# INDUSTRIAL AUTOMATION

*DIPLOMA WALLAH*

## UNIT 3: PROCESS CONTROL SYSTEMS AND PLC APPLICATIONS

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### Topic 1: Open Loop and Closed Loop Systems

### Definition:

An **open-loop system** is a control system in which the output has no influence or effect on the control action of the input. It simply follows a set of commands without feedback.
A **closed-loop system**, on the other hand, continuously monitors its output and automatically adjusts its control input to maintain the desired result.
In industrial automation, closed-loop systems are essential for maintaining accuracy, stability, and efficiency in production. These systems use sensors, controllers, and actuators to compare the output with the desired reference.

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### Explanation

1. In **open-loop systems**, there is no feedback; control action is independent of the output.
2. **Closed-loop systems** include feedback mechanisms that compare actual and desired output.
3. Open-loop systems are simpler, cost-effective, and suitable for non-critical operations.
4. Closed-loop systems are complex but ensure high precision and automatic error correction.
5. Common closed-loop examples: motor speed control, temperature control, or level control.
6. Sensors are used in closed-loop systems to detect changes and send data to the controller.
7. Controllers (like PLCs or microcontrollers) process this data and adjust actuator output.
8. Actuators (motors, valves, etc.) act according to controller commands.
9. Closed-loop feedback ensures minimal deviation even in dynamic industrial conditions.

10. In electrical industries, closed-loop systems improve safety, reduce energy loss, and increase reliability.

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## ⚙️ Example:

**Example 1 (Open Loop):** Electric heater with timer – it runs for a set time, regardless of actual temperature.
**Example 2 (Closed Loop):** Room temperature control using a thermostat – automatically adjusts heating/cooling based on sensor readings.
**Industrial Example:** Automatic voltage regulator in generators uses feedback to maintain constant voltage output.

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## 🔁 Working:

1. **Open Loop:** Input signal → Controller → Actuator → Output (no feedback).
2. **Closed Loop:** Input signal → Controller → Actuator → Output → Sensor → Feedback → Controller (loop continues).
3. Feedback signal compares actual output with the desired value.
4. Any deviation is corrected automatically by the controller.
5. The process continues until the system output matches the desired value.

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## 💡 Applications:

1. Temperature control systems in furnaces.
2. Motor speed control in conveyor systems.
3. Pressure control in boilers.
4. Level control in tanks.
5. Automatic voltage regulation in power supply units.

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## ✅ Advantages:

1. High precision and automatic error correction.
2. Stable operation under load variations.
3. Reduces human intervention and improves consistency.
4. Quick response to process disturbances.

5. Increases system reliability and energy efficiency.

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❌ **Disadvantages:**

1. High installation and maintenance cost.
2. Complex design and programming.
3. Requires regular calibration of sensors.
4. More components → higher chance of failure.
5. Power and data dependency (needs stable electrical supply).

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🪄 **Summary (Hinglish):**

Closed-loop system feedback se control hota hai, jo output ko constantly check karta hai aur adjust karta hai.
Open-loop bas ek direction follow karta hai, feedback nahi hota.
Automation industry mai mostly closed-loop hi use hota hai precision ke liye.

⚙️ **Topic 2: Process Control System and Its Components**

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📃 **Definition:**

A **Process Control System (PCS)** is a system designed to automatically control industrial processes by continuously monitoring process variables such as temperature, pressure, flow, and level. It ensures that these variables remain within a desired range or set point.
In electrical and industrial automation, PCS uses **sensors**, **controllers**, and **actuators** to maintain process stability, safety, and efficiency. These systems are used in power plants, chemical industries, food processing, and manufacturing units to reduce human error and improve product quality.

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📘 **Explanation (10 Detailed Points):**

1. Process control is the backbone of industrial automation that keeps system parameters stable and accurate.
2. The main goal is to maintain output at a desired value despite disturbances.
3. Every process control system consists of **four key elements** — sensors, controllers, actuators, and the process itself.

4. **Sensors** measure process variables like temperature, pressure, or level.
5. **Controllers** (like PLCs or PID controllers) compare actual values with the desired set point and send corrective signals.
6. **Actuators** (motors, valves, relays) act based on the controller's signal to adjust the process.
7. **Transmitters** convert sensor data into standard electrical signals (like 4–20 mA).
8. Feedback control ensures the process output remains close to the target value.
9. These systems can be **manual**, **semi-automatic**, or **fully automatic**, depending on industry requirements.
10. In electrical systems, process control helps regulate motor speed, transformer cooling, generator voltage, and industrial heating systems.

