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Automatic fuel dispensing with payment gateway

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Abstract
Fuel dispensing systems with payment gateways provide a comprehensive solution for managing fuel transactions at filling stations. The system integrates a fuel dispenser with a payment gateway, allowing customers to purchase fuel using various payment methods such as credit/debit cards, mobile wallets, and cash. The payment gateway integrates with the fuel dispenser to securely process payments, while the dispenser measures and dispenses the fuel. The system also features real-time monitoring of fuel transactions, inventory management, and reporting capabilities, enabling station owners to effectively manage their business operations. An ESP32 microcontroller is interfaced with a designed web-based software that was used in controlling the process of fueling with the aid of an LCD, a keypad, and customized RFID cards to help identify users and interface with the system. Additionally, the system ensures that all transactions are recorded and accounted for reducing the risk of fraud and errors.

Keywords: Fuel Dispensing; Payment Gateways; ESP32 microcontroller; RFID

1. Introduction

A pump or fuel dispenser is a device used at a gas station to dispense gasoline, diesel fuel, or any other liquid into a vehicle. The contemporary gasoline dispenser is made up of mainly two sections: a mechanical unit with an embedded electric motor, meters, pumping-unit, valves, and pulsers to pump and regulate the flow of fuel; and an electronic head with an embedded system which controls the of the pump's action, provides a driving system for the pump displays, and enables a communication line with an indoor sales-system [1].

A microcontroller unit, RFID module, LCD, and solenoid valve make up the station unit. The majority of fuel dispensers operate in the same manner on a daily basis. The dispenser control unit receives a signal from the micro switch when the nozzle is removed from the dispenser pump, and the required signals are then sent by the dispenser control unit to the internal components to turn on the dispenser. First, the dispenser and RFID reader module are connected in the setup of the station unit. Data is sent from the reader module to the controller. The necessary information is then shown on the LCD [1-3].

Large vehicle pumps can pump up to 130 litres (34 US gallons) per minute in the UK and 40 US gallons (150 litres) per minute in the US. Pumps serving light passenger vehicles have a flow rate of approximately 50 liters (13 US gallons) per minute which is the maximum allowed in the US; the standard is 10 US gallons (38 liters) per minute. The fuel filler pipe's diameter on the vehicle determines the flow rate, which caps flow at these levels [4].s

1.1 Self-Service System

Pay at the Pump, also referred to as Self Service, as a system is used in gas stations in some developed countries where customers can pay for their fuel by inserting a credit or debit card or fuel card into a slot on the pump, obviating the need to make the payment with the gas station attendant. In Abilene, Texas, pay at the pump was created in 1973, but it did not become popular until the 1980s. In Europe, the technology was originally implemented in 1982, and Mobil asserts that it was the first gas station to do so in the United States in 1986. By 1994, only 13% of convenience stores had the technology. However, by 2002, 80% of American convenience stores had it, and today, almost all American outlets do. The first company to employ touch-screen kiosks near the pump was Sheetz in 2004. The first company to install ordering touch screens on a pump was Zarco USA in 2012.

Pay-at-the-Pump is viewed as a method of lowering the cost of operating a gas station by eliminating the need for staff at filling stations to handle, manage, and regulate the systems. With a self-service system, the existing systems overcome the existing problems. According to a study, knowledge workers who rely on technology will accept the substitution of IT service capabilities with self-service technologies. The samples of the study appeared satisfied with the degree of functionality and security provided by the organization's self-service technologies [2,5-7].

1.2 Research Justification

As a result of the fuel being given to such a huge number of vehicles at conventional fuel stations, there are several accumulated complicating factors in developing nations of the world. One of such factors is that the driver of the car must pay cash for fuel and may have to pay more than the amount of fuel delivered because the station owner does not have access to small amounts of change. Another significant concern is the lack of real-time accurate statistics regarding the supplied, dispensed, and remaining fuel quantities at the fuel stations. These are some of the issues that have been successfully addressed in this research paper.

