Base Load Power Hub (BLPH)

Process Control Logics Description

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Revision / Change Log

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HOLDS LIST

No.	Description
Hold 1	CPY has to confirm the philosophy for the Local/Remote operating modes for Electrolyser package
Hold 2	CPY has to confirm the philosophy for the Local/Remote operating modes for Fuel Cell package
Hold 3	Value to be confirmed During Commissioning Phase
Hold 4	Logic to be confirmed During Commissioning Phase
Hold 5	Time of 0.02 sec. has to be verified and confirmed During Commissioning Phase
Hold 6	The value shall be confirmed by ICSS Vendor based on its library data During Commissioning Phase
Hold 7	The time of negative pressure gradient shall be defined During Commissioning Phase

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

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

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

1.1.1 Project Location

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

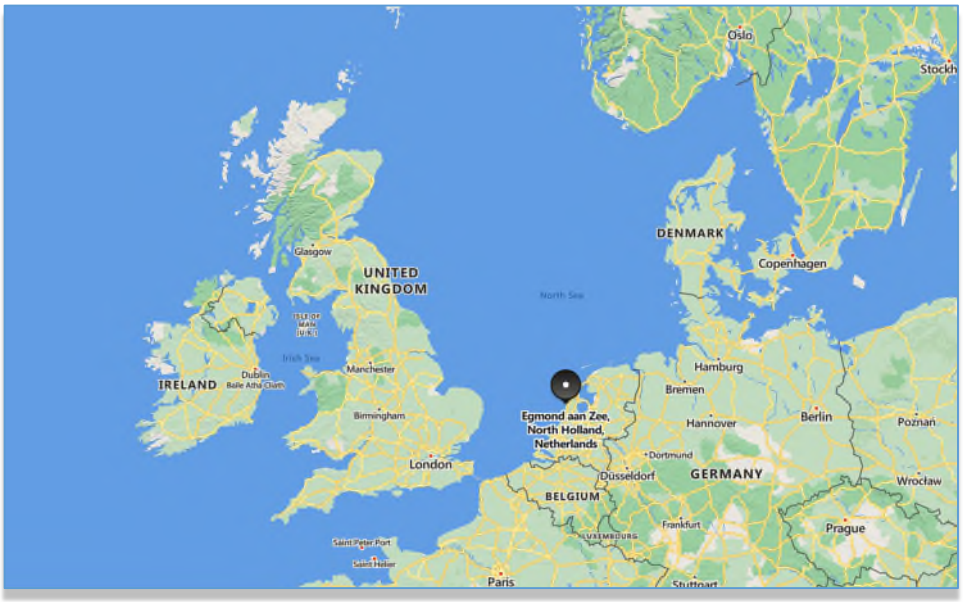


Figure 1 - HOLLANDSE KUST NOORD WIND PARK Location Map

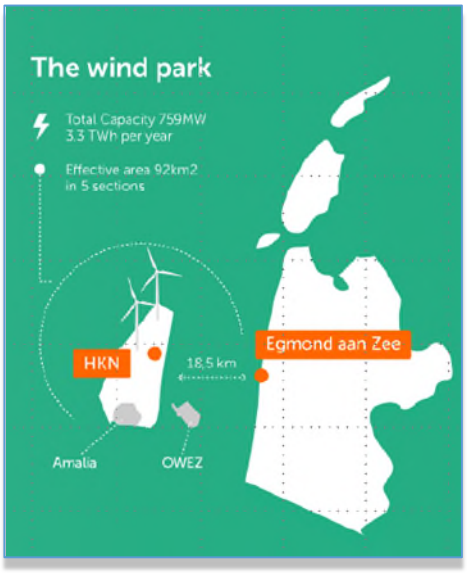


Figure 2 - Wind Park Details

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

1.1.2 Project Concept

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

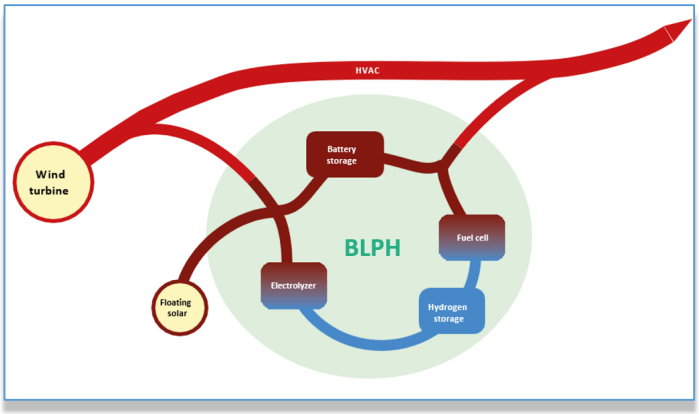


Figure 3 – BLPH Concept

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

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

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2 DOCUMENT SCOPE

The scope of this document is intended to provide a Process Logics description of the Process Control, Operation, Start-up and Shutdown philosophy to be adopted within the BLPH project.

Moreover, the main objectives of the present document are:

- To define the process control Logic functional requirements to achieve safe and efficient control of process systems along the BLPH project.
- To define the electrical interface control logic functional requirements to achieve safe and efficient control of electrical systems along the BLPH project.

2.1 REFERENCES

Doc. No.	Description
K559-2254-PM-PLN-003	Basic Design Engineering Package
123A90-DDL-PR-PID-80009 ÷ 80029 and 80041, 80042	BLPH Piping and Instrumentation Diagram
1724000428-PR-PID-00019	PACKAGE PID - INSTRUMENT AIR PACKAGE
1724000437-PR-PID-00018	PACKAGE PID - NITROGEN GENERATION PACKAGE
1724000448-PR-PID-00013	WATER TREATMENT PACKAGE-PID DIAGRAM
123A90-DDL-PR-RE-80031	Process Control, Operation, Start-up and Shutdown philosophy
1724000594-IN-SP-00019	EMCS Software Functional Design Specification (FDS-SW)
123A90-DDL-IN-CE-40000	Process Safety Cause & Effect Matrix
123A90-DDL-IN-CE-40002	Fire & Gas Cause & Effect Matrix
123A90-DDL-PR-DG-80000	Process Safety Cause and Effect Block Diagram
123A90-DDL-IN-LIS-40089	Instrument I/O List
123A90-DDL-EL-LIS-20156	Electrical Control Alarm and Monitoring Table
1724000594-IN-LIS-00005	EMCS IO List (HW and SW)
1724000594-IN-LIS-00004	PCS and Safety System IO List (HW and SW)
123A90-DDL-IN-PRO-40010	Override Procedures for Process Safeguarding Systems
123A90-DDL-EL-SP-20141	Electrical System Description and Design Philosophy
1724000594-IN-SP-00019	EMCS Software Functional Design Specification (FDS-SW)

Table 1 - Reference Documents

2.2 DEFINITIONS AND ABBREVIATIONS

COMPANY or Client (CPY)	Crosswind
CONTRACTOR (CTR)	ROSETTI MARINO S.p.A.
PROJECT:	HOLLANDSE KUST NOORD WIND PARK Project
2oo3	Two out of three Voting
AMB	Ambient (often referred to Ambient temperature)
BDV	Blowdown valve
BESS	Battery energy storage system
BLPH	Base Load Power Hub
CCS	Central Control System (PCS + EMCS)
EMCS	Electrical Management Control System
ESD	Emergency shut down
FC	Fuel cell
FDS-SW	Software Functional Design Specification
FGS	Fire and Gas System
GUI	Graphical User Interface
HMI	Human Machine Interface
HKN	Hollandse Kust Noord
HV	High Voltage
HVAC	Heating Ventilation Air Conditioning
HW	Hardwire
IA	Instrument Air
IAC	Inter-Array Cable
ICSS	Integrated Control Safety System
I/O	Input/Output
LP	Local Panel
PAH	Pressure alarm high
PAL	Pressure alarm low
PCS	Process Control System
P&ID	Piping & instrumentation diagram

PID	Proportional Integral Derivative
PSV	Pressure safety relief valve
PT	Pressure transmitter
PV	Process Variable
PSA	Pressure Swing Adsorption
TCP/IP	Transmission Control Protocol/Internet Protocol
SIS	Safety Integrated System
SDV	Shut down valve
SoC	State of Charge
SW	Software
SS	Safety System (SIS+FGS)
UCP	Unit Control Panel
UF	Ultra filtration
UPS	Uninterrupted Power Supply
VooW	Van Oord Offshore Wind
WT	Water Treatment

Table 2 - Definitions and Abbreviations

3 ELECTRICAL CONTROL PHILOSOPHY FOR PROCESS UNIT

3.1 GENERAL

The BLPH power system will be synchronised and connected to the wind farm's power system, 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.

Monitoring and control of BLPH will be remote (shore based control room) and the solar farm, battery and fuel-cell shall act cooperatively so that power from all sources will be combined to export power regardless of the prevailing weather.

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.

Whenever possible the fuel-cell will consume the platform's stored hydrogen prior to discharging the battery to ensure SoC is maintained high for it to react instantly to each demand for power.

PCS communicates with EMCS through serial internal communication and the necessary signals (commands, statuses and permissive) will be exchanged between the two systems.

From an electrical point of view, the following operation modes shall be applicable and the Flags on HMI shall indicate to operators (onshore) which of the following mode is active (see EMCS graphic pages):

- Mode 0 = IDLE (Power import only)
- Mode 1 = IMPORT (Charging)
- Mode 2 = HOT STANDBY (Power import: able to export)
- Mode 3 = EXPORT (Discharging)
- Mode 4 = COLD STANDBY (Power import: Not able to export)
- Mode 4A = EMERGENCY MODE (Island)
- Mode 5 = POWER OUT (black-out)
- Mode 6 = MAINTENANCE
- Mode 7 = RESEARCH
- Mode 8= NONE MODE

The Safety logics remain always active in each of the above electrical modes.

The interface signals between Safety Systems and Field Equipment (included Electrolyser, BESS and Fuel cells packages) shall be hardwired type (included the FAULT signals).

For details about under which above indicate scenario the Fuel Cell and Electrolyser Packages will run, reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

The CCS will be switched to fully 'manual' operation for research activities to proceed with the amount of power generated by WTG-57 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.

In the following Table 3 are summarized the above modes and relative unit functionality:

	BLPH CONNECTION MODES			
CCS OPERATING MODES	A - WIND FARM (ONLY)	B - SOLAR FARM (ONLY)	C – BOTH (A & B)	D - NEITHER (NO A & B)
0. IDLE	✓	N/A	✓	N/A
BESS	Operating (Charging)	N/A	Operating (Charging)	N/A
ELECTROLYSER	Operating	N/A	Operating	N/A
FUEL CELL	STOP	N/A	STOP	N/A
SOLAR FARM	N/A	N/A	On-Line	N/A
Aux. (400VAC) Loads	Operating	N/A	Operating	N/A
1. IMPORT	✓	N/A	✓	N/A
BESS	Operating (Charging)	N/A	Operating (Charging)	N/A
ELECTROLYSER	Operating	N/A	Operating	N/A
FUEL CELL	STOP	N/A	STOP	N/A
SOLAR FARM	N/A	N/A	On-Line	N/A
Aux. (400VAC) Loads	Operating	N/A	Operating	N/A
2. HOT STANDBY	✓	N/A	✓	N/A
BESS	Ready to operate	N/A	Ready to operate	N/A
ELECTROLYSER	STOP	N/A	STOP	N/A
FUEL CELL	Ready to operate	N/A	Ready to operate	N/A
SOLAR FARM	N/A	N/A	On-Line	N/A
Aux. (400VAC) Loads	Operating	N/A	Operating	N/A

	BLPH CONNECTION MODES			
CCS OPERATING MODES	A - WIND FARM	B - SOLAR FARM (ONLY)	C – BOTH (A & B)	D - NEITHER (NO A & B)
3. EXPORT	✓	N/A	✓	N/A
BESS	Operating (Discharging)	N/A	Operating (Discharging)	N/A
ELECTROLYSER	STOP	N/A	STOP	N/A
FUEL CELL	Operating	N/A	Operating	N/A
SOLAR FARM	N/A	N/A	On-Line	N/A
Aux. (400VAC) Loads	Operating	N/A	Operating	N/A
4. COLD STANDBY	✓	N/A	✓	N/A
BESS	Not Able to export	N/A	Not Able to export	N/A
ELECTROLYSER	STOP	N/A	STOP	N/A
FUEL CELL	STOP	N/A	STOP	N/A
SOLAR FARM	N/A	N/A	On-Line	N/A
Aux. (400VAC) Loads	Operating	N/A	Operating	N/A
4A. EMERGENCY MODE	N/A	✓	N/A	✓
BESS	N/A	Operating (Discharging)	N/A	Operating (Discharging)
ELECTROLYSER	N/A	STOP	N/A	STOP
FUEL CELL	N/A	Operating	N/A	Operating
SOLAR FARM	N/A	On-Line	N/A	N/A
Aux. (400VAC) Loads	N/A	Operating	N/A	Operating
5. POWER OUT (Blackout)	N/A	N/A	N/A	✓
BESS	N/A	N/A	N/A	STOP
ELECTROLYSER	N/A	N/A	N/A	STOP
FUEL CELL	N/A	N/A	N/A	STOP
SOLAR FARM	N/A	N/A	N/A	N/A
Aux. (400VAC) Loads	N/A	N/A	N/A	Vital Only

	BLPH CONNECTION MODES			
CCS OPERATING MODES	A - WIND FARM	B – SOLAR FARM (ONLY)	C – BOTH (A & B)	D - NEITHER (NO A & B)
6. MAINTENANCE	✓	✓	✓	✓
BESS	Maintenance (only local control)	N/A	Maintenance (only local control)	N/A
ELECTROLYSER	Unstartable / Maintenance (only local control)	N/A	Unstartable / Maintenance (only local control)	N/A
FUEL CELL	Unstartable / Maintenance (only local control)	N/A	Unstartable / Maintenance (only local control)	N/A
SOLAR FARM	N/A	On-Line	On-Line	N/A
Aux. (400VAC) Loads	Operating	Operating	Operating	N/A
7. RESEARCH	✓	✓	✓	✓
BESS	N/A	N/A	N/A	Fully manual operation for research tasks Energy control with WTG-57 is no longer relevant CPI has internal self-protection for internal failure. EMCS will not provide any limitation to manual
ELECTROLYSER	N/A	N/A	N/A	
FUEL CELL	N/A	N/A	N/A	
SOLAR FARM	N/A	N/A	N/A	
Aux. (400VAC) Loads	N/A	N/A	N/A	

				operated commands. Main and auxiliary equipment will be switched to import or export power (generated in BLPH), as necessary to satisfy the research criteria

8. NONE MODE	INITIALIZATION MODE. NO COMMANDS FROM EMCS.	N/A
BESS		N/A
ELECTROLYSER		N/A
FUEL CELL		N/A
SOLAR FARM		N/A
Aux. (400VAC) Loads		N/A

Table 3 – BLPH connection modes

Note = the "Maintenance Mode" is related to maintenance activities without depressurization with operator on BLPH. In this mode only manual command arriving from HMI.

The black start scenario, will happen without any BLPH MODE in execution; at reboot of the EMCS system (in NONE MODE) the operator shall choose the MODE RESEARCH to operate the various activities for total restart of BLPH (see document 123A90-DDL-EL-SP-20141 Rev.01 and 1724000594-IN-SP-00019 Rev.02).

3.2 MODE 0 = IDLE (POWER IMPORT ONLY)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "IDLE Mode" the Electrolyser Package is required to run and the logic will do the following:

1) EMCS requires PCS to enter in "IDLE Mode".
2) PROCESS Healthy State:

- All BDV valves in closed position, the feedback statuses are 25-ZSL-005/007/010/013/016/019/022.
- Shutdown valves 25-SDV-001 and 25-SDV-023 in open position, the feedback statuses are 25-ZSH-001 and 25-ZSH-023.
- Shutdown valve 64-SDV-001 in closed position, the feedback status is 64-ZSL-001.
- On-Off valves 25-XV-024 and 80-XV-001 in closed position, the feedback statuses are 25-ZSL-024 and 80-ZSL-001.

3) Air system Healthy State:
    - Instrument Air package NOT FAULT and
    - Pressure transmitter outlet from IA package 63-PT-003≥ 8 barg
4) N2 system Healthy State:
    - Nitrogen package NOT FAULT and
    - Pressure transmitters outlet from Nitrogen package 64-PT-031A≥ 7 barg or 64-PT-031B≥ 7 barg.
5) H2 storage not full (check at least one pressure transmitter on H2 storage vessels is < 20 barg):
    - 25-PT-035
    - 25-PT-037
    - 25-PT-040
    - 25-PT-043
    - 25-PT-046
    - 25-PT-049
6) Fuel Cell package is STOPPED (not in production)
7) Electrolyser NOT FAULT
8) Water system Treatment package NOT FAULT
9) At least one Seawater Pump NOT FAULT
10) EMCS informs to PCS the "Start request" for Electrolyser package
11) PCS commands to start the Water system Treatment package (see. Section 4.2.4).
12) ~~PCS waits for the signal "Sea water pump start request" by 50-LP-001 WT panel (serial signal 50-HS-001S).~~
13) ~~PCS commands to start the Main Sea water Pump (see Section 4.1)~~
14) ~~PCS sends to 50-LP-001 WT panel the "main sea water pump running" (cumulative serial signal 50-XL-001S). (see section 4.4.2)~~
15) PCS sends to EMCS the **"Permissive to start"** for Electrolyser package.

16) Electrolyser running. (delay Hold 3 Sec)

17) PCS requires the "Process Charging mode" for H2 storage Vessels (see Section 4.4.2)

If "Permissive to start" is not achieved (points from 2 to 14) the logic will remain in this electrical mode and re-execute from 2 to 14 (maximum time Hold 3 sec.). If the time is expired with "Permissive to start" doesn't achieve the logic will remain in this electrical mode, and:

- PCS informs EMCS to remove "Start request" for Electrolyser package
- PCS will stop the Sea water Pumps
- PCS will stop Water Treatment system

As soon as the "Permissive to Start" is no longer active the logic will remain in this electrical mode and:

- Electrolyser will be stopped by EMCS.
- PCS will stop the sequence "Process Charging mode" for H2 storage Vessels (close all inlet valves)
- PCS will stop the Sea water Pumps
- PCS will stop Water Treatment system

The above Step number 10 (Start Request from EMCS) is "NOT Latched" type so shall be checked only once.

