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uijslictr@gmail.com

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Design and Construction of a Wireless Automatic Water Monitoring System

[1]✉ Nwufoh, C. V., [2]Adegbile, A. A., [3]Dada, T. O., [4]Dambazau, A. B., [5]Owosibo, A. R. and [6]Adewale, F. O.,

Federal College of Animal Health and Production Technology
Chinonyelum.tabansi@yahoo.com, alibimpe@gmail.com
,timothydada16@gmail.com
bellorashid@gmail.com, owosiboabiola@gmail.com,
Funmilayo.adewale@fcahptib.edu.ng

Abstract
Water management involves the planning, development, distribution, and control of the optimal use of water resources in an environment—sourced from boreholes, wells, and other means. Ensuring the sustainability of available water resources has become a critical concern globally, as water remains an essential element for human survival. Radio Frequency (RF) refers to the oscillation rate of electromagnetic radiation or radio waves. In this study, a Wireless Automatic Water Monitoring and Pump Control System was proposed, designed, and implemented to wirelessly monitor water levels in a tank using RF technology and to automatically control the pump operation. Sensors were placed at various levels in the tank to detect water levels at any given time. An embedded system, centred around the PIC16F877A microcontroller, was used to process input signals received via RF from the transmitter module. These inputs were processed through an inverter, and the resulting outputs determined whether the pump was activated or deactivated depending on the tank's water level. The system was tested and evaluated. Results showed that it accurately detected water levels and effectively managed the pump, switching it ON when water was low and OFF when the tank was full.

Keywords: *Water Management, Radio Frequency (RF), Wireless Water Monitoring, Pump Control System, Embedded System.*

1. Introduction

Water management is the strategic process of planning, developing, distributing, and regulating the optimal use of water resources available within an environment, particularly from sources such as boreholes and wells. The sustainability of water resources is increasingly becoming a global issue due to the essential nature of water. Experts estimate that the human body requires approximately 1.42 Liters (48 ounces) of water daily to survive [10]. The significance of water is evident in astronomical studies, where the presence of water is a key criterion for determining a planet's suitability for human habitation.

Water wastage arises mainly from poor allocation, inefficient usage, and a lack of adequate and integrated water management systems [3]. In most households and offices, water is manually pumped when the tank is empty and stopped when full. This method is inefficient, time-consuming, and resource-intensive. Several researchers have contributed to the advancement of automated water monitoring systems. Ajay and Yadav [2] developed a wired water level monitoring system using ultrasonic sensors and Arduino, which lacked flexibility for remote applications. Shweta and Kanchan [8] presented an IoT-based solution with Wi-Fi and cloud integration but noted its limitations in low-connectivity areas, supporting the need for RF-based alternatives. Kumar *et. al.* [5] used float sensors and GSM for alerts but did not automate pump control. Patil and Nandurkar [7] utilized ZigBee for wireless detection, highlighting its effectiveness in reducing wiring and deployment complexity. Aye [3] stressed the inefficiencies in manual water management and recommended low-

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cost embedded automation, aligning closely with the RF-based system proposed in this study.

To address this problem, a wireless automatic water level indicator and pump control system has been developed. This system monitors and maintains the water level in a tank without human intervention, ensuring a continuous water supply, conservi ng energy, and preventing pump overuse. It is applicable in residential and industrial settings. The system turns the pump ON when water is below a threshold and OFF when it reaches the upper limit, thus preventing overflow and optimizing resource usage.

2. Related Works

López-Munoz, [6] designed a hybrid water monitoring system using both stationary and mobile (aquatic) sensor nodes. The mobile node navigates water bodies was used to collect real-time data, while stationary nodes relay information wirelessly to a central server. The work demonstrated how combining fixed and mobile sensing improves spatial coverage and data reliability. The work is very useful for large lakes/rivers where fixed sensors alone cannot capture variability.

