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Integrated Water Pump Scheduling and Health Monitoring System for Sustainable Water Supply Management

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ABSTRACT: This paper introduces an automated solution designed to replace our college's manual water pump system, employing advanced technologies such as Programmable Logic Controllers (PLC) and Industrial Internet of Things (IIoT). The primary objectives include enhancing efficiency and enabling real-time monitoring for dynamic pump adjustments based on demand. This system utilizes flow switch and pressure transmitters to track water levels and autonomously shuts off when pressure thresholds are exceeded. Additionally, Internet of Things (IoT) technology is employed to monitor and collect real-time water consumption data, facilitating accurate analysis and anomaly detection. The project aims to improve sustainability and efficiency by cutting operating expenses, reducing water waste, and adhering to sustainable water management principles. The integration of IoT also introduces a data-driven approach, enabling the collection of valuable insights into water usage patterns. This wealth of information not only aids in informed decision-making but also establishes a foundation for proactive water resource management within the college premises.

KEYWORDS: PLC, Water Supply Management, Motor, Pump, Automation, IIoT.

I. INTRODUCTION

Our college currently relies on a manual and inefficient water pump scheduling system, resulting in water wastage and inconvenience for both students and staff. This project aims to create an automated scheduling system for water pumps, optimizing water distribution, minimizing operational costs, and reducing the need for human intervention. The objective is to ensure a consistent water supply that can adapt to the varying demands of different college facilities. Implementing this automated water pump scheduling system is expected to enhance the overall efficiency of water management in our institution. This initiative aligns with our broader goal of promoting sustainability, embracing eco-conscious practices, reducing water wastage, and ultimately providing a more seamless and reliable experience for students and staff who rely on this essential resource for their daily activities. The main goal of this project is to create an automated water pump scheduling system using Programmable Logic Controller (PLC) and Industrial Internet of Things (IIoT) technology.

The system is designed to accomplish the following specific objectives:

- Optimize water distribution.
- Minimize operational cost.
- Real time monitoring and control
- Data collection
- Enhance sustainability.

The primary goal of this research project is to design, create, and bring into practice an effective automated water pump scheduling system. By addressing the inefficiencies inherent in our current manual water pump scheduling system, we

can ultimately strive to optimize water distribution across various college facilities while simultaneously reducing operational costs and human intervention. This adaptability is particularly significant in ensuring a consistent and reliable water supply, catering to the diverse needs of our student body and staff. The incorporation of advanced technologies, by doing so, this project aligns with the broader institutional objective of embracing cutting-edge solutions to enhance overall efficiency and sustainability. In essence, this initiative represents a transformative step towards modernizing our water management practices. By harnessing the power of PLC and IIoT technologies, we aspire to establish a robust, technologically driven framework that not only fulfils the specific objectives outlined in this project but also contributes to the sustainability, efficiency, and improved user experience within our college environment.

Anubha Panchal et al., [1] conducted research to eliminate water theft in government pipelines, ensuring a fair distribution of water resources. The cost-effective system not only effectively prevents drinking water theft but also holds potential for future use in transporting liquid petroleum gas and other fuels through pipelines. By addressing the prevalent issue of water theft, the project aims to establish an equitable distribution mechanism, promoting sustainability and laying the groundwork for versatile applications in resource transportation [2-3]. This initiative underscores a commitment to efficiency, cost-effectiveness, and innovative solutions that address both current challenges and future needs in the management of essential resources.

By automating the water supply system, the system minimizes human effort, reduces processing time, and actively prevents water theft in pipelines [4-6]. The incorporation of PLC technology enables swift detection of leaks, contributing to resource conservation and ensuring a more reliable water distribution network. This development represents a forward-thinking solution that addresses key issues in urban water management through enhanced efficiency and sustainability.

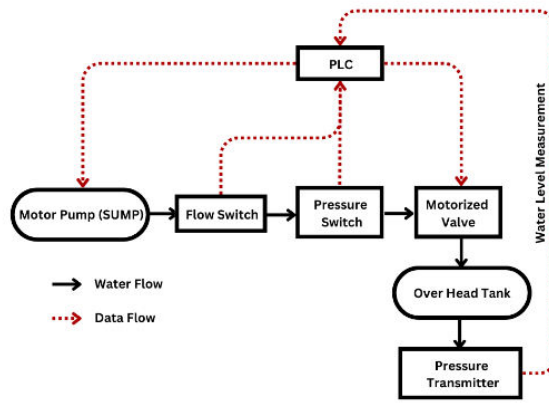
The research conducted by Ayman Alihussein et al., [7] emphasizes the necessity of implementing a SCADA system to manage water pumping stations in Gaza. Currently, the manual management of these stations and the distribution network leads to uneven water distribution and increased operational costs. Introducing a SCADA system offers a solution to these challenges. Automation allows for real-time monitoring and precise control, ensuring a more equitable distribution of water. A key focus is ensuring equitable water distribution, and the cost-effective design makes this technology accessible for wider implementation. Notably, the system excels in providing a continuous and uninterrupted water supply, contributing to sustainability and reliability in water management [8].

