Review Article

Engineering: Open Access

IoT-Based Intelligent Charging System for Kayoola EVs Buses: A Case of Kiira Motors Corporation

Benjamin Ntwali*

Member, IEEE, Ramadhan Sinde, Member IEEE, Mussa Ally

*Corresponding Author
Benjamin Ntwali, Member, IEEE, Ramadhan Sinde, Member IEEE, Mussa Ally.

Submitted: 2024, Apr 29; **Accepted:** 2024, Jun 03; **Published:** 2024, Jun 07

Citation: Ntwali, B. (2024). IoT-Based Intelligent Charging System for Kayoola EVs Buses: A Case of Kiira Motors Corporation. *Eng OA, 2*(2), 01-11.

Abstract
The increasing popularity of Electric Vehicles (EVs) has led to a surge in the need for charging stations. To address this, an IoT-based system has been proposed to manage and monitor these stations. The system comprises multiple components, including EV charging stations, sensors, actuators, communication modules, a central server, and a user interface for desktop, mobile, and web sites. Each charger is equipped with sensors that monitor various parameters, such as charging status, energy consumption, voltage, current, and charging time. The data collected is transmitted to a Controller Area Network (CAN) and processed by a Raspberry Pi4 server application. The central server stores the data in a secure database and performs real-time analysis to ensure efficient charging station operation. A user-friendly mobile application is provided for EV owners, while a web and desktop application is available for charging station operators and administrators. The IoT-based intelligent charging system for KAYOOLA EVs buses enhances the efficiency, accessibility, and sustainability of EV charging infrastructure, providing real-time data, remote control, and actionable insights, thereby fostering the continued growth of the electric vehicle market.

Keyword: Kayoola EVs Buses, Intelligent Charging System, IoT Embedded Sensors, Mobile Application Development, Remote Charging Control Systems

1. Introduction
Kiira Motors Corporation (KMC) is a state-owned enterprise that was established to champion the automotive value chain in Uganda, and advance job and wealth creation. The company developed Africa's first vehicle in 2011, Africa's first hybrid vehicle in 2014 and Africa's first solar electric bus in 2016 [1]. The company's market entry product is the KAYOOLA EVS, a fully electric, low-floor city bus with a range of 300 kilometers on a full charge [2]. The charging infrastructure is the backbone of electric mobility. Electric Buses are emerging as a favorable strategy to meet the increasing environmental concerns. Since Batteries has a finite energy capacity, Plug-in Electric Bus must be charged on a periodic basis. Deployment of Charging infrastructure in every location is expected to maximize the adoption of E-mobility. Understanding the real- time status of Charging Stations can provide valuable information to drivers and Charging Stations attendants, such availability of the charging services [3].

The intent of the proposed system is to provide a better Electric Bus Charging system by utilizing the advantages of the Internet of Things (IoT) technology. The IoT paradigm offers to the present facilities a real-time interactional view of the physical world by a variety of sensors and broadcasting tools. The system operates in such way, it monitors and controls the charger Status by processing data from Controller Area Network (CAN) bus, and send data to cloud for further analysis. This project proposed a real-time server-based charger status and remaining charging duration monitoring to avoid waiting time. The proposed system provides a real-time Charging Station recommendation for KAYOOLA bus driver with economic cost and reduced waiting time at the stations [4]. Electric vehicle (EV) charger levels refer to the different power levels at which electric vehicles can be charged. These levels determine how quickly an electric vehicle's battery can be charged. The levels are standardized and categorized based on the charging power they provide. The most common EV charger levels are Level 1, Level 2, and Level 3 charging [5].

2. Review of Related Works

EV Charging Station Management System – Monitor and Manage It was identified in [6] that the lack of information regarding available EV charging points in the streets might negatively impact the adoption of electromobility nowadays. The system proposed a web based and mobile app platform to ensure ongoing collaboration between the various entities involved Such as charging stations, charging station attendants, and EV drivers. With this platform, the system has used such entities and proposed optimizing Electric Buses allocation to the charging stations [7]. A Proposed System for Electric Charging Vehicle Infrastructure wad developed in [8]. The system provides a design that uses machine learning techniques to improvise the charging and generate billing accurately and generic software stack and how machine learning system has to interact with this stack [9]. A Monitoring System for Electric Vehicle Charging Stations: A Prototype in the Amazon was proposed in [10]. In this system, the charging station management informs the user as soon as the station goes offline while charging, giving the EVs owners to search alternative charging station. In addition, the benefits of implementing smart charging in case of remote support and maintenance was emphasized. An intelligent charging and discharging of electric vehicles in a vehicle-to-grid system using a reinforcement learning-based approach was developed by [11]. This system uses a model-free reinforcement learning (RL) approach to optimize EV charging and discharging decisions until the battery's end-of-life. The goal was to minimize charging costs and maximize battery use. The algorithm was evaluated using real-world data and tested in experimental scenarios. RL was advantageous than other approaches for reducing overall costs but shrinking battery use in EV vehicles was an issue during system development.

An intelligent electric vehicle charging system for new energy companies based on consortium blockchain was also developed by Zhengtang Fu et al [12]. This system, a novel EV charging system for new energy companies, utilizing a tamper-resistant and multi-centralized consortium blockchain was proposed. A smart contract was designed to balance charging user allocation, ensuring fair profits for companies. The Bio- Objective Mixed-Integer Programming model (BOMILP) was used for smart contracts, while a new algorithm, Limited Neighborhood Search with Memory (LNSM), was also developed for faster and better performance. The system and smart contract are validated through a real case study in Beijing, China.

