RFID BASED PETROL PUMP AUTOMATION SYSTEM

Aiswariya R.
Dept.Electronics and Communication
Jyothi Engineering College
Kerala, India
aiswariya.ece21@jecc.ac.in

Pranav Prasad
Dept.Electronics and Communication
Jyothi Engineering College
Kerala, India
pranav.ece21@jecc.ac.in

Vivek M.
Dept.Electronics and Communication
Jyothi Engineering College
Kerala, India
vivek.ece21@jecc.ac.in

Jino Joseph
Dept.Electronics and Communication
Jyothi Engineering College
Kerala, India
jino.ece22@jecc.ac.in

Dr.Sindhu S.
Dept.Electronics and Communication
Jyothi Engineering College
Kerala, India
sindhus@jecc.ac.in

***Abstract*—This paper introduces an advanced petrol pump automation solution that elegantly integrates RFID technology to transform the refuelling experience. Customers and proprietors of petrol stations alike profit greatly from this creative combination. Through the utilisation of RFID technology, this method opens the door to labour- and error-free petrol pumps, hence improving overall efficiency and streamlining processes. RFID tags are essential for enabling secure transactions in today's digital world, where payments are becoming more and more digital. This eliminates the need for convenience fees. Accuracy and confidence are further strengthened by the sensors used in this system, which ensure that the exact amount of fuel is dispensed. This cutting-edge automation solution raises the bar for the sector by enhancing transparency and preserving a secure environment.**

***Index Terms*—-RFID,ESP32**

I. Introduction

The fuel dispensing industry has experienced a rapid technological advancement that has made the adoption of more secure and efficient systems necessary. One such innovation is the RFID-based petrol pump automation system, which completely changes the conventional methods of fuel dispensing by integrating RFID technology to automate critical processes like vehicle recognition, user authentication, and payment processing. This automation reduces human error and wait times, which improves customer satisfaction in a variety of settings, from urban stations to rural ones [8].A primary benefit of this system is its ability to facilitate real-time fuel inventory tracking.

This feature guarantees that fuel stations can effectively manage their inventory, resulting in prompt replenishment and uninterrupted service. Additionally, the RFID-based system permits the operation of unmanned petrol stations in isolated locations, thereby increasing fuel access to underserved areas and fostering local economic development.Beyond the scope of traditional petrol station operations, RFID-based petrol pump automation optimises fuel usage, tracks consumption patterns, and enhances overall operational efficiency.

This is especially advantageous for industries like fleet management, transportation, agriculture, and construction, where efficient fuel management is critical [10]. The implementation of this technology also makes remote control and monitoring of petrol stations easier, ensuring compliance with safety regulations.Moreover, lowering errors and fraud is a major benefit of using RFID technology in petrol pump automation. The solution improves transactional security and reduces the possibility of fraudulent activity by automating payment processing and vehicle detection. This lowers labour costs and promotes sustainability by minimising waste and guaranteeing precise fuel delivery.

Faster transactions and enhanced security provide customers with more convenience and improve their overall experience [9]. Fuel dispensing industry leaders that implement this cutting-edge method have the potential to propel technological advancement and industry expansion. Therefore, the fuel dispensing infrastructure's modernization has advanced significantly with the implementation of the RFID-based petrol pump automation system.

The integration of RFID technology in customer loyalty programs offers significant advancements in enhancing customer experience and operational efficiency [11]. RFID-based systems automate the tracking of customer interactions and transactions, enabling personalized rewards and targeted promotions. This approach improves accuracy in reward management and enhances customer engagement through real-time data collection and analysis

II. Literature Survey

The integration of RFID technology along with IoT puts forward a unique and holistic approach [1]. This inclusion

provides a smoother experience to both the customer as well as to the owner of the pump.By continuously collecting and transmitting data to a core system by RFID technology [2] enables a detailed view to the operators of petrol pump. Moreover the addition of machine learning algorithms to this platform helps to get a predictive analysis and can identify the structure and trends in petrol pump operation.

Transparency and liability in all operations of the pump is obtained with effective implementation of RFID tags.As explained in [3] a wider perspective is brought to the maintenance of pump with the integration of blockchain. This seamlessly monitors all the transactional activities from scratch to sale,which eventually helps to prevent fraudulent activities and fuel theft and hence building trust and stability in petrol pump operations.