Syed Taha [9] focusses on the assessing LoRa communication for transmitting water quality data. Field experiments with LoRa nodes equipped with pH, turbidity, TDS, and dissolved oxygen sensors were used. The work identified optimal LoRa settings for reliability and energy efficiency, highlighting the trade-off between packet success rate and power use and provide practical design insights for long-range, low-power water monitoring systems.

Azghadi [4] emphasis on the development of a low-power LoRa-based system specifically optimized for energy efficiency, duty-cycling strategies and optimized transmission intervals to extend battery life in sensor nodes was propose. The paper demonstrated that a careful scheduling and lightweight edge processing significantly increase system longevity. The work is essential for remote deployments where frequent battery replacement or charging is impractical.

Abrajano [1] designed a low-cost Arduino/ESP32 system for rural/off-grid areas that measured pH, turbidity, and temperature; data sent via Wi-Fi to a cloud platform with SMS alert capability. The work showed feasibility of deploying affordable IoT water monitoring in developing regions with limited infrastructure. The work can be used as a strong case study for community health and accessibility, demonstrating social impact of IoT systems.

3. Materials and Methods

The design and implementation of the wireless automatic water monitoring and pump control system followed the System Development Life Cycle (SDLC), involving the following phases: problem identification, analysis, design, development, coding, testing, and maintenance.

3.1 System Components

The system comprises two main parts:

(i) *Hardware:* Assembled on a Vero board and enclosed in a plastic casing.
(ii) *Software:* Developed in C language using the MikroC compiler for programming the microcontroller.

3.2 Design Phases

(i) *Circuit Design:* This involved drafting the circuit diagram and appropriately placing components for their intended electrical functions.
(ii) *Programming and Application Development:* The PIC16F877A microcontroller was programmed using C. The high-level code was compiled and transferred to the microcontroller using a programmer.
(iii) *Physical Construction:* The final circuit was constructed using the designed schematic and assembled in a durable plastic enclosure.

3.3 Major Components

(i) *Sensors*: Detect water levels.
(ii) *Microcontroller (PIC16F877A):* Processes input signals and controls the pump.
(iii) *LEDs:* Indicate power and status.
(iv) *Vero Board:* Mounts all components.
(v) *Capacitor, Diode, Voltage Regulator, Variable Resistor:* Electronic

components supporting system stability.

(vi) *RF Modules:* Facilitate wireless communication between sensor / transmitter and receiver / microcontroller.

(vii) *LCD:* Displays water level status. *Solar Panel & Battery:* Provide power and backup.

(viii) *Relay & Transistors:* Control pump operation and amplify signals.

(ix) *Cat 5e Cables & Switch:* Enable connectivity and control signal flow.

3.4 Block Diagrams and Circuit Design

Figure 1 shows the block diagram for signal receiver showing how the information about the water level is received wirelessly to the control system for processing.

Figure 2 shows the block diagram showing the signal transmitter side, information about the water level is transmitted wirelessly to the control system.

Figure 3 shows system circuit diagram showing the connections to the microcontroller, the receiver side of the rf (radio frequency) that control all the functions of the system.

