Base Load Power Hub (BLPH)

WATER TREATMENT PACKAGE A-50000
SYSTEM FUNCTIONAL DESCRIPTION (50-LP-001)

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1 INTRODUCTION

1.1 PROJECT OVERVIEW

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

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

1.1.1 Project Location

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

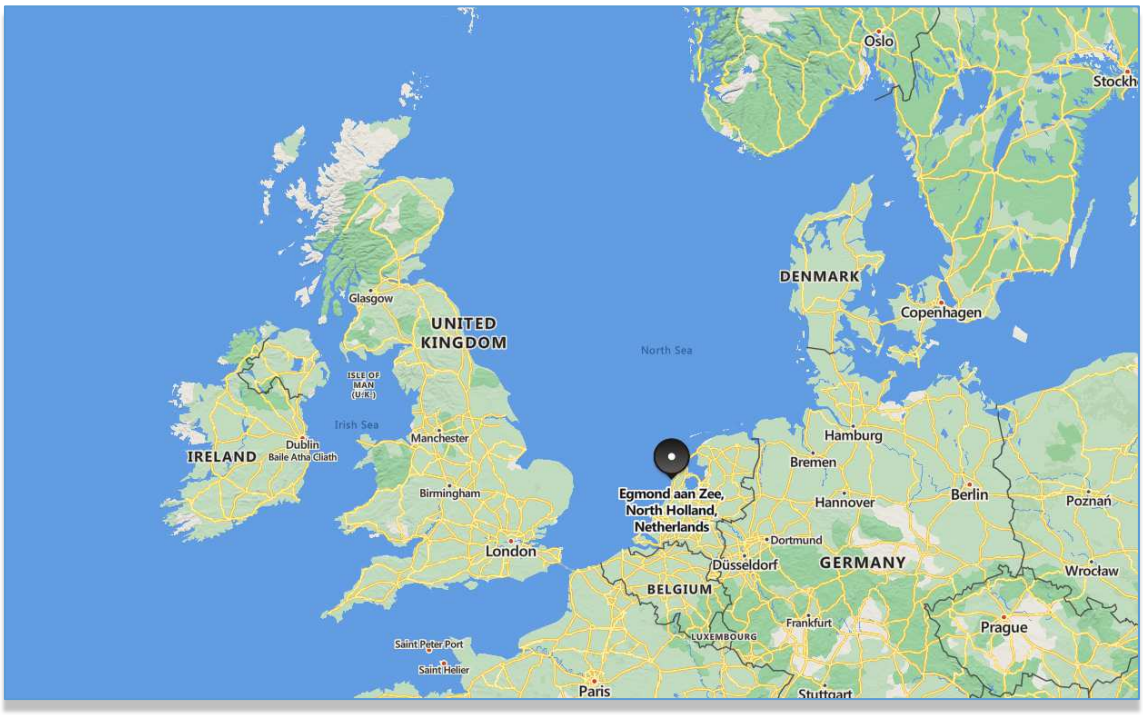


Figure 1 HOLLANDSE KUST NOORD WIND PARK Location Map



Figure 2 - Wind Park Details

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

1.1.2 Project Concept

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

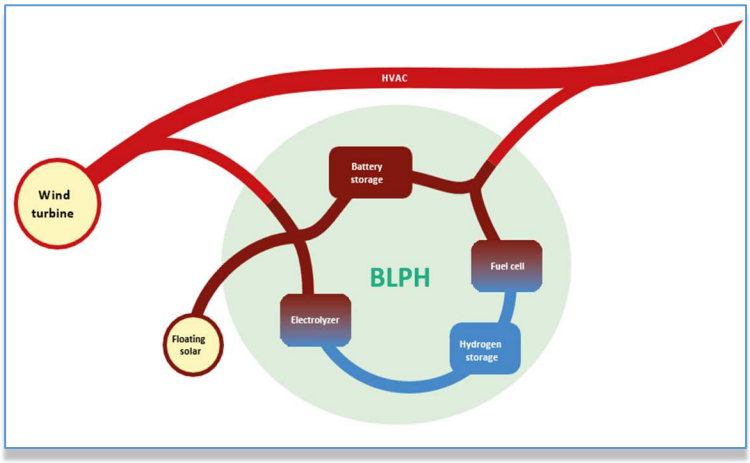


Figure 3 – BLPH Concept

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

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

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2 DOCUMENT SCOPE

Scope of this document is to provide the process and control system description and the details on how the Water Treatment Package operates. The above-mentioned package will be supplied to Rosetti Marino S.p.A. for Crosswind Off-shore project, producing fresh water from sea water.

2.1 REFERENCES

Doc. No.	Description
1724000448-PR-PID-00013 rev.4 - Sheets 1, 2 and 3 - Sheet 4 - Sheet 5 - Sheet 6 - Sheet 7	P&I Diagram – Water Treatment Package: - Seawater Fine Filtration - Seawater Reverse Osmosis - Fresh Water Storage - Chemical Dosage - Biocide Dosage
1724000448-MAC-CE-00004 rev.4	Package Cause & Effect Matrix
1724000448-IN-LIS-00019 rev.4	I & O List
VR no: PSC_002_08052024 In Rosetti Marino Scope	MoM dated 8/5/2024 between PSC and RM, pos.2

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
HKN:	Hollansdse Kust Noord
BLPH:	Base Load Power Hub
VooW:	Van Oord Offshore Wind
HC:	High Cube Container
SW:	Sea Water
SWRO:	Sea Water Reverse Osmosis
RO:	Reverse Osmosis
UV:	Ultraviolet

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UV-C:	A Subtype of Ultraviolet Light
PLC:	Programmable Logic Controller
DCS:	Distributed Control System
SIS:	Safety Instrumented System
TP:	Terminal Point
F&G:	Fire and Gas
LP:	Local Panel
pH:	Potential of Hydrogen
PV:	Photovoltaics
BESS:	Battery Energy Storage System
ΔP:	Difference Pressure
VFD:	Variable Frequency Driver
SCR:	Silicon Controller Rectifier

Table 2 - Definitions and Abbreviations

3 GENERAL

Scope of the Water Treatment Package is to treat the sea water to supply 0.8 m^3/h of fresh water to feed the Hydrogen Electrolyser. Platform will operate normally unmanned with minimal maintenance every 6 months. The operation is discontinuous: it is estimated to operate the package 45 times in 6 months, each operation lasts 8 -12 hours (ref. A).

The Water Treatment Package mainly consists of three process sections:

- Pretreatments
- Sea Water Reverse Osmosis
- Post-treatments.

The desalination plant is mounted inside a container, 40 feet HC; it will have its own independent control system. Other accessories to Water Treatment Package are:

- F&G detection system
- Container Electric Heaters HHS-50003A/B and Container Air Fans HFA-50001A/B/C.

General notes:

- All automatic logics and power feeding distribution described in the next sections are performed by supplied MCC & PLC Panel 50-LP-0001.
- Each stand-by unit and device are automatically switched to service in order to balance running time and to optimize the wearing parts required maintenance.
- PLC collects all running and failure signals from each pump and electric heater, all limit switches position and fault signals from each automatic valve, all fault alarms from each field instrument.
- All package's sections are displayed and controlled by dedicated HMI video pages, where process alarms and trends are available. Alarms thresholds, setpoints, valves and pumps can be changed/manually operated by authorized logged user.
- 3 different HMI users are available, with different control ability:
    - OPERATOR
    - MAINTAINER
    - ADMINISTRATOR
- In order to let the package be controlled by remote client's DCS, all relevant PLC signals and commands are sent to client's system by Modbus communication.

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3.1 PRETREATMENTS

Sea water feeds the container inlet battery limit (A-50000, TP-017) by means of Sea Water Pump P-50001A/B provided by Rosetti Marino.

The automatic flow control valve 50-FV-020 is installed downstream the Sea Water Coarse Filter A-50003, to keep constant the design flowrate 2.5 m^3/h to Electric Heater and Sand Filter, discharging any excess flow rate to drain point.

3.1.1 Sea Water Coarse Filter (A-50003)

Sea water feeds the Sea Water Coarse Filter (A-50003), a self-cleaning filter that eliminates coarse particles greater than 125 micron. Water enters the filter through the (IN) inlet and goes through the internal and vertical filtering element (1) from the inside to the outside. This will retain all non-deformable suspended solids, same size or bigger than the filtration degree installed (i.e. 125 micron). Filtered water leaves through the outlet pipe (OUT).

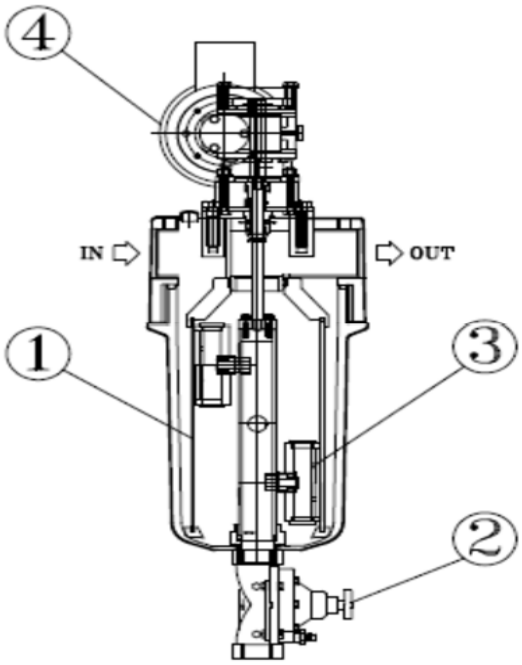


Figure 4 – Sea Water Coarse Filter

The continuous settling of suspended solids layer increasing over the internal filter element reduces the water flow passage, which results in a pressure difference (ΔP). At a preset value of ΔP (range 0.7 - 1 bar) an automatic backwash cycle will start to clean the filter element. The backwash sequence begins with a signal that opens quickly the bottom discharge valve (2) and creates a vacuum condition from the suction nozzles (3) taking the filtered clean water (due to differential hydraulic pressure condition 1.5 barg towards atmospheric value). At the same time, the electric motor (4) drives the internal, vertical rotating arm with suction nozzles to clean the full filtering surface. Deposit solid layer is hydraulic removed by rotating suction nozzles from internal filter element (4) and then discharged through the bottom discharge valve (2) and goes to the water drain header. The self-cleaning cycle lasts approximately 15 seconds.

