IJARSCT
ISSN (Online) 2581-9429
International Journal of Advanced Research in Science, Communication and Technology (IJARSCT)
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
Impact Factor: 7.301
Volume 3, Issue 9, May 2023

Design and Development of Electric Vehicle Charging Station with Solar Power

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Abstract: *Electric vehicles (EVs) are gaining significant traction as a viable and eco-friendly substitute to traditional gas-powered vehicles. These vehicles rely on charging their batteries to operate proficiently. While EV charging has conventionally been contingent on the electrical grid, the emergence of solar-powered chargers presents a fascinating opportunity. Solar chargers harness clean and renewable electricity, aligning with the pollution-free nature of electric cars and yielding positive environmental outcomes. In this research paper, we propose the design of a solar-powered EV charging station that leverages solar energy to charge EVs. To optimize the utilization of solar power while ensuring similar battery levels across all vehicles, we map out a Linear Programming approach for charging EVs. We evaluate the performance of our algorithm using both real-world and synthetically derived datasets, showcasing its ability to equitably distribute the available electric charge among EVs across different seasons with varying demand profiles.*

Keywords: EV, Battery Charging, Arduino, Wi-Fi Controller, IoT, Solar.

I. INTRODUCTION

The increasing global emphasis on sustainable transportation has resulted in a remarkable rise in the adoption of electric vehicles (EVs) as a cleaner and more environmental-friendly way of transportation. However, the widespread adoption of EVs faces obstacles due to the limited availability of charging infrastructure, particularly those powered by renewable energy sources. Conventional charging stations heavily rely on the electrical grid, which predominantly depends on non-renewable energy sources and contributes to carbon emissions. In the current context, global warming and climate change are major concerns that pose significant threats to the environment and life on Earth. Greenhouse gases (GHGs) are the primary contributors to climate change, and the transportation sector, particularly road transportation, is responsible for a substantial portion of GHG emissions and air pollution. It is estimated that the transportation sector accounts for 24 percent of the world's CO emissions, with road transportation contributing three-quarters of these emissions. The adoption of electric vehicles plays a crucial role in improving traffic conditions and maintaining a healthier living environment. With zero or ultra-low tailpipe emissions and significantly reduced noise levels, electric vehicles offer a sustainable solution. Consequently, the global automotive industry is transitioning towards zero-emission vehicles. To facilitate the wider adoption of electrically-propelled vehicles and leverage cheap and clean electrical energy from the grid and renewable resources, the development of an electric vehicle charging station and its optimal placement are of paramount importance. Establishing a well-designed charging station network helps alleviate the range anxiety experienced by electric vehicle owners, ensuring comparable performance to that of internal combustion engine vehicles. However, challenges exist in relation to the adoption of electric vehicles, which can be linked to the "chicken or egg" dilemma. Consumers are waiting for a vigorous charging infrastructure to have complete assurance of successful trip completion with slight or no charging delays. Contrarily, charging infrastructure investors are awaiting a sufficient number of electric vehicles on the road to make their business financially feasible. Stakeholders also differ in opinions concerning the option between fast charging and smart charging (SC) for EV charging stations. Inscribing these issues requires the involvement of government policies. Government policies play a vital role in easing the adoption of EVs and the development of charging infrastructure. Furthermore, the lack of

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suitable batteries that can provide sufficient energy for extended durations and enhance the range of electric vehicles also shackles their extensive adoption.

II. PROBLEM DEFINITION

The current lack of adequate charging infrastructure for electric vehicles poses a significant challenge to their widespread adoption. The problem lies in the limited availability of charging stations that utilize renewable energy sources, resulting in increased reliance on non-renewable energy and hindering the transition to sustainable transportation.

Traditional charging stations rely heavily on the electrical grid, leading to potential strain on the grid infrastructure during peak demand periods. This problem highlights the need for alternative energy sources and strategies to manage energy demand effectively while reducing the carbon footprint of electric vehicle charging.

