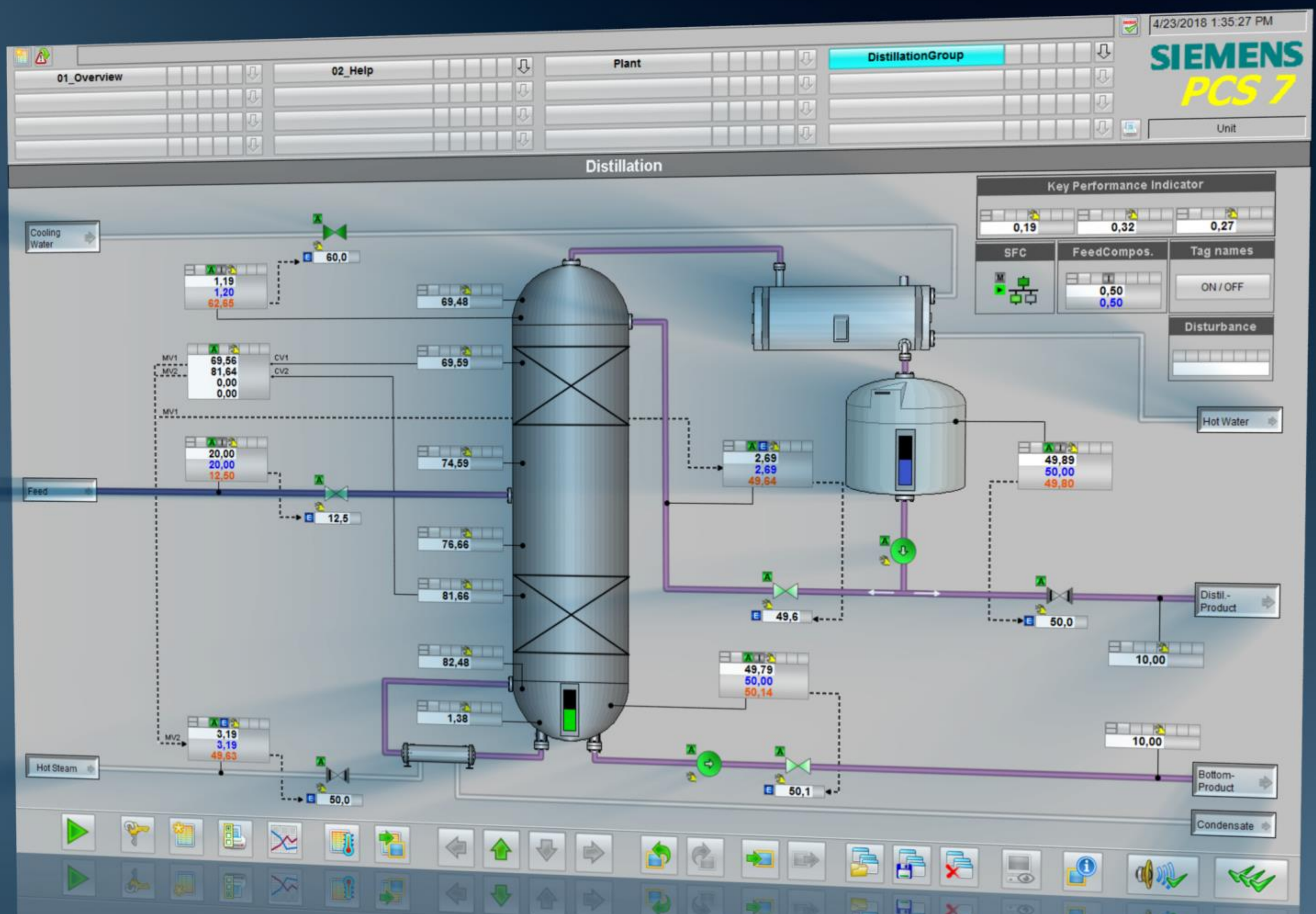
SIEMENS
Ingenuity for life



PCS 7 Unit Template "Distillation Column" using the example of the Chemical Industry

SIMATIC PCS 7

https://support.industry.siemens.com/cs/ww/en/view/48418663

Siemens Industry Online Support

Legal information

Use of application examples

Application examples illustrate the solution of automation tasks through an interaction of several components in the form of text, graphics and/or software modules. The application examples are a free service by Siemens AG and/or a subsidiary of Siemens AG ("Siemens"). They are non-binding and make no claim to completeness or functionality regarding configuration and equipment. The application examples merely offer help with typical tasks; they do not constitute customer-specific solutions. You yourself are responsible for the proper and safe operation of the products in accordance with applicable regulations and must also check the function of the respective application example and customize it for your system.

Siemens grants you the non-exclusive, non-sublicensable and non-transferable right to have the application examples used by technically trained personnel. Any change to the application examples is your responsibility. Sharing the application examples with third parties or copying the application examples or excerpts thereof is permitted only in combination with your own products. The application examples are not required to undergo the customary tests and quality inspections of a chargeable product; they may have functional and performance defects as well as errors. It is your responsibility to use them in such a manner that any malfunctions that may occur do not result in property damage or injury to persons.

Disclaimer of liability

Siemens shall not assume any liability, for any legal reason whatsoever, including, without limitation, liability for the usability, availability, completeness and freedom from defects of the application examples as well as for related information, configuration and performance data and any damage caused thereby. This shall not apply in cases of mandatory liability, for example under the German Product Liability Act, or in cases of intent, gross negligence, or culpable loss of life, bodily injury or damage to health, non-compliance with a guarantee, fraudulent non-disclosure of a defect, or culpable breach of material contractual obligations. Claims for damages arising from a breach of material contractual obligations shall however be limited to the foreseeable damage typical of the type of agreement, unless liability arises from intent or gross negligence or is based on loss of life, bodily injury or damage to health. The foregoing provisions do not imply any change in the burden of proof to your detriment. You shall indemnify Siemens against existing or future claims of third parties in this connection except where Siemens is mandatorily liable.

By using the application examples you acknowledge that Siemens cannot be held liable for any damage beyond the liability provisions described.

Other information

Siemens reserves the right to make changes to the application examples at any time without notice. In case of discrepancies between the suggestions in the application examples and other Siemens publications such as catalogs, the content of the other documentation shall have precedence.

The Siemens terms of use (https://support.industry.siemens.com) shall also apply.

Security information

Siemens provides products and solutions with Industrial Security functions that support the secure operation of plants, systems, machines and networks.

In order to protect plants, systems, machines and networks against cyber threats, it is necessary to implement – and continuously maintain – a holistic, state-of-the-art industrial security concept. Siemens' products and solutions constitute one element of such a concept.

Customers are responsible for preventing unauthorized access to their plants, systems, machines and networks. Such systems, machines and components should only be connected to an enterprise network or the Internet if and to the extent such a connection is necessary and only when appropriate security measures (e.g. firewalls and/or network segmentation) are in place.

For additional information on industrial security measures that may be implemented, please visit https://www.siemens.com/industrialsecurity.

Siemens' products and solutions undergo continuous development to make them more secure. Siemens strongly recommends that product updates are applied as soon as they are available and that the latest product versions are used. Use of product versions that are no longer supported, and failure to apply the latest updates may increase customer's exposure to cyber threats.

To stay informed about product updates, subscribe to the Siemens Industrial Security RSS Feed at: https://www.siemens.com/industrialsecurity.

Table of contents

Legal information **2**

1 Introduction **5**

1.1 Overview 5
1.2 Mode of operation 7
1.2.1 Core functionality 8
1.2.2 Control concept 10
1.2.3 P&ID flow diagram 11
1.3 Hardware and software components 12

2 Preparation and commissioning **13**

2.1 Preparation 13
2.2 Commissioning 14
2.3 Components of process visualization 15
2.4 Controlling the application 18
2.4.1 Overview 18
2.4.2 Scenario A - Changing the feed amount 18
2.4.3 Scenario B - Changing the feed concentration 19

3 Integrating the unit template in the user project **21**

3.1 Preparation 21
3.2 Copying templates 21
3.3 Copying units 22
3.4 Adapting the OS project 23

4 Engineering **24**

4.1 Equipment modules and control modules 24
4.2 Head pressure control "Pressure" 25
4.2.1 Setup 25
4.2.2 Parameter assignment 26
4.3 Inflow "Feed" 27
4.3.1 Setup 27
4.3.2 Parameter assignment 28
4.4 Evaporator "Heating" 29
4.4.1 Setup 29
4.4.2 Parameter assignment 30
4.5 Capacitor with reflux "Reflux" 31
4.5.1 Setup 31
4.5.2 Parameter assignment 31
4.6 Removal of the head product "HeadLevel" 33
4.6.1 Setup 33
4.6.2 Parameter assignment 33
4.7 Removal of the bottom product "BottomLevel" 34
4.7.1 Setup 34
4.7.2 Parameter assignment 34
4.8 Distillation 35
4.8.1 Setup 35
4.8.2 Parameter assignment 36
4.9 Process simulation (Process) 38
4.10 Sequences 44
4.11 Process key figures "KPI" 45
4.12 Maintenance 45
4.13 Task-related overview screens with APG 46
4.13.1 Integration of APG 46
4.13.2 APG measuring points (AS) 46
4.13.3 Detecting deviations in the process mode with APG 48

4.14 Smart Alarm Hiding 52

5 Useful information 57

5.1 Basics 57
5.1.1 Distillation column (rectification column) 57
5.1.2 Temperature characteristic 58
5.2 Details on functionality 59
5.2.1 CFC naming convention 59
5.2.2 Plant view 60
5.3 Automation 61
5.3.1 The "unit" concept 61
5.3.2 PCS Engineering with control modules 61
5.3.3 Key Performance Indicators 62
5.3.4 MPC controller 62
5.3.5 Linearization 62
5.4 Further Notes, Tips and Tricks, etc. 64
5.4.1 Configuration of the PID controller 64
5.4.2 Configuration of the MPC controller 66

6 Appendix 71

6.1 Service and support 71
6.2 Links and literature 72
6.3 Change documentation 72

1 Introduction

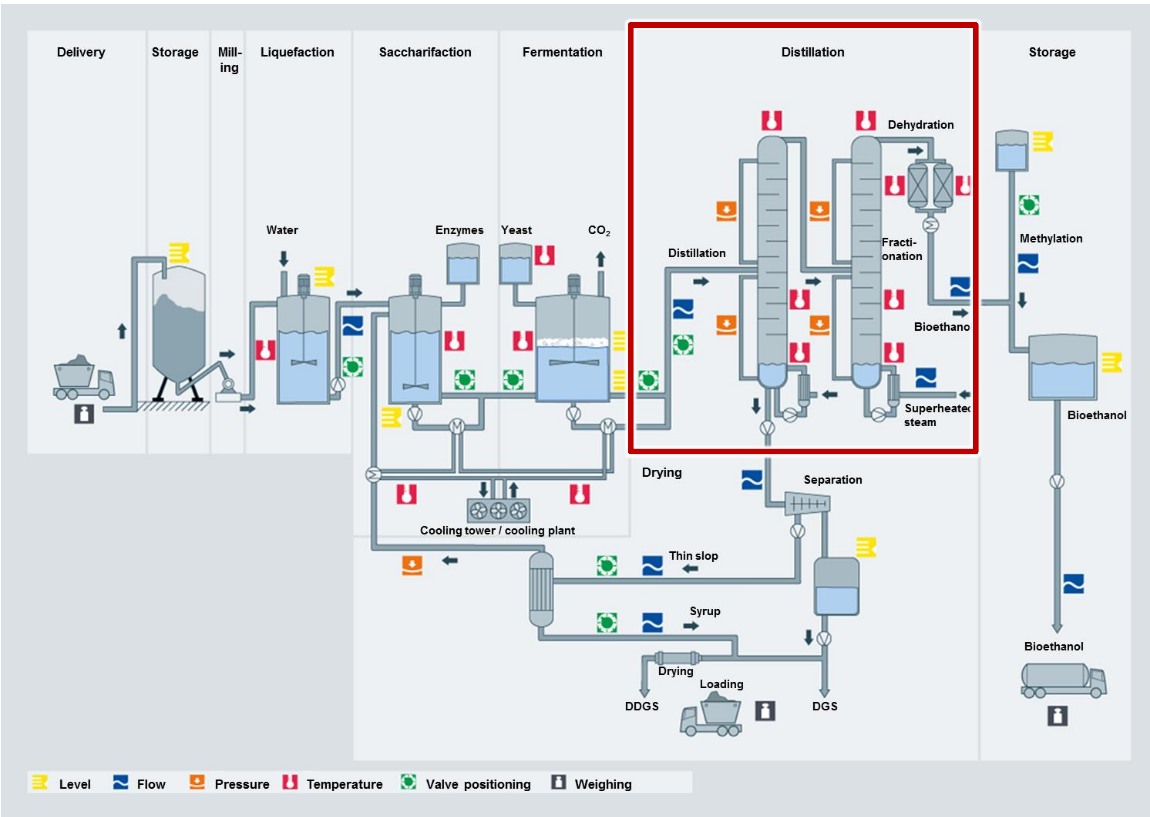
1.1 Overview

The standardization of automation engineering for process plants, such as in the chemical industry, is a major challenge. Different process steps and procedures, and diverse equipment and flexibility levels in production make the task even more difficult.

This includes the plant structure according to the ISA-106. This specifies the lower four levels, i.e. plant area, unit, equipment and device. A plant always consists of units. The units contain standardized equipment modules.

Overview of complete solution

The following picture shows the process scheme of a typical chemical plant with three stirred tank reactors and two distillation columns (highlighted with a red frame).



Description

The "Distillation Column" unit template includes several pre-built, unified and ready-connected equipment modules. Using this sample solution as a basis, numerous instances with different parameter assignments can be generated with adapted characteristics to be widely integrated in automation solutions. The PCS 7 project is configured to be hardware-independent and can be flexibly incorporated into existing projects.

Exclusions

The following cases are not covered by the "Distillation column" unit template:

- Multicomponent distillation, i.e. columns with additional side draws
- Columns with gaseous head products that require a different pressure control structure
- Vacuum columns with a special pressure control structure
- Strippers, i.e. columns without the reinforcement part
- Columns that have no representative temperature as a control variable

Required knowledge

Fundamental knowledge of the following specialist fields is a prerequisite:

- Engineering with SIMATIC PCS 7 and the APL library
- Knowledge of control technology
- Basic knowledge of process technology

1.2 Mode of operation

The quality of material separation is measured by the purity of the separation products, i.e. after concentration by low and high boilers in the head and bottom outlet. The measuring of these concentrations by means of online analyzers is so complex, that it is omitted in most plants. Thermodynamic correlations are formed in the phase equilibrium (between vapor and liquid) at the individual trays of the column, so there is also a correlation between the concentrations and temperatures. The easily measurable temperatures are used as substitute control variables. This has the additional advantage that the relationship between the temperatures and control interventions can linearize more easily than the connection between the concentrations.

The "Distillation column" unit template provides an example of a process plant. The example project has been implemented as a PCS 7 multiproject as follows:

- One project for the automation system (AS) and one project for the operator station (OS) are included in the component view.
- A hierarchy folder has been created in the technological hierarchy for each equipment module.

The AS project contains all open- and closed-loop control functions in the form of CFC (Continuous Function Chart) charts. The PCS 7 project also contains an example simulation of a distillation column (random packings or packed columns) for distilling isopropanol (low boilers) and butanol (high boilers).

Note Technical functions are referred to as equipment modules, whereas individual control units and individual control unit types are called control modules or control module types. This documentation uses the terms: equipment module, control module (CM) and control module type (CMT).

The AS project was created using the APL library (Advanced Process Library), which among other things also includes a model predictive multivariable controller. The multivariable controller is the core element of the control strategy and takes over the regulation of the head and bottom temperature in the distillation column. Further closed-loop controllers are connected subordinately to the multivariable controller.

The process screens contain the most important parameters (KPI: Key Performance Indicators) of the distillation column, as well as all detailed information on the individual components and components for operation and monitoring.

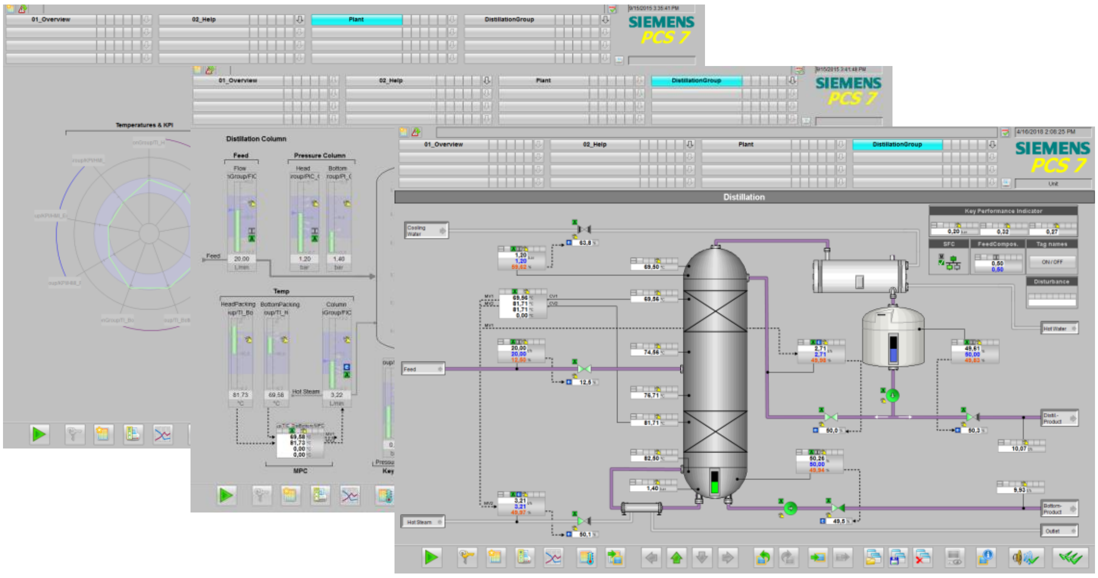
For an optimized process control and monitoring, two additional process screens have been created with Advanced Process Graphics (APG). They are clear and reduced to the essentials. The process images focus on how to consider the relevant process screens within the work areas.

1.2.1 Core functionality

The individual components of the column are described in the following section. It is operated in the PCS 7 Operator Station.

The visualization interface of the "Distillation column" unit template is composed of the following pictures:

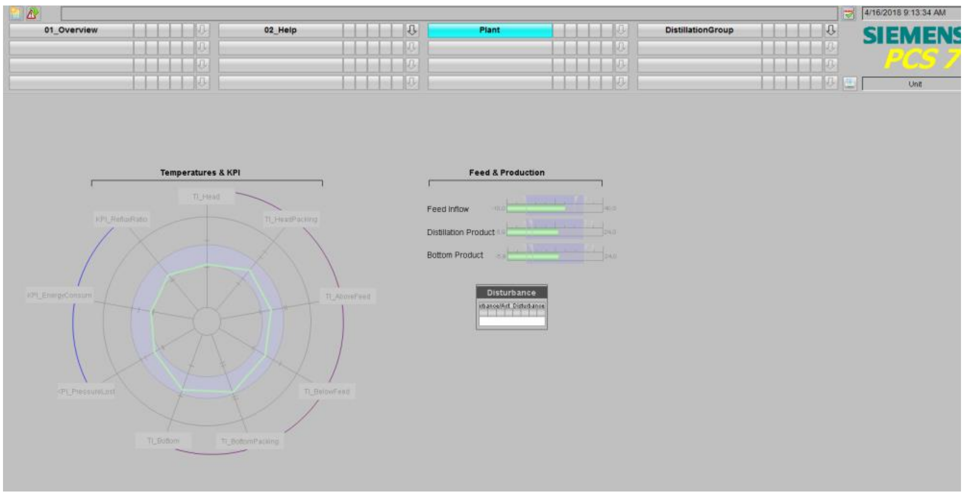
- Plant overview picture for orientation and navigation (Level 1)
- Process screen for operation and monitoring (Level 2)
- Detailed process screen in P&ID representation with all components (Level 3)



Plant overview

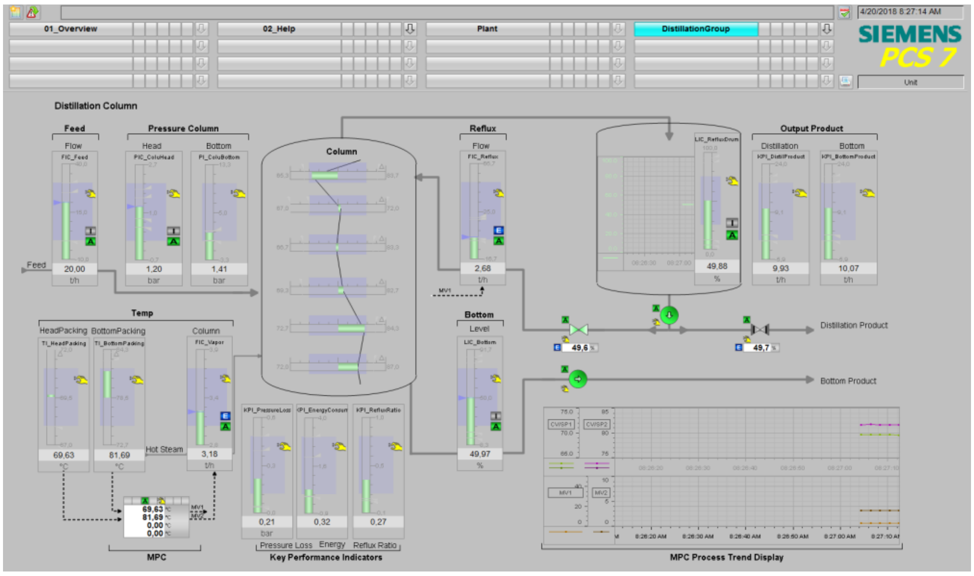
The overview picture consists of the following objects:

- Spider graph representation of typical distillation column parameters and temperatures
- Bar graph representation of the feed into the column and removal of the two products from low boilers and high boilers



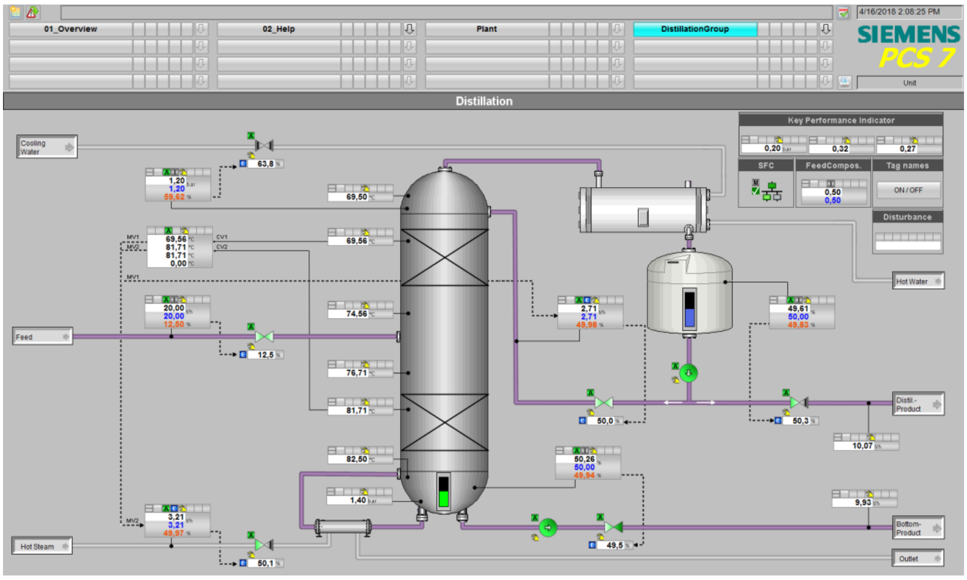
Process image

The process screen shows the most important process values for monitoring and operating the distillation column. From the associated faceplate, you can get further detailed information about each displayed value and make changes. The trend display shows the actual, target and control variables of the multivariable controller.