2. Materials and Methods

2.1 System Overview

In the developed fuel dispensing automation system, RFID cards were used to access fuel at various stations owned by different petroleum firms in selected locations. All the gas stations were connected using a single web server. The only people who know the password to access this web server are the agents of the petrol companies. Thus, with this, the system can be classified into two main subsystems, control and manage administrator accounts, fuel station data, and customer accounts in addition to controlling the fuelling operation.

The account management system is an application built using NodeJS for server-side programming and React JS for client-side programming. Users are provided the ability to credit their account, and see their transaction history, admins are given the ability to add users and monitor their balance. The fueling system is a microprocessor-based system [8], designed to identify users using the registered RFID cards and with a pin protection provide a measure of safety before allowing the purchase process. A circuit diagram of the system is as shown in Figure 2.1.

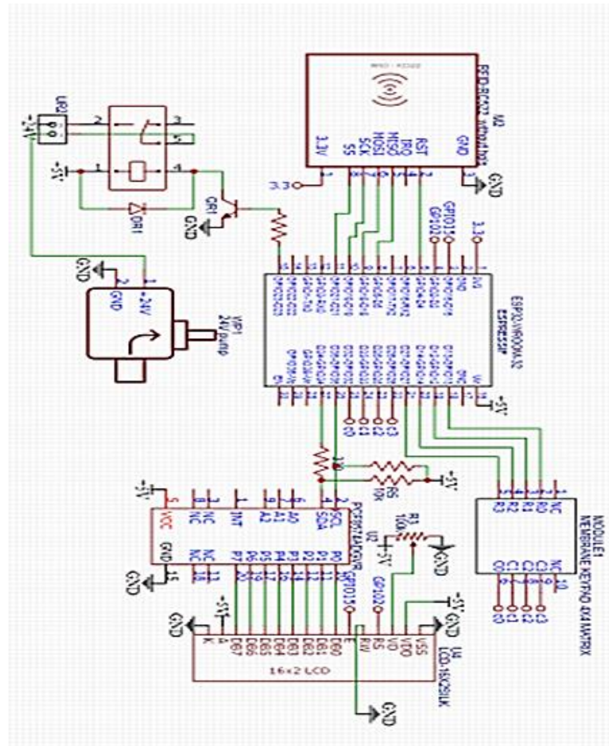

Figure 2.1: Fuel Dispensing Circuit Diagram

2.2 Registration and Management

This stage depicts the system's application software, which includes the forms used for account registration, management, and data management. This application was created using JavaScript and NodeJS. A block diagram for this level is shown in Figure 2.2. Each block stands for a form with a distinct activity and process. These forms are in charge of opening new accounts, charging for them, and updating the status and information on existing accounts. Additionally, it is possible to manage all of the fuel station-related data. At this point, the thorough details of each fuelling procedure can be seen. Such information is highly helpful to this system since it gathers information that includes crucial statistics about different fuel prices, users who purchase fuel, and the day and time of fueling. These statistics can be utilized to generate a variety of reports that can be very effectively used to improve the system as well as the entire fuel distribution process.

