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E-Bike Charging Dock with RFID Access Control

Dr. Chandrashekhar Reddy S[1], B Shivani[2], V Akhila[3]
[1]Professor in Dept. of Electrical & Electronics Engineering
[2,3]UG Student, Dept. of Electrical & Electronics Engineering
Christu Jyothi Institute of Technology & Science, Jangaon, Telangana, India

Abstract: *Electric vehicles (EVs) are surging in popularity globally, offering a greener and more energy-efficient alternative to traditional cars. The proliferation of electric bicycles (e-bikes) as a sustainable mode of transportation necessitates the development of secure and efficient charging infrastructures. This project introduces an E-Bike Charging Dock integrated with RFID (Radio Frequency Identification) Access Control, aiming to provide authenticated charging services to registered users [1]. The system employs an RFID reader to scan user-specific RFID tags, granting access to the charging facility upon successful verification [1].*

A microcontroller, such as the Arduino UNO, coordinates the authentication process, controls the charging mechanism via a relay module, and communicates status updates through an LCD display. Additionally, the GSM module monitors the battery's charge level, sending an SMS notification to the user when the charge falls below 15%, prompting timely retrieval of the vehicle [2]. This setup ensures that only authorized users can access the charging dock, thereby enhancing security and preventing unauthorized usage. The implementation of such a system is particularly beneficial in urban settings, campuses, and public transportation hubs, promoting organized and secure e-bike charging solutions [3].

Keywords: RFID, Microcontroller, GSM

I. INTRODUCTION

The rapid adoption of electric bicycles (e-bikes) has transformed urban transportation, offering an eco-friendly and efficient alternative to traditional vehicles [4]. However, this surge in e-bike usage has necessitated the development of secure and efficient charging infrastructure. Integrating Radio Frequency Identification (RFID) technology into e-bike charging docks has emerged as an innovative solution to address these challenges. RFID-enabled charging stations facilitate secure user authentication and authorization, ensuring that only registered users can access the charging facilities. This integration not only enhances security but also streamlines the charging process, providing a seamless user experience. Moreover, RFID systems enable operators to monitor and manage charging sessions effectively, offering valuable data for maintenance and optimization. As urban areas continue to embrace sustainable transportation options, the implementation of RFID-based e-bike charging docks represents a forward-thinking approach to supporting the growing demand for e-bike usage.

The proposed e-bike charging dock system utilizes RFID technology to authenticate users and manage charging sessions. Each e-bike is assigned a unique RFID card containing essential information, including the bike's ID, owner's details, and charging limits. Upon scanning the RFID card at the charging dock's reader, the system retrieves and displays the bike's details on an integrated LCD screen. Simultaneously, a countdown timer is initiated, indicating the remaining charging time. If the charging time exceeds the predefined limit, the system sends an alert via a GSM module to notify the user to disconnect the vehicle [5].

II. LITERATURE SURVEY

A comprehensive literature survey on E-bike Charging Docks with RFID Access Control reveals a growing interest in integrating smart access technologies into electric vehicle infrastructure to address challenges related to security, user authentication, and efficient energy usage. RFID (Radio Frequency Identification) has emerged as a reliable and cost-

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effective method for controlling access to public systems, including EV charging stations, as highlighted by Singh and Sharma (1518) and Zhou et al. (1515) [1]. Several studies have explored the deployment of modular and secure charging solutions for two-wheelers, such as Shahidinejad et al. (1512), emphasizing the lack of standardized e-bike charging systems and the need for user-based access. Integrating RFID with microcontrollers like Arduino and communication modules (e.g., ESP32) allows real-time monitoring, user identification, and data logging, as demonstrated in IoT-based designs by Al-Mashaqbeh et al. (1519) and Kumar et al. (1521). Additionally, security-focused implementations such as encrypted RFID tags, discussed by Wang et al. (1517), help mitigate risks of unauthorized access.

Despite promising developments, gaps remain in areas such as mobile-based RFID alternatives, integration with renewable energy sources, and scalable payment systems, which present opportunities for further research and innovation in developing smart and secure e-bike charging docks. Security considerations in charging stations have also been a subject of research. As the adoption of electric mobility solutions increases, the potential for cyber attacks and unauthorized access to charging infrastructure becomes a concern. A study published in the *International Journal of Electrical and Computer Engineering Research* examines the vulnerabilities and risks associated with EV charging stations. The research identifies potential cyber attacks and proposes countermeasures such as secure coding practices, tamper detection sensors, and intrusion detection systems to fortify charging systems against threats. These findings underscore the importance of implementing robust security measures in RFID-based charging systems to protect both users and infrastructure.

