1. INTRODUCTION TO AUTOMATION

1.1 Definition of Automation

Automation is one of the most important technologies used in modern manufacturing industries. It refers to the use of mechanical systems, electronic devices, computers, and control technologies to perform manufacturing operations with minimum human involvement.

In an automated system, machines are capable of:

- Performing operations automatically
- Controlling process parameters
- Detecting errors
- Making decisions based on programmed instructions
- Correcting deviations using feedback systems

A general definition of automation can be stated as:

Automation is the technology by which a process or manufacturing operation is performed automatically through the coordinated use of mechanical, electrical, electronic, and computer-based systems with reduced human intervention.

1.2 Meaning and Concept of Automation

In traditional manufacturing systems, human operators are responsible for:

- Operating machines
- Controlling processes
- Inspecting products
- Making adjustments
- Correcting errors

However, human involvement creates certain limitations:

- Limited working speed
- Fatigue after continuous operation
- Variation in product quality
- Human errors

- Safety risks

Automation replaces or assists human activities by introducing intelligent machines and control systems.

A modern automated manufacturing system generally consists of:

1. **Power system**
2. **Control system**
3. **Program of instructions**
4. **Sensors**
5. **Actuators**
6. **Computer systems**

1.3 Evolution of Automation

Automation has developed gradually through different stages of industrial development.

Stage 1: Manual Manufacturing

Description

The earliest manufacturing systems depended completely on human labour.

Workers performed:

- Material shaping
- Assembly
- Inspection
- Handling

using simple hand tools.

Characteristics

- High dependence on human skill
- Low production rate
- High product variation

- Suitable for customized products

Example

Traditional blacksmith workshops where tools and components were manufactured manually.

Limitations

- Low productivity
- High labour requirement
- Poor repeatability
- Difficult quality control

Stage 2: Mechanization

Definition

Mechanization refers to the use of machines to replace human physical effort while humans continue to control and operate the machines.

The objective of mechanization is to increase human capability.

Examples

- Power-driven lathes
- Milling machines
- Hydraulic presses

Characteristics

- Machine performs physical work
- Human performs control operations
- Higher production rate than manual systems

Difference Between Manual Production and Mechanization

Manual Production	Mechanized Production
Human provides physical effort	Machine provides physical effort
Low speed	Higher speed
More fatigue	Reduced fatigue
Lower output	Higher output

Stage 3: Automation

Description

Automation introduced automatic control systems that allowed machines to perform operations with limited human supervision.

Machines could now:

- Follow programmed instructions
- Monitor operations
- Adjust parameters automatically

Examples

- CNC machines
- Automatic assembly lines
- Industrial robots

Stage 4: Computer-Based Automation

The introduction of computers greatly improved manufacturing automation.

Computers enabled:

- Numerical control
- Computer-aided design
- Computer-aided manufacturing
- Automated inspection

Examples

CNC Machine

A CNC machine uses computer programs to control:

- Tool movement
- Cutting speed
- Feed rate
- Machining sequence

Stage 5: Intelligent Automation

Modern automation combines computers with advanced technologies such as:

- Artificial Intelligence
- Machine Learning
- Industrial Internet of Things (IIoT)
- Robotics
- Big data analytics

This is known as smart manufacturing.

Example: Smart Factory

A smart factory uses:

- Sensors
- Connected machines
- Real-time monitoring
- Automatic decision making

to improve manufacturing efficiency.

1.4 Need for Automation in Manufacturing

Industries adopt automation because modern manufacturing requires:

- Higher productivity

- Better quality
- Lower production cost
- Safer working conditions
- Faster production cycles

1.4.1 Increase in Productivity

Explanation

Productivity is the relationship between output and input resources.

Productivity=OutputInputProductivity = \frac{Output}{Input}Productivity=InputOutput

Automation increases productivity by:

- Increasing machine operating time
- Reducing idle periods
- Increasing production speed
- Reducing unnecessary operations

Example

A manually operated drilling machine requires:

- Operator positioning
- Manual measurement
- Manual adjustment

An automated drilling system performs:

- Automatic positioning
- Automatic drilling
- Automatic inspection

resulting in higher output.

