DumGal Against Pylons (DGAP) Alternative to SPENs Proposal

1 Introduction

DGAP oppose SPENs current proposal for three reasons. First, SPEN have yet to produce a Needs Case. This document should set out the arguments, taking account of energy policy, generating mix and transmission capability, and backed up by data to justify the proposal and choice of implementation against a range of criteria that include, technical, economic and environmental factors. Until such a document is made available SPENs current proposal remains no more than an aspirational target, without substance, and based on information that is, in all likelihood, out of date and consequently over-estimates the need.

The second reason for DGAPs campaign against SPENs current proposal is because the deployment of a 400kV super-grid based on an overhead line supported on pylons up to 50m tall through a region that has hitherto remained largely free of signs of industrial architecture will significantly de-value the natural, cultural and historic assets of the area. Added to this, people who subsequently find themselves situated near to the pylon route or to the site of new substations will likely suffer a loss of residential amenity and well-being. Furthermore, the region as a whole, which presently has outstanding natural landscape qualities that create a world-class destination for visitors, is likely to suffer a loss too – albeit a socio-economic one, due to the loss of tourism income and consequent fall in employment that will inevitably result if SPENs proposal goes ahead as planned.

The final reason for DGAPS opposition to SPENs proposal, which also depends on the proposal that emerges from the Needs Case, is because much of the above mentioned blight and loss to people and the economy is avoidable. An alternative proposal exists which eliminates the need for a new super-grid overhead route while still achieving the basic aim of providing an infrastructure that will transfer excess electrical energy from renewable sources to Harker in Cumbria and then south to England and Wales where demand exists. The downside is that this alternative will initially cost more. However, in relation to SPENs proposal, DGAPs alternative is advantageous in many respects and when viewed over the life of the proposed infrastructure and the economic loss that could ensue, the net present value is positive.

This paper describes the background to the infrastructure project and assumes SPENs Needs Case, when it is made available to the public, will continue to be based on a low-cost option using overhead lines and pylons. DGAPs alternative proposal together with the resultant benefits over SPENs proposal is outlined. Other mitigation options that may be employed are considered and discussed.

2 Historical Perspective

The industrial, commercial and domestic sectors of Dumfries & Galloway have grown and prospered over the past 80 years or so through the use of an electrical transmission network operating at 132kV with substations[1] strategically placed at Chapelcross, Dumfries and beyond to facilitate connection of local rural 132kV distribution circuits to the transmission network. Figure 1 illustrates this transmission network, shown black. It can be seen that some circuits, such as that between Newton Stewart and Glenluce are shown as a double line while others are shown by a single line. The double line indicates a double circuit while a single line indicates a single circuit only.

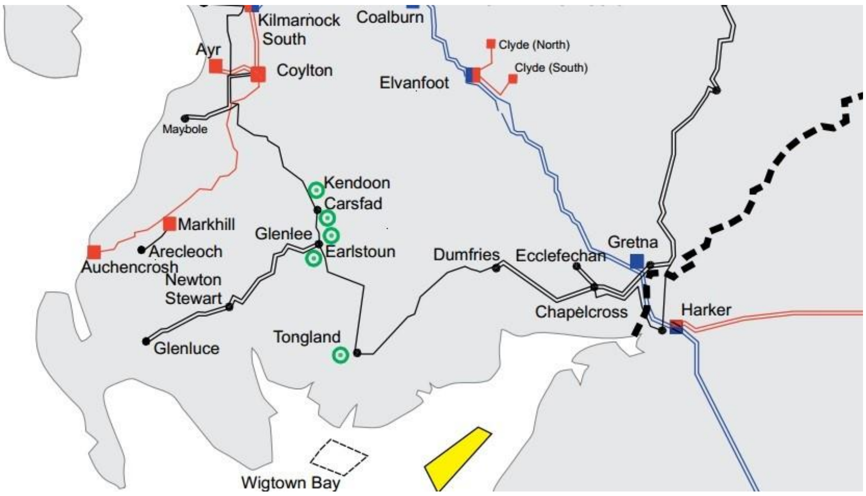

Figure 1

Source: National Grid (2014)

Although the existing 132kV transmission system is old, such systems were installed throughout the UK and were designed to have long operational lifetimes and, in the short-

[1] These are sometimes referred to as Grid Supply Points.

term at least, SPEN have confidence in being able to maintain the availability of the system within the south of Scotland. DGAP recognise that replacement of the transmission assets will be needed at some stage but also recognise that even following such an upgrade consumers may continue to experience power outages due to problems associated with older, rural 132kV and lower voltage distribution networks mounted on wooden poles.

For completeness, Figure 1 also shows a double circuit 400kV transmission network, in blue, running from Kilmarnock to Harker and continuing south. This is similar to that which SPEN propose for Dumfries & Galloway and, if their proposal is consented, it will run from Harker to Newton Stewart. The red line represents a single circuit transmission network operating at 275kV running between Kilmarnock and Auchencrosh where there is a sub-sea link to Northern Ireland known as the Moyle Interconnector. Finally, the green circles represent existing sources of hydro-generation, although other network developments[2] taking place in south Ayrshire are not shown on this diagram.

3 Load Demand and Line Rating

The rating of an overhead line (the ability to carry power up to a certain level – usually defined in terms of MVA, but for ease of understanding the term MW is used here) is influenced by thermal limitations of the conductor (the maximum temperature) which is dependent on the ambient temperature, the type of conductor and the line design. The effect of conductor sag has also to be taken into account to ensure minimum statutory ground clearance is maintained. For pylons or lattice steel towers constructed between 1930–1975 up to 22.6m high, it is usual for the thermal rating to be assigned based on a 50^0C maximum temperature, which includes the ambient temperature. Using this logic the rating of a transmission network tends to be lower in summer when the ambient is higher and for the 132kV network running through Dumfries & Galloway this rating is nominally 105MW.[3]

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[2] There are several developments planned from 2015 to 2022. Those taking place over the next couple of years include, extending the 275kV network from Coylton to the west of New Cumnock to form a collector for renewables generation in south and east Ayrshire together with re-conductoring the line from Coylton to Mark Hill to allow for wind farm expansion.

