Base Load Power Hub (BLPH)

OTP – Electrolyser Package

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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.

1.2 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.

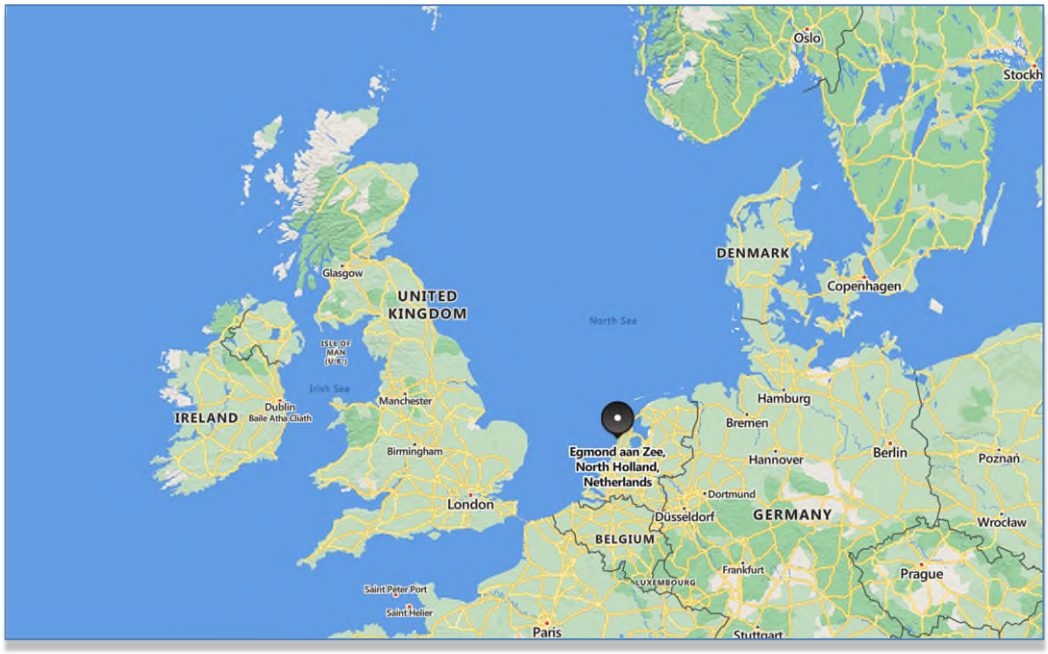


Figure 1 - HOLLANDSE KUST NOORD WIND PARK Location Map

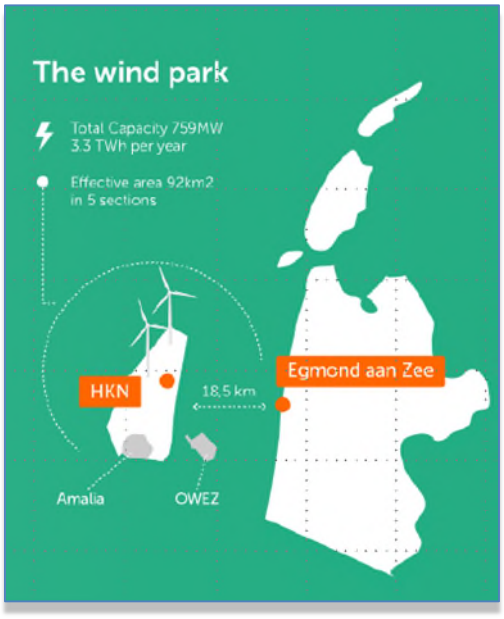


Figure 2 - Wind Park Details

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 is located on coordinates E 590719.1, N 5841602.3 and 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.

1.3 Project Concept

All components included in the BLPH will be integrated onshore on a topside 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.

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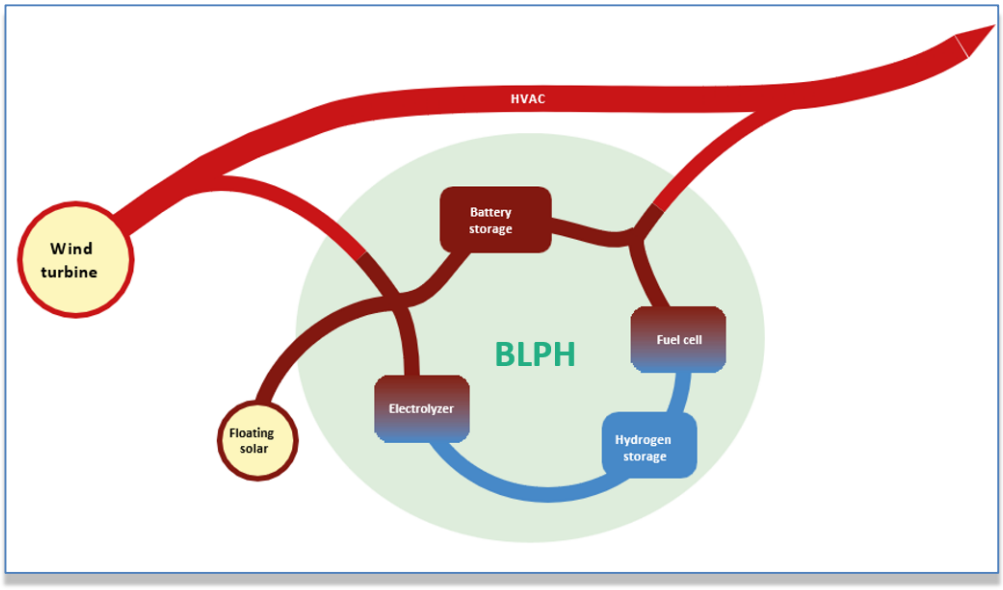


Figure 3 – BLPH Concept

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 is 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 procedure covers Pre-start-up, Start-up and Ramp-up activities of the BLPH Electrolyser. These activities go from the electrolyser's Start-Up & Operation in automatic mode (referred as Start mode in Manuel user cf. C63-PMO-001), to the progressive increment in current fed by the rectifiers into the stacks, hence, increasing the hydrogen flowrate produced. For more details about the principle of electrolysis and the operation of the process through the HMI (Human Machine Interfaces) refer to the electrolyser's Manuel User (cf. C63-PMO-001).
Despite the different categories of activities (i.e. Pre-start up, Start-up and Ramp-up), it has been chosen to summarise all these activities in one document for practical use, since these activities must be carried out in series and the scope of some of them are overlapped.
The prerequisites listed in sections 3.4 and **Error! Reference source not found.**3.4.1 must be guarantee before setting the machine in start mode (section 6.4.1.2). A detailed description of activities is given in section 6.4.

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3 OTP SUMMARY

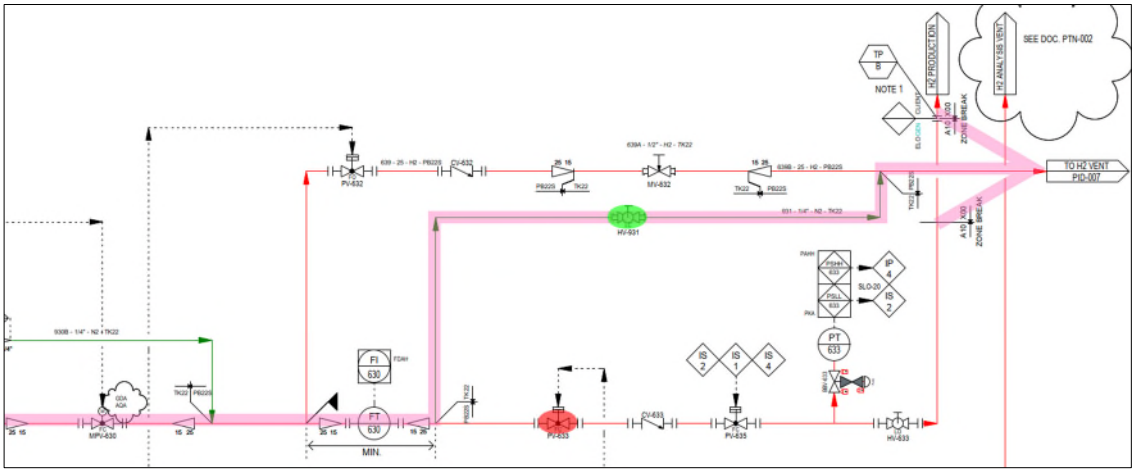
3.1 Test Objective

The operating test of the Electrolyser system is executed to ensure that the system is started up in a safe and controlled manner and to verify the correct operation according to the project requirements.

Aim of this document is to provide the sequence and appropriate actions to verify the safety systems of the Electrolyser system along with proving the design intent of the system to produce hydrogen gas (H2).

Prerequisites for proceeding with the OTP:

- The UPS is charged at 100%.
- All Utilities are operational.
- The electrolyser is stopped, depressurized and cold (T < 40 °C).
- Piping system is Lined Up to route the hydrogen produced to the H2 vent (Line Up as per the P&ID Mark Up below, PV-633 locked closed, HV-931 locked open).
-



- All design documentation is approved or relevant TQ / CQ approved to proceed with introduction of combustible gas.
- It is mandatory to have the written authorization to send the hydrogen to the vent during these activities.

- Onshore pre-commissioning and commissioning activities at Contractor site (WORKSITE)
  - PHASE 1: Pre-commissioning (powered) activities listed in C063-ELO-PRO-CO- 0003 (NOT PART OF THIS OTP)
  - PHASE 2: Commissioning (powered) activities listed in C063-ELO-PRO-CO- 0004 (NOT PART OF THIS OTP)
  - PHASE 3: Vendor SAT & Integrated function test of Electrolyser package including:

- Confirming Unit Settings on the START mode
- Stack polarization
- Hydrogen Setpoint Achievement
- Functionality of electrolyser's Sequences during Operation
- Hydrogen Leak Detection
- Safety Stops at 10%
- Increasing current by 10% up to 100%
- Production Settings at 100%

