



Intelligent Hybrid Fuel and EV Charging Station with IoT Based Automated Dispensing and Monitoring System

Ponnakayala Shivani^{1*}, Arukonda Chandana², Koneru dhanalaxmi², Janupala Tharun Kumar², Pamu Arjun²

¹Assistant Professor, ²UG Student, ^{1,2}Department of Electronics & Communication Engineering

^{1,2}Vaagdevi Engineering College, Bollikunta, Warangal, 506005, Telangana, India.

*Correspondence: Ponnakayala Shivani(pshivani0101@gmail.com)

Abstract

The increasing demand for intelligent fuel management systems has grown with the rapid expansion of transportation and electric mobility, with global fuel consumption exceeding 100 million barrels per day and smart fuel station technologies projected to grow at over 15% annually. Additionally, the rise of hybrid fuel stations integrating conventional fuels and EV charging infrastructure highlights the need for automated, secure, and connected dispensing solutions. Traditional fuel dispensing systems rely heavily on manual supervision, which can lead to issues such as fuel theft, inaccurate measurement, delayed monitoring of tank levels, and lack of real-time data visibility. Furthermore, conventional systems lack integrated security mechanisms and cloud connectivity, limiting their ability to support automated operations and predictive maintenance. To address these challenges, the proposed IoT-cloud integrated automatic fuel & EV dispenser system utilizes the ESP32 microcontroller to enable a fully automated and intelligent dispensing platform. The system incorporates RFID-based authentication with password protection to ensure secure access, while a 16x2 LCD provides real-time operational feedback. An ultrasonic sensor continuously monitors fuel tank levels, and a GSM module sends instant alerts during low fuel conditions or unauthorized access attempts. IoT cloud integration facilitates remote monitoring, data logging, and inventory management through mobile or web applications. The system ensures precise fuel dispensing, enhanced security through buzzer alerts, and seamless integration of hybrid fuel and EV infrastructure. This innovative solution improves operational efficiency, reduces human intervention, and supports the development of smart, connected, and sustainable fuel dispensing ecosystems.

Keywords: Cloud Integration, ESP32, Fuel Dispensing System, Hybrid Fuel Station, Internet of Things, Inventory Management, RFID Authentication, Smart Energy Systems, Ultrasonic Sensor

1. Introduction

The growing demand for intelligent fuel management systems is closely linked to the rapid expansion of transportation and electric mobility worldwide [1]. Global fuel consumption has exceeded 100 million barrels per day, reflecting the increasing reliance on both conventional and hybrid energy systems. At the same time, smart fuel station technologies are projected to grow at a rate of over 15% annually, driven by advancements in automation, IoT, and digital infrastructure [2]. The emergence of hybrid fuel stations that combine traditional fuel dispensing with EV

charging further emphasizes the need for integrated and intelligent solutions [3]. In real-world environments such as fuel stations, smart cities, highway service centers, and EV-fuel hubs, there is a critical requirement for systems that provide accurate dispensing, real-time monitoring, secure access, and seamless connectivity to ensure efficient and uninterrupted operations [4].

Problem Statement: Traditional fuel dispensing systems primarily rely on manual supervision and basic electromechanical mechanisms, which limit their efficiency and scalability. These systems often lack advanced

monitoring and control capabilities, making them dependent on human intervention for operations such as fuel measurement [5], inventory tracking, and maintenance. Additionally, conventional dispensers do not support real-time data communication or remote accessibility, restricting the ability to monitor system performance from centralized locations. Security features in traditional setups are minimal, increasing vulnerability to unauthorized access and operational discrepancies [6]. As a result, these systems are not well-suited to meet the demands of modern, connected fuel infrastructures.

Research Motivation: In real-time scenarios, these limitations lead to several operational challenges that affect both efficiency and reliability. Manual monitoring can result in fuel theft, inaccurate dispensing, and delayed detection of low fuel levels, leading to financial losses and service disruptions. The absence of real-time alerts and cloud-based data analysis prevents proactive decision-making and predictive maintenance [7]. Furthermore, lack of secure authentication mechanisms increases the risk of unauthorized usage and system misuse. These issues highlight the necessity for an intelligent, automated solution capable of ensuring precise fuel dispensing, continuous monitoring, enhanced security, and remote accessibility. Such a system not only improves operational efficiency and reduces human dependency but also supports the development of smart, sustainable, and interconnected fuel and EV infrastructure ecosystems.

