Chapter I : General Concepts of Automated Production Systems

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1 Introduction

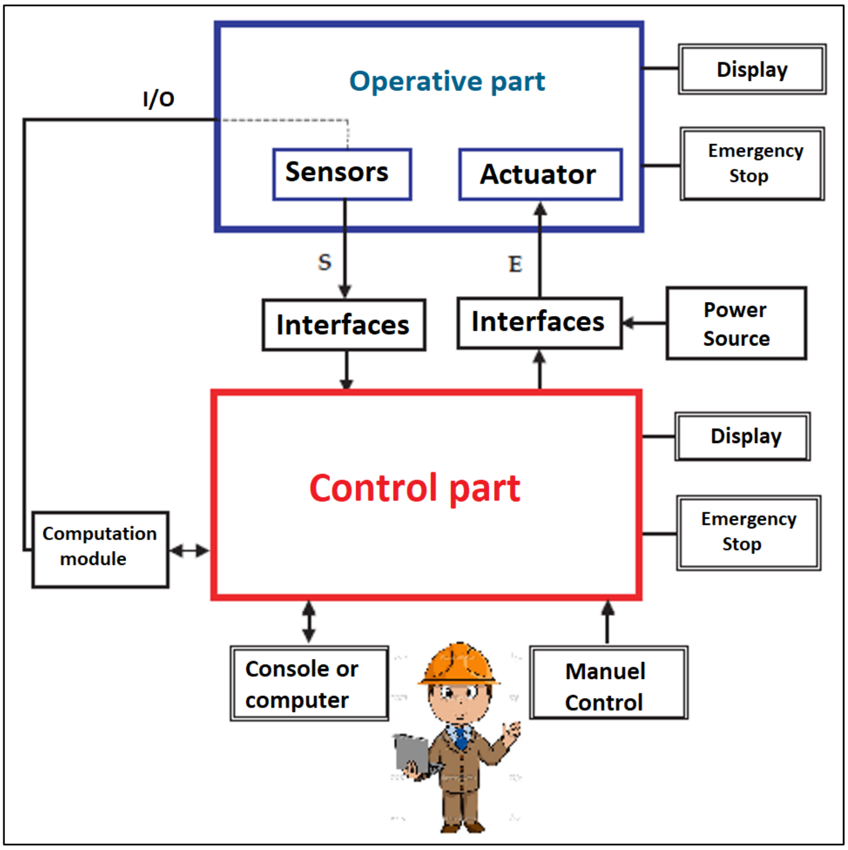
Automation involves integrating production means with automatic control systems to reduce or even eliminate human intervention. It enables companies to enhance their competitiveness by optimizing product costs, improving quality, and more.

2 Definition of an Automated System

A production system is considered automated when it can autonomously manage a predefined work cycle, which is divided into sequences and/or steps. Automated systems, widely used in the industrial sector, share a common basic structure (Figure 1.1). They are generally composed of two interconnected and complex parts:

- **The operative part (PO)**
- **The control part (PC)**

These two parts communicate with each other through an interface. There is also a relational component that facilitates dialogue between the system user and the automated system through the control part.



*optional **Figure 1.1.** Automated Process

3 Description of the Different Parts

3.1 The Operative Part

This is the visible part of the system. It includes the process elements, which are: sensors, pre-actuators, and actuators.

3.1.1 Sensors:

A sensor is characterized by several criteria, such as:

- The observed physical quantity,
- Sensitivity,
- Precision,
- Measurement range,
- Linearity,
- Bandwidth,
- Operating temperature range,
- Resolution, etc.

Sensors can be classified according to several criteria:

- **Energy supply**: Passive sensors or active sensors.
- **Output type**: Analog sensors or digital sensors.

The figure below illustrates some types of sensors, such as: liquid level sensor, shock detector, humidity sensor, limit switch, ultrasonic proximity sensor, gas detector, photoelectric cell, push button, switch, and emergency stop button.