III. EXISTING SYSTEM

Several existing systems have been developed to address the need for secure and user-specific access to e-bike charging infrastructure using RFID technology. In academic and prototype settings, systems commonly use microcontrollers like **Arduino Uno, ESP32** paired with **RFID readers** (e.g., RC522) to authenticate users through RFID cards or tags before enabling the charging circuit. These setups are often integrated with **relays** to control power delivery and may include **LCD displays** or **mobile apps** for status updates. On the commercial front, some **smart city pilot projects** and **university campuses** have implemented secure charging stations where users tap an RFID card to initiate charging.

Companies such as **Bolt Mobility** and **Yulu (India)** have explored similar access control mechanisms, although many rely on mobile apps and QR/NFC rather than RFID alone. Some smart dock systems are linked with **cloud platforms,** enabling features like **session logging, usage tracking,** and **billing per user ID [7].** Furthermore, government-backed smart mobility projects in countries like Germany, China, and India have introduced **semi-public charging docks** equipped with RFID-based or NFC access control, especially in metro stations, tech parks, and EV-friendly zones. Despite this, most RFID-based e-bike docks are still in **experimental** or **pilot phases**, with few mass-scale deployments. These systems demonstrate the feasibility of combining RFID technology with IoT and power management to create secure, user-friendly, and scalable charging infrastructure for micro-mobility.

IV. PROPOSED SYSTEM AND IMPLEMENTATION

The proposed e-bike charging dock system integrates RFID access control, an Arduino UNO microcontroller, an LCD display, and a GSM module to provide a secure, user-friendly, and efficient charging solution. Upon docking, the RFID reader scans the user's tag, authenticating access and displaying vehicle details on the LCD. The LCD then shows a countdown from 15 to 0, indicating the charging progress. Once the countdown reaches zero, the system signals full charge completion. Additionally, the GSM module monitors the battery's charge level, sending an SMS notification to the user when the charge falls below 15%, prompting timely retrieval of the vehicle. This system enhances user experience by combining real-time feedback, remote notifications, and secure access, making it a scalable solution for modern urban mobility needs.

The objectives of the RFID-based e-bike charging dock system is to establish a secure, efficient, and user-friendly infrastructure that addresses the growing demand for electric bicycle charging solutions. By integrating Radio Frequency Identification (RFID) technology, the system aims to authenticate users, ensuring that only authorized individuals can access the charging facilities [8]. Upon scanning the RFID card, the system retrieves and displays

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pertinent information about the e-bike and its owner on an integrated LCD screen, providing real-time feedback to the user. Simultaneously, a countdown timer is initiated, indicating the remaining charging time. If the charging time exceeds the predefined limit, the system sends an alert via a GSM module to notify the user to disconnect the vehicle.

