Proceedings of the 7th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC 2023)
IEEE Xplore Part Number: CFP23OSV-ART; ISBN: 979-8-3503-4148-5

2023 7th International Conference on I-SMAC (IoT in Social, Mobile, Analytics and Cloud) (I-SMAC) | 979-8-3503-4148-5/23/$31.00 ©2023 IEEE | DOI: 10.1109/I-SMAC58438.2023.10290505

A Payment System for Electric Vehicles Charging and Peer-to-Peer Energy Trading

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***Abstract*— The popularity of vehicles based on electricity is increasing as they are considered a sustainable mode of transportation. The charging infrastructure for electric vehicles are suffering various issues. There are limited availability of public charging stations, the high costs associated with installing private charging stations, and the high variability of electricity prices. The peer-to-peer (P2P) energy stability will be seen as a potential solution to facilitate electric vehicle (EV) charging in a manner that is both cost-effective and environmentally sustainable. The paper presents a novel system energy trading and charging payment for electric vehicles (EVs). The desired system enables EV owners to exchange surplus electricity with other EV owners in their location. The system being proposed utilizes blockchain technology to guarantee secure and transparent transactions. Additionally, it incorporates a smart contract to automate the trading and charging process. The system utilizes a dynamic pricing mechanism that adjusts in real-time to reflect the current electricity prices. This feature is designed to encourage electric vehicle owners to engage in energy stabilization during maximum usage hours. The Optimistic results shows that the described system has the efficacy on minimising the cost of vehicle charging and to decrease peak demand on the grid. Additionally, the system encourages the utilization of renewable energy sources.**

Keywords- Vehicle, vehicle- Motor, vehicle Speed, cost Optimization, Error, Time response.

I. INTRODUCTION

In this development in EV vehicle segment, there are several reasons why some operators and public stations offer free charging facilities for electric vehicles (EVs). One of the primary reasons is to encourage the adoption of EVs as a more sustainable mode of transportation. By providing free charging facilities, it becomes more affordable for owners on charging the vehicles. they are more likely to choose an EV over a fossil fuel vehicle [1].

Furthermore, offering free charging facilities can also be a marketing strategy for public stations or operators. It can help to attract more customers and increase traffic to their location. Additionally, some public stations or operators may receive subsidies or incentives from the government or other organizations to promote the use of clean energy and reduce carbon emissions. But, the important on note by giving free charging facilities may not always be sustainable in the long term. It requires significant investment in infrastructure and maintenance costs. Therefore, some operators may choose to offer a mix of free and paid charging facilities or implement time-based or usage-based charging fees to ensure the sustainability of the charging system [2].

Modern information technology can play a critical role in addressing the challenges associated with payment systems for electric vehicle (EV) charging. One solution is to implement a universal payment system that is widely accepted and secure. This system should makes EV owners to pay for charging services using a range of transaction ways, such as Bank-cards, Android based payments and wallets. By leveraging modern information technology, power companies can develop and deploy secure and efficient payment systems that meet the needs of consumers. This includes implementing measures to prevent fraud, such as two-factor authentication, encryption, and monitoring systems. In addition, power companies can utilize blockchain technology to create secure and transparent payment systems that are resistant to fraud and tampering [3-5].

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Furthermore, new method will also help charging providers better understand consumer preferences and behaviors, enabling them to tailor their charging services to meet these needs. This includes offering personalized recommendations for charging times and locations, as well as providing real-time updates on charging status and prices. Hence, modern information technology can provide power companies with the tools and resources they need to adapt to the changing landscape of EV charging and meet the evolving needs of consumers. By investing in these technologies, power companies can create innovative and efficient payment systems that enable a more seamless and enjoyable experience for all EV owners [6].

The system under consideration employs Hyperledger Fabric, an open-source platform developed by IBM that is specifically designed for private blockchain applications and is known for its user-friendly interface. The capacity to facilitate smart contracts is a prominent attribute of Hyperledger Fabric. Smart contracts are automated agreements wherein the conditions of the contract between the purchaser and vendor are encoded directly into programmatic code, allowing for self-execution. Upon initiation, a smart contract executes its encoded rules autonomously, obviating the necessity for intermediaries and mitigating the likelihood of errors or fraudulent activities. The aforementioned functionality enables users to specify a predetermined set of regulations that are to be executed automatically, thereby enhancing the efficiency and transparency of the system.

