System Design for Measuring and Monitoring Fuel Consumption Remotely Using Embedded System

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Abstract. Recently, many industrial companies, farms, universities, remote projects and others needed to use Power Generators (Fossil Fuel Engines). It is difficult in some cases to know the status of the Generator (whether it ON or OFF?), the average of fuel discharging currently and it’s motor efficiency statues needed to be estimated. In addition, to measuring the fuel spend in the main tank of that institution. There are many methods for measuring fuel discharging, but in this case, the most basic way that has a very good impact and big challenges comparing with manual observations. A Flow Meter Sensor (YF-S201) correlated by Arduino microcontroller "1" which used as a master. For checking the strategical fuel tank, a waterproof ultrasonic sensor (JSN-SR04T) has been used. The collected data transmitted by transmitting chip (RS-485) to second Arduino microcontroller "2" which used as a slave that plugged by serial port into the computer , as well as for transmit the information into the database. The data was remotely viewed by web as a report through Public IP. This research has shown that the method of digital monitoring for fuel discharges was more accurate, safer than manual monitoring and explain how the remote observations give a good impact for the workers.

Keyword. Arduino, generator, engine, flow meter, ultrasonic and sensors.

1. introduction

Electric Generators (fossil fuel engines) play fundamental roles for the economic fields these days; it has the main point for boost up the system for the modernist life. Because the technology depended completely onto the electric circuit, the generator be very important for supplying the power all the time especially over the critical time in the sensitive institute and industrials factories[1]. Therefore, observing these generators electrically is important and even major, in the other words; the factory most has a team of workers for monitoring and fast maintenance (daily and hourly) which requires a hard work.

For solving and make these difficulty easier and more accurate; an automatic gaging and remote monitoring is a very good idea especially with the jumping in the technology over the evolution of 21 century[2].
To make the whole process more facilitate and to solve the problem mentioned above, the suggestion solution is through building an online monitoring system (real time monitoring) for observe the generator state including the average of spending fuel and the level of fuel in the main tank (strategical fuel tank).

All this information are manipulated as an understandable data for saving in a database and provide it as downloadable reports. This approach has an impact contribution to the present technological world to provide intelligent and innovative solutions that help and enhance smart wireless monitoring.

As a work related of this achievement, estimate fluid flow (water or gasoline) are provoke many companies and factories. This article would to mention about several synopsis as follows:

- A. S. Rao, et al. in 2013 IEEE, “International Conference on Advances in Computing, Communications and Informatics”, this system used low-cost sensors and low-cost hardware as an open source for both which secedes to analyze the data that collected from sensors for giving an alert while level of water are reduced[2].

- R. Fransiska, E. Septia, W. Vessabhu, W. Frans, and W. Abednego. in 2013 IEEE, “3rd International Conference on Instrumentation, Communications, Information Technology, and Biomedical Engineering”, which uses a wattmeter by Arduino for measuring the power, current, voltage and total fuel consumption[3].

- M. Husni, D. Siahaan, H. Ciptaningtyas, H. Studiawan, and Y. Aliarham. In 2016, an IOP Conference, the authors used (UsS), Arduino UNO microcontroller, GPRS/GSM/GPS Shield modules and Bluetooth module; monitoring the fuel volume level inside the tank and detect continuously if there are leakage via web based application. The experiment done by the road condition (tilt or flat), the results (accuracy rate) in flat road was 99.33%, while in tilted road the result dropped to 84%. This system could implemented in any road condition usefully[4].

- K. R. Haque, M. A. Muyeed, S. Sadat, and R. Palit. In 2017, an IEEE conference, used sensors to control and monitoring remotely the irrigation system then estimate the fossil fuel spent[5].

- B. A. Ali, V. O. Mihalca, and T. R. Cătălin. MATEC Web of Conferences, (2018), H & S system including imbedded system for monitoring and managing the level of fuel that transporting from the station in to the end user wirelessly, the article notice that 90% of user suffering from the manual monitoring[6].

