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A novel approach to transparent and accurate fuel dispensing for consumer protection

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ABSTRACT

Consumer rights are exploited around the world and it is necessary for to protect consumer rights by means of safeguarding consumers from various unfair trade practices. Those most vulnerable to such exploitation must be shielded, and this is achieved through consumer protection measures. One such example of unethical behavior is fuel stealing at fuel stations. To overcome this critical issue, a low-cost fuel quantity sensing and monitoring system is proposed in this paper. A fuel detection system will ensure the exact quantity of fuel filled in fuel tank and will detect fuel theft, if any, at fuel pumps. An embedded system is developed for this purpose, consisting of sensors, display devices, communication devices and microcontroller. The quantity of fuel filled in the tank is transmitted to mobile phone of the consumer to avoid fuel theft. Performance of the system is validated by comparing the displayed amount of fuel dispensed and actual filled in the tank and achieve 99.95% accuracy. With this consumer right to get the value for amount paid for the petrol will be protected. This novel feature can be added in the fuel tank of the smart vehicle development and design as a future scope.

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1. INTRODUCTION

The fuels like petrol and diesel are often being robbed in various different ways to sell that stolen fuel in black market. One of the ways of such type of larceny is petrol/diesel stealing at petrol stations where the consumer is being cheated while he/she is filling fuel in their vehicles. The fuel pump employees often by some malpractice techniques and by tampering with the fuel delivery system give less amount of fuel than the actual amount of fuel the consumer pays for. Therefore, by such acts of dacoit the consumers are being cheated. In order to take action against such felony we have designed a portable device system which will detect such theft, a fuel theft detecting system is proposed in this paper, which uses ATmega microcontroller and combination of sensor like flow sensor and some communication interfaces like radio frequency (RF) module, global system for mobiles (GSM) module and IEEE standard 802.15 (Bluetooth) module which will detect the exact amount of fuel to filled in the petrol/diesel tank and cross verify it with the actual amount and also transfer this data for different applications by using these communication interface.

Many fuels theft detecting systems are proposed by the researchers by addressing different technologies. Some of those are reviewed to know the technology development scenario. Wable and Shinde [1] proposes the system includes mechanisms to monitor fuel levels in real-time and can identify sudden drops or inconsistencies in fuel volume. The system is equipped with GSM technology, enabling it to send alerts or notifications (via short message service (SMS)) to the vehicle owner or authorities in case of fuel theft or anomalies in fuel levels. This system incorporates mechanisms to detect unusual fuel level changes, particularly unauthorized or sudden decreases that may indicate fuel theft [2]. The system is designed to detect unauthorized removal or theft of fuel from a vehicle's tank. It uses sensors to monitor the fuel level, and any abrupt changes in the fuel volume are treated as a potential theft. A cost-effective and practical solution for preventing fuel theft using microcontroller and GSM technologies, offering vehicle owners real-time monitoring and immediate notifications is proposed in [3]. A robust, automated solution for detecting and preventing fuel theft, providing vehicle owners with real-time monitoring and protective responses to safeguard their fuel resources is presented by Islam *et al.* [4].

Our country is on a road of progress and to keep it like that every citizen must contribute in removing flaws like corruption and burglary of economy. Fuel theft is one such type of corruption and economic burglary. Petrol theft is also violation of consumer rights. Also removing contribution to black market economy by stopping this act will be beneficial for the growth of our country’s economy. Also, common man will be relieved of such act of larceny. Also, in commercial transport-based companies (for example: Ola Cabs, Uber, and FedEx) fuel filling allowances are given to the employees working for that company. While all the employees don’t work honestly for the company, there are few who take advantage of this allowance and falsify the petrol filling records, thus cheating their own company for personal benefits. Thus, our proposed project design is very much needed by the present society and economical condition of our country. This theft will be stopped by the results of the device. The device will analyze the value of fuel displayed on the fuel delivery machine and the value displayed on the fuel theft detector and thus show any act of stealing of fuel. Also, the value calculated by our device will be send over directly to the company’s record maintenance department through SMS service using a GSM module. Also, an option for Bluetooth based transfer of data and then handover to the servers of the company which are already connected to the employees’ handsets is available [5]-[8].