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A local switchboard (LP-A-50003) controls the washing phases. The signal that starts the cleaning cycle is given by an internal differential pressure switch. The switchboard gives a "general alarm" signal in case of problems in the washing system. The washing phase can also be controlled also by a timer (filtration time to be set).

During filter backwashing, the filtered water accumulated in the Filtered Water Tank T-50006 allows the following reverse osmosis section to be fed.

3.1.2 Electric Heater (H-50001)

Site data conditions: Sea Water Temperature (min/max) 1.3 / 20.2 °C.

Since sea water minimum temperature is too low to feed the Water Treatment Package, an Electric Heater (H-50001) is installed downstream Sea Water Coarse Filter (A-50003) to increase sea water temperature up to minimum 10°C during cold season. Sea water inlet temperature is measured by 50-TT-021 and controlled by 50-TIC-021.

3.1.3 Container Ventilation (HFA-50001A/B/C) and Heating (HHS-50003A/B)

Site data conditions: Ambient Temperature (min/norm/max) -8.4 / 10.5 / 25 °C.

Since ambient minimum temperature is too low, Container Electric Heaters (HHS-50003 A/B) are installed inside container to increase ambient temperature up to minimum 10°C during cold season. Inlet temperature is measured by 50-TT-023 and controlled by 50-TIC-023.

The ventilation inside container is maintained with HFA-50001A/B/C fans (3 x 50%, two in operation and one stand-by) that provide enough air change per hour (minimum 15 air change per hour).

3.1.4 Sand Filter (S-50001)



Sand bed filtration is the physic process to remove suspended particles from water.

Sand (dual media layers) Filter S-50001 is installed with automatic backwash of the filtering bed by means filtered water. The media filter includes several layers of selected quartz-sand with different size, and anthracite as upper layer. As the filter retains particles, the resistance to the passage of water and thus the pressure drop between inlet and outlet increases. The maximum permissible pressure drop is 1 bar. Backwashing means restoring the efficiency of the filter bed by removing from it the suspended solid particles retained during operation. Backwashing is commanded by PLC after a settable service time or when a pressure drop of 0.7 bar is reached. A local switchboard (LP-S-50001) controls the washing phases.

Backwashing is performed with filtered water stored in T-50006 with pumps P-50002A or P-50002B. A flow transmitter (50-FT-020) is installed at the inlet of the filter and gives an alarm in case of low and high flow. Spent filter backwash goes to water drain header.

Figure 5-Sand Filter

3.1.5 Antiscalant Dosage

Antiscalant is dosed upstream cartridge filters, in order to avoid the occurrence of scaling phenomena on Sea Water Reverse Osmosis.

An antiscalant continuous dosage is foreseen on the filtered water to avoid clogging and scaling phenomena on RO membranes.

Antiscalant Dosing Pumps P-50006 A/B shall be equipped with a manual stroke adjustment which allow to regulate the dosage flow.

Antiscalant Dosing Pumps shall be fed from Antiscalant Storage Tank T-50003 equipped with a level transmitter 50-LT-023, which provides an alarm for the refilling requirement (50-LAL-023) and the trip (50-LALL-023) for avoid the dry running of the pumps.

The chemical Storage Tank T-50003 shall be manually re-filled opening the top inspection cover.

3.1.6 Cartridge Filters (S-50002A/B, S-50003A/B)

Filtered water is stored in Filtered Water Tank T-50006 equipped with level transmitter 50-LT-020, which provides the alarms and trip for the SW Booster Pumps P-50003A/B and Backwash Pumps P-50002A/B.

Filtered sea water conductivity is measured by analyser 50-AT-023 upstream cartridge filters: High level conductivity shall give an alarm.

Two lines (2x100%) of cartridge filters and SWRO are installed: line A operates when valve 50-XV-021 opens (and 50-XV-022 closes), line B operates when valve 50-XV-022 opens (and 50-XV-021 closes).

A double stage of fine filtration system is foreseen with cartridge filters having size poring of 20 and 5 microns to protect the RO membranes from very fine solids clogging phenomena. Each SWRO line has two cartridge filters: S-50002A 20 micron and S-50003A 5 micron for line A, S-50002B 20 micron and S-50003B 5 micron for line B. Cartridges are not reusable type and the substitution is required after reaching high differential pressure value. Cartridges substitution is scheduled every six months, even if differential pressure does not reach high value.

At SW Booster Pump P-50003A delivery, a pressure transmitter, 50-PT-025 is installed to report the pressure value to PLC. At the outlet of Cartridge Filter S-50003A a pressure transmitter, 50-PT-026 is installed to report the pressure value to PLC. When pressure difference between 50-PT-025 and 50-PT-026 is more than 2 bar cartridge filters S-50002A and S-50003A need to be changed.

At SW Booster Pump P-50003B delivery, a pressure transmitter, 50-PT-027 is installed to report the pressure value to PLC. At the outlet of Cartridge Filter S-50003B a pressure transmitter, 50-PT-028 is installed to report the pressure value to PLC. When pressure difference between 50-PT-027 and 50-PT-028 is more than 2 bar cartridge filters S-50002B and S-50003B need to be changed.

3.1.7 Biocide Dosage

Non-oxidant biocide is dosed to inhibit bacterial growth and the formation of organic silt. Non-oxidant biocide is dosed in three different points:

- A continuous dosage is foreseen at the inlet of Water Treatment Package.
- A shock dosage (20 min every two days) is foreseen on the Intake Sea Water Pumps P-50001 A/B.
- A shock dosage (60 min every week) is foreseen on Waste Water Tank T-55001.

Biocide Dosing Pumps shall be equipped with a manual stroke adjustment which allow to regulate the dosage flow.

All dosing pumps shall be fed from Biocide Storage Tank T-50004 equipped with a level transmitter 50-LT-024, which provides an alarm for the refilling requirement (50-LAL-24) and the trip (50-LALL-24) for avoid the dry running of the pumps.

Dosing Pumps P-50007A/B dose the biocide at the inlet of container, upstream SW Coarse Filter A-50003, continuously when the plant is in operation.

Dosing Pumps P-50008A/B dose the biocide to sea water intake: every two days one pump starts for 20 minutes. It may be necessary to do the shock dosing when the Water Treatment Package is not in operation, because the permeate may contain slightly elevated levels of organics to promote the biological growth.

Dosing Pumps P-50010A/B dose the biocide to Waste Water Tank T-55001: every week one pump starts for 60 minutes.

The chemical Storage Tank T-50004 shall be manually re-filled opening the top inspection cover.

3.2 SEA WATER REVERSE OSMOSIS

Sea Water Reverse Osmosis will be used to provide the removal of dissolved solids and ions from the feed filtered water. Reverse osmosis membranes reject the salts contained in the feed water in a salt concentrated stream leaving a low salinity stream called “permeate”.

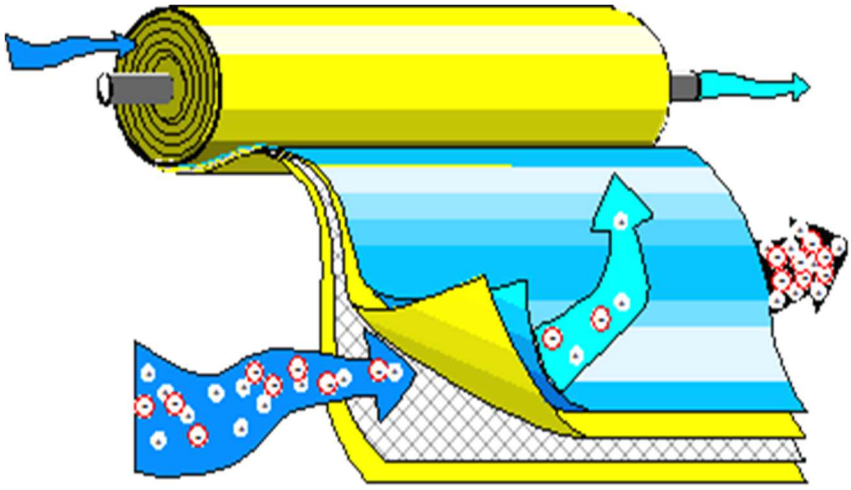


Figure 6 – Reverse Osmosis Membrane

In normal condition Reverse Osmosis unit shall operate with one line in operation and the second in conservation.

Chemically conditioned and filtered water will reach the suction side of the RO High Pressure Pumps

(P-50004 A or P-50004B) and will be fed to the RO units (A-50007 A or A-50007B).

These pumps shall operate in a fixed pressure range and are protected from the suction low pressure (and therefore from low flow) by the pressure transmitter 50-PT-026 / 50-PT-028, which give an alarm.

RO High Pressure Pumps P-50004A/B are protected from high suction pressure by pressure transmitter 50-PT-026 / 50-PT-028, which give an alarm and from safety valves 50-PSV-034 / 50-PSV-037 that will open in case of overpressure.

RO High pressure pumps P-50004A/B are equipped with VFD in order to maintain the constant RO water recovery flow rate (permeate). Pumps delivery pressure is controlled by 50-PIC-030/ 50-PIC-032, that operates on pump's VFD. Then set pressure point value could be re-adjusted by 50-FIC -024 that measures the permeate flowrate.

