

Description of Shetland electrical system and prospective projection of NINES project results to GB

Project #4

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TABLE OF CONTENTS

Executive Summary	3
Introduction.....	6
The Shetland Network	6
<i>Shetland Generation</i>	<i>9</i>
Lerwick Power Station	9
Voltage Constraints.....	10
Sullom Voe Power Station	10
Burradale Wind Farm.....	11
<i>Demand.....</i>	<i>12</i>
<i>Lerwick District Heating Scheme.....</i>	<i>12</i>
Current Shetland Network Operation	12
Shetland system profile	14
<i>Generation</i>	<i>14</i>
<i>Demand.....</i>	<i>14</i>
Shetland system and GB system comparison.....	15
<i>Demand.....</i>	<i>15</i>
<i>Generation</i>	<i>19</i>
Shetland characteristics under NINES	21
<i>Generation</i>	<i>21</i>
<i>Demand.....</i>	<i>21</i>
Addressing GB wide questions.....	22
<i>Future GB power system challenges</i>	<i>22</i>
<i>Key GB power systems questions.....</i>	<i>23</i>
Discussion	24

Executive Summary

This document provides a comprehensive description of the Shetland electrical system including the generation resources, load requirements and current system operation methodology. The current Lerwick district heating scheme is also discussed.

Building on the electrical system description, this document then goes on to address the question of the relevance of NINES project learning to wider GB issues. This question was addressed by first drawing out the main characteristics of the Shetland system and comparing them to that of the GB system. Secondly, important questions and challenges for future GB systems as raised by National Grid and recent horizon scanning projects by Ofgem and the ENSG were reviewed and the potential for NINES to answer these questions was discussed.

The main characteristics of the Shetland system were described primarily in terms of generation and demand.

The main points of interest noted from the demand characteristics were:

- Peak Demand differs by a factor of approx x1200. Shetland peak is approx 50MW. GB peak is approx 60GW
- Shetland minimum demand is approximately 11MW compared to a GB minimum of approximately 20GW
- Shetland minimum demand = 22% of peak
- GB minimum demand = 33% of peak
- The various demand profiles compared are of a similar shape, however the Shetland profiles are choppier, implying less smoothing effects. There is a greater peak to minimum variance in Shetland.
- Shetland time above 50% of peak demand = 55%
- GB time above 50% of peak demand = 80%
- Weekly maximum and minimum curves have a similar profile and follow a general trend of weekly maximum being approximately equal to weekly minimum times two.
- Daily profiles are similar but GB is more pronounced with the main difference being the timing of peak. Shetland peak is in midday although it also has a secondary 6pm peak that matches GB peak.

The conclusion was that proportionately, operation across the variations in system conditions is more onerous on Shetland (although daily demand pick up and drop is more severe on GB) than on GB as a whole so approaches successfully trialled on Shetland can be translated to GB.

The main points of interest noted from the generation characteristics were:

- Shetland installed capacity = 89.55 MW
- GB installed capacity = 79 GW

- Factor of comparison of Shetland to GB generation portfolios is approximately x1000
- Shetland plant margin = 89% (with wind at 100% on day of peak demand)
- GB plant margin = 43 % (with wind at 100% on day of peak demand)¹
- Shetland installed wind = 4%
- GB installed wind = 3%

The conclusion here was that the wind power starting points for Shetland and GB are broadly similar and while the generation plant margin on Shetland appears to be greater the operating regime of SVT and Lerwick Power Station bring the plant margin closer into line with the GB case.

If the scenario should occur where maximum wind generation output occurs at the time of minimum demand the following condition would emerge:

- Shetland percent demand met by wind = 29%
- GB percent demand met by wind = 14%

This analysis shows that Shetland already has a more onerous task in integrating wind power so it is anticipated that stretching this condition with the connection of further wind power will yield learning on system operational measures for high penetrations of wind power.

In general, the main challenges for Shetland system operation are as follows.

- Voltage Concerns
- Stability Issues in certain scenarios
- System balancing of intermittent renewable
- High electric water and space heating load
- Frequently 29% of generation is wind (in times of minimum demand)
- DNO responsible for system operation
- Additional firm wind connections are unfeasible.

Potential developments under NINES are:

- 4MW heating load (district heating boiler)
- Frequency responsive and dispatchable
- 3MW domestic load – hot water tanks (Phase 2)
- 6MW domestic load – storage heating (Phase 3)
- Demand response will facilitate additional wind connections

The Shetland power system and the developments that will take place within and alongside the NINES project are clearly not a direct analogy or scaled down version of the GB system, however there are common challenges faced in both systems as outlined below.

¹ Existing GB Plant Margin is 37.7% as wind is discounted by National Grid. With wind at 100% on day of peak demand, GB Plant Margin is 43.1%

- Increased renewable penetration (primarily wind)
- Greater fluctuations in Supply and Demand
- System operation challenges – intermittency, operating margins.
- Shifts in energy vector introducing new electrical loads
- Management of demand response
- More active distribution networks (DSO operation)

The Shetland power system therefore provides a contained/controlled, measureable and risk managed experimental demonstration site where the major issues and innovations of operating power systems with high penetrations of renewable energy can be understood prior to national roll-out.

Introduction

In response to Ofgem's call for LCNF proposals, SSEPD have proposed the NINES project. As an academic partner to SSEPD, the University of Strathclyde (UoS) has engaged in preparatory work to assist the SSEPD bid. The UoS and SSEPD have extensive history of collaborative research in the Northern Islands undertaking detailed studies from both a power systems and economic perspective.

This document tackles the question – “By deploying LCN/Smart Grid technology and solutions in the NINES project, can lessons be learned that inform the wider GB context?”

This is not a detailed analysis at this stage, but a higher level discussion on the potential for wider learning outcomes from the NINES project. More comprehensive research proposed by Strathclyde over the duration of the NINES project would use the data generated and practical case studies provided by NINES to draw out wider learning outcomes.

The following sections of the document highlight the main characteristics of the Shetland electrical system, compares this to the current status of the main GB system, reviews the important questions for power systems that are relevant in the GB context and explore how insights to these questions can be gained and learning extracted from the NINES project.

The Shetland Network

The Shetland power network consists of three 33kV circuits emanating from a hub at Lerwick, together with 11kV and low voltage circuits from the core 33kV system. The two northern 33kV circuits can be reconfigured by means of normally open points at their points of mutual interconnection. The 33kV network is shown topologically in Figure 1 and geographically in Figure 2.