The system proposed by Prabhu *et al.* [9], uses sensors to measure fuel levels and sends real-time alerts via SMS using a GSM module if theft is detected. The system is designed to notify vehicle owners instantly, making it practical for preventing fuel-related fraud or tampering. It focuses on low-cost implementation and real-time monitoring for consumer protection. It reviews various techniques and technologies, such as sensors and internet of thing (IoT) devices, to monitor fuel levels in real time. The system alerts users through mobile apps about suspicious activities [10]. The system in [11], highlights the system's potential to improve vehicle maintenance and theft prevention through smart technology integration, offering an effective solution for managing e-vehicle performance remotely.

Some of the systems performs both monitoring and alerting the owner about the fuel status. An Arduino module-based fuel monitoring system can detect and notify vehicle owners of fuel theft in parking lots [12]. The paper proposes using IoT sensors and technologies like GSM, global positioning system (GPS), and cloud computing to detect and prevent fuel theft [13]. The paper proposes an IoT-based system to monitor fuel levels, authenticate access, and track the location of fuel tankers to prevent fuel theft during transport [14]. A smart fuel theft detection system using ARM7 microcontroller, GPS, and GSM to monitor fuel levels and location [15]. The proposed system involves continuously monitoring fuel levels, sending alerts, using dual password authentication, and tracking the location of the tanker to prevent fuel theft during transport [16]. A mobile application using ultrasonic sensors and GSM can monitor fuel levels, detect theft, and report fuel consumption data to prevent fuel theft [17]. An IoT-enabled fuel level monitoring and automatic fuel theft detection system using sensors and GPS [18]. The paper proposes using MAC address detection of customer mobile devices and car plate numbers to prevent and detect petrol theft [19]. The paper proposes an IoT-based fleet tracking system that can monitor fuel consumption and detect fuel theft using ultrasonic sensors and radio frequency identification (RFID) technology [20].

Some fuel detector systems inform the cost of the fuel too. An IoT-based smart fuel meter system can help prevent fuel theft by providing accurate fuel level and cost information to consumers [21]. An automatic fuel management and remote monitoring system using IoT can help prevent fuel theft [22]. The paper describes a smart vehicle anti-theft system that integrates GPS, GSM, and motion sensors to track, monitor, and disable the vehicle in case of theft [23]. An IoT-based system using flow and ultrasonic sensors can detect and report fuel theft in vehicles [24]. The systems based on IoT are vulnerable to the internet connectivity and cyber issues [25]. Though lots of systems are proposed to detect the fuel theft, validation of the system is a main concern. An attempt is made to contribute to the development in real time fuel detection, monitoring, and alert system.

2. PROPOSED SYSTEM

The social impact and schematic view with individual functioning block is explored in following subsections.

2.1. Social impact

As the petrol/diesel prices are rising day by day and for a common man it has become difficult to handle his/her monthly budget maintaining a vehicle. After this entire problem if citizens are being robbed at the petrol pumps, then it's a violation of their consumer rights. In order to stop this petrol stealing and bring such felony to justice we are designing a portable electronic device which will give precise information about the petrol filled in the vehicle on user/consumer level. So that the consumer can check on user level the amount of petrol shown on the petrol station display and value shown on the system display we have designed. Thereby analyzing both the values we can detect any theft happening. One such example of unethical behavior is fuel stealing at fuel stations. It may come to you as a surprise, but there are many ways in which your employees can indulge in fuel theft, providing incorrect fuel purchase reports, fuel pumped out of the tank, fuel not totally filled to the tank's capacity and many more.

