**1.0 Introduction**

**1.1 Purpose**

This document provides the detailed functional design specifications for the control and monitoring of a Simple Automated Bottling Station. It defines the operational logic for the Programmable Logic Controller (PLC) and the design and functionality of the Human-Machine Interface (HMI).

**1.2 Project Scope**

The scope covers the design, implementation, and visualisation of a sequential process involving conveying, filling, and capping bottles. This document will serve as the primary reference for software development, testing, and operator training.

**1.3 System Overview**

The system consists of a conveyor belt that transports empty bottles to two sequential stations: a filling station and a capping station. Sensors detect the bottle's presence at each station to trigger the respective operations. The entire process is automated and monitored via an HMI panel.

**1.4 Definitions and Acronyms**

* **PLC:** Programmable Logic Controller
* **HMI:** Human-Machine Interface
* **FDS:** Functional Design Specification
* **I/O:** Input/Output
* **PB:** Pushbutton (Normally Open)
* **NC:** Normally Closed

**2.0 System Architecture**

**2.1 Hardware Components**

* **PLC:** Siemens S7-1200 series (or equivalent)
* **HMI:** Siemens Basic/Comfort HMI Panel (e.g., KTP700 Basic)
* **Field Devices:**
  + Proximity Sensors (x2)
  + Solenoid Valve (x1)
  + Pneumatic Actuator (x1)
  + AC Motor (x1)
  + Control Panel Pushbuttons and Indicator Lights

**2.2 Software Components**

* **Engineering Platform:** Siemens TIA Portal
* **PLC Programming:** Structured Control Language (SCL)
* **HMI Design:** WinCC (Basic/Comfort/Advanced)

**3.0 Operational Philosophy**

The system shall operate in the following modes:

* **Stopped Mode:** The default state. All outputs are de-energised.
* **Automatic Mode:** The system automatically processes bottles through the conveying, filling, and capping sequence.
* **Emergency Stop (E-Stop) State:** Triggered by the hardwired E-Stop circuit. This state shall immediately and unconditionally de-energise all system outputs.

**4.0 PLC Functional Specification**

**4.1 PLC Input/Output List**

| **Address** | **Tag Name** | **Type** | **Description** |
| --- | --- | --- | --- |
| I0.0 | Start\_PB | Bool | Physical Start Pushbutton (N.O.) |
| I0.1 | Stop\_PB | Bool | Physical Stop Pushbutton (N.C.) |
| I0.2 | E\_Stop\_Circuit | Bool | Emergency Stop Circuit (N.C.) |
| I0.3 | Bottle\_At\_Fill\_Sensor | Bool | Sensor at Fill Station |
| I0.4 | Bottle\_At\_Cap\_Sensor | Bool | Sensor at Capping Station |
| Q0.0 | Conveyor\_Motor | Bool | Conveyor Motor Contactor |
| Q0.1 | Fill\_Valve | Bool | Filling Solenoid Valve |
| Q0.2 | Capper\_Actuator | Bool | Capping Pneumatic Actuator |
| Q0.3 | System\_Running\_Light | Bool | Green indicator for Auto Mode |

**4.2 Automatic Mode Logic (State Machine)**

The core logic shall be a state machine. The system will only proceed from one state to the next when all transition conditions are met.

**4.2.1 State 0: Idle**

* **Entry Condition:** System startup or after a **Stop** command.
* **Actions:** All outputs are OFF. **System\_Running\_Light** is OFF.
* **Transition:** **Start** command is received.

**4.2.2 State 10: Waiting for Bottle at Fill Station**

* **Actions:** **Conveyor\_Motor** is ON.
* **Transition:** **Bottle\_At\_Fill\_Sensor** becomes TRUE.

**4.2.3 State 20: Filling Bottle**

* **Actions:** **Conveyor\_Motor** is OFF. **Fill\_Valve** is ON. A fill timer is started.
* **Parameters:** Fill Time = **3.0 seconds**.
* **Transition:** Fill timer elapses.

**4.2.4 State 30: Moving Bottle to Capping Station**

* **Actions:** **Fill\_Valve** is OFF. **Conveyor\_Motor** is ON.
* **Transition:** **Bottle\_At\_Cap\_Sensor** becomes TRUE.

**4.2.5 State 40: Capping Bottle**

* **Actions:** **Conveyor\_Motor** is OFF. **Capper\_Actuator** is ON. A cap timer is started.
* **Parameters:** Cap Time = **1.5 seconds**.
* **Transition:** Cap timer elapses.

**4.2.6 State 50: Cycle Complete**

* **Actions:** **Capper\_Actuator** is OFF. **Bottle\_Count** is incremented.
* **Transition:** Immediate transition back to State 10.

**5.0 HMI Functional Specification**

**5.1 HMI Screen Design**

A single main screen, "Bottling\_Station," shall be created with a process mimic, control buttons, and status displays.

**5.2 HMI Controls**

* **START Button:** Initiates the automatic cycle.
* **STOP Button:** Halts the automatic cycle and returns it to the Idle state.
* **RESET COUNT Button:** Resets the **Bottle\_Count** to zero.

**5.3 HMI Visualisation**

* **Process Mimic:** A graphical representation of the conveyor, filler, and capper. The state of each component (e.g., motor running, valve open) shall be dynamically animated.
* **System Status Display:** A text field shall display a descriptive message indicating the current state of the process.
* **Bottle Counter:** An I/O field shall display the total number of bottles completed.

**6.0 Alarms and Events**

| **Alarm ID** | **Alarm Text** | **Trigger Condition** | **Priority** |
| --- | --- | --- | --- |
| ALM-001 | **EMERGENCY STOP ACTIVATED** | E-Stop circuit is open. | High |
| ALM-002 | Process Halted by Operator | Stop button pressed. | Low |