University Training Documents for SIMATIC PCS 7

Siemens Automation Cooperates with Education | 02/2020

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Learn-/Training Documents PCS 7
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MODULE 2

- P02-01 HMI generation
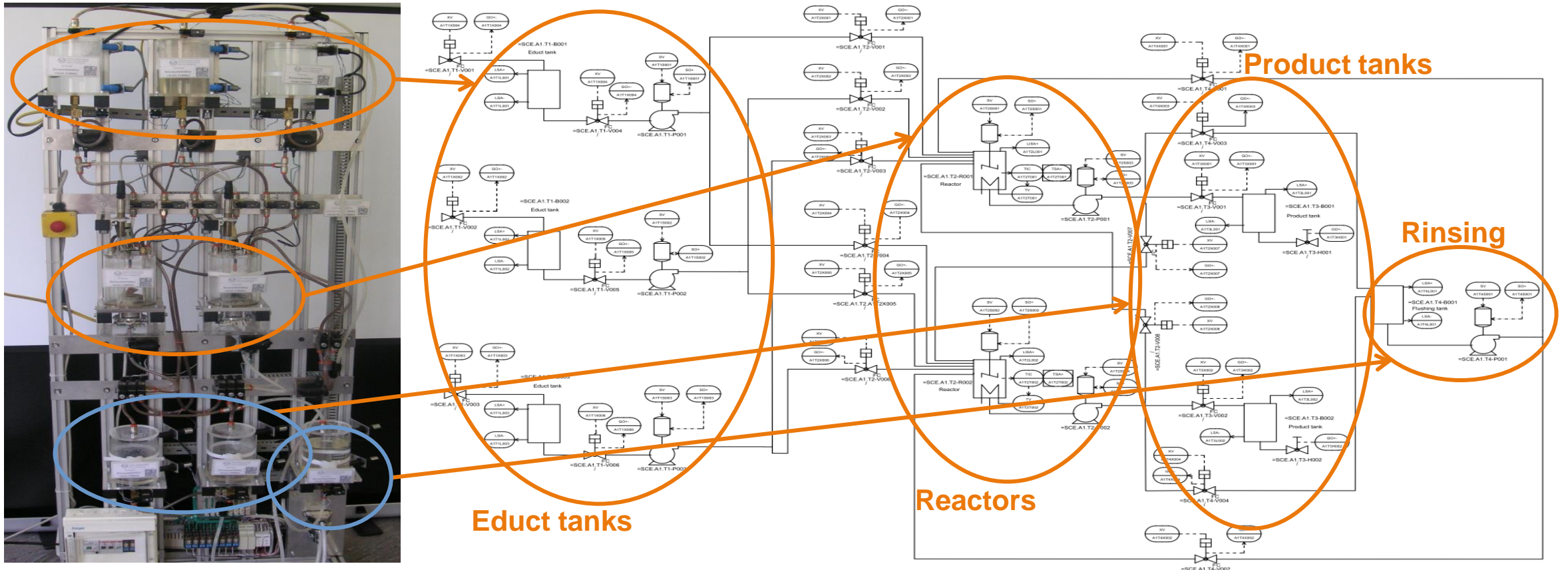- P02-02 Alarm engineering
- P02-03 Archiving and trend reporting

Objectives

- Classification of process plants

- P&ID of the laboratory plant

- Interlocks and recipes for the laboratory plant

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Classification of process plants

- Classification by the number of basically different products
  - Single product process plant
  - Multi-product process plant

- Classification according to the physical structure of the plant
  - Single-train process plant
  - Multi-train process plant
  - Multi-train & multi-path process plant

- Laboratory plant as learning example
  - Multi-product, multi-strand & multi-path plant
  - Hierarchical breakdown into 4 plant units

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P&ID of the laboratory plant

Interlocks and recipes

- Safe operation of the plant requires monitoring of process interventions

- Requirements for the laboratory plant:

  - Control of actuators only when the main power switch is on and EMERGENCY OFF is unlocked

  - Protection of the tanks against overflow

  - Prevent the intake of air at the pumps

  - Pumps must not work against closed valves

  - …

- Production of a product requires a standard operating procedure

- Recipe for laboratory plant:

  - 350 ml of educt 3 to reactor 1 and 200 ml of educt 1 to reactor 2

  - Heating of reactor 1 up to 25 ˚C and 150 ml of educt 2 to reactor 2
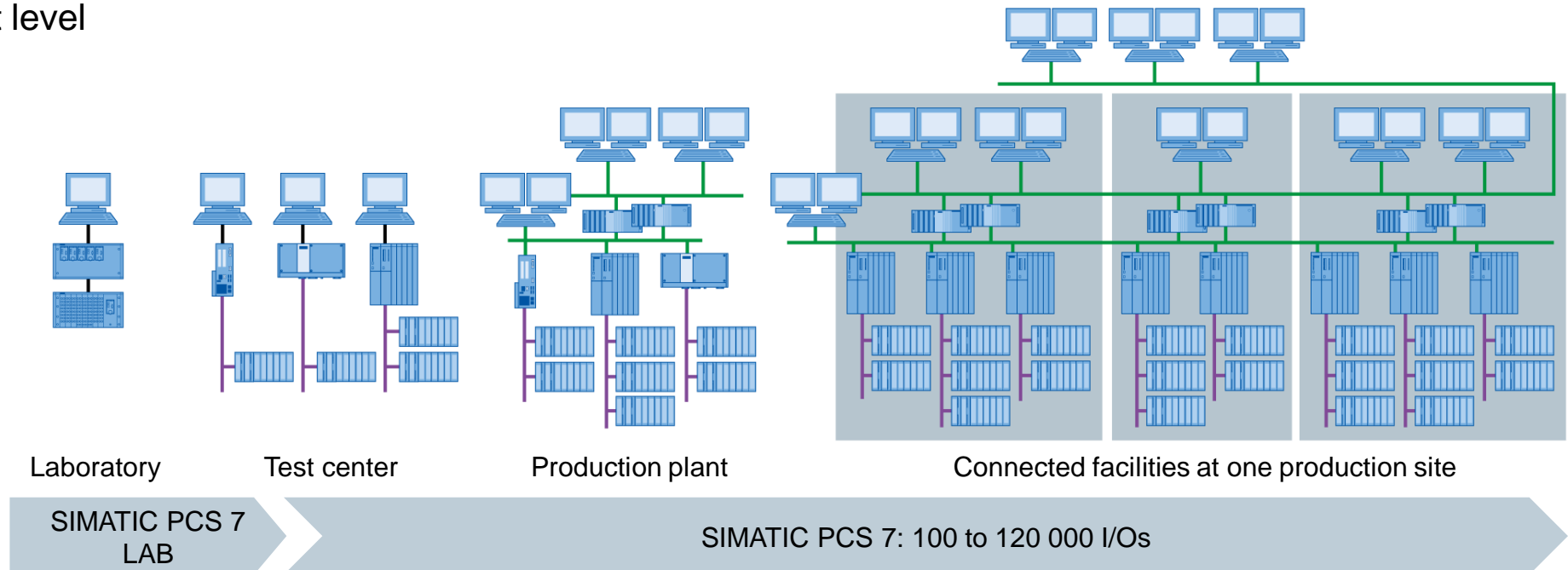
  - …

Objectives

- Theory
  - Distributed structures
  - Connection to the process
  - Operating principle of a programmable logic controller (PLC)

- Step-by-step instruction
  - Creating a project
  - Configuring the hardware
  - Configuring the communication

