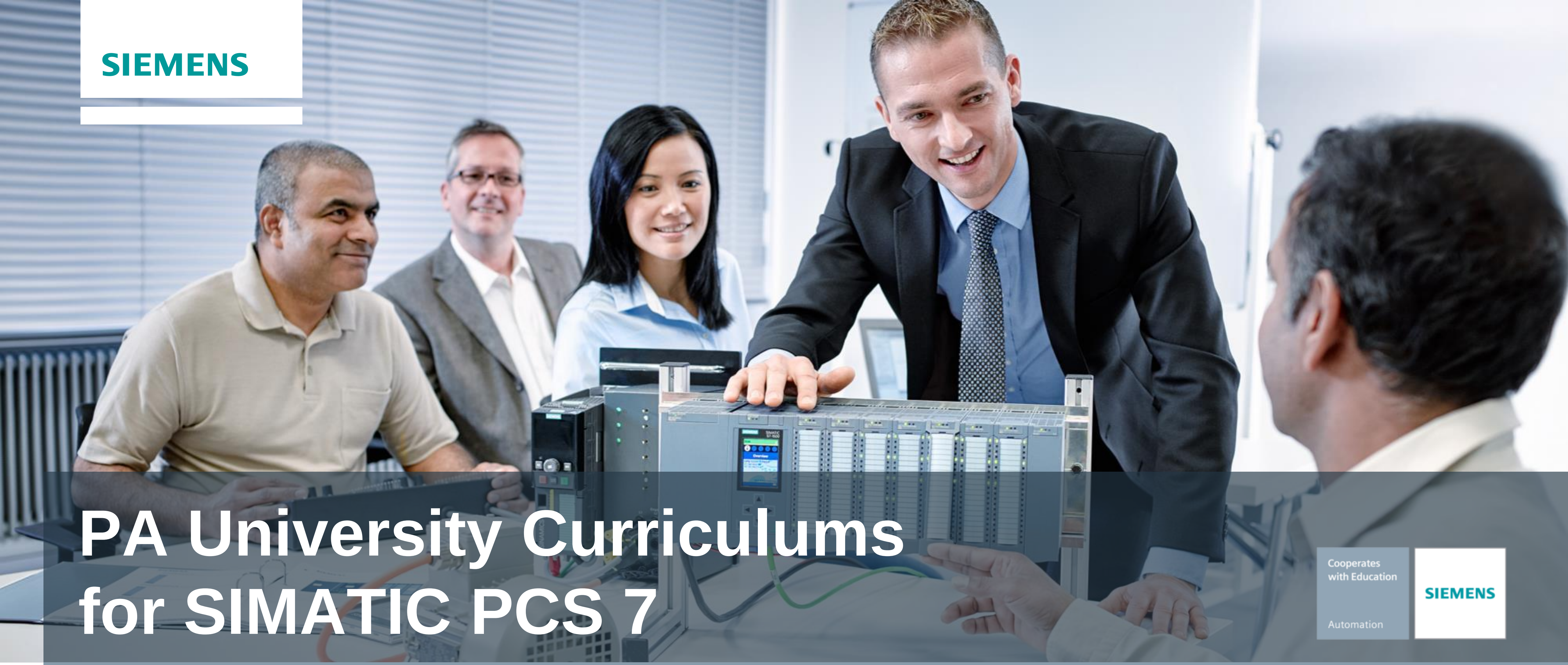

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PA University Curriculums for SIMATIC PCS 7

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PA University Curriculums
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- P01-01 Process description
- P01-02 Hardware configuration
- P01-03 Plant hierarchy
- P01-04 Individual drive functions
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- P01-07 Importing plant design data
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MODULE 2

- P02-01 HMI generation
- P02-02 Alarm engineering
- P02-03 Archiving

Objectives

- Categorization of process cells
- P&ID of the laboratory process cell
- Locks and recipes for the laboratory process cell

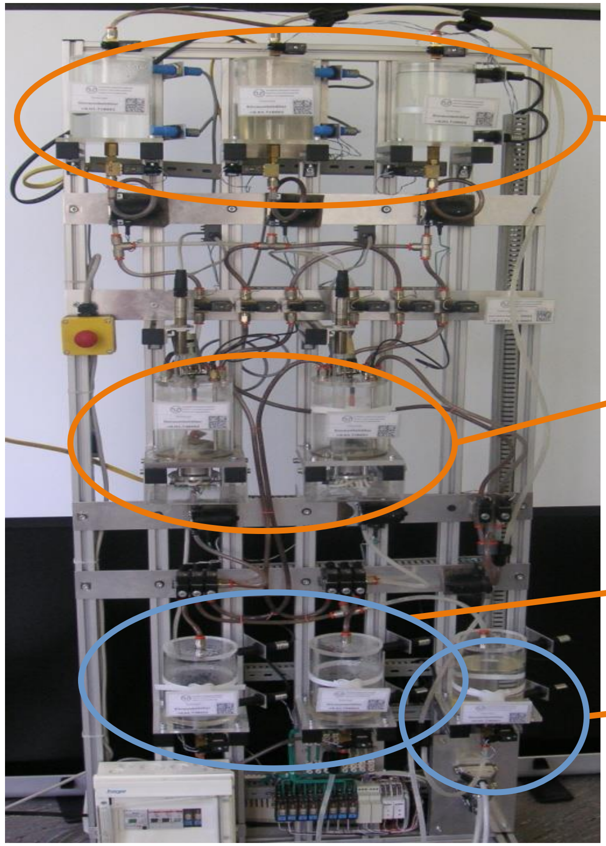
Classification of process control systems

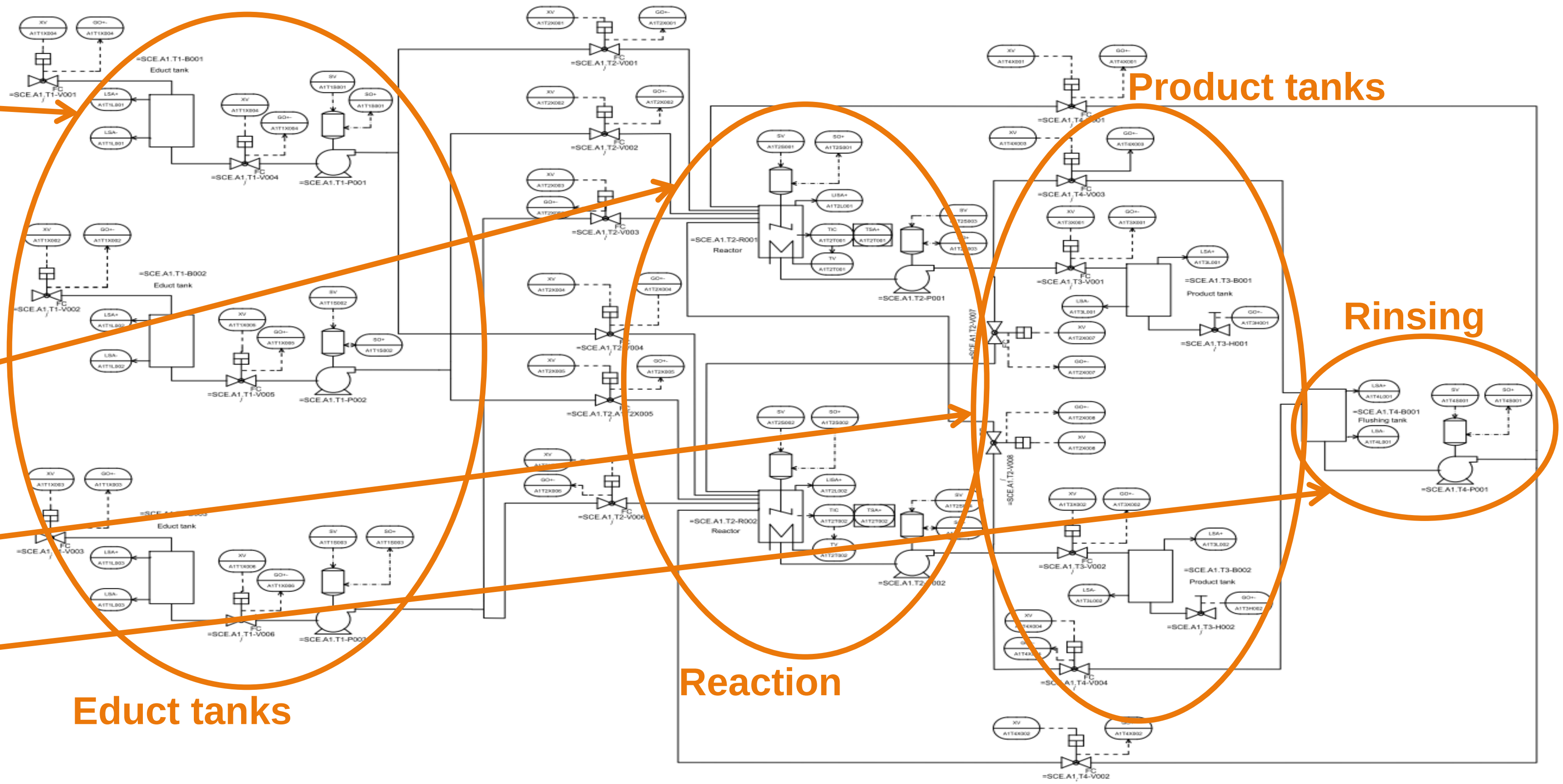
- Classification by the number of basically different products
  - Single product process cell
  - Multi product process cell

