targeted costs where early access for renewables is at a forecast short-term price prior to the reinforcement date, with a more stable long-term price after the reinforcement date;

(iii) Capacity Auction with a flexible short-term access regime with early access for renewables at stable long-term prices provided they are able to out-bid existing generation, or generation currently in the queue;

(iv) Capacity Auction alternative with a flexible short-term access regime where prices in constrained areas are likely to be high in the short and medium-term, however new renewables get a share of long-term access through equal treatment of new and existing users; and finally

(v) a flexible short-term access regime with finite long-term access rights where 'x' year notice period for reduction can be provided.

Subsequently, the Transmission Access Review will consider the above arrangements so that the best possible model is selected in order for generation access to the grid to be as efficient as possible without biased treatment towards customers while still optimising network and user costs.

Managing Intermittency

National Grid was exploring developments which may be required to their network control systems to manage the increase in intermittent generation onto the system in order to support an efficient operation of the transmission network. Two fundamental changes which National Grid consider as having an high impact on their network includes increased variability of power flows as the relative output of renewables and therefore conventional generation varies as weather conditions change, and also transmission technology that will be required to be

implemented in order to manage the increase in power flows resulting from increasing renewable generation and eventually nuclear generation located remotely from major demand centres.

There is a general consensus within National Grid that the operating plans or characteristics of smaller generators, which were not required to be visible in the past, may need to be provided to the system operator to review such information in order to aide in the management of the system as it will become more important that these small generators continue to operate when network disturbances occur. In addition to this, the contingency and emergency procedures which help protect consumers from large scale electricity supply losses will need to be reviewed frequently through the use of new technology to replace or complement the existing emergency actions available and through the efficient replacement of Black Start service providers who are expected to close over the next decade. It is also envisaged that energy storage, electric cars, smart metering and smart metering enabled control systems will aide in the management of intermittency through co-ordinated demand side management.

On an operational front, National Grid has observed periods where the electricity generated from wind within the UK, Ireland and parts of Northern Europe has been very low which can coincide with days of peak electricity demand when cold and still conditions persist. Therefore, plans are underway for periods where the amount of electricity generated from wind is low at times of peak electricity demand. This does mean that other forms of generation are required at times when wind generation output is low, however a larger emphasis is being placed on demand side management during these periods.

National Grid will also attempt to utilise interconnection capacity, particularly between GB and Northern Europe where the import capability is high as sharing intermittency across a wider area will effectively reduce its impact on one area. For this reason, National Grid have already engaged with their European counterparts on processes to understand the European network operation as the level of import capacity available will depend on the European energy market reactions.

Wind Forecasting

In the initial stages of wind forecasting development, National Grid has assessed the differences seen between forecast generation output and actual generation for all types of generator. An in-house generation output forecasting tool specifically for wind has been

developed, however continued research and development in this area in still under-way as well as investigating third party packages.

Based on initial studies that have been performed where the majority of wind farms are located in Scotland, National Grid has concluded that the way wind output can vary throughout a day can be demonstrated by observing the current wind pattern compared to the output four hours ahead of time – persistence forecasting. Results have shown that wind forecasting errors are higher with higher wind outputs and there appears to be evidence that this occurs at dawn and dusk, i.e. coincident with rapidly changing demand or at peak demand times. The wind forecasting error, along with persistence forecasting, is taken into consideration when determining the amount of reserve required catering for wind forecasting uncertainty.

National Grid anticipate the level of forecasting errors to reduce as the geographic diversity of metered wind increases and also aim to quantify how forecasting errors vary under different wind conditions and different wind generation configurations. Their first step towards this is through the development of a sophisticated wind power forecasting system which essentially makes use of multiple forecasting methods which include:

- historical wind and actual generation output data,
- a linear regression model which optimises relationships between generation output and wind speed,
- a physical wind turbine model using a specific wind turbine power output curve and wind speed forecast to produce a generation output forecast, and
- extrapolation of a time series model from recent behaviour.

The new tool will also model wind direction using a probabilistic model as well as compare metered outputs with forecasts to aide in the selection of the most appropriate forecast method. National Grid expects their new wind forecasting tool to be implemented in late 2010.

