PLC BASED WATER TREATMENT PLANT

Project report submitted in partial fulfillment of the requirement for the degree of

BACHELOR OF TECHNOLOGY

IN

ELECTRONICS AND COMPUTER ENGINEERING

By

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UNDER THE GUIDANCE OF

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MAY 2025

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DECLARATION

We hereby declare that the work reported in the B.Tech Project Report entitled **"PLC BASED WATER TREATMENT PLANT"** submitted at **Jaypee University of Information Technology, Waknaghat, India** is an authentic record of our work carried out under the supervision of **Prof. (Dr.) Shruti Jain.** We have not submitted this work elsewhere for any other degree or diploma.

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This is to certify that the above statement made by the candidates is correct to the best of my knowledge.

Signature of the Supervisor
Prof. (Dr.) Shruti Jain
Date: 9 May 2025

Head of the Department/Project Coordinator

ACKNOWLEDGEMENT

We are really grateful and wish our profound indebtedness to Supervisor Prof. (Dr.) Shruti Jain Assistant Professor, Department of ECE, Jaypee University of Information Technology, Waknaghat. The deep knowledge & keen interest of our supervisor in the field of "**Image and Signal Processing, Soft Computing, Internet-of-Things, Pattern Recognition, Bio-inspired Computing, and Computer-Aided Design of FPGA and VLSI circuits .**" helped us to carry out this project. Her endless patience, scholarly guidance, continual encouragement, constant and energetic supervision, constructive criticism, valuable advice, reading many inferior drafts, and correcting them at all stages have made it possible to complete this project.

We would like to express our heartiest gratitude to Prof. (Dr.) Shruti Jain, Department of ECE, for her kind help to finish our project.

We would also generously welcome each one of those individuals who have helped us straightforwardly or in a roundabout way in making this project a win. In this unique situation, we might want to thank the various staff individuals who have developed their convenient help and facilitated our undertaking.

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ABSTRACT

The driving force behind advances in water treatment technology has been demand for potable and safe drinking water. This is a design and implementation for an automated drinking water treatment system that employs the use of a PLC. The main objective for this project is to introduce automation into the critical stages of the water treatment process ensuring high-quality drinking water. In doing so, maintain traditional treatment methods. This conventional PLC-based control could be visualized as the efficiency of handling the steps in water treatment like filtration, disinfection, RO, and pH adjustment.

Programmable Logic Controllers(PLCs) will automate the treatment processes. They monitor the key operational parameters that include flow rates, chemical dosing, management of filtration, and real-time monitoring of key water quality indices such as turbidity, pH, total dissolved solids TDS, hardness, and residual chlorine. The sensors are placed systematically around the system and give feedback to the PLC at constant intervals. In real-time, the method fine-tunes the processes toward upgradation of water quality and efficacy within the system.

This kind of PLC system makes it possible to implement a highly accurate control system of every step of the treatment process, at the same time minimizing the need for man-in-the-loop intervention that makes errors minimal and the treatment procedure easy and effective. It aims to improve the effectiveness of treatment, ensure good quality water, reduce man power, and make the whole treatment process simple yet reliable.

It captures an automated drinking water treatment solution through PLC technology-know efficiency and sustainability in this sense, thus it fits really well for small-to-medium sized water treatment plants. Its service of critical needs in the resource-poor areas in which automation would upgrade dependability on producing waters which meet the high quality criterion makes a very strong case. This means that the project acknowledges the possibility of PLC-controlled automation to transform a traditional water treatment plant into a modern, efficient system capable of producing highly reliable and clean drinking water.

CHAPTER 1

INTRODUCTION

1.1 Background

One of the most acute problems for communities around the world is the provision of clean and safe drinking water. Urbanization, industrialization, and population increase all necessitate an adequate supply of potable water, hence the need to have enough water treatment plants. Such plants transform raw untreated water into safe drinkable water by removing the harmful pollutants, pathogens, and unwanted chemicals.

Historically, different physical, chemical as well as biological techniques have always been used to treat water- filtration, sedimentation, and reverse osmosis, adjustment of pH, and disinfection-in the processes involved. While these processes, however result in effective water treatment practices, they mostly depend on human input. This most of the time leads to errors, ineffectiveness and inconsistency in outcome.

Advances in automation and control technologies have enabled the general application of programmable systems, primarily Programmable Logic Controllers (PLCs), with a chance for further development and automation of various steps in water treatment processes. PLCs have been extensively applied in industrial process automation but have recently gained greater popularity in water treatment processes because of its strength, flexibility, and capability for real-time control. It can help ensure better reliability, efficiency, and accuracy in water treatment systems through PLC-based automation, using efforts on reducing the amount of interference from humans in watering.

1.2 Problem Statement

The problems include fluctuation of water quality, misuse of the resources, and human mistakes in the treatment processes that may cause a lot of contamination or lead to an unsafe drinking of water through the system when one tries to observe and monitor the quality of the water. More so, a manual running of the operations does not allow real time adjustment from changes in quality or from the system efficiencies.

Therefore, there is currently a great need for full automation of the process concerned with water treatment-from abstraction of raw water through any necessary treatment to final chlorination-all in conformity to strict standards of water purity to ensure safe drinking waters. The objective of the project is to create automatic control of drinking water treatment within PLC-based control so all activities of the water treatment process can be monitored and directed with precision to guarantee smooth production of high-quality-drinking water.

1.3 Objectives of the Project

The project focuses on automating the existing water treatment process by implementing PLC-based control, taking inspiration from the drinking water treatment plant at JUIT.. Major automation without compromising on the actual core steps: intake of raw water, pre-treatment, microfiltration or ultra-filtration, reverse osmosis, removal of hardness, disinfection, pH and final treatment. This allows streamlining of such process variables by introduction of PLCs while at the same time ensuring that one has control, and, secondly, enhanced operational output. It is mainly targeted at the reduction of human error intervention during the operational processes so as to effect a very clean water treating process.

Additionally, it should give real-time monitoring and control of all significant parameters, such as flow rate, turbidity, TDS, pH, residual chlorine, and hardness. Utilizing sensors specifically meant for measurement of these parameters and linking them with a PLC-based control system will do so. This will allow the facility to have dynamic adaptation of conditions in treatment in real time through data derived from sensor measurements. Not only that, the water produced will be of best quality as it is cleared of impurities. The automatic machine is designed to automatically carry out relevant steps, for example, adjustment of dosing chemicals and adjustment of filtration pressure based on feedback from sensors with the intent of minimizing opportunities for poor water quality.

In summary, it will be able to monitor in detail its activities by recording more details about its activities: both regulatory compliance and performance. These developments will eventually culminate into increased operational efficiency, energy saving, resource management, among other benefits, and they will still provide safe water for the community.

1.4 Scope of the Project

This project is meant to automate the existing drinking water treatment plant to increase efficiency and enhance the accuracy of controlling the process. The most important thing is to work on automation technology while continuing the processes involved in the current water treatment process. This will enhance the performance as a whole, reduce the degree of manual intervention required, and also ensure consistent water quality without changing the fundamental treatment methods.

Monitoring and controlling the critical parameters of the water treatment process such as flow rates, pH, hardness, residual chlorine, and filtration efficiency using PLCs. Providing real-time data, changes done in that, and actionable insights to the operators through the integration of PLC with all types of sensors and control systems.

The scope will also cover designing the system scalable and flexible. The first implementation will be based on the capacity of treatment presently available but will expand as new equipment, sensors, and control systems are added as the plant grows or with the changed requirements of the treatment process.

Not to redesign or replace the water treatment process but an automated control and monitoring system on top of that existing infrastructure, what it is intended for. It is designed to be more efficient and more reliable while still achieving or even elevating the level of water quality standards which are present at this moment with fewer human interferences.

