International Journal of Trend in Scientific Research and Development (IJTSRD)
Volume 8 Issue 5, Sep-Oct 2024 Available Online: www.ijtsrd.com e-ISSN: 2456 – 6470

Smart Water Pumping System with IoT Monitoring and Metering

Mbonu, Ekene S.; Kalu, Godswill; Moffat, Emediong A.; Madu, Ben K.; Sam-obisike Chibueze W.; Mbegbu, Chukwudi A.; Maduwuba, Ifesinachi F.; Okemeziem, Godstime U.; Ugodu, Chimaobi M.

Department of Mechatronics Engineering, Federal University of Technology, Owerri, Nigeria
(Email: godswillkalu.gk@gmail.com)

ABSTRACT

This paper presents the design and implementation of a smart water pumping system with integrated IoT monitoring and metering capability. Water management scheme has led to collapse of many governments owned water corporations. IoT can be used to improve water management system. In this work, a smart water pumping system that pumps water automatically, computes the volume and equivalent price while transmitting the same to a cloud-based resource is developed. In the methodology, ultrasonic sensor interfaced to ATmega328 microcontroller is used as an input sensor that measures the water level. A DC pump interfaced to the controller using a relay as a driver is used to pump water from the underground reservoir to the overhead tank. A closed loop control algorithm for automation of the system was developed using embedded C, hybrid assembly, C and C++ languages. Arduino Integrated Development Environment was used to develop the code for implementation of the flowchart for the control algorithm. The entire system was integrated with an (Internet of Things) IoT gateway SIM808 which transmits selected parameters of the system to the cloud. Specifically, the volume of water and associated price calculated using a mathematical model developed in the work are transmitted to a cloud resource, Thing Speak server. Simulation results showed that the system design worked as expected even as the proof-of-concept prototype demonstrated that the concept of this work can be implemented. The result of this work is recommended for individuals that would want to get into commercialization of water distribution, as well as government agencies that would want to adopt IoT management system for Wide Area Water distribution (WAW).

***KEYWORDS:** ATmega328 Microcontroller, Ultrasonic Sensor, IoT monitoring, C++, Wide area water distribution, Smart water pumping system, Water management*

How to cite this paper: Mbonu, Ekene S. | Kalu, Godswill | Moffat, Emediong A. | Madu, Ben K. | Sam-obisike Chibueze W. | Mbegbu, Chukwudi A. | Maduwuba, Ifesinachi F. | Okemeziem, Godstime U. | Ugodu, Chimaobi M. "Smart Water Pumping System with IoT Monitoring and Metering" Published in International Journal of Trend in Scientific Research and Development (ijtsrd), ISSN: 2456-6470, Volume-8 | Issue-5, October 2024, pp.498-505, URL: www.ijtsrd.com/papers/ijtsrd69391.pdf

IJTSRD69391

I. INTRODUCTION

Water pumping systems play a vital role in various sectors, including agriculture, industrial processes, and domestic water supply. However, some lapses in the present water pumping systems include:

- Conventional pumping systems often lack real-time monitoring and efficient control mechanisms, leading to wastage of water, energy, and resources.
- Manual monitoring and metering processes result in limited visibility and hinder the ability to promptly detect and address issues such as leakages, equipment malfunctions, or abnormal usage patterns.

The ultrasonic sensor is a digital level gauge controlled by a microprocessor. In the measurement, the ultrasonic pulse is emitted by the sensor (transducer). The sound wave is reflected by the liquid surface and received by the same sensor. It is converted into an electrical signal by a piezoelectric crystal. The time between the transmission and reception of the sound wave is used to calculate the measure of the distance to the surface of the liquid.

Advantages: non-contact measurement, fast response time and the measured medium is almost unlimited, and it can be widely used for measuring the height of various liquids and solid materials.

SIM808 module is a GSM,GPRS and GPS three-in-one function module. It is based on the latest GSM/GPS module SIM808 from SIMCOM, supports GSM/GPRS Quad-Band network and combines GPS technology for satellite navigation. The module can used easily for realtime tracking applications. The tracking is done by reading the GPS coordinates (longitude and latitude) and then sending them by using a HTTP request to a web server. Then you can use any internet browser to load the PHP webpage such as Google maps to show the location in realtime. You send location by sms message.

SIM900 is the most suitable for interfacing with arduino UNO but it had issues connecting to network, so customers had troubles using it and the market demand for it became low. The market switched to SIM808 with GPRS/GSM enabled and SMS capacity which enables us to simulate project completely.

