Base Load Power Hub (BLPH)

Operations and Maintenance Manuals

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Table of contents

1 INTRODUCTION 10
1.1 PROJECT OVERVIEW 10
1.1.1 Project Location 10
1.1.2 Project Concept 11
2 DOCUMENT SCOPE 13
3 REFERENCES 14
4 DEFINITIONS AND ABBREVIATIONS 17
5 SIMPLIFIED PROCESS DIAGRAM FOR THE SYSTEM ELECTRIFICATION 19
5.1 ELECTRICAL OPERATING MODES 20
5.2 ELECTRICAL SCENARIOS 24
5.2.1 Islanding 24
5.2.2 Recover From Island 24
5.2.3 Black Start 24
6 SEAWATER INTAKE SYSTEM 26
6.1 EQUIPMENT LIST AND DESIGN BASIS 26
6.2 OPERATING DATA 26
6.3 PROCESS DESCRIPTION (NORMAL OPERATION) 26
6.4 LOGIC CONTROL DESCRIPTION 28
6.5 INTERLOCK LOGIC DESCRIPTION 28
6.6 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 29
6.7 UNIT START UP PROCEDURE 34
6.7.1 Remote Mode Start Up 35
6.7.2 Local Mode Start Up 36
6.8 SHUTDOWN PROCEDURE 37
6.9 DEPRESSURIZATION PROCEDURE 37
6.10 PURGING PROCEDURE 37
6.11 PRESSURIZATION PROCEDURE 37
7 HYDROGEN STORAGE SYSTEM 38
7.1 EQUIPMENT LIST AND DESIGN BASIS 38
7.2 LOGIC CONTROL DESCRIPTION 39

7.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 40
7.4 INTERLOCK LOGIC DESCRIPTION 80
7.5 NORMAL OPERATION CONDITION 81
7.5.1 Charging Activity 81
7.5.2 Discharging Activity 82
7.6 UNIT START UP PROCEDURE 83
7.7 SHUTDOWN PROCEDURE 84
7.8 DEPRESSURIZATION PROCEDURE 84
7.9 PURGING PROCEDURE 85
7.9.1 Purging Operation With Nitrogen (For Air Displacement) 85
7.9.2 Purging Operation With Hydrogen (For Nitrogen Displacement) 104
7.9.3 Purging Operation With Nitrogen (For Hydrogen Displacement) 118
7.10 PRESSURIZATION PROCEDURE 135
8 WATER DISPOSAL 140
8.1 EQUIPMENT LIST AND DESIGN BASIS 140
8.2 LOGIC CONTROL DESCRIPTION 140
8.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 141
8.4 INTERLOCK LOGIC DESCRIPTION 145
8.5 NORMAL OPERATION CONDITION 145
8.5.1 Brine Discharge Caisson 145
8.5.2 Waste Water Tank 147
8.6 UNIT START UP PROCEDURE 147
8.7 SHUTDOWN PROCEDURE 147
8.8 DEPRESSURIZATION PROCEDURE 147
8.9 PURGING PROCEDURE 147
8.10 PRESSURIZATION PROCEDURE 147
8.11 EMPTYING PROCEDURE 147
9 HYDROGEN VENT 148
9.1 EQUIPMENT LIST AND DESIGN BASIS 148
9.2 LOGIC CONTROL DESCRIPTION 148
9.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 149
9.4 INTERLOCK LOGIC DESCRIPTION 154

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9.5 NORMAL OPERATION CONDITION 154
9.6 UNIT START UP PROCEDURE 154
9.7 SHUTDOWN PROCEDURE 154
9.8 DEPRESSURIZATION PROCEDURE 154
9.9 PURGING PROCEDURE 155
9.10 PRESSURIZATION PROCEDURE 156
10 INSTRUMENT AIR 157
10.1 EQUIPMENT LIST AND DESIGN BASIS 157
10.2 LOGIC CONTROL DESCRIPTION 157
10.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 158
10.4 INTERLOCK LOGIC DESCRIPTION 164
10.5 NORMAL OPERATION CONDITION 164
10.6 UNIT START UP PROCEDURE 164
10.7 SHUTDOWN PROCEDURE 165
10.8 DEPRESSURIZATION PROCEDURE 166
10.9 PURGING PROCEDURE 166
10.10 PRESSURIZATION PROCEDURE 166
11 NITROGEN SYSTEM 167
11.1 EQUIPMENT LIST AND DESIGN BASIS 167
11.2 LOGIC CONTROL DESCRIPTION 167
11.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS 169
11.4 INTERLOCK LOGIC DESCRIPTION 178
11.5 NORMAL OPERATION CONDITION 178
11.6 UNIT START UP PROCEDURE 178
11.7 SHUTDOWN PROCEDURE 179
11.8 DEPRESSURIZATION PROCEDURE 179
11.9 PURGING PROCEDURE 179
11.10 PRESSURIZATION PROCEDURE 179
12 EMERGENCY AND PROCESS SHUTDOWN 180
12.1 ASD-ESD-PSD LEVELS 180
12.2 INHIBIT FUNCTIONS RESTART SEQUENCE 182

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12.3 RESET FUNCTION 182

13 ESCAPE, EVACUATION AND RESCUE 183

13.1 BLPH PLATFORM PHILOSOPHY 183

13.2 F&G SYSTEM 183

13.3 ESCAPE AND EVACUATION STRATEGY 185

13.4 OPERATORS TRAINING REQUIREMENTS 187

13.5 HAZARDOUS AREA CLASSIFICATION 188

13.6 HEALTH AND SAFETY REQUIREMENTS 188

14 ELECTRICAL SYSTEM 189

14.1 OPERATING PHILOSOPHY 190

List of Figures

Figure 1 - HOLLANDSE KUST NOORD WIND PARK Location Map 10
Figure 2 - Wind Park Details 11
Figure 3 - BLPH Concept 11
Figure 4 - BLPH Concept Diagram 19
Figure 5 - SWEEP-Through purging CALCULATION for removal of O2 by means of N2 for Vessel A 89
Figure 6 - SWEEP-Through purging CALCULATION for removal of N2 by means of H2 for Vessel A 106
Figure 7 - SWEEP-Through purging CALCULATION for removal of H2 by means of N2 for Vessel A 122
Figure 8 - EMCS Flow Chart 191

List of Tables

Table 1 - Reference Documents 16
Table 2 - Definitions 17
Table 3 - Abbreviations 18
Table 4 – CCS Operation Modes 22
Table 5 - Sea Water Lift Pumps Design Data 26
Table 6 - Sea Water Lift Pumps Caisson Design Data 26
Table 7 - Seawater intake system alarm instrument list 32
Table 8 - Seawater intake system unit start-up check list table 35
Table 9 - Hydrogen Storage Vessels Design Data 38
Table 10 - Hydrogen Storage System alarm instrument list 67
Table 11 - Hydrogen Storage System trip instrument list 79
Table 12 - AIR purging (with N2) check list table for vessel A 86
Table 13 - AIR purging (with N2) check list table for vessel B 90

This document undergoes an issuance cycle within EDMS Fusionlive". Its distribution is electronically controlled. Once printed shall be considered as "NOT CONTROLLED" copy

Table 14 - AIR purging (with N2) check list table for vessel C 93
Table 15 - AIR purging (with N2) check list table for vessel D 96
Table 16 - AIR purging (with N2) check list table for vessel E 98
Table 17 - AIR purging (with N2) check list table for vessel F 101
Table 18 – N2 purging (with H2) check list table for vessel A 105
Table 19 – N2 purging (with H2) check list table for vessel B 108
Table 20 - N2 purging (with H2) check list table for vessel C 110
Table 21 - N2 purging (with H2) check list table for vessel D 112
Table 22 - N2 purging (with H2) check list table for vessel E 114
Table 23 - N2 purging (with H2) check list table for vessel F 116
Table 24 - H2 purging (with N2) check list table for vessel A 119
Table 25 - H2 purging (with N2) check list table for vessel B 123
Table 26 - H2 purging (with N2) check list table for vessel C 125
Table 27 - H2 purging (with N2) check list table for vessel D 127
Table 28 - H2 purging (with N2) check list table for vessel E 129
Table 29 - H2 purging (with N2) check list table for vessel F 132
Table 30 - Hydrogen Storage Vessels unit start-up check list table 138
Table 31 – Brine Discharge Caisson Design Data 140
Table 32 – Waste Water Tank Design Data 140
Table 33 – Water Disposal System check list table 144
Table 34 - Hydrogen Vent KO Drum Design Data 148
Table 35 - Hydrogen Vent System alarm instrument list 151
Table 36 - Hydrogen Vent System trip instrument list 153
Table 37 - Hydrogen Vent system purging procedure check list table 156
Table 38 - Instrument Air Package Design Data 157
Table 39 - IA System alarm instrument list 159
Table 40 - IA System trip instrument list 163

Table 41 – IA system start-up check list table 165
Table 42 – Nitrogen Generation System Design Data 167
Table 43 - Nitrogen System alarm instrument list 172
Table 44 - Nitrogen System trip instrument list 177
Table 45 – N2 system start-up check list table 179

1 INTRODUCTION

1.1 PROJECT OVERVIEW

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

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

1.1.1 PROJECT LOCATION

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

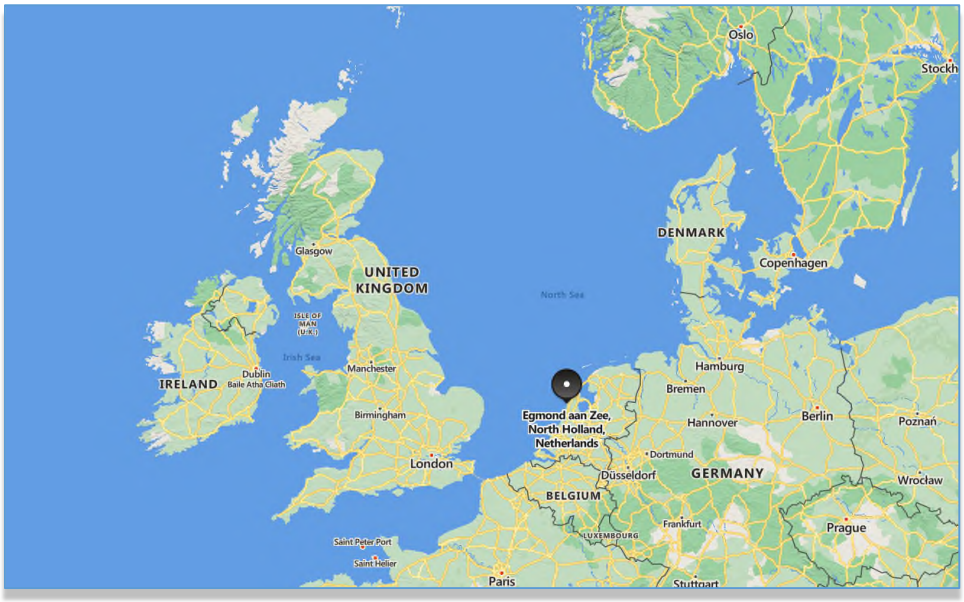


Figure 1 - HOLLANDSE KUST NOORD WIND PARK Location Map

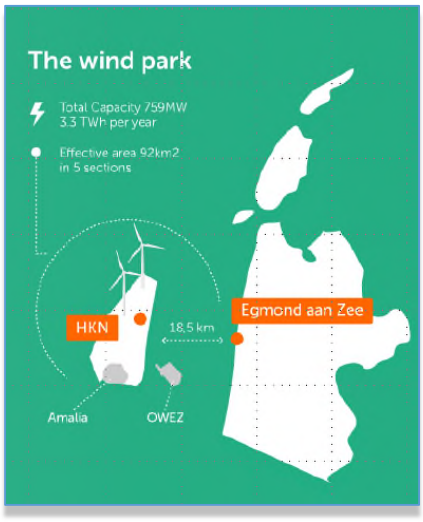


Figure 2 - Wind Park Details

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

1.1.2 PROJECT CONCEPT

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

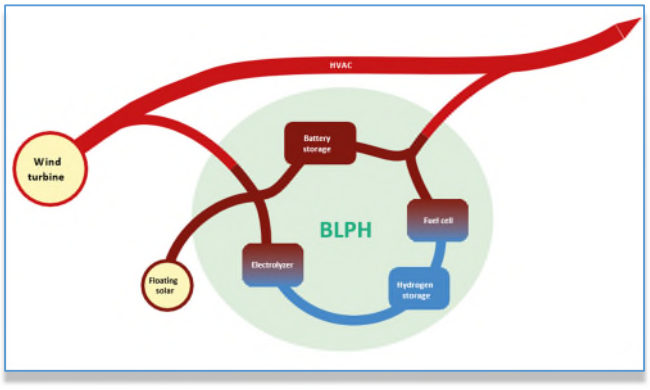


Figure 3 - BLPH Concept

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

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

2 DOCUMENT SCOPE

The scope of this operating manual is to provide details for operational and maintenance of the platform, during start-up, normal and shut-down operations.
It is to be mentioned that the technical aspects/information relevant to the pre-commissioning and commissioning activities are not part of this document.
The operating manual is a "living document". Any change made during the life of the plant and any operation (especially for maintenance) that is modified by new knowledge and experience must be recorded to update the document.
It is out of scope of this document:

- to develop and describe a list of maintenance activities to be performed periodically. For specific description of maintenance activities related to a specific equipment / package, reference shall be made to the vendor pertinent documentation. Details about maintenance schedule can be found within the document . "123A90-DDL-OEM-RE-02013" (Maintenance Schedule), [Ref. [84];
- to describe a full list of spare parts, which can be found within the document n. "123A90-DDL-OEM-LIS-02015" (Two-year operating spares list), [Ref. [85]].

3 REFERENCES

N. ref.	Document number	Document title
Ref. [1]	123A90-DDL-PR-DG-80003	BLPH PROCESS FLOW SCHEME ELECTROLYSER AND HYDROGEN DRYING PACKAGE
Ref. [2]	123A90-DDL-PR-DG-80004	BLPH PROCESS FLOW SCHEME HYDROGEN STORAGE
Ref. [3]	123A90-DDL-PR-DG-80005	BLPH PROCESS FLOW SCHEME FUEL CELL PACKAGE
Ref. [4]	123A90-DDL-PR-UFD-80006	BLPH UTILITY FLOW DIAGRAM WATER TREATMENT PLANT
Ref. [5]	123A90-DDL-PR-UFD-80007	BLPH UTILITY FLOW DIAGRAM INSTRUMENT AIR AND NITROGEN SYSTEMS
Ref. [6]	123A90-DDL-PR-UFD-80008	BLPH UTILITY FLOW DIAGRAM VENT SYSTEMS
Ref. [7]	123A90-DDL-PR-PID-80009	BLPH PIPING AND INSTRUMENTATION DIAGRAM GENERAL NOTES
Ref. [8]	123A90-DDL-PR-PID-80010	BLPH PIPING AND INSTRUMENTATION DIAGRAM PIPING SYMBOLOGY
Ref. [9]	123A90-DDL-PR-PID-80011	BLPH PIPING AND INSTRUMENTATION DIAGRAM ELECTROLYSER PACKAGE
Ref. [10]	123A90-DDL-PR-PID-80012	BLPH PIPING AND INSTRUMENTATION DIAGRAM FUEL CELL PACKAGE
Ref. [11]	123A90-DDL-PR-PID-80013	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSELS HEADER (INLET)
Ref. [12]	123A90-DDL-PR-PID-80014	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSELS HEADER (OUTLET)
Ref. [13]	123A90-DDL-PR-PID-80015	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSEL A
Ref. [14]	123A90-DDL-PR-PID-80016	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSEL B
Ref. [15]	123A90-DDL-PR-PID-80017	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSEL C
Ref. [16]	123A90-DDL-PR-PID-80018	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSELD
Ref. [17]	123A90-DDL-PR-PID-80019	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSEL E
Ref. [18]	123A90-DDL-PR-PID-80020	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN STORAGE VESSEL F
Ref. [19]	123A90-DDL-PR-PID-80021	BLPH PIPING AND INSTRUMENTATION DIAGRAM SEA-WATER INTAKE SYSTEM SHEET 1
Ref. [20]	123A90-DDL-PR-PID-80022	BLPH PIPING AND INSTRUMENTATION DIAGRAM SEA-WATER INTAKE SYSTEM SHEET 2
Ref. [21]	123A90-DDL-PR-PID-80023	BLPH PIPING AND INSTRUMENTATION DIAGRAM WATER TREATMENT PLANT SHEET 1
Ref. [22]	123A90-DDL-PR-PID-80024	BLPH PIPING AND INSTRUMENTATION DIAGRAM WATER TREATMENT PLANT SHEET 2
Ref. [23]	123A90-DDL-PR-PID-80025	BLPH PIPING AND INSTRUMENTATION DIAGRAM WATER DISPOSAL SHEET 1
Ref. [24]	123A90-DDL-PR-PID-80026	BLPH PIPING AND INSTRUMENTATION DIAGRAM WATER DISPOSAL SHEET 2
Ref. [25]	123A90-DDL-PR-PID-80027	BLPH PIPING AND INSTRUMENTATION DIAGRAM INSTRUMENT AIR PACKAGE
Ref. [26]	123A90-DDL-PR-PID-80028	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN VENT HEADER
Ref. [27]	123A90-DDL-PR-PID-80029	BLPH PIPING AND INSTRUMENTATION DIAGRAM HYDROGEN VENT DRUM
Ref. [28]	123A90-DDL-PR-PID-80041	BLPH PIPING AND INSTRUMENTATION DIAGRAM INSTRUMENT AIR DISTRIBUTION HEADER
Ref. [29]	123A90-DDL-PR-PID-80042	BLPH PIPING AND INSTRUMENTATION DIAGRAM INSTRUMENTATION SYMBOLOGY
Ref. [30]	123A90-DDL-PR-PID-80043	BLPH PIPING AND INSTRUMENTATION DIAGRAM OPEN DRAIN SYSTEM
Ref. [31]	123A90-DDL-PR-DG-80000	BASE LOAD POWER HUB (BLPH) - PROCESS SAFETY CAUSE & EFFECT BLOCK DIAGRAM
Ref. [32]	123A90-DDL-PR-BL-80002	HEAT & MASS BALANCE
Ref. [33]	123A90-DDL-PR-LIS-80035	PROCESS LINE LIST
Ref. [34]	123A90-DDL-PR-DG-80038	PROCESS SAFEGUARDING FLOW SCHEMES (PSFS)
Ref. [35]	123A90-DDL-PR-RE-80040	PROCESS DESIGN PHILOSOPHY
Ref. [36]	123A90-DDL-PR-RE-80030	RELIEF, VENT AND BLOWDOWN REPORT
Ref. [37]	123A90-DDL-PR-RE-80031	PROCESS CONTROL, OPERATION, START-UP AND SHUTDOWN PHILOSOPHY
Ref. [38]	123A90-DDL-PR-RE-80032	INSULATION AND WINTERISATION PHILOSOPHY
Ref. [39]	123A90-DDL-PR-CA-80033	EQUIPMENT SIZING PHILOSOPHY AND CALCULATIONS
Ref. [40]	123A90-DDL-PR-RE-80034	LINE SIZING REPORT

N. ref.	Document number	Document title
Ref. [41]	123A90-DDL-PR-RE-80037	CHEMICALS / UTILITY CONSUMPTION REPORT
Ref. [42]	123A90-DDL-MAT-RE-60011	MATERIALS SELECTION REPORT
Ref. [43]	123A90-DDL-MAC-DS-50008	TDS - WASTE WATER TANK - T-55001
Ref. [44]	1724000428-PR-PID-00019	PACKAGE PID - INSTRUMENT AIR PACKAGE
Ref. [45]	1724000437-PR-PID-00018	PACKAGE PID - NITROGEN GENERATION PACKAGE
Ref. [46]	1724000448-PR-PID-00013	WATER TREATMENT PACKAGE-PID DIAGRAM
Ref. [47]	1723001756-MAC-DS-00007	TECHNICAL DATA SHEETS - H2 STORAGE VESSEL-V-25001 A-F
Ref. [48]	1724000936-MAC-DS-00012	PUMP DATA SHEETS INCLUDING WEIGHT DATA SHEET-PROGRESSIVE CAVITY PUMPS
Ref. [49]	1724000163-MAC-DS-00006	TECHNICAL DATA SHEET - HYDROGEN VENT KO DRUM - V-43001
Ref. [50]	1724000887-MAC-DS-00006	EQUIPMENT DATA SHEETS - HYDROGEN VENT
Ref. [51]	1724000448-MAC-MAN-00032	INSTALLATION, OPERATING AND MAINTENANCE MANUAL (WATER TREATMENT)
Ref. [52]	1723001756-MAC-MAN-00019	INSTALLATION AND OPERATING MAINTENANCE MANUAL - H2 STORAGE VESSEL
Ref. [53]	1724000887-MAC-MAN-00017	INSTALLATION OPERATING AND MAINTENANCE MANUAL (HYDROGEN VENT)
Ref. [54]	1724000428-MAC-MAN-00030	INSTALLATION, OPERATING AND MAINTENANCE MANUAL - INSTRUMENT AIR PACKAGE
Ref. [55]	1724000437-MAC-MAN-00029	INSTALLATION, OPERATING AND MAINTENANCE MANUAL - NITROGEN GENERATION PACKAGE
Ref. [56]	C63-PMO-001	ELOGEN - USER MANUAL
Ref. [57]	1724000448-MAC-MAN-00032	INSTALLATION, OPERATING AND MAINTENANCE MANUAL
Ref. [58]	K559-2254-CWIWP4202202-N01-002	BLPH PROJECT - OPERATOR MANUAL
Ref. [59]	K559-2254-CWIWP4202202-N01-003	BLPH PROJECT - SERVICE AND MAINTENANCE MANUAL
Ref. [60]	1724000428-MAC-SP-00003	INSTRUMENT AIR PACKAGE A-63000 SYSTEM/PACKAGE FUNCTIONAL DESCRIPTION
Ref. [61]	123A90-DDL-IN-LIS-40027	MASTER ALARM DATABASE
Ref. [62]	1724000594-IN-DG-00027	LOGIC DIAGRAM PRINT OUT EMCS
Ref. [63]	1724000594-IN-DD-00028	HMI SCREENS PRINT OUT
Ref. [64]	1724000594-IN-MAN-00037	INSTALLATION, OPERATING AND MAINTENANCE MANUAL (IOM).
Ref. [65]	1724000594-IN-SP-00019	EMCS SOFTWARE FUNCTIONAL DESIGN SPECIFICATION (FDS-SW)
Ref. [66]	1724000428-MAC-CE-00004	PACKAGE CAUSE EFFECT MATRIX -LOGIC DIAGRAMS - INSTRUMENT AIR PACKAGE
Ref. [67]	1724000437-MAC-CE-00004	PACKAGE CAUSE EFFECT MATRIX -LOGIC DIAGRAMS -NITROGEN GENERATION PACKAGE
Ref. [68]	123A90-DDL-IN-CE-40000	PROCESS SAFETY CAUSE AND EFFECT MATRIX
Ref. [69]	123A90-DDL-IN-RE-40095	PROCESS CONTROL LOGICS DESCRIPTION
Ref. [70]	123A90-DDL-SAF-RE-30013	HAZARDOUS AREA CLASSIFICATION SCHEDULE
Ref. [71]	123A90-DDL-SAF-DL-30022	HAZARDOUS AREA CLASSIFICATION - LOWER DECK & UPPER
Ref. [72]	123A90-DDL-SAF-DL-30024	HAZARDOUS AREA CLASSIFICATION - ELEVATION LOOKING NORTH AND EAST
Ref. [73]	123A90-DDL-EL-SP-20141	ELECTRICAL SYSTEM DESCRIPTION & DESIGN PHILOSOPHY
Ref. [74]	123A90-DDL-EL-LIS-20142	ELECTRICAL EQUIPMENT LIST
Ref. [75]	123A90-DDL-EL-RE-20152	ELECTRICAL EQUIPMENT SIZING CALCULATION REPORT
Ref. [76]	123A90-DDL-EL-RE-20182	LV ELECTRICAL EQUIPMENT SIZING CALCULATION REPORT
Ref. [77]	123A90-DDL-EL-DG-20158	OVERALL KEY SINGLE LINE DIAGRAM
Ref. [78]	123A90-DDL-SAF-DL-30027	F&G DETECTORS LAYOUT - LOWER AND UPPER DECK
Ref. [79]	123A90-DDL-SAF-DL-30028	F&G DETECTORS LAYOUT – BELOW LOWER DECK

