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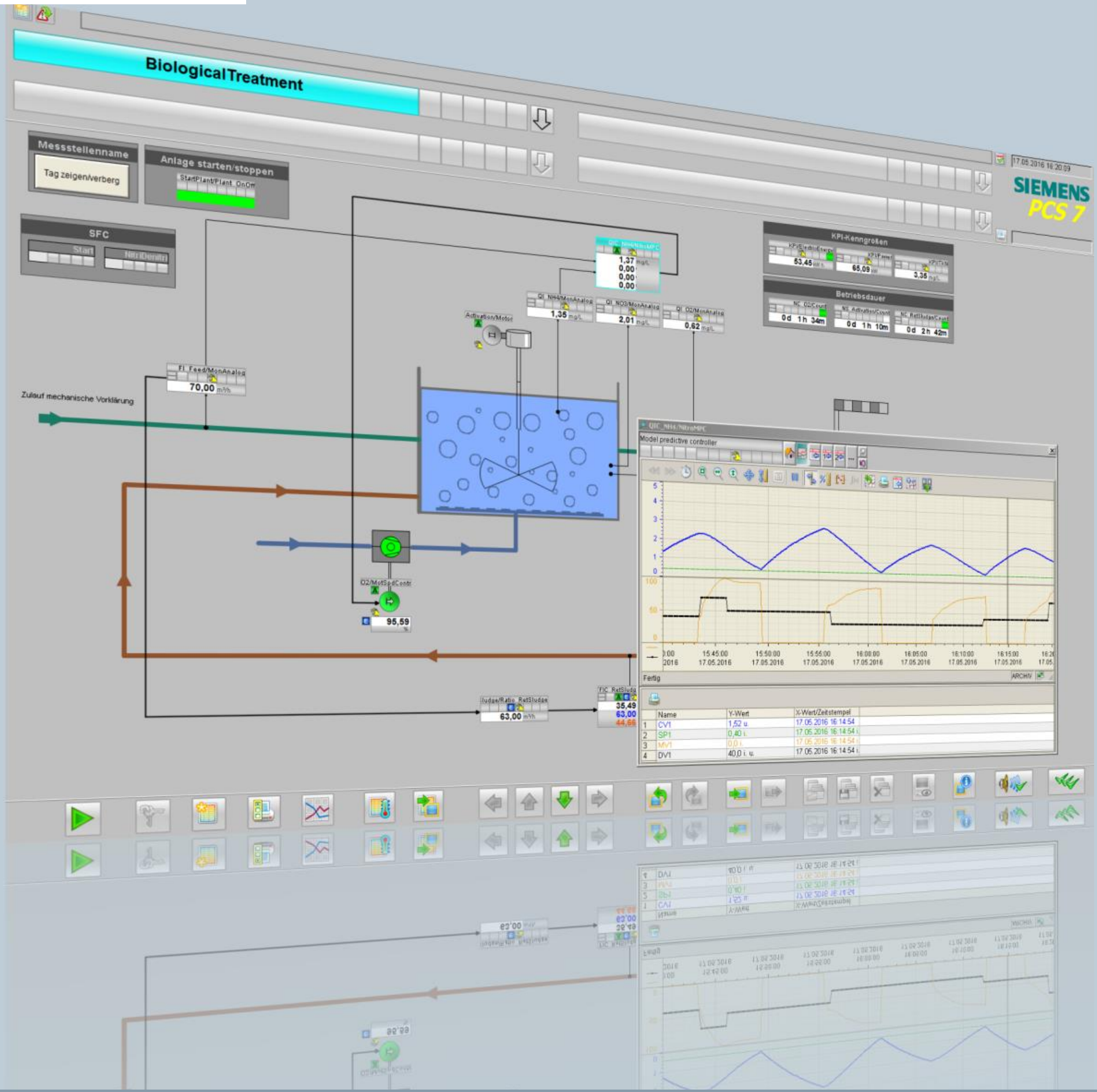

Application example • 07/2016

PCS 7 Unit Template – Control of Biological Stage of a Wastewater Treatment Plant with Intermittent Operation

SIMATIC PCS 7 V8.1 SP1

https://support.industry.siemens.com/cs/ww/en/view/109485916

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Preface

Aim of the Application Example

The aim of this application example is to provide you with a ready-made and unified example project for a wastewater treatment plant as a quick introduction and to support the development of APC knowledge (Advanced Process Control), based on the corresponding equipment modules. This example project can be used as a model for projects of your own and adapted to individual requirements.

Key Content

The following core contents are covered in this application example:

- Structure and instrumentation of aeration tanks and secondary clarifiers of wastewater treatment plants with intermittent operation
- Description of the individual functions and parameter assignment
- Working with the application example

Validity

From PCS 7 V8.1 SP1 with IL (Industry Library) and CFC V8.1 SP1 Update 3

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1 Task Description and Solution

1.1 Task

The standardization of automation engineering for urban water management plants, such as water treatment, is a major challenge. Different process steps and procedures, different equipment and flexibility in the plant configuration make the task even more difficult.

The largely automated operation of wastewater treatment plants is considered state of the art. Compared to process plants in other industries, such as the chemical industry, a wastewater treatment plant has fewer sensors and control loops. Nevertheless, the automation of wastewater treatment plants has its own special challenges:

- The wastewater treatment plant generally discharges directly into public flowing waters. The wastewater treatment plant operator is therefore liable for complying with legal limits in purified wastewater, such as limits for ammonium nitrogen NH_4-N, total nitrogen, chemical oxygen demand (COD), and phosphate.
- The biological processes for purification of the wastewater using different partial stages such as e.g. COD degradation, nitrification and denitrification sub-steps are complex and not easily modeled. Care must be taken that the bacteria, as living beings, are provided with the right environmental conditions so that they fulfill exactly the desired task with their metabolic processes.
- Many of the variables important for closed-loop control, especially concentrations, are not measured online but are available only at longer intervals as lab samples.
- The influent to a wastewater treatment plant is subject to strong fluctuations – both in terms of quantity and its contents. This is due to weather-related and seasonal fluctuations as well as the behavior of the high numbers of private households and industrial companies that discharge wastewater to the sewer network.
- Wastewater treatment plants and, in particular, the aeration of biological purification steps, represent the largest communal energy consumer in many cities and municipalities. Measures that reduce energy consumption can therefore pay for themselves after a short time.
- Based on the typical size of mainly municipal wastewater treatment plants, engineers with relevant know-how about wastewater-specific, biotechnological issues are usually available on-site, but not control engineers. That is why any control engineering solution must have a clear and transparent structure so that it can be operated and maintained by the available personnel.

The use of instrumentation and control (I & C) technology in wastewater treatment plants has the following basic objectives:

- Improvement of purification performance for compliance with discharge limits.
- Minimization of operating costs, especially energy costs.
- Saving of investment costs through optimal use of existing infrastructures. (Whitepaper "Optimization of Wastewater Treatment Plants with Advanced Process Control" \9\.)

The configuring of the plant is in accordance with the physical model of the DIN EN 61512 or ISA 196 standards. This specifies the lower four levels, i.e. plant, unit, technical systems and control module. On the three lower levels pre-built, re-usable solutions can be employed: Process tag types (“Control Modules”) on the control module level, Equipment Modules on the technical system level and “Unit Templates” on the unit level.

1.2 Solution

1.2.1 The Biological Stage of a Wastewater Treatment Plant with intermittent Operating Mode

The application example "PCS 7 Unit Template – Control of Biological Stage Wastewater Treatment Plant with intermittent operation" (referred to below as the "Biological Stage") is a Unit Template for waste water treatment plants, which can be integrated as a plant section in the most diverse sewage treatment plants.

The Unit Template provides a template that comprises all typical components, their open- and closed-loop control, the necessary logic and interlocks as well as the visualization. The template design is modular and based on standardized functions. Its utilization offers the following advantages:

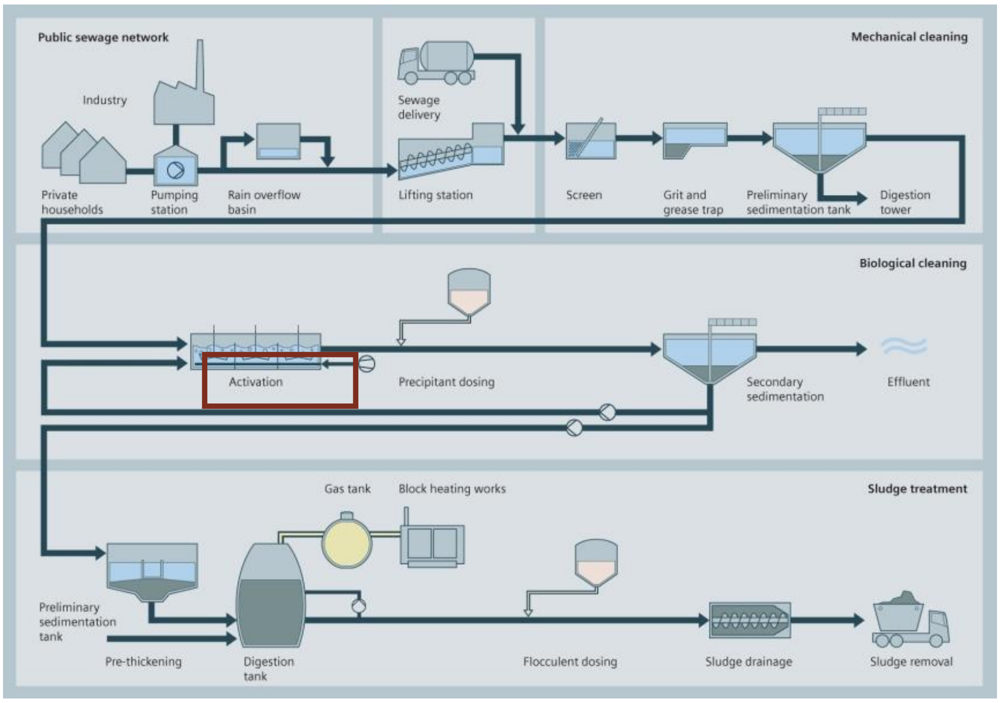
- A reduction of the knowledge necessary to develop applications.
- A decrease in the engineering effort
- A reduction of the technical risk.
- More flexible setup and adaptations through equipment modules.
- Standardized structures.

1.2.2 Overview of the complete Solution

Diagram

The following figure shows a typical layout of a wastewater treatment plant that operates an activated sludge process in intermittent mode. For an easy-to-understand explanation of the activated sludge process, see the white paper "Optimization of Wastewater Treatment Plants with Advanced Process Control" \9\.

Figure 1-1 Process flow diagram of a typical wastewater treatment plant with intermittent operating mode. The biological stage is marked in red.



Description

The Unit Template "Biological Stage" includes several pre-built, unified and ready-connected equipment modules. From this sample solution, numerous instances can be generated with different parameter assignments and adapted structure to be widely integrated in different automation solutions. The PCS 7 project is configured to be hardware-independent and can be flexibly incorporated in existing projects.

The Unit Template "Biological Stage" has been realized as a PCS 7 multiproject, as follows:

- One project for the automation system (AS) and one project for the operator station (OS) are contained in the component view.
- In the plant hierarchy (technological view), a hierarchy folder is created for each equipment module of the biological treatment.

In the AS project, all open- and closed-loop control functions are implemented in form of CFC (Continuous Function Chart) and SFC (Sequential Function Charts). Furthermore, the AS project also contains a hierarchy folder with simulation charts that simulate a biological process, e.g. a concentration change, within an equipment module.

All the control modules are available in the project's master data library as Control Module Type (CMT) and contain function blocks of the PCS 7 Advanced Process Library (APL) and of the Industry Library (IL).

The OS project contains the visualization of the biological stage with all the equipment modules and shows:

- A schematic structure of the biological stage of a wastewater treatment plant with intermittent operating mode.
- The relevant parameters (KPI: Key Performance Indicators)
- The sequence control of a continuous treatment process with alternating phases of nitrification and denitrification.

Delimitation

The chemical and micro-biological processes in the unit are not simulated in detail; they are only approximately described by schematic linear behavior model. After the simulation has been extended, the Unit Template could also be used within the framework of an operator training system.

