Project Report: PLC Programming and Single-Screen HMI Design

Introduction

This project involved designing and implementing a Programmable Logic Controller (PLC) program and a Human-Machine Interface (HMI) for a fully automated water filtration system. The system is designed to provide clean water by automatically filtering and managing backwash cycles when the filter becomes clogged with contaminants. The project aimed to ensure seamless operation, efficient automation, and user-friendly interaction through a single-screen HMI.

System Overview

Water Filtration Process

The water filtration system operates in two primary modes:

1. **Normal Operation**:
    - Water is drawn from the supply, filtered, and stored in a tank.
    - Pressure transmitters monitor the system to ensure efficient operation and detect filter clogging.
    - A flow switch protects the pump by ensuring water flow.
2. **Backwash Cycle**:
    - The system reverses water flow through the filter to clean it.
    - Contaminants are flushed out into a drain using stored clean water from the tank.
    - The system automatically returns to normal operation after backwashing.

Hardware Components

- **Solenoid Valves** (`SV1–SV6`): Control water flow paths in the system.
- **Pump** (`P1`): Moves water through the system.
- **Flow Switch** (`FS1`): Ensures water flow for pump protection.
- **Pressure Transmitters** (`PT1`, `PT2`): Monitor system pressure and detect differential pressure for filter clogging.
- **Level Transmitter** (`LT1`): Tracks water level in the storage tank.
- **Ball Valve** (`BV1`): Manual valve for tank drainage.

PLC Programming

Objectives

The PLC program was designed to automate the following:

1. Control the solenoid valves and pump based on system requirements and operating modes.
2. Monitor sensor inputs (flow switch, pressure transmitters, and level transmitter) to ensure safe and efficient operation.
3. Automatically initiate and manage the backwash cycle when the differential pressure across the filter exceeds a predefined threshold.
4. Provide alarm mechanisms for fault detection (e.g., low flow, high-pressure differential).

Key Logic Implementations

- **Normal Operation**:
  - SV1, SV3, and SV5 open; SV2, SV4, and SV6 closed.
  - Pump (P1) runs to move water through the filter into the storage tank.
  - FS1 ensures sufficient flow; otherwise, the pump is stopped, and an alarm is triggered.
- **Backwash Cycle**:
  - SV2, SV4, and SV6 open; SV1, SV3, and SV5 closed.
  - Pump reverses water flow to clean the filter and flush contaminants into the drain.
- **Alarm System**:
  - Monitors for low flow, pump cavitation, and high-pressure differential.
  - Provides visual and audible indicators for system faults.

HMI Design

Tool Used

The HMI was developed using **AdvancedHMI** in Visual Studio, leveraging its free and customizable features for creating interactive operator interfaces.

Design Objectives

1. Provide a single-screen interface for simplicity and usability.
2. Display real-time system information, including:

    - Current mode (Normal/Backwash).
    - Status of all devices (e.g., solenoid valves, pump).
    - Sensor readings (flow rate, pressure, and tank level).
3. Integrate alarm management with reset and silence capabilities.
4. Maintain a clean and professional layout, avoiding screen clutter.

HMI Features

1. **System Overview**:
    - Visual representation of the water flow, including real-time status of solenoid valves and pump operation.
2. **Sensor Readouts**:
    - Displays pressure readings from PT1 and PT2, flow status from FS1, and tank level from LT1.
3. **Alarms**:
    - Indicators for low flow, pump failure, and high-pressure differential.
    - Reset and silence buttons for operator interaction.
4. **Mode Indication**:
    - Clear indication of whether the system is in Normal Operation or Backwash Mode.

Challenges and Solutions

1. **Challenge**: Managing screen space to fit all required information on a single screen.
   Solution: Designed an intuitive layout with distinct sections for device status, sensor readings, and alarms.
2. **Challenge**: Ensuring seamless communication between the PLC and HMI.
   Solution: Used Modbus TCP for reliable data exchange between the PLC and AdvancedHMI.
3. **Challenge**: Handling alarm conditions efficiently.
   Solution: Implemented a simple alarm management interface with reset/silence functionality.

Outcomes

- **Automation**: The system now operates autonomously, minimizing operator intervention.
- **Efficiency**: The backwash cycle is triggered automatically, ensuring the filter remains effective without disrupting water supply.

- **Usability**: The single-screen HMI provides a clear, user-friendly interface for monitoring and control.

Conclusion

This project demonstrates the effective integration of PLC programming and HMI design to automate a real-world water filtration system. The use of AdvancedHMI and Visual Studio enabled the creation of a functional, professional interface tailored to system requirements. This system exemplifies how automation and intuitive design can enhance operational efficiency and reliability in industrial processes.