A smart contract refers to an autonomous computer program that is capable of self-execution and operates on a blockchain platform. A programmable digital agreement is a contractual arrangement between two or more parties, whereby the terms and conditions of the agreement are encoded into a software program. Upon initiation, the smart contract autonomously enforces the pre-programmed regulations, obviating the necessity for intermediaries, thereby rendering the process transparent and devoid of trust-related concerns. The contractual provisions are stored on the blockchain, a technology that is resistant to modification, and once the contract is implemented, it is impervious to alteration or interference. The implementation of smart contracts obviates the requirement for intermediaries, thereby enhancing the efficiency and cost-effectiveness of the process. Furthermore, it offers an elevated level of security due to the transparent nature of the contractual terms, which are immutable. Smart contracts possess a diverse array of potential uses, including but not limited to supply chain management, financial services, and real estate.

II. LITERATURE SURVEY

On topology [7] proposes a distributed blockchain-based (P2P) energy stability framework for electric vehicles (EVs) in intelligent-grids. The framework uses blockchain technology to prise safer and opened type energy stability among EV owners and other grid participants. The proposed framework consists of three main components: a blockchain-based distribution ledger, a smart contract system, and a decentralized P2P energy stability platform. In decentralized P2P energy stability platform facilitates matching of buyers and sellers based on their preferences and energy needs.

A theoretic framework for (P2P) [8] and charging on vehicles based electrical (EVs) framework aim to maximize the benefits of EV owners while ensuring the stability of the power grid. The authors consider a scenario where EV owners can trade electricity with each other and also charge their vehicles from the grid.

A comprehensive review [9] explains the various categories of P2P energy optimization models, including direct trading, indirect trading, and auction-based trading. It also discusses the role of different technologies in enabling P2P energy trading for EVs, such as blockchain, smart contracts, and IoT devices. They highlight the advantages and limitations of each technology and identify the challenges and opportunities for their integration.

In [10-11] proposes a multi-stage distributed energy optimization schematic for peer-to-peer (P2P) charging and trading of electric vehicles (EVs) in micro-grids. The scheme aims to minimize the cost of energy consumption and reduce the peak demand of the micro-grid while ensuring the satisfaction of EV owners' charging requirements. The Described scheme consists of two stages. In the first stage, EV owners make bids for the usage of Power they require and the cost to be calculated. The micro-grid aggregator collects these bids and determines the optimal energy allocation and pricing using a mixed integrated programming in a linear type (MILP) model.

From system evaluates the scheme [12] using simulations and compares it with other charging and trading schemes. It show that described scheme can manages in reduce peak demand and energy cost of the micro-grid while ensuring the satisfaction of EV owners' charging requirements.

The studies [13-15] explore the Energy Management Scheme for P2P Charging and Trading of Electric Vehicles" proposes an energy management scheme for (P2P) charging and stability of electric vehicles. The scheme aims to manage the energy consumption and trading between vehicle in electrical based and electricity- grid while considering the constraints of the EV batteries. The scheme consists of two main components: an energy consumption optimization module and an energy trading module.

In [16-19] the module uses a smart contract-based trading platform to enable secure and transparent energy transactions among the participants. The platform allows EV owners to set their own prices and preferences for energy trading, and it automatically matches buyers and sellers based on their preferences and the current energy prices.

The proposed energy management scheme [20] provides a novel approach to P2P charging and trading of EVs, which can help to minimise the cost of electrical usage for vehicle and promote integration on renewable sources into the power grid. The authors propose a framework consisting of various types of agents: vehicle agents, cost-aggregator

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agents, and marketing agents. The EV agents represent the EVs and the needs, while the aggregator agents represent the charging infrastructure and coordinate the charging process

III. PROPOSED SYSTEM

The proposed system has the following modules in its architecture.

