**Pump Control System with PID & Alarm Handling**

*Studio 5000 Emulator-Based Control Project*

**1. Project Objective**

This project implements a pump control system using Studio 5000 with a ControlLogix-based architecture and emulator-compatible I/O. It controls a water tank level using a VFD-driven pump. The system supports both **manual (operator speed)** and **automatic (PID-regulated)** modes, with analog signal scaling, alarm management, and structured ladder routines.

This project mirrors real-world industrial control designs and is structured for clarity, modularity, and extensibility.

**2. Scope of Work**

* Build logic to control pump operation based on tank level
* Implement **Manual Mode** (fixed speed input) and **Auto Mode** (PID control)
* Perform analog scaling on tank level and flow rate inputs (4–20 mA)
* Output analog VFD speed via analog output module
* Implement alarm system for overfill and underfill conditions
* Design modular routines: IO, MODE\_SELECTION, CTRL, ALARMS\_NOTIFICATION
* Ensure the system runs entirely on **Studio 5000 Emulator**

**3. Modes of Operation**

**🔘 Manual Mode:**

* Operator manually sets pump speed via MANUAL\_VFD\_SPEED
* Pump starts and runs at constant analog speed output

**🔄 Auto Mode:**

* Operator enters desired flow (FLOW\_SP)
* PID controller adjusts pump speed to maintain flow using FLOW\_LEVEL feedback

**🟢 System Logic:**

* Start system via START\_PB
* Stop and clear modes via STOP\_PB
* LT\_AUTO\_MODE and LT\_MANUAL\_MODE indicate active mode

**4. Hardware Configuration**

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| --- | --- | --- |
| **Slot** | **Module** | **Description** |
| 0 | Emulator CPU | Studio 5000 Logix Emulator |
| 1 | 1756-IA16 | Digital Inputs – Pushbuttons |
| 2 | 1756-OA16 | Digital Outputs – Pump, VFD, Lights |
| 3 | 1756-IF8 | Analog Inputs – Tank Level, Flow Rate |
| 4 | 1756-OF8 | Analog Output – VFD Speed Control |

✅ All modules configured for simulation; logic runs without hardware.

**5. Analog Signal Scaling**

|  |  |  |  |
| --- | --- | --- | --- |
| **Signal** | **Raw Range** | **Scaled Range** | **Use** |
| Tank Level | 6554–32767 | 0–100% | Controls start/stop logic |
| Flow Rate | 6554–32767 | 0–500 LPM | PID process variable |
| VFD Speed Output | 6554–32767 | 0–100% | VFD command output |

✅Scaling is done using CPT blocks and clamped to valid engineering ranges.

**6. Control Logic Overview**

* **Pump Start**: TANK\_LEVEL < 20% (held for 5 sec)
* **Pump Stop**: TANK\_LEVEL > 80% (held for 5 sec)
* TRIGGER\_PUMP and TRIGGER\_PUMP\_STOP control latching
* In **Manual Mode**:  
  → MANUAL\_VFD\_SPEED → VFD\_SPEED → analog output
* In **Auto Mode**:  
  → FLOW\_SP → PID.SP, FLOW\_LEVEL → PID.PV, PID.CV → VFD\_SPEED → analog output
* PID block only runs when AUTO\_MODE and PUMP = TRUE

**7. Alarm and Notification System**

The system monitors the tank level and provides both **Low-Level** and **High-Level** alarms using structured logic:

**🔻 Low-Level Alarm:**

* Triggered when TANK\_LEVEL < 10% for 5 seconds
* Activates LL\_ALARM, LL\_NOTIFICATION
* Uses a one-shot pulse (TRIGGER\_LL\_ALM) and latch

**🔺 High-Level Alarm:**

* Triggered when TANK\_LEVEL > 90% for 5 seconds
* Activates HH\_ALARM, HH\_NOTIFICATION
* Uses TRIGGER\_HH\_ALM and a similar latch

**🔄 Reset Logic:**

* RESET\_ALARM clears all alarms and indicators
* FAULT\_LT output turns on when any alarm is active

✅ Alarm system is clean, debounced, and HMI-ready

**8. Tag and Interface Overview**

* **Digital Inputs**: START\_PB, STOP\_PB, AUTO\_PB, MANUAL\_PB
* **Digital Outputs**: OUT\_PUMP, OUT\_VFD, LT\_MANUAL\_MODE, LT\_AUTO\_MODE, FAULT\_LT
* **Analog Inputs**: RAW\_TANK\_LEVEL, RAW\_FLOW\_LEVEL
* **Analog Output**: RAW\_VFD\_SPEED
* **Control Tags**: FLOW\_SP, MANUAL\_VFD\_SPEED, RESET\_ALARM
* **PID Block**: PID\_CTRL (SP, PV, CV)

**9. Functional Test Criteria**

|  |  |
| --- | --- |
| **Test Case** | **Expected Behavior** |
| Force TANK\_LEVEL < 20% | Pump starts after 5 seconds |
| Force TANK\_LEVEL > 80% | Pump stops after 5 seconds |
| Set MANUAL\_VFD\_SPEED = 60 | Output analog = 22281 (≈ 13.6 mA) |
| Set FLOW\_SP = 300, flow = 250 | PID raises VFD\_SPEED to reach setpoint |
| TANK\_LEVEL < 10% for 5s | Low-level alarm active, FAULT\_LT ON |
| TANK\_LEVEL > 90% for 5s | High-level alarm active, FAULT\_LT ON |
| Press RESET\_ALARM | Clears alarms and FAULT\_LT |
| Press STOP\_PB | Cancels all operations and resets modes |

**10. Summary & Portfolio Highlights**

This Studio 5000 project demonstrates:

* ✔️ PID-based process control with flow feedback
* ✔️ Analog scaling and signal clamping (4–20 mA)
* ✔️ Structured ladder routines (IO, CTRL, MODE\_SELECTION, ALARMS)
* ✔️ Realistic control logic (delayed starts, stop conditions, fault handling)
* ✔️ Alarm latching, operator reset, and notification architecture
* ✔️ Designed for full testing using Studio 5000 Emulator