The transportation sector is a major contributor to greenhouse gas emissions. Electric vehicles offer a solution to reduce emissions, but the environmental benefits can be diminished if the charging infrastructure is not powered by clean energy sources. Therefore, the problem is to develop a charging station that minimizes carbon emissions and promotes sustainable energy usage.

EV Charging has conventionally been grid based. Reconstruction of the distribution grid to meet the EV's charging requirement is difficult and require time and capital investments.

The initial installation cost and operational expenses of charging stations can be significant barriers to their widespread deployment. The problem is to design and develop a modest charging station solution that utilizes solar power, minimizing the overall expenses and making it more accessible and affordable for both station owners and electric vehicle owners.

The control and monitoring of Battery charging is not always convenient and user friendly and require the need of proper interface for the punctilious operation of battery charging.

By addressing these problem definitions, the research paper aims to contribute to the development of an electric vehicle charging station that overcomes the limitations of current charging infrastructure, promotes sustainability, reduces carbon emissions, and enhances the overall viability of electric vehicles as a clean transportation option.

III. LITERATURE SURVEY

In the study of IEEE paper published by Shubham Mishra, Shreya Verma, Shubhankar Choudhary, Ambar Gaur in their paper titled "A Comprehensive Review on Developments in Electric Vehicle Charging Station Infrastructure and Present Scenario of India" states that adoption of new technologies like V2G, Smart Grid, Smart charging technique, etc., for EV charging will be very helpful in maintaining the energy balance of the power system and effectiveutilization of available renewable energy. It will also help in meeting customer satisfaction and economic charging rates.

IEEE paper by Maria Carmen Falvo; Danilo Sbordone; I. Safak Bayram; Michael Devetsikiotis titled "EV charging stations and modes: International standards" have worked on possible types of Energy Storage Systems (ESSs), that are important for the integration of EVs fast charging stations of the last generation in smart grids. Finally, a brief analysis on the possible electrical layout for the ESS integration in EVs charging system, proposed in literature, is reported.

Prasetyo Aji; Dionysius Aldion Renata; AdisaLarasati; Riz in their paper titled "Development of Electric Vehicle Charging Station Management System in Urban Areas" focus to make a tool in the form of a CSMS application to monitor and control CS with the name SONIK (electric vehicle charging operation system).

The paper titled "Concept of charging stations for electric cars" published by Oliver Marcincin; ZdenekMedvec is about active charging stations for electric cars. Active charging station is usually part of modern electrical grids, known as a Smart Grids or Micro Grids.

The paper titled "Solar based electric vehicle charging station" by authorsSohail Tanveer; Sunil Gupta; Rahul Rai; Neeraj Kumar Jha; Mohit Bansalinvestigates the possibility of charging the battery of electric vehicles at various working place like offices, colleges, hospitals, universities etc in Delhi, India using solar energy.

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In a related study by Johnson and Brown, titled "Renewable Energy Integration for Electric Vehicle Charging Stations," the authors discuss the challenges and opportunities associated with integrating renewable energy sources into EV charging stations. The paper traverses through various renewable energy technologies, such as solar and wind power, and their potential application in powering EV charging infrastructure. The authors also highlight the benefits of renewable energy integration, including reduced dependence on fossil fuels and lower operating costs.

IV. METHODOLOGY

In this Project, we are focusing on developing a prototype for an Electric Vehicle Charging System which will take the power from AC Supply and will convert the charge to DC according to the Battery.

In this system, we also focus on some points like monitoring the Voltage and current of the Battery charged by the system. For better performance and sustainability, we are using a low power Solar panel that will power up the controller circuit i.e., Microcontroller, Sensors, Relays etc.

This project involves the following objectives:

1. The primary objective of this project is to design and develop an electric charging station, incorporating power electronics components and embedded circuits.
2. One of the key applications of this project is to offer charging services to electric vehicle users.
3. The charger's design incorporates a variable output power source, allowing adjustment based on the specific vehicle and power requirements.
4. The system incorporates an additional solar panel to supply power to the embedded circuitry.
5. This project aims to tackle the real-time challenge of electric vehicle charging in public spaces, benefiting both the users and service providers.