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Ref. [80]	123A90-DDL-SAF-RE-30016	EMERGENCY RESPONSE PLAN
Ref. [81]	123A90-DDL-SAF-DL-30029	SAFETY SIGN EQUIPMENT LAYOUT DRAWING – BELOW LOWER DECK
Ref. [82]	123A90-DDL-SAF-DL-30030	SAFETY SIGN EQUIPMENT LAYOUT DRAWING – LOWER AND UPPER DECK
Ref. [83]	1724001660-SAF-MAN-00007	INSTRUCTION AND OPERATING MAINTENANCE (IOM) - FIREFIGHTING AND SAFETY EQUIPMENT
Ref. [84]	123A90-DDL-OEM-RE-02013	MAINTENANCE SCHEDULE
Ref. [85]	123A90-DDL-OEM-LIS-02015	TWO-YEAR OPERATING SPARES LIST
Ref. [86]	1724000936-MAC-MAN-00031	INSTALLATION, OPERATING AND MAINTENANCE MANUAL (PUMP AND MOTOR, INCLUDING SITE ERECTION INSTRUCTIONS AND PROCEDURES)
Ref. [87]	123A90-PML-PM-LIS-00036	ATEX REGISTER
Ref. [88]	123A90-PML-DIG-LIS-00005	MASTER TAG REGISTER
Ref. [89]	123A90-PML-COM-PRO-03036	OTP - BLACK START PROCEDURE
Ref. [90]	123A90-DDL-SAF-RE-30046	HSE design philosophy
Ref. [91]	123A90-DDL-SAF-RE-30001	Fire protection philosphy
Ref. [92]	123A90-DDL-SAF-RE-30012	ALARP workshop report
Ref. [93]	123A90-DDL-SAF-RE-30003	Safety Critical Elements and Performance Standard

Table 1 - Reference Documents

4 DEFINITIONS AND ABBREVIATIONS

DEFINITIONS

COMPANY or Client (CPY):	Crosswind
CONTRACTOR (CTR):	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
EVACUATION	Evacuation means the leaving of an installation and its vicinity, in an emergency, in a systematic manner and without directly entering the sea. Successful evacuation will result in persons being transferred to a place of safety, by which is meant a safe onshore location, or a safe offshore location or marine vessel with suitable facilities.
ESCAPE	Escape means the process of leaving the installation in an emergency when the evacuation system has failed; it may involve entering the sea directly and is the 'last resort' method of getting personnel off the installation. For the scope of this project, escape means leave the platform via life rafts.
FIRE	The outcome of combustion of flammable substance released in the atmosphere as a consequence of a LOC, which can produce effects to exposed persons and to process equipment and structure due to thermal radiation.
MUSTER POINT	Muster is the process of assembling personnel in a muster area where it is safe to assemble allowing time for the emergency to be assessed and for control to be taken. Generally, a muster area should provide protection against a foreseeable major incident for a specified endurance period.

Table 2 - Definitions

ABBREVIATIONS

BESS	BATTERY ENERGY STORAGE SYSTEM
BLPH	BASE LOAD POWER HUB
CCS	CENTRAL CONTROL SYSTEM
DC	DIRECT CURRENT
FC	FUEL CELL
HKN	HOLLANDSE KUST NOORD
IA	INSTRUMENT AIR
LIP	LOCKED IN PLACE
PCS	PROCESS CONTROL SYSTEM
PV	PROCESS VARIABLE

SIS	SAFETY INTEGRITY SYSTEM
SP	SET POINT
SW	SOFTWARE
WTG	WIND TURBINE GENERATOR

Table 3 - Abbreviations

5 SIMPLIFIED PROCESS DIAGRAM FOR THE SYSTEM ELECTRIFICATION

The below diagram simply illustrates the general process of the project with different alternative energy sources such as floating solar 2x0.25 with MW BaseLoad Power Hub (WTG 70) and connection through Wind turbine HNA5 (WTG 57) to offshore HV Substation

The BLPH platform will be located on the 70th monopile (designated as HKN-70) and it will be electrically connected to the wind turbine HNA5. The connection is done by a 66kV sub-sea cable. The solar farm connection to BLPH is done by a separate sub-sea cable. At BLPH, the sub-sea cable will be connected to a single busbar 66kV GIS switchgear.

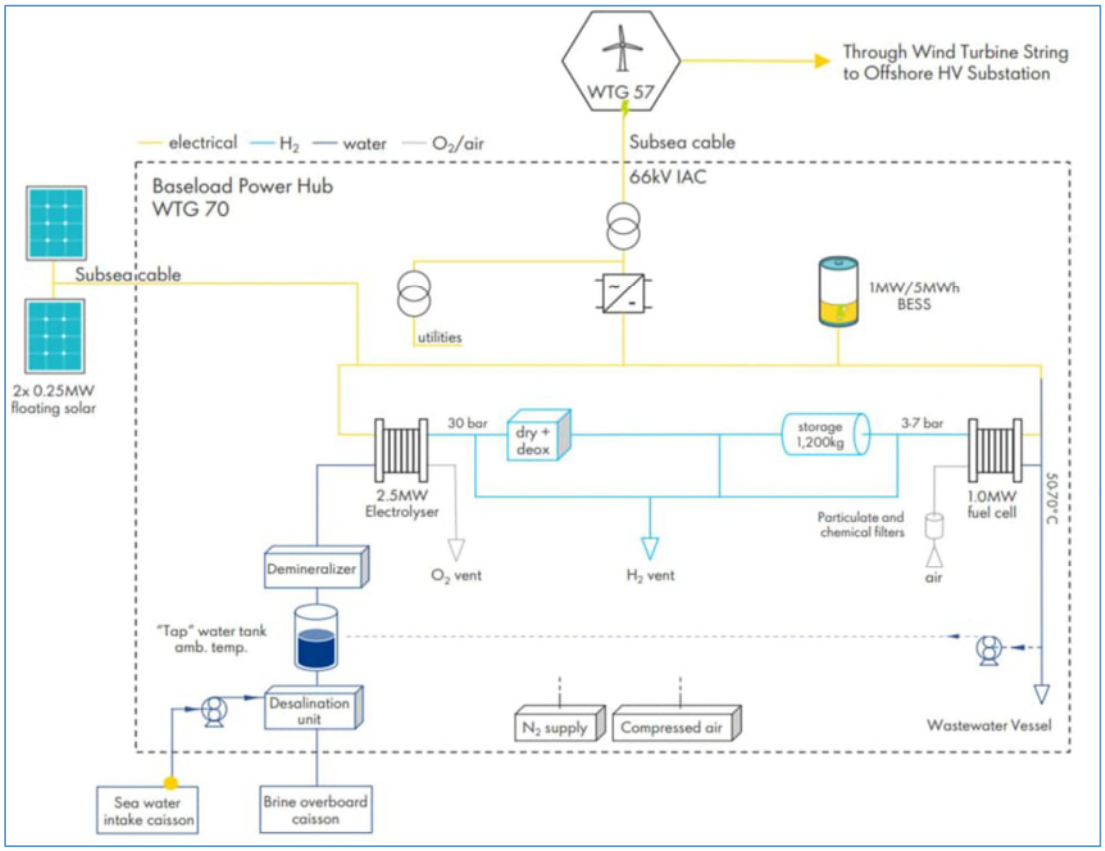


Figure 4 - BLPH Concept Diagram

The dips and peaks associated with offshore wind production need balancing for better integration with the power grid; to this end the wind farm will include several new technological showcases to demonstrate and prove the potential improvement and usage for their future implementation at larger scale.

The technologies being demonstrated at BLPH are:

1. Floating Solar Park.
2. Short-term Battery Energy Storage System (BESS).
3. Long-term Hydrogen Energy Storage (Electrolyzer to create green hydrogen).
4. Fuel-Cell.

Monitoring and control of BLPH will be remote (shore based control room) and the Solar Farm, BESS and Fuel-Cell shall act cooperatively so that power from all sources will be combined to export power regardless of the prevailing weather.
The Fuel-Cell is slow-acting whilst the BESS is fast acting. Therefore, the BESS (whenever available) will be used as 'lead supply' / 'load follower' and operate in its most efficient / effective manner with the Fuel-Cell operating in parallel or series to optimise both the efficiency and availability of the entire system.
Whenever possible the Fuel-Cell will consume the platform's stored hydrogen prior to discharging the BESS to ensure the energy is maintained high for it to react instantly to each demand for power.

5.1 ELECTRICAL OPERATING MODES

When wind turbine HNA5 is connected / operating and providing at least 1 MW to the wind farm 'surplus' power will potentially be available for import to BLPH. This renewable surplus energy will be used to run the plant whilst simultaneously charging the BESS and/or running the Electrolyser to create & store hydrogen. Conversely, when wind turbine HNA5 provides less than 1 MW, BLPH will export Solar Power (if available) and/or the energy stored in the BESS or hydrogen to ensure the wind farm continues to receive at least 1 MW.
The BLPH power system will be synchronised and connected to the wind farm's power system with both 66 kV and 6.6 kV circuit breakers being equipped with a synch. check relay to ensure the AC supplies are synchronised before a circuit breaker will be allowed to close.
An operation mode that involves the simultaneous charging of the BESS and/or running the Electrolyser whilst also discharging the BESS and/or running the Fuel Cell is not considered for the design.

The CCS will control all equipment and packages during 'Normal' (wind farm connected) and 'Abnormal' (windfarm not connected) periods of plant operation selecting one of the operation modes described below.
The solar farm, BESS, fuel cell and electrolyser will all be constantly monitored by the CCS for their operating status / mode e.g. 'Ready' (equipment 'hot standby' = immediately ready to operate) or 'Not Ready' (equipment 'cold standby' = not immediately ready to operate).

	CCS OPERATION MODES
0	MODE 0 - IDLE MODE BLPH will import power to harvest energy from either / both renewable sources (wind farm and solar park). This operating mode is selected by the CCS whenever HNA5-AFA70 circuit breaker QA1 is OPEN or the turbine itself is faulty and unable to produce power (even though it's windy). Supply Guarantee is considered ACTIVE and there are no constraints on the power import.
1	MODE 1 - IMPORT BLPH will import power to harvest energy from either / both renewable sources (wind farm and solar farm). Power generation from HNA5 is greater than 1 MW. Surplus renewable energy is imported to BLPH from wind farm for charging BESS and running the electrolyser whilst also feeding the BLPH loads. 1. If connected, the Solar Farm will provide whatever amount of power it can at any time of the day. 2. Wind turbine HNA5 produces sufficient 'surplus' power at any time (night or day). Supply Guarantee is considered ACTIVE.
2	MODE 3 - HOT STANDBY BLPH is capable of exporting power should generation from HNA5 drop below 1 MW. Renewable energy is imported to BLPH from wind farm and/or solar farm for feeding the BLPH loads. Solar farm, Fuel Cell and BESS are synchronized and connected to the 6.6 kV power system, ready to generate. 1. BESS is fully charged and healthy. 2. H2 vessels are fully loaded. 3. Solar Farm will provide power for the period possible on any particular day. Supply Guarantee is considered ACTIVE.
3	MODE 2 – EXPORT (NOTE 1) Power generation from HNA5 has dropped below 1 MW. Export of power is required from BLPH from BESS, Fuel Cell and/or solar farm to support HNA5 production. BLPH exports power from the Solar Farm, BESS and/or Fuel Cell to support wind turbine HNA5. 1. BLPH will use available power from solar, battery and/or fuel cell to export not more than what's necessary for wind turbine HNA5 to provide the wind farm with >1MW (to maximise the period of assistance that will be provided). Supply Guarantee is considered ACTIVE.
4	MODE 4 - COLD STANDBY BLPH is not capable of exporting power (stored and/or non-stored renewable energy) should generation from HNA5 drop below 1 MW. Renewable energy is imported to BLPH from wind farm and/or solar farm for feeding the BLPH loads. Supply Guarantee is considered ACTIVE and there are no constraints on the power import.

	CCS OPERATION MODES
4A	MODE 4A - EMERGENCY MODE (Island) BLPH is operating as an 'Island' and is not connected to Wind Farm. 1. BESS and/or Fuel Cell will use their stored energy to support BLPH for the maximum time possible. 2. BLPH plant utility loads will consume the stored energy in BESS and hydrogen (hydrogen will be consumed first) and/or the renewable energy from the solar farm. Supply Guarantee is considered INACTIVE.
5	MODE 5 - POWER OUT (Black-out) BLPH is operating as an 'Island' and is not connected to Wind Farm, BESS and Fuel-Cell have consumed all their stored energy whilst supporting BLPH. Only essential loads are supplied by UPS systems. 1. It is possible to connect a temporary generation in order to avoid power loss to the essential loads according to the document 123A90-DDL-EL-RE-20174 - Electrical System Study Report - Vital Supply Recovery. NOTE: The temporary power supply will be connected to a junction box located nearest the 400V Switchroom (B-200) to supply all Essential loads. Supply Guarantee is considered INACTIVE.
6	MODE 6 - MAINTENANCE BLPH will intentionally enter and remain in this MODE, under operator request, only during normal maintenance in BLPH. Supply Guarantee is command by operator in ACTIVE/INACTIVE.
7	MODE 7 – RESEARCH (NOTE 1) BLPH will intentionally enter and remain in this MODE, under operator request. The CCS will be switched to fully 'manual' operation for research activities to proceed with the amount of power generated by wind turbine HNA5 no longer being relevant. Main and auxiliary equipment will be switched to import or export power, as necessary to satisfy the research criteria. Auxiliaries needed for the platform to remain safe and permit the research to proceed will be prevented from being shut down in this operation mode. Supply Guarantee is command by operator in ACTIVE/INACTIVE.
8	MODE 8 – NONE MODE This is the default mode for the CCS, for example at the CCS initialization after a complete black-out or as an entrance status and last fallback if no other status is possible due to unmanaged logic conditions, if any.

Table 4 – CCS Operation Modes

NOTE: "Supply Guarantee" refers to if the Wind Farm is Connected or Disconnected from the BLPH.
A more detailed description of the Platform operating modes and the status of all users and equipment is shown in the specification 1724000594-IN-SP-00019 "EMCS Software Functional Design Specification (FDS-SW)", [Ref. 65] and 123A90-DDL-IN-RE-40095 - Process Control Logics Description, [Ref. [69].

NOTE 1: Manual control into export mode for depleting hydrogen onboard contained within the Fuel Cell Package prior to maintenance is not allowed under "MODE 2 – EXPORT2. It is noted that there is a possibility for the operator onshore depleting hydrogen onboard contained within the Fuel Cell Package prior to maintenance only in research mode ("MODE 7 – RESEARCH").

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5.2 ELECTRICAL SCENARIOS

In the transition between some operating modes three different electrical scenarios could be identified, which required automatic or manual procedure to adjust the electrical system configuration making possible the following operating mode.

These scenarios are:

1. Islanding
2. Recover from island
3. Black start

For details reference shall be made to [Ref. [65]]

5.2.1 ISLANDING

Sudden disconnection from the grid could occur in case of opening of the 66 kV breaker or the incoming breaker on the 6.6 kV switchgear.

These two breakers can be manually opened or, most likely, can be opened automatically by the protection system, which could detect a grid failure.

In both cases, the 6.6 kV system could remain in operation with the power generation feeding the auxiliary loads on the 6.6. kV switchgear.

In particular the BESS system should change its control system switching to "grid forming" status, so that it can control the voltage and the frequency of the isolated system, balancing the load demand.

In this transition there is no need of any manual operation, since all actions needed are taken automatically by protection and control system, being necessary a very fast action to try to keep the 6.6 kV system alive.

5.2.2 RECOVER FROM ISLAND

Once the voltage is back on the wind farm up to the BLPH 66 kV GIS, it is possible to reconnect the 6.6 kV system, which was operating in island, to the grid by means of manual procedure.

The operator first of all has to close the line switches and the circuit breaker of the 66 kV GIS in order to energize the step-up transformer TR-100AD1, to be ready to take the load from the 6.6 kV system.

Once the transformer is energized, the operator will request from the CCS to close the incoming breaker on the 6.6 kV switchgear.

The closure of the breaker will be managed by the BESS system, which has the facilities necessary to synchronize the isolated 6.6 kV system with the grid.

With the closure of the 6.6 kV incoming breaker, the 6.6 kV system will be connected back to the grid and the BLPH platform will return in the operating mode requested by the battery limit condition in that moment.

5.2.3 BLACK START

When the BLPH is disconnected from the grid (windfarm) and there is no power supply from solar, BESS and fuel cell, BLPH enters the power out mode of operation. This is an electrical blackout condition, and the vital loads will be maintained solely by the DC, AC UPS systems and Navigation System.

Batteries in DC UPS system are located within the B-100 HV equipment room on the lower deck.

Batteries in AC UPS systems and Navigation System are located within the B-300 UPS equipment room on the lower deck.

If the blackout condition lasts long such that the batteries are close to full discharge and hence, no longer available, then BLPH suffers a total loss of power.

In this case a black start of the platform via an offshore mobile power source will be needed to supply to recover the supply to vital loads by charging the batteries in DC and AC UPS systems, and to feed the vital loads under the main LV switchgear SG-200N1 until the network is recovered so that it is possible to reconnect the BLPH platform to the grid (windfarm). For black start up procedure reference shall be made to "OTP - BLACK START Procedure", doc. n. "123A90-PML-COM-PRO-03036", [Ref. [89], as well as to "ELECTRICAL SYSTEM DESCRIPTION & DESIGN PHILOSOPHY", doc. n. "123A90-DDL-EL-SP-20141", [Ref. [73].

6 SEAWATER INTAKE SYSTEM

6.1 EQUIPMENT LIST AND DESIGN BASIS

The seawater intake system includes the following equipment:

Service	Sea Water Lift Pumps
TAG	P-50001A/B
Quantity	1
Power	1.6 kW
Flow	2.5 m^3/h
Design pressure	7.6 barg
Design temperature	80 °C
Material	SDSS

Table 5 - Sea Water Lift Pumps Design Data

Service	Sea Water Lift Pumps Caissons
TAG	B-50013A/B
Quantity	1
Size	343 mm (ID) x 27308 mm (H)
Material	CA+CA

Table 6 - Sea Water Lift Pumps Caisson Design Data

6.2 OPERATING DATA

The seawater lift pumps are characterized by the following main operating data:

- Normal Operating mass flowrate ~2500 kg/h
- Normal Operating volumetric flowrate ~2.5 m^3/h
- Normal Discharge pressure (min./max) ~4.0 / 5.0 barg
- Normal Discharge temperature ~ 22.4 °C

6.3 PROCESS DESCRIPTION (NORMAL OPERATION)

Seawater is the raw water to be treated and then electrochemically converted into hydrogen (for energy accumulation purposes) and oxygen. The seawater is lifted by means of 2 x 100% submersible Seawater Lift Pumps P–50001A/B (one running and the other in stand-by mode), and then fed through the water treatment plant to remove the biological and inorganic pollutants, that shall be eliminated prior to be served to the electrolyser package. Downstream the sea water lift pumps, to monitor the temperature of brine going

back to the brine discharge caisson B-50014, a temperature measurement (50-TI-001) is required just at inlet of water treatment system, to compare it with the one of the return-stream (50-TI-002) via differential function 50-TDI-002. By measuring the temperature difference between these two streams, one can ensure that the discharged water will not be too warm back into the sea, which could potentially harm the marine ecosystem. This process is crucial for environmental conservation as it helps maintain the temperature balance in the marine environment. By controlling the temperature of the discharged water, any adverse effects on marine life and ecosystem are mitigated.

A biocide injection into the seawater intake system is provided. The biocide injection points are the following:

- Biocide is injected into the Seawater Lift Pumps Caissons B-50013A/B, to also disinfect the seawater in the suction side of each Seawater Lift Pumps
- Biocide is injected into the Seawater Lift Pumps P-50001A/B discharge side, when a pump is not running (the scope is of this dosing is to disinfect the seawater lift pump discharge tube of the pump that is not running, to avoid biological growth)
- Biocide is injected at the Water Treatment System inlet line.

