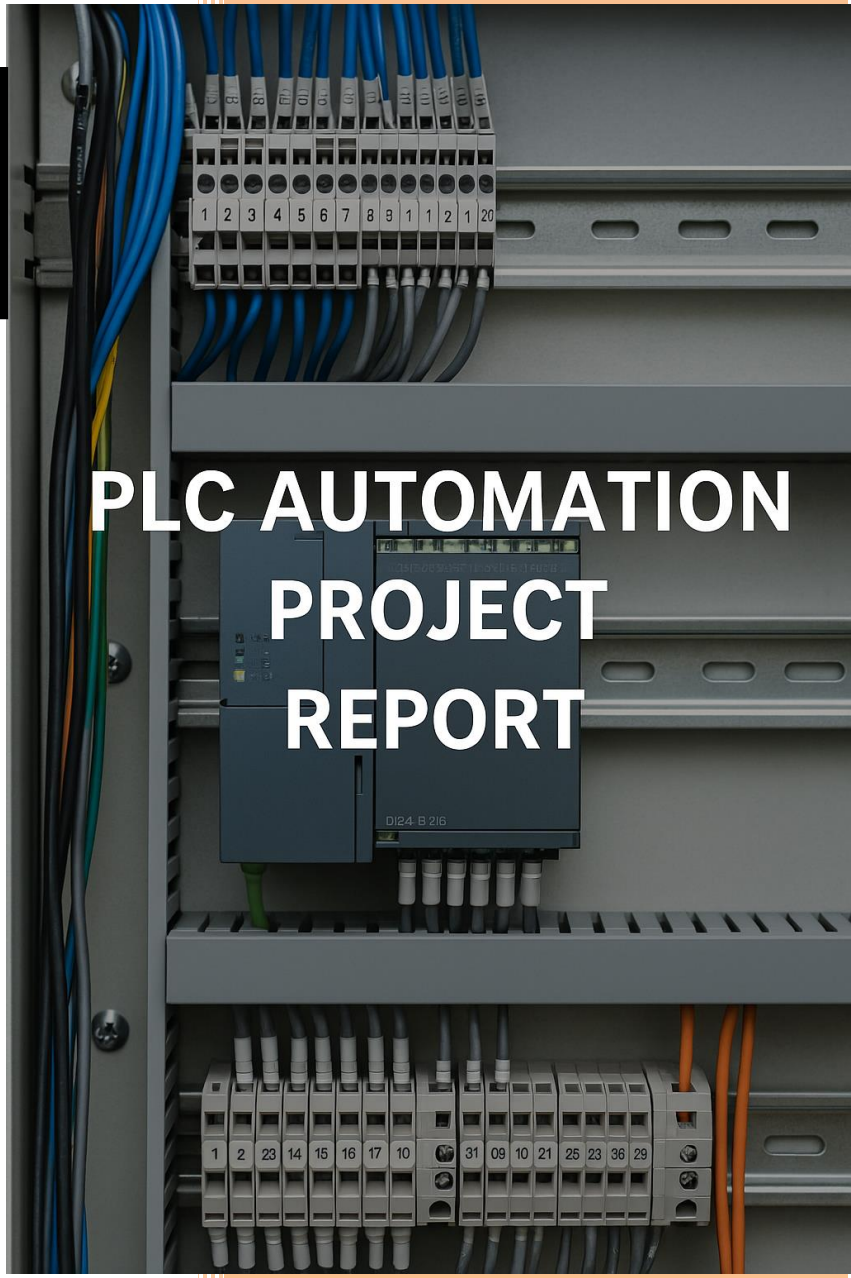
2023

Machine Programming



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1. Introduction

This report presents a comprehensive overview of the PLC-based automation system developed for a glass product manufacturing line. The primary objective of this system is to ensure efficient, safe, and reliable operation of the production machine table used for handling hot raw glass. The system has been designed using programmable logic controllers (PLCs), integrating sensors, timers, motors, alarms, and actuators to automate the key phases of the production process.

In the glass industry, precision and consistency are critical due to the fragile nature of the material and the high temperatures involved during handling. Manual operation of such systems is prone to errors, delays, and safety risks. To mitigate these issues and optimize production throughput, this automation system was implemented.

