Scottish and Southern Energy
Power Distribution

Co-funded by
the European Union

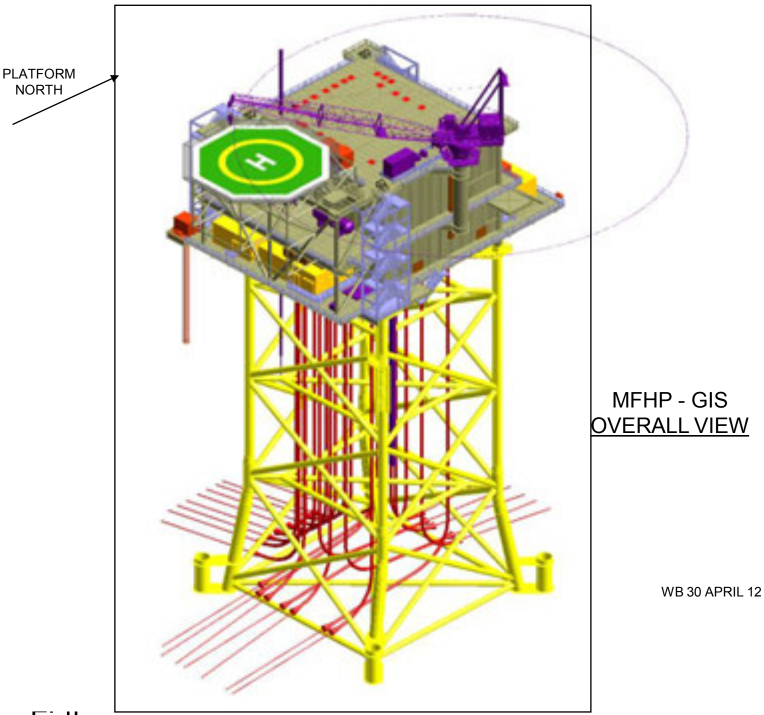
Offshore HVDC Hub project (2009 – 2012)

A Scottish Hydro Electric Transmission plc project co-funded by the European Union under the European Energy Programme for Recovery (EEPR)

Scottish Hydro Electric Transmission plc, July 2015

Summary

In 2009, Scottish Hydro Electri plc (SHE Transmission) secure of €74 million from the EU Eu Programme for Recovery (EEP grant was to support the ir offshore HVDC hub in the rou HVDC link from Shetland alrea by SHE Transmission and wh close to the sites of future offsl in the Moray Firth, northeast Sc



The hub was intended to economic transmission solutio including offshore windfarm co provide a supply-chain o deployment of offshore multi-t technology.

As at July 2015, SHE Transm important Caithness to Moray link under construction through the Moray Firth to accommodate the export of onshore renewable energy from Caithness. The link is scheduled to be commissioned in 2018 but, following a decision in 2012, it does ***not*** include an offshore HVDC hub. Nevertheless, the offshore hub pre-construction work co-funded by the EU up to termination of the grant agreement at December 2012 has delivered several outputs of value to the future development of offshore grids:

- Front End Engineering Design (FEED) reports for the offshore structure that represent a significant starting point for the engineering design of any future offshore HVDC substation.
- An HVDC multi-terminal design specification – subsequently adapted and developed for use on the current Caithness Moray HVDC scheme.
- Demonstration that the necessary structures and HVDC technology for offshore HVDC grids can be engineered and are deliverable.
- Justification for establishment of a National HVDC Centre to enable the modelling and simulation of multi-vendor HVDC systems whilst protecting the intellectual property of equipment suppliers. (Centre due to open 2017.)

Project presentation material from a knowledge sharing seminar on 20th July 2015 is available to be downloaded at https://www.ssepd.co.uk/transmissioninnovation/ where the detailed FEED reports and the initial HVDC multi-terminal specification can also be requested.

