Base Load Power Hub (BLPH)

SAFOP Report

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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.

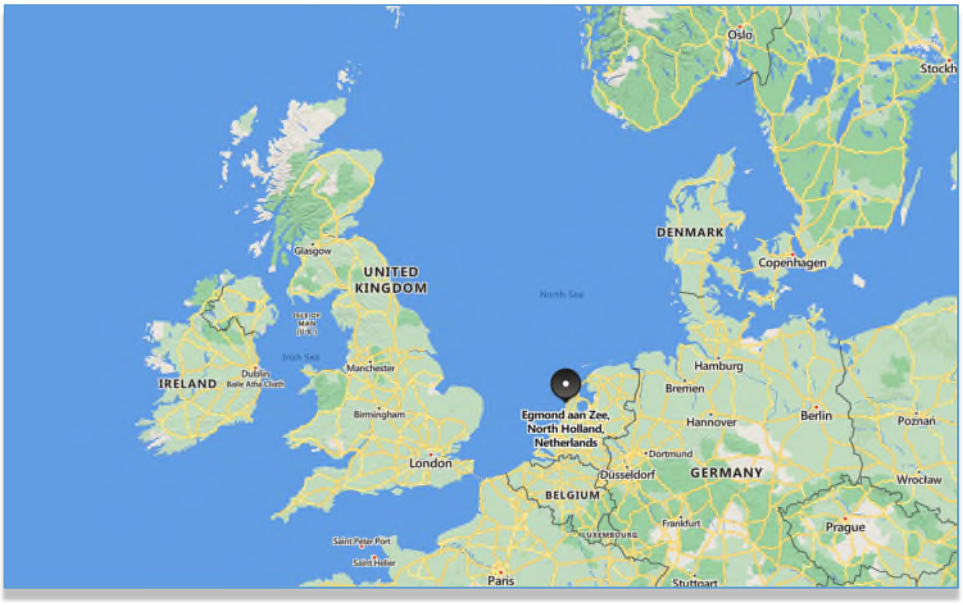


Figure 1 - Hollandse Kust Noord Wind Park Location Map

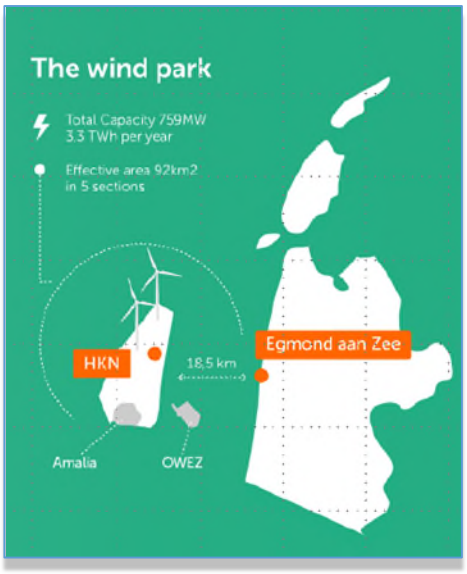


Figure 2 - Wind Park Details

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.

1.2 REFERENCES

Doc. No.	Description
123A90-DDL-EL-RE-20179	SAFOP CLOSE OUT REPORT

1.1.21.2.1 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.

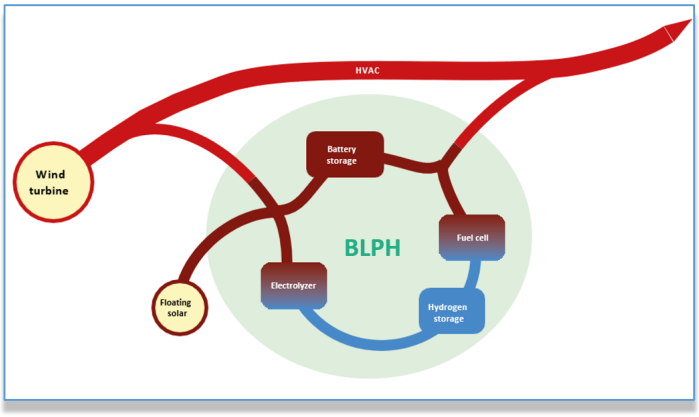


Figure 3 – BLPH Concept

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 OBJECTIVES

2.1 SAFOP PROCESS

This SAFOP has been addressing the Base Load Power Hub (BLPH). Located on the 70th monopile designated as HKN70, BLPH will be backing up WTG57, such that it can guarantee 1 MW of power towards the string for 99% of the time of a year, excluding its utility consumption.

A SAFOP on the entire platform, including the company provided items packages hosted on it (Fuel cell, Electrolyzer, Li-ion Battery or BESS) was performed in February 2023, during FEED phase. The open action items were revised upfront and used as starting point for this session.

The SAFOP team successfully reviewed the main items of the electrical installation resulting in activities that need to be performed to ensure that the BLPH is safe to operate.

The SAFOP was conducted on June 12th and 13th at the Shell office located in Den Haag (NL).

