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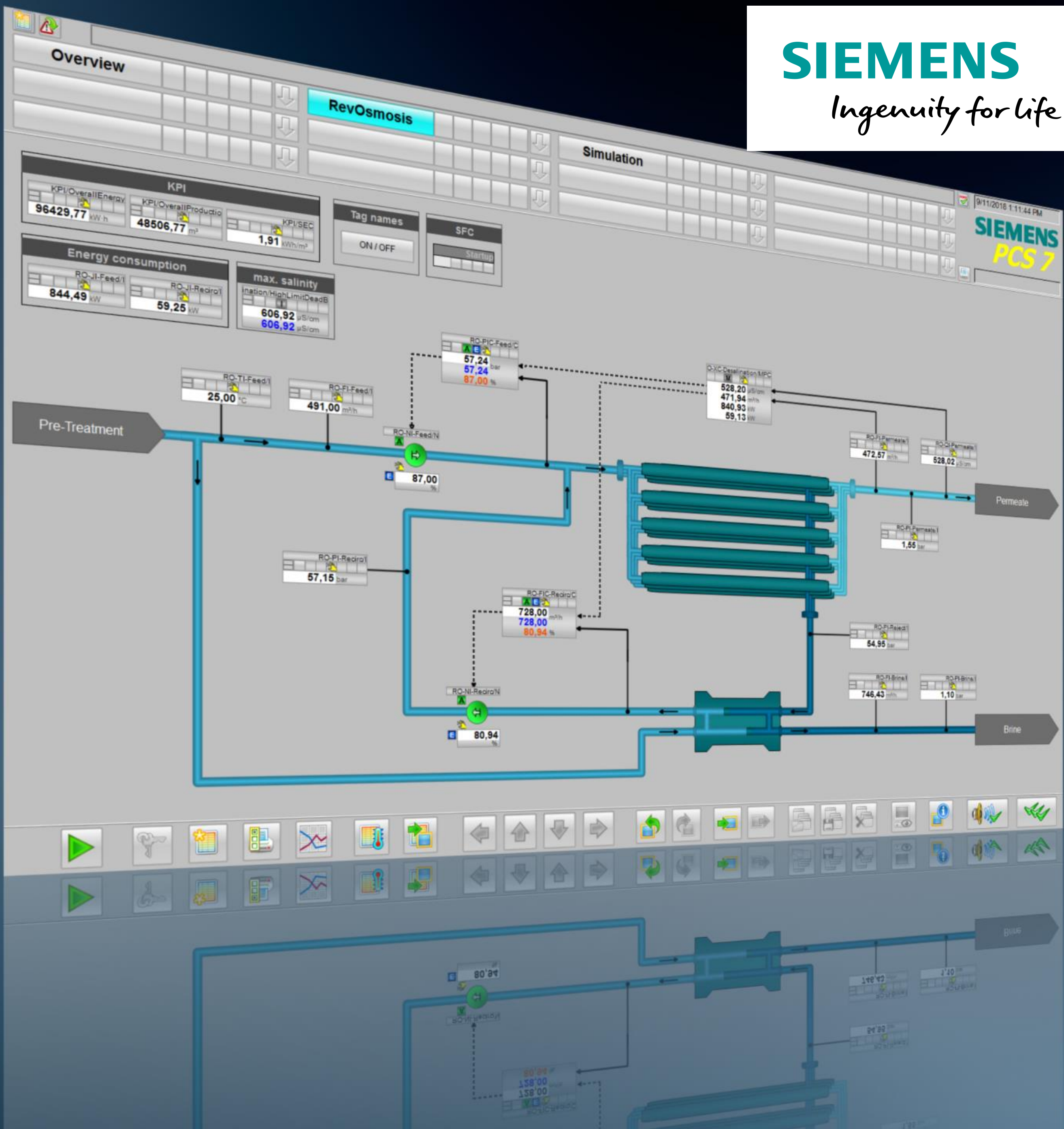

PCS 7 Water Unit Template - Seawater Desalination by Reverse Osmosis

SIMATIC PCS 7 V9.0 SP1

https://support.industry.siemens.com/cs/ww/en/view/109741119

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1 Introduction

1.1 Overview

Almost 97 percent of the water on earth is saline and cannot be used as drinking water or for irrigation purposes. Desalination of seawater offers an opportunity to obtain additional drinking or process water for people, industry and agriculture. Efficient automation solutions are required to ensure the supply of fresh water, especially in dry areas.

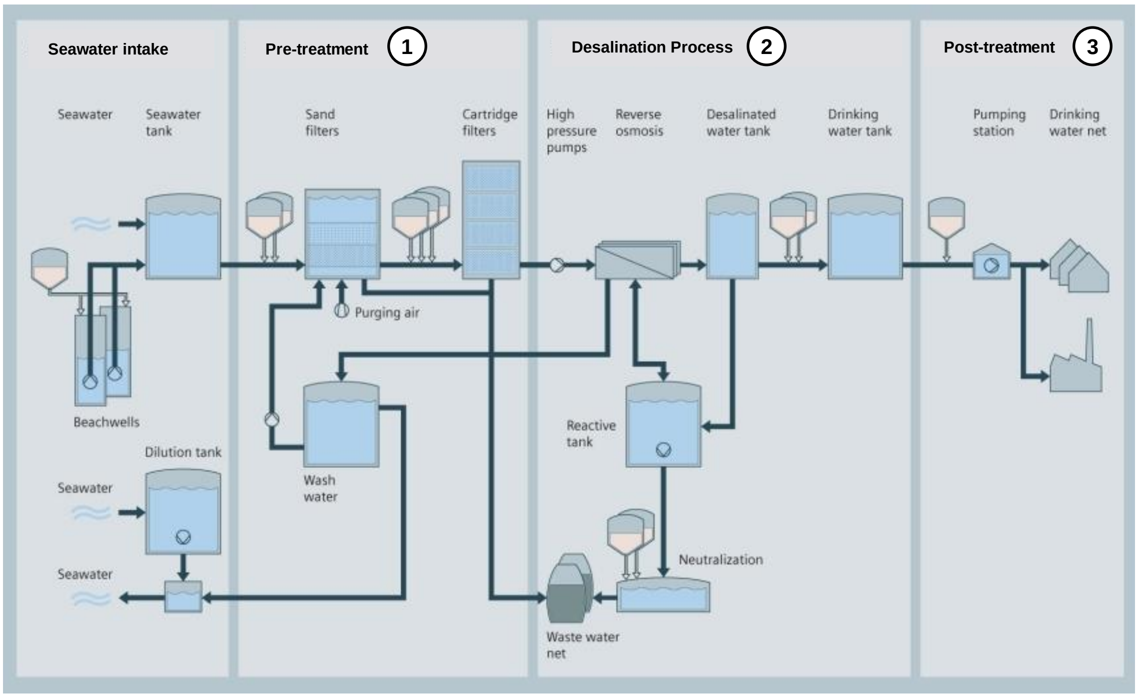
There are two types of processes for the desalination of seawater:

- Thermal processes such as multi-stage flash distillation (MSF)
- membrane processes such as reverse osmosis

The processes for desalinating seawater are very energy-intensive. In direct comparison, pressure-driven membrane processes generally require slightly less energy than thermal processes.

Seawater desalination based on reverse osmosis uses semipermeable membranes to filter the dissolved salt from the seawater. For this purpose, the salt water is pressed through the membranes at a higher pressure than the osmotic pressure of the salt water. The high energy input is necessary to generate the high pressure in front of the membrane.

A seawater desalination plant contains several sub-processes, which are shown schematically in the following figure.



1. **Pre-treatment:**
   The salt water is cleaned of dirt and sand by mechanical filtration and ultrafiltration. In addition, the pH value is balanced and bacteria is killed by adding chlorine.
2. **Desalination process:**
   In the actual desalination process, the salt water is pressed at high pressure into a filter system containing a large number of osmosis membranes.
   The osmotic pressure of the sea water must be overcome (reverse osmosis).
   The product is purified water and the by-product brine.

3. **Post-treatment:**
   Finally, the pH value is regulated again and the drinking water is enriched with minerals.

Detailed information on the application background can be found in \3\.

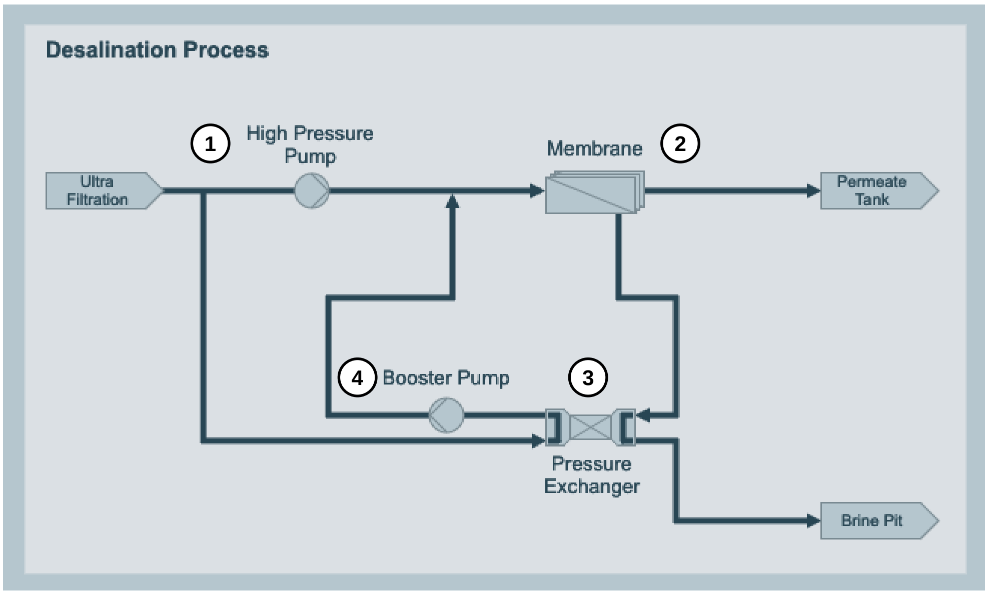
1.2 Principle of operation

Only the central desalination process is covered in this application example.

A high-pressure pump (1) is used to lift the pressure of the pre-purified seawater to a level that significantly exceeds the osmotic pressure of seawater (approx. 30 bar). The filter membranes (2) allow only the water molecules to pass through and retain the dissolved salt. This separates seawater into water with a very low salinity (permeate) and water with a very high salinity (retentate).

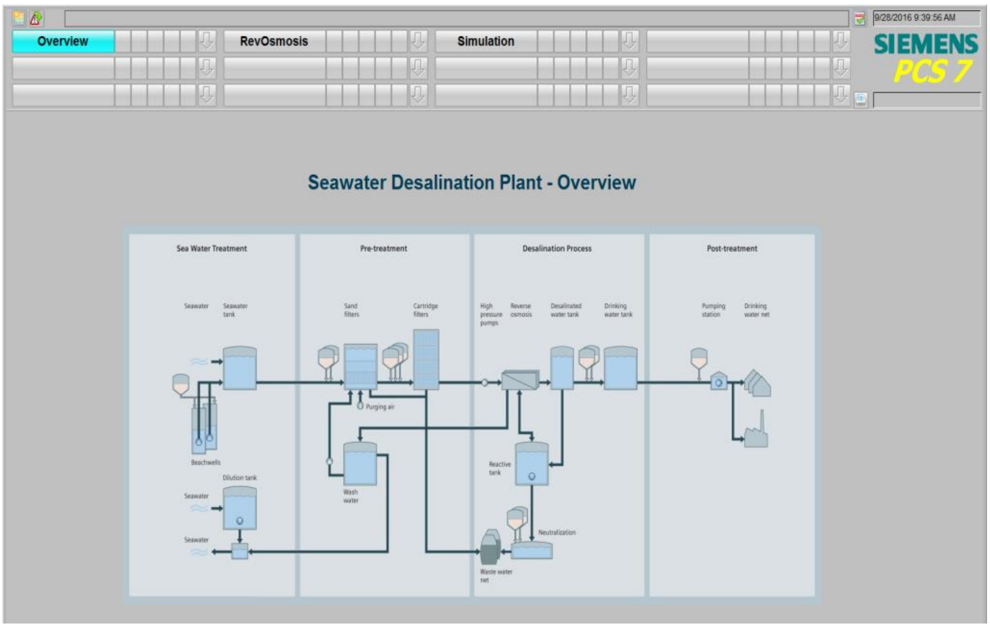
The still very high pressure at the retentate outlet can be recovered to a very large extent with a pressure exchanger (3). Together with the booster pump (4) a part of the fresh sea water is lifted to the pressure level of the high pressure side. In this way, a large part of the energy consumed by the high-pressure pump at the inflow is saved.

The PID controls for the high-pressure pump and the booster pump are supplied with their respective setpoints by a superimposed multi-variable controller. This enables a constant production quantity and product quality, as fluctuations are automatically compensated without operator intervention.



Overview picture

This process picture contains a schematic representation of a seawater desalination plant. The components of the schematic representation are described in section 1.1 "Overview".



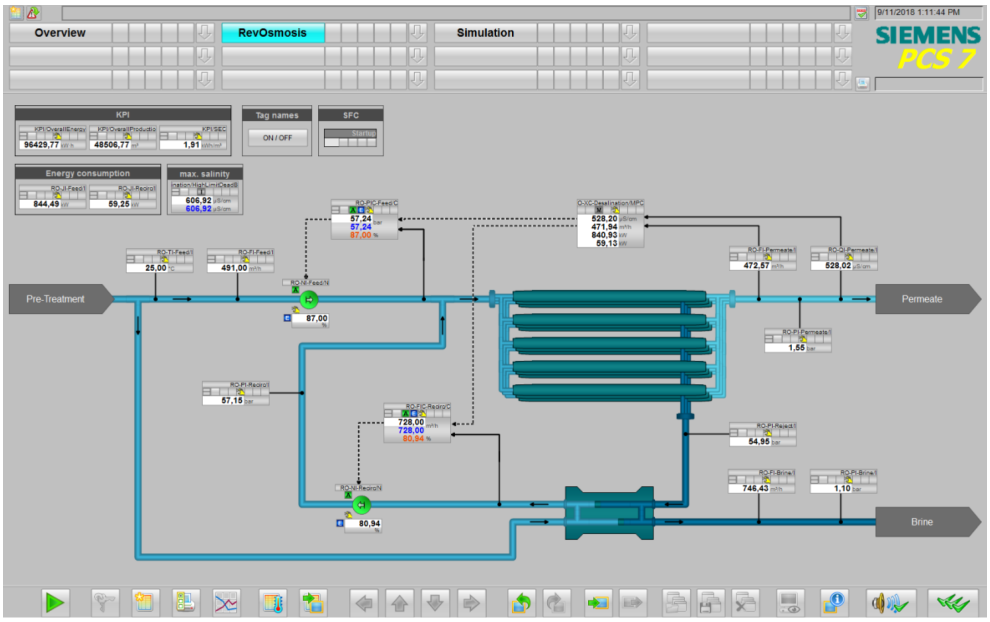
Process picture

The reverse osmosis process picture shows all process tags, drives and controllers required for operation of the plant unit.

The majority of the process tags are analog value displays, which show the (simulated) process values as well as violations of specified upper or lower limits. The displayed block symbols and faceplates are part of the PCS 7 Advanced Process Library.

Note

Further information can be found in the manual "SIMATIC Process Control System PCS 7 Advanced Process Library":
https://support.industry.siemens.com/cs/ww/en/view/109754967



Control concept

A multi-variable controller (MPC) is used to control flow rate and salinity (salt concentration) of water. This controller manipulates the process via setpoint values for the pressure at the membrane and the flow rate in recirculation.

In the MPC, the different target values are weighted differently. Product quality (salinity) has the highest priority but remains within its dead zone during normal operation. The controller only has to intervene if the salinity should be higher than permitted. Therefore, the main controlled variable in normal operation is the production output (permeate flow).

The electrical power consumption of high-pressure pump and booster pump are low-priority controlled variables. The target values correspond to the operating points with optimum pump efficiency.

PID controllers "PIDConL" of the APL are used for the flow of recirculation and pressure at the membrane, which are slave controllers for the MPC master controller.

1.3 Used hardware and software components

This application example was created with the following hardware and software components:

Component	Note
SIMATIC PCS 7 ES/OS IPC547G W7	For the PCS 7 V9.0 SP1 example project
SIMATIC PCS 7 V9.0 SP1	Part of SIMATIC PCS 7 ES/OS IPC547G W7
S7 PLCSIM	Not a part of SIMATIC PCS°7 V9.0 SP1, additional licenses required
APL V9.0 SP1	Part of SIMATIC PCS 7 V9.0 SP1

Note If the hardware is different, observe the minimum requirements for installing the software components. The minimum requirements can be found in the PCS 7 Readme at the following link: https://support.industry.siemens.com/cs/ww/en/view/109750097.

