IoT-Based Dam Automation and Monitoring System

Pradyumna Manoj Kolhe[1], Gaurav Mohan Shankhe[2], Abhijeet Shivaji Panpatte[3]

Under: Prof. S.S.Patil

Dept. of Electrical Engineering, PES Modern college Of Engineering Pune -411005, India

---***---

Abstract - This paper addresses the gap in real-time dam water level and flow rate monitoring. It enables remote monitoring of water parameters which is important for energy, irrigation, and flood control. Often, traditional monitoring systems for dams lack automation and real-time data acquisition, and there is no information exchange between various dams in actual time. In order to fill these gaps, the current work proposes an IoT based automation and monitoring system using ESP32 microcontrollers, ultrasonic distance measuring sensors, and wireless communication modules. The system under consideration measures the water level continuously and makes asociates the data available on a mobile application and a local display. This data is also relayed over Wi-Fi available in the ESP32 module. Related works shows the application of IoT and ML techniques in increasing the responsiveness and reliability of dam infrastructure. The focus of the measures in this project is on continuous monitoring, operational effectiveness, improving disaster management, and system agility. This work is a prototype model. The results from the experiment are confirmed to supply precise measurements on the water level within the reservoir and operational gates in good time. All in all, the project is intended to use much less resources while expanding the supporting structure for future smart water management initiatives within the field of environmental engineering.

Key Words: Key words: wireless communication, dam automation, smart water management, environmental engineering, IoT-based monitoring system, ESP32, ultrasonic sensor, and real-time water level monitoring.

1. INTRODUCTION

The management and monitoring of dam water levels are crucial for ensuring efficient water resource management, energy generation, irrigation control, and disaster preven- tion. However, traditional dam monitoring systems often lack real-time automation, efficient data acquisition, and inter- dam communication, which limits their effectiveness during critical scenarios. The advancements in Internet of Things (IoT) technologies offer promising solutions to overcome these challenges by enabling real-time monitoring, remote operation, and intelligent decision-making capabilities.

Recent studies have explored IoT integration for automating dam functionalities [1], highlighting its potential for improv- ing responsiveness and operational safety. Further research emphasized the role of IoT intervention in enhancing dam infrastructure performance and disaster management systems [2]. The application of real-time monitoring and controlling of dam water levels through IoT-based systems has demonstrated improvements in early warning mechanisms and operational efficiency [3].

Efforts to incorporate machine learning alongside IoT frameworks have shown promising results in developing smart dam control systems, capable of predictive analysis and better management strategies [4]. Moreover, alternative communica- tion methodologies, such as laser communication and ZigBee technologies, have been investigated to ensure reliable data transmission in water management systems [5].

In addition to automation, energy monitoring in hydroelec- tric power plants using advanced control systems has been proposed to optimize the interconnected water-energy nexus [6]. Studies have also introduced low-cost, IoT-enabled water level monitoring systems aimed at scalable and affordable deployment, particularly in developing regions [7]. Efficient dam water management using IoT for real-time tracking and predictive maintenance has also been a key focus in recent works [8].

The development of alert systems capable of promptly notifying concerned authorities based on dam water levels has further strengthened disaster preparedness frameworks [9]. More recently, the integration of cloud-based data analytics and LSTM networks has shown effectiveness in predicting water level changes, thus enhancing the accuracy of dam monitoring systems [10].

Motivated by these advancements, the present work pro- poses an IoT-Based Dam Automation and Monitoring System utilizing ESP32 microcontrollers, ultrasonic distance measur- ing sensors, and wireless communication modules. The system is designed to continuously measure water levels and transmit data in real-time to a mobile application and a local display unit. Wi-Fi capabilities embedded within the ESP32 mod- ules ensure seamless remote data transmission. The proposed system emphasizes continuous monitoring, operational effi- ciency, disaster mitigation, and resource optimization, thereby contributing to the development of smart water management solutions for sustainable environmental engineering.

