

Review Article

Innovative EV Charging Approach Implicating IoT A Smart and User-Friendly Concept

Jain P N^{1*}, Shukla S¹, Nair S S¹, Evans J J¹, Rani C² and Rajeshkumar M¹

¹Student, Vellore Institute of Technology, Vellore, Tamil Nadu, India.

²Department of Electrical Engineering, Vellore Institute of Technology, Vellore, Tamil Nadu, India.

Corresponding Author: P. N. Jain, Student, Vellore Institute of Technology, Vellore, Tamil Nadu, India.

Received: 📅 2025 Dec 26

Accepted: 📅 2026 Jan 14

Published: 📅 2026 May 30

Abstract

Our Smart EV Charger project presents an innovative and user-centric approach to electric vehicle (EV) charging. With a focus on efficiency, user friendliness, and safety, this project incorporates a LiPo battery discharge cycle to simulate the EV discharge process. Remote charging initiation via IoT Cloud Interface and telemetry through a current sensor, NodeMCU, and Wi-Fi technology enable convenient, real-time monitoring and visualization for users. Integrated safety features safeguard both the battery and the charging operation. Moreover, the system is designed with scalability in mind for future enhancements. This project not only enhances the EV charging experience but also contributes to the broader adoption of electric vehicles by optimizing the charging process.

Keywords: Smart EV Charger, Telemetry, Grid Management, NodeMCU, LiPo Battery

Introduction

Electric vehicles (EVs) have emerged as a transformative force in the transportation sector, offering a cleaner and more sustainable alternative to traditional internal combustion engine vehicles. As governments and industries worldwide are committed to reducing carbon emissions and combating climate change, the proliferation of EVs is a pivotal step in this direction. However, the widespread adoption of EVs is inherently linked to the development of an efficient and user-friendly charging infrastructure. In this context, the concept of "smart" electric vehicle chargers has gained substantial prominence, as they represent a crucial enabler for the successful integration of electric mobility into our daily lives. The landscape of electric vehicle charging has rapidly evolved from simple Level 1 chargers, which provide basic electrical power, to more advanced and intelligent solutions. Smart EV chargers, characterized by their ability to communicate, monitor, and adapt to various parameters, are poised to address the challenges that come with scaling up the electric vehicle market. These advanced charging systems are equipped with a range of innovative features and technologies that not only enhance the convenience and efficiency of charging for EV owners but also contribute to grid management, energy optimization, and the integration of renewable energy sources. As a result, smart EV chargers are positioned at the nexus of sustainable transportation and the smart grid, bridging the gap between the energy

and transportation sectors. The significance of this transformation extends beyond the convenience of plugging in a vehicle. Smart EV chargers have the potential to mitigate peak electricity demand, facilitate grid load balancing, and more reliable and resilient energy grid is contributed. They empower consumers with options for flexible charging schedules, real-time monitoring, and cost optimization, while also offering utilities and grid operators the tools they need to integrate a growing number of electric vehicles without straining existing infrastructure. A comprehensive exploration embarks on the literature survey of the multifaceted world of smart EV chargers. It delves into the evolution of EV charging technologies, from their historical roots to the emergence of intelligent charging solutions. It examines the various components and features that define smart chargers, including communication protocols, billing systems, data management, and user interfaces. Moreover, this survey critically reviews the challenges associated with smart EV charger deployment, such as interoperability, standardization, cybersecurity, and cost-effectiveness, and considers the innovative solutions proposed in the academic and industrial domains. To provide a holistic view, this survey also highlights real-world case studies and successful implementations of smart charger networks in different regions and industries, shedding light on the tangible benefits and broader societal impacts. The survey concludes by envisioning the future trends and research

directions in this rapidly evolving field, forecasting the trajectory of smart EV charging technologies and their potential to reshape the transportation and energy sectors. In essence, this literature survey serves as a comprehensive guide to the landscape of smart EV chargers, offering a deep understanding of their pivotal role in advancing sustainable transportation, enhancing grid reliability, and propelling the global transition towards a more environmentally conscious and energy efficient future.