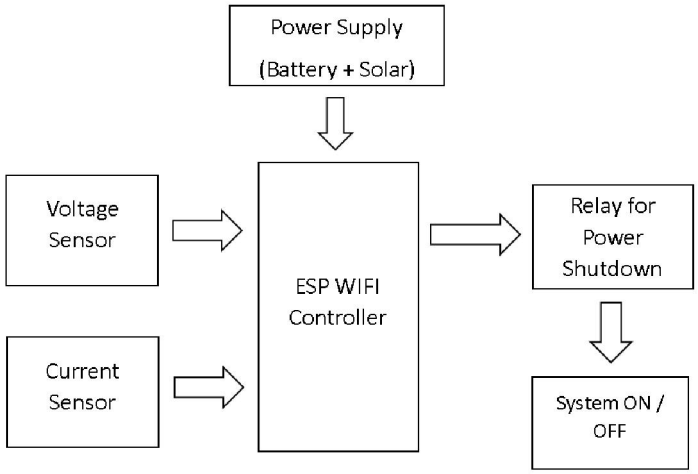

Fig. 1. Block Diagram

The proposed project practically encompasses several stages, each with specific tasks and considerations. The following provides an elaboration of each point:

1. Site Selection:

In this stage, the benchmark for selecting an appropriate site for the charging station are established through audits and calculations. Factors such as accessibility, available space, solar exposure, and proximity to the electric grid are taken into account to identify the most suitable location.

2. Solar Panel Installation:

This stage involves calculating the power requirements based on the supplementary circuit's power needs for the proposed project. It also entails selecting the pertinent solar panels based on their efficiency, capacity, and durability. Factors such as panel orientation, tilt angle, and wiring are considered during the installation process.

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3. Power Management System:
The design of a power management system is crucial to regulate the flow of electricity from the solar panels to the charging station's auxiliary circuit. Additionally, batteries or energy storage systems may be integrated to store excess energy for later use. Smart charging algorithms are carried out to optimize energy usage and minimize dependence on the electric grid.

4. Charging Station Infrastructure:
This stage involves the design and layout of the charging bays and associated equipment. The selection and installation of charging connectors and cables are crucial components of this stage. Safety considerations, including ground fault protection and electrical insulation, are taken into account to ensure the secure and reliable operation of the charging station.

5. Grid Integration:
Grid integration involves connecting the solar-powered charging station to the electric grid. Contemplations are made for bidirectional power flow, enabling energy exchange between the charging station and the grid. Net metering, a mechanism to measure the energy flow in both directions, may be implemented. Compliance with relevant regulations and standards is also ensured.

6. Performance Evaluation:
This stage focuses on measuring and analysing the charging station's performance metrics, such as charging efficiency and energy generation. Environmental benefits, including carbon emissions reduction and decreased reliance on fossil fuels, are assessed. A comparison may be made with conventional charging stations to evaluate the cost-effectiveness and sustainability of the solar-powered station.
These stages represent a comprehensive approach to the design and development of an electric vehicle charging station with solar power, covering site selection, solar panel installation, power management, infrastructure design, grid integration, and performance evaluation.

V. SOFTWARE DESIGN

Software used for the prototype of the proposed project involves-

1. Programming Software- Arduino IDE
The Arduino Integrated Development Environment is a cross-platform application that is written in functions from C and C++. It is used to write and upload programs to Arduino compatible boards, but also, with the help of third-party cores, other vendor development boards. The Arduino IDE simplifies the programming process for Arduino boards by providing an intuitive text editor, compilation and error-checking capabilities, code uploading functionality, and additional features such as the Serial Monitor. It enables users to write, compile, upload, and interact with Arduino programs effectively.

2. Language- Embedded C
In every embedded system-based project, Embedded C programming plays a key role to make the microcontroller run & perform the preferred actions. At present, we normally utilize several electronic devices like mobile phones, washing machines, security systems, refrigerators, digital cameras, etc. The controlling of these embedded devices can be done with the help of an embedded C program. For example, in a digital camera, if we press a camera button to capture a photo then the microcontroller will execute the required function to click the image as well as to store it.