  HPP Start-Up

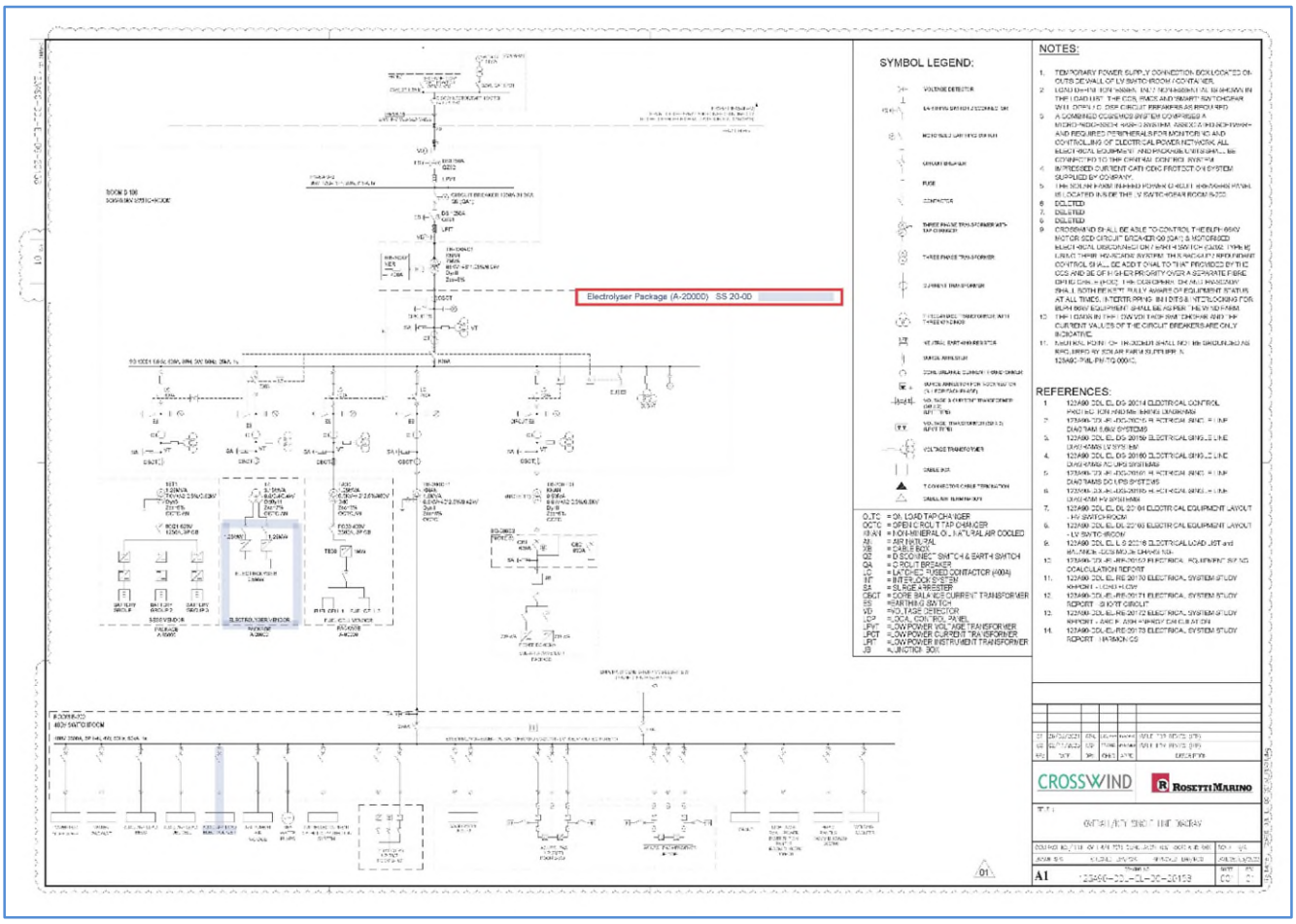
- Offshore commissioning (SITE)
  - PHASE 4: Integrated function test of Electrolyser package (OFFSHORE).

PHASES 1 – 2 are covered by and contained within the vendor documents. PHASES 3 - 4 are included within this OTP document, and the Vendor SAT procedure.

3.2 System Boundary Limits

See below the interested systems and subsystems on the Overall Single Line Diagram

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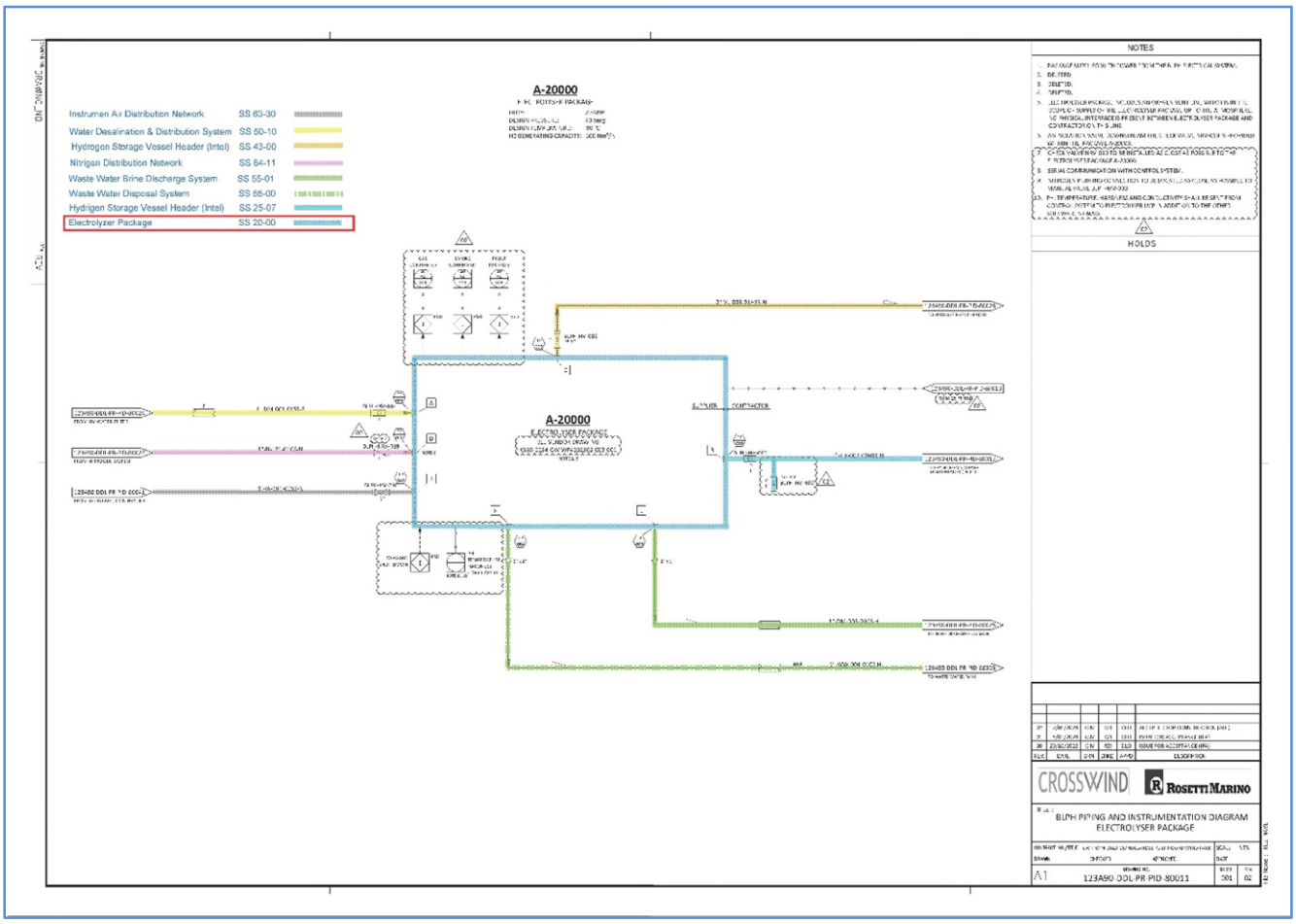


Figure 4 – OTP System Boundary Limits

3.3 Test and System Description

Proceeding with this OTP is confirmation that for the following system:

- 20-00 Electrolyser Package (A-20000)

All equipment is installed in accordance with the following vendor documents:

- ELO-INN-BPH-DWG-00008 Process Flow Diagrams
- ELO-INN-BPH-DWG-00009 AQUAGAS Wiring diagram
- ELO-INN-BPH-DWG-00010 NIDEC Detailed Electrical Drawing of PCS units
- ELO-INN-BPH-DWG-00011 OVIVO Electrical Instrument Detailed Drawing Wiring Diagram
- ELO-INN-BPH-DWG-00012 PAUMIER PAU001 & PAU002 Chiller electrical wiring
- ELO-INN-BPH-DWG-00013 PAUMIER PAU003 HVAC electrical cabinet
- ELO-INN-BPH-DWG-00014 NIDEC Mechanical drawing of skid HCU
- ELO-INN-BPH-DWG-00015 NIDEC Rectifier Mechanical Drawing
- ELO-INN-BPH-DWG-00016 NIDEC - SINGLE LINE DIAGRAM
- ELO-INN-BPH-MAN-00007 Handling and Installation Guidance for finalized stacks

- ELO-INN-BPH-OTH-00005 Lines List
- ELO-INN-BPH-OTH-00017 Interfaces and Utility list
- ELO-INN-BPH-PLN-00010 AQUAGAS Electrical Panel & Connections / Wiring Diagram
- ELO-INN-BPH-PLN-00011 NIDEC Detailed Electrical Drawing
- ELO-INN-BPH-REG-00006 CABLE LIST AND INTERCONNECTING DIAGRAM
- ELO-INN-BPH-RPT-00005 Electrical function & protection philosophy
- ELO-INN-BPH-RPT-00008 Safety Loop Design
- ELO-INN-BPH-RPT-00010 Explosion Protection Document
- ELO-INN-BPH-SPC-00006 Technical specification Control cabinet & Electrical wiring
- ELO-INN-BPH-SPC-00008 O2 and H2 Vent Technical specification (Phase 2)
- ELO-INN-BPH-SPC-00010 Electrolyser Network Architecture

3.4 Safety Devices

These defining rules shall be applied from the initial (total or partial) energizing of the instrumented systems, until the end of the commissioning activities.

- Appropriate PPE must be always worn during loop testing.
- A permit to work has been delivered.
- No equipment will be definitively energized without the subsystem Mechanical Completion.
- As soon as a panel is energized (Relay Panel, cabinets, PLC cabinets or local PLC) a sticker "Panel energized - Commissioning in progress" will be suitably displayed on the door in different languages, indicating that it is available for loop checking.
- Testing of electrical/instrumentation interfaces (i.e. I/O serving electrical switchboards for motors control) will be done in conjunction with the power distribution systems lead engineer.
- The on-site equipment area must be visibly marked with a “Test in Progress” sign.
- In any case this procedure shall not conflict with, or supersede, the electrical lock-out procedure. Only electrical system leaders will be authorized to remove padlocks in electrical cabinets.
- Safety rules in accordance with the risk must be applied (e.g. Calibration Gas, Fluids, Pressure, Electrical Power, etc.)
- Risk assessment must be done prior to any test activity.

3.4.1 HSE Management

- All necessary safety precautions must be taken to avoid any risk of personnel injury.
- All personnel involved in this operational test shall be competent for the tasks they will be required to undertake
- Place safety / warning signs and segregate the entire area with barrier tapes (safety barriers) of a colour distinguished (blue and white) from those used for construction activities
- Restrict access into area only to authorized personnel
- Conduct “Toolbox Talk” with all personnel prior to starting test work
- Appropriate Personnel Protective Equipment (PPE) and safety equipment e.g. safety shoes, hand gloves, helmet, earplugs etc. are available and must be used in line with the site requirements

- All activities carried out on the project shall be performed in accordance with the "Permit to Work" system Doc. PRO-HSE-23
- Electrical and mechanical isolations are to be assured as per Doc. PRO-HSE-08 and "Commissioning and start-up operation" procedure.
- Observe and enforce all international codes and regulations to safeguard personnel, plant and environment.
- Ensure that the working area is clean, tidy, well illuminated and that access and escape routes are free from obstructions.