This application example consists of the following components:

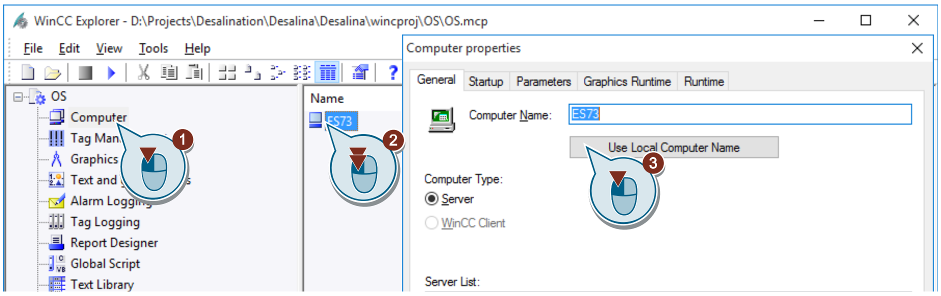
Component	Note
109741119_WUT_SeawaterDesalination_PROJ_PCS7V90SP1.zip	PCS 7 V9.0 SP1 example project
109741119_WUT_SeawaterDesalination_DOC_PCS7V90SP1_en.pdf	This document

2 Preparation and commissioning

2.1 Preparation

The following instructions describe the commissioning of the Unit Template, in which the controller is simulated with the program "S7-PLCSIM". If a real controller is available, you must configure the hardware components in the HW configuration.

1. Copy the file "109741119_WUT_SeawaterDesalination_PROJ_PCS7V90SP1.zip" into any folder on the configuration computer and then open the SIMATIC Manager.
2. Click on "File > Retrieve" in the menu bar and select the file "109741119_WUT_SeawaterDesalination_PROJ_PCS7V90SP1.zip". Then confirm by clicking on "Open".
3. Select the folder in which the project is to be saved and confirm with "OK". The project is retrieved.
4. Confirm the "Retrieve" dialog with "OK" and then click "Yes" in the dialog to open the project.
5. Right-click on "Desalination_OS > OS01 > WinCC Appl. > OS" and click on the menu command "Open object".
6. Confirm the dialog "Configured server not available" with "OK".
7. Right-click the properties of your computer in the WinCC Explorer and click on the button "Use Local Computer Name" in the opened properties dialog.



8. Confirm the message "Change computer name" with "OK".
9. Click on "File > Exit" in the WinCC Explorer and select "Exit WinCC Explorer" in the following dialog.
10. Then confirm with "OK".
11. Open the WinCC Explorer again, as described in step 5.
12. Open the "Tag Management" by double-clicking it.
13. Right-click in the WinCC Configuration Studio on "Tag Management > SIMATIC S7 Protocol Suite > TCP/IP" and select the menu command "System parameters".
14. Check the specified "Logical device name" in the tab "Unit". If the "S7-PLCSIM" program is used, "PLCSIM(TCP/IP)" is selected as the device name.
The program must be restarted after changing the device name. Open the WinCC Explorer again, as described in step 5.

2.2 Commissioning

The following instructions describe how to initialize the Unit Template. The project contains an SFC which drives the system automatically to a predefined operating point after starting.

For commissioning it is assumed that the SIMATIC Manager has already been opened and the Unit Template is selected in the component view.

Starting the simulation (S7 PLCSIM)

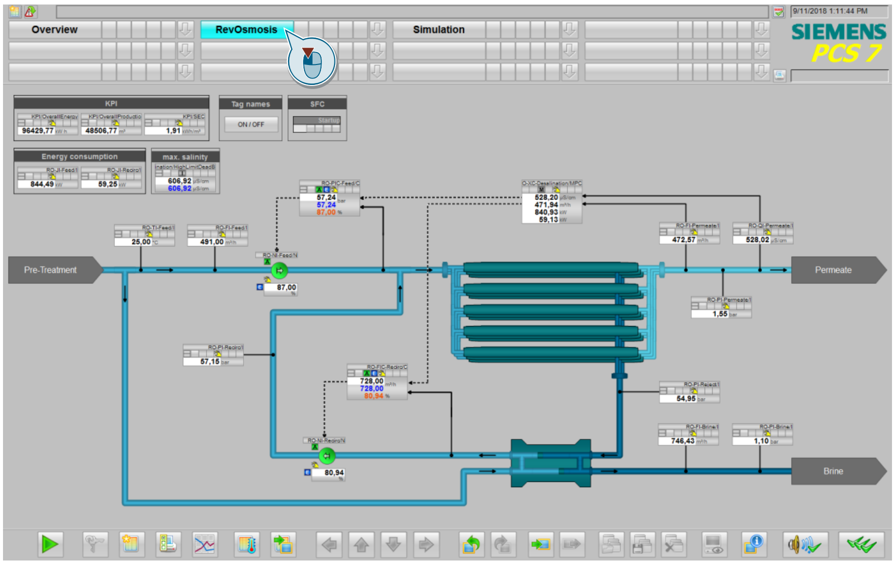
To start the simulation, proceed as follows:

1. Select "Options > Simulate Modules" from the menu.
   The "S7-PLCSIM" dialog window opens.
2. In the dialog "Open project", select the "Open project from file" option.
3. Select the file "Desalination.plc" from the path
   <Project path>\Desalina\Desa_MP\Desalination.plc>.
4. In the menu, change "PLCSIM(MPI)" to "PLCSIM(TCP/IP)".
5. In the menu, select "Run > key switch position > RUN-P".
6. Switch to the component view of the SIMATIC Manager and select "Desalination_AS > AS01".
7. Click on "PLC > Download" in the menu bar and confirm the dialog "Download" with "Yes".
8. Confirm the dialog "Stop Target Modules" with "OK" and then the dialog "Download" with "Yes".

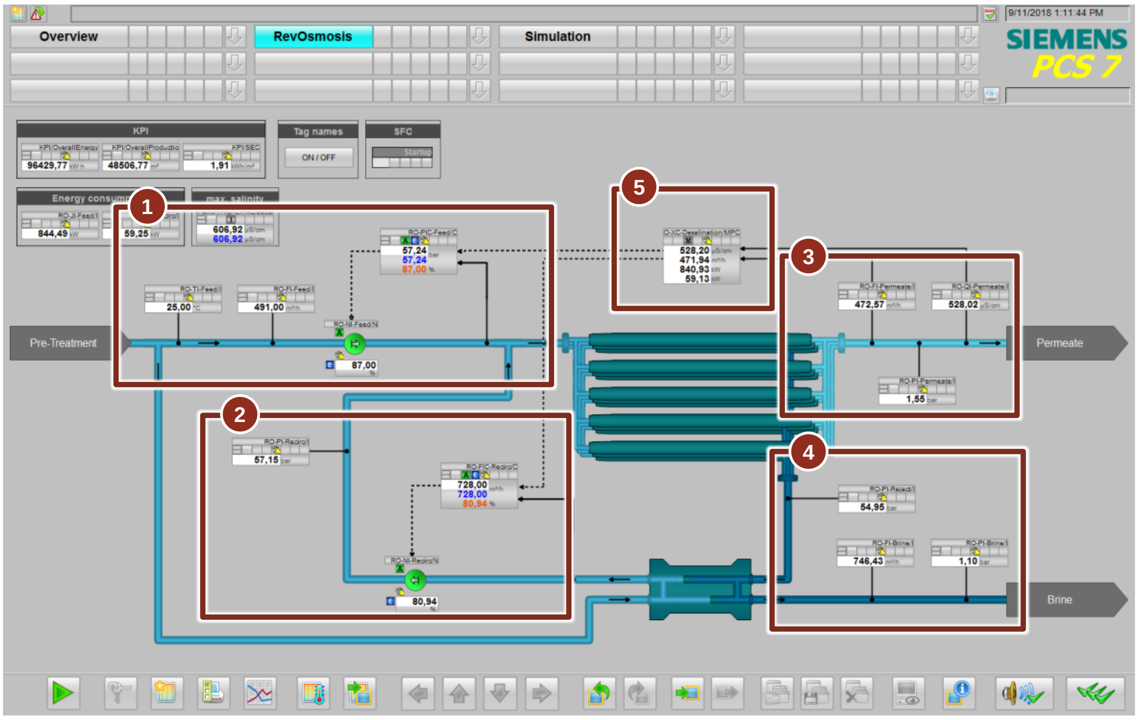
Activate OS (WinCC runtime)

Proceed as follows to activate the OS:

1. Right-click "Desalination_OS > OS01 > WinCC Appl. > OS" and select the "Open Object" menu.
2. To activate the OS (WinCC Runtime), select the menu item "File > Activate" in the WinCC Explorer.
3. In the dialog "System Login", enter the user "Unit" as "Login" and "Template" as the password; then confirm with "OK".
4. Select "RevOsmosis" in the picture tree area.



2.3 Components of process visualization



The process screen consists of the following main components:

1. Inflow (Feed)
2. Recirculation (abbreviation: Recirc)
3. Permeate
4. Brine
5. MPC

Function	Description
Feed	The temperature and flow rate of the salt water from the pre-treatment and the pressure control by means of a high-pressure pump are displayed at the inlet.
Recirc	In the recirculation loop, the water pressure is displayed and the flow rate is controlled by means of a booster pump (to increase the pressure).
Permeate	Contains Control Modules to display the flow rate and quality of the purified water.
Brine	Contains Control Modules to display the pressure and flow rate of the brine discharged.
MPC	Contains the Control Module of the multi-variable controller

2.4 Operating the application

2.4.1 Overview

All components of reverse osmosis can be operated and monitored via the process picture. In addition, the plant operator receives information (KPIs: Key Performance Indicators) on the current process state.

Note Please note that after starting the program (PLCSIM) it takes approx. 2 minutes until the reverse osmosis is at the operating point. During the running production operation, all controllers are released for operation. You can recognize this state for example in the SFC, if it has successfully processed all process steps.

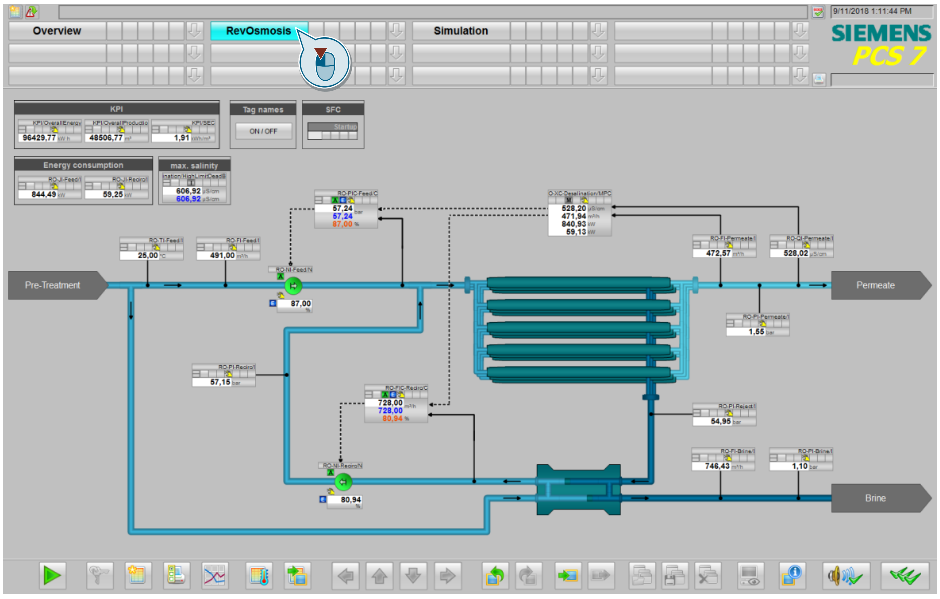
The following two scenarios show different approaches for the compensation of fouling at the filter membranes by comparing:

- Reverse osmosis without multi-variable controller
- Reverse osmosis with multi-variable controller

2.4.2 Scenario A - Reverse osmosis without multi-variable controller

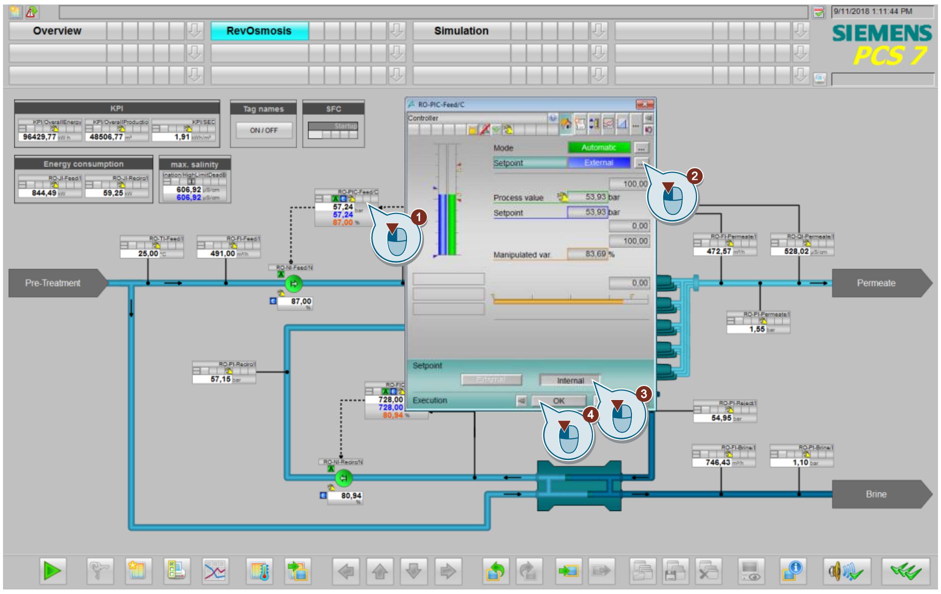
In this scenario the process of reverse osmosis is simulated. Pre-purified seawater is forced through the filter membranes at high pressure. The filter membranes allow only the carrier liquid to pass through and retain the dissolved salt. This leads to fouling of the filter membranes, which in turn reduces the quality and quantity of drinking water produced. In order to compensate for this effect, the setpoints of the inflow and recirculation control must be adjusted again and again. In this scenario, the setpoint adjustments must be performed manually by the operator.

1. Switch to the reverse osmosis process screen.

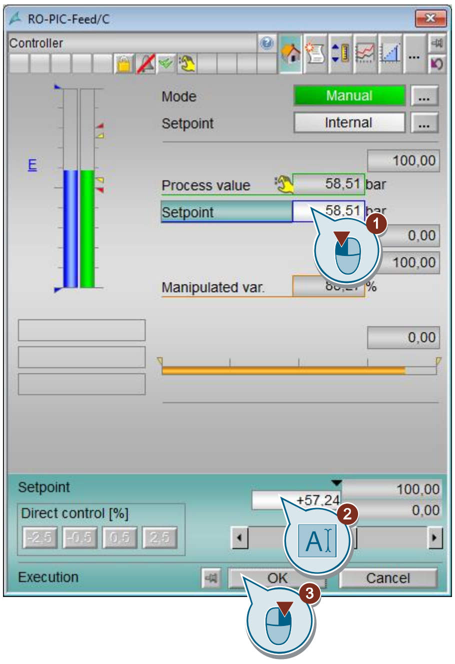


2. Left click the “On/Off” button in the “Tag names” field to display the block names.

3. Click on the block symbol of the "RO-PIC Feed" block and select "Internal" for "Setpoint". Confirm your entry by clicking on "OK".

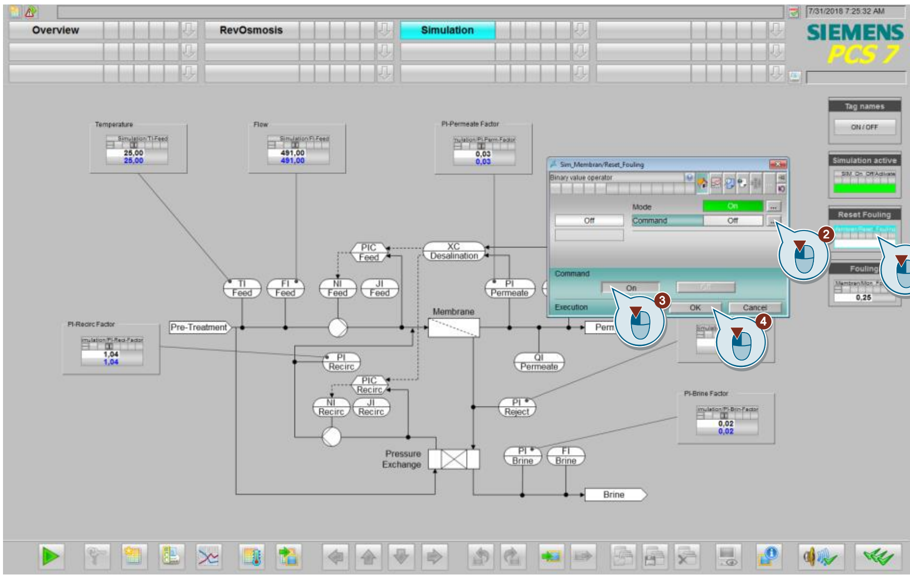


4. Enter the setpoint "57.24" in the faceplate of the "RO-PIC feed" module and confirm the entry by clicking on "OK".

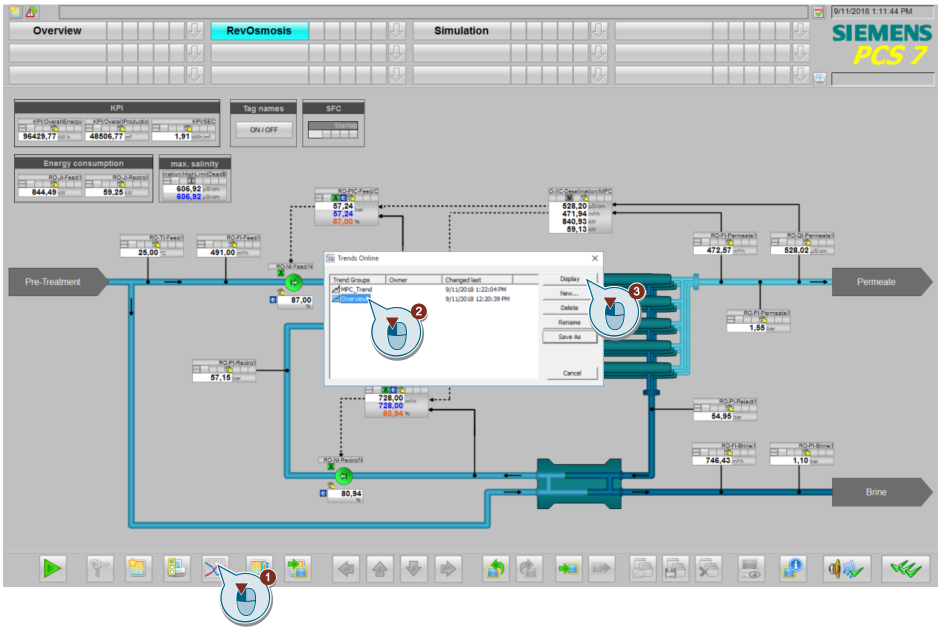


5. Repeat steps 3 and 4 for the PID controller "RO-FIC-Recirc" and enter the setpoint "728.59".
6. Switch to the simulation process screen.

