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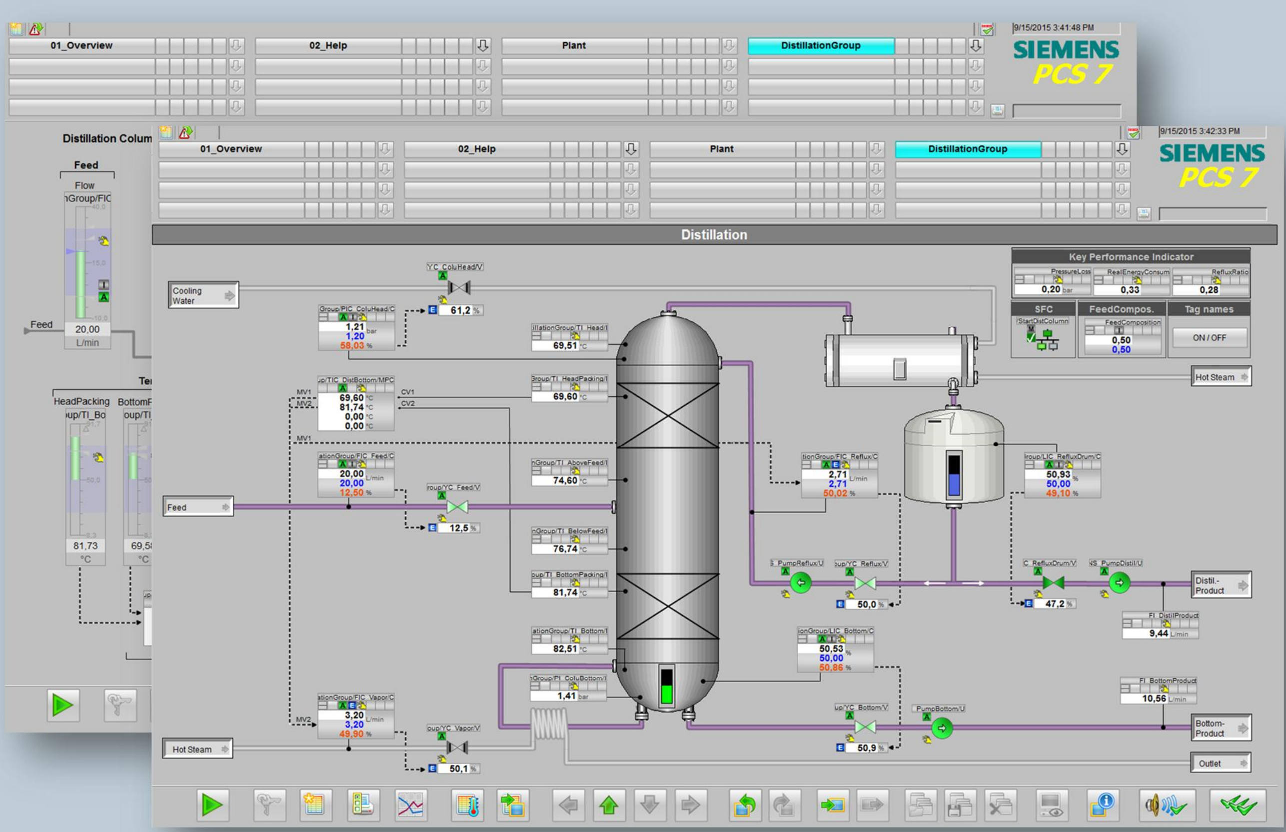

Application Example • 10/2015

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

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1 Task and solution

1.1 Task

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

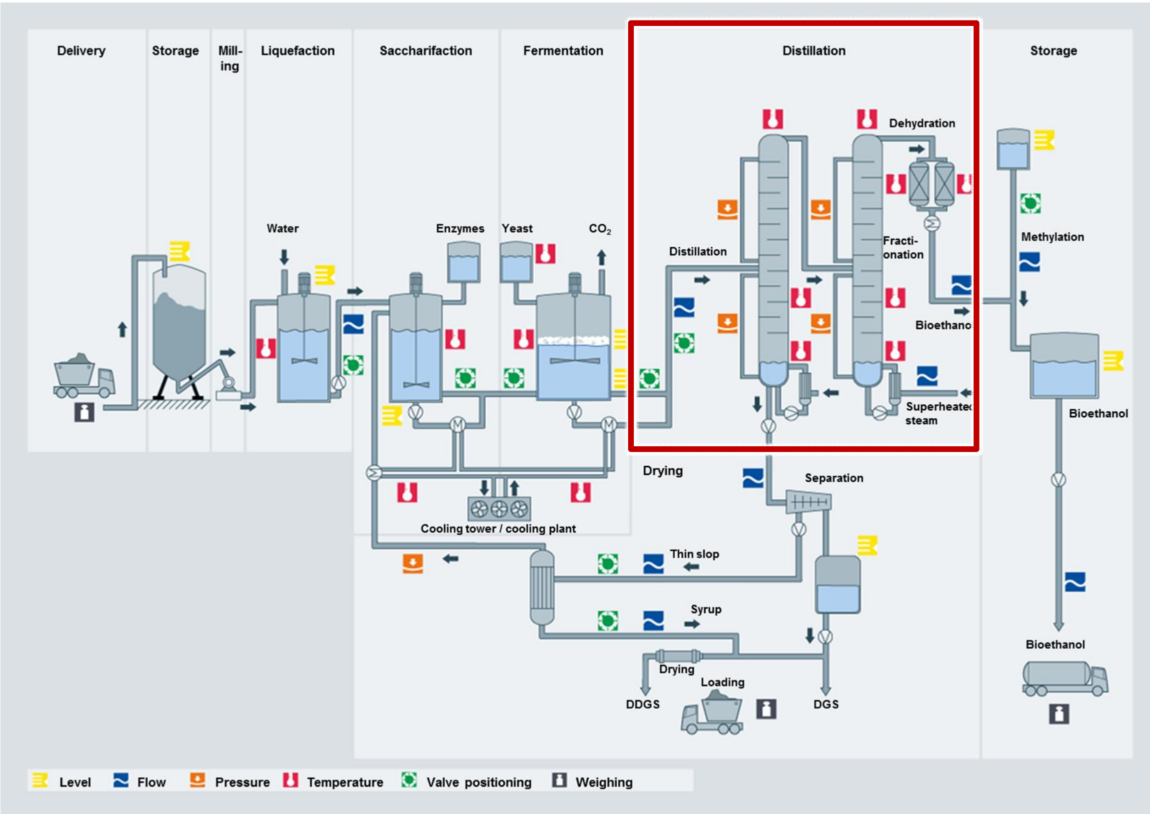
This includes the plant structure according to the ISA-106. This specifies the lower four levels, i.e. plant area, unit, equipment and device. A plant always consists of units. The units contain standardized equipment modules.

1.2 Solution

1.2.1 Distillation column plant section

The unit template "Distillation column" is a template that comprises all typical components of a distillation column, their open- and closed-loop control, the necessary logic and the visualization.

Figure 1-1: A distillation column as part of a process plant



The associated example project is structured in such a way that it enables the direct transfer of predefined elements into an existing PCS 7 project.

The Advanced Process Library (APL) is used with a multivariable regulation concept for the user program. The multivariable controller enables control of the distillation column to maintain the required product quality constant.

The plant section distillation column consists of multiple individual process components, such as devices, actuators and sensors. The closed loop control is the link between all the components of a distillation column and thus an essential component of an automation system.

During configuration, a variety of conditions need to be considered (e.g. interlocks, control structures), which require a high detailed knowledge of the process plant and a high detailed knowledge and experience with PCS 7.

1.2.2 Description of the complete solution

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 Unit Template "Distillation column" 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 respectively contained in the component view.
- A hierarchy folder has been set up in the technical 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 boiler).

The AS project was created using the APL (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.

Delimitation

The following special cases are not covered by the Unit Template "Distillation column":

- 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

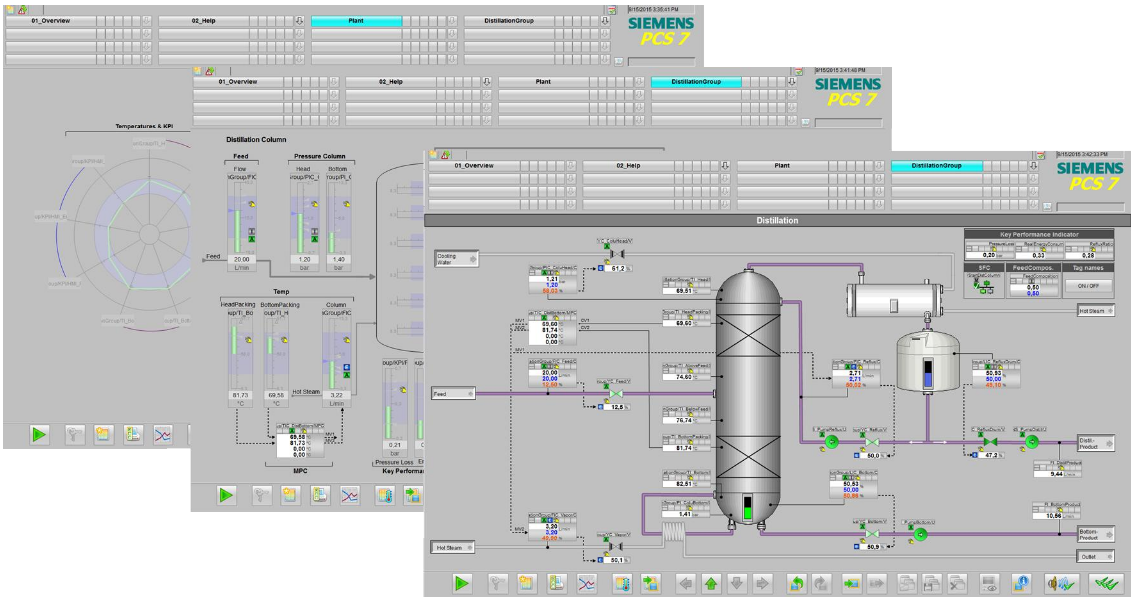
1.2.3 Core functionality

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 Unit Template "Distillation column" 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 R&I representation with all components (Level 3)

