Base Load Power Hub (BLPH)

Electrical/Iter Containers – Fire duration calculation

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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.

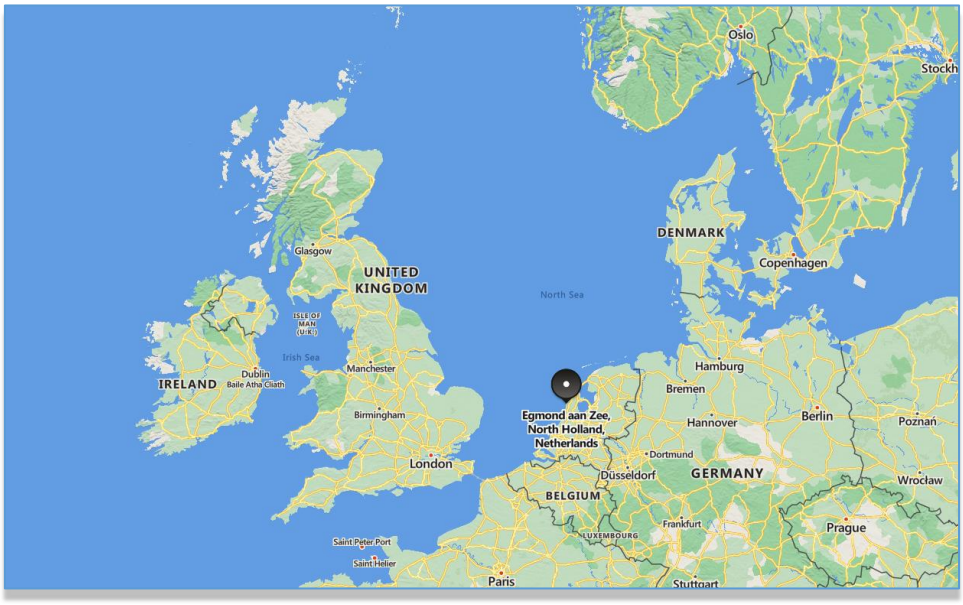


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map

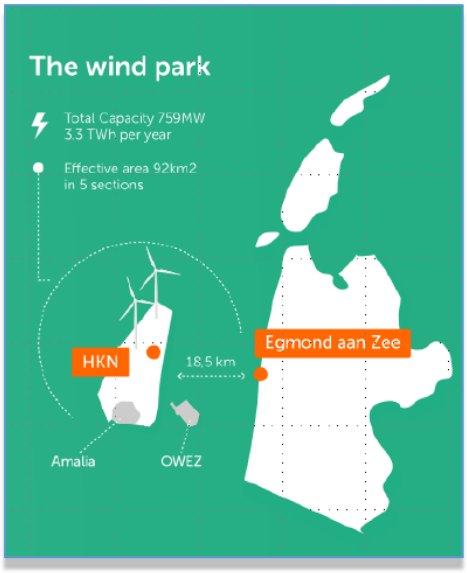


Figure 2 - Wind Park Details

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.

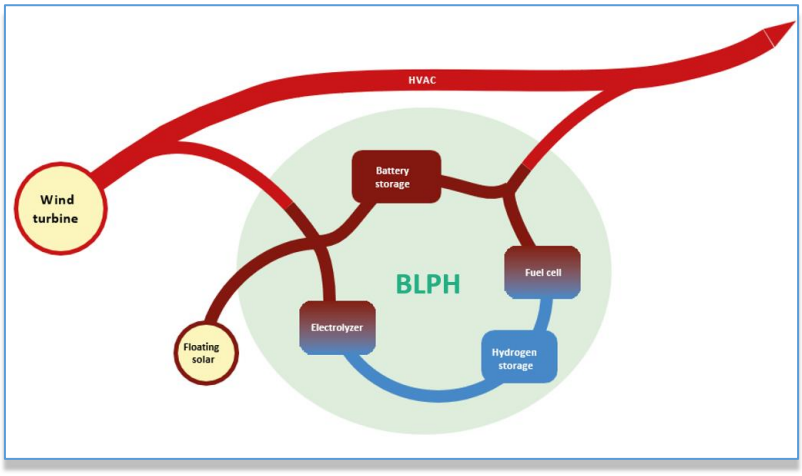


Figure 3 – BLPH Concept

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.

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2 DOCUMENT SCOPE

The scope of this study is to calculate the duration of a fire inside electrical containers and define the fire rated requirements of their structures to avoid possible fire escalation to the surrounding structure in the platform.

2.1 REFERENCES

Doc. No.	Description
[1]	NFPA 555, Guide on Methods for Evaluating Potential for Room Flashover, 2021.
[2]	A. La Malfa, Approccio Ingegneristico alla sicurezza antincendio.
[3]	123A90-DDL-AR-DL-10001 ÷ 10004, Architectural General Layout - Door Map and Door Schedule - Flooring and Lining layout - Architectural - Fire rated requirement, HV-MV (66kV - 6.6kV) Switchgear room.
[4]	123A90-DDL-AR-DL-10008 ÷ 10011, Architectural General Layout - Door Map and Door Schedule - Flooring and Lining layout - Architectural - Fire rated requirement, LV (400 V) Switchroom.
[5]	123A90-DDL-AR-DL-10015 ÷ 100018, Architectural General Layout - Door Map and Door Schedule - Flooring and Lining layout - Architectural - Fire rated requirement, I&T Equipment Room.
[6]	123A90-DDL-AR-DL-10022 ÷ 10025, Architectural General Layout - Door Map and Door Schedule - Flooring and Lining layout - Architectural - Fire rated requirement, AC UPS fitted with UPS system Equipment Room.