1.1 System Design: Sending End Block Diagram

The sending end of the envisioned IoT-based dam au- tomation system, depicted in Fig. 1, is designed to facilitate autonomous monitoring and controlling of dam operations. The design is centered around an ESP32 microcontroller with Wi-Fi onboard, facilitating both local and remote control.

International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 09 Issue: 06 | June - 2025 SJIF Rating: 8.586 ISSN: 2582-3930

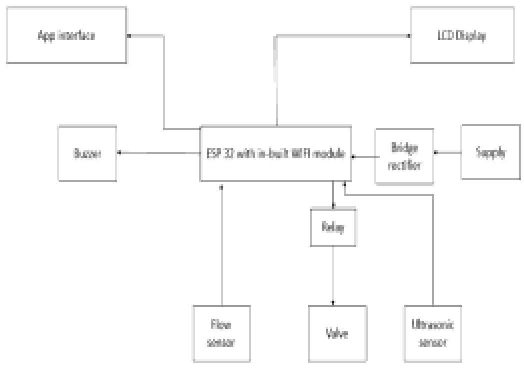

Fig. 1: Sending End Block Diagram of the IoT-Based Dam Automation System.

A. Power Supply Unit

The power supply system provides AC mains to DC conversion through a bridge rectifier. The pulsating DC is filtered and regulated (usually to 3.3V or 5V) for stable delivery of power to the ESP32 and other parts of the system. This is crucial for uninterrupted, consistent operation of the monitoring system.

B. ESP32 Microcontroller with Integrated Wi-Fi

The ESP32 is the processing core of the system that undertakes the following activities:

Sensor Data Acquisition: Reads the data from the ultrasonic and flow sensors. *Local Processing*: Decides threshold violations and makes decisions like triggering the buzzer or relay. *IoT Communication*: Sends sensor values and status information to a mobile app over Wi-Fi using MQTT or HTTP protocols. *Display Update*: Displays real-time sensor readings on an LCD display.

The ESP32's dual-core and wireless capability make it a strong contender for embedded IoT applications.

C. Ultrasonic Sensor (Water Level Detection)

The ultrasonic sensor detects the water level in the dam based on time-of-flight principles. The ESP32 determines the distance to the water surface and compares it with a threshold value set by the user (e.g., 9 cm). If the value is above the threshold, the microcontroller sends a response to avoid possible overflow.

D. Flow Sensor (Discharge Rate Monitoring)

The flow sensor monitors the discharge rate of water. This data is both shown locally on the LCD and sent to the mobile application for remote observation.

E. Relay and Valve Unit

The relay serves as a bridge between low-voltage ESP32 logic and high-voltage valve actuation. When it senses high water levels, the relay opens to allow the valve to drain excess water. This closed-loop action ensures safe water levels and avoids flooding.

F. Alarm (Buzzer)

In adverse conditions (e.g., unusual water heights or im- proper flow), the ESP32 triggers a buzzer. This device sends a real-time, on-site audio warning to maintenance personnel, enhancing response to emergencies.

G. LCD Display

A 20x4 or 16x2 character LCD offers real-time display of water and flow information. This gives local operators instant feedback even when there is no mobile connectivity.

H. Mobile Application Interface (DAM App)

The system comprises a specially designed mobile app, DAM App, developed with MIT App Inventor. The app:

connects either through local IP or cloud, shows water levels and flow rates, reminds users of system status and alerts, facilitates real-time remote monitoring by dam authorities and engineers.

1.2. SYSTEM DESIGN: RECEIVING END BLOCK DIAGRAM

This section describes the real-time water resource display and alerting system, which is a stand-alone part of the entire dam automation system. Using an ESP32 microcontroller and a battery-operated (5V) portable power supply, this simplified system, shown in Fig. 2, operates entirely on its own. It is intended for information display in key locations (such as control rooms or dam gates) and site-specific local alerts.

