§ 1 What is Industrial Automation?

1.1 Definition of Several Basic Terms
1.2 Degree of Automation and Computer Deployment
1.3 Automation of Technical Products and Technical Plants
1.4 Components of an Industrial Automation System
1.5 Levels of Process Management and Automation Functions
1.6 Technical Systems
1.7 Graphical representation of Technical Processes
1.8 Effects of Industrial Automation on People, Society and Environment
Chapter 1 - Learning targets

– to know what Industrial Automation is
– to understand what a real-time system is
– to know what is meant by the „degree of automation“
– to recognize the different kinds of computer deployment
– to be able to differ between product automation and plant automation
– to know the components of an industrial automation system
– to know the different levels of an industrial automation system and their requirements
– to be able to classify processes in technical systems
– to know the different kinds of graphical representation of technical processes
– to become aware of the responsibility of an automation engineer
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Definition 1:

A **technical process** is a process during which material, energy or information is altered in its state. This modification of state can imply the transition from an initial state to a final state.

Technical process means flow of material, energy or information.
## Examples

<table>
<thead>
<tr>
<th>Initial State</th>
<th>Technical Process</th>
<th>Technical System</th>
<th>Final State</th>
</tr>
</thead>
<tbody>
<tr>
<td>Low ambient temperature</td>
<td>Heating of a house</td>
<td>Oil-fueled heating system</td>
<td>Higher ambient temperature</td>
</tr>
<tr>
<td>Dirty laundry</td>
<td>Washing process</td>
<td>Washing machine</td>
<td>Fresh laundry</td>
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<tr>
<td>Unsorted parcels</td>
<td>Transportation and distribution processes</td>
<td>Parcel distribution system</td>
<td>Parcels sorted by destinations</td>
</tr>
<tr>
<td>Energy of fossil or nuclear fuels</td>
<td>Energy transformation and energy generation processes</td>
<td>Power plant</td>
<td>Electric energy</td>
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<tr>
<td>Parts to be stored</td>
<td>Storage process</td>
<td>High bay warehouse</td>
<td>Parts compiled for commissions</td>
</tr>
<tr>
<td>Train at location A</td>
<td>Traffic process</td>
<td>Train</td>
<td>Train at location B</td>
</tr>
<tr>
<td>Monomere substance</td>
<td>Chemical reaction</td>
<td>Chemical reactor</td>
<td>Polymeric substance</td>
</tr>
<tr>
<td>Untested device</td>
<td>Test process</td>
<td>Test laboratory</td>
<td>Tested device</td>
</tr>
<tr>
<td>Parts without a drill-hole</td>
<td>Drilling process</td>
<td>Drilling machine</td>
<td>Parts with drill-hole</td>
</tr>
<tr>
<td>Pollutants</td>
<td>Pollution monitoring</td>
<td>System for air pollution monitoring</td>
<td>Information on pollution concentrations are indicated in monitoring center</td>
</tr>
</tbody>
</table>
1.1 Definition of Several Basic Terms

**Definition 2: DIN 66201**

A process is the entirety of all interacting processes within a system that transforms and stores material, energy or information. A **technical process** is a process in which its physical parameters are recorded and influenced by **technical means**.

- from simple to highly complex: **washing machine, power plant**
- different partial processes are combined to an overall process: **car with automotive electronics**
1.1 Definition of Several Basic Terms

Example

- technical plant: chemical reactor
- technical process: 3 sub-processes (fill, reaction, empty)
1.1 Definition of Several Basic Terms

**Industrial automation**

= process + automation

- cigarette vending machine
- ticket vending machine
- office automation,
- traffic automation,
- railway automation,
- industrial automation

automat = independently operating technical systems

automation = to enable machines, installations and facilities to operate independently
1.1 Definition of Several Basic Terms

**Industrial automation**

= the automation of a technical process

**Industrial automation system**

= technical system with technical process
  + computer and communication system
  + process operators
1.1 Definition of Several Basic Terms

Structure of an industrial automation system

People (process operators) for managing and operating the technical process as well as intervening in exceptional situations

Computer and communication system consisting of e.g., programmable logic controllers (PLC), industrials PCs, micro controllers, bus systems, etc.