Figure 1-2: Visualization interface

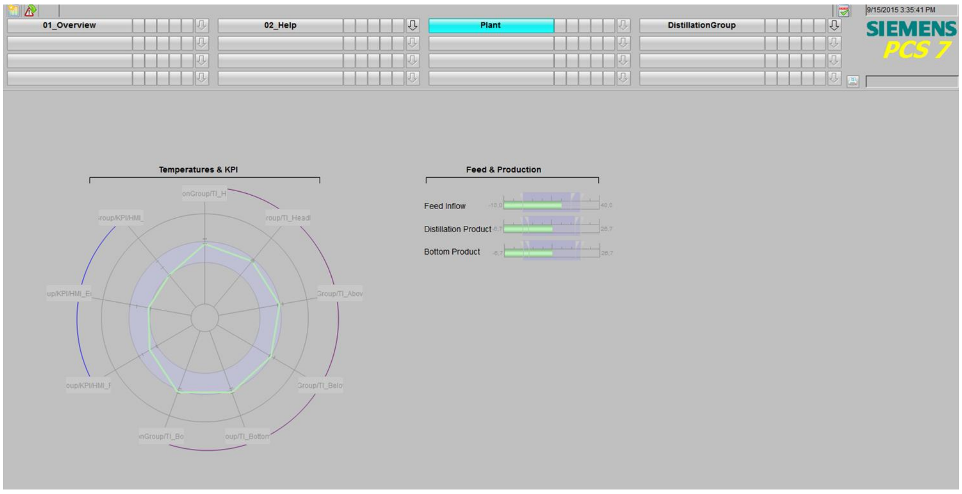


Plant overview picture

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

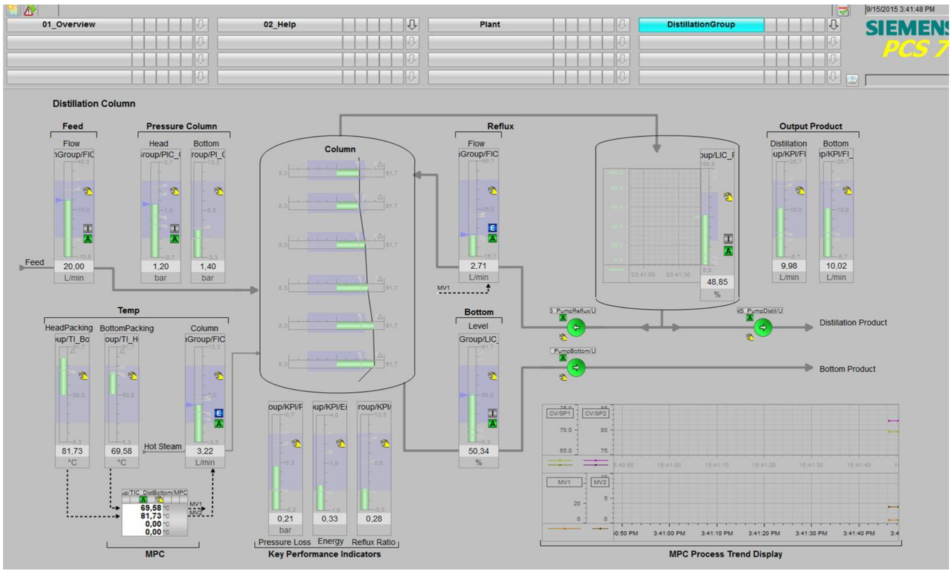
Figure 1-3: Level 1 plant overview picture



Process screen

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.

Figure 1-4: Level 2 process screen

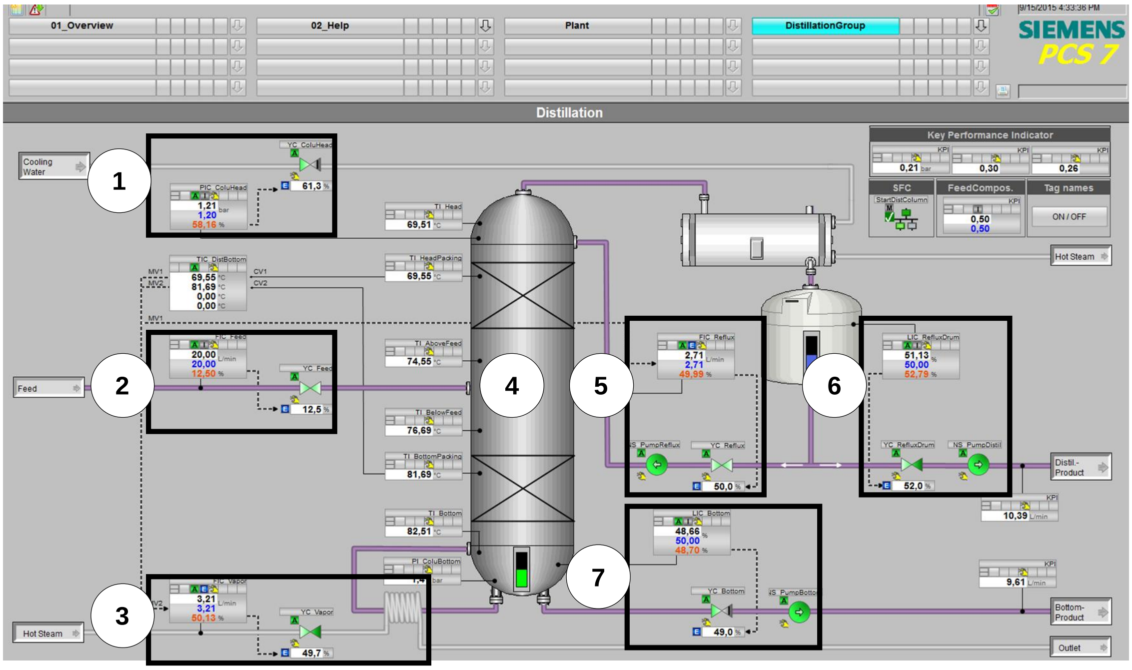


Detailed process screen

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.

1.2.4 Description of the individual functions

Figure 1-5: Level 3 detailed process screen



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 ("Reflux")
6. Removal of the head product ("Low boiler")
7. Removal of the bottom product ("High boiler")

(1) Pressure control

The pressure at the column head is determined by the temperature of the removed gaseous mixture.

(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 head and bottom temperature (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 ("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 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