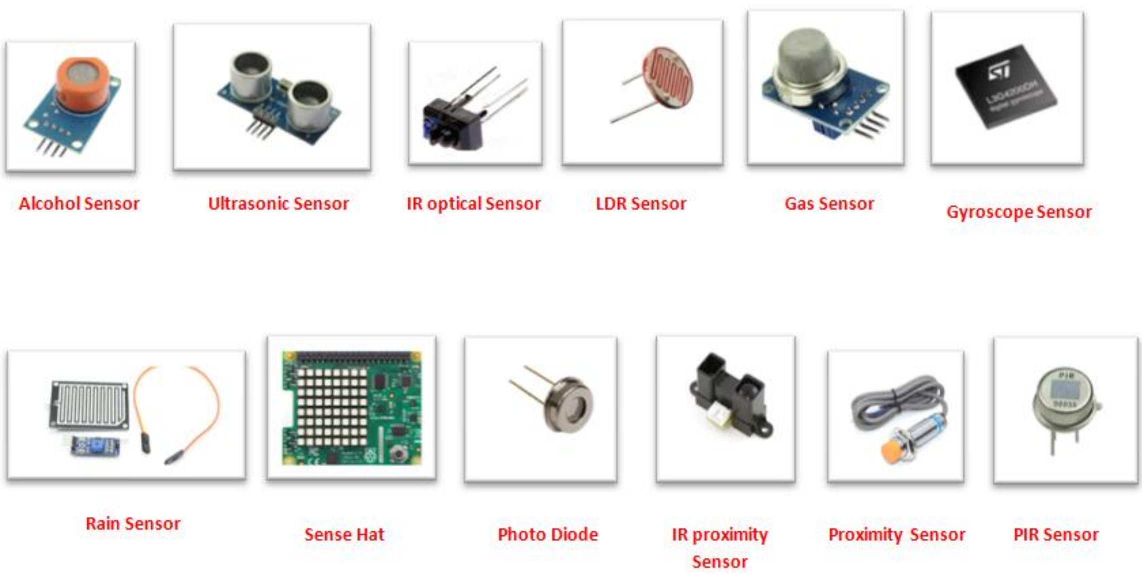


Figure 1.2. Different Types of Sensors

3.1.2 Actuators:

Actuators convert the received energy into a physical phenomenon that performs work (heat generation, light emission, movement, etc.). Automated systems use various types of actuators, which can be classified according to two criteria:

- **The type of energy supply**: Electrical, pneumatic, or hydraulic.
- **The physical phenomenon produced**: Heat, movement, light, sound, etc.

The figure below illustrates some types of actuators, such as: cylinder, rotary actuator, stepper motor, direct current motor, buzzer, indicator light, solenoid valve, heating resistors, 7-segment display, and fan.