Required knowledge

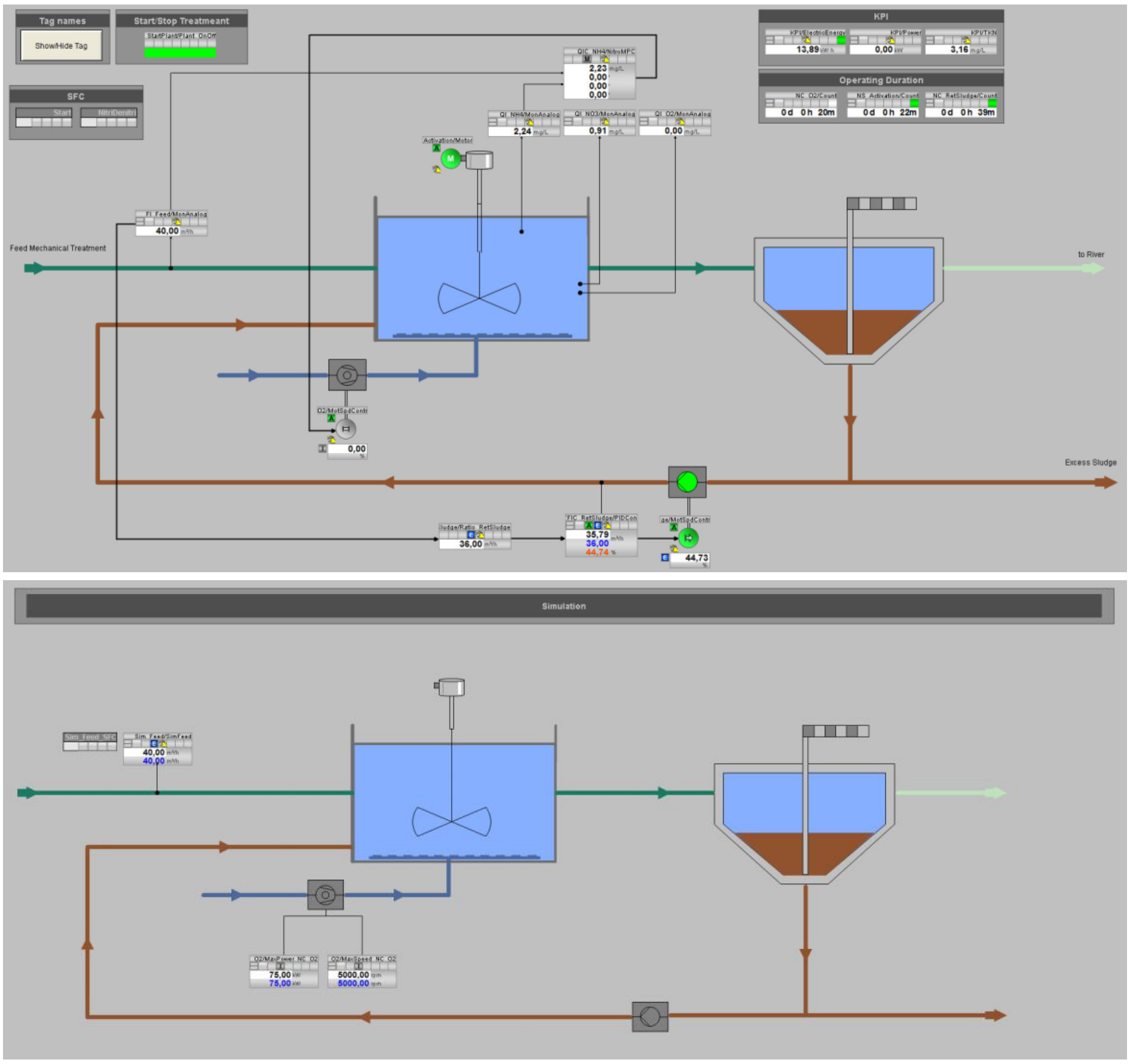
Fundamental knowledge of the following specialist fields is a prerequisite:

- PCS 7 Engineering and APL
- Knowledge of control system technology
- Basic knowledge of process technology

1.2.3 Core Functionality

In the following section, you can find a description of the individual components of the biological stage of a wastewater treatment plant. The entry point is the process picture of the PCS 7 operator station (OS).

Figure 1-2 Process picture of the biological stage, above: OS operating screen, below: Variant for parameter assignment of simulation model



Process picture

The process picture of the biological stage consists of the following components:

- Schematic representation
- Faceplates for controlling the individual plant components
- Overview of the relevant parameters (Key Performance Indicators) and operating time display

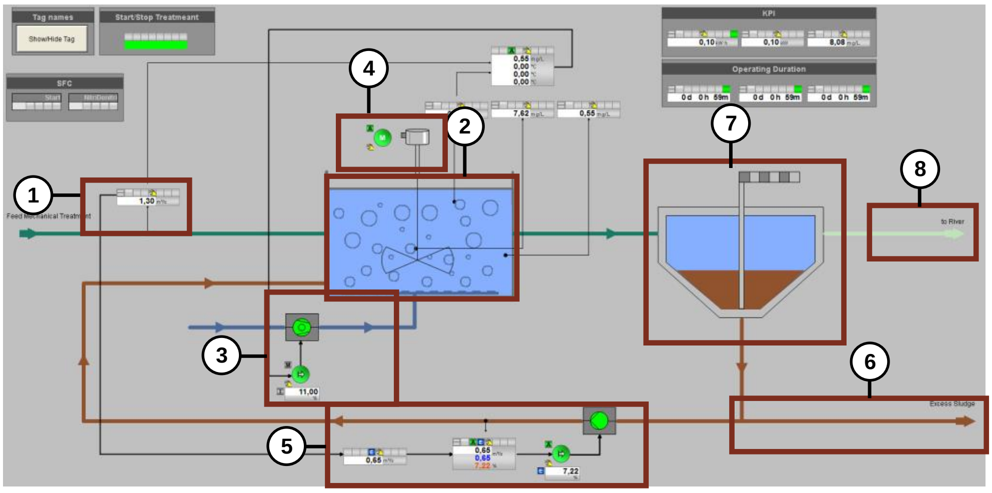
In the process picture, the operator will find an overview of the entire plant section and the operating elements for his interventions.

Process-specific parameter settings

In the underlying process settings in the simulation picture, technical data is predefined for the operating point of the biological stage. In addition, the rated outputs of drives, technical specifications and maximum values are pre-defined. These settings affect both the simulation and the KPI calculations.

1.2.4 Description of the individual Functions

Figure1-3 Components of the wastewater treatment plant



The process picture of the biological treatment consists of the following major components:

1. Inlet
2. Aeration tank
3. Aeration
4. Agitator
5. Return sludge
6. Excess sludge discharge
7. Secondary clarifier
8. Purified water

Inlet (1)

The mechanically pre-cleaned wastewater (by means of screen, sand trap and preliminary sedimentation tank) enters the aeration basin via the feed pipe. The actual feed flow rate is regarded as a measurable disturbance variable in the higher-level model-predictive controller (MPC).

Aeration tank (2)

The ammonium concentration (NH_4) in the aeration tank is regulated by means of an MPC during the nitrification phase. The revolution speed of the fresh-air blower is used as the manipulated variable of the MPC. The manipulated variable is used as setpoint input for the lower-level motor control module. Denitrification phase and Nitrification phase follow each other in a sequential manner in the aeration tank.

Aeration (3)

Fresh air is pumped into the aeration tank (during the nitrification phase).

The blower receives its set-point from the MPC in the aeration tank. The energy consumed by the blower in kWh is calculated in a separate CFC plan.

Agitator (4)

The agitator ensures thorough mixing of wastewater and activated sludge in the aeration tank (during the denitrification phase in which good mixing cannot be guaranteed by the air flowing in from below).

Return sludge (5)

The return sludge is the activated sludge that settles at the bottom of the secondary clarifier and is returned to the aeration tank.

The return flow of activated sludge (controlled variable) is regulated by the rotational speed of a pump (manipulated variable) by a PID controller. The return sludge is fed to the inlet in a defined ratio ("return sludge ratio").

Excess sludge discharge (6)

The excess sludge that forms in the secondary clarifier due to bacterial growth is not pumped back to the aeration tank but removed from the biological treatment and then typically processed for energy generation in a biogas plant.

Secondary clarifier (7)

The activated sludge is separated from the purified water by a settling process in the secondary clarifier. Most of the activated sludge is then fed back to the aeration tank.

Discharge (8)

The purified water is usually introduced into a public flowing water (e.g. river).

Additional functions

After starting the PLC and the unit, an SFC drives the biological treatment to the operating point.

Parameters (KPI = Key Performance Indicators)

The following key performance indicators are measured or calculated:

- Blower electrical power
- Blower energy consumption (essential for operating costs)
- Total nitrogen load (relevant for wastewater quality)

Note The PCS 7 project can be expanded by means of individual KPI calculations, such as the electrical power rating of its return sludge pump.

Operating hours counter

The operating hours counter for the air intake motor, the return sludge pump and the agitator are contained in the process picture and can be used for maintenance planning.

1.2.5 Background Information: Process Optimization in Terms of Energy Consumption and Wastewater Quality

Up to now it has been common practice in sewage treatment plants with intermittent denitrification to determine a constant oxygen level that is maintained by means of a PI controller via a blower. However, the typical duration of the nitrification phase is not always sufficient for the oxygen controller to reach a steady-state oxygen concentration by varying the blower speed. At the same time, the blower speed at the start of the nitrification phase is very high, which wastes a significant amount of energy.

The influent flow rate has a considerable effect on the dynamic processes in the sewage treatment plant. However, the common automation cannot react directly to a change because the influent flow rate is not taken into account in conventional closed-loop control. It is only when a change in the concentrations in the activated sludge tank occurs that the phase durations are changed and the oxygen controller adjusts the blower speed as needed.

The new solution concept described in this article is based on the insight that oxygen concentration in the nitrification phase is only an auxiliary controlled variable for providing the right environmental conditions for aerobic metabolism of bacteria. An oxygen concentration that is constant over an extended period cannot always be achieved, but it is also not necessary for process control.

In the concept presented here, therefore, the blower speed is controlled directly by the process variable of primary interest, that is, ammonium concentration. This is supposed to drop from an initial value at the start of the nitrification phase to a specified target value within a specified time in order to end the nitrification phase. The biggest energy consumers in the wastewater treatment plant are the blowers for the aeration. In comparison to them, the energy consumption of the return sludge pumps is negligible. The considerable potential energy savings by the MPC solution are based mainly on increasing the aeration slowly in a requirement-compliant manner at the beginning of the nitrification phase, that is, to blow in only as much air as the bacteria actually need for their aerobic metabolism.

At the same time, the influent flow rate is interpreted as a measurable disturbance variable. If the effects on the processes in the nitrification phase are known, the controller can adjust the aeration in good time and in an anticipatory manner, preventing, or at least reducing the negative effects of influent fluctuations.

The MPC function “ModPreCon” block is ideally suited for the described tasks. It has a setpoint filter that can determine the desired time trajectory of the ammonium concentration by specifying a transient time.

Due to the above-described limitations of the PI controller the MPC is not cascaded with the existing oxygen controller. This is why the MPC uses the blower speed directly as the manipulated variable in order to control the ammonium concentration while taking into account the measurable disturbance variable “feed”.

Source: Whitepaper \9\.

1.2.6 Control Concept

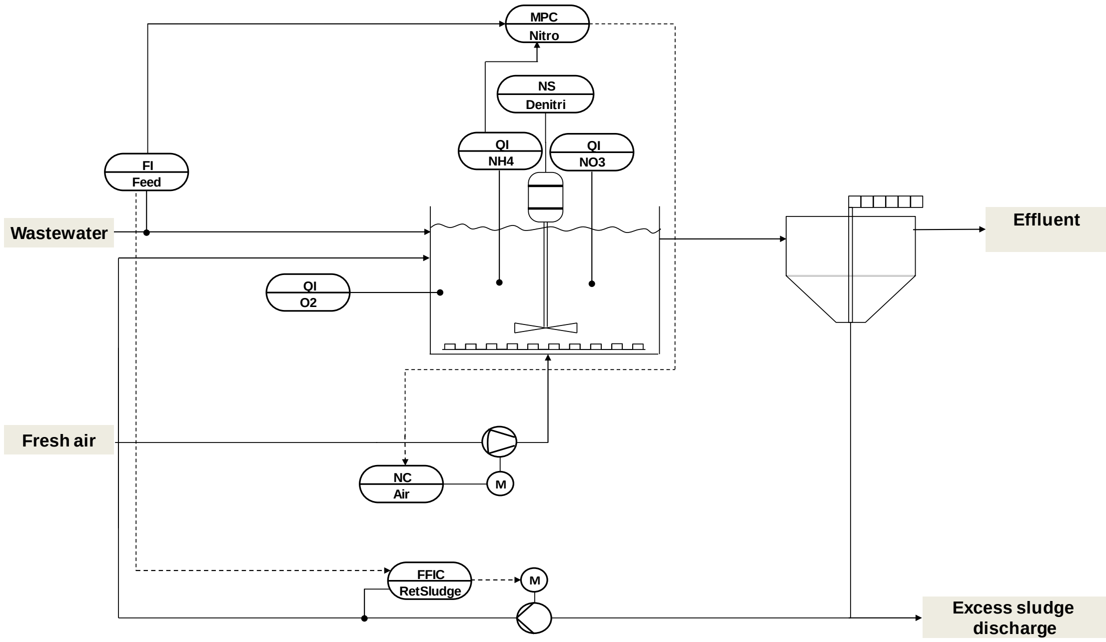
Wastewater quality control during clarifying sequence is performed by regulating the ammonium (NH_4) and nitrate (NO_3) concentrations. The switching between the nitrification and denitrification phases serves this purpose. Switchover takes place when threshold values are undercut. The nitrification phase is ended as soon as the ammonium concentration drops below a threshold value of 0.5 mg/L, meaning that enough ammonium has been degraded (to nitrate) through nitrification. The denitrification phase is ended as soon as the nitrate concentration drops below a threshold value of 0.8 mg/L indicating that enough nitrate has been degraded through denitrification. The switchover logic is supplemented with minimum and maximum phase durations to prevent excessively fast changeovers and excessively long dwell times.