7. Click on the block symbol of the "Reset_Fouling" block.
   The corresponding faceplate will be opened.
8. Select the command "On" and confirm your entry with "OK".



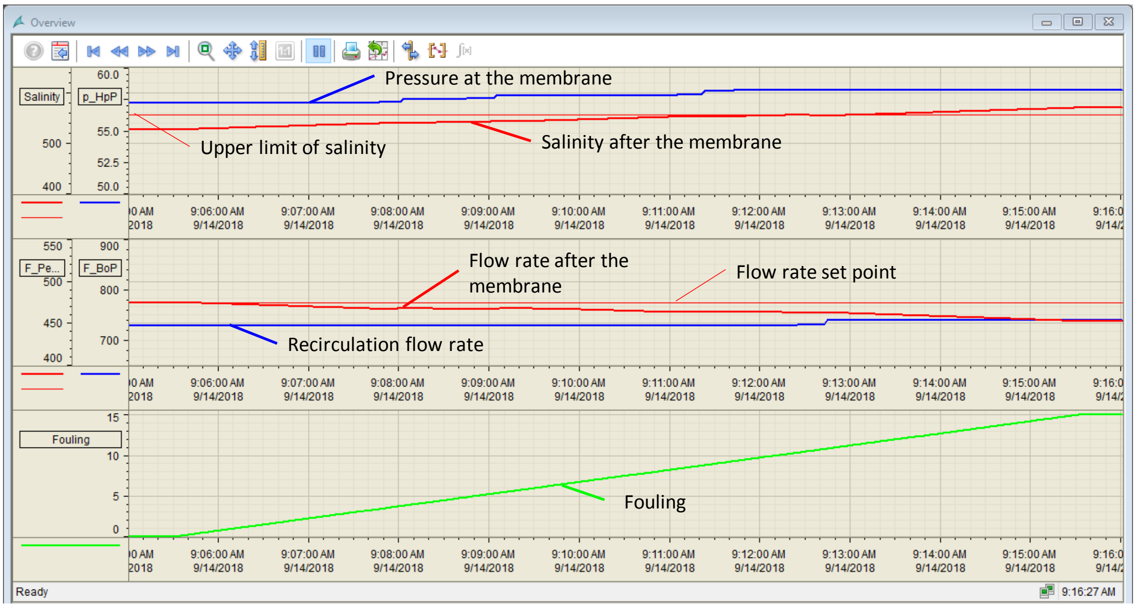
9. Switch to the reverse osmosis process screen.
10. Click on the "Retrieve/Compile trend groups" button and select the "Overview" trend display.
11. Open the trend display by clicking on "Display".



12. Wait 2 minutes and enter a new setpoint of "57.54" for RO-PIC feed.
13. Wait another 1 minute and enter a new setpoint of "57.84".
14. Wait another 2 minutes and enter a new setpoint of "58.24".
15. Wait 2 minutes and enter a new setpoint of "740" for RO-FIC-Recirc.
16. Wait another 3 minutes and click on the "Start/Stop" icon to evaluate the rule result.

Evaluation

The figure shows the trend curves of reverse osmosis.



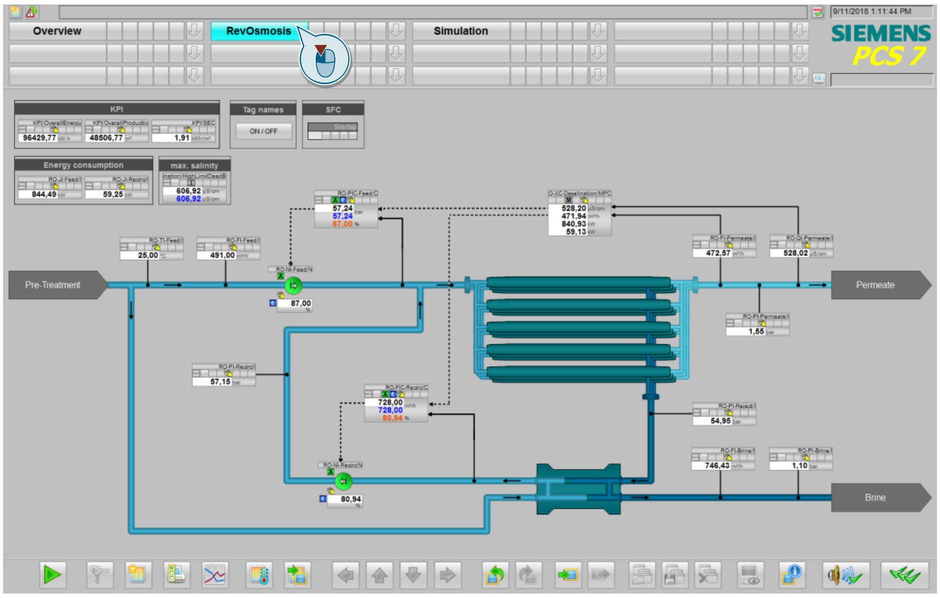
Due to fouling of the filter membranes, the flow resistance of the membrane increases. This leads to a deterioration of the quality and reduction of the amount of drinking water produced. In order to compensate for the deterioration of product properties, the operator must manually increase the setpoint for the PID control loop of the high-pressure pump. By increasing the pressure on the filter membranes in several steps, the fouling effect can be compensated for about 10 minutes. After 10 minutes, the control loop of the inflow reaches the manipulated variable limits and cleaning of the membrane becomes necessary.

Note Cleaning of the membrane is not a part of this application example. In the simulation, only the degree of fouling is reset.

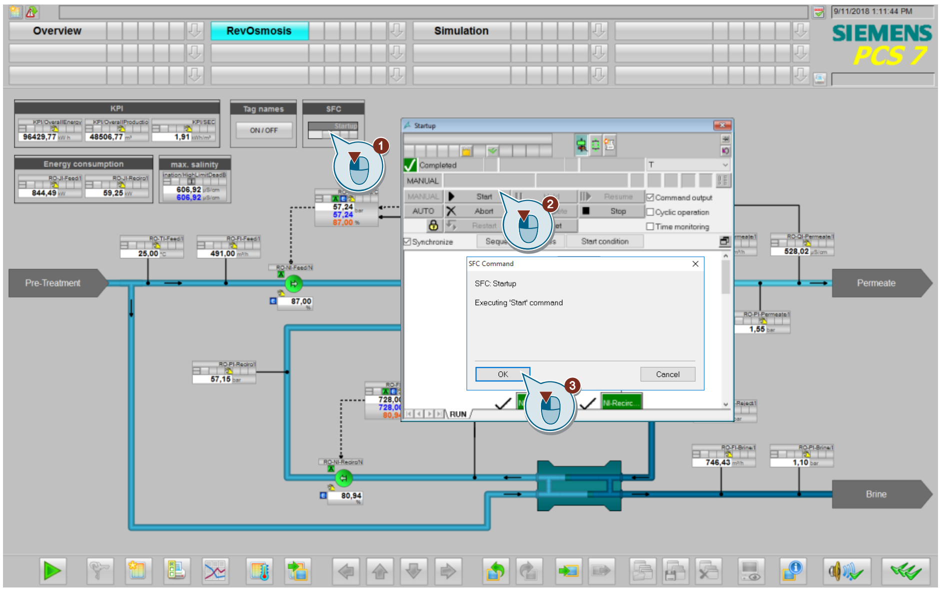
2.4.3 Scenario B - Reverse osmosis with multi-variable controller

In this scenario, the process of reverse osmosis is simulated in the same way as in scenario A. In order to compensate for the fouling effects of the filter membranes, the setpoints of inflow and recirculation control must be adapted. In this scenario, these interventions are not carried out manually by the operator, but automatically by the multi-variable master controller.

1. Switch to the reverse osmosis process screen.



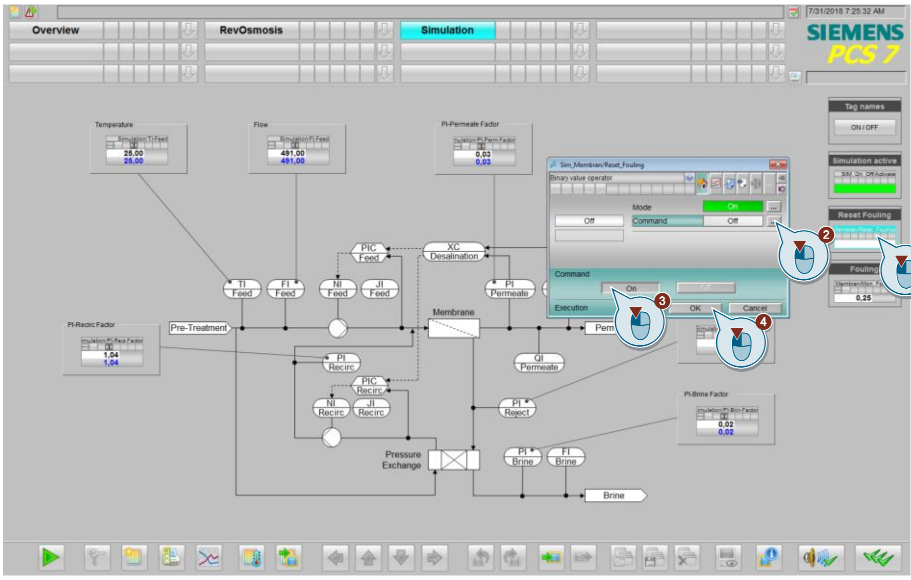
2. Left click the “On/Off” button in the “Process tag name” field to display the block names.
3. Click on the block symbol of the SFC "Startup" and click "Start" in the menu bar. Confirm your entry by clicking on "OK".



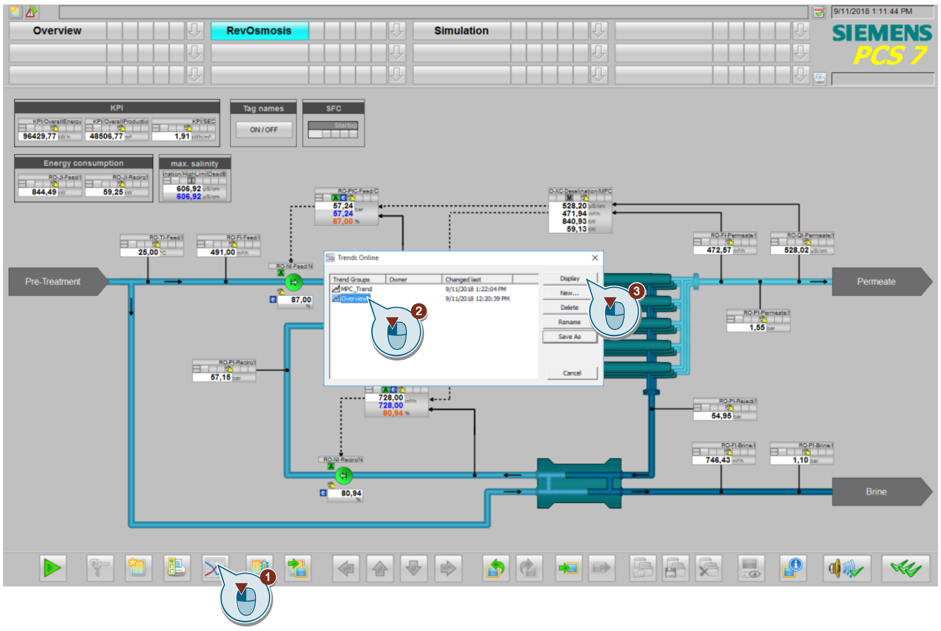
The sequencer set the PID controllers back to automatic mode and to setpoint input from the MPC.

4. Switch to the simulation process screen.

5. Click on the block symbol of the "Reset_Fouling" block.
   The corresponding faceplate will be opened.
6. Click Command on the faceplate and select "On". Confirm your entry by clicking on "OK".



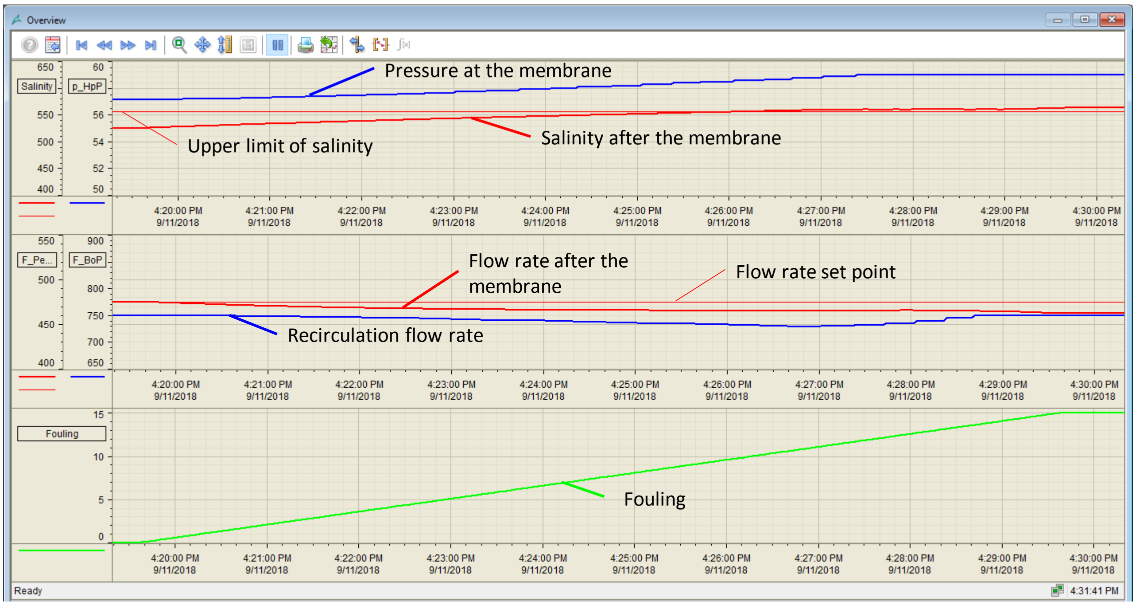
7. Switch to the process screen of reverse osmosis
8. Click on the "Retrieve/Compile trend groups" button and select the "Overview" trend display.
9. Open the trend display by clicking on "Display".



10. Wait approx. 10 minutes and click on the "Start/Stop" icon to evaluate the rule result.

Evaluation

The figure shows the trend curves of reverse osmosis.



Due to fouling of filter membranes, the flow resistance of the membrane increases. This leads to a deterioration of the quality and reduction of the amount of drinking water produced. As long as salinity after the membrane is lower than the specified upper limit, the multi-variable master controller regulates the flow rate after the membrane. As soon as salinity after the membrane exceeds the limit, salinity is primarily controlled. By increasing the pressure on the filter membranes, the effect of fouling on production can be compensated for about 10 minutes. After 10 minutes, the control loop reaches the manipulated variable limits and cleaning of the membrane becomes necessary.

3 Integration of unit template into a user project

3.1 Preparation

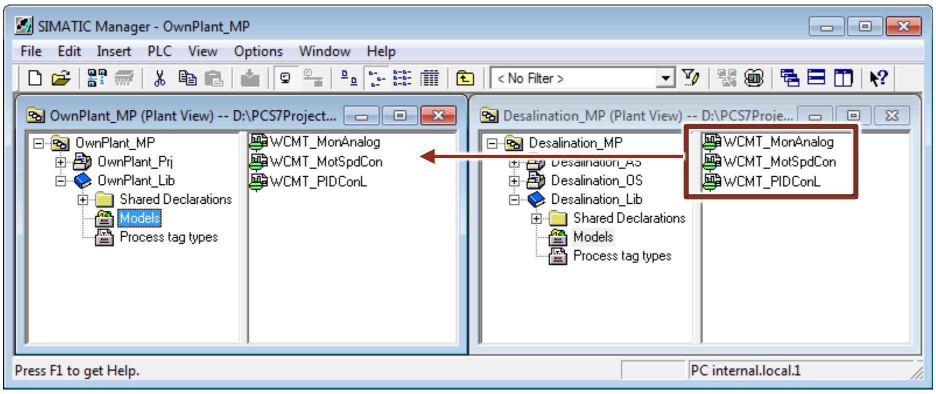
1. Copy the file "109741119_WUT_SeawaterDesalination_PROJ_PCS7V90SP1.zip" to the configuration computer and then open the SIMATIC Manager.
2. Click on "File > Retrieve" in the menu bar and select the file "109741119_WUT_SeawaterDesalination_PROJ_PCS7V90SP1.zip". Then confirm by clicking on "Open".
3. Select the folder in which the project will be saved and confirm with the "OK" button.
   The project will be extracted.
4. In the "Retrieve" dialog, click on the "OK" button and then click on "Yes" in the dialog to open the project.
5. Switch to the "Plant view".
6. In parallel open the project in which the unit template must be integrated.