2. Literature Survey

Kumar et al. [8] proposed a secure and efficient RFID-based authentication protocol for vehicular cloud computing that ensured data confidentiality and integrity during communication. Chen et al. [9] proposed an RFID system integrated with a cloud database backend for centralized data management and real-time access.

Kai et al. [10] proposed a cloud-based RFID mutual authentication scheme that ensured privacy-preserving communication in Internet of Vehicles (IoV) environments. Kondaveeti et al. [11] proposed a systematic review of Arduino-based prototyping that analyzed applications, advantages, and limitations in embedded system development. Alsaify et al. [12] proposed an RFID authentication method using dummy data to enhance security and prevent unauthorized access.

Li et al. [13] proposed a blockchain-based data trading framework in edge-cloud environments that ensured secure and transparent data exchange. Prakash et al. [14] proposed a comprehensive review of RFID technology and its applications, covering system architecture, communication mechanisms, and deployment scenarios. Melo Jr. et al. [15] proposed an IoT-based fuel dispenser surveillance system integrated with blockchain for secure metering and transaction validation.

Prasanna et al. [16] proposed an unmanned petrol bunk system using RFID technology for automated user authentication and fuel dispensing. Swapnil [17] proposed an unmanned fuel station system that automated fuel dispensing and transaction processes using embedded control systems. Jadhav et al. [18] proposed a multi-automated fuel pump system with user security that integrated authentication and automated dispensing mechanisms.

Shreedhar et al. [19] proposed a Programmable Logic Controller (PLC)-based automatic fuel dispensing system using RFID technology for accurate and controlled fuel delivery. Naveen et al. [20] proposed an IoT-based petrol bunk management system using RFID and Raspberry Pi for self-operation and real-time monitoring.

3. Proposed System

The proposed hybrid fuel and EV charging system as shown in Figure 1 is built around the ESP32, which serves as the central control and communication unit to integrate fuel

dispensing, EV charging, and real-time monitoring. The ESP32 directly handles both processing and IoT connectivity due to its built-in Wi-Fi and Bluetooth capabilities, eliminating the need for external networking modules.

The system receives inputs from RFID modules for user and staff authentication, a keypad for manual control and override functions, ultrasonic sensors for monitoring fuel tank levels, and voltage/current sensors to track electrical parameters of the charging system. Based on these inputs, the ESP32 executes control logic to ensure safe operation, authenticate transactions, and manage outputs such as fuel pump relays, EV charger activation/deactivation, and buzzer alerts.

An LCD display provides real-time system feedback including operational status, energy consumption, and warning messages. Additionally, the ESP32 transmits system data to a cloud platform, enabling remote monitoring, billing integration, and system diagnostics.

Beyond basic control, the ESP32-based system incorporates advanced smart energy management and user-centric features. It implements automatic load management, where EV charging power is dynamically reduced or temporarily paused when high-power fuel pumps are active, preventing electrical overload. Priority-based access is enabled through RFID authentication, allowing authorized users such as emergency personnel or staff to bypass queues and access services immediately. The system also generates real-time alerts for critical conditions such as low fuel levels, abnormal voltage fluctuations, or excessive current draw.

Through continuous IoT data logging and cloud-based analytics, the system supports predictive maintenance by identifying potential faults before failure occurs and optimizes fuel inventory and charger utilization. By combining embedded intelligence, wireless connectivity, safety

interlocks, and adaptive energy control within the ESP32 platform, the system enhances operational efficiency, reduces downtime, and provides a seamless and intelligent service experience for both fuel-based and electric vehicles.

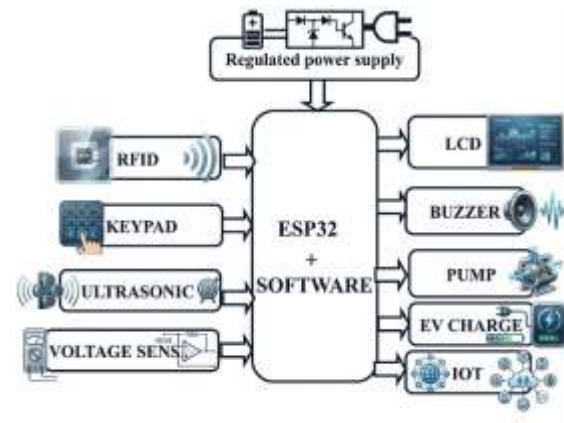


Figure 1. Proposed System Architecture.