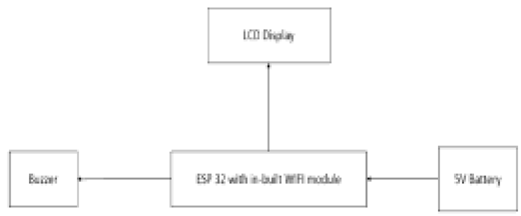

Fig.-2: Receiving End Block Diagram of the IoT-Based Dam Automation System.

A. ESP32 Microcontroller with Integrated Wi-Fi

The ESP32 microcontroller, a powerful dual-core microcontroller with Wi-Fi capability, is at the core of this sub-module. This low-power, tiny device is:

Data Reception: Receives water level and status data wirelessly from the sending end via Wi-Fi. *Local Processing*: Processes the received data to determine dis- play content and buzzer activation conditions. *Output Control*: Controls the LCD display to show relevant information and activates the buzzer for alerts. *Power Conscious*: Operates with power efficiency to prolong battery life, especially when running on the 5V battery.

The ESP32 is crucial for both ephemeral (activating the buzzer for high water or system faults) and persistent (contin- uously updating the LCD with live sensor readings and alerts) operations.

A. 5V Battery

A 5V battery serves as the portable power source for this standalone receiving unit. This allows for flexible deployment in locations where consistent AC power might not be readily available, making the system highly mobile and adaptable. The battery provides stable power for the ESP32, LCD display, and buzzer.

B. LCD Display

The LCD display provides a clear, real-time visual representation of the received water level data and system alerts. This local display is critical for on-site personnel who need immediate access to information, even in the absence of mobile network connectivity. It offers instant feedback on dam conditions.

C. Buzzer

The buzzer acts as an audible alert mechanism. It is triggered by the ESP32 based on received data, such as when water levels exceed predefined thresholds or in case of system anomalies. This local audible warning ensures that dam operators and maintenance staff are promptly notified of critical situations, enabling swift action.

1.3. SYSTEM OPERATION ALGORITHM (DAM SIDE CIRCUIT)

The operational flow of the dam side circuit is depicted in the flowchart in Fig. 3 and detailed in the following algorithm steps. This algorithm ensures continuous monitoring, data dissemination, and automated response to critical water level conditions.

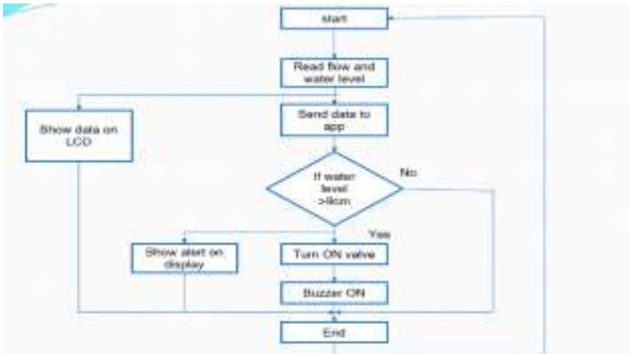

Fig-3: Algorithm for dam side circuit.

A. Algorithm for Dam Side Circuit

1) **Initialize System**: Power ON the ESP32 microcontroller and reset all the devices connected to it, including the water flow sensor, water level sensor, LCD display, valve, buzzer, and the communication module.

2) **Read Flow Rate and Water Level**: Continuously read the values from:

- Water flow sensor (for the flow rate).
- Water level sensor (for the current water level).

3) **Send Data to Mobile App**: Send the real-time value of water flow and water level to a connected mobile application using Wi-Fi or Bluetooth.

4) **Show Data on LCD**: Update the local LCD display with current readings:

- Display current water level.
- Display current flow rate.

5) **Monitor Water Level Condition**: Compare the current water level with a predetermined threshold value (9 cm).

- If water level >9 cm, then proceed to Step 6. If water level 9 cm, then return to Step 2 for continuous monitoring.

