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 post filtration).
- UV treatment for disinfection.
- Real-time IoT quality monitoring.
- Automated self-protection mechanisms.

2   System Architecture and Hardware Layout

The system is made up of four different filters that operate in the pre-filtration phase, a UV lamp to kill microbial contaminants, and various sensors at different stages used to monitor the system and support the automation of the different actuators.
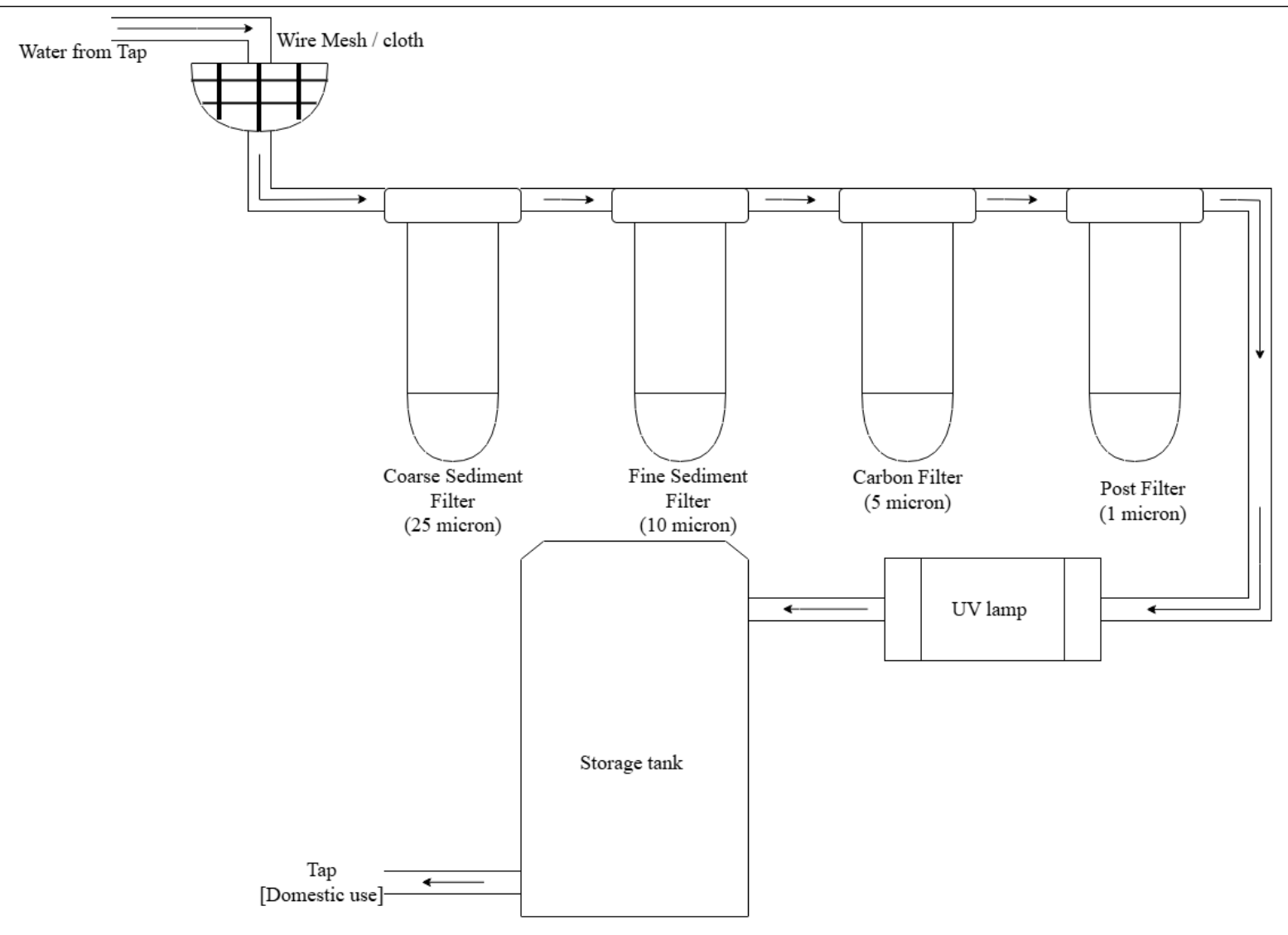
2.1 Hardware Block Diagram

