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Managing Regional Security of Supply: A Case Study from Scotland

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SUMMARY

Securing the supply of electricity to a region of a power system requires either generation capacity within that region, or transmission import capability coupled with generation elsewhere in the power system. The problem is one of co-optimising generation and transmission infrastructure. This paper begins by discussing changes in Great Britain (GB) regulator environment affecting the provision of regional security of supply: changes to the transmission charging regime; new regulatory arrangements including enhancements to the System Operator's role, and the opening up of major new transmission projects to competition; and some limitations of the existing standard defining the methodology for calculating secure transmission capabilities.

Scotland, as a region of the GB power system, provides an interesting case study in which to investigate the allocation of contributions to regional security of supply between transmission and various categories of generation. In particular, intermittent generation is currently ignored when calculating the level of transmission import capability required to maintain security of supply in a region, whilst it is considered in overall generation adequacy calculations at a system level. Whilst wind generation is not dispatchable, it is shown here that it does provide an additional source of generation availability that should be considered in studies into transmission import requirements.

This paper uses historical data for Scottish generation availability from recent winters to investigate the likely impact of changes to the Scottish generation fleet on the need for secure transmission import capability into Scotland. It calculates transmission requirements based on the risk of not meeting demand within a region. Scenarios representing possible generation backgrounds in Scotland over the coming decade show that, measured in this way, wind generation can offset transmission import requirements by up to 25% of its installed capacity.

The key conclusions of the paper are that a risk-based analysis of regional security of supply and transmission requirements can help allocate the true impact of different generators on the transmission import capability needed to secure supply to a region. Such a method can therefore be useful in informing the allocation of charges between parties and in developing planning standards to shape future investment in the system.

KEYWORDS

Security of Supply, Transmission Adequacy, Reliability, Power System Security, Wind Generation.

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1 INTRODUCTION

Maintaining security of supply is a major goal in the planning and operation of electricity systems. It involves ensuring that sufficient generation is available across the power system – generation adequacy – and that sufficient transmission capability is available to transfer that electricity to where it is needed. Security of supply within a region of a power system depends on the type and geographical distribution of generation and sufficient transmission capability to allow access to generation outside the region. In theoretical terms, the problem is one of co-optimisation of generation and transmission including investments and O&M costs in which the collection of services offered by each type of asset (including energy, capacity and various ancillary services) are all fully considered. In the reality of modern liberalised markets, the interests and split of responsibilities between parties, and the imperfect nature of the instruments available to influence investment mean that such an optimal trade-off between generation and transmission is difficult to achieve.

In Great Britain (GB) the current arrangements mean that regional security of supply is defined in terms of the required secure transmission capability in the Security and Quality of Supply Standard (SQSS) [1]. The quantity of transmission required is a function of peak demand and the generation mix within that region (and across GB) and there is no opportunity (with the exception of some short term arrangements) to mandate that generation should be built within a particular region in order to support security. In addition, as the GB electricity market is largely decentralised with no consideration of transmission constraints in bilateral or power exchange trades, there has been little incentive for generators to consider regional security or congestion on the transmission network when deciding where to locate. The one instrument which does provide a locational signal is the Transmission Network Use of System (TNUoS) charging mechanism. Part of this charge on users of the transmission network is location dependent and is designed to reflect the need for network driven by generation or demand in particular regions. The TNUoS methodology has recently been updated by splitting generation charges into peak-security and year-round components, the latter of which reflects the role of transmission in facilitating an effective market [2, 3]. The aim of the cost-reflective aspect is to provide a location-incentive on generation connections, and the splitting out of security and economic backgrounds has the potential to encourage different types of generation in different areas. Therefore low or negative peak-security charges may encourage peaking plant to a region dominated by intermittent generation. However, the ability to do so depends on both the size of the locational element and the split between which generators pay which component.

A second development taking place in 2016 is the Integrated Transmission Planning and Regulation project (ITPR) [4]. The development and operation of the transmission network has historically been a collaboration between the System Operator (SO) – National Grid – and Transmission Owners (TOs) of which there are three in GB: National Grid in England and Wales, Scottish Power Transmission in southern Scotland, and Scottish Hydro Transmission in northern Scotland, although National Grid's SO and TO activities in England and Wales have only recently become quite distinct from each other. Two major changes under ITPR are the enhancement of the SO's role, and the opening up of major new 'high value and separable' transmission assets to competition. This will increase the number of parties involved in maintaining security of supply as it will, in the case of major transmission assets, introduce third party TOs responsible for building and maintaining parts of the transmission network.