1. Electric vehicle: This is the main component of the system, which requires energy for its operation. The EV can receive energy from the grid, from renewable energy sources, or from other EVs through P2P energy trading.
2. Battery management system (BMS): The BMS is responsible for managing the charge and discharge of the EV battery, ensuring its safety and efficiency. The BMS also communicates with power stability system to optimize the charging, trading operations.
3. Energy managing system (EMS): The EMS is central component of the system, which controls the mechanism on energy between the vehicle based on electricity and grids. The EMS monitors the energy demand and supply, forecasts the energy production and consumption, and optimizes the charging and trading operations using various algorithms and techniques.
4. Communication network: The communication network enables the exchange of information and commands between the EV, the BMS, and the EMS.
5. Renewable energy sources: Renewable energy sources such as solar panels, wind turbines, or hydropower plants can provide energy to the EV through the grid or P2P energy trading. The EMS can prioritize the use of renewable energy sources to reduce the carbon footprint of the system.
6. Grid: It is the major point of energy for the EV, which can provide energy through a charging station or a power outlet. The EMS can optimize the use of the grid energy by considering the price, availability, and quality of the energy.

Henceforth, the block diagram illustrates how different components of the system can work together to provide energy stability for EVs, which can reduce the cost of charging, regulation of the u renewable sources usage, and enhance grid stability. The structure of the system is depicted in diagram 1. The architecture of a smart charging methodology typically involves several components and systems working together to optimize the charging process for electric vehicles (EVs). Here is a high-level architecture diagram that illustrates some of the key components.

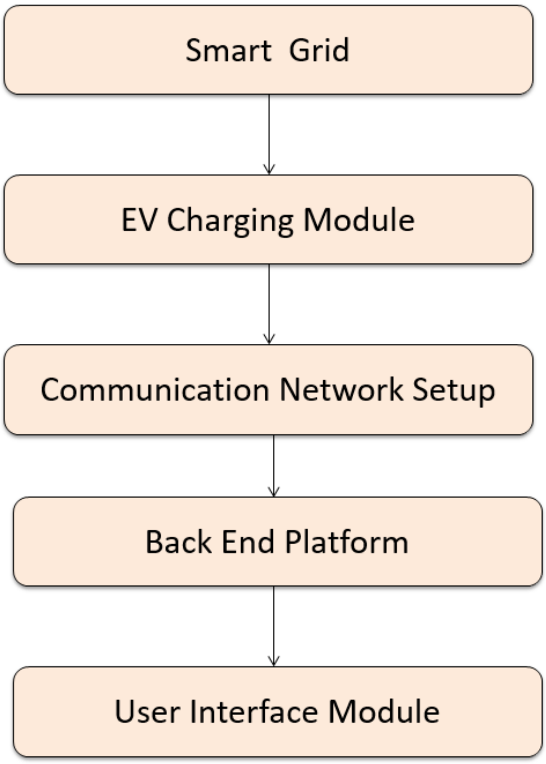

Figure 1. Outlined architecture of the proposed system

- Smart Grid: This is the energy infrastructure that provides electricity to the EV charger. The smart grid can be optimized to manage the flow of electricity and ensure that charging happens efficiently and reliably.
- EV Charger: This is the physical device that charges the EV. It may have a variety of features such as adjustable power output, data logging, and remote control capabilities.
- Communication Networks: This allows the various components of the smart charging system to exchange data and commands. It can be wired or wireless and can use a variety of protocols such as Wi-Fi, Bluetooth, or cellular.
- Backend Platform: This is the central system that manages the smart charging process. It receives data from the EV charger and the smart grid and uses algorithms to optimize the charging process. It may also provide user management, billing, and reporting features.
- User Interface: This is the interface that allows the user to interact with the smart charging system.