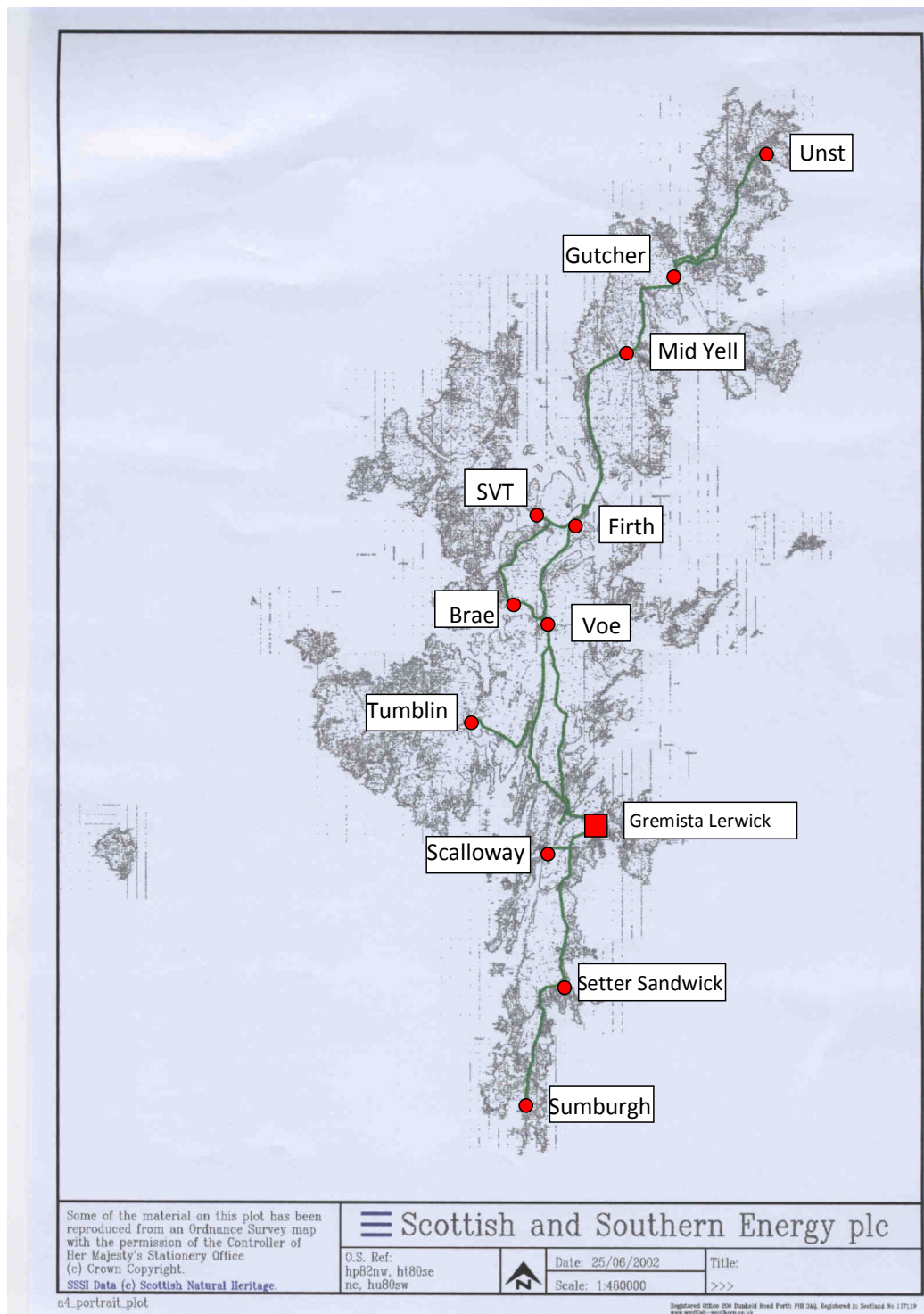


Figure 2 - Geographic of Shetland 33kV Power Network

Shetland Generation

Currently, Shetland has major generators located at three sites. SSE owned Lerwick Power Station and independently owned Sullom Voe Terminal and Burradale. The characteristics, operation and constraints of these generator sites are discussed below.

Lerwick Power Station

Scottish & Southern Energy own diesel generators of varying individual unit sizes at Lerwick Power Station (LPS). Lerwick units are divided into two separately located groups. Older units are located in the “A station” while more recent units are located in the “B station”. LPS is at the hub of the distribution network, but is geographically towards the south of the Shetland Islands. LPS generating units with corresponding capacities are shown below in Table 1.

Table 1 - LPS Units

<i>Unit Number</i>	<i>Station</i>	<i>Type</i>	<i>Rating (MW)</i>	<i>Reactive Capability (MVar)</i>
3	A	Diesel engine	4.6	-1.69 +2.84
4	A	Diesel engine	4.6	-1.69 +2.84
5	A	Diesel engine	4.6	-1.69 +2.84
8	A	Diesel engine	3.5	-1.29 +2.18
10	A	Diesel engine	4.6	-1.69 +2.84
11	A	Diesel engine	4.6	-1.69 +2.84
13	A	Diesel-fuelled gas turbine	4	-1.32 +2.23
14	A	Diesel-fuelled gas turbine	4	-1.32 +2.23
21	B	Waste-heat steam turbine	2	-0.74 +1.24
22	B	Diesel engine	8.1	-2.98 +5.02
23	B	Diesel engine	8.1	-2.98 +5.02
24	B	Diesel engine	12.75	-4.50 +7.50

Voltage Constraints

Experience of operating the Shetland power system has shows than voltage stability problems are liable to occur if LPS output falls below 50% of Shetland demand. These voltage effects are dependent on the load, and particularly on the inductive industrial load, which depends on the time of day and can cause rapid development of voltage problems. An important influence is the large fish factory, accounting for 6 – 7 MW which can transition from fully on to fully off state from one day to the next.

Voltage problems can require de-rating of diesel generators. When alternator excitation is raised to provide significant voltage support, overheating can result. The active power output must be reduced to offset this effect. De-rating of 10% or more can be required – 1MW from the output of the larger units. These problems are more common in summer, when the lower Shetland demand makes it more difficult to maintain the 50% generation share at LPS while accommodating generating units at Sullom Voe (see next section) and other generators. However the problems can occur at any time of year as the Shetland generation and demand is more volatile (proportionate to the whole system) than on mainland GB.

