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Digital Fuel Measuring Techniques: A Review

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Abstract: There have been significant advancements in gasoline metering technology during the last few years. In any event, a key difficulty that all drivers encounter is the inability to obtain volumetric data for the remaining gasoline level, primarily while refuelling the car or driving at reserved fuel levels. As a result, customers find up paying for fuel they don't have. This paper gives an overview of several approaches involving numerous sensors that have been designed to generate a consistent indication of the amount of fuel available. In this study, capacitive, potentiometric, fibre optic, electromagnetic, ultrasonic, and load cell sensors are explored. The aim of this study is to present a report on fuel monitoring strategies that rely on these six sensors. This investigation will aid other researchers working in this field in selecting a sensor for their project.
Keywords: fuel measuring, capacitive, electromagnetic, potentiometric, fibre optic, ultrasonic, and load cell.

I. INTRODUCTION

Automobiles have been around for modern society for more than two centuries, but major electrification of certain vehicles began only in the late 1970s and early 1980s, i.e., in the last forty years. These last 40 years have opened the doors of huge data that combines our electronic and electrical expertise with insights from many other disciplines such as mechatronics, information technology, mechanics, and so on. These links therefore resulted in the contemporary vehicle's basic configuration being fully multidisciplinary, diverse, and complicated. And all elements of the car are influenced by these complicated configurations. Because vehicles are complicated machinery, it is much more vital than ever before to strive to emphasize on optimum standards of improved performance from all of the vehicle's elements. This encompasses various components, such as steering, engine, aerodynamics, and brakes. However, one crucial element that has the most room for development is the fuelling system. Despite the fact that the fuelling system is not as sophisticated as most of the other systems found inside an automobile, it does have a number of areas that may be improved. The monitoring of the current fuel management system is the subject of this study. The reliability of the fuel monitoring system is entirely dependent on two factors: precision and efficiency. Every fuel monitoring system is judged on how precise its estimates and evaluations are, as well as how economical it is in its operation, after all, how it can give the highest level of reliability while using the least amount of energy. As a result, these characteristics are critical when attempting to maximise the effectiveness of fuel metering devices.

Consequently, a great deal of evidence about gasoline bunk scams has emerged, leading to fraud. There is a discrepancy between both the gauged gasoline which is indicated in the gas tank and the quantity of gas inside the customer's tank on the majority of instances. Because the owner of the pump determines the plan of action, the bunk owner benefits. The large number of vehicles use an analogue metre, which cannot display the exact fuel level. As a result, the time has changed to digital, and consumers must know everything. Conventional basic measuring methods, which for the most part contained resistive capacitive transducers, were used to determine fluid levels. Regardless, this Conventional method was ineffective for estimating gasoline use. Because of their low sensitivity and responsiveness. They were also affected by environmental disturbance. Fibre-optic fluid level sensors were introduced to overcome the drawbacks of these kind of guesses. Fibre-optic fluid level sensors offer a higher sensitivity and are more reliable when it comes to measuring fluid levels.

For fuel monitoring, there are a plethora of sensors available. The great majority of companies are eager to develop sensors that can show fuel level and help you save money. In comparison to the previous technique, which had a gauge on the dashboard that used pointers to display the amount of gasoline in the tank, a digital fuel gauge is used to accurately measure the exact amount of fuel in the tank. However, this method isn't accurate and only gives the average figure. Nowadays, all fuel bunks with various complex representations are used to display the estimated gasoline level. However, the customer is unaware of the precise amount of the increased fuel level.

It will cause debasement, and the bunk owner will deceive the customer. As a result, many manufacturer's designs are fully concentrated on the sensors, which are highly essential in displaying fuel levels accurately and saving money. The fuel level is indicated via indicators and a warning structure. It provides an audible and visual signal.

II. RESEARCH METHODOLOGY

This systematic review aims to find publications in the literature that deal with the use of various sensors to get a volumetric output of the gasoline in the tank. Springer, IEEE, Google Patents, Google Scholar, JSTOR, Science Direct, Researcher, and Research Gate were used to search the literature. The following keywords were used to find relevant papers in the first stage: ("digital fuel gauge," OR "volume of fuel," AND "volumetric measurement of fuel," AND "fuel measurement," OR "capacitive sensor," OR "optic fibre," "ultrasonic sensor," OR "load cell sensor," OR "potentiometer sensor)." The time period for this study was limited to all articles submitted after 2005, which is the last 15 years, however a few older studies were considered since they mentioned patents. The research included in this study were submitted in international publications, with some being book excerpts and others being patented designs.