- Classification according to the physical structure of the process cell
  - Single-line process cell
  - Multi-line process cell
  - Multi-line & multi-path process cell

- Laboratory process cell as learning example
  - Multi product, multi-line & multi-path process cell
  - Hierarchical breakdown into 4 units

P&ID of the laboratory process cell





Locks and recipes

- Safe operation of the process cell needs monitoring of interactions with the process
- Requirements for the laboratory process cell:
  - Activation 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
  - …
- Manufacturing of a product needs a recipe
- Recipe of the laboratory process cell:
  - 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
  - …

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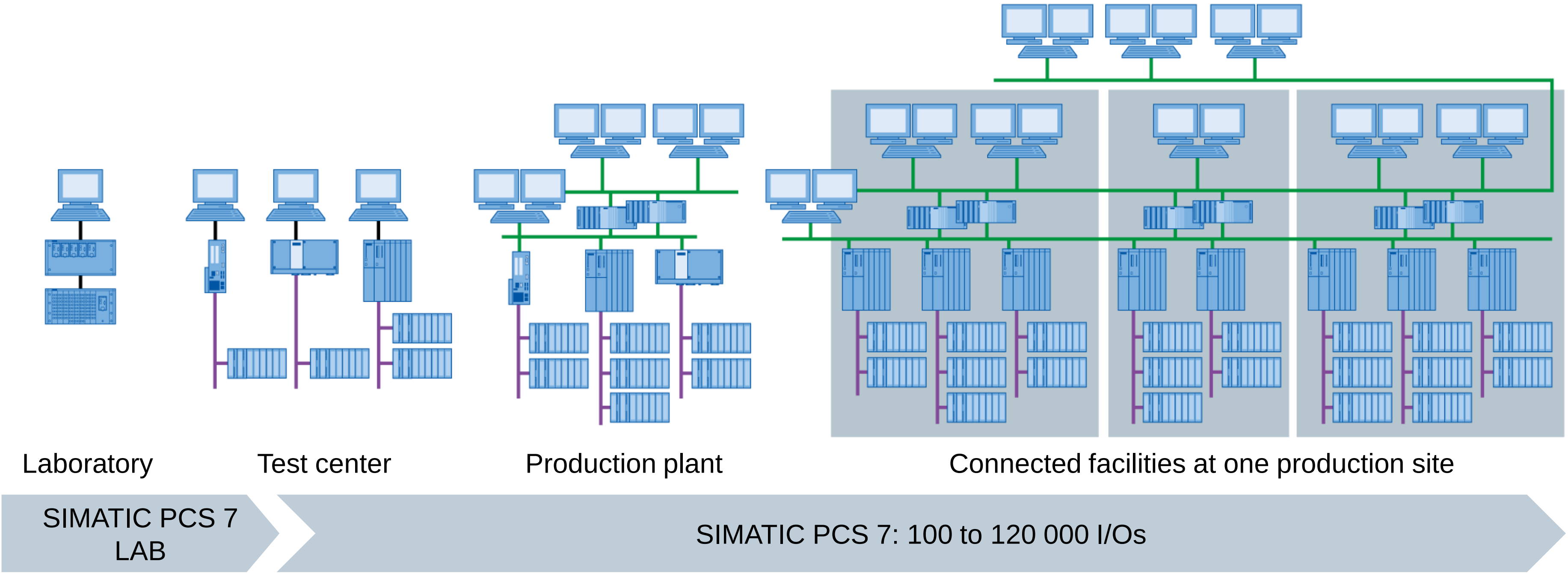
Objectives

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

- Step-by-step instruction
  - Creating new projects
  - Configuring the hardware
  - Configuring the communication network

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 control level
  - Control level
  - Field level



Connection to the process

- Two typical ways to connect sensors and actuators to the process control system
  - Directly by bus system (intelligent devices)
  - To signal modules over 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