- T. Goswami, Conference paper, Springer 2019, an approach for getting the fuel gage more accurate in the bikers tank, display the level tank wirely for protect the people from tempered petrol pump[7].

Works related above, cleared precisely, the importance for this technique; comparing and according to the technique on to this paper, the authors contrivances an impact methods as will illustrate below minutely specifically the availability for the observation and remotely accessing.

The remain of this article: properties and system details considered by 2nd part, 3rd part illustrate the proposal system design, results is the 4th part, 5th part take the conclusions & future works suggestions.

2. Properties and System Details

System are consists of two parts, software part as well as hardware part. software part is used for programing the electronic tools that require for measuring and transmitting the data to the database for saving and display the values remotely via internet (by public IP) whereas hardware part is used for reading (sensing) the spending fuel and estimate the available fuel in the main tank for different shapes as well as: cubic tank, vertical cylinder tank and horizontal cylinder tank. Hardware parts used for arrange the communication between sensors and microcontrollers. The system consists of 3 mainly modules named “Embedded System Module”: ultrasonic sensor (UsS) for measuring the height of the liquid which settled in the strategical tank (main tank) and 2 flow meter sensors with 2 Arduino microcontrollers) which connected by 2 wired amplifier transmitters module.

The system can be used with devices which are suitable for both computer system and mobile system; these devices are powerful with internet connectivity and very familiar with built-in sensors. Most of people used an Android systems; it is very applicable and easy especially for student in the universities because the language that it used “Java Programming Language” is well known [8, 9].
A. Electric Diesel Generator
A combination of electric generator with a diesel engine named diesel electric generator to produce electrical power. Private power generators operate independently of the national power grid. The size of generators (power generation capacity) is very important in order to avoid the decrease in energy or lack of power so as not to affect the performance in the institution or site[10].

B. Microcontroller
There are many types of Microcontroller, the Arduino is the most fundamental one that used integrated development environment language (IDE) which is a cross-platform application that written in Java. The programs of Arduino could be written in C++ or C. The code could uploaded in to the board with specific programs that enable it to perform its required operation(s). Arduino is friendly, flexible (offers a variety of interface, input and output), low cost and can communicate easy with software that running on your computer or mobile[11].

C. Sensors
The detector, probe or sensor is a device that detects the state of the environment. It may measure the temperature, gases, pressure, radiation, electric pulses and others. It transmits (convert) the signals to electrical pulses that can be measured or counted by a device[12].

1. Ultrasonic Sensor
Ultrasonic sensor (UsS) has similar approach features in the surrounded environment as audible sound. The ultrasound prevalence may be in solids, gaseous and liquid. For ultrasound is normally regarded to the sound of a frequency is higher than 20 kHz. Concerning to the use, ultrasound can be divided in to two main parts: Active ultrasound and Passive ultrasound. There are many types of ultrasound devices (sensors) depending on the media that need to use, as an example: the humid environment need to use waterproof ultrasonic sensor [13, 14].

2. Flow Meter (Water Flow)
Flow meters sensors (FmS) has been classified as excellent sensor for measuring the flow of liquids; by use the water flow sensor it is easy to arrange a fluid management system. To measure the amount of fluid, pinwheel sensor could use by sits within a line of water pipe[15].

3. Transmitters
A device for transmitting the signal over long distance, these devices varied and numerous, it is used for transmitting the signals in one or two ways (master or master/slave). It is necessary to mention that there are wire/wireless carriers transmitters[16].

3. Proposal System Design
This system need: two microcontroller of Arduino (MEGA 2560 and UNO R3), Two FmS (1-30L/min, YF-S201, G1/2), two transmitter chips as an amplifier (RS-485) and one waterproof ultrasonic module (JSN-SR04T). 50KVA electrical generator (Perkins Motor + Aqsa Armature) utilized for measuring the rate of spent fuel whereas a horizontal cylinder tank (22,000-liter) use for measuring the level of strategic fuel (main tank).

