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RESEARCH ARTICLE

PROTOTYPE FUEL LEVEL REMOTE MONITORING SYSTEM

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ABSTRACT

The Tanks are the most prevalent type of liquid storage facility today, especially in fuel stations where various tank sizes are used to store different types of fuel. As the global demand for fuel storage continues to rise, there is an increasing need for reliable and efficient monitoring systems that can prevent fuel theft and ensure accurate management of fuel inventory. This study presents the development of a prototype fuel level monitoring and notification system designed to enable users to remotely monitor the real-time fuel level in a tank from anywhere in the world. The system is built around an ATMega328 (Arduino Uno A000066) microcontroller, which is connected to an ultrasonic level sensor for precise measurement and a GSM/GPRS module for communication purposes. Whenever the system receives an inquiry message, the GSM/GPRS module promptly sends an SMS to the owner's phone, providing detailed information about the current fuel level (volume) in the tank. The system demonstrated excellent performance with an average response time of 3.3 seconds, indicating its reliability and efficiency. By integrating this system into contemporary filling stations, owners can achieve better control over their fuel inventory, significantly reduce the risk of fuel theft, and ensure timely and efficient refueling operations. This research underscores the potential for widespread application and adaptation of such advanced monitoring systems, paving the way for the development of more sophisticated, secure, and efficient fuel storage solutions in the future. However, the system may be unable to execute its job in the absence of GSM services.

KEYWORDS

ATMega328, Arduino Uno, Ultrasonic sensor, GSM/GPRS Modem

1.0 Introduction

Given the obvious fact that not all liquids can be consumed immediately since there may be a need for them later, man has continuously looked for novel ways to preserve liquids for convenience and simplicity of usage (Raveena & Deepa, 2017). In the past, the liquid was kept in clay pots, but as time went on, people began keeping liquid in iron or plastic tanks made to hold a variety of liquid volumes (P. Shetty & Shetty, 2019). The most common kind of liquid storage is in tanks. Tanks come in a variety of sizes. Tanks are used in both household and commercial settings. Storage tank utilization is common in the petrochemical, chemical, and petroleum producing and refining sectors (Loizou & Koutroulis, 2015; Patil & Singh, 2014; Santra, et al., 2017; Shetty & Wagh, 2018).

Internal combustion engine-powered machinery such as vehicles, motorbikes, trucks, generators, and compressors need a way to refuel to operate as long and effectively as feasible. To keep people safe,

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secure, and profit from the equipment, It is important to understand how to regulate fuel, what quantity of gasoline remains, and how best to store it (Obikoya, 2014). Many companies, especially those with large car fleets, have seen their expenditures rise in recent years due to rising oil consumption and prices, which has made finding fuel-efficient vehicles more expensive (Aher & Kokate, 2011). For instance, Nigeria's gasoline costs have more than quadrupled since 2003, almost tripled, and are never likely to recover to 2003 levels due to rising consumption (or demands). Along with the rising price of gasoline, there are examples of fuel theft (from stationary tanks as well as transportation tankers), fuel leakage, early dry-out, incorrect fuel replenishing, inappropriate engine usage, and drivers' improper behavior (Daniel, Dayo, & Anne, 2011).

The level of liquid in a tank has been monitored using a variety of techniques, including the conventional dipstick system, the bubbler system, contact meters, etc., to the most modern usage of metallic probes put at various levels in the tank to calculate the amount of liquid at specific levels. These techniques were demanding and distressing for the user. As the demand for liquid storage grows, so does the need for precise monitoring of the level of the storage's contents to guard against theft, wasting, and running out of liquid. Level sensing devices were added to the tanks, and they progressed from simple digital sensing (Discrete/point level) devices that show whether the tank is empty, half-full, or full to more sophisticated analog sensing (Continuous level) devices that can show the precise level of the content of the tank at any given time.

1.1 Related Work

Gajkumar et al., (2020) developed a low-cost, microcontroller-based smart fuel level monitoring system. An ultrasonic sensor and LCD display unit interface with a microcontroller to digitally displace the level of fuel in a bike fuel tank at any time. The fuel level is transmitted remotely to a distant observer via GPS. This technology provides regular data about fuel levels and car location, which will help to eliminate fuel theft and vehicle theft difficulties, but cannot be used to monitor fuel level in the tank at any time in real-time by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

The Authors in Reza et al., (2010) investigated automatic water level detection and control using microcontrollers. A microprocessor obtains data from the sensor device, which detects the amount of water through an inverter. The microcontroller created the consequent signal (ON or OFF) that indicates the tank's water state after processing the input variable. The system was only deployed locally, and the research can only assess specific levels (empty, full, and somewhere in between) in the water storage and cannot remotely determine the amount of water.