Before starting work on any of the activities in this OTP it is the responsibility of the persons performing the work to:

- Familiarize themselves with the plant/equipment to be worked on
- Ensure they are aware of all other work activities that are taking place, or due to take place
- If necessary, re-plan any situation/activity
- Ensure proper communications between parties involved in the execution of the OTP
- Read the relevant Vendor documentation for the equipment covered by this OTP and observe any special requirements and limitations recommended or imposed by Vendor
- Verify that all personnel involved in the implementation of this procedure are familiar with its content as well as the associated safety requirements (Toolbox Talk)

3.5 Acceptance Criteria

- Before Power ON:

Visual inspection and verification are a crucial step to identify any obvious issues with the installation, such as loose connections, missing components, or damage to the equipment.

Crosschecking the installation with engineering documentation ensures that the installation is done correctly and according to the manufacturer's guidelines. These steps can help identify any missing or incorrect components, and wrong connections.

All package ITRs to be completed & RFC issued for sub-system 20-00.

Apply padlocks on all necessary Breakers per LoTo Procedure (if required)

Phase 1 (Not in the OTP) will prove basic function of individual instruments and equipment which may or may not be on final power supplies.

Phase 2 (Not in the OTP) will prove correct function of auxiliary systems or packages and close out of any punch list A activities prior to unit startup phase.

Phase 3 will prove correct:

- Completion of the Vendor SAT procedures.
- Functionality of the Electrolyser package in coordination with Required Associated Subsystems packages on BLPH. (ONSHORE)

Phase 4 will prove correct:

- Functionality of the Electrolyser package in coordination with the other packages on BLPH (OFFSHORE).

Performing the steps in this OTP as per engineering documents is crucial to ensure that the equipment is operating correctly and that it meets the desired design specifications. Observing the results will help identify any issues that may arise during the operation.

Overall, following these steps shall provide a comprehensive and effective way to verify the equipment installation and functionality.

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4 DOCUMENTS REFERENCES AND ABBREVIATIONS

4.1 Reference Documents

4.1.1 Company Documents and Standards

123A90-PML-COM-PRO-03007	BLPH Commissioning Strategy
123A90-PML-QHSE-PRO-00117 Rev.01	Punch List Management Procedure
123A90-PML-QHSE-PL-00001	Project HSE Management Plan
	Base Load Power Hub – Electrolyser Workflows
C063-ELO-PRO-CO-0002	BLPH Electrolyser CSU Method Statements
C063-ELO-PRO-CO-0003	BLPH Electrolyser Pre-Commissioning Manual
C063-ELO-PRO-CO-0004	BLPH Electrolyser Commissioning Manual
C063-ELO-PRO-CO-0005	BLPH Electrolyser Operational Test Procedure
C063-ELO-PRO-CO-0006	BLPH Electrolyser Performance Test Procedure
C063-ELO-PRO-CO-0007	BLPH Electrolyser O&M Training
C063-ELO-LST-CO-0001	BLPH Electrolyser - General Item list

Table 1: Company Documents and Standards

4.1.2 Project Documents

Document ID	Document Title
[1] 123A90-PML-PM-LIS-01001	Master Document Register
[2] 123A90-PML-PM-PL-00001	Project Execution Plan
[3] 123A90-PML-QHSE-PL-00001	Project HSE Plan
[4] 123A90-PRO-HSE-23	RM Yard Permit To Work Procedure
[5] 123A90-PML-COM-PL-03002	Mechanical Completion & Commissioning Execution Plan
[6] 123A90-PML-COM-PRO-03007	Commissioning Strategy
[7] 123A90-PML-COM-LIS-03011	System/Sub-Systems List
[8] 123A90-PML-COM-LIS-03012	System/Sub-System Boundary Limit Diagrams
[9] 123A90-PML-COM-PRO-03038	Leak Test Procedure
[10] 123A90-PML-COM-SP-03032	Pre-Commissioning Functional Test Sheet Template Collection (ITR-B)
[11] 123A90-PML-COM-SP-03014	Commissioning TDS - Temporary Equipment & Facilities
[12] 123A90-PML-COM-PRO-03019	OTP – Onshore Performance & Integrated Test Procedure
[13] 123A90-PML-COM-LIS-03034	Inhibit-Override Register
[14] 123A90-PML-COM-LIS-03035	PSV Calibration Register

Document ID	Document Title
[15] 123A90-PML-COM-PRO-03036	OTP - Black Start Procedure
[16] 123A90-PML-COM-LIS-03024	Commissioning Spare Parts and Consumables List
[17] 123A90-PML-COM-PRO-03022	Initial offshore START-UP procedures
[18] 123A90-PML-COM-SP-03057	Worksite WEF (Work Execution Flow Scheme)
[19] 123A90-PML-COM-SP-03058	Site WEF (Work Execution Flow Scheme)
[20] 123A90-PML-COM-RE-03001	Commissioning Final Dossier (ITR-B)
[21] 123A90-PML-QHSE-PRO-00116	Flushing and Cleaning Procedures
[22] 123A90-PML-QHSE-SP-00118	Mechanical Completion Check Sheet Template Collection (ITR-A)
[23] 123A90-PML-QHSE-RE-00115	Mechanical Completion Final Dossier (ITR-A)
[24] 123A90-PML-QHSE-PRO-00117	Punch list Management Procedure
[25] 123A90-PML-COM-PRO-03041	OTP - Hydrogen Storage & Venting Systems
[26] 123A90-PML-COM-PRO-03042	OTP - Sea Water Intake & Fresh Water Treatment Systems
[27] 123A90-PML-COM-PRO-03043	OTP - Instrument Air System
[28] 123A90-PML-COM-PRO-03055	OTP - Nitrogen Generation System
[29] 123A90-PML-COM-PRO-03044	OTP - HVAC Systems
[30] 123A90-PML-COM-PRO-03045	OTP - HV Switchgear & 66 kV Transformer Systems
[31] 123A90-PML-COM-PRO-03046	OTP - MV Switchgear & 6.6 kV Transformer Systems
[32] 123A90-PML-COM-PRO-03047	OTP - LV Switch Boards & LV Distribution Board Systems
[33] 123A90-PML-COM-PRO-03048	OTP - Lighting & Small Power Systems
[34] 123A90-PML-COM-PRO-03049	OTP - Electrical Heat Tracing Systems
[35] 123A90-PML-COM-PRO-03050	OTP - UPS Systems
[36] 123A90-PML-COM-PRO-03051	OTP - Data Network Systems
[37] 123A90-PML-COM-PRO-03053	OTP - Navaid System
[38] 123A90-PML-COM-PRO-03054	OTP - F&G and ESD C&E Logics
[39] 123A90-PML-QHSE-PRO-00120	Proverlis Management Procedure
[40] 123A90-PML-COM-PRO-03056	OTP – Document Template
[41] 123A90-DDL-IN-RE-40095	Process Control Logics Description

Table 2: Reference Project Deliverables

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4.1.3 Vendor Documents

Document ID	Document Title
[1] C63-NID-ELO-SAT04	SAT Low Voltage & High Voltage Tests Procedure
[2] C63-NID-ELO-SAT07	SAT Functional and Performance Tests procedure
[3] C63-PAU-SAT-001	HVAC SAT Procedure
[4] SWL0841/Elogen/CP/001	Commissioning Plan for OVIVO WTP
[5] SWL0841/MS01	Method Statement for OVIVO WTP
[6] 20230443 DEDR-500_36	DEDR-500_36 P&I Diagram Offshore
[7] N/A	DEDR 500/36 Installation, Commissioning, O&M Manual

Table 3: Company Key Reference Documentation

4.2 Acronyms and Abbreviations

Acronyms / Abbreviations	Description
BLPH	Base Load Power Hub
BOP	Balance of plant
CM	Commissioning
CSU	Commissioning & Start-Up
DEDR	Deoxo & Dryer
E&I	Electrical & Instrumentation
ESD	Emergency Shut Down
FAT	Factory Acceptance Test
FT	Functional Test
GALT	Gross Air Leak Test
HMI	Human Machine Interface
HPP	Hydrogen Purification Package[1]
HSE	Health, Safety, & Environment
HVAC	Heating Ventilation and Air Conditioning
ICSS	Integrated Control and Safety System
ITR	Inspection & Test Record
LC	Locked Closed
LO	Locked Open
LOTO	Lock-Out / Tag-Out
LR	Low regulation point
MC	Mechanical Completion
OTP	Operation Test Procedure (Commissioning)
PC&C	Pre-Commissioning & Commissioning
PCA	Performance Cell Analyser

Acronyms / Abbreviations	Description
PCS	Process Control System
PID	Proportional, Integral, Derivative
P&ID	Piping and Instrumentation Diagram
PL	Punchlist
PLC	Programmable Logic Controller
PPE	Personal Protective Equipment
PSU	Pre-Start-Up
PSV	Pressure Safety Valve
PTW	Permit to Work
PVP	Piping and Vessels Preparation
RFC	Ready for Commissioning
RFO	Ready for Operation
RFSA	Ready For Sail Away
RFSU	Ready For Start-Up
RU	Ramp-Up
SAT	Site Acceptance test
SIS	Safety Instrumented System
SLD	Single Line Diagram
SU	Start-Up
UPS	Uninterruptible Power Supply

Acronyms / Abbreviations	Description
BLPH	BaseLoad Power Hub
CO	Carbon monoxide
EMCS	Electrical Monitoring & Control System
ESD	Emergency Stop Devices
FAT	Factory Acceptance Test
FTE	Full Time Employees
F&G	Fire and Gas
PPE	Personal Protective Equipment
ITR	Inspection & Test Record
LOTO	Lock Out Tag Out
OTP	Operational Test Procedure
PCS	Power Conversion System
SAT	Site Acceptance Test
SOC	State Of Charge

Table 4: Acronyms and Abbreviations

5 OTP AT ONSHORE WORKSITE

This chapter refer to the activities on the Contractor worksite (construction yard).