Thing Speak is an IoT platform that provides data storage, analysis, and visualization capabilities and its communication Protocols are HTTP(S) and MQTT. It has a Channel-based storage with built-in charting and visualization tools and its security features are HTTPS, API keys and user authentication.

This study is done to show the possibility of using an ultrasonic sensor to measure water level and the use of IoT to monitor water level information in a smart water pumping system. The adaptation of IoT and advancements in sensor technology provide an opportunity to transform traditional water pumping systems into smart and interconnected networks.

This work will look at the interfacing of different components, simulation using necessary software and physical implementation of this project.

II. PROBLEM STATEMENT

The current pumping systems suffer from various issues such as lack of automation and real-time monitoring, inaccurate billing, resource wastage and limited control over the system's performance. These issues result in inefficiencies, higher costs, and environmental concerns.

There is need to develop a software solution that enables efficient management of water pumping systems. A smart automatic water control system solves the problem of water conservation by efficiently managing and controlling the distribution and use of water in residential, commercial, and agricultural settings. It can also help to reduce water waste and costs associated with overuse or leaks. There is need to implement an automatic water pumping system to achieve this proposed objective.

III. AIM AND OBJECTIVES

The aim of this project is to design and implement a smart water pumping system with IoT monitoring and metering. In order to achieve the aim the research efforts shall be geared towards the following objectives:

1. To interface:
   - HC-SR04 ultrasonic sensor to ATmega328 microcontroller.
   - DC Pump to ATmega328 microcontroller.
   - SIM808 GSM/GPRS/GPS module to ATmega328 microcontroller.
2. To transmit data from ATmega328 micrcontroller to the ThingSpeak Server..
3. To design and simulate a smart water pumping system with IoT monitoring and metering on Proteus design suite.
4. To physically implement a smart water pumping system with IoT monitoring and metering.

IV. REVIEW OF LITERATURE

In this system [3], the water quality sensors collect data, from industrial water and municipal water storage, which are gathered at the sub-station at which the data are processed. This processed data is sent to the main station through Ethernet networks running on TCP/IP and from the main station that data is again differentiated and given to the environment department and public department using the internet. This system has increased data accuracy, reliability, and efficiency, and also it gives effective data management and fully integrated information systems. However, the drawback is that it cannot provide real-time monitoring of water parameters.

The IoT-enabled Smart Water Management System (ISWMS) proposed in the paper [4] offers an innovative approach to managing water resources, integrating sensors, data analytics, and real-time monitoring. By utilizing ultrasonic sensors, Raspberry Pi, and an IoT-based control system, the platform allows users to monitor and automate water distribution, thus reducing wastage due to overflow and leakage. The system proves beneficial for domestic, commercial, and public applications, enabling efficient water use and conservation. However, several limitations are evident. Firstly, the system's reliance on stable internet connectivity may pose challenges in regions with poor network infrastructure. Additionally, the system is primarily focused on monitoring water levels, without incorporating broader parameters such as water quality or flow rate, which are vital for comprehensive water management. The system also lacks automated alert mechanisms that could further improve proactive maintenance. Furthermore, while the cost is affordable, scalability for larger water management infrastructures or rural areas with scarce internet remains a challenge. These limitations indicate the need for further refinement to enhance the system's adaptability, automation, and efficiency.

From the literature review, the components chosen for this project are: HC-SR04 ultrasonic liquid level sensor, ATmega328 microcontroller embedded in arduino UNO, SIM808 GSM/GPRS/GPS, 5V relay module and 12V DC pump. ThingSpeak is used as the cloud server.

V. MATERIALS AND METHOD

A. Materials

To carry out this project, the following materials and tools were used:

- Hardware tools:

a. HC-SR04 ultrasonic sensor
b. Arduino UNO
c. SIM808 GSM/GPRS/GPS module
d. A simcard
e. A 12V DC pump
f. A 5V relay module
g. Jumper wires
h. Buckets
i. Hose
j. Soldering iron
k. Soldering lead
l. Multimeter
m. A 12V DC power supply
n. 9v adapter

- Software tools:

a. Proteus Design Suite
b. Arduino IDE
c. ThingSpeak Server
d. MATLAB
e. Libraries for electronic component