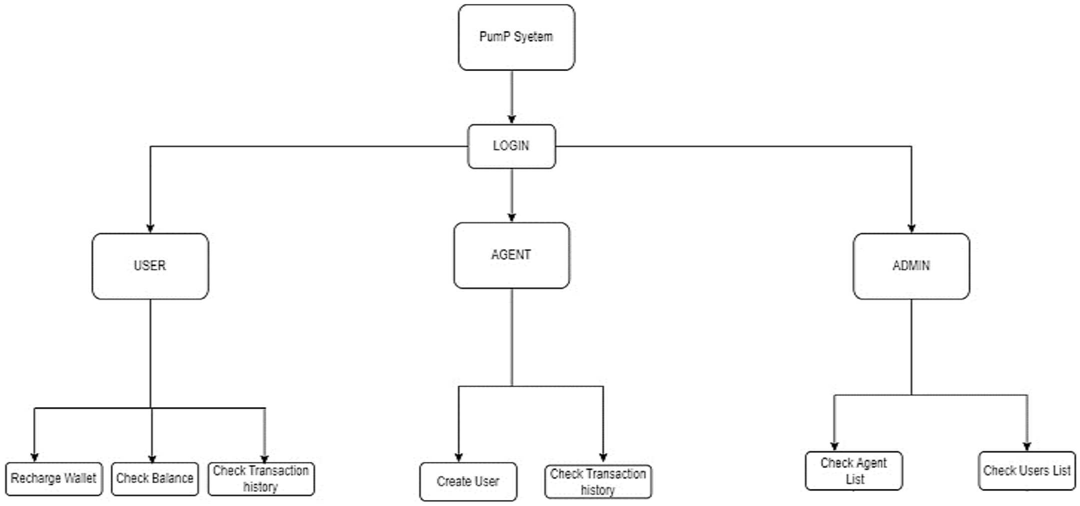

Figure 2.2: Registration and Management Activities

2.3 Fueling Operation

The fuel dispenser tags are recognized by the RFID readers at the gas stations [9–11]. As soon as a tag ID is found, the system will download pertinent data from the database server, validate the ID, and take appropriate action. Unapproved cars are unable to access the fuel. If the car is authorized to receive fuel, the system will otherwise turn on the fuel dispenser and prepare it to deliver fuel to that vehicle. The system shuts off the dispenser after the fuelling procedure is complete. If there are any remaining liters, they will be assigned as the new balance to be filled the following time for this account. Otherwise, until that account is updated, there won't be any liters available for fueling.

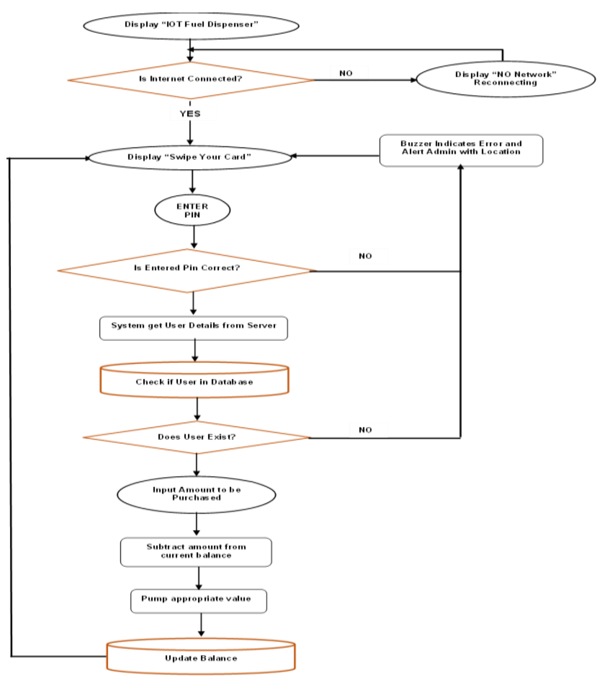

Figure 2.3: Flowchart of the Fuel Dispensing Operation.

2.4 Hardware System Overview

An ESP 32 Microcontroller, an RFID module (a tag and a reader), a card relay, an LCD, and other fundamental electronic parts make up the hardware module. The hardware module was connected to the internal parts of the gasoline dispenser, which included the micro switch, the pulse, the solenoid valves, and the keypad. The fuel dispenser will subsequently be managed by this module, which can be viewed as the dispenser's new embedded system. This new embedded system will control all signals that are used to operate the dispenser unit and its parts. The pulser attached to the fuel meter will send signals to the hardware module used to count the delivered liters when the fuel dispenser is turned on since the fuel will flow through the fuel meter. Since the system will rely on the calculated liters to complete various procedures, this method of implementation is effective.

The full fuelling process is depicted in a flowchart in Figure 2.3, along with the proper steps the system took while the vehicle was in the gasoline station.

2.4.1 ESP 32 Microcontroller

The ESP32 family of system-on-chip microcontrollers (Figure 2.4a) are low-cost, low-power devices with integrated Wi-Fi and dual-mode Bluetooth. The Tensilica Xtensa LX6 dual-core or single-core, Tensilica Xtensa LX7 dual-core, or Tensilica RISC-V single-core microprocessor used in the ESP32 series includes built-in antenna switches, RF baluns, power amplifiers, low-noise receive amplifiers, filters, and power-management modules.

