Ofgem

Calculating Target Availability Figures for HVDC Interconnectors – Viking Link Model

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Executive Summary

Availability targets for the Ofgem Cap and Floor regulatory assessment framework have been based on an agreed methodology and model, developed in 2013 for the Nemo interconnector by Sinclair Knight Merz (SKM).

The SKM report made a recommendation to regularly update the model to ensure developments in VSC converter and HVDC cable technologies are captured.

GHD were engaged by Ofgem in 2016 to review and update the SKM model, reflecting any new information that had become available since the original model was created in 2013, and then use this data to create a North Sea Link (NSL) model.

In 2018, GHD were engaged by Ofgem to create a 3rd version of the model, in order to create a model for the IFA2 project, whilst increasing usability of the model.

GHD have been engaged by Ofgem for a third time, in order to update the model with the latest publically available reliability data and create specific models for the Viking and Greenlink HVDC interconnector projects.

The GHD 3rd review concludes that adjustments can be made to the 2018 third revision model taking in to account the latest converter stations availability data. No new data has been available for cable reliability. Using the updated model, it is suggested that the target level availability for the Viking project (utilising the project characteristics provided) would be in the range of 91.87% to 93.74% with a proposed base target level of 93.40%.

1. Aims

The Ofgem Cap and Floor assessment framework[1] for new electricity interconnectors includes three major stages, i.e. the Initial Project Assessment, Final Project Assessment (FPA) and Post-Construction Review. Ofgem are currently undertaking the FPA stage for the Viking Link project between the UK and Denmark. One of the main deliverables of the FPA stage is a target for the availability incentive, which can increase or decrease the level of the cap on revenues.

The availability target is set based on an agreed methodology and model, developed in 2013 for the Nemo interconnector by SKM. This methodology[2] and spreadsheet tool[3] was made publically available by Ofgem so that the process for setting of targets was completely transparent.

The SKM report made a recommendation to regularly update the model to ensure developments in VSC converter and HVDC cable technologies are captured.

GHD have been engaged by Ofgem over recent years:

- In 2016 to update the model and create a model for the North Sea Link (NSL) project,
- in 2018 to update the model, increase usability and create a model for the IFA2 project,
- In 2020 GHD have been engaged to review latest CIGRE reliability data, update the model and create a model for the Viking Link and Greenlink projects.

This report will discuss the investigation of the Viking Link project and suggests a target level availability for the Viking project.

1 https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors
2 https://www.ofgem.gov.uk/ofgem-publications/59247/skm-report-calculating-target-availability-figures-hvdc-interconnectors.pdf
3 https://www.ofgem.gov.uk/ofgem-publications/59248/skm-model-target-availability-model-hvdc-interconnectors.xlsx

2. Viking Link Project

The Viking Link interconnector project is being developed by National Grid (UK) and Energinet (Denmark). The Viking Link project is due for completion in 2023 and will provide the first link between the UK and Denmark[4].