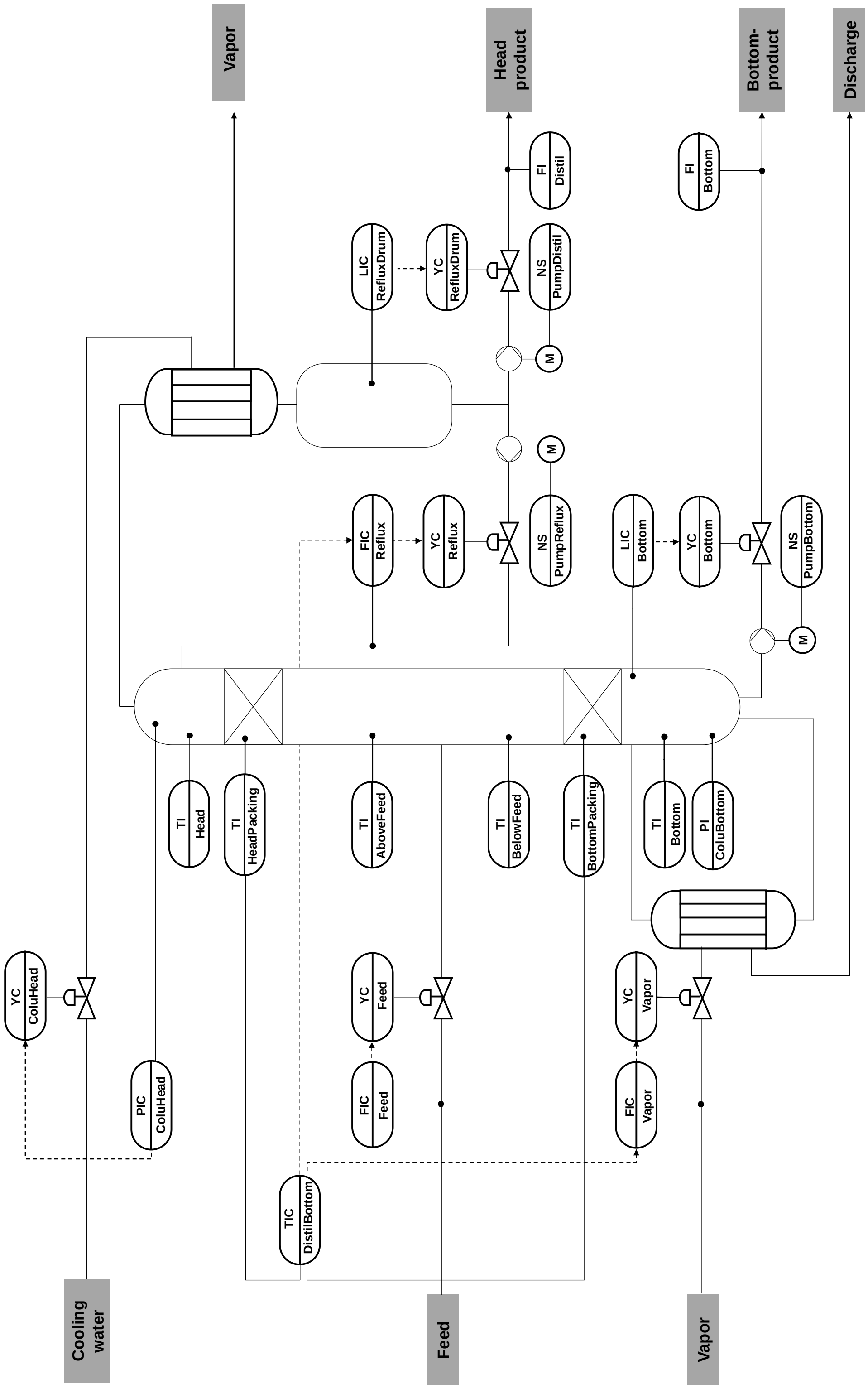
1.2.5 Control concept

A multivariable controller (MPC) is used for controlling the distillation process.
This controls the head and bottom temperature (also refer to Chapter Temperature characteristic). These control variables are detected by the 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.

1.2.6 PI process screen

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

Figure 1-6



1.3 Hardware and software components

1.3.1 Validity

This application is valid from SIMATIC PCS 7 V8.1 SP1.

CAUTION	The engineering in CFC requires CFC V8.1 SP1 Update 3. This can be obtained from the Support Request. The operator station can be started and operated without the CFC update.

1.3.2 Components used

Hardware components

Table 1-1

Component	Note
SIMATIC PCS 7 ES/OS IPC647D	For the PCS 7 V8.1 SP1 example project

Note

In case of different hardware, please take heed of the minimum requirements for installing the software components. The minimum requirements can be found in the Read Me file of the PCS 7.

Software components

Table 1-2

Component	Note
S7 PLCSIM	The license does not form part of the SIMATIC PCS 7 ES/OS
APG library V8.1	The license does not form part of the SIMATIC PCS 7

Example files and projects

The following list contains all the files and projects used in this example.

Table 1-3

Component	Note
48418663_DistillColumn_PROJ_PCS7V811.zip	PCS 7 V8.1 SP1 example project
48418663_DistillColumn_DOC_en.pdf	This document

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.

The ordering information can be found in the Entry ID 104206476.

2 Basics

2.1 Process engineering

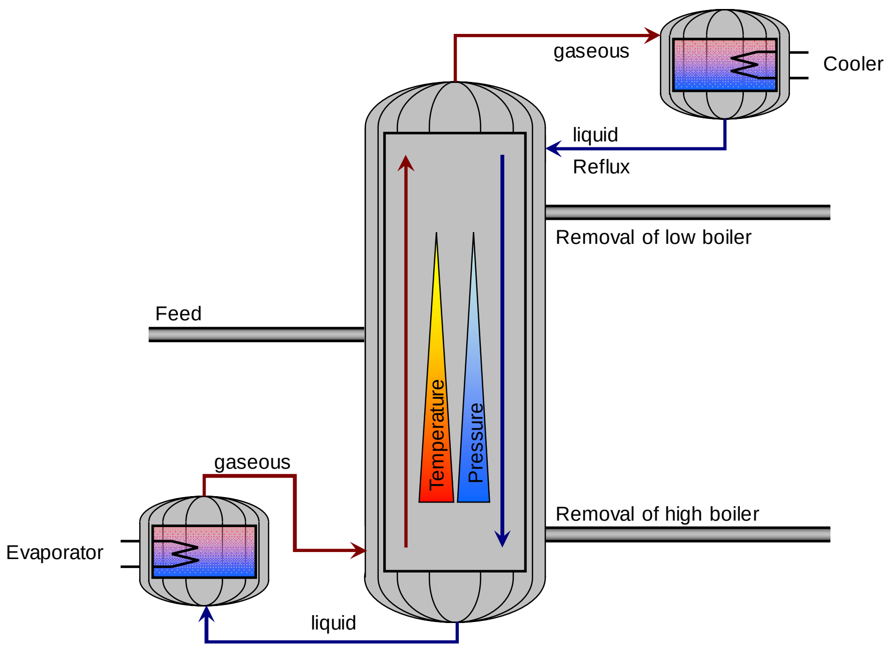
2.1.1 Distillation column (rectification column)

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 (liquid) is fed into the column through an inlet at the bottom of the column 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 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.

Figure 2-1



2.1.2 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. 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.

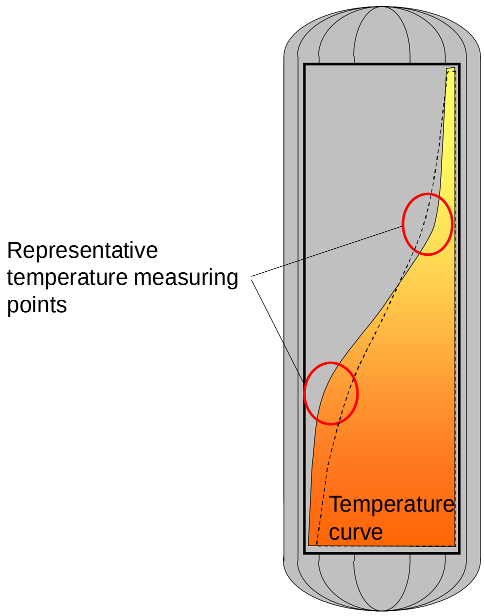
The easily measurable temperatures are used as substitute control variables. This has the additional advantage that the relationship between these temperatures and control interventions can linearize more easily than the connection with the concentrations.

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.

Figure 2-2



2.2 Automation

2.2.1 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 example, package units could be 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.

2.2.2 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.

2.2.3 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.

2.2.4 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.

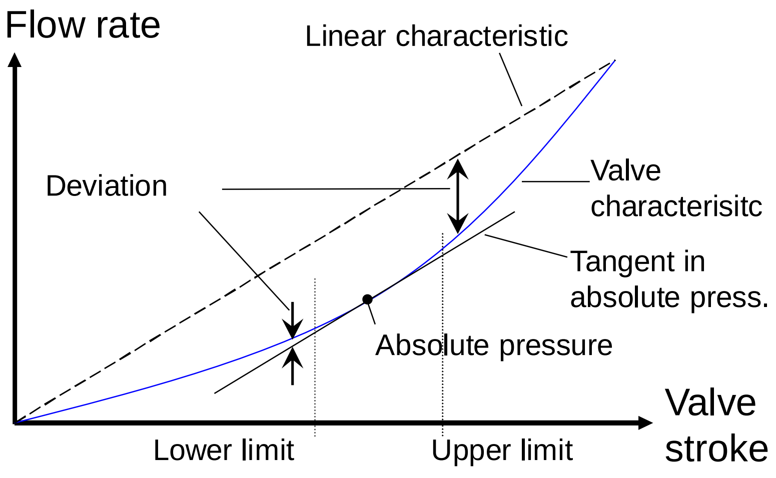
2.2.5 Linearization

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.

Figure 2-3



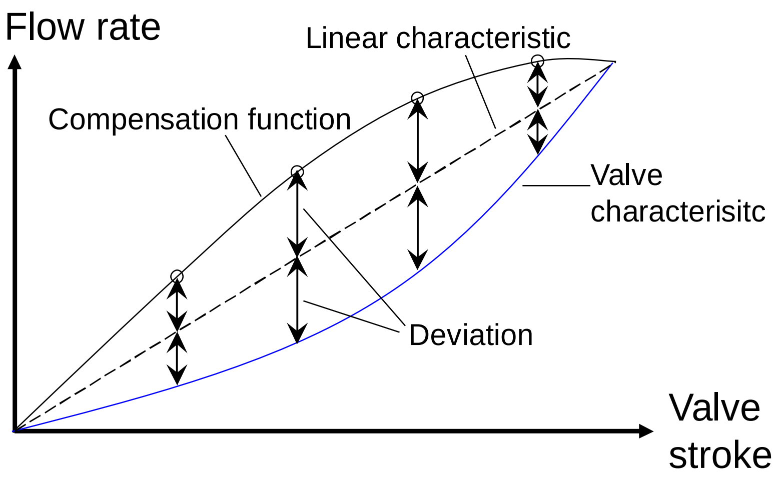
The tangent at the operating point helps reducing the deviations between the actual non-linear characteristic curve and the adopted tangent to such an extent that in most cases, no adjustments to the controller parameters must be made.

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.

Figure 2-4



3 Structure and principle of operation

3.1 Project structure

3.1.1 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.