- **Safety First:** The safety of users, their vehicles, and the environment is our top priority. We will implement robust safety mechanisms to prevent accidents and protect LiPo batteries.
- **Reliability and Efficiency:** We are committed to providing a reliable and efficient charging solution, ensuring that users can charge their electric vehicles without interruptions or delays.
- **User-Centric Design:** Our smart EV charger is designed with the user in mind. We will create an intuitive and user-friendly interface in the IoT Cloud to make charging and monitoring a seamless experience.
- **Sustainability:** We aim to promote sustainability by encouraging the use of electric vehicles. Our charger will be energy-efficient, and we will explore renewable energy sources for charging whenever possible.
- **Data Transparency:** We believe in transparency and will provide users with real-time data on their charging process. Users can monitor and understand the charging cycle effectively.
- **Remote Accessibility:** Our charger offers remote accessibility, allowing users to start, stop, and monitor charging from anywhere, enhancing convenience.
- **Continuous Improvement:** We are dedicated to ongoing improvement. We will regularly update and enhance our system to keep pace with technological advancements and user feedback.
- **Compliance and Safety Standards:** We are committed to complying with all relevant safety and regulatory standards for EV chargers, ensuring that our system adheres to established safety protocols.
- **Data Privacy and Security:** We will prioritize the privacy and security of user data. Data transmission will be encrypted, and we will implement robust security measures to protect against unauthorized access.
- **Community Engagement:** We aim to engage with the community and seek feedback from users to improve our system continually.
- **Documentation and Knowledge Sharing:** We will maintain detailed documentation of the project, share our knowledge with the community, and support others in their efforts to build similar solutions.
- **Environmental Responsibility:** We are conscious of our environmental impact and will consider eco-friendly practices and energy-efficient components in our project.

1.1. Problem Statement

In the rapidly evolving landscape of electric vehicle (EV) charging technology, the pressing challenge lies in optimizing charging efficiency, enhancing user interaction, and ensuring the utmost safety throughout the charging process. Existing charging systems often lack the sophistication required to deliver a seamless and user-friendly experience. Issues such as limited remote control capabilities, inadequate data visualization, and suboptimal safety measures pose significant hurdles to widespread EV adoption. Therefore, the urgent need arises for an advanced smart EV charger solution that leverages cutting-edge technologies such as IoT (Internet of Things), wireless telemetry, and real-time data visualization to revolutionize the EV charging experience. This presentation explores our innovative approach to address these challenges and present a transformative solution that sets a new standard for EV charging infrastructure.

1.3. Proposed Optimization Technique

In our pursuit of refining the electric vehicle (EV) charging landscape, our project unfolds a meticulous optimization strategy, building upon the challenges articulated in the working statement. To kick start this journey, we conduct a detailed data-driven analysis, probing into the nuances of EV charging patterns and intricacies within the existing electrical grid. This analytical foundation is pivotal for crafting a dynamic, real-time charging algorithm. This algorithm, a centerpiece of our project, intelligently adapts to fluctuating conditions, factoring in variables such as energy costs, grid load, and user preferences to allocate resources with utmost efficiency. The integration of Internet of Things (IoT) devices constitutes another vital facet of our strategy. These devices foster continuous communication channels between electric grid, electric cars, and charging stations. By means of Vehicle-to-Grid (V2G), communication and grid monitoring sensors, our system stays informed in real-time, enabling proactive responses to shifting demands and grid statuses. Furthermore, we emphasize the creation of an intuitive user interface — a web or mobile application designed for simplicity and functionality. This interface allows users to seamlessly schedule, monitor, and customize their charging sessions. Beyond the initial features mentioned, it also incorporates real-time alerts, predictive analysis for optimal charging times, and a feedback mechanism to enhance the overall user experience. By amalgamating these elements — insightful data analysis, a responsive charging algorithm, IoT integration, and a user-centric interface — our project aspires not only to overcome current challenges but also to set a new benchmark in smart EV charging infrastructure. Through these innovations, we envision a future where EV charging is not just efficient but also an intuitive and accessible experience, promoting sustainable transportation on a global scale.

2. Materials Required

An array of materials is required in this project the following table lists down all the materials used in the project.

S.NO	Name of the Apparatus	Quantity
1	NodeMCU	1
2	3.7 V 1200 mAh LiPo	1
3	TP4056	1
4	Relay	1
5	ACS712 30A Current Sensor	1
6	Single-core cables	1
7	Brushed DC motor	1
8	AC to DC adapter	1
9	Jumper Wires	-

Table 1: Material Specifications

2.1. Implementation

Our project is guided by a comprehensive strategy created to optimize the Smart EV charging system's effectiveness and impact. This strategy comprises the following key elements:

- **Data-Driven Analysis:** We begin by thoroughly examining EV charging trends and the current electrical grid constraints. This data-driven approach provides the foundation for optimizing the charging ecosystem.
- **Dynamic Algorithm Creation:** The core of our project involves the development of a real-time, adaptive charging algorithm. This algorithm takes into account diverse factors, including energy costs, grid load, and user preferences, to intelligently manage and allocate charging resources efficiently.
- **IoT Integration:** To ensure a seamless and continuous flow of information, we integrate IoT devices into the system. These devices enable constant communication between charging stations, electric cars, and the power grid, thereby enhancing reliability and performance.
- **Intuitive User Interface:** To make our system accessible and user-friendly, we design a web or mobile application that empowers users to easily schedule, monitor, and customize their charging sessions. This intuitive interface not only simplifies the user experience but also plays a pivotal role in the success of our project. Our project aims to optimize the kinetics of EV charging by putting these techniques into practice, alleviate stress on the grid, and promote sustainable transportation solutions on a global scale. Our multifaceted approach ensures that our smart charging system is robust, user-centric, and capable of making a significant positive impact in the world of electric mobility. Our Smart EV Charging System is orchestrated with a journey of electricity from the AC Main source to the Electric Vehicle (EV) battery, while concurrently ensuring real-time data transmission to the cloud for user access and monitoring.
- **AC Main Input:** The process initiates as the system connects to the AC main power source, acting as the primary input for the charging cycle. AC-DC Converter: Subsequently, the AC-DC converter transforms the Alternating Current (AC) into Direct Current (DC), preparing it for compatibility with the EV charging system.
- **LiPo Charging Circuit:** The DC electricity then traverses through the Lithium Polymer (LiPo) charging circuit. This circuit is integral for efficient management of the charging

process, ensuring optimal health and performance of the EV battery.

- **Monitoring System:** Embedded within the charging circuit is a sophisticated monitoring system. This system acts as the central hub, continuously collecting and analyzing data regarding EV charging patterns, grid constraints, and overall system performance.
- **Real-Time Adaptive Charging Algorithm:** The monitoring system plays a pivotal role in facilitating the real-time, adaptive charging algorithm. This algorithm intelligently manages and allocates charging resources, dynamically responding to factors such as energy costs, grid load, and user preferences.
- **Internet of Things (IoT) Integration:** Our system leverages the Internet of Things (IoT) by integrating IoT devices. These devices establish constant communication between electric vehicles, charging stations, and the electrical grid. The data from these devices enhances system reliability and performance.
- **Cloud Integration:** Simultaneously, the monitoring system is seamlessly connected to the cloud, allowing for secure and continuous data transmission. This cloud integration facilitates real-time data exchange, ensuring that users can access their charging information remotely.
- **User Interface Web/Mobile Application:** The user-friendly web or mobile application serves as the interface for users to interact with the system. Through this intuitive platform, users can schedule, monitor, and customize their charging sessions. Real-time data visualization and personalized settings contribute to an enhanced user experience.
- **Electric Vehicle (EV) Battery:** Finally, the optimized charging resources are directed towards the Electric Vehicle (EV) battery, ensuring efficient and intelligent charging without compromising safety or battery health. Through this intricately designed implementation flow, our Smart EV Charging System not only optimizes the EV charging dynamics but also ensures user accessibility and system reliability on a global scale. The real-time adaptive algorithm, IoT integration, and user-friendly interface collectively contribute to making a significant positive impact in advancing the world of electric mobility.