When all Vessels are filled (see section 4.4.3 "Process Fully charged mode") the "Permissive to start" shall be removed and the EMCS logic remains in this mode.

During this electrical mode these systems are DISABLE to START:

- Fuel cells

All the time this mode is active, the sea water punps can be required to start by WT package with the following sequence

1) PCS waits for the signal "Sea water pump start request" by 50-LP-001 WT panel (serial signal 50-HS-001S).
2) PCS commands to start the Main Sea water Pump (see Section 4.1)
3) PCS sends to 50-LP-001 WT panel the "main sea water pump running" (cumulative serial signal 50-XL-001S). (see section 4.4.2)

3.3 MODE 1 = IMPORT (CHARGING)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "Power Import mode" the Electrolyser Package is required to run and the logic will do the following:

1) EMCS requires PCS to enter in "IMPORT MODE".
2) PROCESS Healthy State:

- All BDV valves in closed position, the feedback statuses are 25-ZSL-005/007/010/013/016/019/022.
- Shutdown valves 25-SDV-001 and 25-SDV-023 in open position, the feedback statuses are 25-ZSH-001 and 25-ZSH-023.
- Shutdown valve 64-SDV-001 in closed position, the feedback status is 64-ZSL-001.
- On-Off valves 25-XV-024 and 80-XV-001 in closed position, the feedback statuses are 25-ZSL-024 and 80-ZSL-001.

3) Air system Healthy State:
    - Instrument Air packages NOT FAULT and
    - Pressure transmitter outlet from IA package 63-PT-003≥ 8 barg
4) N2 system Healthy State:
    - Nitrogen packages NOT FAULT and
    - Pressure transmitters outlet from Nitrogen package 64-PT-031A≥ 7 barg or 64-PT-031B≥ 7 barg
5) H2 storage not full (check at least one pressure transmitter on H2 storage tanks is < 20barg):

- 25-PT-035
- 25-PT-037
- 25-PT-040
- 25-PT-043
- 25-PT-046
- 25-PT-049

6) Fuel Cell package is NOT running.
7) Electrolyser NOT FAULT
8) Water system Treatment package NOT FAULT
9) At least one Seawater Pump NOT FAULT
10) EMCS sends to PCS the "Start request" for Electrolyser package.
11) PCS commands to start the Water system Treatment package (see. 4.2.4).
12) ~~PCS waits for the signal "Sea water pump start request" by 50-LP-001 WT panel (serial signal 50-HS-001S).~~
13) ~~PCS commands to start the Main Sea water Pump (see section 4.1)~~
14) ~~PCS sends to 50-LP-001 WT panel the "main sea water pump running" (cumulative serial signal 50-XL-001S). (see section 4.4.2)~~
15) PCS sends to EMCS the **"Permissive to start"** for Electrolyser package.

16) Electrolyser running. (delay Hold 3 Sec)

17) PCS requires the "Process Charging mode" for H2 storage Vessels (see section 4.4.2) (delay Hold 3 sec).

If "Permissive to start" is not achieved (points from 2 to 14) the logic will remain in this electrical mode and re-execute from 2 to 14 (maximum time Hold 3 sec.). If the time is expired with "Permissive to start" doesn't achieve the logic will remain in this electrical mode, and:

- PCS informs EMCS to remove "Start request" for Electrolyser package.
- PCS will stop the Sea water Pumps
- PCS will stop Water Treatment system

As soon as the "Permissive to Start" is no longer active the logic will remain in this electrical mode, and:

- the Electrolyser will be stopped by EMCS.
- PCS will stop the sequence "Process Charging mode" for H2 storage Vessels (close all inlet valves)
- PCS will stop the Sea water Pumps
- PCS will stop Water Treatment system

The above Step number 10 (Start Request from EMCS) is "NOT Latched" type so shall be checked only once.

When all Vessels are filled (see section 4.4.3 "Process Fully charged mode") permissive to start shall be removed and the EMCS logic moves to "HOT STANDBY mode".

During this electrical mode these systems are DISABLE to START:

- Fuel cells

All the time this mode is active, the sea water punps can be required to start by WT package with the following sequence

1) PCS waits for the signal "Sea water pump start request" by 50-LP-001 WT panel (serial signal 50-HS-001S).
2) PCS commands to start the Main Sea water Pump (see Section 4.1)
3) PCS sends to 50-LP-001 WT panel the "main sea water pump running" (cumulative serial signal 50-XL-001S). (see section 4.4.2)

3.4 MODE 2 = HOT STANDBY (POWER IMPORT-ABLE TO EXPORT)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "HOT STANDBY mode" neither the Electrolyser nor the Fuel cells is required to run, and the logic will do the following:

1) EMCS requires PCS to enter in "HOT STAND BY mode"

2) BESS NOT FAULT
3) H2 storage full (check all pressure transmitters on H2 storage tanks are ≥ 20barg):
    - 25-PT-035
    - 25-PT-037
    - 25-PT-040
    - 25-PT-043
    - 25-PT-046
    - 25-PT-049
4) PCS sends to EMCS the "Permissive to start" for "HOT STANDBY mode".

If "Permissive to start" is not achieved (point 2) the EMCS logic moves to "COLD STANDBY Mode.

If "Permissive to start" is not achieved (point 3) the logic will remain in the previously electrical mode.

During this electrical mode these systems are DISABLE to START:

o Electrolyser

3.5 MODE 3 = EXPORT MODE (DISCHARGING)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "Export Mode" the Fuel cells package is required to run and the logic will do the following:

1) EMCS requires to PCS enter in "Export Mode"
2) BESS NOT FAULT
3) PROCESS Healthy State:

- All BDV valves in closed position, the feedback statuses are 25-ZSL-005/007/010/013/016/019/022.
- Shutdown valves 25-SDV-001 and 25-SDV-023 in open position, the feedback statuses are 25-ZSH-001 and 25-ZSH-023.
- Shutdown valve 64-SDV-001 in closed position, the feedback status is 64-ZSL-001.
- On-Off valves 25-XV-024 and 80-XV-001 in closed position, the feedback statuses are 25-ZSL-024 and 80-ZSL-001.

4) Air system Healthy State:
    - Instrument Air packages NOT FAULT and
    - Pressure transmitter outlet from IA package 63-PT-003≥ 8 barg
5) N2 system Healthy State:
    - Nitrogen packages NOT FAULT and

- Pressure transmitters outlet from Nitrogen package 64-PT-031A≥ 7 barg or 64-PT-031B≥ 7 barg

6) H2 storage available (check at least one pressure transmitter is ≥ 10 barg):
   - 25-PT-035
   - 25-PT-037
   - 25-PT-040
   - 25-PT-043
   - 25-PT-046
   - 25-PT-049
7) Since both valves 25-PV-055A/B shall be in closed position (mandatory) following actions shall be taken (see section 4.4.10):
   - Put both controllers 25-PIC-055A/B in Auto mode and force the output to 0%.
   - Time to close the valves is 15 sec
   - The feedback statuses are 25-ZSL-055A and 25-ZSL-055B. When the feedback statuses are active then proceed with below point.
8) Water system Treatment NOT RUNNING
9) Sea water Pumps NOT RUNNING
10) Electrolyser NOT RUNNING
11) Fuel Cell NOT FAULT
12) Remove the forced output 0% of the controllers 25-PIC-055A/B
13) PCS requires the "Process Discharging mode" for H2 storage Vessels (see section 4.4.5) (delay Hold 3 sec).
14) PCS sends to EMCS the "Permissive to start" for Fuel Cells package

If "Permissive to start" is not achieved (point 2) the EMCS logic moves to "COLD STANDBY mode".

If "Permissive to start" is not achieved (points from 3 to 13) the logic will remain in this electrical mode and re-execute from 3 to 13 (maximum time Hold 3 sec.). If the time is expired with "Permissive to start" doesn't achieve the logic will move to "COLD STANDBY" mode, and:

- the Fuel Cells will be stopped by EMCS.
- PCS will stop the sequence "Process Discharging mode" for H2 storage Vessels
- Put both controllers 25-PIC-055A/B in Auto mode and force the output to 0%.
- Time to close the valves is 15 sec
- The feedback statuses are 25-ZSL-055A and 25-ZSL-055B.

As soon as the "Permissive to Start" is no longer active the logic will move to "COLD STANDBY Mode" and:

- the Fuel Cells will be stopped by EMCS.
- PCS will stop the sequence "Process Discharging mode" for H2 storage Vessels
- Put both controllers 25-PIC-055A/B in Auto mode and force the output to 0%.
- Time to close the valves is 15 sec
- The feedback statuses are 25-ZSL-055A and 25-ZSL-055B.

During this electrical mode these systems are DISABLE to START:

- Electrolyser

3.6 MODE 4 = COLD STANDBY (POWER IMPORT - NO ABLE TO START)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "COLD STANDBY mode" neither the Electrolyser nor the Fuel cells is required to run and the logic will do the following:

1) EMCS requires to PCS enter in "COLD STANDBY mode".
2) BESS FAULT
3) PCS sends to EMCS the "Permissive to start" for "COLD STANDBY mode".

If "Permissive to start" is not achieved (point 2) the logic will remain in the previously electrical mode.

As soon as the "Permissive to Start" is no longer active the logic will move to electrical mode according to EMCS logics.

During this electrical mode these systems are DISABLE to START:

- Electrolyser
- Fuel Cells

3.7 MODE 4A = EMERGENCY MODE (ISLAND)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "Emergency Mode (Island)" the Fuel cells package is required to run and the logic will do the following:

1) EMCS requires to PCS enter in "Emergency Mode (Island)"
2) BESS NO FAULT
3) PCS sends to EMCS the "Permissive to start" for "Emergency mode"
4) EMCS sends to PCS the "Command to Load shedding 1" that consists of:
    - PCS Stop Sea water Pumps

- PCS Stop Water Treatment system
- PCS Stop Auxiliary Electrolyser

5) EMCS sends to PCS the "Start request" for Fuel Cell package (see section 4.4.10 to start the control loop 25-PV-055A/B).
6) PROCESS Healthy State:

- All BDV valves in closed position, the feedback statuses are 25-ZSL-005/007/010/013/016/019/022.
- Shutdown valves 25-SDV-001 and 25-SDV-023 in open position, the feedback statuses are 25-ZSH-001 and 25-ZSH-023.
- Shutdown valve 64-SDV-001 in closed position, the feedback status is 64-ZSL-001.
- On-Off valves 25-XV-024 and 80-XV-001 in closed position, the feedback statuses are 25-ZSL-024 and 80-ZSL-001.

7) Air system Healthy State:
    - Instrument Air packages NOT FAULT and
    - Pressure transmitter outlet from IA package 63-PT-003≥ 8 barg
8) N2 system Healthy State:
    - Nitrogen packages NOT FAULT and
    - Pressure transmitters outlet from Nitrogen package 64-PT-031A≥ 7 barg or 64-PT-031B≥ 7 barg
9) H2 storage available (check at least one pressure transmitter is ≥ 20 barg)
    - 25-PT-035
    - 25-PT-037
    - 25-PT-040
    - 25-PT-043
    - 25-PT-046
    - 25-PT-049
10) Since both valves 25-PV-055A/B shall be in closed position (mandatory) following actions shall be taken (see section 4.4.10):
    - Put both controllers 25-PIC-055A/B in Auto mode and force the output to 0%.
    - Time to close the valves is 15 sec
    - The feedback statuses are 25-ZSL-055A and 25-ZSL-055B. When the feedback statuses are active then proceed with below point.
11) Fuel Cell NOT FAULT
12) Remove the forced output 0% of the controllers 25-PIC-055A/B (for this logic see section 4.4.10)

13) BESS NOT FAULT
14) PCS requires the "Process Discharging mode" for H2 storage Vessels (see section 4.4.5) (delay Hold 3 sec).
15) PCS sends to EMCS the "Permissive to start for Fuel Cells package"

If "Permissive to start for Fuel Cells package"" is not achieved (points from 6 to 14) the logic will remain in this electrical mode and re-execute from 6 to 14 (maximum time Hold 3 sec.). If the time is expired with "Permissive to start" doesn't achieve the logic will remain in this electrical mode and will do the same effects of the below permissive no longer active.

As soon as the ""Permissive to start for Fuel Cells package" is no longer active the logic will remain in this electrical mode and:

- Fuel Cells will be stopped by EMCS.
- PCS Stop auxiliary Fuel Cells
- PCS will stop the sequence "Process Discharging mode" for H2 storage Vessels
- Put both controllers 25-PIC-055A/B in Auto mode and force the output to 0%.
- Time to close the valves is 15 sec
- The feedback statuses are 25-ZSL-055A and 25-ZSL-055B.

EMCS sends to PCS the "Command to Load shedding 2" that consists of:

- PCS Stop HVAC systems
- PCS Stop Welding sockets
- PCS Stop BOP Distribution panel
- PCS Stop Crane

If "Permissive to start" for "Emergency Mode" (Island) is not achieved (point 2) the logic will move to "Power Out mode".

As soon as the "Permissive to Start" is no longer active the logic will move to "Power Out mode".

During this electrical mode these systems are DISABLE to START according to Load shedding:

- Electrolyser
- Sea water pumps
- Water Treatment system
- HVAC systems
- Welding sockets
- BOP Distribution Panel
- Crane

3.8 MODE 5 = POWER OUT (BLACK-OUT)

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "Power Out mode" neither the Electrolyser nor the Fuel cells is required to run. Only vital loads will remain powered by UPS systems.

EMCS is informed of ESD-1D activation (refer to doc. "Process Safety Cause & Effect Matrix").

3.9 MODE 6 = MAINTENANCE

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "Maintenance mode" neither the Electrolyser nor the Fuel cells is required to run. Hydrogen production cannot be involved in this electrical mode.

EMCS sent to the PCS the command PCS.EnterMode(MANUAL).time and the PCS will:

1) Stop Sea water pumps
2) Stop Water Treatment Package
3) Close the valve 50-XV-005. Operator has to close the valve locally. When the PCS receives the 50-ZLL-005 (after the open command) will remove the Close command.
4) Stop the following automatic sequences (if active):

- Process Charging mode
- Process Start-up Charging mode
- Process Discharging mode
- Purging mode after Shutdown (for H2 displacement)
- Purging mode after Maintenance (for Air displacement)

5) Command the closure of all XV valves inlet/outlet Hydrogen Vessels:
   - XV inlet Limit switches are: 25-ZSL-004/008/011/014/017/020
   - XV outlet Limit switches are: 25-ZSL-006/009/012/015/018/021

The Operators, if necessary, can decide to open BDV remotely to depressurize the tanks up to desidered pressure in case special operations are needed.

3.10 MODE 7 = RESEARCH

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

All commands will be in manual mode by operators from HMI and all Software Interlocks inside PCS shall be by-passed.

The following push buttons will be active only in electrical "Research mode":

- Software push button = Purging mode after Shutdown (for H2 displacement) (see section 4.4.7)
- Software push button = Purging mode after Maintenance (for air displacement) (see section 4.4.8)
- Software push button = Process Start-up charging mode (see section 4.4.4)
- Software push button = Process Charging mode (see section 4.4.2)
- Software push button = Process Discharging mode (see section 4.4.5)

Operators can any time enter/exit from this electrical mode by a software push button on HMI managed from EMCS.

This Mode shall be used for First energization and re-energization during a Black Start.

All push buttons above recalled will be available only if this mode is selected from any other mode than maintenance; in case research mode is selected after maintenance mode the push buttons "Process Charging mode", "Process Start-up charging mode" must be activated only if pressure in the H2 vessels is ≥ 2 barg (this value depends on the chosen set point of pressure control valves during purging operation), this to ensure there is no air inside the vessels.

The above Software push buttons can be activated one at a time, and only when the complete logic is finished the other push buttons will become available.

3.11 MODE 8 = NONE

For electrical details about this mode reference shall be made to doc. "EMCS Software Functional Design Specification (FDS-SW)".

From process point of view in the "NONE Mode" neither the Electrolyser nor the Fuel cells is required to run.

4 PROCESS CONTROL PHILOSOPHY

4.1 SEA WATER LIFT PUMPS P-50001A/B

4.1.1 General

Seawater is the raw water to be treated and then electrochemically converted into hydrogen (for energy accumulation purposes) and oxygen (to be continuously vented when the plant runs); seawater is lifted by means of 2 x 100% submersible centrifugal 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.

4.1.2 Lift Pumps Control Philosophy

Reference P&ID: Doc. N.123A90-DDL-PR-PID-80021.

The sea water lift pumps P–50001A/B are electric type pumps.

The pumps are provided with pressure relief valves (50-PSV-006 for P-50001A and 50-PSV-007 for P-50001B) to protect from overpressure due to a blocked discharge.

To protect the water treatment package from overpressure due to a blocked discharge the 50-PSV-011 is installed.

The discharge of the pumps can be monitored remotely with pressure transmitters 50-PT-001 for P-50001A and 50-PT-002 for P-50001B (the onshore indications are 50-PI-001 for P-50001A and 50-PI-002 for P-50001B).

Pump discharges are also equipped with high and low alarms available onshore control room (50-PAH/PAL-001 for P-50001A and 50-PAH/PAL-002 for P-50001B) to alert the operator.

All signals for motor control (start/stop) and monitoring are exchanged between SG-200N1 (LV switchgear) and PCS via modbus TCP/IP. The pumps shutdown commands are from SIS with hardwired communication.

A software interlock is provided to prevent simultaneous running of both pumps A and B (only one (1) pump is run at a time).

The main sea water Lift Pump is automatically started/stopped by PCS following electrical control logic requirements (see chapter 3). In addition, PCS requires automatic opening/closing of the (on/off) discharging isolation valves (50-XV-001 for P-50001A and 50-XV-003 for P-50001B).

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

1) If the valve 50-XV-001 is closed (50-ZSL-001 closed valve status active), the software interlock prevents pump "A" to start;
2) If the valve 50-XV-003 is closed (50-ZSL-003 closed valve status active), the software interlock prevents pump "B" to start.

Auto start of designed stand-by pump will be activated on:

- loss of running status of duty pump
- low pressure alarm (50-PAL-001/002) of duty pump

In case of:

1. Pressure transmitter on duty discharge line in High Pressure Alarm (50-PAH-001 or 50-PAH-002), duty pump will be stopped.
2. Pressure transmitter on duty discharge line in Low Pressure Alarm (50-PAL-001 or 50-PAL-002) when the main pump is already started, duty pump will be stopped and stand-by pump started.
3. Running Status (50-XL-001A or 50-XL-001B) of duty pump missing during pump operation, duty pump will be stopped and stand-by pump started.
4. If after the selected pump is started, the relevant PT doesn't reach the min set value, within 2 minuts (Adjustable time), the stand-by pump shall be started.
5. The main seawater pump will be stopped when sand filter S-50001 is in backwash sequence (see section 4.2.2). The signal 50-HS-005S will be serial type from Water Treatment package 50-LP-001 panel to PCS.