6) **High Water Level Detected**: If the water level is above 9 cm, take the following automated actions:

- **Turn ON the valve**: Activate the valve to drain excess water.
- **Activate buzzer**: Produce an audible indication by activating the buzzer.
- **Display alert message**: Show an alert message ("High Water Level") on the LCD screen.
- **End Cycle**: Once the above mandatory emergency ac- tions are taken, either:
- Wait for a manual reset, or
- Automatically repeat Step 2 for uninterrupted monitoring.

1.4. ALGORITHM FOR RECEIVING STATION CIRCUIT

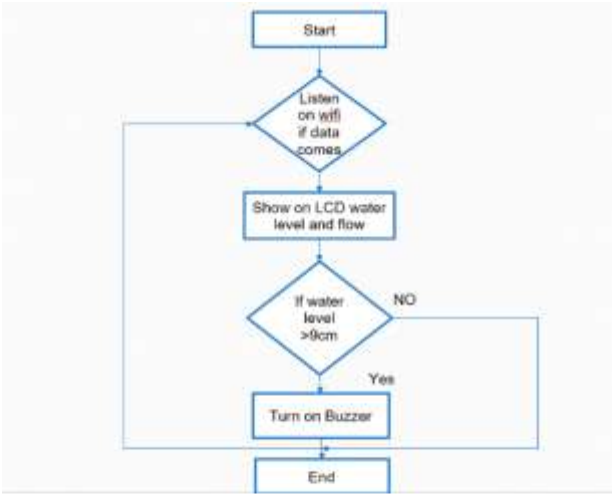

Fig-5. Algorithm for the Receiving Station Circuit.

This section details the algorithm governing the operation of the receiving end, which could be a mobile application or a dedicated display unit, as depicted in Fig.

A. Algorithm for Receiving Station Circuit

1) **Begin System**: Power ON the ESP controller at the receiving end and initialize all connected devices: the Wi-Fi communication module, LCD display device, and buzzer alert system.

2) **Listen for Incoming Data**: Keep the Wi-Fi module continuously ON and listen for incoming data packets from the transmitting end (sending real-time dam status).

- If data is received, proceed to Step 3.
- If no data, keep waiting (loop).

3) **Display Data on LCD**: On receiving data:

- Retrieve water level and flow rate information.
- Show both parameters directly on the local LCD display:
  - Present water level in centimeters (cm).
  - Present water flow rate in liters per minute (L/min).

4) **Check Water Level Condition**: Check the value of the received water level.

- If the water level is above 9 cm, proceed to Step 5.
- If the water level is below or equal to 9 cm, repeat Step 2 and continue monitoring without activating any alert.

5) **Activate Buzzer Alarm**: When the water level is above 9 cm:

- Turn on the buzzer to give an instantaneous acous- tical indication of the high-water level condition.
- The buzzer stays ON for a predetermined notice duration or until the system gets manually reset or the condition returns to normal.

1.5. ALGORITHM FOR MOBILE APPLICATION

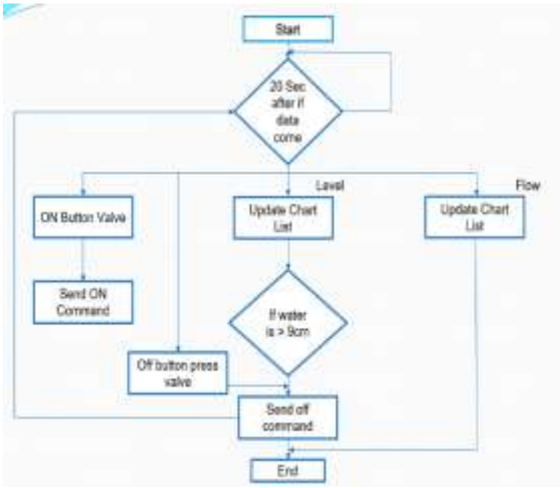

Fig.-5. Algorithm for Mobile Application.

This section describes the operational algorithm for the mobile application, as illustrated in Fig. 5.