1.4.2 Improvement in Product Quality

Quality is one of the major reasons for implementing automation.

Manual manufacturing may produce variations due to:

- Worker skill differences
- Fatigue
- Lack of concentration
- Human errors

Automation provides:

- High accuracy
- Repeatability
- Consistent production

Example

A CNC machining centre can produce thousands of identical components with very small dimensional variation.

1.4.3 Reduction in Production Cost

Although automation requires high initial investment, it reduces long-term manufacturing cost.

Cost reduction occurs because of:

- Reduced labour requirement
- Lower rejection rate
- Reduced material waste
- Faster production

1.4.4 Improved Safety

Many industrial operations are dangerous for humans.

Examples:

- Welding
- Chemical processing
- Handling molten metals

- Nuclear operations

Automation allows machines to perform hazardous tasks.

Example

Robotic welding systems are used in automobile industries because welding produces:

- High temperature
- Harmful fumes
- Radiation

1.4.5 Reduction of Human Fatigue

Continuous repetitive work causes:

- Physical fatigue
- Reduced concentration
- Work-related injuries

Automation performs repetitive operations continuously with consistent performance.

1.4.6 Increased Manufacturing Flexibility

Modern markets demand frequent product changes.

Flexible automation allows industries to manufacture different products by changing:

- Software programs
- Machine settings
- Tool arrangements

Example

A CNC machine can manufacture different components by changing the machining program.

1.5 Objectives of Automation

The major objectives of automation are:

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1. Increase Production Rate

Automation allows machines to operate at higher speeds than manual systems.

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2. Improve Accuracy

Computer-controlled machines provide precise control over:

- Position
- Speed
- Force
- Temperature

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3. Reduce Manufacturing Time

Automation reduces:

- Setup time
- Processing time
- Inspection time
- Material handling time

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4. Improve Reliability

Automated systems provide consistent operation over long production periods.

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5. Reduce Waste

Automation reduces:

- Material wastage
- Energy losses
- Defective products

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6. Improve Working Conditions

Workers can be removed from:

- Dangerous environments
- Heavy physical operations
- Repetitive tasks

1.6 Basic Elements of Automation System

Every automation system consists of three fundamental elements:

1. Power element
2. Program of instructions
3. Control system

1.6.1 Power Element

Definition

The power element provides energy required for machine operation.

Types of Power Sources

Electrical Power

Used in:

- Motors
- Computers
- Controllers

Advantages:

- Easy control
- Clean operation
- High efficiency

Hydraulic Power

Uses pressurized fluid.

Applications:

- Presses
- Heavy machinery

Advantages:

- High force capability

Pneumatic Power

Uses compressed air.

Applications:

- Robots
- Assembly systems

Advantages:

- Fast operation
- Simple construction

1.6.2 Program of Instructions

The program of instructions defines the sequence of operations performed by the machine.

It includes:

- Operation sequence
- Machine movements
- Timing information
- Process parameters

Example

A CNC program specifies:

- Tool path
- Cutting speed
- Feed rate

- Tool selection

1.6.3 Control System

The control system acts as the decision-making unit.

It receives input information and controls machine operation.

Types of Control Systems

Open Loop Control System

A system without feedback.

Example:

Timer-based washing machine.

Closed Loop Control System

A system using feedback.

Example:

CNC servo control system.

2. CLASSIFICATION OF AUTOMATION

2.1 Introduction

Automation systems are classified based on:

- Production quantity
- Product variety
- Degree of flexibility
- Complexity of control system
- Level of human involvement

The selection of an appropriate automation type depends mainly on the relationship between:

1. **Production volume**
2. **Product variety**

3. **Required flexibility**

A manufacturing system producing millions of identical products requires a different type of automation compared with a system producing customized components.