Devi et al., (2023) presented a fuel monitoring system. In the proposal, an ultrasonic sensor, a Global System for Mobile Communication (GSM) transmitter module, a Global Positioning System (GPS) module, and an LCD are all built around the ESP8266 microcontroller. The measured fuel was sent remotely to the intended destination via the internet using the Internet of Things (IoT). However, the proposed system is unable to monitor fuel level in the tank at any time in real-time metric by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Aher & Kokate, (2011) created a Fuel monitoring and automobile tracking devices using a microcontroller. The gadget was installed within a car to detect the fuel level at different times using a switch and locate the car in various areas using GPS technology. The information was subsequently retrieved via the RS232 interface at a central server. This device is thought to identify fuel theft and track the car precisely and continually. Furthermore, the system employs a switch that operates on the Hal-effect principle to calculate the rate of fuel consumption and the amount remaining. The usage of a reed switch, which only provides the level at predefined moments, is what makes it not the most precise kind of fuel level measuring Aher & Kokate, 2011. Furthermore, the system can only access fuel levels at a central server at a certain location; however, fuel levels cannot be monitored outside of the central server placement point.

Priyadharshini et al., (2023) Proposed and simulated a fuel monitoring system. The system was built around an Atmega 328 processor, and capacitance was utilized to measure the amount of fuel. The ESP8266 Wi-Fi chip, in conjunction with the flow sensor, transmits the measured fuel level to the intended destination (the user's mobile phone or web page). The system is yet to be built, and even if it is, it will be unable to monitor fuel level in the tank at any time in real-time metric by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Senthilraja et al., (2013) utilized third-party monitoring tools to detect fuel theft and automobile whereabouts. The complete system consists of an electromagnetic petrol detector, a coded lock (for authentication and security), and third-party tracking programs (to send petrol theft warnings). When gasoline is taken, the sensor stores the information in a database, from which it sends a notice based on computations performed from external monitoring programs by third-party monitoring software. This technology has provided regular data about the gasoline level and vehicle whereabouts, which will aid in the elimination of fuel theft and vehicle theft issues, but cannot be used to monitor fuel level in the tank at any time in real-time by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Rajesh et al., (2019) proposed an automated method to check fuel levels. In the proposed system, a float sensor and variable resistor were used to detect the fuel level, and a 741 integrated circuit was employed to amplify the sensor's modest output signal. It was suggested that GSM and GPS modules be incorporated into the system so as to allow it to communicate measured fuel levels remotely. The system, when constructed, will not be able to monitor fuel level in the tank at any time in real-time by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Loizou & Koutroulis, (2015) created a cheap capacitive detector that tracks water levels in huge storage tanks by using a signal conditioning circuit to produce water level readings that are taken in digital format and then linked to an ALIX 3d2 system board-based data acquisition unit. The developed prototype shares appearance and accuracy characteristics with an ultrasonic water level detector that is sold commercially. The database was not created to store the level of liquid at any given time, and it has yet to be tested on a real city water distribution network to evaluate its long-term performance and to observe whether it will be able to monitor fuel level in the tank at any time in real-time by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Oladoyin et al., (2023) designed and constructed an Internet of Things (IoT)-based generator monitoring system. The system monitors four generator's parameters: the fuel level, battery level, oil quality, and temperature using the HC-SRO4 sensor, PZEM-004T sensor, MG-Oil Quality Sensor, and DS18B20 sensor, respectively. All the sensors, together with a Wi-Fi module interfaced with an ESP32 microcontroller, remotely send the four generator's parameters measured to the user's smartphone. It was concluded that the designed system performed flawlessly. However, because Wi-Fi has a limited transmission distance, the user can only check the generator's parameters a short distance away.