[3] To be precise, the line rating, based on the summer rating, varies between several of the substations. For example, Dumfries to Glenlee is rated at 105MW or 105 MVA to be correct, while Dumfries to Chapelcross is a

Power flow analysis performed by the National Grid[4] on 2015/16 data scenario and based on the spot time of winter peak demand shows that power flowing between Tongland and Dumfries is limited to 59MW, which is within the design specification of the current transmission system. The loading situation has improved over time too, because the energy demand (measured in terms of electrical energy consumption in GWh/annum) within Dumfries & Galloway has fallen over the period 2005-2013 by almost 15% in the domestic market, despite a 3% increase in housing stock, and 7% for the industrial and commercial sector. Figure 2 shows how the consumption of electricity has reduced in the region over this period.

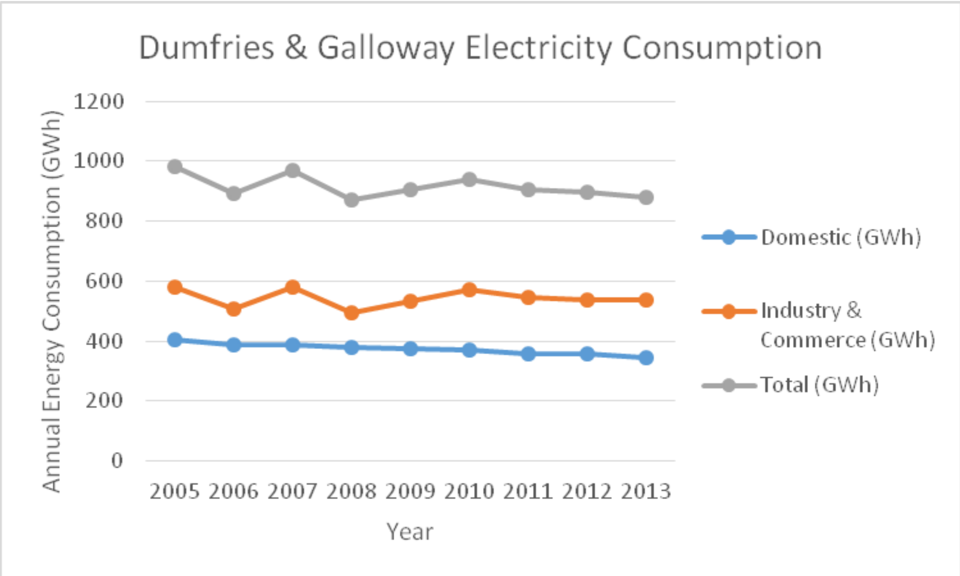

Figure 2

Source: HM Government (2015)

This fall in electrical energy demand is expected to further accelerate over the coming years as public sector organisations and large private sector firms continue to take steps to reduce energy consumption and older private housing stock is refurbished and upgraded with energy efficiency measures. The gradual adoption of energy efficient domestic appliances will further add to reducing demand. It is also unlikely, given the rural nature of the economy within Dumfries & Galloway, that manufacturing organisations which are large

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dual circuit with each line rated at 137MW. Each of the lines between Glenlee to Newton Stewart is rated at 100MW while each circuit from Newton Stewart to Glenluce is only 37MW.

[4] Given in Figure C1: Appendix C, Power Flow Diagrams, to accompany the National Grid Electricity Ten Year Statement (2015).

consumers of electrical energy[5] will relocate to the region to reverse the trend of falling demand.

This falling demand for energy is also mirrored by a falling maximum demand.[6] In the UK, over the same 2005–2013 period, maximum demand fell from around 61.5GW to 55GW and is forecast to continue falling over the next 5–10 years.[7] There is a small possibility, depending on a rare combination of circumstances that include the emergence of high economic growth rates together with a large uptake of electric vehicles and electric heat pumps, that demand may increase after this period.

However, a recent report into the uptake of ultra-low emission vehicles in the UK[8] suggest that demographics characterise electric vehicle as being confined to urban, middle-aged, affluent, well-educated males with households containing two or more cars and with the ability to charge at home; a description that doesn't necessarily accord with rural Dumfries & Galloway which has seen falling economic growth[9] and is classed as a 'less developed' region within the EU.[10] Furthermore, at this point in time, the government grant scheme that offers £5000 off the price of an electric vehicle expires after February 2016.[11]

In addition, and in relation to the use of heat pumps,[12] air-sourced heating is not a compatible form of heating for the many of the older homes in Dumfries & Galloway.[13] Consequently, it is unlikely there will be a large uptake for this form of heating technology other than for new build or refurbished homes where mains gas is unavailable.[14] Even here,

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[5] The largest public user of electricity in the region is the D&G Council which spends in the order of £3.0m or in the private sector, DuPont Teijin Films UK Ltd, where the spend is also several £m per annum.
[6] Maximum demand refers to the peak requirement for electricity which usually occurs at some point during the winter period. Maximum demand is measured in GW where a GW represents 1000MW.
[7] As described in the National Grid (2014) Electricity Ten Year Statement
[8] BrooklyndHurst (2015) Uptake of Ultra Low Emission Vehicles in the UK. Report prepared for the Department of Transport.
[9] ONS (2013)
[10] Eurostat (2014)
[11] IAM (2015) Advanced Driving Magazine, Winter 2015.
[12] Heat pump technology utilizes low-grade heat and is therefore only suitable for use in well insulated, draught-free homes that make use of under-floor heating or force ventilated, over-sized, convection heating.
[13] These are older homes which have low u-value wall insulation without provision for underfloor heating.
[14] Ofgem (2015) Insights Paper on Households with electric and other non-gas heating dated 11 December, 2015, state that of the 26.254m households in Great Britain less than 100,000 make use of air-sourced heat pumps. On a pro-rata basis this would equate to less than 10,000 in Scotland, or less than 0.4% of households. From the report the prime candidate for air-source heat pumps would be as a replacement for night storage or electric panel heaters in single occupancy flats owned by housing associations in order to reduce running costs

however, at low temperatures the coefficient of performance (CoP)[15] of this particular technology falls off significantly leading to the consumption of 'expensive' electricity in relation to the cost of other fuel types.