The study covered the following:

- Review of the open action items from February 2023 SAFOP
- Review of the provided Single Line Diagrams outlining the electrical set-up.
- The electrical protections in place against electrical faults.
- The detection strategy of faults and the consequent response of the whole system.
- The protection and interface with the different CPIs

An Electrical SAFOP consists of the following three studies:

- SYSOP (System Operability):

  The review of the integrity, operability, and maintainability of the electrical installations/systems.
- SAFAN (Safety Analysis):

  The analysis of the safety of all categories of persons possible coming into contact with the electrical installation/system.
- OPTAN (Operator Task Analysis):

  The review of Operator tasks including normal duties, system switching, and abnormal or emergency conditions.

2.2 PARTICIPANTS

Table 1 shows the list of attendees participating the study.

Name	Role	Company
Claudia Giunchi	Project Engineer	Rosetti Marino
Andrea Madaschi	Electrical Lead	Rosetti Marino
Davide Lo Sterzo	Project Manager	Rosetti Marino
Luca Maculan	Electrical Engineer	Rosetti Marino
Anthony Iveson	Commissioning Engineer	Rosetti Marino
Arie Bal	SAFOP Chairman - Electrical Engineer	Shell
Alessandro Sutto	Secretary - Electrical Engineer	CW
Omkar Manmohan Sane	System engineer Green Hydrogen	Shell
Stephen Bremner	BLPH Packages Lead	CW
Dominik Sznajder	BLPH Project Manager	CW
Amulya Sahoo	Team Lead renewable integration Green H2	Shell
Phil Robinson	BLPH I&C Lead	CW
Nicolas Le Brun	BLPH Project Engineer (HSSE)	CW
Ken Rose	BLPH Electrical lead	CW
Marta Iacopetti	BLPH Project Engineer	CW
Paul Van Rossum	BLPH Technical Safety	CW
Martin Taylor	BLPH Commissioning Engineer	CW

Table 1 - List of SAFOP participants

2.3 STUDY METHOD

The following sections provide information on objectives, scope and methodology of the SAFOP process.

Objective and Scope

The objective of the SAFOP is to identify safety hazards or operability problems inherent in the design and operating philosophies of the electrical systems. The outcome of the study should be incorporated as much as practicable into the Design.

The process applied during a SAFOP review of the electrical installation involves implementation of three studies, referred to as SAFOP studies, by a multi-disciplined team of engineers. Each of these studies is specifically structured to aid identification of deficiencies in the design of the electrical installation and remedial actions to address them:

- The functioning and operation of the system and its components (SYSOP)
- The plant layout and accessibility (SAFAN)
- The operability of the facilities (OPTAN)

The SAFOP study is to complement the engineering design by providing an overall assessment of the project from the viewpoints of safety and operations.

Methodology

The study comprises of three main aspects:

1. SYSOP examines the functioning and operation of the system in terms of preventing and minimizing hazards and production losses due to failure, malfunction or maloperation of the equipment.

2. SAFAN examines the physical layout and accessibility of equipment and assesses potential for hazards to personnel who are to operate, work on, or be in the vicinity of the facilities, including during installation and commissioning.

3. OPTAN examines the tasks that operators of the electrical system require to undertake during normal and abnormal conditions and assesses whether adequate facilities are provided for these tasks to be performed safely and without error.

3 ELECTRICAL SYSTEM AND EQUIPMENT

3.1 DESCRIPTION OF THE PROJECT

The BLPH is part of the innovation scope of the HKN wind farm. It is a platform that hosts battery storage and hydrogen production at MW scale that will produce hydrogen in periods of high-power production and will convert the hydrogen to electricity when needed. Connected to it, a floating solar system will support operation with power production during daytime hours. This will provide flexibility on the hours-to-days scale with batteries providing storage for up to several hours and longer-term energy storage using hydrogen for up to around 36 hours.

The BLPH is a novel concept where, in an offshore environment, on an unmanned platform, the electrochemical backup system is being designed to operate in full autonomy.

The electrolizer, fuel cell, li-ion battery and a connected floating solar system are procured in separate packages (CPIs), each with their own control system. The BLPH control system will oversee all the individual packages and ensure the system will operate in a concerted effort.

3.2 ELECTRICAL SYSTEM OVERVIEW

The BLPH platform's electrical system is described in the documents listed in Table 3.

The connection of the platform with the wind farm is ensured by a single 66kVAC, 3-Phase, 50Hz cable. Power is then distributed on the platform via a 6.6kVAC, 3-Phase, 50Hz network feeding in all the CPIs and being the main power distribution for the BLPH platform. A 400VAC, 3-Phase, 50Hz supply will power the BLPH 'balance of plant' auxiliary loads and those directly associated with each CPI and key package.

The communication is handled by a CCS via a fiberoptic network dispatching messages and communicating with the EMCS and 'smart' switchgear to switch circuit breakers and control motor starters, as required to meet the system's operational requirements.

The existing connections can be summarized as:

Main systems	Operating voltage	Network configuration
Wind Farm Connection	66kV	3 Phase, 50Hz.
Solar Farm Connection	800V	3 Phase, 50Hz IT.
BESS AC (input / output power)	6.6kV & 400V	3 Phase, 50Hz IT.
Electrolyser (input power)	6.6kV & 400V	3 Phase, 50Hz IT.
Fuel Cell AC (output power)	6.6kV & 400V	3 Phase, 50Hz IT.
Switchgear Control & Metering: - 66kV and 6.6kV - 400V and 800V	 - 110Vdc - 230Vac	 - 2 Wire (unearthed). - 2 Wire (TN-S)
BLPH Balance of Plant Loads	400V	3 Phase, 50Hz TN-S.
BLPH Balance of Plant Loads	230V	1 Phase,50Hz TN-S.
BLPH ESSENTIAL Loads	400V & 230V	3 / 1 Phase, 50Hz TN-S.
BLPH VITAL Loads	UPS 230V	1 Phase, 50Hz TN-S.