Technical system (technical product or technical plant), in which a technical process takes place
### Industrial automation system

- Goal is the automation of operations in the technical process with the help of appropriate information processing units
- Human operators only place requests on the operating results
- **Automation of the technical process in the foreground**

### Process control system

- Goal is the management of the procedure of the technical process by human operators, supported by the automation of individual operations
- Managing refers to controlling and regulating
- **Operation in the foreground**

### Process computer sciences

- Goal is an automation software system
- Real-time system
- **Computer and communication system in the foreground**
Definition: Real-time operation (DIN 44300)
Real-time operation is the operation of a computer system, in which programs required for the handling of incoming data are in constant operation so that the processing results are available within a given period of time. This data may appear according to a random time distribution or at regular intervals.

Features of a real-time system

- Hardware/software system
- Data reception, data processing, data delivery to the process within a given time interval
- External events
- Processing priority

Real-time system allows real-time operation
1.1 Definition of Several Basic Terms

**Requirements on real-time systems**

- **Timeliness**
  reaction right on time
  \(\text{not too soon, not too late}\)

- **Simultaneousness**
  simultaneous reaction to various events
  \(\text{parallel processes}\)

- **Dependability**
  reliable, safe, available
  \(\text{important reason for purchase}\)

- **Predictability**
  all reactions must be predictable and deterministic
  \(\text{comprehensible in case errors occur}\)
1.1 Definition of Several Basic Terms

**Industrial automation system as real-time systems**

- People
- Time
- Sensor signals
- Control signals
- External influences
- Operating personnel
- Technical process

[Diagram showing the interaction between people, computer and communication system, technical process in a technical plant, sensor signals, control signals, and external influences.]
1.1 Definition of Several Basic Terms

**Features**

Processors applicable in a process automation system are freely programmable digital processors (computers) that have to show mainly 3 features:

- Compliance of real-time operation requirements, that are: recording, processing and output of process data in a timely manner
- Possibilities for input/output of process signals (directly or via a communication system) for process connection
- Processing of numbers, characters and bits

*In 60th and 70th years specific „process computers“ - Antiquated term, because differences have disappeared*
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1.8 Effects of industrial automation on people, society and environment
1.2 Degree of automation and computer deployment

Degree of automation

The sense and benefit of an automation depends on the technical process (accessible / inaccessible) and the general conditions (economically reasonable / senseless). The degree of automation describes the extend of the processes included in the automation.

**bandwidth:** from zero up to fully automated operation

**Caution!** - Also with fully automated operation the human being can make interventions (set point default or malfunction)! 

Types of operation

- **Off-line operation** (operation with indirect process connection) with the lowest degree of automation
- **On-line / open-loop operation** (open on-line operation) for a medium degree of automation
- **On-line / closed-loop operation** (closed on-line operation) for a high degree of automation
1.2 Degree of automation and computer deployment

Operation without computer use

- general management
- orders
- process protocol
- process personnel
- control and regulation devices
- display device and graphical recorder
- technical plant

no automation
1.2 Degree of automation and computer deployment

Off-line operation (indirectly connected operation)

- General management
  - Orders
- Off-line computer
  - Input, operation modes, instructions
- Operation protocol input
- Process personnel
- Control and regulation devices
- Manual device
- Technical plant
- Display and graphical recorder
- Process management instructions
- Operation protocol

Low degree of automation, no connection to the technical process.
On-line/ open-loop operation of a computer system

medium degree of automation, data acquisition from the technical process
On-line-/ closed-loop operation of a computer system

high degree of automation, data recording and influence of the technical process

operation management and control

orders

on-line and closed-loop

computer and communication system

emergency control

emergency instruments

technical plant

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§ 1 What is Industrial Automation?