The assessment of the work was done in three stages:

A. Step 1: Identification stage.

We used the above-mentioned catchphrases to find publications on our subject during the identification step. In addition, all of the evidence obtained from multiple sources was integrated, and duplicates were removed. The title and abstracts were read first to see if the publication was relevant to our area of interest.

B. Step 2: Eligibility stage.

The data was evaluated in the eligibility stage to see if the article fulfilled the eligibility criteria and if the findings and conclusion were acceptable. The representation of the method under consideration, as well as comparisons with other similar strategies, were also considered. The following information was gathered for each legitimate study: author/s, year of publication, design description, and working of the specified design.

C. Step 3: Shortlisting stage.

After eliminating the identical documents, we had a total of 113 publications. The titles and abstracts of the publications were analysed, and 50 articles were chosen for in-depth study and confirmation of the findings. The studies quality standards were validated in the final step of the systematic review. 27 publications were chosen to be considered in this systematic review from the 50 publications acquired in the earlier stages.

III. LITERATURE REVIEW

A. Optic Fibre

[1] stated that perhaps the fibre optic sensor demonstrated in his investigation uses a single optical fibre to assess the fluid level, which has important implications for the silicon diode fluid level measuring experiment. The sensor detects thermal differences and determines regions across an electrically heated fibre optics submerged in fluid and exposed to vapour using optical Rayleigh backscattering technology. The temperature of the fibre optic sections reduced in the fuel is limited by the boiling temperature of the propellant fluid, which is fundamentally not the same as the temperatures of the fibre shards exposed to the fuel vapour at that moment. As the optical signal bridge unit, the researcher used the OBR 4400 from Luna Technologies of Virginia, which has thermal and spatial aims that satisfy the specific fuel monitoring requirements. OBR 4400 is a synchronized optical frequency domain reflectometry with Rayleigh backscattering (C-OFDR). [2] Described a continuous fluid level sensor with millimetre spatial resolution for both room and low-temperature liquids, using self-heated fibres as sensing devices. It is based on the in-fibre Rayleigh dissipating optical frequency domain reflectometry (OFDR) estimates. To expand its applicability for fluid level sensing for both ambient temperature and cold temperatures down to 4 K, this research uses both electrically and optically heated optical fibres. To assess the fluid level with millimetre spatial precision, a specific thermal reaction of fluid is isolated from gas. Undiluted water was tested at ambient temperature, liquid nitrogen was tested at 77 K, and liquid helium was tested at 4 K. The detection range may be extended to over 70 metres. The use of inexpensive metal-coated fibre and high sensitivity strings as the measuring device avoids the difficulties and high costs of constructing specialised fibre sensors, such as fibre Bragg grinding (FBG) with reduced coating. For fluid level monitoring purposes, the suggested sensing model defines low efforts, extended working range, high objectives, and all-temperature responses. The researcher's setup is seen below. [3] A data-acquisition system (DAS) is restricted by a PC (that operates a producer and a sensor) and a single optical fibre in his framework. An optical fibre saturated in the fluid whose quantity we want to measure receives light from an LED. The light passes via the fibre, and the fluid acts as a following coating when the fibre is surrounded by fluid.

As a result, entire internal reflection occurs at the covering contact in the centre, and the light reaches the receiver practically unscathed, except from absorption. When the tank isn't full of fluid, one portion of the fibre is surrounded by fluid, while the other is surrounded by air. Because the fibre contains a (coating of the fibre in combination to the fluid) in the bottom section, entire internal reflection occurs, and light losses are minimal because the major percentage of the rays is confined. Since the fibre has just the coating and there are increasingly more faulty beams in the exposed section, there is less total internal reflection. If we synchronize the test for the various fluid states in the tank, we can basically determine the fluid level by looking at the active indication of the detector. The higher the level, the greater the motivation to investigate the photodiode. [4] The frustrated total internal reflection FTIR phenomenon on the coating layer of the plastic optic fibre (POF) is used by the researcher to determine water level in this article. The liveliness in the core of the fibre moves toward the perimeter when it is twisted in a certain way. Radiation and cladding modes are produced at this stage. The coating type lights reflect on the coating-condition interface, and the temporary field invades into the surrounding medium, especially in POF, which has no covering layer. When the refractive index of the enveloping medium in the range of a transient field (around a frequency) increases (from liquid to vapor), part of the reflection lights will be lost in the enveloping media due to the impact of frustrated total internal reflection. This phenomenon is described by the researcher as "coating mode frustrated complete internal reflection" (CMFTIR). Additional light is lost as the twisted fibre is dropped into the fluid, and the force decay at the fibre's end can be seen. However, since it is so impotent to be choked by foundational upheavals, the CMFTIR detecting signal is difficult to distinguish. The parallel helical macro-bend coupled structure (PHMBCS) and the twisted helical macro-bend coupled structure (THMBCS) were designed by the researcher separately. The bending diameter regulates the radiation force, which may be calculated using the full-vectoral coupled-mode hypothesis.