The system operates through a series of logical steps. It begins by detecting the presence of incoming hot glass using a proximity sensor. If the glass is not detected, an alarm is triggered, and the system halts to prevent malfunction or safety hazards. If the glass is detected, the system initiates a timed sequence that moves the production machine table forward. Additional proximity sensors confirm the proper arrival of the glass at the output stage and ensure successful pickup by a take-out mechanism. Each step is precisely timed and interlocked to avoid errors and enhance operational efficiency.

The automation process also includes a robust safety and reset mechanism, enabling operators to quickly respond to errors or stop the process in case of emergency. The logic is implemented using ladder diagram programming, which is widely recognized in industrial environments for its clarity and ease of troubleshooting.

This report includes the logic design, operational sequence, fault detection strategies, and a detailed ladder diagram that illustrates the entire control system. It serves not only as a technical document but also as a reference for future improvements or scalability within the production line.

2. System Function Overview

The system described in this report is designed to automate and control a **glass production machine table**, enhancing the efficiency, safety, and reliability of the glass handling process. It leverages **PLC programming, proximity sensors, timers, alarms**, and a **take-out mechanism** to coordinate precise movements and material tracking throughout the production line.

The key functions of the system are as follows:

2.1 Glass Detection and Initial Validation

- The process begins with the arrival of **hot raw glass** at the mold area.
- A **proximity sensor** installed at the input side detects the presence of the glass.
- If no glass is detected:
  - The **alarm system** is activated.
  - The **machine halts automatically** using the Stop_Machine command to prevent false operation or mechanical failure.
- If glass is detected:
  - A **timer (T1)** starts to introduce a slight delay, ensuring the glass is fully settled before the next motion.

2.2 Table Movement Control

- After T1 times out, the **machine table moves forward** under PLC control (Move_Forward output).
- This motion ensures the glass is pushed into the correct processing position (typically into the mold).
- Simultaneously, **Timer T2** begins, allowing a predefined window for the output sensor to detect the glass at the far end.

2.3 Output Validation

- A second **output proximity sensor** checks whether the glass has successfully reached the take-out area.
- If the output sensor does **not** detect the glass:
  - The system enters a **fault condition**.
  - An **alarm** is triggered, and the machine stops automatically to prevent further motion or damage.
- If the output sensor **does** detect the glass, it confirms a successful forward motion.

2.4 Take-Out Mechanism Operation

- After output confirmation, **Timer T3** starts.
- Once T3 is complete:

    - The **take-out motor** (Takeout Motor) activates.
    - This mechanism retrieves or picks the glass from the output table using a robotic arm or mechanical lift, depending on the plant's design.
- The motor only activates if the **output proximity sensor is still active**, ensuring safe and confirmed pickup.

2.5 Cycle Completion

- The system confirms the completion of one full cycle if:
    - Move_Forward is active,
    - Forward_Limit_Switch is engaged,
    - and Output_Proximity_Sensor is true.
- If all conditions are met, the **Cycle_Complete_Lamp** is turned ON, signaling the successful end of the cycle and readiness for the next one.

2.6 Emergency Stop and Reset

- Operators have access to a **manual stop button** (Stop_Machine_Button) to immediately halt the machine in case of emergency or observed fault.
- A **Reset Button** is available to:
    - Clear all the alarms,
    - Reset timers,
    - Deactivate outputs,
    - And reinitialize the system to a standby mode for the next cycle.

2.7 Safety and Reliability Enhancements

- Every step is interlocked with sensor verification and timer logic to ensure:
    - Glasses are present when needed,
    - Motion only occurs under valid conditions,
    - Motors do not operate unintentionally,
    - Errors are captured in real-time.
- This dramatically reduces downtime, enhances operator safety, and ensures high-quality output in the glass production process.

3. Detailed Program Flow

This section outlines the logical sequence executed by the PLC to automate the glass production table. The flow integrates sensor feedback, timer coordination, actuator control, fault handling, and cycle verification to ensure safe and efficient operation.

3.1 System Start and Input Glass Detection

- The process begins when the **Start Button** is pressed by the operator.

- The PLC activates and immediately checks the **Input Proximity Sensor** to detect the presence of **hot raw glass** at the mold entry.
- **Decision logic**:
    - If **glass is detected**, the PLC initiates **Timer T1** to introduce a short delay, allowing the glass to fully settle.
    - If **glass is not detected**, the system:
        - Activates the **Alarm** output,
        - Triggers **Stop_Machine** to halt the operation for safety,
        - Waits for the operator to reset and retry.