1.5 Programmable Logic Controller

A **Programmable Logic Controller** or PLC is an industrial computer built to automatically and reliably, efficiently control electromechanical process applications. Due to the benefits of ruggedness, versatility, and dependability PLCs have dominated application scopes in the industrialization spheres such as manufacture, treatment of water, power generations, and transport.
PLCs replace traditional relay-based control systems, offering a more compact, versatile, and efficient solution for industrial automation. The core functions of a PLC include monitoring inputs, executing programmed logic, and controlling outputs to achieve the desired operation.[2][6]

Figure 1.1: PLC

Key Features of PLCs

1. Modularity: PLCs also exist in modular designs; thus, I/O modules can be added according to application requirements.
2. Real-Time Processing: Input and output operations can be processed and controlled in real time.
3. Programming Flexibility: Support of multiple programming languages, namely Ladder Logic, Function Block Diagrams (FBD), and Structured Text (ST).
4. Durability: Built for withstanding the harshness of industrial environments, such as temperature extremes, vibrations, and electrical noise.
5. Scalability: Allows control systems ranging from few devices to highly complex operation involving thousands of I/O points.

Role of PLCs in Automation

At the water treatment plant, it operates in a manner similar to an automation brain, integrating the use of sensors, actuators, and control logic to work harmoniously in the operation, thus making quality become consistent, human errors become low, and the efficiency of the system improves.

It turns out to be invaluable in dynamic processes, when it can handle real time feedback from sensors such as flow meters and pH sensors. Additionally, PLC is also supportive of remote monitoring and control, thus letting the operators manage the plant effectively from centralized or even remote locations.

1.5.1 PLC Architecture and Components Used

This PLC structure would be designed to monitor and control numerous sensors and actuators that make up the water treatment process. The major components used in this system comprise:

1. **PLC Controller**: This represents the brain of the system by processing input signals from sensors and running control algorithms, to send output signals to the actuators. A modular PLC system will be implemented for flexibility and scalability by easy expansion if needed.
    - CPU: The central unit of the PLC that actually executes the control logic.
    - I/O Modules: The modules dealing with signals coming from field devices such as sensors and actuators. The module selected is a digital I/O module if the sensor used is digital and analog if it is analog.
    - Power Supply: Supplies power to a PLC, so it assures all its connected elements, in proper voltage and the necessary current.
2. **Sensors**: Sensors will record the water treatment system's readings for parameters to be checked in:
    - Flow meters in order to track water at several intervals within the water treatment process.
    - pH sensor showing how acidic or alkaline it is
3. **Actuators:** PLC would be performing actuator controlling at so many levels.
    - Pumps: To circulate water across the various filtration units and move water to storage tanks.
    - Valves: Control water flow across various stages as well as dosing chemicals.
    - Motors: Run equipment such as mixers and agitators.

4. **HMI** (Human-Machine Interface): The HMI is a key component by which operators can interact with the automated system. Operators get real-time data visualisation and control capabilities where they can:

    - See the various parameters of water quality as well as the status of the system.
    - Adjust setpoints or parameters if necessary (though this will typically be done automatically).
    - Receive alarms or notification if any parameters are not within the desired range.

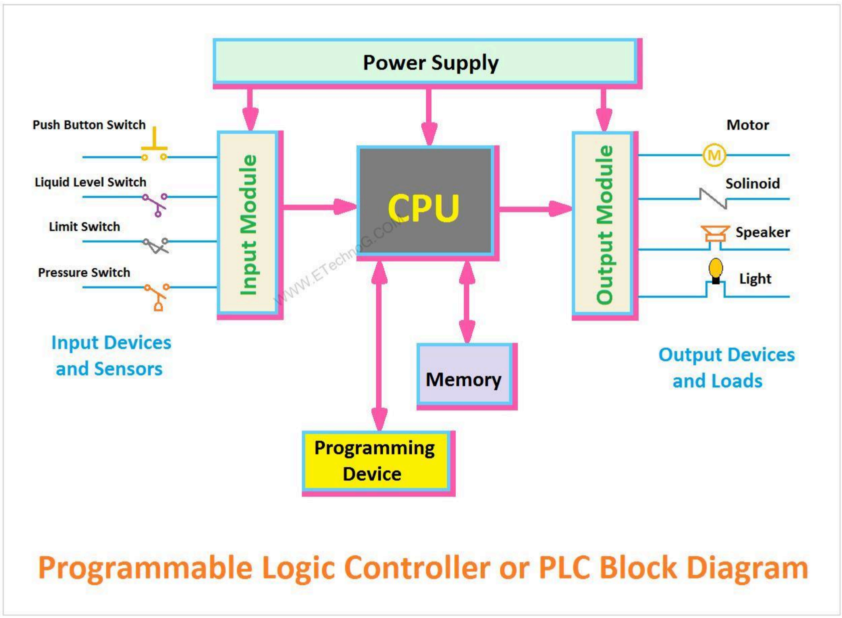

Figure 1.2: Block Diagram of PLC

Communication and Control Strategies

The PLC has field devices and the operator interface that achieve real-time monitoring and smooth running. Some of the main forms of communication and control include;

1. **Field Device Communication:**
   These involve I/O modules that send data to the PLC by means of devices such as sensors and actuators. The computation for the PLC for both analog signals coming from the pH and turbidity sensors while digital signals come from the level sensors and switches.
2. **Human-Machine Interface (HMI):**
   This will be an HMI which interfaces with a PLC and will allow the operator to view real time data, change set points, and view alarms. It includes flow rates, water quality parameters, system status information

3. **Networking and Data Logging:**

   The PLC was set to record data for performance analysis. Water quality and system performance data were recorded for later reference. Modbus, a protocol of networking, was utilized to connect the PLC, HMI, and supervisory systems.

4. **Alarm and Notification Systems:**

   The PLC was continuously monitoring the system parameters. Alarms were provided for anomalies occurring in the system. The notification would notify the operator to correct as soon as possible.

1.6 Literature Review

1. **Programmable Logic Controllers: Fundamentals and Advancements**

   For a detailed treatment of PLCs using architecture, functionalities, and methods of programming, see Bolton, 2006. Actually, the book highly emphasizes ladder logic and sequential function charts as two major methods of programming that could probably automate industrial processes; but it hints at modularity and scalability that might help them be applied to such a wide variety of applications as wastewater treatment. This foundation now allows me to understand in greater detail the capabilities and limitations of PLCs in systems such as those found within a water treatment plant.[2]

2. **Application of PLCs in Wastewater Treatment**

   Rajhans et al. (n.d.) consider the treatment plants of wastewater when discussing the use of PLCs and SCADA systems. The research shows the PLC controls and monitors such main processes as filtration, chlorination, and flow control. It has also shown that it reduces interference from human elements that degrades the quality of the water and reduces the efficiency of the plant's working. SCADA integration with real-time monitoring and visualization of the data to support decisions for operation.[3]

   On a similar note, Bhati et al. (2020) discuss one wastewater treatment plant using PLCs, describing the automation of critical processes to obtain optimum water quality. This work shows that ladder logic programming is used for valve control, pump control and sensor control and describes that PLCs can perform quite complex operations. They underline the economic advantage of this automation: lower cost of operation and higher energy efficiency.

   A very interesting discussion in Water Practice and Technology (2022) shows that PLC-based automatic control systems has a role to play in wastewater treatment, underlining also the methods to precisely control variables for the measurements of pH and turbidity with sensors and actuators associated with PLCs. This study also underlined sensor calibration and sensor maintenance as problems to sustain the performance in such systems.[4]

3. **PLC and Automation in Broader Contexts**

   Koondhar et al. (2023) review the wider aspects of PLCs in terms of automation, industry, and education. They discuss further how PLCs can fit into various sectors and therefore be used to automate some repetitive tasks, improve accuracies, and reduce possible human errors. The current study further emphasizes the value of PLCs in places of learning, which then train future engineers, keeping the workforce ready for automated technologies in industries such as water treatment.[6]

4. **Key Insights and Relevance to the Project**

   The reviewed literature in total establishes the critical role of PLCs in automation of wastewater treatment processes. The key takeaways here are:

- Operational efficiency: PLCs enable one to monitor in real-time and control with accuracy that will ensure consistent water quality and optimized resource utilization.
- Scalability: Through modular designs, PLCs can be adapted for institutions of different sizes, meaning that they are very versatile and ideal for application.
- Challenges: Sensor reliability, calibration, and cost considerations are among the significant challenges that demand careful planning and regular maintenance.