Detailed process screen

The process screen shows a schematic representation of the block icons of the sensors and actuators. The process screen also includes an overview of the Key Performance Indicators. The process screen gives the operator an overview of the entire plant and enables him to take the necessary operator actions.

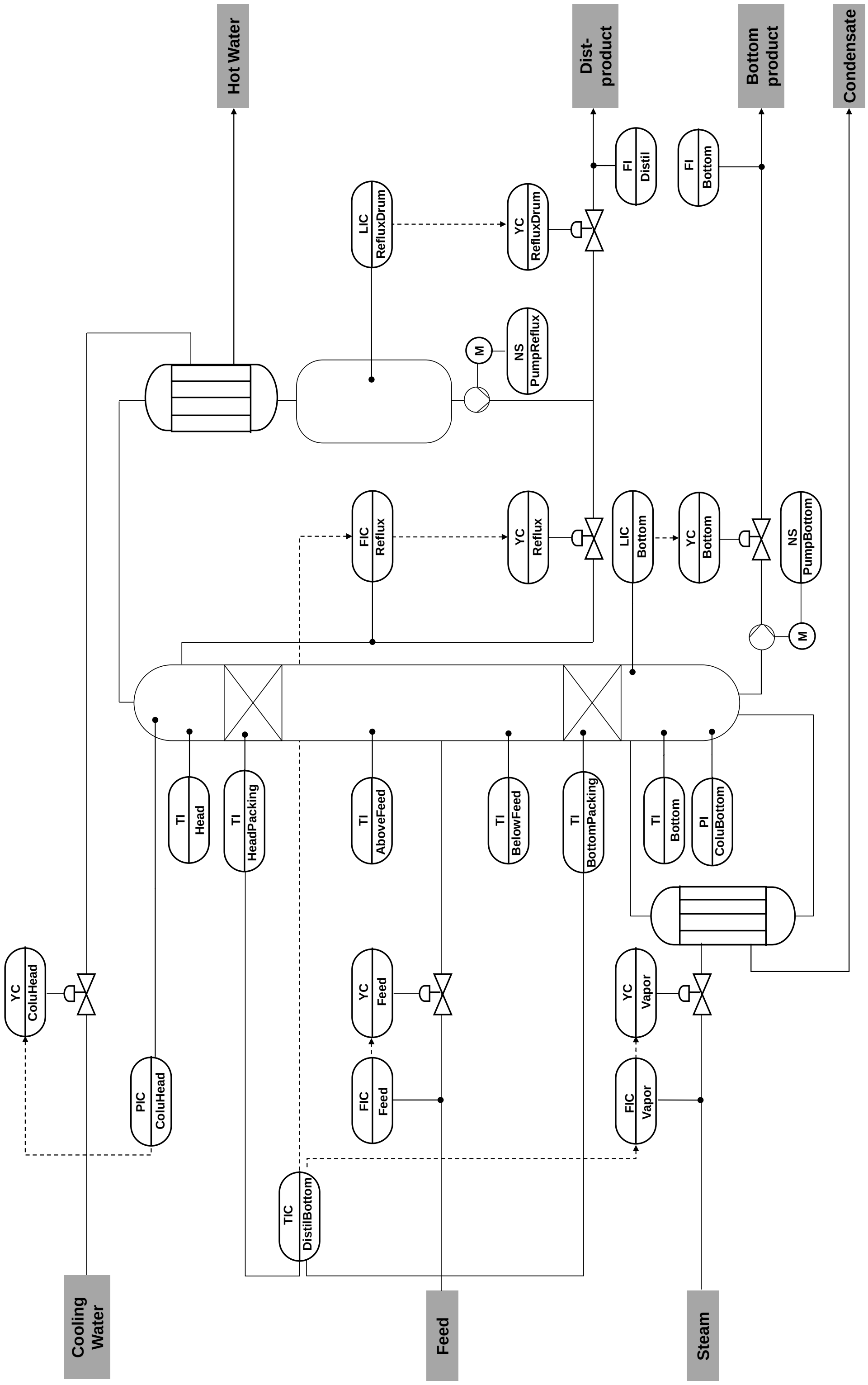


1.2.2 Control concept

A multivariable controller (MPC) is used for controlling the distillation process. This controls the temperatures below the head and above the bottom (also refer to Chapter Temperature characteristic). These control variables are detected by the relevant temperature measuring points of the head and bottom temperatures. The manipulated variables of the multivariable controller are used as a setpoint for underlying PID controllers. The two level controls of the distillation column are provided with PID controllers and work independently.

1.2.3 P&ID flow diagram

The following figure shows the individual elements of a distillation column in a piping and instrument flow diagramm.



1.3 Hardware and software components

Validity

This application is valid from SIMATIC PCS 7 V9.0.

Components used

The application example has been created with the following hardware and software components:

Component	Note
SIMATIC PCS 7 ES/OS IPC547G W7	For the PCS 7 V9.0 example project
SIMATIC PCS 7 V9.0	Part of SIMATIC PCS°7 ES/OS IPC547G W7
S7 PLCSIM	The license does not form part of the SIMATIC PCS 7
APL Library V9.0	Part of SIMATIC PCS°7 V9.0
APG Library V9.0	The license does not form part of the SIMATIC PCS 7

Note In case of different hardware, please observe the minimum requirements for installing the software components. The minimum requirements can be found in the Readme file of the PCS 7.

Note The download contains elements that require a license. Use in your configuration environment or in the process mode obligates you to purchase the appropriate PCS 7 Advanced Process Graphics (APG) license.

Ordering information can found at the following link:
https://support.industry.siemens.com/cs/ww/en/view/109750232.

This application example consists of the following components:

Component	Note
48418663_DistillColumn_PROJ_PCS7V90.zip	PCS 7 V9.0 Example project
48418663_DistillColumn_DOC_PCS7V90_en.pdf	This document

Note The example project for PCS 7 V9.0 is available for download in the Extranet area of the entry:
https://support.industry.siemens.com/cs/ww/en/view/48418663.

This Extranet area is only visible if you have a Managed System Services contract. You can obtain detailed information at:
https://support.industry.siemens.com/cs/ww/en/sc/4361.

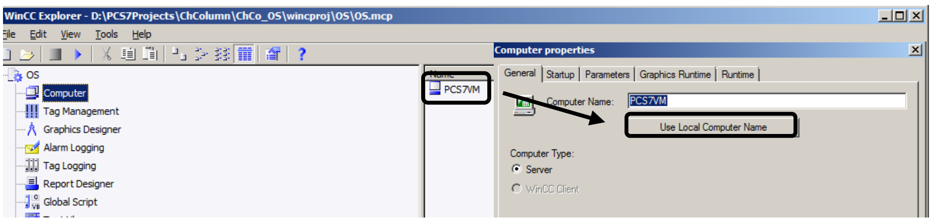
You can find an overview of all technical information and solutions, available to you exclusively in the Extranet, at the following topics page:
https://support.industry.siemens.com/cs/ww/en/view/109755371.

2 Preparation and commissioning

2.1 Preparation

The following instructions describe how to commission the Unit Template by simulating the controller with the "S7 PLCSIM" program. If there is a real controller, you must configure existing hardware components in the HW Config.

1. Copy the file "48418663_DistillColumn_PROJ_PCS7V90.zip" into any folder on the configuration PC and then open the SIMATIC Manager.
2. Click on "File > Retrieve" in the menu bar and select the file "48418663_DistillColumn_PROJ_PCS7V90.zip". Then confirm by clicking on "Open".
3. Select the folder in which the project is to be saved and confirm by clicking on "OK".
   The project is retrieved.
4. Confirm the "Retrieve" dialog by clicking on "OK" and then click on "Yes" in the dialog to open the project.
5. Right-click on "ChColumn_OS_Prj > OS01 > WinCC Appl. > OS" and then click on the menu command "Open object".
6. Confirm the "Configured server not available" dialog with "OK".
7. In WinCC Explorer, open the properties of your computer and, in the opened Properties dialog, click on the "Use Local Computer Name" button.



8. Confirm the "Change computer name" message with "OK".
9. In the WinCC Explorer, click on "File > Exit" and in the subsequent dialog select "Terminate WinCC Explorer and close project".
10. Then confirm with "OK".
11. Reopen the WinCC Explorer as described in step 5.
12. Open by double-clicking on "Variables library".
13. In the "WinCC Configuration Studio", open "Variables library > SIMATIC S7 Protocol Suite > TCP/IP" and select the menu command "System parameters".
14. In the "Unit" tab, check the "Logical device names" setting. If the "S7 PLCSIM" program is used, the device name "PLCSIM.TCPIP.12" is selected.
    A restart is required after a device name change.

Note If the OS cannot establish a connection with the AS (grayed out module icons), select the logical device name "CP_H1_1" and restart the OS runtime.

2.2 Commissioning

The following instructions show how the Unit Template is initialized. The project contains an SFC chart where all the important settings are configured so that die system reaches the operating point.

To put into service, it is required that SIMATIC Manager is already open and that the Unit Template has been selected in the component view.

Starting the simulation (S7 PLCSIM)

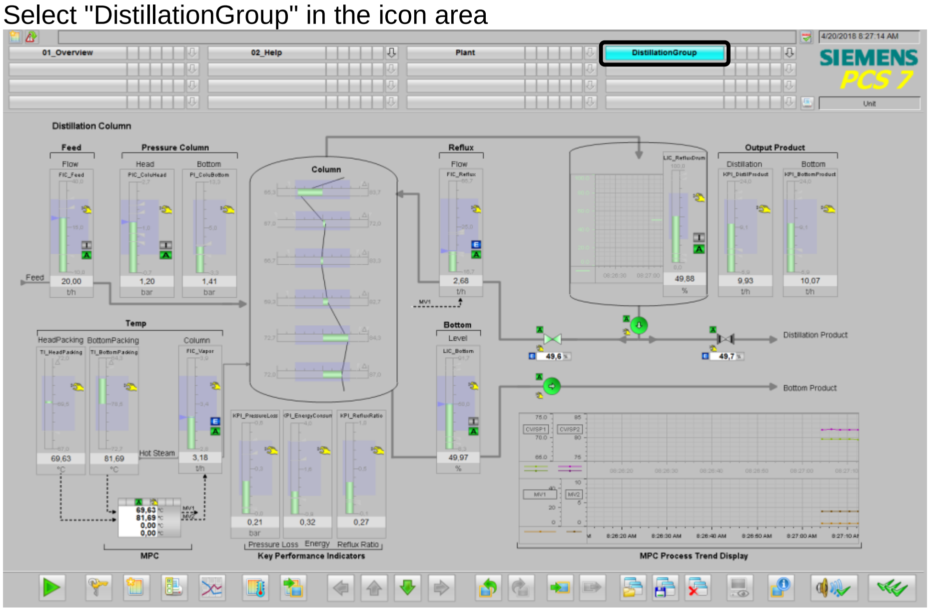
To start the simulation, proceed as follows:

1. Select "Tools > Simulate Modules" from the menu.
   The "S7 PLCSIM" dialog window opens.
2. In the "Open project" dialog, select "Open project from file".
3. Select the file "ChColumn.plc" from the path
   <Projektpfad>\ChColumn\ChCo_AS\ChColumn.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 mark "ChColumn_AS_Prj > AS01".
7. On the menu bar, click on "Target system > Load" and confirm the "Load" dialog with "Yes".
8. Confirm the "Stop target group" dialog with "OK" and the subsequent "Load" dialog with "Yes".

Activate OS (WinCC runtime)

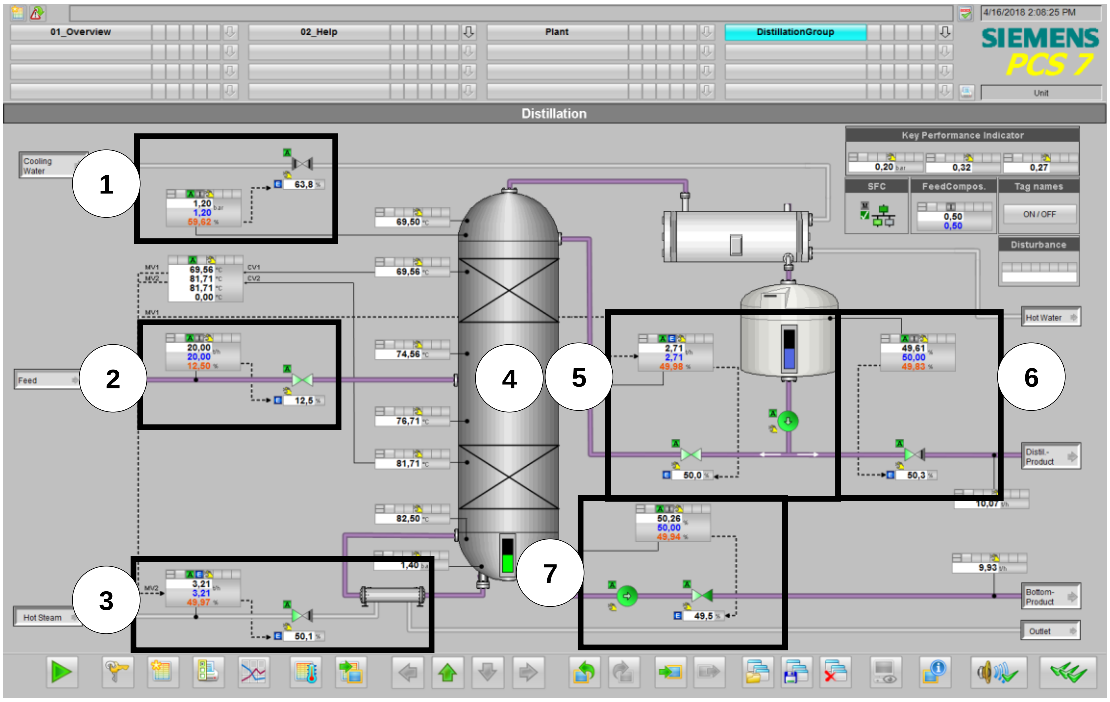
To activate the OS, proceed according to the following instructions:

1. Right-click on the OS and select the menu "Open object".
2. To activate the OS (WinCC Runtime), select the menu command "File > Activate" in WinCC Explorer.
3. In the "System Login" dialog, enter the user "Unit" as "Login" and "Template" as the password; then confirm with "OK".
4. Select "DistillationGroup" in the icon area



2.3 Components of process visualization

Depending on the boundary conditions, distillation columns are controlled with various configurations. The structure described below is an example of a common scenario.



The process screen of the distillation column consists of the following main parts:

1. Pressure control
2. Feed
3. Bottom temperature (vapor)
4. Distillation column
5. Capacitor with reflux
6. Removal of the head product (low boiler)
7. Removal of the bottom product (high boiler)

(1) Pressure control

The head pressure is regulated by the cooling water valve. Using more cooling water leads to heavier condensation. Since the volume greatly reduces during condensation, the condenser "suctions" vapor out from the column. The inflow and outflow of the liquids have very little effect on the pressure due to the different densities of liquid and vapor.

(2) Feed

The mixture flows to the distillation column via the feed.

A PID controller regulates the feed (control variable) to the configured setpoint. The actual value flows as a disturbance variable to the higher-level multivariable controller.

(3) Evaporator (vapor)

The evaporator removes the liquid mixture from the column bottom and heats it until the components evaporate. The gaseous mixture is then returned back into the distillation column.

The vapor (control variable) used for heating the evaporator is regulated by a valve (manipulated variable) with a PID controller, which receives the setpoint from the multivariable controller.

(4) Distillation column

The distillation column is controlled by means of a multivariable controller. The temperatures below the head and above the bottom (control variables) are recorded and regulated by means of the heating vapor amount or the condensate reflux (manipulated variables). The two manipulated variables are used as setpoint entries for lower-level PID controllers.

(5) Capacitor with reflux

The capacitor removes the gaseous mixture from the head of the column and cools it off until both substances (low boilers and high boilers) condense. The liquid mixture is partially recirculated to the distillation column. The capacitor also includes a tank in which the liquid mixture is stored temporarily in order to enable reflux rate control.

The top pressure of the distillation column (control variable) is controlled via the cooling water flow rate (manipulated variable) by means of a PID controller. The setpoint value specification is implemented by the operator.

The reflux (control variable) is controlled by means of a PID controller via a valve (manipulated variable). The setpoint is selected from the multivariable controller of the distillation column.

(6) Removal of the head product (low boiler)

The amount of outflowing head product depends on the fill level of the capacitor and cannot be specified. When the entire distillation column has a stable operating point, the amount of head product to be removed is composed of the following components:

- Concentration of the low boiler in the feed mixture
- Feed amount of the distillation column

The fill level in the condensate tank (control variable) is controlled by a PID controller via a valve (manipulated variable). The setpoint value specification is implemented by the operator.

(7) Removal of the bottom product (high boiler)

The amount of bottom product to be heated depends on the bottom fill level and cannot be specified. When the entire distillation column has a stable operating point, the amount of bottom product to be removed is composed of the following components:

- Concentration of high boiler in the feed mixture
- Feed amount of the distillation column

The fill level in the condensate tank (control variable) is controlled by a PID controller via a valve (manipulated variable). The setpoint value specification is implemented by the operator.

Additional functions

- Temperature and pressure reading
  The distillation column gives 6 temperature readings and 2 pressure readings:
  - Temperature at the distillation column head
  - Pressure at the distillation column head
  - Temperature for head temperature control
  - Temperature above the feed
  - Temperature below the feed
  - Temperature for bottom temperature control
  - Temperature at the distillation column bottom
  - Pressure at the distillation column bottom
- Concentration specification
  With regard to the feed, the concentration of the low boiler can be specified in the simulation in relation to the high boiler. This concentration ratio is an unrecorded disturbance variable for the process.
- Operating point
  A sequential function chart (SFC) for the ramp up of the distillation column in the operating point.

Parameters (KPI = Key Performance Indicator)

The following key performance indicators are measured or calculated:

- Pressure drop = pressure at the bottom of the column – pressure at the head of the column
- Relative energy consumption = amount of vapor / production volume of head product
- Reflux ratio: Reflux / discharge of head product

Note The pressure loss describes a measure of the thermodynamic loading of the column.

2.4 Controlling the application

2.4.1 Overview

All components of the distillation column can be controlled and monitored from the process screen. In addition, the plant operator receives information (KPIs) for the current process.

Note Please note that it takes about 6 minutes for the column to reach the operating point after the program starts (PLCSIM). During operational production, all controllers are enabled for setpoint changes except the cascade controllers.

The following two scenarios are limited to the two variables that are significantly relevant for the operation of a distillation column and which demonstrate the mode of operation of the multivariable controller in compensating for interferences.