3.2 Initiate Forward Motion

- Once **T1 expires**, the PLC:
    - Activates the **Move_Forward** output, causing the machine table to move the glass toward the take-out station.
    - Simultaneously starts **Timer T2**, which is configured to delay long enough for the glass to reach the output position.

3.3 Output Glass Verification

- After **T2** completes, the system checks the **Output Proximity Sensor**.
- **Decision logic**:
    - If **glass is detected**, it confirms that the forward motion was successful.
    - If **glass is not detected**, the system:
        - Activates the **Alarm**,
        - Engages the **Stop_Machine** output to prevent further actions.

3.4 Take-Out Mechanism Control

- If the glass is successfully detected at the output:
    - The PLC starts **Timer T3** to wait a short duration before activating the take-out mechanism.
- After **T3 expires**, the PLC evaluates the **Output Proximity Sensor** again:
    - If the sensor still detects the product, the **TakeOut_Motor** is energized to remove the glass (e.g., via robotic hand or ejector).
    - If the product is no longer detected, the system assumes it was dropped or misaligned, and:
        - Triggers the **Alarm**,
        - Halts the machine using **Stop_Machine**.

3.5 Completion of the Cycle

- The cycle is considered **successfully completed** when all the following are true:
    - The **Move_Forward** output is active,

    - The **Forward_Limit_Switch** is engaged (confirming the machine table is fully forward),
    - The **Output Proximity Sensor** confirms the presence of glass.
- Once validated, the PLC activates the **Cycle_Complete_Lamp**, signaling readiness for the next cycle.

3.6 System Reset and Emergency Stop

- **Reset Button**:
    - Clear all the alarms,
    - Resets timers (T1, T2, T3),
    - Deactivates all outputs,
    - Returns the system to a standby mode for a fresh start.
- **Stop_Machine_Button**:
    - Can be pressed at **any time** by the operator,
    - Immediately halts all operations,
    - Ensures safety during fault conditions or manual interventions.

This structured flow ensures high precision and repeatability in handling fragile hot glass products, while incorporating multiple safety checks and automation layers to minimize operator errors and machine downtime.

4. Safety and Error Handling Summary

Ensuring operator safety and system reliability is a critical aspect of industrial automation, especially when working with high-temperature materials such as hot glass. The PLC automation system for this project integrates multiple layers of safety monitoring and fault-handling protocols. These include real-time sensor validation, alarm triggers, controlled shutdowns, and manual override capabilities.

The table below outlines key fault conditions, how the system responds to each, and the intended outcome of these safety features.

4.1 Safety and Fault Conditions Table

Fault Condition	**System Response**	**Purpose / Outcome**
No glass detected at input sensor	Alarm is activated, Stop_Machine output is triggered	Prevents forward motion without material, avoids equipment damage or misoperation

Fault Condition	System Response	Purpose / Outcome
No glass detected at output after movement	Alarm is activated, Machine is stopped via, Stop_Machine	Indicates possible slippage or obstruction; prevents incorrect processing
Output glass not detected before take-out action	Alarm is activated, TakeOut Motor remains OFF, Machine halts	Avoids take-out arm movement without product, protecting equipment and operators
Any sensor malfunction or disconnection	Treated as absence of signal, Alarm and Stop_Machine triggered	Ensures system halts unreliable data, reducing risk of damage or injury
Timer exceeds the expected limit without sensor change	Interpreted as a stuck or failed operation, System enters fault state	Prevents endless waiting or indefinite actuator engagement
Emergency Stop Button pressed	All outputs immediately de-energized, System goes into manual reset mode	Immediate shutdown in emergencies or abnormal conditions; ensures human control
Power failure / restart	System initializes in safe state, requires operator reset to continue	Prevents unexpected automatic restart; ensures supervised reactivation
Cycle timeout or incomplete sequence	Alarm triggered, System stops and waits for reset	Promotes controlled recovery and investigation of incomplete operations

4.2 Manual Control and Operator Safety Tools

- **Emergency Stop Button**: Accessible on control panel; instantly disables all outputs and halts machine movement.
- **Reset Button**: Used to reset all timers, alarms, and outputs after resolving a fault condition.
- **Status Indicators**:
    - **Cycle_Complete_Lamp**: Signals a successful and validated production cycle.
    - **Alarm Indicator**: Alerts the operator of active faults or issues.