The proposed system is uniquely designed to measure the volume of fuel and display this information on the fuel delivery machine as well as on the fuel theft detector, enabling the detection of any fuel theft incidents. This paper aims in spreading the awareness among the citizens about the fuel theft occurring at fuel stations highlighting how some petrol station owners may engage in such unethical practices. Further, the system will also help curb black-market fuel transaction by detecting the fuel theft thereby reducing the illegal practices. Additionally, it safeguards the consumer rights by ensuring that customers receives the exact amount of fuel that pay for, eliminating the risk of being overcharged for less fuel. This advancement in vehicular technology and digitization benefits not only to everyday customers but also the broader community. Figure 1 illustrates the social impact of implementing a fuel theft detector at fuel stations.

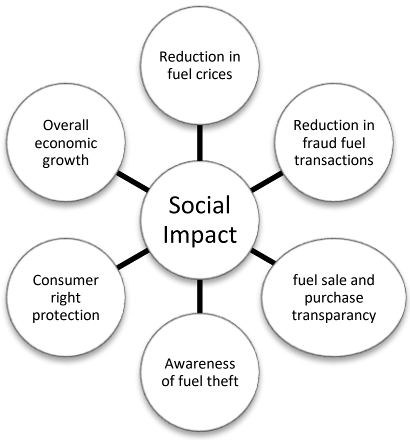


Figure 1. Social impact of fuel theft detector at fuel stations

2.2. Schematic view

Figure 2 illustrates the schematic view of the proposed fuel theft detector system. It consists of following functioning components:

2.2.1. Flow sensor

This block contains the actual fuel sensor used for measuring the flow rate of any liquid pass through it. In our case it measures the flow rate of the petrol flowed through it. We used YF-S201 flow rate sensor for measuring the flow rate of the fuel. Following are the sensor specifications:

- Sensor working principal: hall effect
- Working voltage: 5 to 18 V DC (min tested working voltage 4.5 V)
- Max current draw: 15 mA @ 5 V

– Output type: 5 V TTL
– Working flow rate: 1 to 30 litres/minute
– Working temperature range: -25 to+80 ℃
– Working humidity range: 35%-80% RH
– Accuracy: ±10%
– Maximum water pressure: 2.0 MPa
– Output duty cycle: 50%+-10%
– Output rise time: 0.04 us
– Output fall time: 0.18 us
– Flow rate pulse characteristics: frequency (Hz)=7.5 * flow rate (L/min)
– Pulses per litre: 450
– Durability: minimum 300,000 cycles
– Cable length: 15 cm
– 1/2" nominal pipe connections, 0.78" outer diameter, 1/2" of thread
– Size: 2.5"×1.4"×1.4"

2.2.2. Microcontroller

The main processing and controlling block of our project and also to process the flow rate sensor output and convert it to a finite reading in litres. Also, to display this information on various communication interfaces. We have used to microcontrollers, ATMEGA-328 and ATMEGA-8. ATMEGA-328 communicates with Bluetooth and GSM module to interact with the user whereas ATMEGA-8 displays the fuel quantity on the display through the RF module.

2.2.3. On-board liquid crystal display

Used for displaying reading for on-device indication of the fuel quantity measured by the flow sensor. Further, the power supply comprises of the source of 5 V and 9 V DC power. It is used for providing appropriated and required DC voltage levels to the microcontrollers and different communication modules as per their requirement and operating voltage range.

2.2.4. Radio frequency communication module

This communication module is used for short range transmission and relaying of the data recorded by the fuel theft detector and display it using LCD. Short range transmission for example: dashboard of the car. We have used RF 433 MHz transmitter-receiver module for our project. 433 MHz is RF transmitter and receiver module which is used for wireless transmission.

2.2.5. Bluetooth and global system for mobiles module

This Bluetooth communication module is also used for short range communication distance but it relays the data and displays it on another Bluetooth supporting device like a mobile phone. GSM (global positioning module) module is used to alert the user or fuel station owner about the fuel quantity dispensed on their mobile phones. Figure 2 shows the block diagram or schematic view of the proposed furl theft detector.

