Ofgem

Calculating Target Availability Figures for HVDC Interconnectors – NeuConnect 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 have subsequently been engaged by Ofgem in 2016, 2018 and March 2020 to review and update the SKM model, reflecting any new information that had become available and creating specific models for North Sea Link (2016), IFA2 (2018), Viking and Greenlink (2020) HVDC interconnectors.

GHD have now been engaged to carry out a further update to the technical parameters and key assumptions in the Ofgem HVDC interconnector availability model and create a specific model for the NeuConnect HVDC interconnector project.

The GHD review concludes that adjustments can be made to the GHD 2020 model taking into account new cable reliability data published in CIGRE Technical Brochure 815 “Update of service experience of HV underground and submarine cable systems” (WG B1.57 2020).

No new compelling data has been published since March 2020 which would justify changes to the technical parameters and key assumptions of the HVDC Converter assets.

Using the 2021 updated model, it is suggested that the target level availability for the NeuConnect project (utilising the project characteristics provided) would be in the range of 92.59% to 94.53% with a proposed base target level of 94.37%

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 NeuConnect project between the UK and the Germany, which is scheduled for completion in 2023-24[2]. 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[3] and spreadsheet tool[4] was made publicly 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 the 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 and Greenlink projects.
- In 2021, GHD have been engaged to review latest CIGRE reliability data, update the model and create a model for the NeuConnect project.

This report will discuss the investigation of the NeuConnect project and suggest a target level availability for the NeuConnect project.

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

2. NeuConnect Project

The NeuConnect interconnector project is being developed by Frontier Power, Meridiam and Greenage Power and is due for completion in 2023-24.

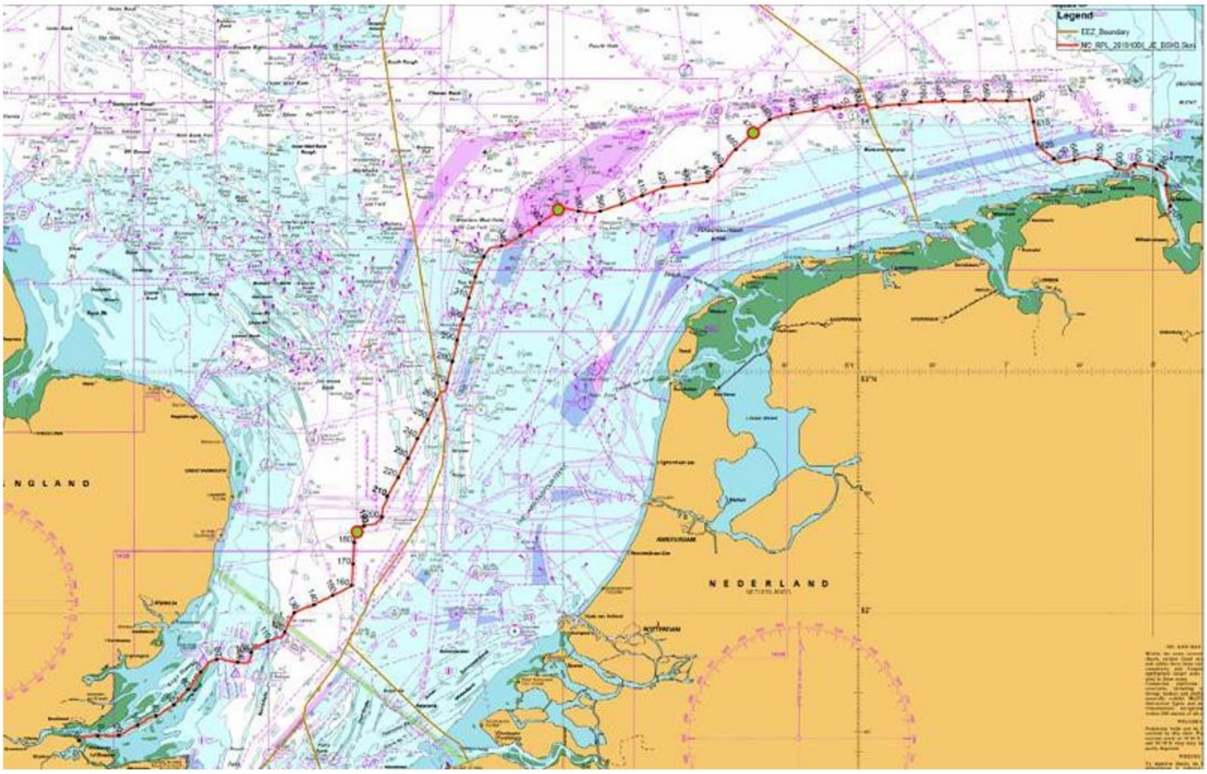

Figure 1 NeuConnect HVDC Interconnector project[5]

The proposed link will provide an interconnection between UK and Germany, providing a capacity of 1400 MW.

