Design and Implementation of a Water Purification and Quality Monitoring System

1 Project Overview

Objective: To design an automated water purification and quality monitoring system prioritizing robust filtration performance, sensor accuracy, and operational safety.

The key features of the system include:

- Multi-stage filtration (Sediment, Carbon, and Ultra-filtration).
- UV treatment for disinfection.
- Real-time IoT quality monitoring.
- Automated self-protection mechanisms.

2 System Architecture and Hardware Layout

The system is divided into two main stages to improve efficiency and safety:

- Stage 1: Filtration and Storage.
- Stage 2: Polishing and Dispensing.

2.1 Hardware Block Diagram

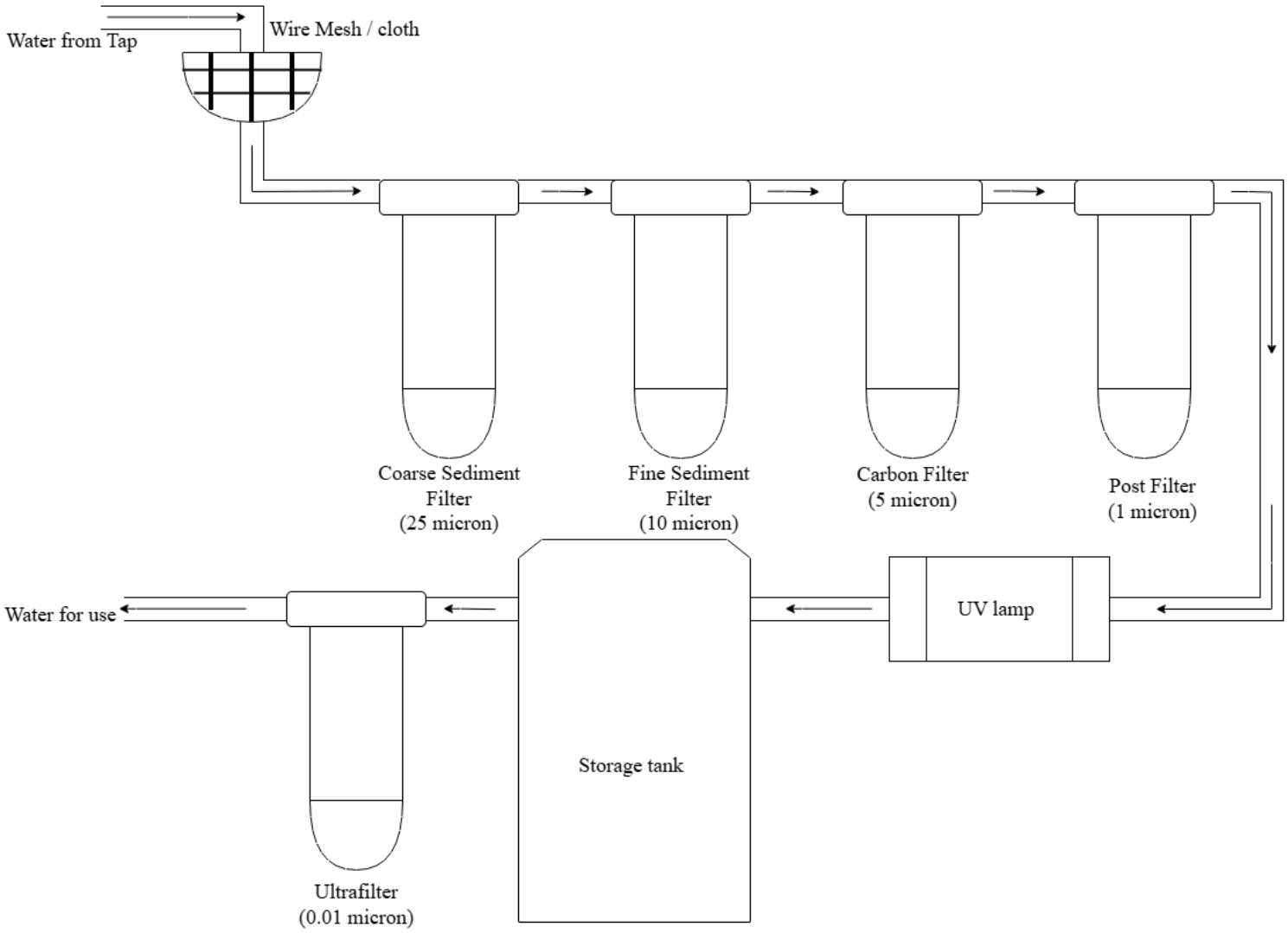

Figure 1: Hardware block diagram of the system.