A. Algorithm for Mobile Application

1) **Begin the Application**: Start the mobile application on the device. Initialize:
• Wi-Fi/Bluetooth communication with ESP controller.
• UI components such as charts, buttons (Valve ON/OFF), etc.

2) **Wait for Incoming Data**: Wait for 20 seconds after start-up to ensure new data packets are being received from the ESP. Data packets will contain:
• Water level data.
• Flow rate data.
Condition Check:
• If new data is received in 20 seconds, go to Step 3.
• If no data, keep waiting (loop).
3) **Update Real-Time Charts**: When data is received:
• Update the Level Chart: Graph/update the water level reading of the dam on a real-time graph or list.
• Update the Flow Rate Chart: Graph/update the water flow reading on a second graph or list.
These updates enable the operator to keep track of dam conditions visually over time.
4) **Monitor Water Level**: Check the most recent water level reading. Decision Point:
• If the water level is greater than 9 cm, go to Step 5.If the water level is ≤ 9 cm, remain in Step 2,
constant chart updating and watching.
5) **Automatically Send OFF Command**: In case the water level goes beyond the 9 cm critical point:
• Automatically issue an OFF command to the ESP.
• Such a command instructs the ESP to:
– Turn OFF the valve (if open).
– Initiate emergency handling mechanisms.

6) **Manual Control of Valve (User Interaction): Besides Automation:**
• Provide a Valve ON button on the app screen.
• If the user clicks the ON button: Send an ON command to the ESP to manually open the valve.
• Provide a Valve OFF button.
• If the user clicks the OFF button: Send an OFF command to ESP to shut down the valve manually.
7)**End Cycle or Continue Monitoring**: Upon auto-matic/manual command execution:
• Go back to Step 2.
• Continue receiving new data and updating charts in real-time.
The cycle runs indefinitely while the app is running.

2. Hardware Implementation

Fig-6. Hardware model.

We utilize, in this project prototype, an ultrasonic sensor placed within the red circular holder seen in the top side of the picture. It is tasked with sensing the water level. The huge transparent vessel signifies the dam reservoir.

Immediately after the dam outlet, the first black device on the pipe is an electrically controlled valve (solenoid valve). After this valve, the round-shaped device on the same pipeline is a flow sensor, which monitors the movement and amount of water flowing after opening the valve.

As the dam gate (valve) is switched on, water comes out through the pipe, and the discharge is sensed by the flow sensor. The control circuit, located at the top of the clear plastic box (similar to a bike carrier), is the central dam-side electronic system. The circuit consists of the ESP32 microcontroller that keeps checking the water level and takes the valve operation accordingly.

An LCD screen is also embedded in the control circuit to display real-time data like water level, system status, or flow rate.

3. ASSUMPTIONS

For ease of prototype construction and experimentation with the IoT-Based Dam Automation and Monitoring System, the following assumptions are made:

Fig-7. LCD Display

A. Water Level Measurement
Measuring the water levels in centimeters (cm) rather than feet or meters, given the miniature prototype tank and native output unit of the ultrasonic sensor. This offers good resolution and quick response for demonstration.

B. Water Flow Measurement
Flow rate is metered in Liters per Second (L/s) with a small-scale flow meter. Though actual dams operate on cubic meters per second (m^3/s), the model works on L/s for calibration and testing ease. This can be scaled mathematically to larger systems.

C. Maximum Water Level Threshold
The system provides a maximum water level limit of 9cm for alarm triggering, pump operation, and remote notification.
This limit is in reference to the physical limits and pumping capacity of the prototype tank, while such limits in full-scale systems are established based on safety and hydrological standards.

4. EXPERIMENTAL RESULTS AND ANALYSIS

Here, the experimental results of the Internet of Things (IoT)-based automation and monitoring system for the dam are presented, with specific emphasis on the real-time data as displayed using the mobile application interface. The system's performance in terms of continuously monitoring water pressure and water level and its automatic response to varying conditions are analyzed.
The home screen of the mobile application, as shown in Fig. 6, displays two most important graphs, which reflect the dynamic behavior of the dam. One of the graphs plots the water pressure (flow rate in Liters per second) against time, and the other the water level of the dam (in centimeters) against time. These graphs give an immediate clear idea of the status of the dam.