3.2 Copying templates

Note

If you have already worked with CMTs in your existing project, then check for equality before the following steps, as this can lead to errors in your existing project or the unit template to be integrated.

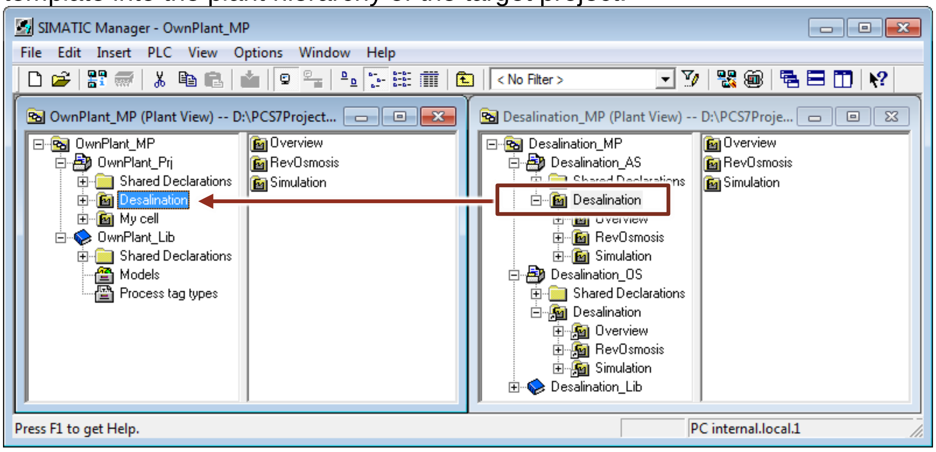
1. Switch to the plant view.
2. Copy the CMTs from the master data library and paste them into the target project.



3. Copy the enumerations from the master data library and paste them into the target project.

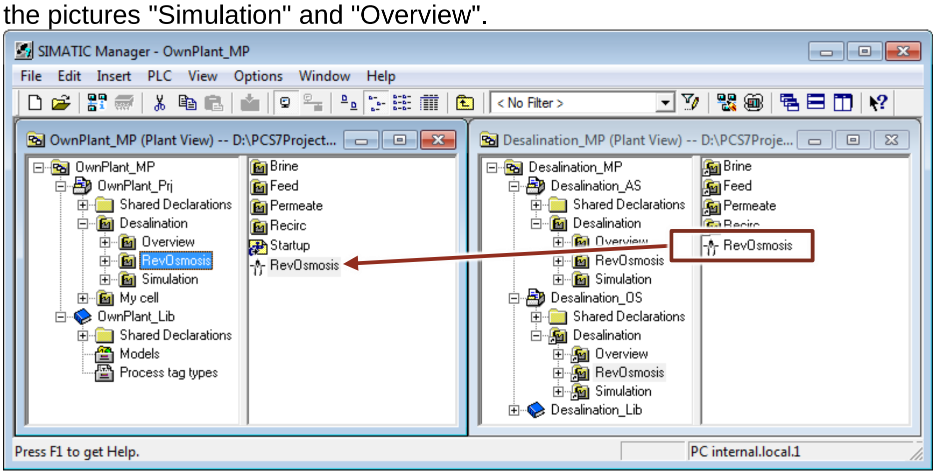
3.3 Copying a plant section

1. Copy the hierarchy folder "Desalination" from the AS project of the unit template into the plant hierarchy of the target project.



Note The hierarchy folders of the plant sections "Overview" and "Simulation" are not necessary for operation. If you want to operate your system without simulation, you do not have to copy them.

2. Copy the process screen "RevOsmosis" from the OS project of the unit template into the plant hierarchy of the target project. If necessary, also copy the pictures "Simulation" and "Overview".

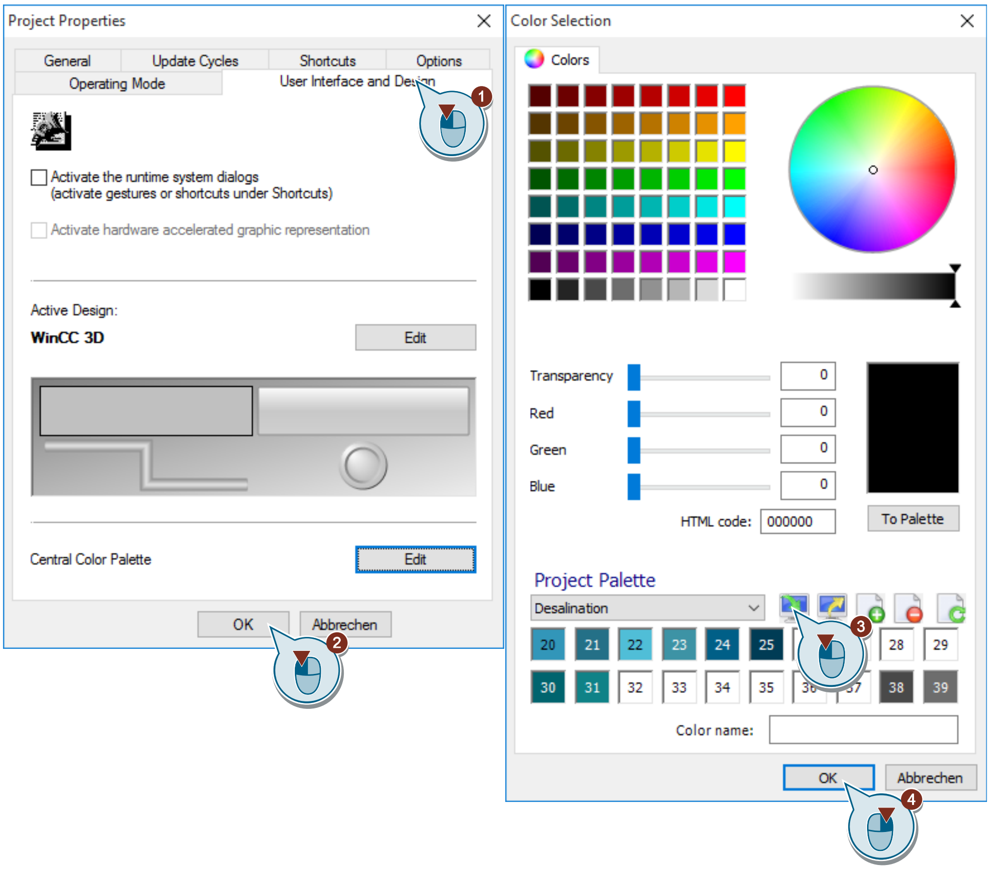


Note When copying the process screens, make sure that you copy the screens to the hierarchy level of the target project that is parameterized as the OS area.

3.4 Customizing the OS project

In order to be able to change the colors in the reverse osmosis process picture at a central location, a central color palette was created in the OS project of the Unit Template. You must import the central color palette so that these colors are also displayed in the process screen of your own project.

1. Select the "OS" in WinCC Explorer and choose "project properties" in the context menu.
2. Choose the "Interface and Design" tab and click the "Edit" button.
3. Import the palette with the "Overwrite" option into your own project. The color palette is in the project folder under the path: "<Project path>\Desalina\Desalina\wincproj\OS\GraCS\Desalination.xml>". All existing colors will be replaced.

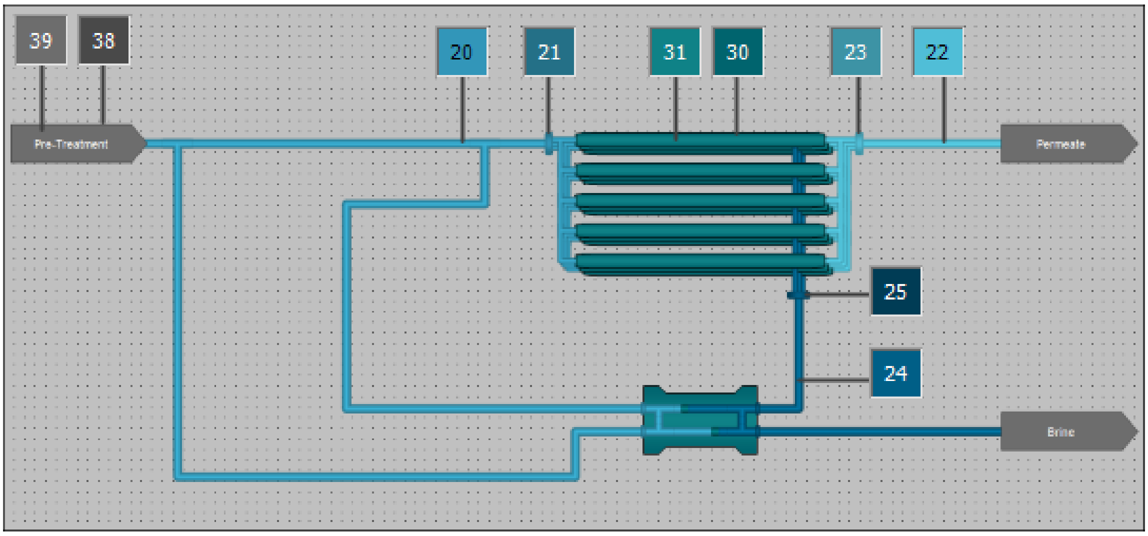


Note When you export or import the colors, all color tables are always taken into account. It is not possible to export individual color tables.

If you have created your own color tables in your project, you can also export these and merge the tables with an editor in the XML file. Alternatively, create a new color table in your project and define the colors individually. Also make sure that the color index does not change, otherwise you would have to adjust the color settings of the objects in the process picture. Of course, it is up to you to change the colors according to your requirements.

Color	HTML Code	RGB Code		
		R	G	B
20	3296B9	50	150	185
21	247087	36	112	135
22	50BED7	80	190	215
23	3D93A5	61	147	165
24	005F87	0	95	135
25	003C55	0	60	85
30	00646E	0	100	110
31	0F8287	15	130	135
38	494949	73	73	73
39	6D6D6D	109	109	109

The following figure shows a simplified representation of how the colors are used in the process picture.



4 Engineering

4.1 Control module types

In this unit template the following Control Module Types from the library "SWL PCS7 V90 SP1" are used.

Control module type	Description
WCMT_MonAnalog	Monitoring of an analog measuring point
WCMT_MotSpdCon	Control of a motor via a frequency converter (FU) with infinitely variable speed variation and two directions of rotation
WCMT_PIDConL	PID controller with continuous output signal (output value)

A detailed description of the Control Module Types can be found in the paper "Standard PCS 7 and S7 Water Templates for the Water Industry" at https://support.industry.siemens.com/cs/ww/en/view/78604785

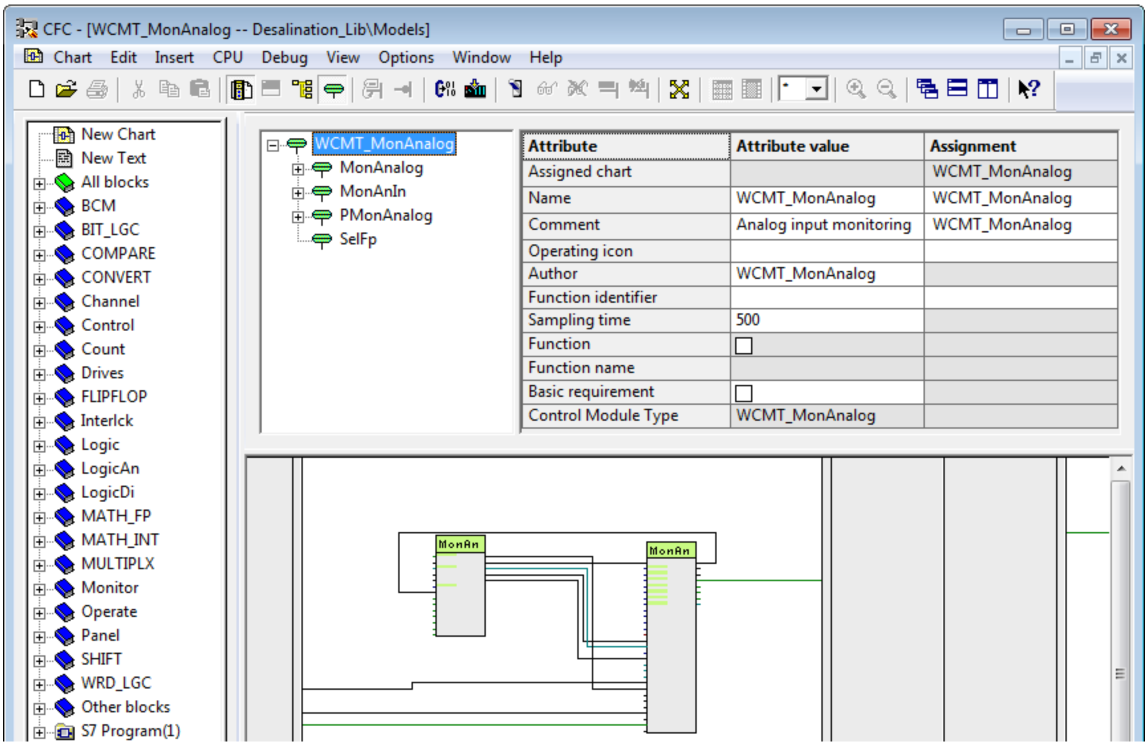
In addition to the Control Module Types from the "SWL PCS7 V90 SP1" library, the Control Module Type "CtrlMPC" from the BMC library is also used.

Control module type	Description
CtrlMPC	MPC multi-variable controller

A detailed description of the Control Module Types can be found in the paper "Equipment Modules for SIMATIC PCS 7 using the example of the Chemical Industry" at https://support.industry.siemens.com/cs/ww/en/view/53843373.

4.1.1 WCMT_MonAnalog

The Control Module Type "WCMT_MonAnalog" is used to monitor an analog measurement tag.



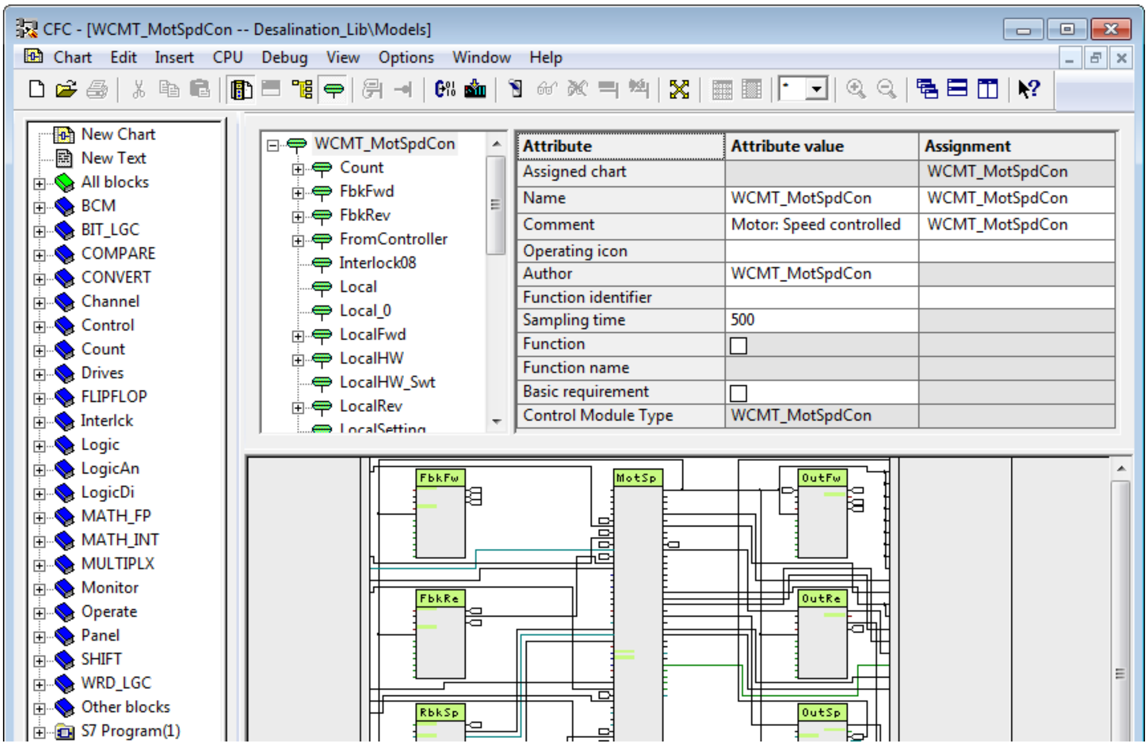
In the application example, from the optional variants, only "MonAnIn" is used. The optional variants "PMonAnalog" and "SelFp" require the PCS 7 Industry Library.