Assume that the sea water pump that is running is the pump "A", then the discharge tube of the pump "B" (stand-by pump) is dosed with treated sea water coming from pump "A" as follows:

1. on/off valve 50-XV-001 installed on the pump "A" is open
2. on/off valve 50 -XV-003 installed on the pump "B" discharge side is closed
3. on/off valve 50 -XV-002 installed on the by-pass discharge side of the pump "A" is closed
4. on/off valve 50-XV-004 installed on the by-pass discharge side of the pump "B" will be open, to allow treated sea water coming from pump "A", which already contains biocide, passing through the by-pass line of the pump "B".

Assume that the sea water pump that is running is the pump "B", then the discharge tube of the pump "A" (stand-by pump) is dosed with treated sea water coming from pump "B" as follows:

1. on/off valve 50-XV-003 installed on the pump "B" is open
2. on/off valve 50 -XV-001 installed on the pump "A" discharge side is closed
3. on/off valve 50 -XV-004 installed on the by-pass discharge side of the pump "B" is closed
4. on/off valve 50-XV-002 installed on the by-pass discharge side of the pump "A" will be open, to allow treated sea water coming from pump "B", which already contains biocide, passing through the by-pass line of the pump "A".

A logic control will be provided to prevent simultaneous running of both pumps A and B.
The following signals will inform about each pump status:

- STOP
- START
- RUNNING/STOPPED
- AUTO START READY
- MOTOR STOPPED BY LOCAL PUSH BUTTON
- FAULT/TRIPPED
- SHUTDOWN ALARM
- LOCAL/REMOTE

6.4 LOGIC CONTROL DESCRIPTION

Section not applicable.

6.5 INTERLOCK LOGIC DESCRIPTION

A software interlock is provided to prevent pump from starting in case the relevant XV valve is closed:

- if the discharge 50-XV-001 valve is fully closed, the software interlock prevents pump "A" from starting
- if the discharge 50-XV-003 valve is fully closed, the software interlock prevents pump "B" from starting.

6.6 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the seawater intake system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
50-PT-001	HI	Sea water from pump P-50001A	P&ID (123A90-DDL-PR-PID-80021)	7	barg	Discharge blocked	N/A	No consequence due to 50-PSV-006 discharge.	Operator can: 1. Manually Stop the sea water pump P-50001A 2. Inform maintenance/intervention team. 3. Monitor process conditions.	
50-PT-001	LO	Sea water from pump P-50001A	P&ID (123A90-DDL-PR-PID-80021)	4	barg	sea water lift pump P-50001A not started when required or sea water lift pump P-50001A in fault	N/A	No consequence, since there is a stand-by pump	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	The alarm will be activated after start with delay of 30 sec.

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
50-PT-001	IO_FAIL	Sea water from pump P-50001A	P&ID (123A90-DDL-PR-PID-80021)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
50-PT-002	HI	Sea water from pump P-50001B	P&ID (123A90-DDL-PR-PID-80021)	7	barg	Discharge blocked	N/A	No consequence due to 50-PSV-007 discharge.	Operator can: 1. Manually Stop the sea water pump P-50001B 2. Inform maintenance/intervention team. 3. Monitor process conditions.	
50-PT-002	LO	Sea water from pump P-50001B	P&ID (123A90-DDL-PR-PID-80021)	4	barg	sea water lift pump P-50001B not started when required or sea water lift pump P-	N/A	No consequence, since there is a stand-by pump	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	The alarm will be activated after start with delay of 30 sec.

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
						50001B in fault				
50-PT-002	IO_FAIL	Sea water from pump P-50001B	P&ID (123A90-DDL-PR-PID-80021)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
50-TDI-002	HI	Difference Temperature T2 - T1	P&ID (123A90-DDL-PR-PID-80025)	10	°C	unexpected high temperature of the drain stream from the electrolyser	N/A	Possible discharge of water towards sea at a temperature higher than the permitted one	Operator can: 1. Monitor 50-TT-001 and 50-TT-002 temperature indication. 2. Evaluete the possibility to stop Electrolyser package	
50-TT-002	IO_FAIL	Water disposal header to	P&ID (123A90-DDL-PR-PID-80025)	3.8	mA	1. Instrument fault	N/A	1. Loss of monitoring and control functionality	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		caisson B-50014				2. Channel fault		2. Loss of channel redundancy		
50-TT-001	IO_FAIL	Sea water from lift pump P-50001A/B	P&ID (123A90-DDL-PR-PID-80022)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
50-PT-014	HI	Water disposal header to caisson B-50014	P&ID (123A90-DDL-PR-PID-80025)	0.5	barg	blocked discharge towards brine discharge caisson	N/A	Delay in drainage operation	Operator can: 1. Inform maintenance/intervention team.	
50-PT-014	IO_FAIL	Water disposal header to caisson B-50014	P&ID (123A90-DDL-PR-PID-80025)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

Table 7 - Seawater intake system alarm instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.
The discharge pressure of the Seawater Lift Pump P-50001A (B) can be monitored by means of the pressure transmitter 50-PT-001 (002), that is installed on the discharge line of the pump.
The above pressure transmitters are also equipped with high- and low-pressure alarms, available in the onshore control room to alert the operator.

6.7 UNIT START UP PROCEDURE

Start-up of the Seawater Lift Pumps P-50001A/B is subject to the following preparatory activities:

- Completion of Start-up preparation activities and prerequisites for the Electrolyser Package, A-20000, as per Vendor recommendations; refer to document number, [Ref. [56]]
- Completion of Start-up preparation activities and prerequisites for the Water Treatment Package, A-50000, as per Vendor recommendations; refer to document number, [Ref. [57]]
- Completion of Start-up preparation activities and prerequisites for the Instrument Air Package, A-63000, as per Vendor recommendations; refer to document number [Ref. 54]
- Completion of Start-up preparation activities and prerequisites for the Nitrogen Generation System, A-64000, as per Vendor recommendations; refer to document number [Ref. 55]
- Completion of Start-up preparation activities and prerequisites for the Hydrogen Vent, Q-43004, as per Vendor recommendations; refer to doc refer to document number [Ref. 53].

Once the above prerequisites are positive it is possible to proceed with the start up. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the manual valve BLPH-MV-043 is open	☐ _____
2	Check that the manual valve BLPH-MV-050 is open	☐ _____
3	Check that the manual valve BLPH-MV-048 is open	☐ _____
4	Check that the manual valve BLPH-MV-051 is open	☐ _____
5	Check that the manual valve BLPH-MV-464 is open	☐ _____
6	Check that the manual valve BLPH-MV-465 is open	☐ _____
7	Check that the manual valve BLPH-MV-044 is closed	☐ _____
8	Check that the manual valve BLPH-MV-044 is closed	☐ _____
9	Check that the manual valve BLPH-MV-054 is closed	☐ _____
10	Check that the manual valve BLPH-MV-241 is closed	☐ _____
11	Check that the manual valve BLPH-MV-471 is open	☐ _____
12	Check that the manual valve BLPH-MV-469 is open	☐ _____

	ACTION	CHECK
13	Check that the manual valve BLPH-MV-470 is open	☐ _____

Table 8 - Seawater intake system unit start-up check list table

Once the above checks and reviews are positive, the startup procedure as per Seawater Lift Pumps Vendor's operating manual (see document number [Ref. [86]]) shall be followed.

A local/remote pushbutton 50-HS-002A (B) is provided for the Seawater Lift Pumps P-50001A (B), so the remote or local status 50-XL-002A (B) is active in the onshore control room.
The following selectors/push button are provided for each Seawater Lift Pumps P-50001A/B:

- Local/remote selector SA1 for the pump A
- Local start push button PM1 for the pump A
- Local stop push button PA1 for the pump A
- Local/remote selector SA1 for the pump B
- Local start push button PM1 for the pump B
- Local stop push button PA1 for the pump B

6.7.1 REMOTE MODE START UP

Start-up op the Seawater Lift Pump can be done in automatic mode or manual mode.

6.7.1.1 Automatic Start Up

Assume that pump A is the one to be started (duty pump), then the initial conditions include:

- 50-HS-002A and 50-HS-002B are set to auto mode;
- 50-HS-003B is set to select pump B to be in standby mode
- No faults, alarms or shutdowns are active in this system
- All XVs valves installed on the discharge side of the Seawater Lift Pumps, 50-XV-001, 50-XV-002, 50-XV-003 and 50-XV-004 are set in auto mode.

Once it is required to start the pump A then the automatic logic will:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-001 valve that is installed on the duty pump discharge line
- Close the 50-XV-003 valve that is installed on the stand-by pump discharge line
- Start duty Lift pump A.

Assume that pump B is the one to be started (duty pump), then the initial conditions include:

- 50-HS-002A and 50-HS-002B are set to auto mode;
- 50-HS-003A is set to select pump A to be in standby mode
- No faults, alarms or shutdowns are active in this system

- All XVs valves installed on the discharge side of the Seawater Lift Pumps, 50-XV-001, 50-XV-002, 50-XV-003 and 50-XV-004 are set in auto mode.

Once it is required to start the pump B then the automatic logic will:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-003 valve that is installed on the duty pump discharge line
- Close the 50-XV-001 valve that is installed on the stand-by pump discharge line
- Start duty Lift pump B.

6.7.1.2 Manual Start Up

Assume that pump A is the one to be started (duty pump), then the initial conditions include:

- 50-HS-002A and 50-HS-002B are set to manual mode;
- 50-HS-003B is set to select pump B to be in standby mode
- No faults, alarms or shutdowns are active in this system

Once it is required to start the pump A then then the operator will:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-001 valve that is installed on the duty pump discharge line
- Close the 50-XV-003 valve that is installed on the stand-by pump discharge line
- Start duty Lift pump A.

Assume that pump B is the one to be started (duty pump), then the initial conditions include:

- 50-HS-002A and 50-HS-002B are set to manual mode;
- 50-HS-003A is set to select pump A to be in standby mode
- No faults, alarms or shutdowns are active in this system

Once it is required to start the pump B then the operator will:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-003 valve that is installed on the duty pump discharge line
- Close the 50-XV-001 valve that is installed on the stand-by pump discharge line
- Start duty Lift pump B.

6.7.2 LOCAL MODE START UP

Under local mode start up the operator, locally, pushes push button PM1-A (PM1-B) to start the pump A (B). After this selection, all the XVs valves that are installed on the discharge lines of the Seawater Lift Pumps A/B will be manually operated by the operator.

Assume that the pump to be started is the pump A, then the operator will perform the following actions on the XVs valves:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-001 valve that is installed on the duty pump A discharge line
- Close the 50-XV-002 valve that is installed on the stand-by pump B discharge line
- Start duty Lift pump A.

Assume that the pump to be started is the pump B, then the operator will perform the following actions on the XVs valves:

- Close the 50-XV-002 and 50-XV-004 that are installed on the pumps by-pass lines
- Open the 50-XV-002 valve that is installed on the duty pump B discharge line
- Close the 50-XV-001 valve that is installed on the stand-by pump A discharge line
- Start duty Lift pump B.

It is noted that when the selector is switched in local mode then the pumps are switched in manual mode and it is not then possible to operate the pumps in auto mode.

6.8 SHUTDOWN PROCEDURE

The shutdown of the Seawater Lift Pump P-50001A (B) can be activated manually from ONSHORE control room by means of the pushbutton 50-HS-005A (005B).

6.9 DEPRESSURIZATION PROCEDURE

Section not applicable.

6.10 PURGING PROCEDURE

Section not applicable.

6.11 PRESSURIZATION PROCEDURE

Section not applicable.

7 HYDROGEN STORAGE SYSTEM

The hydrogen storage system is constituted of six horizontal pressure vessels that will store the hydrogen production. It also includes associate piping and valves that are installed both upstream and downstream hydrogen storage vessels. More precisely the system starts from the exit line of the Electrolyser Package (A-20000) and terminates at the inlet line of the Fuel Cell Package (A-80000).

7.1 EQUIPMENT LIST AND DESIGN BASIS

The hydrogen storage system includes the following equipment:

Service	Hydrogen Storage Vessel
TAG	V-25001 A/B/C/D/E/F
Quantity	6
Size (each one)	2800 mm (ID) x 15500 mm (L T/T)
Design pressure	40 barg
Design temperature	-10 °C / 80 °C
Material	Carbon Steel
Orientation	Horizontal

Table 9 - Hydrogen Storage Vessels Design Data

The Hydrogen Storage Vessels are characterized by the following main operating data:

- Normal Operating overall inlet flowrate 106 kg/h of hydrogen
- Normal Operating overall Vol. Flow 500 Nm^3/hr of hydrogen
- Normal Operating Pressure NOP is a range; from ~4.5 barg to 30.0 barg
- Normal Operating Temperature AMB
- Capacity ~96.0 m^3/each vessel excluding heads volumes

7.2 LOGIC CONTROL DESCRIPTION

During Fuel Cell functionality the only control loop (pressure control loop) present within the hydrogen storage system and which is required to work is the one installed on the outlet manifold of the hydrogen storage vessel (at Fuel Cell Package inlet).
The aim of the above-mentioned control loop is to control the inlet pressure of the hydrogen that is fed to the Fuel Cell Package A-80000. This control loop is identified with:

- pressure controllers: 25-PIC-055A/B;
- pressure transmitters: 25-PT-055A/B (Process Variable);
- final elements: 25-PV-055A/B;
- SP value: normal 6 barg;
- Sub-Controller(s) action: REVERSE (pressure increase, valve close);
- Failure direction: Fail Close

Control valves 25-PV-055A/B work under split range. According to operating condition of the Fuel Cell Package in terms of minimum and maximum pressure as well as minimum and maximum flow rate, a wide range of operating CV is required. Therefore, two control valves in parallel will be used, one valve operates with high CV (valve "A", above a CV of 0.31) while the valve "B" will operate when lower operating CV is required (below a CV of 0.31).

A software interlock prevents control valve 25-PV-055B (A) from opening if control valve 25-PV-055A (B) is working within the required valve opening range. This is to allow both valves to operate within the optimum valves opening range, as designed.
Moreover, software interlock prevents the opening of the control valves 25-PV-055A/B in case Fuel Cell package (A-80000) is not running.

7.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the hydrogen storage system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-FT-031	IO_FAIL	Flow measure - H2 to V-25001A vessel	P&ID (123A90-DDL-PR-PID-80015)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-FT-032	IO_FAIL	Flow measure - H2 to V-25001B vessel	P&ID (123A90-DDL-PR-PID-80016)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-FT-033	IO_FAIL	Flow measure - H2 to V-25001C vessel	P&ID (123A90-DDL-PR-PID-80017)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-FT-034	IO_FAIL	Flow measure - H2 to V-25001D vessel	P&ID (123A90-DDL-PR-PID-80018)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-FT-036	IO_FAIL	Flow measure - N2 to V-25001F vessel	P&ID (123A90-DDL-PR-PID-80020)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-FT-038	IO_FAIL	Flow measure - H2 to V-25001E vessel	P&ID (123A90-DDL-PR-PID-80019)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PT-001	HI	Hydrogen Storage Vessel (Inlet) Pressure	P&ID (123A90-DDL-PR-PID-80013)	33	barg	Blocked discharge toward all six hydrogen	N/A	Impossibility to fill hydrogen storage vessels	Operator can: 1. Inform maintenance/intervention team.	Confirm action of High pressure in the

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
						storage vessels			2. Monitor process conditions.	Electrolyser package
25-PT-001	IO_FAIL	Hydrogen Storage Vessel (Inlet) Press	P&ID (123A90-DDL-PR-PID-80013)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PT-035	LO_LO	Pressure of Hydrogen Storage Vessel V-25001A - During purging modes	P&ID (123A90-DDL-PR-PID-80015)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001A	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-031 and 25-PV-035 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
						under purging operation fall below the set point of 2 barg			response plan 4. Monitor process conditions.	
25-PT-035	LO	Pressure of Hydrogen Storage Vessel V-25001A - During normal operation	P&ID (123A90-DDL-PR-PID-80015)	4	barg	Leakage of Hydrogen from the Vessel V-25001A	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-035	IO_FAIL	Pressure of Hydrogen Storage	P&ID (123A90-DDL-PR-	3.8	mA	1. Instrument fault	N/A	1. Loss of monitoring and control	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		Vessel V-25001A	PID-80015)			2. Channel fault		functionality 2. Loss of channel redundancy		
25-PT-037	LO_LO	Pressure of Hydrogen Storage Vessel V-25001B - During purging modes	P&ID (123A90-DDL-PR-PID-80016)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001B under purging operation fall below the set point of 2 barg	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-032 and 25-PV-037 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 4. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-037	LO	Pressure of Hydrogen Storage Vessel V-25001B - During normal operation	P&ID (123A90-DDL-PR-PID-80016)	4	barg	Leakage of Hydrogen from the Vessel V-25001B	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-037	IO_FAIL	Pressure of Hydrogen Storage Vessel V-25001B	P&ID (123A90-DDL-PR-PID-80016)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-040	LO_LO	Pressure of Hydrogen Storage Vessel V-25001C - During purging modes	P&ID (123A90-DDL-PR-PID-80017)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001C under purging operation fall below the set point of 2 barg	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-033 and 25-PV-040 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 4. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-040	LO	Pressure of Hydrogen Storage Vessel V-25001C - During normal operation	P&ID (123A90-DDL-PR-PID-80017)	4	barg	Leakage of Hydrogen from the Vessel V-25001C	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-040	IO_FAIL	Pressure of Hydrogen Storage Vessel V-25001C	P&ID (123A90-DDL-PR-PID-80017)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-043	LO_LO	Pressure of Hydrogen Storage Vessel V-25001D - During purging modes	P&ID (123A90-DDL-PR-PID-80018)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001D under purging operation fall below the set point of 2 barg	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-034 and 25-PV-043 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 4. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-043	LO	Pressure of Hydrogen Storage Vessel V-25001D - During normal operation	P&ID (123A90-DDL-PR-PID-80018)	4	barg	Leakage of Hydrogen from the Vessel V-25001D	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-043	IO_FAIL	Pressure of Hydrogen Storage Vessel V-25001D	P&ID (123A90-DDL-PR-PID-80018)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-046	LO_LO	Pressure of Hydrogen Storage Vessel V-25001E - During purging modes	P&ID (123A90-DDL-PR-PID-80019)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001E under purging operation fall below the set point of 2 barg	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-038 and 25-PV-046 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 4. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-046	LO	Pressure of Hydrogen Storage Vessel V-25001E - During normal operation	P&ID (123A90-DDL-PR-PID-80019)	4	barg	Leakage of Hydrogen from the Vessel V-25001E	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-046	IO_FAIL	Pressure of Hydrogen Storage Vessel V-25001E	P&ID (123A90-DDL-PR-PID-80019)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-049	LO_LO	Pressure of Hydrogen Storage Vessel V-25001F - During purging modes	P&ID (123A90-DDL-PR-PID-80020)	1.5	barg	Once the desired pressure of 2 barg has been reached, should the pressure inside the vessel V-25001F under purging operation fall below the set point of 2 barg	Valid only during Purging and Process stat-up charging modes when the 2 barg has been reached	No consequences due to the automatic logic that closes the FV inlet and PV outlet control valves when the T4 or T6 time is expired	Operator can: 1. Manually close 25-FV-036 and 25-PV-049 control valves. 2. Inform maintenance/intervention team. 3. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 4. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PT-049	LO	Pressure of Hydrogen Storage Vessel V-25001F - During normal operation	P&ID (123A90-DDL-PR-PID-80020)	4	barg	Leakage of Hydrogen from the Vessel V-25001F	Not Valid during purging mode	No consequences due to the F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.	Operator can: 1. Inform maintenance/intervention team. 2. Evaluate other indications of loss of containment and take necessary actions as per site emergency response plan 3. Monitor process conditions.	
25-PT-049	IO_FAIL	Pressure of Hydrogen Storage Vessel V-25001F	P&ID (123A90-DDL-PR-PID-80020)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PT-055A	LO	Pressure Control for 25-PV-055A - H2 to Fuel	P&ID (123A90-DDL-PR-PID-80014)	3	barg	Malfunction of pressure control loop	Not valid when 25-PV-055A is in closed position	No consequence,due to fact that Fuel cell package has	Operator can: 1. Inform maintenance/intervention team.	The alarm can be valid after the valve not

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		Cell Package						its safety in case of H2 low pressure	2. Monitor process conditions.	close plus 30 sec.
25-PT-055A	HI	Pressure Control for 25-PV-055A - H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80014)	7	barg	Malfunction of pressure control loop	N/A	No consequence due to 80-PSV-001 discharge.	Operator can: 1. Manually close 25-SDV-023 shutdown valve. 2. Inform maintenance/intervention team. 3. Monitor process conditions.	
25-PT-055A	IO_FAIL	Pressure Control for 25-PV-055A - H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80014)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PT-055B	LO	Pressure Control for 25-PV-055B-H2 to	P&ID (123A90-DDL-PR-	3	barg	Malfunction of pressure	Not valid when 25-PV-055B is	No consequence,due to fact that Fuel cell package has	Operator can: 1. Inform maintenance/intervention team.	The alarm can be valid after the

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		Fuel Cell Package	PID-80014)			control loop	in closed position	its safety in case of H2 low pressure	2. Monitor process conditions.	valve not close plus 30 sec.
25-PT-055B	HI	Pressure Control for 25-PV-055B-H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80014)	7	barg	Malfunction of pressure control loop	N/A	No consequence due to 80-PSV-001 discharge.	Operator can: 1. Manually close 25-SDV-023 shutdown valve. 2. Inform maintenance/intervention team. 3. Monitor process conditions.	
25-PT-055B	IO_FAIL	Pressure Control for 25-PV-055B-H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80014)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PI001_002	DEV	Differential Pressure between 25-PI-001	P&ID (123A90-DDL-PR-	± 2.5	% f.s. (40	One of two pressure transmitt	N/A	No consequences: 1. Loss of monitoring	Operator can: 1. Inform maintenance	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		and 25-PI-002 - Hydrogen Storage Vessel (inlet) Press	PID-80013)		barg)	ers blocket or fault		functionality (for 25-PI-001 fault) 2. Loss of Safety functionality (for 25-PI-002 fault): As per hazop action 1.7, in case of High pressure there are the following consequences: - 36 barg (set point of PSV on Electrolyser) H2 from Electrolyser. - Design pressure of storage system is 40 barg, no hazardous consequences.	2. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PI004_035	DEV	Differential Pressure between 25-PI-004 and 25-PI-035 - Hydrogen Storage Vessel A V-25001A Press	P&ID (123A90-DDL-PR-PID-80015)	± 2.5	% f.s. (40 bar g)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-035 fault). The relative logics managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-004 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		
25-PI006_037	DEV	Differential Pressure between 25-PI-006 and 25-PI-037 - Hydrogen Storage Vessel B V-	P&ID (123A90-DDL-PR-PID-80016)	± 2.5	% f.s. (40 barg)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-037 fault). The relative logics	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		25001B Press						managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-006 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PI008_040	DEV	Differential Pressure between 25-PI-008 and 25-PI-040 - Hydrogen Storage Vessel C V-25001C Press	P&ID (123A90-DDL-PR-PID-80017)	± 2.5	% f.s. (40 bar g)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-040 fault). The relative logics managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-008 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		
25-PI009_043	DEV	Differential Pressure between 25-PI-009 and 25-PI-043 - Hydrogen Storage Vessel D V-	P&ID (123A90-DDL-PR-PID-80018)	± 2.5	% f.s. (40 barg)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-043 fault). The relative logics	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		25001D Press						managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-009 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PI011_046	DEV	Differential Pressure between 25-PI-011 and 25-PI-046 - Hydrogen Storage Vessel E V-25001E Press	P&ID (123A90-DDL-PR-PID-80019)	± 2.5	% f.s. (40 bar g)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-046 fault). The relative logics managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-011 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		
25-PI012_049	DEV	Differential Pressure between 25-PI-012 and 25-PI-049 - Hydrogen Storage Vessel F V-	P&ID (123A90-DDL-PR-PID-80020)	± 2.5	% f.s. (40 barg)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality during Process charging/discharging and purging modes (for 25-PI-049 fault). The relative logics	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		25001F Press						managed the process in automatic mode. 2. Loss of Safety functionality (for 25-PI-012 fault): As per hazop action 1.7, in case of High pressure there are the following safeguards: - Pressure Safety Valve designed for fire case - F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
25-PI055A_055B/ 80-PT-002	DEV	Differential Pressure between 25-PI-055A, 25-PI-055B and 80-PT-002- H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80012/14)	± 5	% f.s. (10 barg)	One of three pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality (for 25-PI-055A or 25-PI-055B fault). As per hazop action 3.2.5, there are the following safeguards: - 80-PT-002 High High Pressure trip of PSD closing 25SDV023 and 80-PSV-001 Pressure Safety Valve set point at 10barg. - 80-PT-002 Low Low pressure trip fuel cell and electrolyzer. 2. Loss of Safety	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								functionality (for 80-PI-002 fault): In case of High High pressure the 80-PSV-001 will discharge, in case of low low pressure F&G Detection system will trigger ESD 1D and open all BDV valves on V25001A-F.		