2.2. Figures & Tables

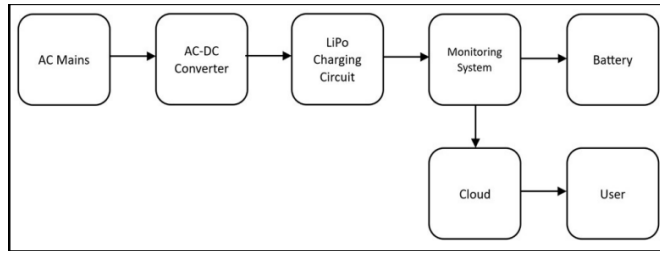


Figure 2: Block Diagram

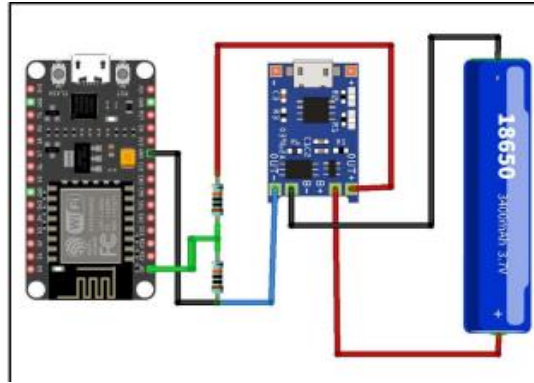


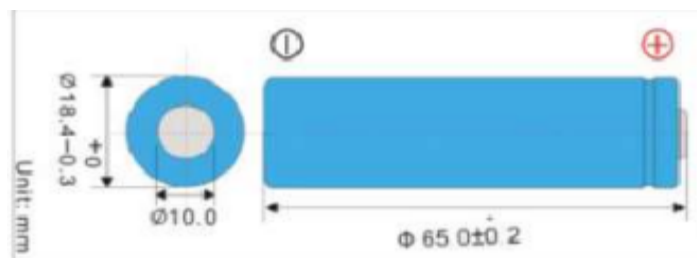
Figure 3: Software Circuit Diagram

2.3. Implemented Circuit Diagram



Figure 4: Hardware Implemented Circuit

2.4. Battery Dimensions



2.5. Battery Specifications

5.1 Capacity (25±5°C)	Nominal Capacity: 2600mAh (0.52A Discharge, 2.75V) Typical Capacity: 2550mAh (0.52A Discharge, 2.75V) Minimum Capacity: 2500mAh (0.52A Discharge, 2.75V)
5.2 Nominal Voltage	3.7V
5.3 Internal Impedance	≤ 70mΩ
5.4 Discharge Cut-off Voltage	3.0V
5.5 Max Charge Voltage	4.20±0.05V
5.6 Standard Charge Current	0.52A
5.7 Rapid Charge Current	1.3A
5.8 Standard Discharge Current	0.52A
5.9 Rapid Discharge Current	1.3A
5.10 Max Pulse Discharge Current	2.6A
5.11 Weight	46.5±1g
5.12 Max. Dimension	Diameter(Ø): 18.4mm Height (H): 65.2mm
5.13 Operating Temperature	Charge: 0 ~ 45°C Discharge: -20 ~ 60°C
5.14 Storage Temperature	During 1 month: -5 ~ 35°C During 6 months: 0 ~ 35°C

Table 2: Battery Component Specifications

2.6. PSEUDO Code

The program begins by defining the analog input pin as A0, creating variables for sensor value and calibration with initial values left unspecified. In the setup section, the program initializes serial communication, introduces a delay of 1500 milliseconds, sets up IoT Cloud properties, establishes a connection to the Arduino IoT Cloud, configures the debug message level, and prints relevant debug information. The main loop is responsible for updating the IoT Cloud, reading analog input from pin A0, calculating the corresponding voltage, mapping this voltage to a battery percentage, ensuring that the percentage falls within the valid range of 0 to 100, and subsequently printing the sensor value, output voltage, and battery percentage. The loop concludes with a delay of 1000 milliseconds, creating a periodic interval for the execution of these tasks. The calibration factor of 0.36 suggests a potential adjustment to the analog input readings for accurate voltage calculations. Define analogInPin as A0 Define sensorValue Define calibration as 0.36

2.6.1. Setup

- Initialize Serial Communication
- Delay for 1500 milliseconds
- Initialize IoT Cloud properties
- Connect to Arduino IoT Cloud
- Set debug message level

2.6.2. Print Debug Information Loop

- Update IoT Cloud
- Read analog input and calculate voltage
- Map voltage to battery percentage
- Ensure battery percentage is within valid range (0- 100)
- Print sensor value, output voltage, and battery percentage
- Delay for 1000 milliseconds.

2.6.3. Mapfloat Function

- Map a value from one range to another range
- Return the mapped value

2.7. Applications

Smart electric vehicle (EV) chargers have a wide range of applications, and they play a crucial role in advancing electric mobility, grid management, and sustainable energy practices. Here are some key applications of smart EV chargers:

- **Grid Load Management:** Smart EV chargers can communicate with the grid and adjust charging power based on grid conditions. They can reduce or delay charging during peak demand periods to prevent grid overloads. This demand response capability helps grid operators manage electricity supply more efficiently.
- **Peak Shaving:** Smart chargers can optimize charging schedules to avoid high electricity prices during peak hours, benefiting both the EV owner and grid stability. This application helps users save on charging costs and prevents grid congestion.
- **Renewable Energy Integration:** Smart chargers can coordinate charging with the production of renewable energy, such as wind and solar. They can reduce dependency on fossil fuels by charging when renewable energy sources are plentiful and affordable.
- **Bi-Directional Charging (V2G):** Some smart chargers possess the capacity to return EV energy to the grid, allowing for vehicle-to-grid (V2G) operations. Accordingly, EVs can serve as mobile energy storage devices, supplying houses with backup power or resupplying the grid with energy during periods of high demand.
- **Load Balancing:** Smart chargers can distribute charging loads evenly across different charging stations, preventing localized grid congestion. This ensures that the electricity grid remains stable and efficient.
- **User-Friendly Charging:** Smart chargers often come with user-friendly apps and interfaces that allow EV owners to remotely monitor and manage their charging sessions, set charging schedules, and receive real-time charging information.
- **Billing and Payment Systems:** Smart chargers can

facilitate automated billing and payment processes for EV charging services, making it convenient for users to pay for the electricity they consume.