Sullom Voe Power Station

Independently-owned and relatively large gas turbine generating units are located at Sullom Voe Terminal (SVT). Sullom Voe is towards the north of the islands. SVT has four gas turbines as detailed in Table 2.

Table 2 - SVT gas turbine generating units

<i>Unit Number</i>	<i>Type</i>	<i>Rating (MW)</i>	<i>Reactive Capability (MVar)</i>
1	Gas Turbine	25.5	-2.50 +21.00
2	Gas Turbine	25.5	-2.50 +21.00
3	Gas Turbine	25.5	-2.50 +21.00
4	Gas Turbine	25.5	-2.50 +21.00

The electronic governors on the gas turbines (GTs) are faster operating than those of the LPS diesel generating units. Power export, by SVT, to the Shetland system is constrained to 22MW (winter) or 18MW (summer) by circuit ratings. Under normal conditions, two SVT units will be running, synchronised to the SSE system - including at periods of minimum Shetland demand. An additional unit may run for changeover purposes or at exceptional demand. SVT export to the SSE system would only be off under fault conditions on the network, or because of commercial considerations involving unavailability of gas.

SVT units are equipped with relatively fast-acting governors. They will therefore react to balance changes in load demand and in wind output before the LPS units, even when not exporting

significant power to the Shetland system. In general, SVT units take significantly more than 50% of peak lopping duty. Following response by SVT units, the SSE operator will react to maintain system constraints by adjusting output at LPS or by asking the SVT operator to adjust power output.

The effect of more wind power output than expected tends to restrict the output at SVT since the LPS units are scheduled and operated to maintain system stability and security.

Burradale Wind Farm

There is an independently-owned wind farm at Burradale, close to Lerwick. Burradale has three 660kW generators and two 850kW units for a total capacity of around 3.7MW. The unit details are provided in Table 3.

Table 3 - Burradale WF

<i>Unit Number</i>	<i>Type</i>	<i>Rating (MW)</i>	<i>Reactive Capability (MVar)</i>
1	Vesta V47	0.66	-0.09
2	Vesta V47	0.66	-0.09
3	Vesta V47	0.66	-0.09
4	Vesta V52	0.85	0.00
5	Vesta V52	0.85	0.00

Burradale generation is highly dynamic in nature and its power output is subject to rapid changes depending on wind conditions. Under certain conditions a major change in output can take place as a result of a relatively small variation in wind. Forecasts of wind conditions are thus of limited value in predicting Burradale output. SSE has no means of controlling the output from Burradale wind farm and effectively operate a must take arrangement with Burradale.

Similarly, there is no guarantee of any output at all from Burradale. The generating units may be unavailable because of electrical system problems, or because the wind speed is too high or too low. The wind turbines will automatically reconnect following disconnection due to high wind speed cut out. The operators may be able to remotely reset and reconnect following some kinds of trip.

It is not uncommon for there to be no output for 24 hours at a time, and during January 2006, Shetland experienced two weeks with very little useable wind resulting in little production at Burradale. In general however, Burradale operates at an average output (capacity factor) of about 50% taken over a full year (c.f. average European wind power capacity factors are closer to 20%). This ranks it among the most effective wind farms in the world and illustrates the high potential for wind power development on Shetland.

Demand

As an electrically islanded network, all variations in system demand must be met by the three generating stations. Maximum Shetland demand is approximately 48MW and minimum demand is approximately 14MW. There is a significant element of concentrated load, including a large fish factory. This industrial demand includes a significant induction motor load.

Sullom Voe Terminal itself requires 20MW on average. Hence the generators at SVT will be operated to provide the internal load plus the required export to the Shetland system.

Lerwick District Heating Scheme

Since 1998 Shetland Heat Energy and Power (SHEAP) Ltd. have operated a District Heating Scheme in the Lerwick area to domestic and non-domestic properties that replaces conventional oil boilers, solid fuel fires and electric storage heaters. Currently there are over a thousand customers (June 2009 figure) participating in this scheme. The Waste to Heat Energy plant (WTE) just outside Lerwick burns waste from Shetland and Orkney to fuel the heat recovery system and in turn reduces the need for landfill. Hot water is then piped to properties participating in the scheme via an insulated piping system and heat exchangers to supply heating and hot water services. With more participants wishing to join the scheme an additional energy-heat source is required. In 2006, an additional insulated storage system was developed to enable excess off-peak heat to be stored and distributed during peak times. This deferred the immediate need for bringing another heat source online and allowed 500 customers to connect. In 2008 an additional boiler was installed and commissioned as the Peak Load Boiler (an oil fired resource, additional to WTE, that balances peak demand fluctuations and ensures security of supply during WTE downtime) facility that lifted the total central 'back up' capacity to 15MW. A further 6MW of distributed back up capacity is located around Lerwick in the form of scheme participant's old boiler systems. The downtime of WTE is approximately 40 days per annum whereby two shut downs are arranged in spring and autumn. This period is kept to a minimum to ensure that the expensive oil fired alternative is kept to a minimum.

Customer meter readings can be transmitted directly to the control centre on demand since the installation of a radio transmission system in 2007-2009.

Current Shetland Network Operation

The Shetland network is operated from a control room at Lerwick. The principal challenge facing the operators is in meeting the varying island load with the best combination of the three sources listed above while respecting system constraints.

Within the constraints of the energy contracts with SVT and the technical constraints on the power system, SSE aims to maximise the output taken from SVT, while at the same time maximising

additional wind connections. This reduces the diesel fuel oil costs for LPS and the running hours of the LPS units.

Except under outage conditions, two SVT generators will operate at all times in order to provide security to the on-site power demand fed from these units.

