Base Load Power Hub (BLPH)

Electrical System Study Report – Power Factor Compensation

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

Crosswind, a Shell and Eneco joint venture, was awarded the tender to develop the offshore Hollandse Kust Noord (HKN) wind farm, located 18.5km off the coast of Netherlands near the town of Egmond aan Zee. The consortium plans to have HKN operational in 2023 with an installed capacity of 759MW generating at least 3.3TWh per year. This is sufficient renewable power to supply more than 1 million Dutch households with green electricity.

Offshore wind farms produce intermittent electricity and balancing these dips and peaks and integrating this electricity into the national energy system requires new technologies. For this reason, the offshore wind farm will include several new technologies that could be implemented at full-scale in the future. The new technologies being explored include a floating solar park, a short-duration battery storage as well as long-term storage via green hydrogen produced by water electrolysis and subsequently consumed in a fuel cell. The combination of these individual measures, herein referred to as the Base Load Power Hub (BLPH) will ensure a continuous power supply regardless of the wind situation.

1.1.1 Project Location

The Hollandse Kust Noord (HKN) wind farm is located 18.5km off the coast of the Netherlands near the town of Egmond aan Zee.

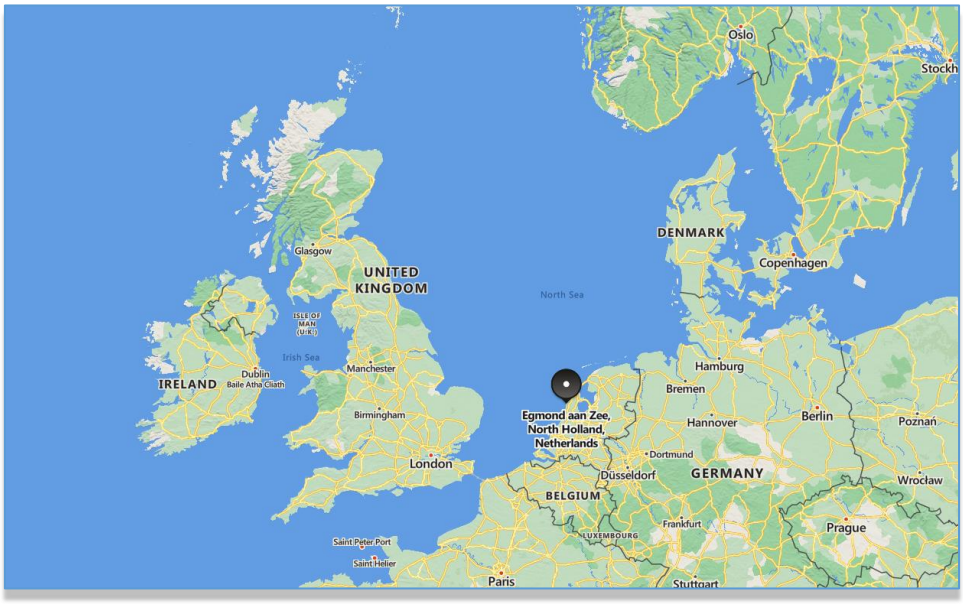


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

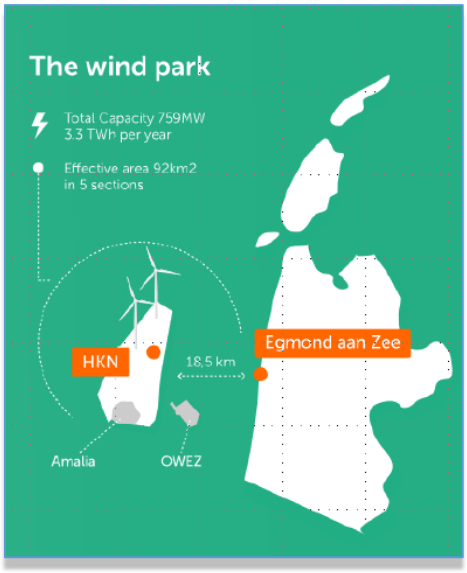


Figure 2 - Wind Park Details

The wind farm will consist of No. 69 x 11.5MW wind turbine generators each to be installed on a dedicated monopile structure. A 70th monopile located on coordinates E 590719.1, N 5841602.3 is reserved for installing the platform accommodating the BLPH. The monopile structure was designed and installed by Van Oord Offshore Wind (VooW) and therefore not part of the BLPH scope.