A. Main Architecture of System Design
Sensors connect wiry with master microcontroller (MEGA Arduino) which located near of the generator for collecting the signals, then send this signals wiry though one transmitter to other which connected into the slave microcontroller (UNO Arduino) that located far away from the master, slave located near of the computer which connected to the internet though public IP for save and display the reports remotely, it also contain database and GUI. As appear in Figure 1.
B. Communication Module

According to the Figure 1, the slave Arduino eventually receives all signals, but the model are installed as follows: A (FmS 1) is located into the pump hose, which connected with the fuel pump that pull-up the fuel from the tank generator but the latter sensor (FmS 2) is located with the pull-down hose. Both of sensors are connected with master Arduino by wire. Figure 2 shows this sensor.

The UsS is located into the main tank (the strategical fuel tank) upon the cover shield then the wires (signal and power) is connected with master Arduino too. Figure 3 clarify the UsS.

The master Arduino has a transmitter chip, transmitter (1) which work as an amplifier for transmitting the signals to the slave Arduino that already has a transmitter chip, Arduino (2) which connected to the computer through serial cable by USB port. Figure 4 cleared the transmitter chip (RS-485 can access the signal more than 1.2 Km).

Finally, the computer receive these data and present it as a GUI or report locally or remotely over the world under Public IP.

C. Main Work and Principals

This design takes in to consideration the state of the generator, currently is it ON or OFF (in the GUI, when generator turned ON red sign changed in to green sign). When the engine start work, the FmS start to work immediately because it is connected with fuel hoses entering in to the engine and this gives a signal that the generator has actually worked to create and start the database to store information into the temporary table. The transmitting speed of data is set to be in 115200 baud /s, This means that a large number of data will achieved Intervally each second (the accuracy of each information cannot match the subsequent information that receive between each seconds) this problem has been reduced satisfactory as will be explained in subsequent paragraphs.

By estimating the average withdrawn of liquid (pull-up gasoline) from the tank of generator at known period time (ON state period) and subtracting the total amount (average) from the value of the amount that returned to the fuel tank (within the same time period) the average spend logically will knew exactly how much at that time, this is can represented in equation 1.

\[ [\text{Av. FmS}(1) - \text{Av. FmS}(2)]_t = [\text{Av. Spend Fuel}]_t \]  

\( (1) \)

Where: \( A_v = \text{Average} , \text{FmS=} \text{Flow Meter Sensor} , \ t = \text{Time} \)

This operation starts when the generator turn OFF then the information (that received in the temporary table) saved in a permanent table (created by SQL Server) that contain the ON/OFF state, the average spent fuel, date and level of main fuel tank,
Finally, resetting the temporary table & interring to the standby state for new iteration.

The UsS also sends the data continuously from the strategic fuel tank with the same mechanism. The large quantity of information (reading) is also stored in a temporary table created by (SQL Server) linked to the database to perform the calculations after a specified period of time then store the data in a permanent table after some mathematical operations. Figure 5 as a main flowchart to clear the mechanisms as illustrate below and Figure 6 as the main GUI information shows these details.

![Flowchart of the whole system mechanism](image)

**Figure 5.** Flowchart of the whole system mechanism

In terms of fuel consumption in the generator, when system start (**ON**) UsS send a signal (sign"1") even FmS "a" and FmS "b" send signals too (sign"1") that mean the generator is in the **ON** mode (a green signal). A temporary table created to save the parameters (a&b) that collected at once.

when the generator get **OFF**, a red signal send(sign"0"), that mean the averages calculations in the temporary table should achieved and subtract "b" form "a" then save the result in a permanent table as a database which can display reports by GUI or through internet remotely.