1 Original concept and grant award

In July 2009 SHE Transmission responded to a call for projects to benefit from the European Commission's European Energy Programme for Recovery, (EEPR). The candidate works which SHETL identified were add-ons to the 600MW Shetland link that was already in development by SHE Transmission at the time (surveyed, tendered and partially consented), required for the Viking Energy windfarm project on Shetland. Commissioning of the link was planned for September 2013 in accordance with the Viking timetable. The proposed incremental works for the hub project were described in two main work packages (WPs) as follows:

i) WP1 - Establish an offshore HVDC substation in the Moray Firth on the route of the 600MW link from Shetland as it passes close to the sites of two large proposed offshore windfarms. (Later confirmed as Beatrice Offshore Wind Limited, 1GW and Moray Offshore Wind Limited, 1.5GW)

ii) WP 2 - Increase the planned rating of the HVDC link from 600MW to 1200MW over the portion southwards from the offshore substation to Blackhillock in Moray.

Figure 1 below shows the incremental work packages super-imposed in orange, and further future export circuits in dotted grey from the hub as required.

Figure 1

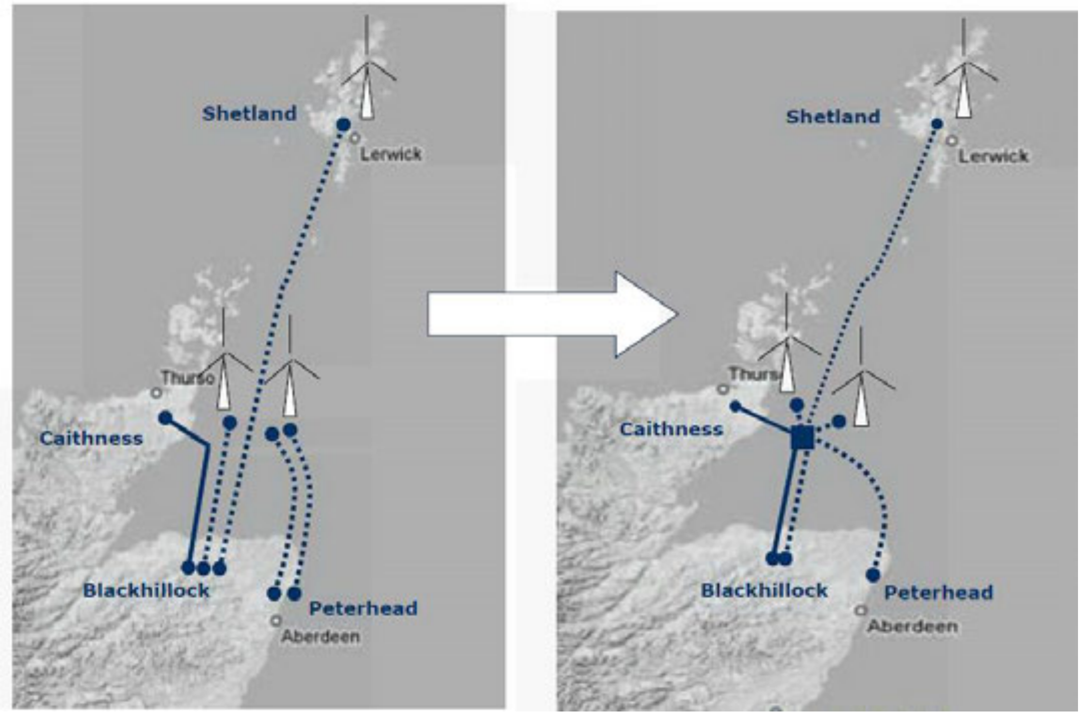
In 2009 an HVDC link from Caithness was recognised as a potential future connection into the hub to accommodate the export of renewable energy from Caithness. However, in 2010 as the Viking Energy wind project on Shetland experienced consenting delays, and renewable developments continued to connect in Caithness, the “base project” onto which the incremental works would be added, became the HVDC link from Caithness instead of that from Shetland. Figure 1 therefore shows the Shetland to hub section dotted as a potential future connection, and Caithness to Moray solid, representing the re-designated base project.

What was the hub trying to achieve?

The left side of **Figure 2** below shows an approach based on dedicated radial links for the connection of known potential generation at the time. An integrated transmission approach shown on the right enabled by the hub would not only deliver the base project, but compared with the radial approach, also offered cheaper, quicker, more flexible connection solutions for initial phases of the offshore wind projects. It also provided a supply chain opportunity to deploy and prove the HVDC technology in this application. When later phases of local generation came forward, further export cables could be added as required from the offshore substation to Blackhillock and Peterhead.

Figure 2 below illustrates radial dedicated connections approach versus an optimised flexible transmission solution facilitated by the offshore hub.