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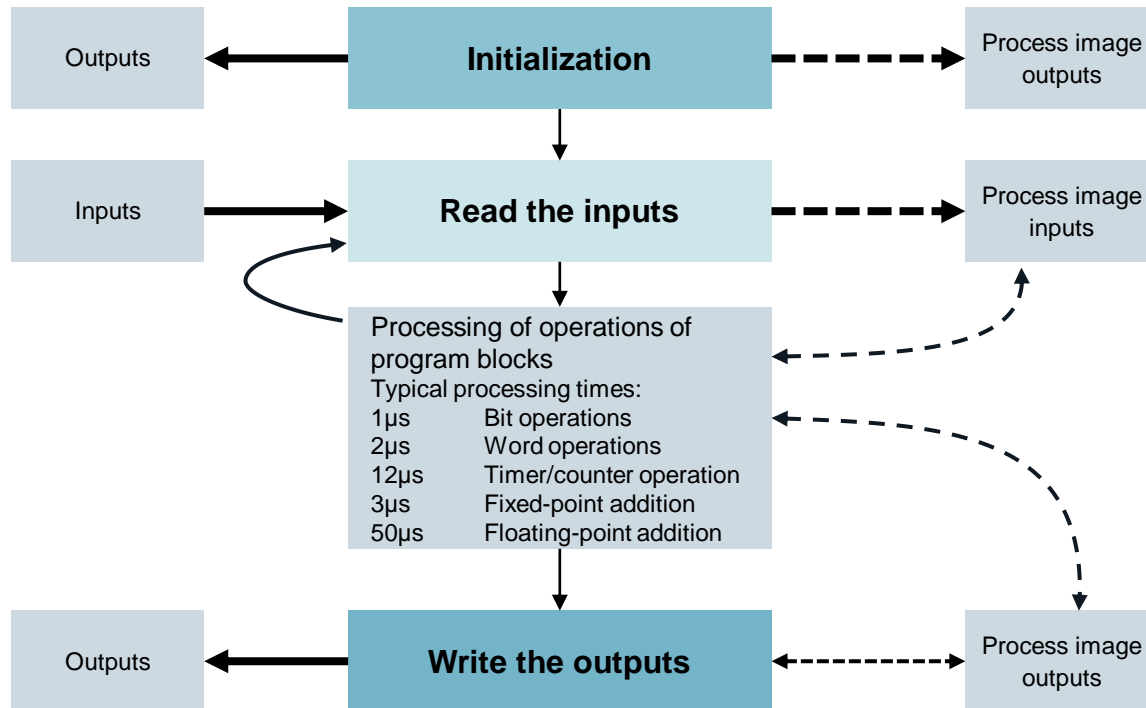## Distributed structures of process control systems

- Special structures lead to scalable process control systems
- Structures are component based and can be easily expanded
- Typical structure:
  - Process management level
  - Control level
  - Field level

Laboratory   Test center   Production plant   Connected facilities at one production site

SIMATIC PCS 7 LAB

SIMATIC PCS 7: 100 to 120 000 I/Os

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Connection to the process

- Two typical ways to connect sensors and actuators to the process control system
  - Directly via a bus system (intelligent devices)
  - To a signal module via a standard electrical signal

- Signal modules for
  - Binary signals: DI/DO modules (DI .. digital input, DO .. digital output)
  - 1 bit of memory required per signal

  - Analog signals: AI/AO modules (AI .. analog input, AO .. analog output)
  - 16 bits of memory required per signal
  - Resolution can still be less, for example, 12 bits
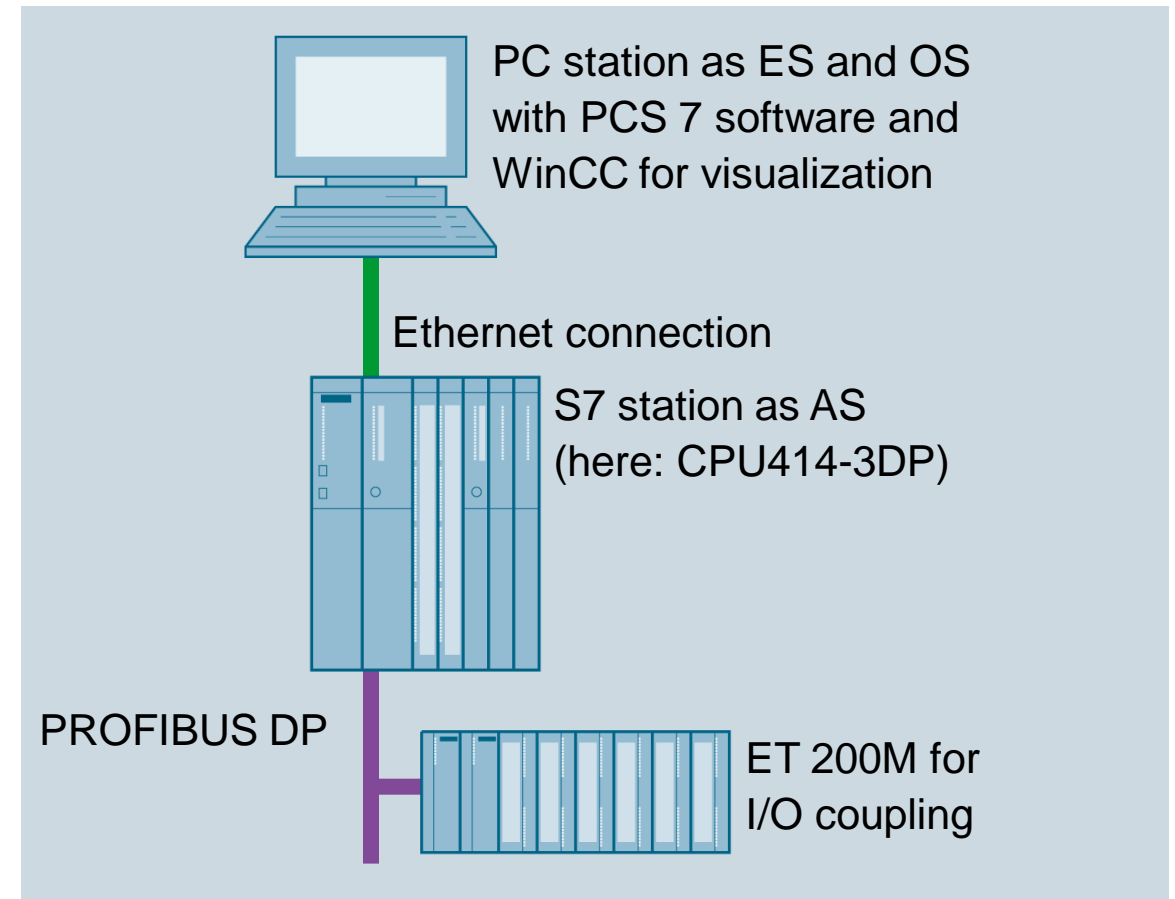
Operating principle of the PLC

- Component on control level typically is a PLC
- Input and output signals are read and written cyclically and buffered in the process image
- Consistency of signals during program processing by accessing process image

Legend:
→ Access to hardware
⇢ Access to process image
→ Processing sequence

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Hardware configuration of the laboratory plant

- AS
  - PS
  - CPU (with PROFIBUS)
    - ET 200M (with PROFIBUS)
      - 7x DI
      - 3x DO
      - 1x AI
      - 1x AO
    - CP (with Ethernet)
- OS
  - PC (with Ethernet)

PC station as ES and OS with PCS 7 software and WinCC for visualization

Ethernet connection

S7 station as AS (here: CPU414-3DP)

PROFIBUS DP

ET 200M for I/O coupling

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Objectives

- Theory
  - Structuring the laboratory plant
  - Deriving the visualization
  - Plant hierarchy (PH) and structure of visualization

- Step-by-step instruction
  - Opening the plant view
  - Creating the plant hierarchy
  - Basic settings of the plant hierarchy