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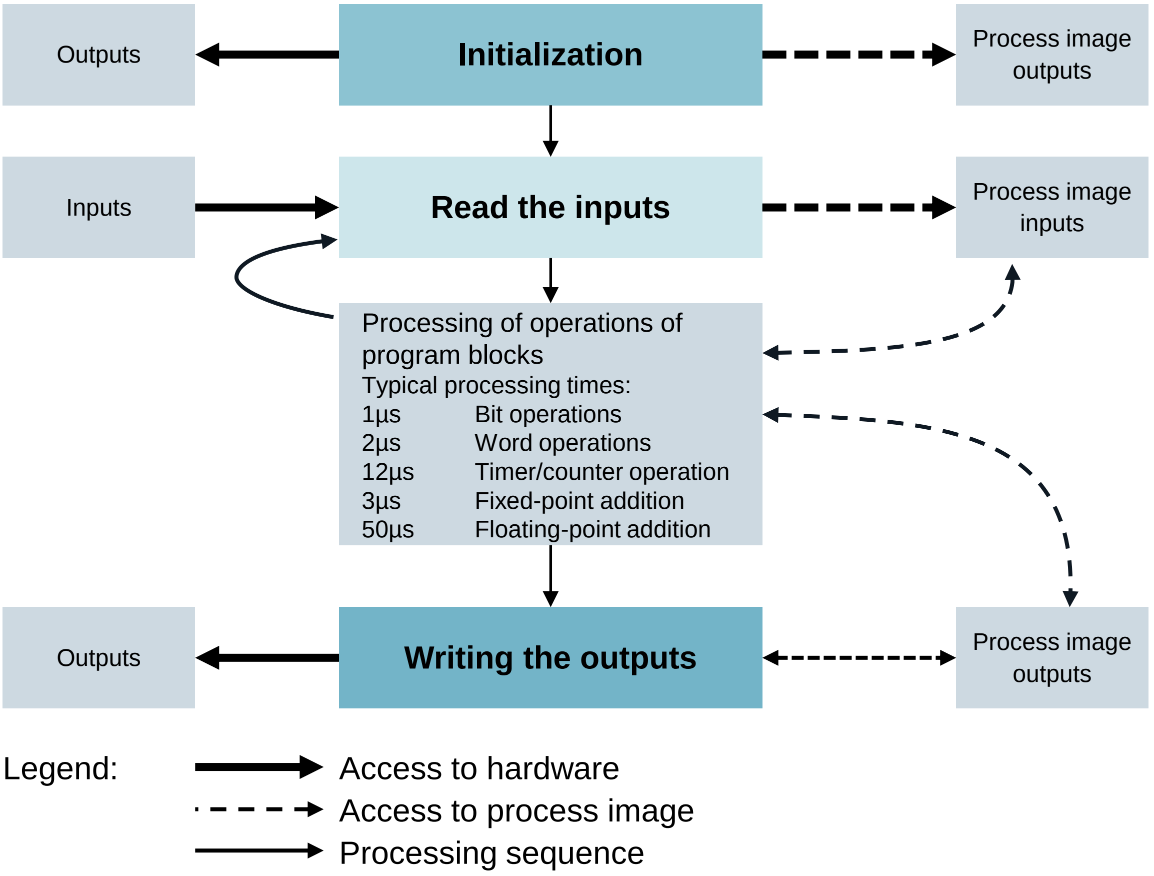
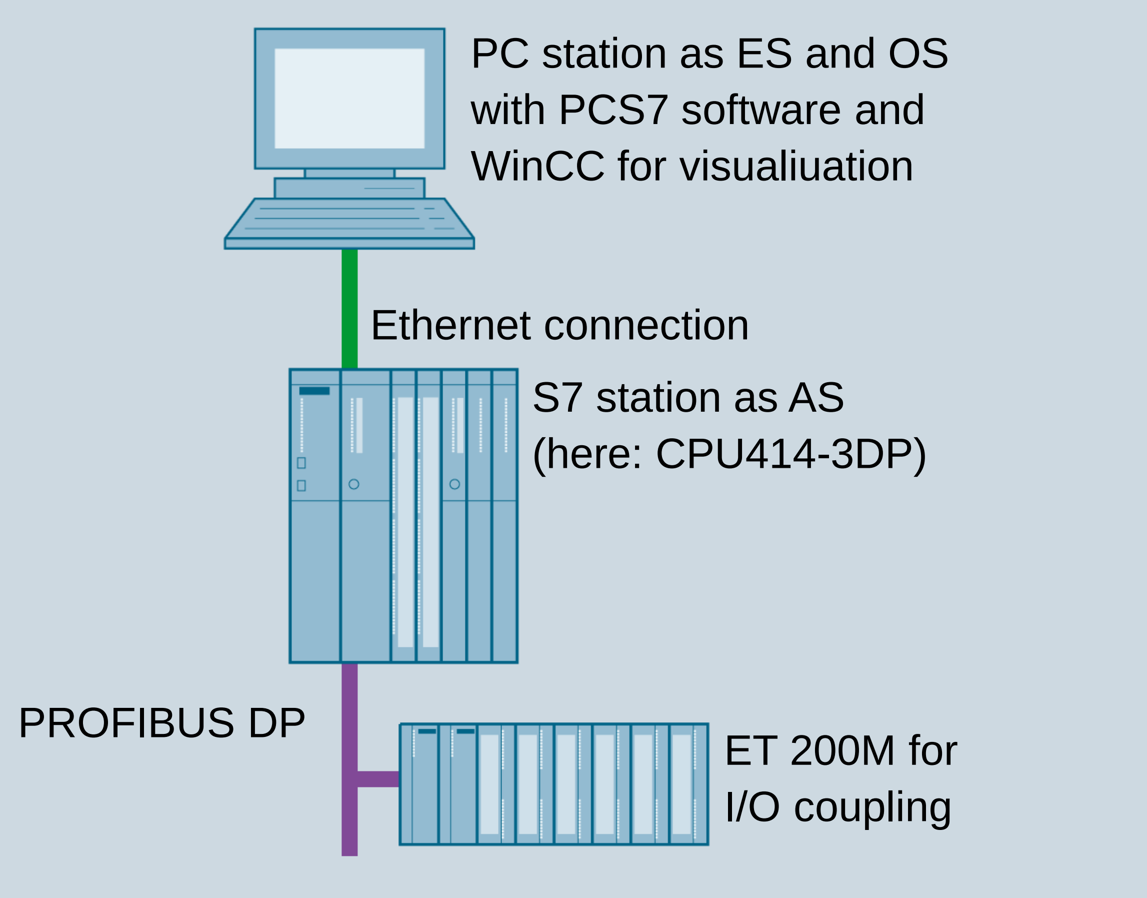
Operating principle of the PLC



- 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

Hardware configuration of the laboratory plant

- AS
  - PS
  - CPU (with PROFIBUS)
    - ET200M (with PROFIBUS)
      - 7x DI
      - 3x DO
      - 1x AI
      - 1x AO
    - CP (with Ethernet)
- ES/OS
    - PC (with Ethernet)



Objectives

- Theory
  - Structuring the laboratory process cell
  - Deriving the visualization
  - Plant View and structure of visualization

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

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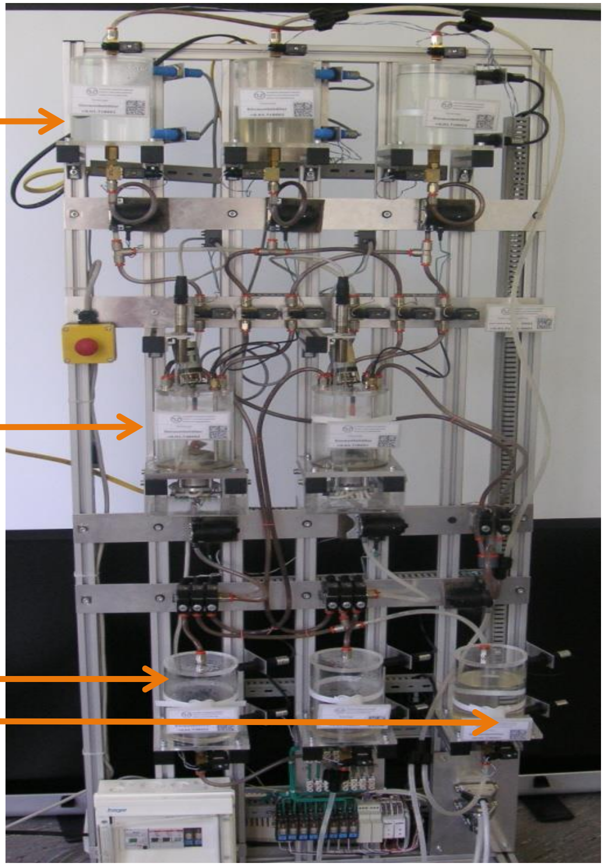
Structuring the laboratory process cell

- Structuring using the functional aspect
- Hierarchical breakdown into units
  - Unit 1: educt tanks
  - Unit 2: reaction
  - Unit 3: product tanks
  - Unit 4: rinsing



- Design of a labeling system according to ISA-88
  - Process cell: A1
  - Unit: T1 .. T4
    - Equipment module: B001, …, B003, R001, …
    - Control module: pump, valve, level, agitator, …

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Deriving the visualization

- Deriving the visualization in the operator system (OS) through the following steps:
  - Structuring the laboratory process cell
  - 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 labeling
  - Navigation hierarchy
  - Operating icons for implemented function blocks
  - Group alarms