Figure 2



In December 2009 the Commission announced an allocation of €74 million to SHETL to support the incremental works of hub and enhanced HVDC rating. The EEPR scoring criteria by which the application had been assessed included maturity of the scheme i.e. how soon Final Investment Decision would be made to drive economic activity, scale-ability for more widespread application of the technology involved, and the extent to which the works facilitated the integration of offshore wind. SHE Transmission's 2009 proposal therefore scored highly against those objectives at the time and a Grant Agreement was subsequently entered into between SHE transmission and the Commission.

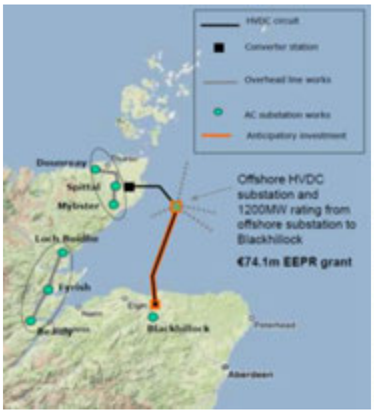
2 Prevailing circumstances in 2012 and termination of Grant Agreement

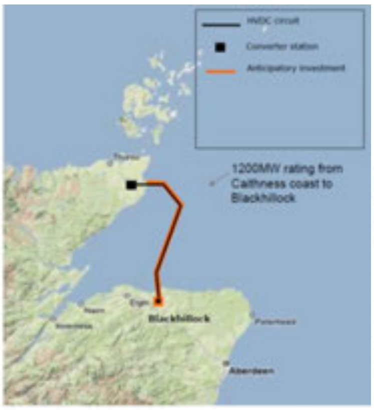
Engineering design, consenting activities and procurement preparations were progressed by SHE Transmission throughout 2010 and 2011, but in 2012 when it was necessary to lock-in to the Caithness reinforcement solution there was insufficient justification for inclusion of the hub in the HVDC link as part of those works. Regret cost considerations made a strong case for the enhanced 1200MW rating of the HVDC system to be retained (vs base of 600MW), but potential hub users, offshore windfarms and Viking, were not in a position to commit to hub based connection solutions. Reasons for this included:

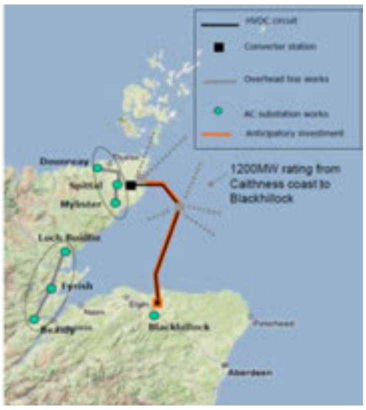
- Immaturity of regulatory and commercial arrangements for meshed offshore transmission. Ofgem's ITPR[1] project (Integrated Transmission Planning and Regulation) had been running in parallel, but when in 2011 offshore windfarms had to definitively commit to a connection solution for their projects, fundamental commercial questions for meshed offshore transmission remained outstanding. These included the basis of offshore transmission charging, the extent of commercial firmness and asset ownership principles.

- Technical assurance. The original connection solutions for the offshore windfarms were based on HVDC technology. Subject to voltage, VSC (Voltage Source Converter) technology is inherently compatible across equipment vendors, but generation project investors and TSOs would require technical assurance through modelling and simulation to ensure secure performance of multi-terminal, multi-vendor HVDC systems. However, equipment vendors had intellectual property concerns associated with exchange of models and no clear arrangements for acceptable modelling simulations were readily available.

The scheme was therefore adjusted to omit the offshore hub and extend the 1200MW rating over the whole subsea section. This reduced the net level of anticipatory investment from £224m (€320m) to £99m (€141m). The resulting scheme remained flexible for a range of future generation scenarios and transmission development paths, including the connection of a Shetland link to an onshore HVDC substation in Caithness, and the inclusion of an offshore HVDC hub at a later date. The adjusted scheme however no longer represented a good fit with the original grant allocation criteria for the EEPR and so the agreement was terminated effective December 2012.







Original scheme:
£224m anticipatory works

Adjusted scheme:
£99m anticipatory works

Indicative flexibility
of adjusted scheme.