The signals of Table 4 will inform about each pump status/commands:

SIGNAL	P-50001A	P-50001B
RUNNING (at 1) STATUS	50-XL-001A	50-XL-001B
LOCAL (at 1)/REMOTE (at 0) STATUS	50-XL-002A	50-XL-002B
AUTO START READY STATUS (at 1)	50-XL-003A	50-XL-003B
FAULT/TRIPPED STATUS (at 1)	50-XA-004A	50-XA-004B
START COMMAND (at 1)	50-HS-001A	50-HS-001B
STOP COMMAND (at 1)	50-HS-005A	50-HS-005B
SHUTDOWN COMMAND	83-XS-001A	83-XS-001B
AUTO/MANUAL MODE	50-HS-002A	50-HS-002B
STAND-BY MODE	50-HS-003	

Table 4 – Lift Pumps Signals

In front of SG-200N1 (LV switchgear) the following selectors/push buttons are provided for each pump:

- Local/Remote selector SA1 (called SA1-A in this document) for pump P–50001A
- Local Start push button PM-1 (called PM1-A in this document) for pump P–50001A

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- Local Stop push button PA1 (called PA1-A in this document) for pump P–50001A
- Local/Remote selector SA1 (called SA1-B in this document) for pump P–50001B
- Local Start push button PM1 (called PM1-B in this document) for pump P–50001B
- Local Stop push button PA1 (called PA1-B in this document) for pump P–50001B

If selector SA1 (SA1-A or SA1-B) is in LOCAL position:

- The Start of duty pump will only be possible locally from push button PM1 (PM1-A or PM1-B)
- The Stop of duty pump will be possible locally from push button PA1 (PA1-A or PA1-B)
- The UMC (Universal Motor Controller) will inhibit the remote Start command
- The Stop of duty pump will be possible remotely from control logic (Software Interlock inhibition)

If selector SA1 (SA1-A or SA1-B) is in REMOTE position:

- The remote Start and Stop commands will be enabled
- The local Start push button PM1 (PM1-A or PM1-B) will be inhibited
- The Stop push button PA1 (PA1-A or PA1-B) will be enabled:
    1. If the Stop push button PA1 (PA1-A or PA1-B) is activated by operator when the selector SA1 is in remote position, the feedback status "PA1 activated" is activated
    2. PCS has to inhibit the remote Start command 50-HS-001A (or 50-HS-001B) until a Software reset will be activated by operator.

4.1.3 Remote Mode

Local/Remote selector SA1-A (or SA1-B), in front of SG-200N1 (LV switchgear), is set in Remote position so the remote status 50-XL-002A or 50-XL-002B is active;

In Automatic mode, the operation sequence is as follows:

1. Initial conditions include:
    a. 50-HS-002A or 50-HS-002B (on HMI) is set to Auto mode;
    b. 50-HS-003 is set to select either pump A or B to be in Standby mode (contact closed means pump A selected main);
    c. No faults, alarms or shutdowns are active in this system.
    d. 50-XV-001/002 in Auto mode for pump A and 50-XV-003/004 in Auto mode for pump B.
2. If from electrical requirements is required to start duty lift pump (see chapter 3):
    a. Close relevant (on/off) by-pass isolation valve of main selected pump (50-XV-002 for P-50001A or 50-XV-004 for P-50001B) (feedback valve position 50-ZSL-002 or 50-ZSL-004 is active);
    b. Open relevant (on/off) discharging isolation valve of main selected pump (50-XV-001 for P-50001A or 50-XV-003 for P-50001B) (feedback valve position 50-ZSH-001 or 50-ZSH-003 is active);

c. Start duty Lift pump;

3. If from electrical Requirements is required to stop duty lift pump:
   a. Stop duty Lift pump;
   b. Close relevant (on/off) discharging isolation valve of main selected pump (50-XV-001 for P-50001A or 50-XV-003 for P-50001B) (feedback valve position 50-ZSL-001 or 50-ZSL-003 is active);

In Manual mode, the operation sequence is as follows:

1. Initial conditions include:
   a. 50-HS-002A and 50-HS-002B (on HMI) are set to Manual mode;
   b. 50-HS-003 is set to select either pump A or B to be in Standby mode (contact closed means pump A selected main);
   d. No faults, alarms or shutdowns are active in this system.
2. If from operator (onshore) is required to start duty lift pump:
   a. Close relevant (on/off) by-pass isolation valve (50-XV-002 for P-50001A or 50-XV-004 for P-50001B) (feedback valve position 50-ZSL-001 or 50-ZSL-003 is active);
   b. Open relevant (on/off) discharging isolation valve (50-XV-001 for P-50001A or 50-XV-003 for P-50001B) (feedback valve position 50-ZSH-001 or 50-ZSH-003 is active);
   c. Start duty Lift pump;
3. If from operator (onshore) is required to stop duty lift pump:
   a. Stop duty Lift pump;
   b. Close relevant (on/off) discharging isolation valve of main selected pump (50-XV-001 for P-50001A or 50-XV-003 for P-50001B) (feedback valve position 50-ZSL-001 or 50-ZSL-003 is active).

4.1.4 Local Mode

Local/Remote selector SA1-A (or SA1-B), in front of SG-200N1 (LV switchgear), is set in Local position so the remote status 50-XL-002A or 50-XL-002B is active;

1. Operator, locally, pushes push button PM1-A (or PM1-B) to start the selected lift pump. In this mode the closure of (on/off) by-pass isolation valve (50-XV-002 for P-50001A or 50-XV-004 for P-50001B) and the opening of (on/off) discharging isolation valve (50-XV-001 for P-50001A or 50-XV-003 for P-50001B) will be manually managed by operators.
2. Operator, locally, pushes push button PA1-A (or PA1-B) to stop the selected lift pump.
3. When the selector is switched in LOCAL the pumps are switched in MANUAL.

4.1.5 Biocide Injection Control Philosophy

An inlet stream of biocide to the Seawater Lift Pumps P-50001A/B discharge line is provided, in order to perform a biocide dosing shock in case the pump is not working, the dosing operation is intermittent type. The scope of this dosing is to disinfect the seawater lifting pump tube.

The biocide injections are fed to the following item:

- Sea water lift pumps caissons B-50013A/B (discontinuous dosage);
- On the common manifold on the discharge line of the Seawater Lift Pumps (discontinuous dosage);
- Wastewater tank T-55001 (discontinuous dosage).

The discontinuous dosage of the seawater lift pump discharge pipe that is not running will be done during the other seawater lift pump is running. Assuming that the pump "A" is running: at time is required to dose the discharge pipe of the pump "B", the valve 50-XV-004 will be open. It is noted that just upstream of such XV valve, an orifice is provided to guarantee a fine dosage of pump "B". Just few liters per hour are required as flow rate during this dosage (and the dosage will last few minutes), therefore the inlet flow rate of the seawater that is fed to the water treatment package will not be impacted considering that the order of magnitude between the two flow rates is more than a thousand.

The biocide system is included within the seawater treatment system, therefore the operating conditions and configuration are vendor specific.

The Biocide Injection will usually be done with the Local/Remote selectors SA1-A and SA1-B, in front of SG-200N1 (LV switchgear), set in Remote position and the software push buttons in Automatic mode.

In Automatic mode, the operation sequence is as follows:

1. Initial conditions include:
    a. 50-HS-002A and 50-HS-002B are set to Auto mode
    b. Sea Water Lift pump P-50001B (or P-50001A) is not working (missing running signal 50-XL-001B or 50-XL-001A)
    c. Sea Water Lift pump P-50001A (or P-50001B) is working (running signal 50-XL-001A or 50-XL-001B is active)
    d. No faults, alarms or shutdowns are active in this system.
2. Delay time (48 hours TBC) expired (time between two injections)
3. Close relevant (on/off) discharging isolation valve of the pump not running (50-XV-003 for P-50001B or 50-XV-001 for P-50001A) (feedback valve position 50-ZSL-003 or 50-ZSL-001 is active);
4. Open relevant (on/off) by-pass isolation valve of the pump not running (50-XV-002 for P-50001A or 50-XV-004 for P-50001B) (feedback valve position 50-ZSH-002 or 50-ZSH-004 is active);
5. Set a delay time (2 min. TBC) (time of injection phase)
6. Delay time (2 min. TBC) is expired and close the relevant (on/off) by-pass isolation valve (50-XV-002 for P-50001A and 50-XV-004 for P-50001B) (feedback valve position 50-ZSL-002 or 50-ZSL-004 is active);

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Moreover, a biocide inlet stream to the Seawater Lift Pumps Caissons B-50013A/B is provided, in order to also disinfect the seawater in the suction side of each Seawater Lift Pumps.

4.1.6 Sea Water Temperature Control Philosophy

Reference P&ID: Doc. N.123A90-DDL-PR-PID-80022/123A90-DDL-PR-PID-80025.

Downstream the sea water lift pumps, in order to monitor the temperature of brine going back to the brine discharge caisson B-50014, a temperature transmitter 50-TT-001 with remote indication (50-TI-001) is required just at inlet of water treatment system.

The 50-TI-001 measurement is compared with the temperature transmitter 50-TT-002 measurement (50-TI-002) installed on discharge line to brine caisson B-50014.

The 50-TDI-002 (50-TI-001 – 50-TI-002) by measuring the temperature difference between these two streams, can ensure that the discharged water will not be too warm back into the sea, which could potentially harm the marine ecosystem.

A High Differential Temperature Alarm 50-TDAH-002 will alert operators onshore control room.

4.2 WATER TREATMENT PACKAGE (A-50000)

Reference P&ID: Doc. N.1724000448-PR-PID-00013.

4.2.1 General

Seawater is the raw water to be treated and then electrochemically converted into hydrogen (for energy accumulation purposes) and oxygen (to be continuously vented when the plant runs); thus seawater is lifted by means of 2 x 100% submersible centrifugal 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.

The seawater treatment system receives seawater from lift pumps and the scope of the system is to produce and provide pure water to the downstream Electrolyser Package.

4.2.2 Water Treatment Package Control Philosophy

The sea water treatment package is a standalone, containerized unit and, excluding lifting pumps, will be controlled by local control panel 50-LP-001.

All the package control signals (status and commands) will be exchanged with BLPH control system (PCS) through a modbus TCP/IP communication.

The main seawater pump will be stopped when sand filter S-50001 is in backwash sequence (see section 4.1.2). The signal 50-HS-005S "Stop main sea water pump" will be serial type by 50-LP-001 WT panel to PCS.

In addition, to permit the automatic start sequence of Water Treatment package, the following serial signals between 50-LP-001 and PCS shall be exchanged:

- PCS waits.for the signal "Sea water pump start request" by 50-LP-001 WT panel (serial signal 50-HS-001S).
- PCS sends to.50-LP-001 WT panel the "Main sea water pump running status" (serial signal 50-XL-001S). This signal shall be a.cumulative between the signals:
    - 50-XL-001A (running sea water pump PM-50001A)
    - 50-XL-001B (running sea water pump PM-50001B)

The following software information of water analysers 50-AT-024/026/027 (installed in water treatment package) are sent to electrolyzer through control system PCS:

- pH (50-AI-027)
- Temperature (50-AI-026)
- Hardness (50-AI-026)
- Conductivity (50-AI-024)

The panel 50-LP-001 will be provided with:

- Local/Remote selector

4.2.3 Remote mode

When the Local/Remote selector is in "Remote position" (50-XL-011S feedback remote position):

- Logics inside LCP control and manage the Water Treatment package.
- The operators (onshore) can remotely:
    - Start/Stop Water Treatment package.

      Start: 50-HS-011S (this is maintained and starts the production of fresh water to restore the internal storage of fresh water).

      Stop: 50-HS-012S

4.2.4 Local mode

When the Local/Remote selector is in "Local position" (50-XL-012S feedback local position):

- Logics inside LCP control and manage the Water Treatment package.
- The operators (offshore) can locally:
    - Start/Stop Nitrogen package.
    - Switch from "Main" unit to "Stand-by" unit.

4.2.5 Water Treatment Package Safety Philosophy

All the package safety signals (status and commands) will be exchanged between local control panels and BLPH safety systems (SIS and FGS) through hardwired connections.

Fire and Gas devices inside of the Water treatment container will be wired directly to Vendor's safety local control panel 50-LP-002, in a point-to-point configuration and 2oo3 voting.

The following signals are exchanged between 50-LP-001/50-LP-002 and F&G and SIS systems:

- Gas Confirmed 50-XA-001 (Status from 50-LP-002): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Smoke Confirmed 50-XA-002 (Status from 50-LP-002): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Fault (Status from 50-LP-002) 50-XA-003: SIS will shut down the package when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 50-XS-001 (command to 50-LP-001): SIS will shut down the water treatment package in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics

4.3 ELECTROLYSER PACKAGE (A-20000)

Reference P&ID: Doc. N.123A90-DDL-PR-PID-80011.

4.3.1 General

The electrolyser package in a standalone containerized unit containing all major components required for the production of hydrogen. The electrolyser operating conditions and configuration are vendor specific.

4.3.2 Electrolyser Package Control Philosophy

The Electrolyser package is a standalone, containerized unit and will be controlled by local control panel. All the package control signals (status and commands) will be exchanged with BLPH control system (PCS and EMCS) through profinet communication.

Moreover, at inlet manifold of the vessels, there is a pressure transmitter (25-PT-001) that indicates the pressure value to the PCS with a high alarm threshold (25-PAH-001). This signal is replicated via software/serial link to the electrolyser package A-20000 in order to communicate the pressure level established inside the whole buffer volume.

The following software information of water analyser 50-AT-024/026/027 are sent to electrolyzer from water treatment package through PCS control system:

- pH (50-AI-027)
- Temperature (50-AI-026)

- Hardness (50-AI-026)
- Conductivity (50-AI-024)

The local control panel will be provided with a Local/Remote selector (CPY has to confirm the following philosophy for the Local/Remote operating modes (Hold 1)):

4.3.3 Remote mode

When the Local/Remote selector is in "Remote position":

- Logics inside LCP control and manage the Electrolyser package.
- The operators onshore can remotely:
    - Start/Stop Electrolyser package.

4.3.4 Local mode

When the Local/Remote selector is in "Local position":

- Logics inside LCP control and manage the Electrolyser package.
- The operators in offshore can locally:
    - Start/Stop Electrolyser package.
    - Switch from "Main" unit to "Stand-by" unit.

4.3.5 Electrolyser Package Safety Philosophy

All the package safety signals (status and commands) will be exchanged between local control panel and BLPH safety systems (SIS and FGS) through hardwired connections.

Fire and Gas devices inside of the Electrolyser container will be wired directly to Vendor's local control panel, in a point-to-point configuration.

The following signals are exchanged between local control panel and F&G/SIS systems:

- Gas Confirmed 20-XA-001 (Status): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Smoke Confirmed 20-XA-002 (Status): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Fault (Status) 20-XA-003: SIS will shut down the package when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 20-XS-001 (command): SIS will shut down the Electrolyser package in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics.

4.4 HYDROGEN STORAGE VESSELS (V-25001A TO F)

Reference P&ID: Doc. N.123A90-DDL-PR-PID-80015 to 80020.

4.4.1 General

The hydrogen storage system is constituted by six horizontal pressure vessels (V-25001A to F) that will store the hydrogen production.

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.

Flags on HMI shall indicate to operators (onshore) which of the following mode is active:

- Process Charging mode
- Process Fully Charged Status (Indication on HMI)
- Process Start-up Charging mode
- Process Discharging mode
- Process Empty Status (Indication on HMI)
- Purging mode after Shutdown (for H2 displacement)
- Purging mode after Maintenance (for Air displacement)

4.4.2 Process Charging mode

The "Process Charging mode" is a normal operating mode when the hydrogen vessels are empty after a process discharging mode and the vessels that previously contained hydrogen shall be refilled.

Start-up conditions are not involved in this operating mode where "Process Start-up charging mode" shall be considered (see section 4.4.4).

A Software push button can activate this logic only in "Research mode" (see section 3.10) in all other electrical modes this Software Push button **must** be disabled so that the charging of H2 vessels can only be done in automatic mode.

When Electrolyser starting to produce Hydrogen the PCS, as per EMCS requirement, starts the "Process Charging Mode" sequence (see section 3.2 and 3.3).

The "Process Charging mode" can be activated only if pressure in the H2 vessels is higher than 2 barg (this to ensure there is no air inside the vessels): 25-PT-035/037/040/043/046/049≥ 2 barg (this value depends on the chosen set point of pressure control valves during purging operation).

All the XV valves shall be forced in AUTO mode.

The sequence of the vessel to be filled is the following:

a. V-25001A,
b. V-25001B,
c. V-25001C,

d. V-25001D,

e. V-25001E,

f. V-25001F,

Then the logic will do the following:

1) Verify that all FV valves (25-FV-031/032/033/034/038/036) inlet H2 vessels are closed and all PV valves outlet are closed.

a. Put the controllers 25-FIC-031/032/033/034/038/036 in Auto mode and force the output to 0%. Close all FV valves that are installed on the inlet lines of each H2 Storage Vessel: 25-FV-031/032/033/034/038/036

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-031/032/033/034/038/036. When all feedback statuses are active proceed with below point.

b. Put the controllers 25-PIC-035/037/040/043/046/049 in Auto mode and force the output to 0%. Close all PV valves that are installed on the outlet lines of each H2 Storage Vessel: 25-PV-035/037/040/043/046/049

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-035/037/040/043/046/049. When all feedback statuses are active proceed with below point.

2) Close all XV valves that are installed on the inlet line of each H2 Storage Vessel:

25-XV-004/008/011/014/017/020

- Time to close the valves is 3 sec.
- The feedback statuses are 25-ZSL-004/008/011/014/017/020. When all feedback statuses are active proceed with below point.

3) Close all XV valves that are installed on the outlet line of each H2 Storage Vessel:

25-XV-006/009/012/015/018/021

- Time to close the valves is 3 sec.
- The feedback statuses are 25-ZSL-006/009/012/015/018/021. When all feedback statuses are active proceed with below point.

