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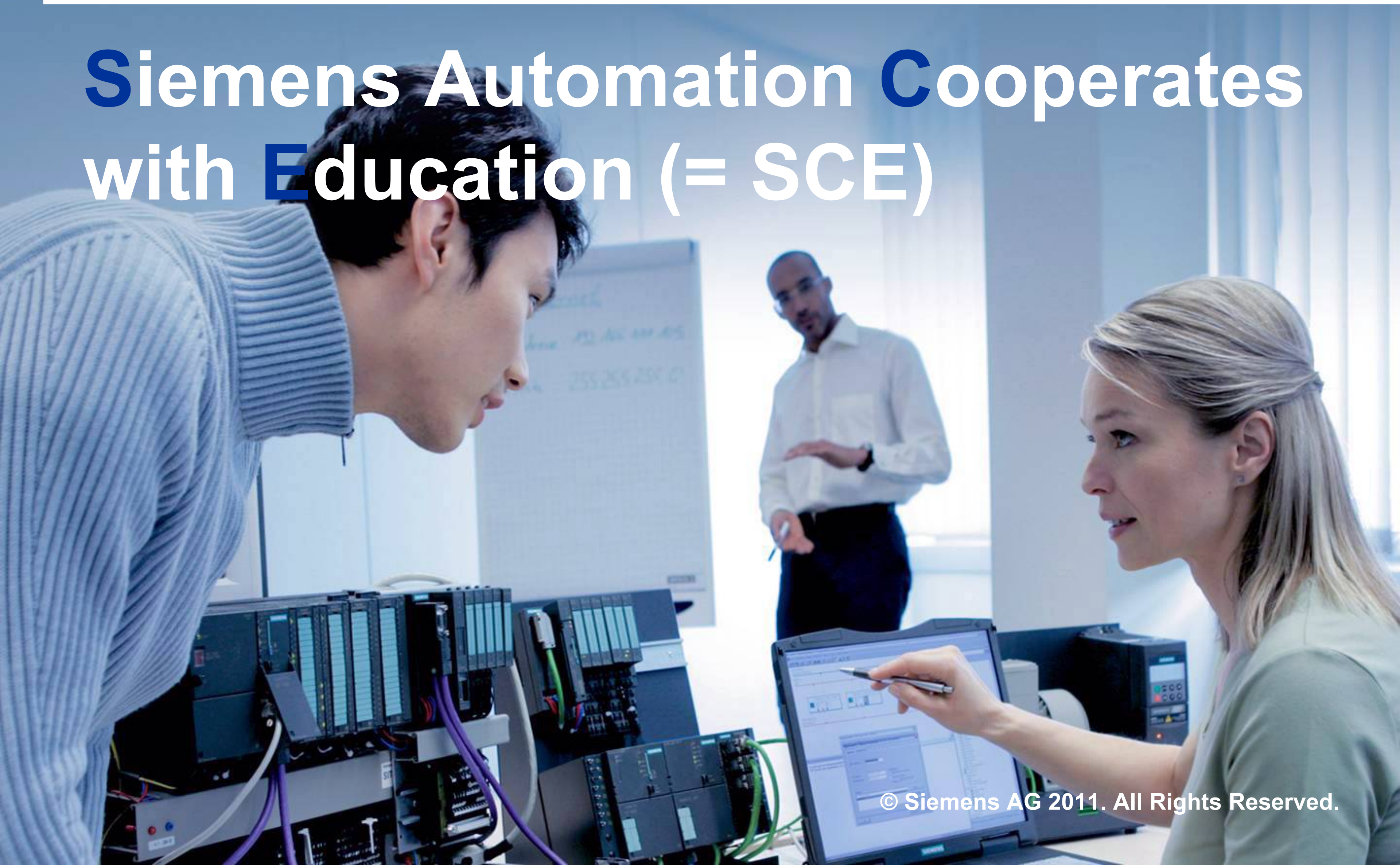

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PCS7 HS - Training Manuals

Status: March 2011

PCS7 Training Manuals
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Objective

- Classification of process engineering plants
- P&ID flow diagram of the lab installation
- Locks and recipes for the lab installation

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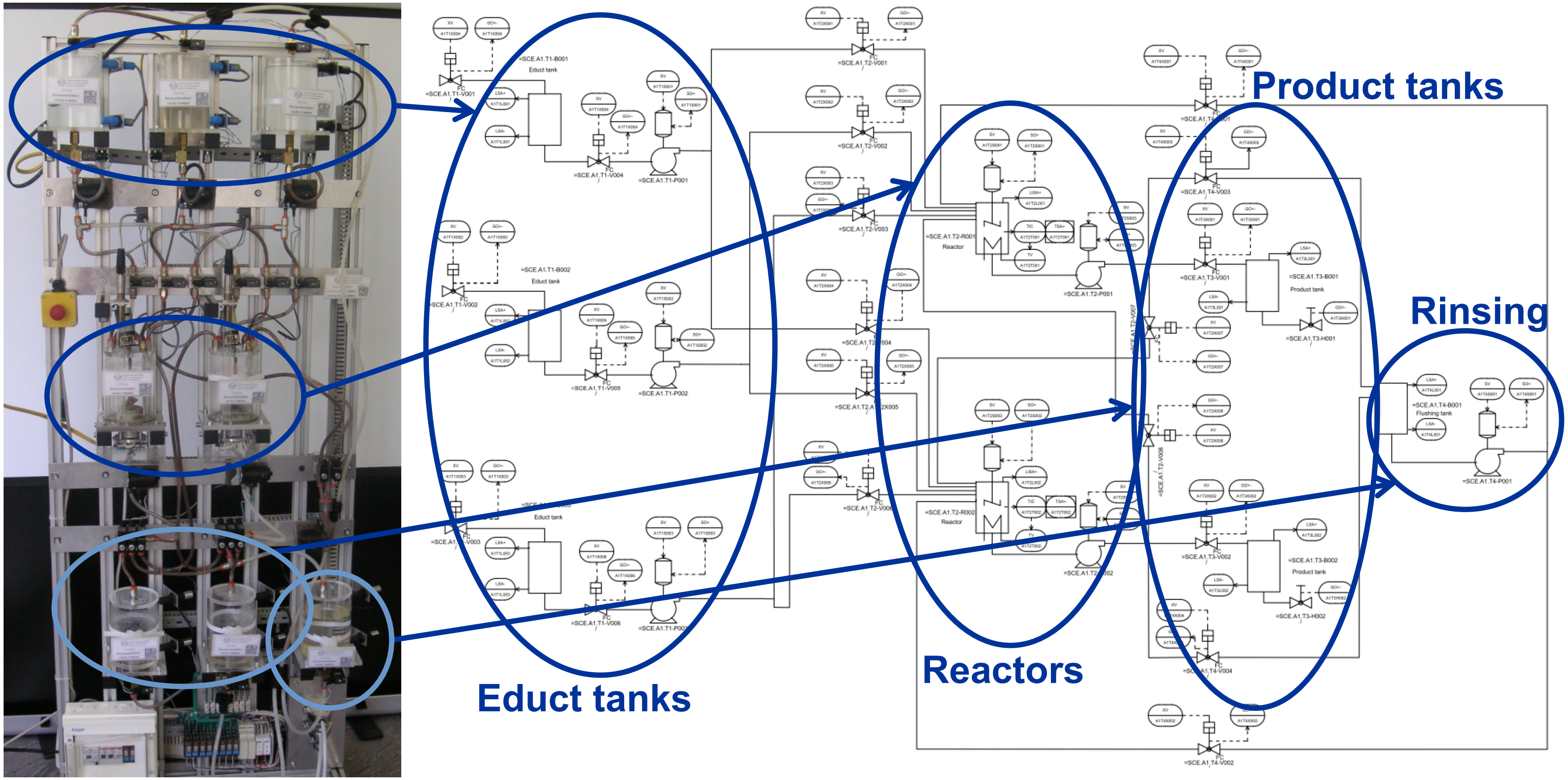
Classification of Process Engineering Plants