1.1.2 Project Concept

All components included in the BLPH will be integrated onshore on a topsides and installed in an offshore location within the boundaries of the HKN wind farm. At its simplest, the BLPH will store energy during periods of high electricity generation from renewable sources (a wind turbine generator and the floating solar PV farm) and release it during periods of low generation. In practice, it is expected that the energy stored will supplement generation from renewable sources to ensure that at least 1.0MW of power is exported to the electrical grid regardless of wind/solar availability.

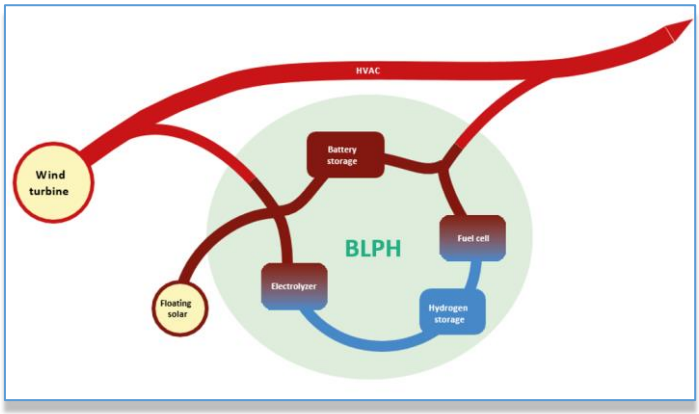


Figure 3 – BLPH Concept

Electricity in the BLPH will be stored in the form of electrons in a battery energy storage system (BESS) as well as converted into green hydrogen via water electrolysis. When the power output from the connecting wind turbine drops to below 1 MWe, the BLPH will return its stored energy to supplement the remaining power output. This will be by discharging the BESS, while stored hydrogen will be converted back into electricity using a fuel cell to extend the discharge duration.

The purpose of the BLPH s to function as a testbed for the integration of energy storage technologies with renewable generation. It is expected that equipment installed on the BLPH will operate as Normally Unmanned Installation for at least two (2) years with no or minimal maintenance and it will have its own independent control room with the ability to communicate with Crosswind's control room.

2 DOCUMENT SCOPE

This document is intended to summarize the results of the analysis on electrical network model, in terms of main electrical equipment dimensioning.

2.1 REFERENCES

Doc. No.	Description
123A90-DDL-EL-LIS-20148 Rev 00	Electrical Power and Control Cable Schedule
123A90-DDL-EL-LIS-20016 Rev. 2	Electrical Load List & Balance (CCS Mode 'Import)
123A90-PML-PM-TQ-00033	Technical Query – Electrical data of WTG-57
123A90-DDL-EL-RE-20170 Rev. 1	Electrical System Study Report – Load Flow
123A90-DDL-EL-DG-20158 Rev. 1	Overall Single Line Diagram
144671-TKF-IAC-INS-SPE-0001	Technical specification – 66 kV Al 3X400 CONF143350 specification (incl. Drain wire)
IEC-60092-352 (2005-09)	Electrical installations in ships – Part 352: Choice and installation of electrical cables
2XS(FL)2Y HDPE High Voltage 36/60 (72.5) kV Cable	Cable catalogue for HV cable
123A90-PML-PM-TQ-00033_REPLY	Technical Query N. 33
123A90-DDL-EL-LIS-20143_ATT1	CCS MODE 3: HOT STANDBY
123A90-DDL-EL-LIS-20144_ATT1	CCS MODE 2: EXPORT
123A90-DDL-EL-LIS-20145_ATT1	CCS MODE 4: COLD STANDBY
123A90-DDL-EL-LIS-20146_ATT1	CCS MODE 5 : EMERGENCY MODE (Island)
123A90-DDL-EL-LIS-20147_ATT1	CCS MODE 6: POWER OUT (Blackout)
123A90-DDL-EL-LIS-20016_ATT1	CCS MODE 1: Import Charging

Table 1 - Reference Documents

2.2 DEFINITIONS AND ABBREVIATIONS

Al	Aluminium
AN	Air Natural
BESS	Battery Energy Storage System
BLPH	Base Load Power Hub
Cu	Copper
COMPANY or Client (CPY):	Crosswind
CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
HV	High Voltage
KNAN	Non mineral oil natural Air Natural
LV	Low Voltage
MV	Medium Voltage
N/A	Not Applicable
NER	Neutral Earthing Resistor
OCTC	Off Circuit Tap Changer
OLTC	On Load Tap Changer
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
U_k	Short-circuit impedance
WTG	Wind Turbine Generator
XLPE	Cross-linked PolyEthylene

Table 2 - Definitions and Abbreviations

3 DESIGN BASIS

The following paragraphs summarize and verify the power factor at the point of connection with the external network to verify if it is necessary to install a power factor correction device; the analysis is based on load flow calculation results.