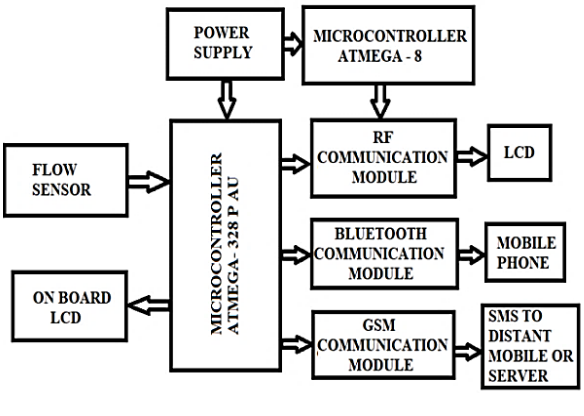


Figure 2. Schematic of proposed system

3. RESEARCH METHOD

An embedded system is developed which will monitor the fuel quantity to be dispensed by the fuel station using flow sensor. The dispensed quantity will be monitored in real time with help of the display devices. The methos is illustrated with the flow chart shown in Figure 3. The following steps depicts the methodology adopted for the functioning of the fuel theft detector:

a. Start: set the system, initializing the necessary components like the Arduino board and sensors.
b. Initialize flow sensor: input from flow sensor connected to an LCD display.
c. Read fuel sensor: there are multiple fuel sensors.
d. Fuel interrupt: a fuel sensor is connected through an interrupt pin to calculate fuel flow.
e. Calculate fuel count: using the input from the fuel sensor, calculate the fuel count using a software algorithm.
f. Display final count: show the calculated final fuel count on an LCD.
g. Bluetooth transmission: the calculated fuel flow can be transmitted via Bluetooth for external monitoring.
h. Delay/software serial: there is a delay added, likely to allow time for sensor readings or to avoid spamming the Bluetooth transmission.
i. Reset/finish: reset the system or stop the flow once the count is done.

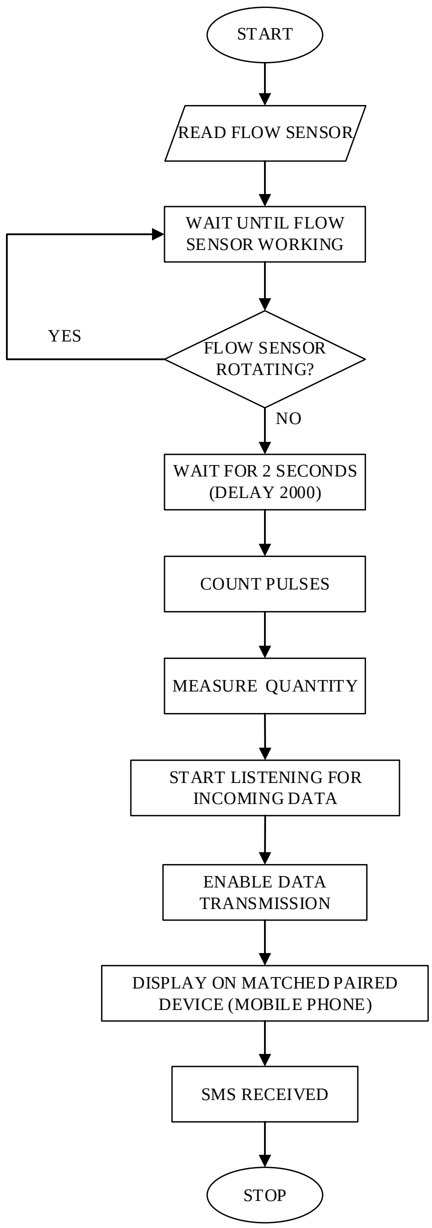


Figure 3. Methodology for proposed system

3.1. System hardware

The proposed system is designed to detect and prevent fuel theft by continuously monitoring fuel levels and triggering alerts in case of any irregularities. To implement this concept, a hardware section is integrated to bring the system to life. Figure 4 depicts the circuit diagram of the proposed system.