Scotland is one part of the GB system where security of supply issues have come to the fore in recent years due to the closure of dispatchable fossil-fuel plant and the anticipated end of life of baseload nuclear generators over the coming decade. This is coupled with a huge growth in wind generation. For many years, Scotland has been a net exporting region. With the closure of much a large fraction of the remaining conventional capacity[1] likely within the next decade Scotland will become more reliant on imports at time of low wind availability and not only the transmission export capability (which has driven major reinforcements in recent years – see section 3 below) but also import capability and security of supply must be assessed. One aspect which will need careful consideration is the role of wind power. The SQSS, the TNUoS regime and new approaches via ITRP all explicitly state that regional security of supply should not depend on wind or other intermittent renewable generators. For example, as part of the Network Options

[1] 'Conventional' is used here to mean: coal, gas, nuclear, hydro and pumped storage generators.

Assessments (NOA) introduced as part of the enhanced SO role within ITPR, '[t]he security criterion is intended to ensure that demand can be supplied securely, without reliance on intermittent generators or imports from interconnectors' [5]. As shown in [6] and in the work reported below, whilst not 'dispatchable', when considered from a probabilistic perspective, wind generation can and does support regional security of supply by reducing the probability that demand cannot be served.

The probabilistic nature of system planning is clearly recognised by methods used to define the required level of generation adequacy. In GB this is specified by a maximum Loss of Load Expectation (LoLE) index which defines the expected maximum number of hours per year that generation availability across GB is insufficient to meet demand. The current target value of LoLE (3 hours) stems from a trade-off between the cost of new capacity and the value consumers are judged to place on being supplied [7]. Assessment of generation adequacy for the capacity market takes no account of generator location or transmission limitations. In respect of transmission requirements, the SQSS identifies a level of import that should be accommodated based on pessimistic but not extreme assumptions about the total available generation and demand in the importing area [8]. However, the basic, 'deterministic criterion' does not allow the specifics of particular regions to be considered, nor the specific impact of particular types of generators.

A probabilistic analysis would allow contributions to security to be identified among multiple generators within a region, including wind power, and clarify the remaining requirement for transmission, which might then inform mechanisms to charge and reward those parties reflecting those contributions. When comparing the level of imports required to the transmission's import capability, care should be taken to model the network, the initial generation dispatch and outages appropriately as power is rarely shared equally between circuits on a region's boundary and the critical outage or limiting factor may be remote from the boundary. The 'deterministic' rules in the SQSS relating to conditions at time of peak demand address either a relatively modest transfer with a double circuit outage or single fault outages on a system that already has one other network outage, or a higher transfer with a single outage. The former condition is typically the more limiting one. Thus, in this paper the term 'secure capability' refers to N-2, that is, secure after a double circuit outage or one fault following some other prior outage.

This paper uses the example of Scotland as a region of the GB power system to consider the need for secure import capability in order to secure demand in the region. The impact of major plant closures and role of the existing and an expanded Scottish wind fleet are investigated, before discussing how the results suggest various parties contribute to regional security of supply.

2 OVERVIEW OF THE SCOTTISH ELECTRICITY SYSTEM

The main existing power stations in Scotland are laid out in Figure 1 and Table 1. In January 2016, four large conventional power stations are operational. Of these, Longannet has announced closure in 2016 [9], Hunterston nuclear power station is expected to close by 2023 [10]. The operators of Peterhead CCGT have been involved in a project to develop CCS capability, however in late 2015 a major source of funding for CCS development was cancelled by the UK government [11]. Torness nuclear plant is expected to run at least until 2023 [10] and it is possible that the operator will apply for a 7 year lifetime extension.

Whilst conventional plant is expected to close, wind generation capacity is expected to increase. The Scottish Government has a target of annual total renewable electricity production equalling the equivalent of 100% of Scotland's electricity demand by 2020 [12]. Legally this target is non-binding (and it should be noted that energy policy is not devolved to the Scottish Government meaning that its greatest influence in respect of energy arguably lies within its role in the planning and consenting regime) but it represents a strong desire for decarbonisation in Scotland. Importantly, Scotland is attractive to wind developers as it has high wind speeds and much of it is relatively sparsely populated. In January 2016, approximately 5GW of wind generation was operational in Scotland, with a further 1.6GW in construction and 6.8GW consented [13].