Overall, therefore, it is unlikely that Dumfries & Galloway, with its dependence on a relatively low-paid rural economy, long journey times between remote communities and where older, poorly insulated homes in rural locations provide a significant proportion of habitable dwellings, will see significant technology adoption driving demand for electricity consumption to a level that might be experienced in urban towns and cities in other parts of the UK. [16]

4 The advent of renewable generation

Over the past decade the region has seen the advent of on-shore wind farms that have required connection to the transmission network. Figure 3 illustrates the scale and location of these operational wind farms (shown in red) in 2014 which collectively accounted for a connected capacity in the order of 355MW.[17] Figure 3 also illustrates the presence of the Moyle Interconnector and a further sub-sea link between Hunterston and Deeside, rated at 2200MW, which is expected to be commissioned in 2017.

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and lower fuel poverty. As such, one form of electric heating would be exchanged for another, albeit, a slightly more efficient one. The overall demand for electrical energy should therefore fall if the demand for air-source heat pumps increases.

[15] The coefficient of performance is the ratio of the low-grade energy extracted from the air in relation to the electrical energy needed in the conversion process.

[16] National Grid (2015) Future Energy Scenario. In this report the NG, in the 'Gone Green' scenario, which is the most optimistic scenario, suggests there could be a large increase in air-source heat pumps by 2035. However, on p.65 of this report it is interesting to note that the authors state that the demand for air-sourced heat pumps has been reduced, in all scenarios, as a result of feedback from stakeholders.

[17] Dumfries & Galloway Council (2014) Renewable Energy Report

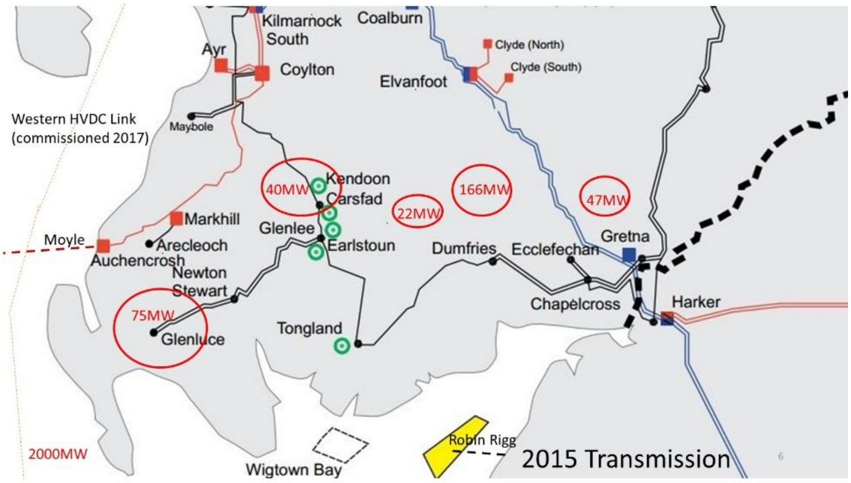

Figure 3

Source: RenewableUK (2015)

Figure 3 introduces several factors that are important to the appreciation of the impact of connecting intermittent generation to a transmission network. First, as the term intermittent implies, the actual generated power output varies at any point in time which infers the actual output rarely matches the connected capacity. The connected capacity is often referred to as the nameplate capacity which, for a larger on-shore wind turbine, may be around 2.5MW and is determined from a range of factors that include wind speed data, the height of the turbine and the design and tip diameter of the rotor blades.

However, in practice the output of a turbine and indeed the output from a group of turbines comprising a wind farm, but especially the collective output from several nearby wind farms, will vary from the combined nameplate capacity because of power output sensitivity to wind speed – which tends to be non-linear, together with variations in topography which means that each turbine, or group of turbines, may experience different wind speeds at any point in time. The former effect is demonstrated by the typical load or capacity factor[18] for an on-shore wind turbine operating in southern Scotland which is in the order of 27% when averaged over a year.[19] What this means is that the actual energy generated in MWh (or for

[18] Load or capacity factor refers to the ratio between the actual energy generated in MWh or GWh and the nameplate energy capability averaged over one year.

[19] Scottish Government (2015) Energy in Scotland

larger wind turbines, in GWh) is only a small fraction of what could be generated if the wind blew at full speed throughout the year.

The latter factor, which is a function of the diversity of power output from one wind farm to the next, is accounted for by transmission network operators when designing the transmission capability. Here, industry practice is based on designing the network transmission capability to accept 70% of the cumulative connected generation.[20] This de-rating factor accommodates the probability of wind speed being lower than the rated wind speed across the range of wind turbines connected to a particular transmission network.

5 Basis for SPENs proposal

SPEN anticipate that over the next decade there will be a considerable increase in the amount of renewable generation in south west Scotland, with a further 350MW[21] contracted to connect to the Dumfries & Galloway network. Other sources suggest an even higher future figure, of 695MW,[22] based on those presently under construction and those already consented. The two datasets are unfortunately irreconcilable because while the former is based on the existence of a commercial contract to connect to a transmission network that may or may not have planning consent, the latter is based on the presence of planning consent which may or may not have a connection contract in place.

The situation has been simplified somewhat because of an announcement by the Secretary for Energy and Climate Change, the Rt Hon. Amber Rudd MP, on the 18 June 2015 informing of an end to public subsidy[23] for on-shore wind. This announcement effectively 'draws a line in the sand' for which projects will be eligible and which won't. Although a further recent announcement provides a little extra flexibility it essentially means that only those projects that have consent or in the process of appealing, have a connection agreement in place and can demonstrate land right agreements on the 18 June, will qualify.