- **Safe Initial State**: Upon power-up or reset, all actuators are OFF, requiring deliberate operator input to begin operation.

4.3 Design Philosophy

The safety logic is designed to:

- Prioritize human safety above automation.
- Halt operations gracefully in case of faults.
- Make fault diagnostics simple and transparent.
- Prevent motion or actuation under uncertain or unsafe conditions.
- Ensure the system can only proceed when all preconditions are safely met.

5. Ladder Logic Diagram

The ladder logic diagram represents the heart of the PLC automation system, visually displaying the control sequences used to manage the operation of the glass production machine. Each rung (horizontal line) in the ladder diagram represents a specific logical condition or action executed by the PLC. The diagram mimics electrical relay logic, making it highly intuitive for technicians and engineers to understand, troubleshoot, and maintain.

The following is a detailed breakdown of the main control logic implemented in the ladder diagram:

5.1 Rung 1 – System Start and Input Validation

- **Inputs:** Start_Button, Proximity_Sensor
- **Logic:**
  - When the Start_Button is pressed and the Proximity_Sensor detects the presence of hot glass, the system enables the process.
  - If no glass is detected, the Alarm coil is energized and the machine halts.
- **Purpose:**
  - Ensures the system does not proceed without a valid input (glass in place), avoiding dry cycles or mechanical damage.

5.2 Rung 2 – Delay Before Table Movement

- **Component:** Timer T1
- **Logic:**
  - Once glass is detected, T1 starts counting (delay before movement).
  - When T1. DN (done bit) is true, it triggers the forward movement.
- **Purpose:**

- Introduces a short wait time allowing the glass to settle properly before motion is initiated.

5.3 Rung 3 – Forward Motion of the Table

- **Output:** Move_Forward
- **Logic:**
  - T1. DN condition activates Move_Forward.
  - As the machine table moves forward, it advances the glass toward the take-out area.
- **Purpose:**
  - Drives the mechanical movement needed to position the glass for extraction.

5.4 Rung 4 – Timer for Output Sensor Detection

- **Component:** Timer T2
- **Logic:**
  - When Move_Forward is active, T2 starts.
  - Provides a window of time for the output proximity sensor to detect the arriving glass.
- **Purpose:**
  - Prevents premature logic transitions and gives time for mechanical motion to complete.

5.5 Rung 5 – Output Glass Detection Check

- **Input:** Output_Proximity_Sensor
- **Logic:**
  - After T2. DN, if the Output_Proximity_Sensor is not active, the system triggers the Alarm and stops the machine.
- **Purpose:**
  - Confirms that glass has reached the output; if not, indicates a jam, misalignment, or fault.

5.6 Rung 6 – Take-Out Mechanism Activation

- **Component:** Timer T3 and TakeOut_Motor
- **Logic:**
  - Once the glass output is confirmed, T3 is initiated.
  - After T3. DN, if the output sensor still detects glass, the TakeOut_Motor is turned ON.
- **Purpose:**
  - Ensures timed and confirmed removal of glass via mechanical arm or pickup device.

5.7 Rung 7 – Cycle Completion Confirmation

- **Conditions:** Move_Forward, Forward_Limit_Switch, and Output_Proximity_Sensor
- **Output:** Cycle_Complete_Lamp
- **Logic:**
  - All three conditions must be TRUE to energize the cycle complete lamp.
- **Purpose:**
  - Provides feedback that the full operation cycle was successful and the system is ready for the next piece of glass.