Table 1 - Reference Documents

2.2 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY):	Crosswind
CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
Flashover	Condition in which all combustible materials within a closed environment participate in combustion.
HRR	Heat Release Rate

Table 2 - Definitions and Abbreviations

3 METHODOLOGY

The calculation of the mass of oxygen consumed in a closed environment during a fire is useful to assess the possibility of flashover scenario, on the basis of combustion duration, specific value of Heat Release Rate (HRR) for the fire, and presence of adequate fuel mass.

Generally, according to the American standard NFPA 555 [1], in a fire-affected space, the minimum volumetric concentration of oxygen that can still support a combustion process with the presence of flame ranges from 8% to 12%. This percentage decreases with increasing temperature. Therefore, the fire can spread until the oxygen mass in the space has approximately halved from the initially available amount.

According to literature [2], during the initial phase of development of the fire the value of the HRR varies with the square of the time t2, the thermal energy (expressed in kJ), released in the enclosure will be limited by the mass of oxygen present in the room environment.

The following equation allows the calculation of thermal energy (E) considering the availability of oxygen in the closed environment, as a fire inside the container.

$$E_{limit}=V_{O_2}\ H_{O_2} \rightarrow E_{limit}=\int_0^{t_{limit}} \alpha\ t^2\ dt = 0{,}333\ \alpha\ t_{limit}^3 \qquad (1)$$

where:

- E_{limit} is thermal energy provided by the fire inside the containers
- Vo2 is the volume expressed in m3 of oxygen consumed before combustion stops
- α is a constant that regulates the evolution of the initial phase of a fire (0,00277 kJ/s3 for fire slow development; 0,01111 kJ/s3 for fire medium development; 0,04444 kJ/s3 for fire fast development; 0,17777 kJ/s3 for fire ultra-fast development)
- $H_{O_2}$is the thermal energy which is released (medium values) by the various materials which can be located inside the container (mainly constituted by plastic) per unit volume of oxygen consumed. At 20°C, HO2 is equal to approximately 17 x 103 kJ/m3 [2].

Considering the fire progress, the oxygen present is consumed and assuming that the enclosure is completely airtight and does not allow any air to enter, the combustion would theoretically stop after a time expressed in seconds equal to:

$$t_{limit} = \left(\frac{3\ V_{O_2}\ H_{O_2}}{\alpha}\right)^{\frac{1}{3}} \qquad (2)$$

Well observe that the calculated time, "t" _"limit" , is greater than the real time since as combustion proceeds the mass of oxygen present becomes smaller.

In these conditions, the fire will no longer be able to develop rapidly and will release, in the container, thermal power values that decrease over time. As a result, the mass of fuel participating in combustion decreases significantly.

3.1 INPUT DATA

The following table shows the dimensions of the electrical/Iter containers analyzed in this study provided by the client [3] [4] [5] [6].

Item	Length (m)	Width (m)	Hight (m)	Volume (m3)
HV-MV (66kV - 6.6kV) Switchgear room	11,6	4	4,4	204,2
LV (400 V) Switch room	9,6	3	3,5	100,8
I&T Equipment Room	12,8	2,1	3,3	88,7
AC UPS fitted with UPS system Equipment Room	11	3	3,5	115,5

Table 3 - Dimensions of the electrical/Iter containers

Depending on the combustible materials present inside the electrical containers, the fire growth rate would be between slow and medium.

In this study, as a conservative approach, slow growth was considered in order to increase the expected fire duration, therefore the constant α is equal to 0,00277 kJ/s3.

As reported in the previously chapter, the present calculation are applicable considering that no air ingress inside the containers is foreseen during a fire scenario.

Considering that the containers:

- Gas detectors are present inside the containers with automatic action that stop HVAC system and close the air exchange dumper;
- no opening to the external are present (doors and windows are closed);
- all the ingress of cable are sealed;
- no air exchange grill is present.

In conclusion, it is possible to consider the ingress of significant amount of air inside the container during a fire very remote.

3.2 ANALYSIS RESULTS

Using the input data and using equation 2 it was possible to calculate the duration of a fire inside the various electrical containers. In table below the results are shown.

Item	Volume (m3)	Growth constant, α (kJ/s3)	Fire Duration (second)	Fire Duration (minute)
HV-MV (66kV - 6.6kV) Switchgear room	204,2	0,00277(slow)	1543	26
LV (400 V) Switch room	100,8		1220	20
I&T Equipment Room	88,7		1169	19
AC UPS fitted with UPS system Equipment Room	115,5		1277	21

Table 4 – Fire duration of the electrical/Iter containers

As shown in the table, the duration of the fire in the various containers is between 19-26 minutes.

For this reason, considering that the calculation comes from theoretical considerations, it is recommended to consider a fire rated at least of 60 minutes for container structures.

4 CONCLUSION AND RECOMMENDATIONS

The following conclusions and recommendations are derived from the results:

- the duration of the fire in the various containers is between 19-26 minutes. For this reason, considering that the calculation comes from theoretical considerations, it is recommended to consider a fire rated of at least 60 minutes for container structures;
- A necessary condition is that the containers are designed in order to avoid ingress of air during a possible fire. Therefore, it is recommended to take all necessary precautions to comply with this condition. For example, if the containers were equipped with forced ventilation, it would be necessary to implement logic that stops the fans upon automatic fire detection, also foreseeing the closure of a damper.

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