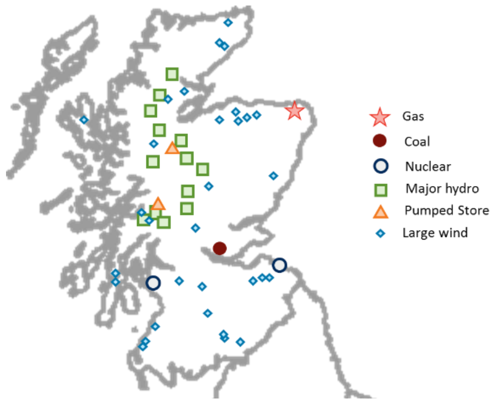

Figure 1: location of main generation plant within Scotland.

Generation Type	Main Stations	Installed Capacity (MW)	Notes
Coal	Longannet	2400	Due to Close March 2016
Gas	Peterhead CCGT	740	Operational capacity in 2015/16
Nuclear	Hunterston B	1016	
	Torness	1280	
Pumped storage	Cruachan	440	
	Foyers	300	
BM wind [a]	31 Locations with 39 Balancing Units	3142	As of Autumn 2015
Other wind	Distributed	2170	
BM hydro [a]		896	

[a] BM generators are those that are active in the balancing mechanism with data on availability at half hour resolution, it includes a mixture of transmission and distribution connected generators. 'Other' generation is not monitored, and its output appears as a reduction in demand.

Table 1: breakdown of main generation plant in Scotland as of December 2015.

Scotland is connected to the rest of GB via two 400kV double circuits (and some minor 132kV circuits) crossing the 'B6 Boundary'. Transmission boundary capabilities are listed annually in National Grid's Electricity Ten Year Statement, and the value quoted for export from Scotland in 2014/15 is 3.5GW; the import capability is 2.6GW [14]. New transmission infrastructure is expected to be commissioned over the coming three years increasing both the import and export capability. During 2015/16 series reactive compensation at a number of locations on both sides of the Scotland – England border will increase the export capacity to 4.4GW; a 2.2GW, 600kV embedded HVDC link from Hunterston in central Scotland to Deeside in North East Wales will increase the secure export capability to 6.6GW and the secure import capability to 3.8GW.

Figure 2 shows cumulative distributions for demand in Scotland [15], and estimated boundary flows for 2015 based on nominated outputs from generators in Scotland at gate closure known as Final Physical Notifications (1 hour ahead of delivery) and post-gate closure balancing actions taken by the SO [16]. Peak demand in Scotland over the winter of 2014/15 was approximately 5.5GW [17].

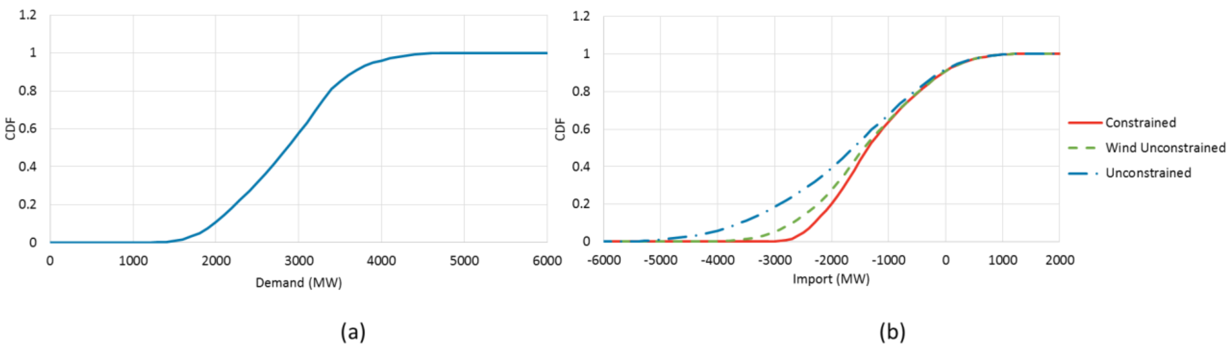

Figure 2: (a) cumulative distribution for demand in 2015; and (b) cumulative distribution for import to Scotland (negative values represent exports) estimated from demand, nominated generation and constraint actions.