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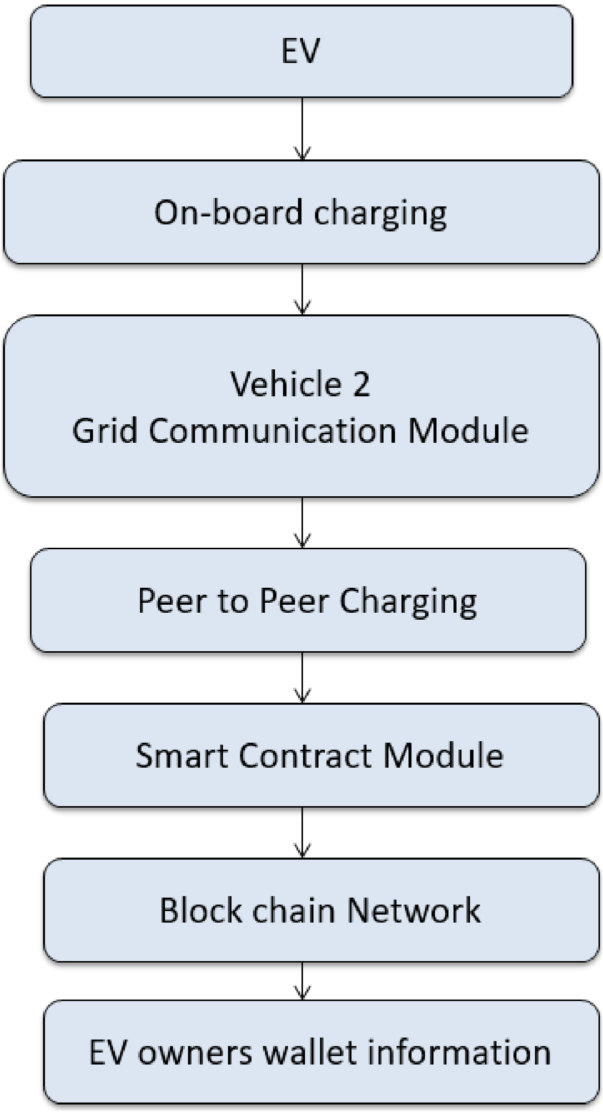

Figure 2. Flow mechanism of the proposed system

It may be a web-based dashboard, a mobile app, or a physical display on the EV charger. Here a flow mechanism diagram for an electric vehicle (EV) using a peer-to-peer (P2P) charging mechanism is depicted in Figure 2. The V2G communication module allows the EV to communicate with the P2P charging platform and share information such as battery status, charging requirements, and available energy. The P2P charging platform facilitates the matching of buyers and sellers based on their energy needs and preferences. The platform uses a smart contract module to define the terms and conditions of energy trading, such as the price, quantity, and duration of the trade.

On blockchain network gives a safer and transparent environment on recording and verifying energy based computation. The EV owner's wallet is used to store and manage the tokens or crypto-currency used for payment in P2P energy trading. Smart charging methodology aims to optimize the charging of electric vehicles (EVs) by taking into account various factors such as grid conditions, user preferences, and vehicle characteristics. Here is a step-by-step algorithm for smart charging methodology:

Step 1 - Collect data: Gather data on EVs, charging stations, and the grid. This includes information such as the stage of charge (SoC) EV battery, charging station capacity, grid demand, electricity prices.

Step 2 - Determine charging requirements: Determine the charging requirements for each EV, based on factors such as the distance the vehicle needs to travel, the SoC battery, and the time available for charging.

Step 3 - Evaluate grid conditions: Evaluate the grid conditions, such as the current and forecasted demand, to determine the optimal time for charging. This ensures that the charging does not overload the grid and cause blackouts.

Step 4 - Determine user preferences: Determine user preferences such as the preferred time of day for charging, the maximum charging time, and the minimum battery level required before starting the trip.

Step 5 - Optimize charging schedule: Use algorithms to optimize the charging schedule for each EV based on the collected data, charging requirements, grid conditions, and user preferences. This ensures that the charging is efficient and cost-effective.

Step 5 - Implement charging schedule: Implement the charging schedule by communicating with the charging station and the EV to initiate and stop charging at the appropriate times.

Step 6 - Monitor and adjust: Continuously monitor the charging process and adjust the charging schedule as necessary based on changes in grid conditions or user preferences.

By following this algorithm, a smart charging methodology can optimize the charging of EVs to be more efficient, cost-effective, and beneficial for the grid.

3.1 Features of Proposed system over conventional charging methods.

Smart charging methodology refers to the intelligent management and optimization of charging processes for electric vehicles (EVs). By leveraging advanced technologies and data analysis, smart charging offers several distinct advantages over traditional charging methods.

