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E S Cornwall Scholarship Advisory Committee
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Dear Simon,

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

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

During my third three months of placement with National Grid, I have been involved in AC power system studies focussing on voltage and thermal compliance of the Great Britain network with the addition of proposed wind generation in order for GB to achieve the UK renewable target by 2020. These studies investigate the planning and operational design of the network required in order to accommodate larger volumes of generation in certain areas and also the possible solutions to network issues should they arise due to the additional generation.

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 third of six reports, and outlines my work experience within the third three months of employment, 2nd September to 2nd December 2009, with the System Strategy Team in National Grid.

National Grid System Strategy Department

In my second report I noted that I was assigned to the Strategy Development team within the System Strategy Department of National Grid. Since then, due to recent recruitment, the roles within the Strategy Development team have been re-allocated.

The following list describes the major responsibilities within the Strategy Development group:

- analysing, summarising and reporting on the electricity network reinforcements previously identified through the work undertaken for the Electricity Network Strategy Group (ENSG) to facilitate changing generation patterns to meet the UK renewable target out to 2020, 2030 and beyond;
- undertaking the analysis and producing the annual publication of the Seven Year Statement (SYS);
- undertaking the analysis and producing the new Offshore Development Information Statement – a 20 year plan on the development and integration of offshore windfarms;

- the development of a long-term regulatory incentive mechanism supporting efficient and timely investment in the electricity transmission network for the price control review which includes producing strategy papers and high level investment proposals for approval through the investment management procedure; and
- reviewing the Smart Grid technology through the production of a road map for developing a 'Smart Grid' and its incorporation into network strategies.

Aligning with my proposed scholarship topic, I have been assigned to the first task which has so far focussed on AC power system analyses of the proposed strategic reinforcements using the 'Gone Green' generation background developed due to changing generation patterns in order to achieve the 2020 UK renewable target. The results of these studies are being collated into a progressive Strategic Report which will eventually be provided to the UK energy regulator Ofgem.

Work Experience

System Studies for Strategic Reporting

As mentioned in my second E.S. Cornwall report, I initially performed DC powerflow system studies investigating the North Wales network thermal capability with the proposed reinforcements identified by National Grid in their report *Our Electricity Transmission Network: A Vision for 2020* provided to the Energy Networks Strategy Group (ENSG) in March 2009, see Figure 1. The reinforcements required form the basis of meeting the UK renewable targets in a timely manner and failure to deliver the increased level of transmission capacity is likely to also result in a reduced level of security of supply to customers.

Results of such studies and those for the rest of the GB network were provided to Ofgem in a July submission summarising system boundary capacities that critical reinforcements could provide in the GB network with the associated level of renewable and/or nuclear generation connections. The submission remained consistent with previous reports however it was noted that further detailed studies are required to observe the stability effects of the reinforcements and also to confirm 'future technology' reinforcements such as series compensation and the effect of HVDC links on the network.

