

# Programmable Logic Controller Based Dam Shutter Control System

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## ABSTRACT

*This study focuses on the utilization of Programmable Logic Controller (PLC) technology for controlling and automating water levels and gates in dam systems. The main objective is to develop effective and dependable systems that can efficiently manage water levels, control gates, and ensure the safe operation of dams at all times. The research incorporates different components and approaches, including float switches, limit switches, PLC, and DC motors, to achieve optimal performance. To monitor the water level in the dam, two float switches were strategically positioned at the 40% and 80% marks of the dam's capacity. Additionally, two gates were employed to regulate the instantaneous water volume flowing out of the dam, with their opening and closing controlled by a DC motor that rotates in clockwise and anticlockwise directions. The duration of motor rotation in each direction is determined by limit switches placed at the upper and lower boundaries of the gates. The ultimate goal is to enhance overall efficiency, minimize human errors, and ensure effective regulation of water resources within dams. The findings underscore the potential of PLC-based automation in enhancing dam operation and management across various applications, including water supply, irrigation, and power generation.*

**Keywords:** Automation, Dam Systems and Monitoring, DC motors, Limit switch.

## 1. INTRODUCTION

Water management is a critical aspect of various economic activities, including agriculture, industry, power generation, and public use (Pandya *et al.*, 2019; Madanhire and Madaka, 2018). As the demand for food production continues to rise and concerns about water scarcity intensify, the efficient management and distribution of water resources have become paramount. Efficient water management is essential not only for sustaining agricultural production but also for supporting industrial processes and power generation. In response to these challenges, there is a growing interest in automating dam operations to improve water control and distribution efficiency. By automating dam operations, water can be effectively allocated to meet the diverse needs of these sectors, while also addressing concerns about water scarcity and ensuring the long-term sustainability of water resources (Bhardwaj *et al.*, 2014). Programmable Logic Controllers (PLCs) have emerged as a valuable tool in gate-controlled dam systems, offering significant benefits in achieving aforementioned objectives (Darshan *et al.*, 2021; Sorte *et al.*, 2015). The significance of automation in dam operations cannot be overstated. By implementing PLCs and utilizing associated technologies, water control, distribution efficiency, and safety can be greatly enhanced. PLCs provide a flexible and reliable means of managing water resources, allowing for precise control and monitoring of water flow (Kumar *et al.*, 2021). Through automation, tasks such as measuring water levels, regulating gates, and directing water for irrigation and power generation can be executed with improved accuracy and efficiency.

In addition, by automating dam operations, the need for manual intervention is significantly reduced, leading to cost savings and increased operational efficiency (Singh, 2022). Furthermore, automation enhances safety measures by enabling the monitoring of dam structures, including the detection of vibrations and early warning signs of potential collapse. The growing concerns about water scarcity and increasing demands for food production have led to the exploration of automation in dam operations. This is the motivation for the continued interest in this research area and this work particularly. Darshan *et al.*

(2021) in their paper titled PLC Based Automatic Dam Shutter Control Using Water Level Sensing, shed light on the extensive dam network in India, particularly in Gujarat, where water management and distribution are crucial. With a large catchment area and complex canal networks, automated systems become indispensable for efficient irrigation and drinking water supply. Their proposed PLC-based systems aim to automatically sense water levels in dams and control gate movements, contributing to labour savings, energy conservation, and improved accuracy.

Pandya *et al.* (2019) worked on a paper titled PLC and Supervisory Control and Data Acquisition (SCADA) Based Dam Shutter Operation for Flow and Level Control. The paper emphasizes on the importance of automation in dam systems, highlighting the benefits of PLCs in providing flexible, accurate, and reliable water control for irrigation purposes. Their proposed system includes measuring water velocity, pressure, and level, as well as effectively channelizing water for irrigation and power generation. Additionally, the system monitors dam vibrations to ensure safety, especially during flood events. By leveraging features such as versatility, easy programming, and self-diagnostic capabilities they concluded that PLCs offer a suitable solution for automating dam operations. Moreover, Kumar *et al.* (2021) worked on Dam Gate Control Using PLC and SCADA. The paper focused on the significance of PLCs in industrial automation, specifically their role in controlling various operations in dams. They demonstrated the integration of Human-Machine Interface (HMI) and SCADA systems with PLCs to enhance overall control and monitoring capabilities. They also showed how Ladder programming which is a common method used in PLCs was used to simplify the implementation of logical operations and facilitates efficient dam automation processes (Kumar *et al.*, 2021).