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<th>Description</th>
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<td>1.3</td>
<td><strong>Automation of technical products and technical plants</strong></td>
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<td>Effects of industrial automation on people, society and environment</td>
</tr>
</tbody>
</table>
1.3 Automation of technical products and technical plants

**Product automation**

industrial automation systems, in which the technical process takes place within a device or within a single machine

**Plant automation**

industrial automation systems, in which the technical process is composed of single partial processes that take place on greater, often geographically wide spread plants
### Examples

<table>
<thead>
<tr>
<th>Examples of products in product automation</th>
<th>Examples of technical plants in plant automation</th>
</tr>
</thead>
<tbody>
<tr>
<td>heating systems</td>
<td>power plants (steam generators, turbines, generators)</td>
</tr>
<tr>
<td>washing machines</td>
<td>energy grid</td>
</tr>
<tr>
<td>sewing machines</td>
<td>high bay warehouse</td>
</tr>
<tr>
<td>kitchen appliances (e.g., dish washer, microwave, etc.)</td>
<td>parcel distribution installations</td>
</tr>
<tr>
<td>TVs, radios</td>
<td>chemical reactors</td>
</tr>
<tr>
<td>cameras</td>
<td>process engineering installations</td>
</tr>
<tr>
<td>alarm systems</td>
<td>steel production plants</td>
</tr>
<tr>
<td>toys</td>
<td>milling installations</td>
</tr>
<tr>
<td>navigation systems</td>
<td>railway traffic system (long distance trains, commuter railways, metros)</td>
</tr>
<tr>
<td>answering machines</td>
<td>traffic light installations</td>
</tr>
<tr>
<td>musical instruments</td>
<td>gas supply installations</td>
</tr>
<tr>
<td>machine tools</td>
<td>purification and water plants</td>
</tr>
<tr>
<td>measuring devices</td>
<td>building system installations</td>
</tr>
<tr>
<td>automobiles with sub-systems: motor control, ABS, distance warning system, route planning, etc.</td>
<td>laboratories and test fields</td>
</tr>
<tr>
<td></td>
<td>environmental measurement installations</td>
</tr>
<tr>
<td></td>
<td>etc.</td>
</tr>
</tbody>
</table>
### Characteristic criteria regarding product automation

- Technical process in a device or machine (embedded systems)
- Dedicated automation functions
- Automation computer in the form of a micro controller or PLC
- Few sensors and actuators
- Degree of automation 100%, on-line/closed-loop operation
- High quantities (serial or mass products)
- Engineering and software costs of inferior importance since they are distributed among large unit numbers

*simple*
Structure with simple product automation

- User or operator
- Micro controller
- Technical product

Set values and display:

Example: kitchen appliance
Example of a simple product automation (chalkboard writing)
1.3 Automation of technical products and technical plants

Structure with complex product automation

- User or operator
- Microcontroller
- Bus system

Example: automotive electronics

Microcontroller 1
Microcontroller 2
... Microcontroller n
Subsystem 1
Subsystem 2
... Subsystem n
Technical product
1.3 Automation of technical products and technical plants

Characteristic criteria regarding plant automation

- Technical process in an industrial plant, often geographically wide spread
- Extensive and complex automation functions
- PLCs, PCs and process control systems are used as automation computer systems
- Large number of sensors and actuators
- Medium to high degree of automation
- Unique system
- Engineering and software costs are critical for overall costs
1.3 Automation of technical products and technical plants

**Structure for a larger technical plant**

- **Level 3**: Master computer, monitoring, operating, protocolling
- **Level 2**: PLCs, pant bus
- **Level 1**: Sub-systems, field bus

Diagram shows the hierarchical structure of a technical plant with control and monitoring through various levels.
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1.6 Technical systems
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1.8 Effects of industrial automation on people, society and environment
1.4 Components of an industrial automation system

Overview

- Technical components of an industrial automation system
  - Technical system to be automated (automation object)
    - Technical product
    - Technical plant
  - Facilities necessary for automation (automation system)
    - Facilities for user-process communication
    - Hardwired individual devices
  - Interface to the technical process: sensors and actuators
  - Communication system
    - Communication system close to the process (field bus)
    - Bus system for the communication between automation computers
  - Automation computer system
    - Hardware system (device system)
    - Automation software system
    - User software
    - System software