SWRO membranes are protected from the high-high delivery pressure by installed pressure safety valves 50-PSV-035 / 50-PSV-038 while pressure transmitters 50-PT-030 / 50-PT-032 give alarm when high pressure is reached (62 barg).

The SWRO desalinated permeate water (fresh water) will be sent directly to the Fresh Water Tank T-50008, whereas the concentrated brine will be sent to water drain.

Permeate quality of both lines is checked by a conductivity meter (50-AT-024), which reports a value on PLC: if conductivity exceeds the design product value (High conductivity alarm, High High conductivity discharge), permeate is automatically discharged, through the opening of the automatic off-spec valve 50-XV-026 and closing the automatic valve 50-XV-025. When the conductivity value will return below the proper value, the treated water is automatically diverted at the Fresh Water tank, closing 50-XV-026 and opening 50-XV-025.

3.2.1 Automatic Flushing

In case of shutdown for a period longer than 1- 3 hours, the SWRO unit must be flushed at low pressure, to displace the salt water after the SWRO Line A or B stop. Flushing is automatically performed with RO permeate through SW Booster Pumps P-50003A or P-50003B and Pumps P-50004A or P-50004B when one RO line has finished its operation. For SWRO Line A, automatic valves

50-XV-023 (flushing inlet), 50-XV-027 (flushing outlet) and 50-XV-026 (off-spec) shall be opened, while

50-XV-025 (permeate outlet) shall be closed. For SWRO Line B automatic valves 50-XV-024 (flushing inlet), 50-XV-030 (flushing outlet) and 50-XV-026 (off-spec) shall be opened, while 50-XV-025 (permeate outlet) shall be closed.

During the flushing all the chemical dosing units shall be stopped. Flushing shall operate for 10-15 minutes to remove the brine. During flushing of one line the plant does not produce fresh water. Flushing discharge is collected into water drain.

3.3 POST-TREATMENTS

SWRO permeate is stored in Fresh Water Tank T-50008 equipped with level transmitter 50-LT-021, which provides alarms for the Fresh Water Pumps P-50009A/B.

The Fresh Water Pumps feed the SWRO permeate to post treatment and are automatically started and stopped, according to the water demand required to electrolyser.

3.3.1 Softening Filter (S-50004)

Softening is a chemical process to reduce any residual calcium and magnesium (hardness) content from water. These two elements, together with the presence of carbonates, are the main causes of limescale build-up.

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Figure 7-Softening Filter

Softening is achieved by passing the water through a bed of cation ion exchange resin. The resin in the columns exchange sodium ions, with which they are charged, against calcium and magnesium ions. The softened water will therefore be free of hardness and have an increased sodium content.

When the resin is exhausted, i.e. fully charged with Ca^{++} and Mg^{++} ions and now have no Na^{+} to exchange, it is necessary to regenerate them. Regeneration means restoring the sodium level in the resins: this is available in the regenerant sodium chloride (NaCl). Frequency of regeneration is approx. every 20 -40 m^3 of produced fresh water, i.e. approx. every two weeks.

The device automatically prepares the required brine from tables salt. This Softening Fiter package contains vessel resins and brine tank assembled in a compact unit. A local switchboard (LP-S-50004) controls the resin regeneration and brine saturated preparation.

3.3.2 UV Sterilizer (S-50010)

Softened permeate is treated with sterilization system, consisting of special low pressure mercury germicidal lamp. The light emitted from this lamp is concentrated (90%) into the luminous spectrum around 254 nm wavelength and is able to destroy or inactivate microorganisms such as bacteria, viruses, yeasts and moulds. The UV-C light emitted by this lamp penetrates the cells wall of microorganism.

The lamp is immersed, inside the disinfection chamber, in the treating fluid and is separated from it with quartz sleeves, transparent for more than 98% to UV-C rays.



A local switchboard (LP-S-50010) controls the operation.

At the outlet of UV are installed the following instruments:

- Hardness 50-AT-026: high level gives and alarm and high high level opens off-spec valve 50-XV-032 and closes 50-XV-031.
- pH 50-AT-027: high level or low level give and alarm and high high level or low low level open off-spec valve 50-XV-032 and closes 50-XV-031.(No longer in use, pH control and related logics have been disabled)
- Pressure 50-PT-041: gives alarm for high and low pressure.
- Temperature 50-TT-024 only for indication
- Flow rate 50-FT-026: gives alarm for high and low flow.

Figure 8-UV-Sterilizer

The following software information are sent to electrolyser through control system PCS via Modbus:

- Total Hardness 50-AI-026.
- pH 50-AI-027.
- Temperature 50-TI-024.
- Flowrate 50-FI-026.

3.3.3 Caustic Soda Dosage (NO LONGER IN USE)

Caustic soda (2% solution) is continuously dosed downstream the softener, to increase the pH of fresh water up to value of 7 – 7.9 as required by the Electrolyser.

Caustic Soda Dosing Pumps P-50005A/B shall be equipped with an automatic dosing stroke adjustment regulator which allow to regulate the dosage flow.

pH through analyser 50-AT-027 is measured downstream UV system: low level pH and high level pH shall give an alarm, while high high and low low level alarm open off-spec valve 50-XV-032 to discharge the flow to drain and close valve 50-XV-031.

Caustic Soda Dosing shall be fed from Caustic Soda Storage Tank T-50002 equipped with a level transmitter 50-LT-022, which provides an alarm for the refilling requirement (50-LAL-022) and the trip (50-LALL-022) for avoid the dry running of the pumps.

The chemical Storage Tank T-50002 shall be manually re-filled opening the top inspection cover.

Note: Fresh water is not sent to Electrolyzer, but it feeds a second water treatment stage that accept pH values around 6, so the dosage of caustic soda is no longer required)

4 FUNCTIONAL DESCRIPTION / PROCESS CONTROL NARRATIVES

4.1 SEA WATER PRE-TREATMENT SYSTEM

4.1.1 Purpose of the Process Control

The purpose of process control of the Sea Water Pre-Treatment System is to ensure the correct filtration and heating of the stream of sea water entering the package. The Sea Water Coarse Filter A-50003 (see Section 3.1.1) is a self-cleaning filter and provides the first filtration of the inlet sea water stream.

The Electric Heater H-50001 (see Section 3.1.2), heats the sea water up to 10°C and operates in cold time when the sea water temperature entering the system is low.

The Sand Filter S-50001 (see Section 3.1.3) provides a better filtration of the sea water. The Sand Filter requires periodic backwash for cleaning.

The filtered water is stored in the Filtered Water Tank T-50006 and the Backwash Pumps P-50002A/B (one operating and the other stand-by) provide water at required pressure for the Sand Filter backwash.

4.1.2 Description of the Process Operation

A stream of sea water enters the package at the required conditions of 2-5 barg and 2.5 m^3/h.

A small flow of biocide is added to the stream before coarse filtration. The flow of biocide is stopped if valve 50-XV-020 is closed, see Section 4.6.

The stream passes through the shutoff valve 50-XV-020, that is opened during the normal operation of the Sea Water Treatment System and it's closed when the Sea Water Filter is in backwash.

The position of the shutoff valve is indicated by the limit switches 50-XZSH-020 (open) and 50-XZSL-020 (closed).

The pressure of the inlet stream is measured and indicated by pressure transmitter 50-PT-020. An alarm is activated in case of low inlet pressure 50-PAL-020.

Automatic tank refilling sequence

Filter Water Tank T-50006 shall be every time filled from low level to high level set points as per the following automatic sequence:

- Open the inlet shutoff valve 50-XV-020.
- Restart Sea Water Intake Pump P-50001A/B, (signal tag 50-HS-001S "Sea Water Pump start request").
- Start again the Biocide Dosing Pump P-50007A or P-50007B.
- Start the Electric Heater H-50001 and temperature controller 50-TIC-021.
- Seawater Coarse Filter A-50003 and Sand Filter S-50001 are already available and in service, no PLC commands from PLC are needed.

When Tank T-50006 high level threshold is achieved, sequence will proceed with the following steps:

- Stop the electric heater H-50001;
- If 50-TI-020 is >50°C, wait 120 sec for heater cooling;
- Stop Sea Water Intake Pump P-50001 A/B (50-HS-005S stop signal by ROSETTI);

- Stop the Biocide Dosing Pump P-50007A or P-50007B;
- Close the inlet shutoff valve 50-XV-020;

The Sea Water Coarse Filter A-50003 is a self-operating package. A pressure switch starts the self-cleaning operation in case of high differential pressure and activates the rotation of cleaning system while opening the bottom discharge valve to flush out the filtered solid and cleans the filter surface.

A dedicated timer (15-30 minutes or more as frequency and 15 sec as duration of self-cleaning) is provided adjustable on PLC, to start the self-cleaning of Sea Water Coarse Filter.

PLC will send the relevant command to local switchboard LP-A-50003 for self-cleaning activation.

The Sea Water Coarse Filter A-50003 package generates a cumulative alarm output 50-XA-A50003.

The sea water pressure downstream the Sea Water Coarse Filter A-50003 is indicated the pressure gauge 50-PI-048.

The temperature downstream the Electric Heater H-50001 is controlled by 50-TIC-021. The temperature is measured by temperature transmitter 50-TT-021. If the temperature measured by 50-TT-021 is below set point of 12°C (adjustable), the controller 50-TIC-021 increases the power of the electric heater (controlled via SCR). If the temperature measured by 50-TT-021 is above set point the controller 50-TIC-021 decreases the power of the electric heater.

The pressure at Sand Filter S-50001 inlet is indicated by pressure gauge 50-PI-022.