Structuring the laboratory plant

- Structuring based on function aspect

- Hierarchical breakdown into units

  - Unit 1: educt tanks

  - Unit 2: reactors

  - Unit 3: product tanks

  - Unit 4: rinsing

- Design of an identification system according to ISA-88

  - Process cell: A1

  - Unit: T1 .. T4

    - Equipment module: B001, …, B003, R001, …

    - Control module: pump, valve, level, agitator, …
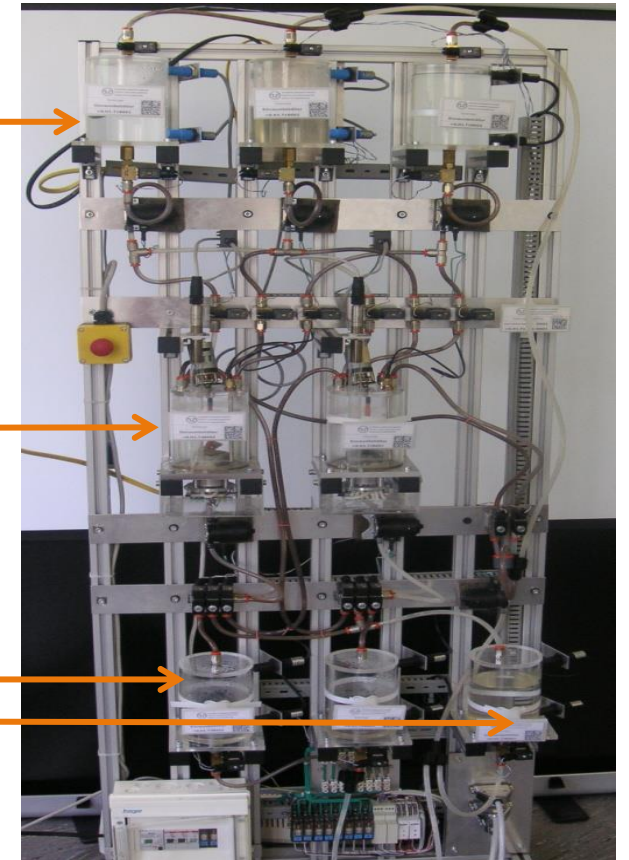
Deriving the visualization

- Deriving the visualization in the operator system (OS) through the following steps:
  - Structuring the laboratory plant
  - Creating the plant hierarchy
  - Selection of a hierarchy level as OS area
  - Running the generating process (see P02-01 HMI generation)

- All hierarchy levels below the level defined as OS area can be displayed automatically
  - Area identification
  - Navigation hierarchy
  - Operating icons for implemented function blocks
  - Group alarms

Plant hierarchy and the effect on visualization
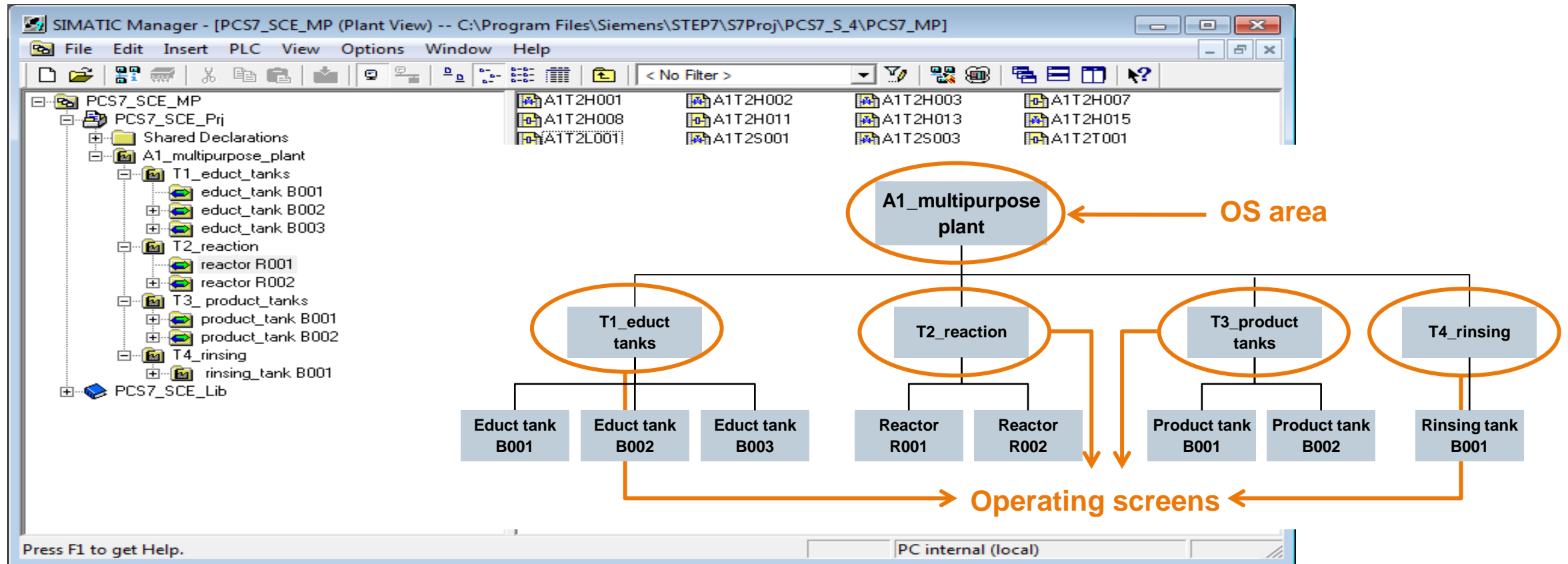
Objectives

- Theory
  - Terminology of individual drive functions (IDF)
  - Individual drive functions in PCS 7
  - Individual drive function Motor

- Step-by-step instruction
  - Creating symbol tables
  - Creating CFC for IDF Motor
  - Testing the IDF

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Individual drive functions (IDF)

- Hierarchical structuring of the plant according to DIN EN 61512

  - Level 0: Control module

- Control module is a recurring element

  - Project wide

  - For more than one project

- Reusing possible

  - Advantages:

    - Parameterization instead of programming

    - Tested functionality

    - Consistent handling and visualization

- Type definition of control modules

  - e. g. motor, valve, …
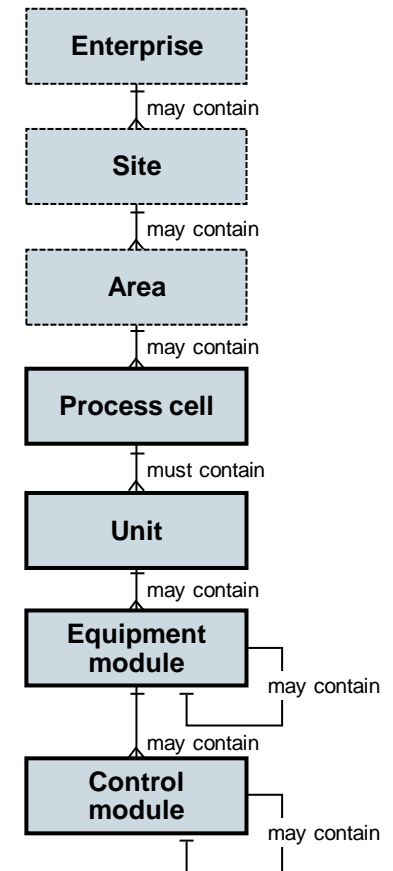
Individual drive functions in PCS 7

- Function blocks as object-oriented model of an equipment module
  - e. g. motors and valves
- Functions:
  - Control and control mode
  - Protection and monitoring functions
  - Operator control and visualization functions
  - Messaging and alarm functions
- Function block as object-oriented model of a (measuring) signal
  - e.g. digital output, digital input, analog output, analog input
- Functions:
  - Scaling the digital value to the physical value range
  - Monitoring the signal quality

Individual drive function MotL (PCS 7 Advanced Process Library)

- Function block MotL

- Used for controlling pumps/agitators in the laboratory plant

- Properties:

  - Control with one control signal (on/off)

  - Monitoring function through running feedback

- Advantages:

  - No programming of the control, protection and monitoring functions

  - Uniform parameters

  - Uniform visualization (see P02-01 HMI generation)
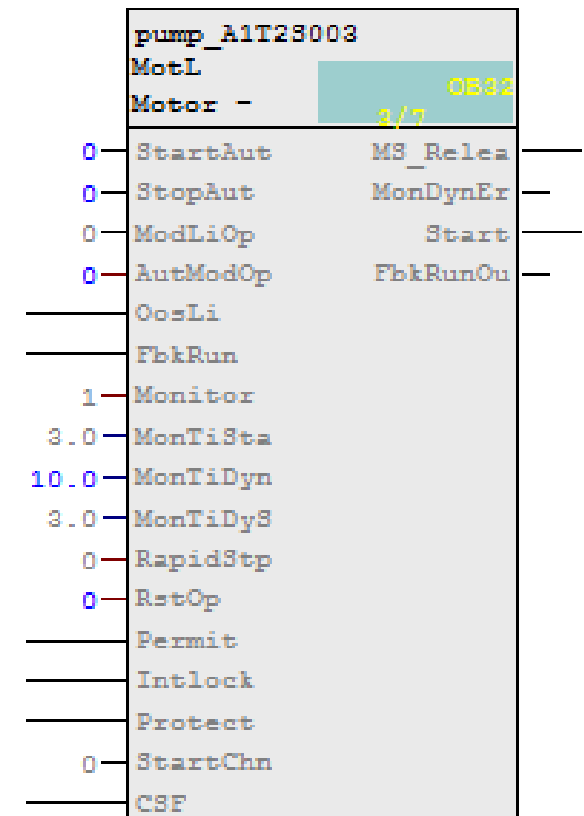

```
pump_A1T23003
MotL
Motor -                        OB32
                               3/7
   0 — StartAut      MS_Relea —
   0 — StopAut       MonDynEr —
   0 — ModLiOp          Start —
   0 — AutModOp      FbkRunOu —
      — OosLi
      — FbkRun
   1 — Monitor
 3.0 — MonTiSta
10.0 — MonTiDyn
 3.0 — MonTiDyS
   0 — RapidStp
   0 — RstOp
      — Permit
      — Intlock
      — Protect
   0 — StartChn
      — CSF
```

Implementation of a pump of the laboratory plant

- Pump SCE.A1.T2-P001 for draining the reactor content
- Pump is driven by a motor
- Motor has the following signals:
  - Signal for control
  - Signal for running feedback
- Template from PCS 7 AP library
  - MotorLean

=SCE.A1.T2-R001
Reactor

SO+
A1T2S003

=SCE.A1.T2-P001

M

SV
A1T2S003
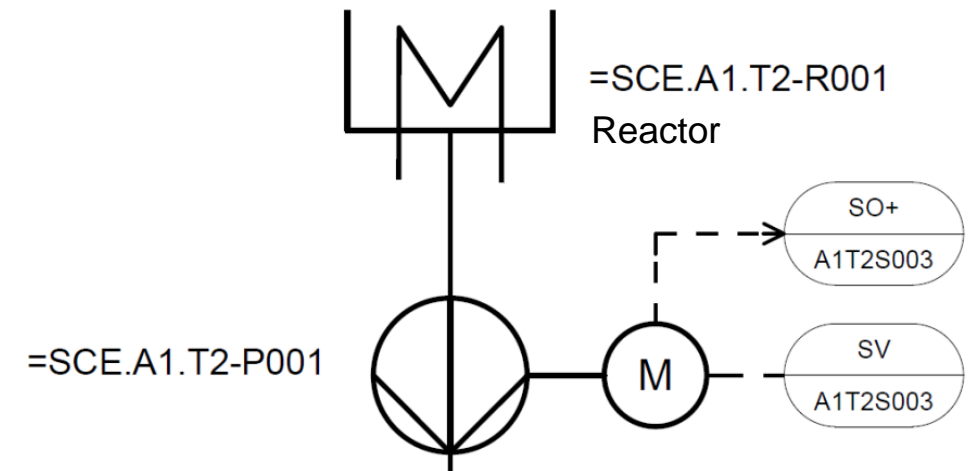
Symbol	Address	Data type	Symbol comment
A1.T2.A1T2S003.SO+.O+	I 1.3	BOOL	pump outlet reactor R001 feedback on
A1.T2.A1T2S003.SV.C	Q 3.4	BOOL	pump outlet reactor R001 actuating signal

Objectives

- Theory
  - Functional safety with tools of process control engineering (PCE)
  - Standard circuits for functional safety
  - Design of an interlock for the laboratory plant

- Step-by-step instruction
  - Creating CFC for manual operation of the motor
  - Adding the interlock for motor in CFC
  - Interconnections between CFCs

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Functional safety with tools of process control engineering (PCE)

- Protection of process plants against fault states
- In reference to the process variables, there are 3 value ranges

process value

Curve 1   Curve 2   Curve 3

Non-intended use

Non-permissible deviation

Non-PCE protective device responds

Event-preventing PCE protective responds

Intended use

Permissible deviation

Process-related limit value

Limit value of protective equipment

Acceptance region

PCE monitoring device responds

Limit value of monitoring device

time

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Design of the interlock for the pump of the laboratory plant

- The pump may only be turned on when the main switch of the plant is switched on and the Emergency Off switch is unlocked

- The pump must not take in air, which means the level of the reactor has to be at least 50 ml

- The pump must not work against closed valves, which means at least one valve has to be open

Symbol	Address	Data type	Symbol comment
A1.A1H001.HS+-.START	I 0.0	BOOL	Switch on main power switch
A1.A1H002.HS+-.OFF	I 0.1	BOOL	Activate EMERGENCY OFF
A1.T2.A1T2L001.LISA+.M	IW 72	WORD	Actual value level reactor R001
A1.T2.A1T2X007.GO+-.O+	I 66.3	BOOL	Open/Closed valve … feedback signal
A1.T3.A1T3X001.GO+-.O+	I 67.4	BOOL	Open/Closed valve … feedback signal
A1.T4.A1T4X003.GO+-.O+	I 68.2	BOOL	Open/Closed valve … feedback signal

Standard circuits for functional safety

- Replacement of analog value A1.T2.A1T2L001.LISA+.M by a binary value that is the result of the comparison with 50 ml
- Function table for design of combinatorial circuit

A1T2L001 > 50ml	A1T2X007	A1T3X001	A1T4X003	LOCK
x	x	x	x	0
x	x	x	x	0
0	x	x	x	0
x	0	0	0	0
1	1	x	x	1
1	x	1	x	1
1	x	x	1	1

- Result according to conjunctive normal form (CNF) is used for the interlock of the pump

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Objectives

- Theory
  - Structure of a control loop
  - PID controller
  - Temperature control of the laboratory plant
- Step-by-step instruction
  - Parameterization of a continuous controller
  - Output of the analog manipulated variable as a binary signal with a pulse generator

Structure of a control loop

- Process variables have to keep or achieve certain values
  - Disturbance behavior: A certain value has to be kept in spite of disturbances
  - Response to setpoint changes: Setpoint shall be achieved in a dynamic and stable manner
- Control loop works as follows:
  - Process variable or controlled variable is measured by a sensor
  - Setpoint minus measured value equals the system deviation
  - Controller calculates a value of the manipulated variable for the actuator on the basis of the deviation
  - Actuator acts on the system

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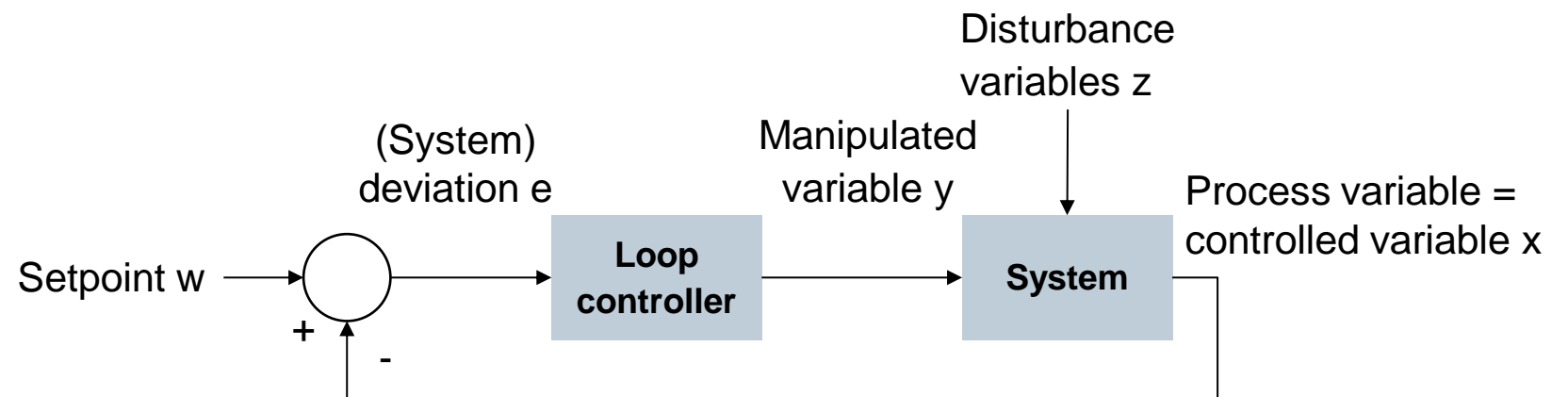
PID controller