3.1 Working Procedure

The flow chart of proposed system as shown in Figure 2 is centered on the ESP32, which acts as the intelligent decision-making core interfacing with sensors, user input/output modules, actuators, power systems, and IoT connectivity. On the input side, the system integrates multiple sensors including an RFID reader for authentication and access control, a keypad for manual commands and PIN-based operations, ultrasonic sensors for monitoring underground fuel tank levels or vehicle presence, and voltage/current sensors for real-time monitoring of electrical parameters such as mains supply and EV charger load.

These sensors are connected to the ESP32 through GPIO pins, ADC channels, and communication interfaces like UART, I²C, and SPI, allowing the controller to collect data, perform safety checks, and execute control decisions. For visual monitoring, a camera module (such as ESP32-CAM) can be optionally integrated, enabling surveillance and diagnostic capabilities without requiring external processing units.

The control and actuator section includes relays or solid-state relays (SSRs) used to

control fuel pump motors, along with EV charger control mechanisms such as contactors for AC charging or communication interfaces (e.g., CAN or control signals) for smart chargers. Additional outputs include a buzzer for audible alerts and pump enable signals.

The ESP32 implements intelligent safety interlocks—for instance, it restricts simultaneous operation of high-power EV charging and fuel pumps when the total electrical load exceeds predefined thresholds.