5.1 Planning and Manpower

5.1.1 Planned tasks with estimated manpower

Estimated manpower for the different phases of the OTP are:

Activity	Staff qualifications	Advised presence
Unit Settings on the START mode	1 site supervisor, 2 electrical technicians	1 automation engineer
Stack's polarization	1 engineer and 1 automation engineer	1 rectifier specialist from NIDEC
Hydrogen Setpoint Achievement	1 automation engineer	
Functionality of electrolyser's Sequences during Operation	1 automation engineer	
Hydrogen Leak Detection	2 piping & mechanical technicians	2 helpers
Safety Stops at 10%	1 engineer and 1 automation engineer	
Increasing current by 10% up to 100%	1 automation engineer	
Production Settings at 100%	1 automation engineer	
HPP Start-Up	1 automation engineer	1 technician from Aquagas

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5.1.2 Pre-Commissioning & Commissioning duration estimate prior to Start-Up:

Activity	Duration (h)
Electrical Transformer SAT	4
Energization Transformer	2
Pre-Commissioning 6.6kV Electrical Supply	4
Pre-Commissioning 400V Electrical Supply	8
Electrolyser Rectifier SAT	8
Electrolyser UCP Electrical Pre-Commissioning	8
Electrolyser HVAC UCP Electrical Pre-Commissioning	8
Electrolyser Water Treatment UCP Electrical Pre-Commissioning	8
Electrolyser VSD Electrical Pre-Commissioning	8
F&G Detector SAT	4
Instrument Air – check HV	1
Non Hazardous Drains – check HV	1
Water Supply – check HV	1
Nitrogen Package Pre-Commissioning / Commissioning	2
Electrolyser HVAC Package SAT	156
Electrolyser Water Treatment Package SAT	214
Electrolyser Hydrogen Purification Package Pre-Commissioning	60
Electrolyser Stacks and BOP Pre-Commissioning & Commissioning	819

5.1.3 Start-Up phases duration estimation

Activity	Duration (h)
Unit Settings on the START mode	24
Stack's polarization	8
Hydrogen Setpoint Achievement	4
Functionality of electrolyser's Sequences during Operation	46
Hydrogen Leak Detection	40
Safety Stops at 10%	8
Increasing current by 10% up to 100%	54
Production Settings at 100%	4
HPP Start-Up	48

5.1.4 Vendor Assistance

Vendor Elogen will lead and/or supervise the onshore commissioning activities. For offshore commissioning Elogen will provide remote support.

5.1.5 Summary of interface signals to be tested:

Please refer to the following documents;

- ELO-INN-BPH-OTH-00009 – Communication table
- ELO-INN-BPH-SPC-00010 - Electrolyser Network Architecture

5.2 OTP Test Requirements – Onshore WORKSITE

5.2.1 Pre-Commissioning Achievement

Prior to commencement of commissioning activities, the relevant pre-commissioning documentation be fully signed.

5.2.2 Commissioning Achievement

The commissioning achievement will be the full successful operation, functionality and integration of the Hydrogen Fuel Cell package installed on BLPH.

5.2.3 Status of Required Associated Subsystems

- PHASE 3

Subsystems required RFC for Commissioning of the Electrolyser Package

- 25-01 to 25-08 (Partial): Hydrogen Storage Vessels & Header
- 43-00: Hydrogen Vent Header and Drum System
- 50-10: Water Desalination Package & Distribution
- 50-11: Non-Oxidant Biocide
- 55-00: Waste Water Disposal
- 55-01: Waste Water Brine Discharge System
- 63-00: Instrument Air Package (A-63000)
- 63-30: Instrument Air Distribution Network
- 64-00: Nitrogen Generator Package (U64000)
- 64-10: Nitrogen Distribution Network
- 70-00: F&G Control System
- 70-11: F&G Devices FZ-02 (Hydrogen Storage Area)
- 70-12: F&G Devices FZ-03 (Electrolyser Area)
- 79-00: Emergency Shutdown Systems (SIS)
- 79-12: Emergency Shutdown Systems (SIS) – Devices FZ-03 (Electrolyser Area)
- 82-00: MV 6.6 kV Switchboard (SG-100D1)
- 82-20: Power Transformer 3.15 MVA
- 82-99: MV 6.6 kV Temporary Yard Supply Integrated Test
- 83-00 400V Switchboard SG200N1
- 83-20 Distribution board
- 83-99: Temporary Yard 400/230V Main and auxiliary power supplies
- 87-00: EMCS
- 87-10: PCS
- 88-00: Earthing System

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5.2.4 Special Tools & Test Equipment

The following special tool and Test Equipment are required:

- Toolboxes: screwdrivers, spanners, pliers, wrenches, pipe wrenches.
- ATEX Field telephone or Walkie-Talkie.
- Leak detector sprays.
- VARIOTEC°460 Tracer gas.
- Chronometer.
- Personal hydrogen detectors for each people on site, calibrated up to date.

All equipment used must have a serial number and a valid calibration certificate up to date (if applicable).

TESTING & MEASUREMENT INSTRUMENT USED			
Type	Serial N.	Calibration certificate	Validity

5.2.5 Commissioning Spare Parts

- See reference document ELO-CMM-BPH-PRD-00006 - BLPH Electrolyser Commissioning Start-Up (CSU) Execution Plan

5.2.6 Temporary Facilities

Phase 3: Temporary emergency stop and/or fire and gas detection may be required if deemed necessary after suitable risk assessment. This will depend on the availability of interacting sub-systems.

5.3 OTP Description – Onshore WORKSITE

5.3.1 OTP Test Preparation

Step	Description	Result	Verified by	Date
1	System Ready for Commissioning Certificate (RFC) is issued and approved.			
2	No Mechanical Completion or Pre-commissioning punch list 'A' items are outstanding against the system to be commissioned.			

Step	Description	Result	Verified by	Date
3	All personnel involved in the implementation of this procedure are familiar with its content as well as with associated safety requirements (Toolbox Talk to be conducted before initiation of activities).			
4	A final walkdown of the system has been completed, to ensure that the system and the area are ready for commissioning.			
5	Check that areas are free for work and escape routes are clear of any obstructions.			
6	All safety barriers and warning signs have been installed.			
7	Ensure that proper communications have been established between parties involved in the implementation of the procedure.			
8	Verify availability of test equipment and spares as per section 5.2.			
9	With reference to Commissioning Temporary equipment & Facilities (refer on Doc. 123A90-PML-COM-SP-03014), check that power is available to any temporary equipment or test equipment (if any).			
10	System(s) isolations as per LOTO procedure defined within HSSE Permits to Work and Commissioning procedures duly prepared and approved			
11	All yard personnel have been duly notified by dedicated LUN (Livening Up Notification) that the system(s) is ready for commissioning.			

5.3.2 Electrical Preparation

Step	**Description**	**Result**	**Verified by**	**Date**
1	Check related punch list 'B' items and confirm acceptability for start of commissioning activities.			
2	Verify that all relevant associated systems / subsystems are completed.			
3	Check that grounding and bonding are in accordance with applicable documents.			

Step	Description	Result	Verified by	Date
4	Verify and confirm the correct circuit breaker protection settings according to latest documentation.			
5	Verify and confirm the completion of the final connections between the LV 400V Switchboard and the Electrolyser, the MV 6.6kV and Electrolyser, and the EMCS.			
6	Assess the need for additional temporary F&G or E-Stop protection during ONSHORE phases and implement necessary changes.			

5.3.3 Mechanical Preparation

Step	Description	Result	Verified by	Date
1	Check the correct flow direction of the valves.			
2	Confirm leak testing is complete and documented.			
3	Confirm mechanical alignment of all package pumps & equipment.			
4	Ensure package PSV setpoints are correct for the designed operating pressure.			
5	Ensure all unnecessary isolations are removed and vent system is ready to receive hydrogen.			

5.3.4 Instrument Preparation

Step	Description	Result	Verified by	Date
1	Check related punch list 'B' items and confirm acceptability for start of commissioning activities.			
2	Verify that all relevant associated systems / subsystems are ready.			
3	Check Inhibit and Override register has been prepared and validated.			
4	Verify that relevant equipment/ components are available and in operation for start of commissioning activities.			

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Step	Description	Result	Verified by	Date
5	Verify availability of test equipment as per section 5.2.4.			

5.3.5 Piping Preparation

Step	Description	Result	Verified by	Date
1	Ensure Treated Water supply connection is correctly connected to the Rosetti system at TP-001			
2	Ensure Nitrogen supply connection is correctly connected to the Rosetti system at TP-046			
3	Ensure Instrument Air supply connection is correctly connected to the Rosetti system at TP-047			
4	Ensure Hydrogen Vent connection is correctly connected to the Rosetti system at TP-003			
5	Ensure Hydrogen Storage connection is correctly connected to the Rosetti system at TP-006			
6	Ensure Waste Water output connection is correctly connected to the Rosetti system at TP-004			
7	Ensure Brine Discharge output connection is correctly connected to the Rosetti system at TP-005			
8	Review Rosetti flange management and confirm all interface connections have been torqued and leak tested with details recorded and signed for.			
9	Ensure Blind flange/ positive isolation is in place at test boundary.			

5.3.6 Additional Discipline Preparation

Not applicable.

5.4 Test Steps – Onshore WORKSITE - PHASES 1-2 (NOT PART OF THIS OTP)

The previous chapters must be successfully performed prior to commissioning of the Electrolyser Package.

Pre-commissioning (powered) activities listed in ELO-CMM-BPH-PRD-00008 (NOT PART OF THIS OTP).

Commissioning (powered) activities listed in ELO-CMM-BPH-PRD-00010 (NOT PART OF THIS OTP).

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5.4.1 OTP Steps WORKSITE - PHASE 3

It is foreseen that previous sections are successfully performed.

In the following steps the functionality of the Electrolyser package shall be tested for operation in all BLPH operating modes.

5.4.1.1 Electrolyser Integrated Testing ONSHORE

This section gives all the steps to perform the Unit Start-Up. The Unit Start-Up Test Report Table in section 7 gives the steps that must be followed progressively. While going through the procedure, complete the columns "Completed by", "Witnessed by" and "Date".

During the Start-Up Procedure follow up, the current fed into the electrolysis stacks is increased from 10% to 100% until reaching the maximum capacity of hydrogen production (500 Nm^3/h). The success in the execution of this procedure depends also on O&M vendors package correct application.

Despite the pre-settings established on the valves previously, some tunings can be performed during the ramp-up.

5.4.1.2 Setting the machine at START mode

Select the Local mode via the Local/Remote/Maintenance switch on the electrical cabinet (See below an example of Local/Remote/Maintenance mode physical switch).