The aeration control loop during the nitrification phase represents the second part of the closed-loop control. The blower revoltuion speed (manipulated variable) is directly adjusted with respect to the process value of primary interest, that is, the ammonium concentration (controlled variable). Control is implemented via the MPC function block “ModPreCon” of the APL.

The PID controller "PIDConL" of the APL is used for control of return sludge.

1.2.7 P&I Diagram

The following figure shows the elements of the biological treatment in a piping and instrumentation diagram.



1.3 Hardware and Software Components

The application example has been created with the following components:

Hardware components

Component	Note
SIMATIC PCS 7 ES/OS IPC847D W7	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 Readme file of the PCS 7.

Standard software components

Component	Note
SIMATIC PCS 7 V8.1 SP1	Part of SIMATIC PCS 7 ES/OS IPC847D W7
S7 PLCSIM	The license does not form part of SIMATIC PCS 7 ES/OS IPC847D W 7
APL library	Part of SIMATIC PCS 7 V8.1 SP1
SIMATIC Industry Library (V8.1 SP1)	Not a part of SIMATIC PCS 7 V8.1 SP1
CFC V8.1 SP1 Update 3	Not a part of SIMATIC PCS 7 V8.1 SP1

Note For information on the Service Pack 1 for SIMATIC PCS 7 Industry Library V8.1, see the following link:
https://support.industry.siemens.com/cs/ww/en/view/109477851

Specific control module types for the water industry are taken from the Industry Library: WCMT (“Water Control Module Type”) \4\.

Example files and projects

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

File	Note
109485916_PROJECT_ASUC_PCS7_V811.zip	PCS 7 V8.1 SP1 example project
109485916_DOCU_ASUC_PCS7_V811_en.pdf	This document

2 Structure and Principle of Operation

2.1 Project Structure

2.1.1 Naming Convention of CFC

A uniform naming convention is used for identifying the control modules, whereby the function has been named according to European standard EN 62424. The following figure shows the composition of a process tag.

FFIC_RetSludge

Function ↗ ↖ Designation

F = Flow rate (first letter)
F = Ratio (subsequent letter)
I = Indication (subsequent letter)
C = Control (subsequent letter)

The following table contains the letters used in the Application Example and their meaning.

First letter	Meaning
F	Flow
Q	Quality, Concentration
N	Motor speed

Subsequent letter	Meaning
C	Control – Controllers
I	Indication
F	Fraction
S	Binary control function or switching function (not safety-oriented)

2.1.2 Technological View

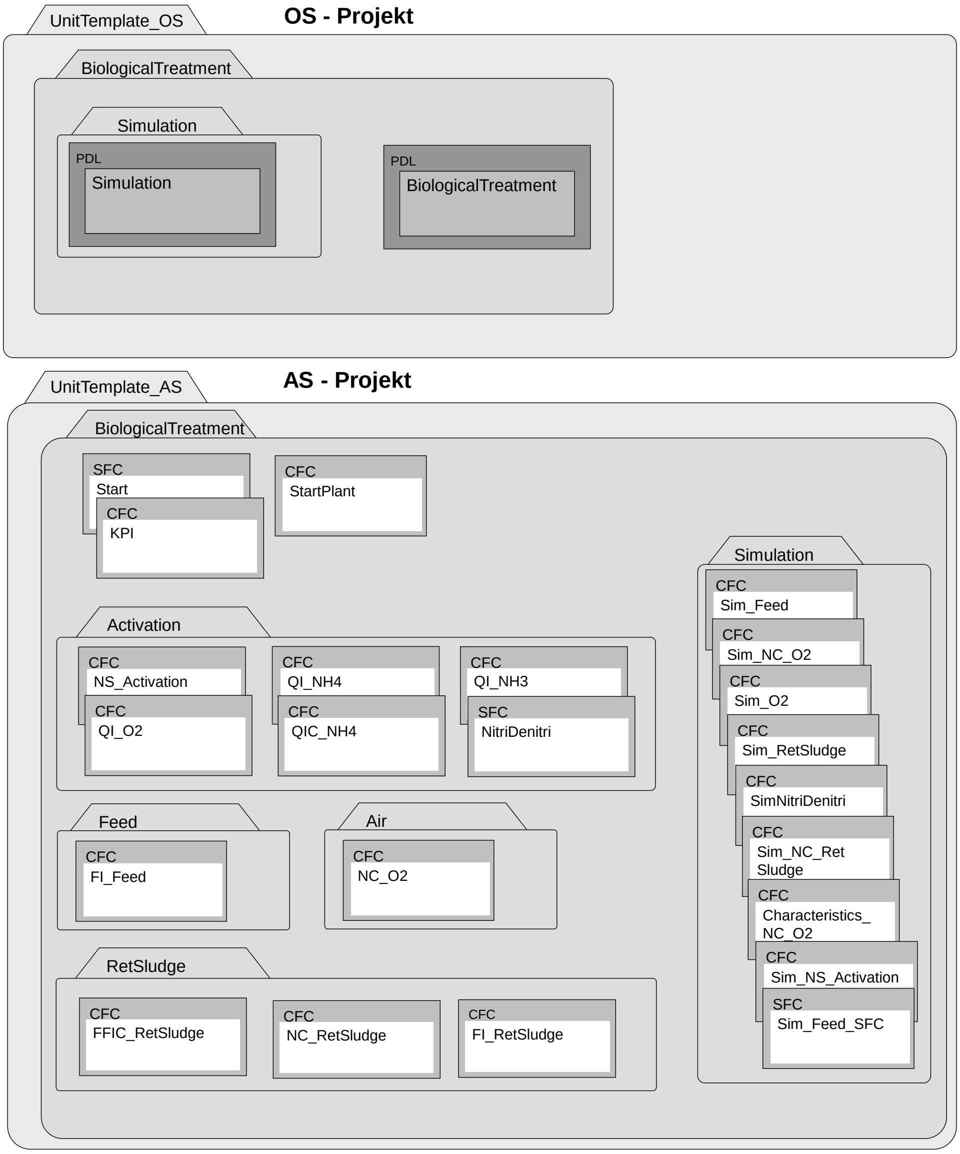
In the technological view, the Unit Template "Biological Stage of a sewage treatment plant with intermittent operation" is realized in three hierarchy levels.

In the first hierarchy level of the AS project "WWTP_AS" there is a CFC for the activation of the system, a CFC for the detection of the KPIs, and an SFC to start the unit template (because these functions cannot be assigned to individual equipment modules). In the lower hierarchy level, there is a hierarchy folder with the necessary CFCs and SFCs for each equipment module of the biological treatment. The "Simulation" hierarchy folder contains the CFCs and the SFCs needed for simulation.

In the first hierarchy level of the OS project “WWTP_OS" the "BiologicalTreatment" folder with the "BiologicalTreatment.pdl" process screen of the biological stage is located. The lower-level hierarchy folder "Simulation" contains the process picture

"Simulation.pdl", in which process-specific settings for the simulation model can be made.

The following figure is a simplified depiction of the PCS 7 multiproject structure:



2.2 Equipment Modules and Control Modules

The "Biological Stage" Unit Template consists of pre-made equipment modules and control modules, for example, for the process simulation. In a PCS 7 project, both the individual control modules and the control modules inside equipment modules are based on control module types (CMTs) from the master data library. You will find the application descriptions "Standard PCS 7 and S7 Water Templates for the water industry" and "Equipment Modules for PCS 7 using the example of the Chemical Industry" as well as the example projects with the individual equipment modules and CMTs at the entry ID:

- 78604785 “Standard PCS 7 Water Templates for the water industry ”\4\
- 53843373 "Equipment Modules for PCS 7 using the example of the Chemical Industry” \5\

The application example "Biological Stage" includes the following equipment modules:

- Feed: Feed rate measurement for feedforward control and set point specification for return sludge
- Aeration tank: Mixing in aeration tank by agitator and closed-loop control of ammonium and nitrate concentrations
- Aeration (air): Blowers for aeration of the aeration tank
- Return sludge (RetSludge): Return sludge flow control
- Sequences (SFCs) for starting the system and intermittent operation of aeration tank
- Overall process simulation (Process Simulation), in addition to the simple simulations which are already integrated in the control module types.
- Process key performance indicators (KPI)

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 original equipment modules used and the original CMTs. In addition the SFCs for startup and operation of the wastewater treatment plant are described.

2.3 Feed

The (mechanically) pre-cleaned wastewater enters the aeration basin via the feed pipe. The control module type "WCMT_MonAnalog" of the master data library for the water industry serves for monitoring of the feed flow.

2.3.1 Setup

The following table provides an overview of the elements and control module types used.

Designation	Control module type	Use
FI_Feed	WCMT_MonAnalog	Measurement of feed flow

2.3.2 Parameter Assignment

Measuring point “FI_Feed” is an instance of control module type “WCMT_MonAnalog” with selected variant “MonAnIn”, i.e. the optional module MonAnIn is effectively built into the instance. The measuring point "FI_Feed" serves to record the wastewater inlet flow. In contrast to the real plant, in this application example the process value input is set by the operator or the SFC. The measuring point "FI_Feed" transmits the process value as a disturbance variable to the MPC control module "QIC_NH4".

The following table provides a summary of parameter settings an interconnections to other control modules:

Block	Connection	Value	Use
MonAnIn	Scale	5.0	Maximum value of the process value
MonAnIn	PV_Unit	1347	Process value unit (m³/h)
MonAnIn	SimOn	1	Simulated process value active
MonAnIn	SimPV_In		Interconnection for the simulated process value (Sim_Feed\SimFeed.SP_Out)
MonAnIn	PV_Out		Interconnection to MPC (QIV_NH4\NitroMPC.DV1)
MonAnalog	PV_Out		Interconnection to Return Sludge (FFIC_RetSludge\Ratio_RetSludge.In; FFIC_RetSludge\Ratio_RetSludge.InPV)

2.4 Aeration Tank (Activation)

The MPC is applied for quality control by which the wastewater quality (i.e. ammonium concentration (NH_4)) is adjusted according to legal limits for permissible nitrogen discharge into public waterways. In nitrification phase the MPC commands the setpoint value for the aeration revolution speed. During the denitrification phase both regulation and ventilation are deactivated. In addition the agitator is activated for mixing of wastewater and activated sludge. Switching over takes place using threshold values and timeframes, via an SFC. For a detailed description of the SFC, please refer to Chapter 2.8 “Sequences (SFC)”.

Setup

Water quality (ammonium concentration (NH_4)) is controlled by means of the MPC “QIC_NH4”. The controller receives the current measured value of the controlled variable (ammonium concentration (NH_4)) and the disturbance variable (wastewater feed) and calculates a setpoint for the aeration revolution speed. Water quality nitrate concentration (NO_3) is controlled by means of the minimum holding time determined by the SFC “NitriDenitri” and the threshold value – it is not a continuous feedback control with a permanent tallying between setpoint and actual values. In the denitrification phase, mixing must be ensured by the agitator, whereas in the nitrification phase it is achieved by the spatially distributed injection of air through the floor of the tank. The control variables are visualized with the measuring points "QI_NH4" and "QI_NO3". The agitator is controlled via the control module “NS_Activation”. Additionally, oxygen concentration in the aeration tank is visualized via the “QI_O2” measuring point.

The following table provides an overview of the elements and control module types used.

