International Journal of Scientific Research in Engineering and Management (IJSREM)
Volume: 08 Issue: 03 | March - 2024 SJIF Rating: 8.176 ISSN: 2582-3930

Ground Based Recharging System for Electric Buses

Sarvesh Kadlag (BE student)
Anshu Chandravanshi (BE student)
Tejas Pradhi (BE student)
Sahil Warekar (BE student)
Project Guide: Prof. Kshipra Pandey
Atharva College of Engineering, Mumbai, Maharashtra

Prof. Sangeeta Kotecha
HOD of Electrical Engineering Dept.
Atharva College of Engineering, Mumbai, Maharashtra

Abstract- In response to the growing demand for efficient and convenient electric vehicle (EV) charging solutions, this paper proposes a novel ground-based charging system tailored for EV buses and trucks. The system utilizes a current collector mechanism akin to pantograph charging, integrating a linear actuator with three terminals for positive, negative, and ground connections. Pogo pins, each rated at 5 amps and connected in series, are employed as connectors for reliable power transfer. The ground infrastructure consists of buried copper terminals arranged in a grid formation, covered with a silicon inductor sheet to ensure safety and durability. Upon the arrival of an EV bus/truck, a proximity sensor detects its position, prompting the driver to initiate the charging process by scanning a QR code and entering identifying information via IoT communication. Activation of the linear actuator, controlled through a relay system, establishes the power connection between the vehicle and the ground-based infrastructure. Upon completion of charging, the system is deactivated, and the vehicle can resume its journey. This paper outlines the design, operation, and potential benefits of the proposed ground-based charging system, offering a promising solution to enhance the efficiency and accessibility of EV charging for public transportation fleets.

I. INTRODUCTION

With the rapid adoption of electric vehicles (EVs) worldwide, there is a pressing need to develop innovative charging solutions capable of meeting the unique requirements of various vehicle types, particularly those used for public transportation such as buses and trucks. Conventional charging methods, while effective for private vehicles, often fall short in terms of scalability, efficiency, and user convenience when applied to larger, commercial vehicles with high energy demands and frequent operational schedules. In this context, ground-based charging systems present a compelling alternative, offering seamless integration with existing road infrastructure and the potential for rapid deployment across urban environments.

This research paper introduces a novel ground-based charging system specifically designed for EV buses and trucks. Building upon the principles of pantograph charging, the proposed system leverages a combination of robust hardware components, including a linear actuator with integrated current collector terminals and high-capacity pogo pins, to facilitate efficient power transfer between the vehicle and the charging infrastructure. The ground terminals, strategically positioned beneath the vehicle's path and shielded with a silicon inductor sheet, ensure reliable and safe operation under various environmental conditions. Key features of the proposed system include automated vehicle detection through proximity sensors, streamlined user interaction via QR code scanning and IoT communication, and precise control of the charging process through relay-based power management. By eliminating the need for overhead infrastructure and offering a flexible, grid-based charging layout, the system aims to optimize space utilization and minimize installation costs while accommodating the diverse needs of public transportation fleets.

Through a detailed analysis of the system architecture, operational workflow, and potential benefits, this paper aims to provide valuable insights into the feasibility and efficacy of ground-based charging solutions for EV buses and trucks. By addressing key challenges such as scalability, interoperability, and user experience, the proposed system represents a significant step towards advancing the electrification of public transportation and fostering sustainable urban mobility ecosystems.

II. LITERATURE REVIEW

Pantograph charging, commonly used in electric buses and trains, serves as a basis for ground-based charging mechanisms. Research in this area has primarily focused on improving the efficiency and reliability of pantograph systems, including contact design, materials selection, and dynamic charging capabilities. These studies provide valuable insights into the fundamental principles and practical considerations for implementing ground-based charging infrastructure.