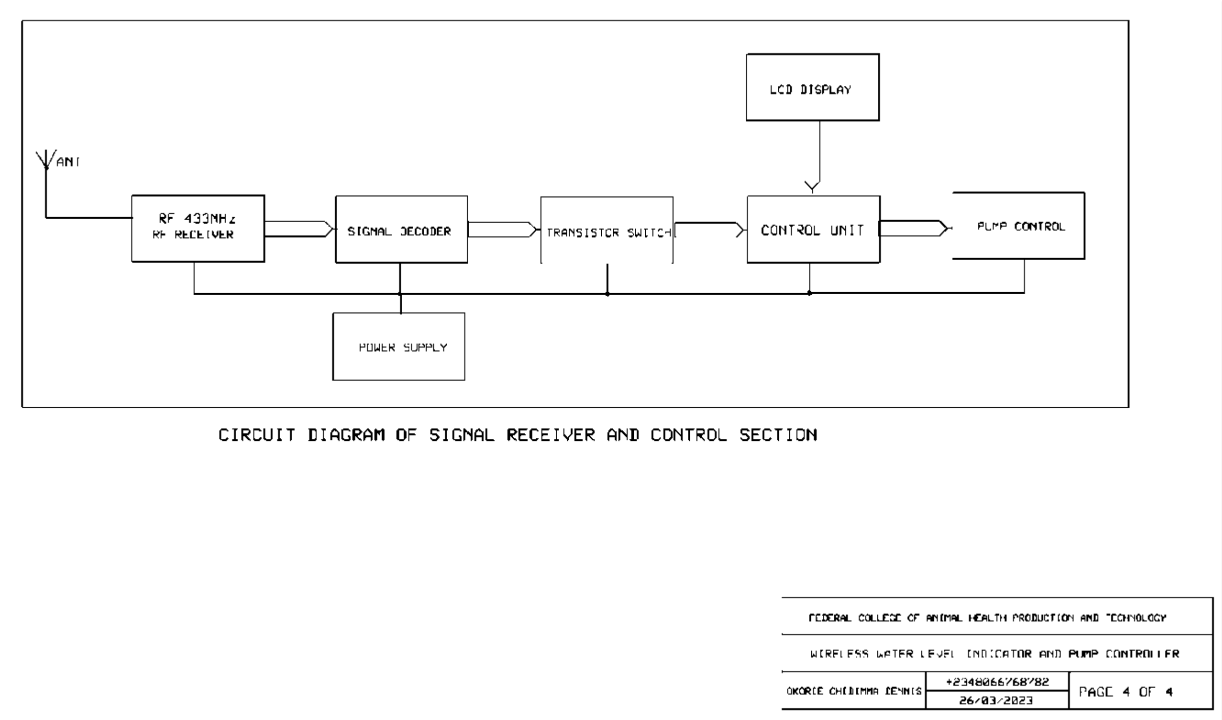

Figure 1: Block diagram of signal receiver and control section

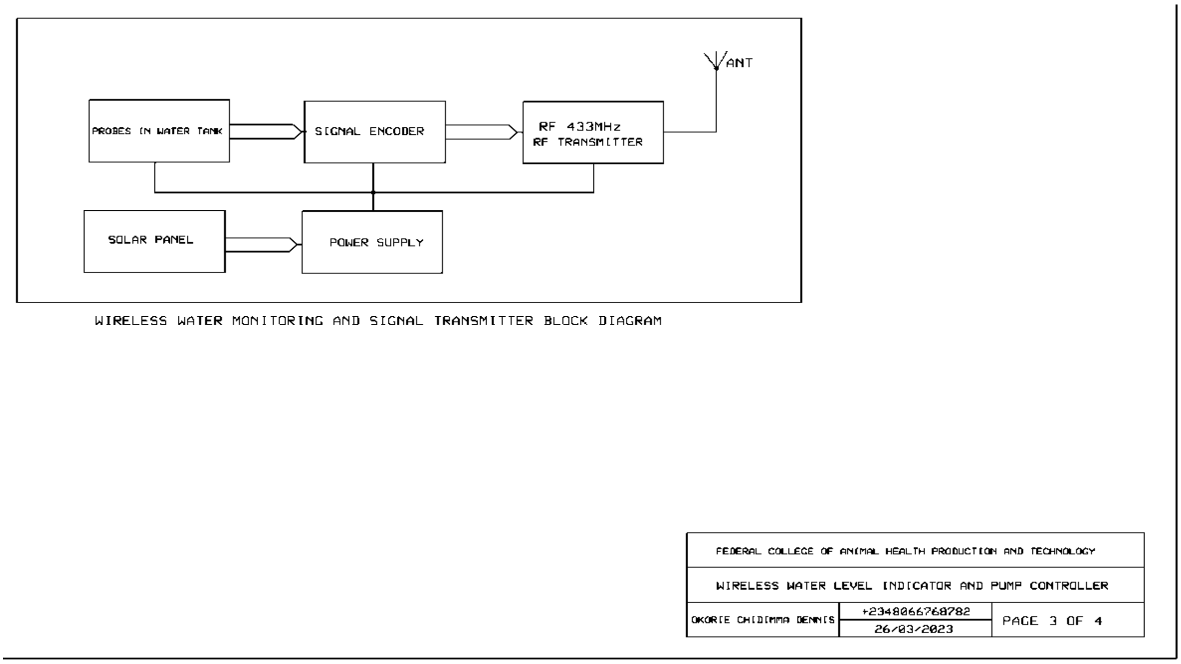