Designation	Control module type	Description
QIC_NH4		MPC serves as controller for ammonium concentration
QI_NH4	WCMT_MonAnalog	Measuring point for displaying ammonium concentration
QI_NO3	WCMT_MonAnalog	Measuring point for displaying nitrate concentration
QI_O2	WCMT_MonAnalog	Measuring point for displaying oxygen concentration
NS_activation	WCMT_MotLean	Mixing in the aeration tank
NitriDenitri		SFC for sequential control of clarification in aeration tank

Note The measured values of QI_NH_4 and QI_NO_3 always provide the concentration of ammonium-nitrogen or nitrate-nitrogen in the water and are therefore referred to as NH_4-N and NO_3-N, respectively.

2.4.1 Parameter Assignment

NS_activation

The agitator, which is actuated by the control module "NS_Activation", mixes together the feed that flows into the aeration tank and the return sludge. In the Application Example, the operator or the SFC chart “NitriDenitri” is responsible for the control of the measuring point. Measuring point “NS_Activation” is an instance of the control module “WCMT_MotLean” with the following select variants:

- Count
- OutStart

The following table shows the interconnections for other measuring points and parameters:

Block	Connection	Value	Use
FbkRun	SimOn	1	Simulated process value active
FbkRun	SimPV_In		Interconnection to simulated process value (Sim_NS_Activation\SimFbkRu.Out)
LocalStop	Sim_On	1	Simulated process value active
StartOut	Sim_On	1	Simulated process value active
StartOut	SimPV_In		Interconnection for the simulated process value (NS_Activation\Motor.Start)
Motor	StartAut		Start in automatic mode (interconnection for SFC chart)
Motor	StopAut		Stop in automatic mode (interconnection for SFC chart)
Motor	ModLiOp		Switchover of operating mode selection (interconnection to SFC chart)
Motor	AutModLi		Automatic mode via interconnection (interconnection to the SFC chart)
Motor	Start		Signal for starting the motor (interconnection to Sim_NS_Activation\SimFbkRu.In)
Motor	FbkRunOut		Motor started feedback message (interconnection to SFC chart)

QIC_NH4

The following relevant values are used and interconnected for quality control with MPC measuring point “QIC_NH4”:

- Controlled variable (CV) Ammonium concentration (NH_4)
- Manipulated variable (MV) blower revolution speed
- Disturbance variable (DV) feed volume

The following table shows the interconnections for other measuring points and parameters:

Block	Connection	Value	Meaning
NitroMPC	CV1		Process value: controlled variable (QI_NH4\MonAnIn.PV_Out)
NitroMPC	DV		Process value: disturbance variable (FI_Feed\MonAnIn.PV_Out)
NitroMPC	SP1	0.4	Controlled variable setpoints
NitroMPC	PreFilt1	300.0	Transient recovery time (s) of the setpoint filter for setpoint SP1
NitroMPC	MV1Man		Manipulated variable in setup mode
NitroMPC	MV1ManLoLim	40.0	Lower limit of setpoint value in manual operation
NitroMPC	AutModLi		Automatic mode via interconnection (interconnection to the SFC chart)
NitroMPC	ManModLi		Manual mode via interconnection (interconnection to the SFC chart)
NitroMPC	ModLiOp		Switchover of operating mode selection (interconnection to SFC chart)
NitroMPC	CV1_Unit	1558	Measurement unit controlled variable (mg/l)
NitroMPC	MV1_Unit	1342	Measurement unit manipulated variable (mg/l)
NitroMPC	DV_Unit	1347	Unit of measurement of disturbance variable (m^3/s)
NitroMPC	DB_No	1	Number, data block with parameter data sets
NitriMPC	MV1		Manipulated variable value (NC_O2\MotSpdContr.SP_Ext)

In a real system, the parameters of the MPC are assigned using learning data by means of the MPC configurator. The general procedure is described in detail in the Application Example “Model-based Predictive Multi-variable Control using a Distillation Column as an Application Example" \10\.

The concrete implementation of the simulated aeration tank is documented in Chapter 2.11. "MPC Configuration".

QI_NH4

The display measuring point "QI_NH4" is used for detecting and displaying the ammonium concentration (control value) of the MPC measuring point. Measuring point “QI_NH4” is an instance of control module type “WCMT_MonAnalog” with selective variant “MonAnIn”.

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
MonAnIn	Scale	10.0	Maximum value of the process value
MonAnIn	PV_InUnit	1558	Process value unit (mg/l)
MonAnIn	SimOn	1	Simulated process value active
MonAnIn	SimPV_In		Interconnection for the simulated process value (SimNitriDentri\Sim_NH4.Out)
MonAnIn	PV_Out		Interconnection to MPC and KPI (QIC_NH4\NitroMPC.CV1; KPI\ActTKN.In1)
MonAnalog	PV_Out		Current process value (interconnection for SFC chart)
MonAnalog	PV_AH_Lim	9.9	Limit PV alarm (high)
MonAnalog	PV_WH_LIM	9.5	Limit PV warning (high)

QI_NO3

The display measuring point "QI_NO3" is used for detecting and displaying the nitrate concentration. Measuring point “QI_NO3” is an instance of control module type “WCMT_MonAnalog” with selective variant “MonAnIn”.

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
MonAnIn	Scale	5	Maximum value of the process value
MonAnIn	PV_InUnit	1558	Process value unit (mg/l)
MonAnIn	SimOn	1	Simulated process value active
MonAnIn	SimPV_In		Interconnection for the simulated process value (SimNitriDentri\Sim_NO3.Out)
MonAnIn	PV_Out		Interconnection to MPC and KPI (QIC_NH4\NitroMPC.CV1; KPI\ActTKN.In2)
MonAnalog	PV_Out		Current process value (interconnection for SFC chart)
MonAnalog	PV_AH_Lim	10.0	Limit PV alarm (high)
MonAnalog	PV_WH_LIM	9.5	Limit PV warning (high)

QI_O2

The display measuring point "QI_O2" is used for detecting and displaying the oxygen concentration. The measuring point "QI_O2" is an instance of measuring point type “WCMT_MonAnalog” with activated variant “MonAnIn”.

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
MonAnIn	Scale	5	Maximum value of the process value
MonAnIn	PV_InUnit	1558	Process value unit (mg/l)
MonAnIn	SimOn	1	Simulated process value active
MonAnIn	SimPV_In		Interconnection for the simulated process value (Sim_O2\Gain_Sim_O2.Out)

2.5 Aeration (Air)

The aeration is affected by a continuous control of the drive speed during the nitrification phase. The drive controls a blower that blows a speed-dependent quantity of fresh air and thus oxygen from below into the aeration tank.

2.5.1 Setup

The MPC measuring point "QIC_NH4" acquires the ammonium concentration (NH_4) and controls it via the revolution speed of the blower.

The following table provides you with an overview of the elements and control module types used:

Designation	Control module type	Use
NC_O2	WCMT_MotSpdCon	Blower revolution speed

2.5.2 Parameter Assignment

The motor measuring point "NC_O2" controls the rotational speed of the fresh air blower to the aeration tank and thus the oxygen concentration in the aeration tank. The motor block receives its external setpoint from the controller measuring point "QIC_NH4".

Measuring point "NC_O2" is an instance of the "WCMT_MotSpdCon” control module type with the following select variants:

- Count
- FbkFwd
- OutFwd
- OutSpeed
- RbkSpeed

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
FbkFwd	SimOn	1	Simulated process value active
FbkFwd	SimPV_In		Interconnection for the simulated process value (Sim_NC_O2\SimFbkFwd.Out)
RbkSpeed	SimOn	1	Simulated process value active
RbkSpeed	SimPV_in		Interconnection for the simulated process value (Sim_NC_O2\MotorRun)
MotSpeedContr	FwdAut		Forward operation in automatic mode (interconnection for SFC chart)
MotSpeedContr	StopAut		Stop in automatic mode (interconnection for SFC chart)
MotSpeedContr	ModLiOp		Switchover of operating mode selection (interconnection to SFC chart)
MotSpeedContr	AutMotLi		Automatic mode via interconnection (interconnection to the SFC chart)
MotSpeedContr	SP_Ext		External setpoint (QIC_NH4\NitroMPC.MV1)
MotSpeedContr	SP_LiOp		Select setpoint source via interconnection (interconnection to the SFC chart)
MotSpeedContr	SP_ExtLi		External setpoint via interconnection (interconnection to the SFC chart)
MotSpeedContr	SP_IntLi		Internal setpoint via interconnection (interconnection to the SFC chart)
MotSpeedContr	Fwd		Control forward (Sim_NC_O2\SimFbkFwd.In
MotSpeedContr	ManAct		Manual operation active (interconnection for SFC chart)
MotSpeedContr	FbkFwdOut		Feedback signal, forward operation (interconnection for SFC chart)
MotSpeedContr	SP_Out		Setpoint used (Sim_NC_O2\SimRbkSpeed.In; Interconnection for SFC chart)
MotSpeedContr	Rbk_Out		Feedback value (interconnection for SFC chart)
OutFwd	SimOn	1	Simulated process value active
OutFwd	SimPV_In		Interconnection for the simulated process value (NC_O2\MotSpeedContr.Fwd)
OutSpeed	SimOn	1	Simulated process value active
OutSpeed	SimPV_In		Interconnection for the simulated process value (NC_O2\MotSpeedContr.SP_Out)

2.6 Return activated Sludge (RetSludge)

The return activated sludge is affected by the continuous control of the drive speed. The drive impels a pump that conveys an rpm-dependent quantity of return activated sludge into the aeration tank. The equipment module includes three measuring points for control, drive and display.

Setup

The display measuring point “FI_Feed” (from the equipment module Inflow) acquires the sewage feed volume. The measured value is transmitted to the controller measuring point "FFIC_RetSludge". A fixed ratio ("return activated sludge ratio") between feed volume and return activated sludge volume is set there with the help of the ratio module "Ratio_RetSludge" and used to calculate an external setpoint for the slave controller. The slave controller records the volume of return activated sludge and requires either an increase or a decrease in the pump revolution speed, depending on the specified return activated sludge volume.

The following table provides you with an overview of the elements and control module types used:

Designation	Control module type	Use
FFIC_RetSludge	WCMT_PIDConL	Return activated sludge volume control
FI_RetSludge	WCMT_MonAnalog	Measuring point for the volume of return sludge
NC_RetSludge	WCMT_MotSpdCon	Pump drive rotational speed

2.6.1 Parameter Assignment

FFIC_RetSludge

In the measuring point "FFIC_RetSludge", the volume of activated sludge returned to the aeration tank is regulated. The current return activated sludge volume is recorded in the measuring point "I_RetSludge" and transmitted to the measuring point "FFIC_RetSludge". The setpoint entry is specified via the display measuring point "FI_Feed" and the "Ratio_RetSludge” ratio module. The measuring point "FI_Feed" transmits the measured value of the sewage feed to the "Ratio_RetSludge" ratio module. The ratio value formed there is transmitted to the controller as a setpoint. The measuring point "FFIC_RetSludge" transmits the manipulated variable to the drive of the "NC_RetSludge” pump. "FFIC_RetSludge" is an instance of the "WPTT_PIDConL" control module type, extended to include the "Ratio" module.

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
Ratio_RetSludge	In		Analog input (FI_Feed\MonAnIn.Out)
Ratio_RetSludge	InUnit	1347	Process value unit (m^3/s)
Ratio_RetSludge	InPV		Process variable (FI_Feed\MonAnalog.PV_Out)
Ratio_RetSludge	SecComPV		Process value of secondary components (FI_RetSludge\MonAnalog.PV_Out)
Ratio_RetSludge	SecComUnit	1347	Secondary components unit (m^3/s)
Ratio_RetSludge	RatioExt		External ratio (interconnection for SFC chart)
Ratio_RetSludge	RatOpScale	2.0	Limit value for bar display scale in image module
Ratio_RetSludge	RatHiLim	2.0	Upper ratio limit value
Ratio_RetSludge	OutHiLim	64.8	Limit (high) for initial value
Ratio_RetSludge	RatLiOp		Selection of ratio source (interconnection for SFC chart)
Ratio_RetSludge	RatExtLi		External ratio value via interconnection (interconnection to the SFC chart)
PIDCon	Gain	0.436	Controller gain
PIDCon	NormPV	10.0	Normalizing the proportional gain (Gain)
PIDCon	TI	1.63	Controller adjustment time
PIDCon	SP_LiOp		Setpoint source internal/external (interconnection for SFC chart)
PIDCon	PV		Process value: controlled variable (FI_RetSludge/MonAnalog.PV_Out)
PIDCon	ModLiOp		Switchover of operating mode selection (interconnection to SFC chart)
PIDCon	MV		Manipulated variable value (NC_RetSludge\MotSpdContr.SP_Ext)
PIDCon	ManHiOut		Limit (high) for manual operation (NC_RetSludge\MotSpdContr.SP_HiLim)
PIDCon	ManLoOut		Limit (low) for manual operation (NC_RetSludge\MotSpdContr.SP_LoLim)
PIDCon	AutAct		Automatic operating mode active (interconnection for SFC chart)
PIDCon	SP_ExtAct		External setpoint active (interconnection for SFC chart)

NC_RetSludge

The motor measuring point "NC_RetSludge" controls the return volume of activated sludge into the aeration tank via the drive speed. The motor module receives its external setpoint from the controller measuring point "FFIC_RetSludge".