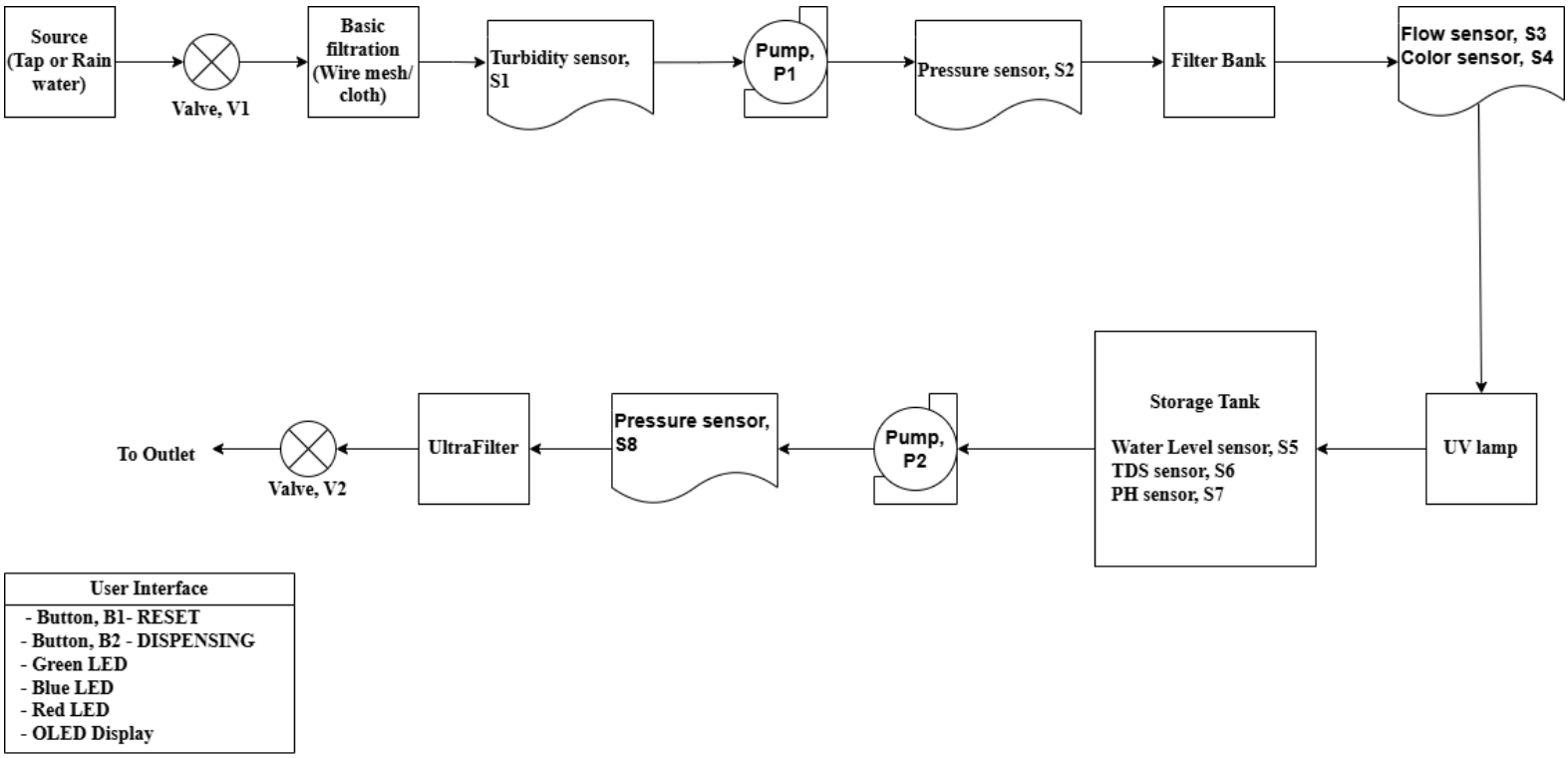

Figure 2: Overall system schematic representation.

2.2 Stage 1: Source to Storage Tank

During this stage, raw water is treated before storage. The process includes:

- **Filtration:** Water is drawn by pump P1 and passed through a filter bank consisting of two sediment filters (25 µm and 10 µm), an activated carbon 5 µm filter, and a 1 µm post-filter.
- **System Protection:** A pressure sensor (S2) and flow sensor (S3) monitor the system conditions to detect clogs.
- **Disinfection:** A UV lamp is installed after the filter bank to reduce microbial load before water enters the storage tank.

2.3 Stage 2: Storage Tank to End-User

The second stage ensures final polishing and safe delivery to the end-user.

- **Polishing:** Pump P2 drives water through a 0.01 µm ultrafilter membrane before it is dispensed as a last line of defense.
- **Safety Monitoring:** Pressure sensor S8 monitors membrane pressure to detect pressure buildups (clogs) or potential membrane ruptures.

3 System Operational Modes

The system is designed with a microcontroller to monitor parameters and automate operations.