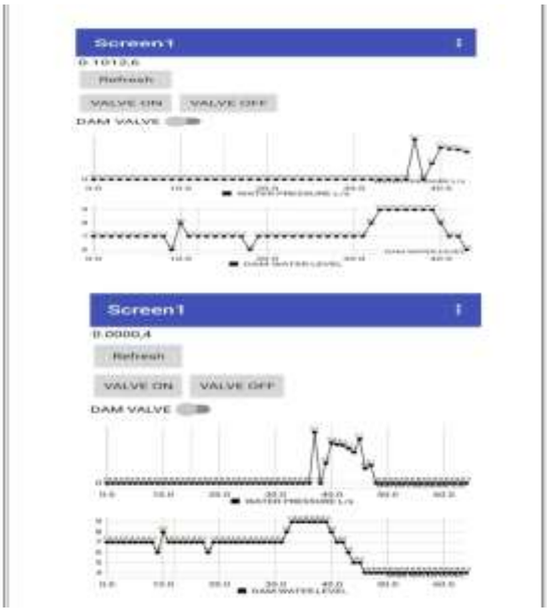

Fig-6. Mobile Application Output Interface Showing Water Pressure and Water Level over Time.

A. Analysis of Water Pressure (L/s) vs Time
From the top graph that we can view in the mobile app output, we notice the water pressure, which shows the rate of water flow. At first, from the beginning time (0 seconds) to about 20 seconds, the water pressure was recorded at 0.0 L/s. This means that the valve of the dam was closed at this time, and thus no water was being released.
As the system reached the 30–40 second interval, a small rise in water pressure was recorded, reaching approximately 0.1 L/s. This is a clear indication that the valve has opened, releasing a small rate of water discharge. Afterwards, between seconds 30 and 50, slight variations in pressure were recorded, still ranging from 0.0 L/s to 0.1 L/s. This trend indicates that the system was in controlled and slow water flow. Lastly, after 50–60 seconds, water pressure went back to 0.0 L/s, indicating that the valve had closed once more and halted the outflow of water.

B. Analysis of Dam Water Level (cm) versus Time
The lower graph on the mobile application interface presents the corresponding changes in the dam's water level over the same time duration. In the initial phase, from 0 to 20 seconds, the water level remained relatively stable, hovering around 7–8cm

3. CONCLUSION

This work effectively introduces the design and experi- mental demonstration of an Internet of Things (IoT) system for automatic dam monitoring and control. Meeting the key requirement of real-time data and responsive automation in dam control, our prototype effectively deployed a holistic solution to continually monitor water levels and flow rates. The system uses ESP32 microcontrollers, ultrasonic and flow sensors, and wireless communication for both local display and remote access via a specially developed mobile app.

The experimental findings conclusively confirm the system's basic functionalities. From the real-time graphs of the mobile application, we noticed the accurate measurement of water level (in cm) and water pressure (flow rate in L/s) with respect to time.

Most importantly, the system demonstrated its ability to control valve operations intelligently, opening the water discharge when the water level in the dam attained the set threshold value of 9 cm. This automatic response was able to cut down the water level to a safe operational level, thus proving the system's effectiveness in preventing overflow and controlling water resources.

Essentially, this work provides a strong and scalable so- lution for continuous dam monitoring, augmenting operating effectiveness, reducing disaster risk through early warnings, and enabling more accurate water resource management. The prototype provides a sound platform for further research in smart water infrastructure, providing an applicative solution for real-time information and automated remedies in dam settings.

4. ACKNOWLEDGMENT

We would like to thank Prof. S. S. Patil of the Electrical Engineering Department at PES Modern College of Engineering in Pune for his invaluable advice, unwavering support, and enlightening criticism during this project.