Figure 4 attempts to interpret this future scenario and is based on the assumption that other commercial schemes, such as Contracts for Difference (CFD), will not play a significant

[20] NG (2015) email communication exchange with reference to NETS SQSS documentation
[21] SPEN (2015)
[22] RenewableUK (2015) Wind Energy Database
[23] Known as Renewable Energy Certificates or ROCs

part in the build-up of renewable on-shore wind generation over the next decade. Having said this, Figure 4 deliberately takes a conservative view in that it anticipates a total of 1045MW connected generation which is almost 700MW greater than exists at present.

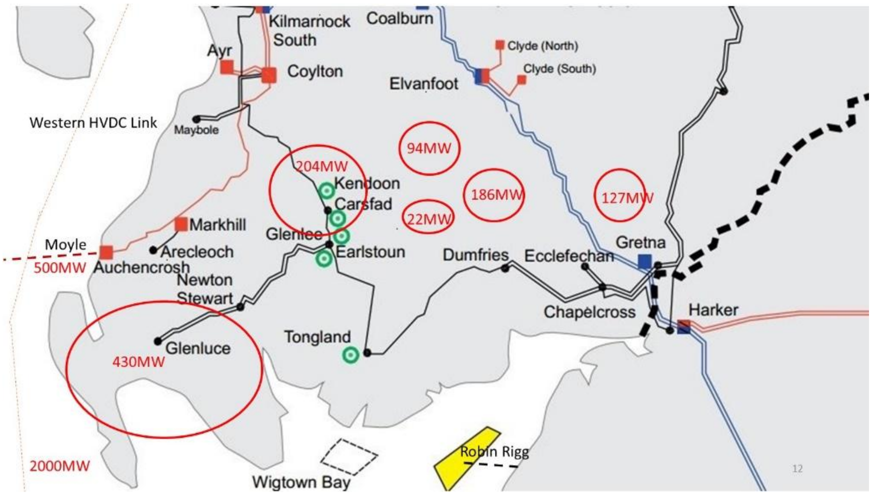

Figure 4

What Figure 4 illustrates is that the majority of any additional generation requiring connection to the transmission network is expected to be situated north of Glenlee or southwest of Newton Stewart.

Against this background, although ahead of DECCs announcement of the 18 June 2015, SPEN, in their consultation document entitled 'Powering your future,' propose a reinforcement scheme that will have almost 17 times the capacity of the existing transmission network.[24] Figure 5 shows SPENs proposal and note here that at a rating of almost 1700MW the proposed 400kV overhead line between Harker and Newton Stewart (shown in blue) will be grossly over-sized if the anticipated additional renewable generation of 700MW proves to be anywhere near to a reasonable estimate. On the other hand, given the falling level of investor confidence in on-shore wind there is every possibility that the level of additional generation, even those that have a consent and connection agreement, may ultimately be far less than this figure.

[24] Based on a discussion with a SP Transmission representative at a consultation session at Dunscore.

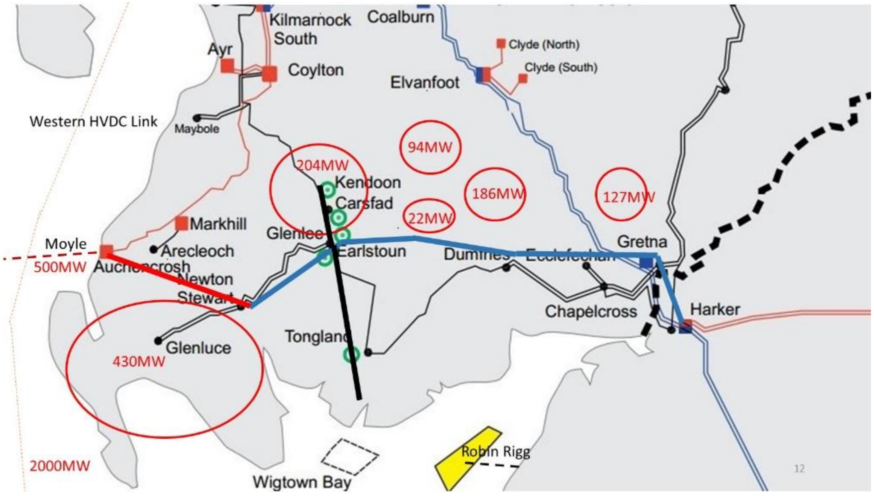

Figure 5

Source: SPEN (2015)

SPENs proposal as set out in Figure 5, therefore, is suggestive of a scenario (not unreasonable in the circumstances) founded a) on a lack of detailed information about the extent of future renewable generation connection requirements and b) the application of design rules in which, in the presence of doubt, the best solution appears to be to double the number thought of and then add yet more to cope with future expansion.

Against this background, and assuming the renewable generation set out in Figure 4 turns out to be a reliable estimate then SPENs proposal in Figure 5, leaving aside any unknown additional renewable generation that may need to be connected in future, suggests the 400kV network would operate for the majority of time at somewhere in the order of 30% capacity. This would be a significant under-utilisation of resource and as an investment would not represent best value for money even taking account of the need for 'future-proofing.'

6 DGAPs Alternative Proposal

DGAPs proposal is predicated on the use of a sub-sea link of sufficient rating to accommodate the additional renewable energy that is anticipated to occur in the west of the region. At 1000MW rating such a link, landing at Auchencrosh, would be around 50% loaded depending on the direction and magnitude of load flow through the Moyle Interconnector and the power available from renewable sources. Elsewhere, as shown in

Figure 6, SPENs proposed 400kV transmission network could be down-rated to 132kV (shown black). It is likely, but by no means a foregone conclusion, that with the sub-sea link in place, the Newton Stewart to Auchencrosh proposal based on a 275kV transmission voltage will have to remain in order to accommodate the additional renewable generation converging on Newton Stewart from Kendoon to Glenlee and that connected to a new substation at Newton Stewart from the Glenluce area. Some parts of this line, particularly where there is a high visual impact, could be mitigated by undergrounding.