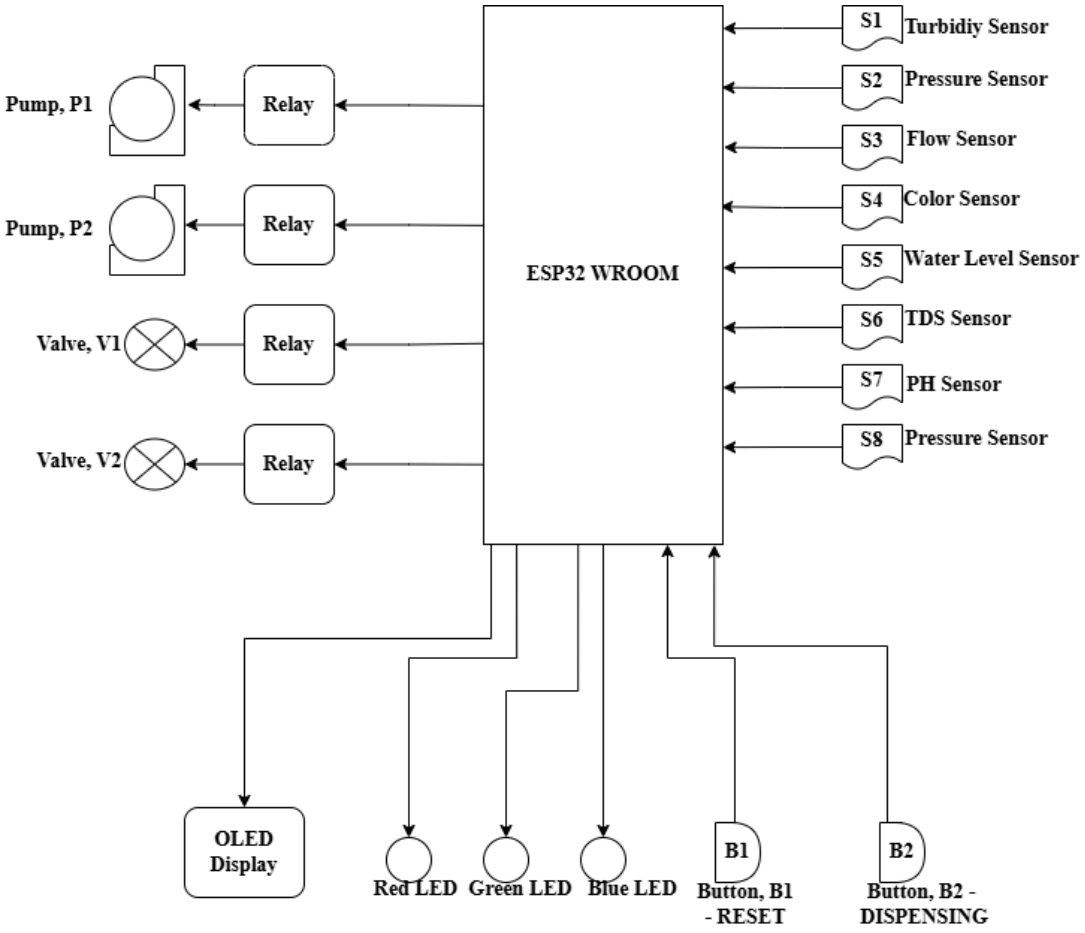

Figure 3: Microcontroller and component integration.

The microcontroller operates in four distinct modes to ensure safety, fault isolation, and energy efficiency:

3.1 Filtration Mode

Objective: To automatically fill the storage tank while protecting hardware components.