The sea water flowrate at Sand Filter S-50001 inlet is measured and indicated by flow transmitter 50-FT-020. An alarm is activated in case of low or high flowrate, 50-FAL-020 / 50-FAH-020.

General notes:

1) Delay time for low flow alarm shall be longer than 30 sec. Alarm is inhibited during self-cleaning filter backwash
2) Set point of alarms during normal operation are different than during sand filter backwash.

The above flow transmitter 50-FT-020 sends the set point value to flow controller 50-FIC-020, that adjusts the Flow Control Valve 50-FV-020, to divert the exceeding flow rate to the drain and to keep constant flow rate to Electric Heater H-50001 and Sand Filter S-50001.

If the measured flowrate value is higher than set point 2.5 m^3/h, then Flow Control Valve 50-FCV-020 is increased opened and vice-versa.

Pressure is measured at inlet and outlet Sand Filter S-50001 by pressure transmitters 50-PT-050 and 50-PT-051.

The differential pressure across Sand Filter S-50001 is computed by control system with the following formula:

[50-PDI-052] = [50-PI-050] - [50-PI-051].

An alarm is activated in case of high differential pressure 50-PDI-052.

Sand filter backwash sequence

The Sand Filter S-50001 is a self-operating package for automatic service and backwashing sequences.

The backwash operation is only performed by PLC control, based on computed differential pressure 50-PDI-052 above a set point of 0.7 bar (adjustable) or based on elapsed service time (settable). Local settings on local switchboard

LP-S-50001 are disable for backwash activation.

Sand Filter S-50001 backwash will be as per following automatic sequence:

- Check the T-50006 level. Wait for high level > 80% to have enough water holdup for backwash; otherwise the Sand Filter is kept in operation until high level is achieved in the tank;
- Automatic tank refilling sequence is inhibited
- Stop the electric heater H-50001;
- If 50-TI-020 is >50°C, wait 120 sec for heater cooling;
- Stop the Sea Water Intake Pump P-50001A/B, (50-HS-005S stop signal by ROSETTI).
- Close the inlet shutoff valve 50-XV-020. In case of valve position failure, the backwash sequence cannot proceed and an alarm is displayed;
- Start the Sand Filter backwash sequence, via PLC command signal to local switchboard LP-S-50001.
- Start the Backwash Pump P-50002A (or P-50002B);
- Differential pressure high alarm from 50-PDI-052 is disabled during backwash (50-PDI-052 is high during sand filter backwash).
- Pressure inlet sand filter is measured by pressure transmitter 50-PT-050
- Flow rate inlet sand filter is measured by flow transmitter 50-FT-020, with another set-point alarms of low or high flowrate, 50-FAL-020 / 50-FAH-020
- Wait for complete backwash cycle (timer 28min, adjustable);
- Inhibit the automatic opening
- Stop the Backwash Pump P-50002A (or P-50002B)
- Automatic tank refilling sequence is restarted once T-50006 low level is reached

The filtered water is collected in the Filtered Water Tank T-50006. The level of this tank is measured and indicated by level transmitter 50-LT-020.

The following alarms are activated in case of following thresholds:

- Low level or very low level, 50-LAL-020, 50-LALL-020
- High level or very high level 50-LAH-020, 50-LAHH-020

4.1.3 Safeguarding Intent

The main safeguarding of the system are:

- Prevent overheating of water downstream Electric Heater H-50001
- Prevent heater H-50001 element's overheating and damage

- Prevent dry running of Backwash Pumps P-50002A/B and SW Booster Pumps P-50003A/B
- Prevent high level of chlorides in fresh water.

In order to prevent overheating of water downstream H-50001and high level of chlorides in fresh water, temperature transmitter 50-TT-022 measures the seawater temperature and the following events will happen:

- In case of temperature > 25 °C, an alarm 50-TIH-022 is displayed and interlock I-020 is activated to open off-spec valve 50-XV-026, close forward valve 50-XV-025;
- For high temperature > 40° C an alarm 50-TIHH-022 is displayed and interlock I-001 is activated to stop Electric Heater H-50001.

In order to prevent Heater H-50001 element's overheating, a temperature element 50-TE-020 is embedded in one of the heater's element. In case of high high temperature (> 110°C) 50-TSHH-020 interlock I-011 trips the electric heater and very high temperature alarm is alerted.

In order to prevent dry running of pumps P-50002A/B and P-50003A/B, Filtered Water Tank T-50006 level is monitored by 50-LT-020, in case of low low level 50-LILL-20 activates interlock I-002 that stops pumps P-50002A/B, P-50003A/B and 50004A/B , and Antiscalant Dosing Pump P-50006A/B.

4.1.4 Start-up of the Section

At startup the following automatic valves shall be closed:

- Main inlet valve 50-XV-020;
- Drains valves 50-XV-033, 50-XV-034, 50-XV-035

Start Sea Water Pump P-50001 A/B (tag signal 50-HS-001S by ROSETTI), then valve 50-XV-020 is then opened to allow the flow of seawater.

Once the inlet flowrate is established and is controlled (check 50-FT-020 and adjustment 50-FIC-020) and the feed pressure is at minimum 1.5 barg switch on the Electric Heater H-50001 and start control loop 50-TIC-021.

Coarse Filter A-50003 and Sand Filter are already for service by means of logic inside the local switchboards LP-A-50003, LP-S-50001 (PLC controls only their start backwash sequence).

Biocide Dosing Pump P-50007A or P-50007B is started.

Adjust manual valve MV-509 (outlet of sand filter) to have a back pressure of 1.3 barg at the outlet of Sea Water Coarse Filter A-50003 by reading pressure gauge 50-PI-048 and a flowrate of 2.5 m^3/h. Re-check that the feed pressure is 1.5 barg.

Once the above manual valve MV-509 is set adjusted during only first start-up, not continuously and no need any operator intervention.

Check also the proper operation of the air vent valve MV-635, at only first start up. This valve shall only release the entrapped air and then be re-closed and not remaining always opened.

4.1.5 Normal Process Shut down of the Section

In case of normal shutdown of the section, turn off the control loop 50-TIC-021 and the Electric Heater H-50001. After 5 minutes demand to DCS to stop the Sea Water Pump P-50001 A/B (tag signal 50-HS-005S by ROSETTI) and stop Biocide Dosing Pump P-50007A or P-50007B, close inlet shutoff valve 50-XV-020.

4.1.6 Equipment Failure or Fault

The backwash pumps (P-50002A/B) operate in a redundant configuration to ensure process continuity. If one of the pumps fails, the standby pump will automatically start when the sand filter backwash is requested. An alarm will be triggered to indicate the fault in the affected pump.

If both pumps are in fault, an alarm will be generated, and the backwash cycle will either not be performed or will be interrupted. However, the system will continue to operate normally.

Pump switching also occurs based on operating hours: when a backwash is requested, the pump with fewer operating hours will start to ensure balanced usage.

Coarse Filter S-50003 will send a common fault alarm (50-XA-50003) to PLC, in case of failure.

The self-cleaning filter is not considered critical for system operation. However, if filtration is insufficient, it may reduce the availability of filtered water. If the water level drops too low, the SWRO Lines A/B will automatically shut down for protection.

Also Sand Filter S-50001 will send a common fault alarm (50-XA-50001) to PLC, in case of automatic backwash sequence failure.

Each automatic valve failure blocks the involved automatic sequence such as tank filling, emptying, sand filter backwash.

Each field instrument fault is transmitted to PLC for diagnostic target with relevant displayed alarm.

4.2 SEA WATER REVERSE OSMOSIS SYSTEM

4.2.1 Purpose of the Process Control

The purpose of process control of the Sea Water Reverse Osmosis System is to control the sea water correct parameters (mainly pressure and flowrate) at SWRO module inlet and to the outlet fresh water characteristics and flowrate.

The Sea Water Reverse Osmosis System is composed by 2x100% SWRO trains, one operating and the other in stand-by.

In normal operation the switchover of the lines is periodically to keep all the lines ready for operation.

The Sea Water Booster Pump P-50003A (P-50003B) pumps water from Filtered Water Tank T-50006 through the 1st and 2nd Cartridge Filters S-50002A (S-50002B) and S-50003A (S-50003B) and to the Sea Water High Pressure Pump P-50004A (P-50004B).

The Sea Water High Pressure Pump P-50004A (P-50004B) is controlled to ensure the correct inlet pressure at SWRO membranes inlet.

The produced fresh water passes through a conductivity analyzer and then is collected in the Fresh Water Tank T-50008 while the SWRO membrane reject (brine) is discharged.

4.2.2 Description of the Process Operation

The seawater coming from Filtered Water Tank T-50006 passes through the conductivity analyzer 50-AT-023. Alarm is activated in case of high conductivity, 50-AAH-023.

A small flow of antiscalant is added to the stream before filtration. The flow of antiscalant is stopped if both valves 50-XV-021 and 50-XV-022 are closed (see Section 4.5) and both SW Booster Pump P-50003A/B are stopped.

There are 2x100% lines of SWRO in parallel, the selection of the operating line is made with shutoff valves 50-XV-021 and 50-XV-022, one is open and the other is closed.

The position of valve 50-XV-021 is indicated by the limit switches 50-XZSH-021 (open) and 50-XZSL-021 (closed).

The position of valve 50-XV-022 is indicated by the limit switches 50-XZSH-022 (open) and 50-XZSL-022 (closed).

Automatic shutoff valves are installed on the fresh water flushing line on the SW Booster Pumps P-50003A/B suctions: 50-XV-023 and 50-XV-024.

The position of valve 50-XV-023 is indicated by the limit switches 50-XZSH-023 (open) and 50-XZSL-023 (closed).

The position of valve 50-XV-024 is indicated by the limit switches 50-XZSH-024 (open) and 50-XZSL-024 (closed).

50-XV-023 and 50XV-024 are closed during the system normal operation.