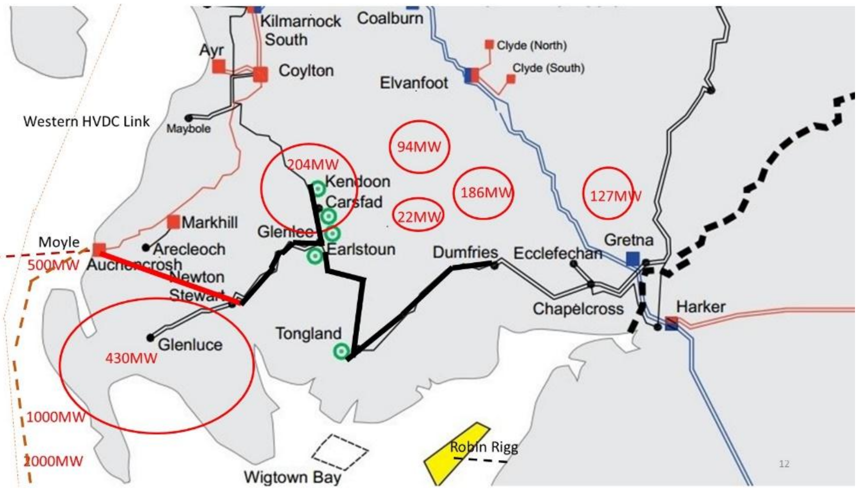

Figure 5

The alternative 132kV network will require to be uprated to some extent and this will entail the replacement of the existing 22.6m tall pylons with, in all likelihood, L7(c) pylons which stand 26.2m tall. The overhead conductors will also need to be uprated to a maximum of 520MW depending on the results of a load flow analysis. At this level of capacity the Great Britain Security and Quality of Supply Standard (GBSQSS) is satisfied for any double circuit fault as the winter peak in 2024/25 between Tongland and Dumfries is calculated, in the worse-case scenario, to be constrained at 459MW.[25]

Because the pylon replacement is only notionally taller an overhead line using broadly the existing corridor but with some modest deviation, to mitigate any adverse landscape impacts of the present line, is recommended. Again, some small sections of undergrounding, close to NSAs or

[25] The value of 459MW is obtained from Figure C5: GB Power Flow Diagram Gone Green from Appendix C to the Electricity Ten Year Statement 2015 which the ETYS (2015, p.22) refers to as one which assumes significant volumes of renewable generation- especially wind – will be deployed. There are three other scenarios that assume the build-up of renewable generation will be lower than this figure.

within RSAs, may be desirable. This uprated line is shown terminating in Dumfries for illustrative purposes but is expected to extend to Harker.

7 The advantages of DGAPs proposal over that offered by SPEN are:

7.1 It does not blight areas that have not previously been blighted and as the replacement pylons are only 3.6m taller than the existing pylons the degree of additional negative visual amenity along the existing route will be minimal. Undergrounding can help off-set any particularly sensitive areas along the existing route if mitigation by some modest deviations to the 132kV overhead line is insufficient.

7.2 Because the transmission voltage remains at 132kV it matches the existing 132kV rural distribution network voltage and hence removes the need for 400kV/132kV transformation at Dumfries and Glenlee substations. Not only does this reduce cost it also reduces the size of the substation footprint as less equipment needs to be accommodated.

7.3 The proposed 400kV switchgear at Glenlee and Dumfries can be replaced by equivalent 132kV switchgear which again is not only cheaper but smaller too.

7.4 On-going maintenance cost will reduce as the transmission voltage reduces due to the removal of equipment and the use of smaller insulator strings. The inventory cost of maintaining spare parts should also reduce.

7.5 In the absence of conducting a detailed analysis of the present Glenlee and Dumfries substation compounds it may be possible to accommodate the new switchgear within the existing substation thus eliminating the need to establish new, large substations at these locations.

7.6 As the majority of additional renewable generation will mainly connect in the west of the region a sub-sea link that takes the power directly south to where demand exists, rather than east to Harker and then south, will possibly result in reduced transmission losses.

7.7 The establishment of the sub-sea link and the establishment of a strengthened network from Kendoon – Glenlee – Newton Stewart – Auchecrosh effectively removes the immediate pressure to strengthen the remainder of the network to the east as the majority of export of renewable generation from the region will be accommodated through this off-shore route.

7.8 Once 7.7 is in place the remainder of the network (from Glenlee to Harker) can be accommodated in a phased approach. This phased approach brings with it the additional benefit of allowing more knowledge to be gained about the likelihood of additional renewable generation requiring connecting to this part of the network which means the optimum design can be selected on fact rather than supposition. It also creates the opportunity of treating this part of the project as revenue[26] rather than capital, thus reducing capital expenditure. Revenue expenditure can create more local long-term job opportunities.

7.9 By taking the majority of any additional renewable generation within Dumfries & Galloway via sub-sea the 400kV boundary condition on the main network between Gretna – Harker will free-up transmission capacity to accommodate future, additional load flows between Scotland and England.

7.10 A sub-sea route and the replacement of the existing 132kv network, with an upgraded network at the same voltage, will attract much less controversy and opposition and hence involve lower costs for developers, public authorities and society as a whole in the approval process. Furthermore, delays to the project implementation will be minimised leading to lower constraint payments.

7.11 The natural, cultural and historic assets of the region will be preserved as will the economic development potential from the growing tourism sector.

7.12 Any health concerns residents may have from the proximity effects arising from low frequency electromagnetic fields (EMFs) are minimised.

[26] There is a distinction between capital and revenue. Where modifications to the network lead to enhanced future revenues the project is classed as capital with such expenditure adding to SPENs asset base. However, it is possible that parts of the network, particularly from Glenlee to Tongland and then to Harker could be classed as revenue as the aim here is simply to replace aged assets with new assets together with a small amount of upgrading that may not lead to foreseeable increased revenues. However, even if this were to be classed as capital it could be undertaken as one or more smaller capital projects rather than a Strategic Wider Works project and thus create jobs for local labour over several years.

