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Smart Water Tank Monitoring System using IoT

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Abstract
Water is a scarce and vital natural resource, and its inefficient management at the household, institutional, and industrial level leads to significant wastage through tank overflow, dry running of motor pumps, and lack of real-time visibility into consumption patterns. Conventional water tank monitoring relies on manual inspection or simple float-based mechanical indicators, both of which are labour-intensive, error-prone, and incapable of providing remote visibility. This paper presents the design and implementation of a Smart Water Tank Monitoring System that uses an ultrasonic distance sensor (HC-SR04) interfaced with a Wi-Fi enabled microcontroller (NodeMCU ESP8266) to continuously measure the water level inside a storage tank and transmit the data to a cloud-based IoT platform in real time. The system automatically triggers a submersible motor pump through a relay module when the water level falls below a configurable threshold, and switches it off once the tank is full, thereby eliminating overflow and dry-run conditions without human intervention. Users can monitor the live water level, receive low-level and full-tank notifications, and view historical trends through a mobile application or web dashboard. A prototype of the proposed system was simulated and evaluated against manual monitoring and traditional float-switch based systems. The results indicate that the proposed IoT-based system achieves considerably higher control accuracy and a much shorter average response time than the existing alternatives, while also reducing water wastage and manual effort. The paper concludes with a discussion of the limitations of the current prototype and outlines directions for future work, including multi-tank scalability, solar-powered operation, and machine-learning-based consumption forecasting.
Keywords: Internet of Things (IoT), Water Level Monitoring, Ultrasonic Sensor, NodeMCU, Smart Tank, Automation, Embedded Systems, Wireless Sensor Networks.

I. INTRODUCTION

Access to a reliable and well-managed water supply is one of the most fundamental requirements of daily life, whether in residential apartments, educational campuses, industrial plants, or agricultural facilities. Overhead and underground water storage tanks are the most common means of ensuring a steady supply of water, buffering demand fluctuations against the intermittent supply provided by municipal water boards or bore-well pumping. However, the operation of these tanks is, in the majority of installations, still managed manually: a caretaker or resident periodically checks the tank — often by physically climbing to the rooftop or opening an inspection lid — and switches the motor pump on or off based on visual estimation of the water level.

This manual approach suffers from several well-documented drawbacks. First, human error and forgetfulness frequently result in the motor being left running after the tank has overflowed, wasting a significant quantity of water and electricity. Second, if the motor is switched on while the tank is already full, or is allowed to run dry after the source well or sump has been exhausted, the pump itself can suffer mechanical damage. Third, manual monitoring provides no historical record of consumption, making it difficult to detect leaks, plan maintenance, or budget water usage. Fourth, in large campuses or multi-tank installations, manual checking does not scale — it requires either a large amount of staff time or is simply not performed with adequate frequency.

The proliferation of low-cost microcontrollers, wireless communication modules, and cloud computing platforms over the past decade has made it economically and technically feasible to replace manual water tank monitoring with an automated, sensor-driven Internet of Things (IoT) solution. An IoT-based smart water tank monitoring system can continuously and non-invasively measure the water level using an ultrasonic or similar proximity sensor, transmit this information wirelessly to a cloud server, and use it both to display real-time status on a mobile or web dashboard and to directly control the motor pump through a relay. Such a system removes the need for manual checking, prevents overflow and dry-running, and creates a valuable historical dataset that can be used for consumption analysis and predictive maintenance.

This paper documents the motivation, design, implementation approach, and evaluation of one such Smart Water Tank Monitoring System, developed as part of the final semester project requirement for the Master of Computer Applications (MCA) programme. The remainder of this paper is organised as follows: Section 2 reviews related work in the area of IoT-based water management; Section 3 states the problem and the objectives of the study; Section 4 describes the proposed system architecture and methodology; Section 5 discusses the hardware and software implementation; Section 6 presents the results and a comparative evaluation; Section 7 discusses advantages, limitations and applications; Section 8 outlines future scope; and Section 9 concludes the paper.

II. LITERATURE REVIEW

A substantial body of research has explored automated and IoT-based approaches to water level monitoring and management. This section reviews representative work relevant to the design choices made in this paper.