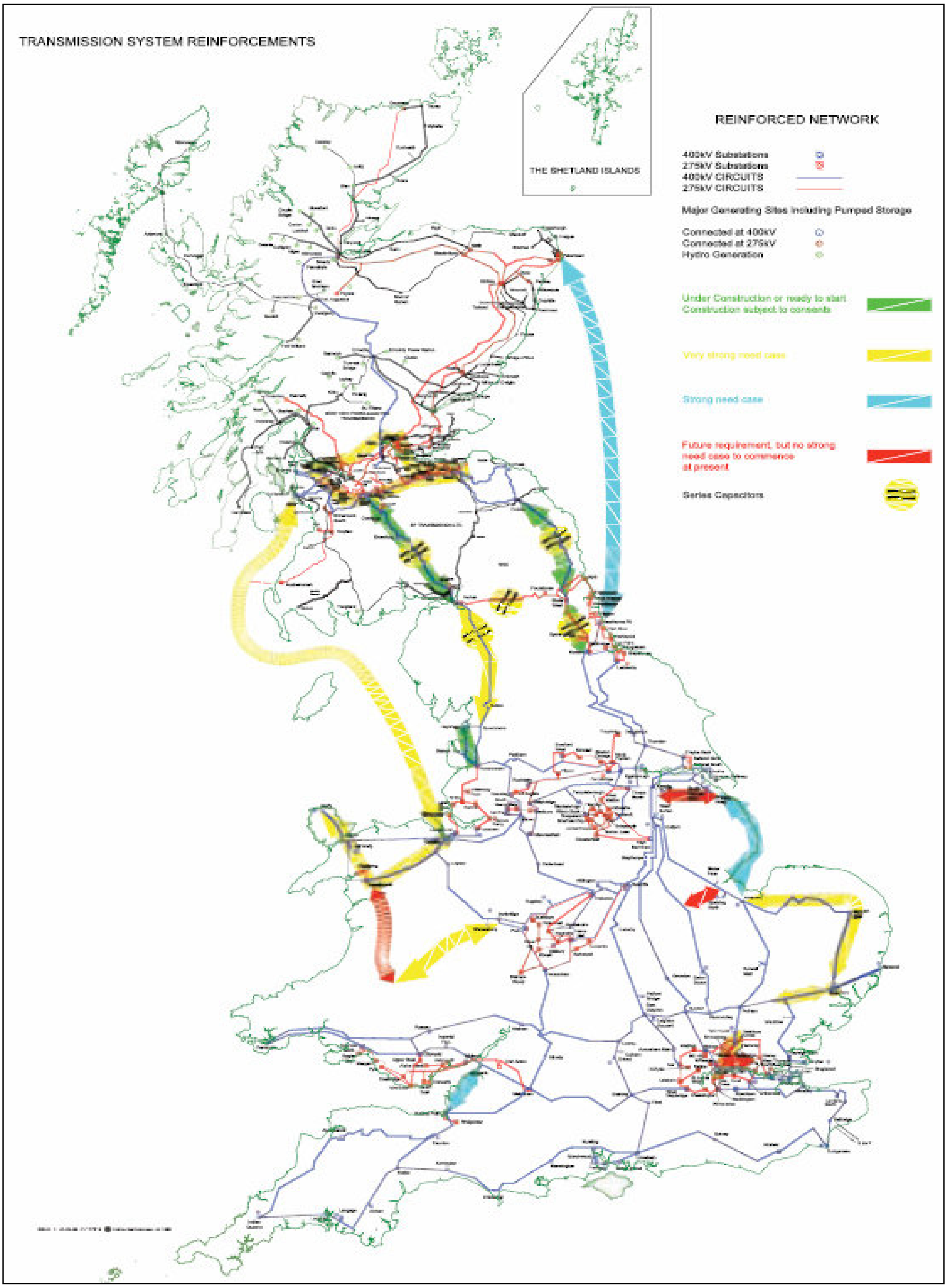

Figure 1 – Proposed GB Transmission Reinforcements[1]

[1] Our Electricity Transmission Network: A Vision for 2020; http://www.ensg.gov.uk/assets/1696-01-ensg_vision2020.pdf

Currently I am performing AC analyses on the GB network based on the Gone Green generation and demand scenario in National Grid's in-house power systems analysis package ELLA. I had previously mentioned the AC studies were going to be performed in Power Factory, however the move to Power Factory has been delayed, hence the AC work is now being completed in ELLA.

The focus of the studies at this stage is on the voltage stability and thermal capability of the network pre- and post- strategic reinforcements for a wide range of double circuit outage combinations (n-2) at the required transfer rate for each GB boundary as identified in National Grid's Seven Year Statement[2]. In accordance with the GB Security and Quality of Supply Standards[3] (SQSS), double circuit outage conditions (n-2) are tested as the GB transmission system is operated and designed in such a way that for a secured event on the outage of a double circuit overhead line, unacceptable voltage conditions and unacceptable overloading of transmission equipment should not occur. This is to ensure that there is a balance between the reliability in supply delivered and the costs that consumers bear.