8 The disadvantage of DGAPs proposal is:

It will cost more. A regression of several recent and future sub-sea link projects suggest at approximately 200km nautical distance between Auchencrosh and a suitable landing point on the Cumbrian or Lancashire coast[27] the capital cost, including HVDC converter stations at either end, will be around £600m as shown in Figure 6. However, set against this additional capital cost is the removal of 400kV overhead lines supported on pylon up to 50m tall, the elimination of 400kV/132kV transformers, and switchgear will also be smaller and hence cheaper. Furthermore, it is possible that one or more new substations will not be required to be developed and capital expenditure to reduce capacity constraints on the 400kV network will be avoided or reduced.

After discounting these factors any additional capital cost is likely to be in the order of £300m. However, when calculated as a lifetime cost, taking account of dis-benefits from a small (typically 10%) fall in tourism income to the region and using Ofgem's weighted average cost of capital (WACC) and historic inflation figures over the past 25 years, avoiding economic loss from falling tourism results in a positive net present value (NPV) over the asset depreciation of 45 years.

However, even on a capital cost basis DGAPs alternative will, most probably, encounter much less public opposition and consequent planning delays. Thus, savings in constraint payments will cover any additional capital cost. The economic decision is therefore clearly weighted in favour of the sub-sea option and consumer willingness to pay for such mitigation has already been established.[28]

There is a further option, which has not been explored so far, that offers the possibility of eliminating any additional cost over SPENs low-cost overhead line approach. This option is similar to the proposed East Coast HVDC Link between Peterhead and Hawthorne Pit where there is provision for an intermediate sub-sea connection to Braxton, just south of Torness. The option here, therefore, is that instead of a sub-sea cable between Auchencrosh to a

[27] There are several options available. Seaton in Cumbria is intended as a Grid Supply Point as part of the North West Connection project being undertaken by National Grid. This connection will feed into Harker. Alternatively, there is Heysham or Blackpool in Lancashire or Deeside in Cheshire. If Seaton is suitable the cost is likely to fall to around £400m due to the reduced length of sub-sea cable required.

[28] National Grid (2014) Consumer willingness to pay survey

suitable point on the Cumbrian or Lancashire coast, the new HVDC convertor station at Auchencrosh could connect into the Western HVDC Link. This has the potential to minimise the length of any sub-sea cable to around 50km as well as eliminate the need for a second convertor station at the receiving end of the line. The practicality of this solution will depend on the actual winter peak loading on the Western HVDC Link.

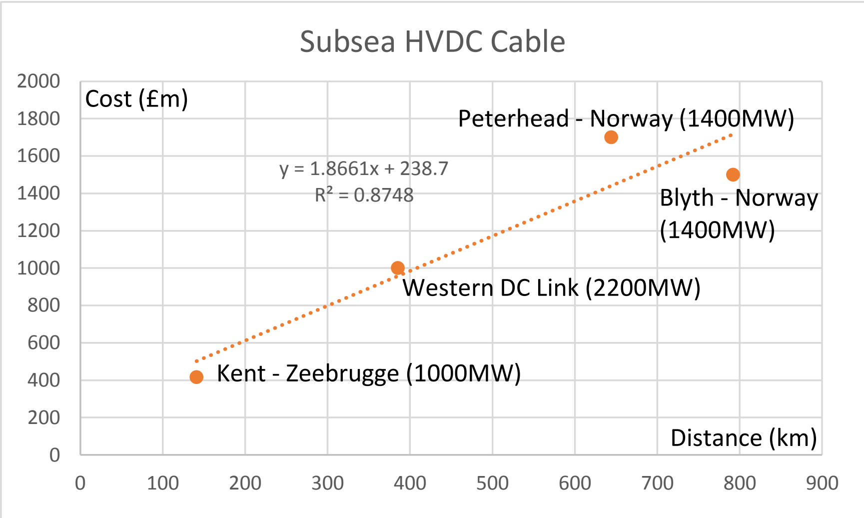

Figure 6

9 Other Mitigation Alternatives

It is possible to advance other means of mitigation to reduce the visual impact of SPENs proposed low-cost option based on an overhead network – if in indeed this is what the Needs Case eventually proposes. The most commonly cited form of mitigation are screening, route selection, alternative pylon design and undergrounding.[29]

9.1 Screening

Screening by trees may help conceal substations (in the summer-time if they are broad-leaved trees) and may lessen the impact of transmission pylons from a particular vantage point. However, even a mature tree at 25m tall would hardly conceal a 50m tall pylon and the resultant wirescape formed by conductors strung between lines of pylons.

9.2 Route Selection

[29] These methods are described in a survey conducted for the National Grid (2010) entitled Consumers' Willingness to Pay Research.

Careful route selection of overhead lines is argued, by SPEN, to form part of their proposal[30] as is the avoidance of the more sensitive areas.[31] However, having said this, SPEN adopt a route selection practice based upon factors such as topography, landscape character and areas of environmental value and historical interest, together with technical considerations such as slope, altitude and the presence of watercourses.[32] In doing so they recognise also the clarification notes to the Holford Rules which gives priority to people and residential areas such that in rural areas they should avoid, as far as possible, dominating isolated houses, farms or other small-scale settlement.[33] A minimum distance of 100m is considered, by the industry, to meet this requirement.[34] [35]

The choice of line route , therefore, even though there may be an expression of intent for a strong focus on local population and environmental sensitivities, including visual amenity,[36] comes down to, especially in the rural areas that describe much of Dumfries & Galloway, as only just avoiding habitable buildings. Against this 'lip-service' practice, one of the few studies conducted in the UK[37] on the impact of pylons on visual amenity finds that even at 400m separation, pylons at 50-59m in height can give rise to very large-scale visual effects. Furthermore, these effects can be further amplified in rural areas by a range of factors such as, where more than one pylon is visible, under high contrast conditions, the time of day, seasonal variation, weather conditions, and the scale of the structure in relation to the scale of the landscape. Line routeing, therefore, only ever attempts to ameliorate an unwanted

