

# Pump Control System with PID & Alarm Handling

## *Studio 5000 Emulator-Based Control Project*

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### 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

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- 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

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#### **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

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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

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- **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

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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

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- **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

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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 ( $\approx 13.6$ 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

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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