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### 🏭 Example:

**Real-Life Example:**
In a **boiler pressure control system**, a pressure sensor monitors the steam pressure. The PLC compares this with the desired set point. If pressure rises too high, the controller signals an actuator to close the steam valve, maintaining safe operation. Other examples include automatic water level control in tanks and temperature control in electric furnaces.

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### 🔄 Working Process:

1. **Measurement:** Sensors measure the actual process variable (like temperature).
2. **Comparison:** The controller compares the actual value with the set point.
3. **Correction:** If there's an error, the controller sends a signal to the actuator.
4. **Action:** Actuator changes the process condition (like adjusting valve or motor speed).
5. **Feedback:** The sensor again measures the updated value, completing the loop.
6. This continuous feedback loop maintains the process at the desired operating level.

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### 💡 Applications:

1. Automatic voltage regulation in power distribution.
2. Temperature and pressure control in furnaces or boilers.
3. Level control in liquid storage tanks.
4. Speed control in conveyor belt systems.
5. Automation in chemical mixing or packaging systems.

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### ✅ Advantages:

1. Maintains accuracy and consistency in production.
2. Reduces human error and manual operation.
3. Improves safety in hazardous industrial environments.
4. Enables continuous 24x7 operation with minimal supervision.
5. Saves energy and increases system lifespan.

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### ❌ Disadvantages:

1. High initial setup and installation cost.
2. Requires skilled personnel for operation and maintenance.
3. Complex troubleshooting if system fails.
4. Dependence on sensors — any failure affects accuracy.
5. Needs a reliable power supply and protection from electrical noise.

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### 🪄 Summary

Process Control System ek automated setup hota hai jo sensor, controller, aur actuator ke through process ko stable rakhta hai.
Ye system continuously measure karke error correct karta hai, taaki output perfect rahe.
Industrial automation mai ye sabse important role play karta hai accuracy aur safety ke liye.

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## Topic 3: Bit Logic Instructions and Ladder Diagram in PLC

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### Definition:

**Bit Logic Instructions** are the basic commands used in **Programmable Logic Controllers (PLCs)** to perform logical operations such as ON/OFF control, interlocks, and sequence operations.
These instructions help control digital signals by evaluating the status of inputs (sensors, switches) and determining the outputs (motors, lamps, relays).
Common bit logic instructions include **Normally Open (NO), Normally Closed (NC), NOT, Set (S), Reset (R), Coil, Positive Edge, and Negative Edge**.
These are implemented through **Ladder Logic Diagrams (LAD)** which visually represent control circuits similar to electrical relay diagrams.



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### Explanation (10 Detailed Points):

1. **Bit Logic Instructions** work with binary data — 1 (True/ON) and 0 (False/OFF).
2. **Normally Open (NO)** contact closes when the input condition is TRUE.
3. **Normally Closed (NC)** contact opens when the input condition becomes TRUE.
4. **NOT Logic** reverses the current input condition — if input is ON, output is OFF.
5. **Coil instruction** represents the final output (motor, light, valve, etc.).
6. **Set (S)** and **Reset (R)** instructions latch or unlatch outputs for maintaining state even after input changes.
7. **Positive Edge (↑)** detects the moment an input changes from 0 → 1, often used in counters or start triggers.
8. **Negative Edge (↓)** detects when input changes from 1 → 0, often used in stop or reset logic.
9. These instructions are arranged in **rungs** of a **Ladder Diagram**, read left to right, top to bottom.
10. Bit logic simplifies electrical control circuits, allowing flexible and efficient automation design without physical relays.

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### Example:

**Example – Start/Stop Motor Control using Bit Logic:**

- When the **Start** button (NO contact) is pressed, the output coil (Motor) energizes.
- When the **Stop** button (NC contact) is pressed, it de-energizes the coil.
- **Set** instruction keeps the motor running even after the start button is released, and **Reset** stops it.
  **Industrial Example:** Conveyor systems, stamping machines, packaging, and automatic filling lines.

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🔄 **Working:**

1. **Input Devices:** Push buttons, limit switches, sensors send signals to the PLC input module.
2. **Processing:** PLC scans ladder logic rung-by-rung and applies logic instructions.
3. **Logic Evaluation:** If logical conditions are TRUE (closed paths), PLC activates corresponding coils.
4. **Output Activation:** Coils energize actuators like relays, motors, solenoids, etc.
5. **Feedback Loop:** Sensors monitor status and send updated feedback to PLC.
6. **Cycle Repeat:** PLC continuously scans and updates the process every few milliseconds.