Figure 1: Hardware block diagram of the system.
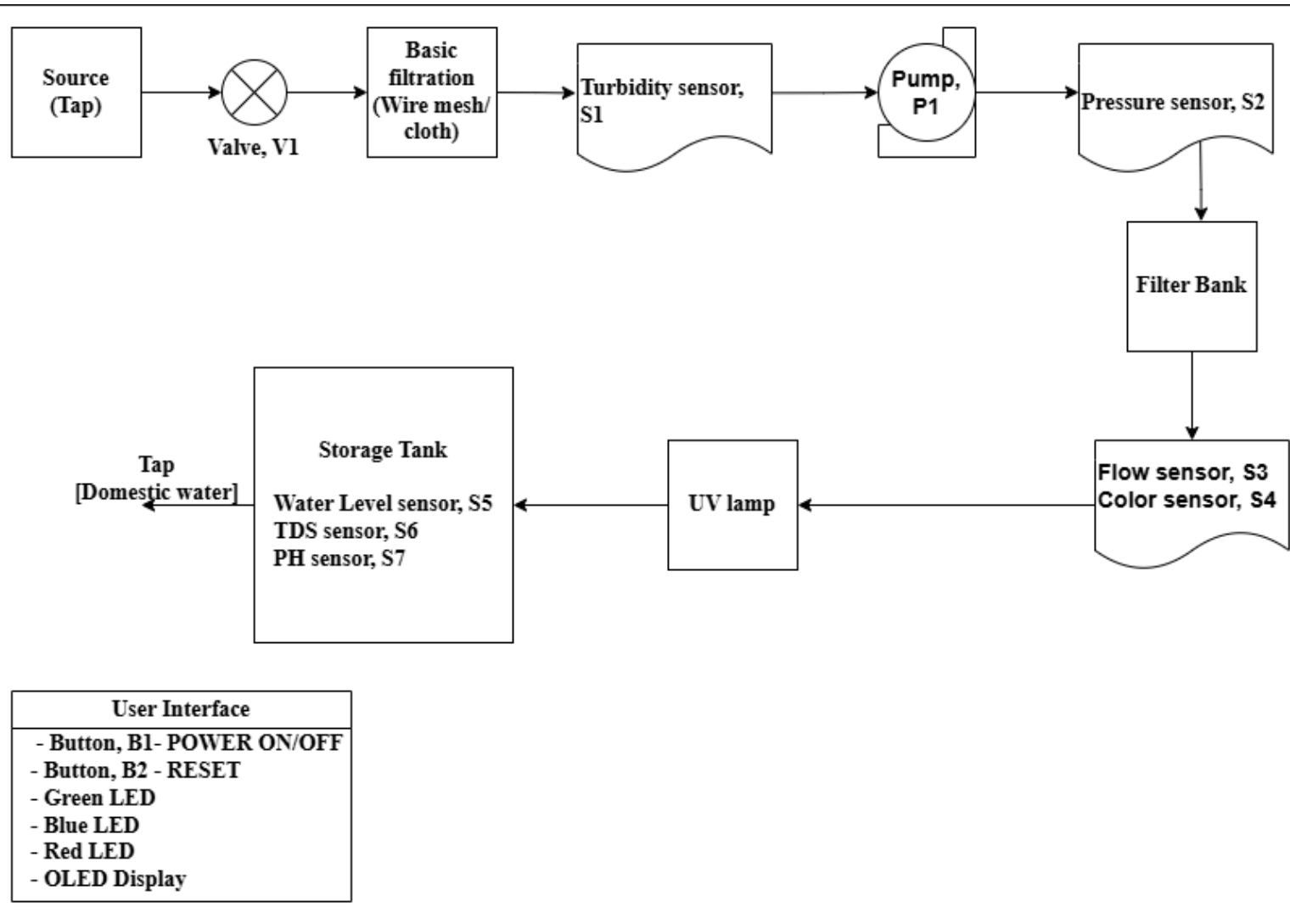
2.2 Overall system representation

Figure 2: Overall system schematic representation.

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.