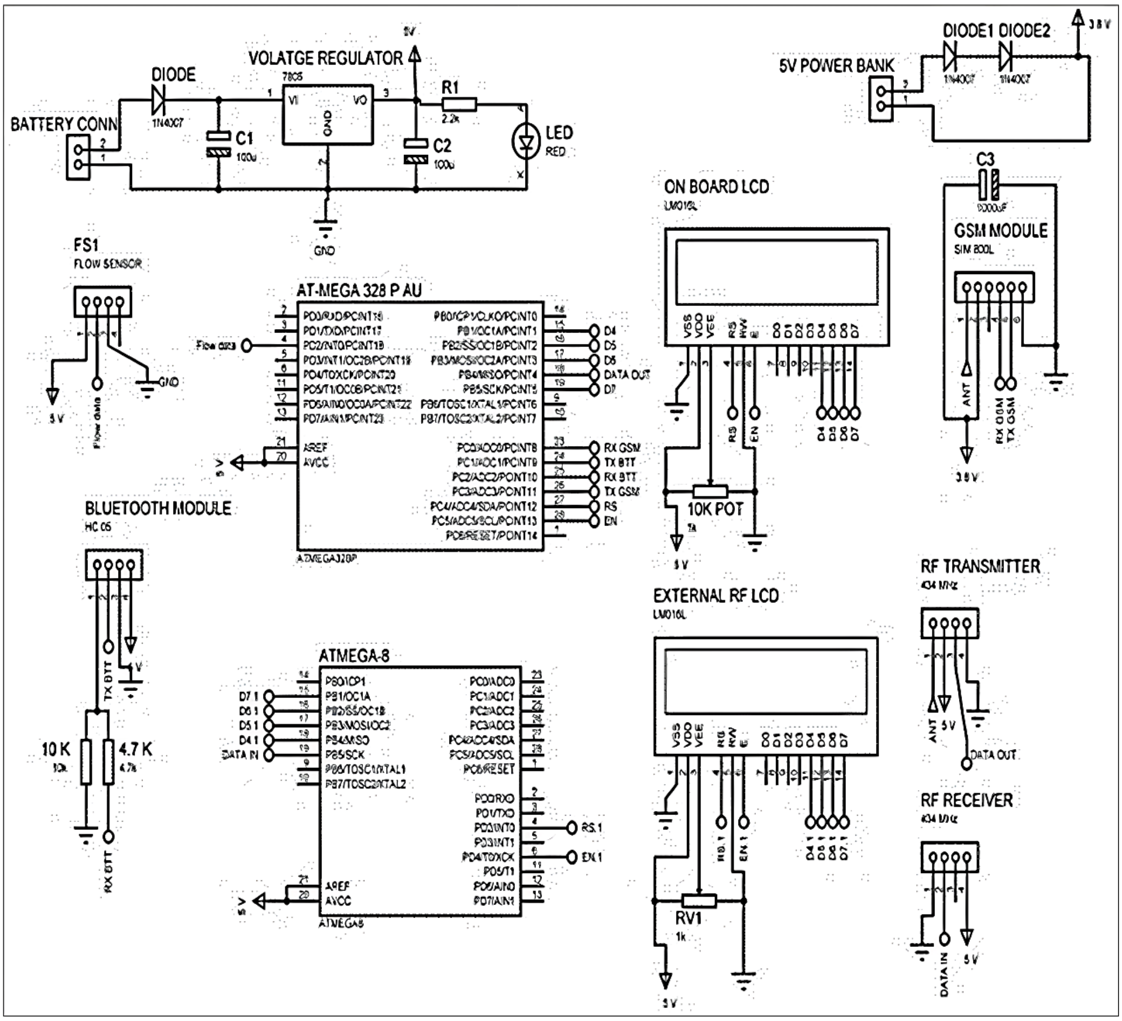


Figure 4. Circuit diagram of fuel theft detector

At the core of the system is the microcontroller, which processes data from the fuel sensors. These sensors are physically installed in the vehicle's fuel tank to measure the fuel level accurately in real time. If the sensors detect an abnormal drop in fuel, indicating potential theft, they send signals to the microcontroller. The microcontroller, in turn, processes these signals and activates the GSM module, which is another key hardware component.

The GSM module sends an SMS alert to the vehicle owner, notifying them of the theft. Additionally, the system can be connected to other actuators or fuel cutoff mechanisms to prevent further theft automatically. This hardware setup enables the practical functioning of the proposed system, ensuring real-time monitoring, theft detection, and immediate response. By linking the hardware components—sensors, microcontroller, and GSM module—with the proposed conceptual design, the system effectively achieves its goal of fuel theft detection and prevention.

4. RESULT AND DISCUSSION

At the beginning of the measurement process, fuel is directed through a flow sensing device, where the flow sensor measures the fuel flow rate and outputs the data in pulses. These pulses are then sent to a microcontroller, which processes the pulse count and calculates the volume of fuel using a calibration formula. The calibration formula is given in (1):

$$\text{Fuel Quantity} = \text{Pulse Count}/\text{k} \tag{1}$$