[1] https://www.ofgem.gov.uk/electricity/transmission-networks/integrated-transmission-planning-and-regulation

3 Project outputs

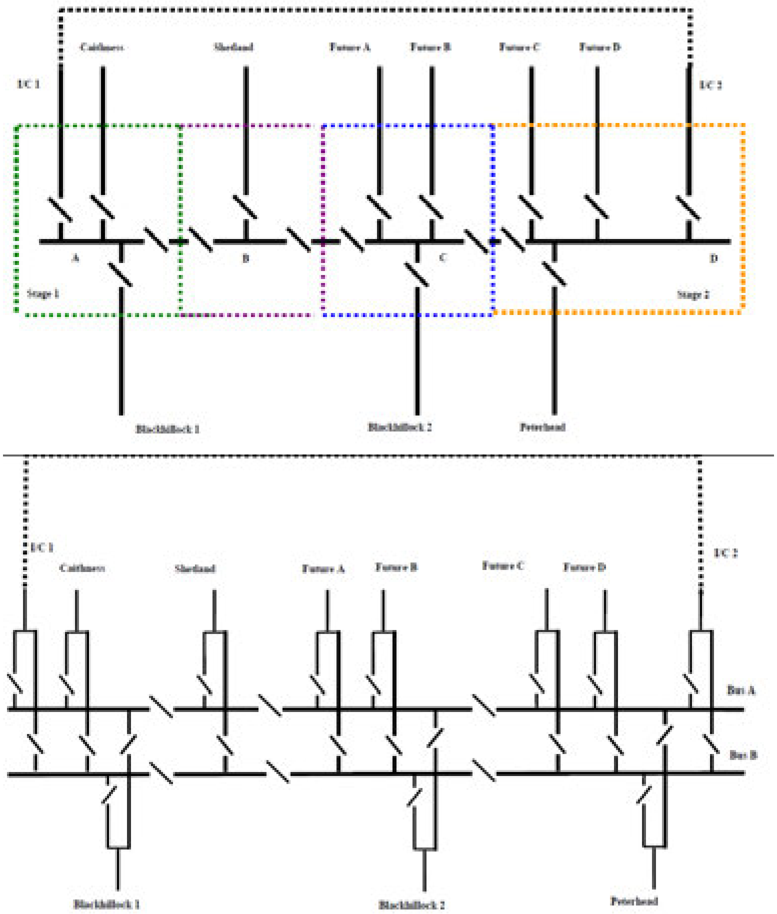
3.1 *Structural design of offshore HVDC hub*
Front End Engineering Design (FEED) studies

Geophysical and geotechnical survey of potential locations for the offshore hub had informed a decision to progress a lightweight jacket structure with pile foundations as the primary structure and foundation concept.

The report output from a Front End Engineering Design (FEED) study was intended as the fundamental specification for competitive tendering of the platform itself. The detailed engineering design would then be undertaken by the successful bidder as part of a contract for detailed design, fabrication and installation.

Gas Insulated Switchgear (GIS) is more compact and would allow for a more flexible double busbar substation configuration in a smaller space than would be necessary for a less flexible, single busbar Air Insulated Switchgear (AIS) arrangement. However, early in 2011, SHE Transmission had concerns about technical assurance and availability of commercial guarantees for HVDC application of GIS at 320kV. In order to maintain a programme option for delivery of a hub structure in 2017/18 it was therefore necessary to progress two FEED studies – one based on a double busbar Gas Insulated Switchgear (GIS) substation, and the other on a single busbar Air Insulated Switchgear (AIS) substation. (Now in 2015, switchgear manufacturers are able to offer GIS switchgear for application at the DC voltage of 320kV).

Figure 3.1 below shows the AIS single, and GIS double busbar layout for the FEEDs.



The FEED studies concluded in May 2012. **Figures 3.2** and **3.3** below are visualisations from the FEED studies of the GIS and AIS platforms respectively.