CHAPTER 2

EXISTING WATER TREATMENT PLANT AT JUIT

The water treatment plant at the college serves as a centralized system for treating water sourced from underground wells or municipal supplies. It supplies potable water across various campus facilities, including hostels, academic buildings, and administrative offices. The plant includes multiple treatment stages, focusing on filtration, chlorination, and storage.[1]

2.1 Key Components and Setup

1. **Filtration Systems**
    - **Sand and Gravel Filtration**:
      This is the initial stage of water treatment to remove suspended solids and all other visible impurities in the water. Sand and gravel media are simple, yet effective, methods of physical filtration.
    - **Operation**: Water passes through a bed of sand and gravel, trapping particulates. The filter should backwash periodically for it to stay efficient.

Figure 2.1: Water tanks at JUIT

2. **Storage Tanks**

The treated water is stored in overhead and ground-level tanks before it is sent to the campus. Reservoirs ensure that even at peak demand, water supply is maintained across the campus.

Figure 2.2: Water storage tanks

3. **Manual Controls and Valves**

Gate valves regulate the flow of water both within the plant and within the distribution network. Manually adjusted, they control inflow, outflow, and distribution into different areas.

Figure 2.3 : Manual control

Figure 2.4 : Manual Control

4. **Chlorination Unit**

The main process of disinfection to provide microbial safety in the water treated is chlorination. Chlorine dosing is controlled manually, based on general observations of water quality.

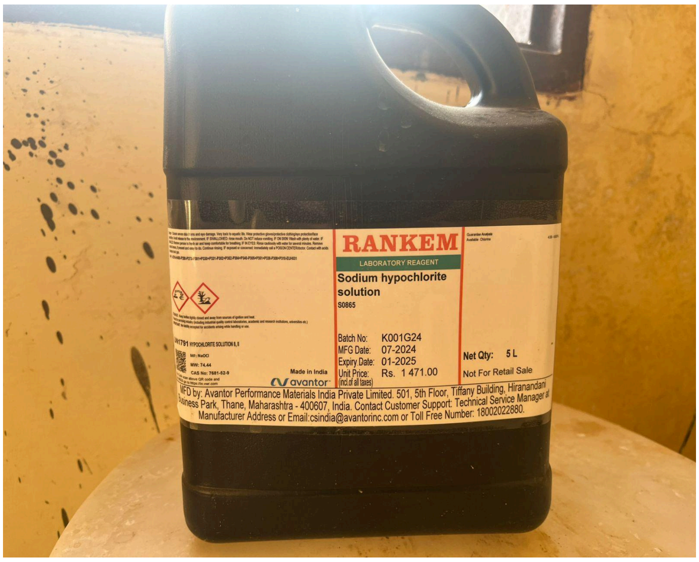

Figure 2.5: Chlorine used

Figure 2.6: Chlorination

5. **Monitoring and Record Keeping**

The operators manually log water levels, treatment performance, and chlorine dosing schedules into logbooks. These records help to monitor daily operations and also trends in water usage.

Figure 2.7: Monitoring Systems

2.2 Process Workflow

1. **Raw Water Inlet**

   Water from the mountain spring is brought into the treatment plant in an open channel or through a pipeline. This natural flow is regulated by using manually operated gate valves.

2. **Filtration**

   Initial treatment of water is given through sand and gravel filters that remove particulates and suspended solids. The filters are cleaned periodically through manual backwashing based on time schedules.

3. **Chlorination**

   The water is treated with chlorine which is dosed manually, to kill harmful microorganisms. This ensures water safety for drinking and achieving basic microbial safety standards.

4. **Storage and Distribution**

   Overhead tanks are used in storing the treated water while distribution is through a system of pipelines. The pipeline flow is regulated by the gate valves, ensuring supply to hostels, academic buildings, and other institutions.

2.3 Maintenance Practices

Proper care of the water treatment system will provide efficiency and life. Currently, the following practices are being used in maintaining tanks and other crucial parts of the plant:

Sand and Gravel Filters:

Regular backwash on these filters to remove dirt and keep the filterage efficient and free from blocking. This scheduled cleaning gives optimal results and prevents choking.

Chlorination Equipment:

Chlorine dosing pumps and ancillaries are serviced through inspection and cleaning. Calibration will ensure there are chlorine levels to administer, hence ensuring proper chlorination, along with the disinfection process.

Storage Tanks:

Storage tanks holding water are checked periodically for structure strength at predefined time limits. This will avoid accretion of sediments along with algae growth and contamination, etc.

Gate Valves:

Manual gate valves are checked and lubricated, so that there is complete flow control in them free from leaks or mechanical inefficiency. Pump and Motor

Pump and motor are the parts of the operational systems in the system which change their services due to time consumption. Oils plus any spare part changed so that it functions without any predictable failure.

2.4 Challenges in Existing Water Treatment Plant

1. Chlorination Challenges

Inconsistent Chlorine Dosing

Chlorination is one of the most important steps in assuring the microbiological safety of drinking water. In the current system, though, chlorination is practiced by operators based on judgment and visual checks for dosing levels. This brings inconsistency and errors in the overdosing or under-dosing of chlorine.

- **Overdosing:** This is a possibility of overdosing that may lead to the presence of excess chlorine in the water, which besides affecting its taste and smell can cause health problems by causing skin irritation, breathing difficulties, and long-term health problems if taken excessively.
- **Underdosing:** It results in improper disinfection where harmful pathogens like bacteria, viruses, and parasites survive in the treated water and subsequently cause waterborne diseases such as cholera, dysentery, and gastroenteritis.

2. Manual Monitoring of Tank Levels

Inefficient Tank Level Management

The current water treatment process includes manual monitoring of tank levels, which risks human errors. Operators need to adjust valves manually to control water levels, and there is no continuous automated monitoring.

- **Overflows:** In case the water levels are not monitored frequently, overflows occur, and thus water is wasted and the equipment or infrastructure damaged.
- **Low water levels:** It will eventually lead to a poor supply of water and subsequently disrupt the treatment process, which implies that there will be less treated water available for drinking. This may cause massive disruptions in water availability during peak demand periods or during emergencies.

3. Challenges Related to Free Residual Chlorine (FRC)

- **Poor Disinfection:** The FRC level in the report under review is at BDL, whereas the permissible limit is 0.2 mg/L. This implies that the water might not be adequately disinfected, thereby leaving surviving bacteria or viruses to cause diseases such as diarrhea or cholera.
- **Low FRC levels:** It may cause biofilm formation in pipes, which can trap bacteria and make it difficult to disinfect the water, thus increasing the risk of contamination.

CHAPTER 3

SYSTEM DESIGN, METHODOLOGY AND PROJECT PROPOSAL

This chapter discusses the design and methodology that enables an automation of the water treatment system with the use of a Programmable Logic Controller. Various components within the automation system, architecture of the PLC setup, and how integration brings out the seamless operations of water treatment plant processes are described.