IoT-Based Advanced Electric Vehicle Charging Infrastructure was developed by J. Surendiran et al [13]. This infrastructure presents an intelligent process-based design for efficient electric vehicle (EV) charging processes. The smart charging station uses three sources: solar system, wind system, and main supply. The controller switches source automatically based on their availability, maintaining power from multiple sources. The IoT Thing Speak cloud service allows users to view available slots, ensuring efficient charging. The design addresses limitations in electrical power distribution and ensures efficient charging for EVs.

IoT-Based Monitoring and Management of Electric Vehicle Charging Systems for DC Fast Charging Facility was designed and developed in [14]. In this system, cloud-based monitoring and management of smart charger stations for electric vehicles (EVs) using security-driven IoT-enabled direct current (DC) fast chargers were discussed. The methodology predicts battery energy consumption and bill payment processes, and considers conventional AC and DC fast chargers. The information is shared with equipment manufacturers, allowing for analysis of charging costs and optimizing energy trading solutions. The EV metering architecture acquires real-time data, providing an execution framework for energy demand solutions.

IoT and Blockchain-Enabled Charging Station for Electric Vehicles was developed in [15]. The proposed Blockchain- Based Electric Vehicle Charging Station (EVCS) system connects all charging stations within a cell using a distributed ledger algorithm. The algorithm routes electric vehicles to the station based on charging requirements. This system helps in futuristic analysis and development of charging stations, considering factors like peak demand and profit. While not entirely based on blockchain, it integrates with IoT [16].

Electric Buses require Charging Infrastructure in their daily operations. Even Bus to charger distribution is a major concern in adopting electric vehicles in East Africa. There is a need for Kiira Motors Corporation, to adopt remote charging station for monitoring daily activities of their charging stations, remote trouble shooting, secure RFID card payment, error and state reporting with the use of IoT to maximize customer satisfaction, resource management and ensure automatic revenue collection. However, the issue of completely charging the EV buses with appropriate verification, dynamic RFID card security key and auto safety control is not entirely solved. Therefore, this paper provides further verification on battery management system (BMS) fully latch information while Battery State of charge is at 100% SOC and dynamic security key for RFID card payment.

3.Materials and Methods

3.1 Battery System Charging Infrastructure

The proposed system as shown in Figure 1 uses USB-CAN adapter to monitor the activities of KAYOOLA bus's chargers. Raspberry pi 4 decode and process the CAN frame data from both the KAYOOLA bus and the charger, then after this information is sent to cloud. Kiira Motor Corporation control center to monitor, control activities, and analyses data for further charging station scalability. The charging station attendants also are able to get charger status notifications, monitor battery health, perform payment transactions, and control charger through smartphone's android application.

Figure 1: System Charging Infrastructure

3.2 EVs Use Case Charging Design

Figure 2 describes how drivers; station attendants interact with the IoT based intelligent charging system. The driver was enabled to register, book charging device port, pay remain charges, got notification regarding charging completeness or errors. In addition, the charging station could get the available charging stations and make payment based on the remaining charges while the station attendant would initiate the charging process and make notification on charging errors or completeness. Figure 2 shows the use case diagram of the EV bus communications between actors.

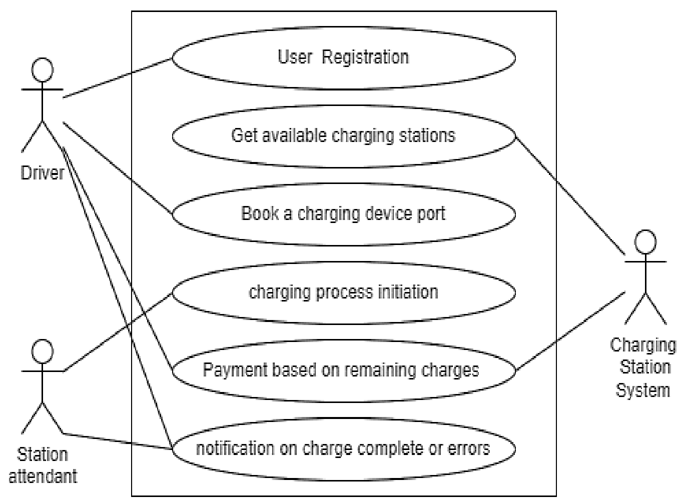

Figure 2: EVs Charging use Case Diagram

3.3 EV Bus Charging Flowchart System

The system was powered by an external backup battery for detecting the status of charger even at the time of blackout. By detecting and decoding charger and BMS CAN messages, the system was enabled to control and report real-time data on what is going on in the charging station. Figure 3 shows the flowchart diagram of EVs bus charging system.

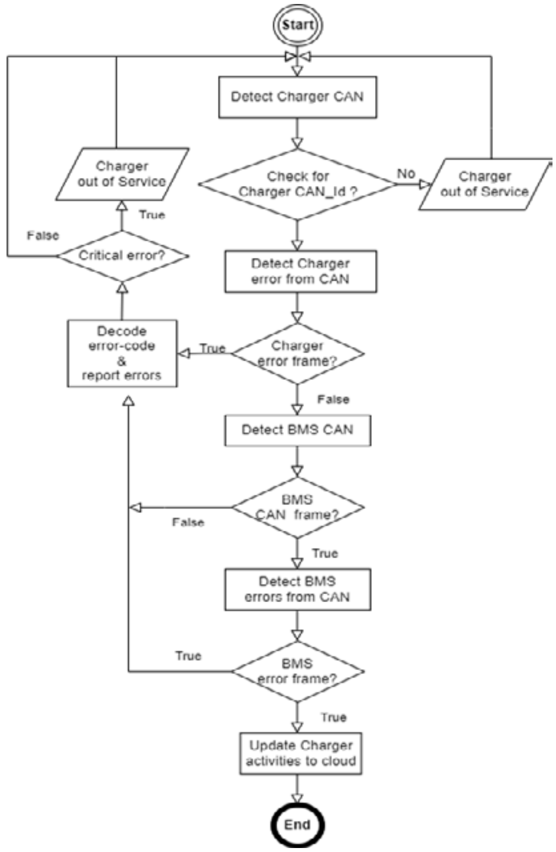

Figure 3: EV Bus Flowchart Charging System

3.4 Hardware System Design

The whole system in Figure 4 was powered by 5VDC, the isolated PCAN module was also powered from the USB of Raspberry pi 4. The real-time clock was also powered directly from Raspberry pi to keep exact time and date. Lithium Polymer module was used as backup power to ensure the reliability in case of blackout.