Table 2 - Electrical connections details

Document Number	REV	Document Title
123A90-DDL-EL-DG-20158	01	OVERALL/KEY SINGLE LINE DIAGRAM
123A90-DDL-EL-DG-20014	01	ELECTRICAL CONTROL, PROTECTION & METERING DIAGRAMS
123A90-DDL-EL-SP-20166	01	ELECTRICAL PROTECTION PHILOSOPHY
123A90-DDL-EL-DG-20015	01	ELECTRICAL SINGLE LINE DIAGRAM HV SYSTEMS
123A90-DDL-EL-DG-20159	01	ELECTRICAL SINGLE LINE DIAGRAMS LV SYSTEM
123A90-DDL-EL-DG-20160	01	ELECTRICAL SINGLE LINE DIAGRAMS AC UPS SYSTEMS
123A90-DDL-EL-DG-20161	01	ELECTRICAL SINGLE LINE DIAGRAMS DC UPS SYSTEM
123A90-DDL-EL-DG-20162	01	ELECTRICAL SINGLE LINE DIAGRAMS (DISTRIBUTION BOARDS, AC UPS, DC UPS)
123A90-DDL-EL-DS-20032	02	TDS - AC UPS Systems
123A90-DDL-EL-DS-20036	01	TDS - DC UPS System
1723001595-EL-DG-00012	02	66KV SWITCHGEAR (GIS)- FUNCTIONAL LOGIC DIAGRAM (HYOSUNG)
1723001595-EL-DG-00013	02	66KV SWITCHGEAR (GIS) - SINGLE LINE DIAGRAM (HYOSUNG)
1723001595-EL-DG-00014	02	66KV SWITCHGEARS (GIS) - GAS SINGLE LINE DIAGRAM (HYOSUNG)
1723001595-EL-DG-00015	01	66KV SWITCHGEARS (GIS) - CIRCUIT AND WIRING DIAGRAM (HYOSUNG)
1723001595-EL-DG-00016	01	66KV SWITCHGEARS (GIS) - INTER-PANEL WIRING DIAGRAM (HYOSUNG)
1723001595-EL-DG-00017	01	66KV SWITCHGEARS (GIS) - INTER-PANEL LOGIC DIAGRAM (HYOSUNG)
1723002197-EL-DG-00010	02	SG-100D1 ELECTRICAL SINGLE LINE DIAGRAM (IMESA)
1723002197-EL-DG-00011	01	SG-200N1 ELECTRICAL SINGLE LINE DIAGRAM - LV SWBD 400-230V (IMESA)
1723002197-EL-DG-00012	02	SG-200D2 ELECTRICAL SINGLE LINE DIAGRAM - LV SWBD 800/460V (IMESA)
1723002197-EL-DG-00013	02	DP-200N1 LV SWBD 400-230V - ELECTRICAL SINGLE LINE DIAGRAM (IMESA)
1723002197-EL-DG-00015	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM - INCOMING FEEDER (IMESA)
1723002197-EL-DG-00016	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM - BUS BAR METERING (IMESA)
1723002197-EL-DG-00017	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM BESS FEEDER A-8500 (IMESA)
1723002197-EL-DG-00018	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM - ELECTROLYSER FEEDER A20000 (IMESA)
1723002197-EL-DG-00019	01	SG-100D1 MV SWBD 6,6kV- FUNCTIONAL DIAGRAM - FUEL CELL FEEDER A-80000 (IMESA)
1723002197-EL-DG-00020	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM - TRANSFORMER FEEDER TR200ED1 (IMESA)
1723002197-EL-DG-00021	01	SG-100D1 MV SWBD 6,6kV - FUNCTIONAL DIAGRAM - TRANSFORMER FEEDER TR200DE1 (IMESA)
1723002197-EL-DG-00030	00	SG-200N1 LV SWG FUNCTIONAL DIAGRAMS - INCOMINGS AND INTERCONNECTING AND AUX DISTRIBUTION (IMESA)
1723002197-EL-DG-00031	00	SG-200N1 LV SWG FUNCTIONAL DIAGRAMS - TYPICAL FEEDERS (IMESA)
1723002197-EL-DG-00032	01	SG-200D2 LV SWBD - ELECTRICAL FUNCTIONAL DIAGRAM (IMESA)
1723002197-EL-DG-00033	00	DP-200N1 FUNCTIONAL DIAGRAM (IMESA)
1724000372-EL-DG-00007	00	AC UPS - SINGLE LINE DIAGRAM and INTERCONNECTING DIAGRAM (3W POWER)
1724000372-EL-DG-00006	00	DC UPS - SINGLE LINE DIAGRAM and INTERCONNECTING DIAGRAM (3W POWER)

Table 3 - Reference documents

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4 OBSERVATIONS DURING THE SAFOP

4.1 ISLAND OPERATIONS AND BLACK START SCENARIO ALTERNATIVES

When sensing an undervoltage and with the correct exchange of signals (HW and SW) agreed with BESS, the BLPH is able to move to island mode from operations (=gird connected), since the transformers are already energized. On the contrary, BLPH is not able to move to island mode when the grid is not initially connected since BESS is not able to energize all the transformers. In this case the BLPH will move to Power out mode.