B. Methods

A. Interfacing of ultrasonic sensor to ATmega 328 microcontroller

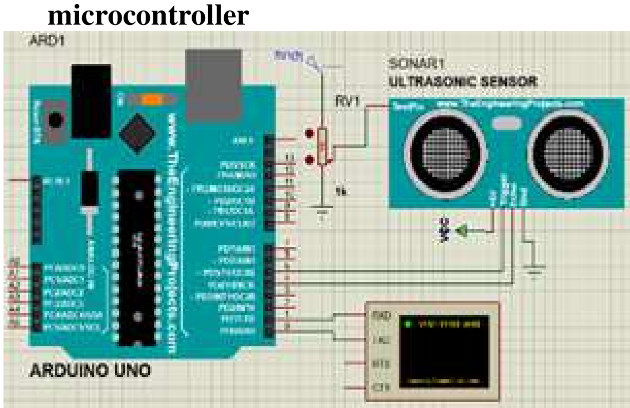

Figure 1: Interfacing of ultrasonic sensor to ATmega 328 microcontroller

The circuit diagram given in figure 1 shows how to interface an HC-SR04 ultrasonic sensor with (Arduino UNO) ATmega328 microcontroller. The sensor has 4 Pins: Vcc, GND, Trigger and Echo. The Vcc and GND are used to power up the sensor and are connected to power and ground rails on microcontroller. The VCC and GND pins of the ultrasonic sensor is connected to the 5V and GND pins of the microcontroller respectively. The trigger pin of the ultrasonic sensor is connected to digital output pin 5 of the microcontroller while the echo pin of the ultrasonic sensor is connected digital input pin 4 of the microcontroller and through these, sound wave distance information is sent to the microcontroller. An active variable resistor (RV1) is connected to the test pin of the Ultrasonic sensor and its terminals are connected to ground and 5v, this allows for change of resistance during the simulation time which changes distances being measured. A virtual terminal is connected to the microcontroller: the Rx pin of the microcontroller is connected to the Tx pin of the virtual terminal and the Tx pin of the microcontroller is connected to the Rx pin of the virtual terminal. When the simulation button is pressed, the data that is received from the sensor is displayed continously on the terminal window. Detailed procedure for programing of Ultrasonic sensor can be found in Appendix A.

Displaying distance data

The Steps for displaying distance data on virtual terminal is given below

- Send a 10μs pulse to the trigger pin of the ultrasonic sensor.
- Vary RV1.
- Wait for the pulse to return to the echo pin.
- Calculate the distance between the sensor and the object using the time it took for the pulse to return.

B. Interfacing of DC motor to ATmega328 microcontroller

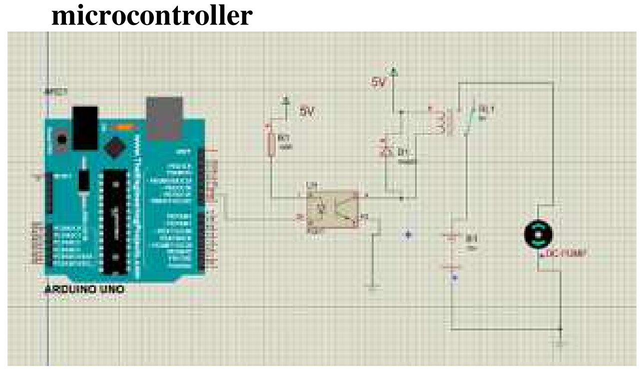

Figure 2: Interfacing of DC motor to ATmega328 microcontroller

Figure 2 shows the interface of DC motor to the microcontroller.

The components used for the interface are:

- Arduino UNO (ATmega328 microcontroller)
- PC817 optocoupler

- IN4007 Diode
- Dc motor
- Battery
- 1 Resistor - 100Ω
- Relay
- 5V power supply

Circuit Design

To control a DC motor using Atmega328 microcontroller, the 5v relay module is used which has an optocoupler embedded in it – PC817 and also a diode is connected - IN4007 with resistors and a DC power source for accurate performance. The IR LED in PC817 (anode) is connected to the resistor (100Ω) which is connected to 5V power source gotten from the terminal mode tab and the other end of the IR LED (cathode) is connected to digital pin 9 of the microcontroller. The emitter of the transistor in the optocoupler is grounded and the collector is connected to the relay. In the Relay; the inductor core is connected to a diode (IN4007) which is to a 5V power source. The relay consists of Normally closed (NC), Normally Open (NO) and Closed (C) contacts. NC and C are connected and read the same value but when it switches, NO and C become connected. The Relay is connected to one end of 12V DC motor (Pump) and the other end of the motor and relay are connected to the 12V DC power supply which is the 12V battery. It is the connected to the ground. When there is low from the IR LED, the transistor is biased and the relay is activated then NO and C become connected and the DC motor starts rotating and when the IR LED is high, the relay switches to NC and C and the rotation stops. The switching action of the relay depends on the state of the pin on arduino board it is connected to (pin 9).