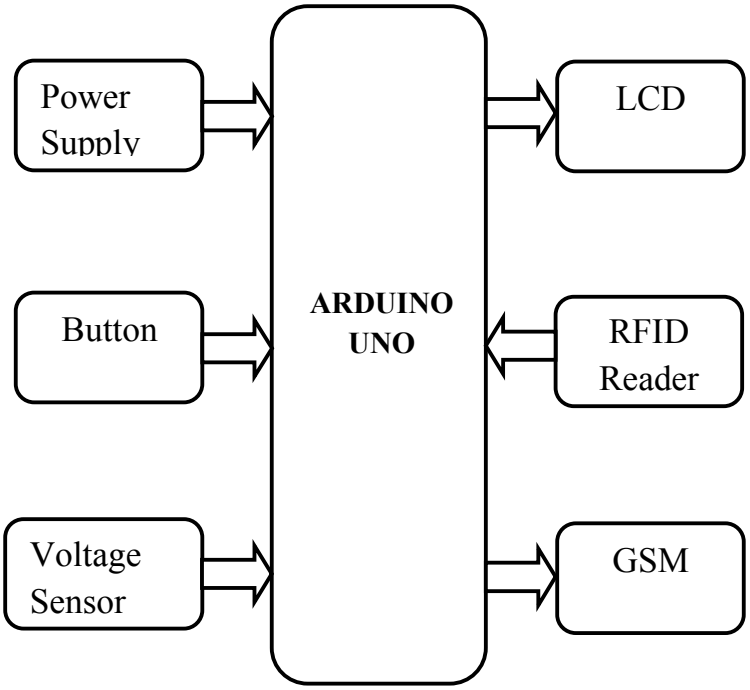

FIGURE 1. Block Diagram

A. HARDWARE EMPLOYED

Hardware employed in 'E-Bike Charging Dock with RFID' includes a combination of sensors and modules integrated to automate and monitor the charging process efficiently. The system primarily consists of an RFID reader, which identifies and authenticates users based on pre-registered RFID tags. Upon successful authentication, the Arduino UNO microcontroller acts as the central processing unit, coordinating signals from various components. A voltage sensor continuously monitors the battery voltage of the e-bike; when it detects the charge dropping below 15%, it triggers a notification system. This notification is handled by a GSM module, which sends an SMS alert to the user prompting them to connect the e-bike to the charging dock.

Battery Management System (BMS) plays a crucial role in protecting the battery by regulating charging and discharging, ensuring that the battery operates within safe voltage and current limits. The LCD display provides real-time feedback to the user, such as system status, authentication success, current voltage level, and charging updates. Together, these components enable a smart and secure e-bike charging system that ensures timely alerts, authorized access, and efficient monitoring of battery status, enhancing the overall usability and reliability of electric vehicle charging infrastructure.

B. SOFTWARE EMPLOYED

The development of an E-Bike Charging Dock with RFID Access Control using Arduino IDE requires a comprehensive understanding of Software programming. The Arduino IDE provides a user-friendly environment for programming Arduino boards, making it accessible for beginners and non-programmers to develop complex systems. The initial step in designing the system involves designing the circuit and selecting the necessary components, including Arduino boards, sensors, and a display unit. The core functionality of an E-bike charging dock with RFID access control revolves around secure user authentication, controlled power delivery. When a user presents an RFID card or tag, the

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RFID reader scans the unique ID and sends it to a microcontroller like Arduino, which then verifies the ID against a pre-stored database or cloud system. If authentication is successful, the system activates the charging when button is pushed up, supplying power to the docked e-bike. During the charging session, the system can log key parameters like charging time, energy consumed, and user ID for billing or analytics. Once the user ends the session—either manually or after full charge—the system safely disconnects power and updates usage records. The integration of RFID access control in E-bike charging docks offers a secure, efficient, and user-specific solution to support the growing demand for electric mobility infrastructure. By enabling authenticated access, these systems prevent unauthorized usage, enhance user accountability, and streamline energy management in public and semi-public spaces. The combination of microcontrollers, RFID technology, and GSM capabilities ensures that charging sessions are both trackable and scalable, paving the way for smarter, more sustainable urban transportation.

V. RESULTS

The expected results of implementing an E-bike charging dock with RFID access control encompass several key performance and security metrics. Firstly, the system is anticipated to achieve rapid and accurate user authentication, with RFID readers identifying authorized users within 1–2 seconds, thereby facilitating seamless access to charging stations [9]. This swift authentication process ensures that users can quickly initiate charging sessions. Secondly, the integration of secure power management is expected to prevent unauthorized usage and ensure safe power delivery. Charging sessions will be initiated only upon successful authentication, thereby safeguarding the charging infrastructure from misuse. Additionally, the system is designed to provide real-time monitoring and logging of charging sessions, capturing data such as user ID, charging duration, and energy consumption. This data can be utilized for billing and usage analytics, offering valuable insights into the charging patterns and behaviours of users.

The incorporation of remote configuration capabilities is projected to allow for easy updates and maintenance of the system, reducing operational costs and enhancing scalability. The ability to remotely configure and update the system ensures that the charging infrastructure can adapt to evolving technological advancements and user needs without requiring significant physical interventions. Lastly, the system is expected to demonstrate robust security features, including resistance to common RFID vulnerabilities, thereby safeguarding user data and preventing unauthorized access. These security measures are crucial in maintaining the integrity and trustworthiness of the charging infrastructure, ensuring that users' personal information and charging activities remain protected.