3 System Operational Modes

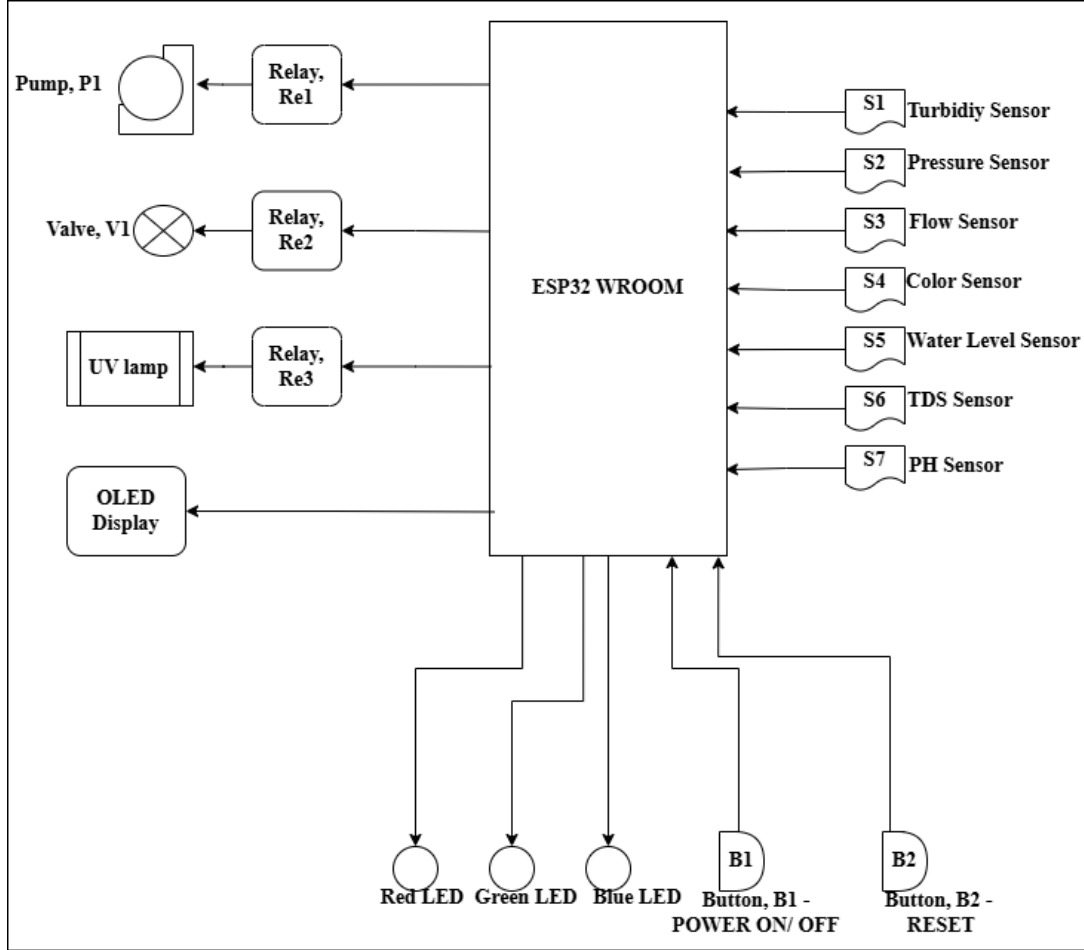The system is designed with a microcontroller to monitor parameters and automate operations.

Figure 3: Microcontroller and component integration.

The microcontroller operates in three 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.

FILTRATION MODE

Purpose: Fill the Tank while protecting the system i.e. filters

START

Check water Level (S5)
Is water level > 85% ?

YES

Activate Idle Mode

NO

Display: PURIFYING...
Green LED is ON
Turn ON UV lamp

(Requires some time to warm up to its killing power)

Open Valve V1

Check the water source i.e.
Read turbidity, S1

Filter Protection
Is Turbidity > 15 NTU?

YES

Close valve, V1
ALERT: Check Source
Activate Maintenance Mode

NO

Source is OK
Start pump

Checking system health i.e. pump and filters
Wait for some time for pressure to stablize (15s or more)
- Read Pressure (S2)
- Read flow rate (S3)

Pressure > 45 PSI and
Flow rate < 0.5 L/min]

Determine system health
Compare pressure and flow rate

Pressure < 5 PSI and
Flow rate < 0.5L/min

Normal conditions
Pressure (20 - 40 PSI)
and Flow rate > 1.0 L/min

Stop pump, P1
ALERT: Filters clogged
Activate Maintenance Mode

System is OK
Alert: Filter Health - OK
Read Color value

Stop Pump, P1
ALERT: Check source or Pump Failure
Activate Maintenance Mode

Is color > 15 PtCo ?