The following Control Modules are of type "WCMT_MonAnalog":

- TI-Feed
- FI-Feed
- JI-Feed
- FI-Permeate
- PI-Permeate
- QI-Permeate
- PI-Recirc
- PI-Reject
- JI-Recirc
- PI-Brine
- FI-Brine

4.1.2 WCMT_MotSpdCon

The Control Module Type "WCMT_MotSpdCon" is used to control a motor via frequency converter with variable speed and two directions of rotation.



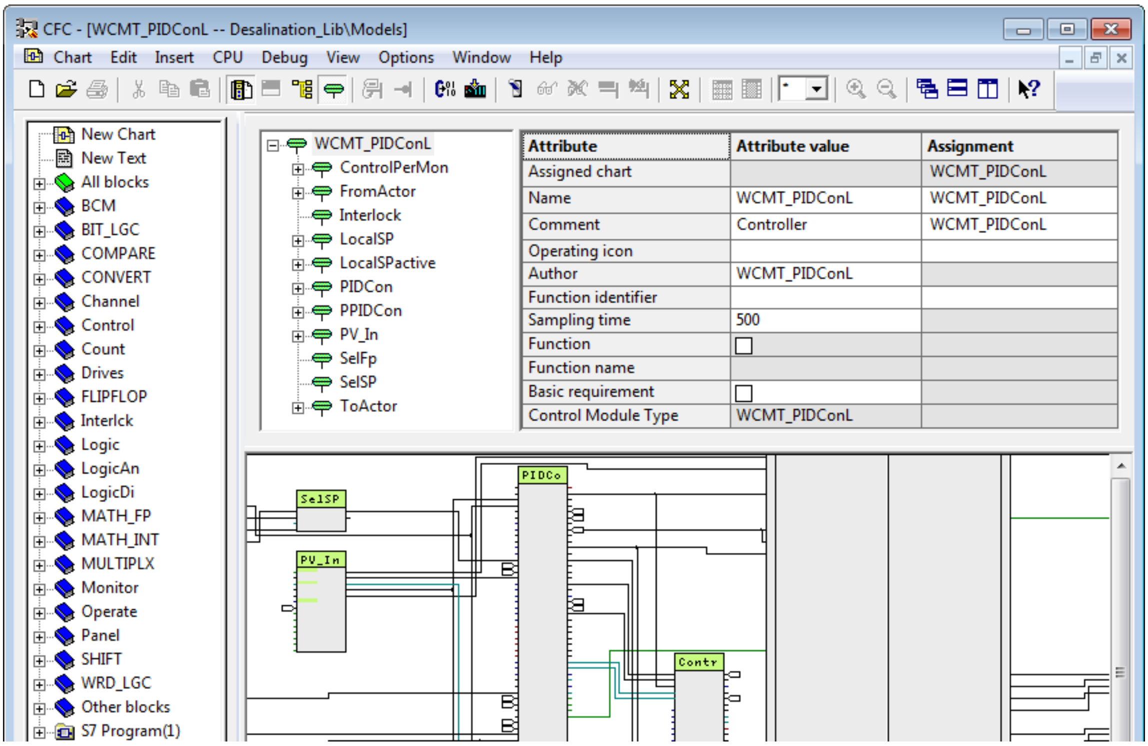
In the application example, the variants "OutFwd", "FbkFwd", "OutSpd" and "RbkSpd" are parameterized at the instances. Only one direction of rotation is required.

The following drives are of type "WCMT_MotSpdCon":

- NI-Feed
- NI-Recirc

4.1.3 WCMT_PIDConL

The Control Module Type "WCMT_PIDConL" is a PID controller with continuous output signal (manipulated variable). The PID controller can be used for fixed-value, cascade, ratio, split-range, Smith predictor and override control.



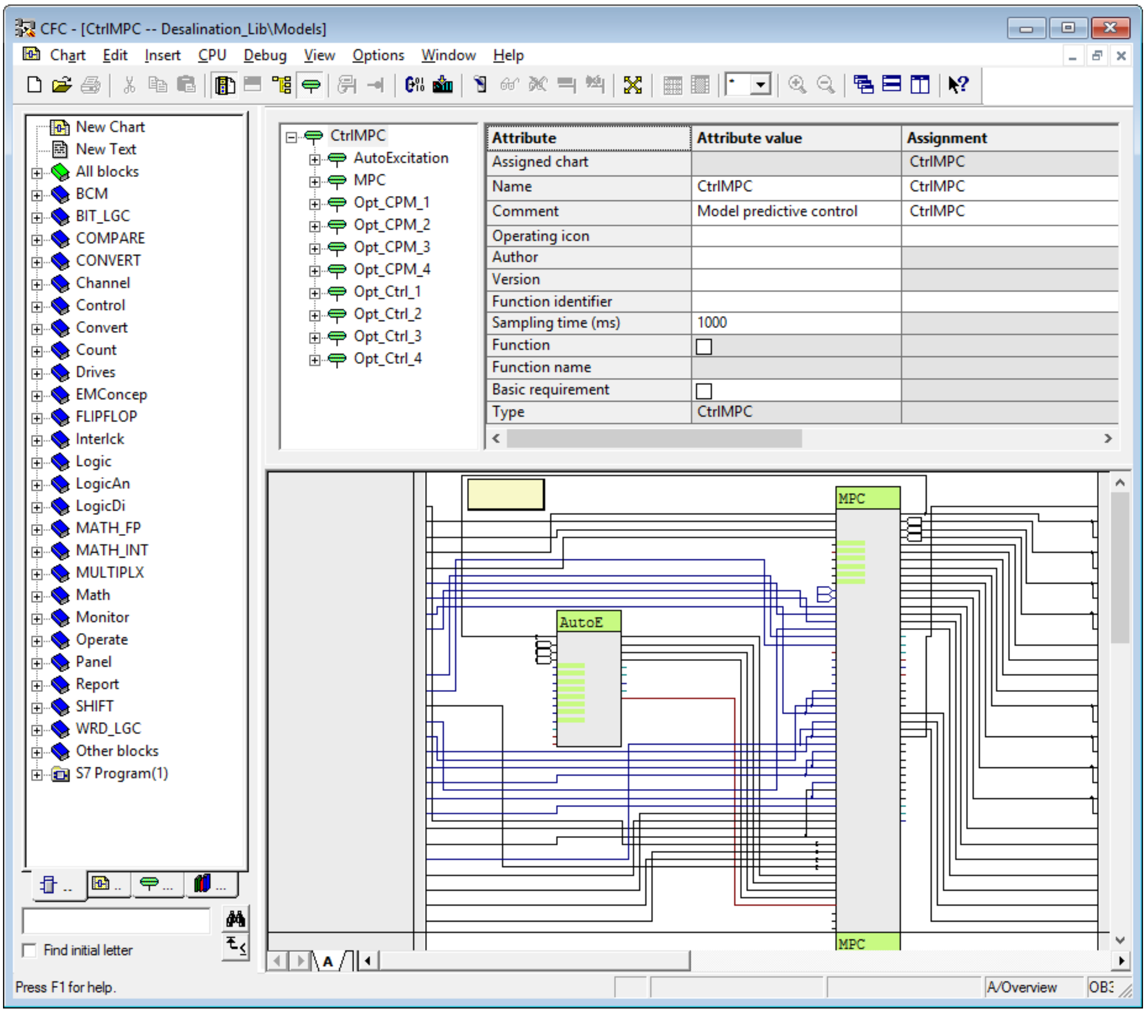
The controller is used in the Unit Template to control the pressure at the membrane and the flow of recirculation. No options are activated at the type instances used.

The following controllers are of type "WCMT_PIDConL":

- PIC-Feed
- FIC-Recirc

4.1.4 CtrlMPC

The CMT "CtrlMPC" is used for multi-variable control. In contrast to the "Ctrl", the multi-variable controller can handle up to four dependent manipulated and controlled variables. MPC is short for "Model Predictive Control".



The multi-variable controller is used in the Unit Template to directly control the target values permeate flow and salinity of the permeate, thus compensating for the effect of "fouling" at the membrane. The following options are activated for the type instances used:

- Opt_Ctrl_1
- Opt_Ctrl_2
- Opt_Ctrl_3
- Opt_Ctrl_4

The controller "XC_Desalination" is of type "CtrlMPC":

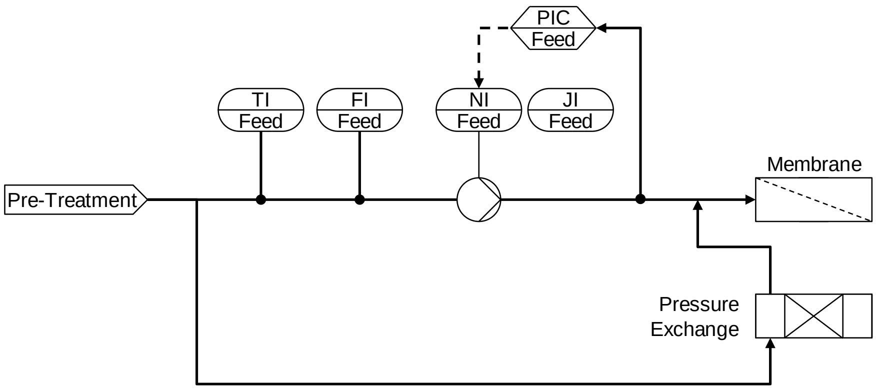
4.2 Equipment Modules and Control Modules

The Equipment Modules are described in detail in the following section. The basis for programming the AS are predefined Control Module Types from the water industry. The description of the used Control Module Types can be found in section 4.1

4.2.1 Inflow (Feed)

The pre-cleaned sea water from the ultrafiltration is transported via the inflow to reverse osmosis unit. In order to exploit the existing pressure of the retentate, part of the fresh sea water is passed through the pressure exchanger (energy recovery device). The high-pressure pump generates the required pressure at the membrane. The pressure level is specified as the setpoint at the controller.

Setup



The following Control Modules are used in the "Feed" area of the plant section:

Control module	Control module type	Variants	Description
RO-FI-Feed	WCMT_MonAnalog	MonAnIn	Flow measurement (m³/h)
RO-TI-Feed	WCMT_MonAnalog	MonAnIn	Temperature measurement (°C)
RO-JI-Feed	WCMT_MonAnalog	MonAnIn	Power measurement (kW)
RO-NI-Feed	WCMT_MotSpdCon	OutFwd OutSpeed FbkFwd RbkSpeed	Variable speed drive
RO-PIC-Feed	WCMT_PIDConL	PV_In	Pressure controller

Parameter assignment

RO-FI-Feed

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	2000 0	Measuring range of the Control Module
	PV_InUnit	1349	Unit of measurement of the Control Module (m^3/h)
I	PV_WL_Lim	300.0	Warning low limit
	PV_AL_Lim	200.0	Alarm Low limit
	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_FI_Feed.SIM_VAL	Simulated process value
I	MsgLock	SFC "Start-up"	Message lock during start-up
	PV_Out	SIM_Feed+Reci.In1	Calculation for the simulation

RO-TI-Feed

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	80 0	Measuring range of the Control Module
	PV_InUnit	1001	Unit of measurement of the Control Module (°C)
I	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_TI_Feed.Out	Simulated process value

RO-JI-Feed

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	1300.0 0	Measuring range of the Control Module
	PV_InUnit	1190	Unit of measurement of the Control Module (kW)
I	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_JI_Feed.Out	Simulated process value
to_MPC	ReStru1	C.PV_Out	Merge connection to MPC
	BoStru1	CSF.Out	
	BoStru2	OosAct.Out	
	Int1	MonAnIn.PV_OutUnit	
	Scale1	MonAnIn.Scale.Out	
	Out	XC_Desalination\from_CV3.In	Connection to MPC

RO-NI-Feed

All parameters were used with the default values.

These connections have been added in addition to the standard:

Block	Connection	Target	Description
FbkFwd	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_NI_Feed.FbkFwd_Out	Simulated process value
RbkSpeed	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_NI_Feed.Spd_Out	Simulated process value

Block	Connection	Target	Description
N	Fwd	SIM_NI_Feed.CmdFwd	Start signal for the simulation
	SP_Out	SIM_NI_Feed.SP_SPD	Target value for simulation
	SP_Ext	RO-PIC-Feed\C.MV	Control value of the controller
	ModLiOp	SFC "Start-up"	A detailed description of the SFC can be found in the section:4.2.7
	AutModLi	SFC "Start-up"	
	ManModLi	SFC "Start-up"	
	SP_LiOp	SFC "Start-up"	
	SP_ExtLi	SFC "Start-up"	
	FbkFwdOut	SFC "Start-up"	
	AutAct	SFC "Start-up"	
	SP_ExtAct	SFC "Start-up"	

RO-PIC-Feed

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
C	Gain	0.6	Controller gain
	TI	8	Controller delay time
	SP_Int	57.24	Internal setpoint
	PV_AH_Lim	80	Alarm high limit
	PV_WH_LIM	75	Warning high limit
	PV_WL_Lim	55	Warning low limit
	PV_AL_Lim	50	Alarm Low limit
	SP_InHiLim	100	Set point range corresponding to the measuring range of the Control Module
	SP_InLoLim	0	
PV_In	PV_InUnit	1137	Unit of measurement of the process value (bar)

The following connections were added to the standard:

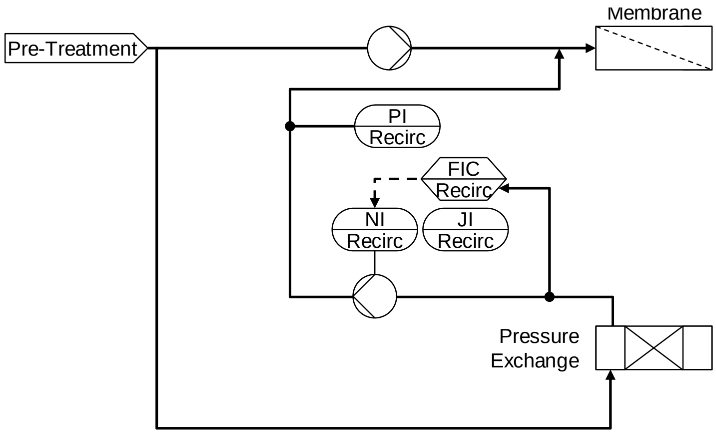
Block	Connection	Target	Description
C	SP	to_Master.ReStru1	Merge connection to MPC
	SP_InHiOut	to_Master.ReStru2	
	SP_InLoOut	to_Master.ReStru3	
	PV_Out	to_Master.ReStru4	
	CasaCut	to_Master.BoStru1	
	LockAct	to_Master.BoStru3	
	SP_Ext	from_Master.Restruc1	Disconnect wiring from MPC
	ModLiOp	SFC "Start-up"	A detailed description of the SFC can be found in the section:4.2.7
	AutModLi		
	ManModLi		
	SP_LiOp		
	SP_ExtLi		

Block	Connection	Target	Description
	SP_IntLi		
	AutAct		
	SP_ExtAct		
	SP		
	PV_WH_Ac		
OosAct	Out	to_Master.BoStru2	Merge connection to MPC
PV_In	PV_In.PV_OutUnit	to_Master.Int1	
	PV_In.ScaleOut	to_Master.Scale1	
to_Master	Out	XC_Desalination\from_Ctrl1.In	Connection to MPC
from_Master	In	XC_Desalination\to_Ctrl1.Out	Connection from MPC

4.2.2 Recirculation

The fresh sea water, which has been lifted to a higher pressure level by the pressure exchanger, is pumped to the membrane by the booster pump. The flow rate to be pumped is specified as the flow setpoint at the controller:

Setup



The following Control Modules are used in the "Recirc" plant section area:

Control module	Control module type	Variants	Description
RO-PI-Recirc	WCMT_MonAnalog	MonAnIn	Pressure measurement (bar)
RO-JI-Recirc	WCMT_MonAnalog	MonAnIn	Power measurement (kW)
RO-NI-Recirc	WCMT_MotSpdCon	OutFwd OutSpeed FbkFwd RbkSpeed	Variable speed drive
RO-FIC-Recirc	WCMT_PIDConL	PV_In	Flow controller

Parameter assignment

RO-PI-Recirc

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	90.0 0	Measuring range of the Control Module
	PV_InUnit	1137	Unit of measurement of the Control Module (bar)
I	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_PI-Recirc.Out	Simulated process value
I	MsgLock	SFC "Start-up”	Message lock during start-up

RO-JI-Recirc

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	140.0 0	Measuring range of the Control Module
	PV_InUnit	1190	Unit of measurement of the Control Module (kW)
I	PV_AH_En	0	High alarm (Off)
	PV_WH_En	0	High warning (Off)
	PV_AL_En	0	Low alarm (Off)
	PV_WL_En	0	Low Warning (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_JI_Feed.Out	Simulated process value
to_MPC	ReStru1	C.PV_Out	Merge connection to MPC
	BoStru1	CSF.Out	
	BoStru2	OosAct.Out	
	Int1	MonAnIn.PV_OutUnit	
	Scale1	MonAnIn.Scale.Out	
	Out	XC_Desalination\from_CV4.In	Connection to MPC

RO-NI-Recirc

All parameters were used with the default values.