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1.4 Components of an industrial automation system

**Sensors**
- Acquisition of information on the progression of process variables
- Sensors, detection devices, measuring devices
- Conversion into electrical or optical signals
  \[ \text{examples: temperature, pressure, velocity} \]

**Actuators**
- Conversion of control information in order to influence process variables
- Actuators (correcting element)
  \[ \text{examples: relays, magnets, servomotors} \]
1.4 Components of an industrial automation system

**Communication system in product automation**

**Simple products**
- few sensors and actuators
- short line distances

**Complex products**
- communication between subsystems via bus system
- examples: CAN bus, Interbus-S
Communication system in plant automation

- Many sensors and actuators, geographically distributed
- Many automation computers, geographically distributed

Communication tasks on several levels

- Factory bus
- Plant bus (process bus)
- Field bus
1.4 Components of an industrial automation system

Different forms of automation computers

- Programmable logic controller (PLC)
- Micro controller
- Personal computer (PC)
- Process control system
### Automation software system

- Set of all programs necessary for the execution of automation tasks, including their documentation

- Differentiation between executive and organizational/administrational tasks

#### Executive programs (application software)
- Input measured values
- Calculation of control variables

#### Organizing and administrating programs (operating software or system software)
- Software device drivers
- Operating system
1.4 Components of an industrial automation system

**Application software**
- programs for acquisition of process variables
- programs for process monitoring
- programs for process control
- programs for process regulation
- programs for process optimization and management
- programs for process safety and security

**System software**
- programs for organizing of application programs
- programs for managing peripheral devices
- programs for organizing data traffic with external memories
- programs for the dialogue between human and computer
- compilation programs
- run-time programs

**Operating system**
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Model of levels in the management of a technical process

- **Strategic level**: Long-term distribution policy
- **Dispositive level**: Distribution planning
- **Tactical level**: Distribution tactics
- **Operative level**: Sales

**Levels of hierarchy**

- Field of action
- Market

**Levels of a company**

- Business management level
- Production and operation management level
- Process control level
- Level of measuring, controlling and regulating process variables (process variable level)

**Technical process in a technical system**
Time requirements on the different levels

<table>
<thead>
<tr>
<th>Level</th>
<th>Time Requirements</th>
</tr>
</thead>
<tbody>
<tr>
<td>Business Management</td>
<td>Effects ranging between months-years</td>
</tr>
<tr>
<td>Production and Operation Management</td>
<td>Effects ranging between days-weeks-months</td>
</tr>
<tr>
<td>Process Control Level</td>
<td>Effects ranging between minutes-hours</td>
</tr>
<tr>
<td>Process Variable Level</td>
<td>Effects ranging between microseconds-seconds</td>
</tr>
</tbody>
</table>
Automation functions

Levels of a company

- business management level
- production and operation management level
- process control level
- process variable level
- field level

Automation functions

- cost analysis, statistical evaluations
- work sequence planning, capacity optimization, evaluation of process results
- process monitoring, start-up and shut-down, malfunction handling, process guidance, process security
- measuring, controlling, manipulating, regulating, interlocking, emergency handling of process variables, shut-down, protection
- recording and influencing process variables with sensors and actuators

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Types of occurring process variables (1)

- Process variables, that are allocated to the course of physical state-variables with a continuous or piecewise continuous range of values
  example: temperatures in a heating system

- Process variables, that are allocated to certain discrete process states
  • physical variables with a continuous range of values that characterize the process states
  • binary process variables that are allocated to state transitions i.e., to events that cause the change of state

example: switch setting: 0/off - 1/on
Types of occurring process variables (2)

- Process variables that are allocated to individually identifiable objects
  - physical variables with a continuous range of values
    example: temperature of a slab in a clogging mill,
    size of a part in a store
  - non-physical variables
    example: type, design, application, depot number
Definition of three process types in technical systems