- Classification according to the number of fundamentally different products
  - Single product plant
  - Multi-product plant

- Classification according to the physical structure of the plant
  - Single line plant
  - Multi-line plant
  - Multi-line/multi path plant

- Lab installation as learning example
  - Multi-product and multi-line/multi-path plant
  - Hierarchical breakdown into 4 units

P&ID Flow Diagram of the Lab Installation



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Locks and Recipes

- Safe operation of the plant requires monitoring the process interventions
- Requirements for the lab installation:
  - Actuators can be activated only if the main switch is on and Emergency Off is unlocked
  - Protection of the tanks against overflow
  - Prevent air intake in the case of pumps
  - Pumps must not work against closed valves
  - …
- Manufacturing a product requires a process specification
- Recipe for the lab installation:
  - 350ml from Educt 3 to Reactor 1 and 200ml from Educt 1 to Reactor 2
  - Heating Reactor 1 up to 25°C and 150ml from Educt 2 to Reactor 2 …
  - …

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Objective

- Theory
  - Distributed structures
  - Interfacing with the process
  - Operation principle of the PLC

- Step-by-step instructions
  - Setting up a project
  - Configuring the hardware
  - Configuring the communication network

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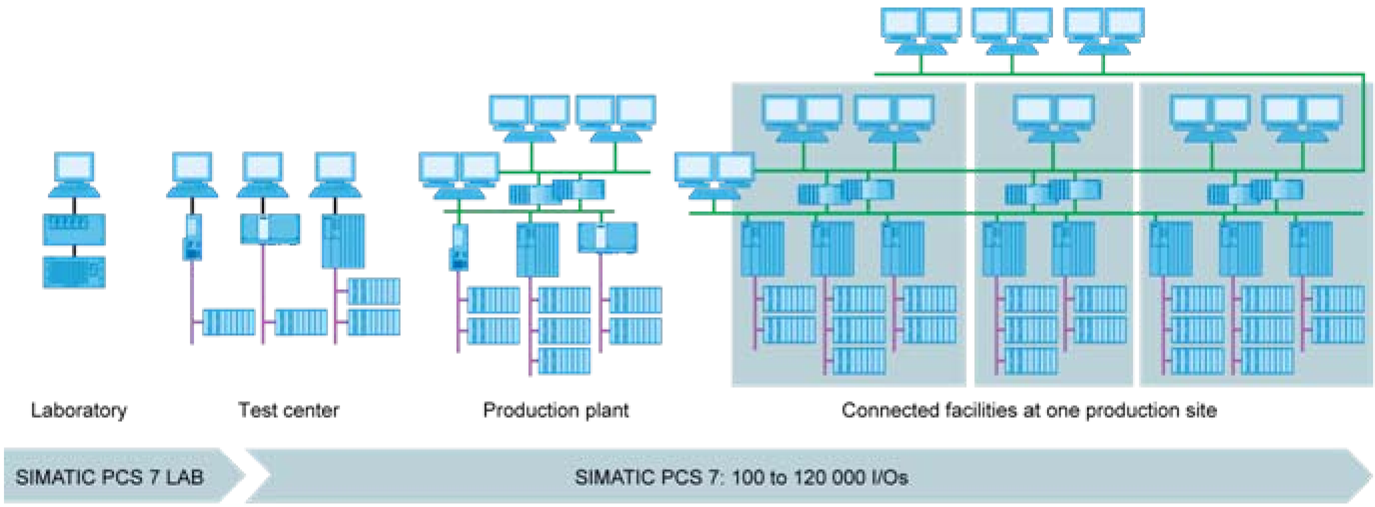
Distributed Structures of Process Control Systems

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



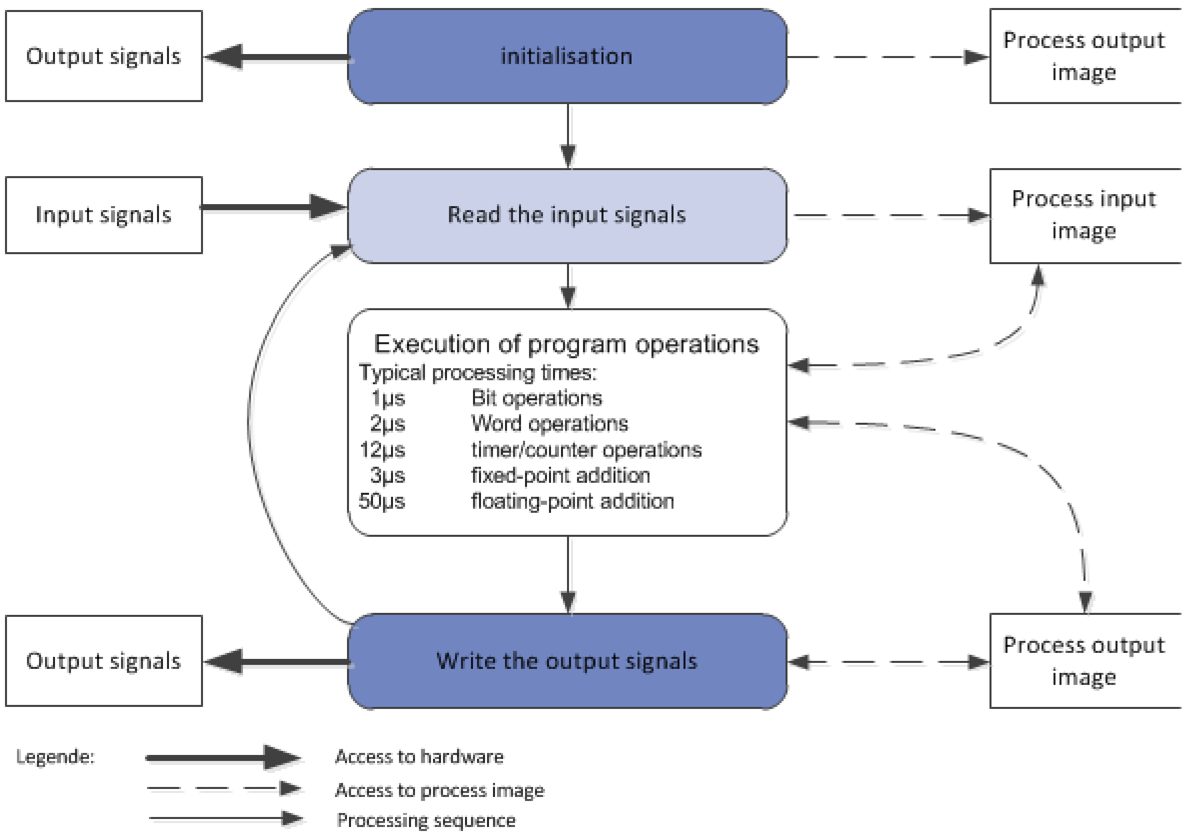
Interfacing with the Process

- Two typical ways to interface encoders and actuators with the PCS
  - Directly by means of the bus system (intelligent devices)
  - By means of an electrical standardized signal to a signal module