C. Interfacing ATmega328 microcontroller with GSM/GPRS/GPS Module

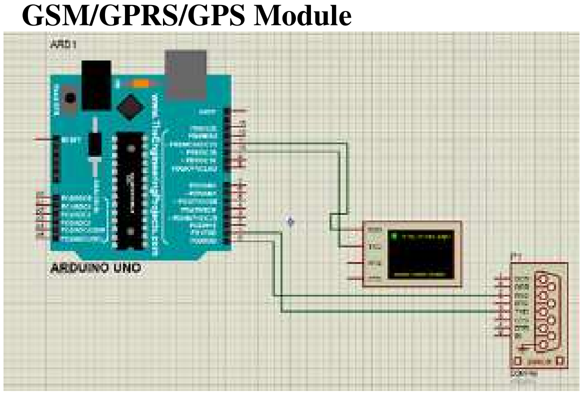

Figure 3: Interfacing of GSM/GPRS/GPS to ATmega328 microcontroller

Circuit Design

The COMPIM models a physical serial port and is used to buffer received serial communication and present it as digital signals to the circuit, it is used to represent the SIM808 as the virtual library model is not available yet. The RX and TX pin of the COMPIM to the RX and TX pin of the arduino board respectively and the virtual terminal is connected to the microcontroller: the Rx pin of the microcontroller is connected to the Tx pin of the virtual terminal and the Tx pin of the microcontroller is connected to the Rx pin of the virtual terminal. Once the RUN button is clicked, it starts processing information to be sent to the cloud platform and it is monitored on the virtual terminal.

D. Combining the Controller's Multiple Interfaces into a Single Design

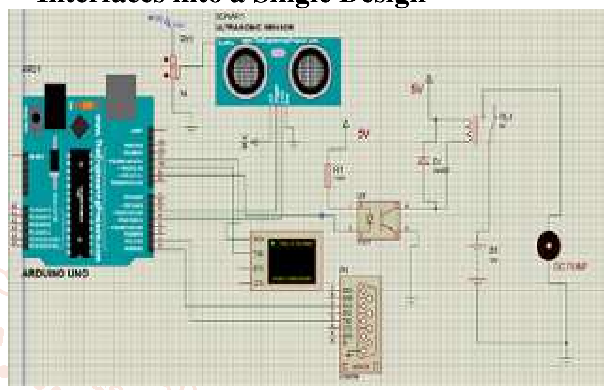

Figure 4: Overall circuit design for a smart water pumping system with IoT metering and monitoring

The overall integration of various components of the system is shown in Figure 4 above, with each section having a distinct designation.

Control Unit

The ATmega328 microcontroller is the brainbox of the system. All other components are interfaced to the ports on the microcontroller to perform the operation.

Power Supply Unit

This is the part of the system that regulates and filters the input voltage.

Sensor and signal conditioning Unit

The signal conditoner is embedded in the HC-SR04 Ultrasonic sensor. The signal conditioner is a component that processes the electrical signals generated by the sensor and prepares them for further processing by a microcontroller or other digital devices. The signal conditioner also adjusts the signal level to match the input requirements of the connected device and removes any noise or interference from the signal

IoT Cloud Gateway

The IoT gateway (GPRS) acts as a communication interface between the microcontroller and the cloud or central monitoring system. It collects data from the microcontroller and sends it to the cloud for further processing and analysis using GSM network.The COMPIM is used here and functions as the SIM808 used in the physical implementation.

Driver
The driver used represents a 5V Relay module comprising of the The PC817 optocoupler, IN4007 diode, 100Ω and Relay which is connected to the microcontroller and uses the level data gotten from the sensor to trigger on/off the DC motor which acts as the pump.

Display Unit
Here, the output devices used in the system is shown. The virtual terminal is used to view the system's operation. And the Thingspeak platform is used to monitor the level information provided.

E. Software Testing
The software testing involved several processes. First the various software to write and upload the code was downloaded. Arduino IDE was used to write and compile the assembly code. The code for each module was written, compiled to hex file and burned to the microcontroller. In burning the code. Several subroutines written to ensure that each module works fine. Initially, a lot of syntax errors were encountered but the code was carefully debugged over and over until everything started as expected. The MATLAB software was also used to plot the infromation gotten from the Thingspeak server. Some of the sample codes are shown in Appendix A.

