Ofgem

Calculating Target Availability Figures for HVDC Interconnectors – Greenlink Model

November 2020

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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, in order to create a model for the IFA2 project, whilst increasing usability of the model.

GHD have now 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 GHD 2018 model taking in to account updated converter stations availability data. No new data has been available for cable reliability[1]. Using the updated model, it is suggested that the target level availability for the Greenlink project (utilising the project characteristics provided) would be in the range of 97.15% to 97.89% with a proposed base target level of 97.55%.

[1] CIGRE Technical Brochure 815 Update of service experience of HV underground and submarine cable systems, published late September 2020 is not taken into account.

1. Aims

The Ofgem Cap and Floor assessment framework[2] 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 Greenlink project between the UK and the Republic of Ireland, which is scheduled for completion in 2023. 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.

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

[2] https://www.ofgem.gov.uk/electricity/transmission-networks/electricity-interconnectors
[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. Greenlink Project

The Greenlink interconnector project is being developed by Greenlink Interconnector Limited which is jointly owned by Element Power (Hudson Sustainable Investments) and Partners Group and is due for completion in 2023.

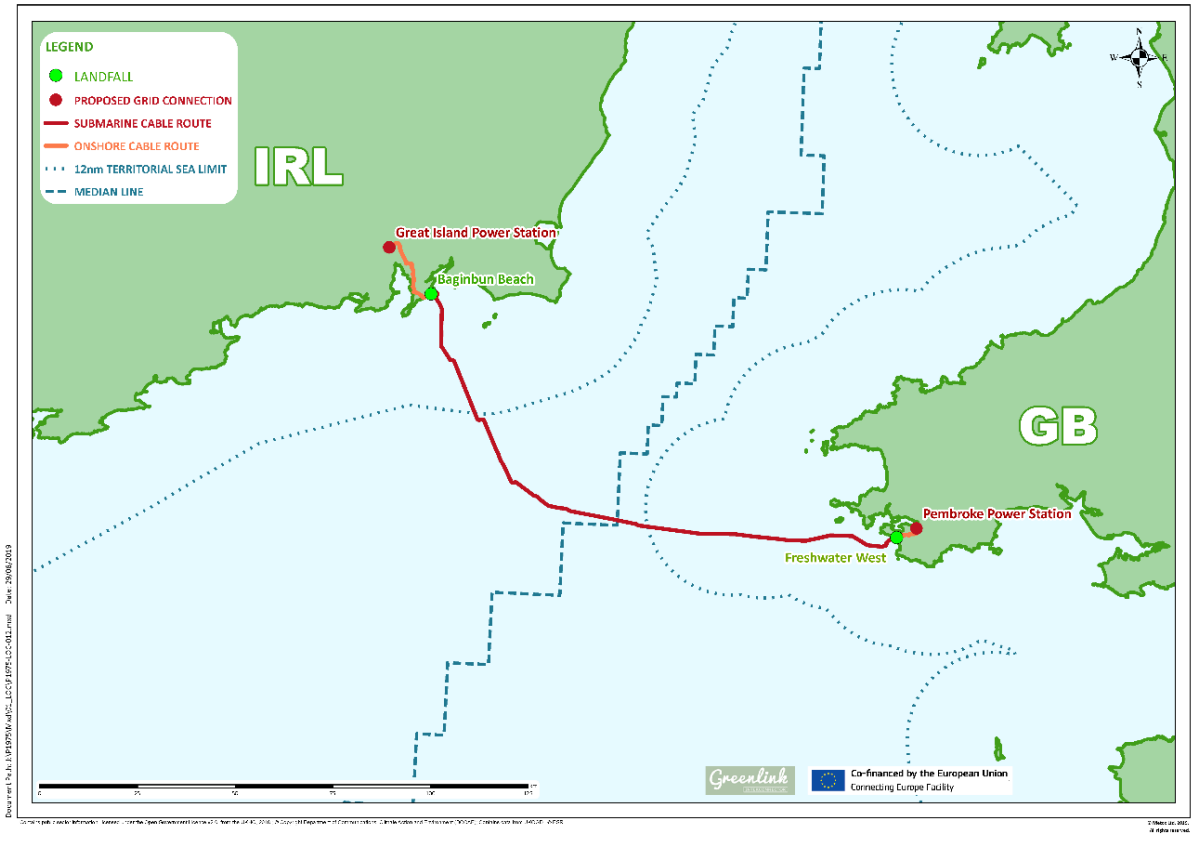

Figure 1 Greenlink HVDC Interconnector project[5]

The proposed link will provide an additional interconnection between UK and Irish grids, providing an increased capacity of 504 MW.

In Ireland the connection point to the existing network would be to EirGrid's Great Island substation in County Wexford. The converter station will be sited on land near the existing substation and require a short length of HVAC cable to connect to the existing substation.

In the UK, the connection to National Grid's existing network would be at the Pembroke substation in Pembrokeshire, Wales. The converter station will be sited at land near the existing Pembroke substation.