B. Load cell

After doing extensive study on numerous sensors, the researchers and investigator decided to use the earth's gravitational force to apply pressure on the fuel and draw it down. Many research groups have used load cell sensors[5] in their approach to determine the amount of gasoline in the fuel tank and display it exactly on the display. The use of a load cell sensor is necessary since it is the only sensor capable of measuring the weight of the fuel while taking the earth's gravity into account. [6] was the first successful individual to use a load cell sensor in their study. He created a system for calculating the fuel load in a tank filled with gasoline. A load cell sensor attached to the tank foundation, a calculation unit or microprocessor, and a visible level indication are all included. The gadget can measure the amount of gasoline in the tank at any moment, whether it is while fuelling or while driving the car. The tank is secured to the support by studs attached to one side of the tank. The sensors are attached to the tank on the support's opposite side. The load cell sensors provide information about the amount of gasoline in the tank. The calculation and correcting modules translate volume data from load cell sensors into % for the vehicle's operational range per kilometre. The term "vehicle" refers to vehicles that run on liquid fuel. There wasn't much progress on load cell sensors for fuel monitoring for a few years until Toyota decided to build the world's first completely working hydrogen fuel cell car. Toyota researchers conducted two studies on load cell sensors, both of which were similar except for the fact that the first test had technical glitches that prevented them from displaying precise fuel levels in the tank; however, in the second test, they managed to overcome the problem and the data displayed on the cluster was precise. The researchers[7] patented their approach of using a load cell. They placed four sensors on the top of each liquefied hydrogen tank and used an average of the total weight generated by each sensor to measure the amount of liquefied hydrogen gas in the tank. If the control unit determines that the speed is zero, the weight recorded by the load cell sensor is sent to the controller module. The weight is monitored by the controller until a predefined monitoring interval has passed. The controller module estimates the average value of the weight acquired by testing and utilises the estimated average value and a plan to compute the amount of liquid hydrogen in the tank, making it easy for the controller module to measure the vehicle's range. Only hydrogen cars were allowed to utilise this approach. Following Toyota's attempt, researchers began employing load cell sensors for monitoring and incorporating them into a variety of ways to make them more efficient. [8] aimed to create a highly precise gauge for liquid fuel in a vehicle's tank, focusing on the use of a load cell installed on the top of the fuel tank, which then takes an average of the overall weight measured by the tank to evaluate the fuel in the tank, a computer, the odometer, and an electronic circuit based on the tank weight prior to loading (Weight 1), the density of the fuel (already stored), and a computer, the odometer, and an electronic circuit $Fuel\,Volume\ = \frac{(Weight\ 2 - Weight\ 1)}{Density\ of\ Fuel}$ This makes it simple for the controller module to calculate the vehicle's range and the quantity of fuel spent per unit of time and/or per kilometre driven. This method is identical to Toyota's, but it can be used to any type of fuel since all you need to know is the density of the fuel and then update the control unit with that information. So, several researchers used load cell sensors to measure fuel level, but they were in different sectors.

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No such work in the automotive industry could be regarded until a few Indian researchers [9] installed the load cell sensor under the fuel tank with the help of the vehicle chassis base. The load cell is linked to the vehicle's chassis on one end and the gasoline tank on the other. The dashboard has a dedicated display screen. When refuelling the tank, press the reset button on the display screen, which will indicate the actual fuel level in the tank in litres. The fact that this display is manual means that we can only view the fuel level if we click the button exactly at that time. There have been many patents and papers on fuel measuring device in vehicles using load cell sensors, but no sensible study on fuel measuring device in motorcycles using load cell sensors was done until researchers [10] wanted to avoid the fraudulent activities that are going on in the fuel stations, we have to cross-check the level of fuel that is available in our tank when it is filled. To avoid such issues as petroleum cheating, the author set out to create a fuel monitoring system that would aid in properly displaying the level of fuel filled in the tank. When the motorcycle is not in use, this design allows the exact amount of fuel in the tank to be shown digitally. We used a weighing scale, which is used to measure weight in a fuel tank, to make this method work. This will happen only if there is a probability that all-out weight is accumulating at a spot, and so we identified the motorbike fuel tank's focal point of mass. We built a circuit utilising an Arduino Uno, HX711 ADC module, LCD module, and a 10k controller in addition to the load cell[11].