Initially, one of the key benefits of smart charging is its ability to optimize energy usage and reduce peak demand on the power grid. By integrating EV charging with smart grid systems, charging can be scheduled on peak hours electrical source usage is low. This not only helps to balance load on the grid but also maximizes the utilization of alternative energy sources, solar or wind source, which typically more abundant during off-peak times. As a result, smart charging contributes to a more efficient and sustainable energy system. Also, smart charging enables demand response capabilities, allowing EVs to act as flexible energy resources. By utilizing bi-directional charging technology, EVs not only draw energy from the grid but also feeds excess energy back into it. During periods of high demand or grid instability, EVs can reduce

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their charging rate or temporarily discharge energy back to the grid, thus providing valuable grid services and helping to maintain grid stability. This vehicle-to-grid (V2G) capability enhances the overall resilience and reliability of the electricity network.

Furthermore, smart charging offers benefits to EV owners through cost savings and convenience. Smart charging platforms can incorporate real-time electricity pricing data, enabling EV owners to take advantage of cheaper electricity rates during off-peak hours. By automatically scheduling charging sessions during these times, EV owners can reduce their charging costs significantly. Moreover, smart charging systems can be integrated with mobile applications or smart home systems, allowing users to remotely monitor and control their charging process. This level of convenience and control enhances the overall user experience and ensures that the vehicle is charged when needed without unnecessary delays.

Lastly, smart charging methodology fosters coordinating charging patterns with renewable energy generation, smart charging can increase the share of clean energy used for EV charging. This synergy between electric mobility and renewable energy promotes a more sustainable and environmentally friendly transportation sector, reducing greenhouse gas emissions and dependence on fossil fuels. Hence, smart charging methodology brings numerous advantages to the charging infrastructure for electric vehicles. From grid optimization and demand response capabilities to cost savings and enhanced user experience, smart charging plays a pivotal role in facilitating the transition to a greener and more efficient transportation system. Table 1 shows the description of the parameter's features.

Table 1. Feature description

Parameters	Features
Efficient energy management	Smart charging optimizes the distribution and allocation of energy resources, leading to efficient energy usage. It helps balance the grid load and reduces strain on the power infrastructure.
Cost savings	By taking advantage of off-peak electricity rates, smart charging can help reduce the cost of charging electric vehicles (EVs). Charging during low-demand periods allows for lower electricity rates, resulting in cost savings for EV owners.
Grid integration and stability	Smart charging enables better integration of EV charging infrastructure with the existing power grid. It helps manage the increased electricity demand from EVs, preventing overloads and ensuring grid stability.
Renewable energy integration	Smart charging can be programmed to prioritize charging when renewable energy sources, such as solar or wind, are generating excess power. This promotes the utilization of clean energy and reduces reliance on fossil fuels.
Demand response capabilities	Smart charging systems can respond to signals from the grid operator or utility company, allowing for demand response programs. This means that EV charging can be adjusted or temporarily paused during peak demand periods, supporting grid reliability.
Battery management and longevity	Smart charging algorithms can optimize the charging process to extend the lifespan of EV batteries. By controlling charging rates and avoiding extreme charging or discharging conditions, the overall battery health is preserved
Integration with smart home systems	Smart charging can be integrated with home automation systems, enabling EV owners to monitor and control charging remotely. This integration offers convenience, allowing users to schedule charging sessions and track energy consumption.
Enhanced user experience	Smart charging solutions often come with user-friendly interfaces and mobile apps that provide real-time data, charging status, and notifications. This enhances the overall user experience by providing greater visibility and control over charging operations.

IV. RESULT AND DISCUSSION

When developing a payment system for electric vehicle (EV) charging and peer-to-peer energy optimization, it is essential to establish a robust testing framework to ensure the system's functionality, safer, reliability. Here is a list of testing parameters to consider:

1. ***Functional Testing:***

   - Validate the basic functionality of the payment system, such as initiating and terminating charging sessions, processing payments, and enabling peer-to-peer energy trading.

   - Test different payment methods, such as credit cards, mobile payments, or prepaid accounts, to ensure smooth and accurate transactions.