Okperigho et al., (2024) designed and constructed an Internet of Things (IoT) storage tank level and monitoring system. The system consists of an ultrasonic sensor for level monitoring, a BME 280 for temperature and humidity measurement, and an ESP32 microcontroller that interacts with all other components to generate data, which is then sent through a web app, an Android phone, and then stored in a database. The system also provides real-time monitoring and control capabilities that allow administrators to track and manage access to the facility remotely. It was concluded that reliable and efficient fuel monitoring has been developed. However, the developed system can only transmit data via web page and cannot be used to monitor fuel level in the tank in real-time by an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Krishnasamy et al., (2020) develop and deploy a low-cost automatic fuel tank level monitoring system for vehicles. The system comprises a float sensor, GSM module, digital display, IC 741-OP-Amp, a GPS, and an Arduino microcontroller (Arduino Mega 2560). When the liquid level rises or falls, or when the flow rate or fuel consumption rate increases above normal, the fuel level plummets, and a message is sent via GSM module to a specified number, signaling something unexpected. The system can only communicate messages concerning specified fuel levels (high or low) and abnormal fuel use; it cannot be used to monitor the real-time level of fuel in the tank at all levels.

Gangurde et al., (2023) create and execute an automated fuel tank level monitoring analysis system for vehicles. The system employs ultrasonic and load sensors for fuel level monitoring, an ADC121CO21 analog to digital converter, an LCD display to digitally display fuel level, a Wi-Fi module (Esp32 Node MCU) to communicate the measured fuel level, and also an alert for low fuel level to the cloud called ThinkSpeak. It was reported that a system was created to replace analogue gasoline meters with digital meters with higher accuracy. The system monitors fuel level with a digital fuel meter but does not monitor the level of fuel in the tank in real-time by sending an SMS message via cell phone to query the current level of fuel from a remote distance.

Shubham et al., (2020) create and install an automated fuel tank level monitoring and leakage detection system in tankers (vehicles). The system uses a Hall Effect Flow Sensor to calculate the information about the tank's current fuel level. The information (data) is delivered to the microcontroller (ESP8266 Wi-Fi), which links the flow sensor and server; the server transmits the data to the user's Android app via the internet of things (IoT). It was concluded that a reliable and low-cost system has been created. The system tracks and sends information when the quantity of fuel in the tank drops, but does not monitor the real-time level of fuel at all levels.

Furthermore, Egho-Promise et al., (2023) developed an automated fuel level monitoring system. The system was created by interconnecting an ultrasonic sensor, a liquid crystal display (LCD), and a microcontroller (Arduino Mega 2560). The microcontroller embedded with software coordinated the operations of the ultrasonic sensor and the LCD. It was concluded that the system functioned effectively. However, the system cannot query the database for real-time measurements.

Several sorts of studies have been undertaken on techniques to lessen the burden and task on the user associated with the duty of liquid level monitoring in a storage, as well as the need for accurate monitoring of the level of the liquid contents in storages so as to prevent any forms of running out of water, waste, and liquid theft. However, evaluation of relevant literature reveals the following:

Many of the developed systems can only monitor fuel levels in a tank at a central server at a certain location; but cannot be used to monitor outside of the central server placement point.

Some of the systems created can only transmit data via web page and cannot be used to monitor fuel level in the tank at any time in real-time by sending an SMS message via mobile phone to query the current level of fuel at a faraway distance.

Most of the established systems can only communicate messages concerning specified fuel levels (i.e., high or low) or when the quantity of fuel in the tank drops, probably due to an abnormal fuel use; they cannot be used to monitor the real-time level of fuel at all levels.

Some of the constructed systems monitor fuel level in the tank with a digital fuel meter but do not monitor and transmit the fuel level in the tank in real-time to a remote location.

While some of the created systems track and send the current fuel level in the tank via Wi-Fi, which has a limited transmission distance, this implies that the user cannot only monitor the current fuel level within a short distance but at a far distance away.

In this regard, it is evident that a fuel level monitoring and notification system that allows users from anywhere in the world to monitor the real-time level (volume) of fuel in a tank at any filling station has not been established. Therefore, this work aims to produce a better system that can monitor the current fuel level in a tank in real time from any place (short or long distance).