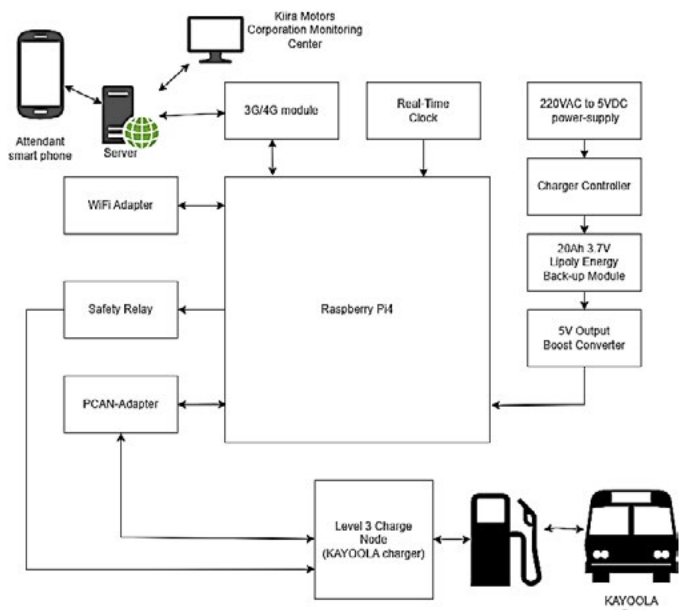

Figure 4: Hardware Interconnection Diagram

4. Results and Discussion

4.1 Mobile Application Design

The KAYOOLA EVs Buses and their drivers are registered at any company branch using Web or Desktop application with their credentials. Upon submission of the registration information, a unique user ID is generated for each user. This information is stored in the database and RFID card to enable driver to login in android app and RFID card to enable driver at EV charger. Once the driver has logged in into android application, the driver can access Kiira Motors Corporation charging station status, charge complete notifications from KAYOOLA EVs Bus and Level3 Charger CAN shared bus, locations, pricing rate per kWh and check remaining money on RFID card. The driver can top up RFID card at any Kiira Motors Corporation branches using the developed Desktop application with smart card technology connected to the server. Kiira Motors Corporation control center through Web and Desktop application will monitor the activity, perform remote charger diagnosis, and generating report of energy used and total revenue. After having the server set up, the Mobile application for driver monitoring was designed with android studio. The designed application screens were accessed by different sets of users to ensure that all the requirements were adequately captured. Then finally the android application was linked to the server application for real-time monitoring as shown in Figure 5.

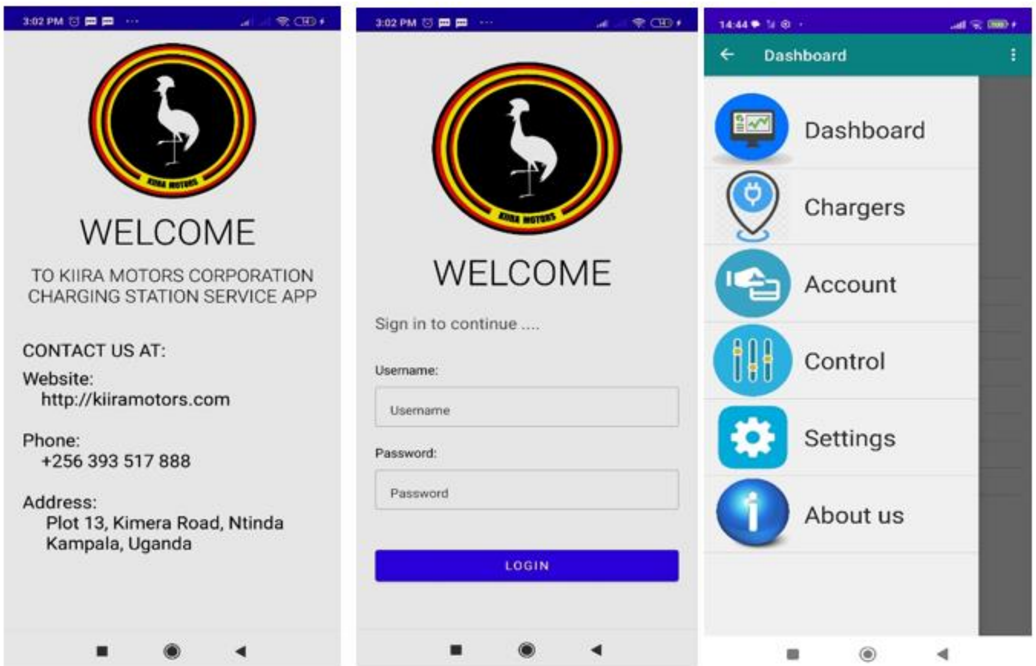

Figure 5: Android application welcome, functional menus and login page

4.2 Webpage Application Design

The driver was enabled to register with personal information, and insert the email address, password and RFID card number as generated by the system as shown in Figure 6. The driver would recharge RFID card to unable card transactions. RFID Card and user IDs, customer name, RFID card balance and money to recharge should appear on the dashboard before making payment in a secured and authenticated card transaction process as shown in Figure 7. Additionally, if the recharge was agreed to be paid, the transaction process would be completed successfully as shown in Figure 8.