Figure 3-1

FIC_Reflux

Function → FIC ← 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:

Table 3-1

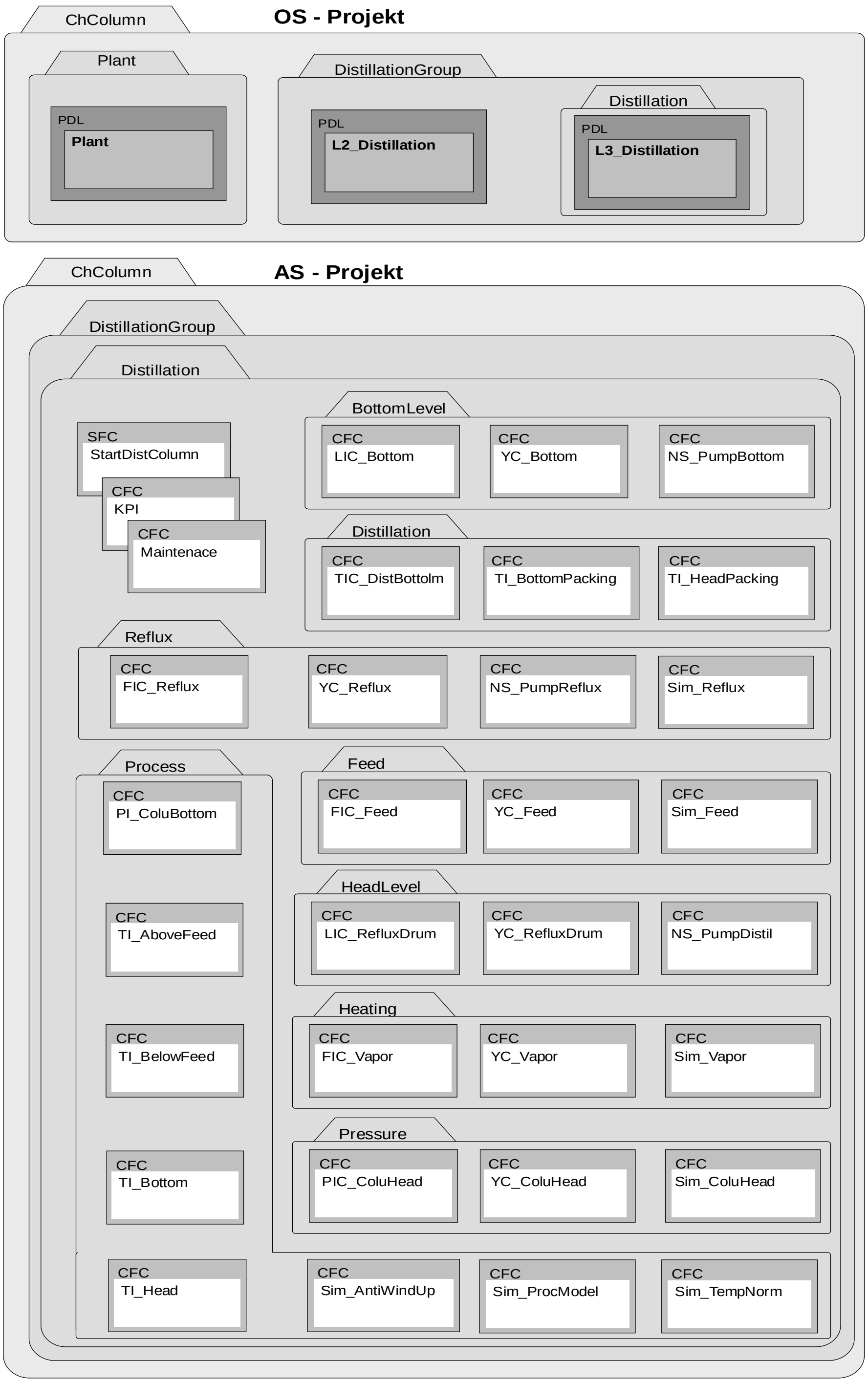
First letter	
Letter	**Meaning**
F	Flow
L	Level
N	Motor
P	Pressure
Q	Amount, quantity
S	Speed (velocity, rotational speed, frequency)
T	Temperature
Y	Control valve
Subsequent letter	
C	Control
F	Fraction
I	Indication
S	Binary control function or switching function (not safety-oriented) ("switching")

3.1.2 Technological view

The Unit Template "distillation column" is designed as a multiproject and structured in the technological 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.

Figure 3-2



3.2 Equipment modules and control modules

The unit template "Distillation column" consists of pre-made equipment modules and additional CFC, e.g. for process simulation. In a PCS 7 project, all measuring points including the measuring points of the equipment modules are based on control module types from the master data library. You will find the application description "Equipment Modules for PCS 7 using the example of the Chemical Industry" and the example projects with the individual equipment modules and control module types under the entry ID: 53843373.

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 "Bottom Level"
- Distillation
- Overarching process simulation "Process"
- Step sequencer (SFC) for starting up the distillation column
- Process parameters "KPI"
- Maintenance characteristics "Maintenance"
- Optimized process control with APG

In the following chapters you will find the setup of the specific equipment modules as well as the extension and modifications made vis-à-vis the original equipment modules and control module types.

Note All necessary descriptions, configurations and procedures pertaining to the reference versions can be found in the documentation under the entry ID: 53843373. You will find the information on the specific equipment modules in Chapter 5 "Equipment Modules" and on the control module types in Chapter 4 "Control Module".

3.3 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.

Structure

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.

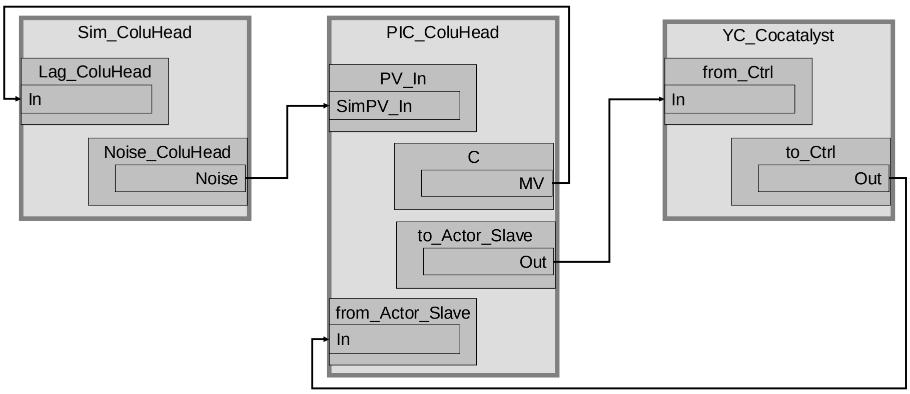
The following table provides an overview of the CM and the selected variants.

Table 3-2

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.

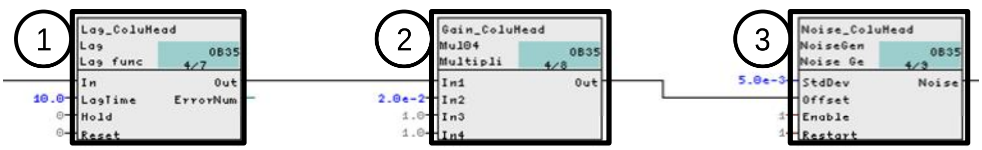
Figure 3-3



"Sim_ColuHead" simulation

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

Figure 3-4



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

Parameter assignment

PIC_ColuHead

The instance has the following parameterization.

Table 3-3

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.

Table 3-4

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)

3.4 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.

Structure

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.

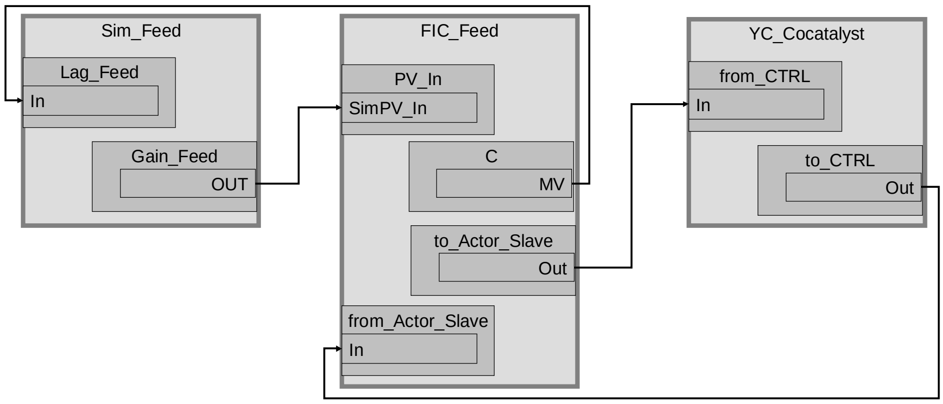
The following table provides an overview of the CM and the selected variants.

Table 3-5

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.

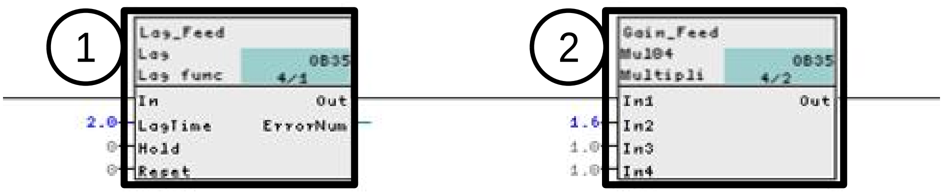
Figure 3-5



"Sim_Feed" simulation

The mixture feed is simulated in the simulation chart.

Figure 3-6



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.

Parameter assignment

FIC_Feed

The instance has the following parameterization.

Table 3-6

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.