4) Check the pressure in V-25001A:

- If 25-PT-035 ≥ 30 barg go to point 7
- If 25-PT-035 < 30 and ≥ 2 barg go to below point
- If 25-PT-035< 2 barg go to point 7

5) Open the valve 25-XV-004, installed on the inlet line of the V-25001A;

- Time to open 25-XV-004 is 8 sec.

- The feedback status is 25-ZSH-004. When feedback status is active proceed with below point.

6) Start a timer T7A= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-035 ≥ 30 barg go to below point
    - If 25-PT-035 < 30 barg when timer is expired alert operator with T7AAH "Process Charging Sequence Vessel A not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) close the 25-XV-004 and proceed with below point
7) Check the pressure in V-25001B:
    - If 25-PT-037 ≥ 30 barg go to point 10
    - If 25-PT-037 < 30 and ≥ 2 barg go to below point
    - If 25-PT-037 < 2 barg go to point 10
8) Open 25-XV-008 installed on the inlet line of the V-25001B, Close the 25-XV-004/011/014/017/020, installed on the inlet line of the V-25001A/C/D/E/F;
    - Time to close 25-XV-004/011/014/017/020, is 3 sec., Time to open 25-XV-008 is 8 sec.:
    - The feedback statuses are 25-ZSL-004/011/014/017/020 and 25-ZSH-008.
    - When feedback statuses are active proceed with below point.
9) Start a timer T7B= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-037 ≥ 30 barg go to below point
    - If 25-PT-037 < 30 barg when timer is expired alert operator with alarm with T7BAH "Process Charging Sequence Vessel B not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) close the 25-XV-008 and proceed with below point
10) Check the pressure in V-25001C:
    - If 25-PT-040 ≥ 30 barg go to point 13
    - If 25-PT-040 < 30 and ≥ 2 barg go to below point
    - If 25-PT-040 < 2 barg go to point 13
11) Open 25-XV-011 installed on the inlet line of the V-25001C, Close the 25-XV-004/008/014/017/020, installed on the inlet line of the V-25001A/B/D/E/F;
    - Time to close 25-XV-004/008/014/017/020is 3 sec., Time to open 25-XV-011 is 8 sec.
    - The feedback statuses are 25-ZSL-004/008/014/017/020 and 25-ZSH-011
    - When feedback statuses are active proceed with below point.

12) Start a timer T7C= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-040 ≥ 30 barg go to below point
    - If 25-PT-040 < 30 barg when timer is expired alert operator with alarm with T7CAH "Process Charging Sequence Vessel C not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) close the 25-XV-011 and proceed with below point

13) Check the pressure in V-25001D:
    - If 25-PT-043 ≥ 30 barg go to point 16
    - If 25-PT-043 < 30 and ≥ 2 barg go to below point
    - If 25-PT-043 < 2 barg go to point 16

14) Open 25-XV-014 installed on the inlet line of the V-25001D, Close the 25-XV-004/008/011/017/020, installed on the inlet line of the V-25001A/B/C/E/F;
    - Time to close 25-XV-004/008/011/017/020 is 3 sec., Time to open 25-XV-014 is 8 sec.
    - The feedback statuses are 25-ZSL-004/008/011/017/020 and 25-ZSH-014.
    - When feedback statuses are active proceed with below point.

15) Start a timer T7D= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-043 ≥ 30 barg go to below point
    - If 25-PT-043 < 30 barg when timer is expired alert operator with alarm with T7DAH "Process Charging Sequence Vessel D not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) close the 25-XV-014 and proceed with below point

16) Check the pressure in V-25001E:
    - If 25-PT-046 ≥ 30 barg go to point 19
    - If 25-PT-046 < 30 and ≥ 2 barg go to below point
    - If 25-PT-046 < 2 barg go to point 19

17) Open 25-XV-017 installed on the inlet line of the V-25001E, Close the 25-XV-004/008/011/014/020 installed on the inlet line of the V-25001A/B/C/D/F;
    - Time to close 25-XV-004/008/011/014/020 is 3 sec., Time to open 25-XV-017 is 8 sec.
    - The feedback statuses are 25-ZSL-004/008/011/014/020 and 25-ZSH-017.
    - When feedback statuses are active proceed with below point.

18) Start a timer T7E= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-046 ≥ 30 barg go to below point
    - If 25-PT-046 < 30 barg when timer is expired alert operator with alarm with T7EAH "Process Charging Sequence Vessel E not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) close the 25-XV-017 and proceed with below point

19) Check the pressure in V-25001F:
    - If 25-PT-049 ≥ 30 barg go to point 23
    - If 25-PT-049 < 30 and ≥ 2 barg go to below point
    - If 25-PT-049 < 2 barg go to point 23

20) Open 25-XV-020, installed on the inlet line of the V-25001F, Close the 25-XV-004/008/011/014/017 installed on the inlet line of the V-25001A/B/C/D/E;
    - Time to close 25-XV-004/008/011/014/017 is 3 sec., Time to open 25-XV-020 is 8 sec.
    - The feedback statuses are 25-ZSL-004/008/011/014/017 and 25-ZSH-020.
    - When feedback statuses are active proceed with below point.

21) Start a timer T7F= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - If 25-PT-049 ≥ 30 barg go to below point
    - If 25-PT-049 < 30 barg when timer is expired alert operator with alarm with T7FAH "Process Charging Sequence Vessel F not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7) proceed with below point

22) Close the 25-XV-020 installed on the inlet line of the V-25001F;
    - Time to close 25-XV-020 is 3 sec.
    - The feedback status is 25 ZSL-020. When feedback status is active proceed with below point.

23) Exit

If during the "Process Charging mode" the logic is required to stop (see section 3.2 and 3.3) or some feedback statuses are not achieved, the above sequence will be interrupted, and all inlet 25-XV-004/008/011/014/017/020 valves shall be closed.

4.4.3 Process Fully Charged Status (Indication on HMI)

When all the six vessels have reached maximum operating pressure (PCS sends the "Process Fully charged Status" to EMCS) the flag indication on HMI shall indicate to operators (onshore) that the "Process Fully charged Status" is active.

At this point all six vessels are full of hydrogen at operating pressure of 30 barg ready for "Process Discharging mode".

4.4.4 Process Start-up Charging mode

The operator through a software push button on HMI will activate the "Process Start-up charging mode".

The "Process Start-up Charging mode" is a start-up mode when the hydrogen vessels contain Nitrogen after a purging mode and the vessels that previously contained Nitrogen shall be refilled with Hydrogen.

When Electrolyser starting to produce Hydrogen the operator can push the Software push button and starts the "Process Start-up Charging Mode" sequence. This push button will be active only in electrical "Research mode".

The "Process Start-up Charging mode" can be activated only if pressure in the H2 vessels is ≥ 2 barg (this to ensure there is not air inside the vessels): 25-PT-035/037/040/043/046/049≥ 2 barg (this value depends on the chosen set point of pressure control valves during purging operation sections 4.4.4 and 4.4.8).

The control valve 25-PV-035/037/040/043/046/049 are used only in case of vessel purging and in this process start-up charging mode. Therefore, a **software interlock** is provided to prevent 25-PV-035/037/040/043/046/049 being open outside of a purging cycle mode (both for Hydrogen and Air displacement) and this process start-up charging mode.

All the XV valves shall be forced in AUTO mode.

The sequence of the vessel to be filled is the following:

a. V-25001A,

b. V-25001B,

c. V-25001C,

d. V-25001D,

e. V-25001E,

f. V-25001F,

Then the logic will do the following:

0) Verify that all FV valves (25-FV-031/032/033/034/038/036) inlet H2 vessels are closed and all PV valves outlet are closed.

   Put the controllers 25-FIC-031/032/033/034/038/036 in Auto mode and force the output to 0%. Close all FV valves that are installed on the inlet lines of each H2 Storage Vessel: 25-FV-031/032/033/034/038/036

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-031/032/033/034/038/036. When all feedback statuses are active proceed with below point.

Put the controllers 25-PIC-035/037/040/043/046/049 in Auto mode and force the output to 0%. Close all PV valves that are installed on the outlet lines of each H2 Storage Vessel: 25-PV-035/037/040/043/046/049

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-035/037/040/043/046/049. When all feedback statuses are active proceed with below point.

1) Close all XV valves that are installed on the inlet lines of each H2 Storage Vessel:

   25-XV-004/008/011/014/017/020

   - Time to close the valves is 3 sec
   - The feedback statuses are 25-ZSL-004/008/011/014/017/020. When all feedback statuses are active proceed with below point.

2) Close all XV valves that are installed on the outlet lines of each H2 Storage Vessel:

   25-XV-006/009/012/015/018/021

   - Time to close the valves is 3 sec
   - The feedback statuses are 25-ZSL-006/009/012/015/018/021. When all feedback statuses are active proceed with below point.

3) Put the controllers 25-PIC-035/037/040/043/046/049 in Auto mode and force the output to 0%. Close all PV valves that are installed on the outlet lines of each H2 Storage Vessel:

   25-PV-035/037/040/043/046/049

   - Time to close the valves is 20 sec
   - The feedback statuses are 25-ZSL-035/037/040/043/046/049. When all feedback statuses are active proceed with below point.

4) If 25-PT-035 < 2 barg go to point 10, If 25-PT-035 ≥ 2 proceed with below point

5) Open the valve 25-XV-004, installed on the inlet line of the V-25001A;

   - Time to open 25-XV-004 is 8 sec.
   - The feedback status is 25-ZSH-004. When feedback status is active proceed with below point.

6) Remove the forced output 0% of the controller 25-PIC-035 and fix the set point to 2 barg;

7) Start a timer T1A= 28 hours, check during the time the pressure of the Vessel A:

   - If the pressure falls (during T1A), 25-PT-035<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-035 and close the inlet 25-XV-004 valve then proceed with below point 10.
   - If 25-PT-035≥ 1.5 barg (during all T1A) when timer is expired proceed with below point.

8) Force output to 0% for the controller 25-PIC-035

   - Time to close 25-PV-035 is 20 sec.

- The feedback statuses are 25-ZSL-035. When feedback status is active proceed with below point.

9) Start a timer T2A= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
   - if the 25-PI-035 ≥ 30 barg then close the valve 25-XV-004 (time to close 25-XV-004 is 3 sec. and the feedback status is 25-ZSL-004) and proceed with below point
   - if the 25-PI-035 < 30 barg when timer is expired, close the valve 25-XV-004 (time to close 25-XV-004 is 3 sec. and the feedback status is 25-ZSL-004) and alert operator with alarm "Process Start-up Charging Sequence Vessel A not completed" and proceed with below point
   - If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-004 (time to close 25-XV-004 is 3 sec. and the feedback status is 25-ZSL-004) and alert operator with alarm "Process Start-up Charging Sequence Vessel A not completed" and proceed with below point
10) If 25-PT-037 < 2 barg go to point 16, If 25-PT-037 ≥ 2 proceed with below point
11) Open the valve 25-XV-008, installed on the inlet line of the V-25001B;
    - Time to open 25-XV-008 is 8 sec.
    - The feedback status is 25-ZSH-008. When feedback status is active proceed with below point.
12) Remove the forced output 0% of the controller 25-PIC-037 and fix the set point to 2 barg;
13) Start a timer T1B= 28 hours, check during the time the pressure of the Vessel B:
    - If the pressure falls (during T1B), 25-PT-037<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-037 and close the inlet 25-XV-008 valve then proceed with below point 16.
    - If 25-PT-037≥ 1.5 barg (during all T1B) when timer is expired proceed with below point.
14) Force output to 0% for the controller 25-PIC-037
    - Time to close 25-PV-037 is 20 sec.
    - The feedback statuses are 25-ZSL-037. When feedback status is active proceed with below point.
15) Start a timer T2B= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - if the 25-PI-037 ≥ 30 barg then close the valve 25-XV-008 (time to close 25-XV-008 is 3 sec. and the feedback status is 25-ZSL-008) and proceed with below point
    - if the 25-PI-037 < 30 barg when timer is expired, close the valve 25-XV-008 (time to close 25-XV-008 is 3 sec. and the feedback status is 25-ZSL-008) and alert operator with alarm "Process Start-up Charging Sequence Vessel B not completed" and proceed with below point

- If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-008 (time to close 25-XV-008 is 3 sec. and the feedback status is 25-ZSL-008) and alert operator with alarm "Process Start-up Charging Sequence Vessel B not completed" and proceed with below point

16) If 25-PT-040 < 2 barg go to point 22, If 25-PT-040 ≥ 2 proceed with below point

17) Open the valve 25-XV-011, installed on the inlet line of the V-25001C;
    - Time to open 25-XV-011 is 8 sec.
    - The feedback status is 25-ZSH-011. When feedback status is active proceed with below point.

18) Remove the forced output 0% of the controller 25-PIC-040 and fix the set point to 2 barg;

19) Start a timer T1C= 28 hours, check during the time the pressure of the Vessel C:
    - If the pressure falls (during T1C), 25-PT-040<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-040 and close the inlet 25-XV-011 valve then proceed with below point 22.
    - If 25-PT-037≥ 1.5 barg (during all T1B) when timer is expired proceed with below point.

20) Force output to 0% for the controller 25-PIC-040
    - Time to close 25-PV-040 is 20 sec.
    - The feedback statuses are 25-ZSL-040. When feedback status is active proceed with below point.

21) Start a timer T2C= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - if the 25-PI-040 ≥ 30 barg then close the valve 25-XV-011 (time to close 25-XV-011 is 3 sec. and the feedback status is 25-ZSL-011) and proceed with below point
    - if the 25-PI-040 < 30 barg when timer is expired, close the valve 25-XV-011 (time to close 25-XV-011 is 3 sec. and the feedback status is 25-ZSL-011) and alert operator with alarm "Process Start-up Charging Sequence Vessel C not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-011 (time to close 25-XV-011 is 3 sec. and the feedback status is 25-ZSL-011) and alert operator with alarm "Process Start-up Charging Sequence Vessel C not completed" and proceed with below point

22) If 25-PT-043 < 2 barg go to point 28, If 25-PT-043 ≥ 2 proceed with below point

23) Open the valve 25-XV-014, installed on the inlet line of the V-25001D;
    - Time to open 25-XV-014 is 8 sec.
    - The feedback status is 25-ZSH-014. When feedback status is active proceed with below point.

24) Remove the forced output 0% of the controller 25-PIC-043 and fix the set point to 2 barg;

25) Start a timer T1D= 28 hours, check during the time the pressure of the Vessel D:

- If the pressure falls (during T1D), 25-PT-043<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-043 and close the inlet 25-XV-014 valve then proceed with below point 28.
- If 25-PT-043≥ 1.5 barg (during all T1C) when timer is expired proceed with below point.

26) Force output to 0% for the controller 25-PIC-043
    - Time to close 25-PV-043 is 20 sec.
    - The feedback statuses are 25-ZSL-043. When feedback status is active proceed with below point.
27) Start a timer T2D= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - if the 25-PI-043 ≥ 30 barg then close the valve 25-XV-014 (time to close 25-XV-014 is 3 sec. and the feedback status is 25-ZSL-014) and proceed with below point
    - if the 25-PI-043 < 30 barg when timer is expired, close the valve 25-XV-014 (time to close 25-XV-014 is 3 sec. and the feedback status is 25-ZSL-014) and alert operator with alarm "Process Start-up Charging Sequence Vessel D not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-014 (time to close 25-XV-014 is 3 sec. and the feedback status is 25-ZSL-014) and alert operator with alarm "Process Start-up Charging Sequence Vessel D not completed" and proceed with below point
28) If 25-PT-046 < 2 barg go to point 34, If 25-PT-046 ≥ 2 proceed with below point
29) Open the valve 25-XV-017, installed on the inlet line of the V-25001E;
    - Time to open 25-XV-017 is 8 sec.
    - The feedback status is 25-ZSH-017. When feedback status is active proceed with below point.
30) Remove the forced output 0% of the controller 25-PIC-046 and fix the set point to 2 barg;
31) Start a timer T1E= 28 hours, check during the time the pressure of the Vessel E:
    - If the pressure falls (during T1E), 25-PT-046<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-046 and close the inlet 25-XV-017 valve then proceed with below point 34.
    - If 25-PT-046≥ 1.5 barg (during all T1E) when timer is expired proceed with below point.
32) Force output to 0% for the controller 25-PIC-046
    - Time to close 25-PV-046 is 20 sec.
    - The feedback status is 25-ZSL-046. When feedback status is active proceed with below point.
33) Start a timer T2E= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-046 ≥ 30 barg then close the valve 25-XV-017 (time to close 25-XV-017 is 3 sec. and the feedback status is 25-ZSL-017) and proceed with below point
- if the 25-PI-046 < 30 barg when timer is expired, close the valve 25-XV-017 (time to close 25-XV-017 is 3 sec. and the feedback status is 25-ZSL-017) and alert operator with alarm "Process Start-up Charging Sequence Vessel E not completed" and proceed with below point
- If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-017 (time to close 25-XV-017 is 3 sec. and the feedback status is 25-ZSL-017) and alert operator with alarm "Process Start-up Charging Sequence Vessel E not completed" and proceed with below point

34) If 25-PT-049 < 2 barg go to point 40, If 25-PT-049 ≥ 2 proceed with below point

35) Open the valve 25-XV-020, installed on the inlet line of the V-25001F;
    - Time to open 25-XV-020 is 8 sec.
    - The feedback status is 25-ZSH-020. When feedback status is active proceed with below point.

36) Remove the forced output 0% of the controller 25-PIC-049 and fix the set point to 2 barg;

37) Start a timer T1F= 28 hours, check during the time the pressure of the Vessel F:
    - If the pressure falls (during T1F), 25-PT-049<1.5 barg, a low pressure alarm is provided, force output 0% of the controller 25-PIC-049 and close the inlet 25-XV-020 valve then proceed with below point 40.
    - If 25-PT-049≥ 1.5 barg (during all T1F) when timer is expired proceed with below point.

38) Force output to 0% for the controller 25-PIC-049
    - Time to close 25-PV-049 is 20 sec.
    - The feedback statuses are 25-ZSL-049. When feedback status is active proceed with below point.