Figure 2 (b) shows that Scotland currently exported the vast majority of the time: 93% across the full year of 2015. The two nuclear power stations operated as baseload when technically available, and generation at Longannet coal power station is dispatched by the operator the majority of the time. Periods of import have been seen mainly during day time concurrent with summer maintenance outages at the main power stations and coinciding with low wind availability.

Estimated historic exports from Scotland in 2015 reached a maximum of 3.5GW consistent with the secure export limit reported in [14]. However, ensuring that the boundary flows remain within that limit requires action by the SO to constrain down generation within Scotland when flows would otherwise exceed it. Two additional curves are shown in Figure 2 (b): the situation if wind generation had been allowed to run un-constrained, and the situation if *all* Scottish generation had run unconstrained – i.e. if the SO had taken no actions to keep export levels within limits. Such unconstrained operation would require significantly greater export capability than is currently provided, with exports rising to greater than 5GW during some periods.

3 SECURITY OF SUPPLY IN SCOTLAND

Security of supply calculations attempt to strike a balance between the risk of disconnecting customers and the cost of providing the capability to meet that demand. In this paper we calculate an estimate of the secure import capability that would be needed in order to ensure that demand in Scotland is met for all but a certain number of hours within a winter. This definition is similar to that of LoLE used in generation adequacy studies. To differentiate the transmission adequacy calculation we call this the 'Regional Demand Reduction Expectation' (RDRE) requirement. To illustrate the method we study two levels of security: an RDRE requirement of no more than 3 hours per winter in line with the generation adequacy standard, and a stricter limit of 1 hour per winter. Four main scenarios are investigated:

1. **Base case:** the intact system during the winter of 2015/16 including Longannet power station.
2. **Longannet Closed:** Longannet power station will close in 2016.
3. **Low conventional:** Longannet, Peterhead and Hunterston closed.
4. **High wind future:** Longannet, Peterhead and Hunterston closed and wind scaled upwards to represent an additional 5 GW of capacity.

In each case, demand in Scotland is distributed as it was over the winters of 2013/14 – 14/15. Other generators including hydro and pumped storage are modelled at their 2015 capacities, and for scenarios 1 – 3 two sensitivities are run to identify the role of the existing wind fleet on security of supply:

a. **Existing Wind Fleet:** uses historic data from the GB balancing mechanism for availability at transmission monitored wind farms (including some embedded generation) during the winter months of 2013-15; this was, on average, 2500MW. Other embedded generation, typically small generators, is not reported however its output is accounted for in the fact that the demand data used is demand seen by the transmission network and therefore net of un-monitored generation.
b. **Zero 'BM' Wind:** the nominated output and availability of wind farms reported in the Balancing Mechanism – 'BM' – is removed; the impact of un-monitored generation in the demand profile remains.

4 WINTER GENERATION AVAILABILITY AND DEMAND IN SCOTLAND

Records of availability for each generation unit in GB Balancing Mechanism in the form of Maximum Export Limits (MEL) is available from [16] – that is, the maximum level of output that the plant can provide at a given time. Figure 3 shows the historic distribution of generation availability in Scotland during the months of November – February inclusive for the years 2013 to 2015. This has been split into 'conventional only' (which excludes wind) and 'total'. The shape of the conventional line shows that generation availability is not smooth reflecting the fact that whilst occasionally generators may operate de-rated, most of the time they are either fully available or fully unavailable, a process that during periods of high demand is usually driven by the rate of forced-outages. Scotland currently includes a fleet of 9 large units, and the main peaks of the distribution represent occasions where various combinations of those units are available.

The addition of wind to conventional generation produces a smoothed distribution. The absolute lower ends of the two distributions are similar highlighting the fact that there are occasions where very little wind generation is available due to calm conditions across the whole of Scotland. However, the relatively rare co-incidence of low wind availability and low availability across the conventional fleet reduces the probability of very low total generation availability.

