

Security of Electricity Supply in Scotland

A paper by National Grid | SP Transmission | SHE Transmission



National Grid continues to monitor and forecast future generation via our UK Future Energy Scenarios and System Operability Framework. The latter is designed to provide greater clarity on the likely system impact of the scenarios. Through this work, it was identified that there is an increased potential that both Peterhead and Longannet power stations could become unavailable sooner than anticipated. With this in mind, National Grid, Scottish Power Transmission and SHE Transmission initiated a series of network studies to review any potential impact this could have on Scottish security of electricity supply.

This paper provides a summary of the requirements for generation at Peterhead and Longannet to secure the future Scottish electricity supply. To assess this effectively, analysis was undertaken on:

- **Security of Supply:** to identify the transmission capacity from England to Scotland needed to secure the Scottish demand over a range of credible generation scenarios, both pre and post commissioning of Western HVDC Link, Beaulieu-Denny and other transmission reinforcements.
- **System Operability:** to identify the level of reactive compensation investment required within Scotland to ensure that the network continues to comply with voltage standards. In addition there is a requirement to ensure there is sufficient transmission capacity available to the System Operator (SO) to allow reasonable and economic access for the Transmission Owner (TO) to undertake maintenance, refurbishment and construction works.
- **Black Start Capability:** to ensure sufficient generation with Black Start capability is available to affect an efficient and timely Black Start restoration in Scotland

Executive Summary

Security of supply (ensuring that there is enough generation to meet demand)

Security of electricity supply in Scotland is a function both of the availability and flexibility of 'local' generation plant located in Scotland and the capability of the Main Interconnected Transmission System (MITS) to support Scottish demand from generation plant located in England and Wales. Having undertaken a review on MITS, it was concluded that the existing transmission system can support a transfer in the winter months of approximately 2.65GW¹ from England and Wales to Scotland. This represents 48% of the approximate 5.5GW winter maximum demand for electricity in Scotland. To secure this maximum demand at times of low wind generation output, around 2.85GW of generation output will be required across Scotland. While due consideration must be given to unforeseen plant breakdown and unavailability, this requirement can presently be met from a combination of generating stations, including Hunterston, Torness, hydro and pumped storage stations, Longannet and Peterhead. However, there remains a low probability although credible risk that during periods of low wind and hydro output combined with low availability of the large thermal plant, the winter peak demand may not be met.

Completion of the Western HVDC Link in 2016/17 will significantly enhance the capability of the transmission system, and enable transfers from England and Wales to Scotland of up to 3.9GW. This represents 70% of the prevailing 5.5GW winter maximum demand.

There is sufficient transmission capability to secure Scottish electricity demand now and this capability will be significantly increased from early 2017 on completion of the Western HVDC Link and Beaulieu – Denny 400 kV reinforcement. There is a low risk that the power transfer from England to Scotland may exceed system capability prior to the completion of the Western HVDC Link. This risk is for limited periods when neither Longannet nor Peterhead generation is available and coincidental with periods of low wind generation. This risk will be mitigated by post fault SO actions.

System operation and voltage control (adequacy of all year round voltage performance and system access)

At times of low and minimum demand coinciding with periods of low wind generation output, voltage control is challenging and high voltages are becoming more frequent and widespread in operational timescales. These are being driven in part by significant changes in the electrical characteristics of the demand served by the transmission system, and are exacerbated with low / reduced availability of large synchronous generation plant. Uncertainties over future availability of large synchronous generation plant in Scotland, in particular Peterhead and Longannet, has led to the investigation of likely voltage performance issues around 2016 and 2017 summer periods. To secure the summer maximum demand at times of low wind generation output and with a depleted transmission system due to outages, the generation output required across Scotland for security remains lower than that required at winter peak with an intact transmission system.

A preliminary requirement has been identified to install an additional 600MVAR of transmission based voltage control equipment in Scotland. This will ensure the effective management of voltage requirements across Scotland, with reduced availability of large synchronous generation plant going forward.