39) Start a timer T2F= 7 hours (to pressurize up to 30 barg) and a pressure gradient calculation, check during the time the following:
    - if the 25-PI-049 ≥ 30 barg then close the valve 25-XV-020 (time to close 25-XV-020 is 3 sec. and the feedback status is 25-ZSL-020) and proceed with below point
    - if the 25-PI-049 < 30 barg when timer is expired, close the valve 25-XV-020 (time to close 25-XV-020 is 3 sec. and the feedback status is 25-ZSL-020) and alert operator with alarm "Process Start-up Charging Sequence Vessel F not completed" and proceed with below point
    - If the pressure gradient becomes negative for a time XXX (Hold 7), close the valve 25-XV-020 (time to close 25-XV-020 is 3 sec. and the feedback status is 25-ZSL-020) and alert operator with alarm "Process Start-up Charging Sequence Vessel F not completed" and proceed with below point

40) Exit

If during the "Process Start-up Charging mode" the logic is required to stop (see section 3.2 and 3.3) or some feedback statuses are not achieved the above sequence will be interrupted and:

- All inlet 25-XV-004/008/011/014/017/020 valves shall be closed
- All the controllers 25-PIC-035/037/040/043/046/049 shall be put in Auto mode and forced the output to 0%.

4.4.5 Process Discharging Mode

The "Process Discharging mode" is a normal operating mode when at least one of the hydrogen vessel contains Hydrogen to feed the Fuel Cell package.

A Software push button can activate this logic only in "Research mode" (see section 3.10) in all other electrical modes this Software Push button must be disabled so that the discharging of H2 vessels can only be done in automatic mode.

When the Fuel Cell is required by EMCS to start, the PCS automatically starts the "Discharging Mode" sequence.

All the XV valves shall be forced in AUTO mode.

The sequence of the vessel to be discharged is the following:

a. V-25001A,
b. V-25001B,
c. V-25001C,
d. V-25001D,
e. V-25001E,
f. V-25001F,

Then the logic will do the following:

0) Verify that all FV valves (25-FV-031/032/033/034/038/036) inlet H2 vessels are closed and all PV valves outlet are closed.

   Put the controllers 25-FIC-031/032/033/034/038/036 in Auto mode and force the output to 0%. Close all FV valves that are installed on the inlet lines of each H2 Storage Vessel: 25-FV-031/032/033/034/038/036

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-031/032/033/034/038/036. When all feedback statuses are active proceed with below point.

  Put the controllers 25-PIC-035/037/040/043/046/049 in Auto mode and force the output to 0%. Close all PV valves that are installed on the outlet lines of each H2 Storage Vessel: 25-PV-035/037/040/043/046/049

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-035/037/040/043/046/049. When all feedback statuses are active proceed with below point.

1) Close all XV valves that are installed on the inlet lines of each H2 Storage Vessel:

   25-XV-004/008/011/014/017/020

   - Time to close the valves is 3 sec
   - The feedback statuses are 25-ZSL-004/008/011/014/017/020. When all feedback statuses are active proceed with below point.

2) Close all XV valves that are installed on the outlet lines of each H2 Storage Vessel:

   25-XV-006/009/012/015/018/021

   - Time to close the valves is 3 sec
   - The feedback statuses are 25-ZSL-006/009/012/015/018/021. When all feedback statuses are active proceed with below point.

3) Check the pressure in V-25001A:

   - If 25-PT-035 ≥ 10 barg go to below point
   - If 25-PT-035 < 10 go to point 6

4) Open the valve 25-XV-006, installed on the outlet line of the V-25001A;

   - Time to open 25-XV-006 is 8 sec.
   - The feedback status is 25-ZSH-006.
   - When feedback status is active proceed with below point.

5) Wait until the pressure inside the vessel V-25001A is ≤ 4.5 barg (pressure indication can be taken from 25-PT-035, installed on the vessel V-25001A);

   - When 25-PT-035 ≤ 4.5 barg proceed with below point.

6) Check the pressure in V-25001B:

   - If 25-PT-037 ≥ 10 barg go to below point
   - If 25-PT-037 < 10 barg go to point 9

7) Open the valve 25-XV-009 installed on the outlet line of the V-25001B, Close the 25-XV-006/012/015/018/021 installed on the outlet line of the V-25001A/C/D/E/F;

   - Time to open 25-XV-009 is 8 sec., Time to close 25-XV-006/012/015/018/021 is 3 sec.,
   - The feedback statuses are 25-ZSH-009 and 25-ZSL-006/012/015/018/021
   - When feedback statuses are active proceed with below point.

8) Wait until the pressure inside the vessel V-25001B is ≤ 4.5 barg (pressure indication can be taken from 25-PT-037, installed on the vessel V-25001B);

   - When 25-PT-037 ≤ 4.5 barg proceed with below point.

9) Check the pressure in V-25001C:

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- If 25-PT-040 ≥ 10 barg go to below point
- If 25-PT-040 < 10 barg go to point 12

10) Open the valve 25-XV-012 installed on the outlet line of the V-25001C, Close the 25-XV-006/009/015/018/021 installed on the outlet line of the V-25001A/B/D/E/F;
    - Time to open 25-XV-012 is 8 sec., Time to close 25-XV-006/009/015/018/021 is 3 sec.,
    - The feedback statuses are 25-ZSH-012 and 25-ZSL-006/009/015/018/021
    - When feedback statuses are active proceed with below point.
11) Wait until the pressure inside the vessel V-25001C is ≤ 4.5 barg (pressure indication can be taken from 25-PT-040, installed on the vessel V-25001C);
    - When 25-PT-040 ≤ 4.5 barg proceed with below point.
12) Check the pressure in V-25001D:
    - If 25-PT-043 ≥ 10 barg go to below point
    - If 25-PT-043 < 10 barg go to point 15
13) Open the valve 25-XV-015 installed on the outlet line of the V-25001D, Close the 25-XV-006/009/012/018/021 installed on the outlet line of the V-25001A/B/C/E/F;
    - Time to open 25-XV-015 is 8 sec., Time to close 25-XV-006/009/012/018/021 is 3 sec.,
    - The feedback statuses are 25-ZSH-015 and 25-ZSL-006/009/012/018/021
    - When feedback statuses are active proceed with below point.
14) Wait until the pressure inside the vessel V-25001D is ≤ 4.5 barg (pressure indication can be taken from 25-PT-043, installed on the vessel V-25001D);
    - When 25-PT-043 ≤ 4.5 barg proceed with below point.
15) Check the pressure in V-25001E:
    - If 25-PT-046 ≥ 10 barg go to below point
    - If 25-PT-046 < 10 barg go to point 18
16) Open the valve 25-XV-018 installed on the outlet line of the V-25001E, Close the 25-XV-006/009/012/015/021 installed on the outlet line of the V-25001A/B/C/D/F;
    - Time to open 25-XV-018 is 8 sec., Time to close 25-XV-006/009/012/015/021 is 3 sec.,
    - The feedback statuses are 25-ZSH-018 and 25-ZSL-006/009/012/015/021
    - When feedback statuses are active proceed with below point.
17) Wait until the pressure inside the vessel V-25001E is ≤ 4.5 barg (pressure indication can be taken from 25-PT-046, installed on the vessel V-25001E);
    - When 25-PT-046 ≤ 4.5 barg proceed with below point.
18) Check the pressure in V-25001F:

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- If 25-PT-049 ≥ 10 barg go to below point
- If 25-PT-049 < 10 barg go to point 22

19) Open the valve 25-XV-021 installed on the outlet line of the V-25001F, Close the 25-XV-006/009/012/015/018 installed on the outlet line of the V-25001A/B/C/D/E;
    - Time to open 25-XV-021 is 8 sec., Time to close 25-XV-006/009/012/015/018 is 3 sec.,
    - The feedback statuses are 25-ZSH-021 and 25-ZSL-006/009/012/015/018
    - When feedback statuses are active proceed with below point.
20) Wait until the pressure inside the vessel V-25001F is ≤ 4.5 barg (pressure indication can be taken from 25-PT-049, installed on the vessel V-25001F);
    - When 25-PT-049 ≤ 4.5 barg proceed with below point.
21) Close the 25-XV-021, installed on the outlet line of the V-25001F;
    - Time to close 25-XV-021 is 3 sec.
    - The feedback status is 25-ZSL-021.
    - When feedback status is active proceed with below point.
22) Go in "Process Empty Status".

If during the "Discharging mode" the logic is required to stop (see section 3.5 and 3.7) or some feedback statuses are not achieved, the above sequence will be interrupted, and all outlet 25-XV-006/009/012/015/018/021 valves shall be closed.

4.4.6 Process Empty Status (Indication on HMI)

When all the six vessels have reached minimum operating pressure (PCS sends the "Process Empty Status" to EMCS) the flag indication on HMI shall indicate to operators (onshore) that the "Process Empty Status" is active.

At this point all six vessels are empty of hydrogen at operating pressure of ≤ 4.5 barg ready for "Process Charging mode".

4.4.7 Purging Mode after Shutdown (for H2 displacement)

The operator through a software push button on HMI will activate the "Purging mode after Shutdown (for H2 displacement)". This push button will be active only in electrical "Research mode".

Moreover, each vessel V-25001A to F is equipped with nitrogen inlet and outlet dedicated nozzles for purging.

This process helps maintain the integrity and functionality of the Hydrogen vessels, ensuring optimal performance and safety during operation by feeding nitrogen under flow control (25-FIC-031/032/033/034/038/036 and the relevant flow control valves) that in turn is in cascade pressure control by

means of dedicated pressure transmitters (and controllers 25-PIC-035/037/040/043/046/049) connected to each vessel respectively. Thus, during the purging activity, should the pressure increase above the established set-point then the FIC set point will be reduced by the correspondent PIC consequently and vice-versa. The pressure control valves 25-PV-035/037/040/043/046/049 will allow for nitrogen pressurization and for sweep-through purging.

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:

1) Flow rate controller: 25-FIC-031;
2) Flow rate transmitter: 25-FT-031 (Process Variable, PV);
3) final element: 25-FV-031;
4) SP value: ~42 Nm^3/hr;
5) Sub-Controller(s) action: REVERSE (flow rate increase, valve close);
6) Failure direction: FC

Should be the operating flow rate (PV) fall under the PID regulator SP, the controller drives the control valve to increase its opening (Cv); vice versa, should the operating flow rate (PV) rise above the PID regulator SP, the controller drives the control valve to decrease its opening (Cv).

The above-described control loop is relevant to H2 Storage Vessel V-25001A. The same applies to the others five H2 Storage Vessel V-25001B/C/D/E/F.

On the vent line of each H2 Storage Vessel 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:

1) Pressure controller: 25-PIC-035;
2) Pressure transmitter: 25-PT-035 (Process Variable, PV);
3) final element: 25-PV-035;
4) SP value: ~2 barg;
5) Sub-Controller(s) action: DIRECT (pressure increase, valve open);
6) Failure direction: FC.

Should the operating pressure (PV) fall under the PID regulator SP, the controller drives the control valve to decrease opening (Cv); vice versa, should the operating pressure (PV) rise above the PID regulator SP, the controller drives the control valve to increase its opening (Cv).

The control valve 25-PV-035 is used only in case of vessel purging and process start-up charging mode. Therefore, a **software interlock** is provided to prevent 25-PV-035/037/040/043/046/049 being opened outside of a purging cycle operation and process start-up charging mode.

A **software interlock** prevents the opening of the control valve 25-FV-031/032/033/034/038/036 outside of a purging cycle operation (both for Hydrogen and Air).

Nitrogen control valves 25-FV-031/032/033/034/038/036 cannot open until pressure within the H2 Vessels (25-PT-035/037/040/043/046/049) is below the Nitrogen supply pressure (64-PT-031A/B).

At the beginning of the purging operation a timer alarm, in the control logic, will be implemented to determine if 25-PIC-035 failure opening the valve 25-PV-035. It is expected that, according to flow rate of N2 entering the vessel under purging operation, it will reach the desired pressure at which purging shall be performed within almost 5 hours. Therefore, after 5 hours, the 25-PT-035 should indicate a pressure less than the above indicate value of 2 barg, a time alarm will alert the operator that the vessel has not reach the pressure within the desired time. Once the pressure has been reached, then the time alarm shall be automatically deactivated.

Moreover, once the desired pressure of 2 barg has been reached, should the pressure inside the vessel under purging operation fall below the set point of 2 barg, a low pressure alarm on the pressure transmitter 25-PT-035 is provided, to alert the operator. This low pressure alarm will be deactivated at beginning of the purging operation (during the pressurization phase), when the desired pressure is not yet reached. Once 2 barg has been reached, then the alarm will be activated. This is to prevent the low pressure alarm is triggered unnecessarily.

The above-described control loop is relevant to H2 Storage Vessel V-25001A under purging operation. The same applies to the other five H2 Storage Vessel V-25001B/C/D/E/F.

The flag indication on HMI shall indicate to operators (onshore) that the "Purging mode after Shutdown (for H2)" is active.

All the XV valves shall be forced in AUTO mode.

The sequence of the vessels to be purged is the following:

a. V-25001A,

b. V-25001B,

c. V-25001C,

d. V-25001D,

e. V-25001E,

f. V-25001F,

Then the logic will do the following:

1) Close all XV valves that are installed on the inlet lines of each H2 Storage Vessel:

   25-XV-004/008/011/014/017/020

- Time to close the valves is 3 sec
- The feedback statuses are 25-ZSL-004/008/011/014/017/020. When all feedback statuses are active proceed with below point.

2) Close all XV valves that are installed on the outlet lines of each H2 Storage Vessel:

25-XV-006/009/012/015/018/021

- Time to close the valves is 3 sec
- The feedback statuses are 25-ZSL-006/009/012/015/018/021. When all feedback statuses are active proceed with below point.

3) Put the controllers 25-FIC-031/032/033/034/038/036 in Auto mode and force the output to 0%. Close all FV valves that are installed on the inlet lines of each H2 Storage Vessel: 25-FV-031/032/033/034/038/036

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-031/032/033/034/038/036. When all feedback statuses are active proceed with below point.

4) Put the controllers 25-PIC-035/037/040/043/046/049 in Auto mode and force the output to 0%. Close all PV valves that are installed on the outlet lines of each H2 Storage Vessel: 25-PV-035/037/040/043/046/049

- Time to close the valves is 20 sec
- The feedback statuses are 25-ZSL-035/037/040/043/046/049. When all feedback statuses are active proceed with below point.

5) Open the valve 64-SDV-001, installed on the nitrogen line 1"-N-128-03HSS-N to Hydrogen Vessel. The 64-SDV-001 valve is normally closed and through a software push button is permitted to open/closed the 64-SDV-001 valve remotely on HMI (onshore). A software interlock permits to open remotely the valve only during purging modes. (for H2 and air displacement).

- Time to open the valve is 8 sec
- The feedback status is 64-ZSH-001. When the feedback status is active proceed with below point.

6) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-035 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-035 go to point 13

7) Remove the forced output 0% of the controller 25-FIC-031 (installed on Nitrogen inlet line to V-25001A) and fix the set point to 42 Nm^3/hr;

8) Start a timer T3A= 5 hours and a Flow Totalizer 25-FQ-031 (by 25-FT-031) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-035≥ 2 barg proceed with below point.
- if the 25-PI-035< 2 barg when timer is expired an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controller 25-FIC-031, stop and reset the Flow Totalizer 25-FQ-031and proceed with below point 13.
- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controller 25-FIC-031, stop and reset the Flow Totalizer 25-FQ-031and proceed with below point 13.

9) Remove the forced output 0% of the controller 25-PIC-035 and fix the set point to 2 barg;

10) Start a timer T4A= 92 hours, check during the time the pressure of the Vessel A:

- If the pressure falls (during T4A), 25-PT-035<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-031 and 25-PIC-035, stop and reset the Flow Totalizer 25-FQ-031 and proceed with below point 13.
- If 25-PT-035≥ 1.5 barg (during all T4A) when timer is expired proceed with below.

11) Force output to 0% for both the controllers 25-FIC-031 and 25-PIC-035 and stop the Flow Totalizer 25-FQ-031.

12) Time to close 25-PV-035 and 25-FV-031 are 20 sec.

- The feedback statuses are 25-ZSL-035 and 25-ZSL-031. When feedback status are active proceed with below point.

13) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-037 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-037 go to point 20

14) Remove the forced output 0% of the controller 25-FIC-032 (installed on Nitrogen inlet line to V-25001B) and fix the set point to 42 Nm^3/hr;

15) Start a timer T3B= 5 hours and a Flow Totalizer 25-FQ-032 (by 25-FT-032) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-037≥ 2 barg proceed with below point
- if the 25-PI-037< 2 barg when timer is expired an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controllers 25-FIC-032, stop and reset the Flow Totalizer 25-FQ-032 and proceed with below point 20.
- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controllers 25-FIC-032, stop and reset the Flow Totalizer 25-FQ-032 and proceed with below point 20.

16) Remove the forced output 0% of the controller 25-PIC-037 and fix the set point to 2 barg;

17) Start a timer T4B= 92 hours, check during the time the pressure of the Vessel B:

- If the pressure falls (during T4B), 25-PT-037<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-032 and 25-PIC-037, stop and reset the Flow Totalizer 25-FQ-032 and proceed with below point 20.
- If 25-PT-037≥ 1.5 barg (during all T4B) when timer is expired proceed with below.

18) Force output to 0% for both the controllers 25-FIC-032 and 25-PIC-037 and stop the Flow Totalizer 25-FQ-032.

19) Time to close 25-PV-037 and 25-FV-032 are 20 sec.

- The feedback statuses are 25-ZSL-032 and 25-ZSL-037. When feedback statuses are active proceed with below point.

20) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-040 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-040 go to point 27

21) Remove the forced output 0% of the controller 25-FIC-033 (installed on Nitrogen inlet line to V-25001C) and fix the set point to 42 Nm^3/hr;

22) Start a timer T3C= 5 hours and a Flow Totalizer 25-FQ-033 (by 25-FT-033) and a pressure gradient calculation, check during the time the following:

- If the 25-PI-040≥ 2 barg proceed with below point
- If the 25-PI-040< 2 barg when timer is expired an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controllers 25-FIC-033, stop and reset the Flow Totalizer 25-FQ-033 and proceed with below point 27.
- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controllers 25-FIC-033, stop and reset the Flow Totalizer 25-FQ-033 and proceed with below point 27.

23) Remove the forced output 0% of the controller 25-PIC-040 and fix the set point to 2 barg;

24) Start a timer T4C= 92 hours, check during the time the pressure of the Vessel C:

- If the pressure falls (during T4C), 25-PT-040<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-033 and 25-PIC-040, stop and reset the Flow Totalizer 25-FQ-033 and proceed with below point 27.

- If 25-PT-040≥ 1.5 barg (during all T4C) when timer is expired proceed with below.