"NC_RetSludge" is an instance of the "WCMT_MotSpdCon" control module type with the following select variants:

- Count
- FbkFwd
- OutFwd
- OutSpeed
- RbkSpeed

The following table shows the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
FbkFwd	SimOn	1	Simulated process value active
FbkFwd	SimPV_in		Simulated process value (Sim_NC_RetSludge\dimFbkFwd.Out)
RbkSpeed	PV_InUnit	1342	Process value unit (%)
RbkSpeed	SimOn	1	Simulated process value active
RbkSpeed	SimPV_In		Simulated process value (Sim_NC_RetSludge\SimRbkSpeed.Out)
MotSpeedContr	FwdAut		Forward operation in automatic mode (interconnection for SFC chart)
MotSpeedContr	ModLiOp		Switchover of operating mode selection (interconnection to SFC chart)
MotSpeedContr	AutMotLi		Automatic mode via interconnection (interconnection to the SFC chart)
MotSpeedContr	SP_Ext		External setpoint (FFIC_RetSludge\PIDCon.MV)
MotSpeedContr	SP_LiOp		Select setpoint source via interconnection (interconnection to the SFC chart)
MotSpeedContr	SP_HiLim		High setpoint limit (FFIC_RetSludge\PIDCon.ManHiOut)
MotSpeedContr	SP_LoLim		Low setpoint limit (FFIC_REtSludge.PIDCon.ManLoOut)
MotSpeedContr	Fwd		Control forward (Sim_NC_RetSludge\SimFbkFwd.In
MotSpeedContr	AutAct		Automatic operation active (interconnection for SFC chart)
MotSpeedContr	SP_Out		Setpoint used (Sim_NC_O2\SimRbkSpeed.In)
MotSpeedContr	Rbk_Out		Readback value (FFIC_RetSludge/PIDCon.MV_Trk)
CascaCut	Out		Control sequence to controller interrupted (FFIC_RetSludge\PIDCon.MV_TrkOn)
OutFwd	SimOn	1	Simulated process value active

Block	Connection	Value	Use
OutFwd	SimPV_In		Simulated process value (NC_RetSludge\MotSpdContr.Fwd)
OutSpeed	SimOn	1	Simulated process value active
OutSpeed	SimPV_In		Simulated process value (NC_RetSludge\MotSpdContr.SP_Out)

FI_RetSludge

The display measuring point "FI_RetSludge" uses the simulated value for the volume of the return activated sludge from the simulation chart "Sim_RetSludge". Measuring point “FI_RetSludge” is an instance of control module type “WCMT_MonAnalog” with selective variant “MonAnIn”.

The following table provides a summary of the interconnections for other measuring points and parameters of the included blocks:

Block	Connection	Value	Use
MonAnIn	Scale	100.0	Maximum value of the process value
MonAnIn	PV_InUnit	1347	Process value unit (m^3/h)
MonAnIn	SimOn	1	Simulated process value active
MonAnIn	SimPV_In		Interconnection for the simulated process value (Sim_RetSludge\Gain.Out)
MonAnalog	PV_Out		Process value (FFIC_RetSludge\Ratio_RetSludge.SecComPV; FFIC_RetSludge\PIDCon.PV)

The "operable and monitorable" attribute is deactivated in the "MonAnalog" block because in the Application Example, the measuring point "FI_RetSludge" is only used for process value detection. The process value is displayed via the controller measuring point "FFIC_RetSludge".

2.7 Process Simulation

The hierarchy folder "Simulation" contains the simulations of the individual plant units and the simulations that have a spanning character.

Ammonium (NH_4) and nitrate concentrations are simulated in the CFC “SimNitriDenitri”. A matrix with linear, dynamic transfer functions is used as a model for process simulation of the ammonium concentration (sheet 2). The process model is a 1x2 MISO system (Multi Input Single Output), where the influence of each input variable is simulated on each output variable by a separate partial transfer function. The model describes the temporal behavior of process deviations from the working point. The signs of the partial transfer functions are physically plausible. For example, an increase in the blower revolution speed (Air) leads to a reduction of the ammonium concentration (NH_4), i.e. the partial transfer function from u1 to y1 has a minus sign. The time constants in the simulation, however, are significantly faster than in a real plant. Additionally, in real plants downtimes can also occur in the partial transfer functions.

In the following figure, the process model is depicted with the corresponding designations.

	Air	Feed
NH_4	yu1	yu2

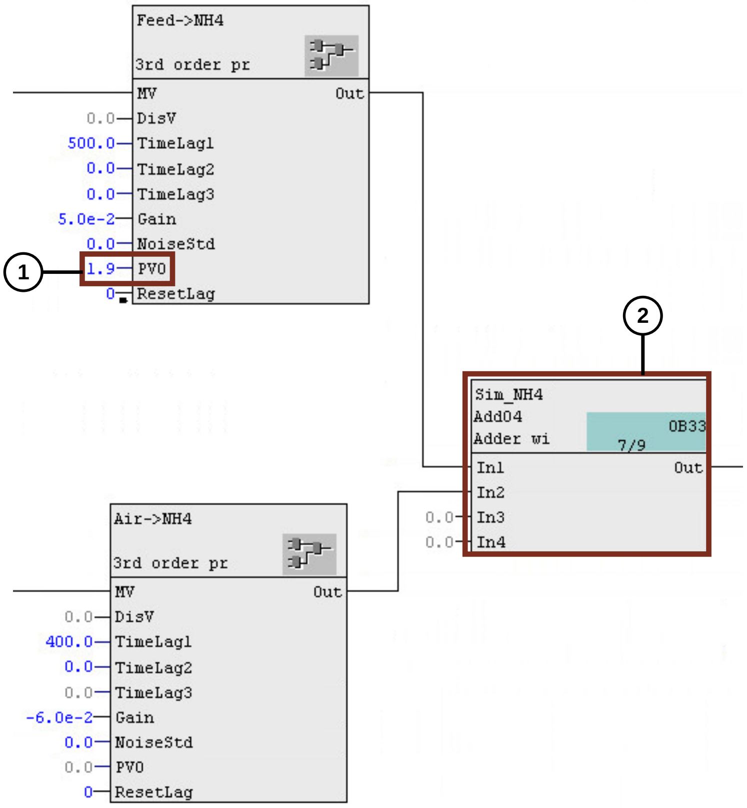
The partial transfer functions influence the respective output values (ammonium concentration (NH_4)) with different dynamic models of the first order (PT_1). Each partial transfer function receives the current value of the input variables and outputs them in accordance with its transfer functions at the output point. At the end the outputs of the partial transfer functions add up and generate the output value for ammonium concentration (NH_4). The operating point of the ammonium concentration is defined at the PT_n transfer function “Feed->NH4” at the “PVO” entry.

Note All PT_n transfer functions are structured as 'chart in chart' according to the same principle (ProcSimC of the APL), whereby only the required functional parts are activated. A transfer function contains three sequentially switched delay elements and a booster element. Furthermore, noise can be added to the output signal.

Nitrate concentration is simulated via two simple balance equations (Sheet 1). The initial value is defined at the entry “OutTrk” in the integral module “NO3 Concentratio”. The inflow and outflow terms of the balance equations are integrated, with nitrification and denitrification phases interchanged.

Oxygen concentration is simulated via two simple balance equations in the “Sim_02” CFC. The inflow and outflow terms of the balance equations are integrated, with nitrification and denitrification phases interchanged.

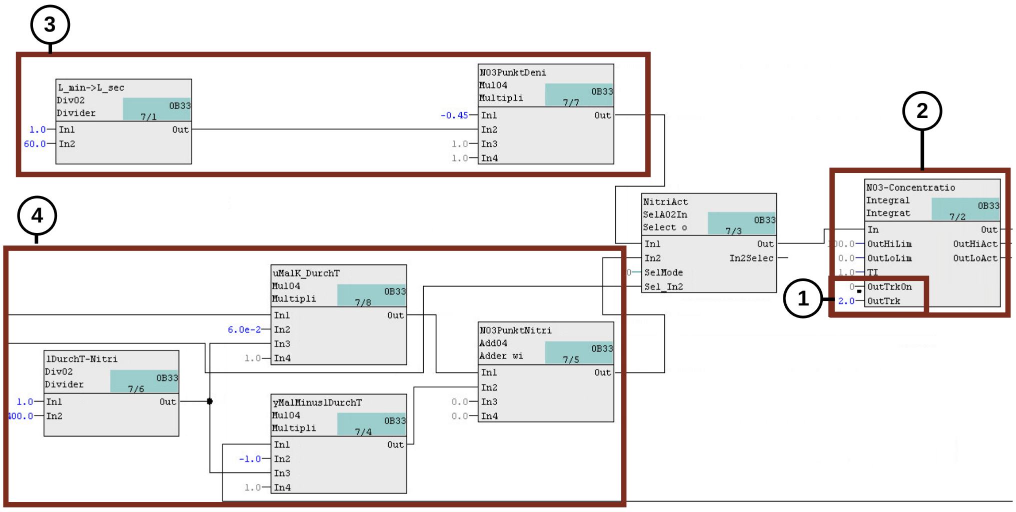
The following figure shows sheet 2 for the CFC “SimNitriDenitri” for the calculation of the ammonium concentration.



1. Operating point:
In this module the operating point for ammonium concentration (output variable of the process model) is indicated.

2. Controlled variable with operating point:
In this module the ammonium concentration is calculated by adding the outputs of the individual transfer functions.

The following figure shows Sheet 1 for the calculation of the nitrate concentration.



1. Operating point:
   The initial value of the nitrate concentration is adjusted at this point, the value that is adjusted when the binary entry OutTrkOn is set.
2. Integrator for balance dimension:
   The nitrate concentration is calculated in this module by integrating the modification over time of the nitrate concentration. The integrator represents the reservoir for the mass of nitrate in the tank.
3. The right-hand side of the balance equation during the denitrification phase represents the constant breakdown speed of nitrate to elementary nitrogen through the bacteria's anaerobic metabolism.
4. Balance equation during the nitrification phase represents the constant formation speed of nitrate from ammonium the bacteria's aerobic metabolism, which depends on the aeration.

You can adjust the numerical values for the initial value to the technical data of your plant without the dynamic response of the system being changed as a result.

The simulation design for the oxygen concentration corresponds to the simulation design for the nitrate concentration. In the nitrification phase the change in the oxygen concentration depends on the aeration, in the denitrification phase it is constantly strongly negative, that is, the oxygen concentration drops very rapidly.

Note

No further physical or biological phenomena, such as the dependency of the bacterial metabolism on temperature, are considered in the simulation. The time constants in the simulation have been chosen to appear around 20 times faster than in real-time.

The simple simulation in the template does not correspond to the simulation shown in the White Paper \9\.

2.8 Sequential Function Chart (SFC)

Sequential function charts support the plant operator in starting up and shutting down a facility, and in the event of faults, and can be adapted to specific circumstances.

The biological stage is designed for operation with continuous feed and intermittent aeration where individual parameters (e.g. feed volume) can change during operation. This application example includes the following sequences “Start”, “NitriDenitri” and “Sim_Feed_SFC”.

Step sequence “Start”

The Step sequence “Start” is the Step sequence to start up the biological stage of the wastewater treatment plant. It conducts the individual components of the system to the Operating point.

The controllers are used with an external manipulated variable in the automatic operating mode and the drive in automatic mode. In the following transitions, the "Automatic" operating mode and control deviation are checked.

Note With regard to real biological stages of wastewater treatment plants, this SFC can be considered only as a first reference point and was created to meet simulation requirements. For use in real systems, start-up controlling must be created according to the process-related requirements.

The “Start” sequence automatically runs when the CPU is restarted.

Step sequence “NitriDenitri”

The step sequence “NitriDenitri” controls the nitrification and the denitrification phases in an alternating time sequence. As long as the sewage treatment plant is active there is an alternance back and forth between nitrification and denitrification phases.