YES

NO

Water Flows to Storage Tank

Stop Pump, P1
ALERT: Change Carbon Filter
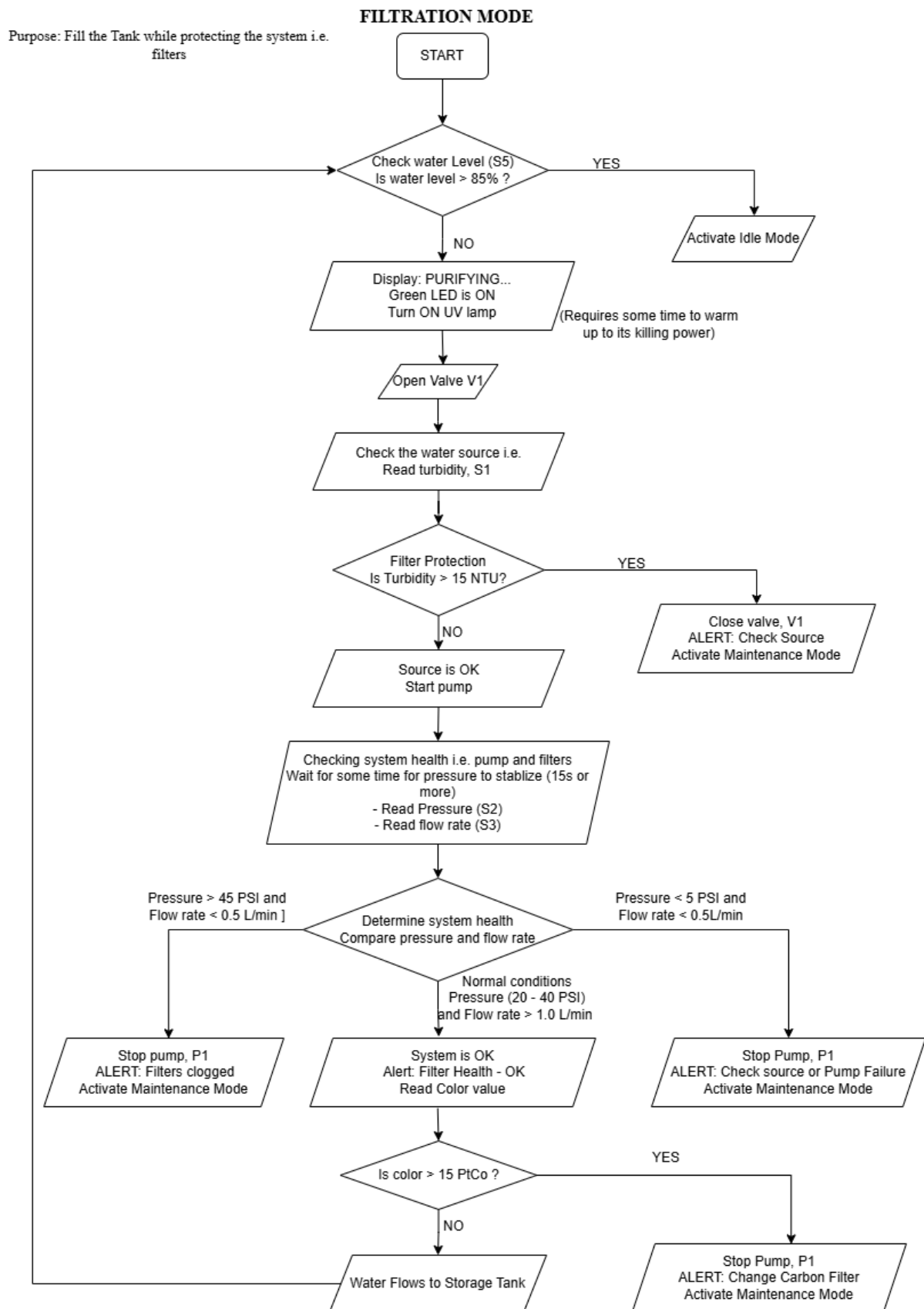Activate Maintenance Mode

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.