When assessing voltage and thermal compliance against the SQSS, National Grid prepare their base dataset for the 2020/2030 project AC studies according to a planned and required transfer for each GB boundary taking into account the respective generation for the boundaries as per the Gone Green ranking order. All of the generators in the network are arranged in order of likelihood of running at the time of ACS (average cold spell) peak demand and this constitutes the ranking order. The planned transfer condition is the power flow across the boundary and is based on the generation and demand of the system being in balance. However, as is the case in all planning studies, more generation than demand is needed to ensure that demand can be met in the event that some generating units are unavailable. The amount by which generation exceeds demand is the plant margin, and for winter peak demand security this has historically been approximately 20% for transmission planning. Although the addition of wind generation increases the plant margin, not all installed generation will be available to run during the winter peak demand time and therefore the assumption that a plant margin of 20% is still reasonable to apply. Throughout the analysis conventional generation is assumed to have an availability factor of 100% and wind generation 72%, however when using the planned transfer condition these availability factors lead to an output of approximately 83% for conventional generation and 60% for wind due to appropriate scaling.

[2] http://www.nationalgrid.com/uk/Electricity/SYS/
[3] http://www.nationalgrid.com/uk/Electricity/Codes/gbsqsscode/DocLibrary/

The capabilities are determined for n-1 and n-2 cases to ensure system robustness against credible contingencies. In order for the system to be capable of supporting power flows against n-2 outage conditions, a boundary's required capability or transfer (RT) is determined by applying an interconnection allowance (IA) to the planned transfer (PT) condition.

For n-1 cases: RT = PT + IA

For n-2 cases: RT = PT + $^1/_2$IA

The interconnection allowance can only be applied to cases where the minimum ACS peak demand is at least 1500 MW. The application of an interconnection allowance reduces the likelihood that the actual boundary transfers will exceed the required capability and to ensure that transmission does not restrict generation from contributing to demand security.

In order to achieve the RT condition in the dataset, demand and generation scaling factors are applied for each GB boundary according to importing and exporting zones. These are based on existing demand, generation and losses in the importing and exporting zones as well as their determined interconnection allowance. In order to achieve a higher boundary transfer, i.e. increase flow towards the importing zone, demand scaling factors of greater than 1 will be applied to the importing zone with less generation while exporting zones will have less than 1 demand scaling factors with an increase in generation. Once these are applied to the dataset and the RT is as expected given the generation and demand scenario, AC studies can then be performed.

Thorough voltage stability studies are necessary for the Blueprint 2020/2030 project as it is important that steady state voltages are controlled within operational ranges and reactive power reserves are available for post-fault support of the network voltage in line with the SQSS. The studies have shown that greater effort is required in order to control voltage levels due to the variations in generation output under the Gone Green scenario which increases the levels in energy balancing.

The studies also highlight the existing parts of the network which are subject to voltage instability as these areas are likely to be problem areas when further generation is added to the network due to higher VAR flows. Therefore once these areas have been identified, the proposed strategic reinforcements for the 2020/2030 project can be implemented in the dataset and investigated to ensure they are relieving the voltage instability issues and also not creating non-compliance in any other area.

AC analysis also provides a better indication on the flows of the network. It is important to observe where the expected flow patterns are for each Gone Green year since additional wind farm projects are being implemented and their generation adding further stress to parts of the network. Therefore, appropriate strategic actions to ensure thermal violations do not occur if additional generation is applied to the area can be proposed and investigated.

If there is more than one reinforcement identified for a particular region, both AC voltage stability and thermal studies can also highlight the reinforcement which is more beneficial to the network before another in order to accommodate larger volumes of generation. It may also show that existing equipment, such as SVC's, MSC's or reactors for voltage support could be used to remove voltage instability and in the case of thermal overloads, existing quadrature boosters (QB's) may be controlled to encourage flow in another direction, therefore reducing the cost of additional equipment required to relieve the violations.