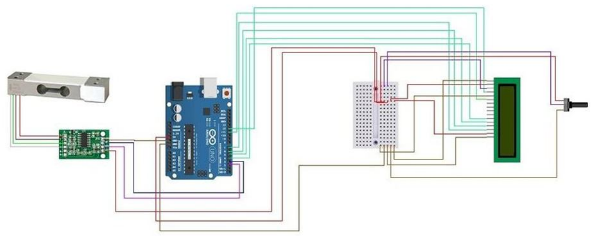

Fig. 1: - Circuit diagram of load-cell based fuel measurement system for automobile fuel tanks

Fig. 2: - Load-cell sensor-based fuel measurement prototype for automobile fuel tank

This is a really unusual study that uses your load sensor and ultrasonic sensor [12]. This project uses a miniaturised scale controller to manage the operation of the Gas Sensor, Load cell Amplifier, Bluetooth Module, and Ultrasonic Distance Sensor. The ultrasonic sensor is connected to the Arduino via pins 7 and 8 on the Arduino board, where the pulse signals is delivered to the sensor and subsequently received by the receiver. The sensor is installed on the bottom side of the gasoline tank top cap to measure the depth of the room in the tank, which can then be used to estimate the volume and, as a result, the number of kilometres the vehicle can go with the remaining petroleum in the tank. The Load Cell (Strain Gauge) is used to calculate the mass of petroleum, which is then used to determine the fuel's density. When a load is applied, the strain gauge of the pressure load cell is distorted, and it is used to give the estimation.

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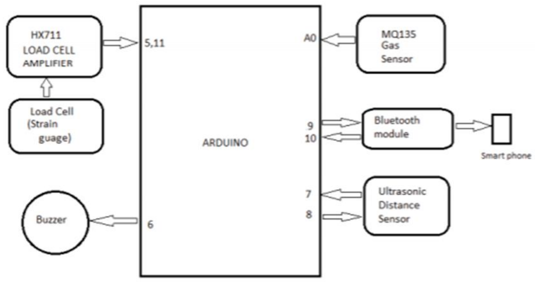

Fig. 3: - Block diagram of Sensor-Based Quality Check and Automated Fuel Level Indication System