3.1 Description of the Automation System

This project involves controlling all the different stages of water treatment with a PLC system for the main purpose, ensuring accuracy and increased efficiency in the water by efficient monitoring of its quality. The automated system consists of the control and monitoring of the entire process from the intake of raw water into final filtration and drinking water distribution. This will comprise the management and regulation of many operations such as pre-filtration, reverse osmosis, disinfection, pH adjustment, and final filtering

The system will basically comprise of the following elements:

- Sensors: For in-situ measurement of several water quality parameters such as pH, hardness, chlorine residual etc.
- Actuators : Pumps, valves and motors that regulate the input as well as output of water and chemicals in a treatment system.
- PLC : This will be the Control Unit that processes all information from sensors, acts according to an established logic and then, sends on commands to the actuator.
- Human-Machine Interface (HMI): The human-machine interface is going to ensure operators having a graphically oriented interface to oversee the system and manually control them wherever necessary, though most of the system will work in automation.

The automation of the system will reduce human intervention, increase consistencies in water treatment, and allow remote monitoring and operation. The PLC will use real-time data to optimize flow rates and chemical dosing levels, which will make it more efficient and the quality of water better.

3.2 Process Stages in the Water Treatment System

Raw Water Inlet

- **Function**: The raw water is admitted to the treatment plant through the inlet. The flow is measured through flow meters.
- **PLC Role**: The PLC will measure the flow of water admitted into the plant to ensure it falls within the range. If fluctuations or anomalies such as low flow or high flow are noted, the PLC will act on it or throw an alarm.

Pre-Filtration

- **Function**: At this point, water undergoes a preliminary process of filtration to eliminate big particles and debris. This usually involves sand and gravel filters that help remove suspended solids.
- **PLC Role**: Main responsibility of the pre-filtration process control for the PLC is that, it will continuously monitor all the turbidity, and with turbidity sensors, if there is an occurrence of exceeding the limit of turbidity cross; the systems take cleaning cycles or alter the flow rates to get water clear of the turbidites.

Membrane Filtration and Reverse Osmosis (RO)

- **Function**: Treat water through membrane filters and reverse osmosis units to get rid of dissolved solids and other impurities and contaminants in it. This will be very important in trying to ensure that water standards are of drinking quality standards.
- **PLC Role**: The PLC will control components such as TDS (Total Dissolved Solids) and hardness through the use of individual sensors. When these get to be too high, the PLC can control the system and, for example, it can change the working of the RO system or change the flow rate to optimize treatment.

Disinfection and Chlorine Treatment

- **Function**: Chlorine is added to the water to disinfect any bacteria or germs still left in the water.
- **PLC Role**: With residual chlorine sensors, the chlorine dosing will be done by PLC by controlling the chlorine in safe limits for drinking water. Also, PLC will help adjust the chemical dosing according to the readings of chlorine levels that it may get in real-time and opt for better practice in disinfection.

pH Adjustment

- **Function**: Adjust the pH of water to make it fit for consumption to prevent any form of corrosion in parts of the distribution system.
- **PLC Role**: The amount of lime or acid added would, therefore, be controlled in the PLC based on what the pH sensors are detecting against the desired pH value maintained. Chemical dosing is checked by the PLC and in conjunction with the dosing rate chemicals, the pH stays with the recommended limits.

Final Filtration

- **Function**: The water undergoes final filtration to remove any remaining small particles or suspended solids after all major impurities have been removed.
- **PLC Role**: The PLC will ensure that the final filtration process is functioning optimally. It will monitor the flow and turbidity of the water entering and exiting the filter and will adjust the filtration process if required to maintain water quality.

Water Storage and Distribution

- **Function**: After completion of water treatment, it gets stored in overhead tanks. This treated water then starts distributing at all required places.
- **PLC Role**: The PLC controls the pumping system that water has to be transported into the storage tanks but without overflowing and running empty. This will also detect the levels in the tank and thus control the storage to achieve the right water volume for water availability all time.

3.3 Automation System Workflow

The automation system will ensure that all stages of the process are running efficiently. The concept and design of the workflow guarantee quality water to be attained, monitored, and met with thresholds set. Work of the workflow will then be presented as described herein.

1. **Regulation Flow of Water**: All movements in treatment will be managed by the PLC that will track the flow rate of water; in case such flow is below or is above the given optimum level, the control PLC regulates the movement of the valve and pump to regain a right standard flow that ensures the right standard flow persists in the cycle of the continuing treatment.

2. **Continuous water quality monitoring:** Sensors installed across the system will monitor parameters such as turbidity, pH, chlorine, TDS, and hardness. Decisions will be made regarding action- for example, switch a pump on, adjust flow rates, or apply chemical dosing-through the PLC.
3. **Automatic Chemical Dosing**: The PLC controls, independent of itself, chemical dosing that includes chlorine addition and pH adjustment chemicals. The latter is done according to sensor data and in real time. No interference, and water stays under optimal chemical balance.
4. **Controls for Valves and Pumps:** The PLC will control actuators in the system that include valves, pumps amongst others based on readings by sensors and through predetermined logic. The PLC will thus control water flow, chemical dosing, and treatment cycles so as to ensure optimal water quality.
5. **System Monitoring and Alerts:** An HMI shall monitor the performance of the system. Apart from information about the status of the system, the following shall be readily available to it including alerts: information on water quality and events that need attention, triggering of alarms through the PLC that would happen under situations which are not likely to be encountered during the normal run of the system-filter blockage, chemical imbalance, faulty equipment.

3.4 System Design Principles

The design of the PLC-based automated system below was, therefore, based on the following principles:

1. **Reliability**: The system must ensure the continuous supply of treated drinking water. Non-stop operations can be maintained. It can avoid failure by installing redundancies for sensors and actuators.
2. **Scalability:** The design should scale well, so one can easily add future expansions, such as adding more filtration units or sensors, without requiring major redesigns.
3. **User-friendliness:** The Human-Machine Interface (HMI) and alarms shall be intuitive, having clear views of system performance and problems to the operators.
4. **Energy Efficiency**: The system will optimize the pump operation, chemical dosing, and valve controls to reduce energy consumption and operating costs.

3.5 Project Proposal to mitigate the challenge

The existing water treatment plant is plagued by operational inefficiencies, manual monitoring, and potential health hazards from the inconsistent control of water quality. This project presents an automation-based solution that would ensure 24/7 quality monitoring, enhanced operational efficiency, and adherence to health standards. The proposed solution integrates PLC systems to replace manual interventions with precise automated controls for critical water treatment processes.[3][4][5]

3.5.1. Objective

This project proposal primarily aims at eliminating manual intervention in crucial activities, enhancing the accuracy of the water treatment procedures, and reducing the hazards related to uneven water quality. It consists of the following:

- Applying sensors to enable free residual chlorine control to allow accurate dosing
- Installing tank level sensors to ensure proper management of stored water.
- Implement monitoring systems at all stages of the filtration process that can identify contamination for real-time quality assurance.
- Design a PLC-based centralized system to monitor and control the entire treatment plant.

3.5.2. Key Areas of Automation

The following sections detail the proposed solutions to mitigate the identified challenges:

1. Chlorination Control

Challenges:

- Manual dosing leads to uneven chlorine levels, a chance of under or overdosing.
- Ineffective ph levels compromise water safety.

Proposed Solution:

- **ph Sensor Integration:** Install ph sensors to monitor chlorine levels accurately.
- **Closed-Loop Control:** Develop a PLC-based closed-loop system adjusting the dosing pump based on real-time ph sensor reading, maintaining ph levels consistently within the safe range.

- **Benefits:** Ensures precise chlorination, improves pathogen removal, and reduces chemical wastage.

2. Tank Level Monitoring

Challenges:

- Manual tank level checks are labor-intensive and prone to human error.
- Inconsistent water levels cause operation and water supply disruptions.

Proposed Solution:

- **Level Sensors in Tanks:** Install analog level sensors on all three tanks to detect the water levels constantly.
- **Automated Filling System:** Integrate PLC logic with the inlet valves to regulate water levels without human interference.
- **Benefits:** Assures constant water supply, less manual labour, and avoids overflows or shortages.