Since the strategic reinforcements for all regions of the GB network have already been proposed in *Our Electricity Transmission Network: A Vision for 2020*, the above AC studies are further confirming that such reinforcements are beneficial and at what level of additional generation. The studies have also highlighted events which could trigger unacceptable operating conditions and therefore provide an indication on the actions required to avoid the risk of such unacceptable conditions for pre- and post- fault situations, which aides the planning and operation of the transmission network under the Gone Green scenario forecast.

I have observed that when undertaking transmission planning studies involving the accommodation of significant amounts of renewable generation such as the Gone Green scenario, the scope for variation in generation output is much greater, which may indicate that the changing flow patterns from wind generation could present the most onerous operational condition which does not necessarily occur at peak demand times. Therefore all possible network and generation sensitivities must be investigated to determine the strategic reinforcement which is most beneficial to the network while maintaining a cost-effective approach. I have also learnt in the case where existing controllable transmission equipment such as SVC's and QB's are available, the flexibility of and co-ordination between the control systems for such equipment becomes more critical as the operating capacity of the transmission system is tested and therefore further operational development may need to be undertaken to co-ordinate the optimal pre- and post- fault settings on these equipment under certain scenarios. This also leads to the option of developing operational systems which may accommodate certain forward-looking security assessments which can be performed in timescales appropriate to resolve network security issues which may arise under different generation and demand scenarios.

System Studies for North-West Quadrature Booster (QB) Scheme

In addition to the studies required for the Strategic Reporting, I was required to perform AC voltage and thermal system studies on the north-western part of GB where there is a scheme request, currently at the IP3[4] stage, for a pair of QB's by 2012/13 as part of National Grid's normal investment plan, i.e. separate to the ENSG strategic proposals, to support higher power flows from the north due to the proposal of a large amount of additional wind generation to be connected in that area by 2015. At this stage, there is some uncertainty as to whether the QB's are actually required since the strategic proposal of the Western HVDC link between Scotland and England should alleviate the high network flow problem once connected, which is planned for operational use by 2015 also.

The studies investigated at what level of wind generation the existing system could accommodate, taking into account the appropriate generation availability/scaling factors and Gone Green generation background and then to investigate different sensitivities involving the impact of the connection of the HVDC link with and without the support of QB's in the area.

The main purpose of this exercise was to demonstrate if there was any benefit to National Grid if they pursued with their business investment plan by purchasing QB's for their network prior to the longer-term strategic investment of the Western HVDC link given the proposed timing of additional wind generation into the area.

This exercise demonstrated that there are two inter-related objectives that National Grid must maintain when it comes to proposing and investing in transmission reinforcements; firstly to continue business on a 'best view' basis in regards to transmission scheme requests, and secondly to continue business with the 'Gone Green' scenario in mind so that the UK renewable target is achieved through strategic reinforcements. Therefore, it is necessary to be aware of and investigate the comparison between the proposed transmission reinforcements identified as 'business as usual' with those identified as part of the 'strategic work' so that redundancy in achieving the main objective of the reinforcement/s does not occur. It is also necessary to assess the risks or effects on the network associated in any delay to the

[4] IP3 is the third stage of the TP146 Investment Process which develops the scheme to confirm feasibility. At the conclusion of this stage the scheme is sanctioned.

reinforcement/s so that the most beneficial network reinforcement is invested in to maintain the security of the system in a cost-effective manner whilst still meeting company obligations.

Future Direction

In my final three months at National Grid, I will be collating the results of the 2020 Gone Green AC analyses of voltage and thermal compliance studies into a Strategic Report which is required in order for the planned/proposed works to be provided with the appropriate funding to commence or continue. I also plan to be involved in further work involving studies investigating the planning and operational requirements for the integration of wind farms into the GB network. This will include performing transient stability analyses to provide an indication on the full impact of the proposed strategic reinforcements, especially those around the Anglo-Scottish border, North Wales and East Anglia regions. In particular, it will investigate the reinforcements of series compensation and HVDC links proposed to increase network capability from the north in order to support the connection of large volumes of offshore wind farms in the areas mentioned.