Table 10 - Hydrogen Storage System alarm instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

Here is below the list of instruments connected to the SIS that are included within the seawater intake system (see [Ref. 61]):

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-002	25-P-002	HI_HI	Hydrogen Storage Vessels (inlet) Press	P&ID (123A90-DDL-PR-PID-80013)	36	barg	High pressure from Electrolyser	N/A	PSD activation: CLOSE 25-SDV-001 ON H2 HEADER TO STORAGE TANKS, SHUTDOWN ELECTROLYZER PACKAGE A-20000, SHUTDOWN SEAWATER LIFT PUMP P-50001A, SHUTDOWN SEAWATER LIFT PUMP P-50001B	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.
25-PT-002	25-P-002	IO_FAIL	Hydrogen Storage Vessel (inlet) Press	P&ID (123A90-DDL-PR-PID-80013)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of	Operator can: 1. Inform maintenance

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
									channel redundancy	
25-PT-002_MOS ACTIVE	25-P-002	BYPASS_ON	25-PT-002 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
25-PT-002_MOS	25-P-002	BYPASS_ON	25-PT-002 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.
25-PT-004	25-P-004	HI_HI	Hydrogen Storage Vessel A V-25001A Press	P&ID (123A90-DDL-PR-PID-80015)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization	Operator can: Take necessary actions as per site emergency response plan.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
									3.BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Monitor process conditions.
25-PT-004	25-P-004	IO_FAIL	Hydrogen Storage Vessel A V-25001A Press	P&ID (123A90-DDL-PR-PID-80015)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-004_MOS ACTIVE	25-P-004	BYPASS_ON	25-PT-004 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-004_MOS	25-P-004	BYPASS_ON	25-PT-004 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.
25-PT-006	25-P-006	HI_HI	Hydrogen Storage Vessel B V-25001B Press	P&ID (123A90-DDL-PR-PID-80016)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-006	25-P-006	IO_FAIL	Hydrogen Storage Vessel B V-25001B Press	P&ID (123A90-DDL-PR-PID-80016)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-006_MOS ACTIVE	25-P-006	BYPASS_ON	25-PT-006 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
25-PT-006_MOS	25-P-006	BYPASS_ON	25-PT-006 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-008	25-P-008	HI_HI	Hydrogen Storage Vessel C V-25001C Press	P&ID (123A90-DDL-PR-PID-80017)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.
25-PT-008	25-P-008	IO_FAIL	Hydrogen Storage Vessel C V-25001C Press	P&ID (123A90-DDL-PR-PID-80017)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-008_MOS ACTIVE	25-P-008	BYPASS_ON	25-PT-008 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										when no longer required.
25-PT-008_MOS	25-P-008	BYPASS_ON	25-PT-008 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.
25-PT-009	25-P-009	HI_HI	Hydrogen Storage Vessel D V-25001D Press	P&ID (123A90-DDL-PR-PID-80018)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-009	25-P-009	IO_FAIL	Hydrogen Storage Vessel D V-25001D Press	P&ID (123A90-DDL-PR-PID-80018)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-009_MOS ACTIVE	25-P-009	BYPASS_ON	25-PT-009 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
25-PT-009_MOS	25-P-009	BYPASS_ON	25-PT-009 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
25-PT-011	25-P-011	HI_HI	Hydrogen Storage Vessel E V-25001E Press	P&ID (123A90-DDL-PR-PID-80019)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.
25-PT-011	25-P-011	IO_FAIL	Hydrogen Storage Vessel E V-25001E Press	P&ID (123A90-DDL-PR-PID-80019)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-011_MOS ACTIVE	25-P-011	BYPASS_ON	25-PT-011 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										when no longer required.
25-PT-011_MOS	25-P-011	BYPASS_ON	25-PT-011 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.
25-PT-012	25-P-012	HI_HI	Hydrogen Storage Vessel F V-25001F Press	P&ID (123A90-DDL-PR-PID-80020)	38	barg	External Fire	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS,	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
									NO Solar, NO Fuel Cell	
25-PT-012	25-P-012	IO_FAIL	Hydrogen Storage Vessel F V-25001F Press	P&ID (123A90-DDL-PR-PID-80020)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
25-PT-012_MOS ACTIVE	25-P-012	BYPASS_ON	25-PT-012 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
25-PT-012_MOS	25-P-012	BYPASS_ON	25-PT-012 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										remaining 1 hour and extend the MOS Timer if required.

Table 11 - Hydrogen Storage System trip instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

7.4 INTERLOCK LOGIC DESCRIPTION

The following software interlocks are provided within the Hydrogen Storage System:

Vessel A:
- software interlock to prevent 25-PV-035 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-035 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-031 being opened outside of a purge cycle operation;

Vessel B:
- software interlock to prevent 25-PV-037 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-037 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-032 being opened outside of a purge cycle operation;

Vessel C:
- software interlock to prevent 25-PV-040 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-040 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-033 being opened outside of a purge cycle operation;

Vessel D:
- software interlock to prevent 25-PV-043 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-043 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-034 being opened outside of a purge cycle operation;

Vessel E:
- software interlock to prevent 25-PV-046 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-046 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-038 being opened outside of a purge cycle operation;

Vessel F:
- software interlock to prevent 25-PV-049 being opened outside of a purge cycle operation and process start-up charging mode purging or process start-up charging modes. Control valve 25-PV-049 is used only in case of vessel purging operation or process start-up charging modes;
- software interlock to prevent 25-FV-036 being opened outside of a purge cycle operation;

HYDROGEN OUTLET MANIFOLD
- software interlock to prevent opening of the control valves 25-PV-055A/B in case Fuel Cell (A-80000) is not ready to start

7.5 NORMAL OPERATION CONDITION

Routing valves (XVs) are installed upstream and downstream at the hydrogen storage vessel manifolds to direct the flow of hydrogen during charging and discharging activities.

7.5.1 CHARGING ACTIVITY

In case of charging activity, the system allows the possibility to charge one vessel at time by selecting the related upstream and downstream XVs valves.
During charging activity all XVs valves that are installed on the outlet of each vessel are closed, while only the XVs valves installed on the inlet lines of the vessels to be filled will be open. When the desired pressure inside the vessel is reached (say 30barg), the logic will close the XVs valve at the inlet of the vessel and at same time the XV valve installed on the inlet line of the next vessel to be filled will be open.
The above description is intended to be the normal operating functionality of the system when a vessel is full of hydrogen and at a pressure lower than the maximum operating pressure (lower than 30 barg) since the hydrogen previously contained within the vessel has been fed to the downstream Fuel Cell Package A-80000. At this point the vessel needs to be filled with hydrogen in order to bring the internal pressure at its maximum possible operating pressure of 30 barg.

Let assume the sequence of the vessel to be filled is the following: V-25001A, V-25001B, V-25001C, V-25001D, V-25001E, V-25001F, then the logic will do the following:

1) Close all XVs valves that are installed on the outlet lines of each H2 Storage Vessel: 25-XV-006/009/012/015/018/021;
2) Open the valve 25-XV-004, installed on the inlet line of the V-25001A;
3) Wait until the pressure inside the vessel V-25001A is at 30 barg (pressure indication can be taken from 25-PT-035, installed on the vessel V-25001A);
4) When 25-PT-035 indicates 30 barg, then close the 25-XV-004 and at same time;
5) Open 25-XV-008, installed on the inlet line of the V-25001B;
6) Wait until the pressure inside the vessel V-25001B is at 30 barg (pressure indication can be taken from 25-PT-037, installed on the vessel V-25001B);
7) When 25-PT-037 indicates 30 barg, then close the 25-XV-008 and at same time;
8) Open 25-XV-011, installed on the inlet line of the V-25001C;
9) Wait until the pressure inside the vessel V-25001C is at 30 barg (pressure indication can be taken from 25-PT-040, installed on the vessel V-25001C);
10) When 25-PT-040 indicates 30 barg, then close the 25-XV-011 and at same time;
11) Open 25-XV-014, installed on the inlet line of the V-25001D;

12) Wait until the pressure inside the vessel V-25001D is at 30 barg (pressure indication can be taken from 25-PT-043, installed on the vessel V-25001D);
13) When 25-PT-043 indicates 30 barg, then close the 25-XV-014 and at same time;
14) Open 25-XV-017, installed on the inlet line of the V-25001E;
15) Wait until the pressure inside the vessel V-25001E is at 30 barg (pressure indication can be taken from 25-PT-046, installed on the vessel V-25001E);
16) When 25-PT-046 indicates 30 barg, then close the 25-XV-017 and at same time;
17) Open 25-XV-020, installed on the inlet line of the V-25001F;
18) Wait until the pressure inside the vessel V-25001F is at 30 barg (pressure indication can be taken from 25-PT-049, installed on the vessel V-25001F);
19) When 25-PT-049 indicates 30 barg, then close the 25-XV-020.

At this point all six vessels are full of hydrogen at operating pressure of 30 barg.

7.5.2 DISCHARGING ACTIVITY

During the discharge activity, the hydrogen stored inside the vessels is fed to the downstream Fuel Cell Package (A-80000).

Let assume that all six Hydrogen Storage Vessels are full of hydrogen and at same time at a pressure suitable to feed the Fuel Cell Package, then the logic will do the following:

1) Close all XVs valves that are installed on the inlet lines of each H2 Storage Vessel: 25-XV-004/008/011/014/017/020;
2) Close all XVs valves that are installed on the outlet lines of each H2 Storage Vessel: 25-XV-006/009/012/015/018/021
3) Open the valve 25-XV-006, installed on the outlet line of the V-25001A. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel A approaches to a minimum pressure value, then;
4) Open the valve 25-XV-009, installed on the outlet line of the V-25001B and close the valve 25-XV-006, installed on the outlet line of the V-25001A. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel B approaches to a minimum pressure value, then;
5) Open the valve 25-XV-012, installed on the outlet line of the V-25001C and close the valve 25-XV-009, installed on the outlet line of the V-25001B. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel C approaches to a minimum pressure value, then;

6) Open the valve 25-XV-015, installed on the outlet line of the V-25001D and close the valve 25-XV-012, installed on the outlet line of the V-25001C. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel D approaches to a minimum pressure value, then;
7) Open the valve 25-XV-018, installed on the outlet line of the V-25001E and close the valve 25-XV-015, installed on the outlet line of the V-25001D. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel E approaches to a minimum pressure value, then;
8) Open the valve 25-XV-021, installed on the outlet line of the V-25001F and close the valve 25-XV-018, installed on the outlet line of the V-25001E. At this point the pressure control loop that is installed upstream the Fuel Cell Package will control the hydrogen feeding pressure (see Logic Control Description Section 7.2 above). When the hydrogen pressure inside the vessel F approaches to a minimum pressure value, then;
9) Closed the valve 25-XV-021, installed on the outlet line of the V-25001F.

At this point all hydrogen vessels have an internal pressure that is not sufficient to feed the Fuel Cell package and therefore the discharging activity can be considered concluded.

7.6 UNIT START UP PROCEDURE

As unit start-up operation for the Hydrogen Storage System is intended the operation aimed to fill the vessels with hydrogen after the necessary purging operation for nitrogen displacement has been completed. Therefore, for this procedure reference shall be made to section "pressurization procedure" of this operating manual (see section 7.10).

7.7 SHUTDOWN PROCEDURE

The shutdown of the Hydrogen Storage Systems will be activated for all causes indicated in the document "Base Load Power Hub (BLPH) - Process Safety Cause & Effect Block Diagram" (Ref. [31]). It is noted here that the shutdown of hydrogen storage system is intended as a complete isolation of the system by means of SDVs, which will be closed to isolate the inventory.

The logic will cause:

- the closure of 25-SDV-023 installed on the hydrogen outlet manifold
- the closure of 25-SDV-001 installed on the hydrogen inlet manifold

In case of maintenance activity on the hydrogen system it is necessary to depressurize the system:

- the closure of 25-SDV-001 installed on the hydrogen inlet manifold
- the closure of 25-SDV-023 installed on the hydrogen outlet manifold
- the opening of the valve 25-BDV-005 on the Hydrogen Storage Vessel V-25001A
- the opening of the valve 25-BDV-007 on the Hydrogen Storage Vessel V-25001B
- the opening of the valve 25-BDV-010 on the Hydrogen Storage Vessel V-25001C
- the opening of the valve 25-BDV-013 on the Hydrogen Storage Vessel V-25001D
- the opening of the valve 25-BDV-016 on the Hydrogen Storage Vessel V-25001E
- the opening of the valve 25-BDV-019 on the Hydrogen Storage Vessel V-25001F
- the opening of the valve 25-BDV-022 installed on hydrogen outlet manifold

Once the planned maintenance is completed, prepare the unit for a new start-up.

7.8 DEPRESSURIZATION PROCEDURE

The depressurization procedure of the hydrogen storage vessels can be performed remotely from ONSHORE.

7.9 PURGING PROCEDURE

All six Hydrogen Storage Vessels require three different types of purging operation, depending upon the type of fluid that is necessary to displace from the vessel as well as depending on the type of fluid used to displace:

1) PURGING OPERATION WITH HYDROGEN (FOR NITROGEN DISPLACEMENT)
2) PURGING OPERATION WITH NITROGEN (FOR HYDROGEN DISPLACEMENT)
3) PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)

7.9.1 PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)

The initial condition of a vessel that requires a purging operation for air displacing are below indicated:

- Pressure: almost 0 barg
- Temperature: Ambient
- Fluid contained within the vessel: AIR

This purging operation is used when, after maintenance activities, displacement of air is required, before to reinsert H2 inside the vessel. The purpose of displacing the air from the vessel is to create an inert atmosphere inside the vessel before starting the hydrogen loading phase.

Purging with nitrogen serves this purpose effectively. Nitrogen, being inert, displaces any remaining air present in the vessel. By purging each vessel individually with nitrogen.

Hydrogen Storage Vessel V-25001A

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel A. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-004 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-006 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-005 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-035 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-035 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 12 - AIR purging (with N2) check list table for vessel A

Nitrogen is supplied under flow control (25-FIC-031) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-035).

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The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-031;
- Flow rate transmitter: 25-FT-031 (Process Variable);
- final element: 25-FV-031;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-035 failure opening the valve 25-PV-035. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-035 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-035 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-035 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-035):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-031 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-035 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-035 will alert the operator.

On the vent line of the Hydrogen Storage Vessel A, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-035;
- Pressure transmitter: 25-PT-035 (Process Variable);
- final element: 25-PV-035;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-035 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-035 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-031 outside of a purge cycle operation.

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The below figure shows the required time necessary to displace the fluid inside the vessel.

Operation Scope:

Displace (with nitrogen) remaining O2 after maintenance, reaching inside the Hydrogen Storage Vessel a final O2 concentration of C2

H2 vessel initial condition:

Pressure almost ATM, containing air with O2 initial concentration of C1

SWEEP-Through purging CALCULATION

Final concentration of O2 to be reached at the end of purging operation	C2	%	3.00
Initial concentration of O2 inside vessel at beginning of the purging operation	C1	%	21.00
H2 Storage vessel volume	V	m3	101.19
Required N2 volume to reach C2 concentration (note1, 3)	Q*t	m3	787.63
Temperature, Tpurging		°C	20.00
Pressure during purging operation, Ppurging		bara	3.00
Purging fluid (N2) density @ Tpurging and Ppurging		kg/m3	3.45
Required N2 mass to reach C2 concentration		kg	2714.41
Imposed N2 volumetric flow rate		Nm3/hr	42.50
N2 density @ normal condition (1 bara, 20°C)		kg/m3	1.26
Imposed N2 purging mass flow rate		kg/hr	53.38
Time required to pressurise the vessel from ATM up to Ppurging	tpres	hr	4.55
Time required for SWEEP-Through purging (note2)	tpurge	hr	**50.85**
Total time (pressurisation + purging)	ttot	hr	55.40

NOTES

1) Q*t value has been calculated considering k=0.25,
where k is the correction factor to take into consideration degree of mixing.
2) Time required for SWEEP-Through purging is pressure dependent.
At lower Ppurging, lower tpurge is obtained
3) Assumption: Calculation performed considering that the content of oxygen in the inert gas is negligible.

Figure 5 - SWEEP-Through purging CALCULATION for removal of O2 by means of N2 for Vessel A

The following assumptions and considerations are valid for the above calculation:

- The calculated time is pressure depending;
- The calculated time also depends on the flow rate of the fluid being used to perform the purging operation;
- The above calculation has been carried out for one hydrogen storage vessel;
- All the six vessels are of the same dimensions and volume; therefore, the above calculation and result is also valid for all the other vessels B/C/D/E/F;
- The calculated time considers that a perfect mixing of different fluids inside the vessel is not always reached during the purging operation. Therefore, a correction factor of 0.25 has been considered to obtain a very conservative value of the time required to reach the desired final concentration;
- At the end of the above indicated time, it is assumed that the vessel is ready to move on to the next purging phase (purging with hydrogen for nitrogen displacement).

Hydrogen Storage Vessel V-25001B

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel B. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-008 installed on the Hydrogen Storage Vessel B inlet line is closed	☐ _____
2	Check that the valve 25-XV-009 installed on the Hydrogen Storage Vessel B outlet line is closed	☐ _____
3	Check that the valve 25-BDV-007 installed on the Hydrogen Storage Vessel B depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-037 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-037 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 13 - AIR purging (with N2) check list table for vessel B

Nitrogen is supplied under flow control (25-FIC-032) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-037).

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The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-032;
- Flow rate transmitter: 25-FT-032 (Process Variable);
- final element: 25-FV-032;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-037 failure opening the valve 25-PV-037. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-037 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-037 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-037 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-037):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-032 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-037 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low-pressure alarm on the pressure transmitter 25-PT-037 will alert the operator.

On the vent line of the Hydrogen Storage Vessel B, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-037;
- Pressure transmitter: 25-PT-037 (Process Variable);
- final element: 25-PV-037;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-037 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-037 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-032 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001C

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel C. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-011 installed on the Hydrogen Storage Vessel C inlet line is closed	☐ _____
2	Check that the valve 25-XV-012 installed on the Hydrogen Storage Vessel C outlet line is closed	☐ _____
3	Check that the valve 25-BDV-010 installed on the Hydrogen Storage Vessel C depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-040 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-040 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 14 - AIR purging (with N2) check list table for vessel C

Nitrogen is supplied under flow control (25-FIC-033) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-040).

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The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-033;
- Flow rate transmitter: 25-FT-033 (Process Variable);
- final element: 25-FV-033;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-040 failure opening the valve 25-PV-040. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-040 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-040 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-040 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-040):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-033 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-040 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-040 will alert the operator.

On the vent line of the Hydrogen Storage Vessel C, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-040;
- Pressure transmitter: 25-PT-040 (Process Variable);
- final element: 25-PV-040;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-040 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-040 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-033 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001D

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel D. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-014 installed on the Hydrogen Storage Vessel D inlet line is closed	☐ _____
2	Check that the valve 25-XV-015 installed on the Hydrogen Storage Vessel D outlet line is closed	☐ _____
3	Check that the valve 25-BDV-013 installed on the Hydrogen Storage Vessel D depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-043 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-043 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 15 - AIR purging (with N2) check list table for vessel D

Nitrogen is supplied under flow control (25-FIC-034) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-043).

