ISSN 2278-3091
Volume 8, No.1.6, 2019
International Journal of Advanced Trends in Computer Science and Engineering
Available Online at http://www.warse.org/IJATCSE/static/pdf/file/ijatcse7881.62019.pdf
https://doi.org/10.30534/ijatcse/2019/7881.62019

Gas Station Fuel Storage Tank Monitoring System using Internet of Things

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ABSTRACT
This paper presents the development of a prototype of gas station fuel storage tank monitoring system using Internet of Things (IoT). In Malaysia, the current method to measure the fuel level in the underground tank is by using dipstick; which is inefficient and unsafe. The proposed monitoring system is automatic, gives real time reading of fuel level and fuel temperature in the underground storage tank collected from an ultrasonic sensor and waterproof temperature sensor. All the input values from these sensors are transmitted to an IoT platform called Blynk, through the medium of an open-source microcontroller board: NodeMCU. The fuel storage tank monitoring system alerts the users whenever the fuel is on low stock; or at a high temperature above 35°C. The proposed IoT-based system may help gas station operators to monitor the fuel parameters from anywhere via devices with internet connection. Efficient monitoring without physical presence at the local site can be achieved.

Key words: Fuel monitoring, Internet of Things (IoT), Temperature sensor, Ultrasonic sensor.

1. INTRODUCTION

Monitoring the underground fuel storage tank periodically is essential to gas station operators as they need to control the quantities of the fuel stock and detect if there is any leakage on the storage tank. Currently, workers at gas stations use dipstick to measure the volume of the fuel in the underground tank. This task normally takes half an hour which is inconvenient, especially under the hot weather in Malaysia. Not only that, the workers are at risk of inhaling hydrocarbon released by gasoline which can cause health problems [1]. There are more than 30,000 persons affected by hydrocarbon toxicity every year [2]. Furthermore, this conventional method might be inaccurate due to human errors when performing the measurement [3].

Apart from the dipping method, a modern alternative tool is known as Automatic Tank Gauge (ATG). ATG is an electronic device that enables gas station operators to monitor the fuel level in the storage tank and give warnings of the low fuel level. ATG uses a probe which consists of a long rod with float and it is placed in the tank [4]. The position of the float determines the height of the fuel and sends the information to a console which will display the fuel volume. Despite of the advanced technology, ATG is not widely used because of its high price [5].

In recent years, the industry has evolved rapidly towards the fourth industrial revolution (IR 4.0). This 4.0 revolution is much often related with another term that is more widespread called the Internet of Things [6] or simply known as IoT. IoT is a seamless communication system between machine to machine over a network without human medium. This system represents various potential applications such as for medical or healthcare [7-9], web service [10], agriculture [11-12], home automation [13-14], industrial automation [15-16], transportation [17], and general system monitoring [18-22]. For instance, in healthcare, IoT-based system has been vigorously developed to e-monitor the patients, to gather data from various sources like the pharmacies and laboratories. The physicians and hospital administrators are able to monitor the data constantly via their personal devices [7-9]. For web services [7], IoT facilitate the collection of raw data and analysis by withdrawing the raw data into useful information and provide them to the client using web services. Few existing works related to the proposed application (vehicle fuel) using GSM and IoT are presented in [23-24], however, the authors focused on the fuel level in the vehicle tank (not on the underground gas station tank).

To overcome the problem described above (in paragraphs 1 and 2) and taking into account the advantages of IoT technology, we propose to develop a prototype of Gas Station Fuel Storage Tank Monitoring System using IoT via the Blynk application. The monitoring system gives real time reading of fuel level and temperature in the underground storage tank collected from an ultrasonic sensor and waterproof temperature sensor. The system will alert the users whenever the fuel is on low stock; or at a high temperature above 35 °C. This IoT-based technology will help gas station operators to monitor the fuel in storage tank remotely. They can save time, energy and reduce the health risk from performing the manual dipping. Furthermore, gas station operators could save the costs of upgrading their monitoring system as this tool is much cheaper compared to the ATG.