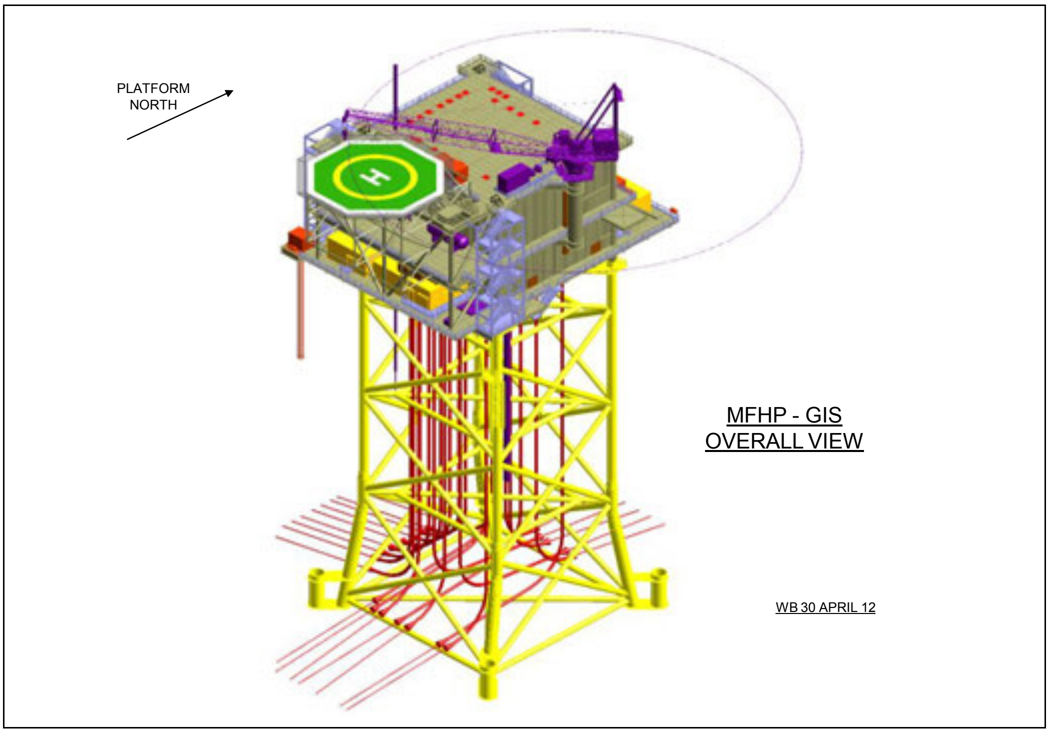


Figure 3.2 FEED overall view of jacket and topsides for Gas Insulated Switchgear *double* busbar substation