Madanhire *et al.* (2018) addressed the limitations of manual water outlet operations in dams in their paper titled Design of an Automated Dam Shutter Control System. They highlighted need for automation and monitoring control systems. The proposed systems not only improved reliability but also enable the early detection of potential wall collapse, ensuring the safety of dam structures. They concluded that although the initial implementation costs may be significant, the long-term economic benefits of such systems make them a viable solution. The conventional approaches rely on time-based mechanisms to determine the duration for opening and closing the gates. However, this can lead to potential issues, such as the motors continuing to operate even when the gates have reached their maximum or minimum limits. This research introduces a novel solution by incorporating limit switches that effectively mark the upper and lower boundaries of the gate, thereby enhancing the accuracy of the opening and closing process. Moreover, the materials chosen in this study offer a cost-effective alternative compared to previous methods, making it an economical option to achieve the desired objectives.

## 2. METHODOLOGY

### 2.1 Materials

**Water Level Switch:** Water Level switches, also known as float switches, are crucial components of the dam shutter control system. The system utilizes two float switches, FS40 and FS80, strategically positioned at specific levels within the dam. FS40 is located at the 40% capacity mark, while FS80 is positioned at the 80% capacity mark. These switches provide real-time water level information to the PLC. By continuously monitoring the signals from these switches, the PLC can initiate programmed actions based on the current water level readings.

**DC Motors:** DC Motors are electromechanical devices essential for precise control of the dam gate movements. The system employs two 24V DC motors to regulate the opening and closing of different dam gates in response to the water level inside the dam. Each motor can rotate clockwise (opening the gate) or counter clockwise (closing the gate). Consequently, each motor is assigned two PLC output addresses, one for closing the gate and the other for opening the gate.

**Limit Switches:** Limit switches are electrical switches that change state when force is applied to them. In this project, they are used to restrict the opening and closing of the dam gates. Each gate is equipped with two limit switches. The upper limit switch prevents the gate from moving further upward (maximum open position), while the lower limit switch stops the gate from moving further downward by sending a signal to turn off the motor controlling the gate.

**FX1N32MR PLC:** The FX1N32MR is a model of PLC manufactured by Mitsubishi Electric. It plays a vital role in the dam shutter control system as the central control unit. With 32 digital input/output ports, the PLC enables connection and control of various devices and equipment. Integrated with water level switches, the PLC continuously monitors the water level in the dam and receives real-time feedback. Based on the input signals from the water level switches, the PLC analyses the data and makes informed decisions on whether to open or close the gates to maintain the desired water level. The GX-developer software was used to write and download ladder logic codes to the PLC.

**SMPS:** SMPS stands for Switched-Mode Power Supply. It is an electronic device used to efficiently convert electrical power from one form to another. In the dam shutter control system using PLC, an SMPS is employed to provide the required 24VDC power supply for the PLC, water level switches, and DC motors. The SMPS takes an input voltage of 240VAC from the main power supply and converts it to a regulated 24VDC output voltage suitable for the system components. This is achieved by switching the input voltage on and off at a high frequency and then filtering and regulating the resulting waveform to provide a stable output voltage. Table 1 provides an overview of the utilized components, their respective aliases in the ladder logic code, the assigned PLC addresses, voltage ratings, and the contact type of each component.

**Table 1:** Components used, PLC address Assigned and Ratings

S/N	Component	Alias	PLC Address	Ratings	Contact
1	Start Button	STR	INPUT- X000	24VDC	NO
2	Stop Button	STP	INPUT- X001	24VDC	NC
3	40% Float switch	FS40	INPUT- X002	24VDC	NO
4	80% Float switch	FS80	INPUT- X003	24VDC	NO
5	gate 1 lower limit switch	LJS40	INPUT- X004	24VDC	NC
6	gate1 upper limit switch	ULS40	INPUT- X005	24VDC	NC
7	gate 2 lower limit switch	LJS80	INPUT- X006	24VDC	NC
8	gate 2 upper limit switch	ULS80	INPUT- X007	24VDC	NC
9	System ON LED	SYS_ON	OUTPUT-Y000	24VDC	N/A
10	system OFF LED	SYS_OFF	OUTPUT-Y001	24VDC	N/A
11	open gate 1 motor 1	OGM40	OUTPUT-Y002	24VDC	N/A
12	close gate 1 motor 1	CGM40	OUTPUT-Y003	24VDC	N/A
13	open gate 2 motor	OGM80	OUTPUT-Y004	24VDC	N/A
14	close gate 2 motor	CGM80	OUTPUT-Y005	24VDC	N/A