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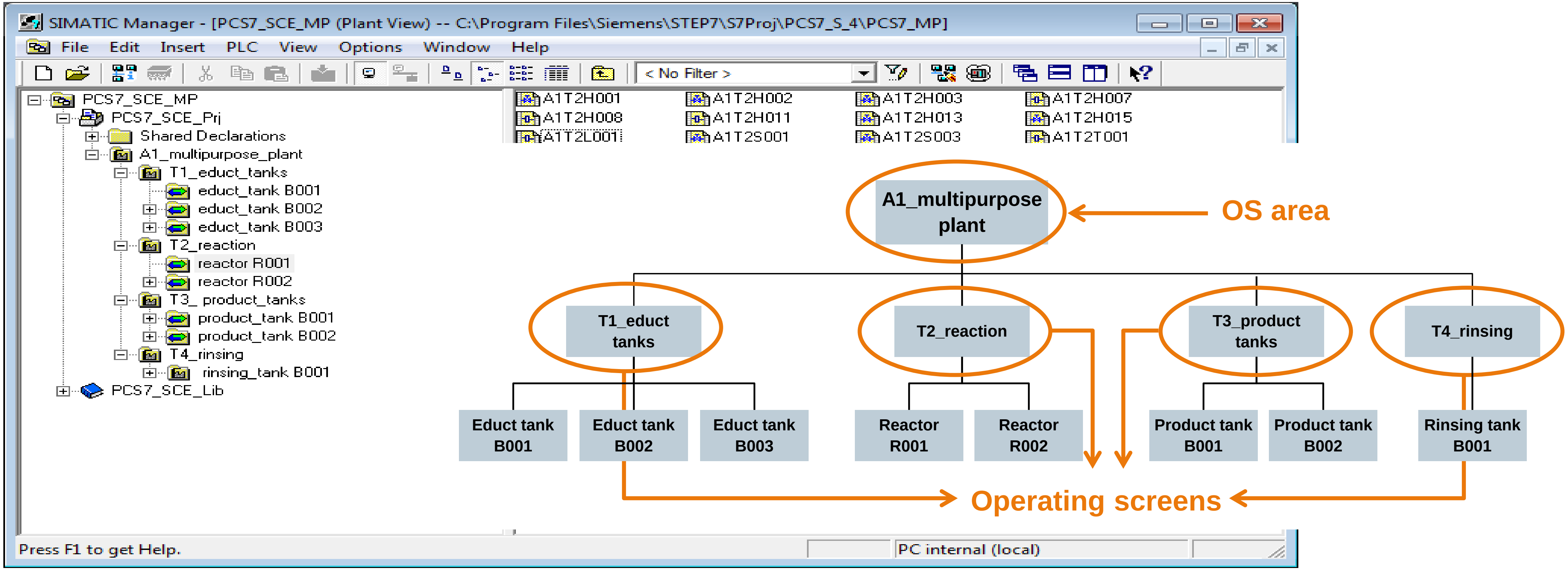
Plant hierarchy and the effect on visualization



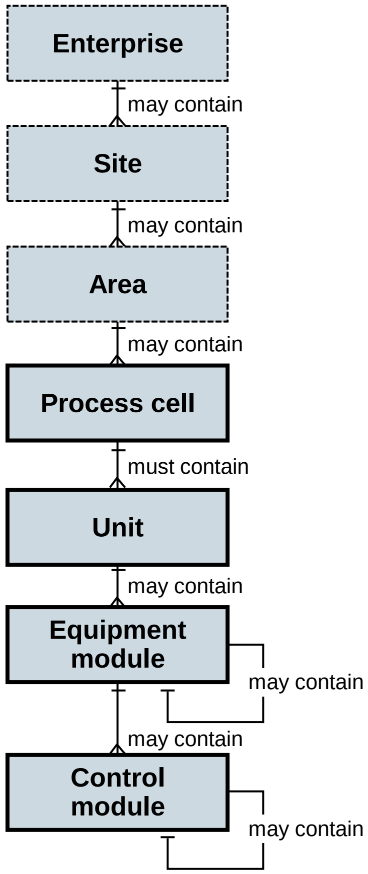
Objectives

- 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

Individual drive functions (IDF)

- Hierarchical structuring of the plant according to DIN EN 61512
  - Level 0: Control module
- Control module is a frequently used component
  - Project wide
  - For more than one project
- Reusing possible
  - Advantages:
    - Parameterization instead of programming
    - Tested functionality
    - Consistent handling and visualization
- Classification of control modules
  - e. g. motor, valve, …



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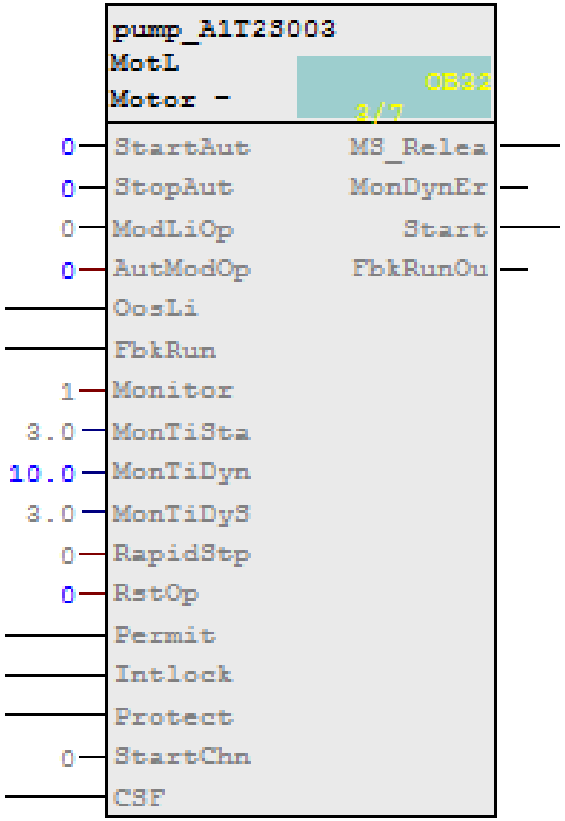
Individual drive functions in PCS 7

- 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 blocks 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

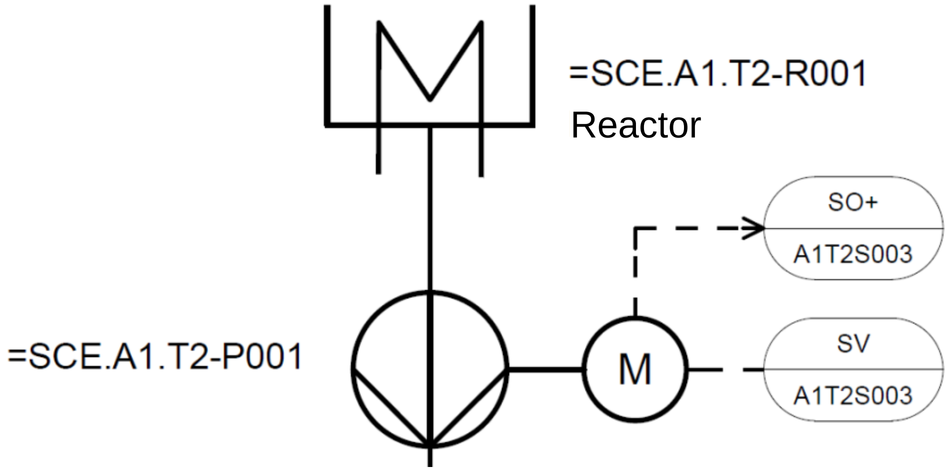
Individual drive function Motor_Lean (PCS 7 Advanced Process Library)

- Function block MotL
- Used for controlling pumps and stirrers in the laboratory process cell
- 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)



Implementation of a pump of the laboratory process cell

- Pump SCE.A1.T2-P001 to empty the reactor
- Pump is driven by a motor
- The motor has the following signals
  - One signal for control
  - One signal for running feedback
- Template from PCS 7 AP library
  - MotorLean