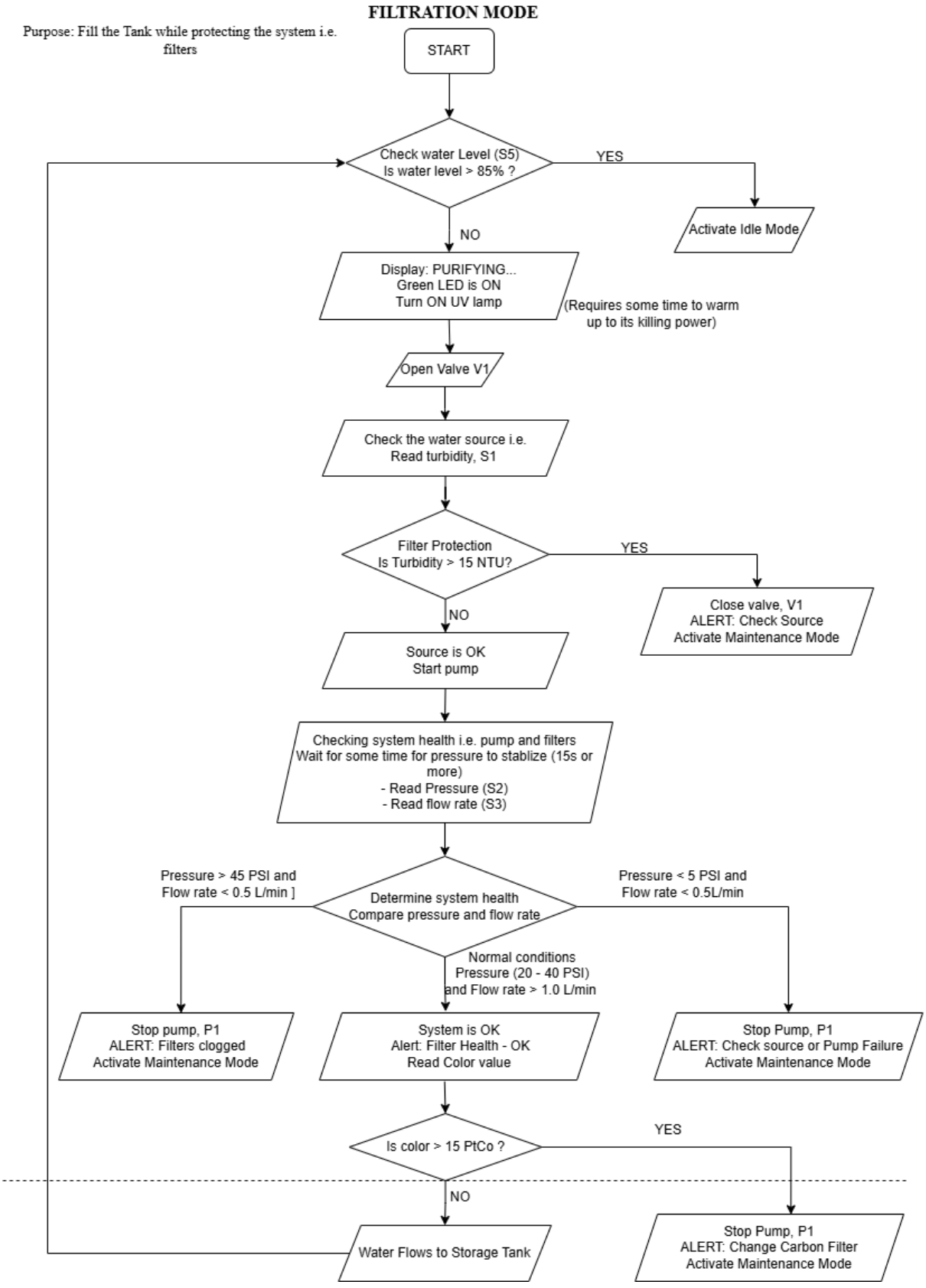

Figure 4: Filtration mode.

- **UV Warm-up:** The UV lamp activates before the pump starts to ensure no

untreated water enters the storage tank.

- **Clog and Dry Run Detection:** The system differentiates faults by comparing Pressure (S2) and Flow Rate (S3).
- **Source Quality:** Turbidity (S1) is checked to prevent fouling the filters. Color (S4) is monitored to ensure effective UV transmission.