2. METHODOLOGY

2.1 Framework and Product Design

For the prototype: we uses two input devices which are ultrasonic sensor to measure the fuel level and waterproof temperature sensor to measure the fuel temperature. Fig. 1 shows the process flow diagram of our proposed work. The system starts off with the microcontroller (on the NodeMCU board) being initialized. Then, both of the sensors will simultaneously measure the fuel and temperature level. The microcontroller will calculate the fuel volume and process the temperature value of the fuel. These measured data are stored in cloud and can be monitored through the IoT platform that we use (Blynk). The system will alert the user when the fuel is on low stock (lower than 0.5 Litres) and when the fuel temperature is high (greater than 35℃).

The design shown in Fig. 2 is the prototype made for this work using SolidWorks software. A stainless-steel container is used to store the petroleum. This type of material prevent the container from being corroded. The control box containing all the electronic components is from plastic-based material. A waterproof temperature sensor holder is placed inside, attached to the inner wall of the stainless-steel container to make sure the sensor is intact.

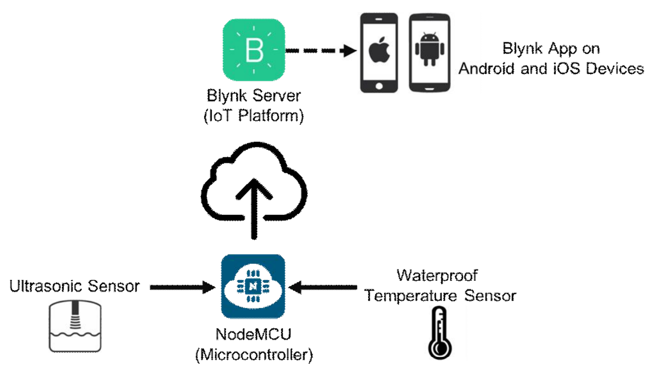


Figure 1: Process flow diagram of the proposed work

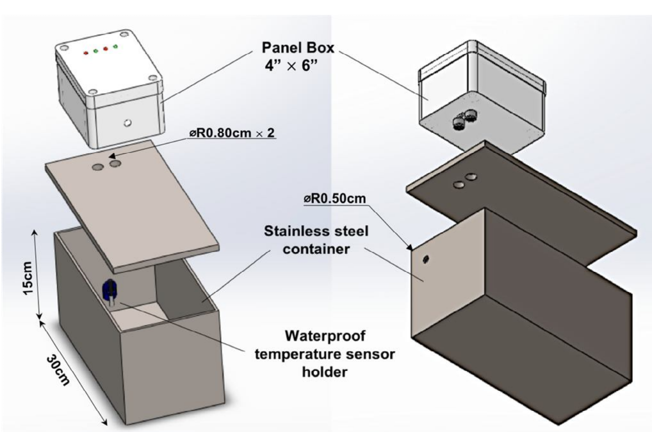


Figure 2: The proposed prototype design

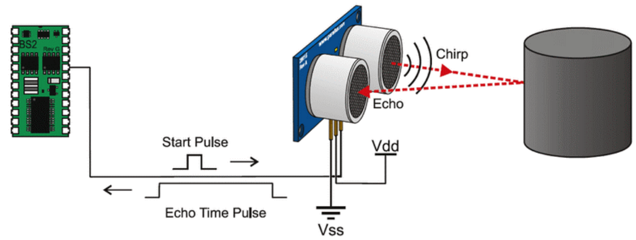


Figure 3: Working principle of an ultrasonic sensor

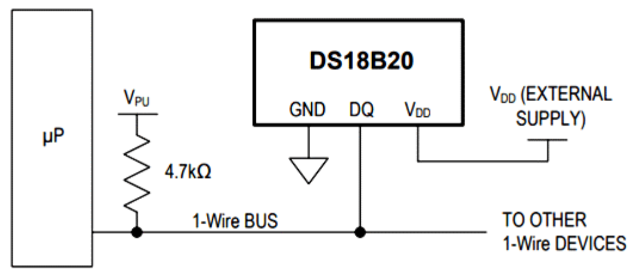


Figure 4: DS18B20 Circuit Diagram

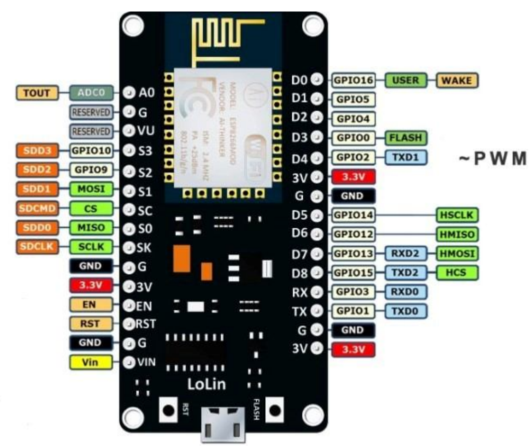


Figure 5: NodeMCU Lua V3 pins assignment

2.2 Hardware Components

A. Ultrasonic sensor HC-SR04

Ultrasonic sensor measures distance of an object by using ultrasonic sound waves. It uses transducer to emit ultrasonic waves, and the waves will be reflected back to the sensor; transmitting all the information about an object's proximity distance. The diagram of ultrasonic sensor working principle is illustrated in Fig. 3. These sensors are insensitive of light, smoke, dust, colour and material, except for soft surfaces because the ultrasonic sound waves will be absorbed by soft surfaces (thus, no wave reflection). For our work, ultrasonic sensor is suitable to measure the volume (in Litre) of the fuel in storage tanks.