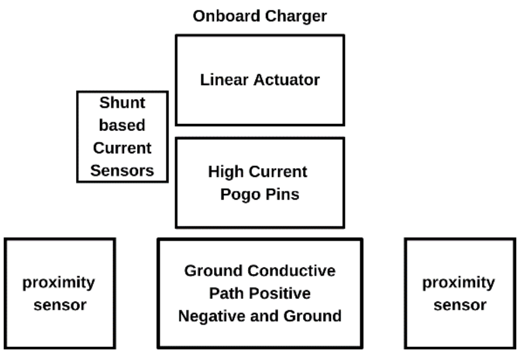

Fig 1. Block diagram of bus conductive path mechanism

1.Pogo Pins

Connecting two 5A pogo pins in series on a PCB can help pass high currents by effectively distributing the current load across multiple pins. **Current Sharing**: When pogo pins are connected in
series, the total current flowing through the series connection is the same as the current flowing through each pin. In this case, each pogo pin is rated for 5A, so the series connection can effectively handle a higher total current. **Reduced Resistance**: By connecting multiple pogo pins in series, the overall resistance of

the connection is reduced. This is because the resistance of each
pin adds up in series, but the combined resistance is still lower
compared to using a single pin. Lower resistance leads to less voltage drop and more efficient current flow. **Improved Heat Dissipation**: High current flow generates heat and distributing the current across multiple pins helps to dissipate this heat more effectively. This reduces the risk of overheating and ensures reliable performance of the connection over time**. Mechanical Stability**: Connecting multiple pogo pins in series enhances the mechanical stability of the connection. It provides redundancy and reduces the risk of a single point of failure. This is especially important in applications where vibration or movement may occur, such as in-vehicle charging systems.

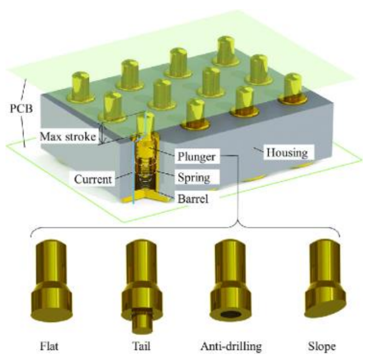

Fig 2. Pogo Pins PCB Connections

2. Shunt-based current sensors: The 500amp current shunt-based sensors offer high accuracy and precision in current measurement, providing real-time data on the amount of current flowing through the system. This is crucial in EVs, where precise monitoring of current flow is essential for various functions such as battery management, motor control, and charging system operation.

Shunt-based current sensors can detect overcurrent conditions, which may occur due to faults or abnormal operating conditions in the vehicle's electrical system. By continuously monitoring current levels, these sensors can trigger protective measures, such as disconnecting the circuit or reducing power output, to prevent damage to components and ensure safety. Shunt-based current sensors also facilitate diagnostic and maintenance activities in EVs by providing valuable data on the performance and health of electrical components. Abnormal current patterns or deviations from expected values can indicate potential issues or faults, allowing technicians to identify and address problems proactively.

3.Linear Actuator

A 300mm linear actuator plays a crucial role in this ground-based charging system for EVs. As per the vehicle, a ground clearance 300mm linear actuator is the perfect match for it. Connecting and Disconnecting: The linear actuator facilitates the connection and disconnection of the current collector to the ground-based charging system. When activated by the driver through the monitor interface, the linear actuator extends downwards, ensuring proper contact between the current
collector on the EV and the terminals embedded in the ground. Controlled Deployment: With a length of 300mm, the linear actuator provides sufficient extension to reach the terminals embedded in the ground without being excessively long, which could increase the complexity of the system or pose hazards. This controlled deployment ensures safe and efficient charging operations.
The linear actuator allows for precise positioning of the current
collector, ensuring optimal alignment with the terminals in the
ground-based charging grid. This precision is essential for establishing a reliable electrical connection and maximizing charging efficiency. By using a linear actuator with a specified stroke length of 300mm, the system can reliably deploy and retract the current collector as needed for charging. This helps prevent misalignment or incomplete contact, reducing the risk of charging failures or safety hazards.

4.Onboard Charging System

Onboard charging system help during the recharging process Current Regulation: The onboard charger monitors the current flowing from the conductive path and regulates it according to the requirements of the vehicle's battery. It ensures that the current supplied to the battery is within safe operating limits and matches the charging capabilities of the battery.Voltage Conversion: The voltage supplied by the conductive path may not match the voltage required by the vehicle's battery. The onboard charger converts the incoming voltage to the appropriate level required for charging the battery. This conversion process ensures that the battery receives the correct voltage for charging without overcharging or damaging it. Power Management: The onboard charger manages the power flow from the conductive path to the battery efficiently. It optimizes the charging process to minimize energy loss and maximize charging speed. Additionally, it may incorporate features such as power factor correction to improve the efficiency of energy transfer. Safety Features: The onboard charger includes safety mechanisms to protect both the vehicle and the charging infrastructure. These features may include overcurrent protection, overvoltage protection, short circuit protection, and temperature monitoring. In case of any abnormal conditions or faults, the onboard charger can safely shut down the charging process to prevent damage to the vehicle or the charging system. Communication Interface: The onboard charger communicates with the vehicle's control system to exchange information about the charging process. It provides status updates, such as charging progress, battery state-of-charge, and any error or warning messages. This communication enables the vehicle to adapt its operation accordingly and ensures a smooth and reliable charging experience.