Further details are available in the ETAP printout plots and calculations reports in attachments of document no. 123A90-DDL-EL-RE-20170_01 (Electrical System Study Report - Load Flow).

As detailed in these documents, to perform all electrical calculations, plant loading data have been considered as per the Electrical Load List and Balance for the main operating scenarios.

3.1 SYSTEM STUDIES BACKGROUND

According to the design philosophy, 9 operation modes are defined. Load flow shall be performed for only 5 operation modes and the results are presented in the study.

These modes of operation are as listed below:

1. CCS MODE 1: IMPORT / CHARGING (corresponding to project IDLE and IMPORT modes): power generation from WTG-57 is greater than 1 MW, or WTG-57 is out of service (IDLE mode). Surplus renewable energy is imported to BLPH from wind farm and/or solar farm for charging BESS and running the electrolyser whilst also supplying the balance of plant loads.
2. CCS MODE 2: EXPORT: Power generation from WTG-57 has dropped below 1 MW. Export of power is required from BLPH from all sources available i.e. BESS, Fuel Cell and/or solar farm.
3. CCS MODE 3: HOT STANDBY: BLPH is capable of exporting power should generation from WTG-57 drop below 1 MW. In this mode the power generation from WTG-57 is greater than 1 MW, so renewable energy is imported to BLPH from wind farm and/or solar farm for feeding the BLPH loads.
4. CCS MODE 4: COLD STANDBY: BLPH is not capable of exporting power, being power generation from WTG-57 below 1 MW. Renewable energy is imported to BLPH from wind farm and/or solar farm for feeding the BLPH loads.
5. CCS MODE 5: EMERGENCY/ISLAND: Windfarm is no longer connected. BLPH consumes its stored renewable energy and/or renewable energy from the solar farm.

The PCC (point of coupling point) is at the connection of BLPH with the HKN-57 (WTG-57) monopile's 66kV switchgear. Therefore, the power factor is calculated to include the capacitive and inductive reactance values of the sub-sea interconnector cable.

3.2 SUMMARY OF TOTAL GENERATION, LOADING & DEMAND

The power factor at the point of connection (i.e. the connection point on the HKN-57 66kV switchgear of WTG-57) of the system power supply for BLPH loads is calculated and presented in the following tables.

The source of the system power supply for BLPH loads differs for different operation modes.

Total Demand Power	LOAD FLOW CALCULATION RESULTS				
	LF CASE 1	LF CASE 2	LF CASE 3	LF CASE 4	LF CASE 5
kW Demand [kW]	4931.00	507.00	584.00	562.00	506.00
kVAr Demand [kVAr]	1342.00	279.00	321.00	309.00	278.00
kVA Demand [kVA]	5110.35	578.70	666.41	641.35	577.34
PF [%]	96.49	87.61	87.63	87.63	87.64

Table 3: Summary Total Load Demand

Total Generation Power	LOAD FLOW CALCULATION RESULTS				
	LF CASE 1	LF CASE 2	LF CASE 3	LF CASE 4	LF CASE 5
kW Generation [kW]		2480.00			508.00
kVAr Generation [kVAr]					292.00
kVA Generation [kVA]		2480.00			585.94
PF [%]		100.00			86.70

Table 4: Summary Total Power Generated

Total Power Exchanged with External Grid	LOAD FLOW CALCULATION RESULTS				
	LF CASE 1	LF CASE 2	LF CASE 3	LF CASE 4	LF CASE 5
kW Exchanged [kW]	4964.00 (*)	-1962.00 (**)	588.00 (*)	565.00 (*)	
kVAr Exchanged [kVAr]	1247.00 (*)	-134.00 (**)	-163.00 (**)	-178.00 (**)	
kVA Exchanged [kVA]	5118.23 (*)	1966.57 (**)	610.17 (*)	592.38 (*)	
PF [%]	96.99 (*)	99.77 (**)	96.37 (**)	95.38 (**)	

(*) Adosorbed
(**) Generated

Table 5: Summary total Excenged Power with External Grid

4 CONCLUSION

Criteria for power factor correction: The overall system power factor, including reactive power losses in transformers and other distribution system equipment, is above 0.9. Therefore, addiction equipment is not necessary for the power factor compensation.

It can pointed out that the PF factor above 1.0 leading has been calculated in cases 2, 3, and 4. This value is due to the reactive power generated by the subsea cable.