IMPROVED DESIGN OF SOLAR POWERED EV CHARGING INFRASTRUCTURE WITH SMART PAYMENT SYSTEM USING ADVANCED GRID CONNECTION SYSTEM

A PROJECT REPORT

Submitted by

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BONAFIDE CERTIFICATE

Certified that this project report **"IMPROVED DESIGN OF SOLAR POWERED EV CHARGING INFRASTRUCTURE WITH SMART PAYMENT SYSTEM USING ADVANCED GRID CONNECTION SYSTEM"** is the bonafide work of **"VASHANTH SP (927621BEC235), YUVAN SANKAR RAJA S (927621BEC249), YUVARAJ S (927621BEC251), SURYA S (927621BEC313)" who** carried out the project work under my supervision in the academic year 2024-2025.

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INTERNAL EXAMINER **EXTERNAL EXAMINER**

INSTITUTION VISION AND MISSION

Vision

To emerge as a leader among the top institutions in the field of technical education.

Mission

M1: Produce smart technocrats with empirical knowledge who can surmount the global challenges.

M2: Create a diverse, fully -engaged, learner -centric campus environment to provide quality education to the students.

M3: Maintain mutually beneficial partnerships with our alumni, industry and professional associations

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Mission

M1: Attain the academic excellence through innovative teaching learning process, research areas & laboratories and Consultancy projects.

M2: Inculcate the students in problem solving and lifelong learning ability.

M3: Provide entrepreneurial skills and leadership qualities.

M4: Render the technical knowledge and skills of faculty members.

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PEO1: **Core Competence:** Graduates will have a successful career in academia or industry associated with Electronics and Communication Engineering

PEO2: **Professionalism:** Graduates will provide feasible solutions for the challenging problems through comprehensive research and innovation in the allied areas of Electronics and Communication Engineering.

PEO3: **Lifelong Learning:** Graduates will contribute to the social needs through lifelong learning, practicing professional ethics and leadership quality

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PO1: Engineering knowledge: Apply the knowledge of mathematics, science, engineering fundamentals, and an engineering specialization to the solution of complex engineering problems.

PO2: Problem analysis: Identify, formulate, review research literature, and analyze complex engineering problems reaching substantiated conclusions using first principles of mathematics, natural sciences, and engineering sciences.

PO3: Design/development of solutions: Design solutions for complex engineering problems and design system components or processes that meet the specified needs with appropriate consideration for the public health and safety, and the cultural, societal, and environmental considerations.

PO4: Conduct investigations of complex problems: Use research-based knowledge and research methods including design of experiments, analysis and interpretation of data, and synthesis of the information to provide valid conclusions.

PO5: Modern tool usage: Create, select, and apply appropriate techniques, resources, and modern engineering and IT tools including prediction and modeling to complex engineering activities with an understanding of the limitations.

PO6: The engineer and society: Apply reasoning informed by the contextual knowledge to assess societal, health, safety, legal and cultural issues and the consequent responsibilities relevant to the professional engineering practice.

PO7: Environment and sustainability: Understand the impact of the professional engineering solutions in societal and environmental contexts, and demonstrate the knowledge of, and need for sustainable development.

PO8: Ethics: Apply ethical principles and commit to professional ethics and responsibilities and norms of the engineering practice.

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PO10: Communication: Communicate effectively on complex engineering activities with the engineering community and with society at large, such as, being able to comprehend and write effective reports and design documentation, make effective presentations, and give and receive clear instructions.

PO11: Project management and finance: Demonstrate knowledge and understanding of the engineering and management principles and apply these to one's own work, as a member and leader in a team, to manage projects and in multidisciplinary environments.

PO12: Life-long learning: Recognize the need for, and have the preparation and ability to engage in independent and life-long learning in the broadest context of technological change.

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PSO1: Applying knowledge in various areas, like Electronics, Communications, Signal processing, VLSI, Embedded systems etc., in the design and implementation of Engineering application.

PSO2: Able to solve complex problems in Electronics and Communication Engineering with analytical and managerial skills either independently or in team using latest hardware and software tools to fulfil the industrial expectations.