The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-034;
- Flow rate transmitter: 25-FT-034 (Process Variable);
- final element: 25-FV-034;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-043 failure opening the valve 25-PV-043. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-043 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-043 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-043 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-043):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-034 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-043 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-043 will alert the operator.

On the vent line of the Hydrogen Storage Vessel D, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-043;
- Pressure transmitter: 25-PT-043 (Process Variable);
- final element: 25-PV-043;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-043 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-043 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-034 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001E

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel E. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-017 installed on the Hydrogen Storage Vessel E inlet line is closed	☐ _____
2	Check that the valve 25-XV-018 installed on the Hydrogen Storage Vessel E outlet line is closed	☐ _____
3	Check that the valve 25-BDV-016 installed on the Hydrogen Storage Vessel E depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-046 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-046 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 16 - AIR purging (with N2) check list table for vessel E

Nitrogen is supplied under flow control (25-FIC-038) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-046).
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-038;
- Flow rate transmitter: 25-FT-038 (Process Variable);
- final element: 25-FV-038;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-046 failure opening the valve 25-PV-046. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-046 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-046 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-046 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-046):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-038 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-046 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-046 will alert the operator.

On the vent line of the Hydrogen Storage Vessel E, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-046;

- Pressure transmitter: 25-PT-046 (Process Variable);
- final element: 25-PV-046;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-046 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-046 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-038 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001F

This purging operation for air displacement can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the following:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the purging operation of the vessel F. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-020 installed on the Hydrogen Storage Vessel F inlet line is closed	☐ _____
2	Check that the valve 25-XV-021 installed on the Hydrogen Storage Vessel F outlet line is closed	☐ _____
3	Check that the valve 25-BDV-019 installed on the Hydrogen Storage Vessel F depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-049 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
5	Check that the low-pressure alarm of the 25-PT-049 has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____

Table 17 - AIR purging (with N2) check list table for vessel F

Nitrogen is supplied under flow control (25-FIC-036) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-049).

The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-036;
- Flow rate transmitter: 25-FT-036 (Process Variable);
- final element: 25-FV-036;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-049 failure opening the valve 25-PV-049. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- low-pressure alarm of the 25-PT-046 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-046 will alert the operator.

At the time the 25-PV-049 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-049):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-036 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-049 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-049 will alert the operator.

On the vent line of the Hydrogen Storage Vessel F, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-049;
- Pressure transmitter: 25-PT-049 (Process Variable);
- final element: 25-PV-049;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

* Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

The control valve 25-PV-049 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-049 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-036 outside of a purge cycle operation.

7.9.2 PURGING OPERATION WITH HYDROGEN (FOR NITROGEN DISPLACEMENT)

Once the electrolyser package is ready to divert the pure hydrogen stream towards the H2 storage vessels, the startup sequence begins with purging each hydrogen storage vessel. The sweep purging method is applied to displaced under a constant pressure all residual gases or contaminants from the vessels.
During first vessel filling operation it is important to displace the nitrogen that is present within the vessel, in order to ensure a pure hydrogen feed stream to the downstream Fuel Cell Package.

Hydrogen Storage Vessel V-25001A

It is assumed that the vessel V-25001A is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel A. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-004 installed on the Hydrogen Storage Vessel A inlet line is open	☐ _____
2	Check that the valve 25-XV-006 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-005 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-035 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-035 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 18 – N2 purging (with H2) check list table for vessel A

On the vent line of each H2 Storage Vessel V-25001A, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-035;
- Pressure transmitter: 25-PT-035 (Process Variable);
- final element: 25-PV-035;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-035 will alert the operator.

The below figure shows the required time necessary to displace the fluid inside the vessel.

Operation Scope:			
Displace (with hydrogen) remaining N2 after purging, reaching inside the Hydrogen Storage Vessel a final N2 concentration of C2			
H2 vessel initial condition:			
Pressure 2 barg inside vessel with N2 initial concentration of C1			
SWEEP-Through purging CALCULATION			
Final concentration of N2 to be reached at the end of purging operation	C2	%	0.00
Initial concentration of N2 inside vessel at beginning of the purging operation	C1	%	97.00
H2 Storage vessel volume	V	m3	101.19
Required N2 volume to reach C2 concentration (note1)	Q*t	m3	4647.64
Temperature		°C	20.00
Pressure during purging operation, Ppurging		bara	3.00
Purging fluid (H2) density @ Tpurging and Ppurging		kg/m3	0.25
Required H2 mass to reach C2 concentration		kg	1149.81
Imposed H2 volumetric flow rate		Nm3/hr	500.00
H2 density @ normal condition (1 bara, 20°C)		kg/m3	0.08
Imposed H2 purging mass flow rate		kg/hr	41.23
Time required for SWEEP-Through purging (note2)	tpurge	hr	**27.89**
NOTES			
1) Q*t value has been calculated considering k=0.25, where k is the correction factor to take into consideration degree of mixing. 2) Time required for SWEEP-Through purging is pressure dependent. At lower Ppurging, lower tpurge is obtained			

Figure 6 - SWEEP-Through purging CALCULATION for removal of N2 by means of H2 for Vessel A

The following assumptions and considerations are valid for the above calculation:

- The calculated time is pressure depending;
- The calculated time also depends on the flow rate of the fluid being used to perform the purging operation;
- The above calculation has been carried out for one hydrogen storage vessel;
- All the six vessels are of the same dimensions and volume; therefore, the above calculation and result is also valid for all the other vessels B/C/D/E/F;
- The calculated time considers that a perfect mixing of different fluids inside the vessel is not always reached during the purging operation. Therefore, a correction factor of 0.25 has been considered to obtain a very conservative value of the time required to reach the desired final concentration;
- At the end of the above indicated time, it is assumed that the vessel is ready to move on to the charging phase (pressurization up to the maximum operating pressure of 30 barg).

Hydrogen Storage Vessel V-25001B

It is assumed that the vessel V-25001B is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel B. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-008 installed on the Hydrogen Storage Vessel B inlet line is open	☐ _____
2	Check that the valve 25-XV-009 installed on the Hydrogen Storage Vessel B outlet line is closed	☐ _____
3	Check that the valve 25-BDV-007 installed on the Hydrogen Storage Vessel B depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-037 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-037 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 19 – N2 purging (with H2) check list table for vessel B

On the vent line of each H2 Storage Vessel V-25001B, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-037;
- Pressure transmitter: 25-PT-037 (Process Variable);
- final element: 25-PV-037;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-037 will alert the operator.

Hydrogen Storage Vessel V-25001C

It is assumed that the vessel V-25001C is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel C. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-011 installed on the Hydrogen Storage Vessel C inlet line is open	☐ _____
2	Check that the valve 25-XV-012 installed on the Hydrogen Storage Vessel C outlet line is closed	☐ _____
3	Check that the valve 25-BDV-010 installed on the Hydrogen Storage Vessel C depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-040 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-040 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 20 - N2 purging (with H2) check list table for vessel C

On the vent line of each H2 Storage Vessel V-25001C, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-040;
- Pressure transmitter: 25-PT-040 (Process Variable);
- final element: 25-PV-040;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-040 will alert the operator.

Hydrogen Storage Vessel V-25001D

It is assumed that the vessel V-25001D is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel D. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-014 installed on the Hydrogen Storage Vessel D inlet line is open	☐ _____
2	Check that the valve 25-XV-015 installed on the Hydrogen Storage Vessel D outlet line is closed	☐ _____
3	Check that the valve 25-BDV-013 installed on the Hydrogen Storage Vessel D depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-043 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-043 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 21 - N2 purging (with H2) check list table for vessel D

On the vent line of each H2 Storage Vessel V-25001D, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-043;
- Pressure transmitter: 25-PT-043 (Process Variable);
- final element: 25-PV-043;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-043 will alert the operator.

Hydrogen Storage Vessel V-25001E

It is assumed that the vessel V-25001E is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel E. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-017 installed on the Hydrogen Storage Vessel E inlet line is open	☐ _____
2	Check that the valve 25-XV-018 installed on the Hydrogen Storage Vessel E outlet line is closed	☐ _____
3	Check that the valve 25-BDV-016 installed on the Hydrogen Storage Vessel E depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-046 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-046 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 22 - N2 purging (with H2) check list table for vessel E

On the vent line of each H2 Storage Vessel V-25001E, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-046;
- Pressure transmitter: 25-PT-046 (Process Variable);
- final element: 25-PV-046;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-046 will alert the operator.

Hydrogen Storage Vessel V-25001F

It is assumed that the vessel V-25001F is already at a pressure at which the previous purging operation (for air displacement by mean of nitrogen) has been performed. Therefore, let assume the previous purging operation has been carried out at 2 barg (see section 7.9.1 for "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)").

The displacement of nitrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid;
- Electrolyser Package is capable to deliver, towards the vessel to be purged, a constant on spec. hydrogen flow rate of 500 N m^3/hr

Once the above prerequisites are positive it is possible to proceed with the nitrogen displacement contained within the vessel F. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-020 installed on the Hydrogen Storage Vessel F inlet line is open	☐ _____
2	Check that the valve 25-XV-021 installed on the Hydrogen Storage Vessel F outlet line is closed	☐ _____
3	Check that the valve 25-BDV-019 installed on the Hydrogen Storage Vessel F depressurisation line is closed	☐ _____
4	Check that the pressure transmitter 25-PT-049 indicates a pressure equal to the pressure at which "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)" has been performed (see section "PURGING OPERATION WITH NITROGEN (FOR AIR DISPLACEMENT)")	☐ _____
5	Check that the low-pressure alarm of the 25-PT-049 has been activated	☐ _____
6	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
7	Check that the SDV 25-SDV-001 installed on the hydrogen inlet manifold is open	☐ _____
8	Check that the high pressure alarm of the 25-PT-001 installed on the hydrogen inlet manifold has been activated	☐ _____
9	Check that the high-high pressure trip of the 25-PT-002 installed on the hydrogen inlet manifold has been activated	☐ _____
10	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 23 - N2 purging (with H2) check list table for vessel F

On the vent line of each H2 Storage Vessel V-25001F, a pressure control loop in provided, in order to control the pressure inside the vessel during purging operation. The pressure control loop is identified with:

- Pressure controller: 25-PIC-049;
- Pressure transmitter: 25-PT-049 (Process Variable);
- final element: 25-PV-049;
- SP value: ~2 barg *;
- Sub-Controller(s) action: DIRECT (pressure increase, valve open);
- Failure direction: FAIL CLOSE.

During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-049 will alert the operator.

7.9.3 PURGING OPERATION WITH NITROGEN (FOR HYDROGEN DISPLACEMENT)

The aim of this purging operation is to displace the hydrogen that is present inside the vessels after depressurisation has been carried out. During maintenance procedures, it's crucial to ensure that the hydrogen storage vessel is thoroughly cleaned and free of any contaminants or residual gas. Purging with nitrogen serves this purpose effectively. Nitrogen, being inert, displaces any remaining hydrogen or other gases present in the vessel, creating a clean and safe environment for maintenance activities. By purging each H2 storage vessel individually with nitrogen, maintenance technicians can ensure that each vessel receives proper attention and cleaning tailored to its specific requirements.

It is assumed that the vessel being purged has been previously depressurised and therefore the pressure inside the vessel is ATM. At this pressure, and depending on the ambient temperature at the time of the purging operation, the estimated hydrogen density that is contained within the vessel is in the range of 0.09 – 0.1 kg/ m^3. Therefore, having each vessel a volume of 101 m^3, the estimate amount of hydrogen contained within 1 vessel is in the range of 9-10 kg, that is the quantity to be displaced each time one vessel is purged.

Hydrogen Storage Vessel V-25001A

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel A. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-004 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-006 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-005 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-035 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-035 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 24 - H2 purging (with N2) check list table for vessel A

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel A.
It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-031) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-035).

The operation (time = 0) starts as the nitrogen flow control valve 25-FV-031 opens. At this time the pressure timer alarm is activated.

The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-031;
- Flow rate transmitter: 25-FT-031 (Process Variable);
- final element: 25-FV-031;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-035 failure opening the valve 25-PV-035. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-035 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-035 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-035 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-035):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-031 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-035 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-035 will alert the operator.

The control valve 25-PV-035 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-035 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-031 outside of a purge cycle operation.

The below figure shows the required time necessary to displace the hydrogen inside the vessel.

Operation Scope:
Displace (with nitrogen) remaining H2 after depressurization, reaching inside the Hydrogen Storage Vessel a final H2 concentration of C2

H2 vessel initial condition:
Pressure almost ATM with roughly 10 kg of H2 inside (initial H2 concentration, C1)

SWEEP-Through purging CALCULATION

Final concentration of H2 to be reached at the end of purging operation	C2	%	3.00
Initial concentration of H2 inside vessel at beginning of the purging operation	C1	%	100.00
H2 Storage vessel volume	V	m3	101.19
Required N2 volume to reach C2 concentration (note1, 3)	Q*t	m3	1419.31
Temperature		°C	20.00
Pressure during purging operation, Ppurging		bara	3.00
Purging fluid (N2) density @ Tpurging and Ppurging		kg/m3	3.45
Required N2 mass to reach C2 concentration		kg	4891.41
Imposed N2 volumetric flow rate		Nm3/hr	42.50
N2 density @ normal condition (1 bara, 20°C)		kg/m3	1.26
Imposed N2 purging mass flow rate		kg/hr	53.38
Time required to pressurise the vessel from ATM up to Ppurging	tpres	hr	4.55
Time required for SWEEP-Through purging (note2)	tpurge	hr	**91.63**
Total time (pressurisation + purging)	ttot	hr	96.18

NOTES

1) Q*t value has been calculated considering k=0.25,
where k is the correction factor to take into consideration degree of mixing.
2) Time required for SWEEP-Through purging is pressure dependent.
At lower Ppurging, lower tpurge is obtained
3) Assumption: Calculation performed considering that the content of oxygen in the inert gas is negligible.

Figure 7 - SWEEP-Through purging CALCULATION for removal of H2 by means of N2 for Vessel A

The following assumptions and considerations are valid for the above calculation:

- The calculated time is pressure depending;
- The calculated time also depends on the flow rate of the fluid being used to perform the purging operation;
- The above calculation has been carried out for one hydrogen storage vessel;
- All the six vessels are of the same dimensions and volume; therefore, the above calculation and result is also valid for all the other vessels B/C/D/E/F;
- The calculated time considers that a perfect mixing of different fluids inside the vessel is not always reached during the purging operation. Therefore, a correction factor of 0.25 has been considered to obtain a very conservative value of the time required to reach the desired final concentration.

Hydrogen Storage Vessel V-25001B

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel B. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-008 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-009 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-007 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-037 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-037 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 25 - H2 purging (with N2) check list table for vessel B

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel B.
It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-032) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-037).
The operation (time = 0) starts as the nitrogen flow control valve 25-FV-032 opens. At this time the pressure timer alarm is activated.
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-032;
- Flow rate transmitter: 25-FT-032 (Process Variable);
- final element: 25-FV-032;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-037 failure opening the valve 25-PV-037. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-037 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-037 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-037 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-037):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-032 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-037 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-037 will alert the operator.

The control valve 25-PV-037 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-037 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-032 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001C

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel C. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-011 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-012 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-010 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-040 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-040 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 26 - H2 purging (with N2) check list table for vessel C

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel C.

It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-033) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-040).
The operation (time = 0) starts as the nitrogen flow control valve 25-FV-033 opens. At this time the pressure timer alarm is activated.
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-033;
- Flow rate transmitter: 25-FT-033 (Process Variable);
- final element: 25-FV-033;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-040 failure opening the valve 25-PV-040. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-040 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-040 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-040 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-040):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-033 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.

- low-pressure alarm of the 25-PT-040 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-040 will alert the operator.

The control valve 25-PV-040 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-040 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-033 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001D

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel D. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-014 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-015 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-013 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-043 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-043 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 27 - H2 purging (with N2) check list table for vessel D

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel D.
It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-034) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-043).
The operation (time = 0) starts as the nitrogen flow control valve 25-FV-034 opens. At this time the pressure timer alarm is activated.
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-034;
- Flow rate transmitter: 25-FT-034 (Process Variable);
- final element: 25-FV-034;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-043 failure opening the valve 25-PV-043. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-043 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-043 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-043 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-043):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-034 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;

- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-043 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-043 will alert the operator.

The control valve 25-PV-043 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-043 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-034 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001E

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel E. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-017 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-018 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-016 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-046 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-046 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 28 - H2 purging (with N2) check list table for vessel E

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel A.
It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-038) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-046).
The operation (time = 0) starts as the nitrogen flow control valve 25-FV-038 opens. At this time the pressure timer alarm is activated.
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-038;
- Flow rate transmitter: 25-FT-038 (Process Variable);
- final element: 25-FV-038;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-046 failure opening the valve 25-PV-046. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-046 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-046 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-046 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-046):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-038 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;

- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-046 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-046 will alert the operator.

The control valve 25-PV-046 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-046 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-038 outside of a purge cycle operation.

Hydrogen Storage Vessel V-25001F

The displacement of hydrogen can be performed remotely from the onshore control room. Before proceeding with this purging operation, it is assumed the followings conditions:

- Instrument Air Package A-63000 is running with no fault signals active;
- Nitrogen System A-64000 is running with no fault signals active;
- Vent System available and ready to receive displaced fluid.

Once the above prerequisites are positive it is possible to proceed with the hydrogen displacement contained within the vessel F. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve 25-XV-020 installed on the Hydrogen Storage Vessel A inlet line is closed	☐ _____
2	Check that the valve 25-XV-021 installed on the Hydrogen Storage Vessel A outlet line is closed	☐ _____
3	Check that the valve 25-BDV-019 installed on the Hydrogen Storage Vessel A depressurisation line is closed	☐ _____
5	Check that the pressure transmitter 25-PT-049 indicates a pressure close to atmosphere (almost 0 barg)	☐ _____
6	Check that the low-pressure alarm of the 25-PT-049 has been dactivated (to prevent the low-pressure alarm is triggered unnecessarily)	☐ _____
7	Check that all XVs valves that are installed on the inlet lines of the vessels that are not being purged are closed	☐ _____
8	Check that the XV valve 25-XV-024 installed on the hydrogen inlet manifold purging line is closed	☐ _____

Table 29 - H2 purging (with N2) check list table for vessel F

At beginning of the purging operation there will be a pressurisation phase where the vessel is pressurised from initial pressure of ATM to 2 barg, the set point of the control loop installed on the vent line of the vessel A.
It is noted the this set point is adjustable and as such can be modified before starting the purging. Different values can be set, depending on the available time to carry out the purging operation. It is noted here that the higher the pressure at which sweep-through purging operation is carried out, the longer it will last.

Nitrogen is supplied under flow control (25-FIC-036) and the relevant flow control valves to ensure a constant N2 flow rate during the time to pressurize the vessel under purging operation. Being the inlet N2 flow rate constant, it is possible to calculate and establish a time that is required to pressurise the vessel from 0 barg up to the chosen pressure at which sweep-through purging is performed (this will be the set point of the 25-PIC-049).
The operation (time = 0) starts as the nitrogen flow control valve 25-FV-036 opens. At this time the pressure timer alarm is activated.
The nitrogen flow rate control valve controls the nitrogen supply to each H2 Storage Vessel during purging operation by means of the control loop identified with:

- Flow rate controller: 25-FIC-036;
- Flow rate transmitter: 25-FT-036 (Process Variable);
- final element: 25-FV-036;
- SP value: ~42 N m^3/hr;
- Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
- Failure direction: FAIL CLOSE

At the beginning of the purging operation (more specifically during pressurisation of the vessel to be purged) a timer alarm, in the control logic, is implemented to determine if 25-PIC-049 failure opening the valve 25-PV-049. It is expected that, according to:

- the constant flow rate of N2 entering to the vessel under purging operation;
- the above indicated pressure set point of 2 barg,
- the pressure set point of the 25-PIC-049 will be reached in roughly 4.5 hours. Therefore, after such time, should the 25-PT-049 indicate a pressure less than the above indicated set point, a time alarm will alert the operator that the vessel has not reached the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be deactivated.

At the time the 25-PV-049 set pressure is reached, the pressure control loop (below described) is used to keep constant the pressure at which the sweep-through purging operation is carried out. Thus, once the desired pressure is reached (set point of 25-PIC-049):

- the flow control loop will be deactivated. It is important to note here that at the time the pressure set point is reached, the flow control valve 25-FV-036 will be commanded to remain in the last open position, this is to guarantee a constant nitrogen flow rate to the vessel under sweep-trough purging operation;
- the pressure control loop will be activated. The pressure will be kept constant by means of the pressure control loop.
- low-pressure alarm of the 25-PT-049 will be now activated. During this phase, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, the low pressure alarm on the pressure transmitter 25-PT-049 will alert the operator.

The control valve 25-PV-049 is used only in case of vessel purging. Therefore, a software interlock is provided to prevent 25-PV-049 being opened outside of a purge cycle operation. Another software interlock prevents the opening of the control valve 25-FV-036 outside of a purge cycle operation.

7.10 PRESSURIZATION PROCEDURE

As unit start-up operation for the Hydrogen Storage System is intended the operation aimed to fill the vessels with hydrogen after the necessary purging operation for nitrogen displacement has been completed. Therefore, it is assumed that the vessels have previously been purged with hydrogen to displace nitrogen and the initial conditions of the vessels being filled with hydrogen are the following:

1) Pressure at almost 2 barg. To be noted that this value represents the pressure at which purging operation (to displace nitrogen by means of hydrogen) is carried out. For details about procedure to be followed for the above-mentioned purging operation see section "purging procedure" of this document;
2) The composition of the fluid contained within the vessels is hydrogen on-spec.

