Transmission Working Group

Western Isles Links
Review of Transmission Costs of Offshore Route Options

Paper by Scottish Hydro-Electric Transmission Ltd
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1. Introduction

Two major Western Isles windfarm proposals, totalling 550MW, have received quotes for connection to the GB transmission system at Beauly, near Inverness and further renewable developments are proposed. This paper presents the findings of a review, commissioned by Scottish Hydro-Electric Transmission Ltd (SHETL), into route options for the subsea link of up to 600MW of proposed Western Isles generation to the GB mainland. It reviews the capitalised costs of connection, system electrical losses and lost energy due to outages on the link.

Annual costs to the W.Isles generators are identified for transmission use of system (TNUoS) charges, together with lost energy, where commercially non-firm contracts may be taken.

The route option to connect to Beauly by subsea and underground cable is confirmed as the most economic option in terms of these transmission-related costs.

2. Scope of Review Paper

2.1 The PCS Consulting paper, entitled 'Western Isles HVDC Connection Options', reviews possible route options to link Western Isles generation output to four mainland locations, accessed by the West coast, as shown in Figure 1 and Table 1.

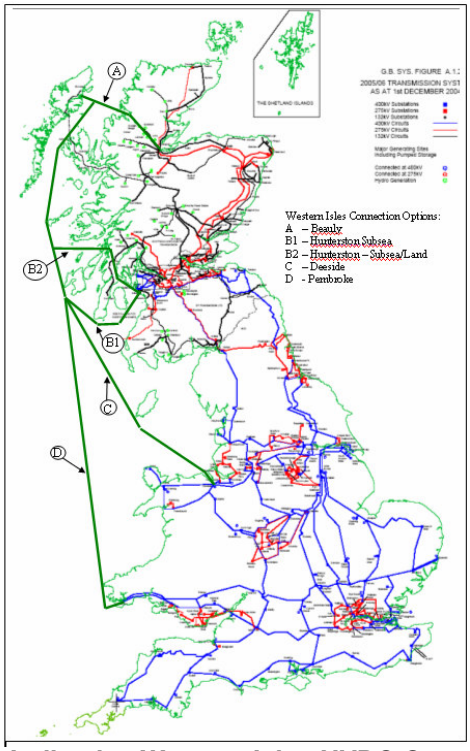

Figure 1: Indicative Western Isles HVDC Connection Routes

		Distances (km)	
Option	**Location**	**Subsea**	**Land**
A	Beauly	93	73 (HVDC Cable)
B	Hunterston	480	-
C	Deeside	675	-
D	Pembroke	770	-

Table 1: Western Isles HVDC Link Connection Options

Two options were considered for both Beauly and Hunterston, but, for simplicity, only one is represented here. For the Beauly route, the two options included HVDC land cable extending eastwards from the subsea cable landing point on the Scottish mainland towards Beauly. The extent that such a cable might be utilised will depend upon a number of factors, including cable costs relative to overhead line, and the required interconnection on the route for other potential generation schemes. The scheme taken into this paper is a fully-cabled option and is likely to be the highest capital cost of the Beauly alternatives.

2.2 Two technology options are considered using voltage sourced convertor technology (VSC) or current commutated technology, often referred to as HVDC Classic.

2.3 Transmission infrastructure is planned to the standards defined in the GB Security and Quality of Supply Standard (GB SQSS), which, in principle, allows for full generation output to be maintained in the event of a transmission outage. The paper compares the transmission-related costs resulting from applying this standard with those resulting from a lower standard of connection; a technically non-firm arrangement whereby some generation output would be lost in the event of a transmission outage.

The options, for a given route, are

i) A firm GB SQSS compliant link, with the generator paying full TNUoS charges, and being compensated for lost energy, when transmission system capacity is restricted, i.e. 'commercially firm',
ii) A non-firm link, GB SQSS non-compliant, with the generator paying reduced TNUoS charges, with no compensation for lost energy; i.e. 'commercially non-firm',
iii) A non-firm link, GB SQSS non-compliant, with the generator paying full TNUoS charges, with full compensation for lost energy, i.e. 'commercially firm'.

Options i) and ii) would be informed by developer choice, whilst option iii) would be an option for the TSO to assess against option i). Option ii) would not be a standard option for the main interconnected transmission system, but would be a valid option in the case of infrastructure extensions being provided specifically for the benefit of a single or small group of generators.

2.4 The GB Transmission Use of System Charges are based on 2005 tariffs, and have been assumed stable for the addition of 600MW of generation into each of the four zones. In practice, the balance of zonal charges may alter disproportionately with such addition, or in developments in the charging model.

The 2005 DTI 's185' consultation on adjusting TNUoS charges for island generation has considered two main options based on 50% reduction above £25/kW or above the highest current zonal charge. These options have been factored into the SHETL review.