F. Physical circuitry of a smart water pumping system with IoT monitoring and metering

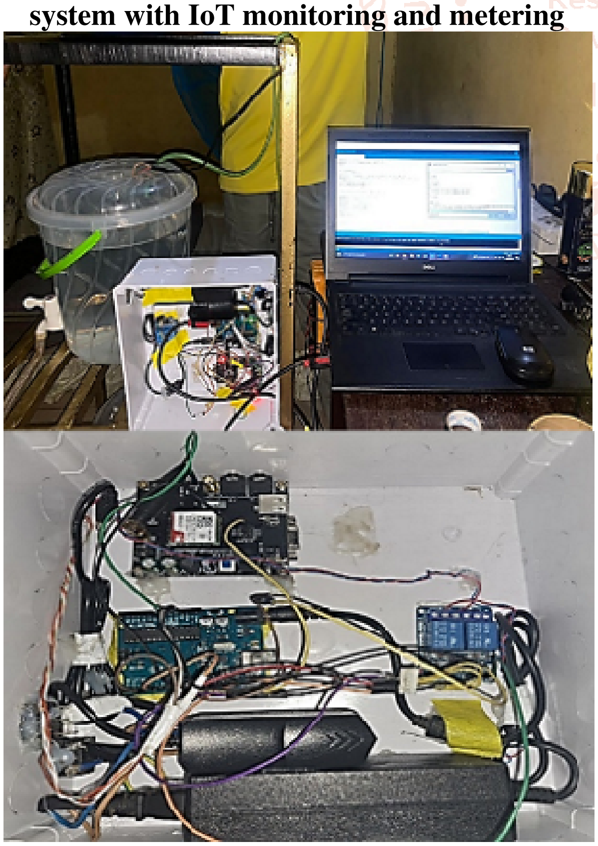

Figure 5: Physical circuitry of a smart water pumping system with IoT metering and monitoring

Circuit design
The +5v and GND pins of the ultrasonic sensor are connected to the 5V and GND pins of the Arduino UNO microcontroller, respectively. The trigger pin of the ultrasonic sensor to digital is connected pin 5 of the Arduino UNO microcontroller and the echo pin of the ultrasonic sensor to digital pin 4 of the Arduino UNO microcontroller. Power is given to arduino board via 12V DC adapter. A sim card is inserted to the simslot on the SIM808 expansion shield.

The RX and TX pin of the SIM808 is connected to pin 11 and 10 of the arduino board respectively. The GND of SIM808 is connected to GND of arduino board. The SIM808 is connected with a 9V adapter to a power source. The VCC pin of the relay module is connected to 5V on Arduino UNO and the GND pin is connected to GND pin of the arduino board on K1 side. The signal pin (IN1) of the relay is connected to pin 9 of the arduino board.

In the Relay; the inductor core is connected to a diode (IN4007) which is to a 5V power source. The relay consists of Normally closed (NC), Normally Open (NO) and Closed (C) contacts. NC and C are connected and read the same value but when it switches, NO and C become connected.

The NO pin of relay is connected to one end of 12V DC pump and the other end of the pump and C pin of relay are connected to the 12V DC adapter connected to a power supply. It is the connected to the ground. The code on the Arduino IDE is written, compiled and sent to to the arduino board via printer cable.

Run the program to view results on the serial monitor of IDE and observe the system physically. Thingspeak server is used to monitor the data sent from system.

VI. RESULTS AND DISCUSSION

A. Results of Interfacing Ultrasonic Sensor to Arduino UNO
The diagram below shows the readings displayed on the virtual terminal after running the simulation. Based on results obtained, it is clear that the Ultrasonic sensor can be used for water level sensing.

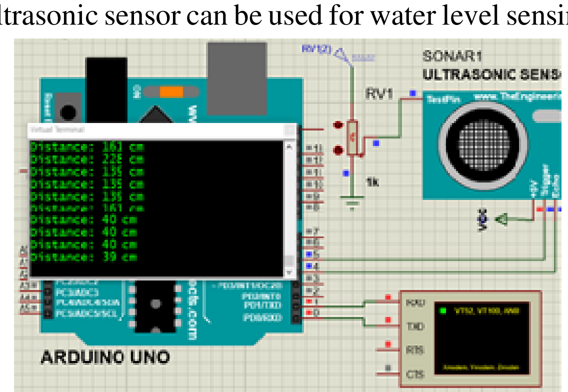

Figure 6: Distance readings displayed on virtual terminal of proteus simulation software

B. Results of Interfacing DC Motor to Arduino UNO

The figure below shows when pin 9 of the arduino is HIGH, there is low from the IR LED, the transistor is biased and the relay is activated then NO and C become connected and the DC pump starts pumping and when pin 9 is LOW, the IR LED is high, the relay switches to NC and C and the pumping stops.