Investment solutions are being progressed that will improve the situation however there is a risk that an insufficient quantity of compensation will be in place by summer 2016 due to engineering and procurement timelines. For an interim period to meet voltage compliance over 2015 and 2016 summer conditions there is a requirement for a single Balancing Mechanism Unit (BMU) at either Peterhead or Longannet at times of low wind generation.

¹ Transmission capabilities assessed in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

Black start (recovering from an event that results in loss of large parts (or all) of the transmission system).

The Scottish Transmission companies and the System Operator, NGET, have an established working relationship with the Scottish Government through the Strategic Coordination Group and a Black Start Memorandum of Understanding was signed in 2013, along with a corresponding Black Start guidance note. Black Start procedures are geographically based and formalised via Local Joint Restoration Plans (LJRPCs). The plans rely on specific generating stations, which are able to commence operation in the absence of a transmission derived supply e.g. pumped storage and some hydro stations, re-energising 'local' large thermal stations, from which larger sections of the transmission network and customer demand blocks can in turn be recovered.

While the operating regime and operational status of large thermal power stations will be a determining factor in the speed with which any Black Start recovery can be initiated, the unavailability and closure of one or more of these stations may require Black Start procedures to be reviewed. The SO has instigated a review of future Black Start procedures in coordination with the Scottish electricity companies.

Methodology & Analysis

Security of Supply

The analysis on boundaries between England to Scotland considered the capability of the network to securely supply Scottish electricity demand². It focused on two key annual operating points when the system could be expected to be most stressed by different generation and demand scenarios. These three points were relative to current construction reinforcements³ that have been designed to reinforce areas of the system being considered (predominately to accommodate increased north to south transfers including from Scotland to England). The system boundaries that were reviewed include north of England, England to Scotland and Scottish internal boundaries.

The existing transmission system can support a transfer in the winter months of approximately 2.65 GW⁴ from England to Scotland. This represents 48% of the approximate 5.5 GW of winter maximum demand for electricity in Scotland. To secure this maximum demand at times of low wind generation output, around 2.85 GW of generation output will therefore be required across Scotland. While due consideration must be given to unforeseen plant breakdown and unavailability, this requirement can presently be met from a combination of generating stations, including Hunterston, Torness, Longannet and Peterhead. However, there remains a low probability although credible risk that during periods of low wind and hydro output combined with low availability of the large thermal plant, the winter peak demand may not be met.

Completion of the Western HVDC Link in 2016/17 will significantly enhance the capability of the transmission system, and enable transfers from England to Scotland of up to 3.9 GW. This represents 70% of the prevailing 5.5 GW winter maximum demand. To secure the maximum demand at times of low wind generation output, the requirement for generation output across Scotland may therefore reduce to around 1.6 GW from winter 2017/18.

Considering the north of Scotland area served by SHE Transmission, the existing transmission system can support a transfer in the winter months of approximately 1 GW from the south and central Scotland to the north. This represents around 67% of the 1.5 GW winter maximum demands for electricity in the north of Scotland. To secure this peak demand at times of low wind generation output, up to 0.5 GW of generation output is therefore required across the north, which can be met by a combination of hydro and pumped storage plant, providing there is sufficient water available.

The completion of the Beaulieu - Denny 400 kV upgrade in 2015/16 and the Western HVDC Link in 2016/17, by virtue of the re-distribution of power flow and additional voltage support, will increase the ability to serve demand in the north of Scotland from central and southern Scotland. The England to Scotland boundary limit in winter is 2.65 GW before the Western HVDC link and 3.9 GW after commissioning; in the summer this boundary capability reduces to 2 GW and 3.75 GW respectively.

To provide a high level assessment of likely future power flow across the year, the SO reviewed historic transfers for year 2013/14, and removed contribution from both Peterhead and Longannet. The resultant transfers⁵ are shown in the Figure 1 below.

² The security of electricity supply in Scotland is a function of both the availability and flexibility of 'local' generation located in Scotland and the capability of the Main Interconnected Transmission System (MITS) to support Scottish demand from 'remote' generation located in England and Wales.