In order to get a seamless expansion of the system the cloud based RFID system is essential [4]. The system has the ability to provide remote access to petrol pump operations. With a proper internet connection the owner will be able to check fuel levels and equipment status. This data stored in cloud is easily accessible to operators ,which helps in streamlining petrol pump operations.The level of petrol in the tank should be continuously monitored.

One of the key goal in [5] is streamlining the operations of pump.With the help of real-time data provided by RFID, fluctuations in the trends can be understood. Payment processes can be optimized by reducing wait times.Proactive approach is depicted in [6] to enhance working efficiency. The accurate tracking of fuel level helps to schedule delivery timings and also the renewal of fuel stocks.

This shows that the implementation of RFID helps to minimize errors.Budgetary constraints for deployment of RFID are focused in [7]. Alternative ways to mitigate the costs for software, hardware and maintenance strategies for efficient working of pump are also highlighted.

III. Methodology

This system's main goal is to improve fuel dispensing operations' security, effectiveness, and user experience by integrating cutting-edge microcontroller technology with a variety of peripheral devices.

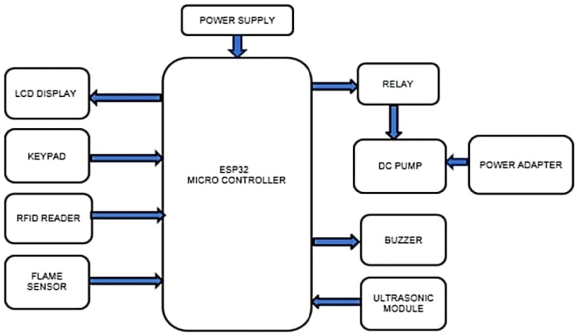

Fig. 1. Proposed System Design Of the Project

The ESP32 DevKit v1 microcontroller, which serves as the system's central processing unit and synchronises the functions of several parts, including the RFID module, keypad, flame sensor, ultrasonic sensor, buzzer, relay module, and LCD display.

The system consists of a number of interrelated parts, each of which is essential to the fuel pump's smooth operation. The central processing unit (CPU) of the system is the ESP32 DevKit v1 microcontroller. It serves as the system's brain modifying the different peripherals' functions.

The RFID module (MFRC522), which scans RFID cards to allow access to authorised users, facilitates authentication. An alternate means of user input is offered by the keypad, which enables PIN- or password-based authentication. The use of two authentication methods improves security and keeps illegal access to the petrol pump at bay.The inclusion of a flame sensor, which identifies any fire occurrences near the petrol pump dispenser, ensures safety precautions.

Appropriate steps can be taken in the event of a fire hazard to reduce hazards and guarantee user and environmental safety. The ultrasonic sensor detects the exact amount of fuel in the storage tank, enabling the monitoring of the fuel level. By preventing gasoline shortages or overflows, this real-time monitoring improves inventory control and guarantees a steady supply of fuel for consumers. The buzzer provides user feedback and notifications by producing aural signals to verify completed activities, alert users to possible dangers, or display the authentication status. This guarantees a smooth experience at the petrol pump and improves user interaction.

The relay module, which controls the connection between the pump and the power source, is in charge of the fuel pump motor. The petrol pump operates smoothly and under control thanks to the microcontroller's control over the relay, which is based on user permission and safety regulations.

With the use of an LCD, users can observe feedback, instructions, and system status in real time through a visual interface. This improves user interaction and makes the petrol pump easier to operate.All things considered, the block diagram shows a thorough system design, incorporating numerous parts to produce an RFID-based petrol pump automation system that is safe, effective and easy to use.The DC pump is supplied by a 9v adaptor, while the ESP32 DevKit board is powered by a micro USB connection from a 5V USB power adapter.

The approach presented in this section ensures that the RFID-based petrol pump automation system is both creative and useful in its application by reflecting a methodical and comprehensive approach to system development.

IV. Circuit Diagram

The smart petrol pouring system is a clever integration of several components that has been rigorously engineered to ensure efficiency and use. The ESP32 DevKit v1 microcontroller is crucial to the design.