## 2.2 Methods

The programmed logic of the PLC ensures specific actions based on the water level in the dam. When the water level is below the 40% capacity mark, indicating all float switches are open, both dam gates are closed, with the lower limit switches confirming full closure. As the water level rises above the 40% mark,

the first gate is opened by energizing motor GM40 in a clockwise rotation, while the second gate remains closed. Once the water level surpasses the FS80 float switch i.e. 80% capacity mark, the second gate is opened, alongside the first gate that remains open. The upper limit switches ensure the gates reach their maximum open position. As the water level starts to decrease and falls below the 80% capacity mark, the second gate is closed. Continual decrease in water level until it falls below the 40% mark results in both gates being closed. Therefore, the system ensures that the water level in the dam never drops below 40% or exceeds 80%. Start and stop push buttons are utilized to initiate and halt dam operations, while green and red indicator LEDs provide visual indications of the system's status, whether it is ON or OFF. Figures 1 - 3 illustrate the system block diagram, wiring configurations, and operational flowchart of the project, respectively.

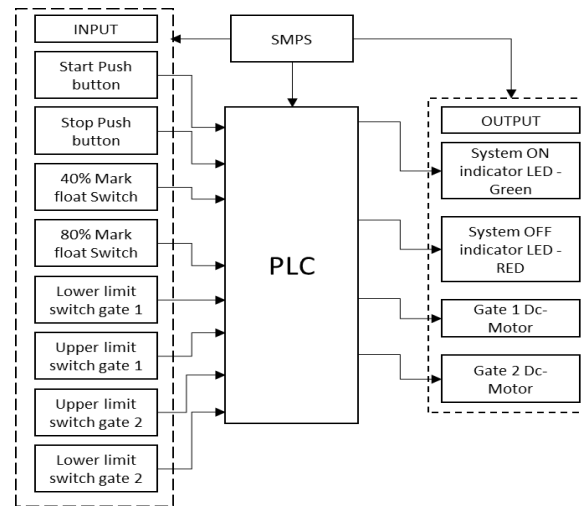


Figure 1: Block Diagram

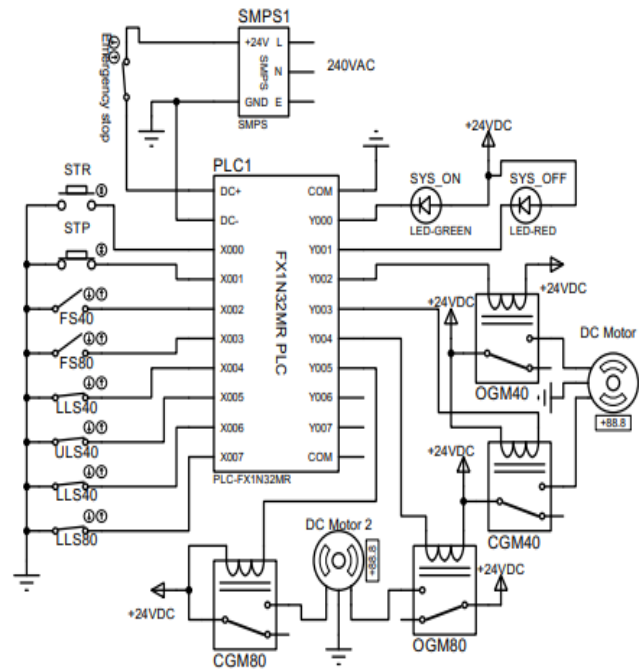
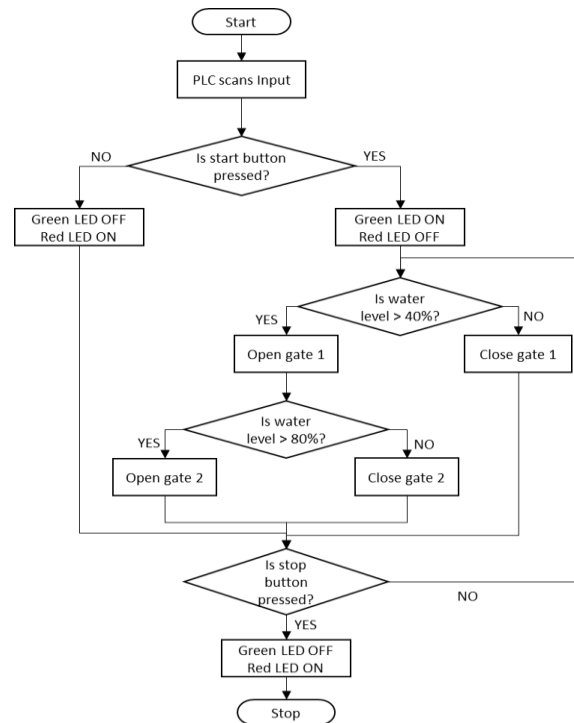