Figure 2: block diagram of signal transmitter

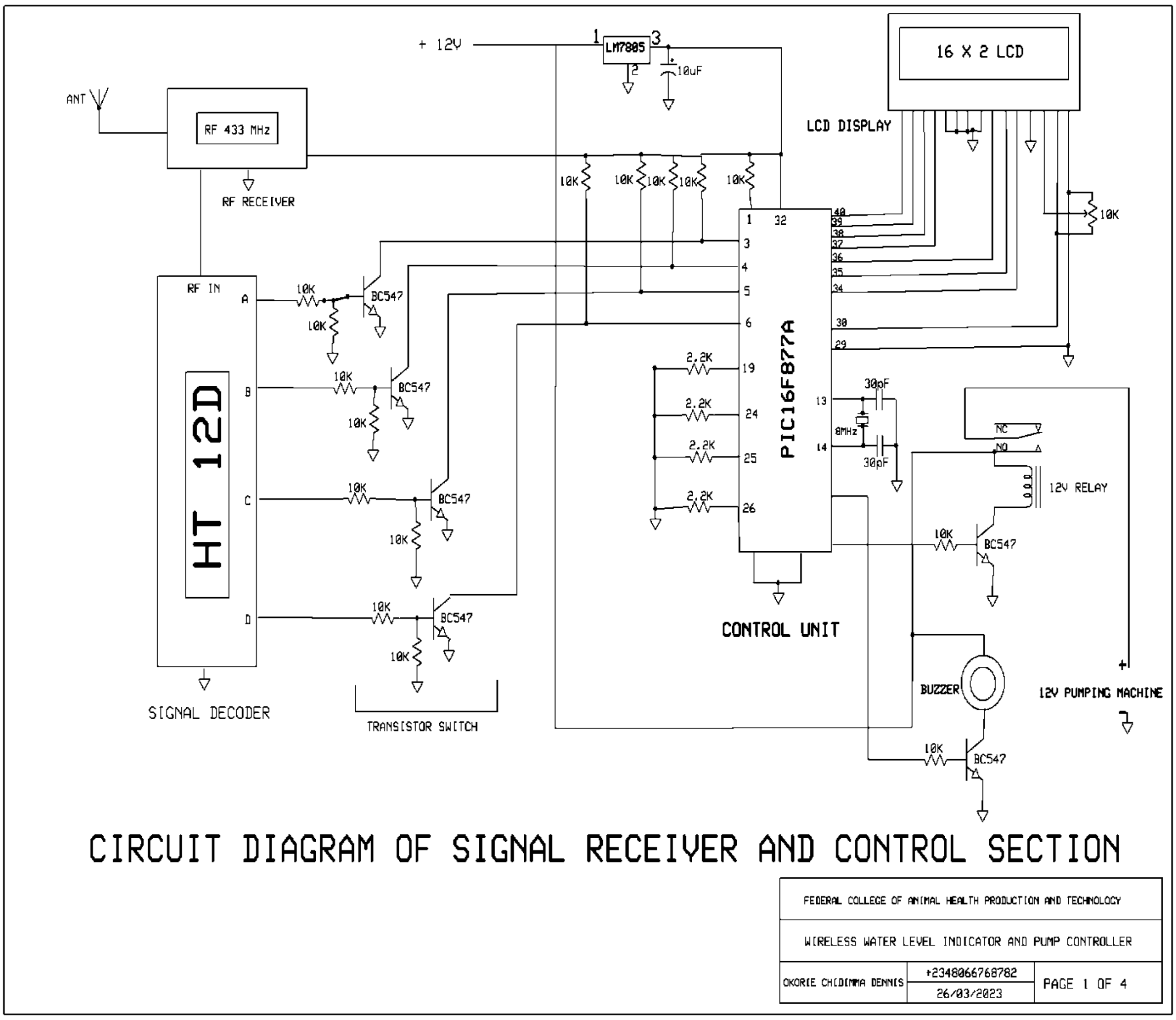

Figure 3: circuit diagram of signal receiver and control system.