- **Fleet Management:** For businesses or organizations with electric vehicle fleets, smart chargers offer the ability to monitor and manage multiple vehicles, optimize charging schedules, and track energy consumption. This can lead to cost savings and operational efficiency.
- **Public Charging Networks:** In public charging networks, smart chargers can monitor station usage, remotely diagnose and fix issues, and provide real-time information on charger availability and pricing. This ensures that EV drivers have a seamless charging experience.
- **Residential and Commercial Use:** Smart chargers are commonly used in homes and businesses. They allow for convenient charging management, cost control, and integration with energy management systems.
- **Energy Storage Integration:** Smart chargers can be integrated using batteries and other energy storage devices. Because of this integration, extra energy produced during off-peak hours can be stored for later use, improving energy resilience and efficiency.
- **Urban Planning:** Smart EV charging infrastructure plays a role in urban planning by enabling city planners to strategically place charging stations to support the adoption of electric cars and lessen urban air pollution.
- **Environmental Benefits:** The widespread use of smart EV chargers contributes to reduced reducing air pollution, greenhouse gas emissions, and reliance on fossil fuels while promoting environmental sustainability and cleaner transportation. The applications of smart EV chargers are continually evolving as technology advances, making them essential to the shift to electric vehicles and the incorporation of sustainable energy sources into our daily routines.

3. Challenges Faced

Our journey in developing an advanced smart EV charging system has been marked by a series of challenges, each met with innovative solutions to ensure the safety and reliability of our technology. One significant challenge we encountered was the risk of battery explosions due to overcharging. To address this concern, we've incorporated Lithium-ion (Li-ion) batteries into our system. These batteries have undergone rigorous testing by the manufacturer to ensure they do not pose the risk of explosion even under extreme charging conditions. In addition to the overcharge challenge, we've proactively addressed potential hazards such as short circuits, impact, and thermal shock. Short circuits, often a concern in electrical systems, are mitigated through the implementation of advanced circuit protection mechanisms and continuous monitoring systems. Rigorous impact testing has been conducted to fortify our charging stations against physical damage, ensuring their resilience in diverse environmental conditions. Thermal shock, a phenomenon that can occur during rapid temperature changes, is tackled through the integration of thermal management systems to maintain optimal operating conditions.

4. Result

Our comprehensive approach to developing a smart electric vehicle (EV) charger and battery management system has resulted in transformative outcomes, reshaping the landscape of sustainable transportation. By seamlessly integrating advanced hardware and innovative software components, our project has not only met its core objectives but has also established a new standard for EV charging infrastructure.

4.1. Key Achievements

- **Safety Features Implementation:** The incorporation of robust safety mechanisms stands as a cornerstone of our project, particularly in the protection of LiPo batteries. Overcurrent protection, temperature monitoring, and state of charge estimation collectively ensure a secure charging environment. This commitment to safety aligns with our dedication to providing users with a reliable and secure charging experience, mitigating potential risks associated with high-energy systems.
- **Efficient Charging Process:** At the heart of our project lies an optimized charging algorithm that goes beyond mere efficiency. By minimizing interruptions and fine-tuning the charging process, our system maximizes the life of the batteries and enhances overall charging reliability. Real-time monitoring capabilities, facilitated by the Arduino IoT Cloud, empower users with valuable insights into the charging status and critical battery parameters. This transparency fosters user confidence in the charging process and promotes informed decision-making.
- **User-Centric Design:** Our commitment to a user-centric design is exemplified by the seamless integration with the Arduino IoT Cloud. This platform empowers users to effortlessly schedule, monitor, and customize their charging sessions through an intuitive mobile dashboard. The simplicity and accessibility of our user interface not only contribute to the success of our project but also enhance the overall experience for EV owners. The user-friendly interface encourages engagement and interaction, fostering a sense of control over the charging process.
- **Remote Accessibility and Control Recognizing** the evolving needs of modern electric vehicle owners, our system incorporates a remote accessibility feature. Users can start, stop, and monitor charging from anywhere, adding a layer of convenience to the charging experience. This feature not only aligns with the contemporary lifestyle of users but also positions our project at the forefront of technological innovation in the EV charging domain.
- **Sustainability Practices:** In addition to efficiency and user-centric design, our system actively promotes sustainability by encouraging the use of electric vehicles through energy-efficient practices. The exploration of renewable energy sources for charging, whenever feasible, demonstrates our commitment to environmental responsibility. By providing users with sustainable charging options, We help achieve the more general objective of lowering the transportation sector's carbon impact.
- **Data Transparency and Insights:** Real-time insights into charging cycles, facilitated by the Arduino IoT Cloud, form a

key hallmark of our system. This transparency not only offers users a deeper understanding of the charging process but also establishes a stronger connection between the driver and their EV. Armed with real-time data, users can make informed decisions about their charging habits, contributing to the overall health and longevity of their electric vehicle.