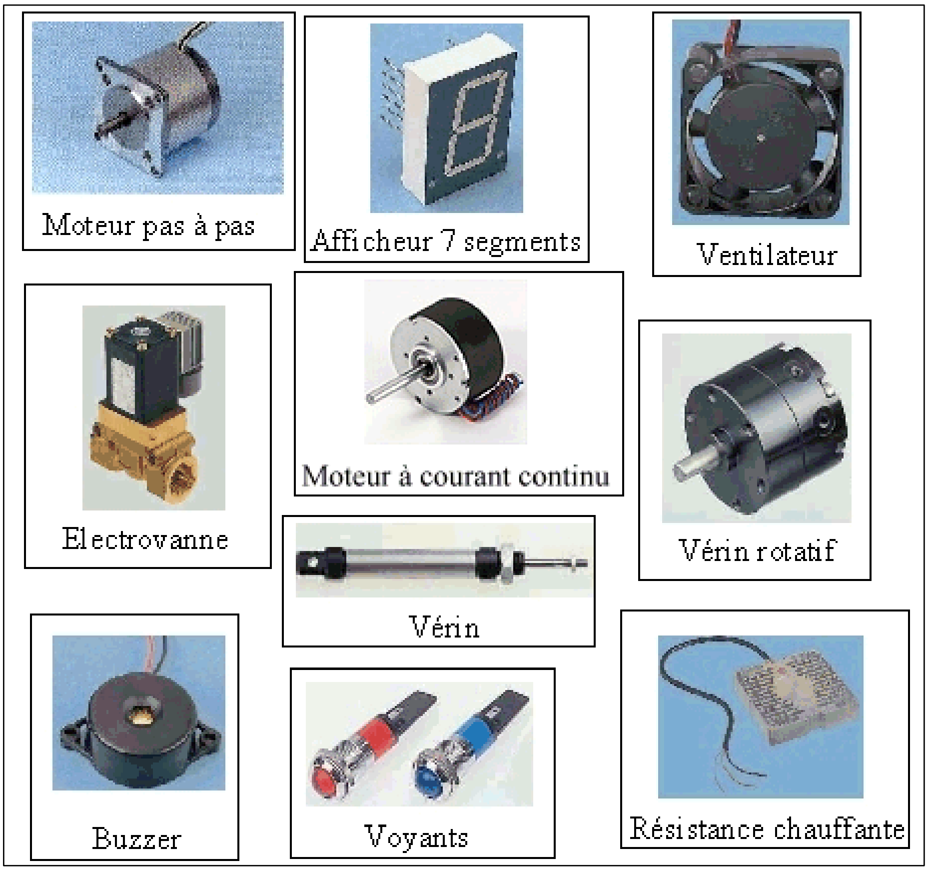


Figure 1.3. Different Types of Actuators

3.1.3 Pre-Actuators:

A pre-actuator is a component that receives commands from the control part (PC). Its role is to distribute the necessary and appropriate energy to the actuator, as the PC is generally incapable of directly providing the energy required by the actuator.
The choice of a pre-actuator depends on the characteristics of the control part, the energy source, and the actuator. If the actuator is electrical, the pre-actuator will also be electrical (e.g., contactor, relay, power card, variable speed drive, chopper), as shown in the figure below. In cases where the actuator is pneumatic, the pre-actuator will be pneumatic (e.g., distributor).

Figure 1.4. Different Types of Pre-Actuators

3.2 The Control Part

The field of automation logically manages the orderly sequence of operations to be performed. It receives information from the sensors in the operative part and sends it back to the same operative part, directed towards the pre-actuators and actuators.

3.3 The Interface

The control part and the operative part differ in nature. To ensure proper communication between these two parts, an object called the "Interface" is used.
These interfaces act as "translators" that connect the control part to the operative part.

3.4 The Relational Part (RP)

This part typically includes a Human-Machine Interface (HMI) for interacting with the control system, such as a control panel. The panel is equipped with control elements allowing: emergency stop, manual control of actuators, powering on/off the installation, selecting operating modes (start/stop), and setting references. It also includes various signaling components, such as screens, indicator lights, displays, buzzers, alarms, etc.

4 Information and Energy Chains

4.1 The Information Chain

The information chain performs the following functions:

- Acquiring data about the state of a product, from the HMI, or a process managed by other systems.
- Processing the data.
- Communicating the data processed by the control unit (usually a Programmable Logic Controller, PLC) to issue commands for the energy chain and/or to send messages to the HMI or other information chains.

4.2 The Energy Chain

The figure below illustrates the energy and information chains of an Automated Production System (APS).