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

  - Analog signals: AI/AO modules (AI .. analog input, AO .. analog output)
  - 16 bits of memory is needed for each signal
  - Resolution may be lower nevertheless; for example, 12 bits

How the PLC works



- Component on the control level is typically a PLC
- Input and output signals are read in/read out cyclically and stored temporarily in the the process image
- Signal consistency during program processing by accessing the process image

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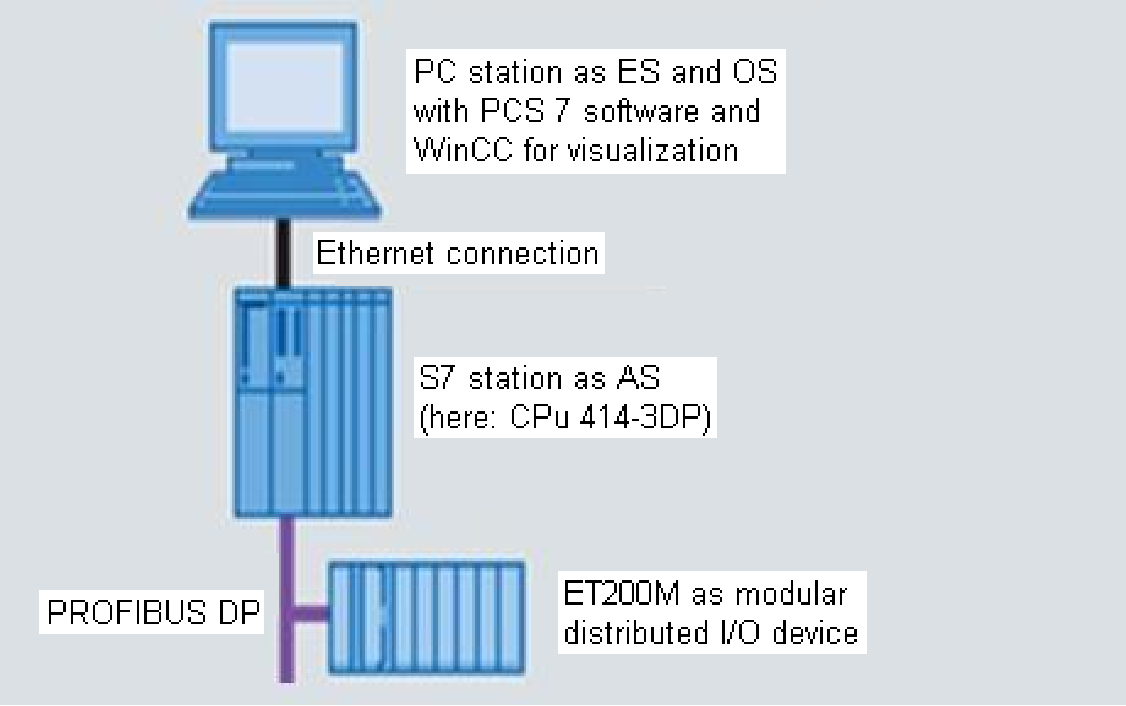
Hardware Configuration of the Lab Installation

- AS
  - PS
  - CPU (with Profibus)
    - ET200M (with Profibus)
      - 4x DI
      - 2x DO
      - 1x AI
      - 1x AO
  - CP (with Ethernet)
- ES/OS
  - PC (with Ethernet)



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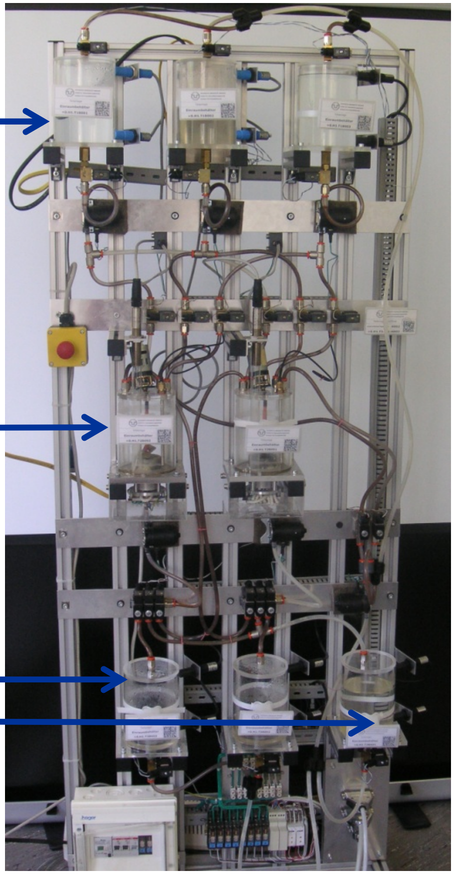
Objective

- Theory
  - Structuring the lab installation
  - Deriving the visualization
  - Plant hierarchy of the plant and visualization structure

- Step by step instructions
  - Calling the plant view
  - Setting up the plant hierarchy
  - Basic settings for the plant hierarchy

Structuring the Lab Installation

- structuring using the functional aspect
- hierarchical decomposition in units
  - unit 1: educt tanks
  - unit 2: reaction
  - unit 3: product tanks
  - unit 4: rinsing
- design of a labelling system according to ISA-88
  - site: SCE_factory
    - process cell: A1
      - unit: T1 .. T4
        - equipment module: pumps P00x, valves V00x, levels L00x, temperature T00x, agitator …



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Deriving the Visualization

- Visualization in the operator system (OS) is derived by using the following steps:
  - Structuring the lab installation
  - Setting up the plant hierarchy
  - Selecting a hierarchical level as OS area
  - Performing a generation run (see P02-01 HMI Generation)

- All hierarchical levels below the level defined as OS area can be automatically displayed
  - Area IDs
  - Navigation hierarchy
  - Face plates for implemented templates
  - Group alarms