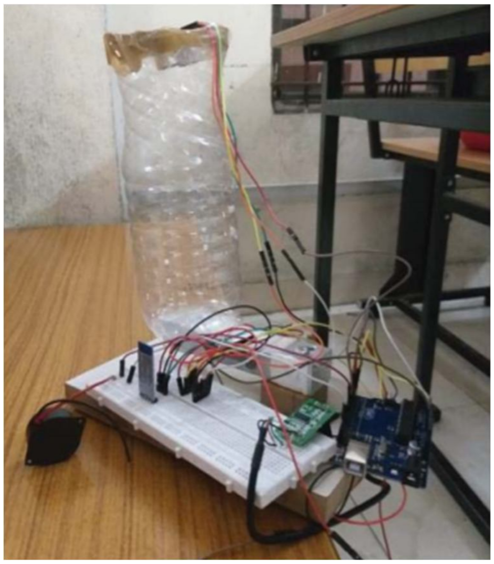

Fig. 4: - Prototype of proposed project*3)*

C. Ultrasonic sensor

[12] This is a really unusual study that uses your load sensor and ultrasonic sensor[13] [12]. This project uses a miniaturised scale controller to manage the operation of the Gas Sensor, Load cell Amplifier, Bluetooth Module, and Ultrasonic Distance Sensor. The ultrasonic sensor is connected to the Arduino via pins 7 and 8 on the Arduino board, where the pulse signals is delivered to the sensor and subsequently received by the receiver. The sensor is installed on the bottom side of the gasoline tank top cap to measure the depth of the room in the tank, which can then be used to estimate the volume and, as a result, the number of kilometres the vehicle can go with the remaining petroleum in the tank. The Load Cell (Strain Gauge) is used to calculate the mass of petroleum, which is then used to determine the fuel's density. When a load is applied, the strain gauge of the pressure load cell is distorted, and it is used to give the estimation. [14] To decrease inaccuracy, the researcher of this research paper utilised an ultrasonic sensor probe that is installed in the geometrical centre of the tank's lid on the outside surface and the receiver is placed next to it. The wavelength of the ultrasonic sensor probe is adjusted at 40 kHz. [14] The author of this article has updated the project by testing the accuracy in various frequencies, the frequency at which tests were conducted was 40 kHz, 100 kHz, 300 kHz. And after various tests and taking the average of all the frequency tests the results of 100 kHz & 300 kHz were better than the previous 40 kHz. [15] The authors are proposing to quantify the fuel in the tank with the assistance of its stream rate likewise assisting with deciding the fuel utilization that is streaming in the motor utilizing an ultrasonic sensor close to the fuel outline. The Ultrasonic Flowmeter is made out of an ultrasonic transducer, electronic circuits and processing framework, which can assemble the liquid utilization originate from the fuel rate transferred data when strung ultrasound through the liquid. The ultrasonic flowmeter dependent on ultrasonic review flow, has qualities of high identification affectability, sensitivity and simple online auto-discovery, rapid information obtaining, information and sign handling advancements, which can be utilized for noncontact stream estimation, establishment and support doesn't influence the dispersion of the deliberate liquid stream field[16].

D. Electromagnetic Sensor

[17] Makes use of an electromagnetic sensor to calculate specific quantities such as pressure, force, etc. The electromagnetic sensor manages the important task of converting the values of these quantities into electronic signals. The electromagnetic sensor is used additionally with the DUT-E sensor which helps in garnering greater accuracy. This system is applicable for the fuel tanks of both, two and four-wheeled vehicles. The telematics system is used for a variety of purposes, including getting accurate data on the volume of gasoline in the automotive fuel tank, measuring the amount of gasoline in the tank, tracking fuel thefts, online fuel level surveillance, and calculating the vehicle's gas mileage. This employs a conventional gasoline level sensor as well as AVL, FMS, TMS (tank monitoring system), and VTS (vehicle tracking system) (vehicle tracking system). The equipment that the researcher devised is shown below.

E. Capacitive Sensor

[18]Utilized a Briggs and Stratton 1450 series Horizontal OHV(Overhead Head Valve) Engine, tank with a capacitive transducer for assessing tank gasoline level, that is an innovation of a modular capacitive transducer comprising of a plug-in gadget that is straightforward to set up and small. In relation to the capacitance fluctuation of the sensor portion, the gadget produces an electronic signal. This approach is unobtrusive, and it takes use of the tank shell's unique structure for device connection. The pros of the sensor component used in this investigation are that the level estimation is non-intrusive with minimal effort and simple to introduce. It was designed in such a way that the sensor could function within the tank while protected by a coating. In terms of results, the system worked admirably, with the most optimal errors amounting to 0.44 percent of the whole tank limit and the most severe errors amounting to 1.97 percent near the tank's emptying. While [19] has used capacitive sensor technology is used for accurate and safe measurement with the error blunder under 1 per cent when fixed. Another technique given by the researcher is to detect the fuel quantity in the tank using a capacitive sensor depending on the monitoring of the coaxial capacitor. To make a precise estimate of gasoline in a tank with a maximum operating current of less than 50 mA, several sensors are used in relation to the tank layout. The segment is divided into two sections: first is a representation of the fitted fuel sensor framework, and the second is a testing of the fitted fuel sensor framework for systems that are fundamentally safe. A highly developed numerical recreation programme, which is employed in a variety of disciplines for scientific study, was used for simulation and inquiry. The second phase of the investigation was to evaluate the safety circuit's limitation, which was performed out using the Keil programme, which simulates the safe circuit. Only a standard safe circuit and a digital output display were included in the improved concept. The experimental results reveal that the circuit consumes very little power, which is far less than what is necessary. Meanwhile [20] in their paper has explained a contactless capacitive fluid level sensor with polymer thick film technology which is suitable for the need. Capacitive fluid level sensors used are rapidly reacting sensors, dependable and cheap. The advantage of utilizing a noncontact capacitive fluid level sensor is the accuracy of sense. The development and recognition of coplanar capacitive fluid level sensors for very small sensor construction using inexpensive conventional polymeric thick film technology, as well as their representation for further usage in extremely precise fluid level monitoring purposes. The sensor's adequacy was seen to increase when the anode length was covered. The non-contact coplanar capacitive fluid level sensor has the advantage of gently monitoring the total difference in the required limit. The other author [21] has discussed the technique of fuel level measuring by the cylindrical tube capacitive liquid meter. This method was picked by the author due to some significant highlights like the minimal effort required for installing, simple structure and low cost. The proposed hardware framework includes CDC chip AD7746 and PIC16F877 and a digital display 1602 are included which communicate internally. Comprehensive considerations showed that a liquid meter can’t contact the fuel tank base. The capacitance of a round hollow cylinder capacitor changed with the distance across the inward cylinder, the height of the cylinder and the relative dielectric constant of the substance between the internal cylinder and the external cylinder. After submerging the liquid meter in the fuel tank, the lower portion was wetted by the fuel and the dry area is the airspace over the fuel interface. During the calibration test was ongoing, the Samsung general ceramic capacitors were used. And [22] is a computational multiphasic modelling and trial estimates research that describes the manufacture, design, and evaluation of a two-axis inclination angle sensor that is based on a dielectric fluid capacitive sensing framework. The sensor consisted of five cathodes, one of which served as the energizing terminal, and two arrangements of recognizing anodes grouped at known locations, all of which were encased in a polymeric capsule that was mainly filled with dielectric liquid. The suggested sensor can distinguish two segments of inclination angle in the x-axis and y-axis using this unusual method. Tile sensors with a highly oriented inclination angle have been investigated for a variety of applications. This suggested system is simple to manufacture, effective, and has a high-accuracy setup that can be used in a variety of devices. The capacitive liquid tilt sensor is made up of five organised copper cathodes mounted in a polymeric tube with a two-period dielectric mode of air and fluid.