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

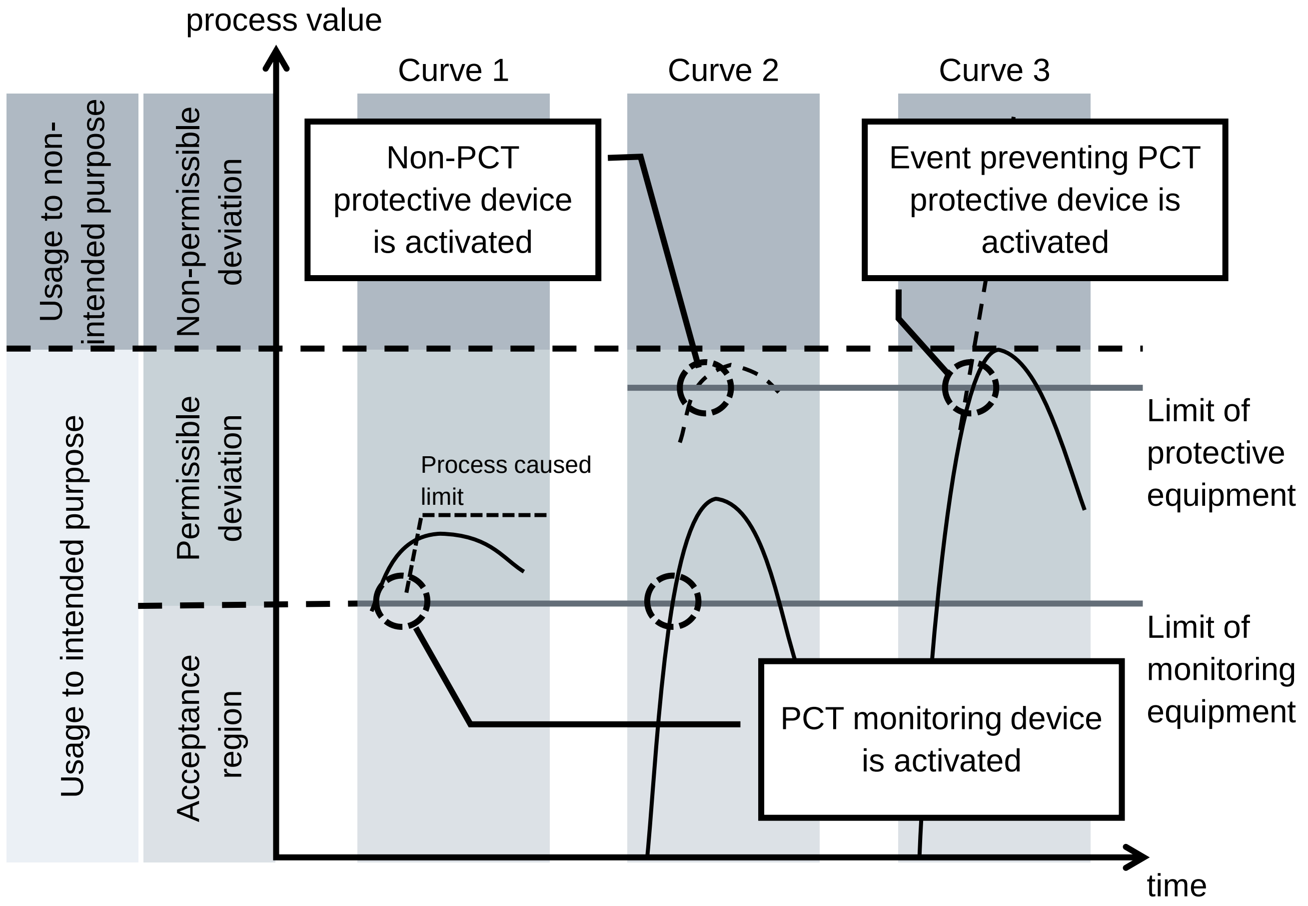
Objectives

- Theory
  - Plant protection by the means of process control engineering (PCE)
  - Standardized circuit for plant protection
  - Design of a lock for the laboratory process cell

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

Functional safety by means of process control engineering

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



Design of a lock for the pump of the laboratory process cell

- The pump may only be turned on when the main switch of the process cell is switched on and the emergency stop 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

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Standardized circuits for functional safety

- Replace the analog value A1.T2.A1T2L001.LISA+.M with a binary value which is the result of the comparison with 50 ml
- Functional table to design the 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 using conjunctive normal form (CNF) is used to lock the pump

Objectives

- Theory
  - Structure of a control loop
  - PID controller
  - Temperature control of the laboratory process cell

- Step-by-step instruction
  - Parameterization of a continuous controller
  - Output of the analog manipulated variable as a binary signal with a pulse generator

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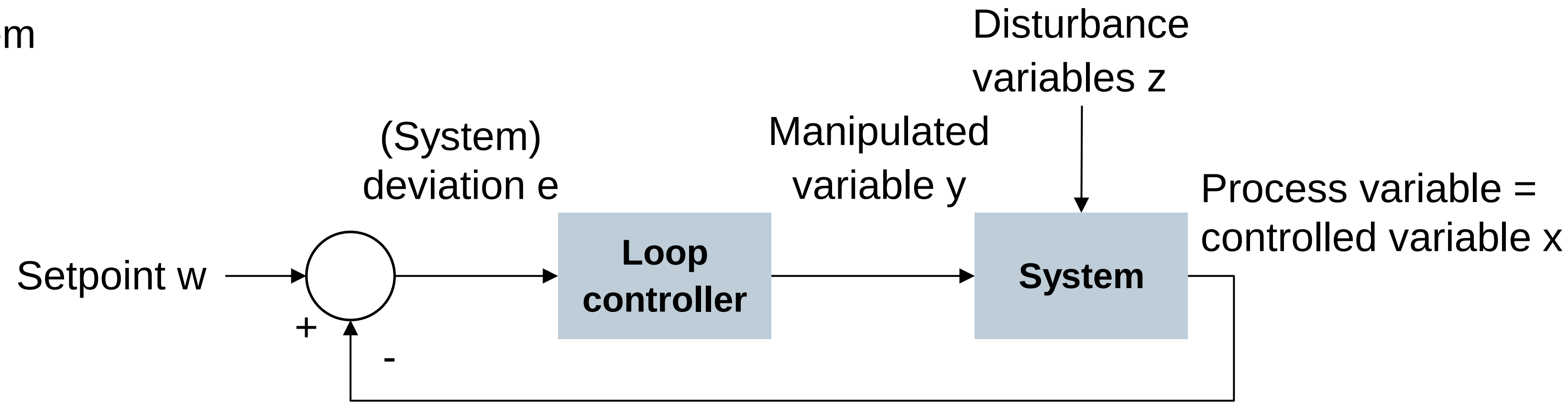
Structure of a control loop

- 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 stable and dynamic
- Control loop works as follows:
  - Process variable is measured by sensor
  - Setpoint minus measured value calculates the system deviation
  - Controller calculates the manipulated variable of the actuator as a function of the deviation
  - Actuator has impact on the system

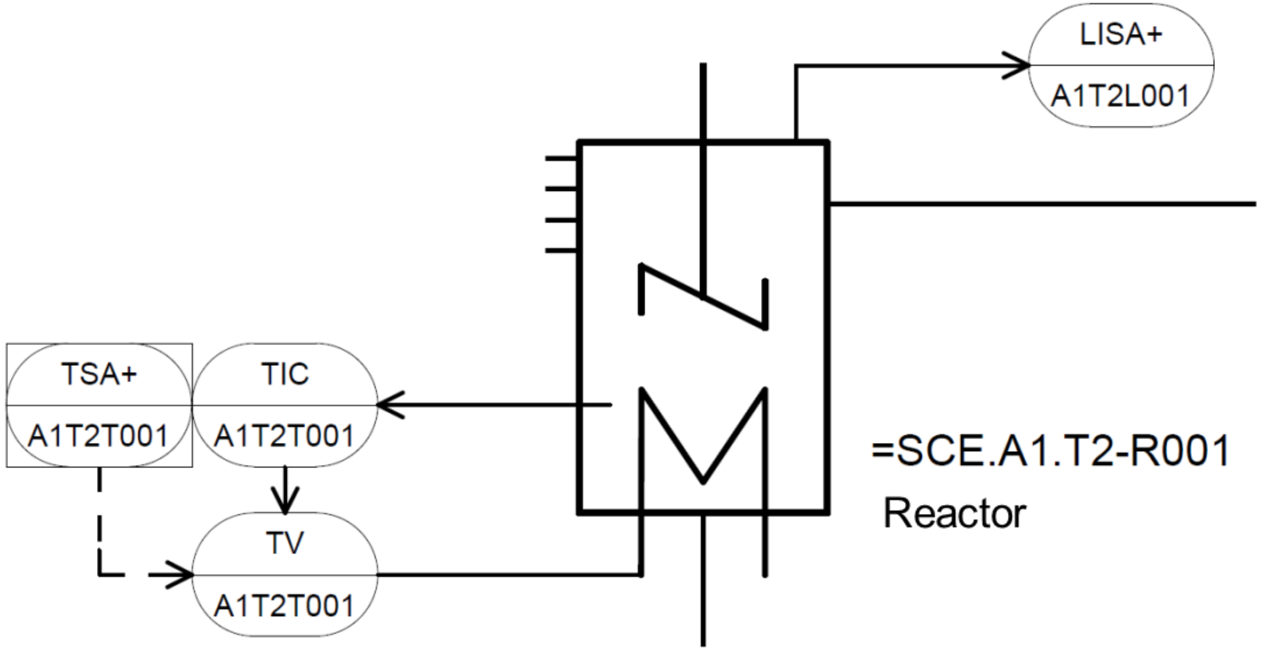


PID controller

- Control algorithm calculates the manipulated variable as a function of the deviation
- Process industry uses the PID algorithm to 95%
  - P means proportional
    - Current manipulated variable only depends on current deviation
  - I means integral
    - Current manipulated variable depends on the sum of the last deviation values
  - D means differential
    - Current manipulated variable depends on the changes in the deviation value
- Adjusting only three parameters (gain, reset time and derivative time)
- Practical adjusting rules exists for systems without dominant dead times
  - Ziegler and Nichols method
  - Chien, Hrones and Reswick