To start, the sequence checks whether the binary control “StartPlant/Plant OnOff” is set. The switched-on state of this binary control is thus a necessary but not sufficient condition for the start of the SFC. The SFC itself has to be started manually. However, it can be deactivated during the nitrification phase via binary control.

Switch-over between the phases takes place depending on the threshold values for nitrate / ammonium concentration and minimum holding times

In the denitrification phase:

- the mixer is put into automatic operating mode and started
- the blower is stopped
- the MPC is put into manual operation with an internal manipulated variable of 0.0 %

In the subsequent transitions, the respective feedback messages (e.g. motor stopped) are checked.

The denitrification phase ends as soon as the nitrate concentration sinks below the threshold value of 0.8 mg/l and a minimum holding time of 3 minutes has elapsed.

In the nitrification phase:

- the agitator is stopped.
- the blower goes into automatic mode with external manipulated variable value

- the MPC controller goes into automatic mode

In the subsequent transitions, the respective feedback messages (e.g. Blower started) are checked.

The nitrification phase ends as soon as the ammonium concentration sinks below the threshold value of 0.5 mg/l and a minimum holding time of 5 minutes has elapsed.

Subsequently the process jumps back to the first stage of the denitrification phase and the step sequence is worked through from the beginning again.

Structurally, this step sequence corresponds with the logic effectively used in the operation of sewage treatment plants with intermittent denitrification. The actual numerical values for the switchover thresholds may differ somewhat from the example values, depending on each system. The minimum holding times are adapted to the time-lapse.

Step sequence "Sim_Feed_SFC"

The step sequence "Sim_Feed_SFC" serves for the simulation of a disturbance in the form of a fluctuation of the inflow volume. The input to real sewage treatment plants is subject to fluctuations, both due to the weather (dry spells, sudden rain showers, etc.) and to variations of the water consumption of the connected households and industries in the catchment area of the sewage treatment plant's sewage network.

The step sequence sets the setpoint input of the analog control module "SimFeed" to external. Then the external setpoint input is set to 40 m^3/h for 450 seconds. After 450 seconds the external setpoint is set to 70 m^3/h for 150 seconds and then it is set to 50 m^3/h for a duration of 600 seconds. At the end of the step sequence a setpoint of 30 m^3/h is set for a duration of 960 seconds. After working through the last step the system jumps back to the first step once again. The sequence chain remains active until it is manually deactivated or the system itself is deactivated. When it ends, switching takes place again to the internal setpoint, which is set to the operating point of 40 m^3/h.

Note

To determine the setpoint value and operating mode selection, the necessary parameterization is used, incl. the schematic representations from the function manual "SIMATIC Process Control System PCS 7 PCS 7 Advanced Process Library V8.1". You will find the function manual and further documentation under the following link: https://support.industry.siemens.com/cs/ww/en/view/59538371

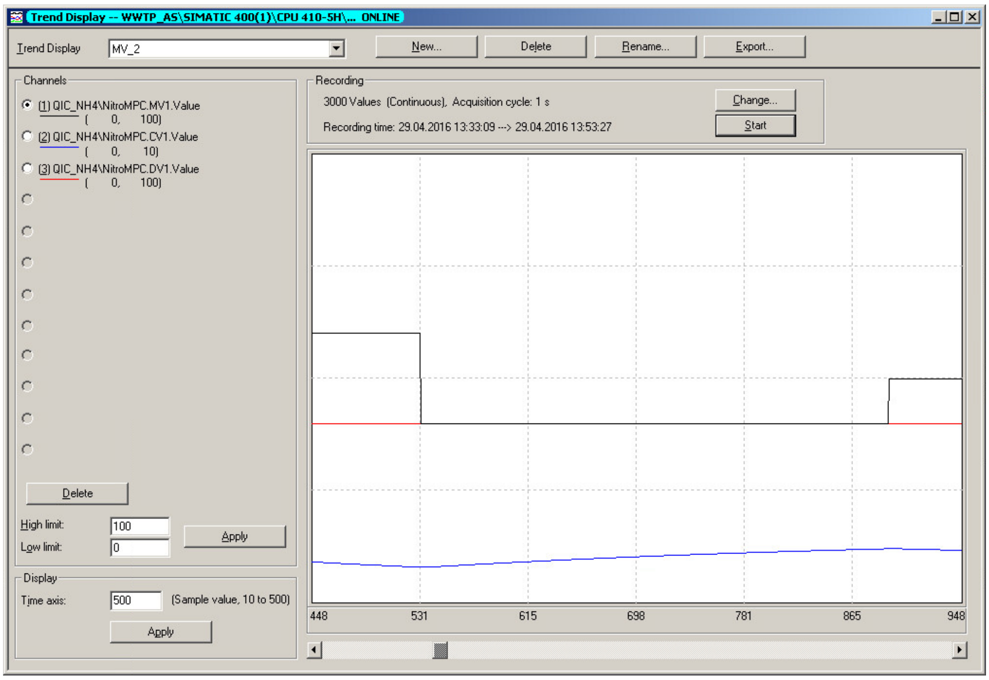
2.9 MPC Configuration

2.9.1 Generation of Identification Data

In order to generate identification data, the process is stimulated with manipulated variable steps and disturbance variable steps in manual mode of the MPC.
The measured data are recorded with the CFC trend chart recorder or WinCC TagLogging and then exported.

The stimulation of the manipulated variable and that of the disturbance variable take place in a separate manner (two trend curves) The stimulation of the manipulated variable in the present example is manual. Stimulation of the disturbance takes place via the SFC "Sim_Feed_SFC".

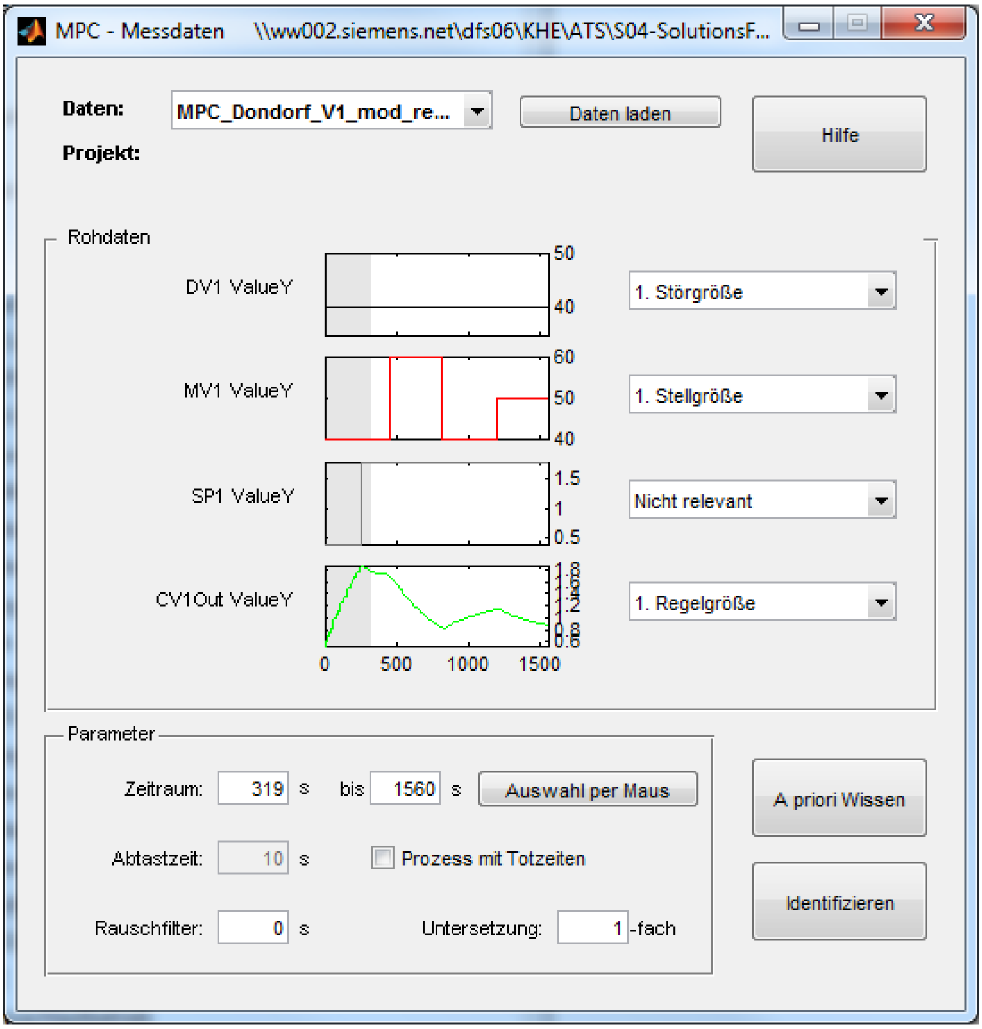
Figure 2-1 Recording of learning data with the CFC trend chart recorder



2.9.2 MPC Parameter Assignment and Commissioning

The parameters of the MPC are configured with the MPC Configurator, which is started from the CFC (mark MPC module, right-click/MPC configure...). This is done by loading the identification data, which has been previously recorded with the CFC trend display, to the MPC configurator. Two identification data sets can be loaded.

Figure 2-2: Learning data for MPC design: Stimulation of Disturbance variable

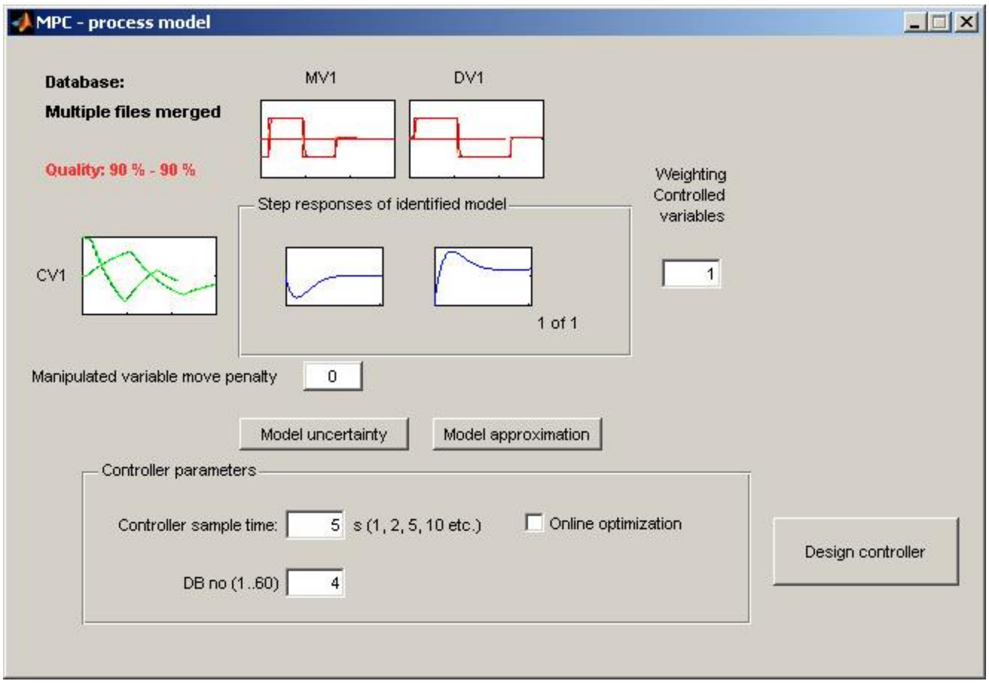


The corresponding meanings are assigned to the measured variables (manipulated, controlled or disturbance variable).

The time range shown above can be restricted in the "Step by Step" configuration. It is important to use an initial state which is nearly stationary (as good as possible) at the start of the time window for the identification. After all settings have been made, the process model is identified.

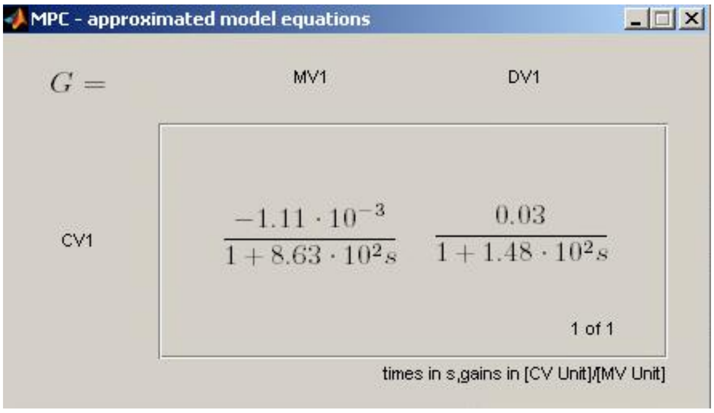
The process model is displayed as a result.