³ The reinforcement under consideration is the series and shunt compensation, Western HVDC Link, the Beaulieu-Denny 400kV upgrade and East - West 400 kV upgrade.

⁴ Transmission capabilities assessed in accordance with the National Electricity Transmission System Security and Quality of Supply Standard (NETS SQSS).

⁵ Note this analysis does not incorporate potential output from additional wind farm generation connected since 2014 and hence underestimates the potential transfers from Scotland to England.

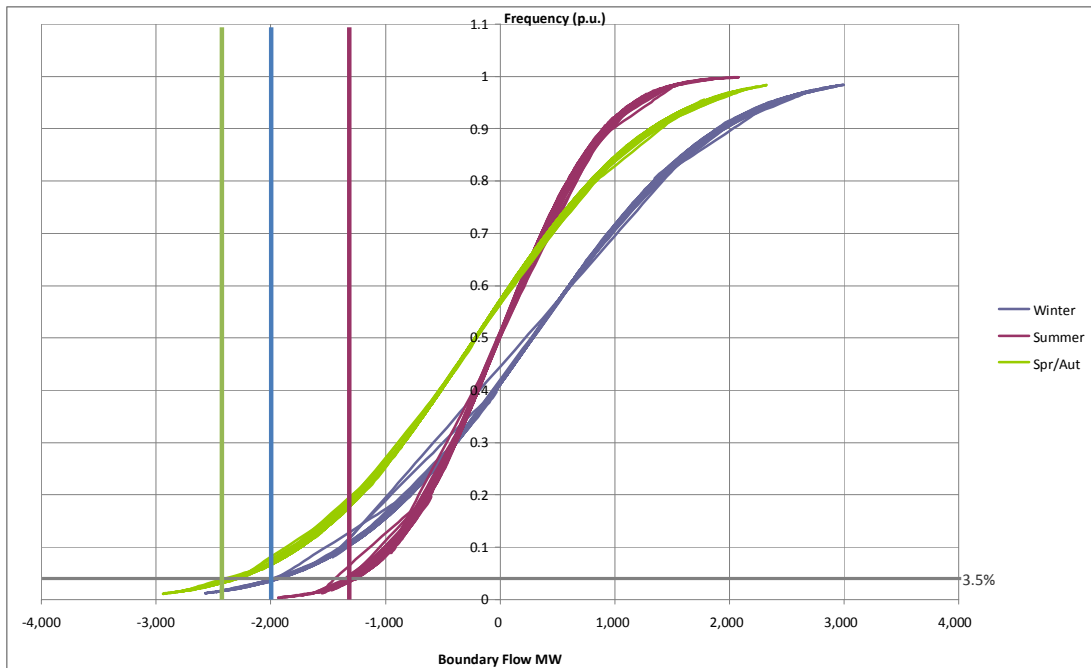


Figure 1. Frequency of Transfers on the England to Scotland Boundary.

Whilst the network capacity between England to Scotland is compliant with the NETS SQSS prior to the completion of the Western HVDC Link there is a small risk that transfers could exceed post fault transmission capacity. The likely frequency of the import capability on the boundary being exceeded is 3.5% per annum and it is most likely to be an issue in spring and autumn. Through SO real time actions this risk can be managed by post fault re-despatch of either hydro or pump storage generation and/or SO to SO trading on the Moyle Interconnector⁶.

All other boundaries in Scotland have been analysed as part of this work. The main other boundary of note is the SHE Transmission to SP Transmission boundary, which has shown to be capable of supplying the whole demand in SHE Transmission area after completion of the Western HVDC Link. Prior to the Western HVDC Link, the boundary is capable of supporting 1 GW of demand and after completion it increases to 1.6 GW at winter peak demands. The internal summer capability limits of the transmission system within Scotland are sufficient to meet all of the demand after the reinforcements.

System Operability

In addition to the above security considerations at time of winter peak demand, the ability to secure demand and operate the transmission system in a manner compliant with the NETS SQSS have been assessed under summer maximum and summer minimum demand conditions (approximately 70% and 30% of winter maximum demand respectively). At these times, some of the generation and transmission assets are withdrawn from service for maintenance or construction outage purposes. The capacity of transmission lines are also reduced due to higher seasonal temperatures. Consequently, the capability of the transmission system is reduced during summer periods.