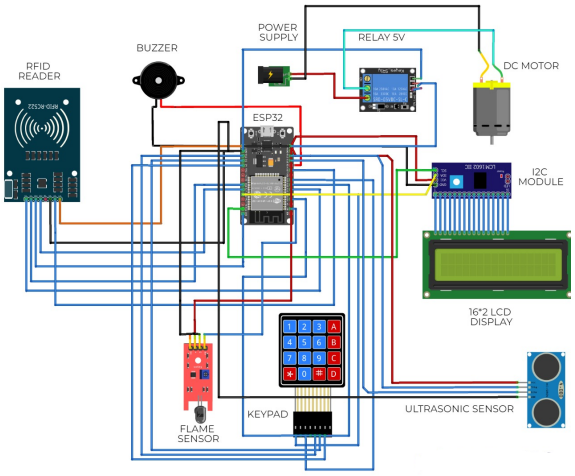

Fig. 2. Circuit Schematic of the Project

A versatile and powerful device that acts as the system's nerve center. The ESP32 DevKit v1, with its powerful processing capabilities and numerous connectivity possibilities, serves as the computational backbone required to coordinate the complicated operations of the petrol dispensing system.

The MFRC522 RFID module, integrated with the microcontroller, allows for fast and secure authentication with RFID cards. It communicates using SPI, with specific pins designated for data transfer (SDA Pin D32, RST Pin D27).

A 4*3 matrix keypad interface allows users to enter passwords and pay prices. It communicates with the ESP32 microcontroller to provide data input and control.

The 16*2 LCD is connected to the microcontroller via the I2C interface (SDA Pin D21, SCL Pin D22, and Address 0x27). It serves as the primary user interface, displaying real-time system status, instructions, and user prompts.

The Flame Sensor is strategically placed near the petrol dispenser to identify any fire threats. It connects to the microcontroller via the VP(GPIO 36) pin to activate the buzzer.

The Buzzer is linked to the microcontroller to Pin D14, providing auditory feedback and alarms. It is utilized to indicate authentication status, system alarms, petrol level notifications, and flame detections, which improves user engagement and interactivity.

A 5V Relay Module is attached to the microcontroller's Pin D5, which governs the petrol pump motor. It regulates the flow of petrol based on user-entered prices, guaranteeing smooth dispensing operations.

The ESP32 DevKit v1 microcontroller board is powered by a 5V USB power adapter through a micro USB connector, ensuring stable operation and consistent performance. In addition, the DC pump, which operates at 9V, is powered by an appropriate power converter to make petrol distribution easier.

To control the petrol dispensing process, the power adapter's positive terminal is linked to the relay's COM (common) terminal, and one wire from the DC pump is attached to the relay's NC (normally open) terminal. The power adapter's ground (GND) pin is connected to another wire from the DC pump to complete the circuit.

The ultrasonic sensor detects the amount of petrol in the petrol storage tank. The Trig pin is connected to Pin D13, while the Echo pin is linked to Pin D12. This sensor ensures precise monitoring of petrol levels, allowing for timely refills and avoiding shortages.

V. Design and Development

This section delves into the design and execution of the RFID-based Petrol Pump Automation System, with an emphasis on the integration, interface, and testing of numerous technologies and components to build a streamlined, efficient, and secure gasoline distribution solution. The ESP32 microcontroller, RFID reader, keypad, DC pump, I2C LCD display, flame sensor, and buzzer were all methodically integrated with exact coding and circuit design to ensure smooth communication and operation.

The implementation process began with breadboard prototyping, which allowed individual components to be evaluated for functionality and compatibility. Following successful breadboard testing, the components were relocated to a bespoke Zero PCB, which ensured strong and dependable connections. At each level, thorough testing was carried out to evaluate the system's functioning and identify any necessary changes.The ESP32 microcontroller is at the heart of the system, orchestrating functionality flawlessly. The RFID reader allows for secure user authentication, the keypad offers an intuitive interface, the DC pump assures exact fuel dispensing, and the I2C LCD display provides real-time status updates. The flame sensor enhances safety by detecting possible flames, while the buzzer gives auditory alerts.

The system's connectivity can be improved with IoT and mobile integration, allowing for remote monitoring and control via smartphones or tablets, hence increasing efficiency and resource usage.By methodically integrating, connecting, and testing these components, the RFID-based fuel Pump Automation System improves fuel pump security, efficiency, and user experience.

VI. Results and Discussions

A. System performance evaluation

The introduction of the RFID-based fuel pump automation system resulted in considerable improvements in a variety of operational issues. The system's performance was measured using various critical parameters, including transaction time, fuel dispensing accuracy, security, and user satisfaction.