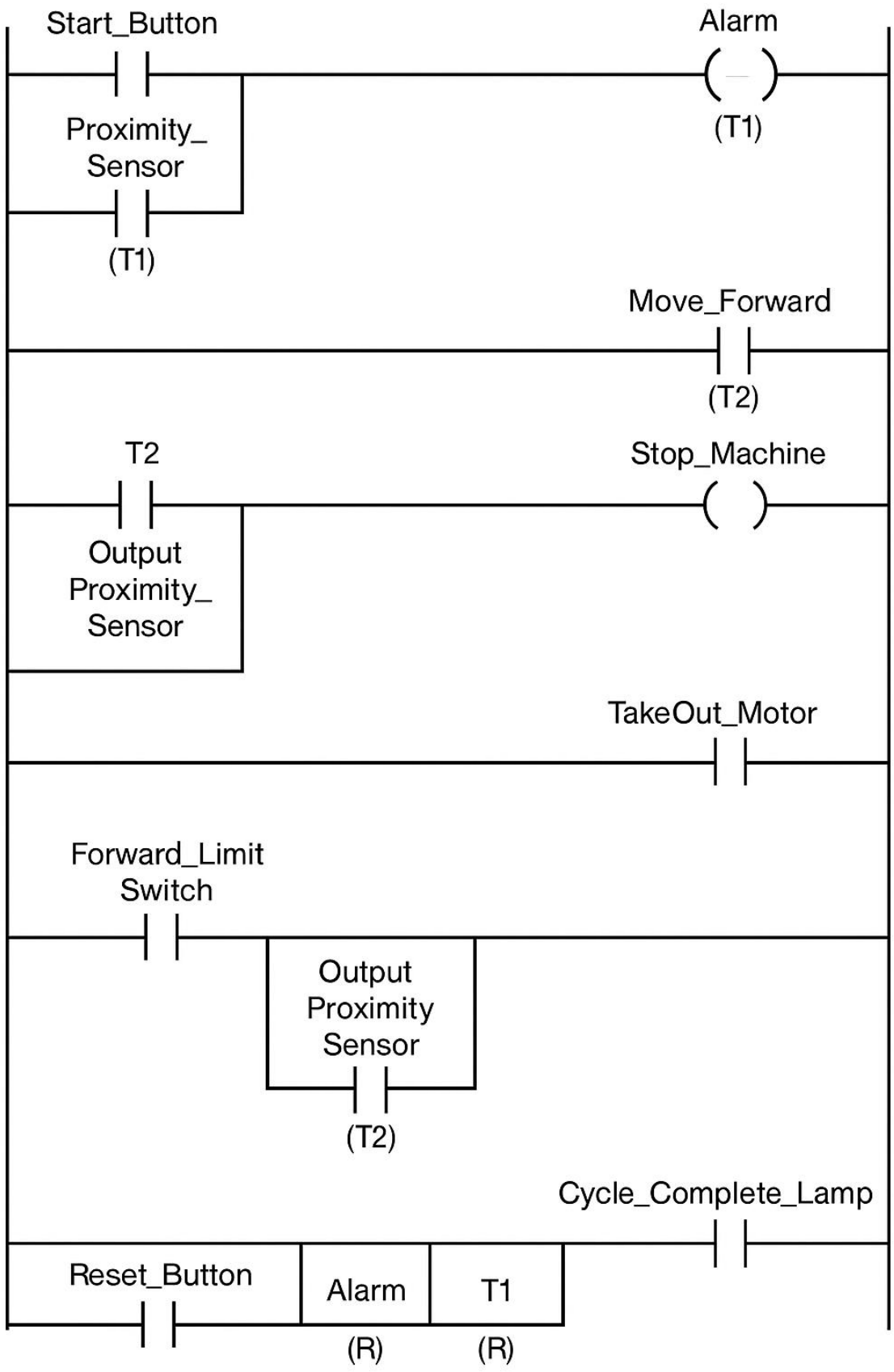
5.8 Rung 8 – Reset and Emergency Stop

- **Inputs:** Reset_Button, Stop_Machine_Button
- **Logic:**
  - The Reset_Button clears alarms, stops timers, and resets outputs.
  - The Stop_Machine_Button overrides all active logic and stops the machine immediately.
- **Purpose:**
  - Manual control features for safety, recovery, and maintenance.

5.9 Additional Features in the Ladder Logic

- **Fail-Safe Programming:** All outputs are de-energized unless certain validated conditions are met.
- **Modular Structure:** Logic is structured in isolated rungs, making troubleshooting straightforward.
- **Interlocks:** Sensor and timer-based interlocks prevent unsafe or unintended actions.

This ladder logic diagram captures the entire control flow—from start-up and material validation, through timed motion and output handling, to cycle completion and emergency handling. Its design ensures **precision, reliability, and safety** throughout the automation process.


Start_Button
Alarm
Proximity_
Sensor
(T1)
(T1)
Move_Forward
(T2)
T2
Stop_Machine
Output
Proximity_
Sensor
TakeOut_Motor
Forward_Limit
Switch
Output
Proximity
Sensor
(T2)
Cycle_Complete_Lamp
Reset_Button
Alarm
T1
(R)
(R)