![Main GUI information details](image)

**Figure 6.** Main GUI information details.

**D. Mathematician Model and Calculations Concept**
As mentioned, the major concept for calculation is to subtracting the total average of \( FmS(1) \) from total average of \( FmS (2) \) according to equation (1); the details of mechanism is as follow:- just the generator begins work, ON signal (Green) is sent. This, as mentioned above, is done by sensing that the rotation of \( FmSs \) had begun, in the other worlds, is the time for generate the temporary table for storing these values in real-time mode. Red signal (Off) is sent in order for that temporary table to calculate the final rate according to Equation (1) then storing these values in the permanent table which is also designed by the SQL Server. This table contains all the necessary details such the work time, spend fuel and storage it in the database as a reference data that could displayed in the form of a report through graphical interfaces or by downloading as a Microsoft Excel File.

It is also necessary to note that there is a possibility to display diagrams for any special relationship, Figure 7 as an example. In addition, UsS have the same concept but the approach different tiny, the temporary table save the value for only 100 reading, with each 100 reading the average operating achieved for obtaining the ultimate value with less error (Randomization) and store the value into the primary table, this procedure proceed with each 100 reading repetitively.

Additionally, in this project, the shape of main tank is Horizontal Cylindrical Tank with 200cm Diameter and 700cm Length. The equation for calculate the volume of contains (liquid) is used depending on the gap (distance) between UsS and the surface of the liquid according to the equation 2 below[17]:

\[
v = \left( r^2 \times A\cos \left( \frac{r-h}{r} \right) - (r - h) \times \sqrt{2} \times r \times h - h^2 \right) \times l \tag{2}
\]

Where: \( V= \) Volume, \( r= \)radius, \( h= \) liquid height, \( l= \)length

Moreover, the ability of this project is to calculate many different kind of tank shape as Vertical Cylindrical Tank or Cubic shape according to the equation 3 and 4[18]:

\[
v = h \times r^2 \times \pi \tag{3}
\]

Where: \( V= \) Volume, \( r= \)radius, \( h= \) liquid height

\[
v = h \times l \times w \tag{4}
\]

Where: \( V= \) Volume, \( h= \) liquid height, \( l= \)length, \( w= \)width

Figure 7. Example diagram as a relationship between time & spend fuel.

For good results with less errors, some procedures are considered, as a Calibration Factor, such that: When the timer begins to store the values (readings), it stores all of them in a temporary table, but once the calculations are done it extract the final value to store in the permanent table, these values are not calculated for all, simply the first 30 reading and the last 10 reading are ignored, this is in order to obtain convergent values that are not different because the FmS does not stabilize when the engine speed is unstable, in the other words, when the engine turn on, the engine is under a state of acceleration for a few seconds, and when the engine turned off, the engine will be slow step after step. This was a problem solved in this research. A comparative table illustrate this point in the results part. It is important to mention that the delay time for sending reads from sensors to the Arduino is 5 seconds periodically.
E. GUI and Reports

The graphical user interface (GUI) is the best way to make a communication between program and users. In this project, the GUI is understandable and provide a clarity for users, the user can surveying data from anywhere in the world through the Internet, as there is a port allows to display interfaces and reports remotely through public IP protocol. Figure 6 in previous page which illustrate the main window, has a login interface (user name and password), then users could view and download all the category depending on the polices that given by admin to that user(s) such as: reports, tank shape, change password, add users and settings for more options.

From the menu bar, user can draft reports daily or weekly, monthly or annually. Figure 8 as an example for a report interface. Moreover, user can convert results & download it as a Microsoft Excel File.

![Figure 8](image)

**Figure 8.** Example for a report in the database.

All the results can convert as a chart for more understandability and clarity, as an example, Figure 9 clarify the ratio between work date and fuel used per minute.

![Figure 9](image)

**Figure 9.** Work date and fuel used / Min.

Finally, most of the interfaces illustrate how the user could deal with the properties of the GUI that designed for this project, the most important one in Figure 10 which is clarified the capabilities of the database such backup, restoration and delete as needed.

