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Dear Simon,

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

Please find enclosed my fourth quarterly report as part of the E.S. Cornwall Memorial Scholarship for the period 2nd December 2009 to 1st March 2010 during my employment with National Grid.

As this is my final report during my placement with National Grid, I have provided a general overview on the insight I have gained over the past year on the planning and operational areas that National Grid are concerned with due to the integration of large volumes of wind generation. I have also included a very brief summary from my visit to Red Electrica de Espana's Control Centre for Renewable Energies in Madrid in February.

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 is aimed at gaining international experience in the integration of wind farms into an electricity market. Specifically, exposure to the network planning required to be considered by the system operator/s in order to cater for large amounts of wind farm output is sought, as well as investigating the issues, and solutions to such issues, which may arise in the integration of wind farms in a market.

The period of my scholarship is from March 2009 to September 2010. My first placement is 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 will be involved in their Blueprint 2020/2030 Project. The Blueprint Project relates to a major review of National Grid's commercial framework and technical standards to accommodate large volumes of renewable, leading to the redrafting of their Security Standards.

This report is the fourth of six reports for my final three months of employment, 2nd December 2009 to 1st March 2010, with the System Strategy Team and outlines my learning of wind farm integration issues and approaches considered within National Grid.

National Grid's Approach

Over the past 12 months with National Grid, I have 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 is currently 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.

Conclusion

Due to the large volumes of additional renewable generation required to be connected to the GB network in order to meet the climate change and renewable energy targets, National Grid have identified numerous issues which will be impacted. As the GB system operator, National Grid see benefit in the sharing of information from market participants and other system operators across Northern Europe to effectively help the security of a system with a higher level of wind generation through interconnector contribution for the management of intermittency, determining operating margins and also in procuring operational agreements for Balancing Services.

Although some possible solutions to the issues mentioned above have been identified and are currently being investigated, there are still further critical developments required, such as the wind forecasting tool, in order for National Grid to be fully satisfied that they are managing wind generation sufficiently. The outcomes of the GB SQSS Review and Transmission Access Review are also in need of prompt finalisation in order for National Grid to progress on large wind farm applications and be confident that system security will and can be maintained once they have been connected to the network.

Site Visit to Red Electrica de Espana Control Centre for Renewable Energies

On Friday 5th February 2010, I was sponsored by AEMO to visit the Control Centre for Renewable Energies (CECRE) at Red Electrica de Espana (REE) in Madrid with fellow E.S. Cornwall Scholarship colleagues, where we met with members of the Operations and Planning departments of the Spanish system operator. The Spanish network consists of approximately 34,000 km of transmission lines with a peak demand of around 45 GW and full generating capacity of approximately 90 GW where currently, renewable energy sources make up approximately 35% of the 90 GW. Approximately 98% of installed wind capacity is currently connected to the CECRE and REE can monitor elements such as wind power, reactive power, wind speed, direction and frequency.

Topics such as undervoltage issues initially encountered by REE and their attempt to resolve this as well as other issues were discussed. It was also interesting to note that REE are not concerned about some issues such as system inertia or frequency control, nor at this stage have they decided to focus on investigating new technology such as FACTS or HVDC to increase network controllability, unlike National Grid in the UK. My visit to REE's control centre facility was very interesting and provided me with an insight into another country's operational and planning approaches used for the integration of larger volumes of wind energy into their power system, and I am very appreciative of the support I received from AEMO to visit this control centre.

Future Direction

As my 12 month term with National Grid has now completed, I move onto the Ontario Power Authority (OPA) in Toronto, Canada for my final 6 months of the E.S. Cornwall Scholarship. The OPA are responsible for planning the Ontario electricity network as well as procuring and managing generation investment within the province in order to help achieve North America's energy targets. I have secured a contract with the OPA from 8th March 2010 to 8th March 2011 where I will be part of the Power System Planning Division reporting to the Director of Transmission Integration. Here I aim to gain insight into Ontario's issues and approaches dealing with increased wind farm integration into a more widely spread electricity network as opposed to the smaller UK network, as well as having a closer involvement in managing government policies and regulations relating to transmission and distribution connections.