Temperature control of the laboratory process cell

- Control loop
  - Process variable is A1.T2.A1T2T001.TIC.M
  - Manipulated variable is A1.T2.A1T2T001.TV.S
  - Setpoint is
    - Determined by recipe
    - Determined by operator
    - Locked
- Conditions for locking
  - Level in the reactor has to be at least 200 ml
  - Temperature must not exceed 60° C



Objectives

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

- Step-by-step instruction
  - Importing plant design data
  - Working with the process object view
  - Duplicating charts by creating process tag types/models

Design of complex systems

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

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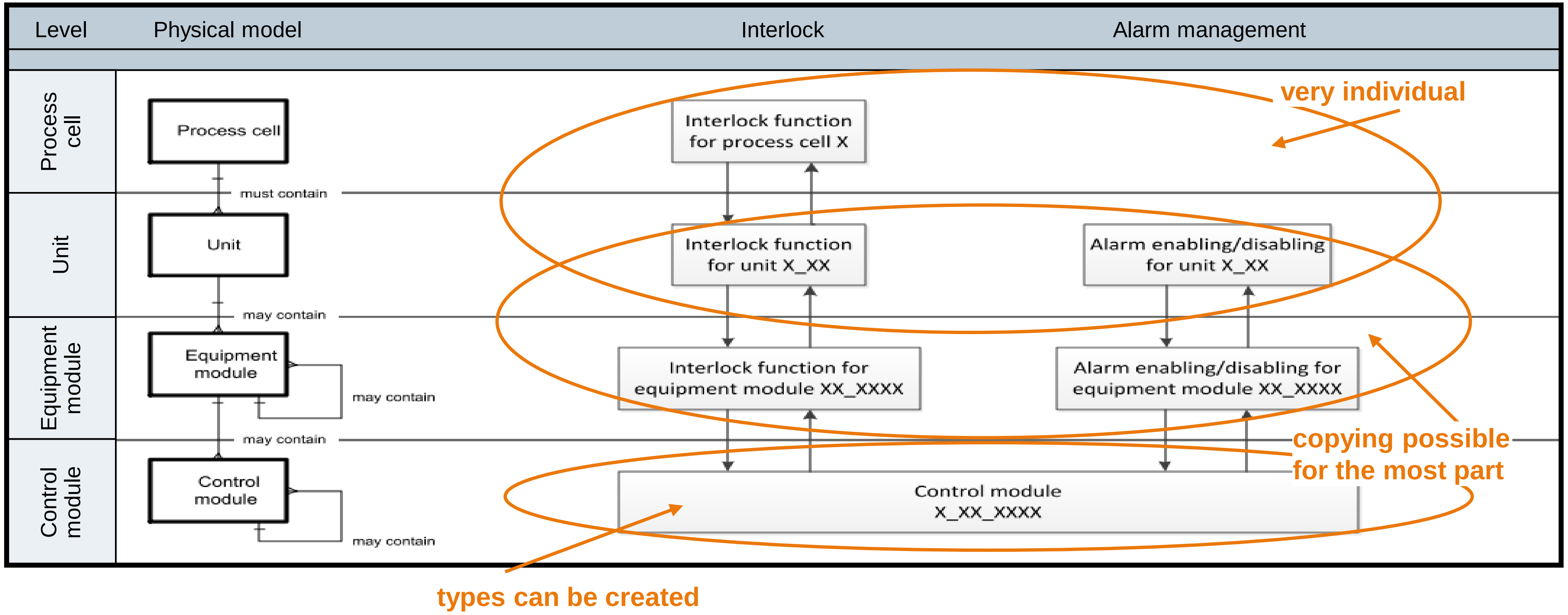
Process tag types and models

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



Process tag types and models of the laboratory process cell

- 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

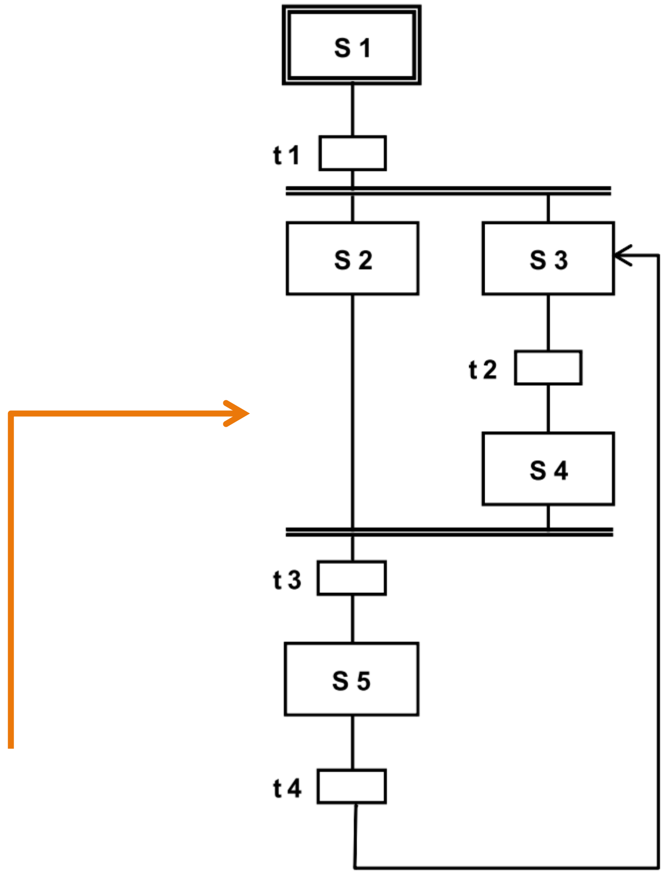
Objective

- Theory
  - Structure of sequential function charts
  - Design of a sequential control system
  - Recipe of the laboratory process cell

- Step-by-step instruction
  - Creating and editing sequential function charts (SFC)
  - Connecting SFC and CFC
  - Testing the SFC

Structure of sequential function charts

- Alternating sequence of steps and transitions
  - First step: start step
  - Final step: end 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 permitted step enabling condition
- One time or cyclical processing of sequential function chart is possible



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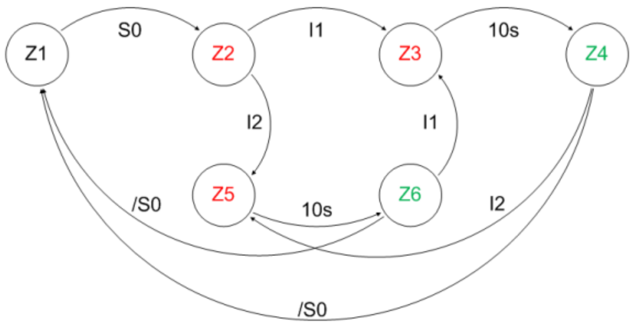
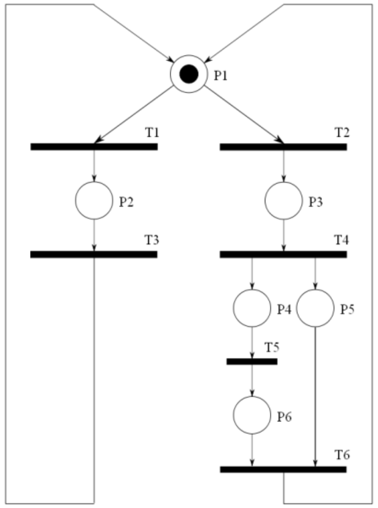
Design of a sequential control system