- Control algorithm calculates the value of the manipulated variable from the deviation

- Process industry uses the PID algorithm to 95%

  - P stands for proportional

    - Current manipulated variable value depends only on the current deviation

  - I stands for integral

    - Current manipulated variable value depends on the sum of the last deviations

  - D stands for differential

    - Current manipulated variable value depends on the change of the deviation

- Only three parameters (gain, integral-action time and derivative-action time) have to be adjusted

- Practical tuning rules exist for processes without dominant dead times

  - Ziegler and Nichols method

  - Chien, Hrones and Reswick

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Temperature control of the laboratory process cell

- Control loop
  - Process variable/controlled variable is A1.T2.A1T2T001.TIC.M
  - Manipulated variable is A1.T2.A1T2T001.TV.S
  - Setpoint is
    - Determined by recipe
    - Determined by operator
    - Interlocked
- Interlock conditions
  - Level in the reactor has to be at least 200 ml
  - Temperature must not exceed 60 ° C
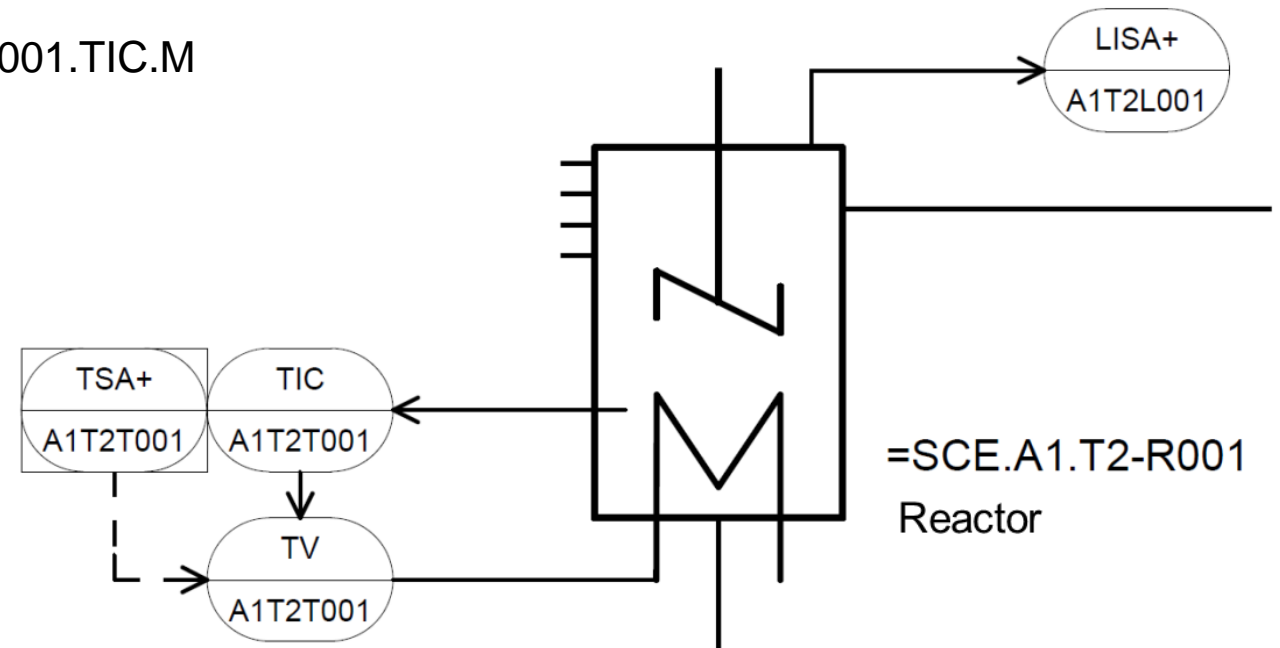
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Objectives

- Theory
  - Design of complex systems
  - Process tag type
  - Model

- Step-by-step instruction
  - Importing plant design data using the Import/Export Assistant
  - Importing plant design data in the process object view
  - Duplicating charts by creating process tag types/models

Design of complex systems

- Three general design principles
  - Principle of hierarchical arrangement
    - Plant hierarchy
  - Principle of modularization
    - Scope and complexity of blocks, CFC and SFC
  - Principle of reuse
    - Process tag types and models
- Reuse also implies
  - Use of proven solutions (standards)
  - Central modifiability
  - Tested implementation

Process tag types and models

- Process tag type (CFC) – corresponds to control module level
- Model (entire hierarchy) – corresponds to equipment module or unit level

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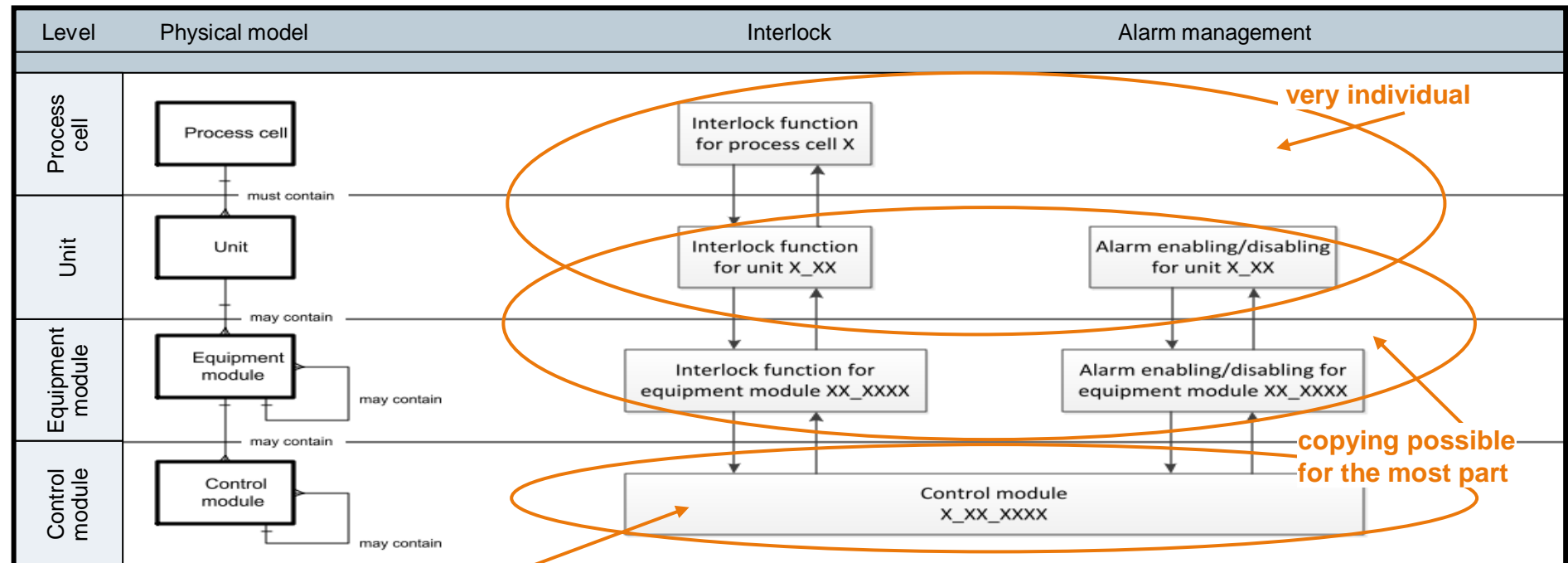
Process tag type and model of the laboratory plant

- Selecting similar control modules
  - Pumps
    - A1T1P001, A1T1P002, A1T1P003 and A1T4P001
    - A1T2P001 and A1T2P002
  - Valves
    - A1T1V001, A1T1V002, A1T1V003, .. , A1T1V006
    - ...
- Selecting similar equipment modules
  - Tanks
    - A1T1B001, A1T1B002 and A1T1B003
    - A1T2R001 and A1T2R002
    - A1T3B001 and A1T3B002

Objective

- Theory

  - Structure of sequential function charts

  - Design of a sequential control system

  - Recipe of the laboratory plant

- Step-by-step instruction

  - Creating and editing a sequential function chart (SFC)