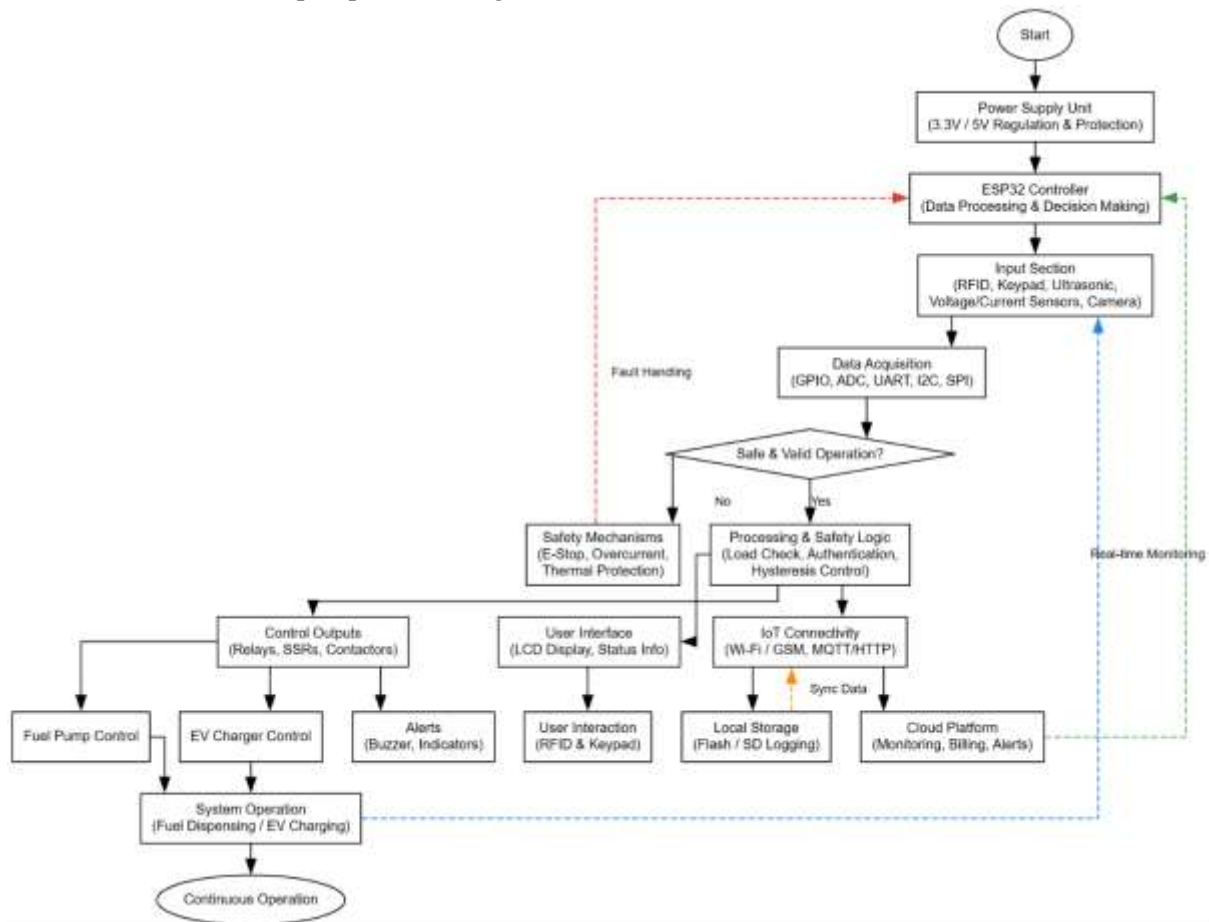


Figure 2. Proposed System Working Procedure.

To ensure system stability, firmware incorporates hysteresis control and minimum ON/OFF timing to prevent rapid switching of relays and protect hardware components. The regulated power supply unit provides stable 3.3V and 5V outputs required by the ESP32 and associated peripherals, and includes essential protections such as voltage regulation, surge protection, and circuit isolation.

For hybrid or renewable setups, battery management and solar charging modules can also be integrated into this block. The user interface section consists of an LCD display that provides real-time information such as

fuel dispensing status, EV charging state, energy consumption, and fault notifications. User interaction is facilitated through RFID authentication and keypad input, while safety is enhanced using emergency stop (E-stop) switches and status indicator LEDs.

The IoT connectivity block leverages the ESP32's built-in Wi-Fi (or optional GSM module for remote areas) to transmit system data—including tank levels, power usage, transaction logs, and fault alerts—to a cloud platform using protocols such as MQTT or HTTP. This enables remote monitoring, automated billing, and instant notifications. Additionally, local data logging using onboard

flash memory or SD card ensures data retention during network failures, with automatic synchronization once connectivity is restored.

The design also incorporates dedicated safety and maintenance subsystems, including overcurrent protection, thermal shutdown mechanisms, controlled manual override (with logging), and periodic self-diagnostic routines. Proper wiring practices—such as separation of power and signal lines, grounding techniques, and EMI suppression—are followed to ensure reliable and noise-free system operation

4. Results and Discussion

Figure 3 shows the complete hardware setup of the hybrid fuel and EV dispenser system built using the ESP32 microcontroller. The prototype integrates modules such as RFID authentication, ultrasonic fuel level sensing, relay control circuits, pump control, buzzer, and LCD display for automated fuel dispensing and monitoring.

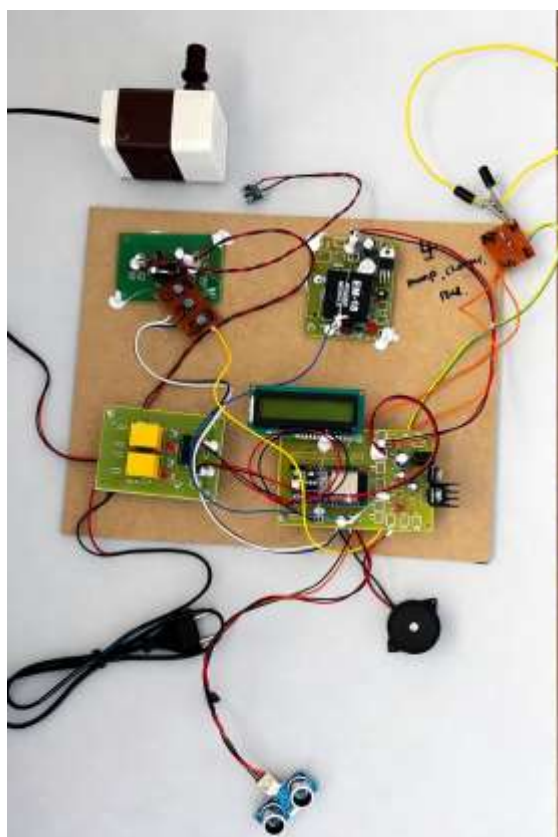


Figure 3. Hardware Prototype of IoT-Cloud Integrated Fuel and EV Dispenser System.