Figure 2: Wiring Diagram



**Figure 3: System Flowchart**

### 3. RESULTS AND DISCUSSION

Figure 4 depicts the graphical representation of the components utilized and their arrangement with respect to the PLC. Comparable result is found in Sorte *et al.* (2015) which performed the task of opening and closing the dam gate in response to water level (40% low level and 80% high level). The ladder logic illustrates the states of the input devices (contacts) and output devices (coils) during the simulation as discussed in stages.

**Stage 1:** Upon powering on the system, the SYS\_OFF coil, indicated by the red indicator LED, is energized to signify system inactivity. The lower limit switches LLS40 and LLS80 are pressed, with a logic 0 state, indicating that both gates are fully closed. All other output coils remain off with a logic 0 state. Figure 5 shows the ladder simulation for stage 1.

**Stage 2:** When the start button contact "STR" is pressed, the SYS\_ON coil, represented by the green indicator LED, turns on, indicating an active system (logic 1 state). The SYS\_OFF coil changes from logic 1 to logic 0, turning off the system indicator LED. The system is latched by providing feedback from the SYS\_ON output coil into the ladder network. This latch ensures that the green LED remains on even after releasing the start pushbutton. Figure 6 shows the ladder simulation for stage 2.

**Stage 3:** As the water level in the dam starts to rise and exceeds the 40% capacity mark, the float switch FS40 changes its contact state from logic 0 to logic 1 (closed). If the upper limit switch of gate 1 (ULS40) is not pressed (logic 1), the motor coil OGM40 responsible for controlling gate 1 is energized, resulting in its opening. The motor coil OGM40 is de-energized when the upper limit switch ULS40 is pressed by the fully opened gate 1 (ULS40 contact changes to logic 0) or when the water level falls below the 40% capacity mark again. Figure 7 shows the ladder simulation for stage 3.

**Stage 4:** When the water level in the dam continues to rise and surpasses the 80% capacity mark, the float switch FS80 changes its contact state from logic 0 to logic 1. If the upper limit switch of gate 2 (ULS80) is not pressed (logic 1 state), the motor coil OGM80 responsible for opening gate 2 is energized, causing it to open. The motor coil OGM80 is de-energized when the upper limit switch ULS80 is pressed by the fully opened gate 2 (ULS80 contact changes to logic 0) or when the water level falls below the 80% mark again. Figures 9 and 10 show the ladder simulation for stage 4.