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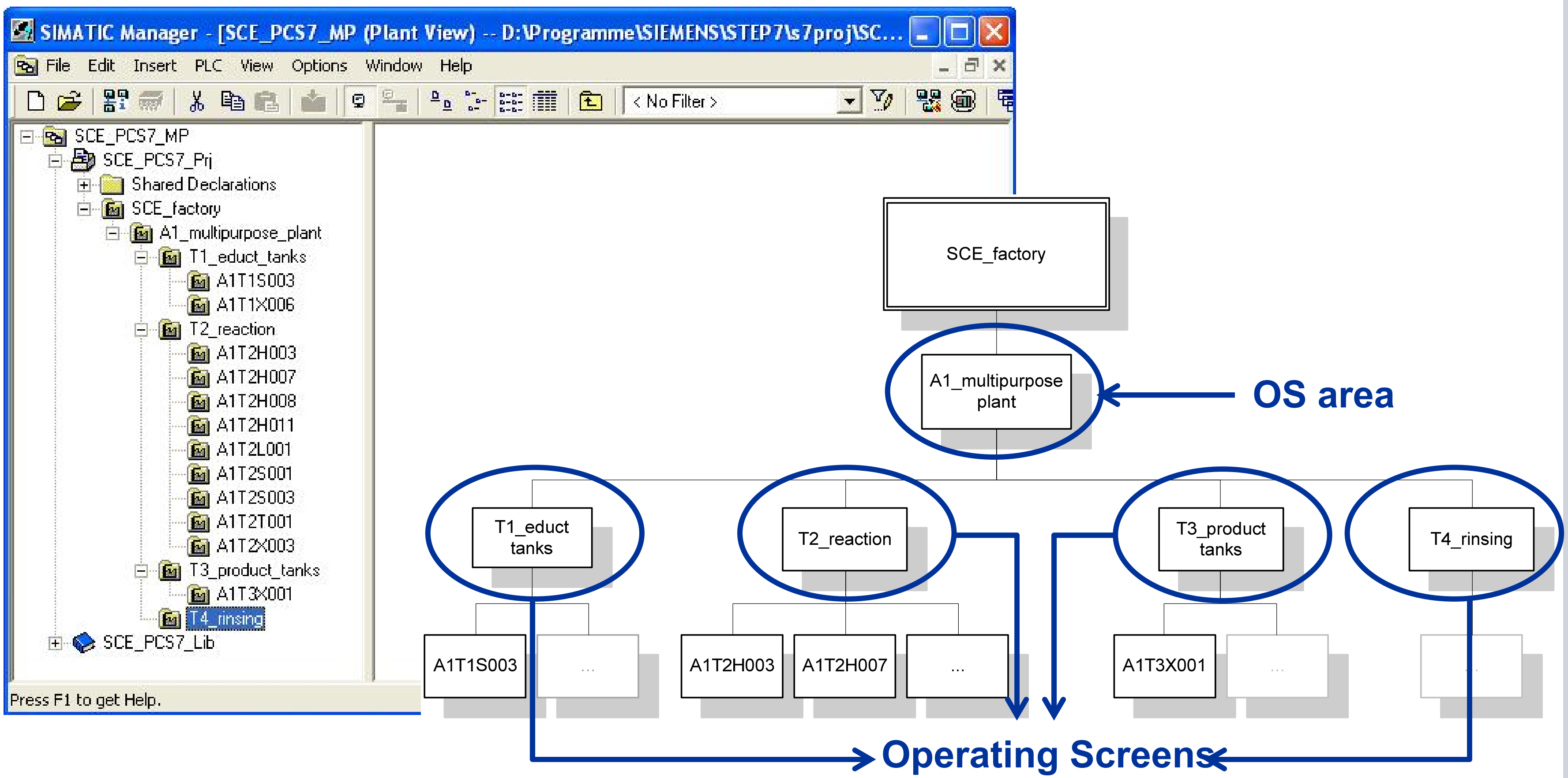
Plant Hierarchy and the Effect on Visualization



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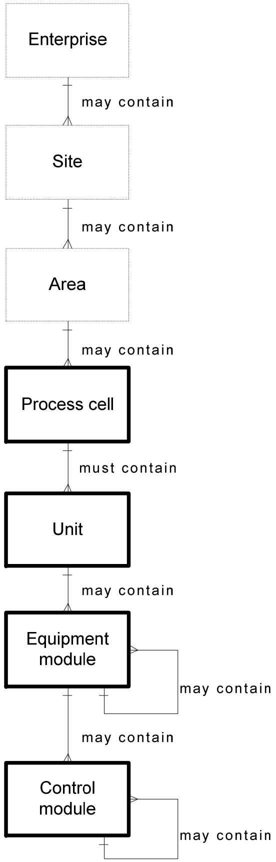
Objective

- Theory
  - Individual drive function (IDF)
  - IDF in PCS7
  - IDF motor

- Step by step instructions
  - Setting up symbol tables
  - Setting up CFC for IDF motor
  - Testing the IDF

Individual Drive Functions (IDF)

- Hierarchical structuring of the plant according to ISA-88.01
  - Level 0: Individual control unit
- Individual control unit is a recurring element
  - Project wide
  - Beyond projects
- Can be reused
  - Advantages:
    - Parameterization instead of programming
    - Tested functionality
    - Uniform handling and visualization
- Standardization of individual drive units
  - e. g. motor, valve, …



Individual Drive Function in PCS7

- Function blocks as object-oriented model of a technical installation
  - e. g. motors and valves
- Functions:
  - Activation and operating modes
  - Protection and monitoring functions
  - Handling and visualization functions
  - Signaling and alarm functions
- Function block as object-oriented model of a (measuring) signal
  - For example, digital output, digital input, analog output, analog input
- Functions:
  - Scaling the digital value to the physical range
  - Monitoring the signal quality

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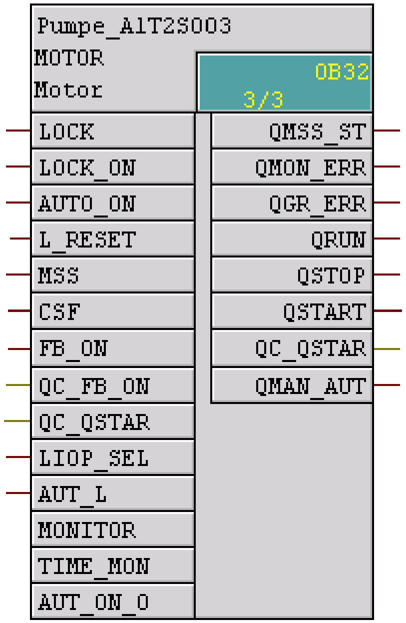
Individual Drive Function Motor (FB 66 in PCS 7 Standard Library)

- Function blocks MOTOR
- Used for controlling pumps and stirrers in the lab installation
- Features:
  - One control signal (on/off)
  - Monitoring by run feedback
- Advantages:
  - No programming of control, protection and monitoring functions
  - Uniform parameters
  - Uniform visualization (see P02-01 HMI Generation)