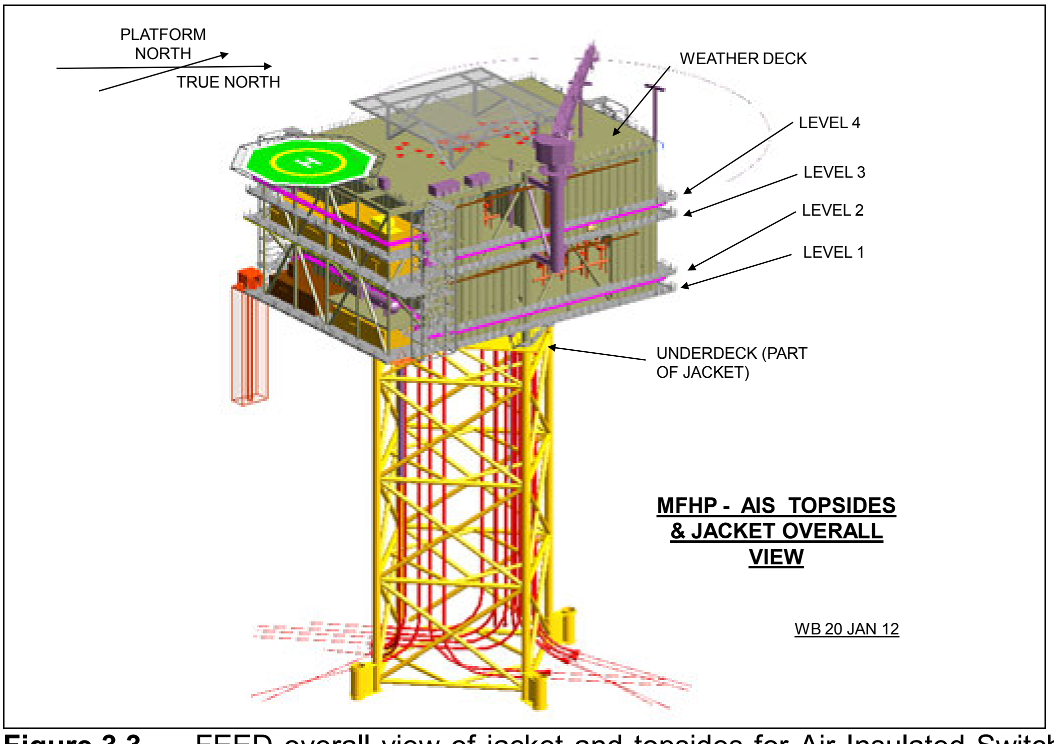


Figure 3.3 FEED overall view of jacket and topsides for Air Insulated Switchgear *single* busbar substation

Table 3.1 below summarises the key outputs from the two FEED studies:

Platform (including switchgear & equipment)	**Gross weight (tonnes)**			**Programme duration (months)**	**Capital cost estimate, GBP (2012)**
	Topside	**Jacket**	**Total**		
GIS double busbar	3,142	6,238	9,380	42	£143m
AIS single busbar	4,475	5,377	9,852	42	£151m

Table 3.1 FEED outputs

Comparing the AIS and GIS approaches, the GIS approach is not only double busbar instead of single, giving better system flexibility, but is also lighter, smaller and slightly cheaper. Importantly, the FEED process tested and demonstrated the engineering and deliverability of an offshore HVDC switching station.

The completed FEED reports, although not used as intended, are available through this project as a significant starting point for the engineering design of any future offshore HVDC bussing hub or bussing point. This is a valuable resource and a useful contribution to the future development of offshore grids.

3.2 Multi-terminal HVDC specification

Despite the absence of an offshore hub from the scheme, the HVDC reinforcement now being taken forward by SHE Transmission between Caithness and Moray was specified to accommodate multi-terminal, multi-vendor potential future connections. The starting point for that specification was the HVDC multi-terminal specification as it stood in 2012. That specification is available by request through the project, https://www.ssepd.co.uk/transmissioninnovation/.

The most significant commercial barrier encountered was how to ensure compatibility of initial equipment with unknown and undefined future HVDC equipment from other suppliers, i.e. “multi-vendor” compatibility. Subject to a common specified voltage, VSC HVDC equipment is inherently compatible, but in order to ensure secure system operation there is requirement for extensive modelling and simulation of control and system interactions.

Such modelling would require exchange of detailed models between suppliers. This requirement however gave rise to concerns over intellectual property. In order to address these concerns the concept emerged of a neutral, secure modelling and simulation facility using replica panels from the relevant equipment suppliers and real time digital simulation of the system. This was referred to as a Multi Terminal Test Environment (MTTE) and was proposed to be housed at a new National HVDC Centre at Cumbernauld in Scotland.

In November 2013 SHE Transmission secured funding (£11.3m) for The National HVDC Centre under the GB regulator’s (OFGEM) Network Innovation Competition (NIC) arrangements. The centre is scheduled to be available for testing and simulations in 2017. http://www.hvdccentre.com/

The MTTE at The National HVDC Centre will provide the means by which HVDC system integration risk and multi-vendor HVDC compatibility risk can be managed to enable deployment of multi-terminal HVDC systems.

4 Project conclusions

Despite not proceeding to construction, outputs from the Offshore HVDC Hub project now provide valuable starting points for the design and specification of future offshore HVDC substations and HVDC multi-terminal schemes.

The project demonstrated that the necessary structures and HVDC technology for offshore HVDC grids can be engineered and are deliverable.

The learning from considering the challenges of multi-terminal, multi-vendor HVDC technology helped specify the Caithness–Moray HVDC project now under construction and justify establishment of The National HVDC Centre that is due to open in March 2017. The centre allows modelling and simulation to manage HVDC system integration risk and multi-vendor HVDC compatibility risk, whilst protecting the intellectual property of HVDC equipment suppliers.

The allocation of the EEPR grant in 2009 is validated by the prevailing impetus for integrated pan-European transmission networks that is embodied in the EU's Energy Union[2] communication, February 2015.

This project has delivered valuable outputs that represent a significant contribution to the future development of offshore grids.

[2] http://ec.europa.eu/priorities/energy-union/index_en.htm