System Inertia and Geographic Correlation of Wind

As wind generation across the network continues to increase in the near future, National Grid is concerned about the reduction to system inertia. As double fed induction generators and full converter turbine become the preferred wind turbine choice for wind farms allowing controllability and flexibility of the injection of real and reactive power into the system, with further wind development involving the use of permanent magnet and superconducting generators connected to the grid via these full converter arrangements, contribution to inertia is expected to be low as opposed to conventional rotating electrical machines. This is due to

the effect of de-coupling the mechanical rotating components of the generator from the transmission system through the use of such power electronic conversion systems. This in turn impacts the volume of frequency control services available to National Grid to maintain system security as they do not decelerate any change in system frequency. Subsequently, National Grid is investigating possible solutions to this challenge.

One beneficial aspect of the evolving GB network which can aide the challenge of system inertia is the geographic diversity of wind farm locations. Unlike the past, where majority of the wind farms lay north in Scotland, the GB network now has wind farms in a variety of areas and National Grid continue to receive applications of wind farms for numerous locations across GB. In order to minimise the impact of reduction to system inertia, recent studies have also been performed to better understand wind farm patterns and the geographic correlation of wind farms in GB using a simulated wind farm model and probabilistic planning. The wind farm model was produced by a consulting company which determines simulated wind farm output using data such as wind speed, obtained from the MET office, turbine hub height and physical terrain of each existing wind farm location. The results of the study have shown that the existing wind farms can be separated into three distribution patterns, in order of lower generation to higher generation output; (i) onshore wind farms located away from the coastline (ii) onshore wind farms located close to the coastline and (iii) offshore wind farms. With knowledge of the above likely generating intensities of wind farms in GB, more accurate system planning of future wind farm connections to the network is possible to better manage issues such as system inertia.

Reserve Requirement and Operating Margin

In my previous reports I have explained the Gone Green scenario and its development based on the changing generation mix in the context of a background for planning studies in order to assess the strategic investments proposed to accommodate the wind generation scenarios up to 2030. In addition to the planning studies, the Gone Green scenario has also been used as the background for some operational work carried out to assess the short-term reserve required to reflect the changes of generation types throughout the years in order to meet the EU renewable energy target.

National Grid has defined their short-term reserve requirement as the reserve capacity required at four hours ahead of real time and the process to calculate this uses historical data to quantify demand and wind output forecasting performances and changes in conventional

generation availability. The short-term reserve requirement is then evaluated to satisfy a '1 in 365' criteria.

At present, National Grid's standard wind forecasting error for short-term reserve requirement evaluation is approximately 10% of wind generation capacity, however, with better forecasting methods under development (as described above) and more geographic dispersion, it is believed that the standard error should improve to 6% of capacity at four hours ahead. Although this improvement is favourable, National Grid are wary that with continual commissioning and planning consents approved for large offshore wind farm developments, the wind forecast error may increase due to the heavy concentration of offshore wind farms in a small geographical area. This assumption has therefore been applied in the short-term operational reserve assessment. The initial analysis that has been performed in assessing short-term reserve also assumes demand forecast error and generator unavailability remain at current levels as well as assuming the existing reserve providers are contracted and can be procured therefore minimising the additional reserve for response requirement. It has been observed that as wind generation capacity increases, the average additional contribution of the short-term operating reserve requirement increases due to the characteristic of the wind turbine that at very high wind speeds, the turbine will shut down in order to protect itself.

National Grid has identified that the procurement of Balancing Services and control room operations will become very important in the future as the possibility of having different daily reserve requirements depending on the wind forecast becomes an issue.

In the assessment of future operating margins under the Gone Green scenario where average wind and interconnectors at float are assumed, National Grid has found that demand is met with a small operating margin shortfall between 2015 and 2020. In order to maintain operating margins in this situation, it has been identified that the use of interconnector capacity or additional reserve providers would be procured. Under low wind conditions, where short-term operating reserve is not required for wind forecast errors, and with full import capacity from interconnectors, it was found that operating margins are generally maintained until the year 2015.

The above emphasises the fact that understanding the European market conditions will not only help in managing intermittency, but will also enable National Grid to apply appropriate interconnector flow assumptions when assessing operating margin. It also highlights the fact that in a low wind scenario, which is credible during winter peak periods, reserve services

from demand side providers, storage facilities or interconnectors will be required to maintain the appropriate level of operating margin. Another option that is being investigated to reduce peak demand is through energy efficiency measures; consumers are given an incentive to avoid discretionary energy consumption during peak demand times. Considering these types of energy efficient options are more beneficial than relying on fossil fuelled conventional generation to relieve any operating margin shortfall, as it is possible that emission and renewable energy targets may not be met.