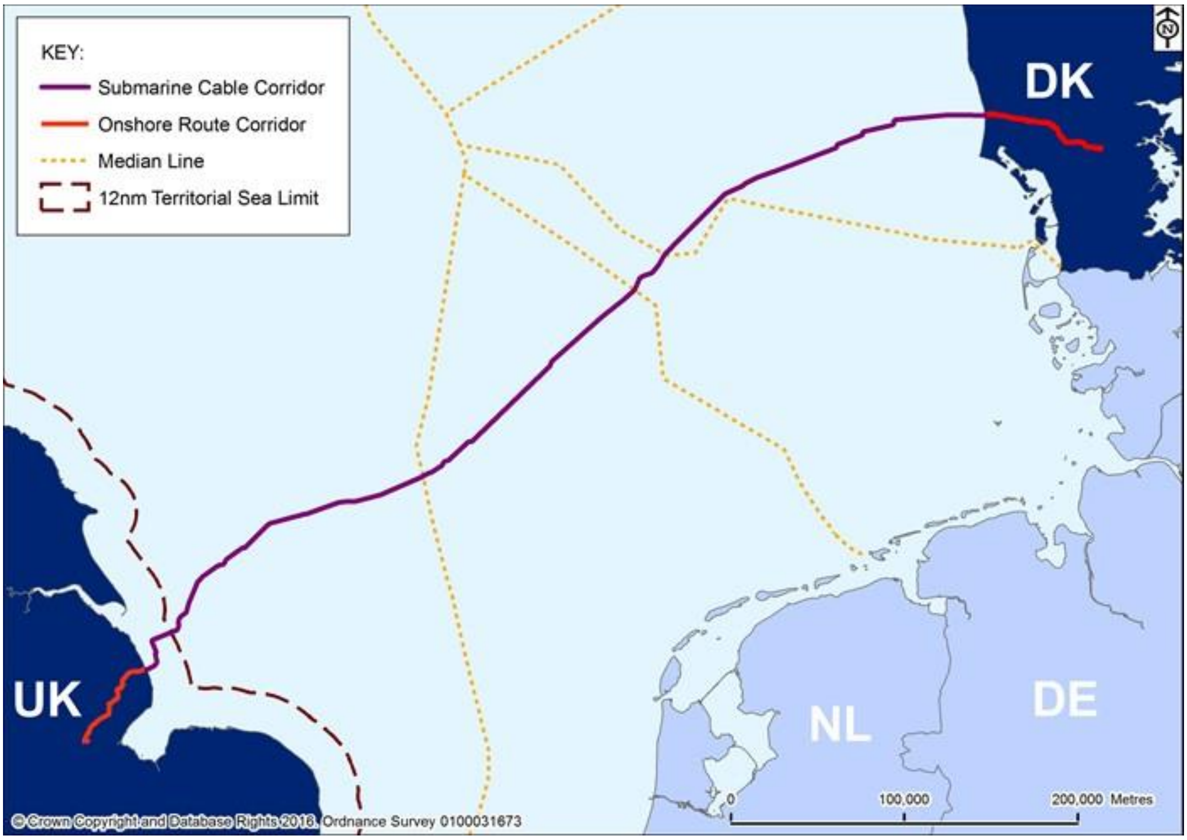

Figure 1 Viking Link HVDC Interconnector project[5]

In Great Britain, the connection point would be a new substation, connected to the existing National Grid substation at Bicker Fen, Lincolnshire. The converter station site will be developed on land south of the Bicker Fen Substation.

The HVDC cables linking Great Britain and Denmark will be routed through Danish, German, Dutch and UK sectors, and will be buried in the seabed. The landfall at the Danish end will be on the Blaabjerg coast in the Varde Kommune municipality. In the UK the landfall is on the Lincolnshire coast at Boygrift, and the onshore cable route will be along a corridor north of Spilsby and Boston.

In Denmark, the connection point will be at the Revising substation, in southern Jutland. The existing substation will be extended for the converter station connection and the converter station will be built on land adjacent to the Revising substation.

[4] http://viking-link.com/

[5] http://viking-link.com/the-project/offshore-work/

3. Modelling Results

GHD's scope for the 2020 update was to update the model with the latest publically availability data and create models for the Viking and Greenlink projects, as well as an example project that is used as the basis for entering a new interconnector.

The project specific details for the Viking interconnector scheme are provided in section 3.1.

3.1 Viking Model

The Viking Link interconnector project was modelled with the details provided in Table 1.

The HVDC offshore cable is 621 km of bundled HVDC subsea MIND cable.

The onshore cables of the Viking link project are HVDC MIND cable; 76 km at the Danish end and 68 km at the UK end.

The unavailability of the VSC converter transformers was applied within the model based on a single transformer but with a spare phase arrangement, which takes three days to establish. There are two converter transformers at each site, each rated at 700 MW. When one VSC converter transformer phase is lost, the capacity is reduced to 50% for the three day on-site repair period to replace the damaged phase.

MTTR for an external fault on the HVDC cable was assumed as 65 days in normal weather and 90 days during restricted access.

Table 1: Viking Link Project Model Details

Project Detail	Value/Technology	Unit
Rated Capacity	1400	MW
Rated Voltage HVDC	±525	kV
Nominal System Voltage HVAC	400	kV
Converter Technology	VSC, Bipole	
Converter Transformer Arrangement	Single transformer (Three single phase units + spare)	
Cable Technology Onshore	HVDC MIND HVAC XLPE	
Cable Technology Offshore	HVDC MIND Bundled	
Offshore HVDC Cable Length	621.0	km
Onshore HVDC Cable Length - UK	68.0	km
Onshore HVDC Cable Length - DK	76.0	km
Onshore HVAC Cable Length	2.0	km
Offshore HVAC GIL Length	Very Short	

Appendix A shows a screen shot of the Viking model data as input into the Project Sheet within the Excel model.

3.2 Viking Link Target availability using GHD model

The system availability of the Viking Link project was calculated within the GHD model using the average sensitivities for weather, maintenance and converter outages. The external cable failure rate for HVDC offshore cables was set as “Low” which is more consistent with the methodical approach to Cable Burial Risk Assessment applied by the Developer and acknowledging there is a general expectation that external failure rate figures for future projects will be lower than previous projects reported by CIGRE. Using the “Low” external cable failure rate results in a probability of failure for the offshore cable section of 0.098 per year compared to a figure of 0.130 per year if the “Average” figure were used. The results for the base case are provided in Table 2.