Ultrasonic sensor provides distance measurement in centimeter. To measure the fuel level, we use the volume formula: *Area*Height*, where *Area* is the surface area of the stainless-steel container (as shown in Fig. 2) and *Height* is the height of the container (15cm), minus the distance measured by ultrasonic sensor (top of container to the fuel surface). This will give the volume of fuel in cubic centimeter, which then converted to Liter by the microchip (Node MCU).

B. Waterproof temperature sensor DS18B20

Waterproof Temperature Sensor DS18B20 is a sealed temperature sensor that allows users to precisely measure temperature in wet environments. It provides 9-bit to 12-bit Celsius temperature measurements, from -55 °C to 125 °C with an accuracy from -10 °C to 85 °C with tolerance of +/-0.5 °C. Not only that, as depicted in Fig. 4, it also communicates over 1-Wire bus, which means it only needs one data line (and ground) with a pull-up resistor of 4.7k Ohm to communicate with a microcontroller. Hence, it does not require any external components to work. The resistor is used to keep the line in high state whenever the bus is not operational, while the other two pins are used for power. On top of that, since every DS18B20 has its own unique silicon serial number, multiple DS18B20 sensors are able to coexist on the same 1-Wire bus.

C. NodeMCU Lua V3 ESP8266 Wi-Fi with CH340G

NodeMCU is a low-cost open-source development board that runs on the ESP8266 Wi-Fi microchip. This board (cf. Figure 5) integrates 16 General Purpose Input/Output (GPIO) pins, Pulse Width Modulator (PWM), serial 2-wire bus interface (Inter-Integrated Circuit, IIC), 1-Wire interface and Analog to Digital Convertor (ADC). It features 4MB of flash memory, 80MHz of system clock, around 50k of usable RAM and an on chip Wi-Fi Transceiver. NodeMCU operates on an external DC voltage supply of 6 to 24 volts. However, if more than 12 volts is used, the voltage regulator may overheat and will damage the microchip. The recommended voltage range is between 7 to 12 volts. NodeMCU is ideal for building IoT projects as it consists of all the necessary components as described above, and can be programmed via Arduino IDE. Several research works presented in [9-10, 13, 18-20] also uses the same microcontroller which is efficient because it integrates wifi module on the board (compared to using Arduino Uno for example, which needs separate wi-fi module).