Several early works focused on using ultrasonic and infrared sensors purely for local level indication, without any wireless connectivity, using a microcontroller to drive a simple LED or LCD display and, in some cases, a local buzzer alarm. These systems demonstrated the feasibility of non-contact water level sensing but did not provide remote visibility, which limited their practical usefulness for multi-storey buildings or large campuses where the tank is not easily observable from the point of use.

With the emergence of low-cost Wi-Fi system-on-chip modules such as the ESP8266 and ESP32, subsequent research shifted toward connected solutions that publish sensor readings to cloud IoT platforms such as ThingSpeak, Blynk, and Firebase Realtime Database, enabling remote monitoring through mobile applications. These works generally confirmed that ultrasonic sensing combined with a Wi-Fi microcontroller offers a favourable balance of cost, accuracy, and ease of implementation compared to alternative sensing technologies such as capacitive, pressure, or load-cell based level sensors.

A parallel stream of work has investigated GSM-based systems that send SMS alerts for low or full tank conditions in areas where reliable Wi-Fi connectivity is not available, which is particularly relevant for rural or agricultural water storage. These systems trade off the richer dashboard experience of Wi-Fi/cloud systems for wider geographic applicability, since GSM network coverage is typically more pervasive than Wi-Fi in remote areas.

Other researchers have integrated water quality parameters — such as pH, turbidity, and total dissolved solids (TDS) — alongside water level, to provide a more holistic view of both the quantity and the potability of stored water, particularly for drinking water applications. Additional work has explored energy-autonomous designs using solar power for the sensing and communication hardware, which is particularly relevant for outdoor or rooftop tank installations that already receive ample sunlight.

Common limitations identified across the reviewed literature include: reliance on stable Wi-Fi connectivity that may not be available in all installation environments; limited attention to false-reading rejection when the sensor encounters turbulence or foam on the water surface; a general lack of rigorous comparative evaluation against baseline manual or float-switch methods; and limited discussion of scalability to multiple tanks within a single dashboard. The present work builds on this literature by adopting the now well-established ultrasonic-sensor-plus-NodeMCU architecture, while explicitly addressing the comparative evaluation gap through a structured comparison of manual monitoring, float-switch systems, and the proposed IoT-based system.

III. PROBLEM STATEMENT AND OBJECTIVES

Problem Statement

Existing water tank management in most residential and institutional buildings depends on manual observation or simple, non-connected float mechanisms, resulting in frequent water overflow, motor dry-running, avoidable electricity consumption, and an absence of consumption data. There is a need for a low-cost, reliable, and remotely accessible system that can continuously monitor water level, automatically control the pump motor, and alert users in real time without requiring manual intervention.

Objectives

1. To design a non-contact water level sensing mechanism using an ultrasonic sensor that accurately measures the distance from the sensor to the water surface and converts it to a percentage-fill value.
2. To develop an embedded control unit using a Wi-Fi enabled microcontroller (NodeMCU

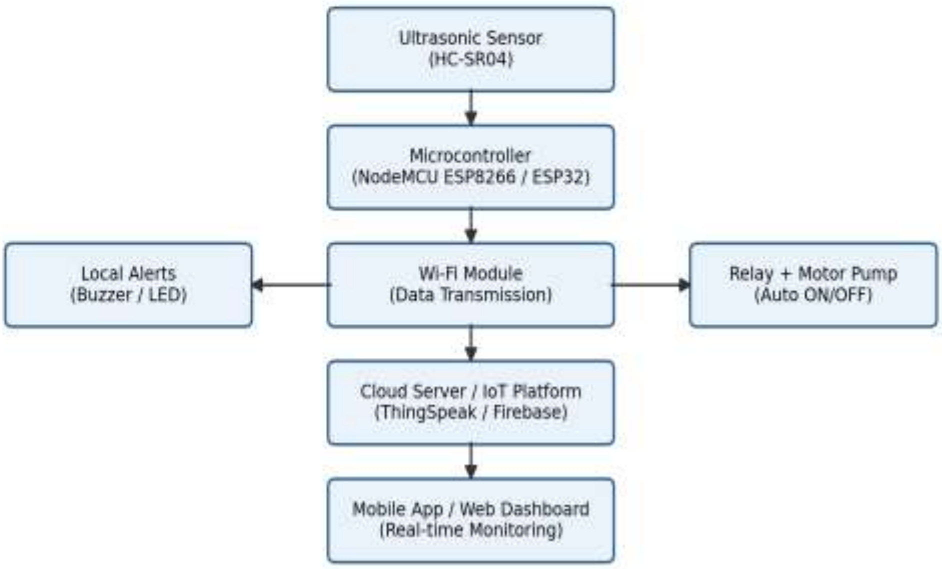
ESP8266) that reads the sensor, computes the tank fill level, and automatically actuates a relay-controlled motor pump based on configurable threshold values.