Table 2: Base System Availability in GHD model

Project	Overall System Availability (%)
Viking Link	93.40

The Viking Link system base case target availability was calculated to be 93.40% with the updated GHD model.

The HVDC submarine cable fault unavailability was found to be the most significant of the overall system availability figures. The proposed HVDC cable length of the Viking link project (621 km) will be relatively long compared to some projects e.g. Nemo (110 km) and IFA2 (204 km), but is comparable to the NSL project (714 km).

The total system availability figure for the NSL project of similar length is similar to that calculated for Viking Link.

3.3 Sensitivity Analysis

Sensitivity analysis was performed to determine how much the system unavailability of the Viking Link project would deviate from the base case of 93.40%, taking into account the range of MTBF and MTTR factors included within the model.

SKM suggested the reliability data associated with HVDC converters suffered from the most uncertainty due to limited data on reliability performance and new developments in technology.

A best and worst case assumption of 1 and 3 converter outages per year as shown in Table 3, was included in the model; a sensitivity study was performed and the results are shown in Table 4.

Table 3: Unplanned Unavailability Range for HVDC Converters in GHD Model

Scenario/Range for MTBF	MTBF (Faults/Year)	MTTR (hours)	Total Annual Outage (hours)	Total Annual Outage (days)	Unavailability %
Base Case	2	14.7	29.3	1.222	0.1674%
Best Case	1	14.7	14.7	0.611	0.0837%
Worst Case	3	14.7	44.0	1.833	0.2511%

An average MTTR figure for cable failures was assumed to be 65 days for offshore cables with a worst case assumption of 90 days due to weather conditions. The system availability figures whilst considering the worst case cable MTTR are provided in Table 4.

The planned unavailability due to scheduled maintenance could vary dependent upon the project maintenance plan and required outage time. The model allows the system availability to be calculated using a range of scheduled maintenance from more frequent (3 days per year) to less frequent (1.5 days per year).

Table 4: Sensitivity Analysis in GHD Availability Model

Project	Overall System Availability (%)				
	Worst Case Converter MTBF	Best Case Converter MTBF	Worst Case Cable MTTR	Most Frequent Maintenance	Least Frequent Maintenance
Viking Link	93.07	93.74	91.87	93.13	93.54

4. Conclusions

Using the updated model, it is suggested that the target level availability for the Viking link project utilising the project characteristics provided, would be in the range of 91.87% to 93.74% with a proposed base target level of 93.40%.

Appendices

Appendix A –Viking Link Model Data Input

Project:	*Viking Link*		
Size:	*1400.0 MW*	**Total availability of Viking Link**	**93.40%**
Timing:	*2023*		
Location:	*UK-Denmark*		

Availability Calculation - Unplanned Outages

Input				Calculation				Output	
Units	**Class**	**Circuit Length (km)**	**Equipment**	**Failure Rate (PA)**	**MTBF (Years)**	**MTTR (Days)**	**Available Capacity %**	**Unavailability (%)**	**% Total**
1	*Cables*	*76*	*Viking Link - Danish HVDC Onshore Cable*	0.067	14.95	40.00	0.0%	0.7329%	11%
1	*Cables*	*621*	*Viking Link - Offshore HVDC Cable*	0.224	4.47	65.00	0.0%	3.9812%	60%
1	*Cables*	*68*	*Viking Link - UK HVDC Onshore Cable*	0.060	16.71	40.00	0.0%	0.6558%	10%
2	*Cables*	*2*	*Viking Link - UK AC Onshore Cable*	0.004	284.09	20.00	50.0%	0.0096%	0%
4	*Other*		*VSC Converter Transformer*	0.016	62.50	29.10	99.2%	0.0011%	0%
4	*Converter*		*Bipole no earth return (onshore)*	8.000	0.13	0.61	50.0%	0.6696%	10%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
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				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%

Total Unavailability Due to Scheduled unplanned outages 6.0502%

Availability Calculation - Scheduled Maintenance/Planned outages

Units	**Class**		**Maintenance Case (H/M/L)**	**Maintenance Rate/year**	**Maintenance Period (Years)**	**Maintenance Duration (Days)**	**Available Capacity %**	**Unavailability (%)**	**% Total**
1	Other		Scheduled Maintenance Medium Case (1)	1.00	1.00	2.00	0.00	0.5479%	8%

Total Unavailability Due to Scheduled Maintenance/Planned outages 0.5479%

Total unavailability	6.60%
Overall availability	93.40%

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