[30] Holford Rules 4, 5 and 6.
[31] Holford Rules 1 and 2.
[32] SPEN (2015) Major Electrical Infrastructure Projects, Approach to Routeing and Environmental Impact Assessment.
[33] SPEN (2015) The Dumfries & Galoway Strategic Reinforcement Project: Routeing and Consultation Document.
[34] Discussion with SPEN staff at Consultation events.
[35] Chapter 24 (Visual Effects) of the Environmental Statement to the Beauly-Denny proposal, paragraph 24.5.1.3. stated that every effort had been made to maintain a minimum distance of 100m between and residential property and the proposed line and in paragraph 24.5.1.4 the 100m separation is said to be based on a property on level ground with a garden extending to 15m in which at the end of the garden is a 10m tall tree which would screen views of a 55m tall pylon at some 100m distance.
[36] SPEN (2015) Background to Needs Case.
[37] Gillespies (2014) Wind Turbines & Pylons: Guidance on the application of separation distances from residential properties. Report prepared for Gwynedd Council, Isle of Anglesey Country Council and Snowdonia National Park Authority.

situation and as one report suggests, "… line routeing does not solve a problem – it simply relocates it."[38]

9.3 Alternative Pylon Design

There are around 88,000 pylons in the UK at up to 50m tall; each weighing around 30 tonne and based on the lattice style design that has hardly changed since the 1920s.[39] SPENs project, if it goes ahead in the form proposed, will add around a further 500 to the total. However, a new design has emerged, known as the T-pylon, which is said to be shorter, lighter and sleeker in appearance. At 35m high, each T-pylon is up to one third lower than the conventional steel lattice design.[40]

Unfortunately, these pylons have no in-built climbing facility for linesmen (as afforded by the lattice design) to provide access to the insulator strings for cleaning and replacement. Consequently a permanent haul road is required running alongside the pylon route to provide access for a powered lift. In much of the terrain to be traversed across Dumfries & Galloway this would not be practicable and is argued by SPEN to be too expensive.[41]

There is at least one other pylon design that is gaining interest; called the 'Land of the Giants.'[42] This is a suite of pylons depicting figures and designed by architectural firm, Thomas Shine + Jin Choi. The first order is expected to be commissioned in Iceland in 2017 and several European network transmission operators are watching how this project develops. There is a differential cost premium over the traditional design but the advantage is that the design is said to captivate rather than reduce the visual amenity – and the construction provides integral climbing access to the insulator strings thus overcoming the need for permanent haul roads.[43] On the downside the structures require guide wires for stability which considerably increases the footprint needed for each pylon.

9.4 Undergrounding

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[38] Accent (2012) Consumers Willingness to Pay Research, p.16. Report prepared for the National Grid.
[39] Royal Institute of British Architects. See www.ribapylondesign.com, accessed 11/6/2015.
[40] The Engineer (2015) National Grid unveils first T-pylon built in UK. 9 April 2015.
[41] Discussion with SP Transmission representative at Dunscore Consultation.
[42] These designs can be found at http://www.choishine.com/index.html
[43] Email communication with Thomas Shine dated 6 October 2015.

Undergrounding provides another form of mitigation and plans have already been drawn up in England and Wales to retrospectively underground sections of existing 400kV pylons and overhead lines from four areas considered to be areas of outstanding natural beauty which, Ofgem concedes, are detrimentally impacted in places due to the presence of overhead lines and pylons.[44] In this case mitigation will be achieved using £500m of funding provided by the National Grid and paid for by an additional £0.22 per year on UK utility bills. This sum is sufficient to remove some 45 pylons in total comprising around 15km of overhead line.[45]

Undergrounding as an alternative to an overhead line proposal can help reverse or reduce public objection to the development of transmission infrastructure resulting in benefits to both parties. For example, opportunity costs from lengthy planning delays are reduced and the expense and complexity of public legal cases is minimised. Other advantages include lower maintenance costs, reduced susceptibility to weather-related issues and storm damage, and underground cables made using copper conductors can result in significantly lower transmission losses and hence improved operating efficiency.[46] Undergrounding cables also generate less concern for low frequency electromagnetic field (EMF) levels than overhead lines; a subject of keen interest to many people living close to existing power lines or having the potential for high voltage overhead lines being erected close to their homes.[47]

Experience suggests that putting some sections of a project underground can help unblock local opposition, allowing a project to proceed much sooner than if a judicial process is used to force a 100% overhead line approach. Savings from these avoided delays can be significantly larger than the incremental cost of underground cables. Examples of where such measures have eventually been agreed after long delays because of local objection include a) undergrounding three sections comprising a total of 14km of a 140km line in

[44] Assertion made by Joan McAlpine in letter dated 26 October 2015 to Kirsty Berge at Ofgem which has not been refuted.
[45] Webster, B. (2015) Giant blots on the landscape to be buried at £11m a time. The Times, 15 September 2015, p.6.
[46] De Keulenaer, H. (2006) Underground High Voltage Cables: Wiring Europe for the Future. E-Book. Leonardo Energy.
[47] Scott, G. (2009) Beauly Denny Public Inquiry 2007, Report of Technical Assessor.