In Germany the connection point would be at the new Fedderwarden 380 kV substation located between Autoroute 29 to the South and a watercourse Grosses Fedderwarden Tief to the North, Lower Saxony. The converter station will be sited on land near and require a relatively short length of HVAC connection to the existing substation.

In the UK, the connection would be at a new Grain West National Grid substation, north west of the existing Grain 400 kV on the Isle of Grain, Kent. The converter station will be sited at land adjacent.

The offshore HVDC route will be 706 km, buried in the seabed between the UK and Germany through UK, Dutch and German waters. In Kent, the landfall will be just north of Grain Coastal Park in Kent and will be installed using the horizontal directional drilling (HDD). In Germany, landfall will be at land at Hooksiel, to the north of Wilhelmshaven in the Jade Bight (bay) in north-western Germany and again the landfall will be achieved using HDD installation.

5 NeuConnect FPA Technical Chapter.docx

3. Changes to the 2021 model

GHD have carried out a review and update of the technical parameters and key assumptions in the Ofgem HVDC interconnector availability model.

The GHD review concludes that adjustments can be made to the GHD 2020 model.

The main new information which has become available since the last update is CIGRE Technical Brochure 815 "Update of service experience of HV underground and submarine cable systems" (WG B1.57 2020). Which has provided sufficient grounds to apply changes to the HVAC and HVDC cable availability technical parameters within the model.

No new compelling data has been published since March 2020 which would justify changes to the technical parameters and key assumptions of the HVDC Converter assets.

On the basis of the new information available, which show reductions of the internal and external cable failure rates, the following changes have been made to the Ofgem 2021 Model availability values:

- Onshore cable external average failure rate has been reduced from 0.0580 faults/yr/100cct.km to 0.0453 faults/yr/100cct.km.
- Subsea XLPE AC cable internal average failure rate has been increased from 0.0270 faults/yr/100cct.km to 0.0463 faults/yr/100cct.km.
- Subsea cable average external failure rate has been reduced from 0.0210 faults/yr/100cct.km to 0.0158 faults/yr/100cct.km.
- Subsea HVDC XLPE and MIND cable internal average failure rate has been decreased from 0.0270 faults/yr/100cct.km to 0.0205 faults/yr/100cct.km.
- In order to maintain the 2020 model worst-case external subsea cable failure rate for unprotected cables, a worst case, very high risk/unburied subsea export cable failure rate multiplication factor has been introduced of 2.4. This factor maintains the potential worst case effective failure rate of the 2020 Ofgem model, and takes into account the above reductions to the subsea cable average external failure rate.

Minor changes have been made to the application of modifying factors to subsea cable failure rates to reflect relative levels of external risk:

- The "Burial Depth" modifying factor for subsea cable external failures has been renamed to "Cable External Risk" (with appropriate changes to the associated categories) to reflect risk from external damage based on a structured approach to cable risk assessment, taking into account likelihood of damage as well as protection level, rather than only burial depth.
- In order to ensure no change to the functionality of the model, new cables are proposed to be input into the model with "low" and "high" external failure rates which are equal to the average external failure rate. This change will result in only the "Cable External Risk" category modifying cable external failure rates and decoupling external failure rates completely from internal failure rates.

4. Modelling Results

GHD's scope for the 2021 update was to update the model with the latest CIGRE availability data and create a model for the NeuConnect project.

The project specific details for the NeuConnect interconnector project are provided in section 4.1.

4.1 NeuConnect model

General

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

There is a single HVDC circuit consisting two cables with 706 cct.km offshore and 12.5 cct.km onshore in Germany and 1.6 cct.km in the UK (from the shore landing points to the converter stations). All HVDC cables are of MIND construction

It is assumed the two subsea HVDC Mind cables are installed in a common trench and are bundled.

There are short HVAC connections at either end of the HVDC interconnector consisting of two 0.4 km circuits at the UK end and two 0.5 km at the Germany end. Each circuit is 100% rated. The UK connection end is gas insulating line (GIL), the German connection is cable. Note that as dual concurrent outages are not considered in the Ofgem model there will be no resultant loss of availability for an AC circuit outage. Therefore, the AC circuits have not been included in the model.

The unavailability of the VSC converter transformers was applied within the model based on a single transformer but with a spare phase arrangement at each end of the connection, which takes 72 hours to replace, test and energise.