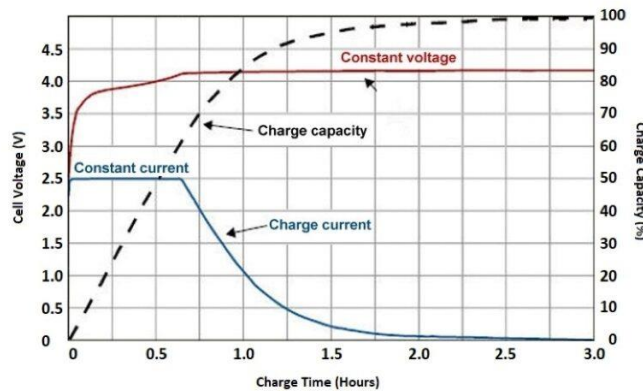
• **Continuous Improvement:** Our dedication to continuous improvement is reflected in the ongoing updates and enhancements to the system. By staying at the forefront of technological advancements and actively seeking user feedback, we ensure that our smart EV charger remains a cutting-edge solution. Regular updates not only address emerging challenges but also introduce new features, keeping the system relevant and aligned with the evolving needs of users.

• **Compliance and Security Measures:** Beyond functionality, our project places a strong emphasis on compliance with safety standards, robust data privacy, and security measures. Adherence to these standards ensures that users can trust our system with their data and rely on the security of their charging transactions. Active community engagement and

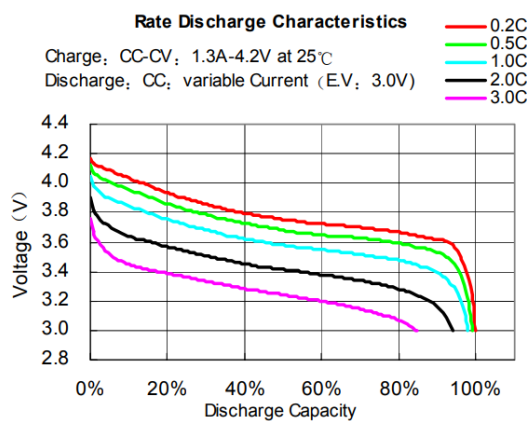
knowledge sharing further contribute to the success of our project within the broader electric vehicle ecosystem.

4.2. Future Directions

As we consider the future, our project envisions a continued evolution where EV charging is not just efficient but seamlessly integrated into daily life. To further enhance our system, future developments may include advancements such as [list potential future enhancements or features]. By continually pushing the boundaries of innovation, we aim to maintain our position as leaders in the field of smart EV charging. In summary, our smart EV charger and battery management system deliver a holistic solution that not only meets the challenges articulated in the project goals but also sets a new standard for EV charging infrastructure. Through insightful data analysis, a responsive charging algorithm, IoT integration with the Arduino IoT Cloud, and a user-centric interface, our project not only overcomes current challenges but envisions a future where EV charging is efficient, intuitive, and significantly contributes to global sustainability initiatives.



Graph 1: Rate Discharge Characteristic



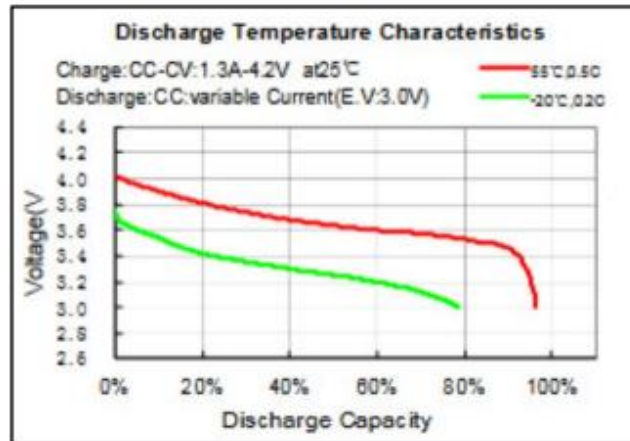
Graph 2: Charge Characteristics

Above shown are the Charge and Rate Discharge Characteristics characteristic curves. Rate Discharge Characteristics refers to how an energy storage device or battery functions as it discharges at varying rates. The rate at which energy is extracted from the batter is known as