- Approved design methods for sequential control systems
  - State transition diagram
    - Connected and directed graph
    - States shown as circle – can be linked with actions
    - State changes shown as arrows – can be connected to transition conditions
  - Petri nets
    - Consists of places and transitions
    - Places as circles
    - Transitions as rectangles/bars
    - Parallel sequences can be displayed





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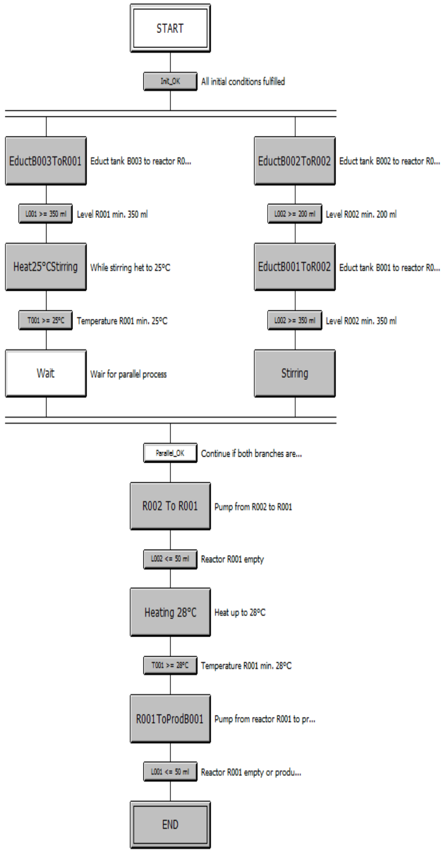
Recipe of the laboratory process cell

- First, 350ml are to be drained from educt tank A1.T1.B003 into the reactor A1.T2.R001 and at the same time 200ml from educt tank A1.T1.B002 into the 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 reactor A1.T2.R002 is filled, 150ml from educt tank A1.T1.B001 is to be added to reactor A1.T2.R002. When this is completed, 10s later the agitator of reactor A1.T2.R002 is to be switched on.
- 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.



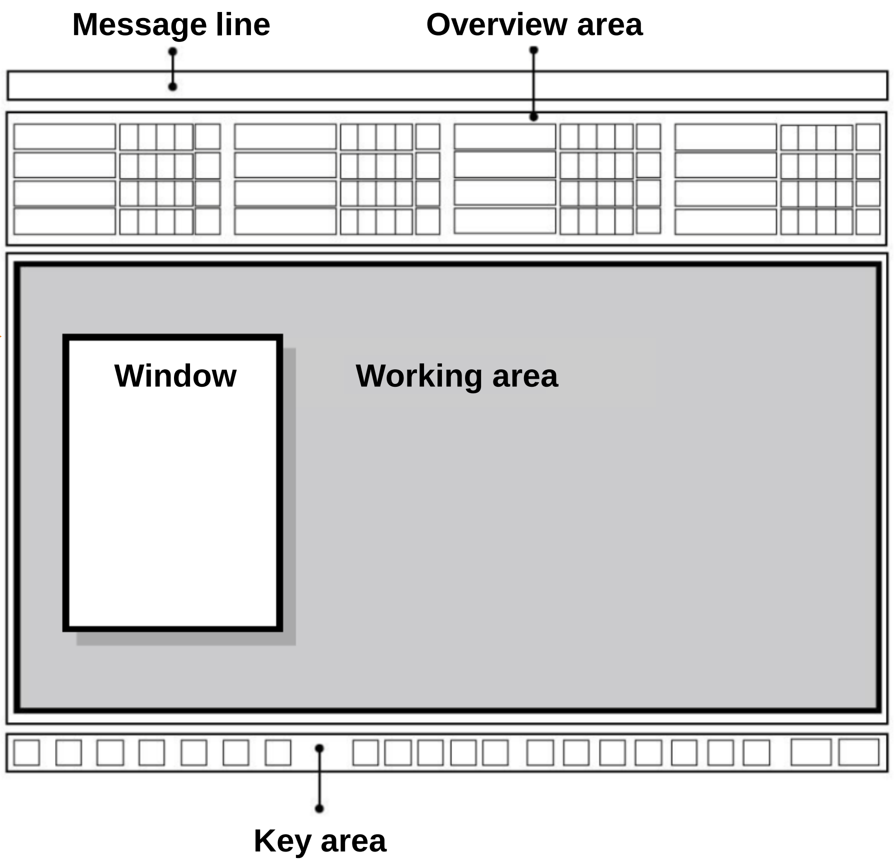
Objectives

- Theory
  - Concepts of visualization
  - HMI generation in PCS 7
  - HMI of the laboratory process cell

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

Concepts of visualization

- Important aspects of visualization
  - Organization of visualization
  - Print growth
  - 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



HMI generation in PCS 7

- Picture tree can be derived directly from plant hierarchy
  - Creating a picture in the corresponding level
- 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
  - Visualization for different resolutions, numbers and arrangement of monitors
- Graphics Designer
  - Drawing the process pictures (static elements)
  - Linking dynamic elements with the process variables

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Graphics of the laboratory process cell