The switching action of the relay depends on state of the arduino pin it is connected to (pin 9).

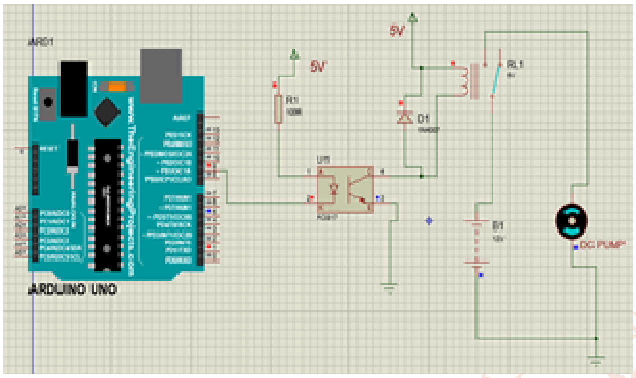

Figure 7: Results of dc motor action shown on proteus simulation software

C. Results of Interfacing ATmega328 microcontroller with GSM/GPRS/GPS Module

The figure below shows the way information from the microcontroller is being uploaded to the cloud platform and the process is monitored on the virtual terminal.

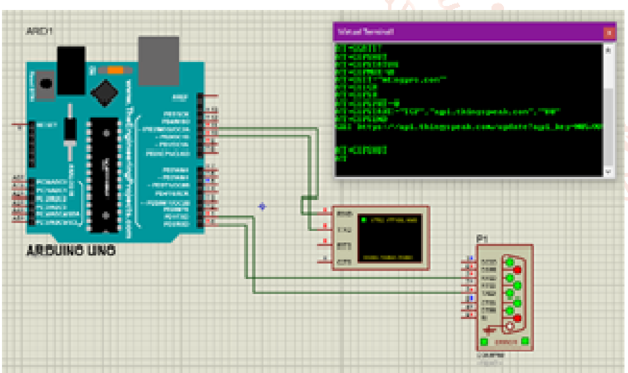

Figure 8: Results showing the uploading of information to the cloud platform on proteus simulation software

D. Results of Combining the Controller's Multiple Interfaces into a Single Design

Results shows that the microcontroller gives digital output to turn ON the water pump when the water in the tank is at a preset minimum level < 7cm) and turn OFF the water pump when the water goes above the chosen maximum level >= 20cm.When the water reaches maximum level (pump turns OFF), data is sent to the cloud (Thingsspeak server) and information on cost, quantity and volume of water is shown when logged into the server. The virtual terminal of proteus also updates information according to the state of the pump

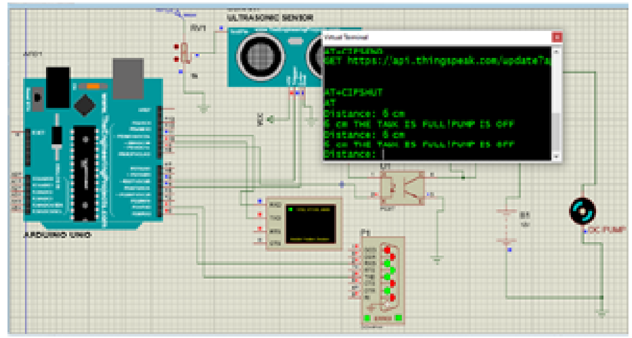

Figure 9: Readings of smart water pumping system implementation displayed on virtual terminal of proteus simulation software

E. Results of Physical Implementation of a Smart Water Pumping System with IoT Monitoring and Metering

Physical results is shown as the water is being pumped at a certain minimum threshold and it stops pumping at the maximum threshold specified by the program used in the system.

Results is also shown on the ThingSpeak server in form of charts which displays a smart water billing system containing price in naira and volume of water consumed. This charts updates at the end of every pumping cycle.