3. Findings

The paper summarises the overall capital costs of each option as tabulated below. Costs include for link investment, including convertor stations, system electrical losses and lost energy due to outages on the link.

			Beauly	Hunterston	Deeside	Pembroke
HVDC VSC	Firm	Capitalised Connection Cost (£M)	424	670	849	942
		Capitalised Outage Cost (£M)	2	8	14	17
		Capitalised Losses Cost (£M)	67	56	67	73
		Total Capitalised Cost (£M)	**492**	**733**	**930**	**1032**
	Non-Firm	Capitalised Connection Cost (£M)	283	447	566	628
		Capitalised Outage Cost (£M)	28	68	93	105
		Capitalised Losses Cost (£M)	74	72	89	98
		Total Capitalised Cost (£M)	**384**	**587**	**748**	**831**
HVDC Classic	Firm	Capitalised Connection Cost (£M)	591	944	1206	1338
		Capitalised Outage Cost (£M)	1	6	10	12
		Capitalised Losses Cost (£M)	48	24	29	31
		Total Capitalised Cost (£M)	**640**	**974**	**1244**	**1381**
	Non-Firm	Capitalised Connection Cost (£M)	306	482	613	679
		Capitalised Outage Cost (£M)	28	74	99	112
		Capitalised Losses Cost (£M)	58	42	50	54
		Total Capitalised Cost (£M)	**392**	**598**	**762**	**845**

Table 2: Summary of Capitalised Transmission-Related Costs (£M)

Annual Generator costs reflecting the various TNUoS charges, together with valued lost energy, where commercially non-firm contracts are taken, are shown below. Only one of the two s185 options is repeated here, as the results of the two options are reasonably similar.

			Beauly		Hunterston		Deeside		Pembroke	
			Full TNUoS Liability	Limited TNUoS Liability	Full TNUoS Liability	Limited TNUoS Liability	Full TNUoS Liability	Limited TNUoS Liability	Full TNUoS Liability	Limited TNUoS Liability
HVDC VSC	Firm	Annual TNUoS Cost (£M)	£ 48	£ 31	£ 64	£ 39	£ 73	£ 44	£ 78	£ 46
		Annual Outage Cost (£M)	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
		Total Annual Cost (£M)	£ 48	£ 31	£ 64	£ 39	£ 73	£ 44	£ 78	£ 46
	Non-Firm	Annual TNUoS Cost (£M)	£ 36	£ 25	£ 45	£ 29	£ 50	£ 32	£ 51	£ 33
		Annual Outage Cost (£M)	£ 2	£ 2	£ 6	£ 6	£ 8	£ 8	£ 9	£ 9
		Total Annual Cost (£M)	£ 39	£ 27	£ 51	£ 35	£ 57	£ 40	£ 60	£ 42
HVDC Classic	Firm	Annual TNUoS Cost (£M)	£ 62	£ 38	£ 87	£ 50	£ 104	£ 59	£ 111	£ 63
		Annual Outage Cost (£M)	£ -	£ -	£ -	£ -	£ -	£ -	£ -	£ -
		Total Annual Cost (£M)	£ 62	£ 38	£ 87	£ 50	£ 104	£ 59	£ 111	£ 63
	Non-Firm	Annual TNUoS Cost (£M)	£ 38	£ 26	£ 48	£ 31	£ 54	£ 34	£ 56	£ 35
		Annual Outage Cost (£M)	£ 2	£ 2	£ 6	£ 6	£ 8	£ 8	£ 9	£ 9
		Total Annual Cost (£M)	£ 41	£ 28	£ 54	£ 37	£ 62	£ 42	£ 65	£ 44

Table 3: Summary of Annual Generator Costs (£M pa)

4. Discussion

4.1 Overall Capitalised Costs

Table 2 shows that:

The initial investment and the overall capitalised costs increase with distance and the link to Beauly has the lowest overall capitalised cost of the four route options.

This is independent of technology choice and selection of firm or non-firm technical arrangement.

Associated investments in mainland grid system upgrades should be funded by the additional contributions of mainland TNUoS charges, particularly where the charges remain cost-reflective.

4.2 Capitalised Costs of Firm/Non-Firm Technical Design

Initial link investment costs are significantly lower for non-firm arrangements than for firm arrangements, due to savings in subsea cables and convertor equipment, being approximately 66% and 50% for VSC and Classic respectively.

The proportional impact of distance is seen in the subsea cable costs, which becomes the dominant element over convertor equipment for the longer non-Beauly routes.

Considering overall capitalised costs, the electrical losses and the risk of link outages generally increases with distance. This becomes a significant cost factor for the non-firm arrangements. However, these capitalised costs for the non-firm arrangements remain lower than the firm arrangements despite an increase in the value of lost energy.

The capitalised costs are lower for the non-firm technical arrangements, with the Beauly option being the lowest, and increase with distance. As such, the non-firm arrangement represents the most economic system design.