These connections have been added in addition to the standard

Block	Connection	Target	Description
FbkFwd	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_NI_Recric.FbkFwd_Out	Simulated process value
RbkSpeed	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_NI_Recirc.Spd_Out	Simulated process value
N	Fwd	SIM_NI_Recirc.CmdFwd	Start signal for the simulation
	SP_Out	SIM_NI_Recirc.SP_SPD	Target value for simulation
	SP_Ext	RO-FIC-Recirc\C.MV	Control value of the controller
	ModLiOp	SFC "Start-up”	A detailed description of the SFC can be found in the section:4.2.7
	AutModLi	SFC "Start-up”	
	ManModLi	SFC "Start-up”	
	SP_LiOp	SFC "Start-up”	
	SP_ExtLi	SFC "Start-up”	
	FbkFwdOut	SFC "Start-up”	
	AutAct	SFC "Start-up”	
	SP_ExtAct	SFC "Start-up”	

RO-FIC-Recirc

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
C	Gain	0.16	Controller gain
	TI	4.7	Controller delay time
	SP_Int	728.6	Internal setpoint
	PV_AH_En	80	Alarm High (Off)
	PV_WH_En	75	Warning High (Off)
	PV_WL_En	55	Alarm Low (Off)
	PV_AL_Em	50	Warning Low (Off)
	SP_InHiLim	900	Set point range corresponding to the measuring range of the Control Module
	SP_InLoLim	0	
PV_In	PV_InUnit	1349	Unit of measurement of the process value (m^3/h)

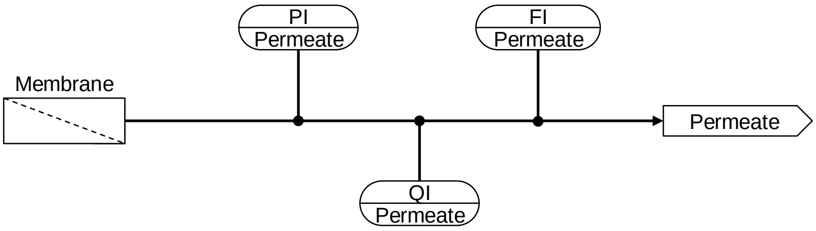
The following connections were added to the standard:

Block	Connection	Target	Description
C	SP	to_Master.ReStru1	Merge connection to MPC
	SP_InHiOut	to_Master.ReStru2	
	SP_InLoOut	to_Master.ReStru3	
	PV_Out	to_Master.ReStru4	
	CasaCut	to_Master.BoStru1	
	LockAct	to_Master.BoStru3	
	SP_Ext	from_Master.Restruc1	Disconnect wiring from MPC
	ModLiOp	SFC "Start-up"	A detailed description of the SFC can be found in the section:4.2.7
	AutModLi		
	ManModLi		
	SP_LiOp		
	SP_ExtLi		
	SP_IntLi		
	AutAct		
	SP_ExtAct		
	SP		
	PV_WH_Ac		
OosAct	Out	to_Master.BoStru2	Merge connection to MPC
PV_In	PV_OutUnit	to_Master.Int1	
	ScaleOut	to_Master.Scale1	
to_Master	Out	XC_Desalination\from_Ctrl2.In	Connection to MPC
from_Master	In	XC_Desalination\to_Ctrl2.Out	Connection from MPC

4.2.3 Permeate

Here, the residual salinity and the quantity of desalinated seawater are recorded.

Setup



The following Control Modules are used in the "Permeate" plant section:

Control module	Control module type	Variants	Description
RO-FI-Permeate	WCMT_MonAnalog	MonAnIn	Flow measurement (m³/h)
RO-PI-Permeate	WCMT_MonAnalog	MonAnIn	Pressure measurement (bar)
RO-QI-Permeate	WCMT_MonAnalog	MonAnIn	Measurement of conductivity (µS/cm)

In addition to conductivity, the quality of the product can also be represented by salinity. For this purpose, the salinity is calculated in simplified form using the following linear conversion factor:

$$1\frac{\mathrm{g}}{\mathrm{L}} \;\widehat{=}\; 1226.1\frac{\mu\mathrm{S}}{\mathrm{cm}}$$

Conductivity S is usually measured at a real plant. However, the conversion into salinity must be carried out individually. Conductivity depends, for example, on salt composition, pressure and temperature.

Parameter assignment

RO-FI-Permeate

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	2000 0	Measuring range of the Control Module
	PV_InUnit	1349	Unit of measurement of the Control Module (m³/h)
I	PV_WL_Lim	100.0	Warning low limit
	PV_AL_Lim	80.0	Alarm Low limit
	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	F_Factor.Out	Simulated process value
I	MsgLock	SFC "Start-up"	Message lock during start-up
	PV_Out	SIM_FI_Brine.In2	Calculation for the simulation
to_MPC	ReStru1	C.PV_Out	Merge connection to MPC
	BoStru1	CSF.Out	
	BoStru2	OosAct.Out	
	Int1	MonAnIn.PV_OutUnit	
	Scale1	MonAnIn.Scale.Out	
	Out	XC_Desalination\from_CV2.In	Connection to MPC

RO-PI-Permeate

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	90.0 0	Measuring range of the Control Module
	PV_InUnit	1137	Unit of measurement of the Control Module (bar)
	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_PI-Permeate.Out	Simulated process value

RO-QI-Feed

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	1800.0 0	Measuring range of the Control Module
	PV_InUnit	0	Unit of measurement of the Control Module ($\mu S/cm$)
	PV_AH_Lim	1300	Alarm high limit
	PV_WH_LIM	1280	Warning high limit
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

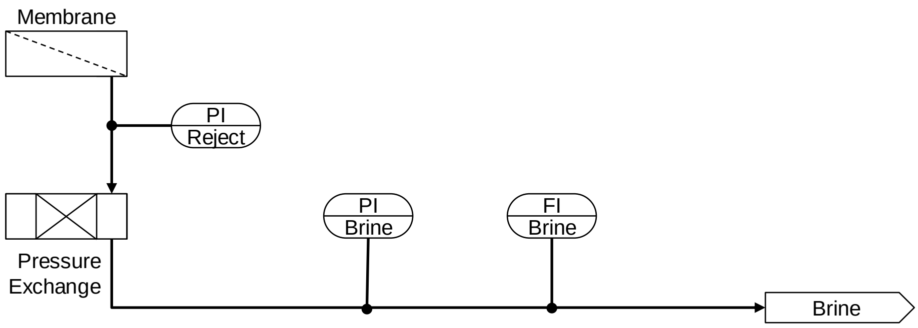
The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_JI_Feed.Out	Simulated process value
to_MPC	ReStru1	C.PV_Out	Merge connection to MPC
	BoStru1	CSF.Out	
	BoStru2	OosAct.Out	
	Int1	MonAnIn.PV_OutUnit	
	Scale1	MonAnIn.Scale.Out	
	Out	XC_Desalination\from_CV1.In	Connection to MPC

4.2.4 Brine

In this system area, the pressure of the retentate is measured and the pressure is transferred to the fresh seawater by the pressure exchanger. Flow of the brine is recorded in the discharge pipe.

Setup:



In the Equipment Modules "Brine" the following Control Modules are used:

Control module	Control module type	Variants	Description
RO-FI-Brine	WCMT_MonAnalog	MonAnIn	Flow measurement (m³/h)
RO-PI-Brine	WCMT_MonAnalog	MonAnIn	Pressure measurement (bar)
RO-PI-Reject	WCMT_MonAnalog	MonAnIn	Pressure measurement (bar)

Parameter assignment

RO-FI-Brine

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	1000.0 0	Measuring range of the Control Module
	PV_InUnit	1349	Unit of measurement of the Control Module (m³/h)
I	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_FI_Brine	Simulated process value
	PV_Out	SIM_FI_Brine.In2	Calculation for the simulation

RO-PI-Brine

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	90.0 0	Measuring range of the Control Module
	PV_InUnit	1137	Unit of measurement of the Control Module (bar)
	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_PI-Brine.Out	Simulated process value

RO-PI-Reject

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MonAnIn I	Scale.High Scale.Low	90.0 0	Measuring range of the Control Module
	PV_InUnit	1137	Unit of measurement of the Control Module (bar)
	PV_AH_En	0	Alarm High (Off)
	PV_WH_En	0	Warning High (Off)
	PV_AL_En	0	Alarm Low (Off)
	PV_WL_En	0	Warning Low (Off)
	GradHUpEn	0	Gradient High Alarm upwards (Off)
	GradHDnEn	0	Gradient High Alarm downwards (Off)

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MonAnIn	SimOn	SIM_On_Off.Activate	Activates/deactivates the simulation
	SimPV_In	SIM_PI-Reject.Out	Simulated process value

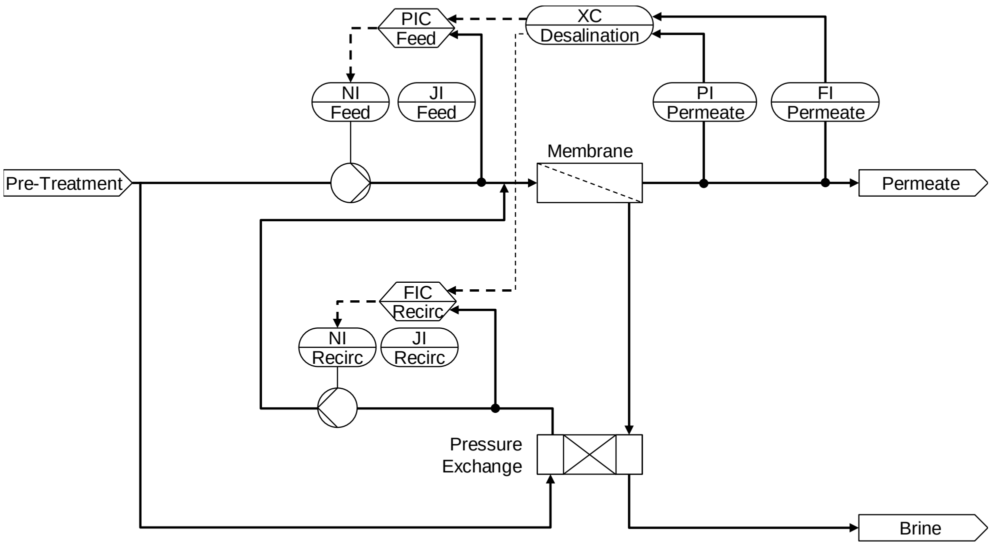
4.2.5 Salinity and flow rate (desalination)

The multi-variable control system regulates flow rate and salt concentration of water as a measure of product quality. For this purpose, the controller delivers its output values as external setpoints to the slave controllers for feed pressure and recirculation flow.

Product quality (salinity) has the highest priority but remains within its dead zone during normal operation. The controller only has to intervene if the salinity should be higher than permitted. Therefore, the main control variable in normal operation is the production output (permeate flow).

The electrical power consumption of high-pressure pump and booster pump are low-priority controlled variables. The target values correspond to the operating points with optimum pump efficiency.

Setup



The following Control Modules are used in the "Desalination" plant section:

Control module	Control module type	Variants	Description
RO-XC-Desalination	CtrlMPC	Opt_Ctrl_1 Opt_Ctrl_2 Opt_Ctrl_3 Opt_Ctrl_4	Multi-variable controller as master controller

Parameter assignment

RO-XC-Desalination

The Control Module contains communication blocks for connecting slave controllers and for displaying controlled variables, and is an instance of the Control Module Type "CtrlMPC". The communication blocks are connected to the following variables.

CVs (Controlled Variables):

- Salinity after membrane (RO-QI-Permante)
- Flow after membrane (RO-FI-Permante)
- High-pressure pump power consumption (RO-JI feed)
- Booster pump power consumption (RO-JI-Recirc)

MVs (Manipulated Variables, setpoint values for slave controllers):

- Feed pressure (RO-PIC feed)
- Recirculation flow rate (RO-FIC-Recirc)

The following parameters were changed from the default values during project planning:

Block	Parameters	Value	Description
MPC	SP1	533.31	Setpoint setting for the process value 1
	SP2	475.0	Setpoint setting for process value 2
	SP3	913.0	Setpoint setting for process value 3
	SP4	65.0	Setpoint setting for process value 4
	PreFilt1	24.0	Settling time in s of setpoint filter for setpoint SP1
	PreFilt1	36.0	Settling time in s of setpoint filter for setpoint SP2
	MV1Man	55.0	Control value in manual mode
	MV2Man	700.0	Control value in manual mode
	DB_No	18	DB number with controller data
DeadBand_SP1	In1	606.92	Upper limit of the deadband

The following connections have been added in addition to the standard connection:

Block	Connection	Target	Description
MPC	SP1DeadB	RO-XC-Desalination\Limit_Deadband.Out	Dead band for set value 1
MPC	SP1OpOut	RO-XC-Desalination\DeadBand_SP1.In2t	Calculate the dead band from the target value
to_Ctrl1	Out	RO-PIC_Feed\from_Master.In	Control value for the inlet pressure
to_Ctrl2	Out	RO-FIC_Recirc\from_Master.In	Control value for recirculation flow rate
from_Ctrl1	In	RO-PIC_Feed\to_Master.Out	Connection from the Control Module Inlet pressure
from_Ctrl2	In	RO-FIC_Recirc\to_Master.Out	Connection of the Control Module Recirculation
from_CV1	In	RO-QI-Permate\to_MPC.Out	Connection of salinity display
from_CV2	In	RO-FI-Permate\to_MPC.Out	Connection of flow rate indicator
from_CV3	In	RO-JI-Feed\to_MPC.Out	Connection to high-pressure pump display
from_CV4	In	RO-JI-Recirc\to_MPC.Out	Connection to booster pump display

4.2.6 Process simulation (simulation)

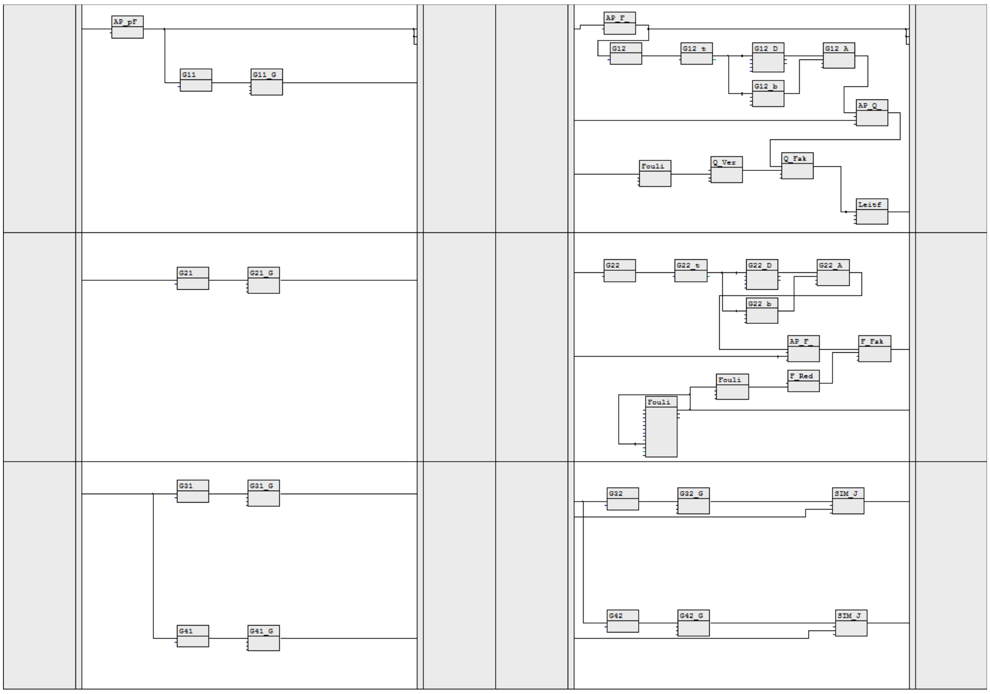
The task of process simulation is to understand or demonstrate the functionality of reverse osmosis, especially with regard to the control functions of the multi-variable controller. There is no claim of exactly reproducing the real physical behavior of a certain desalination plant.

Simulation of the membrane

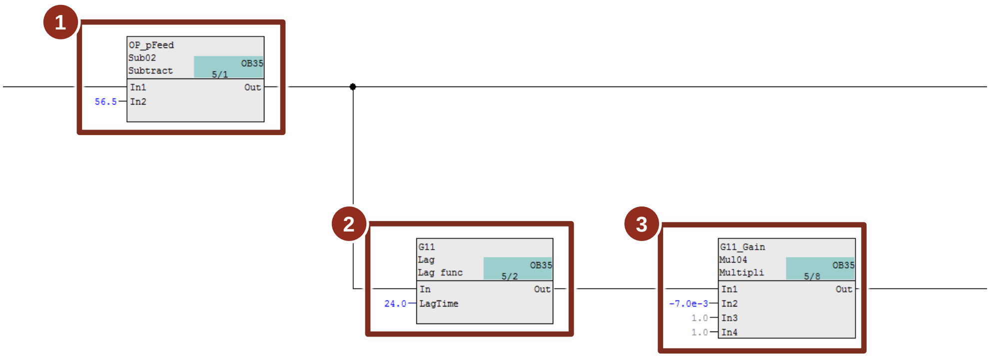
For process simulation, a matrix of linear dynamic transfer functions is used as a model. The process model is a 2x4 multi-variable system in which the influence of each input variable to each output variable is simulated by a separate partial transfer function. The model describes the temporal behavior of process deviations from the operating point. The process simulation runs in real time, only the fouling process runs in time-lapse, i.e. 240 times faster than real time. This means a cleaning of the membrane is necessary after 10 minutes.