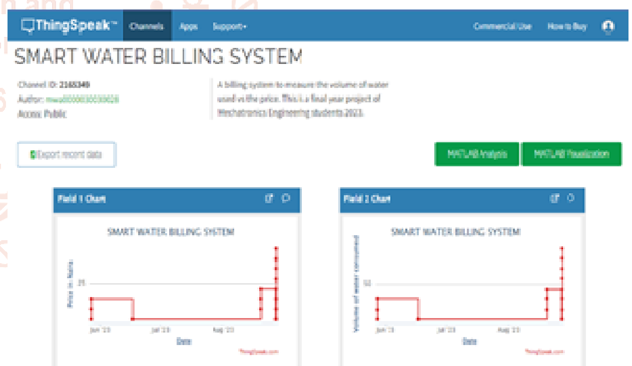

Figure 10: Information of smart water pumping system implementation displayed on ThingSpeak server

MATLAB Simulation Results

MATLAB Code

Time = [0, 1, 2, 3, 4, 5, 6, 7, 8, 9, 10]; % Time in hours

Cost = [0, 5, 10, 15, 20, 25, 30, 35, 40, 45, 50]; % Cost per liter in NGN

Volume = [0, 0.5, 1, 1.5, 2, 2.5, 3, 3.5, 4, 4.5, 5]; % Volume in liters

Figure; % Plot the cost per liter

Plot(time, cost, 'b', 'LineWidth', 2);

Xlabel('Time (hours)');

Ylabel('Cost per Liter (NGN)');

Title('Cost per Liter Over 3 Days');

Grid on;

Hold on;

Plot(time, volume, 'r', 'LineWidth', 2); % Plot the volume of water

Legend('Cost per Liter', 'Volume (Liters)'); % Add legends

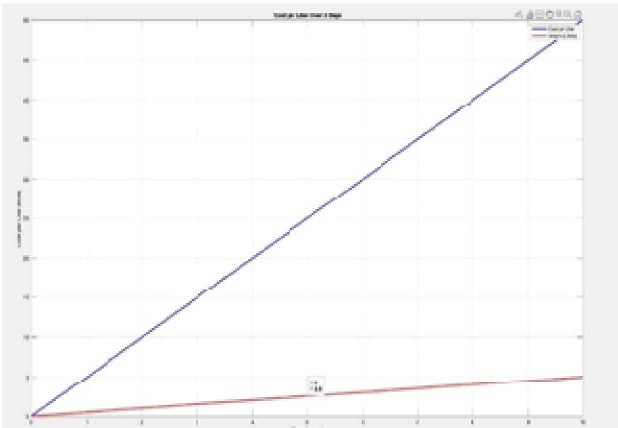

Figure 11: Graph of Cost per liter (NGN) against Time (hours) plotted on MATLAB

Figure 12: Physical results of smart water pumping system implementation

VII. CONTRIBUTIONS TO THE BODY OF KNOWLEDGE

The integration of a smart water pumping system with IoT metering and monitoring contributes significantly to the body of knowledge in several areas:

- It will enhance water resource management by providing real-time data on water levels, consumption patterns, and pricing which will contributes to efficient allocation and conservation of water resources, especially in areas facing water scarcity.
- This integration showcases the application of IoT and sensor technologies in a practical context. It advances the understanding of how sensors like ultrasonic sensors can be utilized to collect accurate data and how IoT can enable remote monitoring and control of devices.
- The DC pump in the system emphasizes energy efficiency and sustainability. By optimizing pump usage based on water levels and demand, energy consumption can be reduced. This contributes to the knowledge base of sustainable technology integration.
- The inclusion of the SIM808 module enables remote monitoring and management of the system which contributes to the understanding of how remote communication technologies can be utilized in various applications, ranging from water management to industrial automation.
- The data collected from the IoT metering and monitoring system can be analyzed to gain insights into consumption patterns, pump efficiency, and other relevant metrics. Researchers can explore data analytics techniques to make informed decisions and predictions.
- The documentation and dissemination of this system contribute to educational resources and serves as a practical example for students, researchers, and hobbyists interested in learning about IoT, sensor integration, and automation.

VIII. RECOMMENDATIONS

The development of more versatile and customizable interfaces should be explored moving beyond platforms like Thing Speak. The integration of solar power supply systems to make the water pumping system more sustainable and resilient should be investigated. Models that can anticipate equipment failures or maintenance needs need to be developed based on real-time data, reducing downtime and maintenance costs. The application of machine learning algorithms and advanced data analytics to gain deeper insights from the collected data. This could include anomaly detection for identifying unusual water usage patterns and predictive analytics for forecasting water demand.

IX. CONCLUSION

This work has successfully implemented a smart water pumping system with IoT monitoring and metering. The results acheieved can be used globally.

X. REFERENCES

[1] "5V Dual Channel Relay Module - Pinout, Features, Applications & Working," Components101, [Online]. Available: https://components101.com/switches/5v-dual-channel-relay-module-pinout-features-applications-working-datasheet. [Accessed 6 July 2023].