4.3 Technology

In terms of technical capabilities, HVDC VSC technology is more suited to the connection of i) renewable generation and ii) existing demand on the Western Isles, due to its ability to operate at low power levels and accommodate power reversals.

Modifications to HVDC Classic could be expected to enable it to operate satisfactorily for the Western Isles, but its use would be regarded as presenting a higher level of technical risk than HVDC VSC technology. The distances of the Hunterston, Deeside and Pembroke connection options are in excess of current submarine cable connected HVDC VSC schemes and the majority of installed HVDC Classic schemes.

The lower operating voltage for HVDC VSC technology (150kV) compared to that of HVDC Classic technology (500kV) and the associated increase in cable losses and voltage may impose distance limitations.

HVDC VSC technology is continuing to develop with increased operating voltages and ratings and may need to be considered during detailed design assessments for a selected route.

On both initial and overall capital costs, HVDC VSC technology remains the lower cost option at all distances for firm and non-firm connection arrangements.

4.4 Use of System Charges

For firm arrangements, and based on fully-reflective charging for the link, with no ‘s185’ adjustment, the annual TNUoS charges range from £73/kW at Beauly to £185/kW at Pembroke. These incorporate mainland zonal charges, based on 2005-06 generation zonal charges, and indicate that overall TNUoS charges increase with distance, as expected.

For non-firm arrangements, corresponding TNUoS charges range from £55/kW at Beauly to £86/kW at Pembroke, and provide a significant reduction in annual costs to the Generator.

When the ‘s185’ charge adjusting options are factored in, the charge ranges decrease to £48-105/kW for firm arrangements, and to £40-54/kW for the non-firm arrangements. The range of £40-54/kW is particularly narrowed as a result of applying the 50% discount factor to the full

length of the link. For the longer distances, this may extend the principle of discounting charges beyond the intent of the s185 provision, given that the balance of costs not recovered through TNUoS would fall on customers.

4.5 Generator Annual Costs

The annual costs falling to the Generator are primarily driven by

i) Distance
ii) Firm or Non-Firm technical design
iii) 's185' Adjustment of Charges
iv) Choice of HVDC Classic technology for longer distances

For both full GB TNUoS charges and for adjusted charges the lowest annual costs falling to the generators are those for a non-firm arrangement at Beauly. The generator sees the benefits of shortest distance, lowest link costs, and lowest annual TNUoS charges, further reduced by 's185' adjustments

For the non-firm arrangement, the annual cost of lost energy falling to the Generator increases the overall annual costs of this option, bringing it closer to the fully firm arrangement. However non-firm remains the lowest overall cost option for the Generator.

4.6 Other Considerations

4.6.1 Time to Connect

The current offers to the two major Western Isles Developers are contingent on Beauly-Denny and Beauly-Blackhillock upgrades, with quoted connection dates around 2010.

On current applications, GB Grid upgrades are likely to be required throughout Scotland, and via new Interconnector circuits to the North of England. Connection dates for Deeside and Pembroke may be offered earlier, dependent upon local grid capacity.

However, the cable manufacture and installation times for the longer distance connection options may be prolonged and prevent earlier connection dates being realised due to the limited cable production capacity and an increased demand for HVDC schemes. At least six years is quoted by PCS for the Hunterston option.

The period required to gain marine consents, in order to address marine environmental concerns, will also be a significant aspect of the link project, particularly as distance increases. Three to five years might be typical for longer schemes.

4.6.2 Uprating the Link Capacity

The review considered link arrangements based on a W.Isles generation export capacity of 600MW based on current applications. Any increase in anticipated export arising from the development of further renewable schemes would require an increase in link capacity.

The modular nature of the HVDC technology allows for the uprating of the link capacity by the addition of further discrete modules. Any required reinforcement of AC grid system, to which the link connects, would have to be considered in parallel.

Depending upon the timing of proposed connection dates for the individual windfarm projects, additional link capacity could be designed into the initial project, or would have to be established in a second phase of development. Either approach would have an impact on costs and timescales, but many of the findings of his review could be extrapolated.

5. Summary

The review of route options for Western Isles renewable generation output has highlighted the key drivers of capitalised and annual costs. Developers are likely to be interested in the options of non-firm technical arrangements, which result in lower TNUoS charges, despite an increase in the costs of lost energy.

The application of adjusted charges, under 's185' options, reduces the overall charges to Generators, but retains Beauly as the lowest cost connection point. The narrowing of the TNUoS differential between the route options is a result of applying 50% discount to the full link investment, which may be regarded as overly-extending the principle of support.

On the basis of the review of the possible route options and their costs, it is proposed that:

i) SHETL continues to develop the link designs to Beauly, utilising HVDC cable technology where justified.

ii) Developers are advised of the options of non-firm technical arrangements, with the corresponding decrease in annual TNUoS payments.

iii) **The degree of TNUoS charge adjustment under potential s185 provision for the longer distance options is considered further.**