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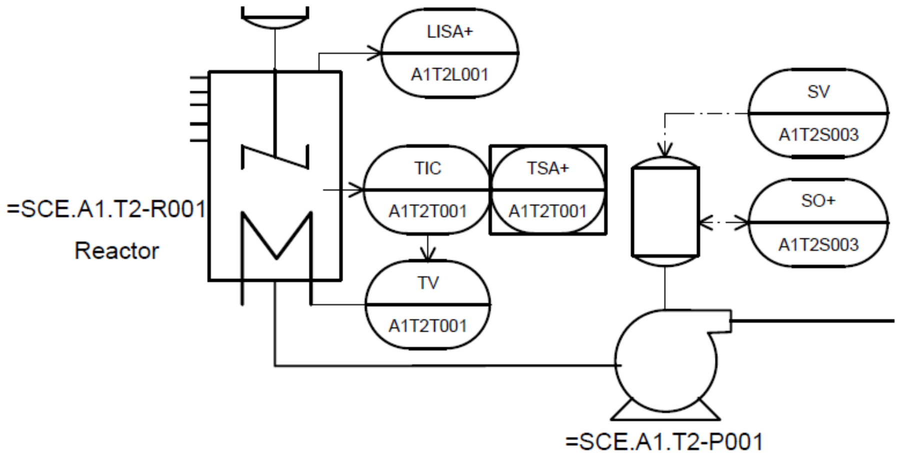
Implementation of a Pump of the Lab Installation

- Pump SCE.A1.T2-P001 to empty the reactor content
- Pump is run by a motor
- The motor has the following signals
  - One signal for control
  - One signal for run feedback
- PCS7 standard library
  - MOTOR



Symbol	Address	Data Type	Symbol Comment
A1.T2.A1T2S003.SO+.O+	I 6.1	BOOL	Pump outlet reactor R001 Feedback on
A1.T2.A1T2S003.SV.C	O 6.3	BOOL	Pump outlet reactor R001 control signal

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Objective

- Theory
  - Plant protection using PCT resources
  - Standardized circuits for plant safety
  - Designing a lock for the lab installation
- Step by step instructions
  - Setting up a CFC for manual motor operation
  - Adding lock for the motor in the CFC
  - Interconnections among CFCs

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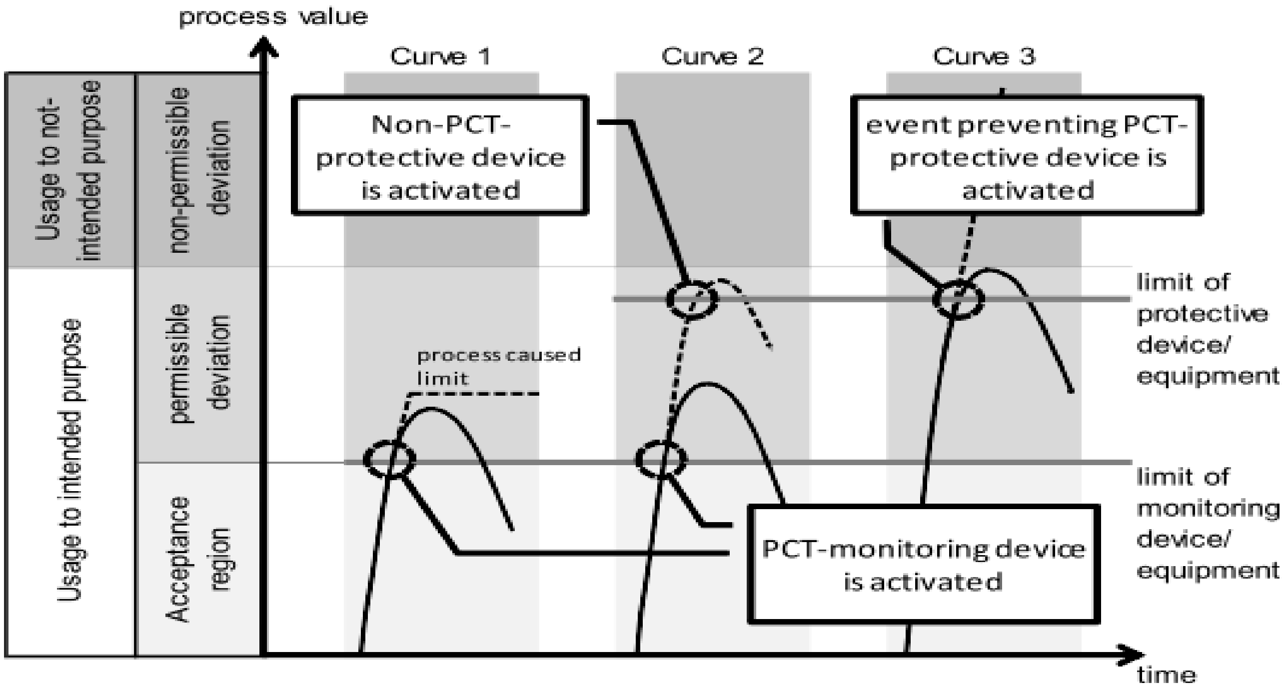
Plant Safety using PCT Resources

- Securing process engineering plants against error states
- In reference to process variables, three areas have to be differentiated



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Designing a Lock for the Pump of the Lab Installation

- The pump must be turned on only if the main switch of the plant is switched on and the Emergency Off switch is unlocked.
- The pump must not take in air; i.e. the level in the reactor has to be at least 50ml
- The pump must not work against closed valves; i.e., at least one valve has to be open

Symbol	Address	Data Type	Symbol Comment
A1.A1H001.HS+-.START	I 0.0	BOOL	Switch on multi-purpose plant
A1.A1H002.HS+-.OFF	O 0.1	BOOL	Activate Emergency OFF
A1.T2.A1T2L001.LISA+.M	IW 512	WORD	Actual value level Reactor R001
A1.T2.A1T2X007.GO+-.O+	I 6.5	BOOL	Open/close valve … indication
A1.T3.A1T3X001.GO+-.O+	I 12.3	BOOL	Open/close valve … indication
A1.T4.A1T4X003.GO+-.O+	I 14.5	BOOL	Open/close valve … indication

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Standard Wiring for Plant Safety

- Substitute analog value A1.T2.A1T2L001.LISA+.M with binary value that is the result of the comparison with 50ml
- Functional table to design the combinatorial circuit

A1H001	A1H002	A1T2L001 > 50ml	A1T2X007	A1T3X001	A1T4X003	LOCK
0	x	x	x	x	x	0
x	0	x	x	x	x	0
x	x	0	x	x	x	0
x	x	x	0	0	0	0
1	1	1	1	x	x	1
1	1	1	x	1	x	1
1	1	1	x	x	1	1

- Result after <<according to>> conjunctive normal form (CNF) is used to lock the pump