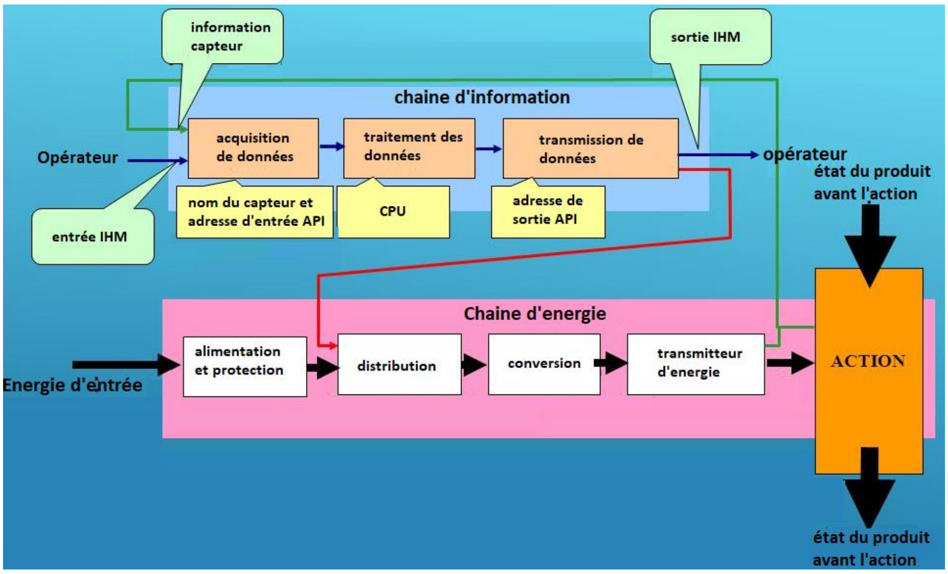


Figure 1.5. Overview of Generic Functions in the Energy and Information Chains of an Automated Production System

The energy chain comprises the following generic functions: **Supply**, **Distribution** (handled by the pre-actuator), **Conversion** (handled by the actuator), and **Transmission**, all of which contribute to executing an action. The primary role of the energy chain is to ensure the execution of a service function, with its characteristics specified in the design specifications.

4.3 Example of Energy Chain Equivalence

The figure below illustrates the equivalence between two different energy chains: one uses electrical energy, while the other uses pneumatic energy.