Relationship Between Production Volume and Automation Type

Production Volume	Product Variety	Suitable Automation Type
Very high	Very low	Fixed Automation
Medium	Medium	Programmable Automation
Medium to high	High	Flexible Automation
Very high with computer integration	High	Integrated Automation

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Main Types of Automation

Automation is mainly classified into four categories:

1. Fixed Automation
2. Programmable Automation
3. Flexible Automation
4. Integrated Automation

2.2 Fixed Automation (Hard Automation)

2.2.1 Definition

Fixed automation is a type of automation in which the sequence of processing operations is permanently fixed by the equipment design.

The machines used in fixed automation are specially designed to perform a particular operation or manufacture a specific product.

Because the equipment configuration cannot be easily changed, it is also called:

Hard Automation

2.2.2 Basic Concept of Fixed Automation

In fixed automation, the machine performs operations automatically according to a fixed sequence.

The sequence is controlled by:

- Mechanical systems
- Electrical circuits
- Hydraulic systems
- Pneumatic systems

The equipment is designed specifically for a particular product.

Example

Automobile Transfer Line

In automobile manufacturing:

1. Body positioning
2. Welding
3. Painting
4. Assembly
5. Inspection

are performed in a fixed sequence using dedicated equipment.

The production line cannot easily manufacture another completely different product.

2.2.3 Characteristics of Fixed Automation

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1. High Production Rate

Fixed automation is designed for producing very large quantities of products.

Since machines are dedicated to specific operations:

- Cycle time is very low
- Production speed is very high

- Human intervention is minimal

Example:

A bottling plant can fill thousands of bottles per hour using automatic filling equipment.

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2. Low Product Variety

Fixed automation is suitable when products have:

- Standardized design
- Stable demand
- Limited variations

The equipment is not designed for frequent product changes.

Example:

A machine designed for manufacturing a specific engine component cannot easily produce another component.

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3. High Initial Investment

Fixed automation requires expensive equipment because machines are:

- Special purpose
- Highly customized
- Complex in design

Initial costs include:

- Machine installation
- Control systems
- Production line setup
- Special tooling

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4. Low Flexibility

Flexibility refers to the ability of a manufacturing system to adapt to changes.

Fixed automation has low flexibility because:

- Equipment arrangement is permanent
- Tools are product-specific
- Control sequence is fixed

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5. High Production Efficiency

Since the system performs repetitive operations continuously:

- Machine utilization is high
- Production losses are low
- Output quality is consistent

2.2.4 Components of Fixed Automation System

A fixed automation system generally consists of:

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1. Special Purpose Machines (SPM)

Machines designed for a particular operation.

Examples:

- Automatic drilling machines
- Automatic assembly machines

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2. Transfer Lines

A transfer line consists of multiple machines connected together.

The workpiece automatically moves from one station to another.

Example:

Automobile engine manufacturing line.

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3. Automatic Material Handling System

Materials are transported using:

- Conveyors
- Transfer mechanisms
- Robots

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4. Control System

Control is usually achieved through:

- Relay logic
- PLC systems
- Dedicated controllers

2.2.5 Examples of Fixed Automation

1. Automobile Assembly Lines

Used for:

- Engine assembly
- Body welding
- Painting

---

2. Continuous Process Industries

Examples:

- Petroleum refining
- Cement manufacturing
- Steel production

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3. Packaging Industries

Examples:

- Bottle filling

- Food packaging

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4. Automatic Transfer Machines

Used for:

- High-volume machining operations

2.2.6 Advantages of Fixed Automation

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1. Extremely High Production Rate

The main advantage is the ability to produce large quantities quickly.

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2. Low Unit Manufacturing Cost

Although investment is high, the cost per product becomes very low because:

- Production volume is high
- Labour requirement is low
- Cycle time is reduced

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3. Excellent Product Quality

Because the same operation is repeated continuously:

- Dimensional accuracy improves
- Product variation decreases

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4. Reduced Labour Requirement

Operators mainly perform:

- Monitoring
- Maintenance
- Loading and unloading

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5. Improved Safety

Workers are removed from hazardous operations.

2.2.7 Limitations of Fixed Automation

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1. High Initial Investment

The cost of:

- Special machines
- Installation
- Control systems

is very high.