Start-up of the hydrogen storage system is subject to the following preparatory activities:

- Completion of Start-up preparation activities and prerequisites for the Electrolyser Package, A-20000, as per Vendor recommendations; refer to document, [Ref. [56]]
- Completion of Start-up preparation activities and prerequisites for the Water Treatment Package, A-50000, as per Vendor recommendations; refer to document "INSTALLATION, OPERATING AND MAINTENANCE MANUAL (WATER TREATMENT)", [Ref. [51]]
- Completion of Start-up preparation activities and prerequisites for the Instrument Air Package, A-63000, as per Vendor recommendations; refer to document "INSTALLATION, OPERATING AND MAINTENANCE MANUAL - INSTRUMENT AIR PACKAGE", [Ref. [54]]
- Completion of Start-up preparation activities and prerequisites for the Nitrogen Generation System, A-64000, as per Vendor recommendations; refer to document "INSTALLATION, OPERATING AND MAINTENANCE MANUAL - NITROGEN GENERATION PACKAGE", [Ref. [55]]
- Completion of Start-up preparation activities and prerequisites for the Hydrogen Vent, Q-43004, as per Vendor recommendations; refer to document "INSTALLATION OPERATING AND MAINTENANCE MANUAL (HYDROGEN VENT)", [Ref. [53]]
- Completion of the following purging operations are also necessary:
  - ✓ Completion of purging operations to displace air;
  - ✓ Completion of purging operations to displace nitrogen.

Once the above prerequisites are positive it is possible to proceed with the start up. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the manual valve BLPH-MV-003, installed at Electrolyser exit line is open	☐ _____
2	Check that the manual valve BLPH-MV-466, installed at Electrolyser exit line is closed	☐ _____
3	Check that the manual valve BLPH-MV-010, installed on the purging line of the hydrogen inlet manifold is open	☐ _____
4	Check that the manual valve BLPH-MV-029, installed at Hydrogen Storage Vessel V-25001A inlet line is open	☐ _____
5	Check that the manual valve BLPH-MV-385, installed at Hydrogen Storage Vessel V-25001B inlet line is open	☐ _____
6	Check that the manual valve BLPH-MV-193, installed at Hydrogen Storage Vessel V-25001C inlet line is open	☐ _____
7	Check that the manual valve BLPH-MV-098, installed at Hydrogen Storage Vessel V-25001D inlet line is open	☐ _____
8	Check that the manual valve BLPH-MV-198, installed at Hydrogen Storage Vessel V-25001E inlet line is open	☐ _____
9	Check that the manual valve BLPH-MV-211, installed at Hydrogen Storage Vessel V-25001F inlet line is open	☐ _____
10	Check that the manual valve BLPH-MV-086, installed at Hydrogen Storage Vessel V-25001A outlet line is open	☐ _____
11	Check that the manual valve BLPH-MV-384, installed at Hydrogen Storage Vessel V-25001B outlet line is open	☐ _____
12	Check that the manual valve BLPH-MV-192, installed at Hydrogen Storage Vessel V-25001C outlet line is open	☐ _____

	ACTION	CHECK
13	Check that the manual valve BLPH-MV-195, installed at Hydrogen Storage Vessel V-25001D outlet line is open	☐ _____
14	Check that the manual valve BLPH-MV-197, installed at Hydrogen Storage Vessel V-25001E outlet line is open	☐ _____
15	Check that the manual valve BLPH-MV-200, installed at Hydrogen Storage Vessel V-25001F outlet line is open	☐ _____
16	Check that the manual valves BLPH-MV-034/032/035/033, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001A are open	☐ _____
17	Check that the manual valves BLPH-MV-266/222/264/201, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001B are open	☐ _____
18	Check that the manual valves BLPH-MV-389/387/388/191, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001C are open	☐ _____
19	Check that the manual valves BLPH-MV-416/423/424/194, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001D are open	☐ _____
20	Check that the manual valves BLPH-MV-433/431/432/196, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001E are open	☐ _____
21	Check that the manual valves BLPH-MV-442/440/441/199, installed on the relief and depressurization lines of the Hydrogen Storage Vessel V-25001F are open	☐ _____
22	Check that the manual valve BLPH-MV-018, installed on the depressurization line of the hydrogen outlet manifold is open	☐ _____
23	Check that the manual valves BLPH-MV-468/024/028, installed on the hydrogen outlet manifold are closed	☐ _____
24	Check that the manual valves BLPH-MV-006/005, installed on the relief line of the hydrogen outlet manifold are open	☐ _____

	ACTION	CHECK
25	Check that the manual valves BLPH-MV-007/009, installed on the purging line of the hydrogen outlet manifold are open	☐ _____
26	Check that the manual valve BLPH-MV-016, installed on the feeding line of the Fuel Cell Package A-80000 is open	☐ _____

Table 30 - Hydrogen Storage Vessels unit start-up check list table

Once the above checks and reviews are positive, the startup procedure of the Hydrogen Storage System can be performed.

Let assume the sequence of the vessel to be filled with hydrogen is the following: V-25001A, V-25001B, V-25001C, V-25001D, V-25001E, V-25001F, then the logic will do the following:

1) Close all XVs valves that are installed on the outlet lines of each H2 Storage Vessel: 25-XV-006/009/012/015/018/021;
2) Open the valve 25-XV-004, installed on the inlet line of the V-25001A;
3) Wait until the pressure inside the vessel V-25001A is at 30 barg (pressure indication can be taken from 25-PT-035, installed on the vessel V-25001A);
4) When 25-PT-035 indicates 30 barg, then close the 25-XV-004 and at same time;
5) Open 25-XV-008, installed on the inlet line of the V-25001B;
6) Wait until the pressure inside the vessel V-25001B is at 30 barg (pressure indication can be taken from 25-PT-037, installed on the vessel V-25001B);
7) When 25-PT-037 indicates 30 barg, then close the 25-XV-008 and at same time;
8) Open 25-XV-011, installed on the inlet line of the V-25001C;
9) Wait until the pressure inside the vessel V-25001C is at 30 barg (pressure indication can be taken from 25-PT-040, installed on the vessel V-25001C);
10) When 25-PT-040 indicates 30 barg, then close the 25-XV-011 and at same time;
11) Open 25-XV-014, installed on the inlet line of the V-25001D;
12) Wait until the pressure inside the vessel V-25001D is at 30 barg (pressure indication can be taken from 25-PT-043, installed on the vessel V-25001D);
13) When 25-PT-043 indicates 30 barg, then close the 25-XV-014 and at same time;
14) Open 25-XV-017, installed on the inlet line of the V-25001E;
15) Wait until the pressure inside the vessel V-25001E is at 30 barg (pressure indication can be taken from 25-PT-046, installed on the vessel V-25001E);
16) When 25-PT-046 indicates 30 barg, then close the 25-XV-017 and at same time;
17) Open 25-XV-020, installed on the inlet line of the V-25001F;

18) Wait until the pressure inside the vessel V-25001F is at 30 barg (pressure indication can be taken from 25-PT-049, installed on the vessel V-25001F);

19) When 25-PT-049 indicates 30 barg, then close the 25-XV-020.

At this point all six vessels are full of hydrogen at maximum operating pressure of 30 barg.

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8 WATER DISPOSAL

Water disposal is composed of the following equipments:

- Brine Discharge Caisson (B-50014);
- Waste Water Tank (T-55001).

8.1 EQUIPMENT LIST AND DESIGN BASIS

The water disposal system includes the following equipments:

Service	Brine Discharge Caisson
TAG	B-50014
Quantity	1
SIZE (DxH)	323 mm x 21808 mm
Material	CARBON STEEL

Table 31 – Brine Discharge Caisson Design Data

Service	Waste Water Tank
TAG	T-55001
Quantity	1
Capacity	16 m^3
Material	CARBON STEEL

Table 32 – Waste Water Tank Design Data

8.2 LOGIC CONTROL DESCRIPTION

Section not applicable since there is no any control loop within the water disposal system.

8.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the water disposal system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
55-LT-001	HI	Vessel T-55001 level	P&ID (123A90-DDL-PR-PID-80026)	250	mm	unexpected liquid quantity accumulated within the tank over a period of less six months	N/A	Possible overfilling of the tank	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	
55-LT-001	LO	Vessel T-55001 level	P&ID (123A90-DDL-PR-PID-80026)	300	mm	operator has not stopped the draining disposal operation when required	Alarm valid only during maintenance	No consequence since the tank has been fully emptied	Operator can: 1. Inform maintenance/intervention team.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
55-LT-001	IO_FAIL	Vessel T-55001 level	P&ID (123A90-DDL-PR-PID-80026)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
25-PI055A_055B/ 80-PT-002	DEV	Differential Pressure between 25-PI-055A, 25-PI-055B and 80-PT-002-H2 to Fuel Cell Package	P&ID (123A90-DDL-PR-PID-80012/14)	± 5	% f.s. (10 barg)	One of three pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality (for 25-PI-055A or 25-PI-055B fault). As per hazop action 3.2.5, there are the following safeguards: - 80-PT-002 High High Pressure trip of PSD closing 25SDV023 and	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								80-PSV-001 Pressure Safety Valve set point at 10barg. - 80-PT-002 Low Low pressure trip fuel cell and electrolyzer. 2. Loss of Safety functionality (for 80-PI-002 fault): In case of High High pressure the 80-PSV-001 will discharge, in case of low low pressure F&G Detection system will trigger ESD 1D and open all		

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								BDV valves on V25001A-F.		

Table 33 – Water Disposal System check list table

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

8.4 INTERLOCK LOGIC DESCRIPTION

Section not applicable.

8.5 NORMAL OPERATION CONDITION

8.5.1 BRINE DISCHARGE CAISSON

During normal operation the Brine Discharge Caisson serves as a discharge point for the following systems, packages and equipments:

- IA system (continuous);
- Fuel Cell Package (discontinuous);
- Electrolyser Package (discontinuous);
- Water Treatment System (discontinuous);
- Hydrogen Vent KOD (discontinuous).

At inlet of the Brine Discharge Caisson a temperature transmitter (50-TT002) is provided in order to monitor the temperature of the fluid discharged to the caisson. Moreover, between this 50-TT-002 and the temperature transmitter 50-TT-001 (installed just at the inlet of the water treatment package) a differential temperature is provided in order to alarm the operator that the fluid being discharged has a temperature too high compared with the seawater temperature. This scenario is due to an unexpected high temperature of the drain stream from the electrolyser.

To monitor the temperature of the water stream discharged from the Water Treatment Package, the temperature transmitter located inside the package can be used. Moreover, in order to sample the water stream discharged from the Water Treatment Package, the sampling point installed inside the package can be used (see [Ref. [46]).

On the inlet line of the Brine Discharge Caisson, a valve 50-XV-005 is provided. The valve will be closed, through the ICSS system.
Upstream of the 50-XV-005 a sampling point is provided in order to perform sampling operation upon operator arrival. This will require to close the 50-XV-005 before the draining operation has finished, to allow sample collection.

SAMPLING

Sampling operation of the water disposal on main discharge line 1-1/2"-WW-073-01CS-H:

1) Activate platform MAINTENANCE mode: the automatic logic will close valve 50-XV-005;
2) Operator manually opens valve BLPH-MV-412 (Always closed);
3) Sample to be taken in a glass or a bottle to be delivered onshore for analysis.
4) Close valve BLPH-MV-412.

For valve position refer to doc. N. 123A90-DDL-PR-PID-80025, [Ref. [25]

Sampling operation of water treatment package, on discharge line 1"-SWR-045-01CS-H:

1) Activate platform REASEARCH mode;
2) Manually start water treatment package;
3) Operator manually opens valve MV-572 inside water treatment package (manual valve MV-572 is installed downstream the Fresh Water Pumps P-50009A/B);
4) The temperature transmitter 50-TT-024 (installed in the proximity of the above-mentioned manual valve MV-572) can be used to know temperature of the water being discharged during sampling operation);
5) Sample to be taken in a glass or a bottle to be delivered onshore for analysis.
6) Close valve MV-572.

For valve position refer to doc. N. 1724000448-PR-PID-00013 sh.5, [Ref. [46].

8.5.2 WASTE WATER TANK

The waste water tank serves as a discharge point for the following systems, packages and equipments:

- Electrolyser package;
- Water Treatment System;
- Liquid Seal Drum.

The discharge of the liquid from the water treatment system to the waste water tank is only performed during maintenance activities, while it is expected that liquid from the Electrolyser Package can be discharge during normal operation of the package.

8.6 UNIT START UP PROCEDURE

Section not applicable.

8.7 SHUTDOWN PROCEDURE

Section not applicable.

8.8 DEPRESSURIZATION PROCEDURE

Section not applicable.

8.9 PURGING PROCEDURE

Section not applicable.

8.10 PRESSURIZATION PROCEDURE

Section not applicable.

8.11 EMPTYING PROCEDURE

The liquid is accumulated inside the large volume and then shipped to disposal for treatment. The waste water tank is provided of a drain line and a drain valve, installed at the bottom of the tank, to allow emptying operation.

The following procedure should be followed:

a) ensure that all the necessary draining operations of the systems to be drained towards the wastewater tank have been finalized;
b) connect the drain line with the ship disposal system;
c) open the manual valve installed on the drain line of the wastewater tank (MV-467);
d) check the liquid level inside the wastewater tank by means of the level transmitter 55-LT-001. When liquid level is approaching to the minimum level, then;
e) close the manual valve MV-467;
f) disconnect the drain line from the disposal system. At this point the emptying procedure can be considered finished.

9 HYDROGEN VENT

The hydrogen vent system is constituted of a Hydrogen Vent KO Drum (V-43001) and a Hydrogen Vent Package (Q-43004). The system is designed to convey the hydrogen stream released during various scenarios to a safe location.

9.1 EQUIPMENT LIST AND DESIGN BASIS

The hydrogen storage system includes the following equipment:

Service	Hydrogen Vent KO Drum
TAG	V-43001
Quantity	1
Size (each one)	600 mm (ID) x 2350 mm (L T/T)
Design pressure	3.5 barg
Design temperature	-10 °C / 80 °C
Material	LTCS + 1 mm CA
Orientation	Vertical

Table 34 - Hydrogen Vent KO Drum Design Data

The Hydrogen Vent KO Drum is characterized by the following main operating data:

- Normal Operating inlet flowrate 9.2 N m^3/hr of nitrogen*
- Max Flow Rate 11274 kg/hr of hydrogen**
- Normal Operating Pressure atmosphere
- Normal Operating Temperature AMB
- Max Operating Pressure ~0.6 barg

*Normal nitrogen flow rate for purging during normal operation.
** max hydrogen flow rate during major relief scenario (not including 10% margin).

9.2 LOGIC CONTROL DESCRIPTION

Section is not applicable since there is no any control loop within the system.

9.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the Hydrogen Vest system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
43-FT-001	HI	Hydrogen form KO DRUM V-43001 to vent stack Q-43004	P&ID (123A90-DDL-PR-PID-80029)	900	kg/hr	PSVs opening	N/A	No consequence, due to the fact that vent system has been sized to cope all relief scenarios	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	
43-FT-001	IO_FAIL	Hydrogen form KO DRUM V-43001 to vent stack Q-43004	P&ID (123A90-DDL-PR-PID-80029)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
43-LT-003	LO	H2 vent Q-43004 low level	P&ID (123A90-	200	mm	wrong filling operation	Alarm valid during maintenanc	No consequences	Operator can: 1. Inform	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
			DDL-PR-PID-80029)			/ wrong draining operation	e and during operation	due to nitrogen to Vent system	maintenance/intervention team.	
43-LT-003	HI	H2 vent Q-43004 high level	P&ID (123A90-DDL-PR-PID-80029)	650	mm	Water unexpected from Electrolyser package	N/A	Shut-down Electrozer, WT package and sea water pumps.	Operator can: 1. Inform maintenance/intervention team.	The logic shall be confirmed by Company
43-LT-003	IO_FAIL	H2 vent Q-43004 low level	P&ID (123A90-DDL-PR-PID-80029)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
43-PT-001	HI	KO DRUM V-43001 pressure	P&ID (123A90-DDL-PR-PID-80029)	1.5	barg	blowdown or relief scenario occurring	N/A	No consequence, due to the fact that vent system has been sized to	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								cope all relief scenarios		
43-PT-001	IO_FAIL	KO DRUM V-43001 pressure	P&ID (123A90-DDL-PR-PID-80029)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

Table 35 - Hydrogen Vent System alarm instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

Here is below the list of instruments connected to the SIS that are included within the Hydrogen Vest system (see [Ref. 61]):

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
43-LT-001	43-L-001	IO_FAIL	KO DRUM V-43001 level	P&ID (123A90-DDL-PR-PID-80029)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
43-LT-001_MOS ACTIVE	43-L-001	BYPASS_ON	43-LT-001 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
43-LT-001_MOS	43-L-001	BYPASS_ON	43-LT-001 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										beyond the remaining 1 hour and extend the MOS Timer if required.
43-LT-001	43-L-001	HI_HI	KO DRUM V-43001 high-high level	P&ID (123A90-DDL-PR-PID-80029)	650	mm	Water unexpected from Electrolyser package	N/A	Shut-down Electrozer, WT package and sea water pumps.	Verify level - could indicate failure in electrolyzer package

Table 36 - Hydrogen Vent System trip instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

9.4 INTERLOCK LOGIC DESCRIPTION

Section is not applicable since there is no any software interlock within the system.

9.5 NORMAL OPERATION CONDITION

The hydrogen vent system is constituted of a Hydrogen Vent KO Drum (V-43001) and a Hydrogen Vent Package (Q-43004). The Hydrogen Vent KO Drum (V-43001) is provided to accumulate within the vessel any water that can be present in the hydrogen stream that is released into the atmosphere. Hydrogen released from the Hydrogen Storage Vessels is dry, therefore it is not expected any water inside the stream, but the hydrogen vent system also receives hydrogen off-spec from the Electrolyser Package (A-20000). The stream of hydrogen off-spec could contain water in vapour phase, therefore, under certain conditions the water could condensate and it is then accumulated within the Hydrogen Vent KO Drum.
The hydrogen stream after passing through the Hydrogen Vent KO Drum, is then sent to the atmosphere through the Hydrogen Vent Package (Q-43003).
The above-described system is continuously purged with a nitrogen stream in order to avoid air entering into the system.

9.6 UNIT START UP PROCEDURE

The section is not applicable since there is no any equipment to be started within the system.

9.7 SHUTDOWN PROCEDURE

The section is not applicable since there is no any equipment to be shut down within the system.

9.8 DEPRESSURIZATION PROCEDURE

The section is not applicable since the system always operates at low pressure (close to the atmosphere). Therefore, there is no need to depressurize the system.

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9.9 PURGING PROCEDURE

The hydrogen system is continuously purged with nitrogen.

As purging procedure operation for the hydrogen vent system is intended the operation aimed to continuously purge the hydrogen vent with nitrogen. Therefore, it is assumed that at the beginning of the hydrogen vent system purging procedure there is air inside the system, which needs to be displaced out of the system. The initial conditions of the hydrogen vent system are:

- Pressure atmospheric
- Ambient temperature.

Purging procedure of the hydrogen vent system is subject to the following preparatory activities:

- Completion of Start-up preparation activities and prerequisites for the Instrument Air Package, A-63000, as per Vendor recommendations; refer to document "INSTALLATION, OPERATING AND MAINTENANCE MANUAL - INSTRUMENT AIR PACKAGE"
- Completion of Start-up preparation activities and prerequisites for the Nitrogen Generation System, A-64000, as per Vendor recommendations; refer to document "INSTALLATION, OPERATING AND MAINTENANCE MANUAL - NITROGEN GENERATION PACKAGE"
- Completion of Start-up preparation activities and prerequisites for the Hydrogen Vent, Q-43004, as per Vendor recommendations; refer to document "INSTALLATION OPERATING AND MAINTENANCE MANUAL (HYDROGEN VENT)".

Once the above prerequisites are positive it is possible to proceed with the purging procedure. However, the listed checks and reviews below indicated are still necessary:

	ACTION	CHECK
1	Check that the valve BLPH-MV-149 installed on the IA Package exit line is open	☐ _____
2	Check that the valve BLPH-MV-269 installed on the IA Package drain line is open	☐ _____
3	Check that all manual valves that are installed at inlet of all distribution pots are open	☐ _____
4	Check that manual valve BLPH-MV-270 installed at Nitrogen System inlet line is open	☐ _____
5	Check that manual valves installed on the nitrogen purge line (BLPH-MV-171/172) are open	☐ _____

	ACTION	CHECK
6	Check that manual valve BLPH-MV-271 installed on the nitrogen generation system outlet line is open	☐ _____
7	Check that manual valve BLPH-MV-275 installed on the nitrogen generation system outlet line (spare connection) is open	☐ _____
8	Check that manual valve BLPH-MV-278 installed on the inlet line of the 64-PSV-001 is open	☐ _____
9	Check that the 64-SDV-001 valve installed on the sub-header manifold line toward the H2 vessels is closed	☐ _____
10	Check that manual valves BLPH-MV-171 and BLPH-MV-172 installed on the nitrogen line connected to hydrogen vent manifold are open	

Table 37 - Hydrogen Vent system purging procedure check list table

Once the above checks and reviews are positive, the purging procedure can be performed.
At this point it is necessary to fix the nitrogen flow rate sent to the vent system, by means of the flow meter 64-FG-001 and the downstream manual valve BLPH-MV-171.
The valve BLPH-MV-171 serves as regulation valve. As per note on the PID 123°90-DDL-PR-PID-80028, the flow meter 64-FG-001 is readable from manual valve BLPH-MV-171. Therefore, it is possible to establish and fix the opening of the manual valve BLPH-MV-171 at which the flow meter 64-FG-001 gives the desired nitogen flow rate of roughly 10 N m^3/hr. The manaul valve BLPH-MV-171 will be then locked in place (LIP), guaranteeing a constant flow rate of nitrogen to the hydrogen vent system.

9.10 PRESSURIZATION PROCEDURE

The section is not applicable since the system does not need to be pressurized.

10 INSTRUMENT AIR

The Instrument Air system is composed of:

- An Instrument Air Package (A-63000): this unit is fully prefabricated and self-standing package; thus, in general, being a vendor specific item, for any further information and details the vendor's operating manual shall be necessarily seen (see [Ref. 54]). The package is provided to ensure that all intermittent and continuous users on the BLPH platform have sufficient supply in the desired conditions at the desired quality;
- At exit of the above-mentioned package a piping network is provided to feed instrument air to the required users. Outside of the above-mentioned package there is no other equipment.

10.1 EQUIPMENT LIST AND DESIGN BASIS

The Instrument Air Package A-63000 is characterized by the following design data:

Service	Instrument Air and Dryer Package
TAG	A-63000
Quantity	1
Capacity	350 S m^3/hr (production)
Design pressure	12 barg
Design temperature	90 °C

Table 38 - Instrument Air Package Design Data

For details about design data for each equipment within the package reference shall be made to the Vendor P&iD ([Ref. 44]).
The operating data of the instrument air at package exit are the following:

- Operating temperature 35°C;
- Operating pressure 9 barg;
- Dew point -40°C @9 barg.