Abstract	Matching with POs, PSOs
keywords	PO1, PO2, PO6, PO7, PO9, PO12, PSO1, PSO2

S.No.	Project Domain	Mapping with POs/PSOs
1.	RFID	PO1, PO2, PO3, PO6, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2
2.	Embedded Systems	PO1, PO2, PO3, PO4, PO6, PO7, PO9, PO12, PSO1, PSO2
3.	Electric Vehicle	PO1, PO2, PO3, PO5, PO6, PO7, PO8, PO9, PO11, PO12, PSO1, PSO2
4.	IoT	PO1, PO2, PO3, PO4, PO5, PO6, PO8, PO9, PO10, PO11, PO12, PSO1, PSO2

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ABSTRACT

This paper presents the design and implementation of a solar-powered electric vehicle (EV) charging system that integrates renewable energy, grid connectivity, and a smart payment mechanism to provide an efficient and sustainable solution for EV charging infrastructure. The system utilizes solar panels to generate electricity, which is then regulated by a DC/DC converter and stored in a battery for use during periods of low sunlight. In case of insufficient solar energy, grid power serves as a backup to ensure uninterrupted operation. An Arduino-based controller manages energy distribution, optimizes power usage, and monitors real-time system performance. The system incorporates an RFID-based smart payment mechanism, enabling secure and automated transactions, providing users with a seamless and user-friendly charging experience. An LCD screen displays real-time charging status and transaction details, enhancing user interaction and transparency. Successful implementation and testing of the system demonstrated its ability to efficiently utilize solar power, optimize energy management, and provide reliable, cost- effective charging services. This system serves as a viable solution for the growing demand for EV charging infrastructure, promoting sustainability and reducing operational costs.

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LIST OF ABBREVIATIONS

ACRONYM	ABBREVIATION
EV	Electric Vehicle
V2G	Vehicle-to-grid
RFID	Radio Frequency Identification
ML	Machine Learning
AI	Artificial Intelligence
ESS	Energy Storage Systems

CHAPTER 1

INTRODUCTION

The growing use of electric vehicles (EVs) is an important step toward lowering global greenhouse gas emissions and reliance on fossil fuels. However, the rapid increase in EV usage necessitates a strong and long-lasting charging infrastructure. Solar energy, as a renewable resource, provides a potential way to meet demand while also addressing environmental concerns. Despite its benefits, integrating solar electricity with EV charging infrastructure presents several problems, including inconsistent energy supply, grid dependency, and user accessibility.

This article seeks to address these issues by offering a holistic solution that incorporates solar energy, smart payment methods and improved grid connection technologies. The combination of machine learning algorithms and efficient communication protocols results in optimal energy management and user convenience. The suggested system promotes sustainable mobility while also aligning with global initiatives toward energy independence and environmental sustainability [1].

The creation of a solar-powered EV charging infrastructure with a smart payment mechanism fills major holes in existing charging systems. This system improves the environment, the economy, and society by utilizing innovative technologies and renewable energy. It encourages mass adoption of electric vehicles by assuring their accessibility, affordability, and reliability. The Grid-connected Solar charging station is shown in Fig.1.

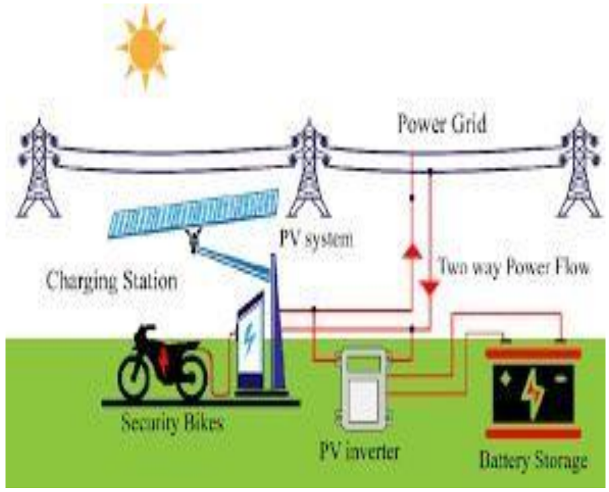

Fig.1.1: Grid-Connected Solar Charging Station

The rapid adoption of electric vehicles (EVs) is reshaping the global transportation landscape, driven by the urgent need to reduce greenhouse gas emissions and dependence on fossil fuels. However, this growth brings a pressing demand for sustainable, accessible, and efficient charging infrastructure. Traditional EV charging stations often rely heavily on the electrical grid, which may lead to increased energy consumption, grid instability, and environmental concerns.