Log into the HMI as "Expert": See below an example of pop-up displayed for log into the HMI:

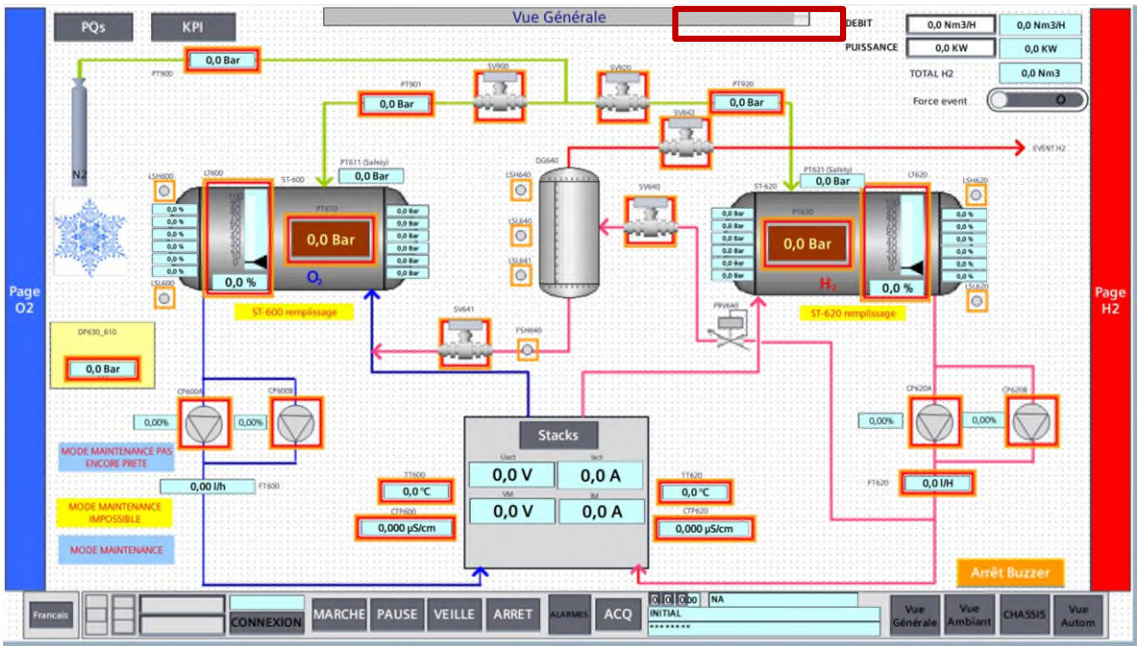
⚠	**Only Elogen staff is responsible for commissioning and maintenance is allowed to use the "Expert" mode. Elogen cannot be held responsible for any malfunctions resulting from unauthorized access to this operating mode.**

Acknowledge all the alarms. Check that the area is clear and all personnel are ready and in position.

Once the installation is powered-on, the user must log in and the HMI shows no alarms displayed, at this point the electrolyser is automatically set to **"STOP"** mode.

⚠	If a "Major" or Safety" fault is present, do not operate the system until troubleshooting the source of the fault and resetting the systems into its normal status.

To start the hydrogen production the electrolyser must be switched into the "START" mode. To do so, enter a desire hydrogen flowrate on the indicated area (for the first time enter 10% of the nominal flowrate, hence 50 Nm³/h) See below HMI Display.



Set admissible pressure range for the hydrogen buffer tank downstream of the hydrogen purification unit (if applicable).
Push the "START" button on the HMI display.
At this point the available oxygen and hydrogen loop pumps (CP-600A or CP-600B and CP-620A or CP-620B) start running automatically according to the regulating function set in the Electrolyser's PLC.

5.4.1.3 Stack's Polarization

Within the start-up sequence, the HVAC system will automatically start-up. The stacks will be polarized as soon as the temperature of 3°C is achieved in the HVAC Loop (HVAC subsystem is used to cool the water passing through the heat exchangers HE-630/631 and HE-600 below its setpoint TT-60X LR). When HVAC Loop is ready, the stacks are polarized at 132.5V (1.25V per cell x 106 cells).

Note: From previous observations, in regard of the possible fluctuations of stacks voltage, it is considered that the polarization point can be achieved once the voltage per stacks is above 119.25 V (so 530 V per rectifier).

5.4.1.4 Hydrogen Production

With the stacks polarised and the 3 °C in the cooling loop reached, the stacks start to produce hydrogen up to the selected setpoint (previously set at 50 Nm^3/h in 10.1). Since the stacks are cold (temperature at inlet TT-600 < 50 °C), the current supplied by the rectifiers to the stacks follows a ramp up limited up to 763 V (and 423 A) at this stage to protect the stacks. This value corresponds to a maximum of 1.8 V per cell (checked through the PCA-00X with X as A, B, C… H). Fluctuations of this value are admissible up to 2.1 V per cell at this stage (890.4 V per rectifier). In case of exceeding the set point stacks inlet temperature (TT-600/TT-620 > 50 °C), the voltage ramp-up is stopped until the temperature goes below 50°C.

Once the temperature of 50 °C is reached (TT-600/TT-620), the electrolyser goes automatically to the "hot start" step. At this stage the operator can set a new hydrogen flowrate set point. During "hot start", the current is incremented by 20A/s.

5.4.1.5 Functional Tests at 10%

From the first molecules produced of hydrogen and oxygen (i.e. current above polarization point), the pressure of both tank separators (ST-600 and ST-620) starts to rise. The delta of pressure between both tanks is managed automatically via a regulation function R-DPC-001. Fill the Check sheet in 11.2. Check the conformity of the control function while the pressure fluctuates (cf. Table in section 7.2). Observe if the corresponding valves open (PV- 631 and MPV-611), and the speed variator VAR-600 is set at the corresponding value, according to the delta pressure.

The regulation of delta pressure keeps on until the pressure at both tank separators reaches the nominal values, 31 barg at hydrogen side (cathodic side), and 11 barg at oxygen side (anodic side). Check the execution of the regulating function R-DPC-001 and take note of the pressurisation time (elapsed from selecting START mode on the HMI until reaching 11 and 31 barg).

While the tank separators are being pressurised, the hydrogen produced on the water / hydrogen loop is sent to the HPP, where the remaining oxygen and water are removed, and this flow is then routed to the vent. In normal operation, the treated hydrogen is then sent to the limit of battery.

Once the operation is stabilised at 10% of nominal flowrate (50 Nm^3/h), some sequences functional test and regulating functions can be achieved. In the Check Sheet, the functions in **bold** required special attention and need to be checked in START mode at 10% of the hydrogen production capacity.

As usual at this stage of Unit Start-Up, some PID (proportional, integral, derivative) tunings can be performed by the automation engineer.

Note: The duration to reach the nominal pressure depends on the flowrate setpoint. The higher the setpoint is, faster is the pressurisation.

5.4.1.6 Leak Checks

While the sequence and regulating functions are being tested, check that there are no leaks on the pipes or equipment. Use the hydrogen tracer gas device (Variotec 460 Tracergas). Any leak

detected must be repaired immediately. If needed, the unit can be stopped, depressurized and purged with nitrogen.

5.4.1.7 Safety Stops at 10%

During START mode when hydrogen is being produced at 10% of the nominal flowrate, the safety stops shall be tested. However, since all safety loops were already triggered/simulated during Commissioning phase (cf. ELO-CMM-BPH-PRD-00010), at this stage, the compliance of safety loops in START mode could be checked by triggering one of the emergencies stop buttons (ESD-00X). Check that all the effects represented in the Cause & Effect diagram are performed for the selected ESD (cf. Cause & Effect diagram-C63-PWI-002).

During commissioning and Start-up, the machine is subject to different tests, therefore the circuit breakers are in high demand. For this reason, the number of Safety stops limit that could be trigger within 24 hours is given by the number of cycles till 10% of the components fails (B10D). For these circuit breakers, it is $2x10^7$ cycles (ref. PLC-RSC- 24DC/21). Hence, to limit the wear of the circuit breakers during commissioning and start-up phase, it is recommended to trigger a maximum of 3 safety stops per day during the whole commissioning period (2 months). So, the number of cycles used will be restricted to 0.001% of the total.

5.4.1.8 Increasing current from 10% up to 100%

This section aims to increase slowly the hydrogen production from 10% of nominal capacity up to 100%. Since it is the first ramp up of the unit, the current will be increased by 10% manually. Set the flowrate as explained on section 10.1.

Percentage of nominal capacity	H_2 flowrate setpoint [Nm^3/h]
10%	50
20%	100
30%	150
40%	200
50%	250
60%	300
70%	350
80%	400
90%	450
100%	500

Once the hydrogen setpoint is changed, the current fed into the stacks start to increase. Follow the voltage ramp-up and take note of this transition duration. Wait until the flowrate of hydrogen produced is stable.

Let the system run at steady state (variations on the flowrate below 2% of the setpoint) at each setpoint for 15 minutes minimum and check for normal operation and the execution of regulating and functional sequences.

5.4.1.9 Setting production at 100%

Once reached the 500 Nm3/h, let the system run at steady state and check for no hydrogen leaks as previously explained (see section 10.5).

Check the compliance of the regulating sequences at 100% of capacity. Especially the Glycol loop flowrate, the direct balancing regulation and in general good overall control and absence of defaults. Use a copy of 11.2 table in Appendix to record these functions compliances. The functions in **bold** must be tested in START at 100% of the hydrogen production capacity.

5.4.1.10 HPP Start-Up

As presented in the Commissioning Manual (cf. ELO-CMM-BPH-PRD-00010), the HPP must be subject to a series of test before bringing process gas into the system. The activities described in this section must be carried out with hydrogen, since the HPP performance, and particularly the heaters, work differently with hydrogen compared to nitrogen or other inert gas.

Hence, after assuring a hydrogen production up to maximum capacity by the electrolyser (100% of nominal flowrate), the adjustment of the performance of the HPP can be carried out to test the compliance of the global process through the reading of the OIHA-800A/B/C and DPT-800A/B/C.

All instructions and information related to the installation and commissioning of the HPP are given in the document DEDR 500/36 Installation, Commissioning, Operation and Maintenance Manual. Here, the activities are summarised and presented in a table format along with the columns "Completed by", "Witnessed by" and "Date", to help the staff to check the compliance of each step while going through the procedure.

The commissioning and performance procedure for the HPP that requires process gas, and is deployed into three main stages:

5.4.1.11 Start of the Deoxo-Dryer

The "Deoxo" is a vessel reactor pre-filled with a catalyst where the oxygen remaining reacts with the hydrogen to produce water, which is later removed through the Dryer. Follow the instructions given the Test Report in section 7.3.1 to start the operation on the Deoxo-Dryer.

⚠	**The Dryer is sensitive to high gas flow velocities since this might cause lifting of the catalyst and desiccant beads. It is therefore very important that an empty gas system always is filled very slowly. It is recommendable to install a pressure maintaining valve in the discharge pipe downstream of the DEDR.**

5.4.1.12 Flow control positioner

In this unit, the gas inlet is divided into two streams, one sent to the heater for regeneration of one of the dryer vessels, and another one going to the active dryer. This enables the recirculation of the process gas during the regeneration process, and to avoid any loss of gas in this process. Hence, a flow controller positioner (FC-64.1) is placed to distribute the flow going through the valves 64-V5 and 64-V6 (cf. P&ID 20230443 DEDR-500_36).

During regeneration stage, approximately 25% of the flow is sent to the heater. Then, the positioner is pre-set at delivery as: zero point at 25% and span at 50%.

The flow sent to the heater must be it to enable a heating time of 75-95% of the heating time. If the heater is ON for more than 95% of the time, it means that the flow is slightly too high. If the heater is ON for less than 75%, it means that the flow is slightly too low. Follow the instructions given in section 11.3.2 to adjust the heater ON vs OFF time.