25) Force output to 0% for both the controllers 25-FIC-033 and 25-PIC-040 and stop the Flow Totalizer 25-FQ-033.

26) Time to close 25-PV-040 and 25-FV-033 are 20 sec.

- The feedback statuses are 25-ZSL-033 and 25-ZSL-040. When feedback statuses are active proceed with below point.

27) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-043 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-043 go to point 34

28) Remove the forced output 0% of the controller 25-FIC-034 (installed on Nitrogen inlet line to V-25001D) and fix the set point to 42 Nm^3/hr;

29) Start a timer T3D= 5 hours and a Flow Totalizer 25-FQ-034 (by 25-FT-034) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-043≥ 2 barg proceed with below point
- if the 25-PI-043< 2 barg when timer is expired then an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controllers 25-FIC-034, stop and reset the Flow Totalizer 25-FQ-034 and proceed with below point 34.

- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controllers 25-FIC-034, stop and reset the Flow Totalizer 25-FQ-034 and proceed with below point 34.

30) Remove the forced output 0% of the controller 25-PIC-043 and fix the set point to 2 barg;

31) Start a timer T4D= 92 hours, check during the time the pressure of the Vessel D:

- If the pressure falls (during T4D), 25-PT-043<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-034 and 25-PIC-043, stop and reset the Flow Totalizer 25-FQ-033 and proceed with below point 34.
- If 25-PT-043≥ 1.5 barg (during all T4D) when timer is expired proceed with below.

32) Force output to 0% for both the controllers 25-FIC-034 and 25-PIC-043 and stop the Flow Totalizer 25-FQ-034.

33) Time to close 25-PV-043 and 25-FV-034 are 20 sec.

- The feedback statuses are 25-ZSL-034 and 25-ZSL-043. When feedback statuses are active proceed with below point.

34) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-046 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-046 go to point 41

35) Remove the forced output 0% of the controller 25-FIC-038 (installed on Nitrogen inlet line to V-25001E) and fix the set point to 42 Nm^3/hr;

36) Start a timer T3E= 5 hours and a Flow Totalizer 25-FQ-038 (by 25-FT-038) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-046≥ 2 barg proceed with below point
- if the 25-PI-046< 2 barg when timer is expired then an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controllers 25-FIC-038, stop and reset the Flow Totalizer 25-FQ-038 and proceed with below point 41.
- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controllers 25-FIC-038, stop and reset the Flow Totalizer 25-FQ-038 and proceed with below point 41.

37) Remove the forced output 0% of the controller 25-PIC-046 and fix the set point to 2 barg;

38) Start a timer T4E= 92 hours, check during the time the pressure of the Vessel E:

- If the pressure falls (during T4E), 25-PT-046<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-038 and 25-PIC-046, stop and reset the Flow Totalizer 25-FQ-038 and proceed with below point 41.
- If 25-PT-046≥ 1.5 barg (during all T4E) when timer is expired proceed with below.

39) Force output to 0% for both the controllers 25-FIC-038 and 25-PIC-046 and stop the Flow Totalizer 25-FQ-038.

40) Time to close 25-PV-046 and 25-FV-038 are 20 sec.

- The feedback statuses are 25-ZSL-038 and 25-ZSL-046. When feedback statuses are active proceed with below point.

41) If 64-PT-031A/B (depends on the control valve 64-PV-031A/B that is working) > 25-PT-049 proceed with below point, if 64-PT-031A/B (depends on the control valve that is working) ≤ 25-PT-049 go to point 49

42) Remove the forced output 0% of the controller 25-FIC-036 (installed on Nitrogen inlet line to V-25001F) and fix the set point to 42 Nm^3/hr;

43) Start a timer T3F= 5 hours and a Flow Totalizer 25-FQ-036 (by 25-FT-036) and a pressure gradient calculation, check during the time the following:

- if the 25-PI-049≥ 2 barg proceed with below point
- if the 25-PI-049< 2 barg when timer is expired then an alarm will alert the operator that the vessel has not reach the pressure within the desired time, force output 0% of the controllers 25-FIC-036, stop and reset the Flow Totalizer 25-FQ-036 and proceed with below point 49.
- If the pressure gradient becomes negative for a time XXX (Hold 7), force output 0% of the controllers 25-FIC-036, stop and reset the Flow Totalizer 25-FQ-036 and proceed with below point 49.

44) Remove the forced output 0% of the controller 25-PIC-049 and fix the set point to 2 barg;

45) Start a timer T4F= 92 hours, check during the time the pressure of the Vessel F:

- If the pressure falls (during T4F), 25-PT-049<1.5 barg, a low pressure alarm is provided, force output 0% of the controllers 25-FIC-036 and 25-PIC-049, stop and reset the Flow Totalizer 25-FQ-036 and proceed with below point 49.
- If 25-PT-049≥ 1.5 barg (during all T4F) when timer is expired proceed with below.

46) Force output to 0% for both the controllers 25-FIC-036 and 25-PIC-049 and stop the Flow Totalizer 25-FQ-036.

47) Time to close 25-PV-049 and 25-FV-036 are 20 sec.

- The feedback statuses are 25-ZSL-036 and 25-ZSL-049.

48) Close the valve 64-SDV-001, installed on the nitrogen line 1"-N-128-03HSS-N to Hydrogen Vessel.

The feedback status is 64-ZSL-001. When the feedback status is active proceed with the below point.

49) Exit.

If during this purging mode the logic is required to stop or some feedback statuses are not achieved, the above sequence will be interrupted, and all control valves (25-FV-031/032/033/034/038/036 and 25-PV-035/037/040/043/046/049) and 64-SDV-001 valve shall be closed.

An alarm to SDV 'not closed' rahter than alarming on 'open' shall be considered.

As soon as the flow totalizers are stopped (25-FQ-031/032/033/034/038/036) the PCS will compare the value with the expected value QH=4074 Nm3 (Total flow expected for purging after shut-down) and:

- If FQH > 25-FQ-031 (or 032/033/034/038/036) an alarm will be generated to alert the operator that there was insufficient flow during purge

If a flow control valve is "NOT Closed" (missing limit switch 25-ZSL-031/032/033/034/038/036) outside of the purging modes (purging after shutdown "H2 displacement") an alarm of flow control valve not closed will be generated.

4.4.8 Purging Mode after Maintenance (for Air displacement)

The operator through a software push button on HMI will activate the "Purging mode after Maintenance (for Air)". This push button will be active only in electrical "Research mode" (see section 3.10).

The same control logic "Purging mode after Shutdown (for H2 displacement)" above described (see section 4.4.7) 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 with nitrogen is to create an inert atmosphere inside the vessel before starting the hydrogen loading phase.

The sequence of the vessel to be purged is the following:

a. V-25001A,

b. V-25001B,

c. V-25001C,

d. V-25001D,

e. V-25001E,

f. V-25001F,

In this sequence "Purging mode after Maintenance (for Air displacement)" the times and relevant time alarms are different from the "Purging mode after Shutdown (for H2 displacement)" see section 4.7.7, exactly will be the following:

- T5A= 5 hours and T5AAH for V-25001A,
- T6A= 51 hours and T6AAH for V-25001A,
- T5B= 5 hours and T5BAH for V-25001B,
- T6B= 51 hours and T6BAH for V-25001B,
- T5C= 5 hours and T5CAH for V-25001C,
- T6C= 51 hours and T6CAH for V-25001C,
- T5D= 5 hours and T5DAH for V-25001D,
- T6D= 51 hours and T6DAH for V-25001D,
- T5E= 5 hours and T5EAH for V-25001E,
- T6E= 51 hours and T6EAH for V-25001E,
- T5F= 5 hours and T5FAH for V-25001F,

- T6F= 51 hours and T6FAH for V-25001F,

The flag indication on HMI shall indicate to operators (onshore) that the "Purging Mode after Maintenance (for air)" is active.

As soon as the flow totalizers are stopped (25-FQ-031/032/033/034/038/036) the PCS will compare the value with the expected value QA=2352 Nm3 (total flow expected for purging after maintenance) and:

- If FQA > 25-FQ-031 (or 032/033/034/038/036) an alarm will be generated to alert the operator that there was insufficient flow during purge

If a flow control valve is "NOT Closed" (missing limit switch 25-ZSL-031/032/033/034/038/036) outside of the purging mode (purging after maintenance "air displacement") an alarm of flow control valve not closed will be generated.

An alarm to SDV 'not closed' rahter than alarming on 'open' shall be considered.

4.4.9 Hydrogen Storage Vessels (V-25001A TO F) Safety Philosophy

All the Hydrogen Storage Vessels safety signals (status and commands) are wired to SIS safety system.

The mechanical design pressure of the storage vessels is safeguarded by dedicated spring-loaded pressure control valve(s) (25-PSV-001A to F) whose set pressure is fixed at 40 barg. Moreover, each vessel is connected to the hydrogen vent system to allow depressurization during emergencies (25-BDV-005/007/010/013/016/019) and, as said above, prior to planned maintenance. The inlet and outlet hydrogen streams across the hydrogen storage vessels are sectioned thanks to the shutdown valves (25-SDV-001 and 25-SDV-023) and the 25-BDV-022 allows for depressurization of the outlet manifold as well.

Moreover, an additional level of safeguard is provided by the High High pressure alarms (25-PAHH-004/006/008/009/011/012); in the event of any abnormal increase in pressure beyond safe operating limits, the transmitter immediately communicates this information to SIS system that activates the ESD-1D,

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

4.4.10 Control Loop 25-PV-055A/B inlet to Fuel Cell package (Hold 4)

The Fuel Cell pressure control valves control the hydrogen supply to the Fuel Cell by means of the control loop identified with:

- pressure control valves 25-PV-055A/B working in split range.
- pressure controllers 25-PIC-055A/B;
- relevant pressure transmitters 25-PT-055A/B with high and low pressure alarms thresholds (25-PAH-055A/B and 25-PAL-055A/B);

During Fuel Cell operation, only one valve (25-PV-055 A or B) will be used, while the other one will be fully closed (when Fuel Cell demands for more Hydrogen, there is a transitional period when both valves need to be open).
The Fuel Cell pressure control valve(s) control(s) the hydrogen supply to the Fuel Cell by means of the control loop above identified:

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

Should the operating pressure (PV) fall under the PID regulator SP, the controller drives the relevant control valve to increase its opening (Cv); vice versa, should the operating pressure (PV) rise above the PID regulator SP, the controller drives the relevant control valve to decrease its opening (Cv).

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.
In order to provide a fine pressure control, a Software Interlock prevents valve 25-PV-055B (A) to open if control valve 25-PV-055A (B) is working within the required valve opening range. This is to allow both valves operating within the optimum valve opening range, as designed.
Therefore, the two control valves in split range are used as follow:

- 25-PV-055B will operate when lower operating CV is required (Cv< 0.31 that corresponds to 90% of 25-PV-055B valve open)
- 25-PV-055A will operate when higher operating CV is required (Cv≥ 0.31 that corresponds to 11% of 25-PV-055A valve open).

Software Interlock prevents opening of the control valves 25-PV-055A/B in case Fuel Cell package (A-80000) is not running.
If Fuel Cell package is not running the control valves 25-PV-055A/B are required to close.
The controller(s) action is reverse type (pressure increase, control valve close).

The logic to permit the Fuel Cell package Start-up and Ramp-up shall consider the control valve Cv calculation and the association between the calculated Cv and the % of valve open (in tabular form).

The DP that will be considered in the Cv calculation is the difference between the Pressure of H2 vessel that is discharging and the 25-PT-055A (or B) depending on which control valve is working. Exactly:

a) If Vessel V-25001A is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-006 (25-ZSH-006 active):

   DP=25-PT-035 – 25-PT-055A (or B)

b) If Vessel V-25001B is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-009 (25-ZSH-009 active):

   DP=25-PT-037 – 25-PT-055A (or B)

c) If Vessel V-25001C is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-012 (25-ZSH-012 active):

   DP=25-PT-040 – 25-PT-055A (or B)

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d) If Vessel V-25001D is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-015 (25-ZSH-015 active):

DP=25-PT-043 – 25-PT-055A (or B)

e) If Vessel V-25001E is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-018 (25-ZSH-018 active):

DP=25-PT-046 – 25-PT-055A (or B)

f) If Vessel V-25001F is discharging (see section 4.4.5), check the open position of the outlet valve 25-XV-021 (25-ZSH-021 active):

DP=25-PT-049 – 25-PT-055A (or B)

The Control valve Cv calculation will use the following formulas:

1) If DP < 0.4 x Pupstream (Critical)

Cv = (0.0545*Q)/(0.9* Pupstream *(Pdownstream* 288/ (T+273)^0.5)

Pupstream = 25-PT-035/037/040/043/046/049 [bara] (depending on which Vessel is discharging)

Pdownstream = 25-PT-055A (or B) [bara] (depending on which control valve is working)

Q = Flowrate [kg/h]

Tinlet= Temperature [°C]

2) If DP ≥ 0.4 x Pupstream (Not Critical)

Cv = (0.0472*Q)/(DP*(Pupstream+Pdownstream)*M/29* 288/ (T+273)^0.5

Pupstream = 25-PT-035/037/040/043/046/049 [bara] (depending on which Vessel is discharging)

Pdownstream = 25-PT-055A (or B) [bara] (depending on which control valve is working)

Q = Flowrate [kg/h]

Tinlet= Temperature [°C] (set 15 °C)

M= Molecular Weight [g/mol] (for Hydrogen M=2 [kg/kmol])

When the Cv has been calculated there is the need for relative flow coefficient- Φ (%).

The selected Cv are Cv=13 for 25-PV-055A and Cv=0.45 for 25-PV-055B:

a) If 25-PV-055A is working:

Φ = Cv/13*100

b) If 25-PV-055B is working:

Φ = Cv/0.45*100

With the "Φ" value It is possible to obtain the % of valve open (relative travel h) using control valve flow characteristic (see Attachment 1 for 25-PV-055A and Attachment 2 for 25-PV-055B).

In the following table 5 are shown the flowrates and times required for the start-up and Ramp-up of the Fuel Cell package:

Scenario	Fuel Cell Modules	Description	Hydrogen Usage Initial [g/s]	Hydrogen Flowrate After [g/s]	Duration of change [s]
Startup	1	A single fuel cell module start up	0	0.9	3
Startup	3	Half (3) of the fuel cell module start up	0	2.7	3
Startup	6	All (6) of the fuel cell module start up	0	5.4	3
Ramp-up	1	Single module ramps from idle to full power	0.9	3.6	18
Ramp-up	3	Half (3) module ramps from idle to full power	2.7	10.8	18
Ramp-up	6	All (6) module ramps from idle to full power	5.4	21.6	18

Table 5 – Fuel Cell Start-up and Ramp-up Requirements

The logic will do the following:

1) Status of "Command to start Fuel Cell" by EMCS (see section 3.7)
2) PCS waits for Fuel Cell feedback status "Number of Fuel Cell Modules Producing power" from EMCS. The Number of Fuel Cell Modules Producing power can be:
   - A single (1) Fuel Cell Module start-up
   - Half (3) of the Fuel Cell module start-up
   - All (6) of the Fuel Cell module start-up
3) Force the controllers 25-PIC-055A/B in AUTO mode.
4) If the Number of Fuel Cell Modules Producing power is "A single (1) Fuel Cell Module start-up" as per above table 5 the required flowrate is 0.9 g/s in 3 sec. If no go to point 5.

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- Initially the set point for 25-PV-055B shall be 18% (obtained with max DP= 24 (30-6 [bar]) and flowrate= 0.9 g/s).
- Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed).
- When the Cv is calculated (from Attachment 1 or Attachment 2) obtain the Φ and the relative travel-H (%) that is the output for control valve 25-PV-055B (or A).
- Continue for 3 sec.
- After this time (3 sec.) the Ramp-up phase "Single module ramps from idle to full power" starts
- As per above table 5 the required flowrate increases from 0.9 g/s to 3.6 g/s in 18 sec.
- Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed for 18 sec.).
- When the Cv has been calculated (from Attachment 1 or Attachment 2) obtain the Φ and the relative travel-H (%) that is the output for control valve 25-PV-055B (or A).
- Continue for 18 sec.
- After this time (18 sec.) the Ramp-up phase "Single module ramps from idle to full power" is stopped and the logic will continue to control with set point of 6 barg of the control valve that is working.
- During the Start-up (3 sec.) and Ramp-up (18 sec.) phases the downstream pressure 25-PT-055A (or B) has to stay inside the range 4÷6.5 barg:
  - If the downstream pressure 25-PT-055A (or B) decreases below 4.5 barg or increases above 6.5 barg (in these 21 sec.) the control shall pass to the pressure control with a set point of 5 barg of the control valve that is working.

5) If the Number of Fuel Cell Modules Producing power is "Half (3) of the Fuel Cell Module start-up" as per above table 5 the required flowrate is 2.7 g/s in 3 sec. If no go to point 6.
   - Initially the set point for 25-PV-055B shall be 51% (obtained with max DP=24 (30-6 [bar]) and flowrate= 2.7 g/s).
   - Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed).
   - When the Cv has been calculated (from Attachment 1 or Attachment 2) obtain Φ and the relative travel-H (%) that is the output for control valve 25-PV-055B (or A).
   - Continue for 3 sec.
   - After this time (3 sec.) the Ramp-up phase "Half (3) module ramps from idle to full power" starts
   - As per above table 5 the required flowrate increases from 2.7 g/s to 10.8 g/s in 18 sec.
   - Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed for 18 sec.).
   - When the Cv is calculated (from Attachment 1 or Attachment 2) obtain the relative travel-H (%) that is the output of control valve 25-PV-055B (or A).
   - Continue for 18 sec.
   - After this time (18 sec.) the Ramp-up phase "Half (3) module ramps from idle to full power" is stopped and the logic will continue to control with set point of 6 barg of the control valve that is working.

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- During the Start-up (3 sec.) and Ramp-up (18 sec.) phases the downstream pressure 25-PT-055A (or B) has to stay inside the range 4÷6.5 barg:
  - If the downstream pressure 25-PT-055A (or B) decreases below 4.5 barg or increases above 6.5 barg (in these 21 sec.) the control shall pass to the pressure control with a set point of 5 barg for the control valve that is working.