2.0 Materials and Method

The research begins by dividing the system into two parts: hardware and software, followed by the design of a remote fuel-level detector, which was simulated to ensure that its operating rules corresponded with the circuit design perfectly, correctly, and in working order as expected. The configuration was subsequently implemented using hardware, leading to remote tracking of fuel levels in a distant reservoir. The components employed in the system design were chosen based on the component-designed values obtained during design calculations. The GSM/GGRPS module (SIM800L), the sensor module (HC-SR04 module), and the microcontroller module (Arduino Uno A000066) all met with the designed specifications criteria as stated in sections 2.2 through 2.4. The power supply in Section 2.5 was designed so as to be able to power all the modules stated in the designed work.

2.1 Hardware Components

The hardware comprises of four modules: the power supply, the level detector, the Arduino microcontroller, and the communication (GPS/GPRS) module. Figure 1 depicts the system's block diagram.

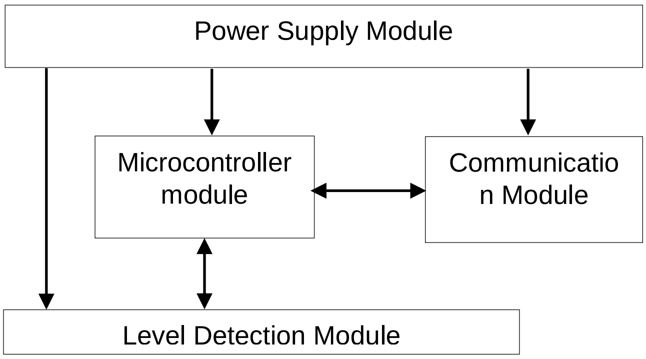

Figure 1: The System's Block Diagram

2.2 Module GSM/GPRS

In this study, a SIM800L GSM / GRPS module is employed. It is a GSM/GPRS module with two antennas that can transmit SMS, GPRS, and make voice calls. It has a cheap cost, portability, a low power consumption rate of roughly 350 mA, a DC power supply range of 3.4 V-4.4 V, a working temperature range of -40 to 80 degrees Celsius, and a Module size of 25 x 23 mm. Figure 2 depicts a SIM800L GSM / GRPS module.

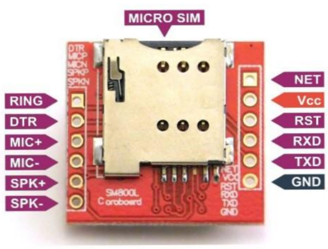

Figure 2: The picture of the SIM800L GSM / GRPS module (Last Minute Engineer, 2022)

2.3 Sensor Module for Level

The HC-SR04 module is utilized as a fuel sensor; it is an ultrasonic sensor. It runs on 5 V DC and draws 15 mA. It generates an ultrasound at 40 000 Hz and has a coverage distance of 2 cm - 4 m. It includes four pins: Vcc, Trigger, Echo, and Ground. The front of the module includes two eye-like projections that constitute the Ultrasonic transmitter and receiver. It has no moving components, is small, dependable, and inexpensive, and is unaffected by the qualities of the substance it perceives (Core Electronics, 2022). Figure 2 depicts an image of an HC-SR04 module.

Figure 2: An Image of an HC-SR04 Module (Core Electronics, 2022)

2.4 Module Microcontroller

The microcontroller utilized is the Arduino Uno A000066. It is an ATmega328p-based, closely packed, and breadboard-friendly produced by Arduino.cc in Italy. It has both analog and digital ports and usually of a physical programmable circuit board and Integrated Development Environment (IDE) and programed in the C programming language (Akanni, et al., (2023). Figure 4 depicts an image of the Arduino Uno A000066.

Figure 4: Picture of the Arduino Uno A000066 (Akanni, et al., (2023)

2.5 Power Supply Module

Figure 5 depicts the power supply unit's circuit diagram. It is made up of a 12 V dc battery (B1) and an LM7805 voltage regulator (U1). From the datasheet of the voltage regulator LM7805, capacitors C1 and C2 were selected to be 0.1 F and 100 F, respectively.

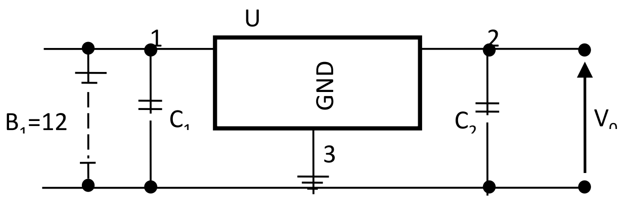

Figure 5: Circuit Diagram of the Power Supply Unit

2.6 Software

The Arduino IDE software was utilized to create software program-building applications for the A0000066 microcontroller, which included the ability to create, troubleshoot, and test incorporated C-programming. Figures 6 and 7 depict the prototype fuel level remote monitoring and notification system's flowchart and circuit diagram, respectively.