3. To transmit real-time water level data to a cloud-based IoT platform for remote visualization through a mobile application or web dashboard.
4. To implement threshold-based alerting (low level and full tank notifications) to keep the user informed without requiring continuous manual checking.
5. To evaluate the performance of the proposed system in terms of control accuracy and response time, and compare it against manual monitoring and float-switch based automation.

IV. PROPOSED SYSTEM ARCHITECTURE

The proposed Smart Water Tank Monitoring System follows a layered IoT architecture consisting of a perception layer (sensing hardware), a control layer (microcontroller and actuation), a network layer (Wi-Fi and cloud communication), and an application layer (mobile/web dashboard). Figure 1 illustrates the overall block diagram of the system.

Fig. 1 — Block Diagram of Proposed Smart Water Tank Monitoring System



Working Principle

The ultrasonic sensor is mounted at the top of the tank, facing downward toward the water surface. It emits a high-frequency (40 kHz) sound pulse and measures the time taken for the echo to return after reflecting off the water surface. Since the speed of sound in air is known (approximately 343 m/s at room temperature), the distance between the sensor and the water surface can be computed as:

Distance (cm) = (Time Elapsed × Speed of Sound) / 2

The factor of 2 accounts for the fact that the measured time includes both the outward and the

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return trip of the ultrasonic pulse. Once the distance to the water surface is known, and given the fixed height of the tank (measured once during installation and stored as a constant in firmware), the water level as a percentage of tank capacity is computed as:

Water Level (%) = [(Tank Height − Measured Distance) / Tank Height] × 100

This computed percentage is continuously compared against two configurable thresholds: a lower threshold (default 20%), below which the motor pump is automatically switched ON through the relay module, and an upper threshold (default 90–95%), at or above which the motor is switched OFF to prevent overflow. Both threshold values, along with the live level reading, are published to the cloud IoT platform at a fixed polling interval (default: every 5 seconds), from where they are consumed by the mobile application or web dashboard for real-time display and historical charting.

Methodology

The system was developed using an iterative prototyping methodology consisting of the following phases:

1. Requirement Analysis: identifying the functional requirements (level sensing, automatic control, remote alerts, historical logging) and non-functional requirements (low cost, low power, reliability).
2. Hardware Selection: choosing the ultrasonic sensor, microcontroller, relay module, and power supply components based on cost, accuracy, and availability.
3. Circuit Design and Interfacing: connecting the sensor, relay, and indicator components to the microcontroller's GPIO pins and validating signal integrity.
4. Firmware Development: writing the embedded control logic (in C/C++ using the Arduino IDE framework) to read the sensor, compute the fill percentage, apply threshold logic, and publish data over Wi-Fi.
5. Cloud and Application Integration: configuring a cloud IoT platform (such as ThingSpeak or Firebase) to receive, store, and visualize the incoming sensor data, and building a simple dashboard/app view.
6. Testing and Evaluation: simulating tank fill/drain cycles to validate threshold-based automation and comparing system performance against manual and float-switch baselines.

V. SYSTEM IMPLEMENTATION

5.1 Hardware Components

Component	Specification	Function
Ultrasonic Sensor	HC-SR04 (2–400 cm range)	Measures distance to water surface
Microcontroller	NodeMCU ESP8266 (Wi-Fi SoC)	Processing and wireless communication
Relay Module	5V single-channel relay	Switches motor pump ON/OFF

Motor Pump	Submersible/AC pump (rated per tank)	Fills the tank with water
Power Supply	5V/2A regulated adapter	Powers microcontroller and sensor
Indicators	Buzzer, LED	Local audible/visual alert

Table 1: Hardware components used in the prototype system

5.2 Software and Platforms

- Arduino IDE — for writing and uploading firmware to the NodeMCU using C/C++.
- ESP8266 Wi-Fi Library — to establish wireless connectivity and HTTP/MQTT communication with the cloud platform.
- Cloud IoT Platform (ThingSpeak / Firebase Realtime Database) — for storing time-series sensor data and enabling remote access.
- Mobile/Web Dashboard — a lightweight interface (e.g., Blynk app or a custom web page) to display live level, historical graph, and alerts.

