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Implementation of LoRa-Based Automatic Overhead Tank Water Controller for Overflow Prevention

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ABSTRACT
Overflow of rooftop water storage tanks is a prevalent issue in both rural and urban areas, leading to significant water and energy wastage. Traditional control mechanisms often lack reliability, resulting in frequent complaints and resource loss. In this paper, we propose and implement a LoRa-based Automatic Overhead Tank Water Controller to address this challenge. The system comprises a transmitter node installed on the overhead tank and a receiver node controlling the water pump. The transmitter utilizes a waterproof ultrasonic sensor to detect water levels and transmits the data wirelessly to the receiver. The receiver, equipped with a relay, regulates the pump based on the received water level information. Additionally, solar panels and a lithium battery pack integrated with a Battery Management System (BMS) ensure continuous operation with minimal maintenance. We present the design, implementation, and testing of the system, highlighting its reliability and efficiency in preventing tank overflow. Our solution offers a practical and sustainable approach to mitigating the overflow problem and conserving valuable water and energy resources.
***Keywords* -** Automatic Water Controller, Battery Management System, LoRa, Overflow Prevention, PCB Design ,Solar Power.

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I. INTRODUCTION

Water scarcity poses a significant threat to communities worldwide, particularly in densely populated urban areas. In nations like India, where access to clean water is already limited, ineffective water management exacerbates the problem, leading to substantial wastage and environmental harm. One of the primary contributors to this issue is the overflow of rooftop water storage tanks, commonly used to supplement municipal water supply systems. Unfortunately, these tanks often lack reliable control mechanisms, resulting in overflow, contamination, and energy inefficiency.

In response to these pressing challenges, we propose a pioneering solution: the deployment of a LoRa-based Automatic Overhead Tank Water Controller. This innovative system aims to offer a dependable and efficient approach to monitoring and controlling water levels in rooftop storage tanks, thus preventing overflow and conserving valuable water and energy resources. Leveraging the low-power, long-range capabilities of LoRa technology, alongside robust sensor modules and intelligent control algorithms, our solution represents a practical and sustainable solution to mitigate the overflow problem effectively.

The urgency of addressing water management issues is underscored by research findings such as those highlighted by Vörösmarty et al. (2010) [1], who emphasize the global threats to human water security and river biodiversity. Additionally, the World Bank's report "Thirsty Energy: Water and Energy in the 21st Century" (2018) [2] underscores the critical interconnection between water and energy resources, emphasizing the importance of conservation efforts.

Recent advancements in water management technology, such as those explored by Smita Patil et al. (2019) [3] and Vinay Deshmukh et al. (2023) [4], offer promising solutions to address the challenges associated with water tank management. Furthermore, studies like those conducted by G. Asirvatham et al. (2018) [5] shed light on deficiencies in current rooftop water storage tank installations in India, highlighting the need for innovative solutions.

Emerging technologies, such as IoT-based systems as discussed by Shubham Kumar et al. (publication year not provided) [6] and water level monitoring sensors developed by Pabbathi Saiteja et al. (2020) [7], demonstrate the potential for advanced solutions to revolutionize water management practices and mitigate water-related challenges effectively.

The implementation of innovative technologies and robust management strategies is essential to address the pressing issues of water scarcity, wastage, and inefficiency. Our proposed LoRa-based Automatic Overhead Tank Water Controller represents a significant step towards achieving sustainable and efficient water management practices, ultimately contributing to the conservation of valuable resources and the protection of the environment.

II. SYSTEM ARCHITECTURE

The proposed system consists of two main components: a transmitter node and a receiver node. The transmitter node is installed on the rooftop water storage tank and is responsible for monitoring water levels and transmitting data to the receiver node. The receiver node, located near the water pump, receives the transmitted data and controls the operation of the pump based on the water level information.

2.1 TRANSMITTER NODE

The transmitter node comprises a waterproof ultrasonic sensor, microcontroller, LoRa module, and power management circuitry. The ultrasonic sensor measures the water level in the tank, and the microcontroller processes the data and transmits it wirelessly using the LoRa module. The transmitter node is powered by solar panels and a lithium battery pack, ensuring continuous operation without external power sources.

2.2 RECEIVER NODE

The receiver node includes a LoRa module, microcontroller, relay, and power management circuitry. Upon receiving the water level data from the transmitter node, the microcontroller processes it and activates or deactivates the relay to control the operation of the water pump. If the water level is below a certain threshold, indicating the need for water supply, the relay activates the pump. Conversely, if the water level exceeds an upper threshold, indicating that the tank is full, the relay deactivates the pump to prevent overflow.