[2] ATMEL, "ATMEGA328P datasheet," All Datasheet, [Online]. Available: https://www.alldatasheet.com/datasheet-pdf/pdf/1425630/ATMEL/ATMEGA328P.html. [Accessed 17 June 2023].

[3] N. An and A. Y, "A monitoring system for water quality," in *International Conference on Electrical and Control Engineering*, 2010.

[4] A. Abebe, "Internet of Things (IoT) Enabled Water Distribution System for Smart Water Management," *International Journal of Wireless Communications and Mobile Computing,* vol. 11, no. 1, pp. 1-10, 2024.

[5] Dejan, "Ultrasonic Sensor HC-SR04 and Arduino-Complete Guide," How To Mechatronics, 2015. [Online]. Available: https://howtomechatronics.com/tutorials/arduino/ultrasonic-sensor-hc-sr04/. [Accessed 6 July 2023].

[6] "Direct Current," Britannica, [Online]. Available: https://www.britannica.com/science/direct-current. [Accessed 6 July 2023].

[7] "Amazon Web Services," AWS IoT, 2021. [Online]. Available: https://aws.amazon.com/iot/. [Accessed 17 June 2023].

[8] "Internet Things Water Management," World Water Council, 2020. [Online]. Available: www.worldwatercouncil.org/en/internet-things-water-management. [Accessed 7 July 2023].

[9] "Alternating Current," Britannica, [Online]. Available: https://www.britannica.com/science/alternating-current. [Accessed 17 June 2023].

[10] "Design Analysis Interfacing Ultrasonic Sensor With Arduino," Elementzonline, 6 December 2017. [Online]. Available: https://elementztechblog.wordpress.com/2017/12/06/interfacing-ultrasonic-sensor-with-arduino/. [Accessed 7 July 2023].

[11] "SIM808 Datasheet," ETC2, [Online]. Available: https://pdf1.alldatasheet.com/datasheet-pdf/view/1131990/ETC2/SIM808.html. [Accessed 7 July 2023].

[12] "Fuse," Britannica, [Online]. Available: https://www.britannica.com/technology/fuse-electronic-device. [Accessed 7 July 2023].

[13] "Gps gprs gsm sim908 module," Future Electronics Egypt, 2023. [Online]. Available: https://store.fut-electronics.com/products/gps-gprs-gsm-sim908-module. [Accessed 18 July 2023].

[14] Helen, "Water Level Sensor Definition, Applications, Benefits and Types," 15 June 2021. [Online]. Available: http://renkeer.com. [Accessed 6 June 2023].

[15] John, "Water Level Sensors," OurPCB, 2017. [Online]. Available: https://www.ourpcb.com/water-level-sensors.html. [Accessed 6 June 2023].

[16] "Electric Power," HyperPhysics, [Online]. Available: http://hyperphysics.phy-astr.gsu.edu/hbase/electric/elepow.html. [Accessed 6 June 2023].

[17] B. K. Mirza, "Virtual Terminal in Proteus," ProjectIot123, 3 April 2019. [Online]. Available: https://projectiot123.com/2019/04/03/virtual-terminal-in-proteus/. [Accessed 17 July 2023].

[18] S. Z. Nasir, "Introduction to Atmega," The Engineering Projects, 4 August 2017. [Online]. Available: https://www.theengineeringprojects.com/2017/08/introduction-to-atmega328.html. [Accessed 18 July 2023].

[19] S. Shah, "How to Simulate Arduino Projects Using Proteus," Maker Pro, 8 May 2020. [Online]. Available: https://maker.pro/arduino/projects/how-to-simulate-arduino-projects-using-proteus. [Accessed 24 June 2023].

[20] J. Smith, "The Internet of Things, Transformer," Britannica, 2020. [Online]. Available: https://www.britannica.com/technology/transformer-electronics. [Accessed 24 June 2023].

[21] "HCSR04 Ultrasonic Range Finder," SparkFun Electronics, [Online]. Available: https://cdn.sparkfun.com/datasheets/Sensors/Proximity/HCSR04.pdf. [Accessed 6 June 2023].

[22] Shawn, "Atmega, The One Microcontroller You Should Start With," 2019. [Online]. Available: https://www.seeedstudio.com/blog/2019/10/22/atmega328p-the-one-microcontroller-you-should-start-with/#:~:text=ATmega328P%20is%20a%20high%20performance,Arduino%20Fio%20and%20Arduino%20Uno.