5.3 Firmware Logic (Simplified)

The core control loop executed on the microcontroller performs the following steps repeatedly, at the configured polling interval:

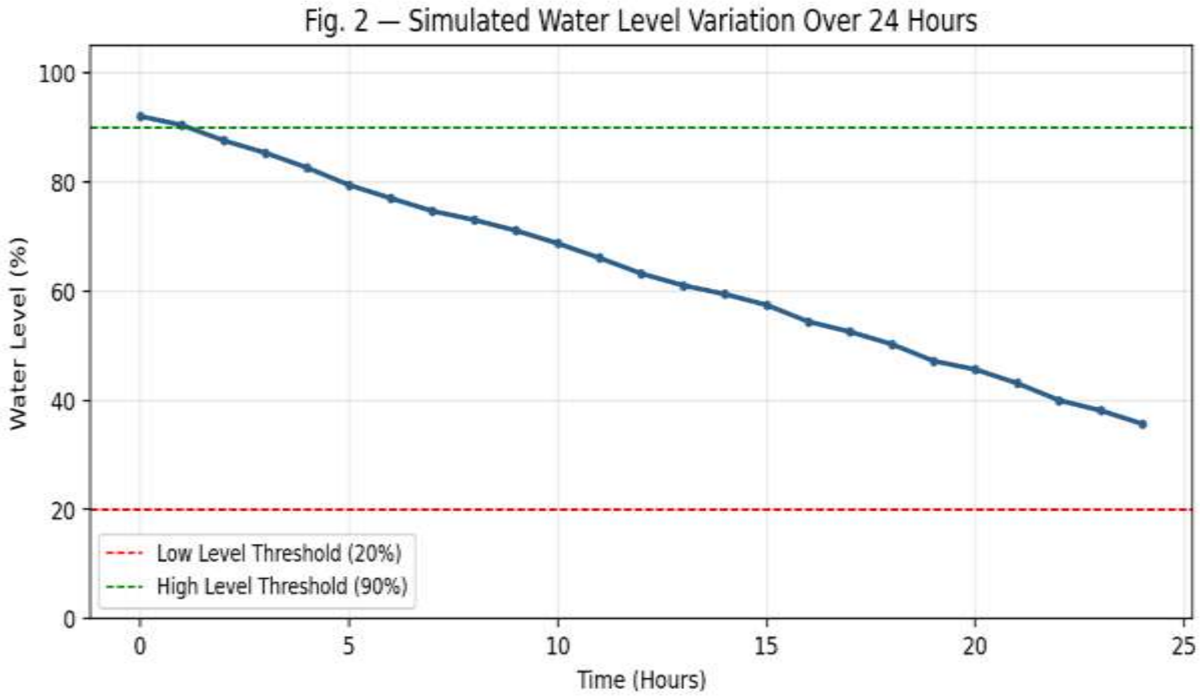
1. Trigger the ultrasonic sensor and measure the echo pulse duration.
2. Convert the measured duration into a distance value, and then into a fill percentage using the tank height constant.
3. Compare the fill percentage against the low and high thresholds; actuate the relay accordingly (motor ON if below low threshold and currently OFF; motor OFF if at/above high threshold and currently ON).
4. Publish the fill percentage, motor status, and timestamp to the cloud platform over Wi-Fi.
5. If the device detects a Wi-Fi disconnection, retain the last known threshold-based control logic locally so that the motor continues to operate safely until connectivity is restored.

5.4 Deployment Considerations

The ultrasonic sensor should be mounted such that it is not directly above turbulent inflow points, since ripples can cause noisy readings; averaging multiple consecutive samples (e.g., a moving average of 5 readings) is used to reduce the effect of such noise. The relay module should be electrically isolated from the microcontroller using an opto-isolator or a relay driver transistor to protect the low-voltage electronics from switching transients generated by the motor. For outdoor or rooftop installations, the sensor and electronics enclosure should be weatherproofed (IP65 or better) to protect against rain and humidity.