The offshore HVDC route will be 160 km, buried in the seabed between Ireland and Wales. In Ireland, the landfall will be on Baginbun Beach and will be installed using the horizontal directional drilling (HDD) method. In Wales, the HDD method is again used at the landfall at Freshwater West. The HDD installation method will limit the impact on the dunes and beaches at each site.

[5] Concept of Public Participation |Ireland Rev 2 https://c3892d5a-7851-4486-8a13-435412051711.filesusr.com/ugd/fe51dc_c301e7580e564ac59e88957033d0d824.pdf

3. Modelling Results

GHD's scope for the 2020 update was to update the model with the latest CIGRE availability data and create models for the Viking Link 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 Greenlink interconnector project are provided in section 3.1.

3.1 Greenlink model

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

The HVDC offshore cable is 160 km of bundled HVDC subsea XLPE cable.

The HVDC onshore cables of the Greenlink project are HVDC XLPE cable; 7 km at the UK end and 21 km at the Irish end.

The unavailability of the VSC converter transformers was applied within the model based on a single transformer per phase, including an additional spare single phase transformer. We have modelled this spare transformer as taking 200 hours to re-establish when required, based on contractor commitments.

Single HVDC and HVAC circuits are used; in the event of a cable fault, either onshore or offshore, 100% capacity loss will result.

MTTR for an external fault on the HVDC cable was assumed as 65 days in normal weather and 90 days during restricted weather access, or where modifications to Marine licences may introduce a slight delay.

Table 1: Greenlink Project Model Details

Project Detail	Value/Technology	Unit
Rated Capacity	504	MW
Rated Voltage HVDC	±320	kV
Nominal System Voltage HVAC (UK)	400	kV
Nominal System Voltage HVAC (Ireland)	220	kV
Converter Technology	VSC, Symmetrical Monopole	
Converter Transformer Arrangement	Single transformer (Three single phase units + spare)	
Cable Technology Onshore	HVDC XLPE HVAC XLPE	
Cable Technology Offshore	HVDC XLPE Bundled	
Offshore HVDC Cable Length	160	km
Onshore HVDC Cable Length (UK)	7.0	km
Onshore HVDC Cable Length (Ireland)	21	km
Onshore HVAC Cable Length (UK)	0.65	km
Onshore HVAC Cable Length (Ireland)	0.3	km

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

3.2 Greenlink Target availability using GHD model

The system availability of the Greenlink 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 0.0252 per year compared to a figure of 0.0336 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 (%)
Greenlink	97.55

The Greenlink system base case target availability was calculated to be 97.55% 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 Greenlink project (160 km) will be much shorter than the recent Viking Link, or NSL projects, but is comparable with the Nemo (110 km) and IFA2 (204 km) projects.

3.3 Sensitivity analysis

Sensitivity analysis was performed to determine how much the system unavailability of the Greenlink project would deviate from the base case of 97.58%, 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
Greenlink	97.21	97.89	97.15	97.27	97.68

4. Conclusions

Using the updated model, it is suggested that the target level availability for the Greenlink project utilising the project characteristics provided, would be in the range of 97.15% to 97.89% with a proposed base target level of 97.55%.

Appendices

Appendix A –Greenlink Model Data Input

Design Availability Spreadsheet

Project:	*Green Link*
Size:	*504.0 MW*
Timing:	*2023*
Location:	*UK-RoI*

Total availability of Green Link	**97.55%**

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*	*21*	*Greenlink - Ireland - HVDC Onshore Cable*	0.018	54.11	20.00	0.0%	0.1013%	4%
1	*Cables*	*7*	*Greenlink - UK - HVDC Onshore Cable*	0.006	162.34	20.00	0.0%	0.0338%	1%
1	*Cables*	*160*	*Greenlink - Offshore HVDC Cable*	0.0576	17.36	65.00	0.0%	1.0258%	42%
1	*Cables*	*0.65*	*Greenlink - UK - AC Onshore Cable*	0.001	1748.25	20.00	0.0%	0.0031%	0%
1	*Cables*	*0.3*	*Greenlink - Ireland - AC Onshore Cable*	0.000	3787.88	20.00	0.0%	0.0014%	0%
2	*Other*		*VSC Converter Transformer*	0.008	125.00	32.83	0.0%	0.0720%	3%
2	*Converter*		*Symmetrical Monopole (Onshore)*	4.000	0.25	0.61	0.0%	0.6696%	27%
				-	-	-	-	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 1.9069%

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%	22%

Total Unavailability Due to Scheduled Maintenance/Planned outages 0.5479%

Total unavailability	2.45%
Overall availability	97.55%

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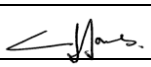
Ofgem - Availability Model - Greenlink Rev 1-0 18112020.docx

Document Status

Revision	Author	Reviewer		Approved for Issue		
		Name	Signature	Name	Signature	Date
Rev 0	Chris Jones	CJ Jones		G Skelly		18/11/2020

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