Figure 2.4a: ESP 32 Microcontroller

2.4.2 RFID Reader

The 13.56MHz electromagnetic field (ISO 14443A standard tags) is used by the RC522 RFID Reader module (Figure 2.4b) to communicate with RFID tags. The reader can connect to a microcontroller at a maximum 10Mbps data rate using a 4-pin Serial Peripheral Interface (SPI). Additionally, it supports the communication protocols I2C and UART.

The module operates in the 2.5 to 3.3V voltage range. However, the module's logic pins are 5-volt-tolerant, so it can connect without a logic level converter directly to an Arduino or any other 5V logic microcontroller.

Figure 2.4b: RC 522 RFID Module.

2.4.3 RFID Cards

RFID Cards (Figure 2.4c) functioning using passive RFID tags. The microchip can store up to 1.5Kb of data which can be read using an RFID reader. Although, the working frequency of the card is low (125 KHz) but can works up to 10cm from reader.

Figure 2.4c: RFID Card.

2.4.4 Relay

The Single Pole Double Throw (SPDT) Relay (30A) in Figure 2.4d is a premium SPDT relay. A coil, one common terminal, one generally closed terminal, and one normally open terminal make up the relay. The common terminal and the normally closed terminal are connected while the coil of the relay is at rest (not activated). The common terminal and the normally open terminal both have continuity when the coil is powered up. It is employed to manage high current equipment.

Figure 2.4d: SPDT Relay.

2.4.5 Pump Motor

The specifications of the pump motor used as shown in Figure 2.4e are as outlined in Table 2.1:

Table 2.1: Pump motor's specifications

Rated Voltage	AC240V
Operating Supply Voltage	DC6V ~ DC12V
Max. Operating Current	1050ma
Outlet & Inlet Sizes	20.3mm
Head	6.0m
Maximum Flow Rate	600L/hr

Figure 2.4e: Pump Motor

2.4.6 LCD Display

This LCD display measures 16 by 2 and has two rows, each of which can display 16 characters. The device operates between 4.7V and 5.3V. With no lighting, 1mA of current is being used. A 5 by 8-pixel box can be used to create any character. The numerals and alphabets on the alphanumeric LCD. The display operates in 4-bit and 8-bit modes, as seen in Figure 2.4f.

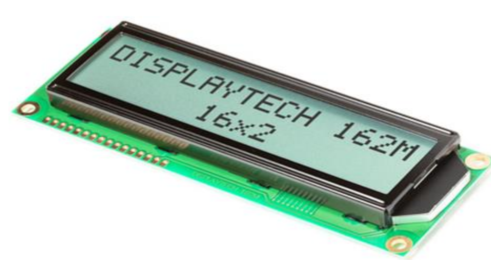

Figure 2.4f: 16 X 2 LCD Display

2.4.7 4x4 Matrix Membrane Keypad

The project's 16-button keypad, which is depicted in Figure 2.4g, serves as a helpful human interface component. Its key attributes include:

i. Ultra-thin and user-friendly design
ii. Excellent price/performance ratio
iii. Simple interface to any microcontroller
iv. 24 VDC, 30 mA maximum rating
v. 8-pin access to 4x4 matrix for interface

Figure 2.4g: 4 X 4 Matrix Keypad

3. Results and Discussion

A model of the system was created to simulate the performance of the proposed approach. The results measuring the performance of the system were greatly dependent on the quality of the internet during the process. The Table 3.1 is a tabular representation of the model results. It is seen that the only cause of failure is based on the failure to connect to the server.

3.1 Testing Results of Software System

After the completion of the development of the software system, the system was put under a series of tests. First, an end-to-end test was conducted to ensure that all levels and sections of the system are communicating with one another without any code failure and crashes. This was done in different scenarios such as testing with different internet speeds and then testing across multiple.