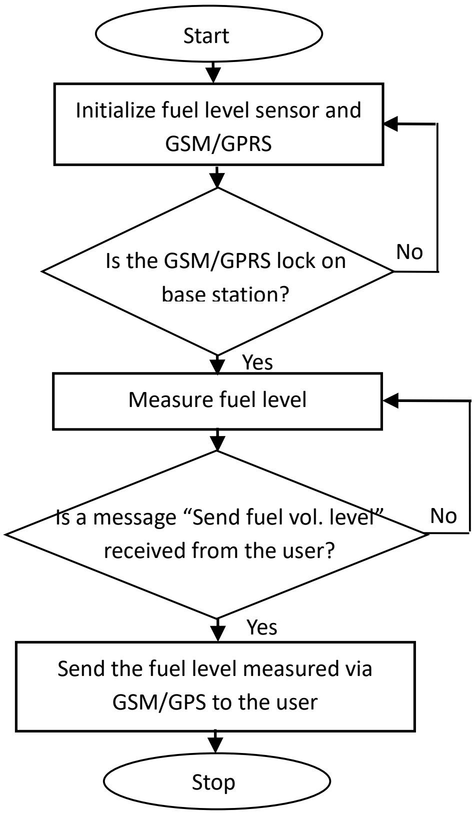

Figure 6: The Prototype Fuel Level Remote Monitoring Notification System's Flowchart

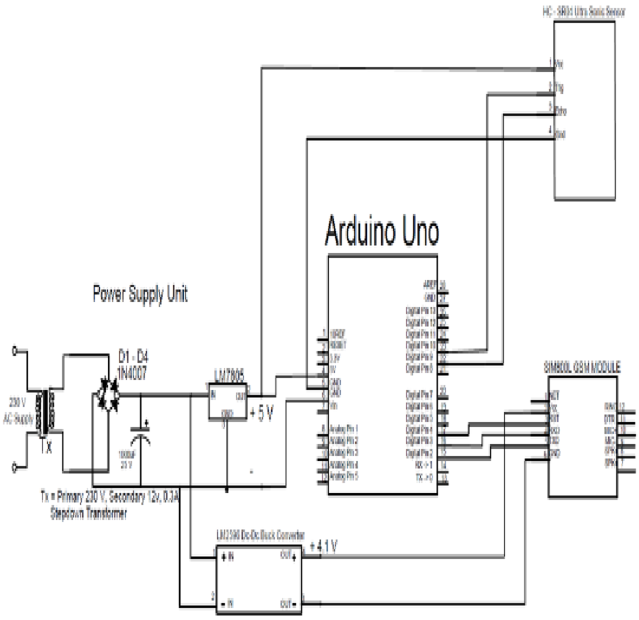

Figure 7: Circuit Diagram of the Prototype Fuel Level Remote Monitoring and Notification System

Figure 8: The Image of layout, soldering, and connections of the modules and components on the Vero Boar

2.7 Hardware Implementation

The procedures involved in hardware execution include setting up the modules and components on a breadboard, connecting and soldering the modules and components on a Vero Board, and assembling the system enclosure. The layout, soldering, and connections of the modules and components on the Vero Board are depicted in Figure 8.

The choice of the system enclosure was made with consideration for both robustness and convenience. An image of the system enclosure is presented in Figure 9.

Figure 9: The picture of the fuel level monitoring and notification system casing.

2.8 Performance Evaluation of the Developed System

To confirm the level of effectiveness and performance of the developed system, the following tests were carried out: a fuel level (volume) measurement comparison test and a notification response time test. The fuel level (volume) measurement comparison test was carried out by comparing the system transmitted received measure fuel level (volume) to that of the fuel volume read on a standard liquid volume measurement instrument (calibrated volume level on the plastic bucket used as fuel tank). The notification response time test was also carried out by sending a tank level query message from a GSM handset to the system and the time taken for the fuel level to appear on the handset was measured with the aid of a digital clock. Table 1 and 2 shows the results for the two tests conducted.