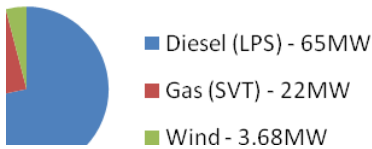
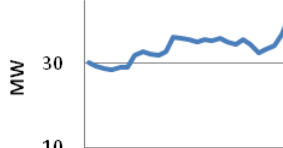
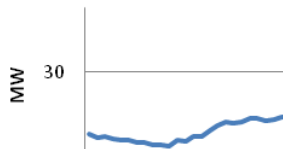
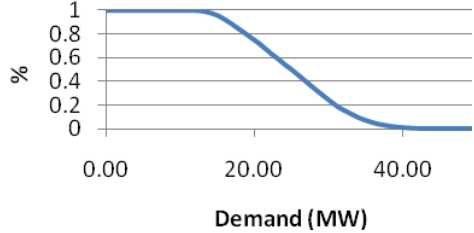
A further constraint is maintenance of voltage stability in the Shetland network which dictates a certain minimum level of operation of LPS generating units. SSE has procured reactive compensation equipment, consisting of fixed, 2 x 2.4MVAR switched capacitor banks. This allows the proportion of Shetland demand met by LPS to reduce to 40% of the minimum demand. This compensation plant is assumed to be in operation at demand levels greater than 17.5MW.

Output from Burradale is not controlled by SSE. Depending on the availability of wind turbines and the wind conditions, Burradale may produce anything between zero and its full rated output, and the output may vary significantly in response to changes in the wind conditions.

Short term system balancing is generally provided by SVT, whose gas turbine unit governors are significantly faster to respond than those of the diesels at LPS. Variations in Burradale output are thus normally absorbed in the first instance by SVT, as are sudden variations in demand. SSE operators subsequently adjust LPS output to achieve the desired power balance between SVT and LPS.

Shetland system profile

The data below provides a summary of the Generation and Demand statistics for Shetland.

Generation	Demand
<p>Key Stats:</p> <p>Installed capacity including SVT – 167.55MW Available max capacity after system constraints – 89.55MW Plant Margin – 41MW – 85% pk demand Renewable - 4%</p> <p>Installed Generation</p>  <p>■ Diesel (LPS) - 65MW ■ Gas (SVT) - 22MW ■ Wind - 3.68MW</p> <p>SVT generating capacity is 100MW however export to Shetland system is constrained to 22MW Wind is firm connection and runs unconstrained, max output can and does occur at any time of year Dispatch nominated for the day ahead Not market based – SSEPD optimise to reduce cost and meet constraints Frequency response provided by SVT initially</p>	<p>Key Stats:</p> <p>Peak Demand – 48MW (Jan 10) Min Demand –11MW (July 09)</p> <p>Average daily profiles:</p> <p>Jan-10</p>  <p>Jul-09</p>  <p>Demand Duration Curve (June 2009 - June 2010)</p> 

Shetland system and GB system comparison

Demand

SSE has provided the University of Strathclyde with 2009/10 half-hourly demand data for the Shetland system. This data has been used to produce profiles of Shetland demand for comparison with GB wide figures. The system peak provided by the half hourly data indicates a peak load of 59.9MW. This peak followed by a second peak of 57MW occurred on one day in Jan 10 and are well above all winter's day peaks which are recorded around the 48MW level. Discussion with SSE planning and control staff indicates that this recording is an anomaly not uncommon in the SCADA records and has hence been omitted from the profiling data.