Island mode it is the only operational mode where Grid Forming will be available.

If all the energy is drained from the UPS before re-connection of the grid is possible, a black start is necessary.

Currently the strategy is to use a temporary 200kW diesel generator that will re-charge the UPS systems proving DC power to switchgears control and metering before starting the sequential reconnection of packages and closing of CBs. For further details please refer to 123A90-DDL-EL-SP-20141.

The need for a generator that can't be kept full time on the platform and has to be transported off-shore in case of necessity, makes the operation extremely costly and time consuming.

An alternative to be explored was discussed during the SAFOP that included re-closing the 66kV CB feeding BLPH without waiting for the UPS to be charged. This operation should be performed without having full access to the EMCS. The solution will be studied by the relevant parties and, if viable and compliant with TENNET's interconnection guidelines, will be presented as alternative.

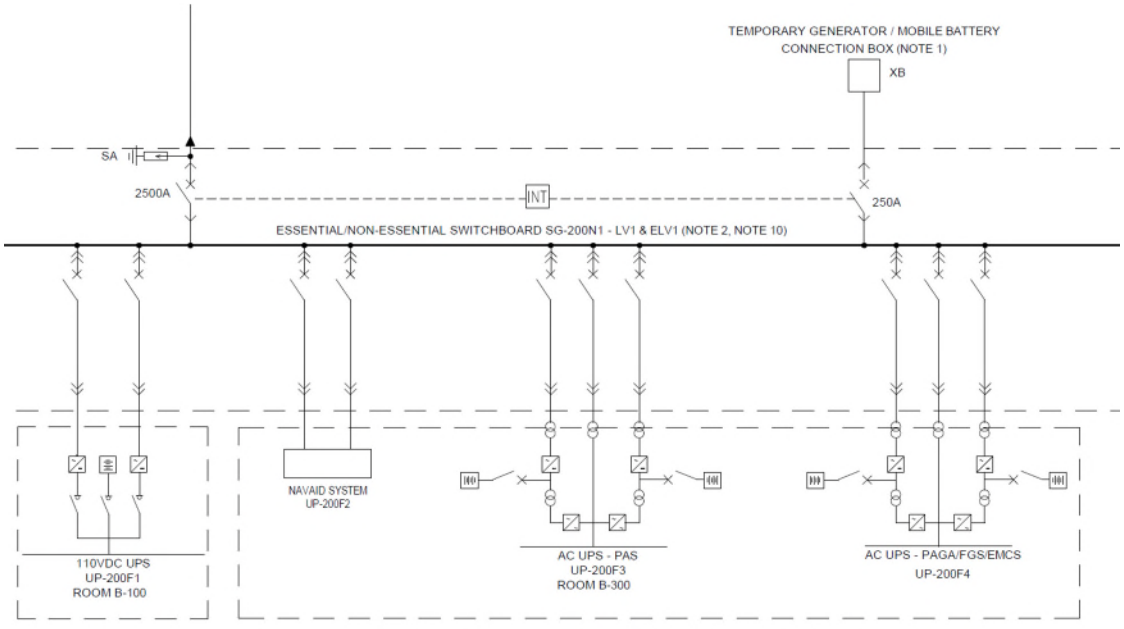


Figure 4 - Detail of Temporary generator and UPS connection

The interface with the WTGs, BLPH and TENNET was discussed as a reaction to opening of CBs located on different points on the 66kV network. Further discussion in dedicated coordination workshops will clarify what is the signal exchange between parties and what are the consequences on the different packages in case of a trip on the 66kV network.

4.2 ISLAND MODE EARTHING STRATEGY

When in Island mode, the 6.6 kV system, normally a TN-S network, will become an IT system with no earth point connection. To properly protect the system a 59N protection function (0 sequence overvoltage) is present on each protection relay. This detects that the neutral point has moved to a phase voltage.

With the correct calibration and settings of the 59N, an earth fault will be detected enabling to switch off the system. This type of protection, however, is not indicating which feeder is experiencing the fault. A procedure is in place where each 6.6kV breaker is opened sequentially to exclude one by one possible sources.

Rosetti Marino confirmed they had previous experience in shifting from TN to IT system in large installations and are willing to share relevant examples and documentation to ensure feasibility and effectiveness.

4.4.10 Overvoltage relay (Device 59)

4.4.10.1 Application

Overvoltage relays are typically used to monitor voltage levels on buses or generators to initiate switching or tripping operations. Other applications for this relay are as follows:

a) *Simple overvoltage bus protection*. The relay may either alarm or trip voltage-sensitive loads or circuits in order to protect them against sustained overvoltage conditions.

b) *Ground-fault detection*. Two methods are currently used to detect ground faults:

1) One method measures the zero-sequence voltage across the corner of a broken delta secondary of three VTs that are connected grounded wye-broken delta. A low-pickup relay is used because normally no voltage exists across the relay. During a ground fault on a high-resistance grounded-neutral or ungrounded system, the applied voltage causes the relay to operate in a predetermined period. A resistor may be required across the relay to prevent damage to the VT due to ferroresonance.