Table 3-7

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)

3.5 Evaporator "Heating"

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

Structure

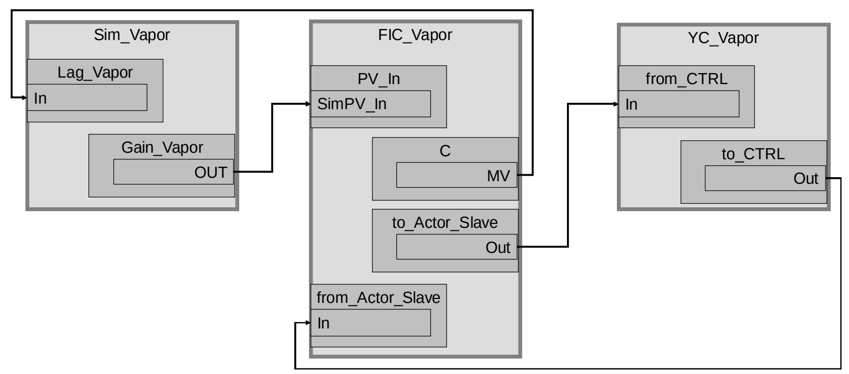
Flow control is performed by means of a standard PID controller and an external setpoint from the multivariable controller "TIC_DistBottom". The following table gives you an overview of the CM and the selected variants.

Table 3-8

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.

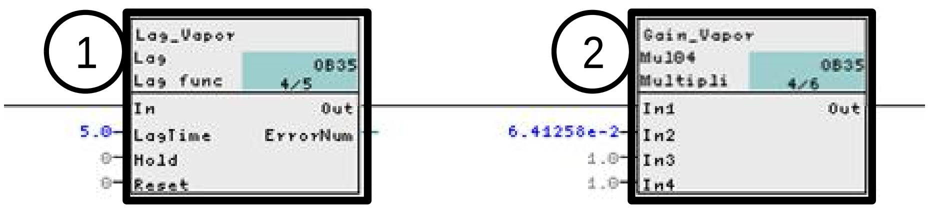
Figure 3-7



"Sim_Vapor" simulation

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

Figure 3-8



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.

Parameter assignment

FIC_Vapor

The instance has the following parameterization.

Table 3-9

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.

Table 3-10

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)

3.6 Capacitor with reflux "Reflux"

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

Structure

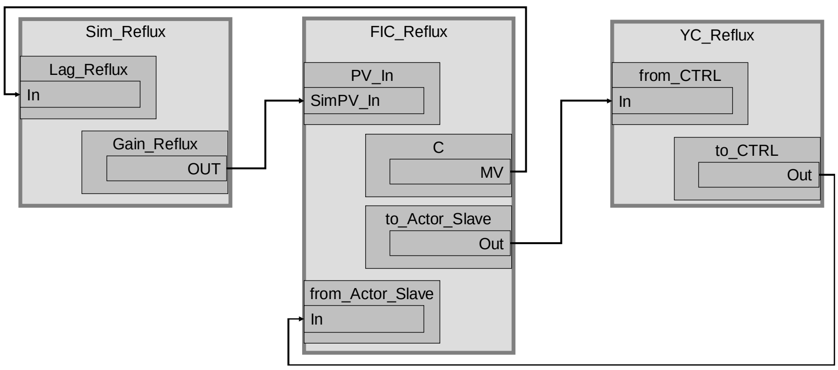
Flow control is performed by means of a standard PID controller and an external setpoint from the multivariable controller "TIC_DistBottom". The following table gives you an overview of the CM and the selected variants.

Table 3-11

CM	CMT	Variant	Description
FIC_Reflux	"Ctrl"	Ctrl_Std Activated option "Opt_IF_Master"	Concensate 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.

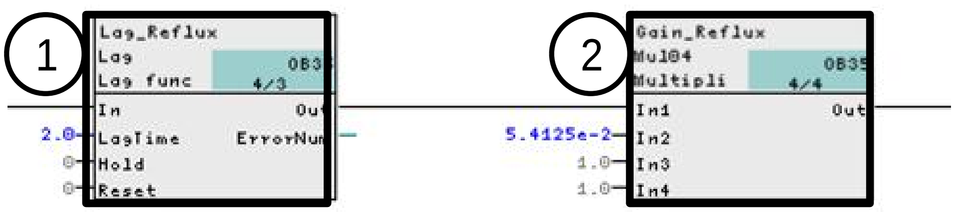
Figure 3-9



"Sim_Reflux" simulation

The condensate flow is simulated in the simulation chart.

Figure 3-10



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.

Parameter assignment

FIC_Reflux

The instance has the following parameterization.

Table 3-12

Block	Connection	Value	Use
PV_Scale	HiScale	50	Process value upper limit
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.

Table 3-13

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.

3.7 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.

Structure

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.

Table 3-14

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
NS_PumpDistil	"Mot"	Mot_Std	Pump (e.g. flow pump) for removing the condensate

Parameter assignment

LIC_RefluxDrum

The instance has the following parameterization.

Table 3-15

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)

Block	Connection	Value	Use
PV	SimPV_In		Interconnection for the simulated process value (Process\\Sim_ProcModel\mD_Prozent.OUT)

YC_RefluxDrum

The instance has the following parameterization.

Table 3-16

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)

NS_PumpDistil

No parameter change with regard to the type.

3.8 Removal of the bottom product "Bottom Level"

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".

Structure

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.

Table 3-17

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

Parameter assignment

LIC_Bottom

The instance has the following parameterization.

Table 3-18

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)
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.

Table 3-19

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.

3.9 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.

Structure

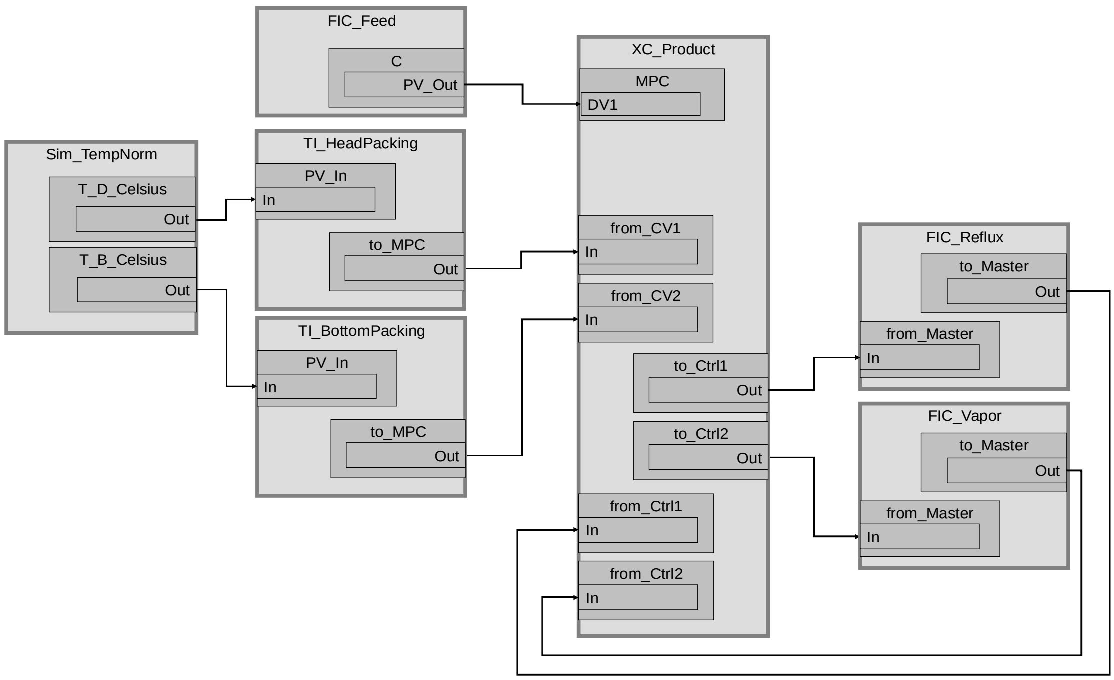
The temperature is controlled as a cascade of multi-variable master controllers "TIC_DistBottom" and the slave controllers "FIC_Reflux" and "FIC_Vapor".
The multivariable controller also monitors the mixture feed as a disturbance.
The following table provides an overview of the CM and the selected variants.

Table 3-20

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.

Figure 3-11



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.

Table 3-21

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.

Table 3-22

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
to_MPC	Out		Interconnection for 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.

Table 3-23

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	69.0	Warning lower limit for the process value
I	PV_AL_Lim	68.0	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 for the multivariable controller (TIC_DistBottom\from_CV1.In)
PV_In	SimPV_In		Interconnection for the simulation: (Process\\Sim_TempNorm\T_D_Celsius.Out)

3.10 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:

Figure 3-12

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
		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	---

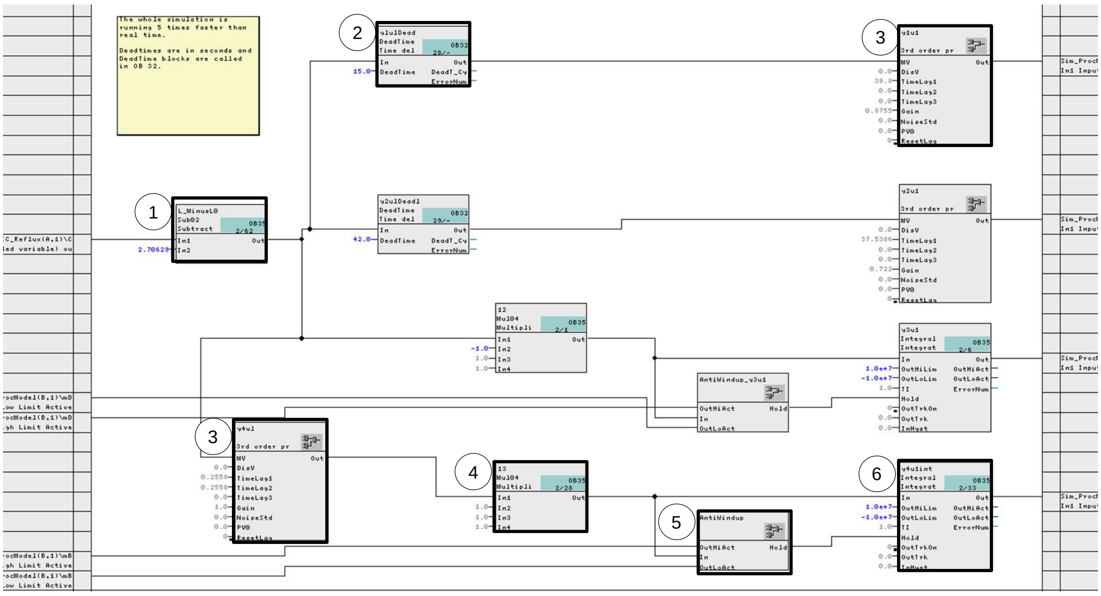
The process model is divided into two chart partitions in the CFC "Sim_ProcModel".