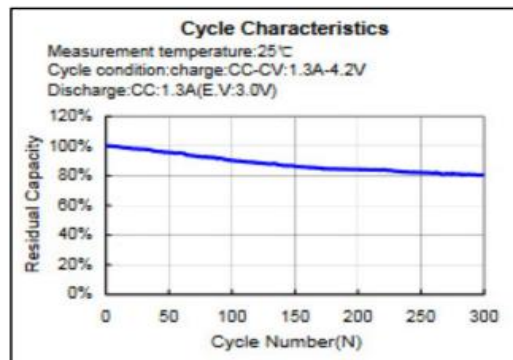
the discharge rate. Different batteries may have different discharge characteristics depending on the rate at which they are being used. Some batteries may maintain a relatively stable voltage across a range of discharge rates, while others may experience voltage drops at higher discharge rates.

Charge Characteristics refers to how a battery or energy storage system behaves during the charging process. It includes aspects such as charging speed, efficiency, and

the voltage and current profiles during charging. Different batteries may have different charge characteristics based on their chemistry and design.



Graph 3: Discharge Temperature Characteristics



Graph 4: Cycle Characteristics

Above shown are the Discharge Temperature and Cycle Characteristics curves. Discharge Temperature Characteristics refers to how a battery or energy storage system performs during discharge at different temperatures.

within the battery, influencing its ability to deliver power. Cycle Characteristics refers to how a battery behaves over repeated charge and discharge cycles.

The temperature at which a battery is operated can have a significant impact on its discharge performance. Some batteries may exhibit changes in capacity, voltage, and overall efficiency at different temperatures. Extreme temperatures, both high and low, can affect the rate of chemical reactions

Batteries, especially rechargeable ones, have a limited number of charge-discharge cycles before their performance begins to degrade. The cycle life of a battery is an important parameter, and it depends on elements include the battery's particular chemistry, charging circumstances, and depth of discharge.



Figure 5: Implemented Web Dashboard Results



Figure 6: Analysis Results

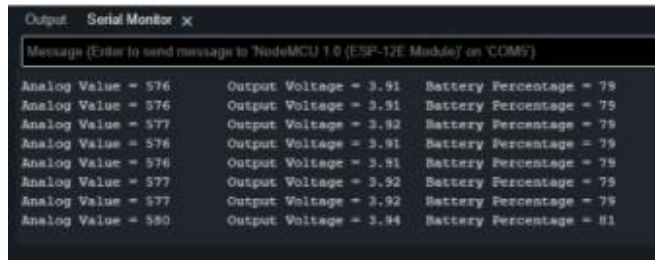


Figure 7: Dashboard Result



Figure 8: Mobile Dashboard

5. Conclusion

In summary, our initiative to develop a smart electric vehicle (EV) charger and an advanced battery management system has yielded a transformative solution tailored to the evolving electric mobility landscape. This comprehensive project seamlessly integrates real-time monitoring, safety features, and user-centric design, setting a new standard for EV charging infrastructure. The intuitive interface of the IoT Cloud, coupled with remote accessibility, not only empowers users but also ensures a transparent and dependable charging experience. Beyond individual user

benefits, the significance of our smart EV charger extends to broader sustainability objectives. By embracing energy-efficient practices and exploring renewable energy sources, our system aligns with global initiatives to curtail carbon emissions. The incorporation of IoT devices and real-time data analysis not only enhances the user experience but also contributes to grid management, energy optimization, and the integration of renewable resources. This synergy bridges the gap between the energy and transportation sectors, highlighting the potential of technology to reshape these realms and move us toward a more sustainable future [1-26].