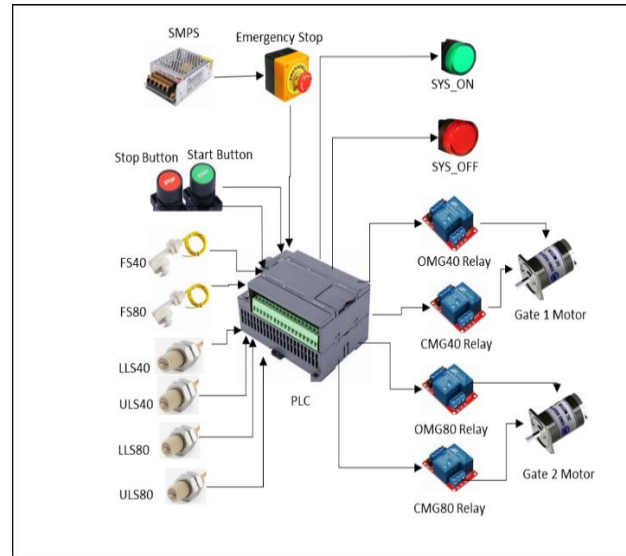


Figure 4: System layout

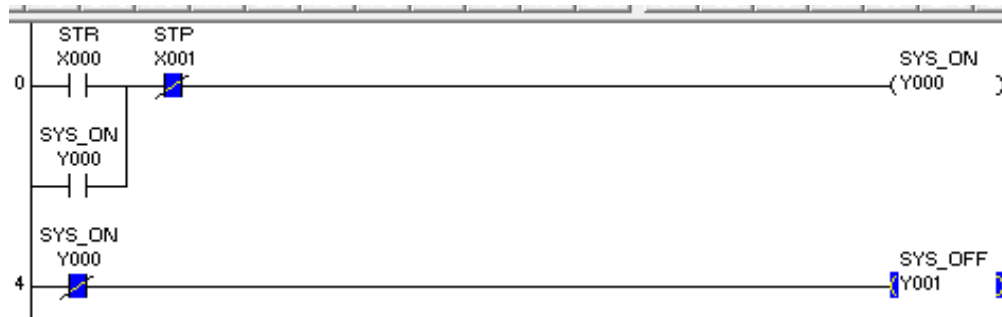


Figure 5: Simulation stage 1

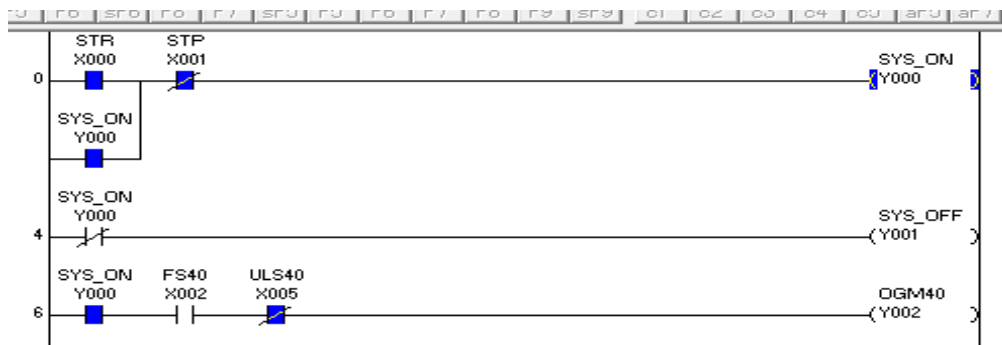
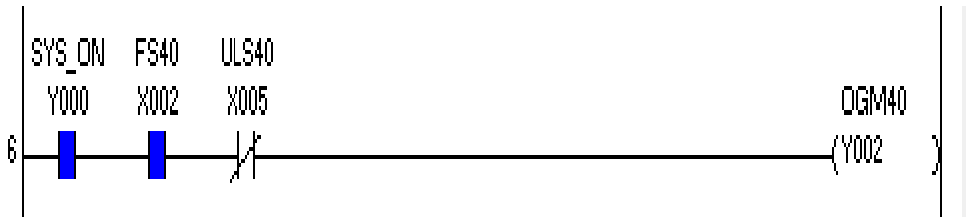