5.Ground Conductive Path

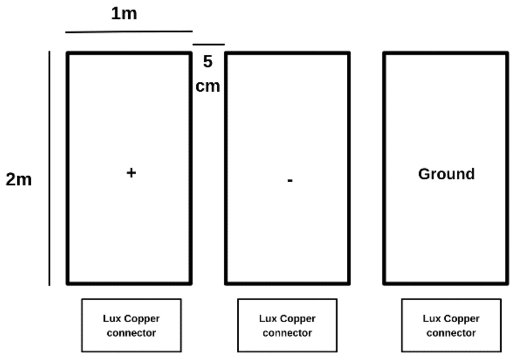

Fig 3. Block Diagram of ground conductive path

Material Composition of Conductive Path:
Copper sheet with a thickness of 10mm.
Dimensions: 2 meters in length, 1 meter in width.
Three segments for positive, negative, and ground, with a 5cm distance gap between each segment.
Side cover with a silicon rubber sheet.
Electrical Connectivity:
Each segment (positive, negative, ground) is connected to the high Ac-Dc grid. Connections are established underground.
Lux connectors are utilized to ensure secure and stable connections between the segments and the grid.
Operational Procedure:
The proximity sensor detects the position of the EV bus on the conductive path.
The driver receives a signal on the monitor indicating proper alignment.
The driver scans a QR code displayed on the monitor for identification.
IoT communication enables the transmission of identification data.
Driver activates the linear actuator, pressing it onto the conductive path.
Relay is triggered, allowing power to flow through the conductive path.
After charging is complete, the driver deactivates the relay and lifts the linear actuator.
Physical Installation:
Conductive path segments are buried beneath the road at a depth of half a meter.
Each segment is positioned parallel to the direction of the road.
Silicon rubber sheet covers the conductive path for protection against external elements and to ensure safety.
Technical Specifications:
Pogo pins rated at 5 amps each, connected in series for each terminal of the linear actuator.
Copper terminals on the ground, each with a length of 1 meter and a width of 2 meters, are buried beneath the road surface.
Safety Measures:
Silicon inductor sheet covers the conductive path to prevent accidental contact.
Proper grounding measures are in place to ensure safety during operation.

6. IOT Module

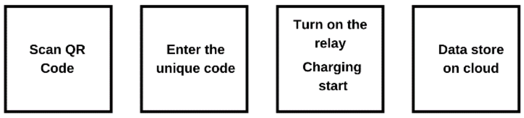

Fig 4. Block Diagram of IOT charging system

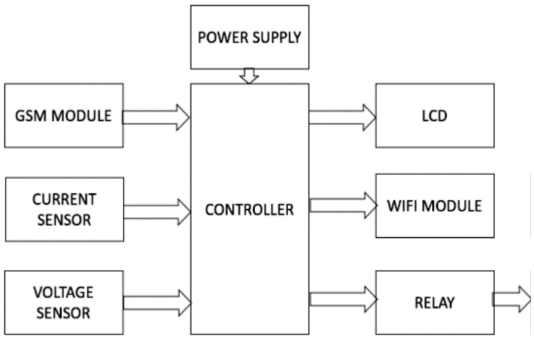

Fig 5. Hardware design of IOT charging system

Arduino Uno: The heart of the ground-based charging system, Arduino ATmega328P microcontroller serves as the main control unit. It manages communication between various components, processes sensor data, and controls the operation of the linear actuator and relay. Its versatility and ease of programming make it an ideal choice for this application.
GSM Module 900: The GSM module enables remote communication with the charging system. It allows for real-time
monitoring and control of the system status, including charging progress and fault detection. With its widespread coverage and reliable communication, the GSM module

ensures seamless integration with IoT networks for remote management.

