Siemens Automation Cooperates with Education (= SCE)
Siemens Automation Cooperates with Education

PCS7 HS - 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
### 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
### 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 ...
- ...
- ...
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
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 process image
- Signal consistency during program processing by accessing the process image
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)
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...
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
Plant Hierarchy and the Effect on Visualization
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
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)
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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Address</th>
<th>Data Type</th>
<th>Symbol Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1.T2.A1T2S003.SV.C</td>
<td>O 6.3</td>
<td>BOOL</td>
<td>Pump outlet reactor R001 control signal</td>
</tr>
</tbody>
</table>
**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
Securing process engineering plants against error states

In reference to process variables, three areas have to be differentiated:

1. Usage to non-intended purpose
2. Permissible deviation
3. Acceptance region
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

<table>
<thead>
<tr>
<th>Symbol</th>
<th>Address</th>
<th>Data Type</th>
<th>Symbol Comment</th>
</tr>
</thead>
<tbody>
<tr>
<td>A1.A1H001.HS+-..START</td>
<td>I 0.0</td>
<td>BOOL</td>
<td>Switch on multi-purpose plant</td>
</tr>
<tr>
<td>A1.A1H002.HS+-..OFF</td>
<td>O 0.1</td>
<td>BOOL</td>
<td>Activate Emergency OFF</td>
</tr>
<tr>
<td>A1.T2.A1T2L001.LISA+.M</td>
<td>IW 512</td>
<td>WORLD</td>
<td>Actual value level Reactor R001</td>
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<tr>
<td>A1.T2.A1T2X007.GO+-..O+</td>
<td>I 6.5</td>
<td>BOOL</td>
<td>Open/close valve … indication</td>
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<tr>
<td>A1.T3.A1T3X001.GO+-..O+</td>
<td>I 12.3</td>
<td>BOOL</td>
<td>Open/close valve … indication</td>
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</table>
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

<table>
<thead>
<tr>
<th>A1H001</th>
<th>A1H002</th>
<th>A1T2L001 &gt; 50ml</th>
<th>A1T2X007</th>
<th>A1T3X001</th>
<th>A1T4X003</th>
<th>LOCK</th>
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<td>0</td>
<td>x</td>
<td>x</td>
<td>x</td>
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<td>x</td>
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<td>1</td>
<td>x</td>
<td>x</td>
<td>1</td>
<td>1</td>
</tr>
</tbody>
</table>

Result after according to conjunctive normal form (CNF) is used to lock the pump
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
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
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
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
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
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.
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
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 VDI 3699
- Flow diagrams
  - Process control flow diagrams
  - Process engineering flow diagrams
  - Basic flow diagram, process diagram, piping and instrumentation diagram (P&ID)
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 arrangement of monitors
- Graphics Designer
  - Drawing the process images (static elements)
  - Linking dynamic elements with process variables
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
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)
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

<table>
<thead>
<tr>
<th>Response time</th>
<th>Seriousness</th>
<th>delay in production</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Shutdown</td>
<td>Off spec</td>
</tr>
<tr>
<td>&lt; 5 min</td>
<td>High</td>
<td>Medium</td>
</tr>
<tr>
<td>5 - 20 min</td>
<td>Medium</td>
<td>Medium</td>
</tr>
<tr>
<td>&gt; 20 min</td>
<td>Low</td>
<td>Low</td>
</tr>
</tbody>
</table>
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
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
Thanks for your attention!

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