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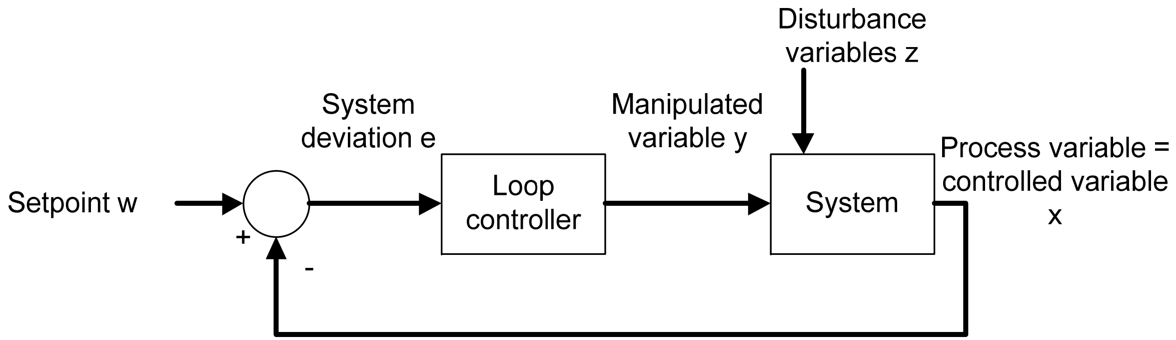
Objective

- Theory
  - Structure of a control loop
  - PID controller
  - Controlling the temperature of the lab installation
- Step by step instructions
  - Establishing more CFCs
  - Parameterizing a continuous controller
  - Output of the analog manipulated value as binary signal by means of a pulse generator

Structure of a Control Loop

- Process variables have to hold or set certain values
  - Disturbance behavior: A certain value has to be held despite disturbances
  - Response to set point changes: Set point is to be reached in the dynamic and stable mode
- The control loop works as follows:
  - Process value/controlled variable is measured by a sensor
  - Measured value is deducted from the set point and thus the deviation is calculated.
  - Based on the deviation, the controller calculates the manipulated value of the actuator
  - The actuator has an effect on the system

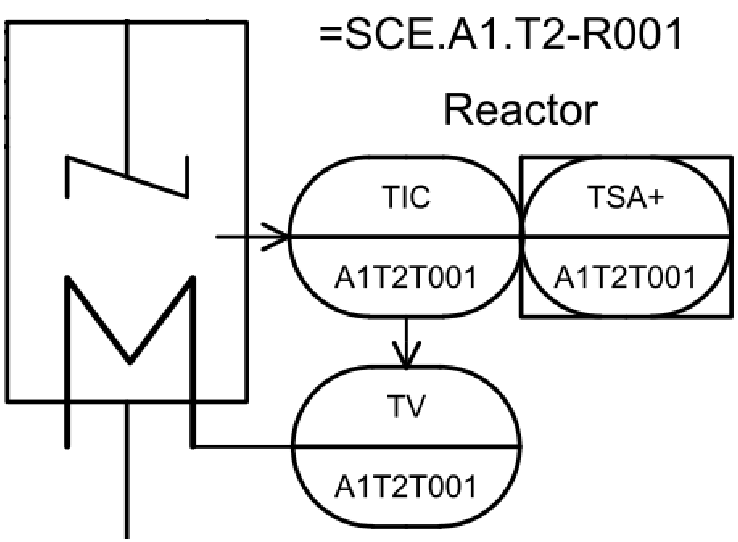


PID Controller

- From the deviation, the control algorithm calculates the manipulated value
- Process industry uses the PID algorithm up to 95%
  - P means proportional
    - Current manipulated value only depends on current deviation
  - I means integral
    - Current manipulated value depends on the sum of the last deviations
  - D means differential
    - Current manipulated value depends on the change in the deviation
- Only 3 parameters (gain, reset time and derivative time) have to be set
- Controller adjustment rules suitable for processes without dominant dead time
  - Method of Ziegler and Nichols
  - Chien, Hrones and Reswick

Temperature Control of the Lab Installation

- Control loop
  - Process/control variable is A1.T2.A1T2T001.TIC.M
  - Manipulated variable is A1.T2.A1T2T001.TV.S
  - Set point is
    - determined by recipe
    - determined manually
    - locked (tracking)
- Conditions for locking
  - Minimum level in the reactor has to be 200ml
  - Maximum temperature is 60°C maximum



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Objective

- Theory
  - Structure of step sequences
  - Designing a sequential control system
  - Recipe of the lab installation

- Step by step instructions
  - Setting up and editing sequential function charts (SFC)
  - Connecting SFC and CFC
  - Testing the SFC

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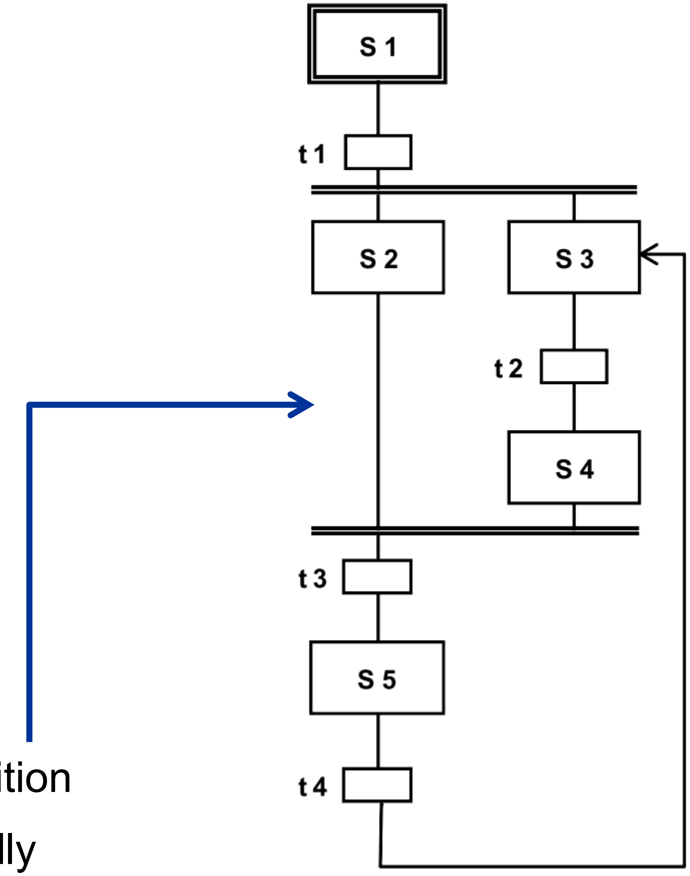
Structure of Step Sequences

- Alternating sequence of steps and transitions
  - First step: start step
  - Final step: end step
- Structures:
  - Unbranched step sequence
  - Alternative branches
  - Parallel branches
- Impermissible structures:
  - Uncertain sequence – accessibility not ensured
  - Partially stuck – internal infinite loop
  - Totally stuck – no permissible step enable condition
- Step sequences can be processed once or cyclically