10.2 LOGIC CONTROL DESCRIPTION

There are no control loops within the system outside of the Instrument Air Package. For details about control loop description installed within the above-mentioned package reference shall be made to Vendor's documentation (see [Ref. 44], [Ref. 54] and [Ref. 60]).

10.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the IA system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
63-PT-003	LO	Instrument air to distribution header	123A90-DDL-PR-PID-80027	4.5	barg	malfunction of the upstream instrument air package	N/A	No consequence due to 63-PT004 that in case of Low Low pressure activates the ESD1.1D	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	
63-PT-003	IO_FAIL	Instrument air to distribution header	P&ID (123A90-DDL-PR-PID-80027)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
63-PI003_004	DEV	Differential Pressure between 63-PI-003 and 63-PI-004 - Instrument air to distribution header	P&ID (123A90-DDL-PR-PID-80027)	± 2.5	% f.s. (11 barg)	One of two pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of monitoring functionality (for 63-PI-003 fault). 2. Loss of Safety functionality (for 63-PI-004 fault): In case of loss instrument air the 64-PT-002 Low Low pressure will activate ESD1.1D.	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

Table 39 - IA System alarm instrument list

For details about alarms and trips of the instruments installed within the IA Package (A-63000), reference shall be made to the Vendor's documentation.
The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

Here is below the list of instruments connected to the SIS that are included within the IA system (see [Ref. 61]):

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
63-PT-004	63-P-004	IO_FAIL	Instrument air to distribution header low low pressure	P&ID (123A90-DDL-PR-PID-80027)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
63-PT-004	63-P-004	LO_LO	Instrument air to distribution header low low pressure	P&ID (123A90-DDL-PR-PID-80027)	4	barg	No flow from IA package A-63000	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS,	Operator can: Take necessary actions as per site emergency response plan. Monitor

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
									NO Solar, NO Fuel Cell	process conditions.
63-PT-004_MOS ACTIVE	63-P-004	MOS_ON	63-PT-004 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.
63-PT-004_MOS	63-P-004	MOS_ON	63-PT-004 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										extend the MOS Timer if required.
63-PT-004_BYPASS ACTIVE	63-P-004	BYPASS_ON	63-PT-004 Start-up Bypass applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct Start-up Bypass has been applied and remove when no longer required.
63-PT-004_BYPASS	63-P-004	BYPASS_ON	63-PT-004 Start-up Bypass Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to Start-up Bypass Removing	N/A	Start-up Bypass timer expiring and device being put back in operation.	Confirm with the field operator if Start-up Bypass Timer needs extending beyond the remaining 1

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
										hour and extend the Start-up Bypass Timer if required.

Table 40 - IA System trip instrument list

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

10.4 INTERLOCK LOGIC DESCRIPTION

Section not applicable, since there are no any interlock logic within the IA system.

10.5 NORMAL OPERATION CONDITION

During normal operation the IA manifold (downstream the IA Package) is pressurized at almost 9 barg and is always ready to feed the required IA to the users. The IA flow rate is variable since the requirement from the various users are variable.
The instrument air system downstream of the IA package is composed only of the main line exiting from the IA package from which the various lines branch off to the various users. The main users of instrument air are the following:

- the Nitrogen Generation System, which is the main consumer of IA since continuous production of nitrogen at 97% purity is required;
- instrumental valves (variable consumption);
- Electrolyser Package (A-20000).

10.6 UNIT START UP PROCEDURE

Instrument Air Package start-up operations must be carried-out in accordance with the Manufacturer's instructions as stated in operating manual ([Ref. 54]). The start-up procedure shall be executed by practiced staff with an appreciable experience.

Start-up of the Instrument Air Package is subject in any case to the following preparatory activities:

- Ensure that no Alarm or Fault are shown on the Instrument Air Package (A-63000);
- Ensure that no Alarm or Fault are shown on the Nitrogen System (A-64000);
- Check that the low-pressure alarm of the 63-PT-003, installed at IA package exit line, has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily);
- Check that the low-low-pressure trip of the 63-PT-003, installed at IA package exit line, has been deactivated (to prevent the low-low-pressure trip is triggered unnecessarily);
- It is assumed that the Hydrogen Vent System is ready to receive the required nitrogen purging flow rate;
- verify that electric power is available;
- Ensure that no the Electrolyser Package A-20000 is ready to receive N2 and instrument air;
- Check that all the manually operated valves are set to the positions indicated in the following Valve Checklist:

	ACTION	CHECK
1	Check that the valve BLPH-MV-149 installed on the IA Package exit line is open	☐ _____
2	Check that the valve BLPH-MV-269 installed on the IA Package drain line is open	☐ _____
3	Check that all manual valves that are installed at inlet of all distribution pots are open	☐ _____
4	Check that manual valve BLPH-MV-270 installed at Nitrogen System inlet line is open	☐ _____
5	Check that manual valves installed on the nitrogen purge line (BLPH-MV-171/172) are open	☐ _____
6	Check that manual valve BLPH-MV-271 installed on the nitrogen generation system outlet line is open	☐ _____
7	Check that manual valve BLPH-MV-275 installed on the nitrogen generation system outlet line (spare connection) is open	☐ _____
8	Check that manual valve BLPH-MV-278 installed on the inlet line of the 64-PSV-001 is open	☐ _____
9	Check that the 64-SDV-001 valve installed on the sub-header manifold line toward the H2 vessels is closed	☐ _____

Table 41 – IA system start-up check list table

For valves position installed within the IA Package, refer to Vendor's operating manual as well as to the Vendor's P&iDs ([Ref. 54] and [Ref. 44], respectively).

10.7 SHUTDOWN PROCEDURE

The following signals will inform about the package A-63000 shutdown status:

- SHUTDOWN STATUS (63-XI-004);
- SHUTDOWN ALARM (63-XI-002).

All signals are exchanged between the UCP and the DCS. The ESD signal trip and stop the package in an unlikely emergency event.

Considering the vital importance of instrument air, the shutdown of this system is possible only during the whole platform shutdown or for causes that are listed within the documents [Ref. [68]], [Ref. [66]] and [Ref. [31]].
For completeness of the signals and action performed during shutdown of the IA package, reference shall also be made to the "INSTRUMENT AIR PACKAGE A-63000 SYSTEM/PACKAGE FUNCTIONAL DESCRIPTION ", [Ref. [60].

10.8 DEPRESSURIZATION PROCEDURE

Not applicable

10.9 PURGING PROCEDURE

Not applicable

10.10 PRESSURIZATION PROCEDURE

For pressurization procedure of the IA package reference shall be made to the Vendor's documentation.

11 NITROGEN SYSTEM

The Nitrogen System is composed of:

- A Nitrogen Generation System (A-64000): this unit is fully prefabricated and self-standing package; thus, in general, being a vendor specific item, for any further information and details the vendor's operating manual shall be necessarily seen (see [Ref. 55]). The package is provided to ensure that all intermittent and continuous users on the BLPH platform have sufficient supply in the desired conditions at the desired quality;
- At exit of the above-mentioned package a piping network is provided to feed nitrogen (with a purity of 97%) to the required users. Outside of the above-mentioned package there is no other equipment.

11.1 EQUIPMENT LIST AND DESIGN BASIS

The Nitrogen Generation System A-64000 is characterized by the following design data:

Service	Nitrogen Generation System
TAG	A-64000
Quantity	1
Capacity	600 N m^3/hr (production)
Design pressure	12 barg
Design temperature	80 °C

Table 42 – Nitrogen Generation System Design Data

For details about design data for each equipment within the package reference shall be made to the Vendor P&iD ([Ref. 45]).
The operating data of the nitrogen package at package exit are the following:

- Operating temperature 35°C;
- Operating pressure 8.5 barg.

11.2 LOGIC CONTROL DESCRIPTION

On the outlet line of the Nitrogen Generation System (A-64000) a pressure control is provided, in order to guarantee a and maintain a pressure of 7 barg on the nitrogen distribution header, which is a suitable pressure to feed all nitrogen users. The control loop is identified with:

1) pressure controllers: 64-PIC-031A/B;
2) pressure transmitters: 264-PT-031A/B (Process Variable);
3) final elements: 64-PV-031A/B;

4) SP value: 7 barg;
5) Sub-Controller(s) action: REVERSE (pressure increase, valve close);
6) Failure direction: FAIL CLOSE

Moreover, a hand selector 64-HS-031 will allow the operator (remotely) for selecting the valve that shall be put in service.

The pressure transmitters 64-PT-0031A/B give a low- and high-pressure alarm, to alert the operator.

On the main manifold of the nitrogen outlet line, a sub-header is derived, to divert nitrogen to six H2 Storage Vessels for purging operations. On such sub-header a shutdown valve (64-SDV-001) is provided, and it is normally left close. Valve 64-SDV-001 can also be operated from DCS system. In fact, in case purging operation is required, then the valve is driven to open to allow sending nitrogen to the selected H2 Storage Vessel.
During H2 vessels purging operation a low-pressure alarm on pressure transmitter 64-PT-002 will be activated. Should the 64-PT-002 reach the low-pressure alarm set point, the valve 64-SDV-001 will be closed, in order to give priority to other nitrogen users.
On the same pressure transmitter, 64-PT-002, a low-low pressure trip is provided, to detect if very low pressure is reached on the N2 Package discharge line. If this happens then the low-low pressure trip will perform ESD1D.

11.3 INSTRUMENT LIST AND TROUBLESHOOTING SCENARIOS

Here is below the list of instruments connected to the PCS that are included within the Nitrogen system (see [Ref. 61]):

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
64-PT-031A	HI	Pressure Control for 64-PV-031A-N2 pressure control to distribution header	123A90-DDL-PR-PID-80027	8	barg	Malfunction of pressure control loop	N/A	No consequence due to the 64-PSV-001 discharge	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	
64-PT-031A	LO	Pressure Control for 64-PV-031A-N2 pressure control to distribution header	123A90-DDL-PR-PID-80027	6	barg	Malfunction of pressure control loop	N/A	No consequence due to 64-PT002 that in case of Low Low pressure activates the ESD1.1D	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	The alarm can be valid after the valve not close plus

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
										30 sec.
64-PT-031A	IO_FAIL	Pressure Control for 64-PV-031A-N2 pressure control to distribution header	P&ID (123A90-DDL-PR-PID-80027)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and control functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance	
64-PT-031B	HI	Pressure Control for 64-PV-031B-N2 pressure control to distribution header	123A90-DDL-PR-PID-80027	8	barg	Malfunction of pressure control loop	N/A	No consequence due to the 64-PSV-001 discharge	Operator can: 1. Inform maintenance/intervention team. 2. Monitor process conditions.	
64-PT-031B	LO	Pressure Control for 64-PV-031B-N2 pressure control to	123A90-DDL-PR-PID-80027	6	barg	Malfunction of pressure control loop	N/A	No consequence due to 64-PT002 that in case of Low	Operator can: 1. Inform maintenance/intervention team.	The alarm can be valid

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
		distribution header						Low pressure activates the ESD1.1D	2. Monitor process conditions.	after the valve not close plus 30 sec.
64-PI_002_031A_031B	DEV	Differential Pressure between 64-PI-002, 64-PI-031A and 64-PI-031B - N2 to distribution header	P&ID (123A90-DDL-PR-PID-80027)	± 5	% f.s. (10 barg)	One of three pressure transmitters blocket or fault	N/A	No consequences: 1. Loss of control functionality (for 64-PI-031A and 64-PI-031B fault). The 64-PT-002 Low Low pressure will activate ESD1.1D in case of Low	Operator can: 1. Inform maintenance 2. Monitor process conditions.	DELAY 0.5 SEC

TAG NUMBER	ALARM CONDITION	SERVICE DESCRIPTION	SOURCE DOCUMENT P&iD	SET POINT	UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE	NOTE
								Low pressure. The 64-PSV-001 will discharge in case of High High pressure. 2. Loss of Safety functionality (for 64-PI-002 fault): In case of Low Low pressure no Nitrogen is sent to Vent Header, but the water inside the Vent Q-43004 wil be a barrier for air.		

Table 43 - Nitrogen System alarm instrument list

For details about alarms and trips of the instruments installed within the IA Package (A-63000), reference shall be made to the Vendor's documentation.

The above table also includes process upsets and troubleshooting scenarios, with the indication of the initiating cause, consequence and the operator response.

Here is below the list of instruments connected to the SIS that are included within the Nitrogen system (see [Ref. 61]):

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
64-PT-002	64-P-002	IO_FAIL	Nitrogen to distribution header low pressure	P&ID (123A90-DDL-PR-PID-80027)	3.8	mA	1. Instrument fault 2. Channel fault	N/A	1. Loss of monitoring and Safety functionality 2. Loss of channel redundancy	Operator can: 1. Inform maintenance
64-PT-002	64-P-002	LO	Nitrogen to distribution header low pressure	P&ID (123A90-DDL-PR-PID-80027)	4	barg	1. No flow from N2 package A-64000 2. high consumption during purging operation	N/A	Closure of 64-SDV-001 valve during purging opration	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
64-PT-002	64-P-002	LO_LO	Nitrogen to distribution header low pressure	P&ID (123A90-DDL-PR-PID-80027)	3.5	barg	No flow from N2 package A-64000	N/A	ESD-1D activation: 1. BLPH Process Shutdown 2. BLPH Depressurization 3. BLPH Safety Loads energized: YES UPSs, No Wind Farm, No BESS, NO Solar, NO Fuel Cell	Operator can: Take necessary actions as per site emergency response plan. Monitor process conditions.
64-PT-002_MOS ACTIVE	64-P-002	BYPASS_ON	64-PT-002 MOS applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct MOS has been applied and remove when no longer required.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
64-PT-002_MOS	64-P-002	BYPASS_ON	64-PT-002 MOS Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to MOS Removing	N/A	MOS timer expiring and device being put back in operation.	Confirm with the field operator if MOS Timer needs extending beyond the remaining 1 hour and extend the MOS Timer if required.
64-PT-002_BYPASS ACTIVE	64-P-002	BYPASS_ON	64-PT-002 Start-up Bypass applied	123A90-DDL-IN-PRO-40010	N/A	N/A	Operator action	N/A	No consequences	Confirm that the correct Start-up Bypass has been applied and remove when no longer required.

TAG NUMBER	LOOP ID	ALARM CONDITION	SERVICE DESCRIPTION	ALARM SOURCE DOCUMENT	SET POINT	SET POINT UOM	INITIATING CAUSES(S)	INVALID OPERATION MODES	CONSEQUENCE DESCRIPTION	OPERATOR RESPONSE
64-PT-002_BYPASS	64-P-002	BYPASS_ON	64-PT-002 Start-up Bypass Timer has 1 hour to expiration.	123A90-DDL-IN-PRO-40010	N/A	N/A	1 hour Remaining to Start-up Bypass Removing	N/A	Start-up Bypass timer expiring and device being put back in operation.	Confirm with the field operator if Start-up Bypass Timer needs extending beyond the remaining 1 hour and extend the Start-up Bypass Timer if required.

Table 44 - Nitrogen System trip instrument list

11.4 INTERLOCK LOGIC DESCRIPTION

Section not applicable, since there are no any interlock logic within the nitrogen system.

11.5 NORMAL OPERATION CONDITION

During normal operation the only user that requires a continuous flow of nitrogen is the hydrogen vent system, while nitrogen to purge the hydrogen storage vessels is required on demand when H2 vessel purging is required.
The other user that requires nitrogen is the Electrolyser Package (A-20000).

11.6 UNIT START UP PROCEDURE

Nitrogen Generation System start-up operations must be carried-out in accordance with the Manufacturer's instructions as stated in operating manual ([Ref. 55]). The start-up procedure shall be executed by practiced staff with an appreciable experience.

Start-up of the Nitrogen Generation System is subject in any case to the following preparatory activities:

- Ensure that no Alarm or Fault are shown on the Instrument Air Package (A-63000);
- Ensure that no Alarm or Fault are shown on the Nitrogen System (A-64000);
- Check that the low-pressure alarm of the 63-PT-003, installed at IA package exit line, has been deactivated (to prevent the low-pressure alarm is triggered unnecessarily);
- Check that the low-low-pressure trip of the 63-PT-003, installed at IA package exit line, has been deactivated (to prevent the low-low-pressure trip is triggered unnecessarily);
- It is assumed that the Hydrogen Vent System is ready to receive the required nitrogen purging flow rate;
- verify that electric power is available;
- Ensure that no the Electrolyser Package A-20000 is ready to receive N2 and instrument air;
- Check that all the manually operated valves are set to the positions indicated in the following Valve Checklist:

	ACTION	CHECK
1	Check that the valve BLPH-MV-149 installed on the IA Package exit line is open	☐ _____
2	Check that the valve BLPH-MV-269 installed on the IA Package drain line is open	☐ _____
3	Check that all manual valves that are installed at inlet of all distribution pots are open	☐ _____

	ACTION	CHECK
4	Check that manual valve BLPH-MV-270 installed at Nitrogen System inlet line is open	☐ _____
5	Check that manual valves installed on the nitrogen purge line (BLPH-MV-171/172) are open	☐ _____
6	Check that manual valve BLPH-MV-271 installed on the nitrogen generation system outlet line is open	☐ _____
7	Check that manual valve BLPH-MV-275 installed on the nitrogen generation system outlet line (spare connection) is open	☐ _____
8	Check that manual valve BLPH-MV-278 installed on the inlet line of the 64-PSV-001 is open	☐ _____
9	Check that the 64-SDV-001 valve installed on the sub-header manifold line toward the H2 vessels is closed	☐ _____

Table 45 – N2 system start-up check list table

For valves position installed within the Nitrogen Generation System, refer to Vendor's operating manual as well as to the Vendor's P&iDs ([Ref. 55] and [Ref. 45], respectively).

11.7 SHUTDOWN PROCEDURE

All signals are exchanged between the UCP and the DCS. The ESD signal trip and stop the package in an unlikely emergency event.

Considering the vital importance of nitrogen system, the shutdown of this system is possible only during the whole platform shutdown or for causes that are listed within the documents [Ref. [68]], [Ref. [67]] and [Ref. [31]].

11.8 DEPRESSURIZATION PROCEDURE

Section not applicable.

11.9 PURGING PROCEDURE

Section not applicable.

11.10 PRESSURIZATION PROCEDURE

Section not applicable.

12 EMERGENCY AND PROCESS SHUTDOWN

12.1 ASD-ESD-PSD LEVELS

As per [Ref. 31], there are four levels of shutdown:

- ASD: abandon;
- ESD-1D: emergency shutdown with depressurisation;
- ESD-1: emergency shutdown without depressurisation;
- PSD: process shutdown.

The platform manual shut-down can be activated by the operators from the "ASD push button". This will cause in cascade the ESD-1D as well as the ESD-1 and it represents the highest level of shutdown, performing the following actions:

- OPERATOR WORKSTATION DISPLAY - EVENT/ALARM
- ALARM ON CAP ONSHORE
- ESD-1D ACTIVATION (for details about actions performed during ESD-1D scenario, see below ESD-1D section)
- ASD ACTIVATION TO FGS SYSTEM
- DISCONNECT AC UPS UP-200F3 BATTERIES A/B (B-300 CONTAINER)
- DISCONNECT AC UPS UP-200F4 BATTERIES A/B (B-300 CONTAINER)
- DISCONNECT DC UPS (B-100 CONTAINER)
- SHUTDOWN ELECTROLYZER PACKAGE A-20000
- SHUTDOWN BESS PACKAGE A-85000
- SHUTDOWN SOLAR FARM PACKAGE
- SHUTDOWN FUEL CELL PACKAGE A-80000
- SHUTDOWN WATER TREATMENT PACKAGE A-50000
- SHUTDOWN INSTRUMENT AIR PACKAGE A-63000
- SHUTDOWN NITROGEN PACKAGE A-64000
- OPEN BESS A-85000 INCOMING CIRCUIT BREAKERS
- OPEN FUEL CELL A-80000 INCOMING CIRCUIT BREAKERS
- OPEN SOLAR INCOMING CIRCUIT BREAKERS
- OPEN WIND FARM INCOMING CIRCUIT BREAKERS
- SHUTDOWN HVAC SYSTEM OF B-100 (HV CONTAINER)
- SHUTDOWN HVAC SYSTEM OF B-200 (LV CONTAINER)
- SHUTDOWN HVAC SYSTEM OF B-300 (UPS CONTAINER)
- SHUTDOWN HVAC SYSTEM OF B-400 (ITER CONTAINER)

- ELECT. ISOLATION UPS POWER UCP (WATER TREAT. A-50000)
- ELECT. ISOLATION UPS POWER UCP (INSTRUMENT AIR A-63000)
- ELECT. ISOLATION UPS POWER UCP (NITROGEN A-64000)
- ELECT. ISOLATION UPS POWER UCP HVAC B-100
- ELECT. ISOLATION UPS POWER UCP HVAC B-200

The operator can also activate the ESD-1D from the "ESD-1D push button" as well as from "ESD-1D onshore push button". Both will cause in cascade also the ESD-1. Below the list of the actions performed during ESD-1D scenario:

- WORKSTATION HMIs - EVENT/ALARM
- ALARM ON CAP ONSHORE
- ESD-1 ACTIVATION (for details about actions performed during ESD-1 scenario, see below ESD-1 section)
- ESD-1D ACTIVATION TO FGS SYSTEM
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001A
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001B
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001C
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001D
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001E
- OPEN 25-BDV-005 ON H2 STORAGE TANKS V-25001F
- OPEN 25-BDV-022 ON OUTLET H2 HEADER TO FUEL CELL PGK
- SHUTDOWN ELECTROLYZER PACKAGE A-20000
- SHUTDOWN BESS PACKAGE A-85000
- SHUTDOWN SOLAR FARM PACKAGE
- SHUTDOWN FUEL CELL PACKAGE A-80000
- SHUTDOWN WATER TREATMENT PACKAGE A-50000
- SHUTDOWN INSTRUMENT AIR PACKAGE A-63000
- SHUTDOWN NITROGEN PACKAGE A-64000
- OPEN BESS A-85000 INCOMING CIRCUIT BREAKERS
- OPEN FUEL CELL A-80000 INCOMING CIRCUIT BREAKERS
- OPEN SOLAR INCOMING CIRCUIT BREAKERS
- OPEN WIND FARM INCOMING CIRCUIT BREAKERS

There is also the possibility for the operator to perform only the ESD-1 by means of the "ESD-1 push button" and the "ESD-1 onshore push button". This two push buttons will only generate the ESD-1 without depressuring the inventory. It represents the lowest level of shutdown, performing the following actions:

- PSD ACTIVATION
- ESD-1 ACTIVATION TO FGS SYSTEM
- SHUTDOWN ELECTROLYZER PACKAGE A-20000
- SHUTDOWN FUEL CELL PACKAGE A-80000
- SHUTDOWN WATER TREATMENT PACKAGE A-50000
- CLOSE 25-SDV-023 ON OUTLET H2 HEADER TO FUEL CELL PKG
- CLOSE 25-SDV-001 ON H2 HEADER TO STORAGE TANKS

12.2 INHIBIT FUNCTIONS RESTART SEQUENCE

For all inhibit fictions, reference shall be made to the "Process Control Logics Description" (see [Ref. 69]) and "Process Safety Cause and Effect Matrix" (see [Ref. 68]).