SW Booster Pump P-50003A (P-50003B) feeds water to the Cartridge Filters S-50002A (S-50002B) and S-50003A (S-50003B).

The pressure at pump discharge is measured by 50-PT-025 (50-PT-027). Alarm is activated in case of low pressure, 50-PAL-025 (50-PAL-027).

Flowrate at pump's discharge is measured by 50-FT-022 (50-FT-023). Alarm is activated in case of low or high flowrate, 50-FAL-022 (50-FAL-023), 50-FAH-022 (50-FAH-023).

The pressure downstream Cartridge Filters S-50002A and S-50003A (S-50002B and S-50003B) is measured by 50-PT-026 (50-PT-028). Alarm is activated in case of low pressure, 50-PAL-026 (50-PAL-028).

Differential pressure across filters 50002A and S-50003A (S-50002B and S-50003B) is calculated by control system with the following formula:

[50-PDI-024] = [50-PI-025] - [50-PI-026]

([50-PDI-029] = [50-PI-027] – [50-PI-028])

Alarm is activated in case of high differential pressure, 50-PDAH-024 (50-PDAH-029) >2bar.

High Pressure Pump P-50004A (P-50004B) delivers high pressure fluid to SWRO membranes.

Pressure at pump's discharge is measured by 50-PT-030 (50-PT-032) and controlled by cascade control loop 50-PIC-030 (50-PIC-032) as slave controller and 50-FIC-024 as master controller.

If the pressure measured by 50-PT-030 (50-PT-032) is below set point (60 barg - adjustable), 50-PIC-030 (50-PIC-032) increases the rotation speed of pump P-50004A (P-50004B) by means frequency changing of the variable frequency drive.

If the pressure measured by 50-PT-030 (50-PT-032) is above set point, 50-PIC-030 (50-PIC-032) decreases the rotation speed of pump P-50004A (P-50004B), by means control of variable frequency drive.

Alarm is activated in case of high and low pressure, 50-PAH-030 (50-PAH-032) 50-PAL-030 (50-PAL-032).

The flowrate of fresh water at common SWRO membranes outlet is measured by 50-FT-024. Alarm is activated in case of low flow and in case of high flow, 50-FAL-024 and 50-FAH-024.

To guarantee the permeate flow rate production all the time, the master controller 50-FIC-024 overrides the pressure set point of 50-PIC-030 (50-PIC-032).

In case of measured flow rate is lower than set point value, then 50-FIC-024 will command to increase the actual feed pressure and consequent the higher rotation speed of the pump P-50004A (P-50004B) and vice-versa.

Pressure at brine outlet of SWRO membranes is measured by pressure gauge 50-PI-031 (50-PI-033).

Automatic shutoff valves are installed on the SWRO membrane brine discharge line: 50-XV-027 and 50-XV-030.

The position of valve 50-XV-027 is indicated by the limit switches 50-XZSH-027 (open) and 50-XZSL-027 (closed).

The position of valve 50-XV-030 is indicated by the limit switches 50-XZSH-030 (open) and 50-XZSL-030 (closed).

50-XV-027 and 50XV-030 are closed during normal system operation.

The seawater coming from both lines of SWRO membranes passes through the conductivity analyzer 50-AT-024 and then flows to Fresh Water Tank T-50008. Alarm is activated in case of high conductivity, 50-AAH-024.

Automatic shutoff valve 50-XV-025 is installed on the freshwater line to Fresh Water Tank T-50008.

The position of valve 50-XV-025 is indicated by the limit switches 50-XZSH-025 (open) and 50-XZSL-025 (closed).

Automatic shutoff valve 50-XV-026 is installed on the fresh water line to drain (off-spec).

The position of valve 50-XV-026 is indicated by the limit switches 50-XZSH-026 (open) and 50-XZSL-026 (closed).

4.2.3 Safeguarding Intent

The main safeguarding of the system are:

- Prevent cavitation at suction side of SW Booster Pump P-50003A (P-50003B)
- Prevent any seawater gravity flow contamination to Tank T-50008;
- Prevent overpressure at suction side of HP Pump P-50004A (P-50004B);
- Prevent overpressure at SWRO membranes A-50007A (A-50007B) inlet;
- Prevent overpressure at SWRO membranes A-50007A (A-50007B) permeate outlet

- Prevent very low pressure at suction side of HP Pump P-50004A (P-50004B);
- Prevent off-spec fresh water to Fresh Water Tank T-50008.

To avoid cavitation at suction side of SW Booster Pumps:

- An Interlock I-025 stops or blocks the SW Booster Pump P-50003A, if automatic valves 50-XV-021 and 50-XV-023 are simultaneously closed
- An Interlock I-026 stops or blocks the SW Booster Pump P-50003B, if automatic valves 50-XV-022 and 50-XV-024 are simultaneously closed

To exclude any seawater flow gravity contamination to Fresh Water Tank T-50008, the following interlocks will be foreseen:

- An Interlock I-021 closes fresh water inlet automatic valve 50-X-023, if the seawater feed automatic valve 50-XV-021 is open and vice-versa (closes automatic valve 50-X-021 if automatic valve 50-X-023 is open)
- An Interlock I-023 closes fresh water inlet automatic valve 50-X-024, if the seawater feed automatic valve 50-XV-022 is open and vice-versa (closes automatic valve 50-X-022 if automatic valve 50-X-024 is open)

In order to prevent overpressure of suction side of HP Pump P-50004A, a pressure safety valve 50-PSV-034 with set point of 4 barg is installed at pump inlet.

In order to prevent overpressure at suction side of HP Pump P-50004B, a pressure safety valve 50-PSV-037 with set point of 4 barg is installed at pump inlet.

In order to prevent overpressure of SWRO membranes A-50007A (A-50007B) a pressure safety valve

50-PSV-035 (50-PSV-038) with set point of 65 barg is installed at membranes inlet, displaying the relevant high pressure alarm. 50-PAH-030 (50-PAH-032)

In case of very low pressure at suction of HP Pump P-50004A, an alarm is advice 50-PALL-026, that activates interlock I-013 to stop the HP Pump.

In case of very low pressure at suction side of HP Pump P-50004B, an alarm is advise 50-PALL-028, that activates interlock I-014 to stop the HP Pump.

In order to prevent overpressure of SWRO membranes A-50007A (A-50007B) a pressure safety valve

50-PSV-036 (50-PSV-039) with set point of 6 barg is installed at permeate outlet.

In order to prevent off-spec fresh water flowing into the Fresh Water Tank T-50008:

- In case of high high conductivity alarm 50-AIHH-024, interlock I-003 closes the shutoff valve to Fresh Water Tank T-50008, 50-XV-025 and open off-spec drain valve 50-XV-026.
- In case of temperature > 22 °C, an alarm 50-TIH-022 is displayed and interlock I-020 is activated to open off-spec valve 50-XV-026, close forward valve 50-XV-025, to avoid any high chlorides in the fresh water, due to expected low membrane salt rejection.

4.2.4 Start-up of the Section

- Open the inlet shutoff valve of the selected line, 50-XV-021 or 50-XV-022;
- Open the off-spec valve 50-XV-026;
- SW Booster Pumps P-50003A or P-50003B shall not start if PLC recognizes the following abnormal conditions:
  - ✓ Simultaneous closure of 50-XV-025 and 50-XV-026 by limit switches signal feedback.
  - ✓ Failure opening of inlet shutoff valve of the selected line 50-XV-021 or 50-XV-022; by means limit switches signal feedback.
  - ✓ Automatic flush inlet valves 50-HV-023 and 50-HV-024 remained in open position, during the production period
- Start the SW Booster Pump P-50003A or P-50003B, when the water level into Fresh Water Tank T-50008 is low, in case of low level into Filtered Water Tank T-50006 is achieved and no signal inhibition is activated by very low level threshold;
- One Antiscalant Dosing Pump P-50006A or P-50006B shall be started;
- Check properly operation of air vent valves MV-640 and MV-641 (at the first start up);
- When the pressure at downstream Cartridge Filters measured by 50-PT-026 or 50-PT-028 is higher than 2 barg and stable, it is allowed to start one High Pressure Pump P-50004A/B;
- Start slowly by VFD ramp the High Pressure Pump P-50004A or P-50004B;
- Gradually throttle manual valve MV-550 or MV-558 until permeate flowrate, measured by 50-FT-024, is 0.8 m^3/h and in same time the 50-PIC-030 or 50-PIC-032 will adjust the feed pressure up to set-point value, changing the pump speed rotation. This manual adjustment is required only for first start-up and after no need operator intervention;
- 50-FIC-024 shall re-adjust the set-point value from 50-PIC-030 or 50-PIC-032 if the permeate flow rate is not kept constant and especially expected after several start-up, not at first start-up period;
- Check the properly operation of air vent valves MV-642 and MV-645 (at the first start up);
- Check the flow and pressure for correct parameters readings: 50-PT-025/026/030, 50-PI-031 and 50-FT-022/024 or 50-PT-027/028/032, 50-PI-033 and 50-FT-023/024;
- Check the conductivity analyzer 50-AI-024: if the value is below the maximum allowable value, then it's possible to open the valve 50-XV-025 to the Fresh Water Tank T-50008 and close the off-spec valve 50-XV-026.

During the production, SWRO Line A-50007A or A-50007B will be normal stopped when high level into Fresh Water Tank T-50008 is achieved (set point expected at 80%).