   - Verify the accuracy of transaction records and billing statements.

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2. ***Security Testing:***
- Conduct vulnerability assessments and penetration testing to identify and address potential security risks, such as unauthorized access, data breaches, or malicious attacks.
- Test the system's encryption mechanisms and data privacy measures to ensure the protection of sensitive user information.
- Validate the authentication and authorization processes to prevent unauthorized usage or fraudulent activities.

3. ***Scalability and Performance Testing:***
- Simulate different load scenarios to assess the system's scalability and performance under varying charging demands and transaction volumes.
- Test the system's response time, throughput, and reliability during peak usage periods.
- Evaluate the system's ability to handle simultaneous charging and energy trading transactions without degradation in performance.

4. ***Compatibility Testing:***
- Ensure compatibility with various EV models, charging infrastructure, and communication protocols, such as Open Charge Point Protocol (OCPP) or ISO 15118, to support interoperability.
- Test compatibility with different payment service providers, banking systems, and financial institutions to enable seamless payment processing.
- Verify compatibility with mobile devices and third-party applications for user convenience.

5. ***Usability Testing:***
- Evaluation of the user interface (UI) and user experience (UX) of the payment system to ensure ease of use and intuitive navigation.
- To Test the system's responsiveness across different devices and screen sizes.
- User feedback collection and conducting usability studies to identify areas for improvement.

6. ***Integration Testing:***
- In order to Test the integration of the payment system with charging station hardware, backend systems, billing systems, and energy management platforms.
- Validation of data exchange and communication between different components of the system to ensure seamless operation.

7. ***Regulatory Compliance Testing:***
- Ensuring compliance with relevant industry standards, regulations, and certifications, such as Payment Card Industry Data Security Standard (PCI DSS), General Data Protection Regulation (GDPR), or ISO 27001.
- Verify adherence to local regulations regarding payment processing, energy trading, and privacy requirements.

8. ***Disaster Recovery and Business Continuity Testing:***
- For Simulate system failures, outages, or cyber-attacks to assess the system's resilience and ability to recover.
- For Test backup and disaster recovery mechanisms to ensure data integrity and minimize service disruptions.

9. ***End-to-End Testing:***
To perform end-to-end testing of the entire payment system workflow, including charging initiation, payment processing, transaction settlement, and energy trading, to validate the system's end-to-end functionality.

By conducting thorough testing based on these parameters, we can ensure the reliability, security, and effectiveness of your payment system.

4.1 Usability testing of the proposed system.

Usability testing in electric vehicles (EVs) involves evaluating the ease of use, user satisfaction, and overall user experience of the vehicle's interface, controls, and features. It aims to identify any usability issues or challenges that users may encounter while interacting with the EV and provides valuable insights for improving its design and functionality. The objectives of usability testing, such as evaluating specific features, assessing user interactions, or identifying usability bottlenecks. Determine the target user group and their typical usage scenarios.

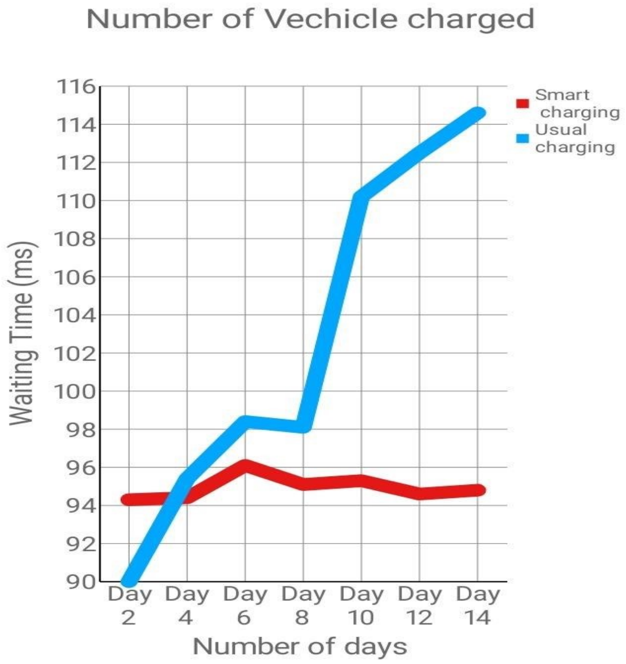

Figure 3. Comparison of effective Usage of charging ports

It also benefits EV owners through cost savings and convenience. Smart charging platforms can incorporate real-time electricity pricing data, enabling EV owners to take advantage of cheaper electricity rates during off-peak hours. By automatically scheduling charging sessions during these