- 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
```

- Plant display
  - 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
  - Signaling systems
  - Alarms and messages
  - Alarm management in PCS 7

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

Signaling 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 reporting occurrence of an event that requires immediate action of the operator
- Message display or reporting occurrence of an event that requires no immediate action of the operator
- Properties for selection of alarms
  - Relevant
  - Unambiguous
  - Timely
  - Prioritized
  - Comprehensible

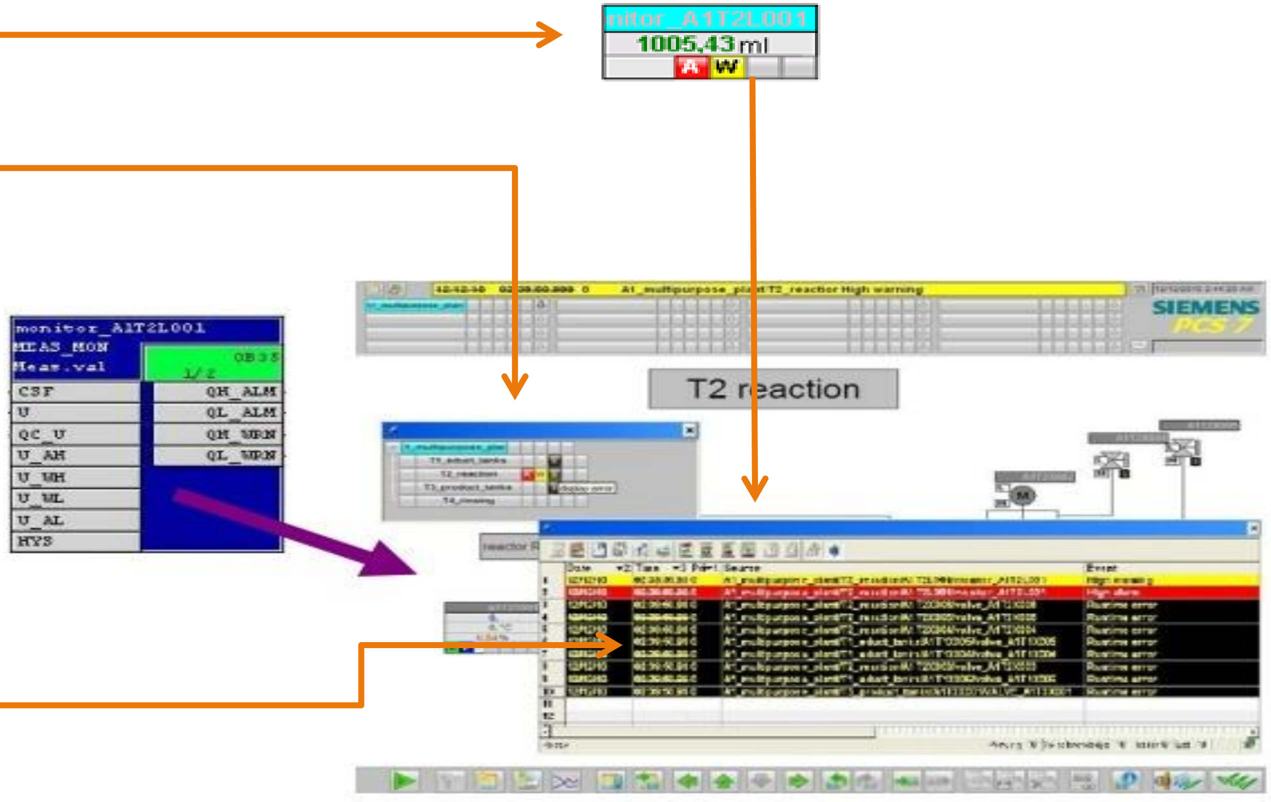
Priority

Priority

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

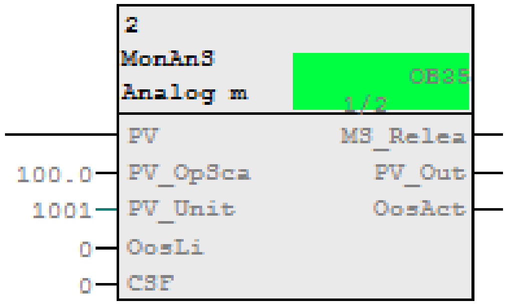
Alarm management in PCS 7

- Function block for generating messages
  - Picture icons to display alarm states
- Group alarms along the plant hierarchy
- Display and management of message lists



Alarms for the laboratory process cell

- Monitoring of levels
- Monitoring of temperatures
- Using MonAnS block (FB 1912) from Monitor folder of the PCS 7 Advanced Process Library V80
  - Monitoring a measurement value (analog signal)
  - Adjustable parameters
    - Warning limit (high/low)
    - Alarm limit (high/low)
- Display of faceplate icon
  - In unit T2_reaction
  - Positioning and compiling



Objectives

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

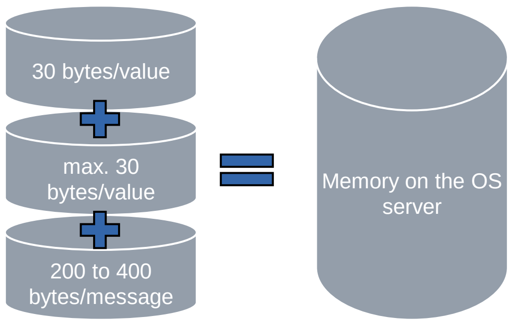
- Step-by-step instruction
  - Activating archiving in CFC
  - Archive settings of the OS server
  - Curves and reports

Goals of archiving

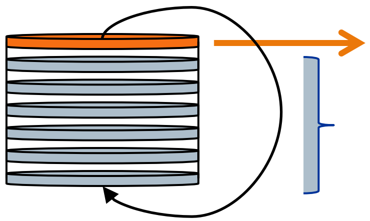
- Why must process data and events be logged?
  - **Rules and regulations:** logging of disturbance, verification of licensing requirements, consistent tracking of the production cycle
  - **Process management:** statistics of production data, optimization of production parameters, increasing of performance, optimization of material and manufacturing costs
  - **Safety:** analysis of production data for adapting production parameters especially limits and response time, verification of functional safety when testing interlocks and EMERGENCY OFF functions
  - **Performance:** increasing of performance of the process database, data backup

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



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

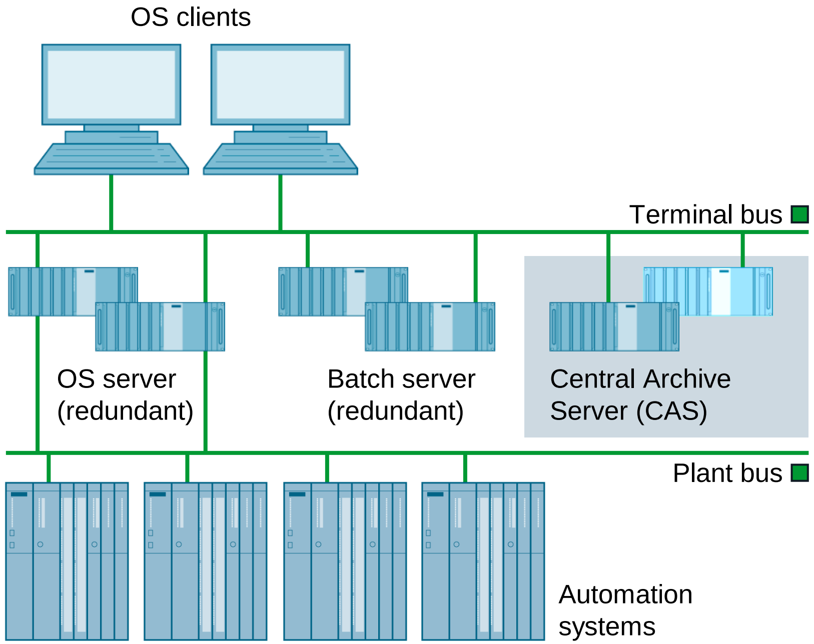


current segment

full segments

Short-term and long-term archiving

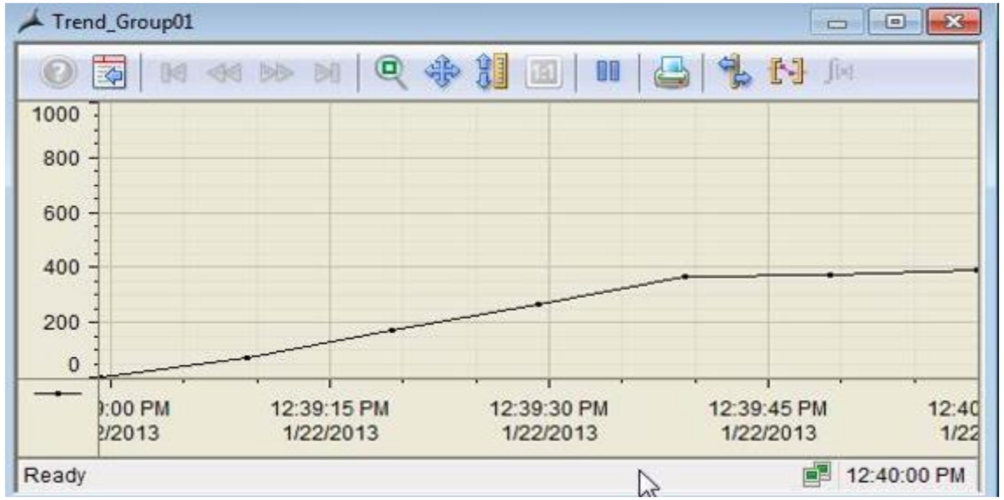
- Short-term archiving on the OS servers
- Long-term archiving on the Central Archive Server
- Process values → archive slow
  → archive fast
- Messages/events → message archive
- Charge reports, OS reports → report archive



- Central Archive Server (CAS) gathers data for long-term archiving from different OS servers and Batch servers
- CAS can be configured as redundant for increased data security
- CAS has no connection to the automation system

Trend reporting

- Trend reporting = Visualization of process values in curves (which means a graphical visualization of process values in dependency of time)
- Visualization options in PCS 7
  - Trend groups
  - Online Trend Control
  - Online Function Control (not according to the definition of trends but displays process values depending on other process values)
- Visualization of archived variables by accessing the logs on the OS server
- Visualization of online variables by buffering the current process values
  - Used for process values that are not archived
  - Buffering only as long as the visualization is shown



PA University Curriculums
Usage

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

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

Test the implementation in a simulated plant

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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