3.2 Idle Mode

Objective: To ensure energy conservation while monitoring the system.

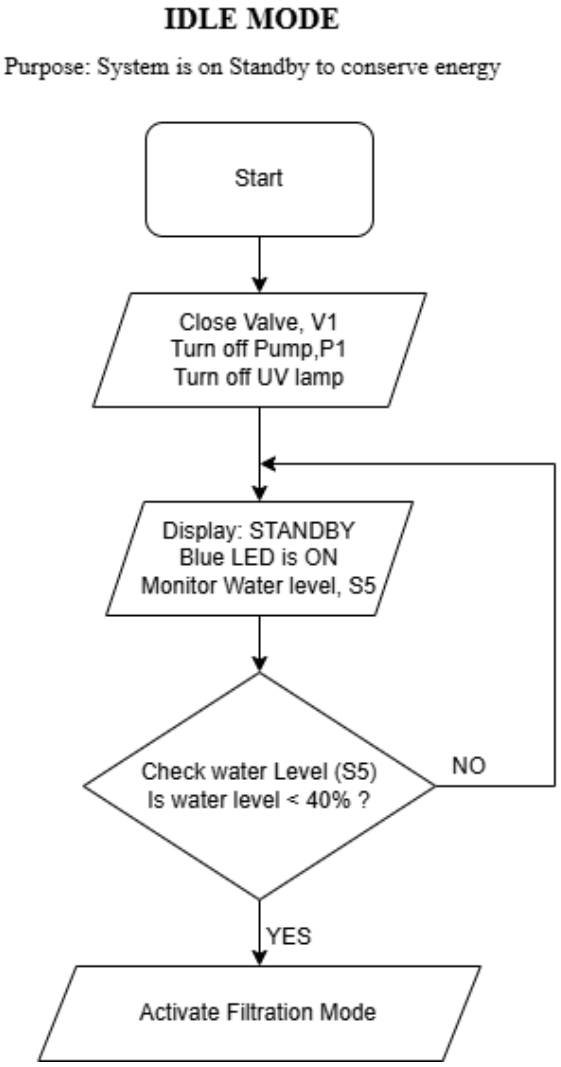

Figure 5: Idle mode.

- Activated when the storage tank is full (water level > threshold).
- High-power consumption components (Pump P1, UV Lamp) are turned OFF.
- **Continuous Monitoring:** The system wakes periodically to check the tank water level.