Denmark that consumed 11 years of political negotiation and b) 20km of a 90km line eventually undergrounded in Austria that took over 20 years to conclude.[48]

Reluctance by transmission operators to undergrounding comes down to cost and the need to justify such additional expenditure with Ofgem; although technical considerations also play a part – particularly in terms of the maximum single length to be undergrounded. Various studies cite different cost premium factors for undergrounding. The National Grid have historically cited figures of 10x or higher for underground cables as opposed to overhead lines although in the Danish example given above the factor was found to be between 4 or 5 : 1. A recent UK study, taking account of life-cycle costs (fixed and variable over the lifetime of the asset) found the ratio to be similar to that found in Denmark for underground lengths of between 15-75km although several factors, and particularly the type of terrain, can significantly influence the final ratio.[49]

At power frequencies cables behave as capacitors thereby generating reactive power which both limits the rating of the cable due to capacitive currents while also limiting the length of cable before inductive reactance is required as compensation. Thus extra high voltage (EHV) underground alternating current (ac) cables require to emerge above ground at intervals, in enclosures known as sealing end compounds, in order to compensate for the capacitance effects. Because of these physical limitations the longest single length of 400kV ac underground cable in the UK is 25.5km,[50] although from a theoretical perspective some authors argue that 50km should be possible[51] while yet others advocate a maximum baseline length of 40km, in one or more sections.[52]

Denmark is one country where, for visual impact reasons, their government has mandated that all new 400kV lines will be undergrounded[53] and while such a move may be feasible in Denmark due to relatively short transmission distances there are other practical difficulties

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[48] De Keulenaer, H. (2006) Underground High Voltage Cables: Wiring Europe for the Future. E-Book. Leonardo Energy

[49] Parsons Brinckerhoff (2012) Electricity Transmission Costing Study.

[50] Barber, K. (2013) Achievement and experience in service of long-length HV AC electrical links by insulated power cables. Cigre, Latin American Workshop 2013

[51] Del Brenna, M., Donazzi, F. and Mansoldo, A. (2004) Long-length EHV underground cable systems in the transmission network. Cigre, B1-304. Session 2004.

[52] Scott, G. (2009) Beauly Denny Public Inquiry 2007, Report of Technical Assessor.

[53] Ametani, A., Ohno, T. and Nagaoka, N. (2015) Cable System Transients; Theory, Modelling and Simulation. Singapore: John Wiley & Sons Ltd.

with undergrounding cables, particularly in hilly or mountainous terrain, typical of parts of Dumfries & Galloway. Issues here include, difficulties with directly buried cable because of access, ground conditions and the need to transport large, heavy drums of cable to site.

These factors serve to increase the cost multiplier of underground against overhead. Beyond this however, while faults on underground cables may be less frequent than those for overhead lines the repair time takes on average 25 times longer. Experience suggests that the duration for an underground repair requires between two weeks and two months depending on the technology and the location of the fault.[54] On the other hand, it is not unusual for repairs to take significantly longer if a replacement cable is unavailable and needs to be ordered from a manufacturer.[55] To guard against such circumstances, and to guarantee security of supply, a dual circuit[56] underground installation would be needed.

10 Areas of unknown

10.1 This analysis has been conducted from information in the public domain but without detailed knowledge of factors such as load flow, maximum demand, substation layout, operational factors, and so on. These can all be developed further in conjunction with SPEN if there is a willingness to consider proposals that fall outside the boundaries of a lowest-capital cost option.

10.2 Detailed, robust information on the amount of renewable generation liable to be connected in future is based on a 'best estimate,' as it is with SPENs present proposal. This is expected to strengthen, however, over the coming months as investor sentiment in the renewable sector begins to consolidate once more and SPENs Needs Case, when it is made available, should contain this level of detail.

11 Conclusions

[54] Parsons Brinckerhoff (2012) Electricity Transmission Costing Study.
[55] Email exchange dated 29 November 2015 with Colin Gibson, former director of National Grid.
[56] This would involve two separate 3-phase cable systems physically separated such that if one or more cables from one system fails the other 3-phase cable system can be brought into service to maintain supplies. The swathe required for a single circuit is usually around 22m in width but if a dual circuit is used this increases to about 33m.

SPENs Strategic Wider Works (SWW) project as set out in the Stage 1 Consultation document, 'Powering Your Future,' and based on a low-cost pylon and overhead line proposal has the potential to both further impoverish a region already poor in economic terms relative to Scotland and the rest of the UK as well as destroy many of the qualities that make the area rich in so many other ways.

There is a possibility that a line shown running east to west through Dumfries & Galloway on a map marked, 'Indicative,' in the Third National Planning Framework NPF3 (Scottish Government, 2014, p.29) may have been interpreted by SPEN as an overhead line when all the document meant to indicate was the need to enhance the electricity grid in the region; not the method by which it should be achieved. Furthermore, the Scottish Government (2014), while recognising the need for electricity grid enhancements to facilitate renewable energy generation across Scotland, also recognise that 'Scotland's landscapes are spectacular, contributing to our quality of life, our national identity and the visitor economy.'

They also go on to say, 'Landscape quality is found across Scotland and all landscapes support place-making.'[57] With this in mind the government accept, 'There will be a need to mitigate the environmental impacts of new or upgraded high voltage onshore transmission lines and that there will be a cost associated with this.'[58] In view of this recognition by government for mitigation, SPEN, in developing their Needs Case, need to arrive at a means of implementing their proposal in such a way that mitigates the negative impacts to the natural, cultural and historic heritage of the region as well as to the economy, employment and health and well-being of residents. The Scottish Government and the residents of Dumfries & Galloway expect no less!

DGAP have developed an alternative proposal, and while it needs to be reviewed when the Needs Case becomes available, it provides a foundation by which to achieve the electricity grid enhancements required by government while also mitigating the blight that will inevitably result if SPENs plans were to be implemented as currently proposed. DGAPs

[57] Third National Planning Framework – NPF3, Clause 4.4
[58] [58] Third National Planning Framework – NPF3, Clause 3.29

proposal will initially cost more that SPENs low-cost option but government also recognise that such mitigation will have an associated cost.

Beyond this, however, DGAPs alternative proposal will cost less than the low-cost option over the longer-term as it avoids the dis-benefits to the region that SPENs plans will bring. In addition, DGAPs proposal will attract far less public opposition thereby minimising planning delays and consequent constraint payments.

Finally, if the Western HVDC Link can be used as a collector for the renewable generation emerging from Dumfries & Galloway then the economic argument, on a simple capital cost basis, becomes as cost effective as SPENs low-cost option.