5.4.1.13 Setup of pressurized condensation system

The DEDR integrates a pre-set condensation water system operating between 8-36 barg of process gas pressure. This pressure is measured at the PT-64.1 (cf. P&ID 20230443 DEDR-500_36) and controlled by a Pbar factor, a parameter to close the drain valve for condensate accumulated at the bottom of the vessels (Deoxo and both Dryers).

As a start point, set this parameter as 50% of the nominal pressure (0.5 x 31 barg = approx. 15 barg). If the alarm PSA 64.1 L is triggered, it means that the system is clogged or that the Pbar factor is set too high. If the drain valve closes directly after it has been opened, but there remains water to be drained, the Pbar factor is set too low. If the drain valve does not close after there is no more water to be drained, the Pbar factor is set too high. Follow the instructions given in section 7.3.3 to set the condensation system.

Consult the DEDR 500/36 Installation, Commissioning, Operation and Maintenance Manual for more information about how to find the correct setting for the Pbar factor.

Once the performance of the HPP has been tested in all the flowrate range (10-100% of nominal), check the conformity of the hydrogen purity (through the reading of the OIHA-800A/B/C and DPT-800A/B/C). Both measures must be below 5 ppmv (i.e. impurities 10 ppmv which corresponds to 0.001%vol).

At this point, when a hydrogen production at maximum capacity is stabilised, along with the HPP operation, the performance test of the whole unit can be carried out. Follow the respective procedure given in the document C063-ELO-PRO-CO-0006 and complete the control list given on the same document.

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5.4.1.14 Electrolyser Integrated Testing ONSHORE Notes and Remarks

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5.4.1.15 Testing of EMCS Operating modes ONSHORE

Step	Description	Result	Verified by	Date
Electrolyser operating modes to be controlled from PCS via ECMS. Gas Production set point of Electrolyser to be agreed prior to test based on current site conditions/limitations.				
1	Confirm on PCS that CCS operating mode is in "IDLE". Confirm Electrolyser Package runs through start up sequence and progresses to H2 production at specified set point .			
2	On PCS, change CCS operating mode to "IMPORT (MODE 1A)". Confirm Electrolyser Package continues to produce H2 at specified set point.			
3	On PCS, change CCS operating mode to "IMPORT (MODE 1B)". Confirm Electrolyser Package progresses to STOP mode, with Unit cooled, depressurised & depolarised, and Chiller OFF.			
4	On PCS, change CCS operating mode to "HOT STANDBY". Confirm Electrolyser remains in STOP.			
5	On PCS, change CCS operating mode to "EXPORT". Confirm Electrolyser remains in STOP.			
6	On PCS, change CCS operating mode to "COLD STANDBY". Confirm Electrolyser remains in STOP.			
7	On PCS, change CCS operating mode to "EMERGENCY (Island Mode)". Confirm Electrolyser remains in STOP.			
8	On PCS, change CCS operating mode to "MAINTENANCE". Confirm Electrolyser can only be operated locally.			
9	On PCS, return CCS operating mode to "IMPORT (MODE 1A)". Confirm Electrolyser Package runs through start up sequence and progresses to H2 production at specified set point .			
10	On PCS, return CCS operating mode to "COLD STANDBY". Confirm Electrolyser Package progresses to STOP mode, with Unit cooled, depressurised & depolarised, and Chiller OFF.			

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Full details of the EMCS HMI control graphics can be found in Document Number: 123A90-DDL-EL-SP-20039 Functional and Technical Design Specification, IDS and DDS for Electrical Monitoring and Control System (EMCS)

5.4.1.16 Electrolyser Integrated Testing ONSHORE - Certifying Authority Table of Attendances

Name and Surename	Certifying Authority	Position	Signature

5.4.1.17 Electrolyser Integrated Testing ONSHORE - Final Signatures and Company Acceptance

Name and Surname	Company Representative	Position	Signature
Name and Surename	**Certifying Authority**	**Position**	**Signature**

6 OTP AT SITE

6.1 Planning and Manpower

6.1.1 Offshore Site overview

It is expected that all pre-commissioning tests, systems energization and commissioning steps will have been successfully performed during the Onshore Phases.
Consequently, during the offshore SITE phase, the respective systems will be inspected prior to re-energization.
No additional test steps will be required on these items of equipment, correct operation and functioning will be verified.

6.1.2 Planned tasks with estimated manpower

Activity	Staff qualifications	Advised presence
Safety Stops at 10%	1 engineer and 1 automation engineer	
Increasing current by 10% up to 100%	1 automation engineer	
Production Settings at 100%	1 automation engineer	
HPP Start-Up	1 automation engineer	1 technician from Aquagas

6.1.3 Test duration estimate

Activity	Duration (h)
Safety Stops at 10%	8
Increasing current by 10% up to 100%	54
Production Settings at 100%	4
HPP Start-Up	48

If necessary, the estimated time can be extended to complete all required pre-commissioning and commissioning activities.

6.1.4 Vendor Assistance

- For offshore commissioning Elogen will provide onsite support.

6.1.5 Items Postponed to C&E OTP

- Not Applicable

6.1.6 HOLDS

- Not Applicable

6.2 OTP Test Requirements – Offshore SITE

6.2.1 Pre-Commissioning Achievement

- Not applicable

6.2.2 Commissioning Achievement

The commissioning achievement will be the full successful operation, functionality and integration of the Electrolyser package installed on BLPH.

The successful commissioning result, achieved during the WORKSITE commissioning phase for the functionality and safeguard of the Electrolyser Package, will allow for a smoother commissioning phase of the offshore SITE.

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- PHASE 4

Subsystems required RFC for OFFSHORE Commissioning of the Electrolyser Package

- 25-01 to 25-08: Hydrogen Storage Vessels & Header
- 43-00: Hydrogen Vent Header and Drum System
- 50-10: Water Desalination Package & Distribution
- 50-11: Non-Oxidant Biocide
- 55-00: Waste Water Disposal
- 55-01: Waste Water Brine Discharge System
- 63-00: Instrument Air Package (A-63000)
- 63-30: Instrument Air Distribution Network
- 64-00: Nitrogen Generator Package (U64000)
- 64-10: Nitrogen Distribution Network
- 70-00: F&G Control System
- 70-11: F&G Devices FZ-02 (Hydrogen Storage Area)
- 70-12: F&G Devices FZ-03 (Electrolyser Area)
- 79-00: Emergency Shutdown Systems (SIS)
- 79-12: Emergency Shutdown Systems (SIS) – Devices FZ-03 (Electrolyser Area)
- 81-20: Power Transformer 7 MVA (TR-100AD1)
- 81-10: GIS 66 kV (HNA6-AFA70)
- 81-00: 66 kV Subsea Cable
- 82-00: MV 6.6 kV Switchboard (SG-100D1)
- 82-20: Power Transformer 3.15 MVA
- 83-00 400V Switchboard SG200N1
- 83-20 Distribution board
- 87-00: EMCS
- 87-10: PCS
- 88-00: Earthing System

6.2.3 Special Tools & Test Equipment

The following special tool and Test Equipment are required:

- Toolboxes: screwdrivers, spanners, pliers, wrenches, pipe wrenches.
- ATEX Field telephone or Walkie-Talkie.
- Leak detector sprays.
- VARIOTEC°460 Tracer gas.
- Chronometer.
- Personal hydrogen detectors for each people on site, calibrated up to date.

TESTING & MEASUREMENT INSTRUMENT USED			
Type	Serial N.	Calibration certificate	Validity

6.2.4 Consumable List

- Not applicable

6.2.5 Commissioning Spare Parts

- See reference document ELO-CMM-BPH-PRD-00006 - BLPH Electrolyser Commissioning Start-Up (CSU) Execution Plan

6.2.6 Temporary Facilities

- Not applicable

6.3 OTP Description – SITE

The SITE test will consist of a repeat of the onshore integration testing with the BLPH now installed in situ to its permanent connections. In the following steps the functionality of the Electrolyser package shall be tested for operation in all BLPH operating modes.

6.3.1 OTP Test Preparation

Step	Description	Result	Verified by	Date
1	System Ready for Operation (RFO) Certificate is issued and approved.			
2	No blocking punch list items are outstanding against the system to be commissioned.			
3	System(s), (de)isolations as per LOTO procedure enclosed within commissioning Work Permits procedures prepared and approved			
4	Verify and confirm that all steps performed at WORKSITE of this procedure are completed without any pending issues that would prevent from proceeding with the offshore SITE PROCEDURE			

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Step	Description	Result	Verified by	Date
5	All personnel involved in the implementation of this procedure are familiar with this procedure as well as with associated safety requirements (Toolbox Talk to be conducted before initiation of activities).			
6	A final walkdown after hook-up of the system has been completed, any preservation items have been removed and to ensure that the system and the area are ready for energization.			
7	Check that areas are free for work and escape routes are clear of any obstructions.			
8	Ensure that proper communications have been established between parties involved in the implementation of the procedure.			
9	Verify availability of test equipment and consumables as per chapters 6.2.4.			
10	All personnel have been duly notified during dedicated daily SIMOPS meetings that the system(s) is ready for operation.			

6.3.2 Electrical Preparation

Step	Description	Result	Verified by	Date
1	Check related punch list 'B' items and confirm acceptability for start of commissioning activities.			
2	Verify that all relevant associated systems / subsystems are completed.			

6.3.3 Mechanical Preparation

Step	Description	Result	Verified by	Date
1	No blocking punch list items are outstanding against the system to be commissioned.			
2	Ensure all unnecessary isolations are removed.			
3	Ensure downstream systems are ready to receive H2.			

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6.3.4 Instrument Preparation

Step	Description	Result	Verified by	Date
6	Check related punch list 'B' items and confirm acceptability for start of commissioning activities.			
7	Verify that all relevant associated systems / subsystems are ready.			
8	Check Inhibit and Override register has been prepared and validated.			
9	Verify that relevant equipment/ components are available and in operation for start of commissioning activities.			
10	Verify availability of test equipment as per section 5.2.4.			

6.3.5 Piping Preparation

Not applicable

6.3.6 Additional Discipline Preparation

Not applicable.

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6.4 OTP Test Steps – Offshore PHASE 4

The previous chapters must be successfully performed prior to commissioning of the Electrolyser Package.

In the following steps the functionality of the Electrolyser package shall be tested for operation in all BLPH operating modes.

6.4.1.1 Electrolyser Integrated Testing OFFSHORE

This section gives all the steps to perform the Unit Start-Up. The Unit Start-Up Test Report Table in section 7 gives the steps that must be followed progressively. While going through the procedure, complete the columns "Completed by", "Witnessed by" and "Date".

During the Start-Up Procedure follow up, the current fed into the electrolysis stacks is increased from 10% to 100% until reaching the maximum capacity of hydrogen production (500 Nm^3/h). The success in the execution of this procedure depends also on O&M vendors package correct application.