Additionally, we would like to express our gratitude to the laboratory staff and college administration for providing the tools and technical assistance required to successfully develop and test the prototype model.

We would especially like to thank our teammates and peers for their hard work and dedication in making this IoT-based solution a reality. Their assistance was crucial to finishing this study.

Finally, we thank the IJSREM platform for providing us with the chance to publish our work and help advance environmental engineering and smart infrastructure.

5. REFERENCES

[1] V. Sathya, K. Arun, H. Mahajan, and A. K. Singh, "Automate the Functioning of Dams Using IoT," 2019 3rd International Conference on Computing Methodologies and Communication (ICCMC), Erode, India, 2019, pp. 1102-1105, doi: 10.1109/ICCMC.2019.8819778.

[2] P. Negi, V. Pachouri, S. Pandey, M. Chaudhary, R. Singh, and G. Chhabra, "Automation Intervention using the Internet of Things in the Infrastructure of Dam," 2023 International Conference on Sustainable Computing and Data Communication Systems (ICSCDS), Erode, India, 2023, pp. 1185-1191, doi: 10.1109/ICSCDS56580.2023.10104629.

[3] S. S. Siddula, P. C. Jain, and M. D. Upadhayay, "Real Time Monitoring and Controlling of Water Level in Dams using IoT," 2018 IEEE 8th International Advance Computing Conference (IACC), Greater Noida, India, 2018, pp. 14-19, doi: 10.1109/IADCC.2018.8692099.

[4] L. R. S. T. Lekamge, N. P. T. D. Samaranayake, N. V. Weer- awarna, D. M. J. C. B. Dissanayake, H. M. S. C. Rathnayake, and N. Amarasena, "Integrated Smart Dam Control System Using Ma- chine Learning," 2024 6th International Conference on Advancements in Computing (ICAC), Colombo, Sri Lanka, 2024, pp. 91-96, doi: 10.1109/ICAC64487.2024.10851035.

[5] N. V. Swami and V. M. Jarali, "Performance measurement of laser communication prototype in free space for water dam using ATmega328 and comparison with ZigBee technology," 2017 International Conference on Big Data, IoT and Data Science (BID), Pune, India, 2017, pp. 167-170, doi: 10.1109/BID.2017.8336592.

[6] Y. H. C. Paucarcaja et al., "Design of a Control System for En- ergy Monitoring in Hydroelectric Power Plants with a Pumping Sys- tem," 2022 International Conference on Mechanical Engineering and Power Engineering (MEPE), Wuhan, China, 2022, pp. 43-47, doi: 10.1109/MEPE56451.2022.10146630.

[7] S. Parveen, S. M. Nabeel Mustafa, S. Soomro, and S. Bano, "Smart Water Level Monitoring System Using Internet of Things (IoT)," 2023 Global Conference on Wireless and Optical Technologies (GCWOT), Malaga, Spain, 2023, pp. 1-7, doi: 10.1109/GCWOT57803.2023.10064661.

[8] S. S. Siddula, P. Babu, and P. C. Jain, "Water Level Monitoring and Management of Dams using IoT," 2018 3rd International Conference On Internet of Things: Smart Innovation and Usages (IoT-SIU), Bhimtal, India, 2018, pp. 1-5, doi: 10.1109/IoT-SIU.2018.8519843.

[9] R. S. Ganesh, S. S, G. B. M, A. K. G, and G. D. S, "An IoT-based Dam Water Level Monitoring and Alerting System," 2022 International Confer- ence on Applied Artificial Intelligence and Computing (ICAAIC), Salem, India, 2022, pp. 1551-1554, doi: 10.1109/ICAAIC53929.2022.9792675.

[10] R. Raman and T. Rathi, "Efficient Dam Water Level Management Using Cloud-Based Data Analytics and LSTM Networks," 2024 11th Interna- tional Conference on Reliability, Infocom Technologies and Optimization (Trends and Future Directions) (ICRITO), Noida, India, 2024, pp. 1-6, doi: 10.1109/ICRITO61523.2024.10522183.