Figures 3 - 8 show 09/10 data for Shetland and GB demand

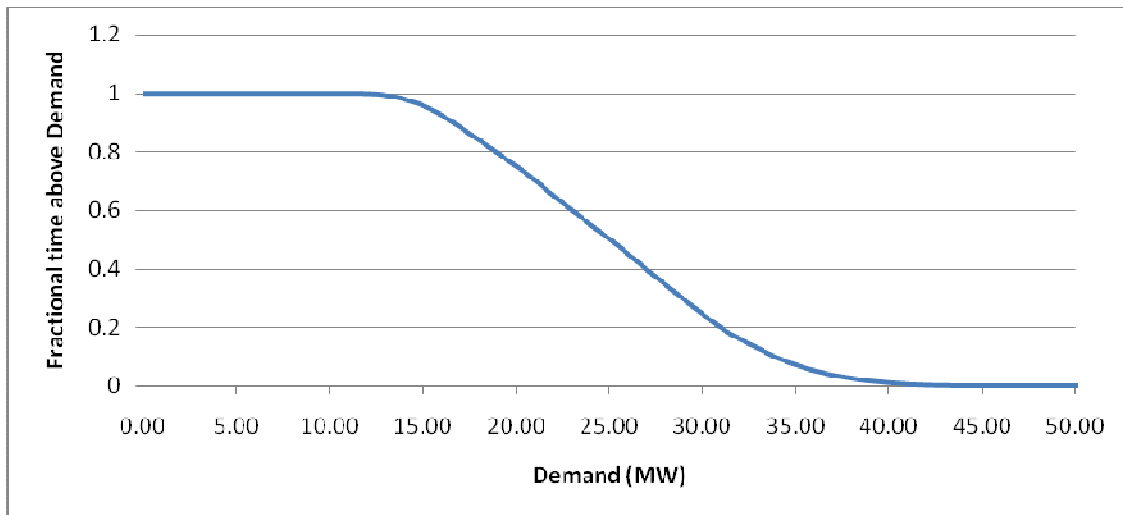


Figure 3: Shetland demand duration curve 09/10 – Source SSE

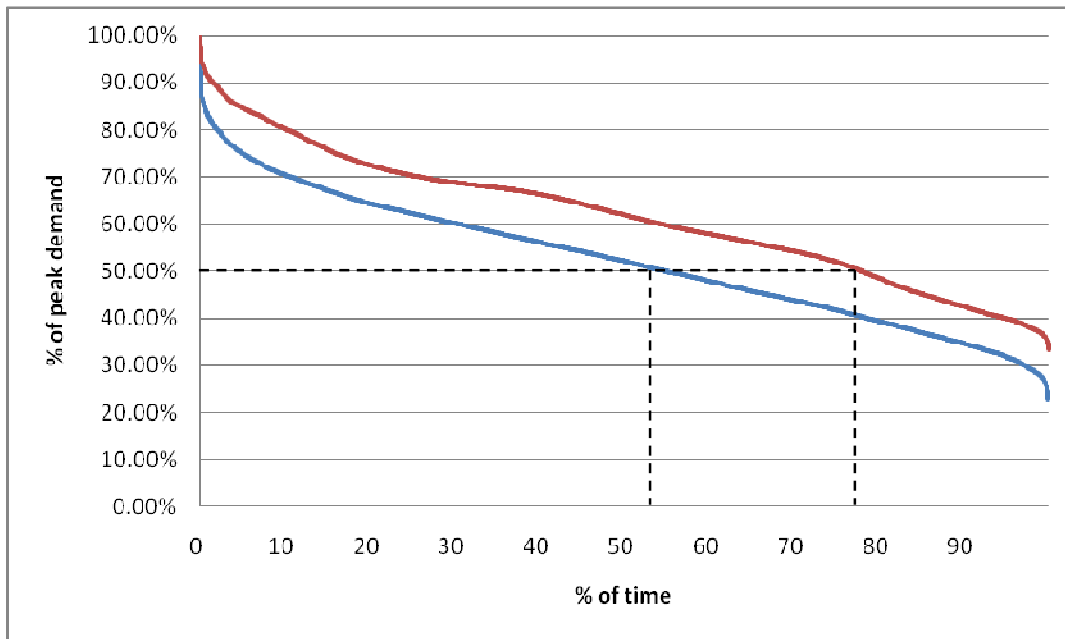


Figure 4: Shetland (blue) and GB (red) Annual Load Duration Curve 09/10 – Source National Grid SYS 09/10 and SSE

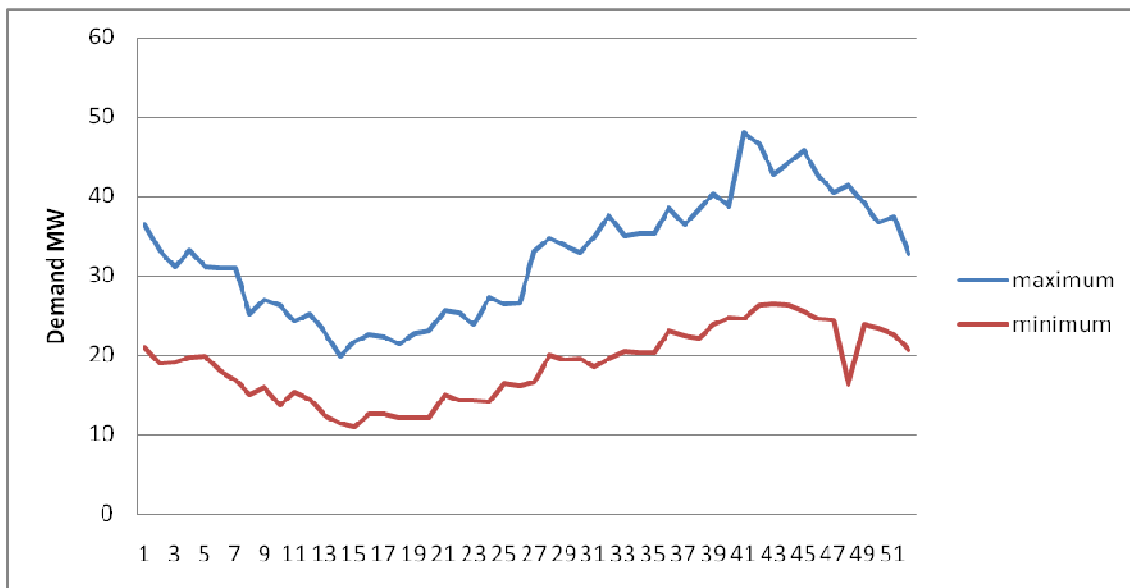


Figure 5: Shetland Weekly Max and Min Demand 09/10 – Source SSE

Note: Figure x above is adjusted for comparison with GB data – week 1 is end of March. Max peak occurs in Jan.