Figure 2-3 Identified process model



It is possible to show the step responses of the model and the approximated model equations.

Figure 2-4 Approximate model equations



An SCL source file is generated via the "Design controller" button. This is then inserted and compiled in the project. The generated data block is copied to the block folder of the S7 program and invoked by the MPC.

2.10 Process Key Performance Indicators (KPI)

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

1. Sheet: Blower electrical power (current energy consumption) [kW]:
   $P_{\text{ElecEnergy}} = P_{\text{MaxPower}} \times \left(\frac{S}{S_{\text{MaxPower}}}\right)^3$
   with nominal output P_{MaxPower}, revolution speed S and nominal revolution speed S_{MaxPower}.
2. Sheet: Electric power consumption in kWh
   $W_{\text{ElecEnergy}} = \frac{1}{3600} \times \int P_{\text{ElecEnergy}}\, dt$
   with the electric power of the blower $P_{\text{ElecEnergy}}$.
3. Sheet: Total nitrogen load in the TKN sequence in mg/l
   $TKN = QI_{NH_4-N} + QI_{NO_3-N}$
   with the concentration of ammonium-nitrogen QI_{NH_4-N} and nitrate-nitrogenQI_{NO_3-N}.

The sum of “Organic compound” Nitrogen and Ammonium (NH_4^+) is called **Total Kjeldahl Nitrogen** (TKN). The measured values of QI_NH_4 and QI_NO_3 always provide the concentration of ammonium-nitrogen or nitrate-nitrogen in the water and are therefore referred to as NH_4-N and NO_3-N, respectively.

Note To calculate the energy consumption, relevant technical data (rated power, etc.) has been pre-selected in the CFC chart "Characteristics_NC_O2". You can adapt this to your specific application.

3 Integration of the Unit Template

3.1 Preparation

The following instructions describe the integration of the Unit Template in a PCS 7 project where the following steps have been completed:

- Adjusting HW Config
- Configuration of the communication between AS and OS (NetPro)
- Settings for the hierarchy folders
- Usage of a uniform master data library

Procedure

1. Copy the file "109485916_ASUC_PROJECT_PCS7_V811.zip" to the configuration PC and then open the SIMATIC Manager.
2. Click on "File > Retrieve" in the menu bar and select the file "109485916_ASUC_PROJECT_PCS7_V811.zip". Then confirm with "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 "Technological view".
6. Open in parallel the project in which the biological stage is to be integrated.

3.2 Procedure

The following instructions describe how to integrate the Unit Template in your project. It has been refrained from describing the interconnection of each individual signal and the setting of individual parameters.

The open Unit Template and the opened target project in the technological view are a prerequisite.

Procedure

1. In the technological view of the biological stage, in the AS project select the hierarchy folder "BiologicalTreatment" and click on "Edit > Copy" in the menu bar.
2. Change over to the target project.
   In the AS project, select the hierarchy folder under which the biological stage is to be inserted and then click on "Edit > Insert" in the menu bar.

Note All plans, incl. the connections and simulation, are copied.

3. In the target project, select the AS project and in the menu bar click on "Extra > Technological hierarchy > Synchronize in multiproject".
   The dialog box for exporting the technological hierarchy will open.

4. Confirm the dialog with "OK" and also confirm the next dialog by clicking "OK". The technological hierarchy will be adapted in the OS project of the target project.
5. Compile and load the AS project and then compile the OS project.

Note You can use the process picture of the biological stage of a wastewater treatment plant with intermittent operating mode from the example project. You will find these in the project path <Projektpfad>\WWTP\WWTP_OS\wincproj\OS(1)\GraCS\BiologicalTreatment.Pdl>

In Chapter 6 of the application description "Equipment Modules for PCS 7 using the example of the Chemical Industry" under the following link: https://support.industry.siemens.com/cs/ww/en/view/53843373 where you will find detailed procedures, including notes on the following topics:

- Integration of equipment modules
  - Adapting parameters of an equipment module
  - Interconnecting an equipment module
  - Integrating a color palette in the OS
- Process interfacing
- Configuration of the PID controller

Note Observe the modified project path when integrating the color palette in the OS. The valid project path for the unit template "Biological Stage of a Wastewater Treatment Plant with intermittent operating mode" is <Projektpfad>\WWTP\WWTP_OS\wincproj\OS(1)\GraCS\UnitTemplates.xml>.

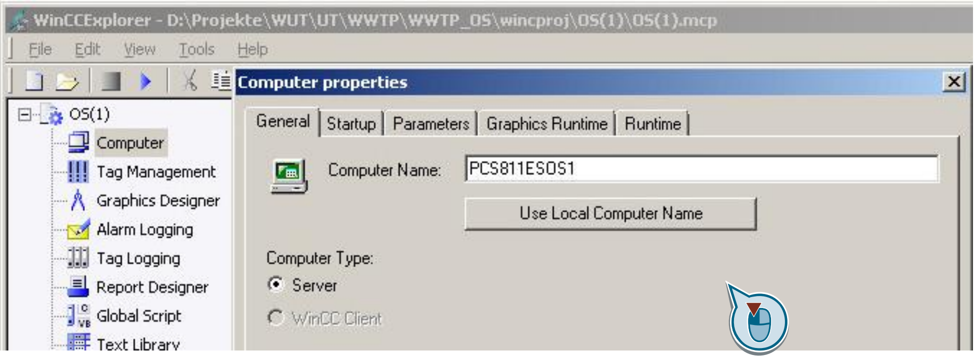
4 Starting the Unit Template

4.1 Preparation

The following instructions describe the commissioning of 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 HW Config.

Procedure

1. Copy the file "109485916_ASUC_PROJECT_PCS7_V811.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 "109485916_ASUC_PROJECT_PCS7_V811.zip". Then confirm with "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 with "OK" and then click on "Yes" in the dialog to open the project.
5. Right-click on "WWTP_OS > PCS811ESOS1" and click on the "Object properties" menu item.
6. Enter the name of your PC in the "Name" box of the “General” register. Accept the change by clicking on "OK".
7. Right-click on "WWTP_OS > Name PC-Station > WinCC Appl. > OS(1)" and then click on the menu command "Open object".
8. Confirm the "Configured server not available" dialog with "OK".
9. In the WinCC Explorer, open the characteristics of your computer and, in the opened Properties dialog, click on the "Use local computer name" button. Confirm the "Change computer name" message with "OK".



10. In the WinCC Explorer, click on "File > Exit" and in the subsequent dialog select "Terminate WinCC Explorer and close project".
    Then confirm with "OK".
11. Reopen the WinCC Explorer as described in step 7.
12. Double-click on “Tag management” to open it.
    Tag management opens in the WinCC Configuration Studio.
13. Right-click on "Tag management > SIMATIC S7 Protocol Suite > TCP/IP" and select the menu command "System parameters".

14. In the "Unit" register, check the "Logical device names" setting. If the "S7 PLCSIM" program is used, the device name "PLCSIM.TCPIP.1" is selected. If the device name has to be changed, the program must be restarted. Reopen the WinCC Explorer as described in step 7.

4.2 Commissioning

The following instructions describe how the Unit Template "Biological stage of a wastewater treatment plant with intermittent operating mode" is initialized.

For commissioning, SIMATIC Manager must be already open and the project must be selected in the component view.

Starting the simulation (S7 PLCSIM)

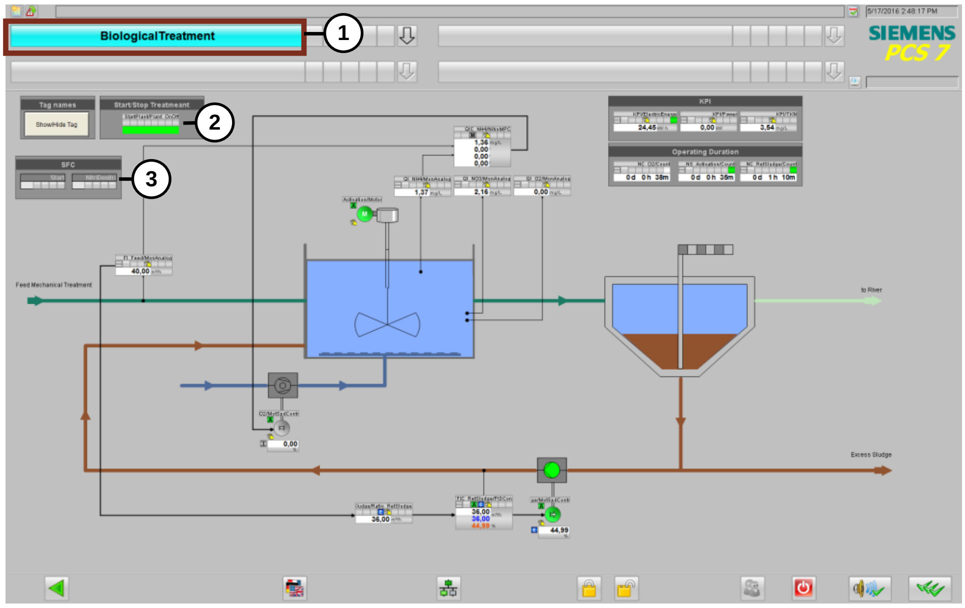
To start the simulation, proceed according to the following instructions:

1. Select "Extra > Simulate Modules" from the menu. The "S7 PLCSIM" dialog window opens.
2. In the "Open project" dialog, select the "Open project from file" option.
3. Select the file "BioTr.plc" from the project path "<Projektpfad\WWTP\WWTP_Prj>".
4. In the menu, select "Execute > Key-switch position > Run P".

Activate OS (WinCC runtime)

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

1. Right-click on "WWTP_OS > Name PC-Station > WinCC Appl. > OS(1)" and then click on the menu command "Open object".
2. To activate the OS (WinCC Runtime), select "File > Activate" in the WinCC Explorer menu.
3. Select the Unit template "BiologicalTreatment" in the image area (1).
4. Click on the module icon of the “NitriDenitri” SFC (3).
   The SFC faceplate opens.
5. Click the “Start” button of the SFC faceplate.
   The SFC starts.
6. Click on the module icon of the “Plant_OnOff” digital control module (2).
   The faceplate of the “Plant_OnOff” module opens.
7. Select the command “On” to start the display.
8. Binary control “Start system”



5 Principle of Operation

5.1 Overview

Some components of the biological stage can be controlled and monitored from the process picture. Furthermore, the process-specific key performance indicators can be changed in the lower-level "Simulation" picture. Based on their data, KPI calculations are then carried out.

The following scenario relates to the handling of the "Biological Stage" Unit Template. It describes disturbance variable compensation when changing the feed volume of wastewater.

5.2 Scenario – Disturbance Variable Compensation

Description

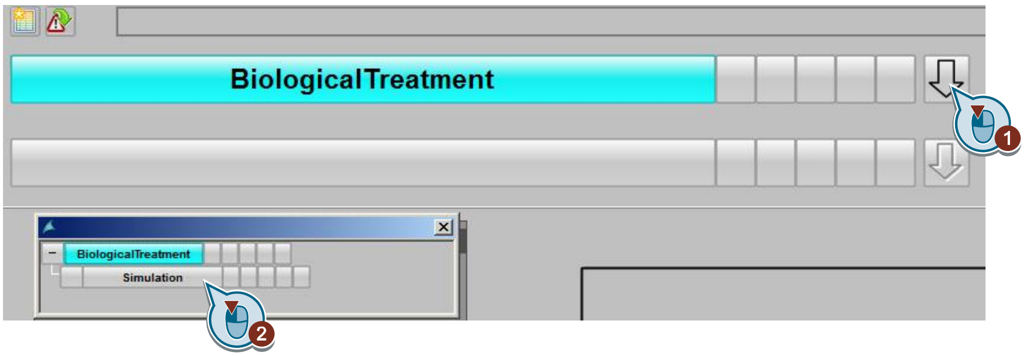
In this scenario, the controller reacts to fluctuations of wastewater feed flow.

It is assumed that the wastewater feed flow changes. With regard to the curve representation, the feed volume fluctuates more frequently than in reality, i.e. on average by 20 m³/s every 9 minutes.

The effect on the controlled variable is monitored in the curve recorder.