Chart partition A

The chart partition "A" includes transfer functions of an input signal which affect the defined output signals (Figure 3-12). 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.

Figure 3-13



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.

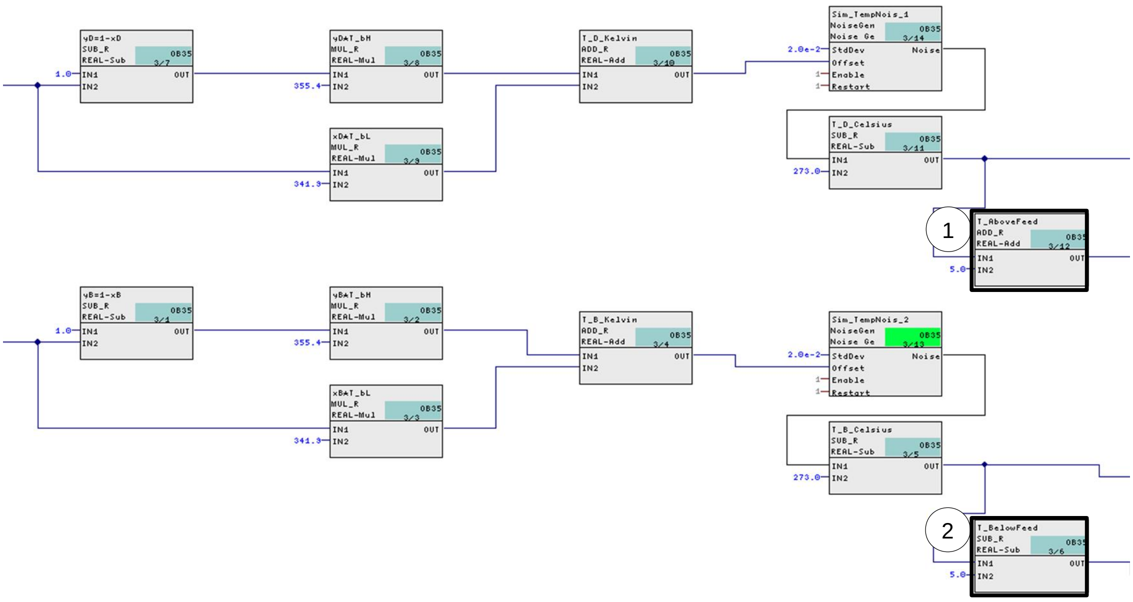
Chart partition B

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 3-14

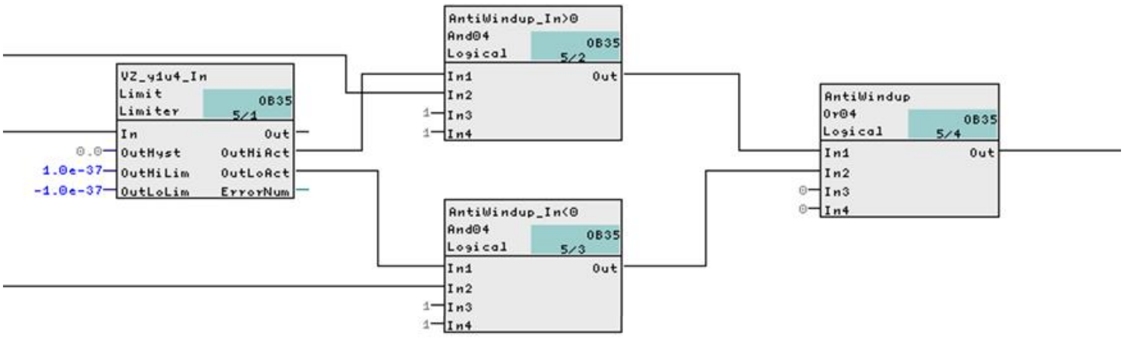


The remaining process values for head temperature, bottom temperature and bottom pressure are fixed and issued with a process noise.

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.

Figure 3-15



Parameter assignment

TI_AboveFeed

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

Table 3-24

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.

Table 3-25

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.

Table 3-26

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.

Table 3-27

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.

Table 3-28

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)

3.11 Sequencers

Different behavior and modes of operation can be realized in SFC. In the sample project the SFC "StartDistColumn" is configured for automatic start-up without user interaction. After start-up, the controller is transferred to the user in automatic mode, allowing him to determine, for instance, the individual setpoint values.
The following actions are configured in the SFC:

- Resetting the simulation
- Initializing the default controller
- Presetting the working ranges (setpoints)
- Operating mode of the pumps to Automatic
- Initializing the multivariable controller

3.12 Process parameters "KPI"

The CFC 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.

3.13 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.

3.14 Task-related overview screens with APG

With PCS 7 Advanced Process Graphics, process screens are displayed more clearly, reduced to the essential 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.

3.14.1 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 about APG, for extension of an existing PCS 7 project with APG and for configuration purposes in the application description "Integration of Advanced Process Graphics in SIMATIC PCS 7" under the entry ID: 89332241.

3.14.2 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" with the entry ID: 109475748 describes how efficiently an existing project is extended to APG by applying the control module technology.

Controller measuring points

The CMT "Ctrl" contains the following parameterization.

Table 3-29

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.

Table 3-30

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
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.

Table 3-31

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.

Table 3-32

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.

Table 3-33

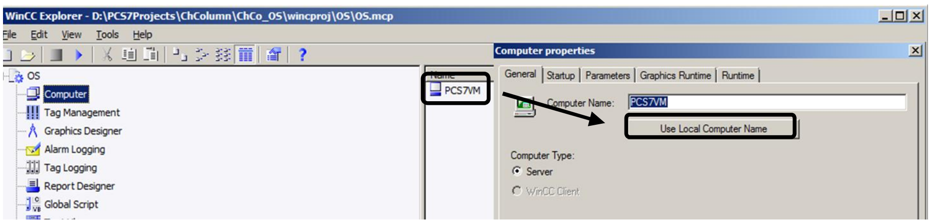
Block	Connection	Value	Use
HMI_FI_DistProd	PX_OH_Li	20.0	Upper limit of the working range
HMI_FI_DistProd	PX_OL_Li	0.0	Lower limit of the working range
HMI_FI_BottoProd	PX_OH_Li	20.0	Upper limit of the working range
HMI_FI_BottoProd	PX_OL_Li	0.0	Lower limit of the working range
HMI_PressureLost	PV_OH_Li	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 Starting the Unit Template

4.1 Preparation

The following instructions describe putting the Unit template into service 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_PCS7V811.zip" into any folder on the configuration PC and then open the SIMATIC Manager.
2. In the menu bar, click on "File > Retrieve" and select the file "48418663_DistillColumn_PROJ_PCS7V811.zip". Then confirm with "Open".
3. Select the folder in which the project should be saved and confirm by pressing "OK".
   The project will be retrieved.
4. Confirm the "Retrieve" dialog with the "OK" button and then click on "Yes" in the dialog to open the project.
5. Right-click on "ChColumn_OS_Prj > PCS7VM > WinCC Appl. > OS" and then click on the menu command "Open object".
6. Confirm the "Configured server not available" dialog with "OK".
7. In the WinCC Explorer, open the characteristics 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 > End" 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 block icons), select the logical device name "CP_H1_1" and restart the OS runtime.

4.2 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)

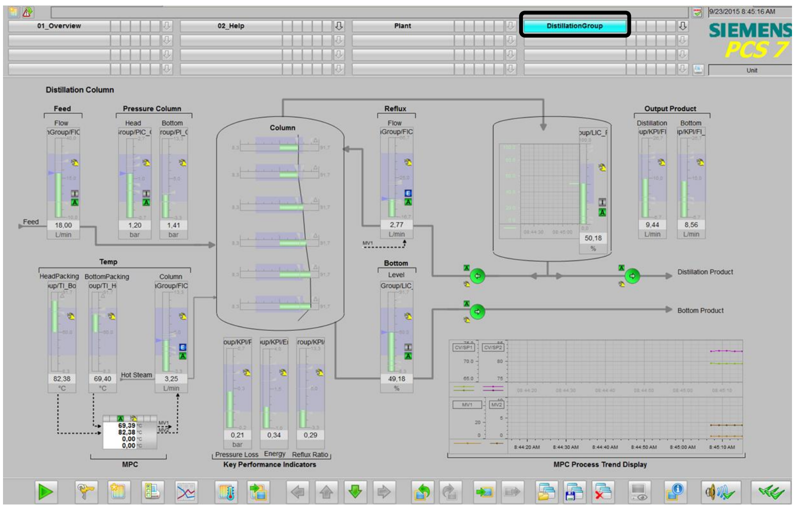
To start the simulation, proceed according to the following instructions:

1. Select "Extras > 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, select "Execute > Key-switch position > RUN-P".
5. Switch to the component view of the SIMATIC Manager and mark "ChColumn_AS_Prj > AS01".
6. In the menu bar, click on "Target system > Load" and confirm the "Load" dialog with "Yes".
7. 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 as "Login" the user "Unit" and "Template" as the password; confirm with "OK".
4. Select "DistillationGroup" in the icon area.