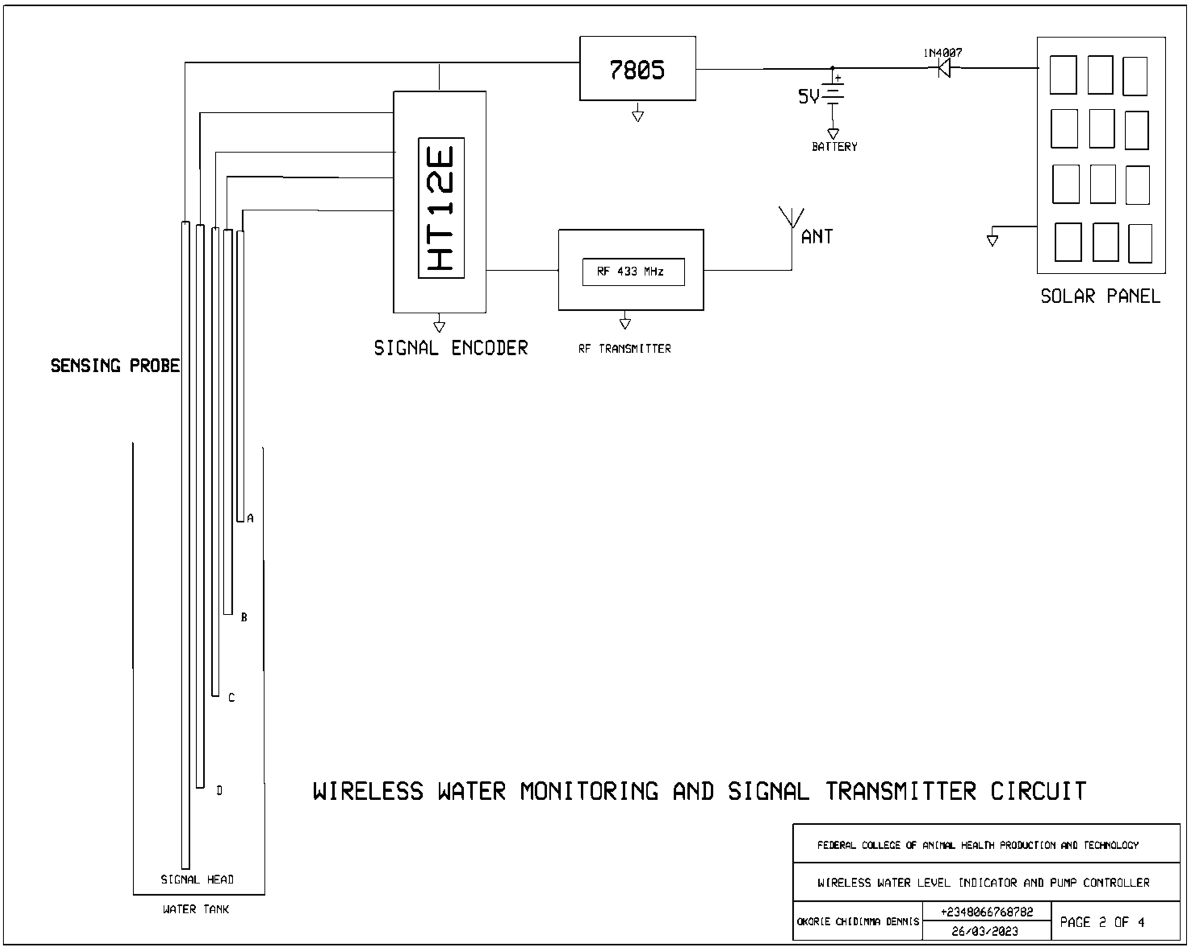

Figure 4: Signal transmitter circuit diagram

Figure 4 is the sensor and signal transmitter circuity diagram showing where the information about water level is sent to the receiver side of the rf (radio frequency).