Figure 4 shows the distribution of demand in Scotland and GB during the months of November – February inclusive for the period 2010-2015. Demand for each winter is normalised by the reported weather corrected Scottish proportion of the GB peak demand outturn for that winter [18] allowing demand from different years to be compared; values greater than 1 represent periods where outturn exceeded the weather corrected peak.

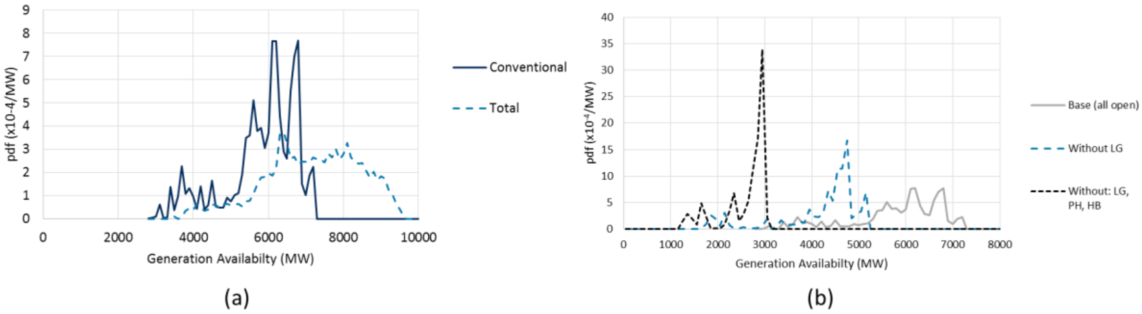

Figure 3: (a) Winter historic generation availability in Scotland 2013 – 15. 'Conventional' includes coal, nuclear, gas, hydro and pumped storage; 'Total' includes all conventional plus wind. (b) Availability representing conventional generation in the main scenarios.

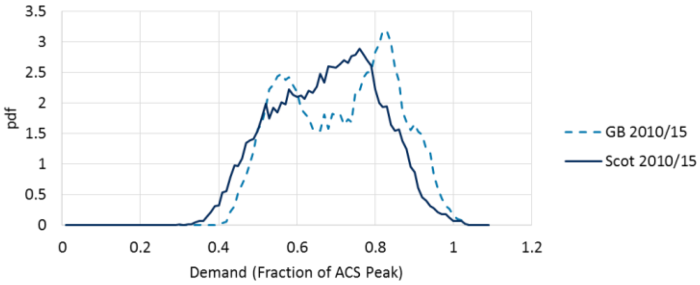

Figure 4: Distribution of winter demand for GB and Scotland 2010 – 2015 as a fraction of weather corrected peak demand.

5 MODELLING BOUNDARY REQUIREMENT DISTRIBUTIONS

Where independence between availability of generation and the level of demand can be assumed, the distribution of import required to secure demand in that region can be calculated as the convolution of the demand and generation distributions. There are some conditions under which the assumption of independence is not valid: importantly, there is some evidence that the availability of wind has a negative correlation with demand for very high demand levels (see for example [19]); and, away from absolute peak demand, conventional un-availability may include some discretionary maintenance. In the analysis below the assumption of independence is used, and further discussed in the final section of the paper.

Figure 5 – Figure 7 show distributions for the required import into Scotland calculated via two methods: firstly direct time-series analysis for outturn data for winter months (November – February inclusive) for the calendar years 2013 – 2015; secondly estimated via a convolution of the demand, conventional availability, and wind availability distributions taken from Figure 3 and 4. Results for both methods are presented for comparison whilst further analysis uses the convolution results.

The sign convention of the distributions is chosen so that the need for import into Scotland is represented by a positive number. For negative values or boundary requirements, there is no necessity from a Scottish security perspective, for import into Scotland. (Although the market may choose to import under some circumstances, it is not required in those conditions for security reasons. Since they reflect all available generation being used, the negative values represent maximum unconstrained export).

Results for the base case show that there is very limited requirement for import capability in the base case. Import is required for security reasons during only 1.6% of the winter when wind is not considered, or 0.02% of the time when wind is considered.

The closure of conventional plant will increase the need for import capability. Figure 6 shows results for the two scenarios with station closures. The closure of Longannet increases the fraction of time that Scotland is likely to require imports to provide security from 1.6% to 10.6% without wind and from 0.2% to 1.8% with wind. The closure of Peterhead and Hunterston further increases the fraction of time import is required to 69% without wind and 24% with wind.