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 NeuConnect project model details

Project Detail	Value/Technology	Unit
Rated Capacity	1400	MW
Converter Technology	VSC	
Converter Arrangement	Rigid Bipole[6]	
Cable Technology	HVDC MIND	
Rated HVDC Voltage	525	kV
Number of HVDC Circuits	1	
Offshore Cable Arrangement	Common trench bundled	
Subsea HVDC Cable Route Length	706	Km
Onshore HVDC Cable Route Length	14.1 (12.5 Germany + 1.6 UK)	Km

[6] Bipole with no earth return.

Project Detail	Value/Technology	Unit
Number of HVDC Converter Transformers	3x 1 phase units per pole + 1x 1 Phase Spare at each end	
Number of HVAC Circuits	2 (each 100% rated)	
HVAC Onshore GIL route length UK	0.4	Km
HVAC Onshore cable route length Germany	0.5	Km

Subsea cable risk

A detailed cable burial risk assessment (CBRA) has been provided for review along with additional information and clarifications. The following factors have been considered in evaluating the relative risk presented to the NeuConnect subsea cables compared to "normal" protected cables.

- All subsea cables will generally be buried or otherwise protected in line with the CBRA.
- The areas of seabed approaching the UK and German landfalls together with other areas (112 km in total) are subject to a very high level of seabed mobility and represent sections of increased risk of external cable failure.
- No additional abnormal risks have been identified which would have a material impact on the in-service availability of the subsea cables.

On the basis of the above considerations the subsea HVDC cable circuit has been modelled in two parts.

- The cable external failure rate has been modelled as "Average risk/protected" for the 594 km of subsea cable not installed in areas of very high seabed mobility.
- The cable external failure rate has been modelled as "High risk/partial protection" for the 112 km of cable installed in very high sediment mobility area.

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

4.2 NeuConnect Target availability using GHD model

The system availability of the NeuConnect project was calculated within the GHD model using the average sensitivities for weather, maintenance and converter outages.

Table 2: Base System Availability in GHD model

Project	Overall System Availability (%)
NeuConnect	94.37

The NeuConnect system base case target availability was calculated to be 94.37% with the updated GHD model.

The HVDC submarine cable fault unavailability was found to be the most significant of the overall system un-availability factors accounting for 82% of the overall un-availability.

The proposed HVDC cable length of the NeuConnect project (706 km) will be much longer than the recent Greenlink (160 km), Nemo (110 km) and IFA2 (204 km) but is comparable with the Viking Link project (621 km) and NSL project (714 km).

4.3 Sensitivity analysis

Sensitivity analysis was performed to determine how much the system unavailability of the NeuConnect project would deviate from the base case of 94.37%, taking into account the range of MTBF and MTTR factors included within the model.

In the 2016 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	0.335%
Best Case	1	14.7	14.7	0.611	0.167%
Worst Case	3	14.7	44.0	1.833	0.502%

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 or other delays. 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
NeuConnect	94.20	94.53	92.59	94.09	94.50

5. Conclusions

Using the 2021 updated model, it is suggested that the target level availability for the NeuConnect project utilising the project characteristics provided, would be in the range of 92.59% to 94.53% with a proposed base target level of 94.37%.

Appendices

Appendix A –NeuConnect Model Data Input

Design Availability Spreadsheet

Project:	*NeuConnect*
Size:	*1400.0 MW*
Timing:	*2023*
Location	*GB - Germany*

Total availability of NeuConnect	**94.37%**

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*	*12.5*	*NeuConnect - Germany HVDC Onshore Cable*	0.009	106.24	40.00	0.0%	0.1032%	2%
1	*Cables*	*1.6*	*NeuConnect - GB HVDC Onshore Cable*	0.001	830.01	40.00	0.0%	0.0132%	0%
1	*Cables*	*112*	*NeuConnect - HVDC Subsea Cable High Mobility*	0.0442	22.63	65.00	0.0%	0.7870%	14%
1	*Cables*	*594*	*NeuConnect - HVDC Subsea Cable Main*	0.216	4.64	65.00	0.0%	3.8398%	68%
2	*Converter*		*Bipole no earth return (onshore)*	4.000	0.25	0.61	50.0%	0.3348%	6%
4	*Other*		*VSC Converter Transformer*	0.016	62.50	3.00	50.0%	0.0066%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%
				-	-	-	-	0.0000%	0%

Total Unavailability Due to Scheduled unplanned outages 5.0846%

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%	10%

Total Unavailability Due to Scheduled Maintenance/Planned outages 0.5479%

Total unavailability	**5.63%**
Overall availability	**94.37%**

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