3. Centralized PLC-Based System

Challenges:

- Decentralized and manual operations lack efficiency and transparency.
- Multiple processes can not be handled at the same time.

Proposed Solution:

- **PLC Integration:** Design and deploy a centralized PLC system to manage all processes, including FRC control, backwashing, tank monitoring, and contamination detection.
- **Human-Machine Interface (HMI):** Develop and implement a centralized PLC system to handle all processes such as FRC control, backwashing, tank monitoring, and contamination detection.
- **Benefits:** It helps streamline operations, improve response times, and allow for comprehensive monitoring of the treatment plant.

3.5.3. Benefits of the Proposed Solution

1. **Better Quality of Water**
    - Precise and uniform chlorination allows for better disinfection and meets safety requirements.
    - Automated backwashing increases the effectiveness of filtration and reduces contamination risk.
2. **Operational Efficiency**
    - Less human error is likely with reduced manual intervention.
    - Problems are solved before they become critical, avoiding the possibility of system failure in real-time monitoring.
3. **Cost-Effectiveness**
    - Less labor cost and less water waste during manual backwashing due to automation.
    - Increased equipment life due to optimal maintenance schedule.
4. **Environmental Sustainability**
    - Effective management of water reduces wastage of resources.
    - Controlled chlorination reduces the environmental impact of excess chemical discharge.

3.6 Ladder Logic Implementation

In this section, we present the ladder logic implementation for the PLC-based water treatment plant. This logic ensures efficient control of water levels across the tanks, optimizing resource allocation and preventing overflow or underflow conditions and ph value .

Logic:

```
// Network 0 - System Start
X5 -------------------------------[ ]------------------------ ( Y1 )
     [START Pushbutton]                       [PUMP 1 ON]

// Network 3 - Read pH Raw Value
M8000 ----------------------------[ ]------------------------[ FROM K0 K1 D100 K1 ]
     [Enable Bit for Reading pH]          [Read pH Value into D100 from Module K0, Channel K1]

// Network 9 - Valve 1 Control Based on Pump 2 and Float Switch 1
Y2 ----+---- X3 ------------------[ ]------------------------ ( Y3 )
     |    [Float 1 High]                   [VALVE 1 ON]
     [PUMP 2 Running]
```

```
// Network 12 - Valve 2 Control Based on Pump 2 and Float Switch 2
Y2 ----+---- X4 ------------------[ ]------------------------ ( Y4 )
      |    [Float 2 High]                    [VALVE 2 ON]
     [PUMP 2 Running]
```

Ladder Logic Description

Explanation:

- **Network 0**: Starts Pump 1 when the START button (X5) is pressed.
- **Network 3**: Reads pH sensor data using the `FROM` instruction and stores it in data register `D100`.
- **Network 9**: Opens Valve 1 (Y3) only if Pump 2 is running and Float Switch 1 (X3) indicates a high level.
- **Network 12**: Opens Valve 2 (Y4) under similar conditions with Float Switch 2 (X4).

3.7 Working Explanation

1. **Source & Chlorination:**
    - Tank 0 holds chlorine solution.
    - The dosing pump injects chlorine into the water line when low FRC is detected by the pH/ORP sensor.
2. **Main Water Line:**
    - Water from Tank 1 is pushed by the supply pump through the chlorination line.
    - The dosing line is connected before distribution to the other tanks.

3. **Distribution:**

   - Based on availability and float switch signals, the PLC opens SOV-2 or SOV-3.
   - Water is directed to either Tank 2 or Tank 3 accordingly.

4. **Level Monitoring:**

   - Each tank has a float switch (digital sensor) that informs the PLC when the tank is full.
   - Once full, the PLC closes the solenoid valve for that tank and switches to the next available tank.

5. **Drain & Recirculation:**

   - Each tank includes a drain system.
   - A manual valve can be used to recirculate water through the dosing loop for maintenance or repeated treatment.

CHAPTER 4

HARDWARE DESIGN OVERVIEW

4.1 Purpose of Hardware Prototype

The hardware prototype of reduced scale was built so as to demonstrate the working operation of a PLC-based water treatment system. Using the least electrical components, the prototype simulates actual field water treatment behavior. This permits testing of automation logic and system reaction under emulated field conditions. The hardware is designed to be interfaced with the Mitsubishi PLC to compose an integrative closed-loop control and monitoring system for critical processes such as tank level sensing and chlorination control.

4.2 System Focus

The hardware prototype focuses on two key functional modules:

Tank Level Monitoring: It simulates two storage tanks with level detection through push buttons.

Chlorination Control: Toggle switches simulated ph levels to control dosing and alarm functions.

These two functions constitute the more important operations in a water treatment plant and stand to demonstrate PLCs in their role in monitoring and processing decisions.

4.3 Hardware Requirements

The table below lists the major components used in the prototype along with their purpose:

1. Solenoid Valves

A solenoid valve is an electromechanical device used to control the flow of liquids or gases .It operates by using an electric current to create a magnetic field that opens or closes the valve.Typically powered by DC or AC voltage (e.g., 12V DC), it acts as an automatic on/off switch for flow.The valve consists of a coil, plunger, and valve body to regulate the passage of fluid . Solenoid valves are commonly used in automation, irrigation, and fluid control systems.

Figure 4.1: Solenoid Valve

2. pH/Chlorine Sensor Module

A pH/Chlorine sensor module measures the acidity (pH) and free residual chlorine (FRC) levels in water.It operates using a 9V power supply and provides analog or digital signals for monitoring.The pH sensor detects hydrogen ion concentration to indicate water's acidic or basic nature.The chlorine sensor (or ORP sensor) measures oxidation-reduction potential to estimate disinfectant levels.These sensors are vital in ensuring safe water quality and enabling automated chemical dosing.

Figure 4.2: ph Sensor Module

3. Float Switch Sensors

Float switch sensors are devices used to detect liquid levels within a tank.They operate by opening or closing a circuit as the liquid level rises or falls.These sensors act as digital (on/off) indicators, signaling when a set level is reached.They typically handle switching voltages like 220V for direct control of pumps or alarms.Float switches are simple, reliable, and widely used in level monitoring applications.

Figure 4.3: Float Sensor Switch

4. Water Pumps

Water pumps are mechanical devices used to move water from one location to another.They operate using a motor, and in this case, run on a 12V power supply.The pump creates pressure to transfer water through pipes or tubing.Commonly used in fluid transfer, circulation, or dosing systems.They are essential for maintaining flow in automated or manual water systems.

Figure 4.4 : Water Pump

5. Programmable Logic Controller

A Programmable Logic Controller (PLC) is a digital device used for automation of electromechanical processes.

It receives input signals from sensors and sends output signals to actuators based on programmed logic.

PLCs are highly reliable, modular, and easy to reprogram for various industrial applications.

They replace traditional relay-based systems, reducing wiring complexity and increasing flexibility.

PLCs are widely used in manufacturing, water treatment, and process control systems.