5 Running the Application

5.1 Overview

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

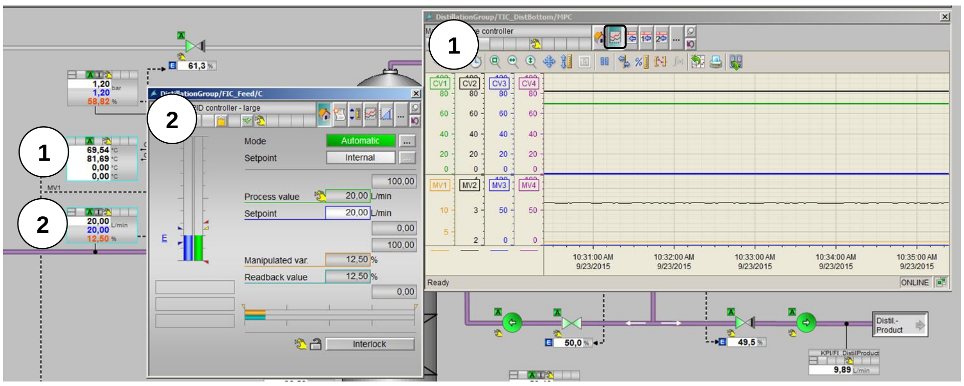
When the distillation column is in a steady state, the feed amount and the feed concentration determine the amount that can be delivered by the head or bottom product. A variable, which acts as a disturbance for the controller, is modified in each of the two scenarios.

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

5.2 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.

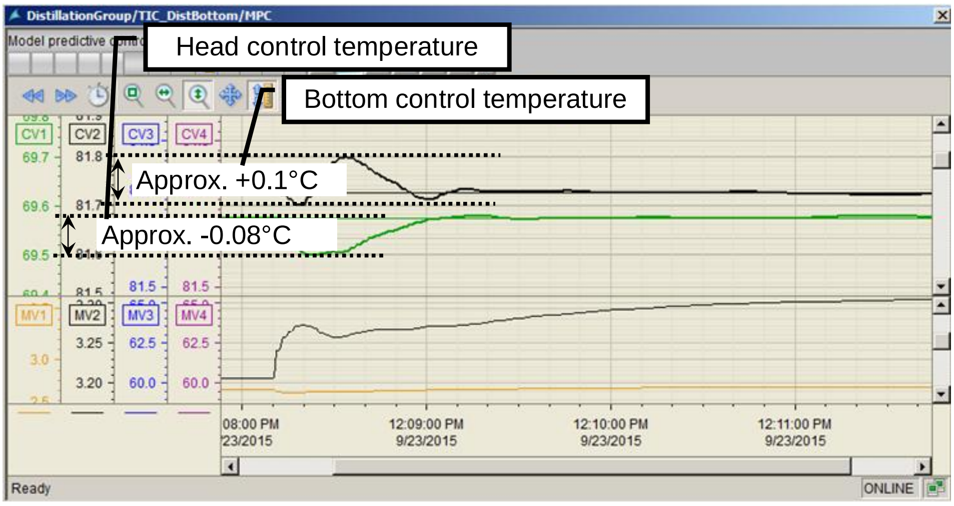
1. Switch to the Detail view of the distillation column.
2. Click on the block icon of "TIC_DistBottom" block and click on the trend icon in the menu bar of the faceplate.
3. Click on the block icon for the "FIC_Feed" to also open its faceplate. Arrange the picture windows in a clear way.



4. 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.
5. 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.



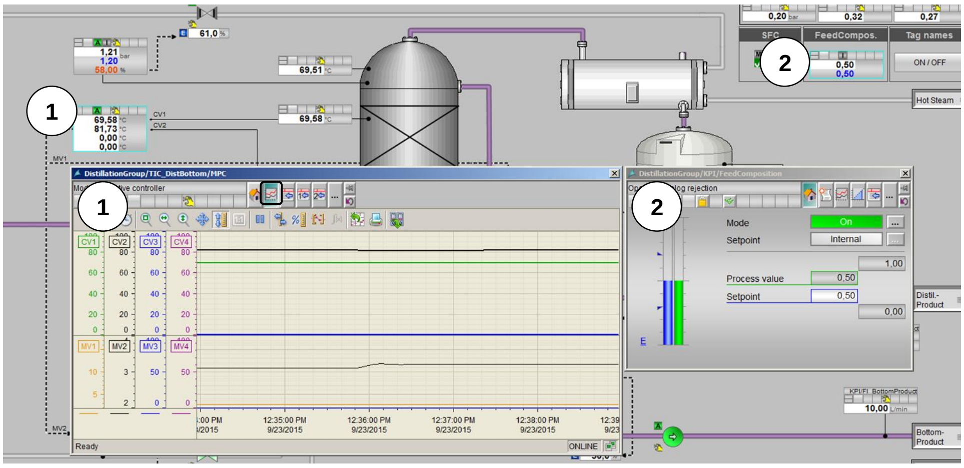
Even a slight deviation of about 0.1 °C gives a good control result, which can be explained by the fact that the disturbance has been detected and that the controller knows the influence of the disturbance. The controller can thus respond immediately to the change of the disturbance with the necessary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

5.3 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.

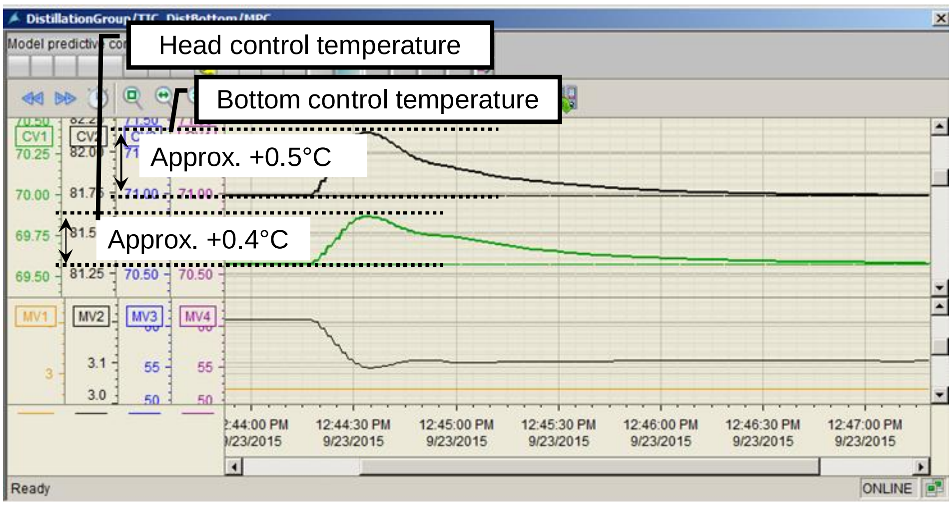
1. Click on the block icon of "ModelPredictCont" and click on the trend icon in the menu bar of the faceplate.
2. Click on the block icon for the "FeedComposition" to also open its faceplate. Arrange the picture windows in a clear way.



3. Click on the input field "Setpoint" in the faceplate of "FeedComposition" and enter
   the value "0.4" in the text box of the extension. 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.

6 Further Notes, Tips and Tricks, Etc.

6.1 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 The document "PID Control with Gain Scheduling and PID Tuning" gives you a practical controlling example.

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 it 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.

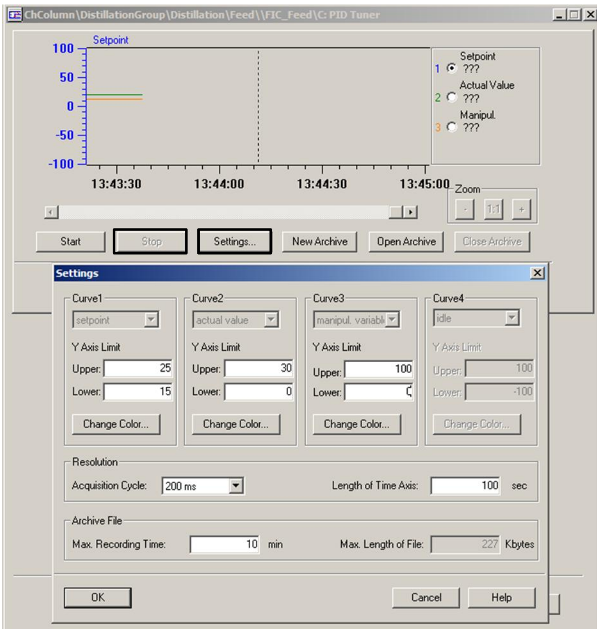
To use the program "PID Tuner", the value "1" must be present at the "OptimEn" input of the "PIDConL" block. If you want to set this input in the ES, follow the steps 1 to 5. If the release on the OS was granted, start with step 1 in the section "Performing controller optimization".

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 check box "Automatic". 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 completion of 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 group "Controller design to", select the check box "Optimal control behavior" 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".

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.

6.2 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.