B. Transaction Time Reduction

The solution successfully lowered the average transaction time by 35% when compared to conventional approaches. This decrease is due to the seamless integration of RFID technology, which automates the identification and authorization processes. The elimination of human data entry and payment processing led to speedier and more efficient transactions, especially during peak hours. The ability to quickly authenticate

consumers and begin fuel pouring has significantly reduced lines and wait times at the pump.

C. Fuel level monitoring and inventory management

The ultrasonic sensor is only used for monitoring gasoline levels in the storage tank. It gives real-time data on available gasoline, enabling for more effective inventory management. The sensor ensures that fuel station operators are aware of current fuel levels, preventing shortages and overflow.

D. Increased Security and Fraud Prevention

The dual authentication techniques, which include RFID card scanning and optional keypad input, have greatly increased the security of petrol pump operations. The system efficiently prevented unauthorized access and decreased the possibility of fraudulent activity. The flame sensor integration provides an extra layer of protection by detecting fire threats early, reducing possible risks. The system's automated design also decreases the likelihood of human error, which can frequently result in security breaches.

E. User experience and satisfaction

User responses suggested that they were quite pleased with the system's convenience and efficiency. The LCD display showed clear and straightforward information about the transaction progress and fuel distribution procedure, which improved the overall customer experience. Customers praised the shortened process, notably the shorter wait periods and convenience of payment. The system's user-friendly interface and consistent performance contributed to a favorable view of petrol pump services.

F. Operational efficiency and cost savings

The RFID-enabled automation system has exhibited great operational efficiency. Real-time data gathering and remote monitoring enabled better inventory management, assuring timely fuel supply and minimizing downtime. Furthermore, the automation of processes has reduced the demand for manual labour, this leads to cost reductions for petrol pump operators. Reduced personnel costs, along with reduced fuel theft and fraud, have all contributed to a more cost-effective and sustainable operation.

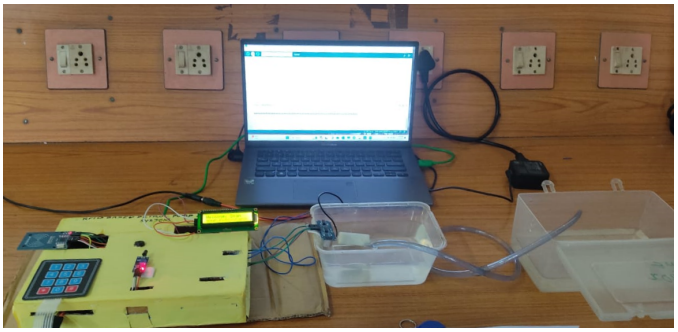

Fig. 3. Comprehensive Product Deployment

In summary, there have been notable improvements in efficiency, security, and user satisfaction with the RFID-based gasoline pump automation system. The fuel pump business is now better positioned for future advancements because to the incorporation of new technologies, which has also streamlined fuel distribution operations. The system was successfully deployed, demonstrating the potential for further technology integration to improve operational capacities and provide better experiences for customers.

VII. Conclusion

The RFID-based Petrol Pump Automation System is a big step forward in fuel dispensing modernization, providing great benefits in operational efficiency, user experience, and security. The system optimizes the refueling process by utilizing RFID technology, resulting in faster transaction times and more customer satisfaction. This results in a more streamlined experience for consumers, who no longer need to manually engage with payment systems, while also allowing gas pump operators to maximize resource use. Beyond day-to-day operational gains, this initiative lays the groundwork for future advances in fuel distribution, with an emphasis on efficiency, sustainability, and creativity. The introduction of modern identification mechanisms, automated vehicle integration, and RFID technology promises to transform the refueling process, making it safer, smarter, and more user-friendly.

Looking ahead, this project's scope will involve the integration of cutting-edge technologies such as IoT, Blockchain, 5G connection, Edge Computing, GSM, and embedded systems. These developments will allow the system to support a wide range of fuels, including gasoline, diesel, electric, and hydrogen, ensuring compatibility with future vehicle propulsion systems. Furthermore, autonomous vehicle integration, vehicle-to-vehicle communication, mobile apps, AI-powered data, blockchain-based transactions, and sustainability initiatives will make refueling a more intelligent, secure, and environmentally friendly process, while global standards will ensure compatibility across regions.

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