Monkey Tests were also carried out to ensure the quality of the written code. This involved inputting random values into different field in expectance of getting appropriate responses without crashes. This involved mainly a smart money test and a brilliant money test. The smart monkey test was done to test for the limit of the software system by overloading the system with unexpected variables. It was observed that the system responded appropriately with expected error messages. For the brilliant monkey test, this was focused mainly for the user test to get a review in terms of experience. The system was said to have a very simple interface system making it easier to use. The code performance and modularity were equally tested. This test focused on the system speed and latency time. The main test was carried out using Chrome Browser Lighthouse extension and results are to have an 86% performance for the users' application and 91% for the admin system. These are shown in Figures 3.1 and 3.2.

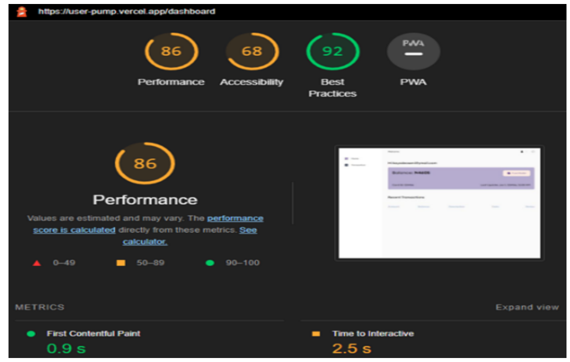

Figure 3.1: Users' Application performance

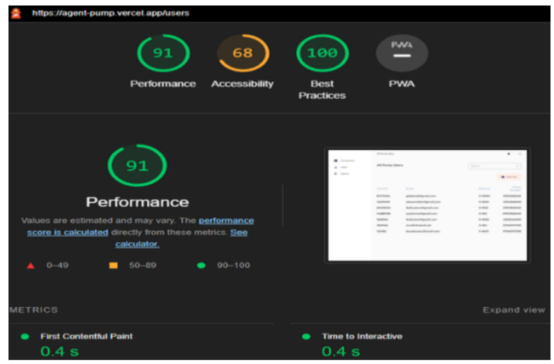

Figure 3.2: Admins' Application performance

For the system security, the software is hosted on an environment that is using a secure environment layer for communication. Then the cross-origin policy for the carrying out communication from end-to-end is ensured not to be a wild card but rather communicates with systems within the hosted domain

3.2 Testing Results of Hardware System

After the completion of development of the hardware system, the system was put under a series of tests focusing on the possible system failures and dispense errors. The system was put under the same environmental conditions and the same test was carried out repeatedly ten (10) times. The results are contained in Table 3.1.

Table 3.1: Hardware test results

S/N	**Successful Connection to Server**	**Quantity of Fuel Requested (L)**	**Quantity of Fuel Dispensed (L)**
1	Failed	-	-
2	Connected	5.00	5.10
3	Failed	-	-
4	Connected	5.00	5.12
5	Connected	5.00	4.96
6	Connected	5.00	5.00
7	Connected	5.00	5.01
8	Failed	-	-
9	Connected	5.00	4.84
10	Connected	5.00	4.98

From Table 3.1, the results show that a good internet connection only had a 20% failure connecting to the software server. This 20% was mainly due to the unstable internet connection. Also, it can be seen that the system had some dispense errors where it over and under dispensed fuel at different intervals. The range of error for dispense is ±0.16 L.

4. Conclusion

The system developed utilizes a web application for users to perform operations that include funding user wallet through a payment gateway and monitoring transactions on the user platform. The developed system has proposed a more streamlined dispensing process providing customers with a convenient and efficient experience while increasing operational efficiency for fuel station owners. Using ESP32 microcontroller and registered RFID cards, registered user data is read from the server using internet connection. Users with sufficient credit balance can proceed to pumping as much quantity of fuel as their credit can allow.

The results of the tests carried out on the model show that with the availability of stable and strong internet connection, the model can be retrofitted into an existing fueling system, taking out the initial control system and integrating the model to function with the old pumps. This model provides more accountability in fueling and eliminates the need of pump attendants at every single pump.

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