- Changing the feed amount
- Changing the feed concentration

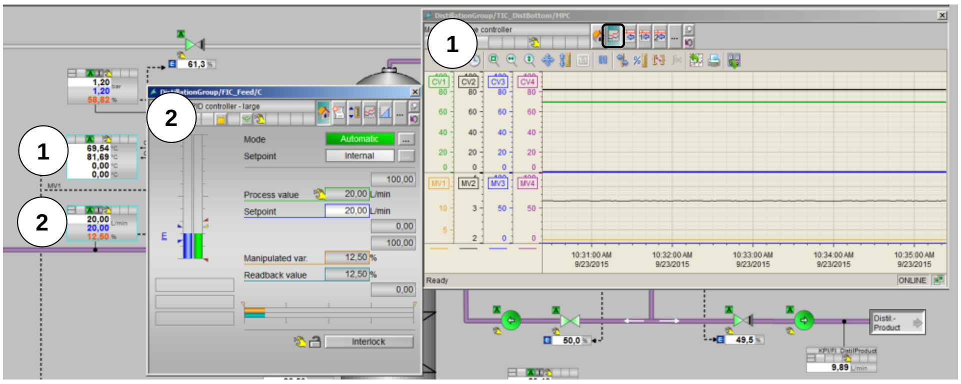
When the distillation column is in a steady state, the feed amount and the feed concentration determine the amount that can be delivered by the head or bottom product. A variable, which acts as a disturbance for the controller, is modified in each of the two scenarios.

Note The signal noise for the two control variables has been disabled for trend recording and evaluation.

2.4.2 Scenario A - Changing the feed amount

In this scenario, the concentration of low boilers in the mixture feed is constant and the feed amount is increased from 20 L/min to 23 L/min (+15%). The feed amount is detected by the controller as a disturbance (DV1 input) and the effect of the disturbance is reflected in the process model.

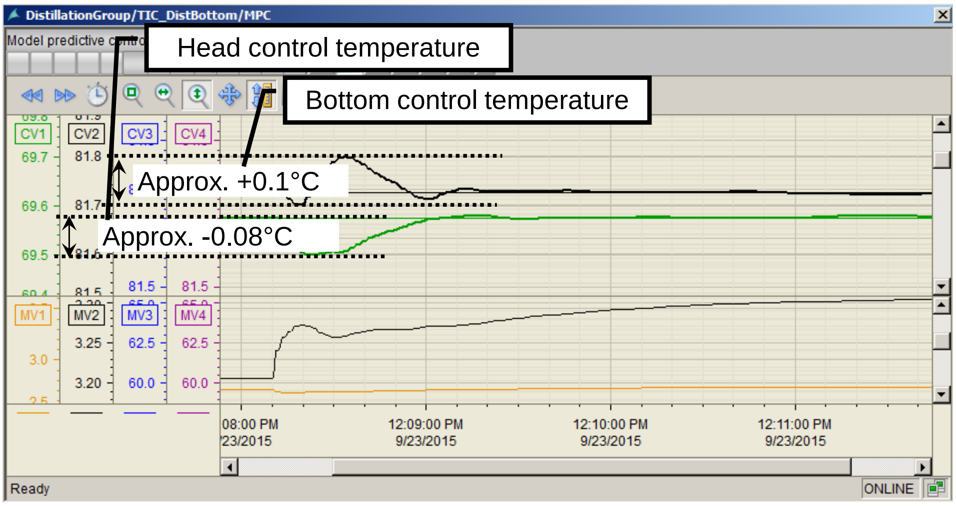
1. Switch to the Detail view of the distillation column.
2. Left click the "On/Off" button in the "Process tag name" field to display the block names.
3. Click on the block icon of "TIC_DistBottom" block and click on the trend icon in the menu bar of the faceplate.
4. Click on the block icon for the "FIC_Feed" to also open its faceplate. Arrange the windows clearly on the screen.



5. Click on the input field "Setpoint" in the "FIC_Feed" block and enter the value "23" in the text box of the extension. Then confirm the entry with the Enter key and click the "OK" button.
   The setpoint for the feed is accepted and the multivariable controller starts compensating the detected disturbance.
6. Wait about 3 minutes and click on the "Start/Stop" symbol to evaluate the control result.

Evaluation

The screenshot gives you the trend curves of the multivariable controller.



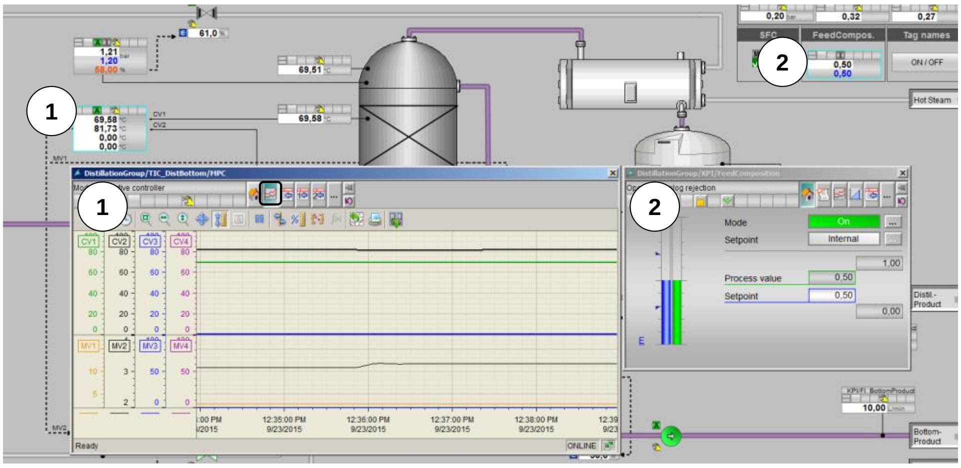
Even a slight deviation of about 0.1 °C gives a good control result, which can be explained by the fact that the disturbance has been detected and that the controller knows the influence of the disturbance. The controller can thus respond immediately to the change of the disturbance with the necessary procedures and does not have to wait for changes in the control variables.

2.4.3 Scenario B - Changing the feed concentration

When the distillation column is in a steady state, the feed amount and the feed concentration determine the amount that can be delivered by the head or bottom product. In this scenario, the inflow amount remains constant and the concentration of low boiler in the feed mixture is lowered from 0.5 to 0.4 (-20%).

The concentration of low boiler in the feed mixture is an unknown disturbance for the controller, which is not recognized according to a model.

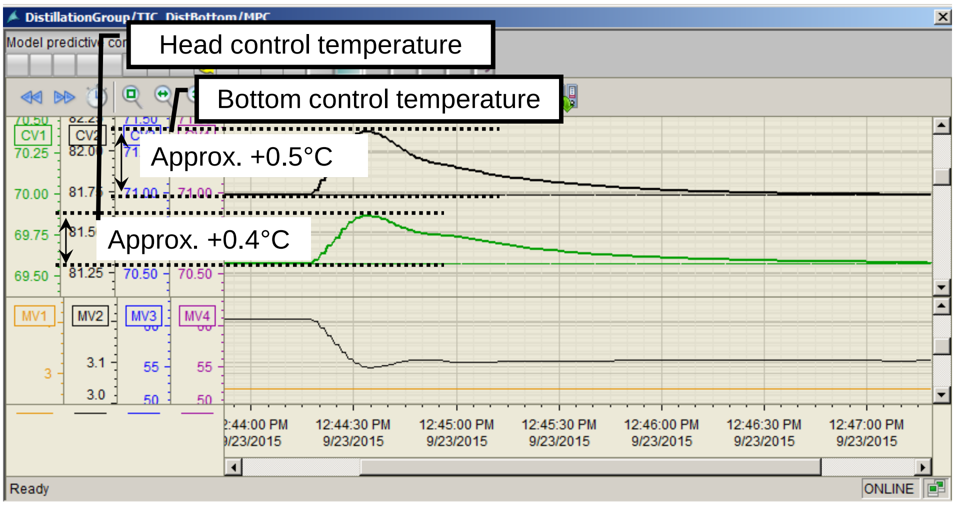
1. Click on the block icon of "TIC_DistBottom" block and click on the trend icon in the menu bar of the faceplate.
2. Click on the block icon for the "FeedComposition" to also open its faceplate. Arrange the windows clearly on the screen.



3. Click on the input field "Setpoint" in the faceplate of "FeedComposition" and enter
the value "0.4". Then confirm the entry with "ENTER" and click the "OK" button. The setpoint for the concentration of low boiler in the fed mixture is applied and the multivariable controller starts compensating the disturbance.
4. Wait about 3 minutes and click on the "Start/Stop" symbol to evaluate the control result.

Evaluation

The screenshot gives you the trend curves of the multivariable controller.



Even a slight deviation of about 0.5 °C gives a good control result, since the size and effect of the disturbance variable are unknown to the controller and the controller can only react to the change of control variables.

3 Integrating the unit template in the user project

3.1 Preparation

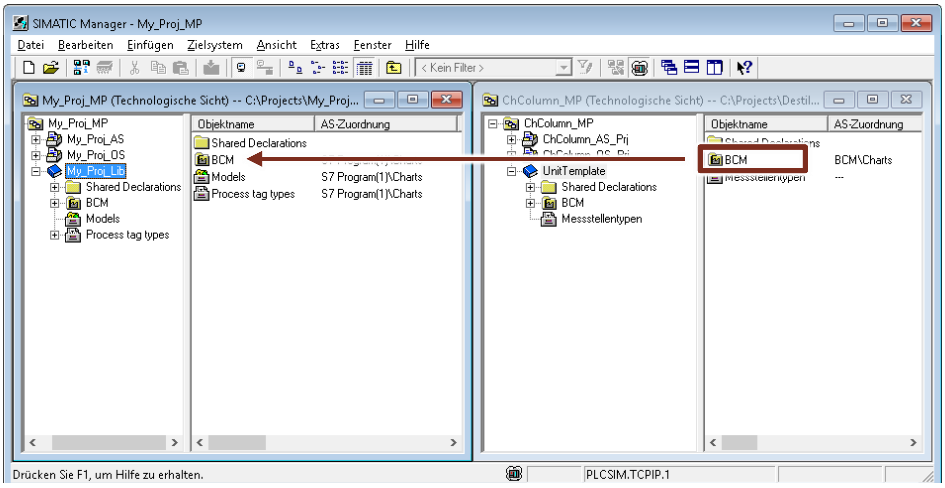
1. Copy the file "48418663_DistillColumn_PROJ_PCS7V90.zip" to the configuration PC and then open the SIMATIC Manager.
2. Click on "File > Retrieve" in the menu bar and select the file "48418663_DistillColumn_PROJ_PCS7V90.zip ". Then confirm by clicking on "Open".
3. Select the folder in which the project 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. At the same time, open the project in which the fermenter is to be integrated.

3.2 Copying templates

Note

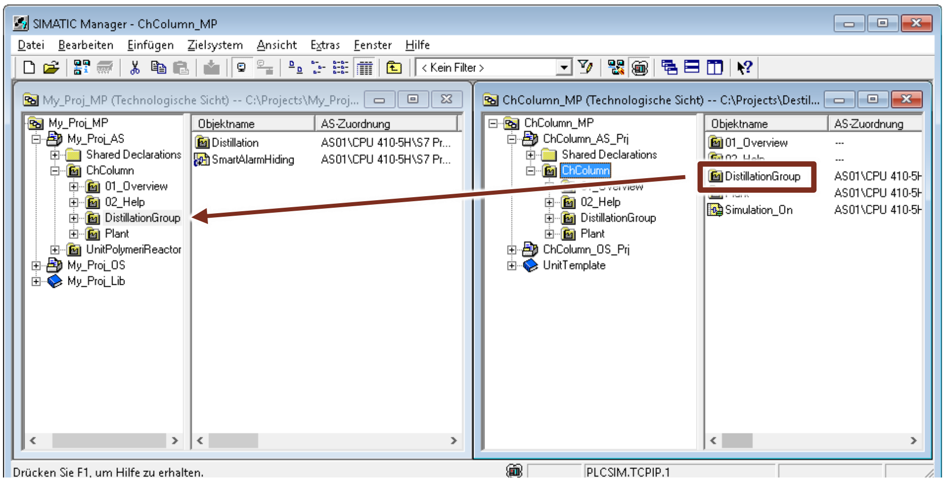
If you have already worked with CMTs in your existing project, then check that they are identical before skipping to the following steps, since this can lead to errors in your existing project or in the unit template you want to integrate.

1. Switch to the plant view.
2. Copy the "BCM" folder containing the CMTs from the master data library into the target project.



3.3 Copying units

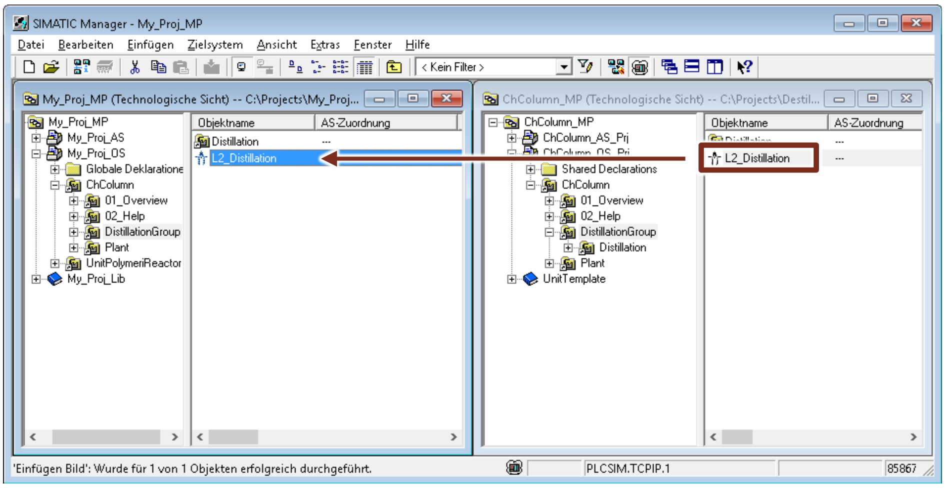
1. Copy the hierarchy folder "DistillationGroup" from the AS project of the Unit Template to the plant view of the target project.



Note

The hierarchy folders of the units "01_Overview" and "02_Help" are not necessary for operation. These do not have to be copied if you want to operate your system without a simulation.

2. Copy the process screen "Plant", the process screen "L2_Distillation" and the detailed process screen "L3_Distillation" from the OS project of the unit template to the plant view of the target project as well. If you wish, you can also copy the pictures "Help" and "Overview".



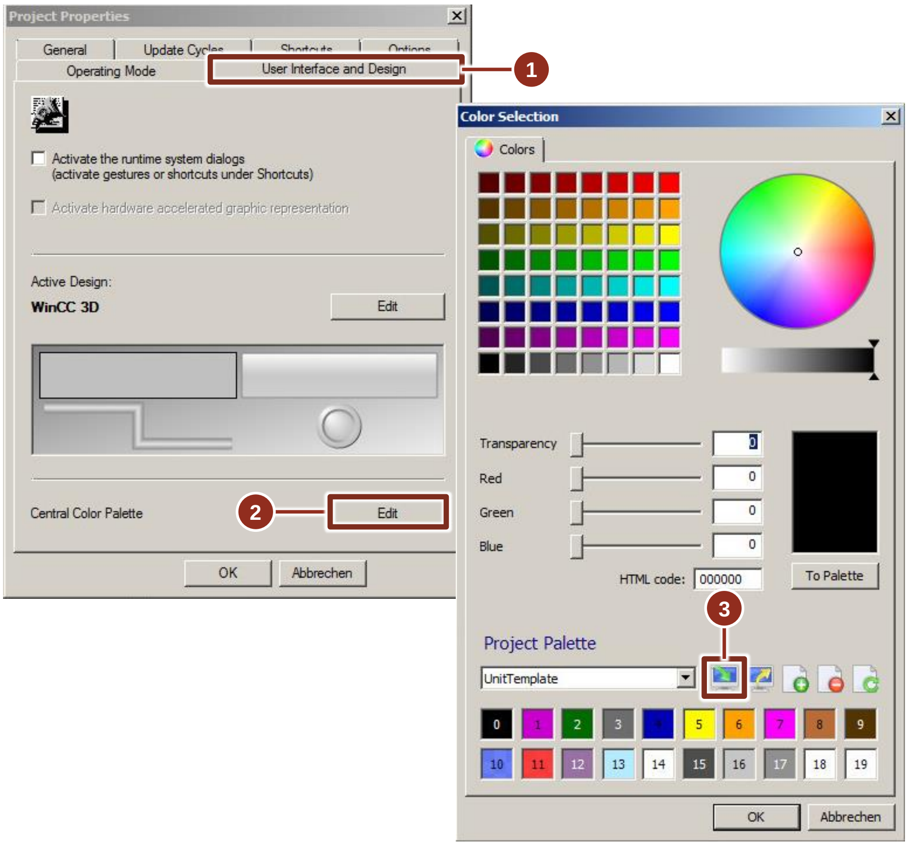
Note

When copying the process screens, make sure that you copy the pictures to the hierarchy level of the target project, which is configured as an OS area.

3.4 Adapting the OS project

In order to facilitate the changing of colors in the process screen from a central point, a central color palette was created in the OS project of the Unit Template. To display these colors in the process screen of your own project, you must import the relevant color palette.

1. Select the "OS" in WinCC Explorer and choose "Object properties..." in the shortcut menu.
2. Choose the "User Interface and Design" (1) tab and click the "Edit" (2) button.
3. Import the palette into your own project (3) by means of the "Overwrite" option. The color palette is located in the project folder of the unit template at the path: "<Project path>\ChColumn\ChCo_OS\wincproj\OS\GraCS\UnitTemplate.xml All existing colors will be replaced.



Note

Please note that all colors are always used when exporting/importing color palettes. It is not possible to export partial color tables.

If you have created your own color tables in your project, you can also export them and use an editor to merge the tables in the Xml file. Otherwise you can create a new color table in your project and configure the colors individually. Make sure, too, that the color index does not change, otherwise you will have to adjust the color settings of the objects in the process screen. Of course it is up to you to change the colors according to your requirements.

4 Engineering

4.1 Equipment modules and control modules

The unit template "Distillation column" consists of pre-made equipment modules and additional measuring points. In a PCS 7 project, all measuring points including the measuring points of the equipment modules are based on CMTs (control module types) from the master data library.

This application example contains the following components:

- Head pressure control
- Inflow "Feed"
- Evaporator "Heating"
- Capacitor with reflux "Reflux"
- Removal of the head product "HeadLevel"
- Removal of the bottom product "BottomLevel"
- Distillation
- Overarching process simulation "Process"
- Step sequencer (SFC) for starting up the distillation column
- Process key figures "KPI"
- Maintenance characteristics "Maintenance"
- Optimized process control with APG

Note

All necessary descriptions, configurations and procedures pertaining to the

- design, functionality of equipment modules including parameters
- integration of equipment modules
- controllers and control response

can be found in the application description "Equipment Modules for SIMATIC PCS 7 using the example of the Chemical Industry" and the example projects with the individual equipment modules and CMTs at the following link: https://support.industry.siemens.com/cs/ww/en/view/53843373. You will find the information on the specific equipment modules in the chapter "Equipment Modules" and on the CMTs in the chapter "Control Module".

In the following sections you will find the setup of the specific equipment modules as well as the extension and modifications made vis-à-vis the equipment modules and the CMTs used. This also includes a description of the SFC for starting up the reactor.

Note

CMTs are pre-configured for different operating ranges. The use of variants allows the corresponding channel block to be selected or deselected based on measured value transfer. It is also possible to use options to activate additional functions without configuring the instance.

4.2 Head pressure control "Pressure"

The amount of mixture removed from the column head is determined with the pressure control.

Note

For more demanding applications where fluctuations or other unpleasant properties of the actuator can be compensated (e.g. nonlinear valve characteristic curve), the equipment module "Temperature-Flow Cascade" can be used for pressure control.

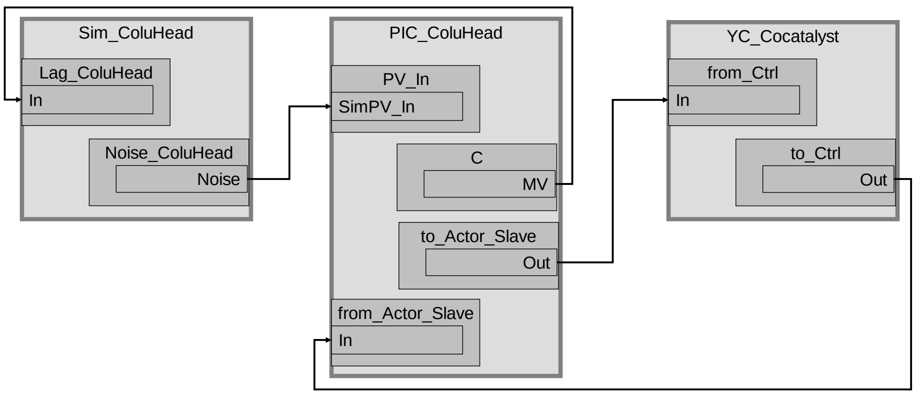
4.2.1 Setup

The pressure is controlled by means of a PID controller with a fixed setpoint value specification by the step sequencer. During process mode, the setpoint can be set by the operator in the defined area.

The following table provides an overview of the CM and the selected variants.