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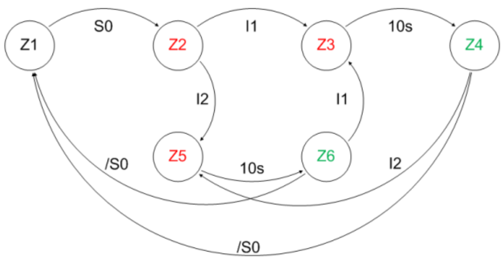
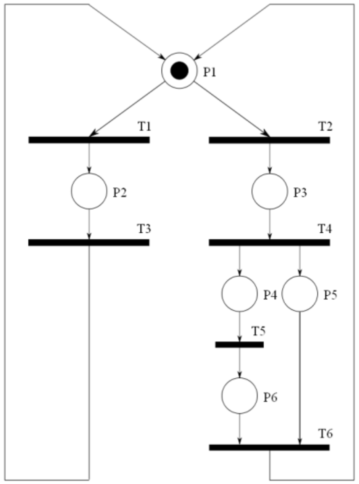
Design of a Sequence Control

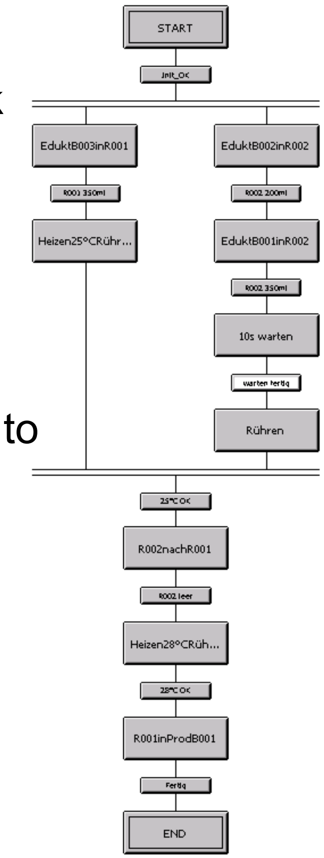
- Proven design method for sequence controls
  - State graphs
    - Connected, oriented graph
    - States shown as circles – can be linked to actions
    - State transitions shown as arrows – subject to transition conditions
  - Petri nets
    - Consists of locations and transitions
    - Locations as circles
    - Transitions as rectangles/cross bars
    - Parallel sequences can be mapped





Recipe of the Lab Installation

- First, 350ml are to be drained from educt tank =SCE.A1.T1-B003 into reactor =SCE.A1.T2-R001 and at the same time 200ml from educt tank =SCE.A1.T1-B002 into the reactor =SCE.A1.T2-R002.
- When reactor =SCE.A1.T2-R001 is filled, the liquid is to be heated to 25°C with the agitator switched on.
- When reactor =SCE.A1.T2-R002 is filled, 150ml from educt tank =SCE.A1.T1-B001 is to be added to reactor =SCE.A1.T2-R002. When this is completed, 10s later the agitator of reactor =SCE.A1.T2-R002 is to be switched on.
- When the temperature of the liquid in reactor =SCE.A1.T2-R001 has reached 25°C, the mixture is to be pumped from reactor =SCE.A1.T2-R002 to reactor =SCE.A1.T2-R001.
- Now, the mixture in reactor =SCE.A1.T2-R001 is to be heated to 28°C and then drained into product tank =SCE.A1.T3-B001.



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Objective

- Theory
  - Concepts of representation
  - HMI generation in PCS 7
  - Graphic of the lab installation

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

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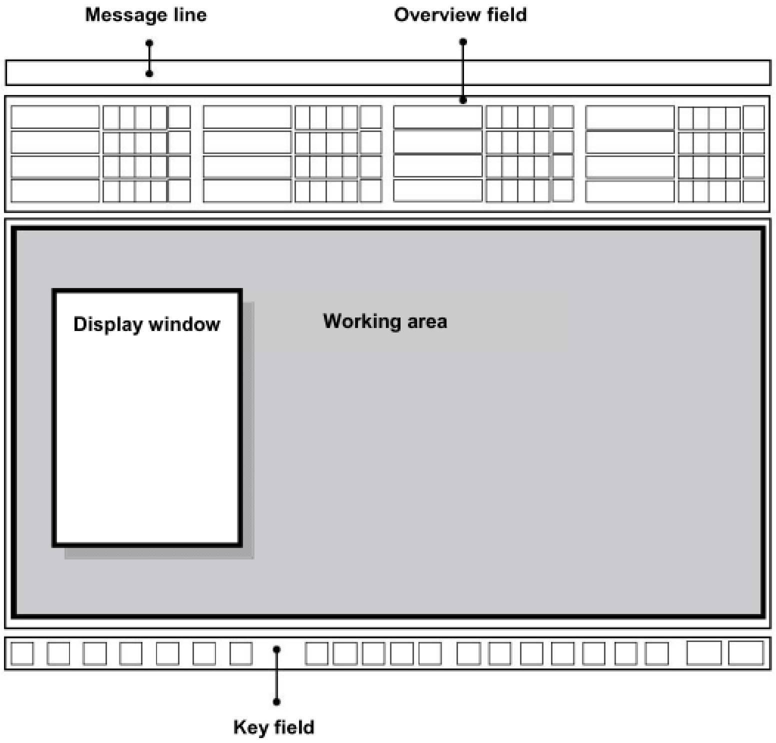
Concepts of Representation

- Important aspects of representation
  - Organization of what is to be represented
  - Density of representation
  - Coding
  - Conspicuousness
  - Consistency
- Basic structure of the display area according to
- Flow diagrams
  - Process control flow diagrams
  - Process engineering flow diagrams
    - Basic flow diagram, process diagram, piping and instumentation diagram (P&ID)



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HMI Generation in PCS7

- Picture hierarchy can be derived directly from the plant hierarchy
  - Setting up a picture in the corresponding levels
- Using the block icons of templates
  - Deriving the 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, number and arrangment of monitors
- Graphics Designer
  - Drawing the process images (static elements)
  - Linking dynamic elements with process variables

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Graphics of the Lab Installation

- The hierarchy is to include levels 2 and 3 <<refer to Notes Page for translation of terms below>>
  - A1_Mehrzweckanlage - A1_Mehrzweckanlage.pdl
    - A1_Mehrzweckanlage/T1_Eduktspeicher - T1_Eduktspeicher.pdl
    - A1_Mehrzweckanlage/T2_Reaktion - T2_Reaktion.pdl
    - A1_Mehrzweckanlage/T3_Produktspeicher - T3_Produktspeicher.pdl
    - A1_Mehrzweckanlage/T4_Spülen - T4_Spülen.pdl
- Overview display
  - Display of all units
  - Display of the most important information
  - Abstract
- Area display
  - Representation of a unit
  - Representation of block icons of motors and valves
  - Representation based on the P&ID

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Objective

- Theory
  - Signaling systems
  - Alarms and indications
  - Alarm management in PCS7

- Step by step instructions
  - Integrating the monitoring and alarming blocks
  - WinCC Signalling system
  - Representation of alarms and warnings on the operator station (OS)

Signaling Systems, Alarms and Indications

- Interface between process and operator
  - Early detection of deviations from the desired state
  - Target oriented intervention to restore the desired state
- Alarm → Display of or report about the occurrence of an event that requires immediate operator action
- Message → Display of or report about the occurrence of an event that does not require immediate operator action
- Characteristics for selecting alarms
  - Relevant
  - Unambiguous
  - Timely
  - Prioritized
  - Understandable