12.3 RESET FUNCTION

For all reset fictions, reference shall be made to the "Process Control Logics Description" (see [Ref. 69]) and "Process Safety Cause and Effect Matrix" (see [Ref. 68]).

13 ESCAPE, EVACUATION AND RESCUE

13.1 BLPH PLATFORM PHILOSOPHY

According to project philosophy, the platform is normally not manned, and people presence are foreseen only during maintenance activities. Planned maintenance activities are foreseen for 1 day each 6 months, meaning 2 days (16 hours) in 365 days (8760 hours), for a maximum of persons on board equal to 10 operators.
Power is imported into the BLPH facility from the wind turbines and the floating solar Photovoltaic array. This power is used to produce green hydrogen via water electrolysis, which is stored in the Hydrogen Storage system until needed. The Hydrogen Fuel Cell Package then converts this hydrogen back into electricity, while the BESS Package provides additional energy storage to ensure a continuous power supply. When power output of the linked wind turbines drops below 1 MW, the power export will be supplemented by discharging the BESS and converting the green hydrogen back into electricity using a fuel cell.
Together, these components facilitate the efficient use of renewable energy and enhance the stability of the electrical grid.

13.2 F&G SYSTEM

Fire and Gas Detection System is required to continuously monitor all areas to detect unplanned process releases and fire events to prevent escalation of the initiating event and minimize its consequences. The intervention of the system shall be as early as possible to enable raising of an alarm and swift intervention by the fire protection system. F&G system, installed at BLPH, will initiate in case of confirmed fire and gas event, a site warning via General Alarm (GA). BLPH will perform ESD-1 (fire zone emergency shutdown) where:

- Process will shut down with or without depressurization.
- Non-zone 1 hazardous rated equipment will shut down - on confirmed outdoor gas detection.
- Reduction of radio RF power (i.e. both non-hazardous rated marine radio base and fixed operation radio bases) - on confirmed gas detection.
- Marine radars zone 2 rated will shut down - on confirmed gas detection Initiate automatic fire fighting actions (as required) - on confirmed fire detection.
- Initiate automatic fire fighting actions (as required) - on confirmed fire detection.

Considering that the platform is normally not manned, the F&G system is the primary safety system for securing the platform. Platform areas are divided into a number of fire zones, so as to assist with identification of fire and gas event locations and to provide definition for detector voting groups. On the platform, the following equipment are installed based on the characteristics of each fire zone:

- UV-IR flame detector.
- Ultra sonic hydrogen detector.
- Point source oxygen detector.
- Point source hydrogen detector.
- Heat detectors.
- Beacon for flammable gas release and fire.
- Sounder.

The location of the above equipment in each fire zone of the BLPH platform is shown in dedicated layouts:

- 123A90-DDL-SAF-DL-30027 sheet 1 of 2 - F&G Detectors Layout - Lower And Upper Deck, [Ref. 78]
- 123A90-DDL-SAF-DL-30027 sheet 2 of 2 - F&G Detectors Layout - Lower And Upper Deck, [Ref. 78]
- 123A90-DDL-SAF-DL-30028 - F&G Detectors Layout – Below Lower Deck, [Ref. 79]

In general terms, the intervention philosophy of the automatic actions of the F&G system is outlined below:

Confirmed Gas:

- Initiate an audible and visual alarm at the control room;
- Initiate an audible general area alarm to alert any personnel that may be present;
- Isolate small power / welding sockets and non-Zone 1 electrical equipment as appropriate;
- Close HVAC dampers if gas detected at inlet and recirculate air.

Confirmed Fire:

- Initiate an audible and visual alarm at the control room;
- Initiate an audible general area alarm to alert any personnel that may be present;
- Initiate emergency shutdown and depressurization of fire zone;
- Close HVAC dampers if smoke detected at inlet and recirculate air;
- On detection within enclosure - initiate HVAC shutdown and closure of air intakes where necessary to control the spread of smoke.

Detailed information about F&G actions are reported in the Fire and Gas Cause and Effect Matrix, doc. N. 123A90-DDL-IN-CE-40002.

13.3 ESCAPE AND EVACUATION STRATEGY

Before accessing the platform the operators shall be adequately:

1. Informed of the specific risk at platform;
2. Properly trained for operation and emergency scenarios; All operators shall have adequate training in first aid to safeguard people's lives and in initial fire response interventions
3. Equipped with necessary Personal Protective Equipment.

All operators on the platform report directly to the "Master Operator," who is the leader of the offshore operations team stationed on the BLPH platform.
The platform is designed to keep a maximum number of 10 (ten) operators on board, lifesaving appliances was designed to cover these maximum number, in case more personnel is expected to access the platform, there shall be a proper assessment with the related increase of necessary equipment.

When operators access to the platform, before starting any inspection or maintenance activity, they shall have to carried on the eye wash units and located in the assigned locations. The decision of having the units only during manned periods is due to avoid any potential salmonella scenario. The platform is equipped with portable fire extinguishers along the platform, distributed at strategic locations, make sure that operators are able to use properly them in case of need of an intervention towards small fires, that could occur during maintenance activities. Please, be conscious that the platform is not equipped with any automatic fixed fire fighting system, the main safety action in case of accidents is to isolate all the platform and, if necessary, to depressurize by the vent system.

In case of any emergency scenario when operators are at the platform, the “Emergency Response Plan”, doc. N. 123A90-DDL-SAF-RE-30016 ([Ref. 80]) shall be followed. The platform is designed with primary and secondary escape routes that are provided to ensure the safe escape of personnel from any location on the installation. Escape routes are arranged to provide direct access to the muster areas. These escape paths are designed in order to minimize the likelihood of having both routes from same location impaired during an emergency. Indeed, at the upper deck, where are located equipment which significant hold up of hydrogen (storage vessel), personnel can always escape in at least 2 directions towards muster points.
Main escape routes are at minimum 1200 mm wide and 2300 mm minimum headroom. Secondary escape routes are at minimum 800 mm wide and 2300 mm height.

Two muster areas are provided at the platform facilities, where personnel can assemble during an incident. When any emergency occurs, operators shall first escape from the hazardous scenarios and go to the primary muster point, if that is feasible, located at the below lower deck. A secondary muster point is located at the north/west side of the lower deck of BLPH Hub. At each muster area operators shall ensure that all coud escape, in case of any injured personnel they can rescue injured personnel using the evacuation stretcher and the first aid kit for initial care. At the platform there is also one resuscitation unit.

The platform is equipped with 3 Embarkation areas and 2 different ways of evacuate the platform; when mustering it shall be selected the evacuation mean depending on the scenario that is ongoing. The preferable mean of evacuate is via the primary muster area (main access platform) and then to Crew Transfer

Vessel at the boat landing. Alternative, as secondary means of evacuation operators can use the life raft, two life rafts are present and installed at lower deck at opposite side, to allow for the different weather conditions. One is located on the northwest of BLPH Hub and the second life raft located on the southeast of BLPH Hub. Evacuation via helicopter is not foreseen.

Platform is equipped with the following safety and lifesaving equipment equipment, well distributed at strategic position near the escape route on decks, which includes:

- life buoys;
- eyewash station (to be carried by operators when accessing to the platform);
- resuscitation unit (ITER cabinet);
- evacuation stretcher;
- first aid kit;
- escape mask;
- immersion suits (inside cabinets);
- life jacket (inside cabinets);
- liferafts and descend device located on lower deck (sized for POB of 10, 2 located at lower deck).
- electrical safety kit (HV/MV switchroom)

Each muster point is provided with following safety equipment:

- Primary muster point: 1 first aid kit, 10 life jacket, 10escape mask
- Secondary muster point: 1 first aid kit, 10 life jacket, 10 escape mask, 10 immersion suits, descent device.

All the platform is equipped with the Safety Signs that indicate to operators where to go for mustering and where are located the safety equipment. The platform is also provided with the emergency illumination system.

For detail on location of life saving appliances and escape route, refer to the following drawings:

- 123A90-DDL-SAF-DL-30025 - Escape route, fire fighting equipment, life saving equipment and safety equipment drawing – below lower deck
- 123A90-DDL-SAF-DL-30026 - Escape route, fire fighting equipment, life saving equipment and safety equipment drawing – below and upper deck

For detail on location of safety signs refer to:

- 123A90-DDL-SAF-DL-30029 – Safety Sign equipment layout drawing – below lower deck, [Ref. 81]
- 123A90-DDL-SAF-DL-30030 – Safety Sign equipment layout drawing – lower and upper deck, [Ref. 82]

For detail instruction on the use of safety equipment, refer to the "Instruction and Operating Maintenance (IOM) - Firefighting And Safety Equipment", doc. N. 1724001660-SAF-MAN-00007 ([Ref. 83]). Additional details can be checked in the "All Equipment Data Sheets-Firefighting And Safety Equipment", doc. N. 724001660-SAF-DS-00004 and the "Manufacturers Record Book (Final Dossier)-Firefighting And Safety Equipment", doc. N. 1724001660-QC-DB-00005.

Details on inspection and maintenance activities related with the Safety equipment and Firefighting equipment can be verified in the document "Inspection And Test Plan-Firefighting And Safety Equipment", doc. N. 1724001660-QC-ITP-00002.

Alarm information and instructions will be available at muster area to allow all personnel to take any further instructed emergency actions (i.e., rescue by a dedicated CTV at boat landing area or to deploy life rafts). This platform is not normally manned, and it was designed without a Public Address system, but instead all personnel must carry hand-held radio devices to facilitate communication with workers in emergency and non-emergency situations. There is a General Alarm system driven from the F&G system. This ensure that on detection of any fire or gas event, the platform sounders and beacons will alert personnel on the platform.

13.4 OPERATORS TRAINING REQUIREMENTS

Training for operators is crucial to ensure they can respond effectively in emergencies. It provides them with the necessary knowledge and skills to handle various situations, such as fires, medical emergencies, or other scenarios. Training required for operators working on the platform includes several key areas to ensure safety and efficiency during operations:

- Emergency Response Training. Operators must be trained to respond quickly and effectively to emergencies, such as fires, gas leaks, or medical incidents. This includes first aid, firefighting techniques, and evacuation procedures.
- Training for Personal Protective Equipment (PPE). Operators must be familiar with different types of PPE, including helmets, gloves, safety boots, goggles, and fire-resistant clothing. The training typically covers:
    1. Proper Usage: How to wear, adjust, and use PPE correctly to maximize protection.
    2. Maintenance: The correct cleaning and maintenance of PPE to ensure it remains effective and safe to use.
    3. Inspection: How to inspect PPE for damage or wear before use, ensuring it is in good working condition.
    4. Situational Application: Understanding which types of PPE are required for different tasks and environments, such as fire, chemical, or electrical hazards.
    5. Emergency Procedures: Training operators on how to remove PPE quickly and safely in case of emergency situations.

For detail operation on how act in any of these scenarios refer to the ERP.

REMARK: To minimize any possibility of spreading or generation of fires no combustibles materials (including paper documents / schematics / carton boxes) shall be present inside the containers. Operators shall ensure removing them after any maintenance operations inside these areas as well after commissioning activities, before the first start-up. The proper waste management plan shall be followed, in order to avoid contamination of the sea, so any collected material shall be properly carried outside the platform.

13.5 HAZARDOUS AREA CLASSIFICATION

The objective of hazardous area classification is to identify the hazardous areas with respect to the presence of flammable/explosive atmosphere, in order to establish the requirements for electrical equipment and other equipment to be located within the classified area. During maintenance activities the devices used shall be suitable for the zone where the activity will be performed. Special considerations shall be given in case the operation conditions during maintenance are change, since it will be reflected in a potential modification of hazardous area.

For more details refer to the following documents:

- Hazardous Area Classification Schedule - 123A90-DDL-SAF-RE-30013_rev04, [Ref. 70]
- Hazardous Area Classification - Lower deck & Upper - 123A90-DDL-SAF-DL-30022, [Ref. 71]
- Hazardous Area Classification - Elevation looking North and East - 123A90-DDL-SAF-DL-30024, [Ref. 72]

All equipment installed is registered in the "ATEX Register", doc. N. 123A90-PML-PM-LIS-00036, [Ref. [87].

13.6 HEALTH AND SAFETY REQUIREMENTS

Reference shall be done to the following documents:

- 123A90-DDL-SAF-RE-30046 – HSE design philosophy, [Ref. [90];
- 123A90-DDL-SAF-RE-30001 – Fire protection philosophy, [Ref. [91];
- 123A90-DDL-SAF-RE-30016 – Emergency Response Plan, [Ref. [80];
- 123A90-DDL-SAF-RE-30012 – ALARP workshop report, [Ref. [92];
- 123A90-DDL-SAF-RE-30003 – Safety Critical Elements and Performance Standard, [Ref. [93].

14 ELECTRICAL SYSTEM

This section provides operational description of electrical system. The intent is to provide the user with an overview of electrical equipment and its operation. This document does not replace the Manufacturer's Operation and Maintenance Manual for each piece of equipment provided by the manufacturer or equipment supplier. The Manufacturer's O&M Manual and the relevant supplier's drawings will be taken as reference for each of the equipment.

Power distribution system serves mainly four different voltage level in order to feed the system equipment; those levels respectively from high to low voltage are 66 kV,6.6 kV, 800 V and 400 V which feeds the system electrical equipment such as transformers, switchgears, MCCs, auxiliary systems as well as process packages through busbars and cables (feeders) at each voltage level as per "123A90-DDL-EL-DG-20158 - Overall Key Single Line Diagram", [Ref. 77].
The 66 kV AC power will be stepped down from the 66 kV gas insulated switchgear HNA6-AFA70 to 6.6 kV AIS switchgear SG-100D1 by a distribution transformer (TR-100AD1).
From the 6.6 kV switchgear, a further step-down transformer (TR-200DE1) will connect to the 400 V switchgear SG-200N1 to supply power to the platform's auxiliary loads. The 6.6 kV AIS switchgear will distribute power to the platform's 6.6 kV rated equipment: BESS, Fuel Cell, Electrolyzer, Solar Array. The solar farm, in particular, will be fed at 800 V, through a dedicated step-up transformer (TR-200ED1).

For more details and info, please refer to the documents:

- 123A90-DDL-EL-SP-20141 - Electrical System Description & Design Philosophy, [Ref. 73]
- 123A90-DDL-EL-LIS-20142 – Electrical Equipment List, [Ref. 74]
- 123A90-DDL-EL-RE-20152 - Electrical Equipment Sizing Calculation Report, [Ref. 75]
- 123A90-DDL-EL-RE-20182 - LV Electrical Equipment Sizing Calculation Report, [Ref. 76].

14.1 OPERATING PHILOSOPHY

The Central Control System (CCS) is responsible for the normal operations of BLPH, with an independent system to the elements of the Safety System. The components that CCS is required to control all process (power generation) systems, utilities systems, and electrical equipment on the platform following Document 123A90-DDL-IN-DD-40019 Data Network Architecture. As agreed with operations, a single operator shall be required for both electrical and process systems on BLPH. CCS reacts to changes from the HNA5 Wind Turbine, active power output only. Only output/status of HNA5 Wind Turbine affects operating modes.
The CCS shall act independently of the safety system and shall not interfere with any of its functions. The objective of the BLPH is to demonstrate time shifting flexibility and capability of providing 1MW Power output using the full capacity of the inventory stored on the platform. BLPH does not plan its output on weather forecast – BLPH output is planned depending on the actual power output of the HNA5 Wind Turbine.
The facility can be operated remotely from on-shore Control room, and has the ability to shut down, start-up, to adjust and/or tune, to connect and disconnect to the grid and to monitor BLPH. The measured response of BLPH will be tied to the power generation profile of an individual wind turbine HNA5.

The technologies being demonstrated at BLPH are:

- Floating Solar farm.
- Short-term Battery Energy Storage.
- Long-term Hydrogen Energy Storage (Electrolyser to create green hydrogen).
- Fuel-Cell.

Energy harvested from both wind and sun will be stored either directly in a BESS or indirectly using water electrolysis to create hydrogen. Stored hydrogen will be consumed onboard by a fuel-cell to produce electrical power. Monitoring and control of BLPH will be remote (shore-based control room) and the battery and fuel-cell shall act cooperatively so that power from all sources will be combined to export power regardless of the prevailing weather.

NOTE: Energy stored as hydrogen will leave only in the form of electricity through the Inter-Array Cable (IAC) connecting BLPH indirectly to a grid sub-station provided by Transmission System Operator (TSO) TenneT.

The fuel-cell is slow-acting whilst the BESS is fast acting. Therefore, the BESS (whenever available) will be used as 'lead supply' / 'load follower' and operate in its most efficient / effective manner with the fuel cell operating in parallel or series to optimize both the efficiency and availability of the entire system. The CCS will be programmed to act upon multiple inputs / factors e.g. BESS available energy. HNA5 (EMCS will receive the data from HNA5 and based on these values will react), stored hydrogen availability, CCS operation mode, equipment operating status, equipment operating mode, circuit breaker status, etc. Whenever possible the fuel-cell will consume the platform's stored hydrogen prior to discharging the BESS.

In Figure 8 - EMCS Flow Chart shows the transition between each operating BLPH MODE with respect to the pre-condition; to obtain more information, refer to the document 1724000594-IN-SP-00019 - EMCS Software Functional Design Specification (FDS-SW).

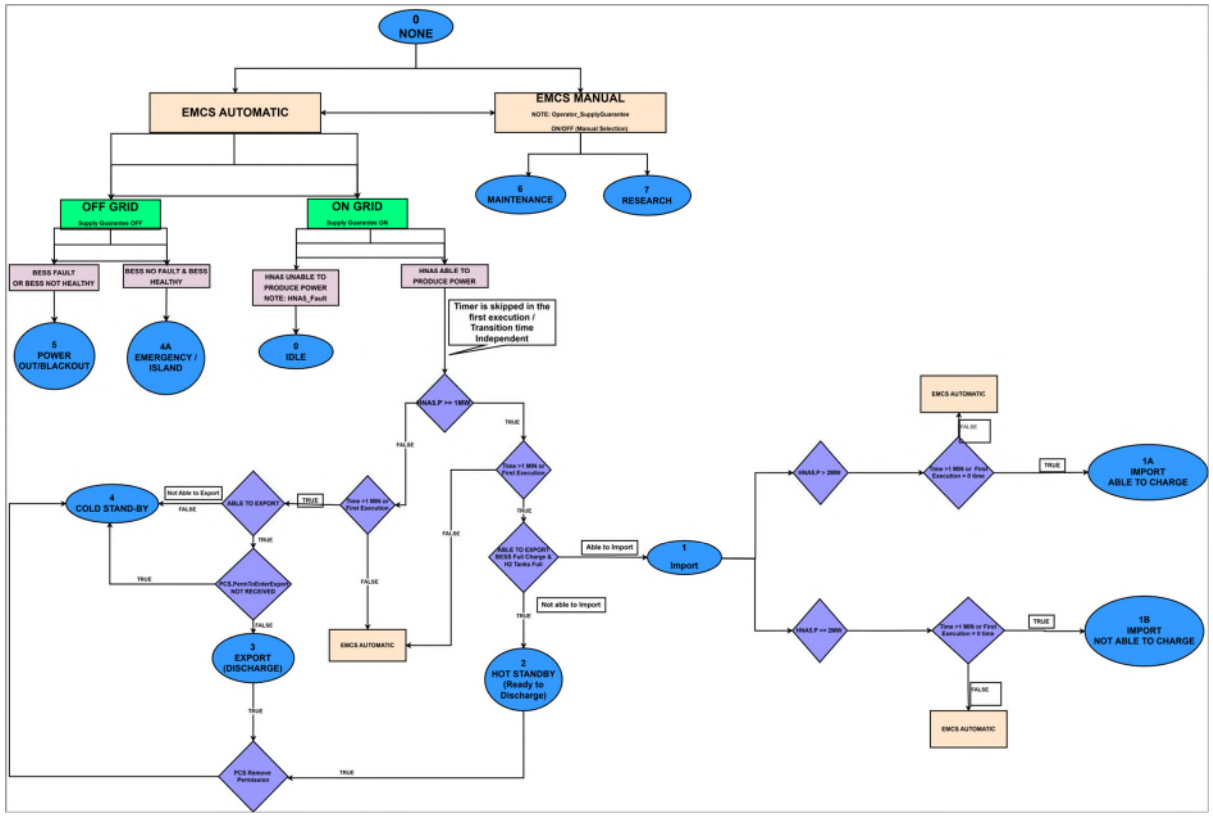


Figure 8 - EMCS Flow Chart

The logic implemented into the software to operate the EMCS are reported in the document: 1724000594-IN-DG-00027 - Logic diagram print out EMCS (see [Ref. 62]). The HMI details are present into 1724000594-IN-DD-00028 - HMI screens print out (see [Ref. 63]); For more details and knowledge of the functionalities refer to the document: 1724000594-IN-MAN-00037 - INSTALLATION, OPERATING AND MAINTENANCE MANUAL (IOM), see [Ref. 64].