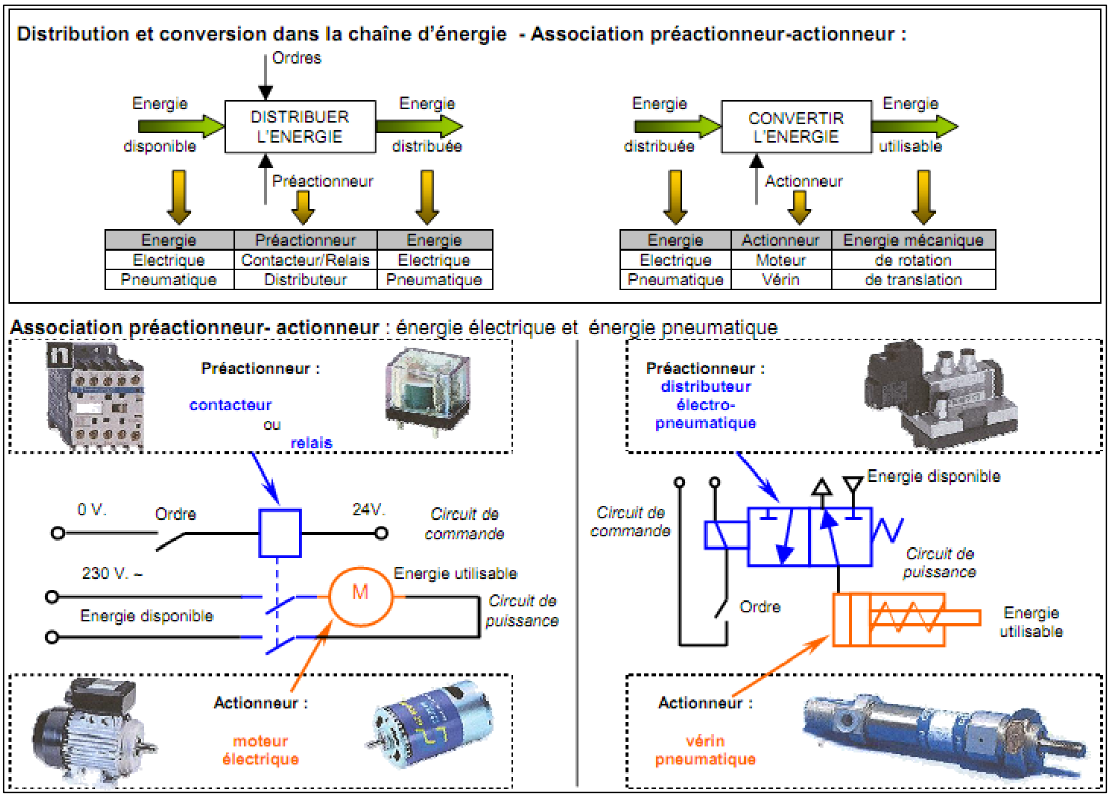


Figure 1.6. Diagram of Equivalence Between an Electrical Energy Chain and a Pneumatic Energy Chain

5 Different Types of Control Systems

5.1 The Combinational Automated System

These systems do not use any memory mechanism: for a given combination of inputs, there is only one corresponding combination of outputs. The associated logic is **combinational logic**, and the tools used for their design include Boolean algebra, truth tables, and Karnaugh maps. Automated systems using "combinational" techniques are rarely employed today. However, they can still be used for simple mechanisms with a limited number of actions to perform. They also have the advantage of requiring very few components.

5.2 The Sequential Automated System

These systems are the most widespread in the industrial domain. The cycle progresses step by step. For a given input situation, several output situations may correspond. The selection of one step or another depends on the previous state of the device.

5.3 Programmed Logic: Electrical Control

The main component is called the Programmable Logic Controller (PLC). Detection is electrical. The control of actuators is carried out through relays or distributors. There are many brands of programmable logic controllers available on the market, including Telemecanique, Siemens, Omron, Allen-Bradley, Cegetel, etc.

5.4 Wired Logic: Pneumatic Control

The primary component is called the **sequencer module**, and the combination of modules forms a system called a sequencer. Detection is pneumatic, and the actuation of distributors is performed by compressed air acting on a piston, which moves the distributor spool to the right or left. This system, known as **all-pneumatic**, is both homogeneous and reliable.

5.5 Servomechanisms

In these systems, the objective is for the output to accurately follow the variations of the input, with minimal response time. Examples include power steering in automobiles or the control of an airplane's flight surfaces. Applications: industrial robots.

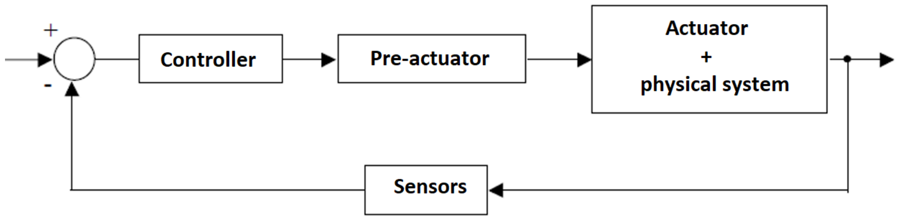


Figure 1.7. Functional Diagram of the Principle of a Servomechanism

6 Application Domains of Automated Systems

Today, it would be challenging to design a production system without relying on automated systems. These systems are found extensively in the field of industrial production and are used daily for various tasks. To operate and maintain these devices, technicians specializing in automation are employed, handling the installation and maintenance of each system.

Advantages of Automated Systems

- Accelerated production capacity.

- Suitability for all production environments.
- Flexibility of use.
- Creation of jobs for automation specialists.

Disadvantages of Automated Systems

- High equipment costs, especially for hydraulic systems.
- Maintenance requires a structured approach.
- Job reduction in certain sectors.