2) The second method measures the actual voltage across a high ohmic value resistance that is connected between the system neutral and ground. The voltage appearing across the relay (and the resistor) during a ground fault may be several times the pickup voltage so that the relay can be set to operate in a specific time. The maximum continuous operating voltage limit of the relay should not be exceeded. In medium-voltage systems, a stepdown transformer is used with windings rated 120 V or 240 V. Using a 240 V secondary of a 4160 V/240 V transformer produces a maximum of 139 V on the secondary during a ground fault. Often, a 150 V meter is used with this relay.

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Figure 5 - extract from IEEE on 59 protection

4.3 COMMISSIONING, INTEGRATED TEST AND MAINTENANCE OPERATIONS

Particular attention should be given to the commissioning activities by the team to ensure the full functionality of the platform including all the packages. Items discussed during the SAFOP were:

- GIS: ensure minimum re-commissioning activities once off-shore, suggest to verify relevant IEC standard and agree with the project team what tests will be done at the FAT, SAT and off-shore.
- Intertrip within the platform: effective communication between CPIs and BLPH, and BLPH and Windfarm
- The 66 kV cable connecting the SWG and the connection point with the subsea cable, stored in the TP during sea transport should be IEC tested in the yard, including the plugs, avoiding the need for testing them off-shore.

- Suitable tests and procedures should be in place for the 66kV cable pre-installed with the windfarm and currently in the monopile

The current strategy around ordinary and extraordinary maintenance was briefly presented. During planned maintenance electrolyser and fuel cell will be off and the H2 system will remain pressurized, creating exclusion zones. During unplanned maintenance activities, to ensure operators safety, BLPH will receive a ESD1D command (emergency stop with depressurization), the incoming breaker will open, so operators will be able to safely board the platform. Suggestion is to re-address this with the team (incl. HHSE) as this could lead to more risks rather than reduce them. Suggestion is to indeed blow out the H2 from the equipment , excluding the H2 tanks, and keep the whole electrical distribution system live and have the possibility of remote monitoring.

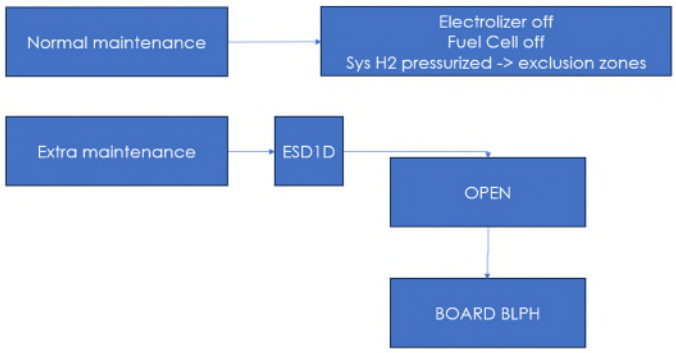


Figure 6 - Schematic overview of current maintenance strategy

4.4 CABLE LAYOUT

The cable layout for the connection of the packages with the switchgears was reviewed. Suggestion was made to route the cables from the side with an offset avoiding water to enter the buildings.

4.5 PROTECTION

A review of the electrical protection for each package was performed. Some observations are:

- Lock-out relay can be reset remotely from shore. This needs a Password protection.
- 6.6 kV feeders will trip at a loss of the 110Vdc system.

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5 CONCLUSION

The SAFOP has revealed several open action points all listed in the table below. All action points have been assigned to the relevant responsible party. The timing for resolution is to be determined by the project team.

The SAFOP team consider the system has progressed successfully yet showing still points that require attention. Therefore, in the effort to deliver the safest possible system, each team will address the open action items. This must be done while adhering to the project schedule.

It is recommended to actively monitor the status of each point, paying particular attention to the critical ones, and maintain active communication with all involved parties to ensure the timely completion of individual tasks.

Considering that different workshops focusing on integration, communication, control strategy, and other technical reviews are scheduled, a formal review of the open points is recommended to take place in Q4 2024 during the execute phase.