The wireless automatic water level indicator and pump control system consists of four conductive sensors connected to the transmitter circuit of the radio frequency (RF) module. These sensors detect the presence or absence of water at specific levels within the tank. The transmitter sends the detected level data wirelessly to the receiver module, which is interfaced with a microcontroller (PIC16F877A). Upon receiving the signal, the microcontroller processes the data, converts it into a digital format, and displays the corresponding water level on the LCD.

Simultaneously, the microcontroller controls the operation of the pump through a relay module. When the system is powered on, it begins monitoring water levels in real time. Based on the sensor inputs, it automatically turns the pump ON when the water level falls below a certain threshold and turns it OFF when the tank reaches its full capacity. This ensures efficient water usage and prevents overflow or pump overuse.

The operational flow of the system is illustrated in Figure 5, which presents the system flowchart from the initial power-up sequence to the automatic regulation of the pump based on real-time water level monitoring.

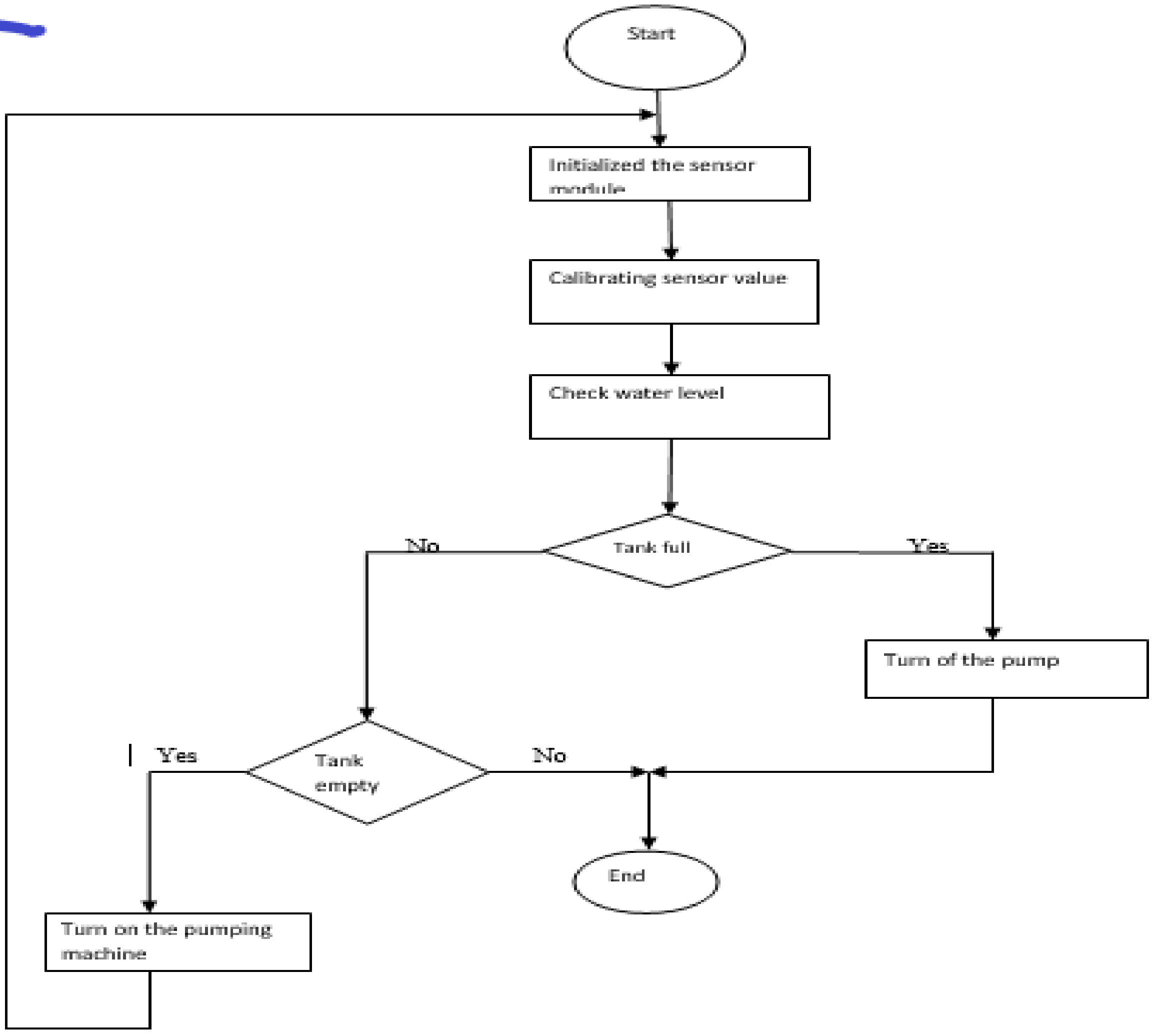

Figure 5: System flow-chart showing the process of operation

4. Results and Discussion

The developed wireless automatic water monitoring and pump control system was thoroughly tested to evaluate its functionality and performance under various operational conditions. Upon powering the system, the initial state displayed “VERY LOW” on the LCD, and an audible alert was triggered—indicating that the tank was empty. This condition automatically activated the pumping machine without human intervention.

As the water level in the tank increased, the sensors positioned at specific intervals detected the change in water levels. The data collected by the level sensors were transmitted wirelessly via the RF transmitter module to the receiver module connected to the microcontroller (PIC16F877A). The microcontroller processed these inputs and controlled the relay circuit, which in turn managed the ON/OFF state of the pump based on predefined water level thresholds.

The system demonstrated real-time responsiveness, consistently turning the pump ON when the water dropped to the "medium" level and OFF when the tank reached the "full" level. The LCD display accurately showed the current water level at each stage of the operation. This automation eliminated the need for manual monitoring or operation, thereby saving time and reducing the chances of overflow or pump burnout.