3.0 Results and Discussion

Table 1 is a fuel level (volume) measurement comparison test, it compares the fuel volume transmitted by the system to the volume measured by a calibrated instrument. The transmitted volumes match exactly with the calibrated instrument volumes in all cases, indicating high accuracy of the system in measuring and transmitting fuel levels.

Table 2 is a notification response time test; it measures the system's response time in seconds at varying distances from the system. From Table 2, the time taken to transmit and receive a message regarding the level (volume) of the fuel in the tank at various locations varies between 3 and 4 seconds, with an average of 3.3 seconds. Figure 10 shows the displays of a screenshot of the send and receive messages interface on a user's phone.

The data demonstrates the high accuracy and reliability of the fuel level monitoring system. The quick response times across various distances suggest robust performance, making it suitable for real-world applications and the visual representation in the figure supports the system's user-friendly interface and practical functionality.

This analysis confirms that the prototype system effectively meets its design goals of accurate, real-time fuel level monitoring and swift notification, offering significant potential for integration into modern fuel stations.

Table 1: Fuel Level (volume) Measurement Comparison Test

S/N	System Transmitted Received Volume (L)	Calibrated Instrument Volume (L)
1	20	20
2	20	20
3	10	10
4	5	5
5	5	5
6	0	0
7	15	15
8	10	10
9	20	20
10	5	5

Table 2: Notification Response Time Test

S/N	Test location distance from the system (m)	Response Time (s)
1	100	3
2	200	3
3	400	3
4	600	4
5	800	3
6	1000	3
7	2000	4
8	3000	3
9	4000	4
10	5000	3

Although, the developed system displayed excellent performance; nevertheless, the system may not work effectively in an environment with temperatures outside the range of -40 to +80 degrees Celsius since many of the modules may not run optimally at that range, as indicated in Section 2.2. Also, the system may be unable to execute its job in the absence of GSM services.

The system can be used for bigger fuel storage facilities by recalibrating the distance between the zero and peak levels of the intended storage and calculating the volume by calibrating the distance to match the volume of the larger storage.

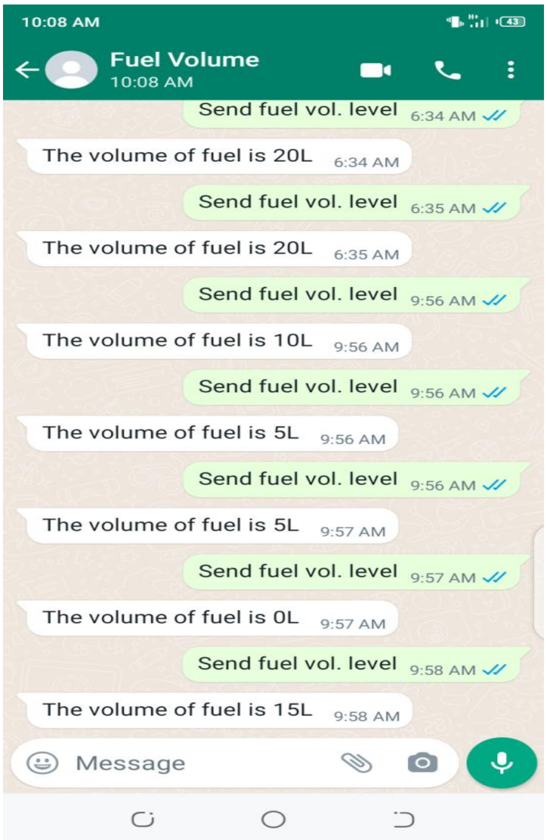

Figure 10: A sample screenshot of send and receive messages on the user's phone (Techno).

4.0 Conclusion

A prototype fuel level remote monitoring and notification system was developed. It performed satisfactorily; it will eliminate the stretch, task, and fuel theft that usually occurs in filling stations. It can be used by the user in any place in the world to check the real-time level (volume) of the fuel in the tank in a filling station anywhere. As a consequence, this system may be customized and connected with modern filling stations. It is also recommended that a method of monitoring the density of the fuel be implemented in order to curb fuel theft by replacing stolen fuel with another fluid, such as water, to compensate for stolen fuel.

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