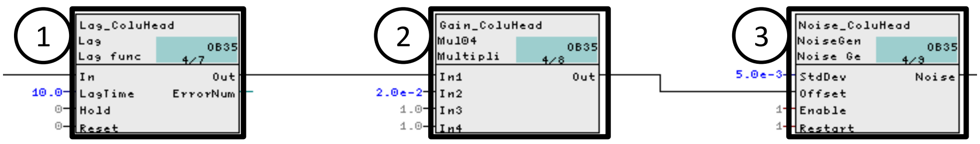
CM	CMT	Variant	Description
PIC_ColuHead	"Ctrl"	Ctrl_Std	Head pressure control
YC_ColuHead	"ValAn"	ValAn_Std	Control valve for the cooling water going to the heat exchanger

In the following figure, the structure with the cross-chart interconnection is depicted in simplified form.



"Sim_ColuHead" simulation

In the simulation chart, the process value is simulated by the setpoint change (delay time and process gain).



1. Lag time of 10 seconds, which is caused by the inertia of the actuator as well as by the time constant of the flow sensor.
2. The gain factor for the simulation of the process gain.
3. Connecting noise to the manipulated variable

4.2.2 Parameter assignment

PIC_ColuHead

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Scale	HiScale	2	Process value upper limit
PV_Unit	In	1137	Process value unit in bar
C	Gain	6	Controller gain
C	TI	3.5	Controller lag
C	SP_InHiLim	1.5	Upper limit of the internal setpoint
C	SP_InLoLim	0.8	Lower limit of the internal setpoint
C	PV_AH_Lim	1.8	Alarm upper limit for the process value
C	PV_WH_LIM	1.5	Warning upper limit for the process value
C	PV_WL_Lim	0.8	Warning lower limit for the process value
C	PV_AL_Lim	0.5	Alarm lower limit for the process value
C	PV_Hyst	0.2	Hysteresis for the limit values
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for the simulation (Sim_ColuHead\Lag_ColuHead.In)
C	PV_Out		Interconnection for (Distillation\\KPI\pBotMinus_pHead.In2)
to_Actor_Slave	Out		Interconnection for the valve (YC_ColuHead\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_ColuHead\to_Ctrl.Out)
PV	SimPV_In		Interconnection for the simulated process value (Sim_ColuHead\Noise_ColuHead.Noise)

YC_ColuHead

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (FIC_ColuHead\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (FIC_ColuHead\from_Actor_Slave.In)

4.3 Inflow "Feed"

The mixture to be separated is fed to the distillation column via the inlet in a constant flow. The flow volume acts as a disturbance on the multivariable controller.

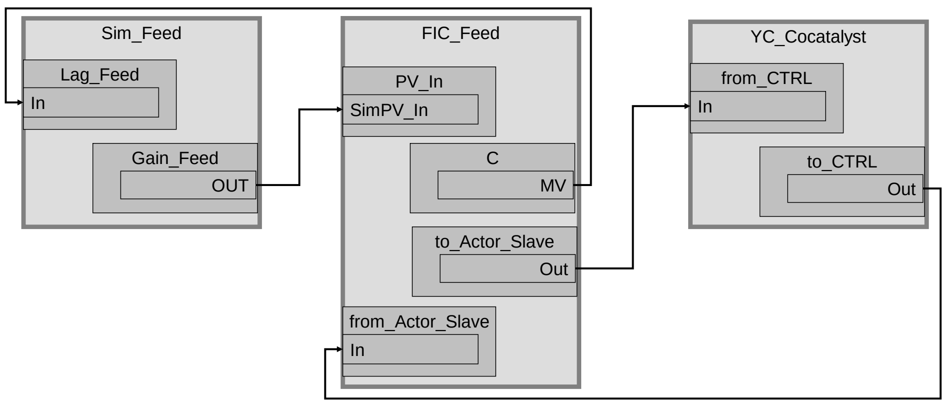
4.3.1 Setup

Inflow control is performed by means of a standard PID controller with a setpoint value specification by the step sequencer. During process mode, the setpoint can be set by the operator in the defined area.

The following table provides an overview of the CM and the selected variants.

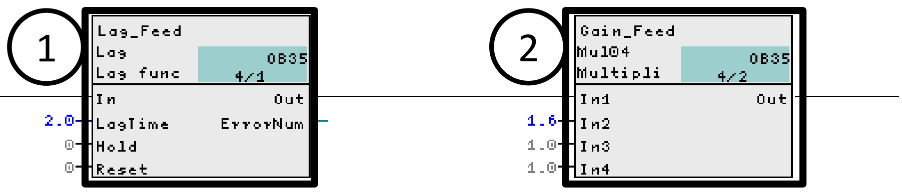
CM	CMT	Variant	Description
FIC_Feed	"Ctrl"	Ctrl_Std	Flow controller for the input material mixture
YC_Feed	"ValAn"	ValAn_Std	Analog control valve for the input material mixture

In the following figure, the structure with the cross-chart interconnection is depicted in simplified form.



"Sim_Feed" simulation

The mixture feed is simulated in the simulation chart.



1. Lag time of 2 seconds, which is caused by the inertia of the actuator as well as by the time constant of the flow sensor.
2. The gain factor for the simulation of the process gain.

4.3.2 Parameter assignment

FIC_Feed

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1352	Unit of the process value in L/min
C	TI	2.0	Controller lag
C	SP_InHiLim	25.0	Upper limit of the internal setpoint
C	SP_InLoLim	15.0	Lower limit of the internal setpoint
C	PV_AH_Lim	30	Alarm upper limit for the process value
C	PV_WH_LIM	25	Warning upper limit for the process value
C	PV_WL_Lim	0	Warning lower limit for the process value
C	PV_AL_Lim	30	Alarm lower limit for the process value
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for the simulation (Sim_Feed\Lag_Feed.In)
C	PV_Out		Interconnection for (Distillation\\TIC_DistBottom\MPC.DV1) (Process\\Sim_ProcModel\F_Norm.In1) (Distillation\\KPI\MassBalance.In1)
to_Actor_Slave	Out		Interconnection for the valve (YC_Feed\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_Feed\to_Ctrl.Out)
PV	SimPV_In		Interconnection for the simulated process value (Sim_Feed\Gain_Feed.Out)

YC_Feed

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (FIC_Feed\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (FIC_Catalyst\from_Actor_Slave.In)

4.4 Evaporator "Heating"

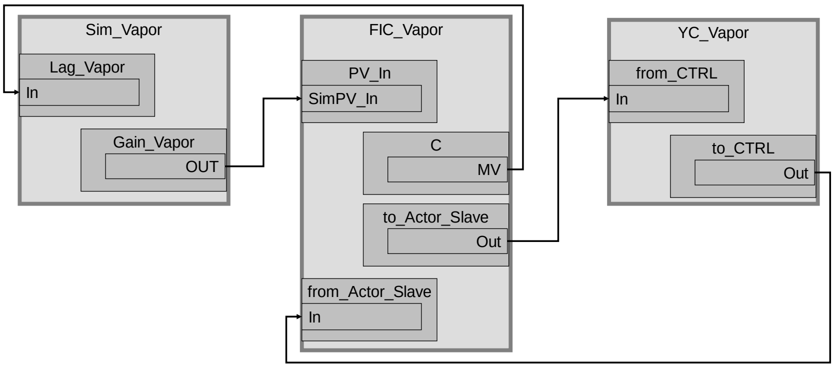
The temperature of the column is determined by pumping the mixture at the column bottom through the external heat exchanger.

4.4.1 Setup

Flow control is performed by means of a standard PID controller and an external setpoint from the multivariable controller "TIC_DistBottom". The following table gives you an overview of the CM and the selected variants.

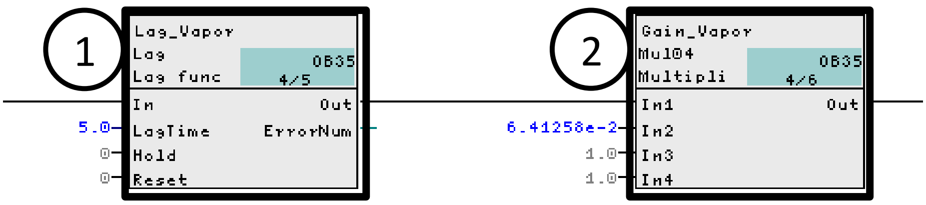
CM	CMT	Variant	Description
FIC_Vapor	"Ctrl"	Ctrl_Std Activated option "Opt_IF_Master"	Vapor flow control
YC_Vapor	"ValAn"	ValAn_Std	Control valve for the vapor feed to the heat exchanger

In the following figure, the structure with the cross-chart interconnection is depicted in simplified form.



"Sim_Vapor" simulation

In the simulation chart, the process value is simulated by the setpoint change (delay time and process gain).



1. Lag time of 5 seconds, which is caused by the inertia of the actuator as well as by the time constant of the flow sensor.
2. The gain factor for the simulation of the process gain.

4.4.2 Parameter assignment

FIC_Vapor

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Scale	HiScale	10	Process value upper limit
PV_Unit	In	1352	Unit of the process value in L/min
C	Gain	10	Controller gain
C	TI	2.5	Controller lag
C	SP_InHiLim	4.0	Upper limit of the internal setpoint
C	SP_InLoLim	2.0	Lower limit of the internal setpoint
C	PV_AH_Lim	4.5	Alarm upper limit for the process value
C	PV_WH_LIM	4.0	Warning upper limit for the process value
C	PV_WL_Lim	2.0	Warning lower limit for the process value
C	PV_AL_Lim	1.0	Alarm lower limit for the process value
C	PV_Hyst	0.1	Hysteresis for the limit values
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for the simulation (Sim_Vapor\Lag_Vapor.In)
C	PV_Out		Interconnection for (Process\\Sim_ProcModel\V_MinusV0.In1) (Distillation\\KPI\VaporDivDistFlow.In1)
to_Actor_Slave	Out		Interconnection for the valve (YC_Vapor\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_Vapor\to_Ctrl.Out)
to_Master	Out		Interconnection for the master controller (TIC_DistBottom\from_Ctrl_2.In)
from_Master	In		Interconnection for the master controller (TIC_DistBottom\to_Ctrl_2.Out)
PV	SimPV_In		Interconnection for the simulated process value (Sim_Vapor\Gain_Vapor.Out)

YC_Vapor

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (FIC_ColuHead\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (FIC_ColuHead\from_Actor_Slave.In)

4.5 Capacitor with reflux "Reflux"

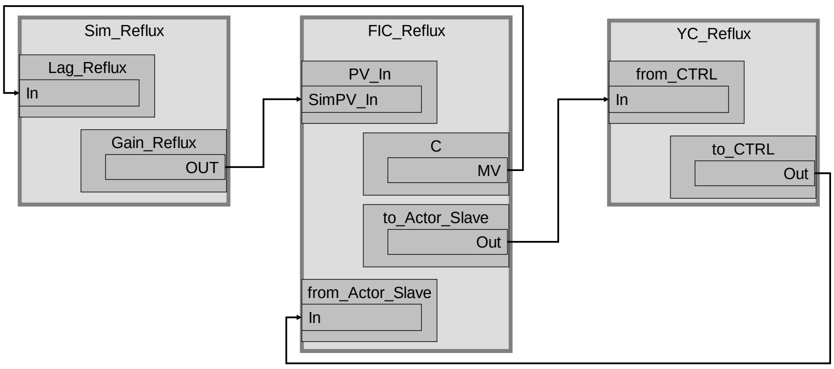
The temperature of the low boiler is reached by returning the condensate (head product).

4.5.1 Setup

Flow control is performed by means of a standard PID controller and an external setpoint from the multivariable controller "TIC_DistBottom". The following table gives you an overview of the CM and the selected variants.

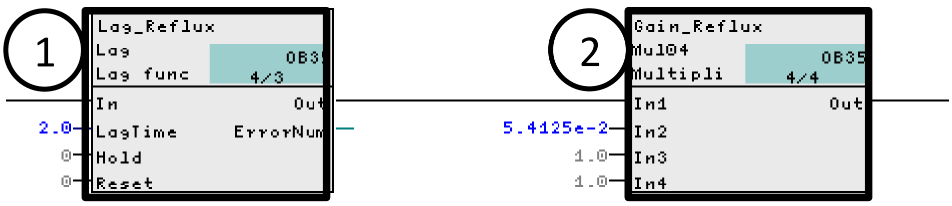
CM	CMT	Variant	Description
FIC_Reflux	"Ctrl"	Ctrl_Std Activated option "Opt_IF_Master"	Condensate flow control
YC_Reflux	"ValAn"	ValAn_Std	Control valve for condensate reflux to the column
NS_PumpReflux	"Mot"	Mot_Std	Pump (e.g. flow pump) for returning the condensate to the column

In the following figure, the structure with the cross-chart interconnection is depicted in simplified form.



"Sim_Reflux" simulation

The condensate flow is simulated in the simulation chart.



1. Lag time of 2 seconds, which is caused by the inertia of the actuator as well as by the time constant of the flow sensor.
2. The gain factor for the simulation of the process gain.

4.5.2 Parameter assignment

FIC_Reflux

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Scale	HiScale	50	Process value upper limit

Block	Connection	Value	Use
PV_Unit	In	1352	Unit of the process value in L/h
C	Gain	10	Controller gain
C	TI	2.5	Controller lag
C	SP_InHiLim	10.0	Upper limit of the internal setpoint
C	SP_InLoLim	2.0	Lower limit of the internal setpoint
C	PV_AH_Lim	20.0	Alarm upper limit for the process value
C	PV_WH_LIM	18.0	Warning upper limit for the process value
C	PV_WL_Lim	2.0	Warning lower limit for the process value
C	PV_AL_Lim	0.0	Alarm lower limit for the process value
C	PV_Hyst	0.5	Hysteresis for the limit values
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for the simulation (Sim_Reflux\Lag_Reflux.In)
C	PV_Out		Interconnection for (Process\\Sim_ProcModel\L_MinusL0.In1) (Distillation\\KPI\RefluxDivDistFlow.In1)
to_Actor_Slave	Out		Interconnection for the valve (YC_Reflux\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_Reflux\to_Ctrl.Out)
to_Master	Out		Interconnection for the master controller (TIC_DistBottom\from_Ctrl_1.In)
from_Master	In		Interconnection for the master controller (TIC_DistBottom\to_Ctrl_1.Out)
PV	SimPV_In		Interconnection for the simulated process value (Sim_Reflux\Gain_Reflux.Out)

YC_Reflux

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (FIC_Reflux\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (FIC_Reflux\from_Actor_Slave.In)

NS_PumpReflux

No parameter change with regard to the type.

4.6 Removal of the head product "HeadLevel"

Condensate level control is performed via the upper product discharge and is realized with the equipment module "Level-Control". The level simulation is performed in the higher-level process simulation "Sim_ProcModel". The return tank serves as a buffer, ensuring that the condensate return to the column is as continuous as possible.

4.6.1 Setup

Level control is performed by means of a standard PID controller with a setpoint value specification by the step sequencer. During process mode, the setpoint can be set by the operator in the defined area.

The following table provides an overview of the CM and the selected variants.

CM	CMT	Variant	Description
LIC_RefluxDrum	"Ctrl"	Ctrl_Std	Source "Level-Control" for level control
YC_RefluxDrum	"ValAn"	ValAn_Std	Source "Level-Control" as a control valve for the product discharge

4.6.2 Parameter assignment

LIC_RefluxDrum

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Scale	HiScale	100	Process value upper limit
PV_Unit	In	1342	Process value unit in %
C	Gain	1.0	Controller gain
C	TI	1.0	Controller lag
C	SP_InHiLim	100.0	Upper limit of the internal setpoint
C	PV_AH_Lim	95.0	Alarm upper limit for the process value
C	PV_WH_LIM	90.0	Warning upper limit for the process value
C	PV_WL_Lim	10.0	Warning lower limit for the process value
C	PV_AL_Lim	5.0	Alarm lower limit for the process value
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for (Process\\Sim_ProcModel\D_Norm.In1) (Distillation\\KPI\ValveCharDist.In1)
to_Actor_Slave	Out		Interconnection for the valve (YC_RefluxDrum\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_RefluxDrum\to_Ctrl.Out)
PV	SimPV_In		Interconnection for the simulated process value (Process\\Sim_ProcModel\mD_Prozent.OUT)

YC_RefluxDrum

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (LIC_RefluxDrum\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (LIC_RefluxDrum\from_Actor_Slave.In)

4.7 Removal of the bottom product "BottomLevel"

The level of the low boiler is controlled via the bottom product discharge and is realized with the equipment module "Level-Control". The level in the column bottom is performed in the higher-level process simulation "Sim_ProcModel".

4.7.1 Setup

Level control is performed by means of a standard PID controller with a setpoint value specification by the step sequencer. During process mode, the setpoint can be set by the operator in the defined area.

The following table provides an overview of the CM and the selected variants.

CM	CMT	Variant	Description
LIC_Bottom	"Ctrl"	Ctrl_Std	Source "Level-Control" for level control
YC_Bottom	"ValAn"	ValAn_Std	Source "Level-Control" as a control valve for the product discharge
NS_PumpBottom	"Mot"	Mot_Std	Pump (e.g. flow pump) for removing the low boiler

4.7.2 Parameter assignment

LIC_Bottom

The instance has the following parameterization.

Block	Connection	Value	Use
PV_Scale	HiScale	100	Process value upper limit
PV_Unit	In	1342	Process value unit in %
C	Gain	1.0	Controller gain
C	TI	10.0	Controller lag
C	SP_InHiLim	100.0	Upper limit of the internal setpoint
C	PV_AH_Lim	85.0	Alarm upper limit for the process value
C	PV_WH_LIM	80.0	Warning upper limit for the process value
C	PV_WL_Lim	20.0	Warning lower limit for the process value
C	PV_AL_Lim	15.0	Alarm lower limit for the process value
C	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
C	MV		Interconnection for the simulation chart (Process\\Sim_ProcModel\B_Norm.In1)

Block	Connection	Value	Use
to_Actor_Slave	Out		Interconnection for the valve (YC_Bottom\from_Ctrl.In)
from_Actor_Slave	In		Interconnection for the valve (YC_Bottom\to_Ctrl.Out)
PV	SimPV_In		Interconnection for the simulated process value (Process\\Sim_ProcModel\mB_Prozent.OUT)

YC_Bottom

The instance has the following parameterization.

Block	Connection	Value	Use
from_Ctrl	In		Interconnection for the controller (LIC_Bottom\to_Actor_Slave.Out)
to_Ctrl	Out		Interconnection for the controller (LIC_Bottom\from_Actor_Slave.In)

NS_PumpBottom

No parameter change with regard to the type.

4.8 Distillation

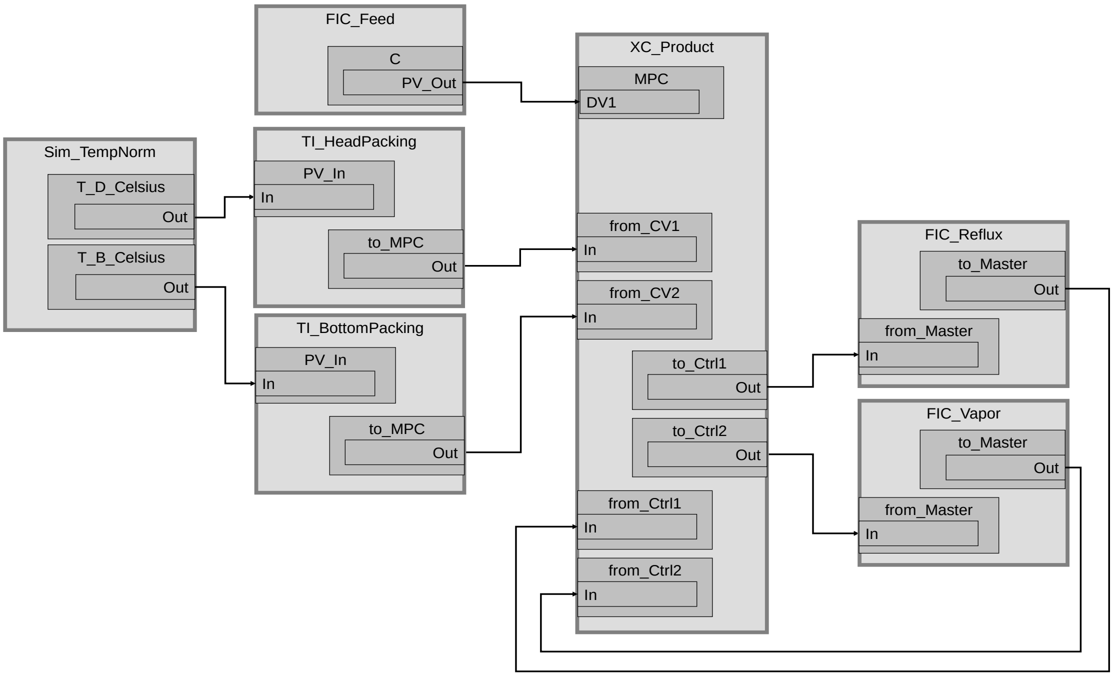
An optimum thermal separation is needed to produce high-quality low and high boilers. For this reason, the different temperature ranges of the column are recorded and monitored. A multivariable controller is used to complete the separating task (production of distillate) with high quality results and to better respond to disturbances.

4.8.1 Setup

The temperature is controlled as a cascade of multi-variable master controllers "TIC_DistBottom" and the slave controllers "FIC_Reflux" and "FIC_Vapor". The multivariable controller also monitors the mixture feed as a disturbance. The following table provides an overview of the CM and the selected variants.