To secure the summer maximum demand at times of low wind generation output and with a depleted transmission system due to outages, the generation output required across Scotland for security remains lower than that required at winter peak with an intact transmission system. Securing the summer maximum demand condition has therefore traditionally been considered to be less onerous than the winter maximum condition.

At times of minimum demand⁷ coinciding with periods of low wind generation output, voltage control is challenging and high voltages are becoming more frequent and widespread in operational timescales. These are being driven in part by significant changes in the electrical characteristics of the

⁶ N.B. The Moyle Interconnector is scheduled to be out of service for 35 weeks in summer 2016, which further reduces risk.

⁷ Minimum real and reactive demands i.e. MW and Mvar.

demand served by the transmission system, and are exacerbated with reduced availability of large synchronous generation. Uncertainties over future availability of this generation type in Scotland, in particular Peterhead and Longannet, has led to investigation of likely voltage performance issues around 2015 and 2016 summer periods.

The analysis described in the Security of Supply above was focused on ensuring that there was adequate transmission to support the Scottish electrical demand when there was low generation in Scotland (i.e. for potential closure of Peterhead and Longannet and low or no wind generation output). However, for periods of low transfers from Scotland, particularly at times of minimum demand, it is essential to ensure that there is sufficient reactive compensation to maintain voltage compliance within planning and operational standards, whilst also maintaining adequate margins of reactive reserve.

A series of studies have been undertaken to determine additional reactive compensation required to ensure that voltages would not exceed the upper limits with no generation on at Peterhead and Longannet. A 2016 minimum system demand level was agreed with all stakeholders that reflected the trend in reduction in minimum demand experienced by the SO over the last five years. These studies clearly identified that without generation at Longannet and Peterhead additional investment in shunt reactive compensation will be required by 2016.

The studies demonstrated that Peterhead was most effective in managing the voltage in north of Scotland. However, in considering total system requirements, it was identified that for periods of minimum demand a single BMU would be required from either⁸ at Longannet or Peterhead. Additional sensitivity studies are still required for minimum generation requirements throughout the summer period (i.e. as demand increases, the need for generation to restrict high voltage reduces). It should also be noted that in operating generation to reduce high voltage, the primary⁹ objective is to have reactive absorption capability. Generation at both Peterhead and Longannet has been modelled with existing reactive capability limitations.

Recognising that utilisation at both Peterhead and Longannet will decrease over time as further new generation connects there is an increased likelihood that this generation will be out of merit during conditions of minimum demand. During such conditions, it will be necessary for the transmission system to be secured without contribution from either Longannet or Peterhead in accordance with the NETS SQSS. Since there is uncertainty about the future of both these power stations, with increasing probability that one or both of them could be closed by 31st March 2016 a joint study was undertaken to determine investment requirements to ensure full compliance with the voltage limits identified in the NETS SQSS.

Voltage Performance

For minimum demand conditions, if there is no generation at either Longannet or Peterhead, the analysis has identified a need for the following reactor investments for voltage compliance:

- a. **National Grid TO for the North of England:** the current sanctioned plan is to commission 300 Mvars in the north of England by the summer of 2016 with 3 x 100 Mvar 275 kV shunt reactors to be installed at;
 - 100 Mvar at Stella West 275 kV
 - 200 Mvar at Greystones A and B 275 kV.
- b. **SP Transmission:** the analysis has identified an additional 420 Mvars of shunt reactive compensation connected on to SGT tertiary windings, subject to detailed site engineering. This will be initially delivered by delaying the timing of some shunt reactor disconnections, which form part of an existing reactor replacement programme, to provide an incremental 180 Mvars of compensation by late 2016, with additional new reactors commissioning by early 2017 at;

⁸ Further sensitivity studies required to confirm that Longannet can resolve all issues identified by SHET.