6.4.1.2 Setting the machine at START mode

Select the Local mode via the Local/Remote/Maintenance switch on the electrical cabinet (See below an example of Local/Remote/Maintenance mode physical switch).



Log into the HMI as "Expert": See below an example of pop-up displayed for log into the HMI:

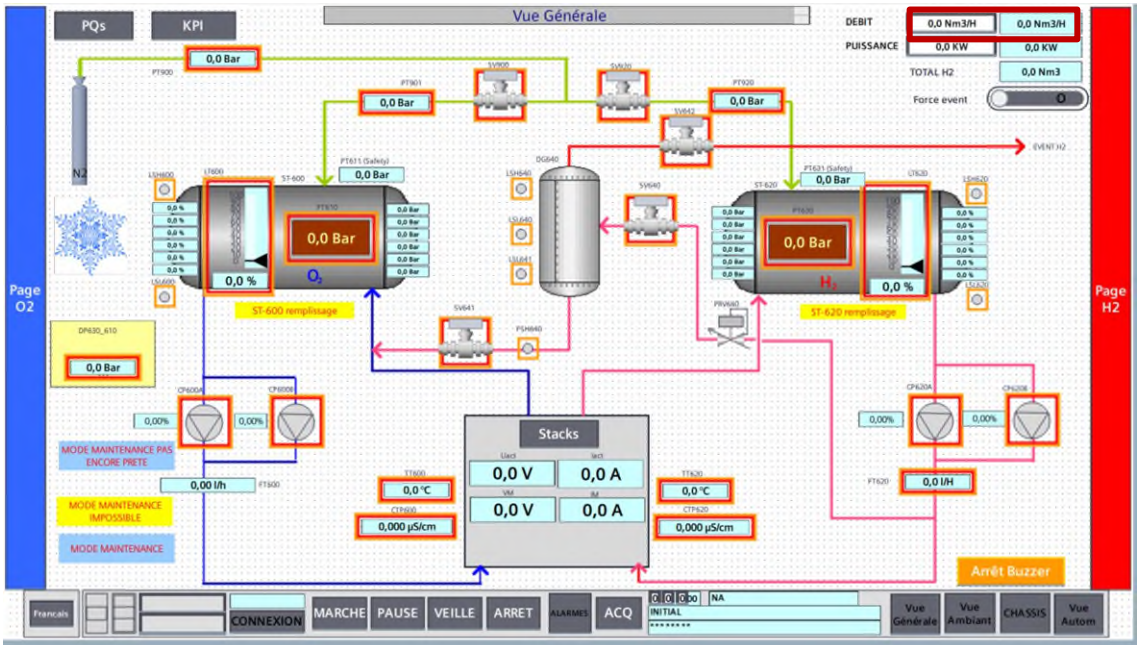
⚠	**Only Elogen staff is responsible for commissioning and maintenance is allowed to use the "Expert" mode. Elogen cannot be held responsible for any malfunctions resulting from unauthorized access to this operating mode.**

Acknowledge all the alarms. Check that the area is clear and all personnel are ready and in position.

Once the installation is powered-on, the user must log in and the HMI shows no alarms displayed, at this point the electrolyser is automatically set to **"STOP"** mode.

⚠	**If a "Major" or Safety" fault is present, do not operate the system until troubleshooting the source of the fault and resetting the systems into its normal status.**

To start the hydrogen production the electrolyser must be switched into the "START" mode. To do so, enter a desire hydrogen flowrate on the indicated area (for the first time enter 10% of the nominal flowrate, hence 50 Nm³/h) See below HMI Display.



Set admissible pressure range for the hydrogen buffer tank downstream of the hydrogen purification unit (if applicable).
Push the "START" button on the HMI display.
At this point the available oxygen and hydrogen loop pumps (CP-600A or CP-600B and CP-620A or CP-620B) start running automatically according to the regulating function set in the Electrolyser's PLC.

6.4.1.3 Stack's Polarization

Within the start-up sequence, the HVAC system will automatically start-up. The stacks will be polarized as soon as the temperature of 3°C is achieved in the HVAC Loop (HVAC subsystem is used to cool the water passing through the heat exchangers HE-630/631 and HE-600 below its setpoint TT-60X LR). When HVAC Loop is ready, the stacks are polarized at 132.5V (1.25V per cell x 106 cells).

Note: From previous observations, in regard of the possible fluctuations of stacks voltage, it is considered that the polarization point can be achieved once the voltage per stacks is above 119.25 V (so 530 V per rectifier).

6.4.1.4 Hydrogen Production

With the stacks polarised and the 3 °C in the cooling loop reached, the stacks start to produce hydrogen up to the selected setpoint (previously set at 50 Nm³/h in 10.1). Since the stacks are cold (temperature at inlet TT-600 < 50 °C), the current supplied by the rectifiers to the stacks follows a

ramp up limited up to 763 V (and 423 A) at this stage to protect the stacks. This value corresponds to a maximum of 1.8 V per cell (checked through the PCA-00X with X as A, B, C… H). Fluctuations of this value are admissible up to 2.1 V per cell at this stage (890.4 V per rectifier). In case of exceeding the set point stacks inlet temperature (TT-600/TT-620 > 50 °C), the voltage ramp-up is stopped until the temperature goes below 50°C.

Once the temperature of 50 °C is reached (TT-600/TT-620), the electrolyser goes automatically to the "hot start" step. At this stage the operator can set a new hydrogen flowrate set point. During "hot start", the current is incremented by 20A/s.

6.4.1.5 Safety Stops at 10%

During START mode when hydrogen is being produced at 10% of the nominal flowrate, the safety stops shall be tested. However, since all safety loops were already triggered/simulated during Commissioning phase (cf. ELO-CMM-BPH-PRD-00010), at this stage, the compliance of safety loops in START mode could be checked by triggering one of the emergencies stop buttons (ESD-00X). Check that all the effects represented in the Cause & Effect diagram are performed for the selected ESD (cf. Cause & Effect Diagram C63-PWI-002).

During commissioning and Start-up, the machine is subject to different tests, therefore the circuit breakers are in high demand. For this reason, the number of Safety stops limit that could be trigger within 24 hours is given by the number of cycles till 10% of the components fails (B10D). For these circuit breakers, it is $2x10^7$ cycles (ref. PLC-RSC- 24DC/21). Hence, to limit the wear of the circuit breakers during commissioning and start-up phase, it is recommended to trigger a maximum of 3 safety stops per day during the whole commissioning period (2 months). So, the number of cycles used will be restricted to 0.001% of the total.

6.4.1.6 Increasing current from 10% up to 100%

This section aims to increase slowly the hydrogen production from 10% of nominal capacity up to 100%. Since it is the first ramp up of the unit, the current will be increased by 10% manually. Set the flowrate as explained on section 10.1.

Percentage of nominal capacity	H_2 flowrate setpoint [Nm^3/h]
10%	50
20%	100
30%	150
40%	200
50%	250
60%	300
70%	350
80%	400
90%	450
100%	500

Once the hydrogen setpoint is changed, the current fed into the stacks start to increase. Follow the voltage ramp-up and take note of this transition duration. Wait until the flowrate of hydrogen produced is stable.

Let the system run at steady state (variations on the flowrate below 2% of the setpoint) at each setpoint for 15 minutes minimum and check for normal operation and the execution of regulating and functional sequences.

6.4.1.7 Setting production at 100%

Once reached the 500 Nm3/h, let the system run at steady state and check for no hydrogen leaks as previously explained (see section 10.5).

Check the compliance of the regulating sequences at 100% of capacity. Especially the Glycol loop flowrate, the direct balancing regulation and in general good overall control and absence of defaults. Use a copy of 11.2 table in Appendix to record these functions compliances. The functions in **bold** must be tested in START at 100% of the hydrogen production capacity.

6.4.1.8 Testing of EMCS Operating modes OFFSHORE

Step	Description	Result	Verified by	Date
Electrolyser operating modes to be controlled from PCS via ECMS. Gas Production set point of Electrolyser to be agreed prior to test based on current site conditions/limitations.				
1	Confirm on PCS that CCS operating mode is in “IDLE”. Confirm Electrolyser Package runs through start up sequence and progresses to H2 production at specified set point .			
2	On PCS, change CCS operating mode to “IMPORT (MODE 1A)”. Confirm Electrolyser Package continues to produce H2 at specified set point.			
3	On PCS, change CCS operating mode to “IMPORT (MODE 1B)”. Confirm Electrolyser Package progresses to STOP mode, with Unit cooled, depressurised & depolarised, and Chiller OFF.			
4	On PCS, change CCS operating mode to “HOT STANDBY”. Confirm Electrolyser remains in STOP.			
5	On PCS, change CCS operating mode to “EXPORT”. Confirm Electrolyser remains in STOP.			

Step	Description	Result	Verified by	Date
6	On PCS, change CCS operating mode to "COLD STANDBY". Confirm Electrolyser remains in STOP.			
7	On PCS, change CCS operating mode to "EMERGENCY (Island Mode)". Confirm Electrolyser remains in STOP.			
8	On PCS, change CCS operating mode to "MAINTENANCE". Confirm Electrolyser can only be operated locally.			
9	On PCS, return CCS operating mode to "IMPORT (MODE 1A)". Confirm Electrolyser Package runs through start up sequence and progresses to H2 production at specified set point .			
10	On PCS, return CCS operating mode to "COLD STANDBY". Confirm Electrolyser Package progresses to STOP mode, with Unit cooled, depressurised & depolarised, and Chiller OFF.			

Full details of the EMCS HMI control graphics can be found in Document Number: 123A90-DDL-EL-SP-20039 Functional and Technical Design Specification, IDS and DDS for Electrical Monitoring and Control System (EMCS)

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6.4.1.9 Electrolyser Integrated Testing OFFSHORE Notes and Remarks

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6.4.1.10 Electrolyser Integrated Testing OFFSHORE - Certifying Authority Table of Attendances

Name and Surename	Certifying Authority	Position	Signature

6.4.1.11 Electrolyser Integrated Testing OFFSHORE - Final Signatures and Company Acceptance

Name and Surname	Company Representative	Position	Signature
Name and Surename	**Certifying Authority**	**Position**	**Signature**

6.5 Post-test Conditions

After functional tests have been completed, system / sub-systems are left in healthy and safety condition and operational.

6.6 Reinstatement tasks

Generally, the system/ sub-system shall be reinstated at its initial condition; and the following activities must be carried out as minimum:

- all inhibition done for the test shall be removed (as per Inhibit / Override List)
- all equipment/devices shall be returned in healthy functional conditions.