---

2. Poor Flexibility

The system cannot easily adapt to:

- New product designs
- Changing customer requirements

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3. Risk of Obsolescence

If market demand changes, the equipment may become useless.

---

4. Suitable Only for Large Production

For low production quantities, fixed automation is economically unsuitable.

2.2.8 Applications of Fixed Automation

Industry	Application
Automobile	Assembly lines
Food	Packaging and bottling

Industry	Application
Chemical	Continuous processing
Steel	Rolling mills
Electronics	Component assembly

2.3 Programmable Automation

2.3.1 Definition

Programmable automation is a type of automation where the sequence of operations can be changed by modifying the control program.

Unlike fixed automation, the equipment can manufacture different products by changing instructions.

It is mainly used for:

- Batch production
- Medium production volume
- Moderate product variety

2.3.2 Basic Concept

In programmable automation:

- Machine structure remains the same
- Production instructions are changed through programming

The machine operates according to stored instructions.

Example

A CNC milling machine can manufacture:

- Gear components
- Machine parts
- Aerospace components

by changing the machining program.

2.3.3 Working Principle of Programmable Automation

The operation involves:

Step 1: Create Program

Instructions are prepared using:

- Computer programming
- CNC codes
- PLC logic

Step 2: Store Program

The instructions are stored in the controller memory.

Step 3: Execute Program

The machine performs operations according to the instructions.

Step 4: Change Program for New Product

A new product can be manufactured by modifying the program.

2.3.4 Characteristics of Programmable Automation

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1. Reprogrammable System

The machine can perform different operations by changing software instructions.

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2. Medium Production Quantity

Suitable for batch production.

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3. Moderate Product Variety

Different products can be manufactured using the same equipment.

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4. Requires Setup Changes

Before producing a new batch, changes may be required:

- Tool replacement
- Fixture change
- Program modification

---

5. Computer-Based Control

Modern programmable automation uses:

- CNC controllers
- PLCs
- Industrial computers

2.3.5 Examples of Programmable Automation

1. CNC Machines

CNC machines are the most common example.

They control:

- Tool movement
- Cutting speed
- Feed rate
- Machining sequence

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2. Industrial Robots

Robots can be reprogrammed for:

- Welding
- Assembly
- Painting

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3. Programmable Assembly Machines

Used in:

- Electronics industries
- Consumer goods manufacturing

2.3.6 Advantages of Programmable Automation

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1. High Flexibility

Different products can be manufactured using the same machine.

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2. Lower Investment Compared with Fixed Automation

One machine can perform multiple operations.

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3. Suitable for Changing Market Requirements

New products can be introduced by modifying programs.

---

4. Reduced Manufacturing Time

Computer-controlled operation improves efficiency.

2.3.7 Limitations of Programmable Automation

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1. Setup Time

Changing production from one product to another requires:

- Program changes
- Tool changes
- Machine adjustment

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2. Lower Production Rate Compared with Fixed Automation

Because the system requires setup operations.

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3. Skilled Personnel Requirement

Operators need knowledge of:

- Programming
- Machine operation
- Maintenance

2.3.8 Applications of Programmable Automation

Industry	Application
Aerospace	Complex component machining
Automotive	CNC machining
Tool manufacturing	Dies and moulds
Electronics	PCB assembly
Medical	Precision components

Fixed Automation vs Programmable Automation

Feature	Fixed Automation	Programmable Automation
Production Volume	Very high	Medium
Product Variety	Very low	Medium
Flexibility	Low	High
Control	Fixed	Programmable
Investment	Very high	Moderate
Examples	Transfer lines	CNC machines

End of Section 2

Next section will cover in the same detailed manner:

3. Flexible Automation

- Definition
- Working principle
- Characteristics
- Flexible Manufacturing System (FMS)
- Components of FMS
- Advantages
- Limitations
- Applications

followed by:

4. Integrated Automation (CIM)

- CAD/CAM
- CAPP
- Robotics
- ERP
- Smart manufacturing
- Industry 4.0 integration
- Complete comparison of all automation types.