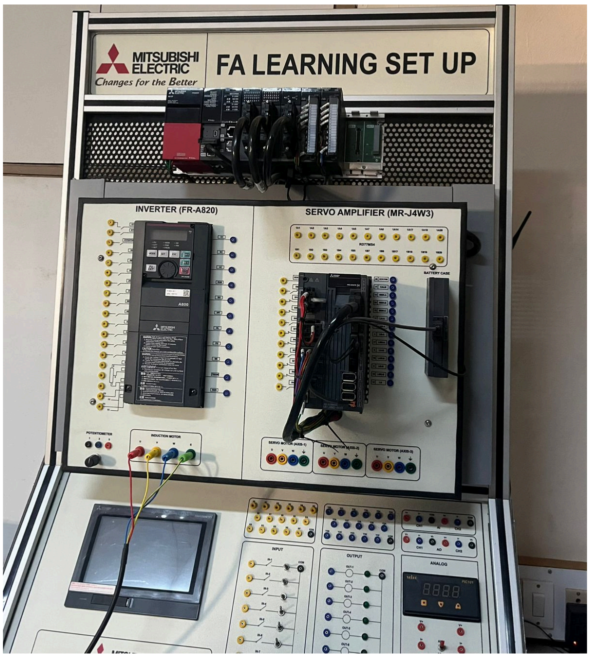

Figure 4.5 : Programmable Logic Controller

CHAPTER 5

RESULTS AND CHALLENGES

5.1 Results

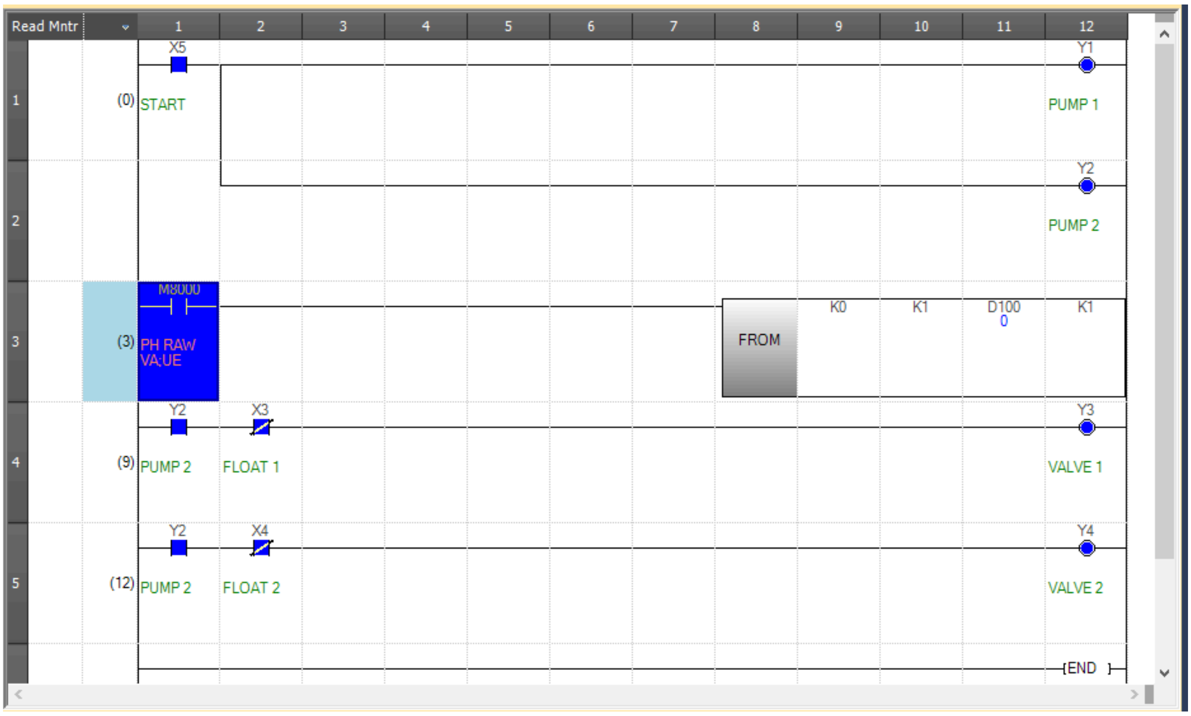

Figure 5.1: Ladder Logic Implementation

Logic Explanation

Network 0: Starts Pump 1 when the START button (X5) is pressed.

Network 3: Reads pH sensor data using the `FROM` instruction and stores it in data register `D100`.

Network 9: Opens Valve 1 (Y3) only if Pump 2 is running and Float Switch 1 (X3) indicates a high level.

Network 12: Opens Valve 2 (Y4) under similar conditions with Float Switch 2 (X4).

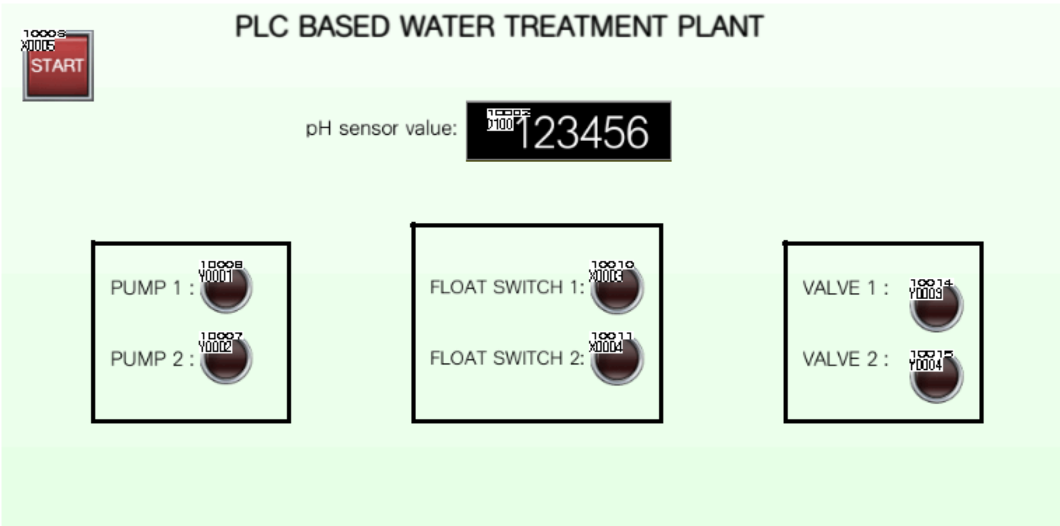

Figure 5.2 : HMI Screen

HMI Integration Suggestions

Element	Address	Type
Numeric Display	D100	Raw pH Sensor Value
Bit Switch	X5	Start Button
Lamp	Y1	Pump 1 Status
Lamp	Y2	Pump 2 Status
Lamp	X3	Tank 3 Full
Lamp	X4	Tank 4 Full
Lamp	VALVE 1	Solenoid 1 ON/OFF

Lamp	VALVE 2	Solenoid 2 ON/OFF

Implementation on PLC

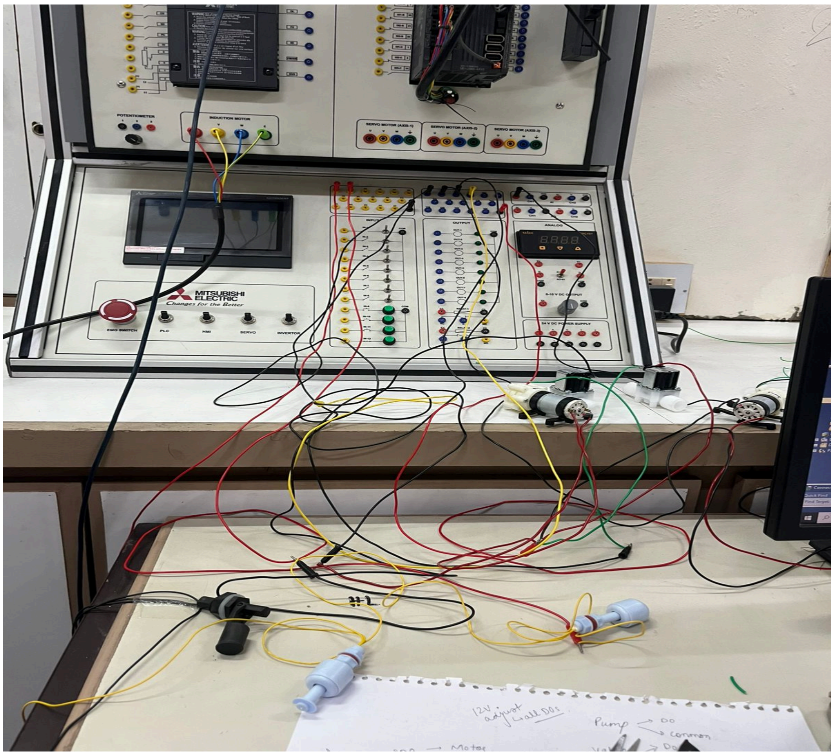

Figure 5.3 : PLC Connection

The test results confirm that the automation system based on PLC met all of our operational and functional prerequisites, some of which are highlighted below.