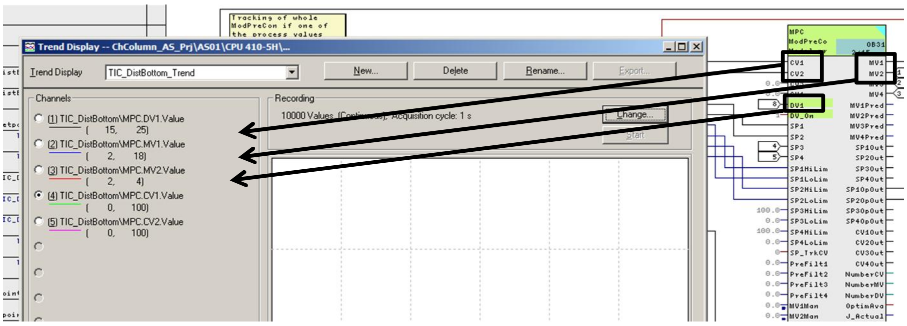
For more information, see the "Help" section of the MPC configurator under "Details on the individual design steps > Recording of measurement series".

Note	You can find a detailed description in Application Example "Model Predictive Control including integral transfer functions".

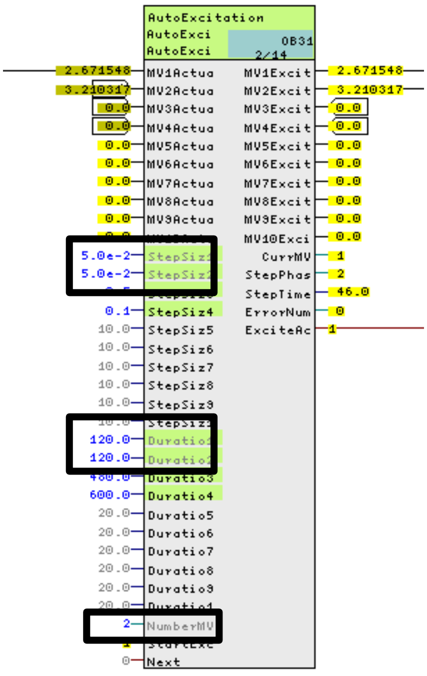
CAUTION	In process interventions are necessary to configure the MPC controller! Before the process intervention, check what implications it will have and inform the appropriate personnel.

Trend recording

1. Open the PCS 7 project in the plant view.
2. Open the folder hierarchy "ChColumn_AS_Prj > ChColumn > DistillationGroup > Distillation > Distillation" and double-click the chart "TIC_DistBottom".
   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.

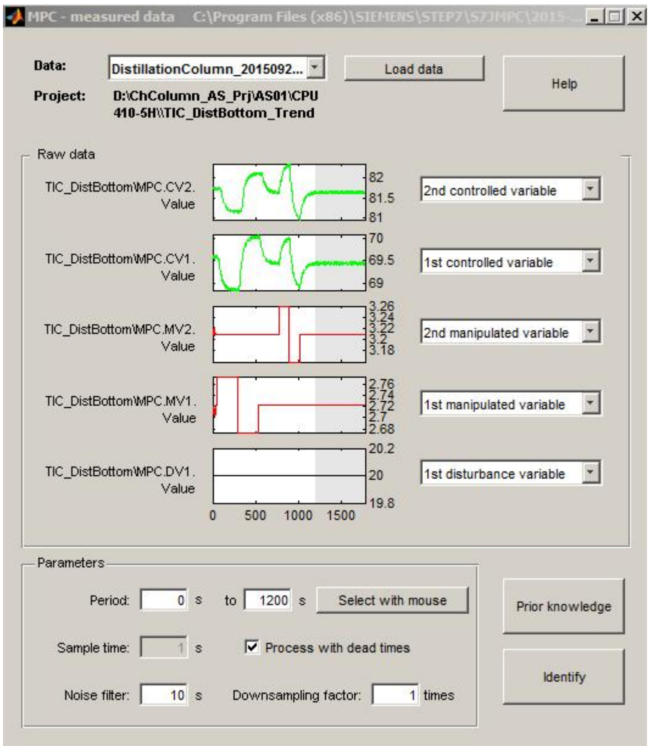
11. Export the trend recording after completion of excitation.
12. Switch to the process process screen (OS) of the distillation column and change the mode of the multivariable controller "TIC_DistBottom" to Auto.

Process identification

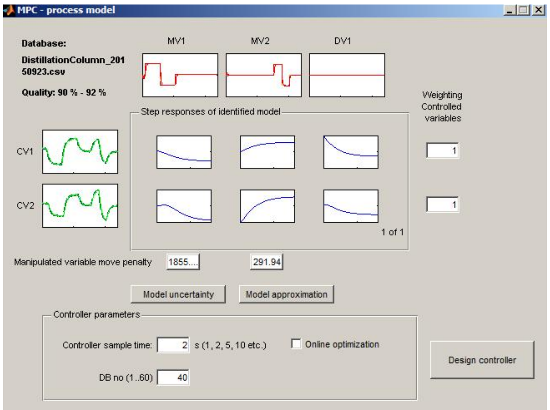
1. Open the PCS 7 project in the plant view.
2. Open the folder hierarchy "ChColumn_AS_Prj > ChColumn > DistillationGroup > Distillation > Distillation" and double-click the chart "TIC_DistBottom".
   The CFC editor is opened.
3. Select the block "MPC" and click in the menu bar "Edit > Configure MPC".
   The MCP Configurator opens.
4. Click the button "Load data" and select the file containing the exported trend curves. Confirm your selection with "OK".
   The selected trend curves are uploaded to the group "Raw data".

Note	In the project path "<Projekt path>\ChColumn" you can find the exported trend log "DistillationColumn_20150923.csv".

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.



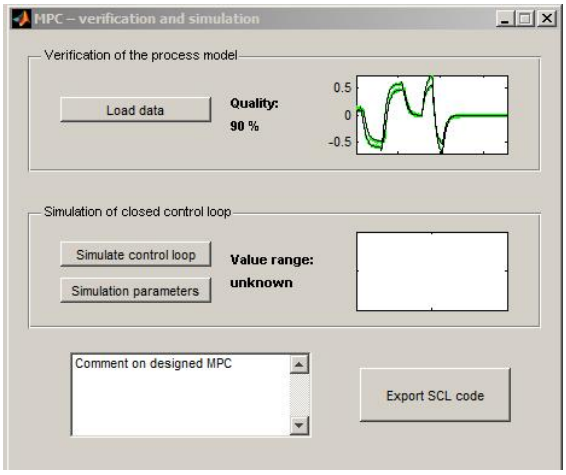
7. In the "Controller parameters" group, enter the controller cycle time (the OB cycle time in which the controller is called) and the DB number for the process model.



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 "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...".

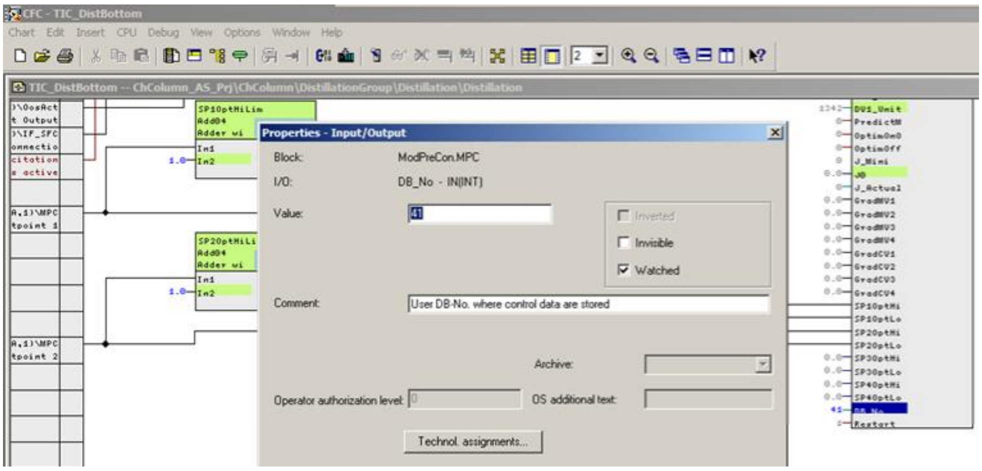
Note	In the project path "<Project path>\ChColumn", you can find the exported SCL source file "ChColumn2015-09-23_MPC_DB41.scl".

3. Select the previously created SCL source file and click "Open." This imports the SCL source file.
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.

7 Related Literature

Table 7-1

	Topic	Link
\1\	Siemens Industry Online Support	http://support.industry.siemens.com
\2\	Download page of this entry	https://support.industry.siemens.com/cs/ww/en/view/48418663
\3\	SIMATIC PCS 7 Overview	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\	How do you do perform controller optimization with the PCS 7 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 example of the Chemical Industry	https://support.industry.siemens.com/cs/ww/en/view/53843373
\8\	PCS 7 Unit Template "Stirred Tank Reactor" using the example of the Chemical Industry	https://support.industry.siemens.com/cs/ww/en/view/60546560
\9\	PCS 7 Unit Template "Fermenter" using the example of the Chemical Industry	https://support.industry.siemens.com/cs/ww/en/view/68098270
\10\	PCS 7 Unit Template "Dryer" using the example of the Chemical Industry	https://support.industry.siemens.com/cs/ww/en/view/74747848
\11\	PCS 7 Unit Template "Polymerization Reactor" using the example of the Chemical Industry	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

8 History

Table 8-1

Version	Date	Modification
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