2.3 Software

A. Arduino IDE

Arduino IDE (Integrated Development Environment) is an open-source software based on the C/C++ language. The algorithm for the monitoring system is first coded using this software and then programmed to the compatible microchip. All the measured data collected from the sensors will be processed by NodeMCU and transmitted to Blynk platform.

B. Blynk

Blynk is an open-source IoT platform that enables user to use their portable devices operating on Android and iOS to communicate with microcontroller board such as Arduino, Raspberry Pi and others. It can help users to build a graphic interface for their projects. Users are able to create an interactive dashboard with widgets, control, and video streaming. In this work, Blynk is used as the platform to monitor the fuel level and temperature in the storage tank. Blynk was shown to be user-friendly for IoT system [21-22].

3. RESULT AND DISCUSSION

3.1 System Interface

The proposed fuel storage tank monitoring system is designed in two-tab interface: Fuel level tab and fuel temperature tab. The first tab (refer to Fig. 6(a)) shows the amount of fuel level in the underground storage tank (in liter unit) and in a display gauge. The maximum fuel level is 10 litres. The distance between ultrasonic sensor and the fuel surface is also displayed (in cm unit) for troubleshooting purposes. If there is no fuel, it will show the distance between ultrasonic sensor and the bottom surface of the container. Two LEDs indicators each represents normal fuel level and low fuel level. The virtual LCD will also display in text the state of the fuel level. On the bottom, the superchart shows the trends of the fuel level measurement in the course of time.

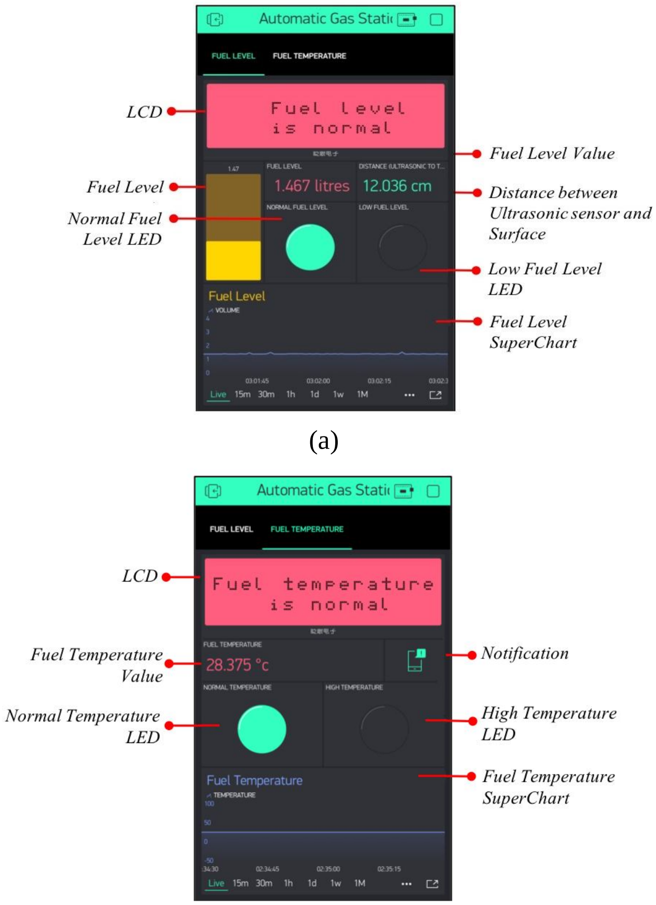
The second interface tab as shown in Fig. 6(b) represents fuel temperature monitoring (in ℃). The notification widget alerts the user on both the fuel level and fuel temperature. Similar to the first tab, the fuel temperature interface is designed with two LEDs indicators for normal and high temperature, a virtual LCD displaying the temperature condition, and a graph of temperature trends.