- **Tank Leveling Logic:** The tank operations are reliably and automatically controlled as tank fill and drain operations are executed due to the float switch inputs being correctly detected.
- **Chlorine pump dosing control:** Controlled chemical dosing to ensure sufficient water quality. Dosing was enabled only when absolutely necessary to prevent overdosing.
- The **solenoid valves** controlled the water supply as expected and responded greatly with respect to the times identified in the ladder logic.

- **Logic of the alarm:** Alarms or messages indicating overdoses as well as malfunctions have and are being triggered and displayed in the HMI thereby allowing users to heed attempts at safe strategy steps.

5.2 CHALLENGES FACED DURING DEVELOPMENT

1. Hardware Control Complexity

It provided significant control challenges because the physical hardware involved, including solenoid valves, pumps, and sensors gave you readings at variable voltage and current levels - and we could not interface directly due to safety concerns. The current switching that was required was sufficiently high current that relay driver modules were needed to interface to safely control the valves and pumps. The electrical isolation between the lower voltage control signals coming from the PLC and the higher voltage power circuits of the pumps and valves were accounted for as well. Other considerations became choosing the appropriate relays and controlling the heat dissipation of the relays to protect them, and protecting the PLC control logic with opto-isolators. All of these considerations became key steps to achieving reliable operation.

2. Sensor Reliability and Signal Noise

Inadequate stability of sensors was a major focus of concern especially in an active fluid medium. Float switch sensors sensing water levels were an example of contact bounce, very brief deviations causing false on and off cycles. Debounce logic was added to the code base to filter out transient changes and respond to consistent signals. The more sensitive pH and ORP sensors represented a somewhat different scenario in that they were subject to more ambient noise and chemical variation and their analog values seemed random at some times because of interference and small scale turbulent flow caused by the water. In order to generate trustworthy data, digital filtering algorithms like moving averages were generated can the PLC to filter the high frequency noise from readings, and stabilize the inputs for control actions.

3. HMI Design Alignment

It was imperative to the control and monitoring of the system to have an intuitive Human-Machine Interface (HMI). Meanwhile, the correlation of the HMI control elements (pushbuttons, indicators, etc.) to the PLC memory locations was not straightforward. Inconsistencies between HMI tags and PLC bits would cause the display to be inactive or confusing. In the process of eliminating all inconsistencies, we verified each interface control against the internal tags and memory registers of a PLC. This involved mounting tests and debugging iterations to make sure that what operators saw on the screen was in sync with what was going on inside the field at real time. Considerable care was given towards response time, visibility under different light conditions, and ease of navigating.

4. Time and Resource Limitations

If one were to look at the project from the lens of resources, what would really stand out would be insufficientness of time and material resources. One could only perform a nagging minimal due to the scarce time given for lab testing facilities for equipment and machinery such as pumps, sensors, and PLC hardware. Further, there was increased pressure on development and debugging periods due to the academic timetable under which results had to be generated within a specified cut-off period. To make this work, development was organized on intense sprints, ironing out hardware testing, simulation, and logic design in very tight anticorrelated cycles. Hence, efficiency came into play: Each testing session adhered to a previously proposed schedule and defined set of goals. Despite the hindrances in mechanization, it was exactly the mechanism that hastened problem-solving and brought the project a step further.

CHAPTER 6

CONCLUSION AND FUTURE SCOPE

This project is an important milestone in the automation of water treatment systems. Critical issues were encountered during the manually operated system existing in the project which had been solved through PLC based automation in this project. The automation systems water quality, efficiency, and dependability all contribute to its importance in the sustained safe and reliable availability of water. This document contains an extensive assessment of the project results and their consequences:

6.1. Key Outcomes of Automation

1. **Better Water Quality**

- The Disinfection process of Chlorination is enabled through gain optimization which guarantees efficient removal of microbes by utilizing the tailored FRC sensors and servomechanism aides of Chlorine meters.

- With PLC automation, the amount of water safely consumed while meeting the requirements under the law was eliminated in the case of under-dosing or over-dosing.

2. **Operational Productivity**

- The backwashing process was no longer unoptimized due to time-based monitoring which allowed for the gaining efficiencies brought on by time-tested processes.

- Reduction in tank supplying level leads to supply cessation, however an operator's judgment to reduce errors response to straddle usage results leads to increased sense responsiveness to changes.

3. **Safety and Reliability**
   - Regular monitoring as well as automatic response to sensitive parameter values decreased failures of the system tremendously.
   - The sound alarm and alerts ensured prompt remedial measures were taken in case of any anomaly occurring, which ensured protection to the system, as well as protection to the quality of water.

4. **Ease of Operation and Monitoring**
   - There was centralization because of the efficiency of the operational efficiency and monitoring due to control by the PLC. It, therefore, streamlined the operations and managed and monitored the system.
   - Lowering manned intervention is also the function of a reduction of labor costs for the management and human mistakes.

6.2. Challenges Addressed

The project remarkably alleviated several challenges within the system:

- **Water quality consistency:** Dosing and manual chlorination errors were eliminated through real-time monitoring.

- **Lack of maintenance foresight:** Maintenance practices became more anticipatory with predictive monitoring for filters and tanks as opposed to reactive.

- **Reduced capabilities to monitor:** Operators gained detailed insight about system performance through enhanced sensor integration, which enabled informed decision-making.

6.3. Limitations of the Project

1. **Relaying too much information to one sensor:** The sensors impact the efficiency of the PLC-based automation system. Any malfunctioning sensor means diminished efficiency across the board. For instance, FRC sensors which determine if the required amount of chlorine is present, are essential. Unfortunately, they are susceptible to the effects of the environment. Aging and fouling can easily incapacitate them.

2. **Critical failure and manual resets:** Automation significantly lessens the need for personnel; however there are situations where human touch is bound to happen. With the breakdown of a PLC or sensors, people will always be required: active control of major processes such as backwashing filters, dosing or chlorinating the water, and assessing its quality.

3. **Limited Adaptability for Future Upgrades**: It lacks adaptability for future upgrades. The system is designed to automate the present processes without changing the overall treatment methodology. In case there is a need for future upgrades or additions, like new treatment processes or advanced water quality monitoring techniques, the system may not be easily adaptable to the newer technologies or expansion to include additional process parameters.

4. **Dependence on Stable Power Supply**: The automation system based on the PLC is dependent on steady power supply. Interruption of power in any form is likely to make automation processes failure, which could eventually bring about water quality problems. Backup power systems like UPS devices are necessary to minimize that risk, but it tends to increase the overall expense and complexity of the whole system.

5. **System Maintenance:** Such an automatic system is good and sound, but continuous maintenance assures it functions normally. In other words, it involves updating software and checking PLC hardware in the long run for its proper operation along with its quality. Such unwanted activities as sensor changing and debugging sometimes bring the whole treatment of water to a screeching halt.

6.4. Future Scope

1. **Integration of Advanced Sensors and IoT Technologies**

   The most promising area to be developed further is sensor networks. As of now, it's a basic system whereby parameters are monitored by basic sensors regarding turbidity, pH levels, chlorine levels, and tank levels. Advanced sensors like real-time turbidity sensors, dissolved oxygen sensors, or even IoT-enabled chemical sensors may allow more granular data in the best decision-making scenarios.