WiFi Module ESP32: The WiFi module provides local connectivity for the charging system. It enables communication with nearby devices, such as smartphones or tablets, for configuration and monitoring purposes. With its high data transfer rates and compatibility with IoT platforms, the ESP32 facilitates efficient data exchange and control over local networks.

Current Sensor ACS712: ACS712 is a Hall-effect current sensor, can measure current up to 30A. The ACS712 current sensor plays a crucial role in monitoring the charging process. It accurately measures the current flowing through the conductive path, allowing the system to regulate charging current and detect any abnormalities or overloads. With its high accuracy and low noise operation, the ACS712 ensures safe and efficient charging of EV buses.

Voltage Sensor ZMPT101B: The ZMPT101B voltage sensor provides essential voltage monitoring capabilities to the charging system. It measures the voltage across the conductive path, enabling the system to detect and respond to variations in voltage levels. This helps ensure stable and consistent power delivery to the EV buses, enhancing overall charging efficiency and reliability.

I2C LCD: I2C LCD is a type of LCD module that uses the I2C communication protocol to communicate with a microcontroller. A controller that communicates with the microcontroller using the I2C bus. I2C LCD display for local monitoring and diagnostics. These displays provide real-time feedback on system parameters, such as current, voltage, and status messages, allowing operators to quickly identify and address any issues. With their user-friendly interface and easy integration, I2C LCD displays enhance the usability and accessibility of the charging system.

7.SOFTWARE DESCRIPTION

For our ground-based charging system project, we utilized the Arduino IDE and C++ programming language to handle data acquisition from sensors, control signals from GSM and Wi-Fi modules, and manage communication with the ThingSpeak platform for cloud-based data storage and analysis.

The Arduino IDE served as our primary development environment, offering a user-friendly interface for coding and uploading firmware to Arduino microcontrollers. Using C++ programming language, we programmed the Arduino to interface with various sensors, including voltage and current sensors, to capture real-time data on the charging process.

With the GSM module, we established communication between the charging system and the ThingSpeak platform, allowing us to remotely monitor and control the system using cellular networks. The Arduino managed the GSM module, sending data to ThingSpeak and receiving commands for system operation.

Similarly, the Wi-Fi module enabled local connectivity and communication with nearby devices, such as smartphones or tablets, using Wi-Fi networks. The Arduino controlled the Wi-Fi module, facilitating data exchange and control over local
networks, while also interfacing with the ThingSpeak platform for cloud-based data storage and analysis.

Using ThingSpeak as our cloud-based IoT platform, we were able to collect, analyze, and visualize data from the ground-based charging system in real-time. ThingSpeak's user-friendly interface allowed us to create custom IoT applications, generate graphs and
charts to visualize data trends, and set up alerts based on predefined thresholds. Overall, the combination of Arduino IDE, C++ programming language, GSM and Wi-Fi modules, and
ThingSpeak platform provided a robust and versatile solution for building our ground-based charging system and integrating it into the Internet of Things ecosystem.

8.IMPLEMENTATION and RESULT

The system is implemented as follow:

1) Arduino board, GSM & Wi-Fi module to the power supply.

2) Connect Wi-Fi module ESP32 to your mobile hotspot for communicating between GSM module and Arduino.

3) Insert SIM card in GSM slot. Ensure SIM card must be link with QR code and program where we can use that application QR code on front panel of box and add the unique number.

4) At the time of Power ON, “EV CHARGER”, “FINDING MODULE” displayed on LCD display. When Wi-Fi module connected to the network then “NETWORK FOUND”, “SYSYEM READY” displayed on LCD display.

5) When user scan QR code and made successful payment then Amount which is paid and “CHARGING START” Displayed. 6) After timer=0 then relay stop and “CHARGING STOP” message displayed on LCD.