In (1), the calibration factor (k) is the average number of pulses counted per litre. It is a constant value derived from averaging the results of multiple tests. To determine the calibration factor (k), we conducted nine test measurements using water and a beaker to ensure standard measurement of litres for the flow sensor. The experimentation is carried out in the laboratory to validate the concept. Table 1 depicts computation of calibration factor ‘k’.

Table 1. Computation of calibration factor (k)

Serial no	Fuel quantity (litre)	Pulse counted by microcontroller
1	1	263
2	1	262
3	1	264
4	2	524
5	2	526
6	2	523
7	5	1311
8	5	1310
9	5	1313
Mean value	2.66	699.54

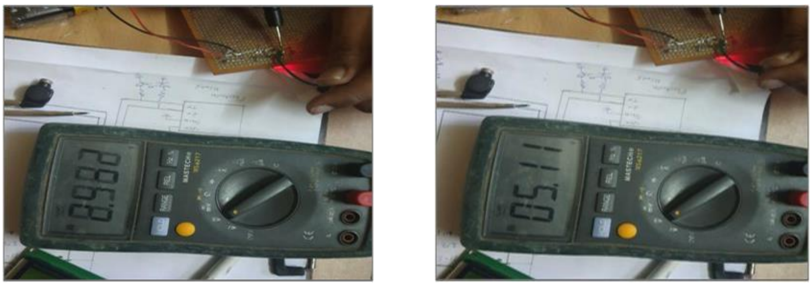
Therefore, k=(699.54/2.66)=262.96, therefore k~ 263. It is the mean value pulse count per litre.

After the fuel flow value is calculated by microcontroller using programming, it the sends this value to different output devices interfaced. Initially, this value is then displayed on the on-board LCD screen. Further, using RF communication interface and radio transmission protocol this value is transmitted to an external LCD. By using the Bluetooth module HC-05, this value is then transmitted to a Bluetooth paired device or a Bluetooth paired mobile phone. Further, by using GSM communication protocol, this value is transmitted over the air to a distant mobile phone or a GSM modem through SMS. Thus, the fuel quantity is calculated using a flow sensor and it is broadcasted over four display and output blocks.