3. GUI- Blynk
Blynk is a platform that allow usto quickly build interfaces for controlling and monitoring our hardware projects from our iOS and Android device. After downloading the Blynk app, we can create a project dashboard and arrange buttons, sliders, graphs, and other widgets onto the screen.The Blynk mobile app allow us to monitor and control our IoT

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project from anywhere. We can receive real-time data from sensors, control actuators, and visualize the information in the form of graphs or gauges.

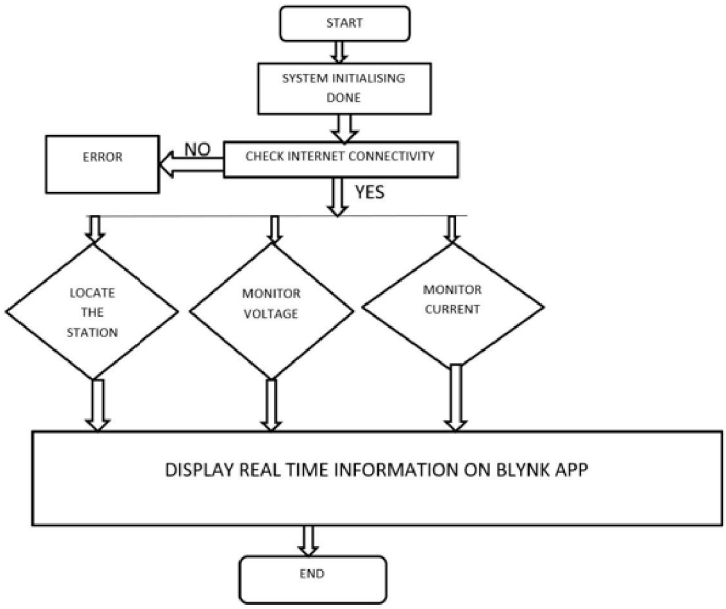

Fig. 1. Flow Chart

VI. FUTURE SCOPES

While we have addressed several real-time problems in this project, there is significant future scope for further enhancements and advancements. Some of the potential future developments are outlined below:

1. Integration of a payment gateway into the system would enable acceptance of various forms of payment, including mobile banking, providing users with convenient and flexible payment options.
2. Incorporating a GPS module into the system would facilitate easy location tracking of the charging station, making it more accessible and convenient for users to find.
3. The concept of battery swapping could be implemented as an additional feature in this charging station. This would reduce the charging time, particularly for level 1 and level 2 charging stations, by allowing users to exchange depleted batteries for fully charged ones.
4. The utilization of AI and deep learning modules could prove beneficial for storing the identities of individuals who have utilized the charger, enabling better tracking and management of user data.
5. Biometric and RFID-based systems, coupled with memory card provisions, can be implemented to securely store customer data.
6. Optimizing the IoT system to send alerts and notifications to existing customers could boost sales and revenue for the system provider.

These scopes mentioned above offer potential avenues for future development and expansion of the charging station system. There may be additional possibilities for improvement and expansion beyond what is listed here.

VII. CONCLUSION

Thus, we conducted a comprehensive study, simulation, and testing of the project concepts using simulation software like Proteus and IoT application like Blynk. We successfully implemented IoT concepts, including live data monitoring of project parameters such as voltage and current. The after-effects of our research and testing lead us to the conclusion that this project has the potential to significantly benefit society by providing an autonomous EV charger system. This system operates on AC supply and converts the charge to DC to effectively charge Level 1 or

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Level 2 EV batteries. Moreover, the incorporation of a solar panel in the system provides an additional advantage by powering the embedded circuitry.

The performance gauging of the solar-powered charging station yielded promising results. The system manifested high charging efficiency and reliable energy generation, primarily due to the optimized utilization of solar power and the integration of intelligent charging algorithms. Additionally, our research paper highlighted the environmental benefits associated with the system. These benefits include a sizeable reduction in carbon emissions and decreased reliance on fossil fuels, thereby making a positive contribution to sustainability.

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