To verify the system, we have first used water with different temperature and different volume. The system responds correctly with respect to the water temperature (alerts when high temperature) and with respect to the water volume (alerts when the water is low quantity). In the second part (sub-section 3.2), we perform several experiments to analyze the fuel trends.

3.2 Data Analysis

Blynk application allows user to store data in *CSV* format through the SuperChart widget. From the collected data, we have studied in 24 hours interval (different ambient temperature: night and day); the trends of fuel level versus time, and fuel temperature versus time. The first is to study the effects of ambient temperature to the fuel level (regarding the property of the petrol itself), and the second is to observe the variation of fuel temperature with respect to the ambient temperature. The fuel used in these experiments is approximately 1.5L.

Results of the first trend (refer to Fig. 7) showed that the fuel level rose up gradually at midnight until noon. Then, it stayed stagnant at 1.53L approximately for 4 hours, before dropping gradually until midnight. From the graph trend, it can be concluded that fuel expands when the ambient temperature increases and contracts when the ambient temperature decreases (not below 0℃), which correspond to the fuel density property (25). For the second experiment of fuel temperature versus time, result as shown in Fig. 8 revealed that the ambient temperature affects the fuel temperature over night and day, which also allowed us to verify the functionality of the waterproof temperature sensor used in this work. The fuel temperature increased for about 2 hours starting from 4pm, which might explain the heat trapped in the stainless-steel container from the afternoon heat.



(a) (b)

Figure 6: Blynk interface for the proposed fuel storage tank monitoring system. Fig. 6(a) shows the Fuel level interface tab and Fig. 6(b) shows the Fuel temperature interface tab.

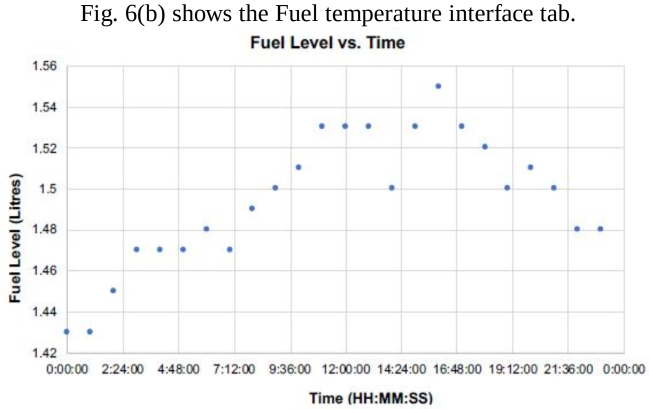


Figure 7: Effects of the ambient temperature on the fuel level

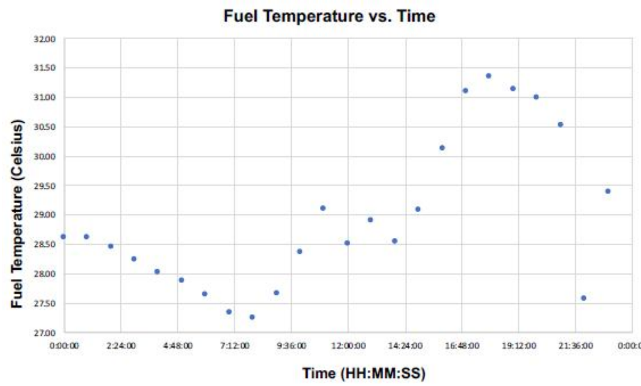


Figure 8: Effects of the ambient temperature on the fuel temperature

4. CONCLUSION

The main objective of this work was to develop a cost-effective and efficient tool to monitor the fuel level of underground storage tank via IoT technology. Results show that the proposed prototype can be very useful for the gas station operators. The end user can monitor their fuel level conveniently using any devices with internet connection.

For future works, other related sensors can be added to monitor the fuel storage tank condition such as humidity sensor. The prototype can be improved to fit the real application. There was inaccuracy issue of the ultrasonic sensor reading caused by noise. A signal conditioning circuit can be embedded to amplify the output signal of ultrasonic sensor, or one can add filtering component.

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