 - Linking of SFC and CFC

  - Testing the SFC

Structure of sequential function charts

- Alternating sequence of steps and transitions
  - First step: initial step
  - Lasat step: final step
- Structures:
  - Unbranched sequential function chart
  - Alternative branches
  - Parallel branches
- Illegal structures:
  - Uncertain sequence – accessibility not assured
  - Partial deadlock – internal infinite loop
  - Total deadlock – no permissible step enabling condition
- One time or cyclical processing of sequential function chart is possible

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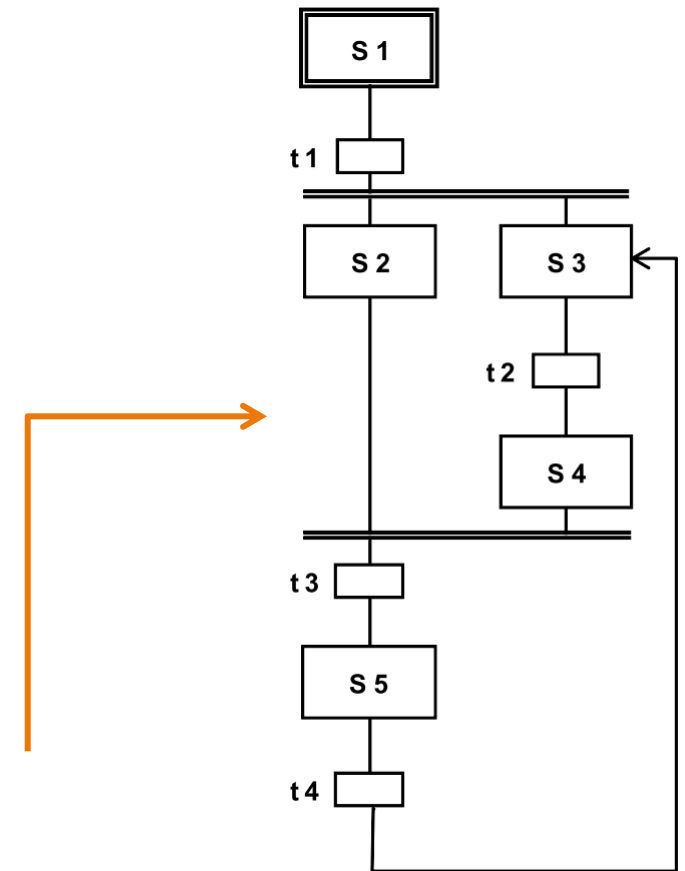
Design of a sequential control system

- Proven design method for sequential control systems
  - State diagrams
    - Connected and directed graph
    - States shown as circles – can be linked with actions
    - State transitions shown as arrows – can be subject to transition conditions
  - Petri nets
    - Consists of locations and transitions
    - Locations shown as circles
    - Transitions shown as rectangles/bars
   - Parallel sequences can be displayed
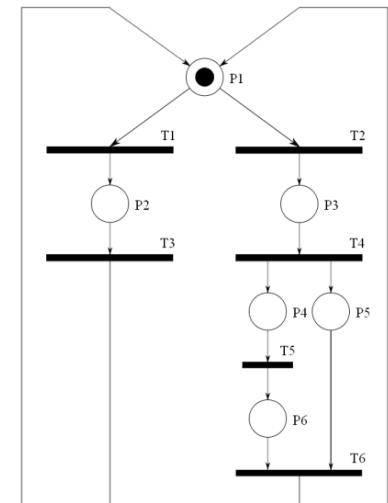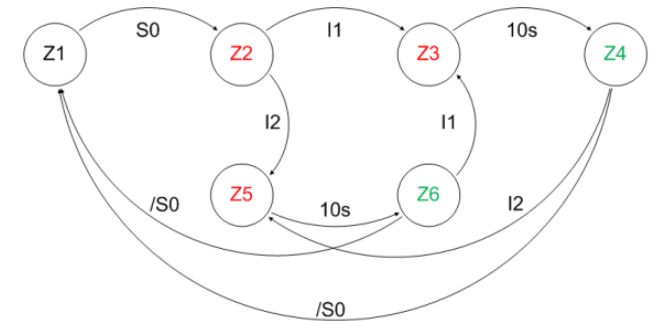
Recipe of the laboratory plant

- First, 350 ml are to be drained from educt tank A1.T1.B003 into reactor A1.T2.R001 and at the same time 200 ml from educt tank A1.T1.B002 into reactor A1.T2.R002.

- When reactor A1.T2.R001 is filled, the liquid is to be heated to 25 ° C with the agitator switched on.

- When filling of reactor A1.T2.R002 is finished, 150 ml from educt tank A1.T1.B001 is to be added to reactor A1.T2.R002. When this is finished, the agitator of reactor A1.T2.R002 is to be switched on 10 s later.

- When the temperature of the liquid in reactor A1.T2.R001 has reached 25 ° C, the mixture is to be pumped from reactor A1.T2.R002 to reactor A1.T2.R001.

- Now, the mixture in reactor A1.T2.R001 is to be heated to 28 ° C and then drained into product tank A1.T3.B001.
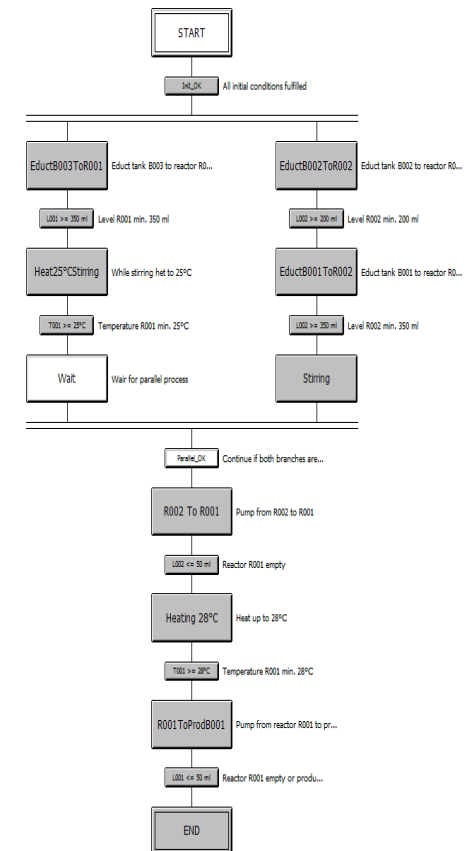
Objectives

- Theory
  - Concepts of representation
  - HMI generation in PCS 7
  - Graphics of the laboratory plant

- Step-by-step instruction
  - Generating the operator station (OS) in SIMATIC Manager
  - Configuration environment WinCC
  - Creating pictures with the Graphics Designer

Concepts of representation

- Important aspects of representation
  - Organization of what is to be represented
  - Degree of filling
  - Coding
  - Conspicuousness
  - Consistency
- Basic structure of display area according to VDI 3699
- Flowcharts
  - Process control flowcharts
  - Process flowcharts
    - Basic flowchart, process flowchart, P&ID flowchart