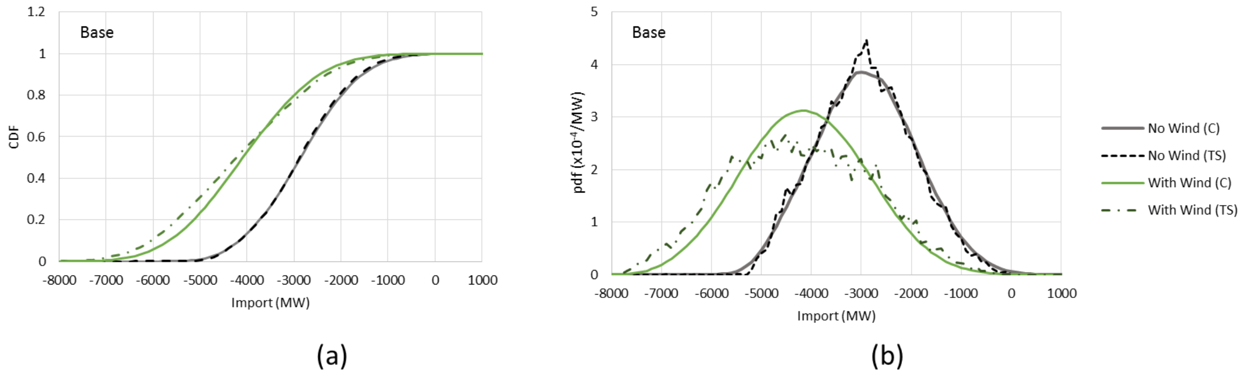

Figure 5: (a) cumulative and (b) density plots of convolved and time series estimations (denoted C and TS respectively) of boundary import requirements for the base case scenario with and without wind.

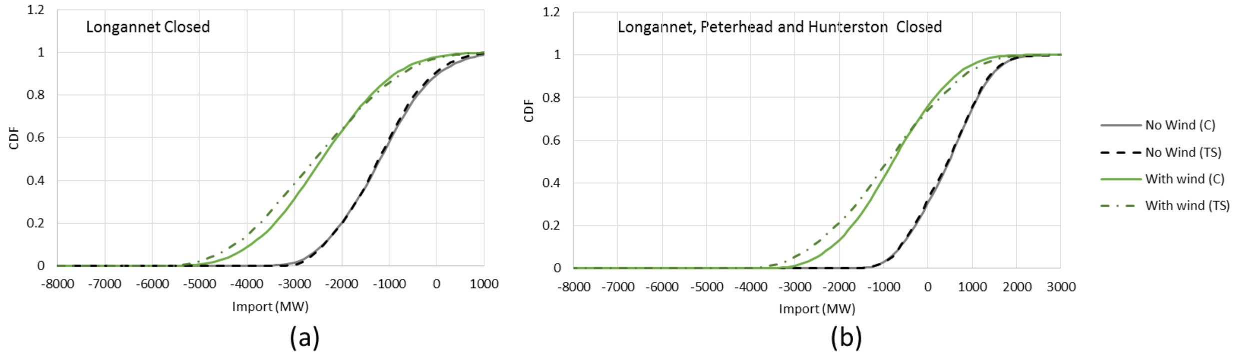

Figure 6: cumulative distribution for 'Longannet Closed' and 'Low Conventional' cases estimated by convolved and time series analysis (denoted C and TS respectively) with and without the existing wind fleet.

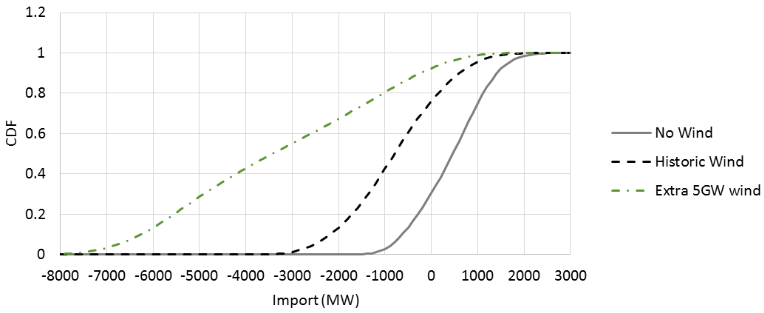

Figure 7: The impact of wind capacity on boundary requirements for the 'Low Conventional' and 'High Wind Future' scenarios.