6) If the Number of Fuel Cell Modules Producing power is "All (6) of the Fuel Cell module start-up" as per above table 5 the required flowrate is 5.4 g/s in 3 sec.
   - Initially the set point for 25-PV-055B shall be 69% (obtained with max DP=24 (30-6 [bar]) and flowrate= 5.4 g/s).
   - Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed).
   - When the Cv is calculated (from Attachment 1 or Attachment 2) obtain Φ and the relative travel-H (%) that is the output for control valve 25-PV-055B (or A).
   - Continue for 3 sec.
   - After this time (3 sec.) the Ramp-up phase "All (6) of the Fuel Cell module start-up" starts
   - As per above table 5 the required flowrate increases from 5.4 g/s to 21.6 g/s in 18 sec.
   - Calculate the Cv considering the above Cv formulas and the Pressure upstream and downstream real value (the Pressure control shall be By-passed for 18 sec.).
   - When the Cv is calculated (from Attachment 1 or Attachment 2) obtain the relative travel-H (%) that is the output of control valve 25-PV-055B (or A).
   - Continue for 18 sec.
   - After this time (18 sec.) the Ramp-up phase "All (6) of the Fuel Cell module start-up" is stopped and the logic will continue to control with set point of 6 barg of the control valve that is working.
   - During the Start-up (3 sec.) and Ramp-up (18 sec.) phases the downstream pressure 25-PT-055A (or B) has to stay inside the range 4÷6.5 barg:
     - If the downstream pressure 25-PT-055A (or B) decreases below 4.5 barg or increases above 6.5 barg (in these 21 sec.) the control shall pass to the pressure control with a set point of 5 barg of the control valve that is working.

During the above points 4, 5 and 6 the logic has to check the following:
- 25-PV-055B will operate when lower operating CV is required (Cv<0.31 that corresponds to 90% of 25-PV-055B valve open)
- 25-PV-055A will operate when higher operating CV is required (Cv≥0.31 that corresponds to 11% of 25-PV-055A valve open)
- If 25-ZI-055B ≤ 90% continue to use the valve 25-PV-055B and force the output of 25-PIC-055A to 0%.
- If 25-ZI-055B > 90% force the output for 25-PIC-055B to 0% and remove the forced output 0% of the controller 25-PIC-055A.
- If 25-ZI-055A ≥11% continue to use the valve 25-PV-055A and force the output of 25-PIC-055B to 0%. If 25-ZI-055A < 11% force the output for 25-PIC-055A to 0% and remove the forced output 0% of the controller 25-PIC-055B.

As Fuel Cell stops ("Fuel Cell NOT running" status) the control logic will force the operating control valve 25-PV-055A and 25-PV-055B to fully close with the following logic (see below table 6):

Stopdown	1	A single fuel cell module performs a controlled stop	4.9 (worst) 3.9 (expected)	0	15
Stopdown	3	Half (3) fuel cell module performs a controlled stop	14.9 (worst) 10.8 (expected)	0	15
Stopdown	6	All (6) fuel cell module performs a controlled stop	29.4 (worst) 23.4 (expected)	0	15

Table 6 – Fuel Cell Stop Requirements

1) If the Number of Fuel Cell Modules Producing power is "A single (1) Fuel Cell Module performs a controlled stop" as per above table 6 the required flowrate decreases from 4.9 g/s to 0 g/s in 15 sec. If no go to below point 2.
   - Close the control valve that is working in 15 sec.
   - Exit
2) If the Number of Fuel Cell Modules Producing power is "Half (3) fuel cell module ramps perform a controlled stop" as per above table 6 the required flowrate decreases from 14.9 g/s to 0 g/s in 15 sec. If no go to point 3.
   - Close the control valve that is working in 15 sec.
   - Exit
3) If the Number of Fuel Cell Modules Producing power is "All (6) of the Fuel Cell module perform a controlled stop" as per above table 6 the required flowrate decreases from 29.4 g/s to 0 g/s in 15 sec. If no go to point 3.
   - Close the control valve that is working in 15 sec.
   - Exit

At the time there is not enough pressure inside all six H2 Storage Vessels ("Empty Status") both control valves 25-PV-055A/B will receive the signal to close.

In case of Fuel Cell package shutdown (80-XS-001) the following logic (see below table 7) shall be follown:

ESD	1	A single fuel cell module performs an emergency stop	4.9 (worst) 3.6 (expected)	0	0.02 (20 ms)
ESD	6	All fuel cell modules perform an emergency stop	29.4 (worst) 23.4 (expected)	0	0.02 (20 ms)

Table 7 – Fuel Cell Shutdown Requirements

1) If the Number of Fuel Cell Modules Producing power is "A single (1) Fuel Cell Module performs an emergency shutdown" as per above table 7 the required flowrate decreases from 4.9 g/s to 0 g/s in 0.02 sec. (Hold 5). If no go to point 2.
   - Close the control valve that is working in 0.02 sec. (Hold 5)

- Exit

2) If the Number of Fuel Cell Modules Producing power is "All Fuel Cell Module perform an emergency shutdown" as per above table 7 the required flowrate decreases from 29.4 g/s to 0 g/s in 0.02 sec. (Hold 5).
   - Close the control valve that is working in 0.02 sec. (Hold 5)
   - Exit

4.5 FUEL CELL PACKAGE A-80000

(Reference P&ID: Doc. N.123A90-DDL-PR-PID-80012)

4.5.1 General

This package is a standalone fully prefabricated and assembled unit containing all major components required for the consumption of hydrogen. The operating conditions and configuration are vendor specific.

4.5.2 Fuel Cell Package Control Philosophy

All the package control signals (status and commands) will be exchanged with BLPH control system (PCS and EMCS) through a modbus TCP/IP communication.

The 80-XV-001, installed on inlet manifold, allows for nitrogen purging prior to maintenance campaign

The local control panel will be provided with a Local/Remote selector (CPY has to confirm the following philosophy for the Local/Remote operating modes (Hold 2):

4.5.3 Remote mode

When the Local/Remote selector is in "Remote position":

- Logics inside LCP control and manage the Fuel Cell package.
- The operators onshore can remotely:
  - Start/Stop Fuel Cell package.

4.5.4 Local mode

When the Local/Remote selector is in "Local position":

- Logics inside LCP control and manage the Electrolyser package.
- The operators offshore can locally:
  - Start/Stop Fuel Cell package.
  - Switch from "Main" unit to "Stand-by" unit.

4.5.5 Fuel Cell Package Safety Philosophy

All the package safety signals (status and commands) will be exchanged between local control panel and BLPH safety systems (SIS and FGS) through hardwired connections.

Fire and Gas devices inside of the Fuel Cell container will be wired directly to Vendor's local control panel, in a point-to-point configuration.

The following signals are exchanged between local control panel and F&G/SIS systems:

- Gas Confirmed 80-XA-001 (Status): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Smoke Confirmed 80-XA-002 (Status): FGS will generate ESD-1D when this signal is active (open contact in alarm).
- Fault (Status) 80-XA-003: SIS will shut down the package when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 80-XS-001 (command): SIS will shut down the Fuel Cell package in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics.

4.6 UTILITIES OTHER THAN WATER TREATMENT

4.6.1 Vent system and hydrogen vent KO Drum V-43001

(Reference P&ID: Doc. N.123A90-DDL-PR-PID-80029)

The Hydrogen Vent will be comprised of:

- A gathering network of hydrogen gas emergency discharges or maintenance discharges
- A Hydrogen Knock-Out Drum V-43001
- A Hydrogen Vent Stack Q-43004 equipped with a Liquid seal at its bottom

The hydrogen vent will be required for all emergency relief and blowdown scenarios and to vent the H2 off-spec from the Electrolyser package (A-20000). Furthermore, the Vent network is continuously purged with nitrogen in order to keep it slightly pressurized and inert.

The hydrogen KO drum V-43001 is equipped with the following transmitters:

- 43-PT-001 as remote pressure indicator to PCS and High alarm threshold 43-PAH-001.
- 43-LT-001 as remote level indicator, providing high and low level alarm to SIS (43-LAH-001 and 43-LAL-001)
- 43-FT-001 ultrasonic flow transmitter with High alarm threshold (43-FAH-001) to monitor the flowrate towards the stack.

The Hydrogen Vent stack Q-43004, is simply equipped with a level transmitter 43-LT-003 as remote level indicator that allows to monitor the liquid level inside the bottom, providing a low level alarm to PCS (43-

LAL-003). The gas line must be kept submerged in a hydraulic seal to prevent the ingress of air into the system. Overall, ensuring that the gas line remains submerged in a hydraulic seal is essential for the reliable and safe operation of the equipment.

4.6.2 Water Disposal

(Reference P&ID: Doc. N.123A90-DDL-PR-PID-80025)

Downstream the sea water lift pumps, in order to monitor the temperature of brine going back to the brine discharge caisson B-50014, a temperature transmitter 50-TT-001 is required just at inlet of water treatment system, to compare it with the one of the return-stream 50-TT-002.

A differential function 50-TDI-002 (50-TI-002 minus 50-TI-001) measures the difference temperature between these two streams, in order to ensure that the discharged water will not be too warm back into the sea, which could potentially harm the marine ecosystem. A High temperature alarm threshold 50-TDAH-002 will alert the operators onshore that the discharged water is too warm back into the sea.

The pressure transmitter 50-PT-014 monitors the pressure of brine going back to the brine discharge caisson B-50014 and alert the operators onshore with the high pressure alarm 50-PAH-014.

4.6.3 Wastewater TANK T-55001

(Reference P&ID: Doc. N.123A90-DDL-PR-PID-80026)

This accumulation tank is characterized by the following main operating data:

- Normal Operating inlet flowrate gathering of the whole BLHP plant
- Normal Operating Pressure slightly above the atmospheric
- Normal Operating Temperature AMB

The tank T-55001 has the scope to accumulate all the wastewaters gathered intermittently from each wastewater stream installed at BLPH plant:

- Liquid from Seal Drum;
- Liquid from the Electrolyser Package;
- Liquid from the Water Treatment Package.

A radar level transmitter 55-LIT-001 sends the signal of liquid level inside the tank to PCS following two level alarms thresholds respectively high and low (55-LAH-001 and 55-LAL-001) to alert the operators onshore.

4.7 INSTRUMENT AIR PACKAGE A-63000

(Reference P&ID: Doc. N. 1724000428-PR-PID-00019)

4.7.1 General

The unit is fully prefabricated and self-standing package controlled by local control panel 63-LP-001.

All the package control signals (status and commands) will be exchanged with BLPH control system (PCS) through profinet communication.

4.7.2 Process Operation and Control Philosophy

However, the instrument air package A-63000 will have the following main sensors installed at distribution header:

- 63-PT-003 pressure transmitter to monitor the pressure value at the distribution header (signal to PCS). that provides a low pressure alarm 63-PAL-003, to alert the operators onshore.

The local control panel 63-LP-001will be provided with:

- Local/Remote selector

4.7.3 Remote mode

When the Local/Remote selector is in "Remote position":

- Logics inside LCP control and manage the IA package.
- The operators onshore can remotely:
    - Start/Stop IA package.
    - Switch from dryer pre-filter S-63001A to dryer pre-filter S-63001B and vice versa
    - Switch from dryer after filter S-63002A to dryer after filter S-63002B and vice versa
    - Switch from dryer unit 1&2 D-63001A/B to dryer unit D-63002A/B and vice versa

4.7.4 Local mode

When the Local/Remote selector is in "Local position":

- Logics inside LCP control and manage the IA package.
- The operators in offshore can locally:
    - Start/Stop IA package.
    - Switch from dryer pre-filter S-63001A to dryer pre-filter S-63001B and vice versa
    - Switch from dryer after filter S-63002A to dryer after filter S-63002B and vice versa
    - Switch from dryer unit 1&2 D-63001A/B to dryer unit D-63002A/B and vice versa
    - Other actions only possible in local mode

4.7.5 Instrument Air Package Safety Philosophy

All the package safety signals (status and commands) will be exchanged between local control panel and BLPH SIS safety system through hardwired connections.

The following signals are exchanged between local control panel and SIS system:

- Fault (Status) 63-XA-003: SIS will shut down the package when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 63-XS-001 (command): SIS will shut down the Instrument Air package in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics.

4.8 NITROGEN PACKAGE A-64000

(Reference P&ID: Doc. N. 1724000437-PR-PID-00018)

4.8.1 General

The unit is fully prefabricated and self-standing package controlled by local control panel 64-LP-001.

All the package control signals (status and commands) will be exchanged with BLPH control system (PCS) through profinet communication.

4.8.2 Process Operation and Control Philosophy

The air stream is derived from the discharge outlet of the instrument air package A-63000 (say as an additional air consumer). The system through molecular sieves separation units will generate pure nitrogen as required. It operates by separating nitrogen gas from compressed air through a process called pressure swing adsorption. In this process, compressed air is passed through a adsorption material that selectively removes oxygen and other impurities, leaving behind a stream of pure nitrogen gas.

The oxygen rich stream (generated during column regeneration cycle) is vented locally to safe location.

On the outlet line of the Nitrogen system (A-64000) a pressure control is provided, in order to guarantee 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: 64-PT-031A/B (Process Variable, PV);
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: FC

Should be the operating pressure (PV) fall under the PID regulator SP, the controller drives the relevant control valve to increase its opening (Cv); vice versa, should the operating pressure (PV) rise above the PID regulator SP, the controller drives the relevant control valve to decrease its opening (Cv).

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

In case of failure of the selected pressure control loop, the PCS will automatically switch and control with the other control loop forcing in closed position the control valve of the loop in fault.

The pressure transmitters 64-PT-0031A/B give a low and high pressure alarm (64-PAH-031A/B and 64-PAL-031A/B, to alert the operators onshore.

Operator can be alerted by 64-PAL-057 and 64-PALL-057 Low/Low Low Pressure Alarms inside Nitrogen package.

The pressure control valves 64-PV-031A/B are FL-DC type, this means that the valves are fail closed in case of loss of instrument air and shall be drifted in closed position by PCS in case of other faults.

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 (see section 4.4.7 and 4.4.8). 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 PCS 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 purging operation the 64-SDV-001 is fully open to allow nitrogen to be sent to the H2 Storage Vessel.

The local control panel 64-LP-001will be provided with:

- Local/Remote selector

4.8.3 Remote mode

When the Local/Remote selector is in "Remote position":

- Logics inside LCP control and manage the Nitrogen package.
- The operators onshore can remotely:
  - Start/Stop Nitrogen package.
  - ~~Switch from PSA Tower C-64001A to PSA Tower C-64001B and vice versa~~
  - Switch from PSA after filter S-64001A to PSA after filter S-64001B and vice versa

4.8.4 Local mode

When the Local/Remote selector is in "Local position":

- Logics inside LCP control and manage the Nitrogen package.
- The operators offshore can locally:
  - Start/Stop Nitrogen package.
  - Switch from PSA Tower C-64001A to PSA Tower C-64001B and vice versa
  - Switch from PSA after filter S-64001A to PSA after filter S-64001B and vice versa
  - Other actions only possible in local mode

4.8.5 Nitrogen Package Safety Philosophy

All the package safety signals (status and commands) will be exchanged between local control panel and BLPH SIS safety system through hardwired connections.

The following signals are exchanged between local control panel and SIS system:

- Fault (Status) 64-XA-003: SIS will shut down the package when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 64-XS-001 (command): SIS will shut down the Nitrogen package in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics.

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5 HVAC SYSTEMS

5.1.1 General

Ventilation and air conditioning (HVAC) systems are dedicated to the following containers:

- B-100: HV (66kV-6.6kV) Switchroom
- B-200: LV (400V) Switchroom
- B-300: AC UPS fitted with UPS system
- B-400: I&T Equipment Room (named "ITER")

HVAC systems provided will be designed to comply with project requirements and international standards, they will be able to guarantee the internal design conditions taking into account external design conditions and the purpose they are provided for.

The systems provide:

- Air conditioning system

- Heating system

The air conditioning system will be composed by 2x100% air conditioning units, that are HUs (Air Handling Units) provided of direct expansion (DX) cooling system, and will be mounted on the module roof.

5.1.2 Process Operation and Control Philosophy

The HVACs systems shall be controlled by local control panels and all the package control signals (status and commands) will be exchanged with BLPH control system (PCS) through modbus TCP/IP communication.

The local control panels have the following tags:

- B100-HSB-001 LCP inside container B-100
- B200-HSB-001 LCP inside container B-200
- B300-HSB-001 LCP inside container B-300
- B400-HSB-001 LCP inside container B-400

The HVAC local control panels will be equipped with two AUT-0-MAN selectors, one for each Air Handling Unit (AHU). The selector positions function as follows:

1. AUT (Automatic) Position:

o The HVAC PLC manages the HVAC system according to its internal control logic.

o The onshore operator can remotely START or STOP the HVAC system.

o When the onshore operator activates a START command, the HVAC system operates under the PLC's internal logic.

2. 0 (Off) Position:

- The AHU is switched off, typically for maintenance purposes.

3. MAN (Manual) Position:

- The HVAC PLC continues to manage the HVAC system based on its internal control logic.
- The onshore operator is unable to remotely START or STOP the system.

~~The local control panels will be provided with:~~

~~1) AUT-0-MAN Selector~~

~~2) 0-REMOTE Selector (valid only in AUTO position of the first selector)~~

~~- If the first selector is in "AUTO" position, the PLC manages the HVAC system as per internal control logics and:~~

~~o If the second selector is in REMOTE position the operator onshore can STOP the HVAC system. When the operator removes the STOP the HVAC system return managed by PLC internal control logic.~~

~~o If the second selector is in 0 position the remote commands are inhibited.~~

~~- If the first selector is in 0 position, the HVAC system is not powered (used for maintenance)~~

~~- If the first selector is in "MAN" position, the PLC manages the HVAC system as per PLC internal control logics but the operator in offshore can START/STOP the HVAC system (the remote command are by-passed).~~

5.1.3 HVACs Systems Safety Philosophy

All the HVACs systems safety signals (status and commands) will be exchanged between local control panel and BLPH SIS through hardwired connections.

The following signals are exchanged between local control panel and SIS system:

1) B100-HSB-001 LCP inside container B-100
   - Fault (Status) 77-XA-001: SIS will shut down the HVAC system when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
   - Shutdown 77-XS-001 (command): SIS will shut down the HVAC system in emergency conditions (signal de-energized in emergency conditions).
2) B200-HSB-001 LCP inside container B-200
   - Fault (Status) 77-XA-002: SIS will shut down the HVAC system when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
   - Shutdown 77-XS-002 (command): SIS will shut down the HVAC system in emergency conditions (signal de-energized in emergency conditions).
3) B300-HSB-001 LCP inside container B-300

- Fault (Status) 77-XA-003: SIS will shut down the HVAC system when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 77-XS-003 (command): SIS will shut down the HVAC system in emergency conditions (signal de-energized in emergency conditions).