The system uses a flow sensor that activates based on the rotations of a fan, and it operates on a microcontroller programmed in Python. Python is known for its simplicity and robustness, making it one of the most widely used programming languages today. Its user-friendly nature allows anyone to operate the system with ease. To test the performance of the system, following parametric tests are conducted,

4.1. Power supply test

After design and implementation of power supply by means of the hardware it is necessary to test for its the output voltage as per the design parameters of the power supply to ensure the functioning of the critical components like integrated circuits and hardware modules. Two voltage requirements are there, 5 V and 9 V. Figure 5(a) show the testing results of supply voltages 9 V which shows the relative error of 0.32 and Figure 5(b) shows the testing results of supply voltages 5 V which shows the relative error of 0.11 and can be accepted as a tolerance.

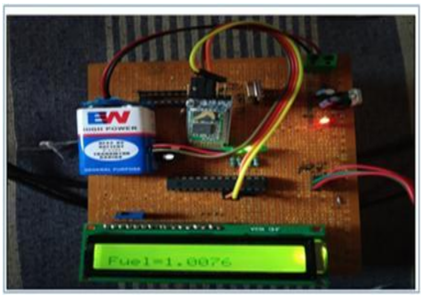


(a) (b)

Figure 5. Power supply testing (a) 9 V power supply and (b) 5 V power supply

4.2. Liquid crystal display test

To test the calibration of the flow sensor, its values are displayed on the LCD. For laboratory experimentation, instead of fuel, water is used to test the performance of the flow sensor. Initially the test is carried out for 1 litre of water and observed if it showed correct value on the on-board LCD. Figure 6(a) illustrates the onboard testing of LCD at transmitter side. After the on-board LCD testing, the functioning of the RF module for successfully transmission of the data signal is tested on LCD at the receiver side, as shown in Figure 6(b). There is slight variation in the voltages levels whereas those are acceptable as per the data sheets of the modules power.


(a)

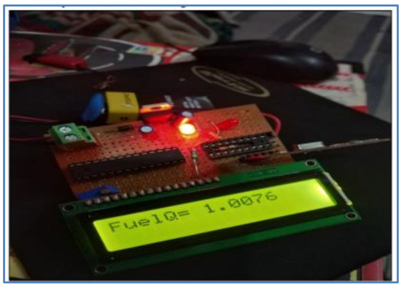
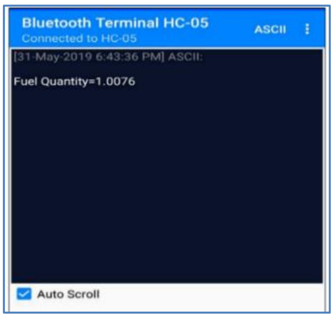

(b)

Figure 6. On-board LCD test (a) display of flow sensor data at transmitter side and (b) display of flow sensor data at receiver side

4.3. Bluetooth and global system for mobiles module test

Bluetooth pairing and data signal transmission testing is carried out using Bluetooth terminal android application on mobile phone is shown in Figure 7(a) and GSM module SMS service data transmission testing is as shown in Figure 7(b). It confirms the functioning of the Bluetooth and RF module for its intended purpose. Results show the 100% success rate of both the communication modules.



(a)

(b)

Figure 7. Testing of android application on mobile phone (a) Bluetooth terminal output window and (b) GSM terminal output window

4.4. On field fuel pump testing

After the system was fully tested and validated for all working operations of data transmission and display, it is time for the actual field test at a fuel pump. Table 2 presents the test results. From table it is seen that the tolerance of error +/- 5% can be considered.

Table 2. Field testing results of the fuel theft detector

Sr. no	Amount of petrol filled (count)	Fuel pump reading	Fuel theft detector reading (+0.05%)	Theft detection
1	80.56	1.00	1.0573	NO
2	100	1.23	1.2272	NO
3	50	0.8	0.7011	YES

After testing of the individual module for its functioning to ensure the system performance, a system need to be validated for its working principal. To validate the sensor reading and system calibration, fuel measurement test of the proposed fuel detector system is conducted at the fuel station. Results of the system testing are shown in Figure 8. From results, it is seen that the amount of the fuel dispensed by the fuel station is 1.00 and the amount monitored in real time by fuel theft detector on android application is 1.05 which confirms the working principal of the proposed system with the accuracy of 99.95% which is much improved as that of [26] which achieved the accuracy of 90%.