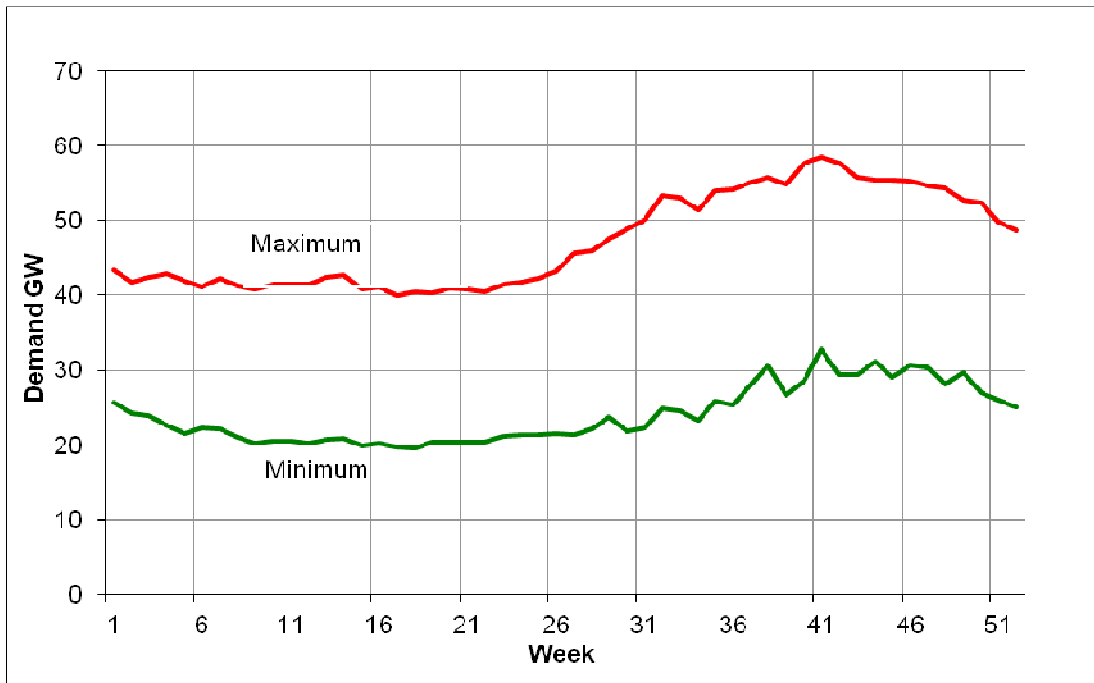


Figure 6: GB Weekly Max and Min Demand 09/10 – Source National Grid SYS 09/10

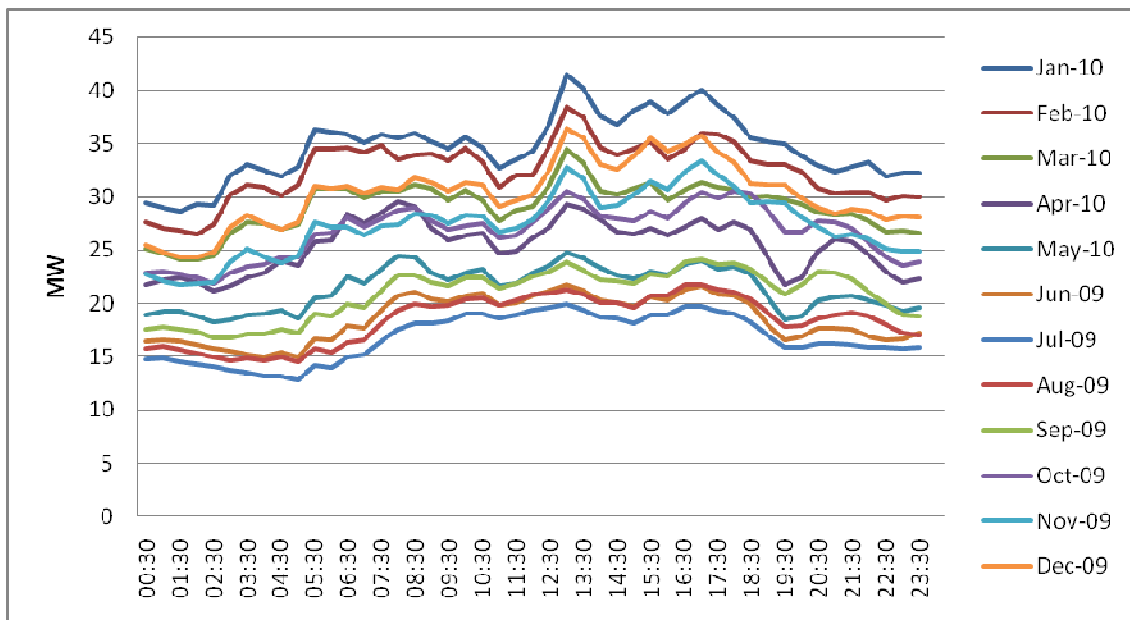


Figure 7: Shetland average daily load profiles 09/10 – Source SSE

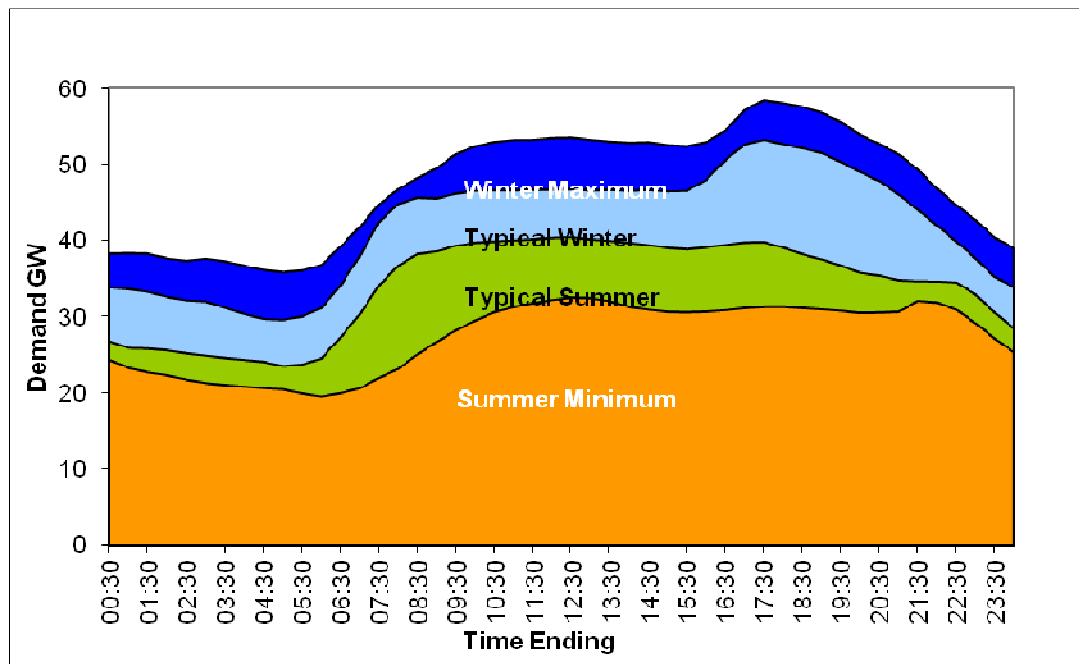


Figure 8: GB Summer and Winter Daily Demand Profiles 09/10– Source National Grid SYS 09/10

The main points of interest noted from the demand characteristics were:

- Peak Demand differs by a factor of approx x1200. Shetland peak is approx 50MW. GB peak is approx 60GW
- Shetland minimum demand is approximately 11MW compared to a GB minimum of approximately 20GW
- Shetland minimum demand = 22% of peak
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- Weekly maximum and minimum curves have a similar profile and follow a general trend of weekly maximum being approximately equal to weekly minimum times two.
- Daily profiles are similar but GB is more pronounced with the main difference being the timing of peak. Shetland peak is in midday although it also has a secondary 6pm peak that matches GB peak.
- The conclusion is that proportionately, operation across the variations in system conditions is more onerous on Shetland (although daily demand pick up and drop is more severe on GB) than on GB as a whole so approaches successfully trialled on Shetland can be translated to GB.

Generation

The generation mix for the Shetland and GB system are presented in Figures 9 and 10.