- continuous processes

- sequential processes, discrete event type processes

- object-oriented processes

Caution! - a clear distinction is not always possible!

example: transportation as a continuous and object-oriented process
## Continuous processes in technical systems

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>processes containing time-dependent continuous process variables</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process variables</td>
<td>physical variables with a (at least piecewise) continuous range of values</td>
</tr>
<tr>
<td>Examples</td>
<td>generation processes, transformation processes, movements, etc.</td>
</tr>
<tr>
<td>Mathematic models</td>
<td>differential equations (time as an independent variable), transfer functions</td>
</tr>
</tbody>
</table>
## Sequential processes in technical systems

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>processes containing sequences of different, distinguishable process states</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process variables</td>
<td>binary signals that cause or indicate discrete process states as well as continuous physical variables allocated to process states</td>
</tr>
<tr>
<td>Examples</td>
<td>sequences of process states during start-up or shut-down of a turbine, sequence of states during the operation of an elevator, sequence of states during production using a machine tool</td>
</tr>
<tr>
<td>Models</td>
<td>flow charts, function plans according to DIN 40719, state models, Petri nets</td>
</tr>
</tbody>
</table>
### Object-oriented processes in technical systems

<table>
<thead>
<tr>
<th>Characteristics</th>
<th>processes during which individually identifiable objects are transformed, transported or stored</th>
</tr>
</thead>
<tbody>
<tr>
<td>Process variables</td>
<td>physical variables with a continuous range of values or non-physical variables (e.g., type, design, application, bay number) that are allocated to the objects, as well as binary variables, that cause or indicate state changes of objects</td>
</tr>
<tr>
<td>Examples</td>
<td>processes during the manufacturing of parts, traffic processes, storage processes, information processes in computers</td>
</tr>
<tr>
<td>Models</td>
<td>simulation models, queue-models, state models, Petri nets, OO-models</td>
</tr>
</tbody>
</table>
Classification methods

Classification according to the kind of...

- transformed or transported medium
  - material related processes, energy related processes, information related processes

- effect
  - generation processes, distribution processes, storage processes

- material-related transformation
  - chemical processes, production processes

- dominating process type
  - flow processes (continuous), successive processes (sequential), piece-related processes (object-related)
Assignment of technical production processes to process types

<table>
<thead>
<tr>
<th>Technical processes</th>
<th>Process types</th>
</tr>
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<tbody>
<tr>
<td>Energy-related processes</td>
<td>continuous processes, sequential processes</td>
</tr>
<tr>
<td>chemical processes</td>
<td>continuous processes, sequential processes</td>
</tr>
<tr>
<td>production processes</td>
<td>continuous processes, sequential processes, object-related processes</td>
</tr>
<tr>
<td>material-handling processes</td>
<td>continuous processes, sequential processes, object-related processes</td>
</tr>
</tbody>
</table>

Technical processes can contain processes of different types, on the other hand a process in turn can be a technical process.
1.6 Technical systems

Examples:

- Generation of electric energy in a turbo generator
  - continuous process
  - sequential process (start-up sequence of plant)

  Energy-related processes

- Batch processes
  - single process steps are continuous processes
  - sequence of steps is a sequential process

  Chemical processes

- Manufacturing a swivel
  - transportation of the machine’ parts is an object-related process
  - manufacturing process consists of a sequence of steps (”mount part”,
    “drive machine to position “ etc.), thus it is a sequential process
  - cutting process is a continuous process

  Production process
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**Flowchart**

- Similar to block diagrams used in control engineering
- Processes and process steps are represented as rectangles
- Arrows represent the information or material flow
- Bundles of connections are shown as double lines with arrow

Example:

```
additive
  → crush
    → additive crushed
  → raw material
    → dissolve
      → material dissolved
  → solvent
      → reaction
        → intermediate product
      → separate
        → final product
```
Information/material-oriented representation