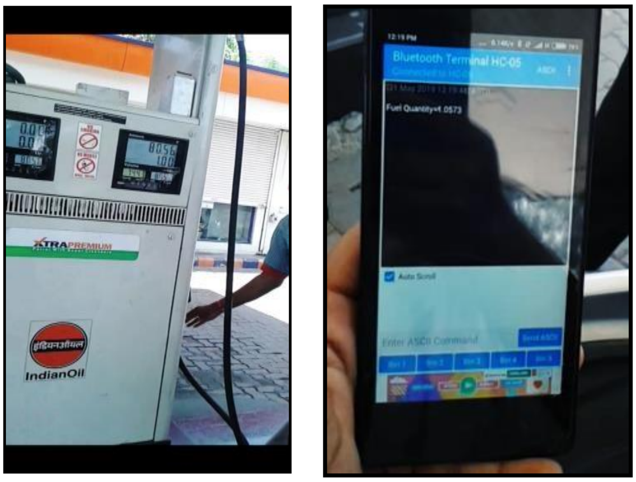


Figure 8. Validation displayed value at fuel station and value detected by fuel theft detector (a) actual value on fuel station and (b) value measured by flow sensor

5. CONCLUSION

This fuel theft detection system helps prevent petrol theft by ensuring accurate measurement of fuel. It provides precise readings of the petrol quantity with 90.95% of accuracy, requiring minimal human intervention due to its user-friendly design. The communication success rate of the RF module, GSM module and Bluetooth module is 100%.

The main goal is to improve the precision of the flow sensor for maximum accuracy in petrol measurement. Results shows that the system allows an error of 1.05% to maintain the accuracy of the measurement. Corrective measures can be taken in the billing of the fuel to avoid financial loss to the consumer. The system is tested for different testing parameters and validated at working environment of the proposed application. The results endorse the validity test of the fuel measurement and real time monitoring. Although the current version focuses on fuel quantity measurement, the system can be further upgraded to measure fuel quality as well. Additionally, with further modifications, it could calculate a vehicle's mileage based on fuel consumption. The device can be installed directly at the petrol tank's inlet, eliminating the need for users to carry it separately. The output can be displayed directly on the vehicle's dashboard, making it a portable solution for user-level petrol measurement.

It is suitable for use by transport companies for accurate fuel measurement and can be installed in larger vehicles in the future. The advantages of this system include, providing an exact measurement of the petrol filled in the tank, preventing fuel theft at petrol stations, compatibility with any type of vehicle and various liquids, displaying output on mobile devices through a Wi-Fi module, easy-to-use and user-friendly design. With the advancement in the technology, the system presented here can adopt the artificial intelligence to reduces the hardware cost.

The system addresses the issue of fuel theft and provides the solution to identify the theft and controlling it by means of real time monitoring by the consumer, thereby protecting the consumers right to get exact quantity of the fuel.

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AUTHOR CONTRIBUTIONS STATEMENT

This journal uses the Contributor Roles Taxonomy (CRediT) to recognize individual author contributions, reduce authorship disputes, and facilitate collaboration.

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C : **C**onceptualization
M : **M**ethodology
So : **So**ftware
Va : **Va**lidation
Fo : **Fo**rmal analysis
I : **I**nvestigation
R : **R**esources
D : **D**ata Curation
O : Writing - **O**riginal Draft
E : Writing - Review & **E**diting
Vi : **Vi**sualization
Su : **Su**pervision
P : **P**roject administration
Fu : **Fu**nding acquisition

CONFLICT OF INTEREST STATEMENT

Authors state no conflict of interest.

DATA AVAILABILITY

The authors confirm that the data supporting the findings of this study are available within the article

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