Figure 4 illustrates the LCD interface displaying operational information such as system initialization, authentication status, and fuel dispensing details. The display provides real-time feedback to the user during fuel dispensing and system operation.

Figure 5 presents the IoT cloud platform used to monitor and record system data remotely. The web dashboard displays fuel dispenser activity, tank level status, transaction records, and timestamps, allowing the station owner to monitor operations and inventory in real time.

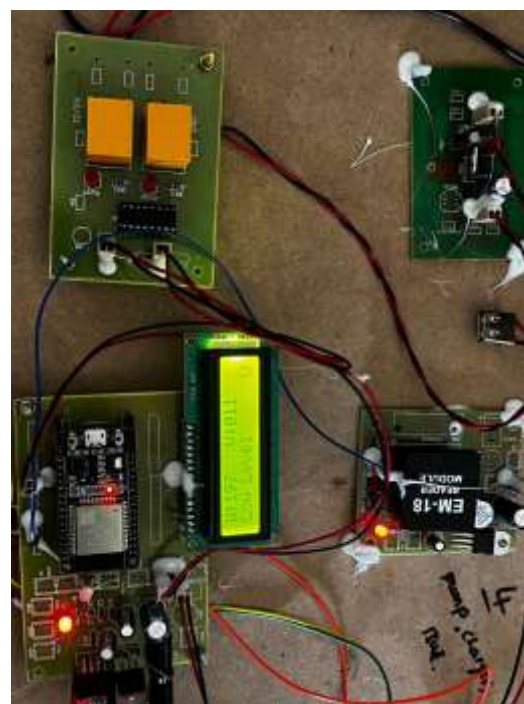


Figure 4. LCD Display Showing Real-Time System Information

S.No	Fuel Dispenser System	Level Status	Date
1		U06_Low_Level	2024-02-09 12:21:00
2		U06_Low_Level	2024-02-09 12:25:17
3		U06_Low_Level	2024-02-09 12:19:38
4	Fuel_Type_Petrol_Correct_Password_Hi_000	U06_Normal_Level	2024-02-09 12:18:52
5	Invalid_Card	U06_Normal_Level	2024-02-09 12:15:39
6		U02_Low_Level	2024-02-09 12:14:47
7		U07_Low_Level	2024-02-09 12:13:53
8	Fuel_Type_Petrol_Correct_Password_Hi_400	U06_Normal_Level	2024-02-09 12:10:27
9	Fuel_Type_Petrol_Wrong_Password	U06_Normal_Level	2024-02-09 12:04:20
10	Fuel_Type_Petrol_Wrong_Password	U06_Normal_Level	2024-02-09 12:03:03
11		U020_Low_Level	2024-02-09 12:19:04
12	Fuel_Type_Petrol_Wrong_Password	U06_Normal_Level	2024-02-09 12:18:27
13		U02_Low_Level	2024-02-09 12:18:09

Figure 5. IoT Cloud Monitoring Dashboard.

5. Conclusion

The proposed Hybrid Fuel: IoT-Cloud Integrated Automatic Fuel & EV Dispenser

System provides a comprehensive and intelligent solution to modern fuel management challenges by integrating automation, security, and real-time connectivity. By leveraging the ESP32 microcontroller along with RFID-based authentication, ultrasonic sensing, GSM alerts, and IoT cloud integration, the system ensures accurate fuel dispensing, continuous monitoring of tank levels, and secure access control. Its ability to deliver instant alerts for low fuel levels and unauthorized activities enhances operational safety and reliability, while cloud-based data logging and remote accessibility enable efficient inventory management and predictive maintenance. Furthermore, the system supports the seamless integration of conventional fuel dispensing with EV charging infrastructure, making it suitable for next-generation hybrid fuel stations. Finally, this solution reduces manual intervention, minimizes fuel losses, improves efficiency, and contributes to the development of smart, secure, and sustainable fuel dispensing ecosystems aligned with the evolving demands of modern transportation.