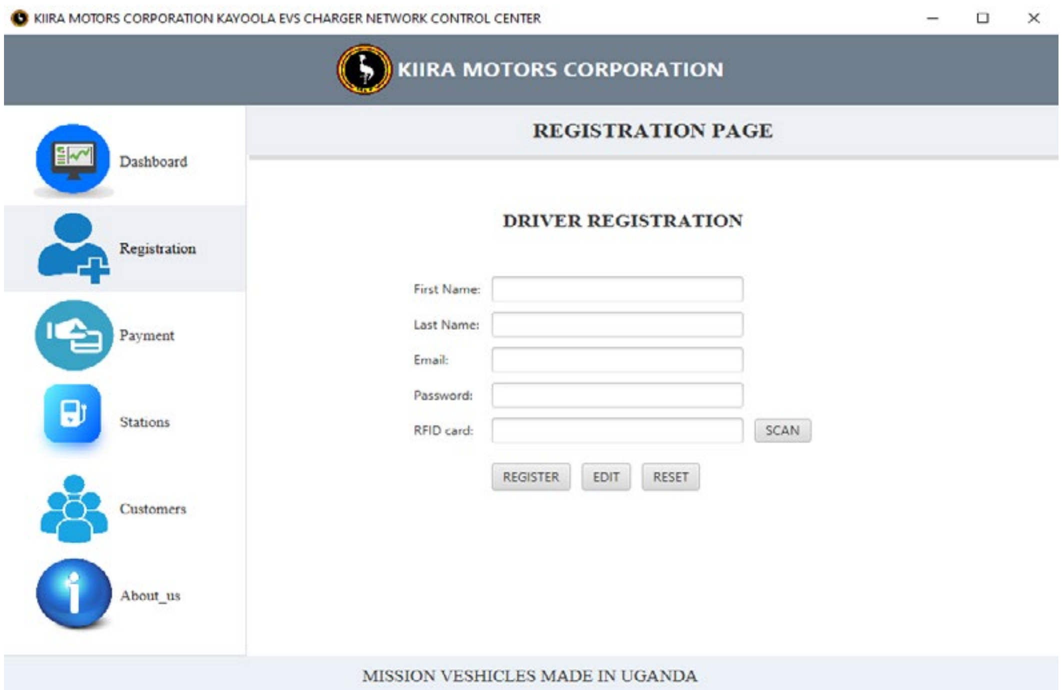

Figure 6: RFID User Registration

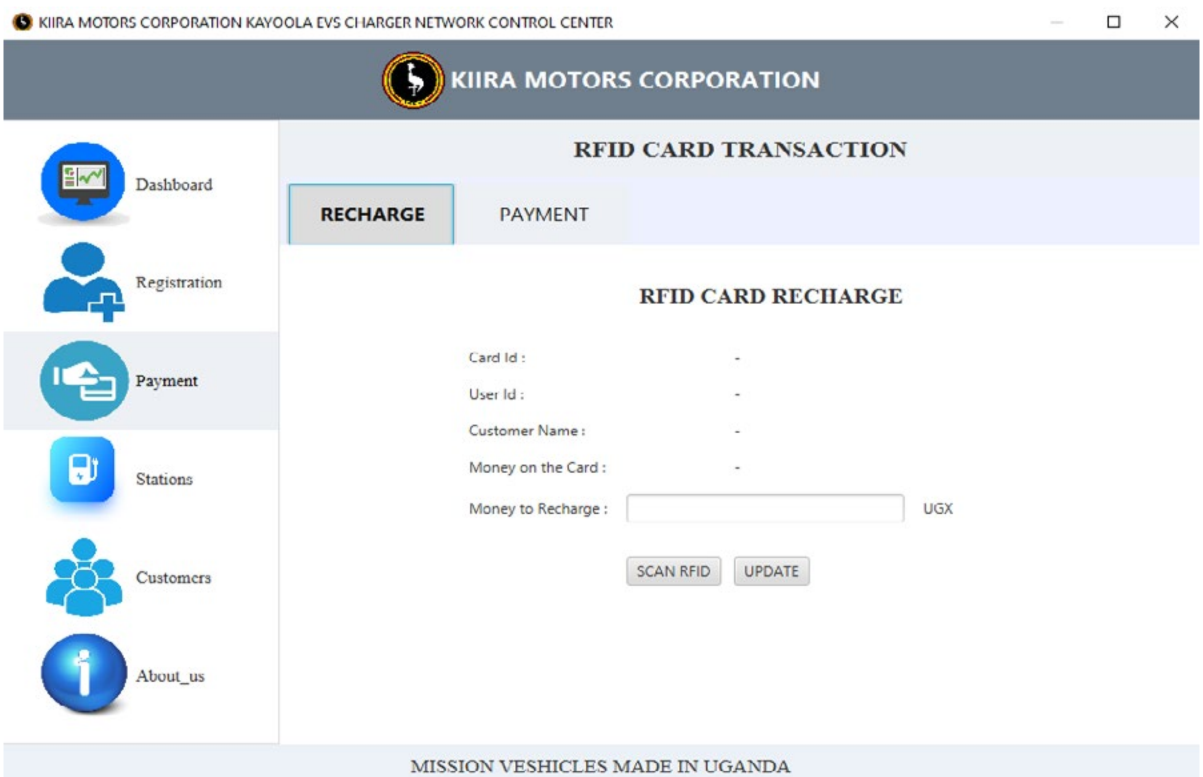

Figure 7: RFID Card Recharging Through Desktop Application

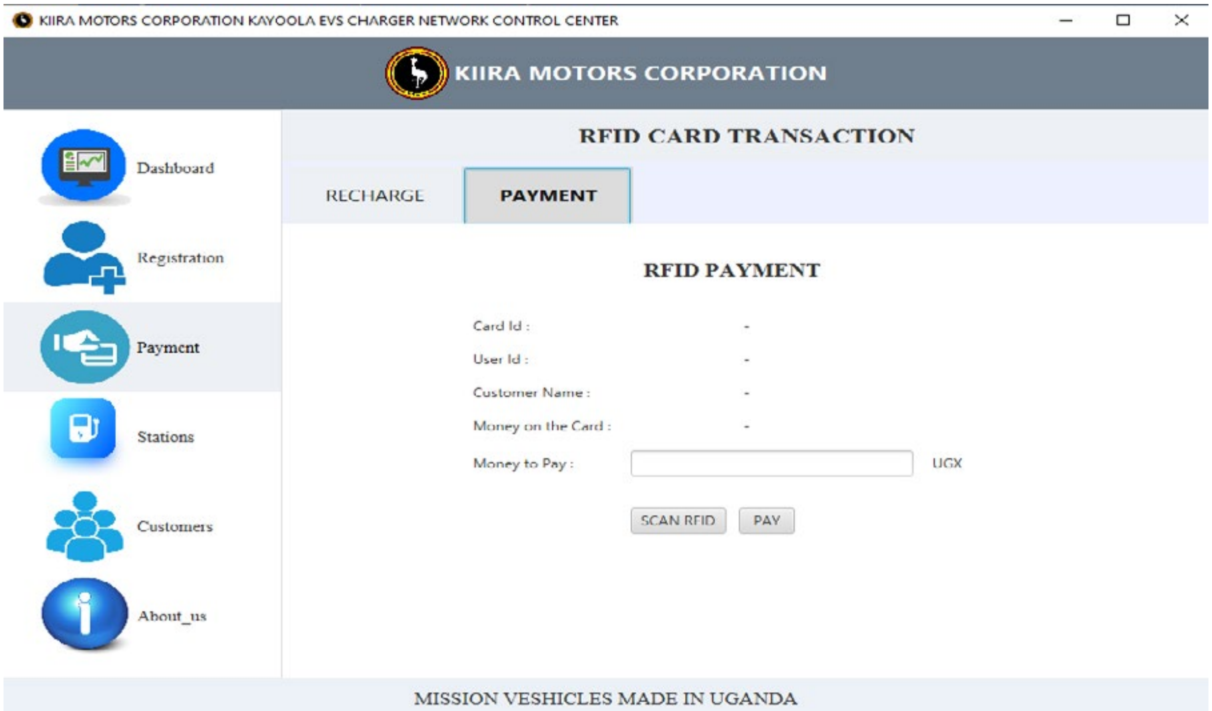

Figure 8: RFID Card Payment Through Desktop Application

4.3 Desktop app Card Writing and Recharge

Figure 9 shows the KMC Dashboard software for Real-time remote charging stations information, Figure 10 shows Driver registration, and Figure 11 shows RFID card Writing and recharge. The identifications of specific driver are written on the card with the use of Desktop application software.