CM	CMT	Variant	Description
TIC_DistBottom	"CtrlMPC"	Ctrl_Std	Multivariable controller as a master controller
TI_HeadPacking	"AMon"	AMon_Std activated option "Opt_IF_MPC"	Measuring point for displaying the upper separating temperature
TI_BottomPacking	"AMon"	AMon_Std activated option "Opt_IF_MPC"	Measuring point for displaying the lower separating temperature

In the following figure, the structure with the cross-chart interconnection is depicted in simplified form.



4.8.2 Parameter assignment

TIC_DistBottom

The instance is configured by activating the options "Opt_CPM_1" and "Opt_CPM_2" for two control variables. The instance has the following parameterization.

Block	Connection	Value	Use
MPC	DV1		Interconnection for the controller that is detected as a disturbance (Feed\\FIC_Feed\C.PV_Out)
MPC	DB	40	Data block with the recorded process behavior (process model)
from_CV1	In		Interconnection for the control variable (TI_HeadPacking\to_MPC.Out)
from_CV2	In		Interconnection for the control variable (TI_BottomPacking\to_MPC.Out)
from_Ctrl1	In		Interconnection for the slave controller (FIC_Reflux\to_Master.Out)
to_Ctrl1	Out		Interconnection for the slave controller (FIC_Reflux\from_Master.In)
from_Ctrl2	In		Interconnection for the slave controller (FIC_Vapor\to_Master.Out)
to_Ctrl2	Out		Interconnection for the slave controller (FIC_Vapor\from_Master.In)

Note The blocks for control quality monitoring and system deviation form part of the CFC. The respective block icons for display of information are not part of the process screens. If necessary, the "Create block icon" function can be activated in the block properties. The respective block icons are available in the process screen once the OS is compiled.

TI_BottomPacking

The instance is configured by activating the "Opt_IF_MPC" option for connection to the multivariable controller as a control variable. The instance has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	84.0	Alarm upper limit for the process value
I	PV_WH_LIM	83.0	Warning upper limit for the process value
I	PV_WL_Lim	72.0	Warning lower limit for the process value
I	PV_AL_Lim	71.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
to_MPC	Out		Interconnection to the multivariable controller (TIC_DistBottom\from_CV2.In)
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_B_Celsius.Out)

TI_HeadPacking

The instance is configured by activating the "Opt_IF_MPC" option for connection to the multivariable controller as a control variable. The instance has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	73.0	Alarm upper limit for the process value
I	PV_WH_LIM	72.0	Warning upper limit for the process value
I	PV_WL_Lim	67.0	Warning lower limit for the process value
I	PV_AL_Lim	66.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
to_MPC	Out		Interconnection to the multivariable controller (TIC_DistBottom\from_CV1.In)
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_D_Celsius.Out)

4.9 Process simulation (Process)

The timing of the simulation model of the distillation column is shortened many times over in comparison to a real installation to obtain a faster reaction ("time-lapse").

The simulation included in the "Process" folder consists of the following parts:

- Simulation of the process (CFC "Sim_ProcModel")
- Conversion of temperature values (CFC "Sim_TempNorm")
- Integration limit (CFC "Sim_AntiWindUp")

The following CMs are also included in the "Process" folder for measured value display:

- "PI_ColuBottom": Pressure at the column bottom
- "TI_Head": Temperature at the column head
- "TI_AboveFeed": Temperature above the mixture feed
- "TI_BelowFeed": Temperature below the mixture feed
- "TI_Bottom": Temperature at the column bottom

Process simulation

The CFC "Sim_ProcModel" contains all of those parts of the simulation model that not only describe an individual system section but also have an overarching nature. The role of process simulation is to understand the functioning of the distillation column, particularly in relation to the control functions of the multivariable controller or to be able to demonstrate it. It does not claim to replicate exactly the real physical behavior of a particular distillation column.

The process model is a 6x4 multivariable system that simulates all the influencing input-output combinations in separate partial transfer functions. The simulation is designed on the operating point of the process.

The following figure shows the process model with the corresponding names:

General Model

		Inputs					
		u1	**u2**	**u3**	**u4**	**u5**	**u6**
Outputs	**y1**	$G_{1.1}$	$G_{1.2}$	$G_{1.3}$	$G_{1.4}$	$G_{1.5}$	$G_{1.6}$
	y2	$G_{2.1}$	$G_{2.2}$	$G_{2.3}$	$G_{2.4}$	$G_{2.5}$	$G_{2.6}$
	y3	$G_{3.1}$	$G_{3.2}$	$G_{3.3}$	$G_{3.4}$	$G_{3.5}$	$G_{3.6}$
	y4	$G_{4.1}$	$G_{4.2}$	$G_{4.3}$	$G_{4.4}$	$G_{4.5}$	$G_{4.6}$

Derived Process Model (with name in CFC)

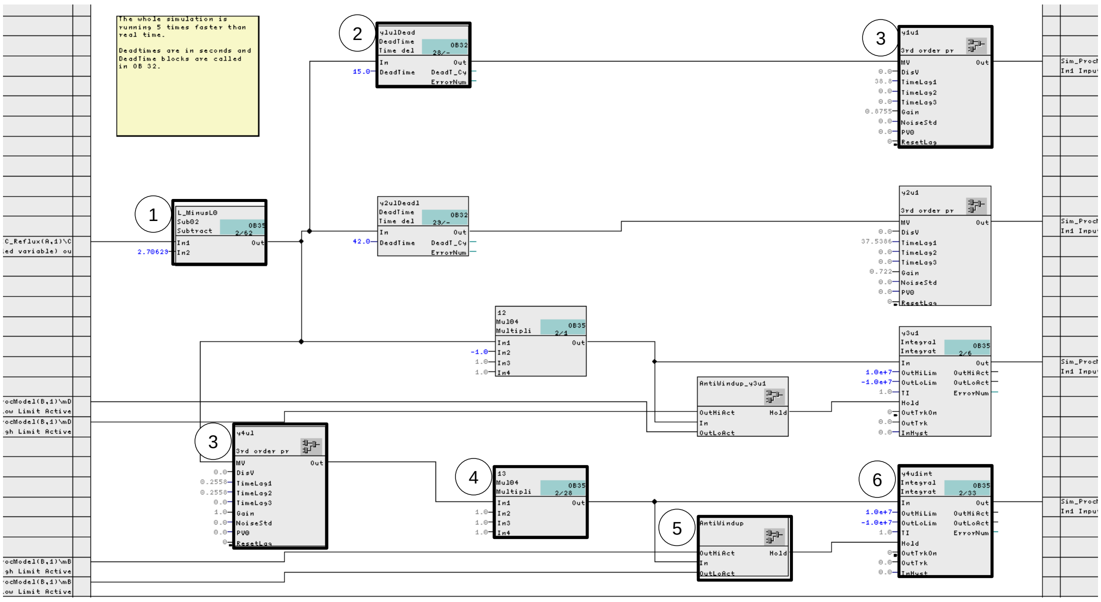
		Reflux	Vapor	Distill. Flow	Bottom flow	Flow Inlet	Concentr. Inlet Inlet
		L	**V**	**D**	**B**	**F**	**zF**
Concentr.Distillation	**XD**	y1u1	y1u2	y1u3	y1u4	y1u5	y1u6
Concentr.Bottom	**xB**	y2u1	y2u2	y2u3	y2u4	y2u5	y2u6
Level Distillation	**MD**	y3u1	y3u2	y3u3	---	---	---
Level Bottom	**mB**	y4u1	y4u2	---	y4u4	y4u5	---

The process model is divided into two chart partitions in the CFC "Sim_ProcModel".

Chart partition A

The chart partition "A" includes transfer functions of an input signal which affect the defined output signals. All partial transfer functions have the same general structure and are reduced to the essential.

The following figure shows the sheet 1, which includes the effects of the "Reflux" input signal (L) on all outputs.



A partial transfer function may contain up to five components, as can be seen in the following examples:

Partial transfer function with PT behavior "y1u1" with the components 1, 2, 3

Partial transfer function with IT behavior "y4u1" with the components 1, 3, 4, 5, 6

1. **Deviation from operating point:** This block allows for the operating point of the input to be indicated and the difference to it to be calculated. If necessary, some input values can be normalized in advance.
2. **Dead time:** Gives the dead time of the partial transfer function.
3. **PT transfer function (Chart-in-Chart):** Three delay elements and a reinforcing member are switched in succession in the transfer function. Furthermore, noise can be added to the output signal.
4. **Sign:** Determination of the sign for integration.
5. **Limitation of integration ("SimAntiWindUp" as Chart-in-Chart):** The input signal for the integrator is pre-checked for overranged and underranged limits and the integration of the output value is stopped (output signal).
6. **Integrator:** The integrators are used for level simulation.

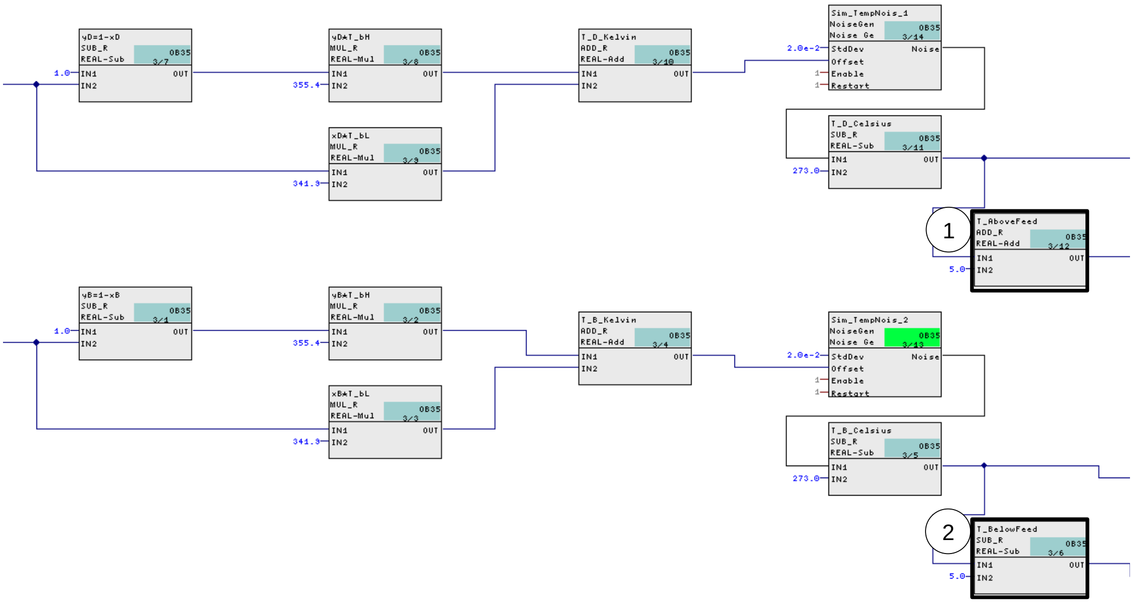
Chart partition B

In chart partition "B", the output signals are calculated from all intermediate values of the individual inputs. To do this, all the influences of all inputs are added and the total is limited to defined limits. The calculated level values are also converted to percent.

Conversion of temperature values

In the CFC "Sim_TempNorm", the normalized temperatures of "TI_HeadPacking" and "TI_BottomPacking", which are used in the simulation model, are converted into degrees Celsius. The temperature values above (1) and below (2) the mixture-addition are output with 5°C difference from the converted temperatures "TI_HeadPacking" and "TI_BottomPacking".

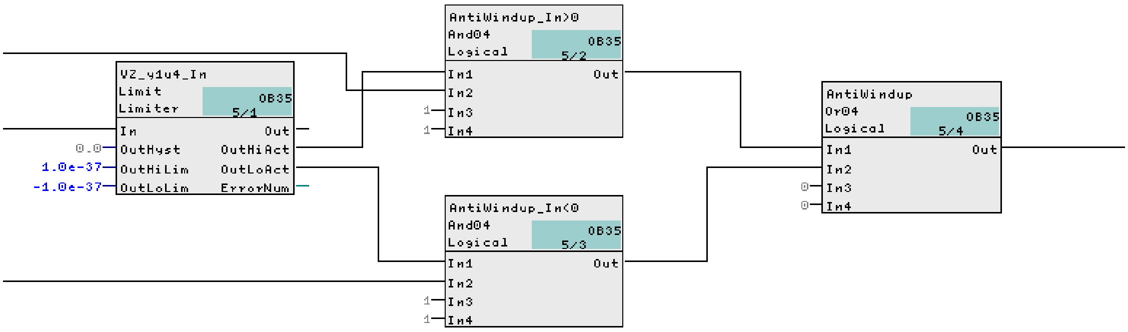
Figure 4-1



The remaining process values for head temperature, bottom temperature and bottom pressure are fixed and issued with a process noise.

Integration limit

The CFC "Sim_AntiWindUp" is carried out using the Chart-in-Chart technique and serves as an integration limit for integral transfer functions of the process model. The following figure shows the structure of CFC.



Parameter assignment

TI_AboveFeed

The instance is used as a variant "AMon_Std" and has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	82.0	Alarm upper limit for the process value
I	PV_WH_LIM	81.0	Warning upper limit for the process value
I	PV_WL_Lim	69.0	Warning lower limit for the process value
I	PV_AL_Lim	69.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_AboveFeed.Out)

TI_BelowFeed

The instance is used as a variant "AMon_Std" and has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	83.0	Alarm upper limit for the process value
I	PV_WH_LIM	83.0	Warning upper limit for the process value
I	PV_WL_Lim	71.0	Warning lower limit for the process value
I	PV_AL_Lim	71.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_BelowFeed.Out)

TI_Bottom

The instance is used as a variant "AMon_Std" and has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	83.0	Alarm upper limit for the process value
I	PV_WH_LIM	83.0	Warning upper limit for the process value
I	PV_WL_Lim	71.0	Warning lower limit for the process value
I	PV_AL_Lim	71.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_Bottom.Out)

TI_Head

The instance is used as a variant "AMon_Std" and has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1001	Process value unit in °C
I	PV_Hyst	0.3	Hysteresis for the limit values
I	PV_AH_Lim	82.0	Alarm upper limit for the process value
I	PV_WH_LIM	81.0	Warning upper limit for the process value
I	PV_WL_Lim	69.0	Warning lower limit for the process value
I	PV_AL_Lim	69.0	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_Head.Out)

PI_ColuBottom

The instance is used as a variant "AMon_Std" and has the following parameterization.

Block	Connection	Value	Use
PV_Unit	In	1137	Process value unit in bar
I	PV_Hyst	0.01	Hysteresis for the limit values
I	PV_AH_Lim	1.9	Alarm upper limit for the process value
I	PV_WH_LIM	1.8	Warning upper limit for the process value
I	PV_WL_Lim	0.2	Warning lower limit for the process value
I	PV_AL_Lim	0.1	Alarm lower limit for the process value
I	PV_AH_En PV_WH_En PV_WL_En PV_AL_En		Activation of the alarm and warning limit monitoring
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\P_ColuBottom.Out)

4.10 Sequences

Step sequencers support the plant operator during start-up and shut-down of a plant or in case of faults.

During start-up the process is placed in the defined operating point. The controllers are optimized for the specific operating point and are switched to automatic mode when reaching the operating point.

Different response and control strategies can be implemented in the SFC. In the sample project, an SFC is configured. The SFC "StartDistColumn" is configured for automatic start-up without user interaction. After start-up, control is transferred to the user in automatic mode, allowing him to determine, for instance, the individual setpoint values. By stopping or terminating the SFC, the unit is switched to a production-free operation. The following sequencers are components of the SFC and are described below:

- Preparation (PREPARING)
- STARTUP

The SFCs should be understood as a reference point and must be modified for use with real plants, if applicable.

Note

The necessary parameters were assigned and the schematic representations from the Function Manual "SIMATIC Process Control System PCS 7 Advanced Process Library (V9.0)" were used to determine the setpoint value and operating mode selection. In the Function Manual you can find information on operating modes and setpoint value selection, as well as more detailed information on all parameters of the APL blocks. You will find the manual at this link: https://support.industry.siemens.com/cs/ww/en/view/109482346.

STARTUP

When starting the distillation column, the sequencer "STARTUP" is executed at the beginning. During the starting phase, the unit from the plant standstill (no production) is prepared for operation in its normal state. For this purpose, the controllers switch to automatic mode and all controllers receive the relevant setpoints for the production process, such as the inflow quantity, the pressure, and the temperature in the distillation column.

After start-up, control is transferred to the user in automatic mode, allowing him to determine, for instance, the individual setpoint values.

The following steps are performed successively in the sequencer:

1. Resetting the simulation
2. Initializing the default controller
3. Presetting the working ranges (setpoints)
4. Initializing the multivariable controller

Shutting down (SHUTDOWN)

In the "SHUTDOWN" sequencer, the unit is taken into production-free operation. This is started in the OS by pressing the "Stop" or "Cancel" buttons within the SFC visualization.

Also, all the controllers, valves and motors/pumps of the distillation column are stopped and released for the operator. The process simulation is additionally reset. The operator has the possibility of operating all plant units as follows:

- Controlling all valves
- Controlling the pumps
- Changing the setpoint value specifications (internal setpoint) of the controllers and monitoring the process
- Performing controller optimization (changing individual controller parameters or using the PID tuner)

4.11 Process key figures "KPI"

The CFC "KPI" comprises key performance indicators that inform the operator about the process performance. The following key performance indicators are calculated and shown in the visualization:

1. Production volume of the head product:
   Manipulated variable for the level control of the condensate * factor 0.2

2. Production volume of the bottom product:
   Inflow of the input material – production volume of the head product

3. Pressure loss in the column:
   Bottom pressure – pressure at column head

4. Reflux ratio:
   Reflux / production volume of head product

5. Relative energy consumption;
   Vapor amount / production volume of head product

You can also find the operator control block "FeedComposition" on sheet 3. This allows the composition of the input material or the separation ratio to be defined.

4.12 Maintenance

In the CFC "Maintenance", the operation time of the column and the pressure loss in the column are continuously monitored with the block "AssetM" and an alarm message is thrown if levels are exceeded.

Note The block icon for displaying the maintenance information does not form part of the process screens. If necessary, the "Create block icon" function can be activated in the block properties. The block icon is available in the process screen once the OS is compiled.

4.13 Task-related overview screens with APG

With PCS 7 Advanced Process Graphics, process screens are displayed more clearly, reduced to the essentials, and are intuitive to use. The focus lies in the consideration of the relevant process variables within the working ranges. In this example, the plant overview screen and the process screen are created with APG.

4.13.1 Integration of APG

The integration of APG is configured in two phases:

1. Insertion and parameter assignment of APG blocks in the measuring points (AS)
2. Placement and interconnection of APG objects (OS)

Note You can find basic information on APG, on the extension of an existing PCS 7 project with APG and on the configuration purposes in the application description "Integration of Advanced Process Graphics in SIMATIC PCS 7" at the following link: https://support.industry.siemens.com/cs/ww/en/view/89332241.

4.13.2 APG measuring points (AS)

In the CMT "Ctrl" and "AMon", the APG connector block has been added in chart partition "A" "Sheet 4" and linked to the controller or display block. The extended CMTs of the master data library are synchronized with the automation project.

Note The Application Example "Control Module (CM) Technology - Efficient Engineering with SIMATIC PCS 7" describes how efficiently an existing project is extended to APG by applying the control module technology and can be found at the following link:
https://support.industry.siemens.com/cs/ww/en/view/109475748

Controller measuring points

The CMT "Ctrl" contains the following parameterization.

Connection	Value	Use
BockType	2	Representation suitable for the "PIDConL" block
ViewMode	1	Absolute representation (value range)
ViewRange	4	Display of the working range
ReadPointer		Connected with "C.Status2"

The following table contains the parameterization of all instances in which the "HMI" option has been activated.

CM	Connection	Value	Use
LIC_Bottom	PV_Ox_Li		No change with regard to the type
FIC_Feed	PV_OH_Li	30.0	Upper limit of the working range
FIC_Feed	PV_OL_Li	0.0	Lower limit of the working range
FIC_RefluxDrum	DispRatio	0.5	Display ratio
FIC_Vapor	PV_OH_Li	10.0	Upper limit of the working range

CM	Connection	Value	Use
FIC_Vapor	PV_OL_Li	0.0	Lower limit of the working range
PIC_ColuHead	PV_OH_Li	2.0	Upper limit of the working range
PIC_ColuHead	PV_OL_Li	0.0	Lower limit of the working range
FIC_Reflux	PV_OH_Li	50.0	Upper limit of the working range
FIC_Reflux	PV_OL_Li	0.0	Lower limit of the working range

Display measuring points

The CMT "AMon" contains the following parameterization.

Block	Connection	Value	Use
HMI	BockType	1	Representation suitable for the "PIDConL" block
HMI	ViewMode	1	Absolute representation (value range)
HMI	ViewRange	4	Display of the working range
HMI	ReadPointer		Connected with "C.Status2"

The following table contains the parameterization of all instances in which the "HMI" option has been activated.