7) This all transactional amount and time duration data w.r.t. date is uploaded on “Thingspeak” platform. So, user can login with thingspeak with their ID which is applied in programme and can access data. Like day by day users, how many users uses the recharging system and how much time etc.

created_at	entry_id	field1
2023-04-07T12:21:0	1	17536
2023-04-07T12:21:4	2	1000
2023-04-07T12:22:1	3	2000
2023-04-07T12:23:0	4	4000
2023-04-07T12:41:2	5	2000

Fig 6. Data Table and Recharging Start

When the system is ON then firstly GSM module is initialized. The “Finding Module” message is displayed on the LCD. When the Wi-Fi module is connected to the network the “Network found” message is shown on LCD. After the “system ready” message is seen on display then we can say that the system is ready to add the code & charging enabled for the vehicle. Code entring process is done by the user for their specific time

requirement then “CHARGING START” is displayed on the LCD along with ID. After completing the recharging for a specific time period we can press relay stop and the “CHARGING STOP” signal shows on the monitor. Collected data is sent to the cloud. Here we use the “Thingspeak” platform. So, all the data can be handled by the owner. In Figure 8, we can see that channel states. In that channel entries, the last entries. So that the owner can check this data and manage the profit/loss ratio. There are two charts on the Thingspeak application. Field 1 chart is ID and Time vs Date.

III. PROJECT ADVANTAGES

Convenience: Ground-based charging offers convenience to EV
bus operators as they don't need to rely on overhead charging
infrastructure, allowing for more flexible deployment and charging locations.
Efficiency: The use of a current collector with pogo pins ensures efficient and reliable charging connections, reducing charging times and optimizing the overall charging process.
Scalability: This system can be scaled to accommodate a fleet of EV buses, providing a scalable solution for mass transit systems in urban areas.
Cost-Effectiveness: Compared to traditional overhead charging systems, ground-based charging may offer cost savings in terms of infrastructure installation and maintenance.
Safety: Burying the charging terminals underground with proper insulation and side coverings enhances safety for both the vehicles and pedestrians, reducing the risk of accidents or damage to the charging system.
Integration with IoT: Integration with IoT technology allows for remote monitoring, management, and data collection, enabling operators to optimize charging schedules, monitor system health, and track energy usage efficiently.

IV. PROJECT SCOPE IN FUTURE

Technology Enhancement: Continuous advancements in charging technology, such as faster charging rates and wireless charging capabilities, can be incorporated into the system to improve efficiency and user experience.
Expanded Deployment: The ground-based charging system can be deployed in various locations beyond bus depots, including taxi stands, delivery hubs, and public parking lots, to support the electrification of different types of vehicles.
Smart Grid Integration: Integration with smart grid systems can enable dynamic charging management based on grid demand and renewable energy availability, optimizing energy usage and reducing the overall carbon footprint.
Vehicle-to-Grid (V2G) Capability: Future iterations of the system can explore V2G capabilities, allowing EV buses to not only receive power from the grid but also provide energy back to the grid during peak demand periods, enhancing grid stability and revenue generation opportunities.
Autonomous Charging: With advancements in autonomous vehicle technology, the ground-based charging system can be adapted to support autonomous charging, allowing EV buses to autonomously navigate to charging stations and initiate the charging process without human intervention.
Environmental Impact: Further research and development can focus on enhancing the sustainability aspects of the system, such as using recycled materials for construction, minimizing energy losses during charging, and integrating renewable energy sources for powering the charging infrastructure.

V. CONCLUSION

Ground-based charging system for EV buses offers a promising solution for efficient and convenient electric vehicle charging. By utilizing a current collector mechanism similar to pantograph charging, coupled with advanced technology such as IoT communication and proximity sensors, this system addresses the challenges associated with traditional charging methods.
The integration of linear actuators with three different terminals for positive, negative, and ground connections, along with pogo pins capable of handling high amperage, ensures reliable and secure electrical connections between the charging infrastructure and the EV buses. The design of the conductive path, consisting of buried copper terminals with a silicon inductor sheet cover, facilitates seamless power transmission while minimizing the visual and physical impact on the surrounding environment. The grid configuration of the terminals optimizes power distribution and enhances system scalability.
The user-friendly interface, including QR code scanning and IoT-enabled identification, streamlines the charging process for drivers, enhancing overall operational efficiency. The automated relay control further improves safety and convenience by regulating power flow based on driver input. Overall, the ground-based charging system presents a viable solution for addressing the growing demand for electric vehicle infrastructure. Its innovative design, coupled with smart technology integration, paves the way for sustainable transportation solutions in urban environments. Further research and development in this field will continue to drive advancements in electric vehicle charging infrastructure, contributing to the transition towards a cleaner and more sustainable transportation ecosystem.

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