		Input variables	
		RO-NI-Feed	RO-NI-Recirc
Output variables	QI_Permeate	G11	G12
	FI_Permeate	G21	G22
	JI_Feed	G31	G32
	JI_Recirc	G41	G42

In the simulation plan "Sim_Membran" the process variables of the MPC are calculated. Operating points, delays and interactions are defined for each process variable. The dynamic model describes deviations from the operating point for the respective process variable.



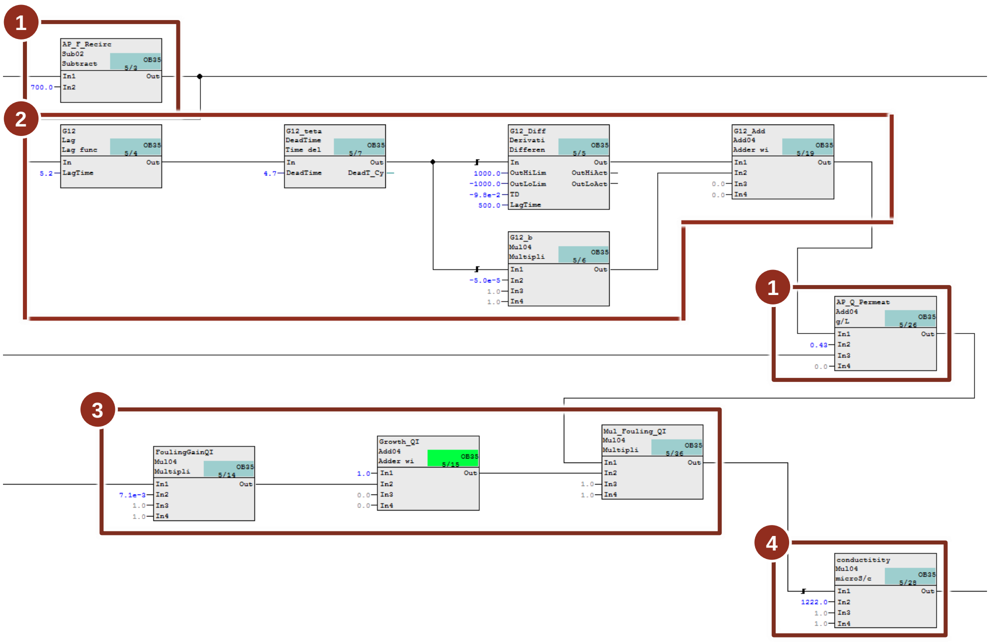
For the transfer functions G11, G21, G31, G32, G41 and G42 a first-order delay function (PT1 behavior) around the operating point is simulated.



1. Calculation of the deviation from the operating point
2. First order delay element
3. Gain

The transfer functions G12 and G22 cannot be realistically simulated by first-order delay functions (PT1 behavior). Therefore, for these two transfer functions, the form

$G(s) = K_p \cdot \frac{1+T_z \cdot s}{(1+T_{p1} \cdot s)(1+T_{p1} \cdot s)}$ is selected



1. Calculation of the deviation from the operating point
2. Transfer function
3. Influence of fouling
4. Conversion to conductivity

Note

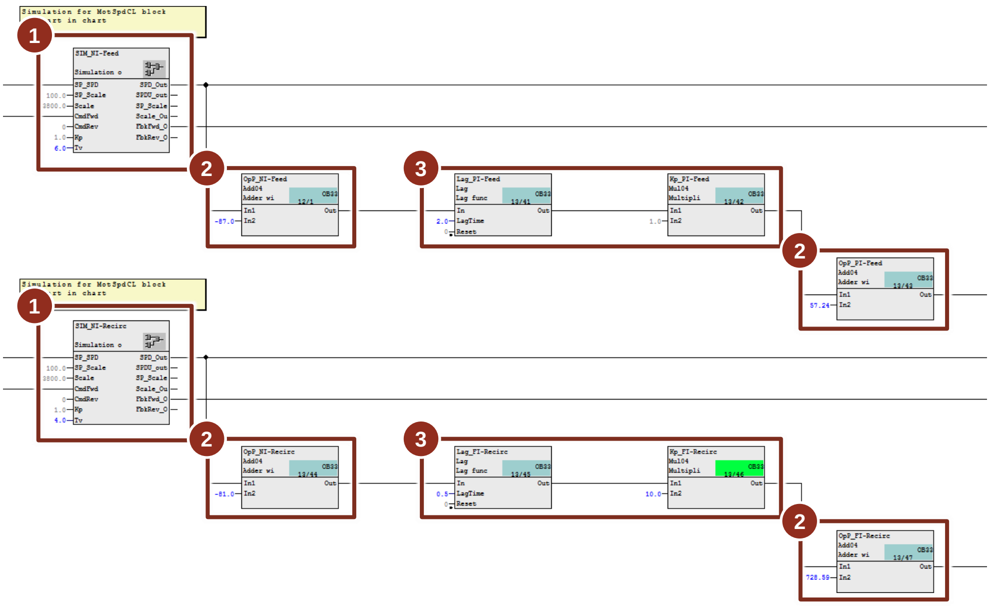
The conversion of salinity to conductivity (measurable at the real plant) is carried out for the template in simplified form with the following linear conversion factor:

$$1\,\frac{\mathrm{g}}{\mathrm{L}} \,\widehat{=}\, 1226.1\,\frac{\mu\mathrm{S}}{\mathrm{cm}}$$

In a real plant, the actual salinity can only be calculated from the measured conductivity. The conversion depends on salt composition, pressure and temperature and must be calibrated individually.

Process simulation

In the simulation plan "Simulation" the process variables of the two PID controllers are calculated. Operating points, delays and interactions are defined for each process variable. The dynamic model describes deviations from the operating point for the respective process variable.



1. Simulation of a motor with two directions of rotation and variable speed
2. Scaling to the operating point
3. Simulation of the process behavior (PT1 element)

A plan-in-plan module is used to simulate a motor with two directions of rotation and variable speed. The following table shows the input parameters of the block.

Parameters	Type	Description
SP_SPD	STRUCT Value: REAL ST: BYTE	Analog setpoint of the engine
SP_Scale	STRUCT High: REAL Low: REAl	Setpoint limits of the engine
Scale	STRUCT High: REAL Low: REAL	Scaling of the motor in revolutions per minute
CmdFwd	STRUCT Value: BOOL ST: BYTE	Command to start the engine in forward direction
CmdRev	STRUCT Value: BOOL ST: BYTE	Command to start the engine in reverse direction
Kp	STRUCT Value: REAL ST: BYTE	Engine gain factor
Tv	REAL	Delay time of the engine (PT_1 behavior)

The following table shows the output parameters of the block.

Parameters	Type	Description
SPD_Out	STRUCT Value: REAL ST: BYTE	Analog output value of the engine in percent
SPDU_Out	STRUCT Value: REAL ST: BYTE	Analog output value of the engine in revolutions per minute
SP_Scale_Out	STRUCT High: REAL Low: REAL	Output of the scaling of the engine in percent
Scale_Out	STRUCT High: REAL Low: REAL	Output of the scaling of the engine in revolutions per minute
FbkFwd	STRUCT Value: BOOL ST: BYTE	Feedback of the engine in forward direction
FbkRev	STRUCT Value: BOOL ST: BYTE	Feedback of the engine in reverse direction

4.2.7 Sequential Function Chart

After the CPU has been started, the SFC "Startup" drives the system into the operating point. The SFC starts the drives and defines setpoints for the controllers. The messages of the Control Modules are blocked until all process values are within the normal range. The SFC is processed only once after the start of the CPU.

(1) "Lock Messages":

The messages of the affected blocks are blocked.

(2) "NI-Feed-Link" and "NI-Recirc-Link":

The operation of the drives is set to automatic and the setpoint source is set to external.

(3) "NI-Feed-Start" and "NI-Recirc-Start":

The drives are started.

(4) "PIC-Feed-Start" and "FIC-Recirc-Start":

The operation of the PID controllers is set to interconnection and the setpoint source is set to internal.

(5) "Start_MPC".

Starting the MPC in manual mode and setting the output value

(6) "PIC-Feed-Ext" and "FIC-Recirc-Ext":

The operation of the controllers is switched over to the external setpoint.

(7) "Auto_MPC":

The MPC is given the setpoints and put into automatic mode.

(8) "NI-Feed-Op" and "NI-Recirc-Op":

The usability of the engines is enabled again for the operator.

(9) "PIC-Feed-Op" and "FIC-Recirc-Op":

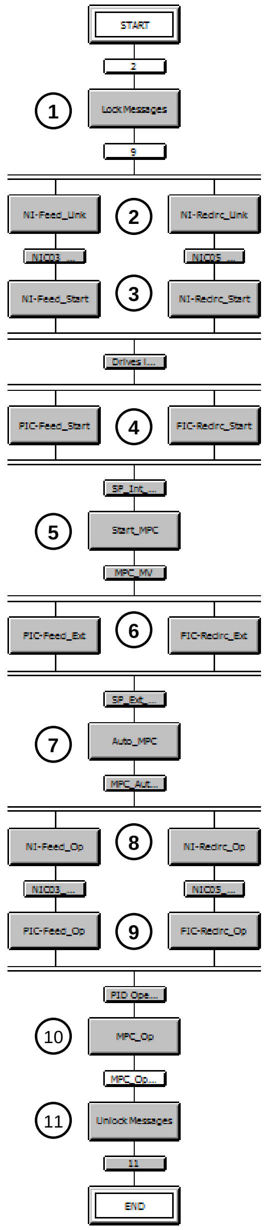
The operation of the controllers is enabled again for the operator.

(10) "MPC-Op" and "FIC-Recirc-Op":

The operation of the MPC is enabled again for the operator.

(11) "Unlock Messages":

The messages of the affected blocks are released.



The SFC "Startup" is implemented in the folder "RevOsmosis" of the plant hierarchy.

4.2.8 Key Performance Indicators (KPI)

The CFC "KPI" contains key figures that inform the operator about the performance of the process. The following key performance indicators are calculated and displayed in the visualization:

1. Sheet: Specific energy consumption: The specific energy consumption is calculated from the ratio of total power consumption to volume flow. The total power is calculated by adding the power of the high-pressure pump and the booster pump. The outgoing volume flow $\dot{V}_{Permate}$ corresponds to the permeate product outflow.

   $$SEC = \frac{P_{\mathrm{Feed}} + P_{\mathrm{Recirc}}}{\dot{V}_{\mathrm{Permeate}}}$$

2. Sheet: Overall energy consumption (OverallEnergy): The energy consumption describes the energy consumed since the last cleaning of the membrane and is calculated from the time integral of the power consumption of the two pumps.

   $$E_{\mathrm{consumption}} = \int (P_{\mathrm{Feed}} + P_{\mathrm{Recirc}})\, \mathrm{d}t$$

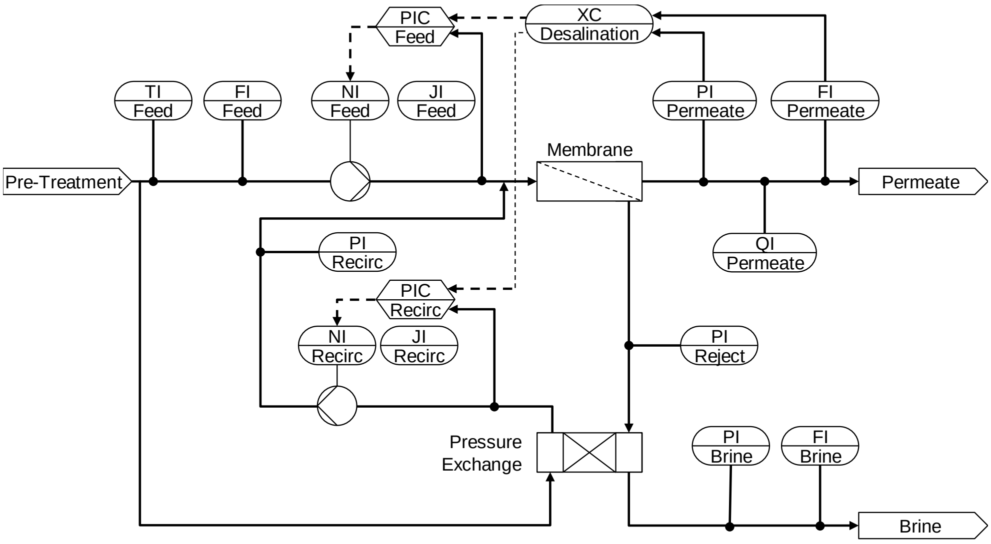
3. Sheet: Produced quantity (OverallProduction): The quantity produced describes the quantity of drinking water produced since the last purification of the membrane and is calculated from the time integral of the volume flow of the desalinated water.

   $$V_{\mathrm{Product}} = \int \dot{V}_{\mathrm{Permeate}}\, \mathrm{d}t$$

5 Basics

5.1 P&I diagram

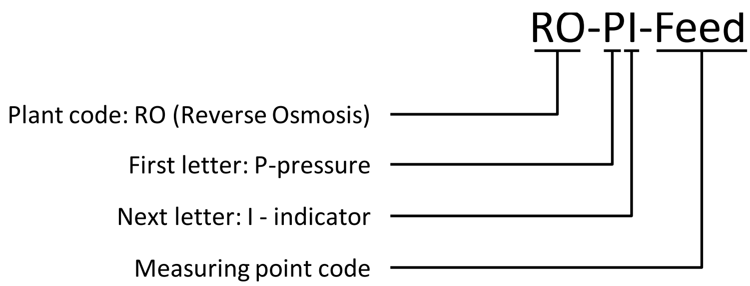
The following P&ID shows the process of reverse osmosis within a seawater desalination plant. This process is described in more detail in this application example.



5.2 Project structure

5.2.1 Naming conventions

For the composition of the process tags a uniform naming convention is used, which corresponds to the European standard EN 62424. As shown here using the example of a process tag for pressure recording, the process tag designations in the AS program are structured as follows:



The following tables contain the designations used in this application example and their meaning:

First letter	Meaning
F	Flow
J	Power
L	Level
M	Moisture
N	Engine

First letter	Meaning
P	Pressure
Q	Amount, quantity or quality
S	Speed (velocity, rotational speed, frequency)
T	Temperature
X	Freely selectable first letter
Y	Control valve

Next letter	Meaning
A	Alarming/Messages
C	Control
F	Fraction
I	Indication
R	Recording/Storage
S	Switching function or binary control function (not safety-relevant)

5.2.2 Plant view

The SIMATIC PCS 7 project is created as a multi-project "Desalination_MP" and contains the following subprojects:

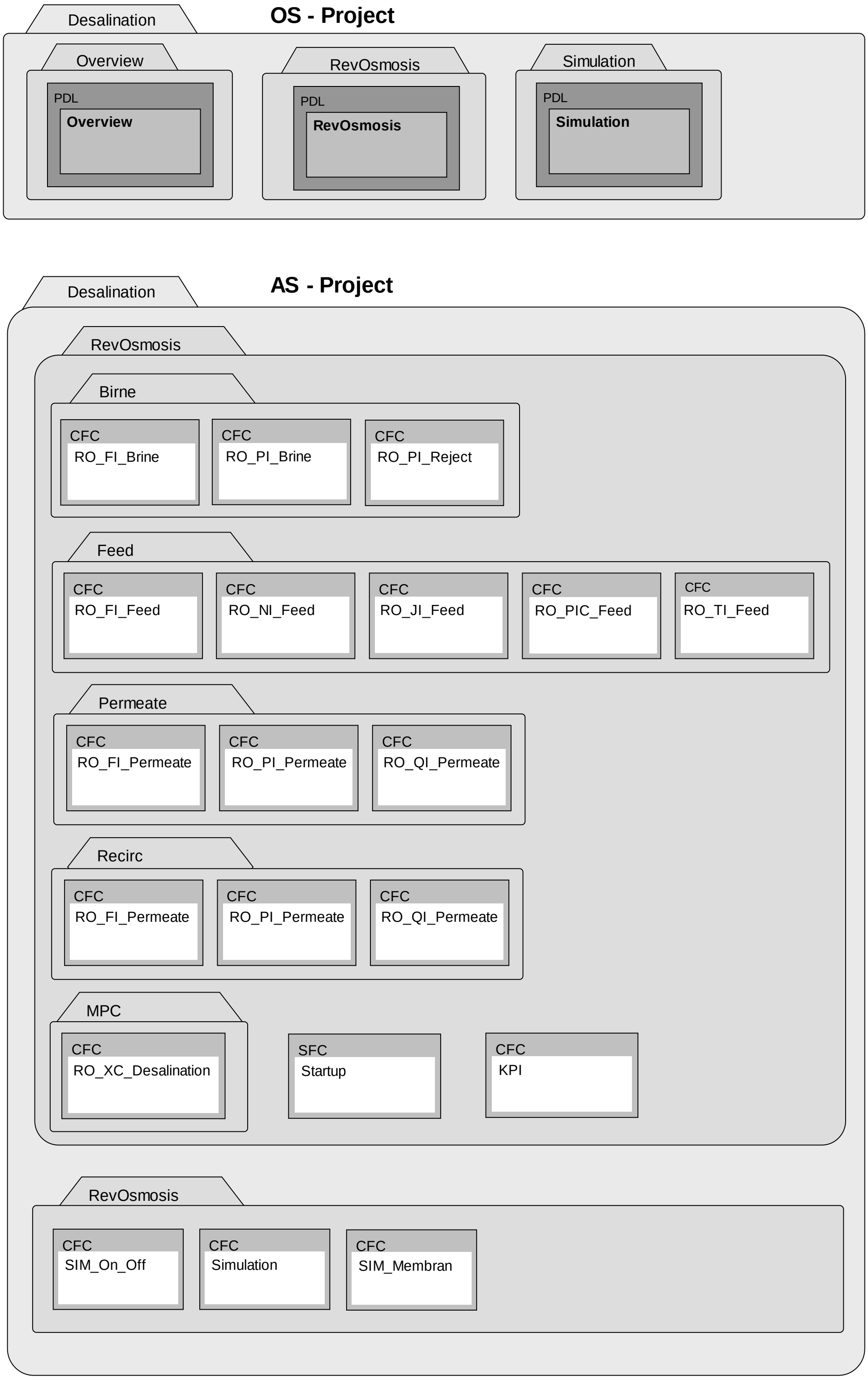
- Desalination_AS
  Contains the hardware configuration of the AS and the AS program.
- Desalination_OS
  Contains the configuration of the OS and the OS project.
- Desalination_Lib
  The master data library provides all the components used.