Priority

Response time	Seriousness		
	Shutdown	Off spec	delay in production
< 5 min	High	Medium	Low
5 - 20 min	Medium	Medium	Low
> 20 min	Low	Low	Low

Priority

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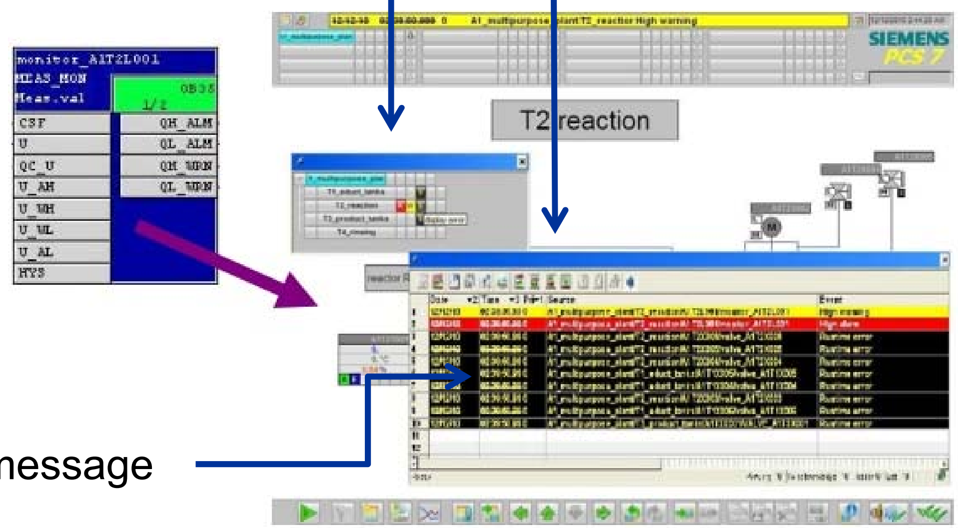
Alarm Management in PCS 7

- Function block for generating messages
  - Block icon to represent alarming states

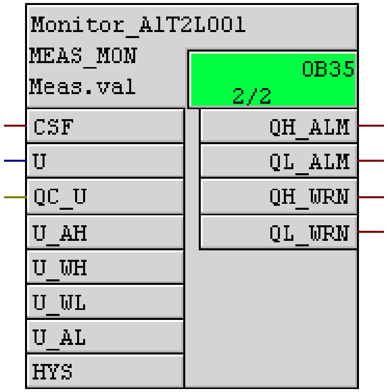
- Group alarms along the plant hierarchy



- Representation and management of message lists

Alarms for the Lab Installation

- Monitoring the level
- Monitoring the temperature
- Using Meas_Mon (FB 65) from the folder Control of the PCS7 Library V71
  - Monitoring a measured value (analog signal)
  - Parameters that can be set
    - Warning limit (high/low)
    - Alarm limit (high/low)
- Representation of the block icon
  - In unit T2_reaction
  - Placing and compiling



Objective

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

- Step by step instructions
  - Importing plant design data using the import/export wizard
  - Importing plant design data in the process object view
  - Duplicating charts by generating process tag types/models

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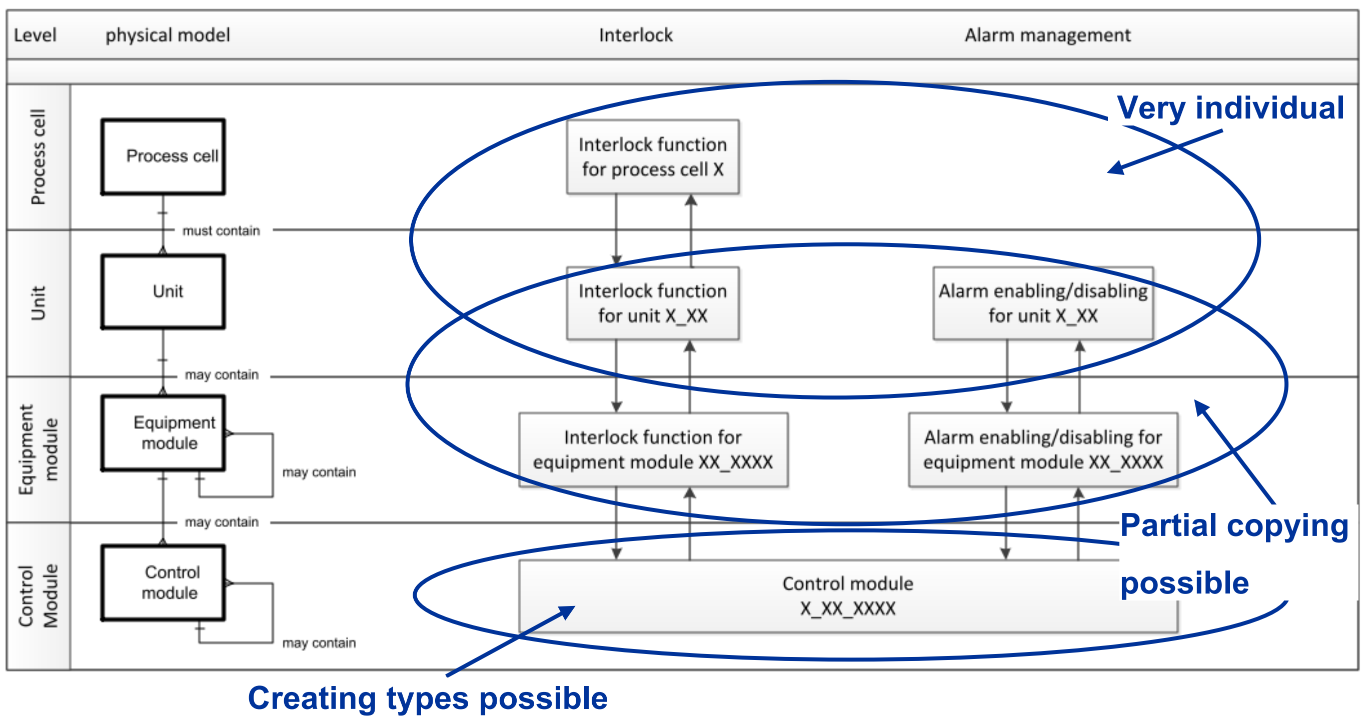
Design of Complex Systems

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

Process Tag Types and Models

- Process tag type – CFC - corresponds to the level: individual control unit
- Model - entire hierarchies – correspond to the levels Technical installation and unit



Process Tag Types and Models of the Lab Installation

- Selecting similar individual control units
  - Pumps
    - A1T1P001, A1T1P002, A1T1P003 and A1T4P001
    - A1T2P001 and A1T2P002
  - Valves
    - A1T1V001, A1T1V002, A1T1V003, .. , A1T1V006
    - ...
- Selecting similar technical installations
  - Containers
    - A1T1B001, A1T1B002 and A1T1B003
    - A1T2R001 and A1T2R002
    - A1T3B001 and A1T3B002

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Thanks for your attention !

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