A challenge that presents itself today for system operators is the ability to comply with relevant governmental policy objectives of meeting energy targets and managing costs while still maintaining security of supply.

Demand Side Management

National Grid has identified that demand side management will play a large role in meeting the emission and renewable energy targets and therefore has been taken into account in the development of the Gone Green scenario. Approximately 8 GW of additional demand side services has been assumed to be available by 2020 to help meet operating reserve requirements.

When considering electricity demand in 2020, three emerging demand side technologies have been identified as having a significant impact:

- smart metering by providing energy management services;
- electric vehicles to reduce emissions from the transport sector in order to achieve the greenhouse gas target for 2050 and also may increase overnight demand in comparison with the daily demand peak; and
- embedded generation including micro-renewable and micro-CHP technologies may change electricity demand at peak periods.

Household appliances including fridges, dishwashers and washing machines could also contribute through co-ordinated demand management in a similar way that generators operate, however significant effort is required to ensure such appliances are beneficial to the energy industry.

National Grid has observed from initial studies that the technologies listed above tend to flatten the daily demand profile in the long-term. By increasing price elasticity of demand,

demand side technologies could reduce overall daily consumption and also shift load away from peak periods.

New Technology

National Grid appears to be proactive in investigating new technologies to improve network controllability and capability. The possibility of operating the transmission network more flexibly to meet emissions and renewable generation targets through the use of new generation technologies such as wind, supercritical coal and the latest design of nuclear power is being investigated.

New transmission technology required to deliver the increase in power flows resulting from the change in generation mix to meet the EU targets are also being explored. Such technologies include HVDC operation in parallel with AC transmission system, series compensation to increase transfer capability where the system stability is limited, and fast acting co-ordinated quadrature boosters (QB's) which can be used to balance the power flows across neighbouring circuits.

The requirement to improve network controllability and capability stems from Electricity Networks Strategy Group (ENSG) work; system studies which I have performed throughout my year with National Grid and which have been detailed in my previous reports. In addition to this work, development on control systems and improvements on real-time data visualisation have also commenced with the aim of effectively managing more complex network situations including evaluation of the risks and consequences of control system failures and its impact on the security and quality of supply to customers.

Balancing Services

National Grid currently procures a wide range of Balancing Services from various sources in order for technical and commercial service requirements to be met. These sources include small demand sites, large demand sites, pump-storage facilities, Balancing Mechanism or Non-Balancing Mechanism providers and a small amount is also procured from interconnectors.

With the changes in the electricity industry to meet the climate change and emissions target, National Grid has accepted that requirements for Balancing Services within GB are affected. It has been observed that there is now a favourable trend in the requirement for reserve services, and the procurement of Balancing Services from new providers and new

technologies are being explored with an initial focus on positive and negative reserve requirements as well as frequency response requirements. The increasing reserve requirement is being viewed against a rapidly evolving market for reserve products characterised by the closure of power stations reaching their operational lives (namely OCGTs) and a much higher dependence on reserves provided from smaller embedded generating units or demand side management.

As a result, National Grid has been investigating numerous options to resolve the above. This includes, dynamic demand management, where a response service can be delivered uniformly through the aggregation of multiple demand sites despatched probabilistically; that is, no single demand site is despatched more frequently than another. Another option includes procuring reserve services from storage facilities such as batteries, flywheels and Compressed Air Energy Storage (CAES) systems. The challenge in this option however, is whether these facilities provide a long-term cost effective provision of services. The development of smart metering also triggers another option to investigate how the procurement of Balancing Services could be achieved. In addition to the above, since the Renewables Obligation Certificate (ROC) regime are issued for energy output, renewable generators will have a strong incentive to run at maximum output, except at times of low demand where negative reserve is required; in this case, they will want compensation for the loss or risk of loss of ROC. Therefore, National Grid is also exploring procurement of reserves from renewable sources.

Closing Remarks

As this is my final report under the E.S. Cornwall Memorial Scholarship, I would like to take this opportunity to thank the Scholarship Committee, the University of Queensland and AEMO (previously NEMMCO at the time the scholarship was awarded) for giving me the opportunity to broaden my professional career as a young engineer with overseas placement. I would also like to thank the colleagues I have worked with overseas whilst at National Grid in Warwick, UK and the Ontario Power Authority in Toronto, Canada for sharing their knowledge in their respective fields, not only in the renewable energy integration arena but also in other engineering and policy development areas; I am very appreciative of the experiences I have gained being an E.S. Cornwall Scholar.