3.3 Dispensing Mode

Objective: To ensure safe, on-demand delivery to the end-user.

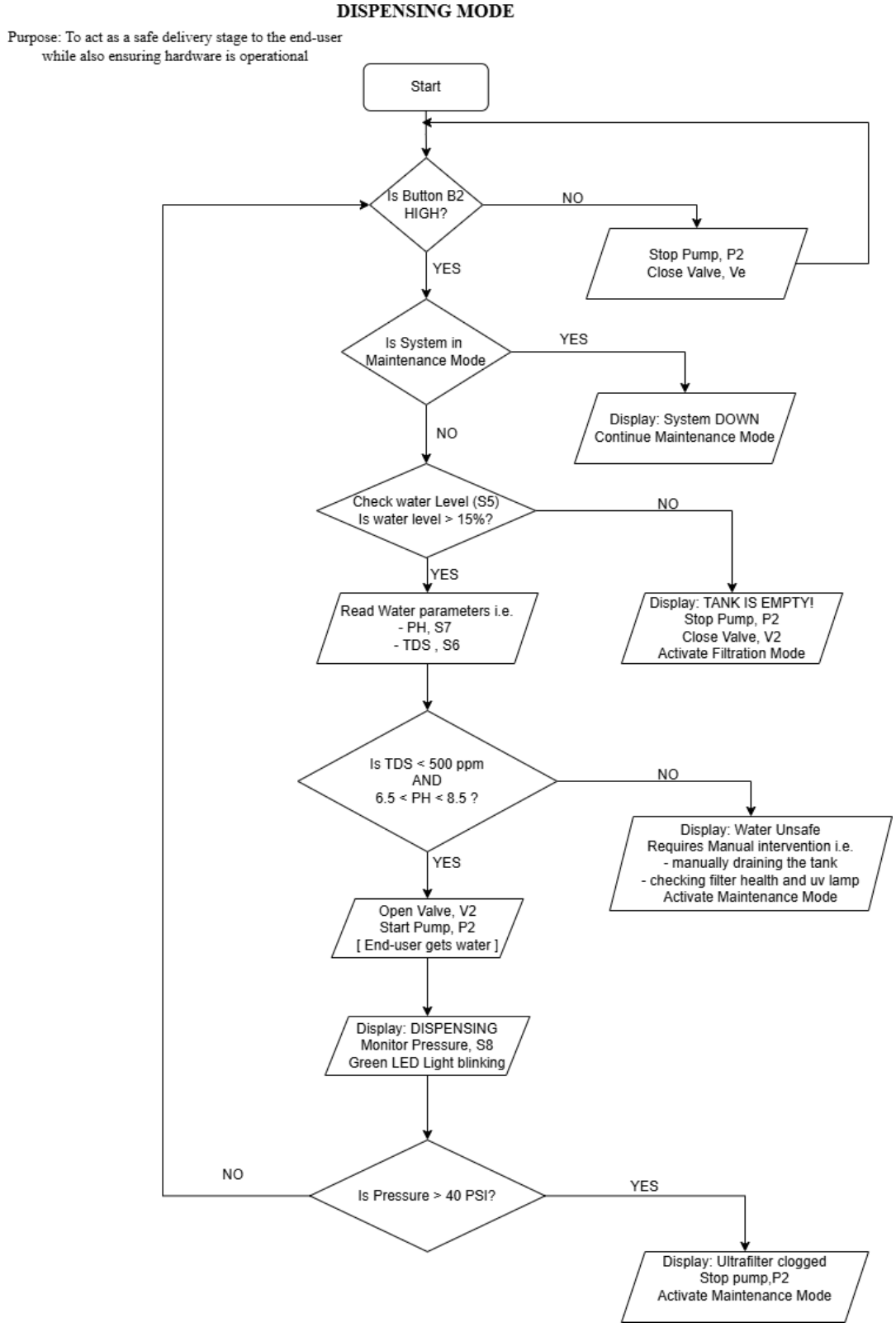

Figure 6: Dispensing mode.