Message line **Overview area**

Window **Working area**

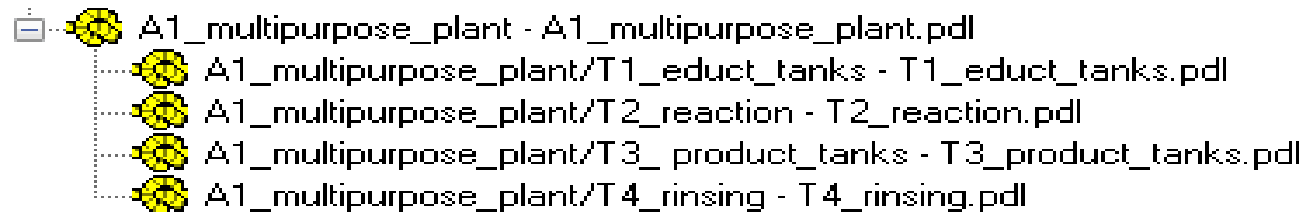**Key area**

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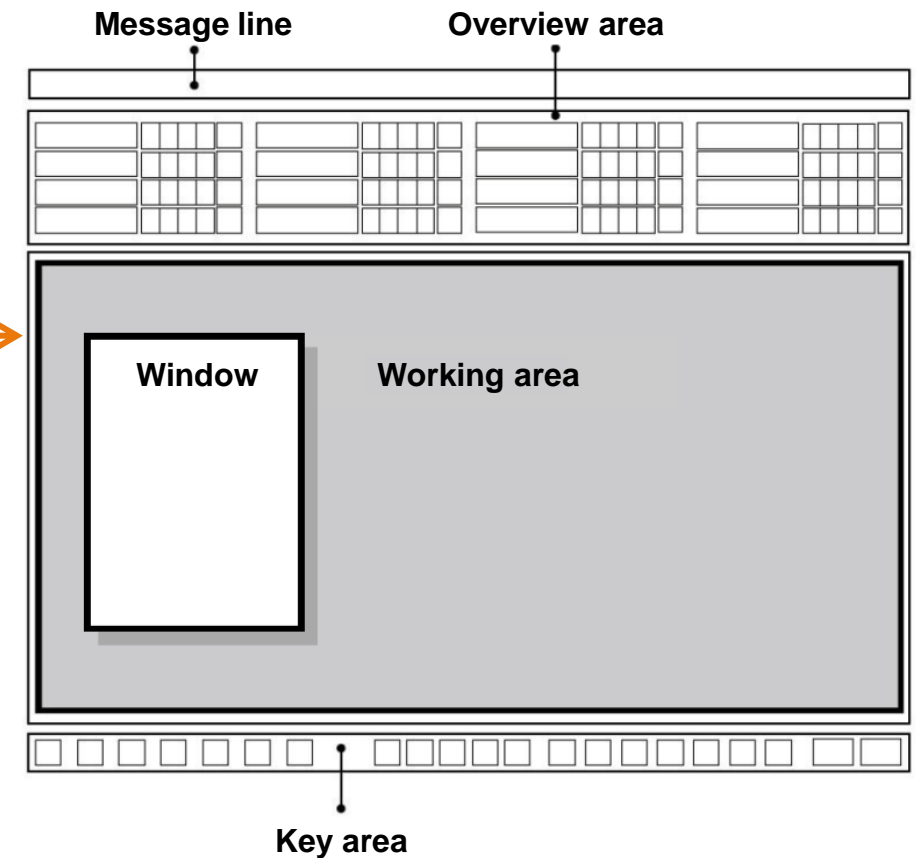
HMI generation in PCS 7

- Picture hierarchy can be derived directly from plant hierarchy
  - Creating a picture in the corresponding levels
- Using the block icons of templates
  - Deriving block icons from the plant hierarchy
- Configuring different OS areas
  - For example, unit T1 is monitored by operator 1, T2 to T4 by operator 2
- Monitor configuration
  - Representation for different resolutions, numbers and arrangement of monitors
- Graphics Designer
  - Drawing the process pictures (static elements)
  - Linking dynamic elements with the process tags

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Module 2 P02-01 HMI generation

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Graphics of the laboratory plant

- Hierarchy includes level 1 and 2

```
A1_multipurpose_plant - A1_multipurpose_plant.pdl
    A1_multipurpose_plant/T1_educt_tanks - T1_educt_tanks.pdl
    A1_multipurpose_plant/T2_reaction - T2_reaction.pdl
    A1_multipurpose_plant/T3_ product_tanks - T3_product_tanks.pdl
    A1_multipurpose_plant/T4_rinsing - T4_rinsing.pdl
```

- Overview screen
  - Displays all units
  - Displays the most important information
  - Abstract
- Area display
  - Display of a unit
  - Display of faceplate icons of motors and valves
  - Display resembling the P&ID

Objectives

- Theory
  - Message systems
  - Alarms and messages
  - Alarm management in PCS 7

- Step-by-step instruction
  - Integration of monitoring and alarm blocks
  - Message system of WinCC
 - Display of alarms and warnings in the operator station (OS)

Message system, alarms and messages

- Interface between process and operator
  - Early detection of deviations from the desired state
  - Specific interventions to restore the desired state
- Alarm display or report of occurrence of an event that requires immediate action of the operator
- Message display or report of occurrence of an event that requires no immediate action of the operator
- Properties for selection of alarms
  - Relevant
  - Unambiguous
  - Timely
  - Prioritized
  - Comprehensible

Response time	Potential effect		
	Plant shutdown	Loss of production	Delay in production
< 5 min	High	Medium	Low
5 - 20 min	Medium	Low	Low
> 20 min	Low	Low	Low

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Alarm management in PCS 7

- Function block for generating messages

  - Block icons for display of alarm states

- Group alarms along the plant hierarchy
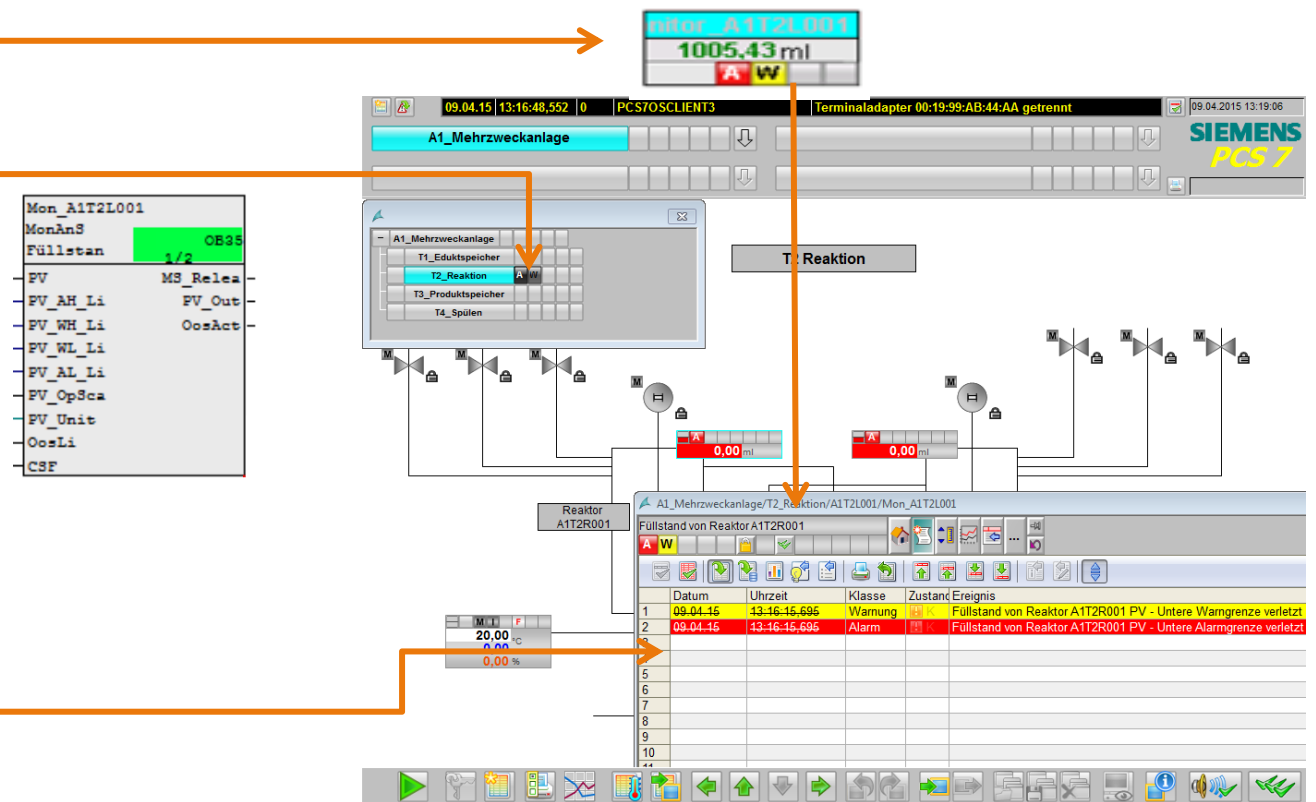
- Display and management of message lists

Alarms for the laboratory plant

- Monitoring of level

- Monitoring of temperature

- Using MonAnS block (FB 1912) from Monitor folder of the PCS 7 Advanced Process Library V80
  - Monitoring a measured value (analog signal)
  - Adjustable parameters
    - Warning limit (high/low)
    - Alarm limit (high/low)
- Display of faceplate icon
  - In unit T2_reaction
  - Positioning and compiling
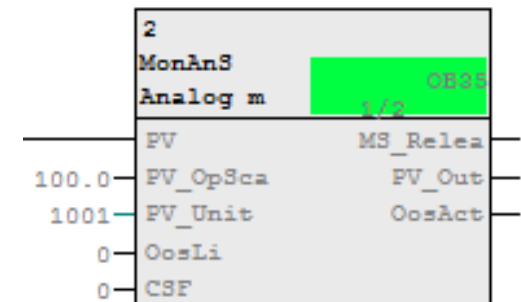
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Module 2 P02-03 Archiving and trend reporting

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Objectives

- Theory
  - Goals of archiving
  - Archiving on the OS server
  - Short-term and long-term archiving
  - Trend reporting

- Step-by-step instruction
  - Activating archiving in CFC
  - Archive settings of the OS server
  - Trend groups and reports

Goals of archiving

- Why must process data and events be saved?