F. Potentiometer

[23]Riley's creation identifies with gadgets for recognizing fluid level inside a holder, and all the more explicitly to sensors for detecting the fluid degree of fuel in an engine vehicle fuel tank. A three-wire potentiometric fluid level sensor used for estimating fluid levels in a holder is uncovered. The sensor incorporates a conductive strip, a buoy, a contact implies connected to the buoy, a resistive strip, and a conductive pole covered underneath a protector. A second exemplification of the innovation incorporates a first conductive strip, a second conductive strip, a buoy, a contact implies connected to the buoy, and a protecting bar. The sensor delivers an obstruction straightforwardly relative to the fluid level in the compartment. The other author[24] discussed the potentiometer coast arm innovation for fuel-level estimation wins in light of its minimal effort, high unwavering quality and solidness. Thick-film resistive tracks are commonly was utilized in the potentiometer. The coast is intended to navigate away close to the tanks inside for all fuel levels. A fitting useful connection between sensor edge and fuel amount for the specific tank shape utilized in every vehicle. A running normal of fuel sensor yield signals are used to make up for fuel slosh made because of vehicle movement. While [25] in this paper, an estimation framework has been depicted that can precisely decide liquid amount within the sight of slosh in the tank. To obtain a momentary degree of the fluid level, the estimation framework employs a single cylinder capacitive sensor. To predict the true amount of liquid under flowing scenarios, a neural network driven grouping procedure was used. Many field preliminaries were performed on a running vehicle at varied tank volume levels ranging from 5 L to 50 L to look at the presentation of the arrangement framework. The study also considers whether major improvements to the neural system-based sign order paradigm are sufficient. Signal smoothing capabilities such as Moving Mean, Moving Median, and Wavelet channels are used to improve the signal. The results of the investigation were compared to commonly used factual averaging techniques, and it was discovered that the neural system-based estimate framework provided extremely exact liquid amount estimations in a specific domain. And[26] this innovation is related by and large to fluid level responsive sending units adjusted for air inside fuel tanks and especially identifies with a sending unit that emanates an electronically damped fuel level sign from inside a fuel tank. The fluid level responsive sending unit is positioned in a vehicle fuel tank to convey a sign to a fuel gauge on the vehicle dashboard. An electrical damping circuit is given on a circuit board carried on the sending unit, to such an extent that transitory variances in a fuel level sensor skim are streamlined. The sign transmitted to the gauge is a sign speaking to a period found in the middle value of a state of the sensor. The damping circuit area in the fuel tank is worthwhile as respects signal precision alignment, producing quality control, simplicity of get together, and access for segment substitution purposes.

IV. CONCLUSION

Hence, after all these comparisons between various systems, subsystems and technologies associated with the fuel management system, we realise that the evolution of the fuel management systems has taken place over the years and continues to improve and become more efficient. The earliest systems were completely analogue with very little connectivity to display in real-time. Then it turned digital with electronically monitored level measurements. And now it is about facilitating that data with immediate upgradations and the usage of control systems and sensors for accurate and real-time reading.

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