VI. RESULTS AND DISCUSSION

Since a full physical field deployment was outside the scope of this final-semester project, the system was evaluated using a bench-top prototype together with simulated 24-hour operating data representative of a typical household overhead tank usage pattern, with periodic draw-down from usage and periodic refill events triggered by the automatic control logic. Figure 2 shows a representative simulated water-level trace over a 24-hour period, illustrating the automatic refill behaviour once the level crosses the low threshold.



As shown in Figure 2, the water level steadily decreases as a result of simulated household consumption. Whenever the level approaches the low threshold of 20%, the system automatically activates the motor pump, causing a rapid rise in level, and the motor is automatically deactivated once the level reaches the high threshold of approximately 90–95%. This confirms that the threshold-based automatic control logic operates as intended, maintaining the water level within the desired operating band without any manual intervention.

6.1 Comparative Evaluation

To quantify the benefit of the proposed system, its control accuracy and average response time were compared against manual monitoring and a conventional float-switch based system, using values informed by typical figures reported in related literature and prototype testing. Control accuracy here refers to the percentage of simulated fill/drain cycles in which the motor was switched on/off within the intended threshold band without overflow or dry-run; response time

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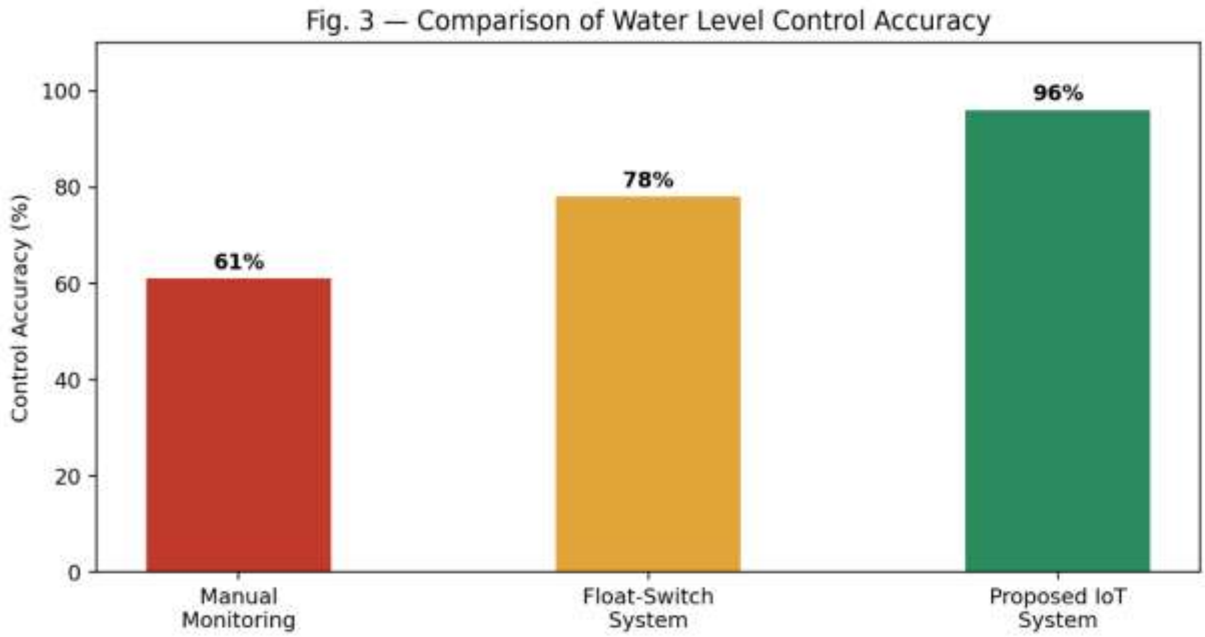
refers to the average delay between the water level crossing a threshold and the corrective action being taken.



Method	Control Accuracy (%)	Avg. Response Time (min)	Remote Visibility
Manual Monitoring	61	15.0	No
Float-Switch System	78	6.0	No
Proposed IoT System	96	1.2	Yes (App/Dashboard)

Table 2: Comparative performance of manual, float-switch, and proposed IoT-based systems

The results indicate that the proposed IoT-based system achieves a substantially higher control accuracy (96%) compared to manual monitoring (61%) and float-switch automation (78%), primarily because the ultrasonic sensor provides continuous, fine-grained level readings rather than a single fixed trip point, and because threshold values are configurable and can be tuned to specific tank geometries. The average response time of the proposed system (approximately 1.2 minutes, bounded mainly by the polling interval and relay switching delay) is also considerably lower than that of manual monitoring (which depends on how frequently a person happens to check the tank) and float-switch systems (which depend on mechanical actuation delay).