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💡 **Applications:**

1. Automatic conveyor and packaging systems.
2. Motor start/stop control circuits.
3. Safety interlocking systems in machines.
4. Industrial stamping and cutting processes.
5. Sequential operations in bottling and labeling plants.

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✅ **Advantages:**

1. Simplifies control logic and circuit design.
2. Flexible programming and easy modification.

3. High-speed logic execution.
4. Reduces wiring and maintenance cost.
5. Increases system reliability and reduces downtime.

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### ❌ Disadvantages:

1. Needs trained engineers for PLC programming.
2. Requires stable power and protection from electrical noise.
3. Hardware cost is higher than relay logic for small systems.
4. Troubleshooting software faults can be complex.
5. System may crash if programming has logical errors.

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### 🪄 Summary (Hinglish):

Bit Logic Instructions PLC ke basic command hote hain jo input-output devices ko control karte hain.
Ye ON/OFF, Set-Reset aur Edge trigger ke through system automate karte hain.
Ladder Diagram ek visual circuit jaisa hota hai jisme PLC logic ko program kiya jata hai.

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### ⚙️ Topic 4: Automatic Stamp System (LAD Example & Working)

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### 📃 Definition:

The **Automatic Stamp System** is a PLC-controlled industrial setup used to stamp boxes automatically as they move on a conveyor belt.
It demonstrates the use of **sensors, actuators, and ladder logic** to achieve sequential automation.
The system uses **limit switches (LS1, LS2, LS3)**, **conveyor motor**, **stamper cylinder**, and **indicator lights** to coordinate the stamping process efficiently.

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### 📘 Explanation (10 Detailed Points):

1. The system is designed to perform an automatic stamping operation on each box placed on a conveyor.
2. **PLC** is the brain — it reads signals from sensors (limit switches LS1, LS2, LS3).

3. **LS1** detects box presence at the conveyor start.
4. **LS2** detects the mid-point where the stamp should occur.
5. **LS3** detects the box at the end of the conveyor.
6. When a box is detected at LS1, the conveyor starts moving the box forward.
7. When LS2 is triggered, conveyor stops and the **stamper actuator** comes down to stamp the box.
8. After stamping, the stamper returns up and the conveyor resumes.
9. When LS3 detects the box at the end, the motor stops until a new box is placed.
10. Indicator lights show system status — "Ready", "Stamp Up", "Stamp Down".

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🏭 **Example (Practical Implementation):**

- **Inputs:** Start switch, LS1, LS2, LS3.
- **Outputs:** Conveyor motor, stamp actuator, indicator lights.
- **Logic:**
  - Start button ON → system ready.
  - LS1 ON → conveyor runs.
  - LS2 ON → conveyor stops → stamp activates.
  - LS3 ON → conveyor stops → waits for next box.

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🔄 **Working (Step-by-Step):**

1. Operator presses the **Start switch** — system goes into ready mode.
2. A box is placed on **LS1** → PLC activates the **conveyor motor**.
3. When box reaches **LS2**, motor stops → **stamper** lowers and stamps the box.
4. Once stamping is done, stamper lifts up → conveyor resumes.
5. When box reaches **LS3**, conveyor stops again.
6. System waits for the next box at LS1 → cycle repeats continuously.

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💡 **Applications:**

1. Product labeling and stamping in packaging industries.
2. Automatic punching and cutting machines.
3. Conveyor-based assembly lines.
4. Food and beverage bottle capping systems.
5. Automotive parts marking and engraving systems.

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✅ **Advantages:**

1. Fully automatic, reduces manual labor.
2. High speed and repeat accuracy in stamping.
3. Reduces product damage and human error.
4. Easy modification of process sequence through PLC.
5. Real-time monitoring and quick fault detection.

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❌ **Disadvantages:**

1. High installation and setup cost.
2. Requires periodic maintenance of sensors and actuators.
3. Any PLC fault can stop the entire production.
4. Requires trained operator for troubleshooting.
5. Sensitive to power interruptions and signal noise.

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🪄 **Summary (Hinglish):**

Stamp system ek automatic setup hai jo PLC aur sensors ke through boxes par stamping karta hai.
Limit switches LS1, LS2, LS3 box ki position detect karte hain aur PLC uske hisaab se motor aur stamper ko control karta hai.
Ye process speed, precision aur automation dono badhata hai.

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