- Triggered by the user holding button B2.
- The system verifies that pH (S6) and TDS (S7) are within safe limits before opening Valve V2.
- Active Ultrafilter health monitoring via pressure sensor S8.

3.4 Maintenance Mode

Objective: To lock the system during critical faults.

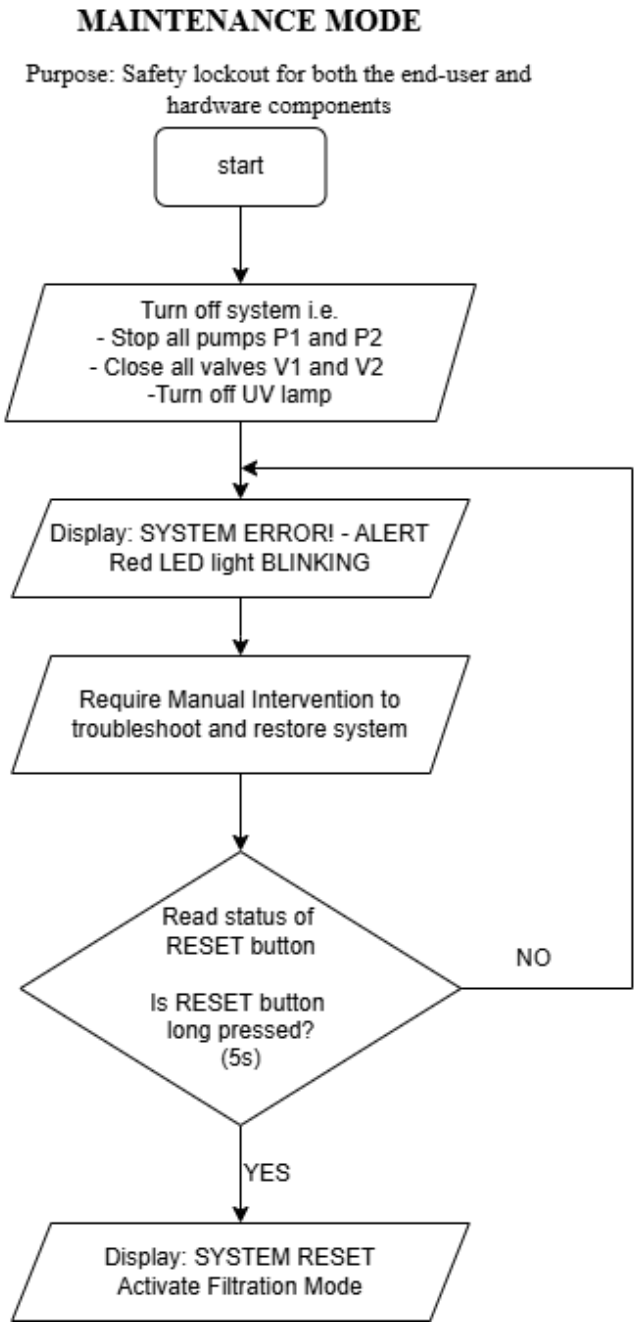

Figure 7: Maintenance mode.

- Activated by critical errors such as clogged filters or unsafe water parameters.
- System enters a full shutdown state, requiring manual intervention/reset from an operator.

4 User Interface and Water Quality Standards

4.1 Status Indicators

The system communicates its operational state using an LED light interface and an OLED screen.

Table 1: System Status Indicators

LED Color	**Mode**	**Description**
Blue	Idle	System ready / Tank full
Green	Filtration / Dispensing	System active and purifying
Red (Blinking)	Maintenance	Critical fault (Technician required)

5 Recommendations

5.1 Removal of the ultrafiltration stage

This stage was intended as a substitute for the Reverse Osmosis membrane, which has low efficiency due to water loss; for every litre of purified water produced, approximately three litres are wasted. However, since the system considers tap water and rainwater at most, the ultrafiltration stage can be eliminated. This reduces cost and improves energy efficiency.