The plant hierarchy is defined with three levels (plant, plant section and Equipment Module) and the OS level is defined as level 2. The AS program for seawater desalination is set up in the "RevOsmosis" plant unit.

The 'RevOsmosis' unit contains the Equipment Modules in which the CFCs are located.

The process picture of reverse osmosis is displayed at the operator station in the plant area "RevOsmosis". The process screen contains the Control Modules of all Equipment Modules.

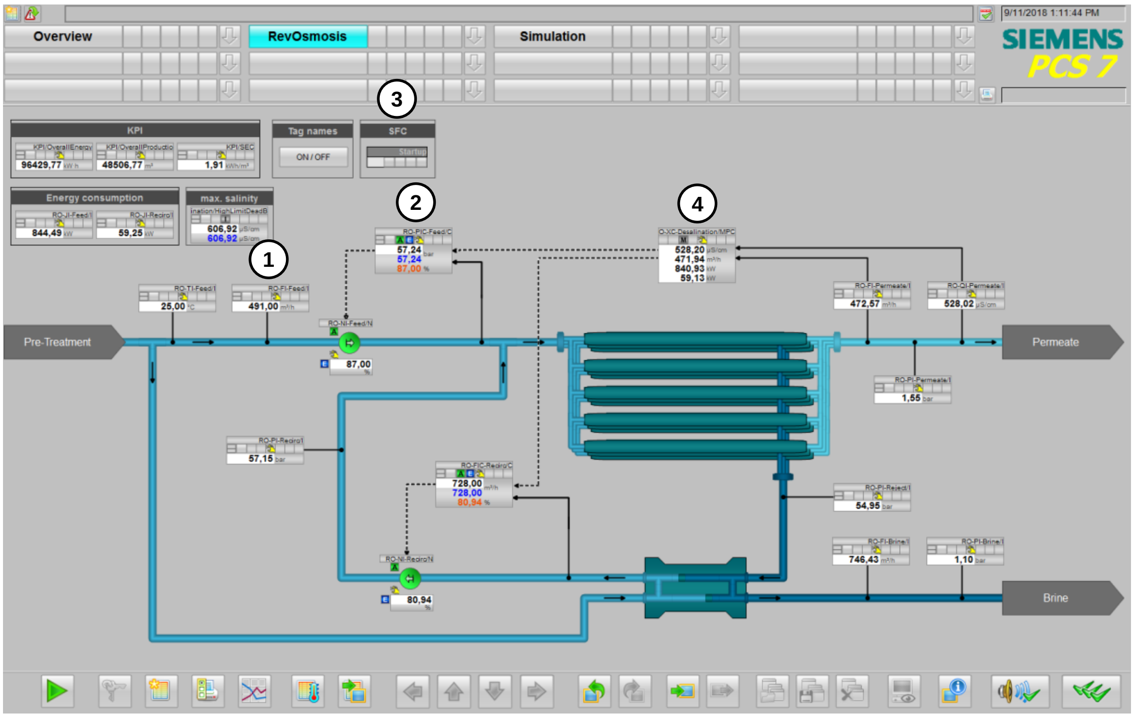
The following figure shows the structure of the PCS 7 multi-project.



5.3 Components of Unit Template

The desalination process is realized with the following components:

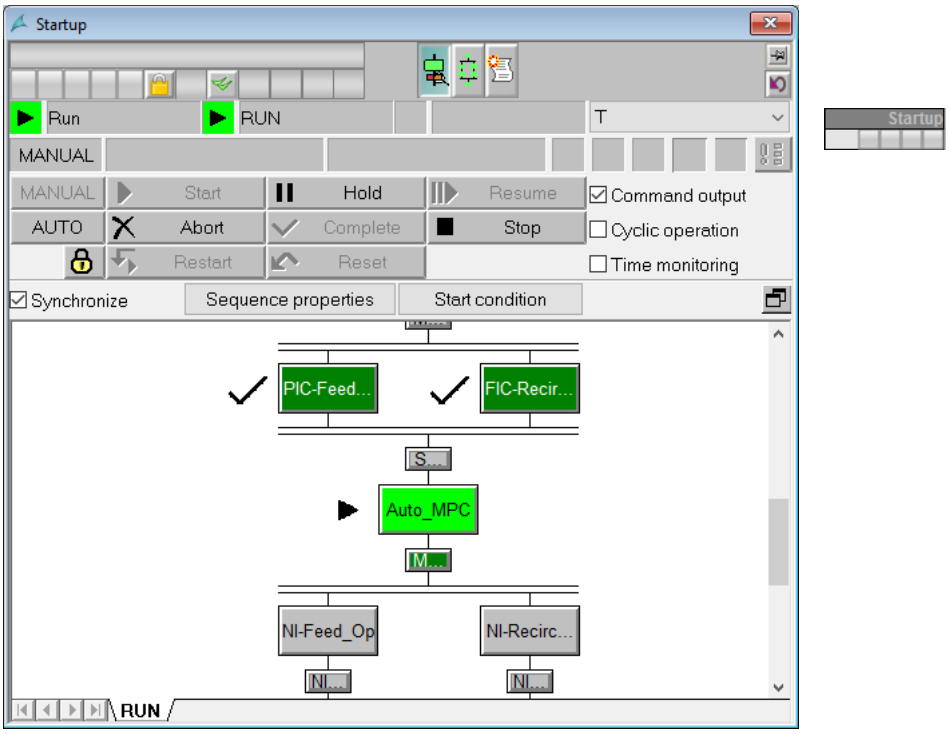
- High pressure pump
- Osmosis membranes
- Pressure exchanger
- Booster pump
- Control Modules for recording pressure, flow rate, performance, quality and temperature



1. Analog process tag
2. Pump drive with PID control
3. Sequential function chart "Startup"
4. MPC

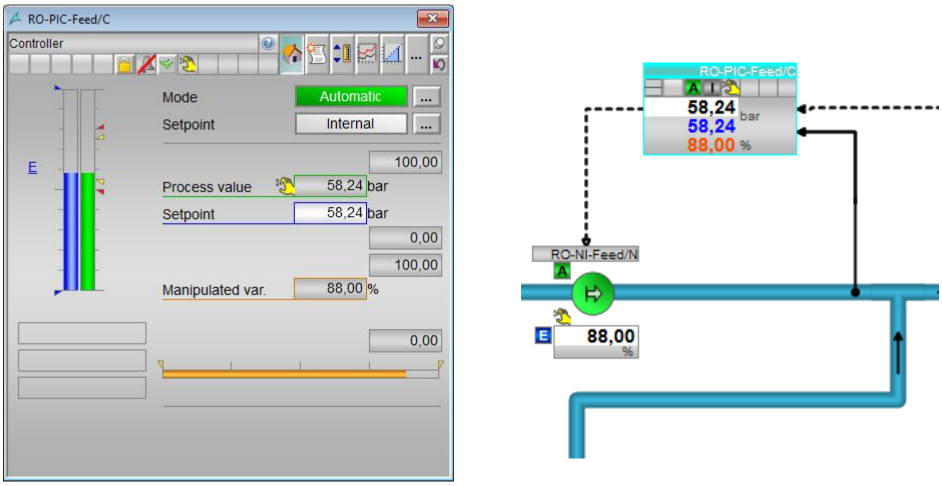
Startup

After you start the CPU, the SFC "Startup" is executed. You can check the status of the SFC at the block symbol with the corresponding faceplate and restart the sequencer if necessary.



PID control

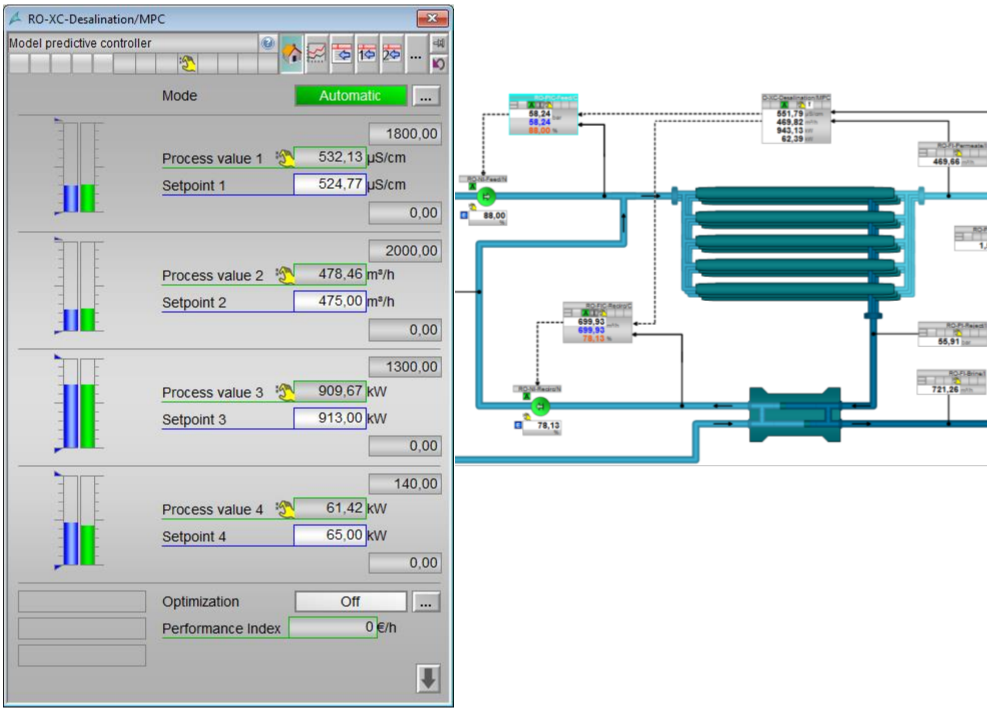
The drives "NI-Feed" and "NI-Recirc" are controlled by a PID controller. The controller "PIC-Feed" controls the pressure "PI-Feed" at the osmosis membrane. The controller "FIC-Recirc" regulates the flow "FI-Recirc" of fresh sea water, which has been brought to a higher pressure level by the pressure exchanger.



The setpoints for PID control of pressure and flow are specified by the multi-variable controller.

MPC

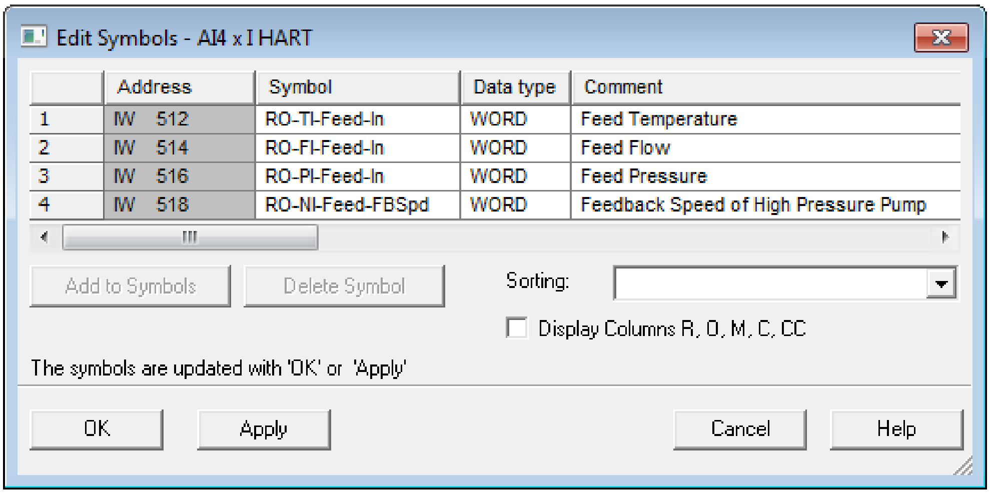
The PID controllers "PIC-Feed" and "FIC-Recirc" receive the setpoints from a master multi-variable controller. The multi-variable controller commands up to four interacting manipulated and controlled variables as well as one measurable disturbance variable. In this case, the flow rate and the quality of the product are read and the manipulated variables for the desalination process are calculated.



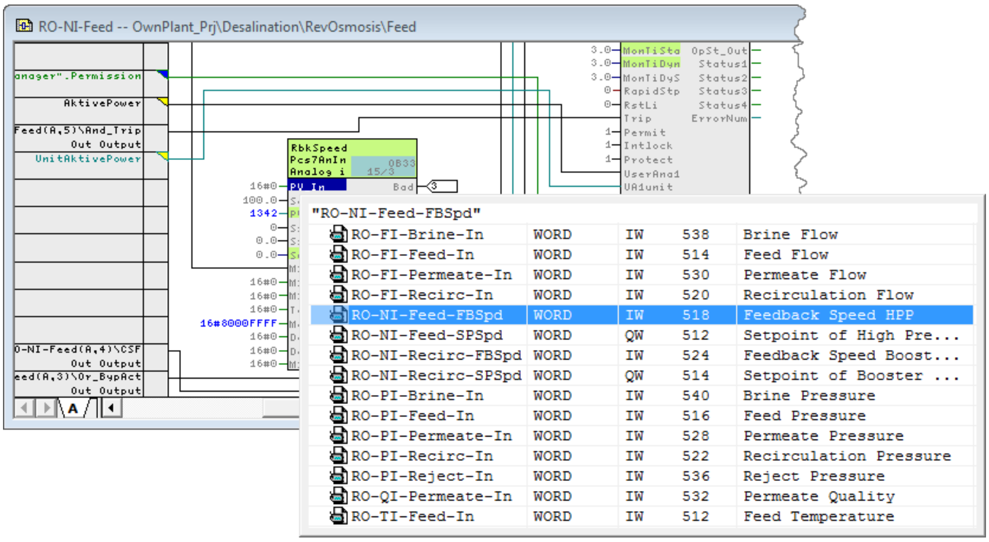
5.4 Connect Control Modules

For the next steps, make sure that the hardware devices including peripherals are completely configured in your project. You should parameterize all used inputs and outputs of the periphery with symbol names. Name the symbols in the same way as the corresponding process tag names. E.g. the following symbolic names are used to control the high pressure pump:

Address	Symbol	Data type	Comment
IW 516	RO-PI-Feed-In	WORD	Feed Pressure
IW 518	RO-NI-Feed-FBSpd	WORD	Feedback Speed HPP
I 0.0	RO-NI-Feed-FBFwd	BOOL	Feedback Run Forward HPP
QW 515	RO-NI-Feed-SPSpd	WORD	Setpoint Speed HPP
Q 0.0	RO-NI-Feed-Start	BOOL	Starting Forward HPP



Then connect the connection "PV_In" or "PV_Out" of all driver blocks to the process periphery.



6 Appendix

6.1 Service and support

Industry Online Support

Do you have any questions or need assistance?

Siemens Industry Online Support offers round the clock access to our entire service and support know-how and portfolio.

The Industry Online Support is the central address for information about our products, solutions and services.

Product information, manuals, downloads, FAQs, application examples and videos – all information is accessible with just a few mouse clicks:
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https://support.industry.siemens.com/cs/ww/en/sc/2067

6.2 Links and literature

No.	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Link to this entry page of this application example https://support.industry.siemens.com/cs/ww/en/view/109741119
\3\	Whitepaper: "Optimization of Reverse Osmosis Seawater Desalination Plants by Advanced Process Control" https://w3.siemens.com/mcms/water-industry/en/desalination/PublishingImages/whitepaper-reverse-osmosis.pdf
\4\	Standard PCS 7 and S7 Water Templates for the water industry https://support.industry.siemens.com/cs/ww/en/view/78604785
\5\	SIMATIC Process control system PCS 7 Advanced Process Library (V9.0 SP1) https://support.industry.siemens.com/cs/ww/en/view/109754967
\6\	Controller optimization with PCS 7 PID Tuner https://support.industry.siemens.com/cs/ww/en/view/8031495

6.3 Change documentation

Version	Date	Modifications
V1.0	10/2018	First version