References

1. Lebeau, C., & González, M. A. (2017). Smart charging of electric vehicles: A review from the grid integration perspective. In *2017 IEEE PES Innovative Smart Grid Technologies Conference (ISGT)* (pp. 1–6). IEEE.
2. Bessa, R. J., & Matos, M. A. (2016). Electric vehicle integration in smart grids and the relevance of considering grid constraints. *IEEE Transactions on Power Systems*, *31*(5), 3718–3726.
3. Wu, D., Xu, Z., Wang, Y., He, H., & Chen, S. (2020). A review of energy management strategies for hybrid electric vehicles with the introduction of plug-in capability and automation functions. *IEEE Access*, *8*, 125478–125502.
4. Yousef, A. A., & Mekhilef, S. (2015). Smart charging strategy for plug-in hybrid electric vehicles in deregulated electricity markets. *IEEE Transactions on Industrial Electronics*, *62*(11), 7178–7187.
5. Liserre, M., Sauter, T., & Hung, J. Y. (2010). Future energy systems: Integrating renewable energy sources into the smart power grid through industrial electronics. *IEEE industrial electronics magazine*, *4*(1), 18–37.
6. Kintner-Meyer, M. C. W., Schneider, K., Pratt, R. G., Maksimovic, D., & Zane, R. (2007). Distributed generation impact on electric grid reliability. *IEEE Transactions on Power Systems*, *22*(3), 944–954.
7. Gajowniczek, K., Bartosiewicz, Z., & Sowa, R. (2018). Analysis of control and management systems in smart EV charging infrastructure. *IEEE Access*, *6*, 6438–6452.
8. Matos, M. A., & Silva, M. V. (2018). Charging electric vehicles in smart cities: Review of the latest trends in the e-mobility scenario. *IEEE Transactions on Industrial Informatics*, *14*(11), 5038–5045.
9. Hall, J., & Fares, R. L. (2018). A review of smart charging for electric vehicles: Infrastructure and vehicle-to-grid systems. *Renewable and Sustainable Energy Reviews*, *82*, 961–975.
10. Yao, Q., et al. (2019). Smart charging for electric vehicles with renewable energy: A review. *Applied Energy*, *240*, 369–383.
11. Guler, O., & Armstrong, M. J. (2014). A review of electric vehicle charging technologies. *Renewable and Sustainable Energy Reviews*, *32*, 156–177.
12. Han, Q., Gu, W., & Lee, W.-J. (2016). A review of the state-of-the-art technologies for electric vehicle fast charging. *IEEE Transactions on Power Electronics*, *32*(12), 9472–9489.
13. Siano, P., et al. (2015). Electric vehicle charging and discharging scheduling for smart grid optimization. *IEEE Transactions on Industrial Informatics*, *11*(1), 85–94.
14. Balijepalli, V. S. K. (2014). Electric vehicle to grid (V2G)–A review. *International Journal of Electrical Power & Energy Systems*, *54*, 261–270.
15. Mwasilu, F., Justo, J. J., Kim, E. K., Do, T. D., & Jung, J. W. (2014). Electric vehicles and smart grid interaction: A review on vehicle to grid and renewable energy sources integration. *Renewable and sustainable energy reviews*, *34*, 501–516.
16. Yu, W., Yu, Z., & Chai, J. (2018). A review of bi-directional electric vehicle chargers. *Renewable and Sustainable Energy Reviews*, *81*, 2536–2547.
17. Aung, N., Zhang, W., Sultan, K., Dhelim, S., & Ai, Y. (2021). Dynamic traffic congestion pricing and electric vehicle charging management system for the internet of vehicles in smart cities. *Digital Communications and Networks*, *7*(4), 492–504.
18. Ahmad, A., Khalid, M., Ullah, Z., Ahmad, N., Aljaidi, M., Malik, F. A., & Manzoor, U. (2022). Electric vehicle charging modes, technologies and applications of smart charging. *Energies*, *15*(24), 9471.
19. Secchi, M., Barchi, G., Macii, D., & Petri, D. (2023). Smart electric vehicles charging with centralised vehicle-to-grid capability for net-load variance minimisation under increasing EV and PV penetration levels. *Sustainable Energy, Grids and Networks*, *35*, 101120.
20. Sultan, V., Aryal, A., Chang, H., & Kral, J. (2022). Integration of EVs into the smart grid: A systematic literature review. *Energy Informatics*, *5*(1), 65.
21. Khobragade, S. S., Dhole, P. M., & Bedarkar, R. V. (2023). Smart EV charging station using hybrid power generation system. *International Research Journal of Modernization in Engineering Technology and Science*.
22. Wang, Q., Liu, X., Du, J., & Kong, F. (2016). Smart charging for electric vehicles: A survey from the algorithmic perspective. *IEEE Communications Surveys & Tutorials*, *18*(2), 1500–1517.
23. Henriksen, I. M., Thronsen, W., Ryghaug, M., & Skjølsvold, T. M. (2021). Electric vehicle charging and end-user motivation for flexibility: a case study from Norway. *Energy, Sustainability and Society*, *11*(1), 44.
24. Sanguesa, J. A., Torres-Sanz, V., Garrido, P., Martinez, F. J., & Marquez-Barja, J. M. (2021). A review on electric vehicles: Technologies and challenges. *Smart Cities*, *4*(1), 372–404.
25. Jadhav, A., Ghorpade, G., Kanthikar, N., & Anwat, N. (2020, April). Smart Charging of Electric Vehicle. In *2nd International Conference on Communication & Information Processing (ICCIPI)*.
26. Hildermeier, J., Kolokathis, C., Rosenow, J., Hogan, M., Wiese, C., & Jahn, A. (2019). Smart EV charging: A global review of promising practices. *World Electric Vehicle Journal*, *10*(4), 80.