- Information/materials as circles
- Processes/functions as linking arrows

Example:
**Phase model representation**

- Mixture of flowchart and information/material-oriented representation

Example:

```
additive
   \rightarrow \text{sub process "crush"}
   \rightarrow \text{additive crushed}
   \rightarrow \text{reaction}
   \rightarrow \text{intermediate product}
   \rightarrow \text{separate}
   \rightarrow \text{final product}

raw material
   \rightarrow \text{sub process "dissolving"}
   \rightarrow \text{material dissolved}

solvent
```

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1.7 Graphical representation of technical processes

Examples for the flowchart representation

simple flow chart

process flow chart
1.7 Graphical representation of technical processes

Pipes and instrumentation flow diagram
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| **1.8** | **Effects of industrial automation on people, society and environment** |
Intentional (positive) effects

- Simplified and more convenient operation
  - automation of a washing machine
  - automation of a heating system

- Production of better, cheaper products of equal quality with lowered production costs
  - automation of chemical production processes

- Reduction of hazards to people
  - ABS system
  - traffic system automation (like inductive train security, automatic barrier close)

- Better, more humane working conditions
  - automation of painting or foundry work

- Securing jobs through higher competitiveness
  - use of robots in automobile manufacturing
Unintentional (negative) effects

- Redundancy of workers may lead to unemployment
  - use of robots in manufacturing

- Restructuring of jobs due to changes in work flow and fields of work
  - lower/ higher qualified jobs
  - drop of ancillary tasks
  - increase of jobs in the service sector

- Reduction of human relationships
  - introduction of ticket vending machines and information systems

- Increase of stress and reduction of relaxing tasks
  - automation of testing systems

- Overtaxing in difficult situations
  - safety-critical decision in a nuclear power plant
Industrial automation has effects on:

- people
- society
- environment
- energy and resources

The automation engineer is responsible for the effects of industrial automation!

Direct, immediate responsibility

- damages in industrial automation systems designed by him
- violations of generally accepted guidelines and regulations (regulations of the VDE, etc.)
- safety of automation systems

Indirect, collateral responsibility

- unintentional side effects

Dilemma: trade-off between benefits and damage
Question referring to Chapter 1.1

In addition to the correctness of the data the timeliness of data is of high relevance in industrial automation. Which of the following statements do you agree?

- Early data is bad data
- Late data is bad data
- As fast as possible data is correct data
- Precise data is bad data
- No data is bad data

Answer
Question referring to Chapter 1.3

A company wants to automate the production of refrigerators. For this purpose, a new production line shall be constructed. In this production line, the coolant will be filled in and the rear will be screwed to the case.

Which kind of automation system is this?

Answer

The given system is a plant automation system. The production process (assembly line) shall be automated and not the product itself.
Question referring to Chapter 1.4

For the control computer of a production line of refrigerators (described in the last question) the company received two offers:

- „ordinary“ PC 3000,- €
- industrial PC with the same performance 5000,- €

Which computer would you choose?
Give reasons for your choice and explain the difference in price.

Answer

There is no difference in the performance range of the two computers. The main difference between an „ordinary“ PC and an industrial PC is that the industrial PC is especially built to endure the higher stress in industrial environments (temperature variations, EMI, vibrations, etc.)

In this case, therefore, the choice would be an industrial PC.
Question referring to Chapter 1.6

The IAS modular production system is shown below. Which kind of processes do you identify in this system?

Answer

- **Sequential processes** (all individual assembly stations are passed through sequentially)
- **Object-related processes** (all work steps are done at the barrels)
- **Continuous processes** (e.g. transportation)
Crosswords to Chapter 1

Across
3 Denomination of systems which have to be in synchrony with activities happening in an external system. (4,4,6)
5 Process type of manufacturing of parts. (6,8)
7 Simultaneous reaction to various events (16)
9 Process in which the physical parameters are recorded and influenced by technical means. (9,7)
10 Automation technical analog to "tactical level". (7,7,5)

Down
1 Device used to influence process variables. (8)
2 Term describing the extent in which a process is automated. (6,2,10)
4 Graphical representation of technical processes, similar to block diagram. (9)
6 Reaction to an event right on time (10)
8 Device used to measure process variables. (6)