CM	Connection	Value	Use
TI_HeadPacking	ViewMode	2	Difference representation
TI_BottomPacking	ViewMode	2	Difference representation
TI_AboveFeed	ViewMode	2	Difference representation
TI_BelowFeed	ViewMode	2	Difference representation
TI_Bottom	ViewMode	2	Difference representation
TI_Head	ViewMode	2	Difference representation
PI_ColuBottom	PV_OH_Li	10.0	Upper limit of the working range
PI_ColuBottom	PV_OL_Li	0.0	Lower limit of the working range

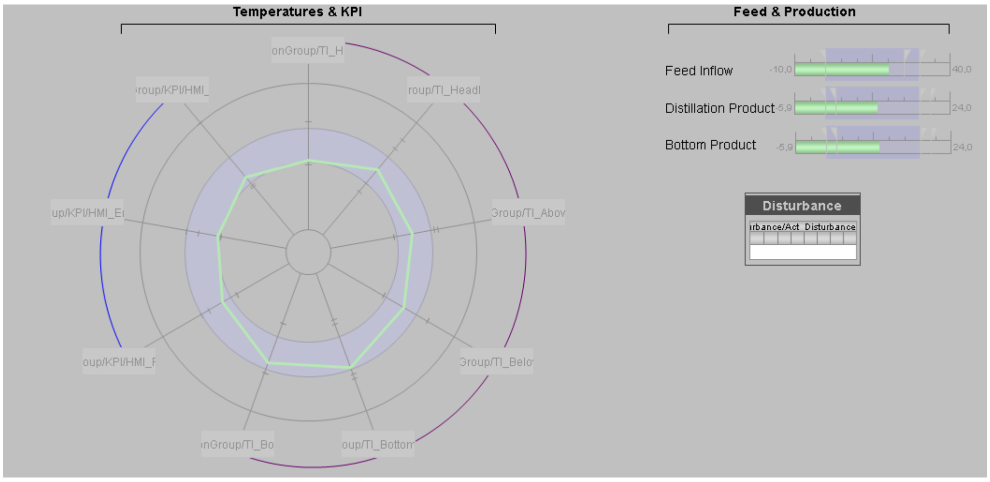
KPI measuring point

The CFC "KPI" contains five instances of the APG connector blocks. The interconnection and parameters of "BlockType", "ViewMode" and "ViewRange" correspond to the parameterization of the display measuring point. The following table contains the parameterization of the display areas.

Block	Connection	Value	Use
HMI_FI_DistProd	PX_OH_Li	20.0	Upper limit of the working range
HMI_FI_DistProd	PX_OL_Li	0.0	Lower limit of the working range
HMI_FI_BottoProd	PX_OH_Li	20.0	Upper limit of the working range
HMI_FI_BottoProd	PX_OL_Li	0.0	Lower limit of the working range
HMI_PressureLost	PV_OH_Li	0.5	Upper limit of the working range
HMI_PressureLost	PX_OL_Li	0.0	Lower limit of the working range
HMI_RefluxRatio	PV_OH_Li	10.0	Upper limit of the working range
HMI_RefluxRatio	PX_OL_Li	0.0	Lower limit of the working range
HMI_EnergyConsum	PV_OH_Li	3.0	Upper limit of the working range
HMI_EnergyConsum	PX_OL_Li	0.0	Lower limit of the working range

4.13.3 Detecting deviations in the process mode with APG

The aim of the control is to operate the system in a normal state. This state is reached when the controllers are in automatic mode and all controllers receive the relevant values for the production process, such as the inflow quantity, the pressure, and the temperature in the distillation column in the work area. The APG block displays visualize the work area in blue within the display. This allows the APG blocks to help visualize the relevant data of the system quickly and clearly. The following figure shows the visualization of the normal state of the "distillation column" plant.



If the work area is exited, warning and alarm messages can be configured to generate messages. This chapter explains the advantages of visualization using the additional APG blocks. For this purpose, a disturbance is applied to the Unit Template "distillation column". This disturbance simulates a temperature loss, e.g. as a result of a heat leak at the measuring point for temperature below the feed. The disturbance can be switched on or off at any time using the "disturbance" digital switch.

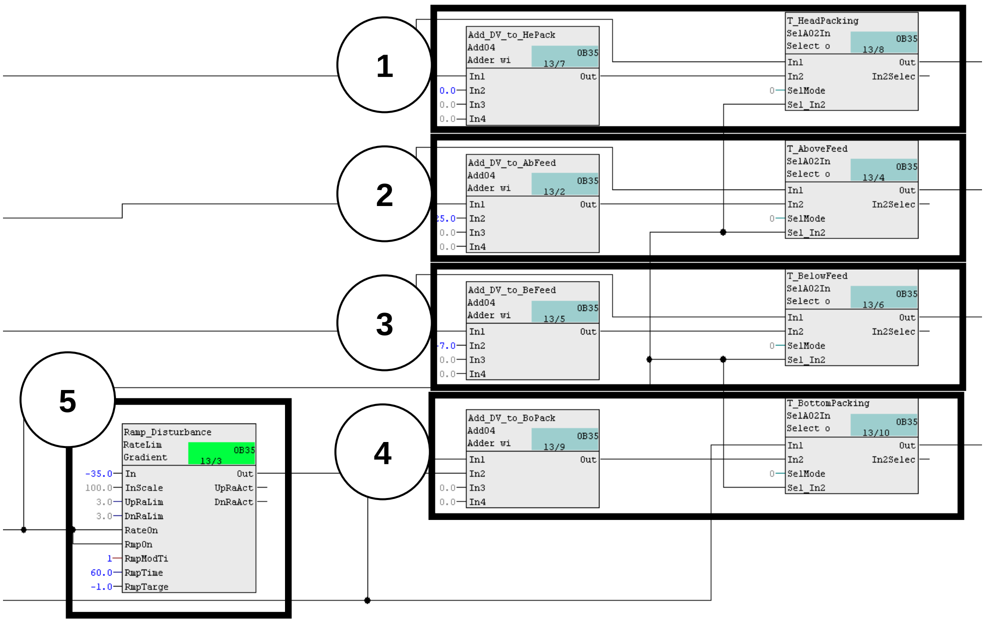
Note

Smart Alarm Hiding for alarm management is implemented in the project. This means that, depending on the system status, messages can be suppressed selectively, preventing them from entering the OS alarm system. Activating the disturbance in the "Operation" system state is recommended to ensure that all messages are displayed. Further information on Smart Alarm Hiding can be found in the chapter "Smart Alarm Hiding".

Setup

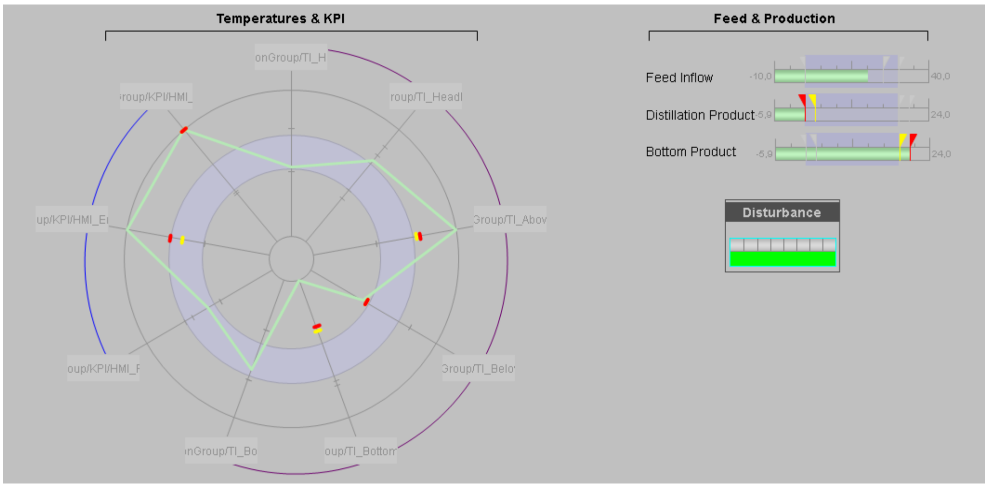
The disturbance is generated in the CFC plan "APG_Disturbance", which switches various temperature values between the simulation and the display. In order to simulate a disturbance that is as real as possible, a large amount of heat loss is simulated at the "TI_BottomPacking" measuring point when the disturbance starts. This heat loss decreases continuously until it reaches a small, constant level of heat loss. In addition, temperature values are displayed on the two displays of the measuring points "TI_AboveFeed" and "TI_BelowFeed". The addition of these temperature values to the displays has no effect on the simulation, as the two displays only show the measured values in the OS and are not used by the controller or the simulation.

The following figure shows the components of the simulation for the disturbance.

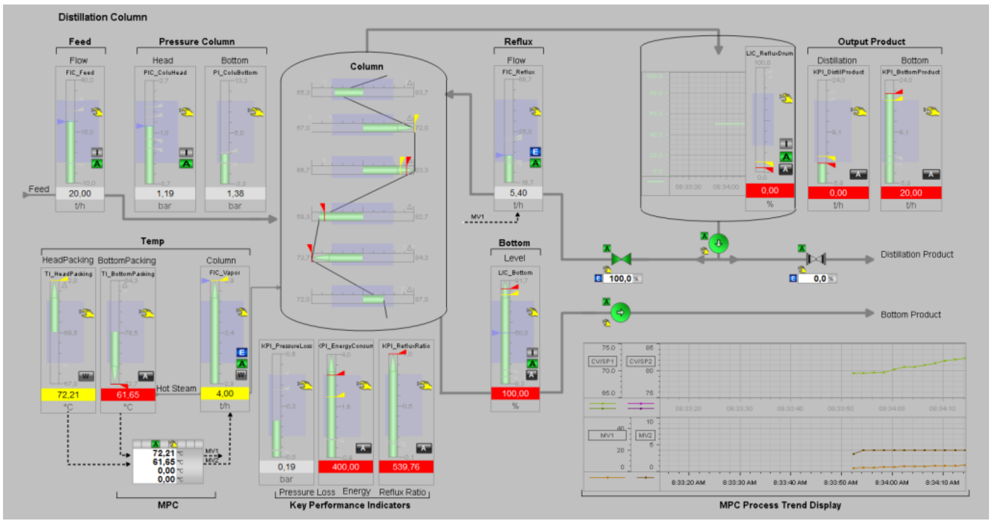


1. Calculation of the new temperature value for the measuring point "TI_HeadPacking" when the disturbance is activated
2. Calculation of the new temperature value for the measuring point "TI_AboveFeed" when the disturbance is activated
3. Calculation of the new temperature value for the measuring point "TI_BelowFeed" when the disturbance is activated
4. Calculation of the new temperature value for the measuring point "TI_BottomPacking" when the disturbance is activated
5. Generation of the ramp value for the temperature difference at the measuring point "TI_BottomPacking"

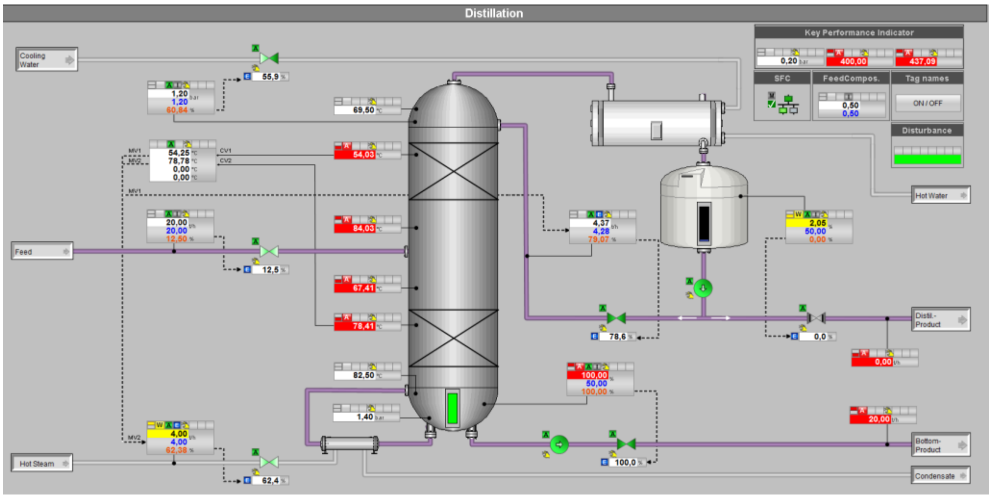
Evaluation



In the plant overview, the intuitive view immediately displays to the user that the plant is not in normal operation. This means that the temperature display for "TI_AboveFeed" is outside the work area or even above the warning and alarm limits. In contrast, the two measuring points "TI_BelowFeed" and "TI_BottomPacking" are below the work area and the warning and alarm limits. In addition, the KPI's energy consumption and reflux ratios are far outside the work area. Also, the amount of high boiler and low boiler production in the alarm area is easy to see in the plant overview.



One level lower in the process screen also clearly shows the system disturbance with the APG library. In addition to the plant overview having determined that the temperatures and the KPI for energy consumption and the reflux ratio of the distillation vessel are not in the work area, the process screen also shows that the top product container has reached the lower alarm limit and that the bottom product container has reached the upper alarm limit. In addition, a warning is also displayed, showing that the steam supply has reached the upper limit for the maximum feed.



The disturbance of the plant can also be seen in the detailed process screen, meaning the temperature, the two KPIs for the energy consumption and the reflux ratio, and the tank levels are in the alarm range. However, it is not very easy to see if the levels are above or below the warning and alarm limits, as the example of the temperature displays shows. Due to the heat loss, the "TI_BelowFeed", "TI_BottomPacking", and "TI_HeadPacking" temperature displays have reached the low limit for the alarm. The additional disturbance on the temperature display "TI_BelowFeed" is only possible upon closer inspection of the plant.

Note

The controllers return the plant to the normal range even with an active disturbance. Only the disturbances of the displays for the temperature "TI_AboveFeed" and "TI_BelowFeed" remain, which are only used for display purposes in the OS and have no influence on the simulation.
Furthermore, the active disturbance and the associated loss of heat lead to the steam supply being opened to the maximum in order to compensate for the heat loss, which then generates a warning message.

Note

By activating the disturbance, the plant leaves its normal range, triggering a few warning and alarm messages. These messages can be acknowledged.

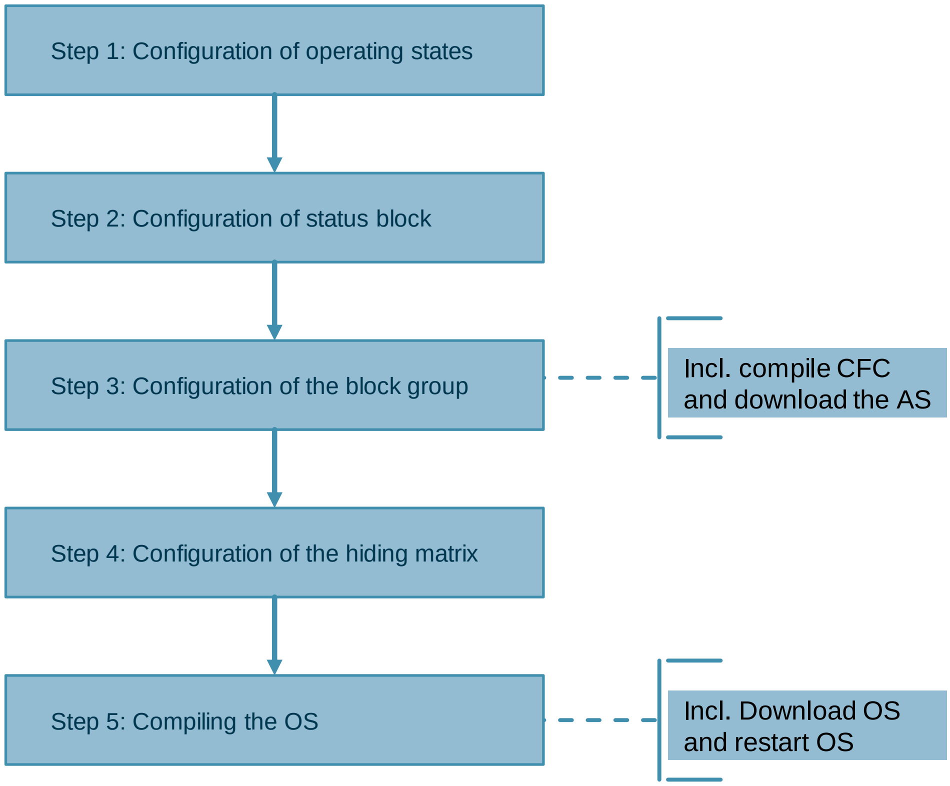
4.14 Smart Alarm Hiding

With the Smart Alarm Hiding, alarms of a measuring point can be filtered or hidden depending on the plant state. This means that the filtered and hidden alarm messages of the measuring points are also sent to the alarm system where they are processed and archived.

A reduction in the message traffic is thus achieved in process mode, which simplifies the operation of a system.

Smart Alarm Hiding in the example project

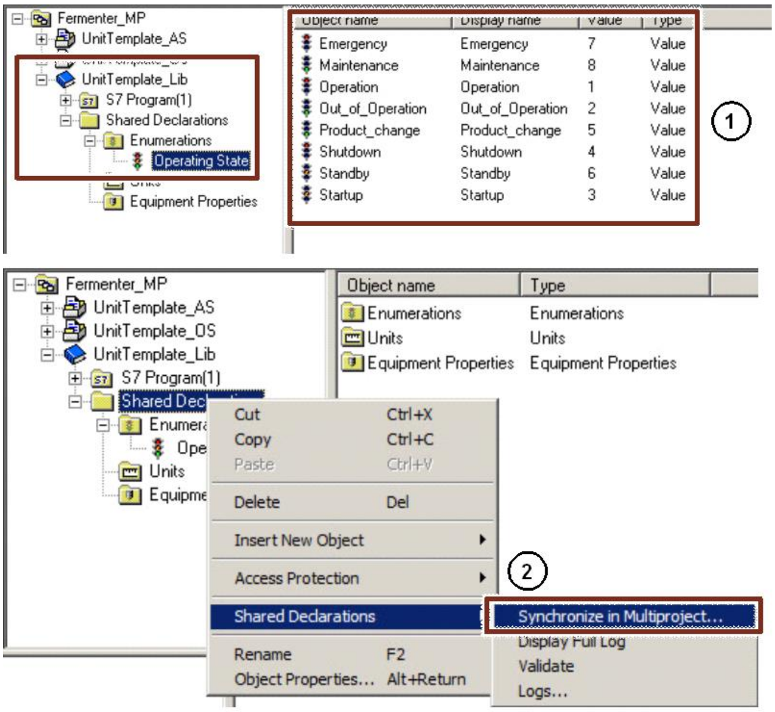
The following sequence has been followed for the configuration of Smart Alarm Hiding.



Note Further information on Smart Alarm Hiding can be found at the following link: https://support.industry.siemens.com/cs/ww/en/view/55699984.

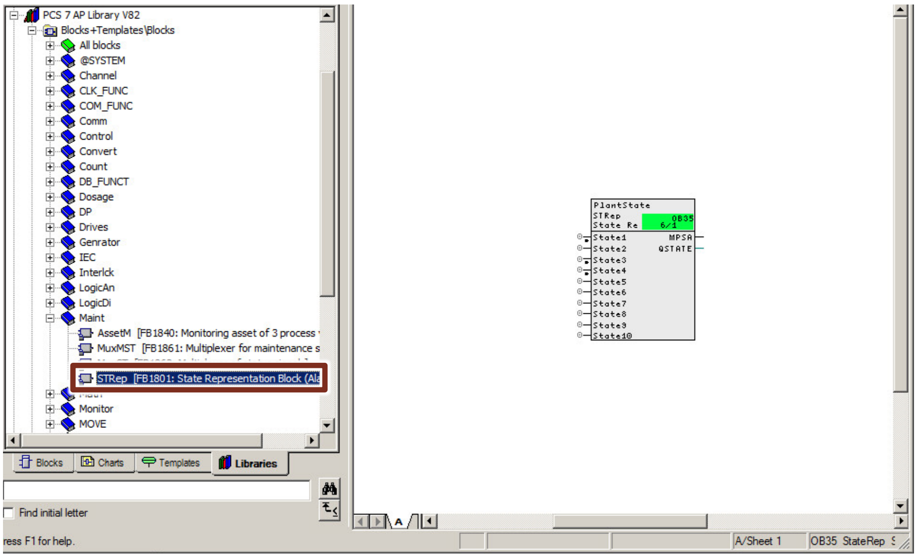
Step 1:

The operating states are configured (1) in the master data library and synchronized in the multiproject (2) as follows. The created enumeration is called "Operating State".



Step 2:

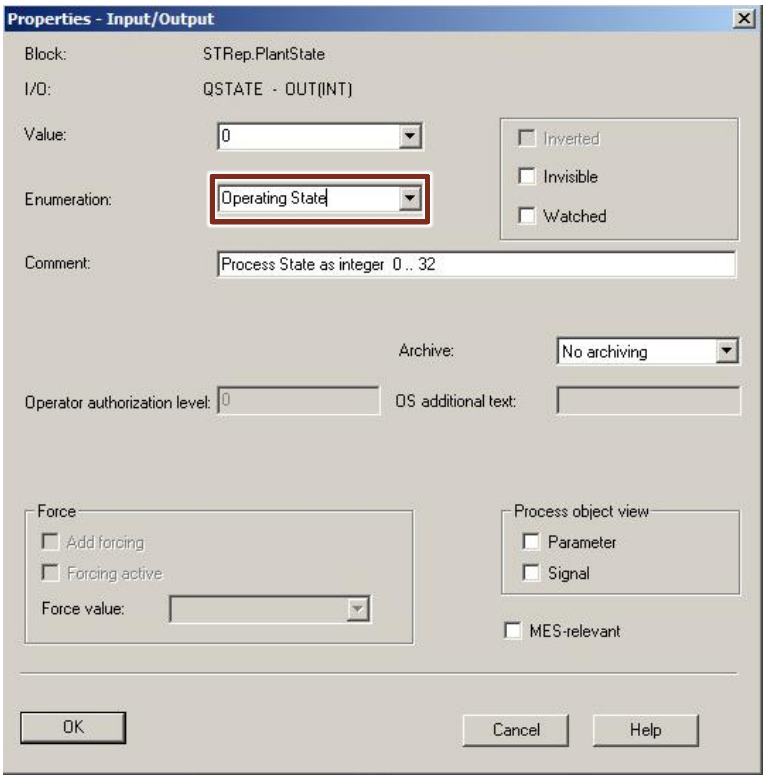
The "STRep" status block is configured and the "State" inputs correspond to the operating states created in step 1.