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6 APPENDIX 1 – ACTION ITEMS

6.1 FROM THE FEED SAFOP ACTION LIST – FEB 2023.

Sr. No.	Item	Description	Recommendation	RM Response	Comment – Execute SAFOP
1	Remote Operation	Remote monitoring and control not working properly. Sluggish control. Difficult to access large data remotely	Standardized remote monitoring for package vendors (Data Tunnel) à copy Siemens WTG method, if possible. Redundant fiber connection from Off to On-shore	Redundant fiber connection from Off to On-shore	**CW** to define data steam and to allow or not remote access and to what extent (High cybersecurity risk) Service network is in place. Missing "rules" for access to non-operators. Ensure suitable equipment to provide full data connection capacity. **YOKOGAWA** will program data stream dedicated to alarm communication to ensure fast communication **Each vendor** shall provide alarm categorization (as per DEP) of their own alarm.
2	Permit to operate	No permit to operate	Not meeting the TSO's connection requirements (Tennet) Unclear responsibilities regarding PCC. Effect of BLPH on PCC to be investigated / communicated with TENNET Both CW and BLPH teams to align towards Tennet.	CW to reply	There is no influence in terms of harmonics and BLPH is compliant to Tennet/grid regulation (ENSOL report). There could be interaction with the grid when full WT string is not producing and only BLPH is operating. Issue for this scenario will be investigated. **CW** (ENSOL) will take care of compliancy by extending the model to cover multiple scenarios for connection requirements – report ongoing (Saran Ganesh might support)
3	Grid-forming	Energizing transformers not working due to insufficient capacity (Q) of inverters to overcome the energization inrush of transformers.	During island operation the network short circuit capacity is too low to energize power transformers resulting in inverter trip. Re-consider the need for grid-forming operations	CW to reply	There is a Black start scenario procedure being produced now. Current strategy is to use a temporary 200kW diesel generator to energize DC power and recharge the UPS to be hoisted on BLPH. For initial installation and commissioning is facilitated by the presence of the crane for BLPH installation. For other operations a vessel will have to bring a generator (can't keep it full with Diesel on the platform) **RM + CW** to explore Alternative by using 66kV breaker re-close discussed and will be considered – Please check **123A90-DDL-EL-SP-20141** for detailed description.
4	Non-standard	Switchgear room allows for a fire&gas sensors leading to tripping the platform.	Consider installing smoke and heat detectors and hook them up to a centralized system for alarm purpose only. E-room should be free from any combustible materials! Note: Electrical switchgear systems have their own protection barriers which will avoid sustained fires.	F&G detectors installed in each room	H2 and smoke detectors are installed. Signal to the offshore control room. Smoke detectors on air ingress (2/3) will trip ESD1D (we do not want smoke inside containers). Same as Smoke in UPS rooms. Smoke in other electrical rooms only de-energization. **RM** Consider guidelines from DEP and consequences from both wanted and unwanted shutdown.
				Crosswind recommendations	
5	New design	Explosion and or fire	System to be transported, filled with H2 and charged batteries Review the details of the (im)possibilities of transporting the module charged or	BLPH will be transported without H2, since explosion risk is elevated and BESS battery charged less than 30%.	Transport has been discussed – No transport philosophy doc –SoC for BESS (~30%) **RM** Generate sea transportation philosophy document of BLPH

Sr. No.	Item	Description	Recommendation	RM Response	Comment – Execute SAFOP
			discharged and create a transportation philosophy document		
6	Operational error	Wrong circuit breaker being switched or maintained, due to 66 and 6.6 kV look alike	Blackout and or wrong selection of panel to maintain Make use of colors and clear text to avoid mistake	Mistakes not possible due to proper tagging of cables and equipment	The item was referring to SCADA HMI interface not to physical tagging. Completely different physical spaces – to be addressed in SCADA – 2 step confirmation (?) **RM** Make Yokogawa aware for SCADA HMI design
7	Standardization with Crosswind	Operators being confronted with different systems leading to confusion	Mishap in switching Ask Crosswind to share the standardized interlocking scheme for the 66 kV ring main unit Ask Crosswind to share the make and model from a WTG RMU and use at BLPH	Mitigation and recommendation taken	CW couldn't cooperate with Siemens, Hyosung provider (identical SLDs) **CW:** follow up with Hyosung to ensure coordinated operations for different system sections
8	Electrical safety rules	Different contractors and package vendors will be working under different safety rules and Permit to Work systems	Come to a minimum safety standard that is valid for all working on BLPH during the commissioning phase	HSSE plan for on-shore and off-shore will be present. SIMOPS workshop will be organized.	HSSE always under control – **RM** Electrical safety operation doc to be shared with CW team before commissioning **RM** organize SIMOPS workshop
9	Interfacing	Incomplete understanding of system	Confusion Show TENNET 66 kV substation on SLD and interfacing signals (maybe via note) to/from BLPH	CW to reply.	Control will not receive messages from Tennet. Information can be requested to HV-SCADA on status of complete grid. In previous WS list of available messages has been provided and **CW** will update the strategy document to include BLPH with those messages. **RM:** Provide operations document
				Crosswind recommendations	
10	New design	New control system covering ENMCS as well as process control functionality (DCS) and packages control. Control system not working as needed/expected leading to unreliable/unsafe situations	-Explore existing ENMC systems early to copy functionality into new system -Explore package control functionality early -Start development of overall control system early	PCS and SIS systems are designed in fail safe mode, so that in case of overall failure commands will be in safe condition.	**CW:** to check. Assessed – logic control of 6.6kV SWG is under review currently – remote control is avail.
11	Fault finding	Clock of different systems not synchronized.	-Define synchronization of time/signal/power for integration of packages in BLPH and Crosswind for event sequencing	NTP server is present in BLPH for synchronizing the packages.	**CW:** to check Assessed during Control Workshop (Oct 23) – Ongoing