6 DEFINING A REQUIRED SECURE IMPORT CAPABILITY

The two levels of security of supply based on the RDRE requirement can be calculated from the distributions shown above. The 1 and 3 hours RDRE requirements correspond to finding the P99.90 and P99.96 value of the boundary flow distribution. Table 2 shows estimated secure import capabilities required for the scenarios studied using the RDRE requirement and compare these against values calculated using the current SQSS methodology and the existing GB generation fleet.

The results highlight several important issues. In the base case the SQSS does not require a secure import capability because Scotland is defined as an 'exporting region'. (The 'planned transfer', which can be best thought of as a 'market neutral' median power flow at time of system peak demand, is from Scotland to England). However, a small import capability is required under the RDRE calculations if wind generation is ignored. With wind included the RDRE method agrees with the SQSS. Whilst in this case the difference is marginal, it is likely that in future it will not be appropriate to designate regions as purely importing or exporting; with high wind penetration and low conventional capacity in a region, it will be important to define both import and export requirements.

Whilst the SQSS explicitly ignores wind capacity in the security calculation, the impact of wind on the distribution of boundary flows can be seen in the RDRE values. With Longannet closed, results with and without wind show that the 2.5GW of wind capacity added between the two sensitivities reduces the required import capability by 630MW and 590MW for the 3 hour and 1 hour cases respectively; this is, in effect, a 'capacity credit' of approximately 25%. Similar results are seen in the Low Conventional scenario, although the impact of the 2.5GW wind is slightly reduced. The addition of an extra 5GW of wind in the High Wind Future scenario further reduces the required import capability, however the impact is significantly smaller and the reduction in secure import requirements due to this extra generation is only 5% of its capacity.

The reason for the relatively high impact of the first 2.5GW of wind is that while the availabilities of wind farms within Scotland are strongly correlated due to weather conditions across the region, wind availability as a whole is not correlated with the availability of conventional units. Wind therefore provides a source of generation-availability independent of other sources. Further farms added to an existing wind fleet have a much smaller effect as they are strongly correlated with an existing source of generation availability, i.e. the existing wind capacity. In this respect new wind contrasts with new conventional units: an additional conventional unit provides a new independent source of generation availability, whilst an additional wind farm does not.

Scenario	Wind?	3 hours Regional Demand Reduction Expectation	1 hour Regional Demand Reduction Expectation	Current SQSS method
Base	No	120	290	0
	Yes	0	0	0
Longannet Closed	No	1600	1750	1840
	Yes	970	1160	1840
Low Conventional	No	2600	2710	3215
	Yes	2050	2250	3215
High Wind Future	Yes + additional 5GW	1760	1950	3215

Table 2: required secure import capacities (MW) in order to limit the expected RDRE within Scotland to less than 3 hours and 1 hour per winter, and comparison against results using the current SQSS methodology.

7 DISCUSSION: MULTIPLE PARTIES PROVIDING SECURITY OF SUPPLY

The optimal situation for Scottish security of supply is to have the least cost combination of transmission and generation infrastructure combined with sufficient generation adequacy across GB. However, this objective is embedded within a range of others including participation by generation in the GB electricity market and the facilitation by transmission of competition among generators. The latter is represented by the capability to export power from a region that has the cheapest generation and a surplus of available power relative to demand in that region. Particular generators may also be able to provide ancillary services such as primary, secondary or tertiary reserve, reactive power or black start capability. Although in respect of reserve it is not always considered, a generator's value in respect of ancillary services will depend on location and transmission network constraints. The various services are typically provided by multiple parties, and allocating the proportion of each service provided by each party is part of the regulatory regime. Different services are typically procured through separate markets. However, this runs the risk that, where a provider is tendering for multiple separate services it may appear expensive for each service separately; but may be capable of providing several services at a lower overall price that the cheapest bidder in each individual tender. An example of that could be a generator that does not win a capacity contract but, by virtue of its location, would have contributed reactive power, black start capability and offset the need for transmission reinforcements to support increased imports into an area. This suggests that bundles of services could be considered in procurement rounds, though this has the disadvantage that the prices of specific services are difficult to discover and, hence, market information is less available to potential new providers.