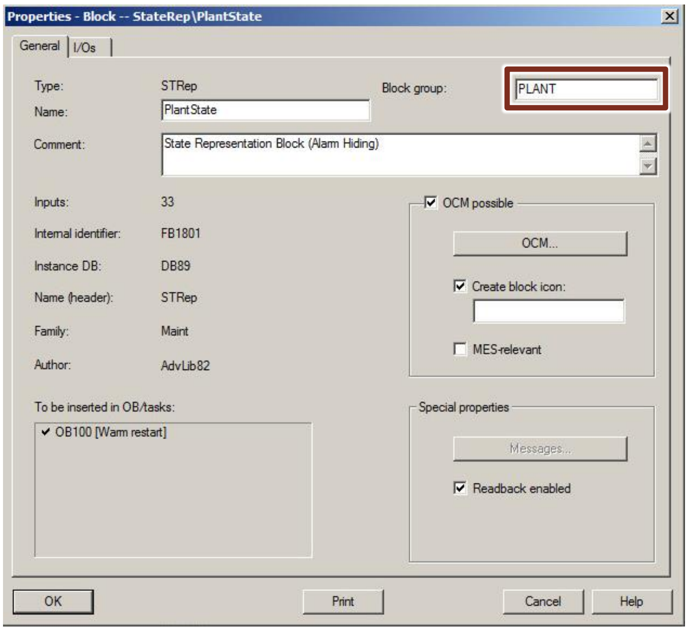
Note

In the project, the plant state is selected via the step sequencers. A direct interconnection of upstream blocks is also possible, however only one position (SFC or upstream block) can be activated at any time.

The enumeration "Operating State" is assigned in the object properties of the output.

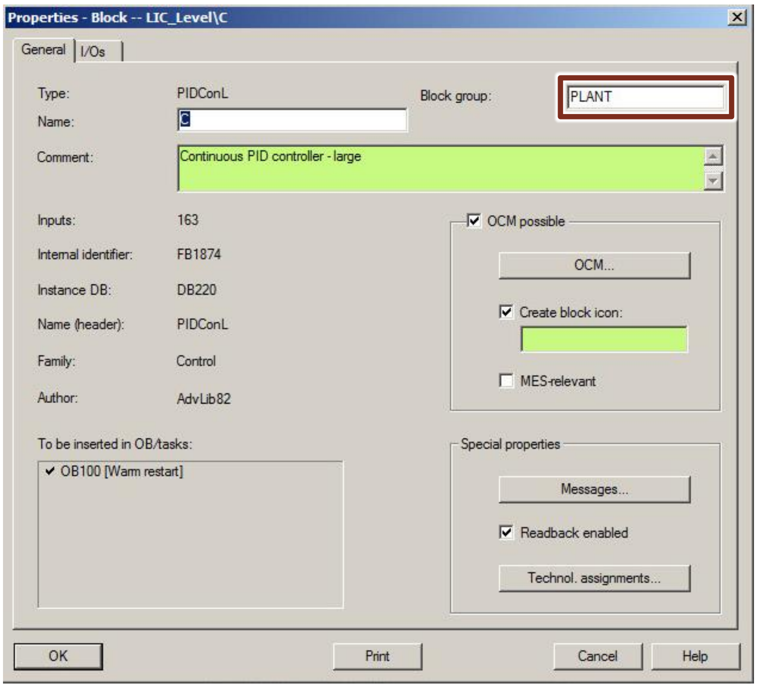


The block group "PLANT" is predefined in the block properties.

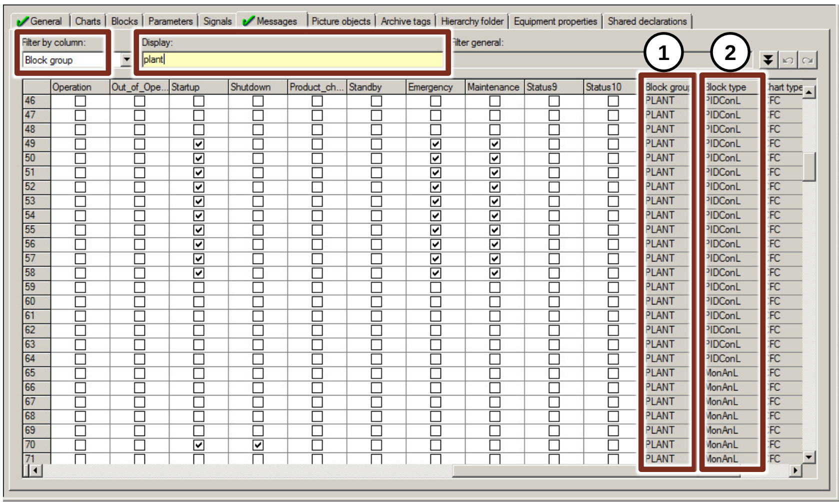


Step 3:

The technological blocks are assigned to the "PLANT" block group.



The following technological blocks (1) belong to the "PLANT" block group (2):



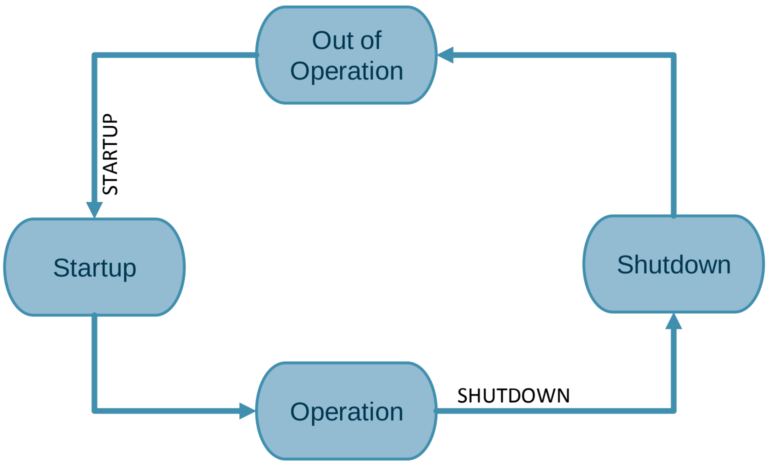
Note

The block group defines which technological elements belong together. It is recommended to define the block group at the unit level.

Step 4:

The Hiding Matrix has been configured for the following plant states:

	Plant state	Activation via	suppressed messages
1.	Operation	End of sequencer STARTUP	None
2.	Out_of_Operation	End of sequencer SHUTDOWN	All messages and alarms
3.	Startup	Start of sequencer STARTUP	Lower limit values of the filling level, flow and pressure measurement and KPI
4.	Shutdown	Start of sequencer SHUTDOWN	Lower limit values of the filling level, flow and pressure measurement and KPI
5.	Product_change	n. A.	
6.	Standby	n. A.	
7.	Emergency	n. A.	
8.	Maintenance	n. A.	



Step 5:

The OS in the project has already been compiled and prepared for operation.

5 Useful information

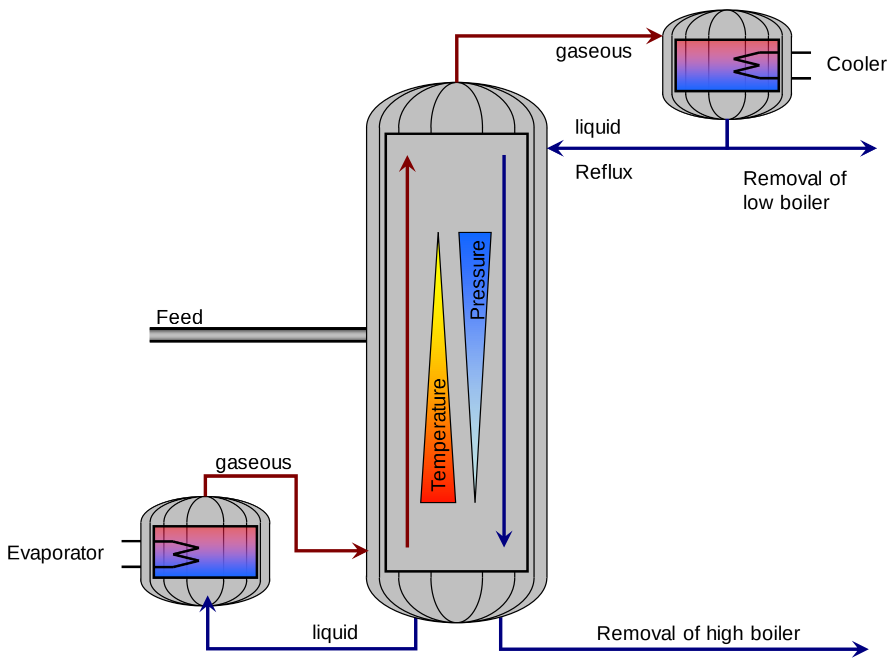
5.1 Basics

5.1.1 Distillation column (rectification column)

During distillation, a multi-component mixture is divided into at least two streams. In this process, the different boiling temperatures of the components are used. The mixture (usually liquid) is fed into the column through an inlet and vaporized.

The gas mixture rises to the top of the column, where the mixture cools and condenses again. The component with a high boiling point (high boiler) accumulates at the base of the column (bottom) and can be removed. The component with a low boiling point (low boiler) accumulates at the head of the column and can be removed from there. The balance between the high boiling and the low boiling constituents shifts along the entire column.

During the rectification process, the gas mixture is fed back again into the column via a reflux by means of a cooler. Thus the reflux drips in countercurrent to the high rising vapor down numerous shelves where it evaporates again. The rectification process therefore constitutes an extension of the distillation process or a series connection of several distillation steps.



5.1.2 Temperature characteristic

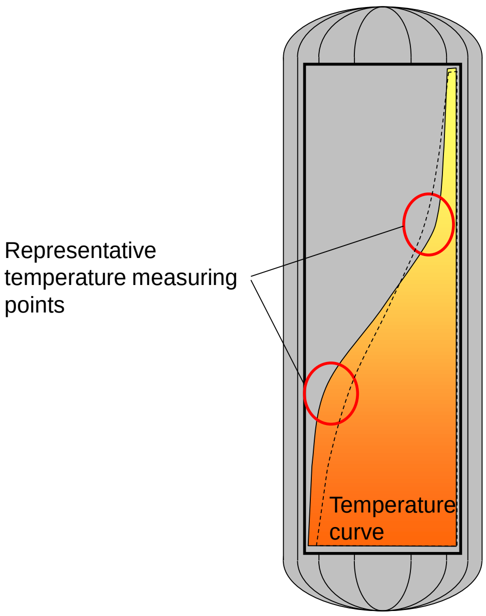
The quality of material separation is measured by the purity of the separation products, i.e. after concentration by low and high boilers in the head and bottom outlet. Measuring these concentrations using online analyzers is such a complex process, that it is omitted in most plants. On the individual trays of the column, the concentration of the substance in vapor and liquid are in approximate phase equilibrium. This means that the concentrations are highly dependent on the respective temperature.

The easily measurable temperatures are used as substitute control variables. This has the additional advantage that the relationship between these temperatures and control interventions can linearize more easily than the connection with the concentrations.

In the process design of the column, an s-shaped, vertical temperature profile is fixed inside the column to achieve the desired concentration profile and therefore the desired purity of the products. Two representative temperature measuring points are placed in the rectifying and output section of the column for control. The following points should be noted:

- In order for the measuring points to react properly to the changes inside the column (e.g. to changes in the feed rate or the composition of the feed), they should be located in the part of the s-shaped profile where a significant base-to-base temperature difference prevails.
- The dead times of the temperature control increase with the distance from the measurement points to the head and bottom.

The following figure shows the s-shaped temperature profile of a distillation column for two different temperature distributions.



5.2 Details on functionality

5.2.1 CFC naming convention

A uniform naming convention was used for identifying the control modules, whereby the function has been named according to the European standard EN 62424. The following figure shows how a label is composed.

FIC_Reflux

Function — Name

F	=	flow	(first letter)
I	=	indication	(subsequent letter)
C	=	control	(subsequent letter)

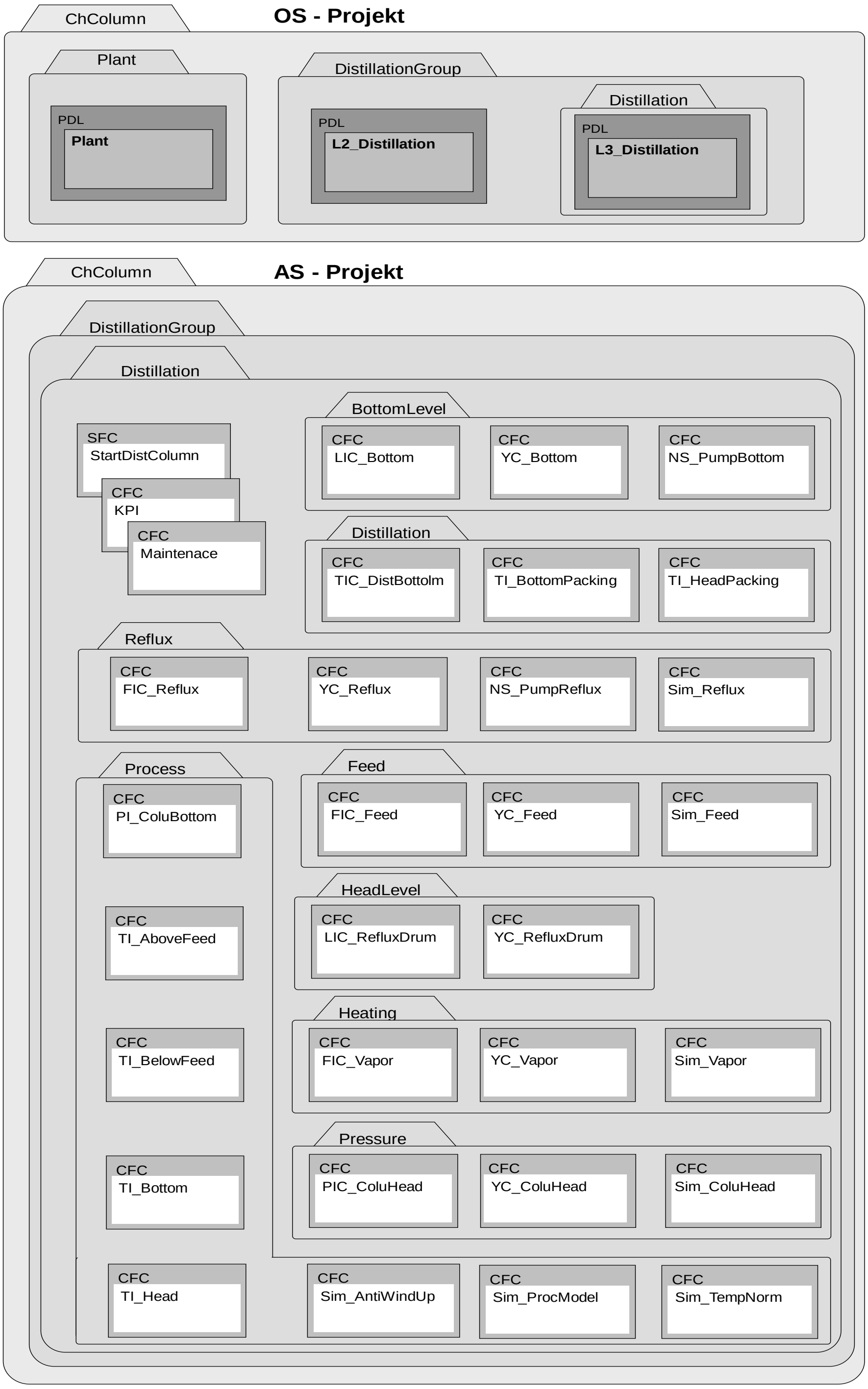
The following table provides all the letters used in the application and their meanings:

First letter	
Letter	**Meaning**
F	Flow
L	Level
N	Motor
P	Pressure
Q	Quantity
S	Speed (velocity, rotational speed, frequency)
T	Temperature
Y	Control valve
Subsequent letter	
C	Control
F	Fraction
I	Indication
S	Binary control function or switching function (not safety-oriented) ("switching")

5.2.2 Plant view

The Unit Template "distillation column" is designed as a multiproject and structured in the plan view of an OS and AS project.

All process screens can be found in the hierarchy folder of the OS project whereas the automation program is stored in the AS project in a structured manner. The following figure shows the structure in the plant view.



5.3 Automation

5.3.1 The "unit" concept

The term "unit" represents a plant section, device, machines in a process plant together with the sensors, actuators and automation systems required in this combination of components. This unit serves as a template for identical or similar devices in terms of standardization.

A subset of the process plant sections are so-called "package units". For examples, package units include refrigeration systems, vacuum systems and packaging machines. In this case, the manufacturer of the mechanical or technical device includes automation, specially tailored for this device, and which is mounted locally on special hardware on the device. The package unit is integrated as a whole into a process control system. No detailed knowledge of the package unit's automation system is required in order to plan the control system.

In contrast to the package units, automation solutions for process plants are unified, pre-made and created in the unit concept in form of templates that are not bound to specific hardware or only partially so. Therefore, the templates must be only adapted to the existing hardware and the special requirements. This significantly decreases the engineering effort required for several similar automation tasks.

Unit Template

In a Unit Template, CMs (control modules) are combined into an automation function. All CM relevant blocks are connected in a CFC. A uniform naming convention was used for names.

A Unit Template also contains a CFC with economic and process indicators (KPI parameters), a CFC for monitoring the operating time and CFC charts for simulation.

The Unit Template is summarized in a hierarchy folder and can be integrated into existing projects.

5.3.2 PCS Engineering with control modules

A CMT (Control Module Type) in a process control system is a unified template for creating signal flow charts, which occur more than once in the automation system of a plant. The signal flow charts (CFC: Continuous Function Chart) for many similar measuring points are produced by forming instances of a CMT and have to be subsequently configured and connected with concrete measured/manipulated variables. The parameterization and interconnection of the CM can be automated by means of a mass data engineering tool.

A Unit Template in SIMATIC PCS 7 covers all the functions required for the automation of a plant section:

- CFC charts (instances of CMT)
- SFC charts
- OS pictures

All functions are combined in a hierarchy folder of the SIMATIC Manager plant view.

5.3.3 Key Performance Indicators

Key Performance Indicators are economic or procedural parameters that describe the production progress, the degree of fulfillment of certain requirements, or the quality of a plant.

5.3.4 MPC controller

The MPC controller is a model predictive multivariable controller (Model Predictive Control) used for the control of complex linear systems.

If there are several manipulated and control variables influencing each other in a plant section, a multivariable controller leads to significantly better control results. The aim of the closed loop control is to run each control variable to the individual setpoint regardless of the other control variables. This reduces the probability that an intervention on a manipulated variable acts not only on a control variable but also affects other control variables.

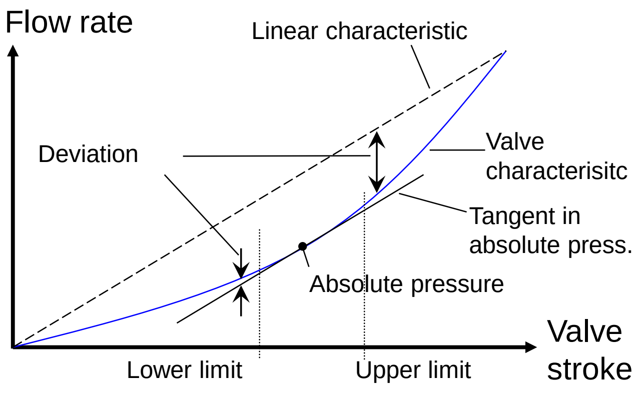
A model predictive multivariable controller additionally uses a complete mathematical description of the controlled system. This description allows the controller to calculate the process behavior over a defined period of time ("prediction horizon") without controller intervention. An optimization method allows the most efficient setting strategy to be selected and the planned optimal course to be calculated. There are several possibilities in the formulation of the optimization problem. Besides the future control deviation and the adjustment effort, even limit values for control variables and other economic objectives can be incorporated in the performance criterion.

5.3.5 Linearization

Many components in industrial plants have nonlinear characteristic curves. The characteristic curve of many valves does not give a flow rate of 50% at 50% of the maximum value. The greater the deviation of the flow rate from the linear characteristic is, the worse the control result of a linear regulator is. Since the planning of a nonlinear controller is more difficult than that of a linear controller, the characteristics are usually linearized.