Sr. No.	Item	Description	Recommendation	RM Response	Comment – Execute SAFOP
		Can't put the events that have been recorded by the different systems/packages in sequence			
12	Isolation	Isolation of package / transformer omitted Fault not fully isolated due to LV and HV power sources	-Ensure implementation of inter-trips to isolate packages and transformers -Make use of protection DEP 33.64.10.17-Gen	Electrical intertrips have not been requested for packages (CPIs included) Intertrip signals are managed by serial connection to each CPI. To be noted that reported DEP is not contractual.	**CW:** to check Use of individual package intertrips – details to be finalized
13	Freeze protection	Heat-tracing not operational when BLPH is isolated from the grid Damage to equipment	-This could be a reason to have a grid-forming capability. Understand the risk of freezing and decide if mitigation is required. -Consider Heat-tracing breakers (contactors?) with remote control. -Consider heat-tracing EF protection with high threshold	Heat tracing will be powered through DP-200N1 and have a general contactor commanded by ambient thermostat (NO remote control) 30mA RCD are provided according to project requirements	**CW:** to check No grid forming from blackstart available – Heat tracing have been discussed – to be checked
14	Integration	Lose components not interfacing with digital protection relay. Operator confusion when system trips with no information on what caused the trip	Consider including the protection functions 86 and 87 as well as 94 into the digital protection relay	See ELECTRICAL CONTROL, PROTECTION & METERING DIAGRAMS	**CW:** to check
15	Arc flash	Switching in front of the 66 kV, 6.6 kV and 400 V switchboard due to absence of control station. Short circuit and arc flash incidents leading to trauma.	Provide a possibility to remote switch the main breakers on BLPH, with a possible safe location in the Plant Instrument Room.	CCS HMI is accessible on BLPH from the sliding monitor installed in the Server panel	**CW:** to check general rule no switching in the room – level 2 PPE required

6.2 FROM EXECUTE PHASE SAFOP JUNE 12TH – 13TH

Sr. No	Item	Description	Recommendation	Responsible	Actions
16	Document	CPI SAFOP Reports	-	CW	Share CPI SAFOP Reports with RM
17	Earthing management during island	In case of earth fault during island mode the 6.6kV bus will move from TN to IT network.	The strategy is to sequentially open the 6.6kV breakers to exclude packages/lines. Max time limit of ~8h not to generate dangerous voltages, procedures on BLPH might take ~1min.	RM CW	**RM**: Check voltage specs with CT, VT and switchgear manufacturers. **RM**: Share previous experiences with 59(N) protection for IT earth faults. **RM**: Check internally with specialist on ferro-resonance and possible addition to the model **CW**: Share paper on phenomenon of ferro-resonance
18	Protection during island	Protection of BLPH during island à low SC current	ENSOL will be developing a model for load flow and SC analysis - RM checked on load flow and SC but ONLY for BLPH not for anything 'above' the interface.	CW	Engage with ENSOL for model developing
19	Protection coordination relay BLPH	-	Protection specialist is working on it this week, next week will be available for review.	RM	Share protection coordination study for review
20	EMCS & Alarm management	Alarm management philosophy is a project requirement but it has not been developed fully yet. There is one for process control. Electrical is still missing.	Will there be 24/7 monitoring? All alarms are collected and communicated to CCS but currently there is not yet a defined strategy on how to distribute it to "outside world" ERP - Emergency response plan will be available for BLPH	CW (CPI) RM	**CW:** Provide alarm lists with "priority" and expected operator follow-up reaction. **RM:** Develop electrical alarm management philosophy.
21	Alarm management	Batteries and UPS will be in the same room	Tripping strategy for smoke detection in UPS room	CW/RM	Pending on the assessment of the risk of having a sustained fire in the UPS room, determine if tripping on smoke detection is a requirement.
22	Commissioning	Commissioning of BLPH done in steps	Precom: IO list, checking all the switchgears and boards 1st step: connecting 400V aux from external source 2nd step: connecting after transformer on 6.6kV energize aux transformer, close aux circuit breaker.	RM	Share the commissioning schedule and activity plan
23	Commissioning	66kV cable termination	What tests will be performed on the cable connection between TP and 66kV switchgear? Company terminating and connecting cable to supply required qualifications. Cable connecting the SWG and the connection point with the subsea cable (stored in TP during transport) should be IEC tested in the yard, to avoid re-test offshore.	RM	Provide test results Supervise tests of connection cable

Sr. No	Item	Description	Recommendation	Responsible	Actions
			Note: monopile has the 66 kV cable installed with surplus length. Verify if it can be routed directly to the 66 kV switchgear.		
24	Commissioning	Yard commissioning	For the integrating testing 5MVA across 4 generators in parallel with 2 step-up transformers and load bank 1MW Procurement is ongoing. Planning is finalizing to generate a contract in few weeks. BESS powers won't be able to be given back to the grid. Synchronization will be done via generators.	RM	Finalize and share plan for yard commissioning (generators, load bank procurement)
25	Commissioning	Yard commissioning – H2 operation	Expectation is to finalize all the packages installation before introducing H2 in the system. Generally, sensors are tested with actual calibrated H2 or CH4 to ensure proper reading.	RM	Define H2 operations for commissioning in the yard and offshore.
26	Commissioning	Preparation for sailing/transport	Sail away plan will be developed. UPS will be fully charged. H2 storage fully discharged and fully inerted. BESS should be around 30% SOC. There will be no power during transport. -> blind transport Every requirement from CPI or other packages is expected. NAVAID battery will be fully charged.	RM CW	Sail away plan development Share sail away/transport requirement of CPIs
27	66kV -GIS	It will be partially commissioned in the Yard. Canister with filling gas will be provided by supplier for partial refill.	Recommended to have it fully tested before sail away. CW representative to witness FAT.	RM	Prepare a table listing risks of commissioning activities to be repeated offshore – All the offshore tests will be performed without power on the GIS
28	Metering	Smart metering for BLPH	Smart/fiscal metering was not considered for the platform. Existing protection and control relay (REX640 and REF615) has embedded functions for monitoring power and energy exchanged.		
29	CPI control	Control strategy for power request	Currently discussion was always on providing ">1MW" 99% of the time. However, control EMCS should take into consideration both P (kW) and Q (kVAR) to be communicated to CPIs (BESS in particular)	RM CW	**RM**: Define the setpoint given to CPIs based on information exchange with WTG. More definition needed on control strategy for V, P & Q. **CW**: define what is WTG contribution to Q