4.2.5 Normal Process Shut down of the Section

The sequence for normal shutdown of SWRO Line A-50007A or A-50007B is as per following positions:

- Stop Antiscalant Dosing Pump P-50006A or P-50006B (if Both SWRO Lines A/B are stopped);

- Open brine drain valve 50-XV-027 or 50-XV-030 of SWRO Line A/B to be shut down;
- Close the fresh water valve 50-XV-025 and open off-spec valve 50-XV-026;
- High Pressure Pump P-50004A or P-50004B must be slowly stopped by VFD deceleration ramp;
- Stop SW Booster Pump P-50003A or P-50003B;
- Close the filtered water inlet valve 50-XV-021 or 50-XV-022;
- Wait period 1 - 3 h or longer (timer adjustable) before proceeding to next flushing sequence. If DCS client's signal requires again fresh water within waiting period, then the previous stopped SWRO Line A/B shall be again ready for service and must not be flushed, otherwise the flushing sequence is activated.

4.2.6 Automatic Flushing of the Section

To avoid scaling and corrosion issues to the installed equipment and SWRO membrane, the long stopped SWRO Line A/B must be mandatorily flushed by fresh water.

Fresh water from tank T-50008 flows in the SWRO Line A-50007A/B to displace the brine through the brine outlet to the drain.

When automatic flushing is activated, the following sequence will be as per below described:

- Check if the water level inside the Fresh Water Tank T-50008 is approximately 80%, otherwise the SWRO Lines A/B shall be kept in operation until to achieve high level threshold into Tank T-50008;
- Very low level stop the SW Booster pump P-50003A or P-50003/B in case of the automatic flushing sequence;
- Fresh Water Pumps P-50009A or P-50009B and Caustic Soda Dosing Pumps P-50005A orP-50005 B was already stopped;
- UV lamp of Sterilizer S-50010 was already switch-off and stopped any new automatic analysis cycle of Total Hardness Analyzer 50-AT-025;
- Open automatic flushing inlet valves 50-XV-023 (SWRO Line A), or 50-XV-024 (SWRO Line B);
- Only one brine drain valve 50-XV-027 or 50-XV-030 of the SWRO Line in stand-by must be closed;
- Start the SW Booster Pump P-50003A or P-50003B;
- High Pressure Pump P-50004A or P-50004B is slowly started by VFD acceleration ramp;
- Wait for 10-15 minutes for a complete flushing

Then the automatic flushing of SWRO Line A or B shall be stopped according to following sequence:

- Let brine drain valve 50-XV-027 or 50-XV-030 of SWRO Line A/B in open position;
- High Pressure Pump P-50004A or P-50004B must be slowly stopped by means VFD deceleration ramp;
- Stop SW Booster Pump P-50003A or P-50003B;

- Close the fresh water inlet valve 50-XV-023 or 50-XV-024;
- Close the brine drain valve 50-XV-027 or 50-XV-030.

At next fresh water production, the last flushed SWRO Line will be in stand-by and the other SWRO Line will be switched from stand-by to service or ready for the running. Equipment Failure or Fault

If one of the SWRO line pumps P-50003A/B or P-50004A/B is in fault, the affected line will not start or will shut down, and no flushing will be performed. Alarms will be displayed accordingly.

Only the SWRO line with operational pumps will remain available, or it will start in place of the stopped one due to a fault. If both SWRO lines are unavailable, the pre-treatment and fresh water sections will remain active, provided that the level transmitters in the storage tanks are functional and providing reliable measurements.

If any fault happens due to dedicated field instrumentation for an SWRO Line A-50007A/B, this affected line must shut down and generate a fault alarm.

This scenario includes the following instruments failures:

- Flow transmitters: 50-FT-022 or 50-FT-023
- Pressure transmitters: 50-PT-025 or 50-PT-026 or 50-PT-027 or 50-PT-028 or 50-PT-030 or 50-PT-032.

If a SWRO Line A-50007A/B has instrumentation in fault and was not yet started, the PLC will not authorize its startup. However, if the line was already in operation when the failure occurred, the system must immediately stop the line and initiate a normal stop procedure as per section 4.2.5.

If below conditions are met, the flushing procedure as per section 4.2.6 will activate, otherwise the sequence is disable.

- Pressure transmitter 50-PT-026 or 50-PT-028 is healthy
- Level transmitter 50-LT-021 is healthy

The following field instruments and analyzers are critical for both SWRO Lines A-50007A/B operation and for fresh water production:

- Flow transmitter 50-FT-024 (permeate flow measurement)
- Conductivity transmitter 50-AT-024 (permeate conductivity measurement)
- Level transmitter 50-LT-020 (filtered water tank T-50006)
- Permeate conductivity analyzer 50-AT-024
- Fresh water hardness analyzer 50-AT-026
- Fresh water pH analyzer 50-AT-027 (No longer involved)

Any fault happens due to the above listed instruments, both SWRO Lines A/B must be stopped or prevented from starting, while the automatic flushing will still be alone allowed both SWRO Lines A/B.

Each field instrument fault is transmitted to PLC for diagnostic target with relevant displayed alarm.

In case of any automatic switching valves failure, (feedback limits switch signals), the relevant involved automatic sequence is immediately interrupted, SW Booster Pump and High Pressure Pump are stopped and advise alarm is displayed.

4.3 FRESH WATER STORAGE AND POST-TREATMENT

4.3.1 Purpose of the Process Control

The purpose of the process control of the Fresh Water Storage and Post-Treatment System is to collect the produced fresh water, pump it to the user at battery limits while performing the final treatments and check on the water quality.

The fresh water flows from the Fresh Water Tank T-50008 to the Fresh Water Pumps P-50009A/B (one operating and the other stand-by).

The pump discharge flows into a softening filter, an UV Sterilizer, it's added with a sodium hydroxide solution to control the pH (caustic dosage for pH control has been disabled) and then goes to the battery limit after a series of transmitters and analyzers to monitor the following water physical and chemical parameters:

- Total Hardness
- pH (pH is only monitored)
- Temperature
- Pressures at upstream and downstream Softener Filter and UV Sterilizer
- Flowrate

A dedicated shutoff valve discharges the fresh water to the drain in case of off-spec.

4.3.2 Description of the Process Operation

The Fresh Water Tank T-50008 shall be filled every time from low level to high level set points, starting one SWRO Line A or B.

The level in the Fresh Water Tank T-50008 is measured by level transmitter 50-LT-021, providing the following controls signals to PLC:

- An alarm is activated in case of low low level, 50-LLAH-021: trips Fresh Water Pumps P-50009A or P-50009B and SW Booster Pumps P-50003A or P-50003B in case of the automatic flushing of SWRO Lines A or B
- An alarm is activated in case of low level, 50-LAL-021: PLC starts the SW Booster Pumps P-50003A/B and HP Pressure Pumps P-50004A/B for the Tank Refilling and fresh water production
- An alarm is activated in case of high level 50-LAH-021: PLC stops the SW Booster Pump P-50003A or P-50003B and HP Pump P-50004A or P-50004B

  Elapsed waiting period 1 – 3 h and if other fresh water is not requested by DCS, the automatic flushing sequence of previous running SWRO Line A/B will be started,

- An alarm is activated in case of high high level 50-LAHH-021: PLC stops the SW Booster Pump and HP Pressure Pump as additional safety control guard P-50003A or P-50003B and P-50004A or P-5000B.

Fresh Water Pump P-50009A or P-50009B is started when low level setpoint achieved and PLC receives the relevant DCS's start command signal.

The same Fresh Water Pump P-50009A or P-50009B is stopped when PLC receives the relevant DCS's stop command signal or in case of very low level into a Tank T-50008.

The new sequence implemented during commissioning activities for start and stop the feeding of fresh water to the next package is described below (Ovivo Package is the package next to the Water treatment package supply by PSC):

1) The production On/Off 50-XV-031 is opened and the Off spec On/Off valve 50-XV-032 is closed
2) On/Off Valve to Ovivo Package, tag 1EBV1(not installed in PSC package) is opened and feedback open signal is sent to PLC panel 50-LP-001

When the above configuration is achieved Pump P-50009A or P-50009B is started and the sequence continue with the following steps

3) Fresh water tank recycle valve 50-XV-036 is opened
4) Pump 1ROP1 installed in the Ovivo Package is started and the running signal is sent to PLC panel 50-LP-001
5) After 25 sec of delay the On/Off recycle valve 50-XV-036 is closed

With point nr.5 the sequence is complete and Ovivio package is correctly fed with fresh water from the Water Treatment Package.

The stop sequence is described below:

1) The pump 1ROP1 installed in the Ovivo Package is stopped and the stop (not running) signal is sent to PLC panel 50-LP-001
2) Pump P-50009A or P-50009B is stopped
3) On/Off Valve to Ovivo Package, tag 1EBV1(not installed in PSC package) is closed and feedback not open signal is sent to PLC panel 50-LP-001
4) The production On/Off 50-XV-031 is closed

The pressure downstream the Fresh Water Pumps P-50009A/B is measured by pressure transmitter 50-PT-047. An alarm is activated in case of high or low pressure, 50-PAH-047, 50-PAL-047.

The Softening Filter S-50004 is a package and includes all the equipment for regeneration. Regeneration is activated from PLC control system on the basis of the totalized flow or off-spec residual hardness concentration.

When the softener regeneration is activated by PLC and sends the command to the local switchboard

LP-S-50004 to perform the resin backwashing by fresh water and then to transfer the brine solution hydraulically to resin. The brine solution not consumed by the resin is discharged to the drain. As a last sequence step, the regenerated resin is fresh water rinsed again to displace the exceeding brine solution.

During the regeneration sequence, a status indication is displayed to HMI and the Fresh Water Pump

P-50009A or P-50009B is in service.

To reduce the service water consumption and instantaneous flow for the resin regeneration, at the upstream the Softening Filter S-50004, the Automatic On/Off Valve 50-XV-036 is opened to recycle the exceeding flow to back the Fresh Water Storage Tank T-50008.

At the end of the regeneration, the Softening Filter S-50004 returns in service and the above Automatic On/Off Valve 50-XV-036 is reclosed.