Linearization in the operating point

In the linearization at the operating point, it is not the entire characteristic curve what gets considered, but rather the part of the characteristic curve that lies at the intended operating point and which is required during normal operation. In the operating point of the characteristic curve, a tangent is laid and the deviation between the tangent and the characteristic curve is considered.

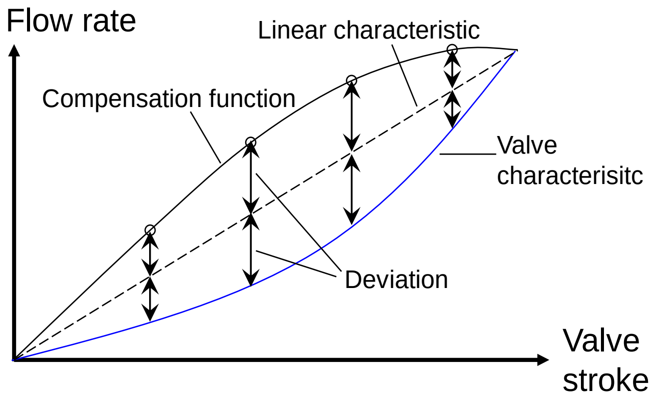


The tangent at the operating point helps in reducing the deviations between the actual non-linear characteristic curve and the adopted tangent to such an extent that in most cases, no adjustments to the controller parameters must be made.

If a controller is designed for the working range between the lower and upper limits (working range), the controller applies only for this range. If several operating points of a characteristic curve are required, a controller can be designed for each operating point and the controller parameters can be then adapted to the respective operating point depending on the process value.

Linearization with compensation function

The linearization with a compensation function is typically used when the working range takes up most of the characteristic curve. In this linearization, a polynomial is generated, which gives a linear function when multiplied by the valve characteristic curve. The following figure shows how the compensation function is determined mathematically or graphically.



5.4 Further Notes, Tips and Tricks, etc.

5.4.1 Configuration of the PID controller

The program "PID Tuner" is available for the configuration of the PID controller. This program determines the optimum PID parameters for the connected controlled system. The following instructions describe the general procedure using the example of the PID controller in the CFC "FIC_Feed".

Note	A practical example for operating the "PID Tuner" can be found at: https://support.industry.siemens.com/cs/ww/en/view/8031495.

Requirements

- The controller is connected to the process or to the simulation.
- The control program is compiled and loaded.

CAUTION	The optimization results in an intervention in the system process. You should be aware of the implications this may have. To obtain an optimal result, carry out the controller optimization between the minimum and maximum working range of the corresponding variable (for FIC_Feed: 15-25). During optimization, observe the process constantly from the curve recorder.

Granting optimization release

The program "PID Tuner" runs on the engineering station (ES). Since the operator control and monitoring station (OS) and the ES do not generally run on the same computer, PCS 7 offers the coordination of users function. The release takes place in the operating screen of the controller (View > Parameters). With this release, you grant the engineering system (PID Tuner) the right to intervene actively in the process. The respective possible operations on the OS are blocked during optimization.

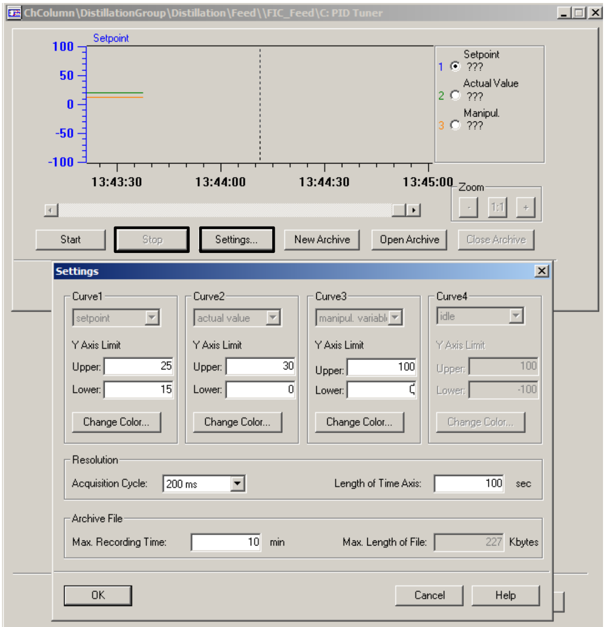
To use the program "PID Tuner", the value "1" must be present at the "OptimEn" input of the "PIDConL" block. If you want to set this input in the ES, follow the steps 1 to 5. If the release on the OS was granted, start with step 1 in the section "Performing controller optimization".

1. Open the PCS 7 project in the plant view.
2. Open the folder hierarchy "Ch Column_AS_Prj > ChColumn > DistillationGroup> Distillation > Feed" and double-click the chart "FIC_Feed". The CFC editor is opened.
3. In the menu bar of the CFC Editor, click on "Test > Test mode" and confirm the "Log in CPU for testing" dialog with "Yes".
4. Double-click the block "C" in sheet 1 of the CFC and click on the "Connections" tab.
5. Change the value of the connection "OptimEn" to the value "1" and confirm with "OK". Then close the block.

Carrying out the controller optimization

The following instructions describe controller optimization for a control system with PT behavior.

1. Click on "Edit > Optimize PID controller..." in the menu bar of the CFC editor. The PID Tuner opens.
2. Click the "stop" button under the curve recorder to stop the recording and then click the "Settings" button.



3. Insert appropriate Y axis limits for the 3 curves (setpoint, actual value, manipulated variable).
4. Adapt the "Acquisition cycle" and the "Timeline length" to the expected process behavior and confirm your entries with "OK".

Note For detailed information on controller optimization, refer to the online help. To open the online help, click the "Help" button in the lower part of the PID Tuner.

5. Click on the "Start Controller Optimization" button in the lower part of the PID Tuner.
6. In Step 1, select the check box "without integral component in the process from" and click "Next".
7. In the group "Operating mode" select the "Automatic" check box. Enter the typical operating point (e.g. 20 L/min) of the control variable. Please observe the warning in the lower part of the dialog and then click "Next".
8. As a "Step excitation, new setpoint:" enter a setpoint (e.g. 25 L/min.) well above the typical operating point. Please observe the warning in the lower part of the dialog and then click "Next".
   The controller optimization has now been completed.
9. After completing the optimization, select the check box "Withdraw" in the "Processes excitation" group. Please observe the warning in the lower part of the dialog and then click "Next".
10. In the group "Controller design to", select the "Optimal control behavior" check box and click "Next".
    An additional window will open with the identification result.

11. In the "Controller parameters" group, select the check box of the PI controller and click "Next".
12. In step 8: "Simulate a control loop with the optimized parameters", click "Next".
13. Click the "New" button to implement the determined values.
    Heed the warning in the lower part of the dialog and then click "Finish" to complete the optimization.

5.4.2 Configuration of the MPC controller

Step responses form the basis for the controller design. These are incorporated in the manual mode of the controller and recorded in trend curves. The trend curves show all excited manipulated variables and all control variables. The excitation of the manipulated variables begins at the operating point and contains a step to the upper limit and to the lower limit (linearization in the working point) of the typical position value for the operation of the plant. Each change in the manipulated variable is only carried out when the system has reached a steady state. The same procedure can be used for measurable disturbance variables. These can be considered in the controller design.

Trend curves can be additionally evaluated for checking (verification) the controller design.

The required trend curves can be created and exported in the CFC trend display.

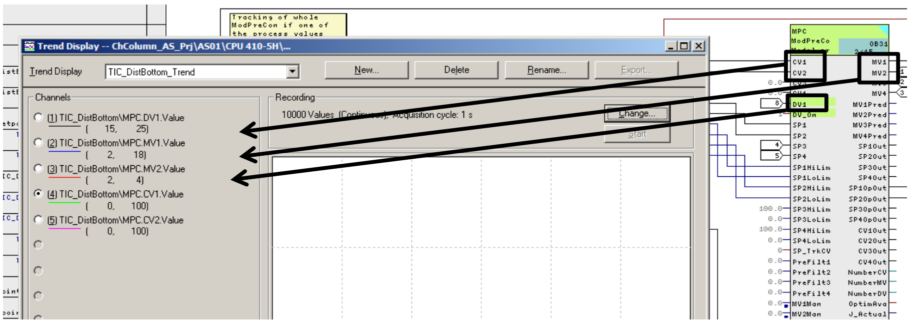
For more information, see the "Help" section of the MPC configurator under "Details on the individual design steps > Recording of measurement series".

Note	You can find a detailed description in the application example "Model Predictive Control including integral transfer functions" at the following link https://support.industry.siemens.com/cs/ww/en/view/42200753

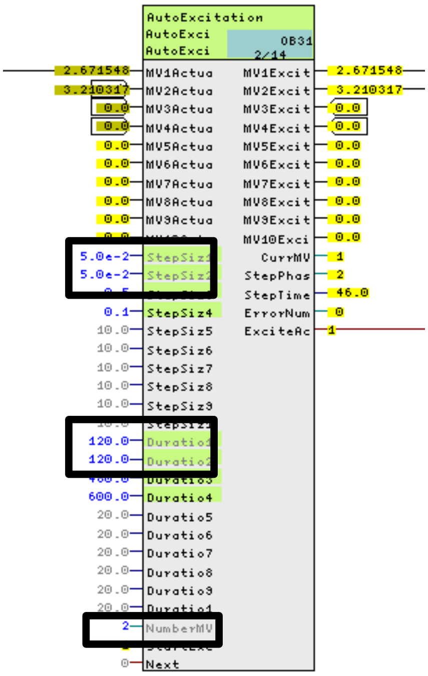
CAUTION	In-process interventions are necessary to configure the MPC controller! Before the process intervention, check what implications it will have and inform the appropriate personnel.

Trend recording

1. Open the PCS 7 project in the plant view.
2. Open the hierarchy folder "ChColumn_AS_Prj > ChColumn > DistillationGroup > Distillation > Distillation" and double-click the "TIC_DistBottom" chart.
   The CFC editor is opened.
3. Open the trend display from the menu "Display > Trend display".
4. Drag all relevant process values to the trend and set the upper and lower limits for each value.



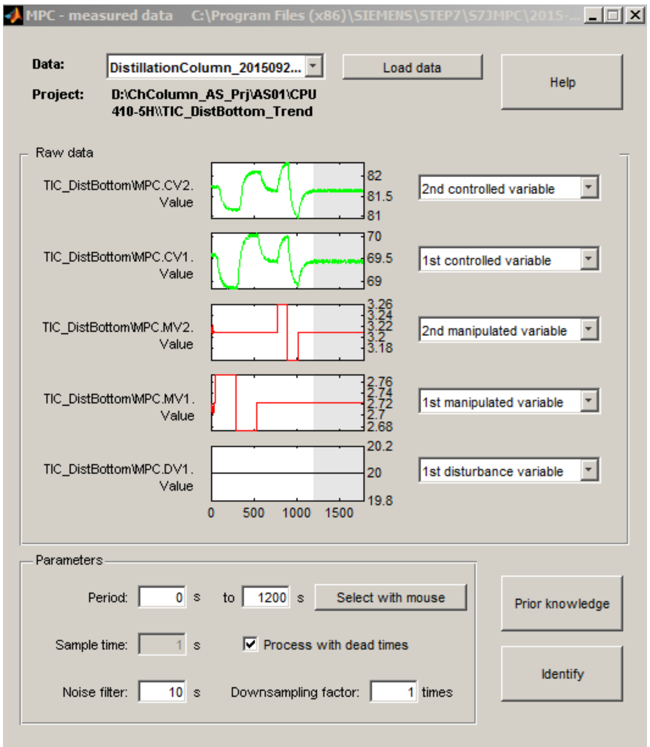
5. Register the CPU in test mode.
6. In the excitation block "AutoExcitation", enter the parameters "StepSize", "Duration" (duration of excitation) and the number of manipulated variables (interconnected controllers with MPC).



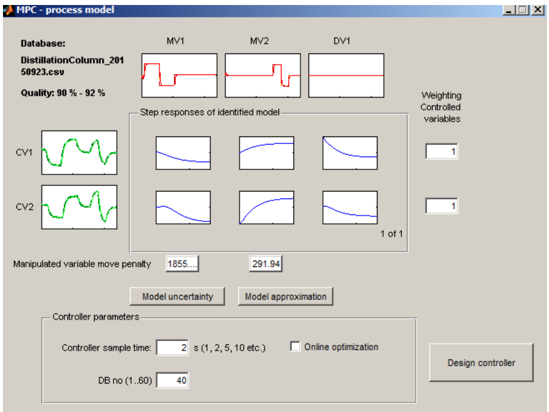
7. In the process screen (OS) of the distillation column, change the mode of the multivariable controller "TIC_DistBottom" to Manual.
8. Switch back to the CFC and start the trend recording using the "Start" button.
9. Wait about 40 seconds until the first values (no steps) are recorded.
10. In the excitation block, start the process excitation with the value "1" at the connection "StartExcite" and wait until all the excitation processes are completed.
11. Export the trend recording after excitation is complete.
12. Switch to the process screen (OS) of the distillation column and change the mode of the multivariable controller "TIC_DistBottom" to Auto.

Process identification

1. Open the PCS 7 project in the plant view.
2. Open the hierarchy folder "ChColumn_AS_Prj > ChColumn > DistillationGroup > Distillation > Distillation" and double-click the "TIC_DistBottom" chart.
   The CFC editor is opened.
3. Select the block "MPC" and click in the menu bar on "Edit > Configure MPC".
   The MCP Configurator opens.
4. Click the button "Load data" and select the file containing the exported trend curves. Click "OK" to confirm your selection.
   The selected trend curves are uploaded to the group "Raw data".
5. In the drop-down lists to the right of the trend displays, select the displayed signal and press the "Step by Step" button.
6. Determine the period for authentication, select the check box "Process with dead times" and then click the "Identify" button.



7. In the "Controller parameters" group, enter the controller cycle time (the OB cycle time in which the controller is called) and the DB number for the process model.

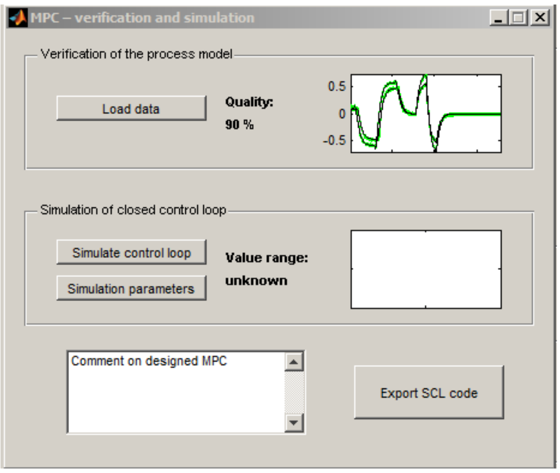


8. Then click the "Design controller" button. This opens the "MPC – verification and simulation" dialog.

Note

The quality of the trend curves is displayed in the upper left corner of the dialog "MPC process model". The quality should be above 50% for a controller design.

9. Click the "Load data" button in the group "Verification of the process model" and select the file with the verification data in the file selection dialog.



10. The verification is started and the quality of the process model is shown.
11. Click on the "Simulate control loop" button to check the value range.
12. The result between button and trend display is subsequently rated and can also be viewed by clicking the trend display.
13. Click on the "Export SCL code" button and select the folder where to save the SCL source file in the file selection dialog that follows.
14. Enter a name for the file and click on "Save".
15. Confirm the message with "OK" and then close all dialog boxes of the MPC configurator and the CFC.
16. Save the session log of the MPC configurator by right-clicking on the user interface background.

Generating a data block from the process model

1. Switch to the component view of the project.
2. Right click on "ChColumn_AS_Prj > AS01 > CPU 410-5H > AS01 > Sources" and in the menu item choose "Insert new object > External source...".

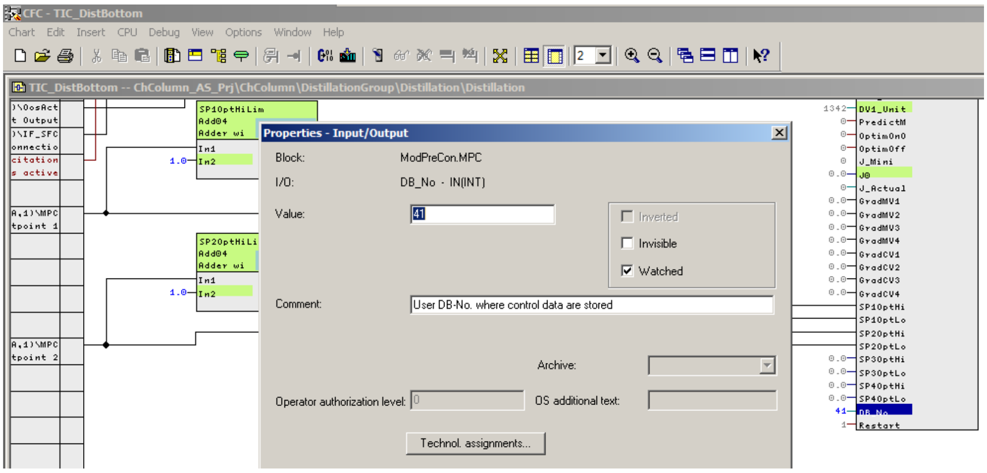
Note In the project path "<Project path>\ChColumn", you can find the exported SCL source file "ChColumn_MPC_DB41.scl".

3. Select the SCL source created previously and click on "Open".
   This SCL source file is imported.
4. Double-click the SCL source file and click on the menu bar "File > Compile" in the open SCL editor. Then close the SCL editor.

Note In the first line of the source code you will see the currently applied DB number of the block. In order not to overwrite the available one, this should be changed to the value 41

CAUTION	If a data block already exists with that DB number, you will receive a message asking if you want to overwrite the data block. Data blocks should only be overwritten if you know their exact function. If in doubt, interrupt the compiling process and change the DB number of the first line to a non-allocated DB number. The MPC function block must be invoked at the appropriate watchdog interrupt OB. The cycle time of the OB and the specified time "OB-Timing" in the head of the SCL source must be identical.

5. Right-click on "ChColumn_AS_Prj > AS01 > CPU 410-5 > AS01 > Charts" and double-click the chart "TIC_DistBottom", which contains the MPC controller.
6. Select the input "DB_No" and change the value to the number of the previously generated data block.



Note	The process model is updated the next time the control is compiled and uploaded. If the control program has already been uploaded, the DB number can also be changed online. In order to do this, the DB must be uploaded to the controller and the "Restart" input set online to "Reset". Steps may occur in the manipulated variable after restarting the controller.

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:
https://support.industry.siemens.com

Technical Support

The Technical Support of Siemens Industry provides you fast and competent support regarding all technical queries with numerous tailor-made offers – ranging from basic support to individual support contracts. Please send queries to Technical Support via Web form:
www.siemens.com/industry/supportrequest

SITRAIN – Training for Industry

We support you with our globally available training courses for industry with practical experience, innovative learning methods and a concept that's tailored to the customer's specific needs.

For more information on our offered trainings and courses, as well as their locations and dates, refer to our web page:
www.siemens.com/sitrain

Service offer

Our range of services includes the following:

Plant data services

Spare parts services

Repair services

On-site and maintenance services

Retrofitting and modernization services

Service programs and contracts

You can find detailed information on our range of services in the service catalog web page:
https://support.industry.siemens.com/cs/sc

Industry Online Support app

You will receive optimum support wherever you are with the "Siemens Industry Online Support" app. The app is available for Apple iOS, Android and Windows Phone:
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 the entry page for the application example https://support.industry.siemens.com/cs/ww/en/view/48418663
\3\	SIMATIC PCS 7 Overview - Quick Start https://support.industry.siemens.com/cs/ww/en/view/63481413
\4\	Model Predictive Control including integral transfer functions https://support.industry.siemens.com/cs/ww/en/view/42200753
\5\	Controller optimization with the PID Tuner https://support.industry.siemens.com/cs/ww/en/view/8031495
\6\	Integration of Advanced Process Graphics in SIMATIC PCS 7 https://support.industry.siemens.com/cs/ww/en/view/89332241
\7\	Equipment Modules for PCS 7 using the Chemical Industry as an example https://support.industry.siemens.com/cs/ww/en/view/53843373
\8\	PCS 7 Unit Template using the example of the "Stirred Tank Reactor" from the chemical industry https://support.industry.siemens.com/cs/ww/en/view/60546560
\9\	PCS 7 Unit Template using the example of the "Fermenter" from the chemical industry https://support.industry.siemens.com/cs/ww/en/view/68098270
\10\	PCS 7 Unit Template using the example of the chemical industry "Dryer" https://support.industry.siemens.com/cs/ww/en/view/74747848
\11\	PCS 7 Unit Template using the example of the Chemical Industry "Polymerization Reactor" https://support.industry.siemens.com/cs/ww/en/view/84061788
\12\	How do you procure documentation for PCS 7 (including the PCS 7 Manual Collection)? https://support.industry.siemens.com/cs/ww/en/view/59538371

6.3 Change documentation

Version	Date	Change
V1.0	02/2011	First edition
V1.1	06/2013	Valid for PCS 7 V7.1 SP1 and V8.0 SP1, additional links, minor text corrections
V2.0	10/2015	Integration of APG, Update for PCS 7 V8.1 SP1
V3.0	05/2018	Integration of Smart Alarm Hiding, addition of chapter "Detecting Deviations in Process Mode with APG" and Update for PCS 7 V9.0, Note on Managed System Services in Chapter 1.3