IDLE MODE
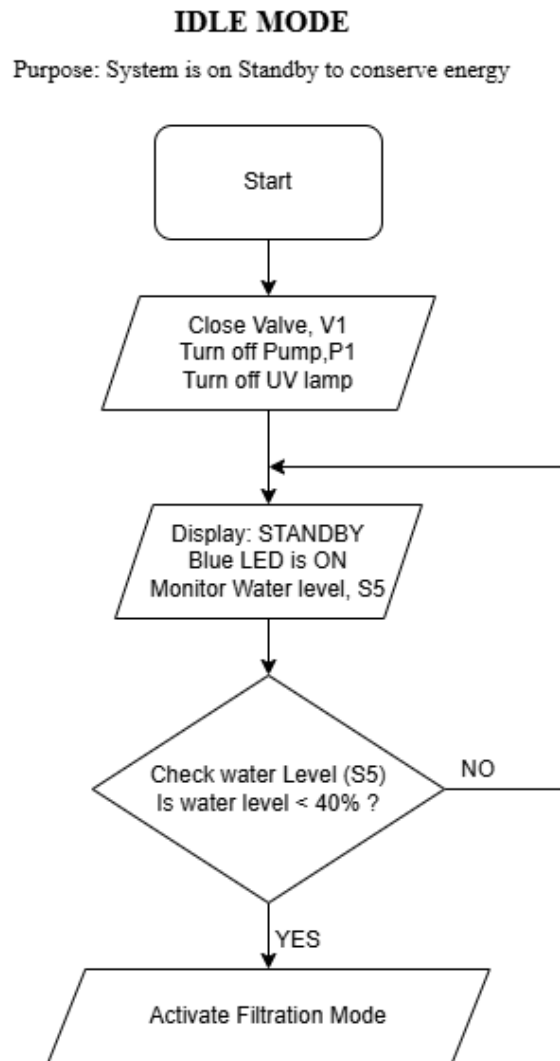
Purpose: System is on Standby to conserve energy

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 Maintenance Mode

Objective: To lock the system during critical faults.

MAINTENANCE MODE

Purpose: Safety lockout for both the end-user and hardware components

start

Turn off system i.e.
- Stop pump P1
- Close all valve V1
-Turn off UV lamp

Display: SYSTEM ERROR! - ALERT
Red LED light BLINKING

Require Manual Intervention to
troubleshoot and restore system

Read status of
RESET button

Is RESET button
long pressed?
(5s)
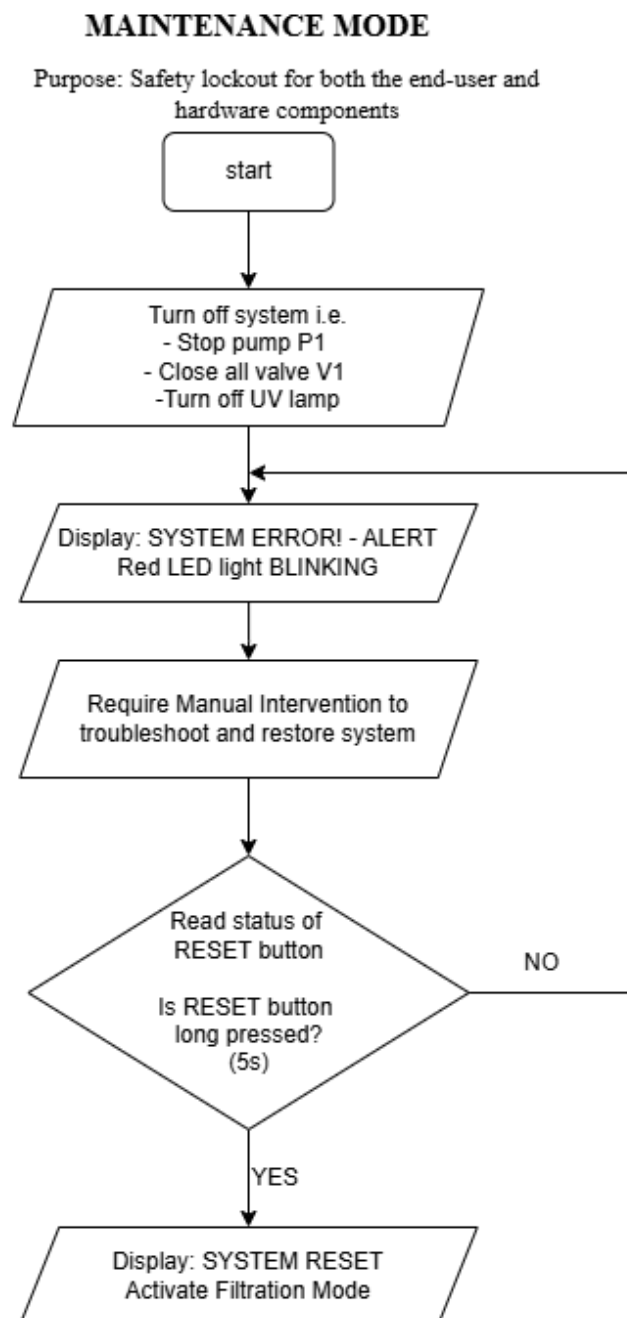
NO

YES

Display: SYSTEM RESET
Activate Filtration Mode

Figure 6: 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)