The UV Sterilizer S-50010 ensures final sterilization of the fresh water.

Fresh Water outlet temperature is measured by temperature transmitter 50-TT-024, without any alarms.

Fresh Water outlet pressure is measured by pressure transmitter 50-PT-041. An alarm is activated in case of high and low pressure, 50-PAH-041 and 50-PAL-041.

Fresh Water outlet total hardness is measured by analyzer 50-AT-026. An alarm is activated in case of high hardness, 50-AAH-026.

Fresh Water outlet pH is measured by analyzer 50-AT-027 and controlled by pH controller 50-AIC-027. An alarm is activated in case of high and low pH, 50-AAH-027 and 50-AAL-027.

Fresh Water outlet flow is measured and totalized by 50-FT-026. Alarm is activated in case of high and low flow, 50-FAH-026 and 50-FAL-026.

pH controller 50-AIC-027 automatically controls the flowrate sodium hydroxide dosing pump P-50005A/B, basing to gap annulling between measured and set-point values. (pH control and caustic soda injection has been disabled, currently the pH parameter is only monitored)

Automatic shutoff valve 50-XV-031 is installed on the fresh water line to battery limit.

The position of valve 50-XV-031 is indicated by the limit switches 50-XZSH-031 (open) and 50-XZSL-031 (closed).

Automatic shutoff valve 50-XV-032 is installed on the fresh water line to drain (off-spec).

The position of valve 50-XV-032 is indicated by the limit switches 50-XZSH-032 (open) and 50-XZSL-032 (closed).

4.3.3 Safeguarding Intent

The main safeguarding of the system includes the following safeguard protection:

- Prevent dry running of Fresh Water Pumps P-50009A/B and pumps SW Booster Pumps P-50003A/B;
- Prevent off-spec fresh water (high pH) to battery limit;(alarm disabled no longer required)
- Prevent off-spec fresh water (low pH) to battery limit; (alarm disabled no longer required)
- Prevent off-spec fresh water (high total hardness) to battery limit;

- Prevent Fresh Water Pumps P-50009A and P-50009B running simultaneously;
- Prevent overpressure and pump shut-off condition;
- Prevent Fresh Water Tank T-50008 overfilling.
- Prevent UV Lamp Sterilizer lifetime

To prevent dry running, in case of low low level of Fresh Water Tank T-50008, 50-LILL-021 activates interlock I-004 that stops Fresh Water Pumps P-50009A/B.

To prevent off spec (high pH) fresh water to battery limit, in case of high high pH 50-AIHH-027, interlock I-006 closes shutoff valve to battery limit 50-XV-031 and opens off-spec valve 50-XV-032.

To prevent off spec (low pH) fresh water to battery limit, in case of low low pH 50-AILL-027, interlock I-007 closes shutoff valve to battery limit 50-XV-031 and opens off-spec valve 50-XV-032.

To prevent off spec (high total hardness) fresh water to battery limit, in case of high high total hardness 50-AIHH-026, interlock I-005 closes shutoff valve to battery limit 50-XV-031 and opens off-spec valve 50-XV-032.

To prevent pumps P-50009A and P-50009B running simultaneously, interlock I-018 stops pump P-50009 if P-50009B is running and interlock I-019 stops pump P-50009B if P-50009A is running.

In order to prevent overpressure and shut-off condition of HP Pump P-50009A or P-50009B, a pressure safety valve 50-PSV-053 with set point of 6 barg is installed at common pump delivery and high pressure alarms 50-PAH-047 and 50-PAH-041 are triggered.

To extend the UV Lamp lifetime, command to the device is given only when fresh water pumps P-50009A/B are running.

4.3.4 Start-up of the Section

At startup the valves 50-XV-031/032 are closed.

- Open the off-spec valve 50-XV-032;
- If PLC recognizes the simultaneous closure of 50-XV-032 and 50-XV-031 by limit switches, Fresh Water Pump P-50009A or P-50009B shall not start;
- Start the Fresh Water Pump P-50009A or P-50009B;
- Check the flowrate, temperature and pressure indicator for correct parameters readings: 50-FT-026, 50-PT-041 and 50-TT-024;
- Caustic Soda Dosing Pump P-50005A or P-50005B is started (disabled no longer required)
- Switch on the UV Sterilizer Lamp S-50010;

- Start the total hardness analyzer 50-AI-026 and check its value and check pH analyzer 50-AI-027: if the value of total hardness is below the maximum allowable value and the value of pH is inside the acceptable range, then it's possible to open the valve 50-XV-031 and close the off-spec valve 50-XV-032.

  Total Hardness Analyzer 50-AT-026 must be in service, as soon as Fresh Water Pump P-50009A or P-50009B running and correct pressure measured by 50-PT-041. (Expected water analysis cycle is every 2 h interval and a few minutes for test analysis result).

  The water analysis done by the analyzer cannot start when Fresh Water Pump P-50009A or P-50009B is stopped. Its relevant analysis cycle timer shall be reset.
- Check the proper operation of air vent valves MV-652, (requested only at first start-up)

4.3.5 Normal Process Shut down of the Section

- Switch-off the UV Sterilizer Lamp S-50010;
- Stop the Fresh Water Pump P-50009A or P-50009B on DCS's command request or in case of very low level inside Tank T-50008;
- Stop Caustic Soda Dosing Pump P-50005A or P-50005B; (Caustic Soda dosing pumps are currently disabled)
- Total Hardness Analyzer 50-AT-026 must stop the automatic cycle water analysis
- Close fresh water valve 50-XV-031

The Softening Filter S-50004 regeneration is scheduled during normal shutdown and without fresh water production request from DCS, as per following sequence

- Check if totalized flow is above 20 - 40 m^3 (adjustable) or AT-026 high alarm is activated, then proceed with Softening Filter regeneration.
- Check if the high level of fresh water inside the Fresh Water Tank T-50008 is active; otherwise, the Softener Filter regeneration is postponed until high level is achieved;
- Open off-spec valve 50-XV-032 and close the fresh water valve 50-XV-031;
- Open exceeding recycle flow valve 50-XV-036 to reduce the feed pressure;
- Total Hardness Analyzer 50-AT-026 must stop the automatic cycle water analysis;
- Start the Fresh Water Pump P-50009A or P-50009B;
- PLC send a command to local switchboard LP-S-0004, to start the softener filter regeneration sequence;
- Fresh water from tank T-50008 flows in the Softening Filter S-50004 to perform regeneration;
- After 45 minutes (adjustable) the regeneration is complete;
- The regenerated Softener Filter is available for service;
- Close exceeding recycle flow valve 50-XV-036;

- Stop Fresh Water Pump P-50009A or P-50009B;
- The previous totalized volume shall be reset and re-counted;

4.3.6 Equipment Failure or Fault

In case of one Fresh Water Pump P-50009A/B failure, the other stand-by pump will be available for the operation or started on DCS's demand and relevant alarm will be displayed.

Each automatic valve failure blocks the involved automatic sequence such as tank filling, emptying, Softening Filter regeneration.

Each field instrument fault is transmitted to PLC for diagnostic target with relevant displayed alarm.

In case of Softener Filter regeneration failure, an alarm fault will be displayed to local switchboard LP-S-50004.

4.4 CAUSTIC SODA DOSING SYSTEM (CURRENTLY DISABLED AND NO MORE REQUIRED)

4.4.1 Purpose of the Process Control

The purpose of the process control of the Caustic Soda Dosing System is to store and dose sodium hydroxide for pH correction of the fresh water at package outlet.

Sodium Hydroxide solution (from 1 % to 5% based on the sea water characteristic and sodium hydroxide consumption) is stored in Caustic Soda Dosing Tank T-50002 and dosed by Caustic Soda Dosing Pumps P-50002A/B (one operating and the other in stand-by).

4.4.2 Description of the Process Operation

The level of Sodium Hydroxide tank T-50002 is measured by 50-LT-022. Alarm is activated in case of low level, 50-LAL-022.

Sodium Hydroxide from T-50002 is dosed by Caustic Soda Dosing Pumps P-50005A (P-50005B) to fresh water pipe downstream Softening Filter S-50004.

P-50005A (P-50005B) dosing speed is linked to operation of Fresh Water Pumps and dosing speed is automatically controlled by 50-AIC-027, comparing the measured value with set point value (7.5 adjustable).

Available range is between pH 7.1 to 7.9.

Pressure downstream P-50005A/B is indicated by pressure gauge 50-PI-042.

4.4.3 Safeguarding Intent

The main safeguarding of the system is:

- Prevent dry running of pumps P-50005A/B.
- Prevent overdosage of chemicals.

In case of low low level of tank T-50002, 50-LALL-022, interlock I-008 stops pumps P-50005A/B.

Dosing pump start/stop is linked to Fresh Water Pump P-50009A/B running.

Fault alarm of pH analyser is displayed in case of instrument failure and dosage control is automatically interrupted.

4.4.4 Start-up of the Section

Check if level in T-50002 is above minimum level and start dosing pump P-50005A or P-50005B.

4.4.5 Normal Process Shut down of the Section

Stop Caustic Soda Dosing Pumps P-50005A or P-50005B.

5.2.6 Equipment Failure or Fault

The stand-by pump will be automatically switched in service, in case of not availability or any failure of selected operating pump.

If level instrument is in fault, the Caustic Dosing Pump will be automatically stopped and alarm will be displayed to PLC

4.5 ANTISCALANT DOSING SYSTEM

4.5.1 Purpose of the Process Control

The purpose of the process control of the Antiscalant Dosing System is to store and dose antiscalant agent upstream the SWRO system (at T-50006 outlet to SW Booster Pumps P-50003A/B).