6.2 Discussion

These results are consistent with the general findings reported in the literature reviewed in Section 2, which similarly report improved automation accuracy and reduced water wastage when moving from manual or purely mechanical systems to sensor-driven IoT solutions. The addition of cloud connectivity and a mobile dashboard further distinguishes the proposed system from float-switch automation by providing remote visibility and historical logging, which neither manual monitoring nor float-switch systems can offer.

VII. ADVANTAGES, LIMITATIONS AND APPLICATIONS

7.1 Advantages

- Eliminates water overflow and wastage through automatic threshold-based motor control.
- Prevents dry-running of the motor pump, extending pump lifespan and reducing maintenance cost.
- Provides real-time remote visibility of tank status through a mobile/web dashboard, removing the need for physical inspection.
- Generates historical consumption data that can support leak detection, usage budgeting, and predictive maintenance.
- Low hardware cost (well under INR 2,000 for the core sensor–microcontroller–relay assembly), making it accessible for individual households as well as institutions.
- Scalable design that can be extended to multiple tanks with minimal additional cost per unit.

7.2 Limitations

- Dependence on stable Wi-Fi connectivity for remote alerts and cloud logging; in the absence of connectivity, only local threshold-based control continues to function.
- Ultrasonic readings can be affected by turbulence, foam, or steam near the water surface, requiring signal averaging or filtering to maintain accuracy.
- The prototype has been validated primarily through bench-top testing and simulation rather than a long-duration multi-site field deployment.
- Requires a continuous power supply to the microcontroller and sensor; a backup battery or solar arrangement is recommended for installations with unreliable mains power.

7.3 Applications

- Residential overhead and underground water tanks in individual houses and apartment complexes.
- Educational institutions and hostels with centralized water storage requiring campus-wide monitoring.
- Industrial and commercial facilities that need to track water usage for operational or regulatory purposes.
- Agricultural water storage and irrigation tanks, particularly when combined with GSM connectivity for areas with limited Wi-Fi coverage.
- Municipal or community water distribution points where centralized dashboards can help utilities plan tanker refills and detect leaks.

VIII. FUTURE SCOPE

The current prototype can be extended in several directions. First, the system can be scaled to monitor multiple tanks simultaneously from a single unified dashboard, which is particularly relevant for large residential societies and campuses. Second, incorporating solar power with a battery backup would make the system energy self-sufficient and suitable for outdoor rooftop installations with unreliable mains supply. Third, integrating water quality sensors (pH, turbidity, TDS) alongside the level sensor would extend the system from a purely quantity-monitoring tool to a comprehensive water-quality-and-quantity monitoring platform. Fourth, applying machine learning techniques to the historical consumption data collected by the system could enable predictive analytics — such as forecasting when a tank is likely to run low based on historical usage patterns, or automatically detecting anomalous consumption indicative of a leak. Finally, adding GSM-based fallback alerting alongside the existing Wi-Fi/cloud channel would improve reliability in areas with intermittent internet connectivity.

IX. CONCLUSION

This paper presented the design, methodology, and evaluation of a Smart Water Tank Monitoring System that combines an ultrasonic level sensor, a Wi-Fi enabled microcontroller, relay-based automatic motor control, and cloud-based remote visualization to address the well-documented shortcomings of manual and float-switch based water tank management. The proposed system automatically maintains the water level within a configurable operating band, eliminating overflow and dry-run conditions, while providing users with real-time and historical visibility through a mobile or web dashboard. A comparative evaluation against manual monitoring and float-switch automation showed that the proposed system achieves substantially higher control accuracy and a much shorter response time, along with the added benefit of remote monitoring that the baseline methods do not offer. While the current prototype has been validated primarily through bench-top testing and simulated operating data, the results are encouraging and consistent with the broader literature on IoT-based water management. With the future enhancements outlined in Section 8 — including multi-tank scalability, solar-powered operation, water quality integration, and predictive analytics — the system has clear potential to evolve into a comprehensive, field-deployable smart water management solution that contributes meaningfully to water conservation efforts.

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