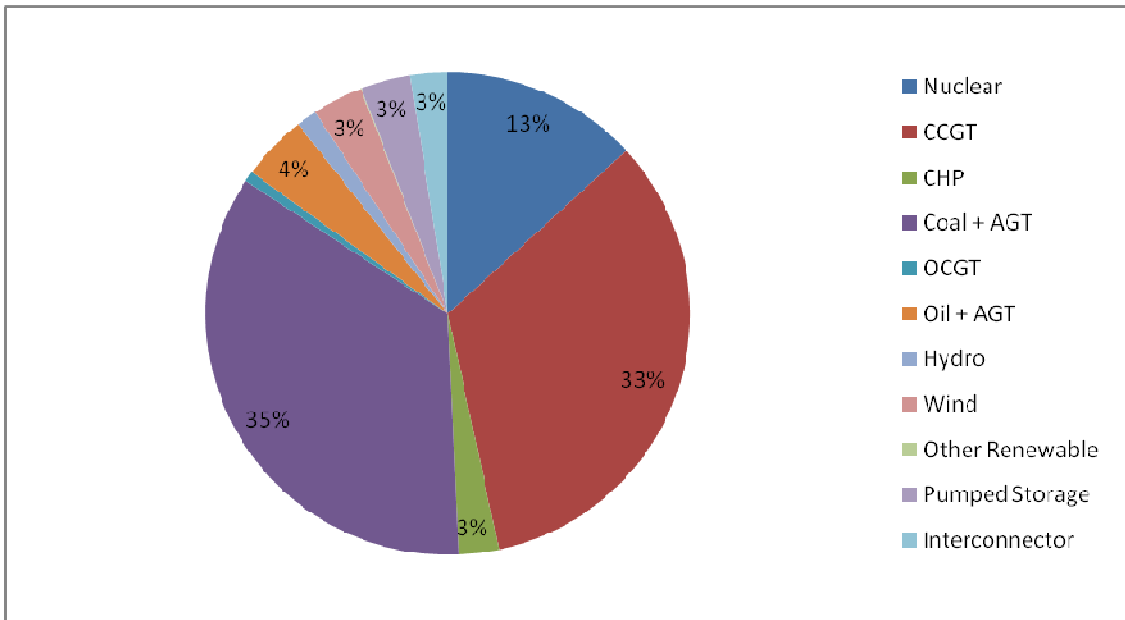


Figure 9: GB installed capacity generation mix 09/10 – Source National Grid SYS 09/10

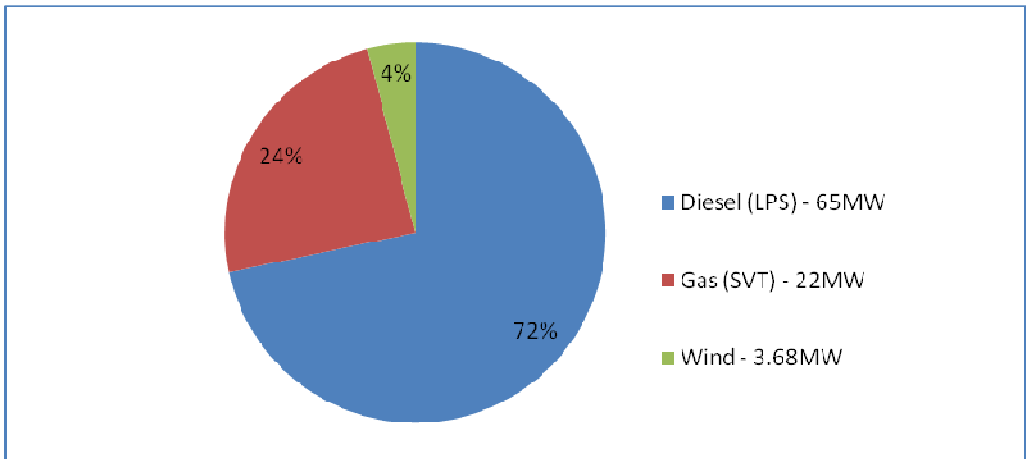


Figure 10: Shetland installed capacity generation mix 09/10 – Source SSE

Main points of interest from generation comparison:

- Shetland installed capacity = 89.55 MW

- GB installed capacity = 79 GW
- Factor of comparison of Shetland to GB generation portfolios is approximately 1000
- Shetland plant margin = 89% (with wind at 100% on day of peak demand)
- GB plant margin = 43 % (with wind at 100% on day of peak demand)²
- Shetland installed wind = 4%
- GB installed wind = 3%
- Conclusion is that the wind power starting points for Shetland and GB are broadly similar and while the generation plant margin on Shetland appears to be greater the operating regime of SVT bring the plant margin into line with the GB case.


If the scenario should occur where maximum wind generation output occurs at the time of minimum demand the following condition would emerge:

- Shetland percent demand met by wind = 29%
- GB percent demand met by wind = 14%
- This analysis shows that Shetland already has a more onerous task in integrating wind power so it is anticipated that stretching this condition with the connection of further wind power will yield learning on system operational measures for high penetrations of wind power.

² Existing GB Plant Margin is 37.7% as wind is discounted by National Grid. With wind at 100% on day of peak demand, GB Plant Margin is 43.1%

Shetland characteristics under NINES

The following data provides a summary of the proposed generation and demand development under NINES.

Generation	Demand
<p>Key Stats:</p> <p>Available max capacity after system constraints – 96MW % renewable - 10% Additional 6MW wind likely to be installed.</p> <p>Installed Generation</p>  <p>■ Diesel (LPS) - 65MW ■ Gas (SVT) - 22MW ■ Wind - 10MW</p> <p>With wind power installed capacity at 10MW there is potential to go 100% renewable at time of minimum demand.</p>	<p>Phase 1:</p> <p>Large scale DSM (Phase 1) – 4MW district heating load. This will be both dispatchable and frequency responsive. What are the characteristics of this? Like statistical availability etc. The main purpose of this will be to follow the additional wind generation – where will it be located ?</p> <p>Domestic DSM (Phase 2):</p> <p>3MW of hot water loads consisting of approx 1000 customers. Frequency Responsive. Around 20% of these will be monitored directly. The total DSM resource will then be estimated using models along with weather data etc.</p> <p>Increased domestic DSM (Phase 3):</p> <p>6-10MW of storage heaters provided by Dimplex.</p>

Addressing GB wide questions

Future GB power system challenges

The GB government is committed to clear, law-bound targets on emission reductions. Achieving these targets has been the focus of energy policy in recent years and the current strategy is outlined in the UK Low Carbon Transition Plan³(DECC, 2009).

A section of the LCTP focuses specifically on the Power Sector where it becomes clear that the majority of emissions reductions anticipated will be achieved within the Power and Heavy Industry Sector.

A central target is set as: Generate 30% of electricity from renewables by 2020. This target is driven by the overall strategy of moving the energy consumption from areas such as domestic water and space heating and transport into the electricity sector.