References

- [1] Babburi, S. Privacy-Preserving Collaborative Framework with Auditable Federated Learning.
- [2] Gaddam, S. INTELLIGENT SYSTEMS AND APPLICATIONS IN ENGINEERING.
- [3] Kumara, S. (2025). Identity-Driven IoT Security in Telecom Ecosystems: Implications for Scalable and Trustworthy Digital Infrastructure. *Int. J. Appl. Math*, 38(12s), 2797-2816.
- [4] S. Sheth, K. H. Patel, and H. Patel, "Design of automatic fuel filling system using a mechatronics approach," in *Robotics and Factories of the Future*, 2016, pp. 785–795.
- [5] M. Naveed, W. Habib, U. Masud, et al., "Reliable and low-cost RFID-based authentication system for large-scale deployment," *International Journal of Network Security*, vol. 14, no. 3, pp. 173–179, 2012.
- [6] Z. Saleh, I. Alsmadi, and A. Mashhour, "Improving enterprise access security using RFID," *International Journal of Computer Science and Information Security*, vol. 9, no. 5, 2021.
- [7] M. B. Pranto, M. M. Rahman, and Z. B. Zahir, "Vehicle fuel monitoring and management using RFID authentication and telematics notification: An automated petrol refueling and notifying system," in *Proc. 2019 International Conference on Advanced Computer Science and Information Systems (ICACSIS)*, Bali, Indonesia, Oct. 2019, pp. 477–482, 2020.
- [8] V. Kumar, M. Ahmad, D. Mishra, et al., "RFID-based secure and efficient authentication protocol for vehicular cloud computing," *Vehicular Communications*, vol. 22, pp. 1–13, 2019.
- [9] Purmani, S. S. R. (2025). Streamlining IT operations and service management with agile frameworks. *European Journal of Advances in Engineering and Technology*, 12(4), 76–81.
- [10] Prodduturi, S. M. K. To Secure Your Paper as Per UGC Guidelines We Are Providing A Electronic Bar code.
- [11] Reddy, S. K. R. (2024). Designing Blockchain Architecture to Transform Loyalty Rewards into Cryptocurrency Investments.
- [12] Poojari, R. INTELLIGENT SYSTEMS+B108 AND APPLICATIONS IN ENGINEERING.
- [13] Kalae, U. K. (2020). Developing scalable Power BI dashboards for enhanced data analysis and strategic business decision-making. *International Journal of Enhanced Research in Science, Technology & Engineering*, 9(3), 8–15.

- [14] D. Prakash, T. Kundu, and P. Kaur, "The RFID technology and its applications: A review," *International Journal of Electronics, Communications and Instrumentations Research and Development*, vol. 2, no. 3, pp. 109–120, 2012.
- [15] Patel, S., & Patrykin, K. (2025). Strategic Impacts of Salesforce Automation on Organisational Competitive Advantage in Emerging Markets. *Journal of Posthumanism*, 5(12), 357–372. <https://doi.org/10.63332/joph.v5i12.3782>
- [16] T. L. Prasanna and P. N. S. Madhusudan Rao, "Design of unmanned petrol bunk system using RFID technology," *International Journal of Engineering in Advanced Research Science and Technology*, vol. 1, no. 4, pp. 459–464, 2017.
- [17] P. B. Swapnil, "Unmanned fuel station," *International Journal of Advanced Research in Computer and Communication Engineering*, vol. 5, no. 4, pp. 925–928, 2016.
- [18] A. H. Jadhav, R. S. Pawar, P. M. Pathare, et al., "Multi automatized fuel pump with user security," *International Journal of Scientific & Technology Research*, vol. 3, no. 5, pp. 132–136, 2014.
- [19] M. B. Shreedhar and B. S. Shivashankara, "PLC-based automatic fuel dispensing system using RFID technology," *International Journal of Engineering Applied Sciences and Technology*, vol. 4, no. 1, pp. 89–94, 2019.
- [20] B. Naveen, B. K. Rashmitha, K. S. Parthasarathi, et al., "IoT-based petrol bunk management for self-operation using RFID and Raspberry Pi," *International Journal of Recent Technology and Engineering*, vol. 8, no. 1C, pp. 216–219, 2019.