Furthermore, the RF-based wireless transmission proved reliable over a distance of up to [specify range if known], maintaining consistent communication between the transmitter and receiver modules without signal interference or data loss.

The following observations were made during testing:

(i) ***Low Water Level Detection:*** Accurately detected and displayed on the LCD; pump activation was immediate.
(ii) ***Medium Water Level:*** Triggered the pumping mechanism if below the threshold; ensured intermediate refill functionality.
(iii) ***Full Tank Detection:*** Promptly shut off the pump; prevented overflow and minimized power usage.
(iv) ***Response Time:*** The system responded within 1–2 seconds of level detection, indicating high sensitivity and efficient signal processing.
(v) ***Power Reliability:*** With the inclusion of a solar panel and battery backup, the system maintained uninterrupted operation even during brief power outages.

Figures 6 and 7 illustrate the system in active operation. Figure 7 shows the pumping action triggered by low water level detection, while Figure 8 captures the control system managing the pump in real-time based on input from the water sensors.

These results validate the effectiveness of the system in automating water tank management. The integration of wireless communication, sensor-based monitoring, and microcontroller logic provides a robust and scalable solution suitable for both residential and industrial environments.

This is the system in operation where the whole system is connected together and power on to pump water and the pumping operation was successful.

Figure 6: System testing showing pumping operation.

Figure 7: The control system in operation.

5. Conclusion

Effective water management is vital for sustainability. This study successfully designed and constructed a wireless automatic water level monitoring and pump control system using locally sourced components. The system accurately monitors water levels and automates pump operation, displaying levels on an LCD and ensuring the pump is only active when necessary. This contributes to reduced water wastage, energy savings, and enhanced convenience, making it suitable for both residential and industrial applications.

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