The research conducted by Gaikwad Sonali et al., [9] suggests the integration of PLC and SCADA technologies for real-time monitoring and control of water networks from the operator's desk, ensuring prompt adjustments for efficient operation. PH value measurements play a crucial role in preventing the entry of non-potable water and reducing the risk of water pipe corrosion due to acidic content. [10] The study focuses on a mathematical model and an IoT framework for creating a smart city in Nepal and explores the application of an IoT framework in water supply management for smart cities. In the framework of a smart city, the paper underscores the need of effective water supply management and the role of IoT in creating a framework for it.

The creation and testing of an automated system for measuring water flow consumption in open channels and natural watercourses using an Arduino platform is covered in the publication [11]. It examines the difficulties in determining the flow rate of free-flowing water and the many water flow measurement techniques now in use, such as the "variable flows" and "velocity-area" methods.

II. PROPOSED SYSTEM

The proposed system consists of an underground water sump with a submersible water pump, pressure and flow switches, motorized valve, and an overhead tank with pressure transmitter. The proposed block diagram is shown in fig 1. These sensors monitor the pressure and flow of water within the system [12-13]. The water pumped from the underground sump is kept in reserve in the overhead tank. The sensors provide input data to the Programmable Logic Controller (PLC) regarding the status of water flow and pressure. If the pressure of the water is increased beyond a certain predefined condition, this will put stress on the motor pump leading it to decreasing the working efficiency. In case of this condition, the water pump will be automatically cut off to prevent it from overloading.



Integration with Weintek IIoT device

Fig. 1. Block diagram.

Moreover, the tank's exit has a pressure transmitter attached to keep track of the water level. For control purposes, this data is also transmitted back to the PLC. The PLC (Simatic S7-1200) acts as the system's main control unit. The pressure transmitter in the overhead tank, as well as the flow and pressure switches, provide input data to the PLC. In order to maintain ideal water flow and pressure levels inside the system, it regulates the submersible water pump and motorized valve based on this input. To ensure continuous functioning, the system also includes diagnostic tools that proactively identify and handle any problems like single phasing and dry run conditions. The water management system maximizes productivity, minimizes human interaction, and improves dependability by utilizing intelligent automation and state-of-the-art technology, eventually supporting long-term water conservation initiatives.

III.HMI INTEGRATION

The suggested water management system gains the additional functionality and accessibility with the integration of the IIoT device Weintek [14-15]. Fig. 2 shows the integration of the Weintek device (cMT-sVR-102) with the PLC and the mobile app Easy access 2.0.



Fig. 2. PLC integration with Weintek HMI

The device is connected to the PLC with the help of an ethernet cable. The device makes it easier to gather data from the water management system's numerous sensors and parts. Status of the motorized valve, motor, pressure transmitter in the overhead tank outlet, pressure and flow switches are included in this. The cMT-sVR-102 device serves as a Human-Machine Interface (HMI), offering a simple user interface for tracking and visualising the information gathered from the system. On the Weintek HMI, operators can see current data on water pressure, flow rates, tank levels, and the water consumption.

Operators can be able to remotely access and monitor the water management system using their mobile devices from any location with the help of cMT Viewer App and Easy Access 2.0 VPN. Even when they are not physically present at the site, this allows operators to keep informed about system performance and remote monitoring. Easy builder pro, a software used to configure and customise the Weintek HMI interface. Using the data collected by the Weintek device, operators can do more thorough analysis of system performance and trends over time. With this data, inefficiencies may be identified, system performance can be optimised, and maintenance needs can be predicted, all of which help to reduce downtime and provide dependable operation.

Overall, the water management system's functionality, accessibility, and monitoring capabilities are improved by the integration of Weintek IIoT device with Easy Builder Pro software and the cMT Viewer mobile app, allowing for effective operation and maintenance.