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times, EV owners can reduce their charging costs significantly. From Figure 3, it is depicted that the allocation of charging ports for needy EV vehicles is maintained in a stable manner in comparison to traditional charging methodology. The proposed system efficacy is maintained even for a number of days to get rolled out.

4.2 Security testing of the proposed system.

Security testing in EV vehicle charging is essential to ensure the safety and integrity of the charging infrastructure. Here are some key aspects of security testing in EV vehicle charging:

1. *Authentication and Authorization:* Test the authentication mechanisms used to verify the identity of users and ensure that only authorized individuals have access to the charging infrastructure. This includes testing username/password combinations, token-based authentication, and any other access control mechanisms in place.
2. *Data Encryption*: Evaluate the encryption methods employed to protect sensitive data transmitted between the EV, charging station, and backend systems. Test the encryption algorithms, key management practices, and the overall integrity of data in transit.
3. *Communication Security:* Verify the security of communication protocols used for EV charging, such as OCPP (Open Charge Point Protocol) and ISO 15118. Test for vulnerabilities, including man-in-the-middle attacks, message tampering, and session hijacking.
4. *Charging Infrastructure Vulnerability Assessment:* Conduct penetration testing and vulnerability scanning on the charging infrastructure.

In spite of many parameters in security modules, an efficient system has to check all the parameters will an EV vehicle needs to charge its battery. Also, the efficiency should maintain even when the number of vehicles gets increased. The security inspection of various counts of vehicles is shown in figure 4.

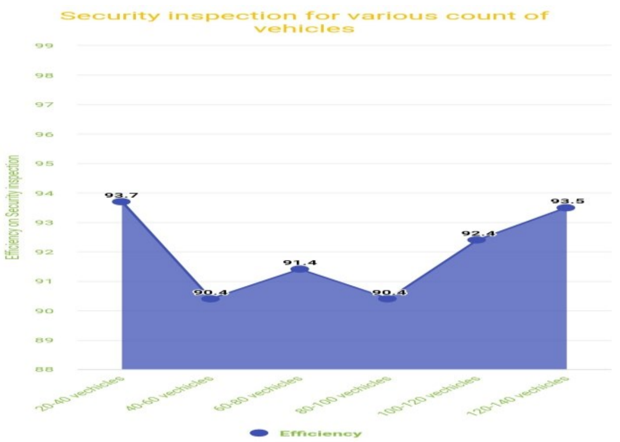

Figure 4. Comparison of security metrics on various vehicles count.

V. CONCLUSION

The implementation of a payment system for charging of electric vehicle and energy optimization is a crucial measure toward establishing a sustainable and efficient energy ecosystem. The system provides a convenient way for electric vehicle owners to charge their vehicles while also reducing their carbon emissions. Additionally, energy consumers have the option to purchase renewable energy from local producers. The payment system has the potential for improvement in various areas. One potential solution to improve the payment process is to integrate the payment system with established payment platforms. This could enhance the user experience by streamlining the payment process. One potential improvement for the system could be to broaden the range of payment options available to users. This could involve incorporating additional methods, such as crypto currencies or mobile payments, with the aim of enhancing user convenience. The implementation of two-factor authentication or biometric verification can enhance the security of the system and safeguard its safety and integrity. The potential for expansion of the payment system exists as the usage on vehicles based on electricity and alternative sources increases. Hence, proposed solution entails expanding the existing infrastructure and creating innovative technologies to accommodate the surge in demand. The implementation of a payment system for electric vehicle charging and energy optimization is a important development in the creation of a sustainable energy ecosystem. The system has the potential to revolutionize energy consumption and trading practices in the future, as it undergoes further development and improvement.

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