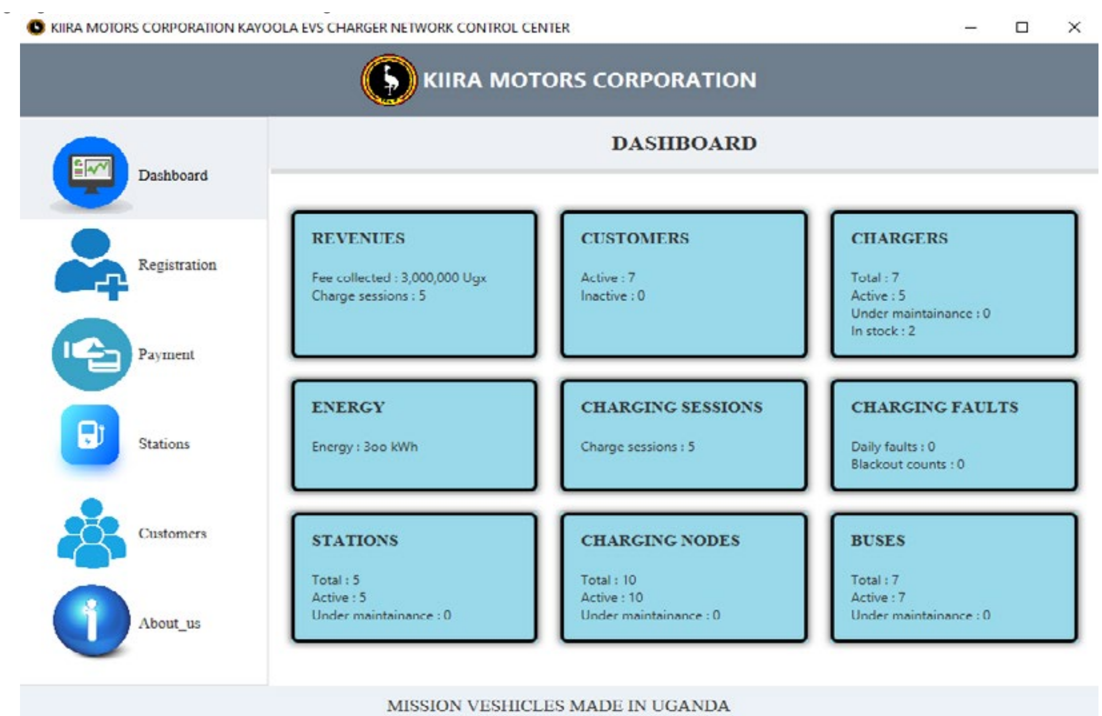

Figure 9: KMC Station Remote Monitoring

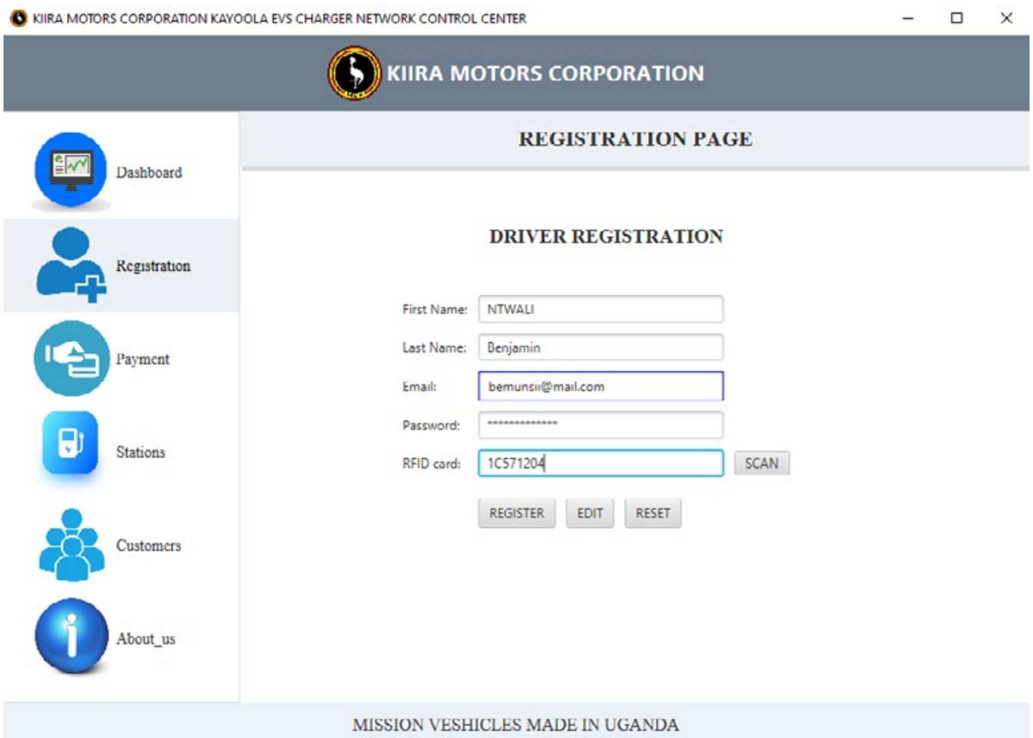

Figure 10: Driver Registration

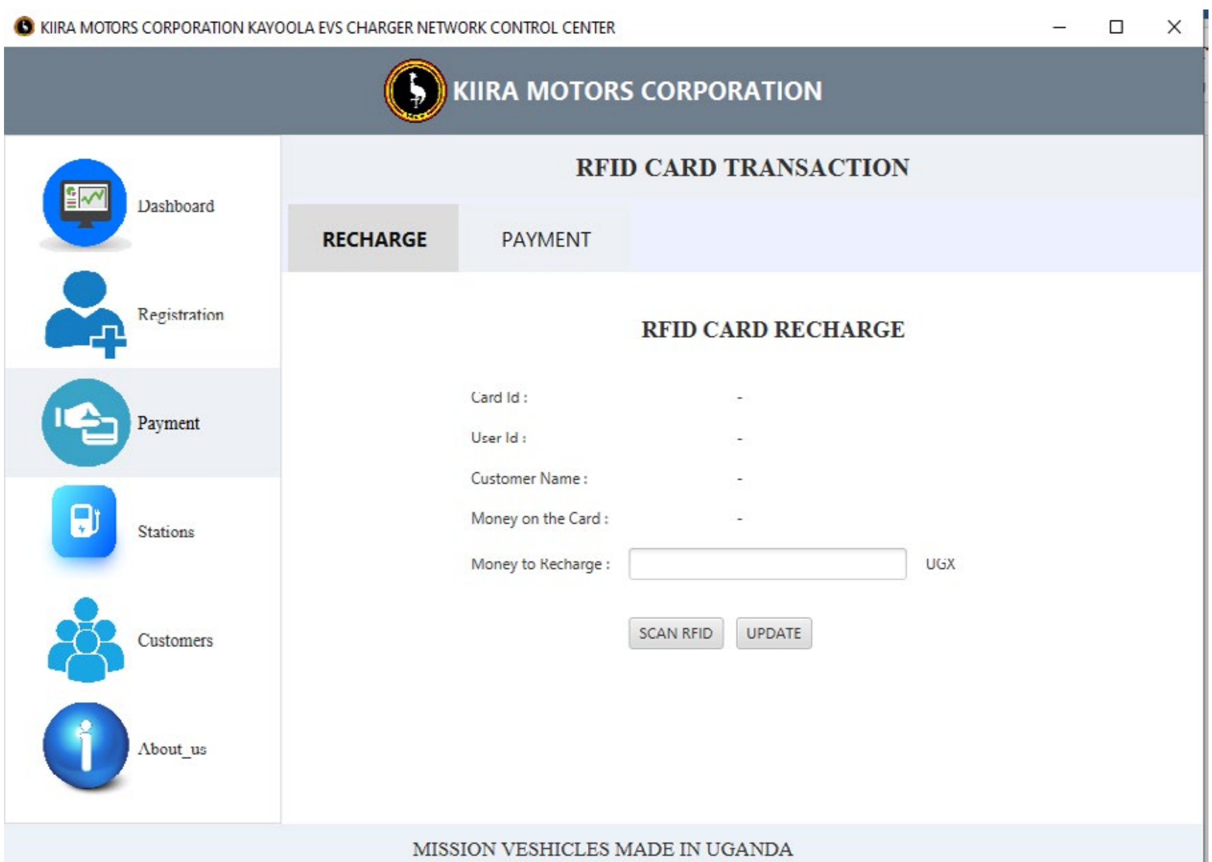

Figure 11: RFID Recharge

4.4 Desktop Application Real-time Monitoring

Figure 12 shows Desktop application page for monitoring level 3 chargers' status, and offering remote emergency safety controls.