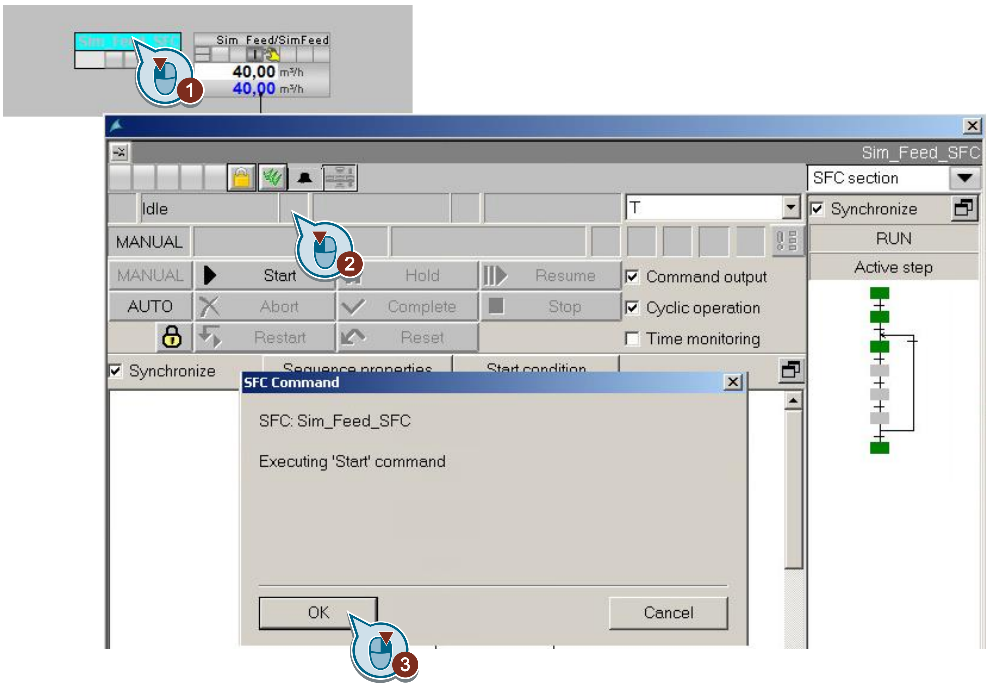
Procedure

1. In the OS, change to the lower-level "Simulation" picture.

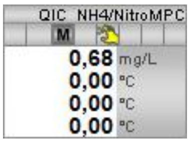


2. Click on the “Sim_Feed_SFC” block icon.
   The SFC chart faceplate opens.

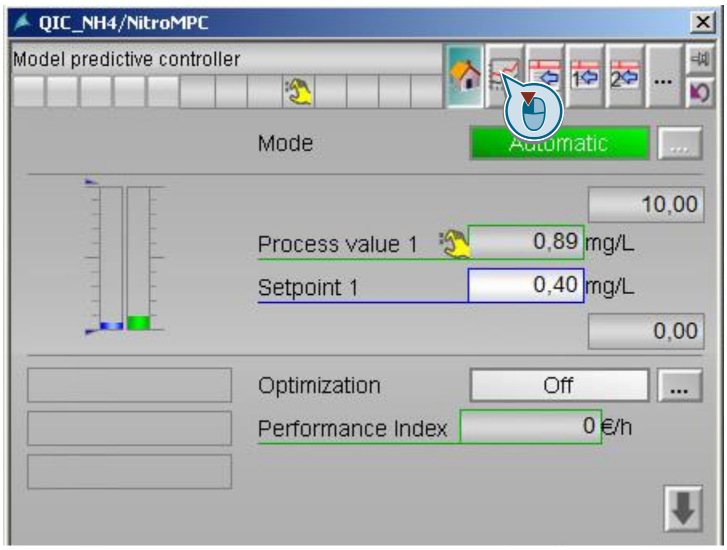
3. Click the "Start" button and then on "OK".
   The step sequence is started.



4. Switch to the "BiologicalTreatment" process picture.
5. Click on the module icon of the “QIC_NH4”.
   The MPC faceplate opens.



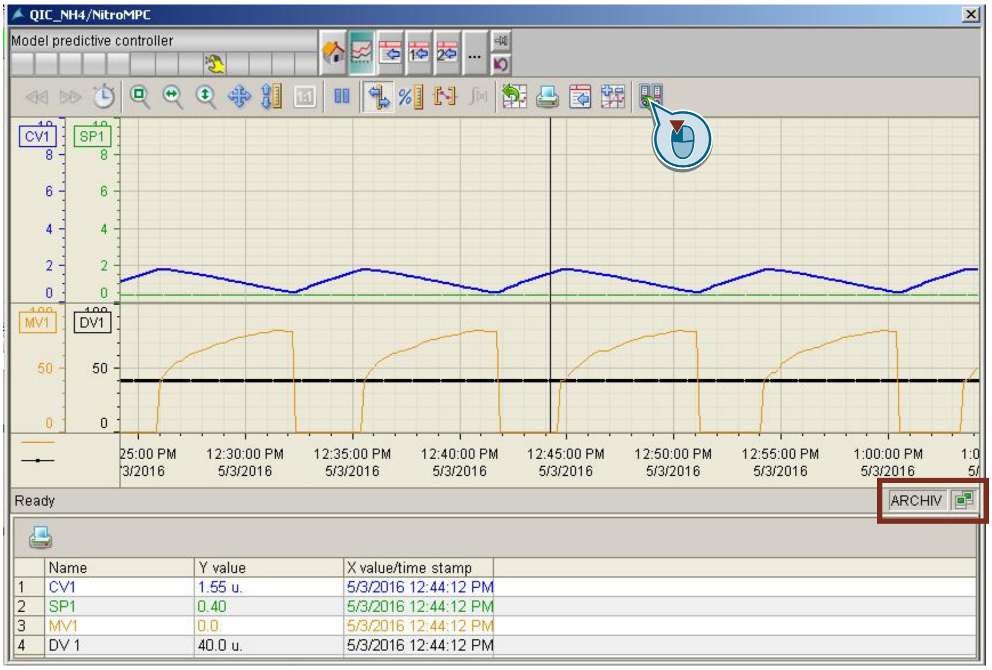
6. Click on the “Curves” button of the faceplate.



The trend view is displayed.

Note In addition to the MPC target, actual and manipulated variables, the trend display also shows the disturbance variable. The modified trend display is saved in the project under the name “@PG_APL_TrendMPC_WUT.pdl” Variables and colors can be adapted at will. In order to show the standard MPC trend view, enter the value “@PG_APL_TrendMPC.pdl” in the property “Trend > TrendPictureName” of the module icon MPC.

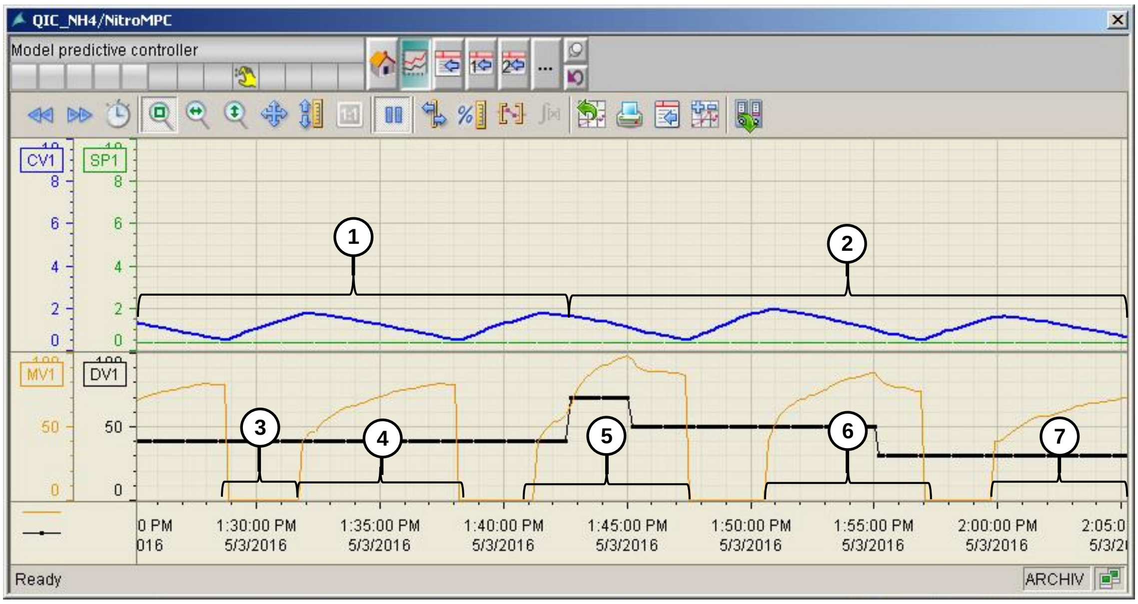
7. In the Trend view, click on the button for toggling between archive and online variables.



8. Stop the curve recorder after approx. 35 minutes in order to carry out an evaluation of the recorded data.

Note The individual controller values (SP, CV, MV and DV) are archived, so that you can select your own time ranges in the curve recorder.

Evaluation



In the upper part of the curve recorder the nominal value SP1 (green) is constantly just below the switchover threshold, i.e. below the targeted ammonium concentration to be reached at the end of the nitrification phase. Through the setpoint pre-filter in MPC channel 1 with a time constant of 300 s (= 5 mins) a trajectory is defined internally that slowly leads the setpoint in the direction of the switch-over threshold.

At a constant feed rate (DV1 black, time sector 1), during the nitrification phase (e.g. time sector 4) the blower revolution speed (MV1 orange) first rises steeply to around 40 %. Then the manipulated variable is only raised slowly and remains constant at the end of the nitrification phase. This way the MPC reaches the prescribed setpoint in the allocated time. During the denitrification phase (time sector 3) the blower speed is independent of the feed volume 0 %. After switching on the feed volume change, the wastewater feed volume is abruptly changed several times (time sector 2). If this change happens during the nitrification phase, the reaction of the MPC can be clearly seen (5 and 6).

After the feed volume change is engaged, two jumps (5) fall in the primary nitrification phase. The nitrification phase begins with a feed volume of 40 m³/h. After a steep rise of the revolution speed to around 40 %, the revolution speed continues to rise, but only slowly. When the feed volume jumps from 40 m³/h to 70 m³/h the MPC reacts increasing the blower speed to c. 98% in order to reach the setpoint in the allocated time. In the same nitrification phase the feed volume drops from 70 m³/h to 50 m³/h. The MPC adapts the blower speed and keeps it constant at around 87 %. The required setpoint value is reached in the allocated time.

In the subsequent nitrification phase the feed volume is 50 m³/h to start (6). Compared with the preceding nitrification phase the blower speed rises steeply to 60 %. It then rises further to around 85 %. Here, too, a steeper rise takes place compared to a feed volume of 40 m³/h. After around 2/3 of the nitrification phase the feed volume drops to 30 m³/h. The MPC reduces the blower speed and the required setpoint value is reached in the allocated time. In the last nitrification phase of the evaluation presented here (7) the feed volume is at 30 m³/h. Compared with the nitrification phases with a feed volume of 40 m³/h, the increase in the blower revolution speed is significantly less steep.

6 References

Table 6-1

	Topic
\1\	Siemens Industry Online Support https://support.industry.siemens.com
\2\	Download page for this entry https://support.industry.siemens.com/cs/ww/en/view/109485916
\3\	SIMATIC PCS 7 Overview (collection of links for FAQ, manuals, compendia, forum, application examples and multimedia) https://support.industry.siemens.com/cs/ww/en/view/63481413
\4\	Standard PCS 7 and S7 Water Templates for the water industry https://support.industry.siemens.com/cs/ww/en/view/78604785
\5\	Equipment Modules for PCS 7 using the example of the Chemical Industry https://support.industry.siemens.com/cs/ww/en/view/53843373
\6\	How do you do perform controller optimization with the PCS 7 PID tuner? https://support.industry.siemens.com/cs/ww/en/view/8031495
\7\	Fluidized Bed Dryer - Design of Model Predictive Control with Economical Steady State Optimization https://support.industry.siemens.com/cs/ww/en/view/61926069
\8\	How do you procure documentation for PCS 7 (including the PCS 7 Manual Collection)? https://support.industry.siemens.com/cs/ww/en/view/59538371
\9\	Whitepaper "Optimization of Wastewater Treatment Plants with Advanced Process Control" https://cms5.siemens.com/mcms/water-industry/en/ihre-wasseranlage/Seiten/abwasser.aspx
\10\	Multivariable Model Predictive Control - Distillation Column as an Application Example https://support.industry.siemens.com/cs/ww/en/view/37361208
\11\	PCS 7 Unit Template – Control of Biological of a Wastewater Treatment Plant with Upstream Denitrification https://support.industry.siemens.com/cs/ww/en/view/109478073

7 History

Table 7-1

Version	Date	Change
V1.0	07/2016	First edition