Figure 6: Simulation Stage 2, system is ON when start button is pressed

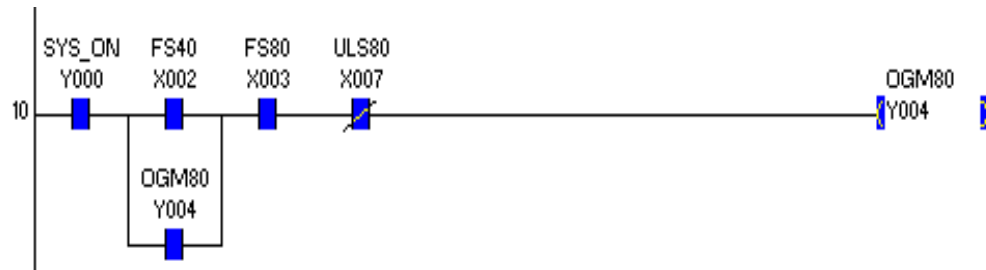




**Figure 7:** Simulation stage 3, Gate 1 opens when water level rises above 40% mark



**Figure 8:** Simulation stage 6, Gate 1 coil de-energized when gate 1 is fully opened



**Figure 9:** Simulation Stage 4, Gate 2 opens when water level rises above 80%



**Figure 10:** Simulation stage 4, gate 2 coil de-energized when gate 2 is fully opened

**Stage 5:** As the water level in the tank decreases and drops below the 80% capacity mark, the float switch FS80 changes its contact state from logic 1 to logic 0. If the lower limit switch of gate 2 (LLS80) is not pressed (indicating that gate 2 is currently opened), the motor coil CGM80 responsible for closing gate 2 is energized, resulting in its closure. The motor coil responsible for closing gate 2 is de-energized only when the water level rises above the 80% mark again or when the lower limit switch LLS80 is pressed upon reaching the fully closed position. Figures 11 12 show the ladder simulation for stage 5.

**Stage 6:** When the water level falls below the 40% capacity mark of the dam, the float switch FS40 changes its state from logic 1 to logic 0. The coil CGM40, which is responsible for closing gate 1, is energized, leading to the closure of gate 1. The coil CGM40 is de-energized only when the water level rises above the 40% capacity mark again or when the lower limit switch LLS40 is pressed upon reaching the fully closed position. Figures 13 14 show the ladder simulation for stage 6.

**Stage 7:** Pressing the stop push button STP results in the de-energization of the SYS\_ON coil while energizing the SYS\_OFF coil. Additionally, all other coils are changed to logic zero. Figure 15 shows the ladder simulation for stage 7. Comparing this procedure with the work of Singh (2022), Madanhire and Madaka (2018), Sorte *et al.* (2015) the work presented herein based on PLC application is better for being flexible, versatile and less human labour involvement. With the implementation of PLC based dam shutter control system presented herein, the growing concern about water resources and its attendant scarcity has been successfully ameliorated.



**Figure 11:** Simulation stage 5, gate 2 closes when water level falls below 80%



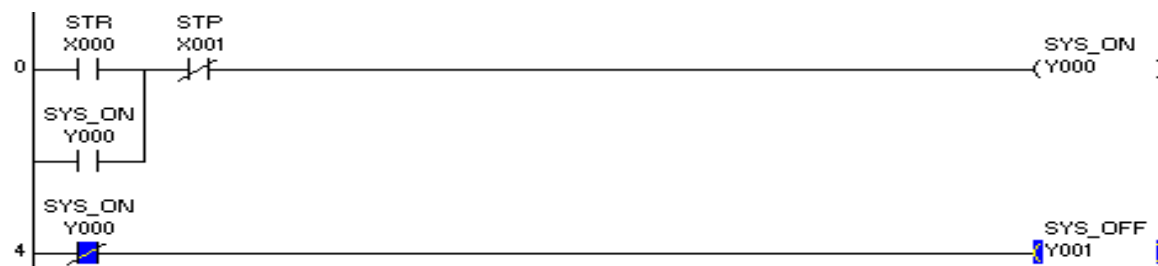
**Figure 12:** Simulation stage 5, gate 2 coil de-energized when gate is fully closed.



**Figure 13:** Simulation stage 6, gate 1 closes when water level falls below 40% mark



**Figure 14:** Gate 1 coil is de-energized when gate is fully closed.



**Figure 15:** Simulation stage 7, system stops when stop pushbutton is pressed



#### 4. CONCLUSION

This study has successfully demonstrated the control and automation of water levels and gates in dam systems using Programmable Logic Controller (PLC) technology. The objective of developing efficient and reliable systems for managing water levels, controlling gates, and ensuring the safe operation of the dam has been achieved. The simulation results have shown the successful operation of the system through different stages, ensuring that the gates are opened or closed based on the water level conditions. The integration of indicator LEDs, push buttons, and limit switches has provided clear visual feedback and control options for monitoring and managing the dam system. Overall, the project has demonstrated the effectiveness of utilizing PLC technology in the control and automation of dam systems, contributing to increased operational efficiency, enhanced safety, and more reliable management of water resources. Further research and implementation of such systems can greatly benefit the water industry in terms of efficient resource utilization and sustainable development. Implementation of more accurate sensors (e.g., ultrasonic, pressure) for precise water level monitoring as well as the use of remote control to enable remote monitoring and control through IoT technologies for increased flexibility and utilization of data analytics for insights, predictive maintenance, and optimized gate control strategies are recommended for further works.

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