4) B400-HSB-001 LCP inside container B-400

- Fault (Status) 77-XA-004: SIS will shut down the HVAC system when this signal is active (open contact in alarm). The Fault status will be a cumulative of all critical alarms of the package.
- Shutdown 77-XS-004 (command): SIS will shut down the HVAC system in emergency conditions (signal de-energized in emergency conditions).

Refer to Process Safety Cause & Effect Matrix for more details of the safety logics.

Refer to Fire & Gas Cause & Effect Matrix for more details of the safety logics.

6 INTRUSION DETECTION SYSTEM

Onboard BLPH platform there shall be an Intrusion Detection System. This system will include door contacts and motion detectors directly connected to the PCS and with relevant statuses and alarms displayed onshore by GUI pages. Scope of this system is to monitor, from remote, all 4 offshore containers (B-100/200/300/400) hosted by the BLPH platform against unauthorized access.

Here below the list of signals for each container:

1) B-100: HV (66kV-6.6kV) Switchroom
   - B100-TDC-001: Primary door open feedback
   - B100-TDC-002: Emergency door open feedback
   - B100-TIR-001: Room motion detection

2) B-200: LV (400V) Switchroom
   - B200-TDC-001: Primary door open feedback
   - B200-TDC-002: Emergency door open feedback
   - B200-TIR-001: Room motion detection

3) B-300: AC UPS fitted with UPS system
   - B300-TDC-001: Primary door open feedback
   - B300-TDC-002: Emergency door open feedback
   - B300-TIR-001: Room motion detection

4) B-400: I&T Equipment Room (named “ITER”)
   - B400-TDC-001: Primary door open feedback
   - B400-TDC-002: Emergency door open feedback
   - B400-TIR-001: Room motion detection

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7 DISCREPANCY ALARM

In case of discrepancy between output commands and feedback statuses or two different transmitters installed on the same line, a discrepancy alarm shall be generated to alert operators onshore.

7.1 DISCREPANCY ALARM FOR PRESSURE TRANSMITTERS

- If the pressure indications 25-PI-001 and 25-PI-002 differ by ± 2.5 % f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-004 and 25-PI-035 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-006 and 25-PI-037 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-008 and 25-PI-040 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-009 and 25-PI-043 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-011 and 25-PI-046 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-012 and 25-PI-049 differ by ± 2.5 % (Hold 6) f.s. (40 barg) then an alarm will be generated.
- If the pressure indications 25-PI-055A, 25-PI-055B and 80-PT-002 differ by ± 5 (Hold 6) % f.s. (10 barg) then an alarm will be generated.
- If the pressure indications 63-PI-003 and 63-PI-004 differ by ± 2.5 % (Hold 6) f.s. (11 barg) then an alarm will be generated.
- If the pressure indications 64-PI-031A, 64-PI-031B and 64-PI-002 differ by ± 5 % (Hold 6) f.s. (10 barg) then an alarm will be generated.

7.2 DISCREPANCY ALARM FOR CONTROL VALVES

1) 25-PV-055A/B Control Valves (Hydrogen Manifold to Fuel Cell)

- If both pressure control valves 25-PV-055A/B are open (check 25-ZSH-055A and 25-ZSH-055B) then an alarm will be generated.
- Discrepancy alarm between the output of the controller 25-PIC-055A and the position indication 25-ZI-055A, open position 25-ZSH-055A and closed position 25-ZSL-055A shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-055B and the position indication 25-ZI-055B, open position 25-ZSH-055B and closed position 25-ZSL-055B shall be generated.

2) 64-PV-031A/B Control Valves (Nitrogen Manifold)

- If both pressure control valves 64-PV-031A/B are open (check 64-ZSH-031A and 64-ZSH-031B) then an alarm will be generated.
- Discrepancy alarm between the output of the controller 64-PIC-031A and the position indication 64-ZI-031A, open position 64-ZSH-031A and closed position 64-ZSL-031A shall be generated.
- Discrepancy alarm between the output of the controller 64-PIC-031B and the position indication 64-ZI-031B, open position 64-ZSH-031B and closed position 64-ZSL-031B shall be generated.

3) 25-FV-031 and 25-PV-035 Control Valves (H2 Vessel V-25001A)

- Discrepancy alarm between the output of the controller 25-FIC-031 and the position indication 25-ZI-031, open position 25-ZSH-031 and closed position 25-ZSL-031 shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-035 and the position indication 25-ZI-035, open position 25-ZSH-035 and closed position 25-ZSL-035 shall be generated.

4) 25-FV-032 and 25-PV-037 Control Valves (H2 Vessel V-25001B)

- Discrepancy alarm between the output of the controller 25-FIC-032 and the position indication 25-ZI-032, open position 25-ZSH-032 and closed position 25-ZSL-032 shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-037 and the position indication 25-ZI-037, open position 25-ZSH-037 and closed position 25-ZSL-037 shall be generated.

5) 25-FV-033 and 25-PV-040 Control Valves (H2 Vessel V-25001C)

- Discrepancy alarm between the output of the controller 25-FIC-033 and the position indication 25-ZI-033, open position 25-ZSH-033 and closed position 25-ZSL-033 shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-040 and the position indication 25-ZI-040, open position 25-ZSH-040 and closed position 25-ZSL-040 shall be generated.

6) 25-FV-034 and 25-PV-043 Control Valves (H2 Vessel V-25001D)

- Discrepancy alarm between the output of the controller 25-FIC-034 and the position indication 25-ZI-034, open position 25-ZSH-034 and closed position 25-ZSL-034 shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-043 and the position indication 25-ZI-043, open position 25-ZSH-043 and closed position 25-ZSL-043 shall be generated.

7) 25-FV-038 and 25-PV-046 Control Valves (H2 Vessel V-25001E)

- Discrepancy alarm between the output of the controller 25-FIC-038 and the position indication 25-ZI-038, open position 25-ZSH-038 and closed position 25-ZSL-038 shall be generated.
- Discrepancy alarm between the output of the controller 25-PIC-046 and the position indication 25-ZI-046, open position 25-ZSH-046 and closed position 25-ZSL-046 shall be generated.

8) 25-FV-036 and 25-PV-049 Control Valves (H2 Vessel V-25001F)

- Discrepancy alarm between the output of the controller 25-FIC-036 and the position indication 25-ZI-036, open position 25-ZSH-036 and closed position 25-ZSL-036 shall be generated.

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- Discrepancy alarm between the output of the controller 25-PIC-049 and the position indication 25-ZI-049, open position 25-ZSH-049 and closed position 25-ZSL-049 shall be generated.

7.3 DISCREPANCY ALARM FOR XV VALVES

- Discrepancy alarm between the output to the solenoid 50-XY-001 and the open position 50-ZSH-001 and closed position 50-ZSL-001 shall be generated.
- Discrepancy alarm between the output to the solenoid 50-XY-002 and the open position 50-ZSH-002 and closed position 50-ZSL-002 shall be generated.
- Discrepancy alarm between the output to the solenoid 50-XY-003 and the open position 50-ZSH-003 and closed position 50-ZSL-003 shall be generated.
- Discrepancy alarm between the output to the solenoid 50-XY-004 and the open position 50-ZSH-004 and closed position 50-ZSL-004 shall be generated.
- Discrepancy alarm between the output to the solenoid 50-XY-024 and the open position 50-ZSH-024 and closed position 50-ZSL-024 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-004 and the open position 25-ZSH-004 and closed position 25-ZSL-004 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-006 and the open position 25-ZSH-006 and closed position 25-ZSL-006 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-008 and the open position 25-ZSH-008 and closed position 25-ZSL-008 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-009 and the open position 25-ZSH-009 and closed position 25-ZSL-009 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-011 and the open position 25-ZSH-011 and closed position 25-ZSL-011 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-012 and the open position 25-ZSH-012 and closed position 25-ZSL-012 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-014 and the open position 25-ZSH-014 and closed position 25-ZSL-014 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-015 and the open position 25-ZSH-015 and closed position 25-ZSL-015 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-017 and the open position 25-ZSH-017 and closed position 25-ZSL-017 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-018 and the open position 25-ZSH-018 and closed position 25-ZSL-018 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-XY-020 and the open position 25-ZSH-020 and closed position 25-ZSL-020 shall be generated.

- Discrepancy alarm between the output to the solenoid 25-XY-021 and the open position 25-ZSH-021 and closed position 25-ZSL-021 shall be generated.
- Discrepancy alarm between the output to the solenoid 80-XY-001 and the open position 80-ZSH-001 and closed position 80-ZSL-001 shall be generated.

7.4 DISCREPANCY ALARM FOR SDV AND BDV VALVES

- Discrepancy alarm between the output to the solenoid 25-SDY-001 and the open position 25-ZSH-001 and closed position 25-ZSL-001 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-SDY-023 and the open position 25-ZSH-023 and closed position 25-ZSL-023 shall be generated.
- Discrepancy alarm between the output to the solenoid 64-SDY-001 and the open position 64-ZSH-001 and closed position 64-ZSL-001 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-005 and the open position 25-ZSH-005 and closed position 25-ZSL-005 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-007 and the open position 25-ZSH-007 and closed position 25-ZSL-007 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-010 and the open position 25-ZSH-010 and closed position 25-ZSL-010 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-013 and the open position 25-ZSH-013 and closed position 25-ZSL-013 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-016 and the open position 25-ZSH-016 and closed position 25-ZSL-016 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-019 and the open position 25-ZSH-019 and closed position 25-ZSL-019 shall be generated.
- Discrepancy alarm between the output to the solenoid 25-BDY-022 and the open position 25-ZSH-022 and closed position 25-ZSL-022 shall be generated.

7.5 DISCREPANCY ALARM FOR FGS DAMPERS

In case of discrepancy between output commands to FGS dampers and feedback status of closure, a discrepancy alarm shall be generated to alert operators onshore.

The control logic will be done inside FGS system that close the FGS dampers in case of Fire and Gas shutdown conditions.

1) B-100: HV (66kV-6.6kV) Switchroom

- Discrepancy alarm between the output 77-HY-001 of the FGS damper 77-HFD-001 and its closed position 77-ZSL-001 shall be generated.

- Discrepancy alarm between the output 77-HY-002 of the FGS damper 77-HFD-002 and its closed position 77-ZSL-002 shall be generated.
- Discrepancy alarm between the output 77-HY-003 of the FGS damper 77-HFD-003 and its closed position 77-ZSL-003 shall be generated.

2) B-200: LV (400V) Switchroom

- Discrepancy alarm between the output 77-HY-004 of the FGS damper 77-HFD-004 and its closed position 77-ZSL-004 shall be generated.
- Discrepancy alarm between the output 77-HY-005 of the FGS damper 77-HFD-005 and its closed position 77-ZSL-005 shall be generated.
- Discrepancy alarm between the output 77-HY-006 of the FGS damper 77-HFD-006 and its closed position 77-ZSL-006 shall be generated.

3) B-300: AC UPS fitted with UPS system

- Discrepancy alarm between the output 77-HY-007 of the FGS damper 77-HFD-007 and its closed position 77-ZSL-007 shall be generated.
- Discrepancy alarm between the output 77-HY-008 of the FGS damper 77-HFD-008 and its closed position 77-ZSL-008 shall be generated.
- Discrepancy alarm between the output 77-HY-009 of the FGS damper 77-HFD-009 and its closed position 77-ZSL-009 shall be generated.
- Discrepancy alarm between the output 77-HY-010 of the FGS damper 77-HFD-010 and its closed position 77-ZSL-010 shall be generated.
- Discrepancy alarm between the output 77-HY-011 of the FGS damper 77-HFD-011 and its closed position 77-ZSL-011 shall be generated.

4) B-400: I&T Equipment Room (named "ITER")

- Discrepancy alarm between the output 77-HY-012 of the FGS damper 77-HFD-012 and its closed position 77-ZSL-012 shall be generated.
- Discrepancy alarm between the output 77-HY-013 of the FGS damper 77-HFD-013 and its closed position 77-ZSL-013 shall be generated.
- Discrepancy alarm between the output 77-HY-014 of the FGS damper 77-HFD-014 and its closed position 77-ZSL-014 shall be generated.
- Discrepancy alarm between the output 77-HY-015 of the FGS damper 77-HFD-015 and its closed position 77-ZSL-015 shall be generated.
- Discrepancy alarm between the output 77-HY-016 of the FGS damper 77-HFD-016 and its closed position 77-ZSL-016 shall be generated.

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8 SHUT-DOWN ACTIVATION

In case of Shut-down conditions some (or all) of the automatic sequences (if active) will be stopped and the XV valves inlet/outlet Hydrogen Vessels shall be closed.

The SIS/F&G system will send the Shutdown signals to PCS that will active the stop of sequences and close the XV valves inlet/outlet Hydrogen Vessels.

8.1 SHUT-DOWN CONDITIONS: ASD, ESD1-D, ESD-1, PSD

3) In case of ASD, ESD-1D and ESD-1 Shut-down conditions, the following automatic sequences (if active) will be stopped, and the XV valves inlet/outlet Hydrogen Vessels shall be closed.

- Process Charging mode
- Process Start-up Charging mode
- Process Discharging mode
- Purging mode after Shutdown (for H2 displacement)
- Purging mode after Maintenance (for Air displacement)
- Command the closure of all XV valves inlet (25-XV-004/008/011/014/017/020) /outlet (25-XV-006/009/012/015/018/021) Hydrogen Vessels:

- XV inlet Limit switches are: 25-ZSL-004/008/011/014/017/020
- XV outlet Limit switches are: 25-ZSL-006/009/012/015/018/021

4) In case of Electrolyser package shutdown (20-XS-001) and/or Water Treatment package (50-XS-001), the following automatic sequences (if active) will be stopped, and the XV valves inlet Hydrogen Vessels shall be closed.

- Process Charging mode
- Process Start-up Charging mode
- Command the closure of all XV valves (25-XV-004/008/011/014/017/020) inlet Hydrogen Vessels:

- XV inlet Limit switches are: 25-ZSL-004/008/011/014/017/020

shutdown of

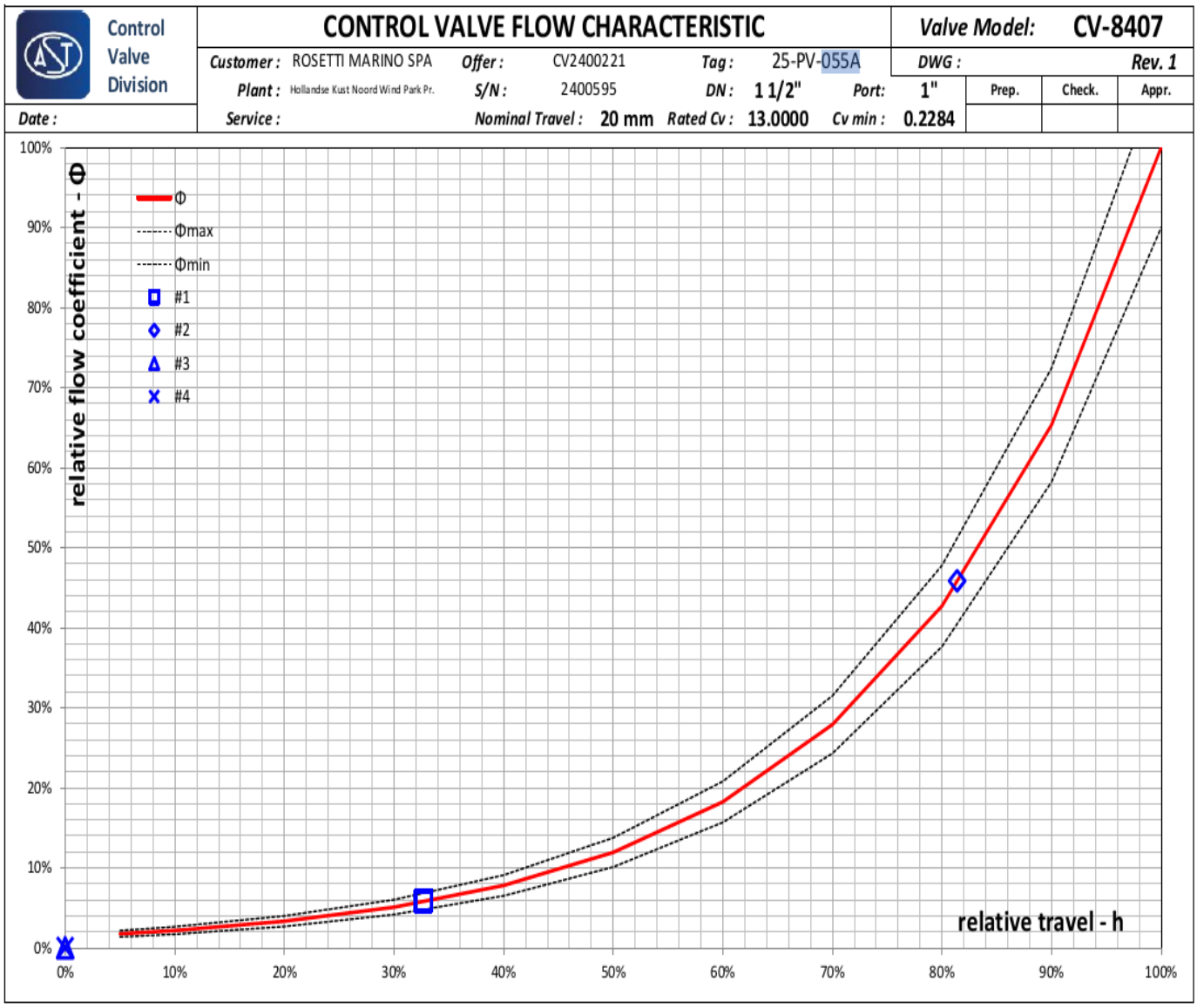
5) In case of Fuel Cell package shutdown (80-XS-001), the following automatic sequence (if active) will be stopped, and the XV valves outlet Hydrogen Vessels shall be closed.

- Process Discharging mode
- Command the closure of all XV valves (25-XV- 006/009/012/015/018/021) outlet Hydrogen Vessels:

- XV outlet Limit switches are: 25-ZSL-006/009/012/015/018/021

9 ATTACHMENTS

9.1 ATTACHMENT 1



9.2 ATTACHMENT 2