Antiscalant is stored in Antiscalant Dosing Tank T-50003 tank and dosed by dosing pumps Antiscalant Dosing Pumps P-50006A/B (one operating and the other in stand-by).

4.5.2 Description of the Process Operation

The level of Antiscalant tank T-50003 is measured by 50-LT-023. Alarm is activated in case of low level, 50-LAL-023.

Antiscalant from T-50003 is dosed by Antiscalant Dosing Pumps P-50006A (P-50006B) at Filtered Water Tank T-50006 outlet to SW Booster Pumps P-50003A/B and linked to these pumps operation to produce fresh water.

Antiscalant Dosing Pump P-50006A (P-50006B) dosing speed is fixed and pre-set during commissioning.

Pressure downstream P-50006A/B is indicated by pressure gauge 50-PI-043.

4.5.3 Safeguarding Intent

The main safeguarding of the system are:

- Prevent dry running of pumps Antiscalant Dosing Pumps P-50006A/B.
- Prevent antiscalant dosing when SWRO is not operating.

In case of low low level of tank T-50003, 50-LILL-023, interlock I-009 stops Antiscalant Dosing Pumps P-50006A/B.

If shutoff valves 50-XV-021 and 50-XV-022 are contemporaneously both closed interlock I-015 stops Antiscalant Dosing Pumps P-50006A/B.

4.5.4 Start-up of the Section.

Check if level in Antiscalant Dosing Tank T-50006 is above minimum level and start Antiscalant Dosing Pumps P-50006A or P-50006B.

4.5.5 Normal Process Shut down of the Section.

Stop Antiscalant Dosing Pumps P-50006A or P-50006B.

4.5.6 Equipment Failure or Fault

The stand-by pump will be automatically switched in service, in case of not availability or any failure of selected operating pump.

If level instrument is in fault, the Caustic Dosing Pump will be automatically stopped and alarm will be displayed to PLC

4.6 BIOCIDE DOSING SYSTEM

4.6.1 Purpose of the Process Control

The purpose of the process control of the Biocide Dosing System is to store and dose biocide agent to several positions:

- To Sea Water Package Inlet, upstream Coarse Filter A-50003 – continuous dosing.
- To Sea water Intake System (outside our scope of supply) – shock dosing (20 minutes every 2 days).
- To Waste Water Tank (T-55001, outside our scope of supply) – shock dosing (1 hour every week).

Shock dosages are controlled by PLC on a time basis.

Biocide is stored in Biocide Dosing Tank T-50004 and dosed by Biocide Dosing Pumps P-50007A or P-50007B (package inlet), P-50008A or P-50008B (sea water intake), P-50010A or P-50010B (Waste Water Tank T-55001). At each injection point, one pump is operating and the other is as ~~in~~ stand-by.

4.6.2 Description of the Process Operation

The level of Biocide Dosing Tank T-50004 is measured by 50-LT-024. Alarm is activated in case of low level, 50-LAL-024.

Biocide from Biocide Dosing Tank T-50004 is dosed by Biocide Dosing Pumps P-50007A (P-50007B) to package inlet, upstream Coarse Filter A-50003. P-50007A (P-50007B) dosing speed is fixed and pre-set during commissioning. Pressure downstream P-50007A/B is indicated by pressure gauge 50-PI-044.

Biocide from Biocide Dosing Tank T-50004 is dosed by dosing pump P-50008A (P-50008B) to sea water intake system. P-50008A (P-50008B) dosing speed is fixed and pre-set during commissioning. Pressure downstream P-50008A/B is indicated by pressure gauge 50-PI-045.

Biocide from Biocide Dosing Tank T-50004 is dosed by dosing pump P-50010A (P-50010B) to Waste Water Tank T-55001. P-50010A (P-50010B) dosing speed is fixed and pre-set during commissioning. Pressure downstream P-50010A/B is indicated by pressure gauge 50-PI-046.

4.6.3 Safeguarding Intent

The main safeguarding of the system are:

- Prevent dry running of pumps Biocide Dosing Pumps P-50007A/B, P-50008A/B, P-50010A/B.
- Prevent biocide dosing when package is not operating.

In case of low low level of tank Biocide Dosing Tank T-50004, 50-LALL-024, interlock I-010 stops pumps - 50007A/B, P-50008A/B, P-50010A/B.

If shutoff valves 50-XV-020 is closed, interlock I-012 stops pumps P-50007A or P-50007B.

Biocide dosing pumps P-50008A or P-50008B and P-50010A or P-50010B will continue dosing biocide to sea water intake and Waste Water Tank, with the dosing pre-set during startup, even if the Water Treatment Package is stopped for any reason. Start-up of the Section

Check if level in Biocide Dosing Tank T-50004 is above minimum level and start Biocide Dosing Pumps

P-50007A or P-50007B, P-50008A or P-50008B, P-50010A or P-50010B.

4.6.4 Normal Process Shut down of the Section

Stop Biocide Dosing Pumps P-50007A or P-50007B, P-50008A or P-50008B, P-50009A or P-50009B.

4.6.5 Equipment Failure or Fault

The stand-by pump will be automatically switched in service, in case of not availability or any failure of selected operating pump.

If level instrument is in fault, the Caustic Dosing Pump will be automatically stopped and alarm will be displayed to PLC.

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4.7 CONTAINER VENTILATION (HFA-50001A/B/C) AND HEATING (HHS-50003A/B)

4.7.1 Purpose and Description of the Process control

Container Electric Heaters (HHS-50003 A/B) are installed inside container to increase ambient temperature up to minimum 10°C during cold season.

Inlet temperature is measured by 50-TT-023 and controlled by 50-TIC-023.

If the temperature inside container is lower than 10°C, 50-TIC-023 switch on the Container Electric Heater HHS-50003A or HHS-50003B.

If the temperature inside container is higher than 12°C, 50-TIC-023 switch off the Container Electric Heaters HHS-50003A and HHS-50003B.

The automatic drainage of Water Treatment Package will be activated by a timer or when air ambient temperature is lower than 2°C inside container (measured by temperature transmitter 50-TT-023).

The ventilation inside container is maintained with HFA-50001A/B/C fans (3 x 50%, two in operation and one stand-by) that provide enough air change per hour (minimum 15 air change per hour).

The ventilation is automatically started when signal "Switch ON/OFF container lighting/fan" 50-HSA-50001 is on and automatically stop when the above signal is off.

The same ventilation is automatically started in case of high high ambient temperature and stop in case of low temperature

4.7.2 Safeguarding Intent

N/A

4.7.3 Start-up of the Section

Container ventilation is always in operation.

Heating is started up when required by the ambient temperature (50-TIC-023). If after starting up of one Container Electric Heater it does not start automatically according to ambient temperature (due to default or various problems), after a certain delay switch on the other heater that was in stand-by in automatic.

4.7.4 Normal Process Shut down of the Section

N/A

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4.8 WATER TREATMENT PACKAGE SHUTDOWN

4.8.1 Purpose of the Process Control

The normal shutdown of each package section is described in the relevant chapters above.

In some cases, it's necessary a particular shutdown of the whole Water Treatment Package:

- Long Period Stop of Water Treatment Package or very cold ambient air temperature;
- SIS Shutdown
- Fire & Gas detection

4.8.2 Long Period Stop Safeguarding Intent

Interlock I-012.

The package will be automatically drained, in case of:

- A long stop of the water treatment package, longer than one month, (50-XV-020 is closed)

From various equipment water will be discharged into water drain collector.

The following actions will be done:

- Open drain valve 50-XV-033
- Open drain valve 50-XV-034
- Open drain valve 50-XV-027
- Open drain valve 50-XV-030
- Open drain valve 50-XV-035
- Open off-spec valve 50-XV-026
- Open off-spec valve 50-XV-032
- Close inlet main valve 50-XV-020
- Close forward valve 50-XV-031

4.8.3 SIS Shutdown Safeguarding Intent

Shutdown signal 50-XS-001 from ROSETTI SIS System or Emergency PB signal from 50-HS-020 or Container Flooding signal from 196SL1 activate Interlock I-017 performing the following actions to following items:

- Close inlet battery limit valves 50-XV-020
- Close forward valve 50-XV-031
- Any backwash Coarse Filter A-50003 interrupted or not allowed
- Any backwash Sand Filter S-50001 interrupted or not allowed
- Any Softening Filter S-50004 regeneration interrupted or not allowed
- Trip Container Electric Heater HHS-50003A/B
- Trip Container Air Fan HFA-50001A/B/C
- Switch-off UV Lamp S-50010, LP-S-50010
- Trip Heater H-50001

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- Stop Pump P-50002A/B
- Stop Pump P-50003A/B
- Stop Pump P-50009A/B
- Stop Pump P-50004A/B
- Stop Pump P-50005A/B
- Stop Pump P-50006A/B
- Stop Pump P-50007A/B
- Stop Pump P-50008A/B
- Stop Pump P-50010A/B
- Open drain valve 50-XV-033
- Open drain valve 50-XV-034
- Open drain valve 50-XV-027
- Open drain valve 50-XV-030
- Open drain valve 50-XV-035
- Open off-spec valve 50-XV-026
- Send 50-XA-003 common container fault

4.8.4 Fire & Gas detection Safeguarding Intent

Fire & Gas are monitored by N° 3 Fire detectors and N° 3 Gas Hydrogen detectors, located in different zones inside the container.

In case of fire or gas event, the dedicated detector alerts any presence to F&G Panel 50-LP-002:

- 50-AT-020A, 50-AT-020B, 50-AT-020C
- 50-AT-021A, 50-AT-021B, 50-AT-021C

In case of fire or gas detection into container, the following actions are realized:

- Sounder and visual alarm lamps activated
- SIS signal should cut off the main power supply and the UPS feeding line based on detected level threshold

A Manual call point is provided to activate and advise the hazardous conditions and not access to container.