   With the inclusion of IoT in automation, the system will provide for remote monitoring and data analysis. Sensors will be linked to cloud platforms, and this means real-time monitoring of water quality can be conducted from any location. Water quality changes will thus be noticed in time with the aid of real-time monitoring. It makes the system proactively respond to issues arising beforehand and reduce the possibility of escalations through use of advanced sensor networks involving machine learning algorithms to predict and detect anomalies within a water treatment process.

2. **Artificial Intelligence (AI) and Machine Learning (ML) Integration**

   The automation of the water treatment process will greatly improve the performance of the system through the integration of AI and machine learning. This can make models of machine learning learn the pattern in data related to the quality of water, adjusting the control strategies correspondingly. In this way, it may predict dosing of chlorine required based on historical data of water quality, temperature, flow rate, or seasonal variations. In this process, chemicals will be more efficiently and accurately dosed, waste minimized, and above all, water safe to drink.

   Further backwash cycle on filters optimizes through the application of machine learning. It merely represents changing in real time frequency and intensity of cleansing cycles as provided by differential pressure sensors and not based upon set schedule. Over time the system learned, hence adjusting the cycle of backwash to levels best suited for optimal filter activity together with a reduction in loss and an increase in medium life.

3. Conservation and Sustainability of Energy

Water treatment plants incur significant costs for operating pumps, filtration systems, and dosing units, all of which consume a considerable amount of energy. Future enhancements may incorporate energy optimization algorithms that enhance the tailored control logic in PLCs for real-time water quality parameters toadjust pump's rotational speeds, filter backwash timings, and other energy-demanding processes dynamically.

4. Integration with Smart Water Distribution Networks

An example of future expansion can also be the integration of this PLC controlled water treatment system with the smart water distribution network. In the wake of a smart city, sensors for monitoring pressure, flow rate, and water quality within the entire distribution network will be installed in water distribution networks. Linking the treatment system with the distribution system could potentially allow operators to monitor water quality real-time at any point in the network, detecting contamination, leaks, and flow disruptions for operational improvements much earlier.

This may also allow for dynamic management of the distribution of water according to demand or quality data in order to ensure that the water is distributed to the neediest places. This will come in handy especially in regions where the demand for water changes with time, hence the system can optimize its flow according to the changes in usage.

5. **Real-Time Water Quality Assurance and Advanced Contamination Detection**

Most scope of improvement would be required toward advanced contamination-detection systems installed in future ones. Among the key parameters monitored in present systems, which have turbidity, chlorine and pH, their system does not detect them in appropriate time regarding the detection of certain contaminants like pathogens and heavy metals.

Future systems can entail high-tech chemical and biological sensors that will determine very diverse contaminants in a live real-time manner. The water supply can use a biosensor or a type of molecular diagnostics that may detect the harmful nature of microorganisms. Thus, it makes a way of safer water treatments that have immediate feedback when handling such potential hazards at various operational levels.

More so, the integration of the automated sampling and analysis process from the laboratory can be instrumental in upgradation in the monitoring process wherein there is continuous monitoring of the water quality with the minimal interference of humans for greater confidence in the safe consumptability of the treated water, thereby reducing the probabilities for waterborne diseases.

6. **Regulatory Compliance and Reporting**

As water quality standards develop, the system must allow for flexibility enough to not only keep local and international regulations in pace but perhaps to include capabilities such as reporting, perhaps even advanced automated compliance and data logging to make it even easier to show that the operating plant does meet regulatory compliance.

Furthermore, the system can be designed to throw automatic alerts in case water quality crosses the regulatory threshold, so the operators could take corrective action on time. Furthermore, when the system is integrated with the regulatory bodies, reporting becomes less cumbersome, and it reduces administrative burden on the operators.

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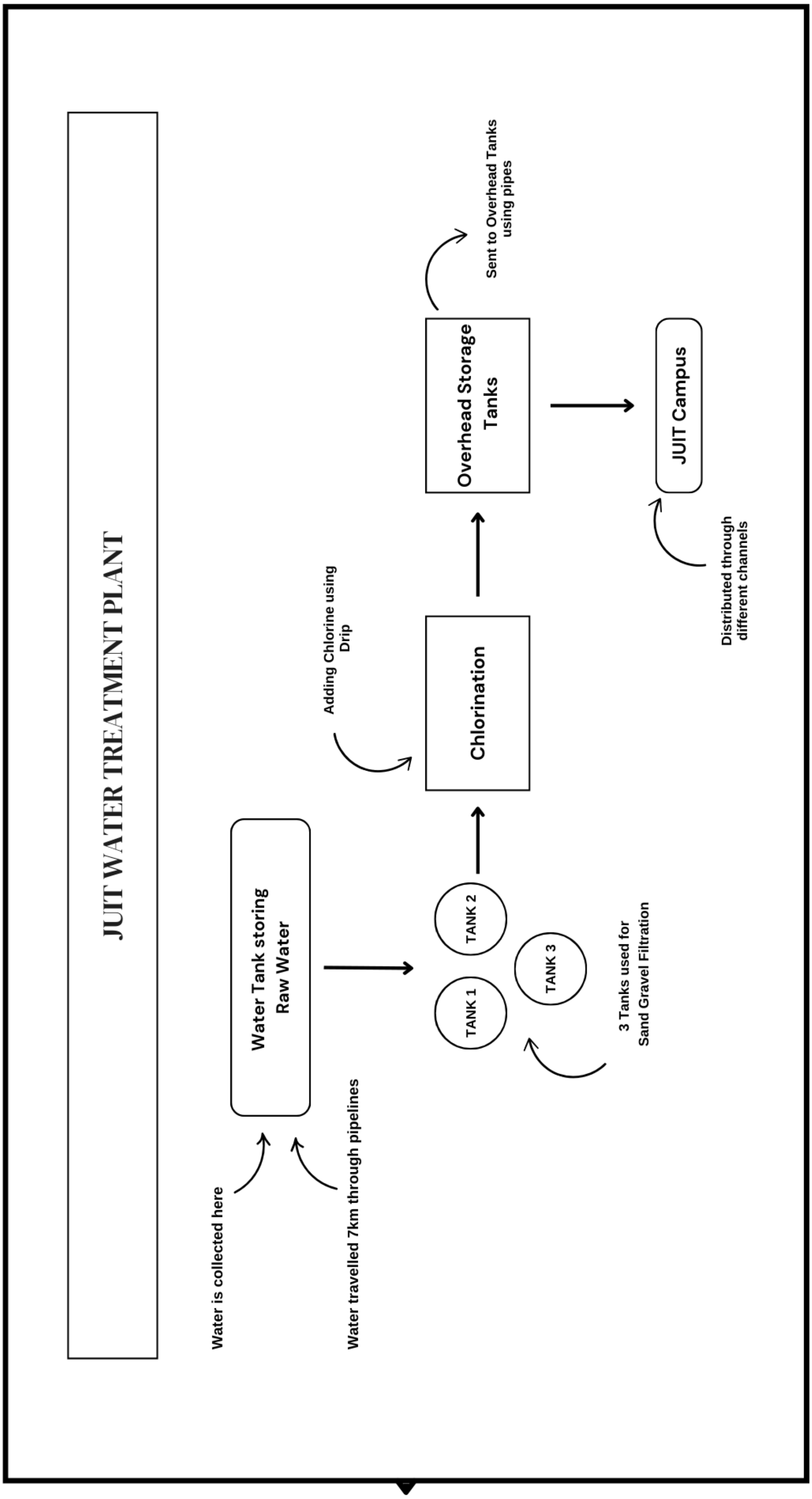
ANNEXURE


JUIT WATER TREATMENT PLANT
Water is collected here
Water travelled 7km through pipelines
Water Tank storing Raw Water
TANK 1
TANK 2
TANK 3
3 Tanks used for Sand Gravel Filtration
Adding Chlorine using Drip
Chlorination
Overhead Storage Tanks
Sent to Overhead Tanks using pipes
JUIT Campus
Distributed through different channels