Government expect that by 2050 we may be generating more electricity but also require it to be low carbon. It is also anticipated that there will be greater fluctuations in Supply and Demand.

It is noted that the wholesale electricity market is going to change as more Renewables are connected. Investors in flexible, dispatchable generation will need confidence in good financial returns if they are only to generate at peak demand or when Renewables are unavailable.

The ENSG Smart Grid vision⁴ (ENSG, 2010) delves deeper into some of the technical challenges that power networks will face:

- Facilitate connection and operation of generators of all sizes and technologies
- Enable the demand side to play a part in optimising the operation of the system
- Extend system balancing into distribution and the home
- Provide consumers with greater information and choice of supply
- Significantly reduce the environmental impact of the total electricity supply system
- Deliver required levels of reliability, flexibility, quality and security of supply
- Balance consumption and production to optimise the output of low carbon sources and integrate intermittent renewables
- Where economic and sustainable, reduce the need for network reinforcement, in relation to heating or transport electrification or the connection of new renewable generation

Recent scenario exercises by Ofgem⁵ (LENS, 2009) and National Grid⁶ (Gone Green, 2008) have also explored the challenges facing GB power systems. National Grid's Gone Green scenario presented a

³ <http://www.decc.gov.uk/publications/>

⁴ <http://www.ensg.gov.uk/index.php?article=126>

⁵ <http://www.ofgem.gov.uk/Networks/Trans/Archive/ElecTrans/LENS/Pages/LENS.aspx>

potential view of 2020 energy mix that meets the Govt targets. This includes 19GW of offshore transmission connected wind and 11 GW of total onshore wind making up almost 30% of GB electricity generation. This scenario highlights major challenges in managing system intermittency and operating margins. Ofgem's Long Term Electricity Network Scenarios for 2050 used three themes to formulate a set of 5 scenarios:

- Big T&D
- Energy Services Market Facilitation
- DSOs
- MicroGrids
- Multi Purpose Networks

The LENS themes were: Environmental Concern, Consumer Participation and Institutional Governance.

The scenarios describe a relatively wide range of plausible outcomes for GB electricity networks in the longer term. Many of the scenarios paint pictures of future electricity networks with technical and operational challenges in areas such as: system operation in high renewable and high interconnection situations, microgrid-type operation in local areas, the development of DSO functions, and management of demand response.

Across most scenarios (to varying degrees), there are more active distribution networks.

This brief summary of recent policy, planning, industry vision and horizon scanning exercises highlight some of the challenges widely believed to face future GB power systems.

- Increased renewable penetration (primarily wind)
- Greater fluctuations in Supply and Demand
- System operation challenges – intermittency, operating margins.
- Shifts in energy vector introducing new electrical loads
- Management of demand response
- More active distribution networks (DSO operation)

It is clear that the proposal for innovative technological, system operational and commercial arrangements on Shetland address the questions posed by the recent policy and vision for GB to a high degree.

Key GB power systems questions

Elsewhere in the NINES bid document, National Grid outline the areas of learning they believe are possible from the Shetland power system.

Supply Chain Perspective:

⁶<http://www.nationalgrid.com/corporate/Our+Responsibility/Our+Impacts/ClimateChange/Seealso/gonegreen2020.htm>

- Developing demand responsiveness
- Integration of micro generation and 'large scale' generation
- Integration of low carbon heat and transport
- Efficient and reliable network investment and operation

System Operation and Control perspective:

- Dynamic behaviour of renewable generation and flexible demand, with particular reference to low carbon demand
- Development of forecasting tools and techniques for demand behaviour and demand response to external signals, both direct and price driven
- Despatch methods
- Frequency control methods
- Development of contingency arrangements
- Local network constraint management and how this impacts on despatch (market balancing) and system balancing

Discussion

In previous sections of this document we outline the main characteristics of the Shetland power system, its future challenges and proposed developments under NINES. These are summarised below.

Present:

- Voltage Concerns
- Stability Issues in certain scenarios
- System balancing of intermittent renewable
- High electric water and space heating load
- Frequently 29% of generation is wind (in times of minimum demand)
- DNO responsible for system operation
- Additional firm wind connections are unfeasible.

Developments:

- 4MW heating load (district heating boiler)
- Frequency responsive and dispatchable
- 3MW domestic load – hot water tanks (Phase 2)
- 6MW domestic load – storage heating (Phase 3)
- Demand response will facilitate additional wind connections

Comparing these to the future challenges facing GB networks below, it is clear that the current and future Shetland power system faces many of the issues awaiting the GB system.

- Increased renewable penetration (primarily wind)
- Greater fluctuations in Supply and Demand
- System operation challenges – intermittency, operating margins.
- Shifts in energy vector introducing new electrical loads
- Management of demand response
- More active distribution networks (DSO operation)

The Shetland power system and the developments that will take place within and alongside the NINES project are clearly not a direct analogy or scaled down version of the development on the GB system, however the challenges faced in both systems are clearly similar.

As an electrically islanded system, Shetland experiences system operation challenges in economically balancing supply and demand and dealing with intermittent generation. With the limited level of interconnection currently in place between GB and mainland Europe a GB system with levels of intermittent generation would have considerably greater system operation challenges than other well connected countries with high penetrations of intermittent generation. Although the generation mix is more diverse in the GB system, there is a clear Shetland to GB similarity between the level of intermittent renewable versus dispatchable generation.

Lessons learnt on wind generation forecasting, scheduling and dealing with higher or lower than forecast output should be of considerable value GB wide and for any other islanded system operator dealing with high wind penetration.

Demand response is a clear objective of GB policy and is a main feature of the NINES proposals. From a GB system operator perspective, they may not expect to have direct control of demand response resources as these are likely to be embedded in distribution networks or at the domestic level and are likely to be either operated in an active distribution network by a DSO or will be aggregated as a virtual power plant (VPP) type resource.

However, increased understanding of the control requirements and likely methods of DSO operation will be directly relevant to the GB perspective. The GB system operator will need to understand the capabilities of demand resource deployed in distribution networks, how to interface with the various DSO's managing the resource and also on the likely communications and control methods of accessing domestic energy resources for system operational support purposes (such as the implications for response times and operation as an aggregated resource). The Shetland power system provides a contained/controlled, measureable and risk managed experimental demonstration site where the major issues and innovations of operating power systems with high penetrations of renewable energy can be understood prior to national roll-out.