Sr. No	Item	Description	Recommendation	Responsible	Actions
30	Hotspot measurement	6.6kV SWG has hotspot measurement in each of the SWG columns	There are multiple sensors located in the best spots (according to manufacturer) The connected reaction is a simple alarm and not a trip. These devices are generally used to predict long term maintenance (20+ yrs) Suggested to exclude it from future project unless strictly necessary for economical purposes AND to have it installed but not connected in the current layout to avoid additional commissioning and maintenance.	CW	Decision on hotspot measurements use and commissioning.
31	6.6kV SWG	Lock out relays reset management	The relay is able to reset from shore - After a 3ph fault the system CAN be reset remotely. The logic and philosophy documents will be specifying on operators actions. SUGGESTION to have some sort of 'barrier' to ensure only dedicated operators can reset it. SCADA from Yokogawa is password protected and one can choose the access level.	RM CW	Define control philosophy and operators access management.
32	Solar Feeder	Specs and ratings of connections equipment	Due to IT management of network on solar farm, in case of earth faults the voltage would rise from 800VAC to 1385VAC. Can the switchboard withstand the voltage (SG-200D2) – rated for 3kV but what is the operating voltage? ABB seems to be rated for 690VAC with max voltage 1000VAC. Strongly recommended to trip the system on detection of earth fault to limit damages. Need to be checked with OOE for ability to trip low voltage when they have fault.	RM CW/OoE OoE	To check on devices/ratings.
33	Solar interface	Subsea cable might not have circular external profile	Define the interface to properly design junction box on BLPH for cable entry, cable glands.	RM/CW	Coordinate with OOE with the support of CW
34	AUX	5x3x(1x300)+3x(1x300) cables lay-down	Ensure clear instructions are given to installers for trefoil configuration of phases (L1,L2,L3)	RM	Provide clear instruction for cable layout

Sr. No	Item	Description	Recommendation	Responsible	Actions
35	Fire safety	No paper allowed in LV and MV switchgear rooms	To avoid spreading/generation of fires no combustibles (including paper documents/ schematics) should be present in the containers. Operators to ensure removing them after maintenance operations.	RM	Ensure correct procedure/check in place to avoid combustible materials in switchgear rooms.
36	Fuse – Contactor combo for protection		Check design of fuse + contactor (curves intercepts) considering the SC levels to minimize the risk of accidental fuse trip and ensure correct selectivity. Is the contactor's rating Fault-making or -breaking?	RM	Check design and selectivity
37	Fuel cell transformer interface		Clarify the interface with the incoming transformer MV cables – space requirements and connections	RM / CW / Ballard	Coordinate with Fuel Cell
38	Electrolizer	Latest interface schematics and transformer connections	Review the latest drawings received from Fores. Review SAFOP open points with Fores to ensure implementation	CW,	Review SAFOP open points with Fores to ensure implementation
39	Electrolizer	Grounding of piping system	Due to floating system of stacks, necessity to ensure proper insulation of metal piping for gas and liquid from ground. Electrolizer should list requirements and RM should study solutions to accommodate	CW,	Coordinate with electrolizer on requirements and solutions around piping grounding
40	BESS	Neutral connection to ground missing	Previous electrical system schematic showed direct connection between transformer 2nd start center with PE. On current design this connection is missing. Need explanation and strategy to manage faults. Need explanation on why connecting transformer star center to DC bus mid-point.	CW	Confirm neutral point connection and grounding strategy with BESS
41	Interfaces	SW interface with packages	Missing definition of SW interfaces and interactions between EMCS and packages.	RM	Define SW interfaces
42	Interfaces	Interface with WTGs, BLPH and TENNET	The interfaces were discussed as a reaction to opening of CBs located on different points on the 66kV network. Further discussion in dedicated coordination workshops will clarify what is the signal exchange between parties and what are the consequences on the different packages in case of a trip on the 66kV network.	RM/CW	Follow up during coordination workshops
43	Maintenance operations	Ordinary and extraordinary maintenance procedures	During planned maintenance electrolizer and fuel cell will be off and the H2 system will remain pressurized, creating exclusion zones. During unplanned maintenance activities, to ensure operators safety, BLPH will receive a ESD1D command (emergency stop with	RM	Reconsider the risks connected to the maintenance strategy and the need for complete ESD1D during extraordinary maintenance.

Sr. No	Item	Description	Recommendation	Responsible	Actions
			depressurization), the incoming breaker will open, so operators will be able to safely board the platform. Suggestion is to re-address this with the team (incl. HHSE) as this could lead to more risks rather than reduce them. Suggestion is to blow out the H2 from the equipment , excluding the H2 tanks, and keep the whole electrical distribution system live and have the possibility of remote monitoring.		

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