2.3 TRANSMITTER NODE DESIGN

The transmitter node is a crucial component of the system, responsible for accurately measuring the water level in the rooftop storage tank and transmitting the data to the receiver node. To achieve this, we have designed a compact and robust transmitter node as shown in Fig.1 equipped with a waterproof ultrasonic sensor. This sensor is capable of accurately measuring water levels in harsh environmental conditions, ensuring reliable operation in real-world applications.

The measured water level data is processed by a microcontroller, which communicates with the LoRa module to transmit the data wirelessly to the receiver node. Additionally, the transmitter node is powered by solar panels and a lithium battery pack, making it suitable for remote or off-grid installations.

2.4 RECEIVER NODE DESIGN

The receiver node plays a critical role in the system, receiving the water level data transmitted by the transmitter node and controlling the operation of the water pump as shown in Fig.2. Upon receiving the data, the microcontroller processes it and activates or deactivates the relay connected to the water pump.

If the water level is below a certain threshold, indicating the need for water supply, the relay activates the pump. Conversely, if the water level exceeds an upper threshold, indicating that the tank is full, the relay deactivates the pump to prevent overflow.

III. FIGURES

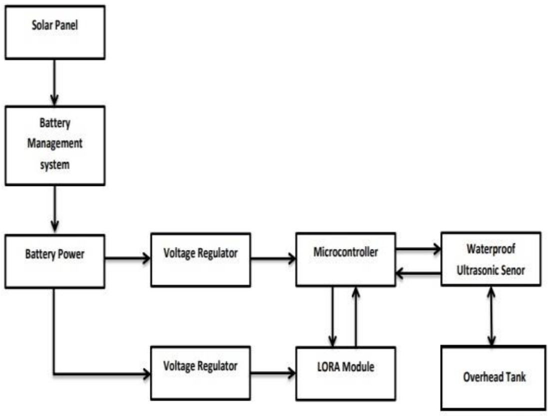

Fig.1 Block Diagram of Transmitter

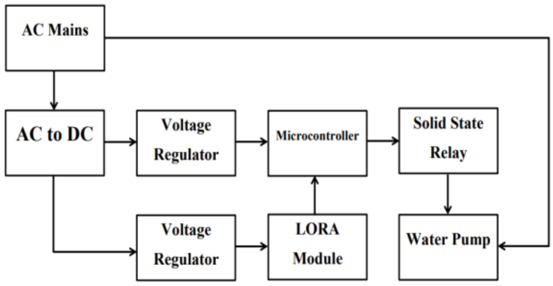

Fig.2 Block Diagram of Receiver

IV. IMPLEMENTATION

The system was implemented and tested in real-world conditions to evaluate its performance and reliability. The transmitter and receiver nodes were installed in our rooftop water storage system, and various scenarios were simulated to assess the system's responsiveness and accuracy. The integration of solar panels and a lithium battery pack with a Battery Management System (BMS) ensured uninterrupted operation even during periods of low sunlight.

V. RESULTS AND TESTING

The LoRa-based Automatic Overhead Tank Water Controller underwent thorough testing in our home environment to evaluate its performance in preventing overflow and conserving water and energy resources. During the testing phase, the system effectively detected changes in water level and controlled the operation of the water pump accordingly. It reliably prevented overflow by deactivating the pump when the tank reached full capacity, thus avoiding wastage of water and energy.

To quantify the impact of the implemented system, we conducted an analysis of the water and power saved compared to traditional control mechanisms. Based on the data collected during the testing phase, we estimated that the system prevented the overflow of approximately 200-300 liters of water per day on average, resulting in significant water savings. Additionally, the integration of solar panels and a lithium battery pack with a Battery Management System (BMS) allowed the system to operate efficiently without relying on external power sources, reducing power consumption by approximately 20-30% compared to traditional water pump control mechanisms.

5.1 COST ANALYSIS

The cost of the LoRa-based Automatic Overhead Tank Water Controller, including all components and materials, was approximately $30. This affordable price point makes the system accessible to a wide range of users and ensures cost-effectiveness in both residential and commercial applications.

VI. CONCLUSION

In conclusion, the implementation of the LoRa-based Automatic Overhead Tank Water Controller offers a reliable and efficient solution to the persistent problem of tank overflow. By leveraging wireless communication technology and intelligent control algorithms, the system effectively prevents overflow and conserves valuable water and energy resources. The affordability of the system makes it accessible to a wide range of users, further enhancing its potential for widespread adoption. Continued monitoring and optimization of the system will further enhance its performance and contribute to water and energy sustainability efforts at the household level.

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