IV. HARDWARE IMPLEMENTATION

The hardware implemented in our college has a panel board, which is the main controlling unit in the system. This panel board consists of the Power supply module, PLC, 4 pole MCB, contactor, overload relay and a PLA relay shown in fig. 3.



Fig. 3. PLC Panel board

The power supply module takes 230V AC as input and provides 24V DC [16] to the PLC. The PLC (Simatic S7-1200, CPU 1214C DC/DC/DC) takes 24V DC input to operate and it has 14 digital and 2 analog inputs with 10 digital outputs. The 4 pole MCB, contactor and overload relay serves as the DOL Starter for the motor pump. The PLA relay is used to turn ON and OFF the motor whenever required and it is connected to the first digital output pin of the PLC. The pressure transmitter shown in fig 4, is connected in the outlet of the overhead tank and is connected to the PLC via analog input pin 1.



Fig. 4. Pressure transmitter in the tank outlet.

This pressure transmitter is used to measure the water level in the tank. The output ranges from 4 to 20mA. This current is converted into voltage by placing a 470-ohm resistor in parallel with the output, since the PLC only takes 0-5V DC or 0-10V DC as analog input. Based on the voltage value obtained, the calculation of the water level in the tank can be done. The maximum tank capacity is 55,000 litres. If the percentage of the water in the tank is decreased, i.e. for every decrease in percentage, the water level in the tank drops by 550 litres.

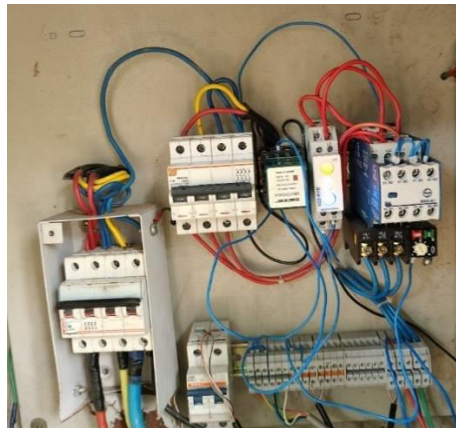


Fig. 5. Single phase prevention setup

In this automated system, maintaining a balanced power supply is paramount to ensure the smooth operation of equipment (here motor) and prevent costly damages. One of the key concerns in this regard is single-phase prevention, which involves safeguarding against imbalanced voltage or power supply situations. This single phase prevention system in fig 5 will protect the motor by cut off the supply when one or more phases are in imbalanced condition [17].



Fig. 6. Plumbing setup with sensors

Fig 6 shows the plumbing setup made in the college campus consisting of flow switch, pressure switch and motorized valve. The flow switch gets turned ON if water tends to flow in the pipeline and pressure switch will turn ON if the pressure in the pipeline reaches certain threshold. Based on these conditions the motorized valve and the motor will operate.



V. RESULT

The implementation of the automated water pump system utilizing Programmable Logic Controllers (PLC) and Industrial Internet of Things (IIoT) technologies has yielded significant improvements in efficiency, sustainability, and operational oversight within our institution.



Fig. 7. HMI in cMT Viewer

The water level in the overhead tank can be monitored i.e., 90.34% of water is present at that time in the tank and motor turn ON and OFF can be done using this application and is shown in fig 7.

Pressure Switch	Flow Switch	Condition	Motor
OFF	OFF	Dry run condition	OFF
OFF	ON	Normal Condition	ON
ON	ON	Overload condition	OFF

Table 1. Conditions and operations

Conditions and respective operations for the automated system is given in table 1.

VI.CONCLUSION

In conclusion, an essential step toward sustainable water supply management has been made with the creation and application of IIoT and Programmable Logic Controllers (PLC). This system efficiently optimizes water pump scheduling by integrating automated processes, which increases operational efficiency and reduces energy usage. By using PLC and IIoT systems, operators may monitor and manage processes in real time, responding quickly to changes in water demand and unanticipated occurrences to guarantee a steady and dependable supply of water. All things considered, the integrated system's successful deployment highlights how revolutionary it may be in terms of water supply management techniques, opening the door to more robust, effective, and ecologically friendly water infrastructure. The system's modular design minimizes deployment costs and interruptions by enabling seamless connection with current infrastructure. By using the strength of automation and data-driven decision-making can reduce risks, maximize the use of available resources, and ultimately support the sustainability of ecosystems and water resources over the long run [18].

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