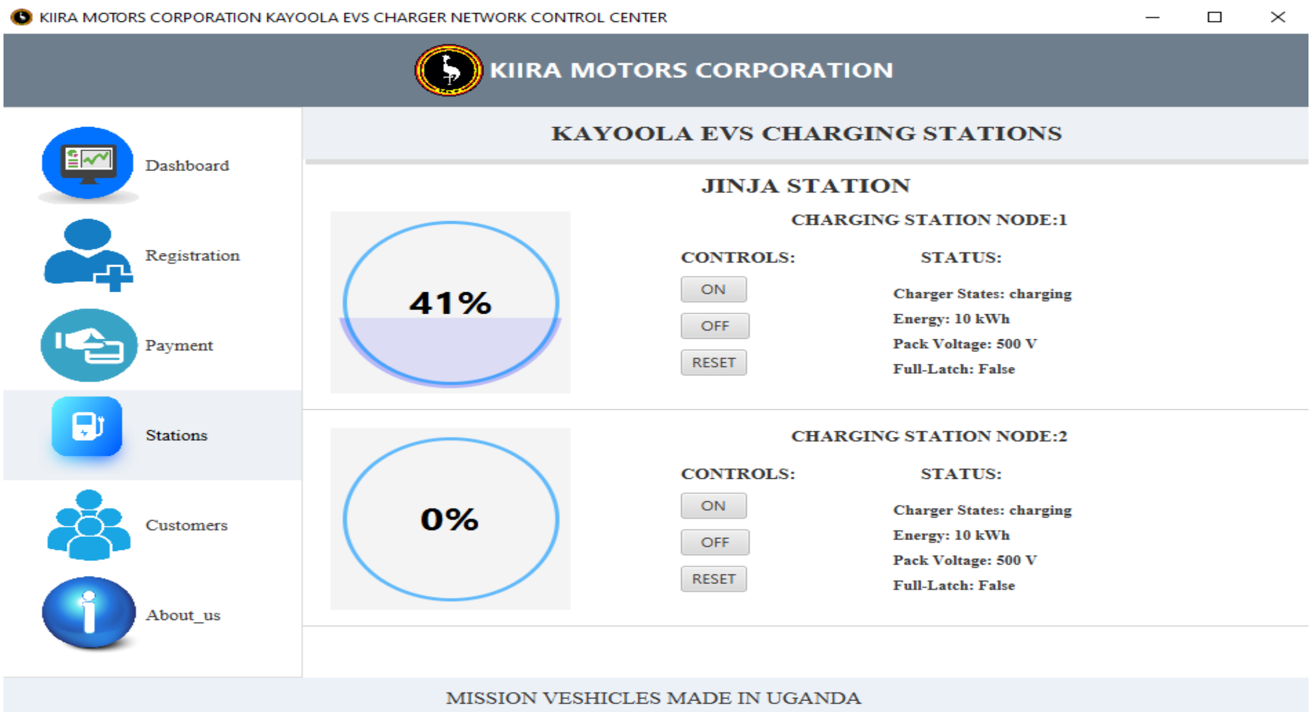

Figure 12: Remote Monitoring of Charging Progresses

4.5 Mobile Application Real-Time Monitoring

Figure 13 shows Mobile application enabling the Driver to receive charge complete notification, checking the status KMC Charging Station, and checking the amount remaining on the RFID card. Figure 14 indicates the Account and Charging Station Information.