⁹ Additional generation can increase load flows and result in reduced reactive gain observed from transmission at light load, but this is seen as a second order effect.

- 1 x 60 Mvar Mark Hill.
- 1 x 60 Mvar Kilmarnock South.
- 1 x 60 Mvar Coalburn.
- 1 x 60 Mvar Elvanfoot.
- 1 x 60 Mvar Moffat.
- 1 x 60 Mvar Eccles.
- 1 x 60 Mvar Crystal Rig.

c. **SHE Transmission:** the analysis has identified an additional 300 Mvars of shunt reactive compensation connected directly to 132 kV busbars or on SGT tertiary windings, with a 50-100% tapping range. It is envisaged that the installation of the reactors could be achieved by late 2016 or early 2017, subject to detailed site engineering, connecting at:

- Peterhead 132 kV 100 Mvar shunt reactor.
- Kintore 132kV 100 Mvar shunt reactor.
- Tealing 132 kV 100 Mvar shunt reactor.

System Access

With the significant increase in volumes of renewable generation being connected to the Scottish transmission system, it has necessitated an unprecedented requirement to upgrade transmission capacity within Scotland and between Scotland and England. This has led to a significant increase in the volume of transmission circuit outages required to facilitate this upgrade programme.

Completion of this upgrade programme, which includes the Beaulay – Denny 400 kV upgrade, Series and Shunt Compensation, Western HVDC Link and Caithness-Murray reinforcement, will result in significant additional transmission capacity being made available however in the short term it will be necessary to withdraw some capacity to facilitate these upgrades.

SP Transmission and SHE Transmission have now provided their final outage planning request for the 2015 outage season and the SO is undertaking its year ahead analysis to determine system implications of these outage requests. Whilst these studies are not scheduled to be complete until the end of December 2014, the initial phase has focused on outages which are perceived to be generation critical. This analysis demonstrates that the outage combination to accommodate the SP Transmission East – West 400 kV Upgrade works require a BMU from either Longannet or Peterhead for periods of low wind generation output. Given the nature and duration of this work, it cannot be planned on the assumption that wind generation output will be available and therefore, there is a requirement for either a Peterhead or Longannet BMU being available.

Not progressing with the reactive compensation identified in this report and the construction works would delay the release of capacity required to accommodate planned connection of further renewable generation and delays would mean continued reliance on this generation to facilitate future outages.

Moyle interconnector may be unavailable for up to 35 Weeks (further analysis being undertaken to identify potential options to reduce to 20 weeks) in 2016 due to an outage on the Auchencrosh 275kV line which is required to upgrade the existing line to accommodate further connections of renewables in this area. Given flows on the Moyle interconnector are typically from Scotland to Northern Ireland this will reduce volumes of transfers from England to Scotland at periods of low wind generation output.

Black Start Capability

The Scottish TOs and the SO have an established working relationship with the Scottish Government. Black Start procedures are geographically based and formalised via Local Joint Restoration Plans (LJRPCs). The plans rely on specific generating stations, which are able to commence operation in the absence of a transmission derived supply e.g. pumped storage and some hydro stations, re-energising 'local' large thermal stations, from which larger sections of the transmission system and customer demand blocks can in turn be recovered.

Scotland is a single Black Start contracting zone and currently the SO has Black Start contracts with four generators in Scotland (neither of which are Longannet or Peterhead) with each TO having 1 LJRPC to manage. If Longannet or Peterhead remain open the SO is able to use them with the hydro and pump storage stations to Black Start and provide skeleton restoration in the SP Transmission and SHE Transmission areas within 12 – 18hrs. If Longannet and Peterhead close then the SO will adopt the alternative strategy, which is based on energising from England and Wales transmission system, in conjunction with hydro and pump storage generation in Scotland providing a skeleton restoration in 24+hrs.

While the operational status of large thermal power stations will be a determining factor in the speed in which this Black Start recovery can be affected, the unavailability, closure or displacement of these stations will require Black Start procedures to be reviewed. The Scottish electricity companies and the SO have met to progress discussions on Black Start plans.