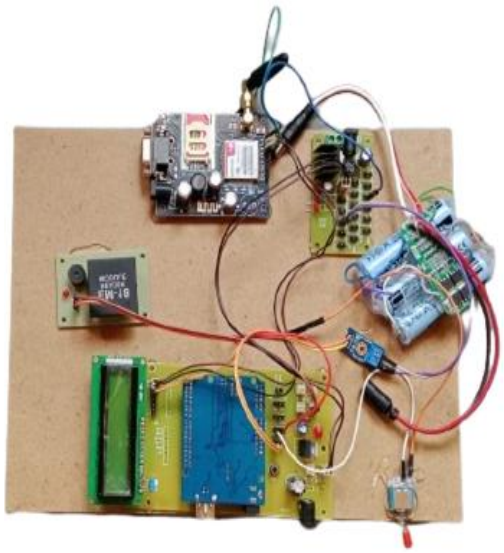

FIGURE 2. Project Prototype

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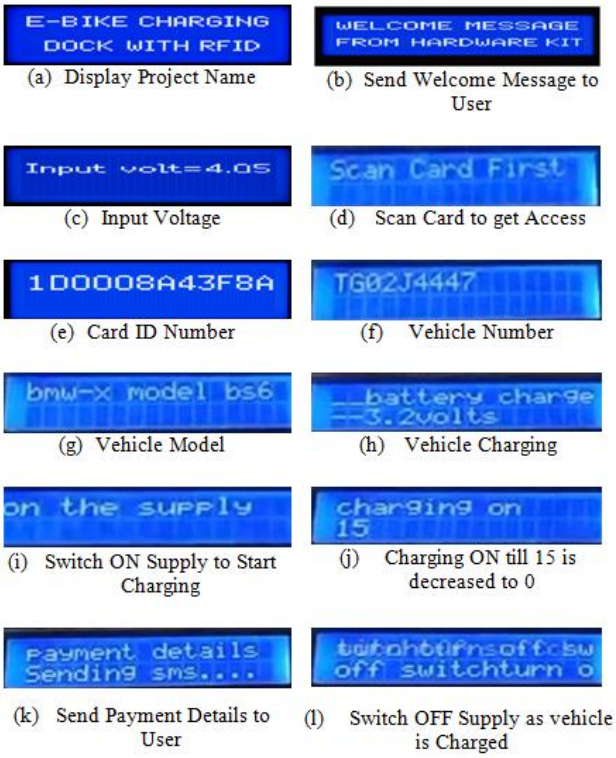
FIGURE 3. Messages from the Kit



(a) Display Project Name
(b) Send Welcome Message to User
(c) Input Voltage
(d) Scan Card to get Access
(e) Card ID Number
(f) Vehicle Number
(g) Vehicle Model
(h) Vehicle Charging
(i) Switch ON Supply to Start Charging
(j) Charging ON till 15 is decreased to 0
(k) Send Payment Details to User
(l) Switch OFF Supply as vehicle is Charged

FIGURE 4. LCD Display Output

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VI. CONCLUSION

In conclusion, the integration of RFID access control into e-bike charging docks presents a secure, efficient, and user-friendly solution for managing charging infrastructure. By requiring users to authenticate with RFID tags or cards, the system effectively prevents unauthorized access and potential energy theft, enhancing the overall security of the charging facility. Furthermore, RFID technology streamlines the charging process. Users can initiate and terminate charging sessions quickly and effortlessly with a simple tap of their RFID credential [10]. This eliminates the need for cumbersome manual processes, such as key entry or payment handling at the charging station, leading to a more convenient experience for e-bike owners. Beyond security and convenience, RFID access control enables better management and monitoring of charging resources. The system can track charging sessions, energy consumption, and user behavior, providing valuable data for optimizing the charging infrastructure and planning for future needs. This data can also be used for billing purposes in commercial charging stations.

VII. FUTURE SCOPE

The future scope of implementing an "E-Bike Charging Dock with RFID Access Control" that incorporates Arduino UNO, RFID reader, GSM module, LCD display, and a momentary push button is expansive, particularly in the context of urban mobility and smart city initiatives. As electric vehicles (EVs) become more prevalent, the demand for secure, efficient, and user-friendly charging solutions grows. This system addresses these needs by offering secure access through RFID authentication, ensuring that only authorized users can utilize the charging dock. The momentary push button allows users to manually connect or disconnect their e-bike from the charging dock, offering an additional layer of control and flexibility. Looking ahead, the integration of wireless charging technologies, such as Inductive Wireless Power Transfer (IWPT) and Capacitive Wireless Power Transfer (CWPT), presents opportunities to eliminate the need for physical connectors, enhancing user convenience and reducing wear and tear on equipment. Additionally, the incorporation of Artificial Intelligence (AI) can optimize charging schedules, predict maintenance needs, and personalize user experiences, further enhancing the efficiency and appeal of the charging infrastructure [11]. Moreover, the scalability of this system allows for easy replication and integration into various urban locations, such as public parks, residential complexes, and commercial areas, contributing to the development of a comprehensive and accessible charging network.

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