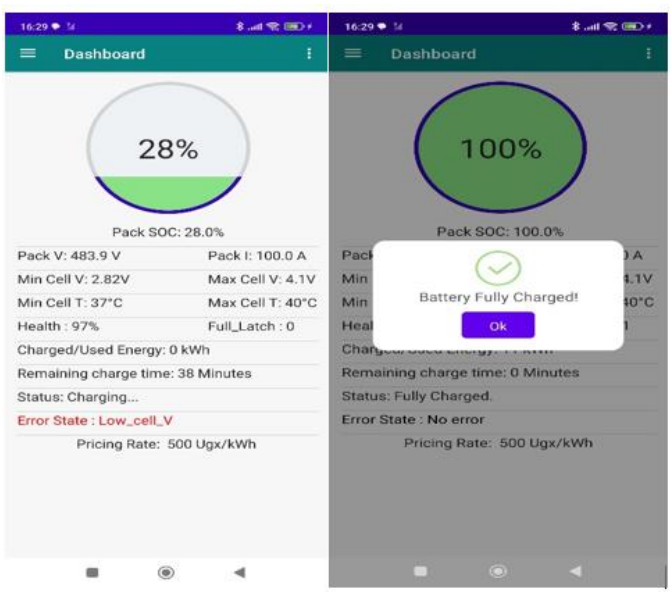

Figure 13: Dashboard for Charge Compete Notification

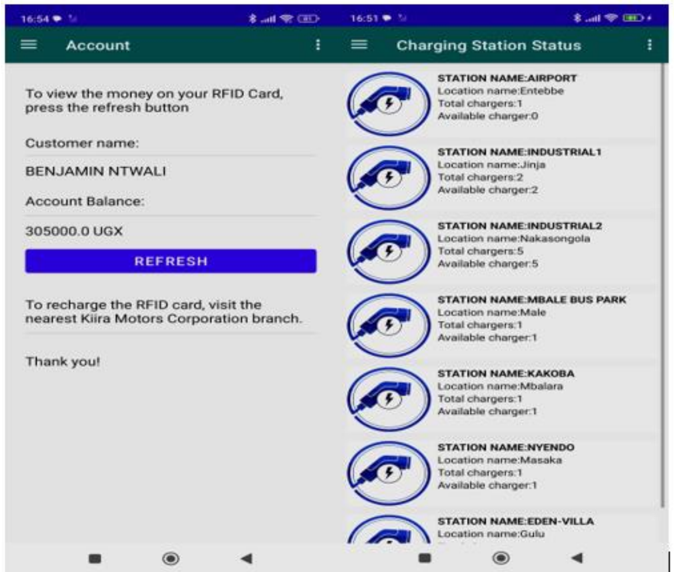

Figure 14: Account and Charging Station Information

5. Conclusion and Future Work

An IoT based Mobile system that allow KAYOOLA Bus drivers to receive charge complete notification, Web and desktop app that allows charging station attendant and KMC management to monitor charging station operations, technicians to easily troubleshot charger issue remotely wad developed and tested. The partial charge and unplugging KAYOOLA EV Bus before BMS calibration can lead to potential problems and inconveniences. Batteries are designed to undergo full charging and discharging cycles to maintains their health and longevity. Interrupting the KAYOOLA EVs charging process by disconnecting it from the charger before BMS coulomb counting recalibration by SOC-OCV may results in incorrect SOC prediction, leading to reduced battery life over time and poor reliability of battery pack. Relying on charge complete notification by ensuring all the necessary BMS's SOC calibration has completed instead of relying on SOC by coulomb counting which is inaccurate due to BMS's Lithium-ion cell passive balancing, the developed system was able to verify BMS charge complete information and other hidden information from shared CAN bus and notify the users when these conditions are met. The developed IoT Based Charging System has saved maintenance cost, helped KMC in early detection of charging errors and battery end of life for replacement, and ensuring reliable transportation for KAYOOLA EVs Bus and adoption in Uganda. Further study should then be upgraded by including machine learning for better mains power load distribution and dynamic electricity cost depending on time and peak hours.

Data Availability

Upon request, the corresponding author will provide the data that support the conclusions of this paper.

Conflicts of Interest

The authors declare that there are no conflicts of interest regarding the publication of this paper.

References

1. N. M. KMC, "Kiira Motors: Electric vehicles made in Uganda by 2021," Kiira Motors Corporation, 29 August 2020.
2. V. Tinka, "Full specifications of the Kayoola EVS™," TechJaja, 23 May 2020.
3. Das, H. S., Rahman, M. M., Li, S., & Tan, C. W. (2020). Electric vehicles standards, charging infrastructure, and impact on grid integration: A technological review. *Renewable and Sustainable Energy Reviews, 120*, 109618.
4. Philipp Kampshoff, Adi Kumar, Shannon Peloquin, Shivika Shahdev, "Building the electric-vehicle charging infrastructure America needs," Mc Kinsey & Company.
5. US. Department of Transportation, "Electric Vehicle Charger Levels and Speeds," US Department of Transportation, 31 August 2023.
6. T. Technology, "EV Charging Station Management System – Monitor and Manage It," 21 December 2022.
7. Aldeen, Y. A. A. S., Jaber, M. M., Ali, M. H., Abd, S. K., Alkhayyat, A., & Malik, R. Q. (2024). Electric charging station management using IoT and cloud computing framework for sustainable green transportation. *Multimedia Tools and Applications, 83*(10), 28705-28728.
8. Salpekar, M. (2022). A Proposed System for Electric Charging Vehicle Infrastructure. In ISUW 2019 (pp. 119-126). Springer, Singapore.
9. Renesas, "Battery Management System Tutorial," Renesas.
10. Lobato, E., Prazeres, L., Medeiros, I., Araújo, F., Rosário, D., Cerqueira, E., ... & Antloga, A. (2022). A monitoring system for electric vehicle charging stations: A prototype in the amazon. *Energies, 16*(1), 152.
11. Maeng, J., Min, D., & Kang, Y. (2023). Intelligent charging and discharging of electric vehicles in a vehicle-to-grid system using a reinforcement learning-based approach. *Sustainable Energy, Grids and Networks, 36*, 101224.
12. Fu, Z., Dong, P., & Ju, Y. (2020). An intelligent electric

vehicle charging system for new energy companies based on consortium blockchain. *Journal of Cleaner Production, 261*, 121219.
13. J. Surendiran, R.G. Vidhya, S.S. Sivasankari, B.P. Pradeep kumar, N. Balaji, "IoT-Based Advanced Electric Vehicle Charging Infrastructure," in IEEE Fourth International Conference on Cognitive Computing and Information Processing (CCIP).
14. Suresh Kumar, R., Rajesh, P. K., Joys Nancy, J., Abirami, S., & Vishnu Murthy, K. (2020). IoT-based monitoring and management of electric vehicle charging systems for DC fast charging facility. *Internet of Things for Industry 4.0: Design, Challenges and Solutions,* 147-159.
15. Shanmugapriyan, J., Karuppiah, N., Sarveshwaran, V., & Muthubalaji, S. (2023). IoT and Blockchain-Enabled Charging Station for Electric Vehicles. In *Modern Approaches in IoT and Machine Learning for Cyber Security: Latest Trends in AI* (pp. 93-101). Cham: Springer International Publishing.
16. Martins, J. P., Ferreira, J. C., Monteiro, V., Afonso, J. A., & Afonso, J. L. (2019). IoT and blockchain paradigms for EV charging system. *Energies, 12*(15), 2987.

Copyright: *©2024 Benjamin Ntwali. This is an open-access article distributed under the terms of the Creative Commons Attribution License, which permits unrestricted use, distribution, and reproduction in any medium, provided the original author and source are credited.*