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7 APPENDICES

7.1 Unit Start-up Test Report

Step	Description	Completed by	Witnessed by	Date
01	Select the LOCAL Mode.			
02	Log-in as “Expert” on the HMI.			
03	Check that all alarms are acknowledged, and all areas are clear.			
04	Check that Electrolyser is in STOP mode.			
05	Set the Hydrogen production at 50 Nm^3/h. (10% of hydrogen production).			
06	Press START and monitor the progression (Check that oxygen and hydrogen pumps CP-600A or B and CP-620A or B, and HVAC system are starting-up).			
07	Check that 3 °C is reached in the HVAC Loop system.			
08	Check that the stacks are polarized at 132.5 V.			
09	Check that the cold start-up is in good process (TT-600 < 50 °C). Separator tanks (ST-600 and ST-620) are being pressurized by the hydrogen produced. **Warning:** The voltage per stack must not exceed **222,6 V** (**890,4 V** per rectifier).			
10	Observe that hot start-up reached (TT-600> 50 °C). Ramp-up shifts to 20 A/s automatically.			
11	Check that the Pressure in separator tanks is being regulated via PV-631 and MPV-611, until reaching the nominal pressure on both loops (11 barg at ST-600 and 31 barg ST-620). At this point Hydrogen is routed to the HPP.			

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Step	Description	Completed by	Witnessed by	Date
12	Check if the production is stabilized at 50 Nm3/h of hydrogen (monitor FT-630) and the unit is working at its nominal pressure (11 barg at ST-600 and 31 barg at ST-620).			
13	Perform a Leak Check at 10% of nominal production.			
14	Check that all sequences and regulating functions are working as expected at 10 % of nominal flowrate (see table in section 11.2).			
15	Proceed to the Safety Test at 10% of nominal production are compliant (One ESD trigger).			
16	Do the ramp up manually and until 100% of Hydrogen production (cell voltage between the range and setting of current according to R-REC-001).			
17	Check that Hydrogen production stabilized at 100% (500 Nm3/h)			
18	Check that the sequences and controls are working as expected within the range of 10-100% of nominal flowrate.			
19	Check that the HPP is working as expected with an hydrogen quality produced as expected. OIHA-800A/B/C < 5 ppmv and DPT-800A/B/C < 5 ppmv			
21	Sequences and regulating functions are working as expected at 100 % of nominal flowrate (11.2 to be completed again for 100%).			
22	Perform a Leak Check at 100% of nominal production.			

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7.2 Test Report For Functional Tests

Function – Description. Tested at 10% or 100% of nominal flow[3]	Completed by	Witnessed by	Date	Comment
S-A5-001 – STOP in progress (from START/STANDBY/IDLE states)				
S-F2-001 – START in progress (from STOP)				
R-DPC-001 – Delta Pressure H2/O2 control (START) *If ΔP[4]> 21 barg, then PV-631 OPEN. If ΔP < 21 barg, then PV-631 CLOSED.* *If ΔP < 5 barg, then PV-631 CLOSED, MPV-611=100% OPEN, VAR-600 = VAR600_LR*				
R-LC-600 – ST-600 Water Level Control (Direct Injection) *If LT-600 < 38% & LT-300 > 20%[5], then LP-300 START. If LT-600 > 48%, then LP-300 STOP*				
R-LC-610 – CS-610 water level control *If LSH-610 COVERED[6] & VAR-300 = 0%, then SV-600 OPEN. If LSL-610 UNCOVERED or VAR-300 > 0%, then SV-600 CLOSED*				
R-LC-620 – ST-620 Water Level Control (Direct balancing) *If PT-630 > 11 barg & LT-620 > 54%, then SV-640 OPEN.* *If LT-620 < 35% or PT-630 < 11 barg, then SV-640 CLOSED.*				
R-LC-630 – CS-630 water level control If LSH-630 COVERED, then SV-620 OPEN. If LSL-630 UNCOVERED, then SV-620 CLOSED.				

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Function – Description. Tested at 10% or 100% of nominal flow[3]	Completed by	Witnessed by	Date	Comment
R-LC-642 – DG-640 Hydrogen Purge If LSL-640 UNCOVERED & SV-640 CLOSED & LSH-640 UNCOVERED & PT-630 > 20 barg & ΔP > 2 barg, then SV-642 OPEN. If LSH-640 COVERED, then SV-642 CLOSED.				
R-LC-500 – Water Level Control of H2 vent condensates If LSH-500 COVERED, then PV-500 OPEN. If LSL-500 UNCOVERED, then PV-500 CLOSED.				
R-PC-610 – Pressure Control Oxygen Loop If PT-610 > 11,5 barg, then MPV-611 = 100 % OPEN. If PT-610 < 10,8 barg, then MPV- 611 = 0% (CLOSED).				
R-PC-630 – Pressure Control Hydrogen Loop If PT-630 > 31,5 barg, then PV-631 OPEN. If PT-630 < 29,7 barg, then PV-631 CLOSED.				
R-REC-001 – Rectifier setting current. This function can be validated by comparing the hydrogen setpoint entered by the user and the flowrate measured by the FT-630.				
R-TC-600 – O2 Water Temperature Control Loop				
The M3WV-200 is commanded by a PID regulation, where the setpoint is TT-601 = 65 °C. Check that the TT-601 is stable and that the 3WV-200 opens to approach the setpoint.				

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Function – Description. Tested at 10% or 100% of nominal flow[3]	Completed by	Witnessed by	Date	Comment
S-PC-610 – O2 Depressurisation ΔP > 1 barg & ΔP < 21 barg & LT-600 < 50%, then MPV-611 = 100%. If PT-610 < 0,15 barg & PT-630 < 0,15 barg, then MPV-611 = 0%. If this sequence is still active after 20 minutes, MPV-611 = 0% and displayed "O2 depressurisation failed. Going to safety O2 depressurisation"				
S-PC-630 – H2 Depressurisation If PT-610 > 0,35 barg & ΔP < 21 barg & ΔP > 1 barg & LT-620 < 62%, the PV-631 OPEN. If ΔP < 1 barg, the PV-631 CLOSED. If LT-620 > 62%, then PV-631 CLOSED. If PT-630 < 0,15 barg, then PV-631 CLOSED.				
S-REC-001 – Stack polarization See section 5.4.1.3				
S-REC-003 – Stop rectifier (decreasing current) This function can be validated by an observed decrease in the hydrogen flowrate (measured by the FT-630)				

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7.3 HPP Start-Up Test Report

7.3.1 HPP commissioning performance adjustment and test – Start of Deoxo-Dryer

Step	Description		Completed by	Witnessed by	Date
01	Check inert gas is available and all connections have been checked against leakages.				
02	Check that instruments and electrical power are available.				
03	(If the DEDR has been opened against the atmosphere) Purge it with inert gas before feeding the hydrogen.				
04	Open cooling water to the coolers.				
05	Open the compressed hydrogen gas intake slowly. In case there is no valve to isolate the electrolyser and the HPP, once the previous steps completed, start the hydrogen production through the HMI at 10% of production (50 Nm3/h). And wait until the systems starts to be pressurised as described in previous sections.				
06	Check for leakages.				

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7.3.2 HPP Commissioning performance adjustment and test – Flow controller positioner

Step	Description	Completed by	Witnessed by	Date
01	Check that the PLC control have a linear output signal (0-100% = 4-20 mA)			
02	Check the positioner's output when no pilot pressure is supplied to the 64-V6. Positioner must indicate 100% open			
03	Test with pilot pressure: 4 mA: Positioner indicates 0% open. 8 mA: Positioner indicates ~10% open. 12 mA: Positioner indicates ~25% open 16 mA: Positioner indicates ~50% open. 20 mA: Positioner indicates ~75% open.			
04	Start the dryer in heating sequence at 100% of hydrogen nominal flow capacity.			
05	Check that positioner FC-64.1 indicates ~75% open.			
06	Adjust the by-pass needle valve 64-V14.1: count the turns from fully open to fully close and set it at 50% open.			
07	Partly close valve 64-V14 to about 50%.			
08	Wait 15 minutes and read the regeneration temperature (DR-TT-64-6 or DR-TT-64-8 depending on which tower is in regeneration sequence).			
09	If the temperature is below 155°C, partly close valve 64-V14 step by step until 155-160°C is reached. Wait 10-15 minutes between every step. You can also use by-pass needle valve 64-V14.1 for fine tuning,			
10	If the temperature is above 165°C, partly open valve 64-V14 step by step until 160-165°C is reached. Wait 10-15 minutes between every adjustment. Use the by-pass needle valve 64-V14.1 for fine tuning. If 155-160°C cannot be reached, increase the heater set point by 25°C and restart from step 04.			
	Check the heater ON vs OFF time. If the heater is ON between 75% and 95% of the heating time, proceed to the control of operation at 25-100%			

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11	capacity If ON time > 95%, then partly close the valve 64-V14 until the heater ON time drops to 75-95% of the time. If ON time < 75%, then partly open the valve 64-V14 until the heater ON time increase up to 75-95% of the time. Use the by-pass needle valve (64-V1431) for fine tuning. (Wait 15 minutes between every adjustment)			
12	Start the dryer in heating sequence at 75% of hydrogen nominal flow capacity (375 Nm3/h). From the electrolyser's HMI, as indicated in section 10.1			
13	Check that positioner indicates ~50% open.			
14	Wait 15 minutes and read the regeneration temperature (TT-64.6 or TT-64.8 depending on which tower is in regeneration sequence). If TT-64.6 or TT-64.8 < 155 °C, then remove the cover of the positioner and slightly increase the span until reaching 155-160 °C. If TT-64.6 or TT-64.8 > 165 °C, then slightly decrease the span until reaching 160-165 °C. (Wait 15 minutes between every adjustment)			
15	Start the dryer in heating sequence at 25% of hydrogen nominal flow capacity (125 Nm3/h). From the electrolyser's HMI, as indicated in section 10.1. Let it stabilise and run for 15 minutes.			
16	Ramp-up the hydrogen flow every 15 minutes by 25% (i.e. 25%, 50%, 75% and 100%).			
17	Check regeneration temperature (TT-64.6 or TT-64.8). It must be around 160 - 180 °C for the range of flowrates, if not, contact Aquagas for assistance.			

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7.3.3 HPP commissioning performance adjustment and test -Setup of condensation system

Step	Description	Completed by	Witnessed by	Date
01	Start the dryer at 100% of hydrogen nominal flow capacity (500 Nm^3/h) and let the system to stabilise.			
02	If the Pbar factor is set too high. Reduce it by a factor of 0.1 (ex. If initially set at 15 barg, then reduce it at 13.5 barg). If the Pbar factor is set too low. Increase it by a factor of 0.1 (ex. If initially set at 15 barg, then increase it at 16.5 barg). For both cases, repeat with a smaller difference if needed.			
03	Check if there is remaining water to be drained, by activating the solenoid valve 64-V12 and check how much water is coming out.			

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7.4 Vendor SAT Procedure

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7.5 Proverlis Summary System Reports

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7.6 Equipment Related Technical Queries

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7.7 As Built Documentation

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7.8 Management of Change – Summary Table of Tasks and Details of Affected Related Documentation

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