Table 1. Comparative results with calibration and without calibration.

| Work Time / Hourly | Sensor Measure/ Ltr. | Mechanical Measure/ Ltr. | Error Ratio % |
|--------------------|----------------------|--------------------------|---------------|
|                    |                      |                          |               |


4. Results
In this project, examples of important results clarified in section III, but in this section, the results are more precisely.

Table 2. Comparative results between digital monitoring & mechanical gage for Liquid.

| Work Time / Hourly | Deviation Rate by Calibration | Deviation Rate Without Calibration | Error Ratio % |
|--------------------|-------------------------------|-----------------------------------|---------------|
| 1                  | 0.914                         | 5.9                               | 84.50         |
| 2.30               | 0.831                         | 7.5                               | 88.92         |
| 3                  | 0.695                         | 8.9                               | 92.19         |
| 4.30               | 0.544                         | 10.2                              | 94.66         |
| 5                  | 0.454                         | 11.8                              | 96.15         |

As comparatives in Table 1 shows some experiments as an error rate / (hour) comparing the results when calibration procedure proceed or not.

**Note:** The load power vary (250-500) Ampere and the recording was 1-5 Hours.

The reader can perceive from table above, with using the calibration, error ratio increased as the runtime increases and vice versa.

The other results are focused about the accuracy of fuel spend in the generator. In the other words, the comparative between digital measuring & mechanical gage measuring illustrated below by Table 2.

**Note:** The load power vary (250-400) Ampere and the recording was 1-5 Hours.

Table 2 above, explain that the error ration varying over time, this is depending on the load over the generator (≥250-400≤) Ampere.

Third result is about the main fuel tank (strategical tank); both reading as in Table 3 below are comparing the accuracy between sensor reading and manual reading, manual reading is done by flexible spiral ruler approximately.
Table 3. Accuracy comparative between sensor reading & manual reading monitoring.

| Manual Monitor/ cm | Manual Liter | Sensor Monitor/ cm | Liquid by Sensor/ Ltr. | Err. Rate % |
|--------------------|-------------|--------------------|------------------------|-------------|
| 0                  | 0           | 200                | 0                      | 0           |
| 39.4               | 4560        | 159.66             | 4677.61                | 2.51        |
| 81.2               | 10310       | 119.87             | 10153.72               | 1.53        |
| 141                | 18820       | 59.145             | 18801.83               | 0.09        |
| 189                | 23875       | 9.606              | 23962.91               | 0.36        |

In the third table, the error rate is very tiny (negligible) when comparing between the two methods (manually & digitally).

5. Conclusion and suggestions for Future Works
From the tables that cleared in the previous section, according to the Table 1 using calibration factor gave better result (less error) with more stability and accuracy. Table 2 cleared that using the electrical measuring (sensors) got a very good accuracy for fuel spent estimation, this is gave an indication according to the properties of the generator if there are any problem or abnormal spend (or losses) in the fuel comparing to the runtime that built from the primary table which used as a dataset. Finally, the digital gaging for measuring the fuel in the main tank as appeared in Table 3 gave a very good accuracy for calculate and estimate the amount of fuel (achieved milliliters accuracy), in the other words, it’s provide more secure for saving the amount of fuel. With this system, the ability to know the status of generator in general, including (ON/OFF) status remotely.

Many suggestions can be illustrated here, such that:
1. Use a dynamic calibration equations for both FmS according to the current that achieved by generator.
2. Calculate the currents by clap meter located on each phases and connect it with master Arduino.
3. Estimate the voltage for each phase in real-time.
4. Remote controlling for the generator, make the engine start or down by mobile device.
5. Many other sensors and microcontrollers can used with this project such as: Raspberry Microcontrollers and others, flow meter that uses in the gas stations, transfer data wirelessly between master/slave Arduino by RF transmitters and finally can use IR sensors for measuring the liquid level or even can use laser sensor for more accuracy.
6. Using shield Arduino, web server or cloud server instead of Public IP for remote access.

Note that: as a challenges for this project, the cost are suitable, the kits are less than 150$ except the financial value of the Public IP and GUI design.

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