  - **Legal requirements:** logging of faults, verification for compliance with requirements, gapless tracking of the production cycle for product liability purposes

  - **Process management:** statistics of production data, optimization of production, increasing of performance, optimization of material and manufacturing costs

  - **Safety:** analysis of production data for adapting production parameters, in particular limits and response times, verification of functional safety when testing interlocks and EMERGENCY OFF functions

  - **Performance:** increasing of performance of the process database, data backup

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Archiving on the OS server

- Archiving on the OS server = short-term archiving

  - Process values

    - Slow cycle →————→ Tag logging slow

    - Fast cycle →————→ Tag logging fast

  - Messages/events →————→ Alarm logging

30 bytes/value

✚

max. 30 bytes/value

✚

200 to 400 bytes/message

═

Memory on the OS serve

- Structure of the archives (Tag logging slow/fast, Alarm logging)

  - Circular archive consisting of segments

current segment

full segments

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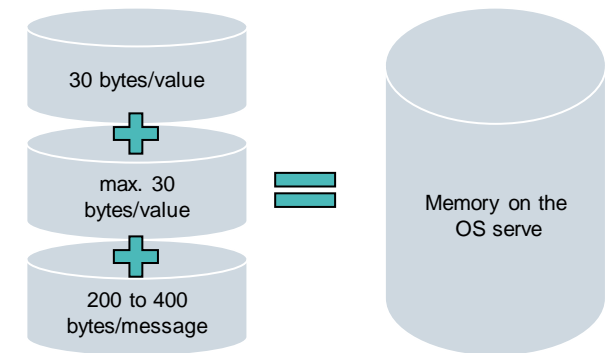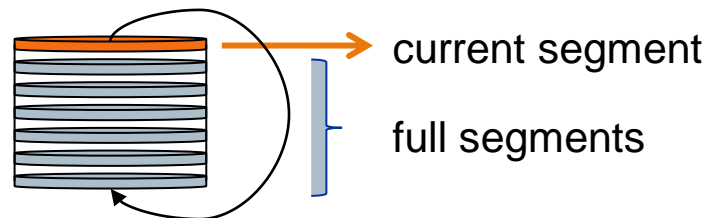
## Short-term and long-term archiving

- Short-term archiving on the OS servers

- Long-term archiving on a Central Archive Server

- Process values ⟶ archive slow
  ⟶ archive fast

- Messages/events ⟶ message archive

- Charge reports, OS reports ⟶ report archive

- Central Archive Server (CAS) gathers data for long-term archiving from multiple OS servers and Batch servers

- CAS can be configured redundantly for increased data security

- CAS has no connection to the automation system

OS clients

Terminal bus

OS server (redundant)

Batch server (redundant)

Central Archive Server (CAS)

Plant bus

Automation systems
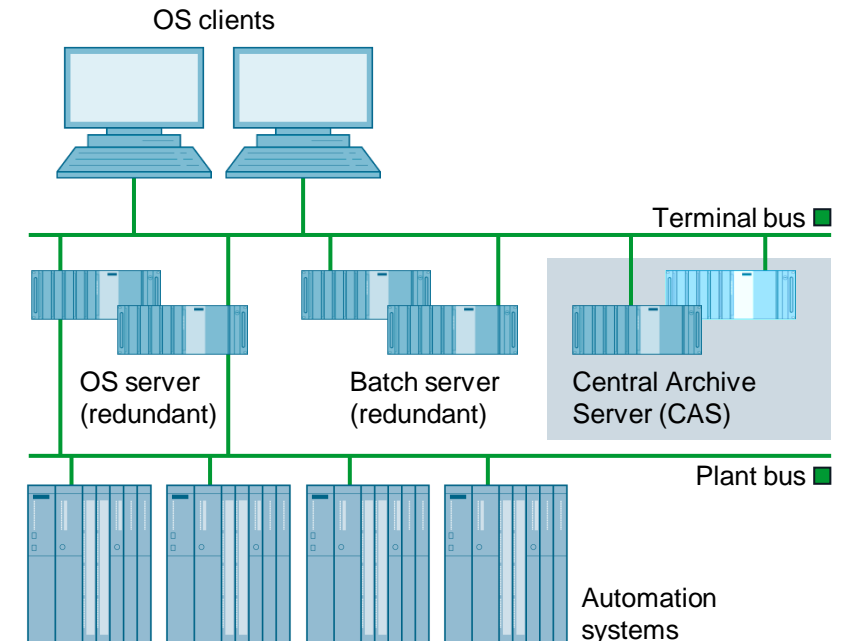
Trend reporting

- Trend reporting = Representation of process values in curves (i.e. graphical representation of process values over time)

- Possible representations in PCS 7

  - Trend groups

  - Online Trend Control ⟶

  - Online Function Control (deviates from the definition of trends but displays process values depending on other process values)

- Representation of archive tags by accessing the archives on the OS server

- Representation of online tags by buffering the current process values

  - Useful for process values that are not archived

  - Buffering only as long as the display is shown
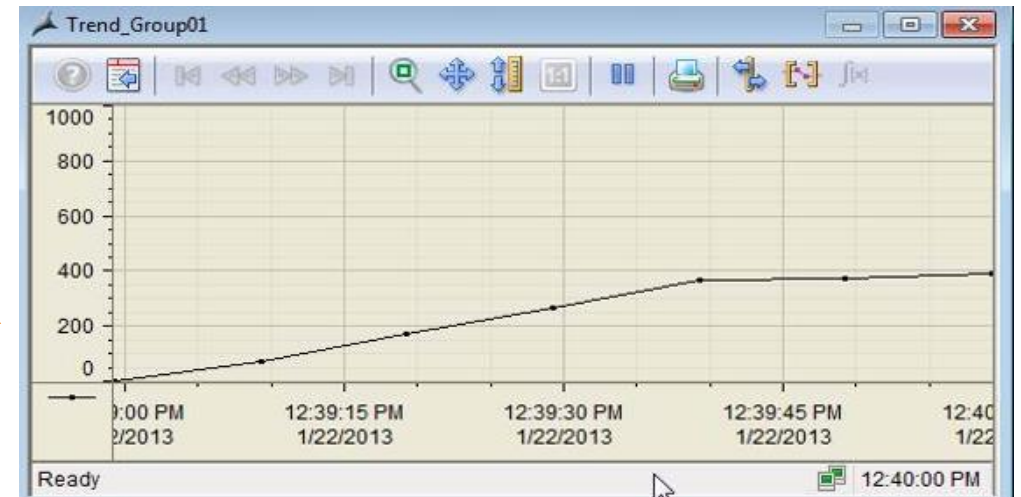
Learn-/Training Documents PCS 7
Benefits

Theoretical and practical introduction to process control engineering of a process plant – in general and with PCS 7 at the university level

Guided implementation based on available projects or implementation of your own designs possible

Testing the implementation in a simulated plant

Learn-/Training Documents PCS 7
Outlook

Use of the documents in training/education

- As a lecture (= theory) with practice (= exercises) to design a solution and to implement the design in PCS 7
- As practical training (= exercises) to design a solution and to implement the design in PCS 7

or

- As self-study to implement projects with PCS 7

Thank you for your attention!

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