Planning and charging methods continue to discount wind entirely from regional security of supply calculation. In particular, the recent TNUoS revisions exempt wind from the 'Peak Security' charge. Whilst it is true that wind cannot reliably provide full power on demand to support security of supply, the same is true of any conventional generator. A CCGT generator, for example, has approximately an 88% probability of providing full availability and a 12% probability of providing zero [16]. Availability of the Scottish wind fleet has a different distribution and analysis of historical meteorological data suggests an availability of at least 10% during 82% of the time - ignoring a large wind fleet entirely when calculating transmission capacities or charging for access at peak times will ignore this contribution. With any regional generation fleet, the contribution of generation to security within that region is not simply additive over individual units but arises from the probabilistic interaction of un-correlated (or partially correlated) sources of generation.

The results of the analysis presented here suggest that, to some extent, both conventional and wind generation can support regional security of supply, although the credit given to wind power should depend on the total size of the existing fleet. Further, a more detailed analysis of any correlation between wind availability and demand is required. Studies used to inform the use of 'Effective Firm Capacity' for wind power in the GB generation adequacy calculation note that there is some evidence of a negative correlation between wind and demand at high levels of demand, for example where demand is greater than 0.95 of the expected weather corrected peak demand for that winter [20]. However, the authors of [19] argue that, due to the relatively small number of times this occurs and the short time span over which significant wind generation has been installed, there is insufficient data to draw meaningful conclusions. If wind is negatively correlated with high demand, the true impact of wind on regional security of supply would lie between the zero – the value currently used – and the values calculated using the RDRE approach. However, in spite of the relative paucity of operational experience, it may be possible to construct the relevant correlations through synthesis of wind power outputs at given times in the past from historic meteorological records and compare them with the demands at that time. (Such synthesis methods are described in, for example, [21])

The combination of more wind and less conventional capacity in Scotland will mean that transmission across B6 will play more of a dual role, facilitating both economic export and security related import. A limitation of the current SQSS is that the required boundary transfer capability is generally defined only in one direction, determined by a calculation of the 'planned transfer'[2]. As has been shown above, an area with a mix of wind and conventional generation can spend almost equal periods of time importing and exporting and it is important that these considerations are reflected in the standards: both import and export capabilities should be defined in respect of each region. However, transmission expansions predicated in serving power flows in one direction will generally help also in the other. For example, the embedded Western HVDC link is driven by the need for greater export capacity year-round to allow wind generation in Scotland to meet demand across GB. However, the link can also contribute to Scottish security of supply. One issue to address, though, is the risk of commutation failure in the absence, in this case, of a strong voltage source at Hunterston.

For some scenarios in which conventional generation is closed in Scotland (and the direction of the 'planned transfer' flips relative to today), the transmission capability required by the SQSS is comparable to that suggested by the probabilistic assessment. The impact of wind is one area which the SQSS does not take account and can lead to over estimation required transmission import capabilities. A second effect, in the opposite direction, is that of large population effects, i.e. the change to the shape of a probability distribution when generation capacity comprises many small units compared with that of a few large units but same overall capacity. The SQSS is predicated on the former whilst Scotland, particularly after further closures of conventional plant, has the latter which leads to the SQSS under-estimating required transmission import capability).

When new transmission assets are built and owned by third party developers as it proposed under ITPR it will become even more important to clearly articulate the requirements of each component of the system so that assets designed for one function – such as export – are capable of performing others – such as import at a particular level. A number of risks have been identified associated with increased numbers of

[2] To be more precise, the SQSS defines two 'planned transfers': one intended to reflect 'economy driven' need and the other 'security driven' need. Depending on the 'generation background', it is possible that these would point in opposite directions.

transmission developers and owners [22]. In particular, the risk associated with development delays has the potential to impact security of supply if transmission infrastructure is not delivered in time for planned closure of generation. During operation, whilst an asset may have been built to facilitate an economic market, there is likely to be a higher societal impact associated with unavailability during periods when it is required to support regional security of supply. Operation by a third party TO may therefore require a carefully designed set of incentives to encourage the owner to ensure availability at crucial times.

8 ACKNOWLEDGEMENTS

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