To address these challenges, integrating solar energy into EV charging systems offers a promising solution. Solar-powered EV charging stations harness renewable energy, minimizing carbon footprints while enhancing energy independence. However, to make such systems truly viable and user-friendly, they must go beyond energy generation — incorporating smart technologies for payment processing, real-time monitoring, and intelligent grid interaction.

1.1 SCOPE AND OBJECTIVES

This project focuses on the development and optimization of a solar-powered electric vehicle (EV) charging infrastructure integrated with a smart payment system and an advanced grid connection. It aims to create a sustainable, user-friendly, and intelligent charging network that not only supports green energy adoption but also ensures grid reliability and operational efficiency. The scope includes:

- Designing a modular solar charging station layout suitable for urban and semi-urban deployment.
- Integrating a smart, secure, and cashless payment interface (e.g., RFID, mobile app, QR code).
- Incorporating an advanced grid connection system for dynamic load management, energy storage, and bi-directional power flow (V2G – Vehicle-to-Grid).
- Evaluating system performance through simulations or a scaled prototype, including energy output, user accessibility, and grid interaction.
- Ensuring scalability and compatibility with existing renewable energy policies and grid standards.

To design a solar-powered EV charging infrastructure that efficiently captures and utilizes solar energy for charging electric vehicles.

To develop a smart payment system that supports multiple cashless transaction methods, enhancing user convenience and system automation.

To integrate an advanced grid connection system that allows for:

- Smart energy distribution and load balancing
- Storage management (battery backup or supercapacitor systems)
- Potential Vehicle-to-Grid (V2G) capabilities for energy feedback to the grid

To ensure system sustainability and reliability by incorporating weather-resilient solar technology and real-time monitoring systems.

To analyse the cost-effectiveness and energy efficiency of the proposed design through modelling, simulation, or prototype testing.

To contribute to the reduction of carbon emissions and support the global shift toward green mobility and renewable energy infrastructure.

Advantages

1. **Environmentally Friendly**

Utilizes solar energy, a clean and renewable resource, significantly reducing greenhouse gas emissions and the carbon footprint of EV charging.

2.Cost-Efficient Operation

Reduces dependence on conventional electricity, lowering operational costs over time and providing long-term energy savings.

3.Smart Payment Convenience

Supports cashless, contactless, and automated payment systems (RFID, mobile apps, QR codes), offering users a seamless and modern payment experience.

4.Grid-Friendly Integration

The advanced grid connection enables smart load management, peak shaving, and potential Vehicle-to-Grid (V2G) support, enhancing grid stability and efficiency.

5.Energy Independence

Can operate partially or fully off-grid with battery storage, ensuring uninterrupted service even during power outages or peak load periods.

6.Scalability and Flexibility

Modular system design allows easy scaling for deployment in urban, rural, and remote locations without major infrastructure changes.

7.Real-Time Monitoring and Control

IoT-enabled sensors and controllers allow for live tracking of energy usage, system status, and user access, improving maintenance and service reliability.

8.Reduced Load on Conventional Grid

Diverts a portion of EV charging demand from the main grid to the solar system, helping reduce grid congestion and blackout risks.

9.Enhanced User Experience

Smart features, fast payments, and reliable power make the system user-friendly and appealing for both private and commercial EV owners.

10.Support for Sustainable Development Goals (SDGs)

Contributes directly to global goals such as clean energy (SDG 7), sustainable cities (SDG 11), and climate action (SDG 13).

CHAPTER 2

LITERATURE REVIEW

Research in the field of renewable energy-based EV charging has shown that integrating solar power with grid connectivity can significantly reduce dependency on fossil fuels. Studies highlight the importance of DC/DC converters and battery storage in ensuring stable energy supply for EVs. The use of RFID-based payment systems has also gained traction in the transportation sector, enabling secure, automated, and user-friendly payment transactions. Furthermore, recent advancements in microcontroller-based energy management systems have demonstrated improved efficiency in smart power distribution and real-time monitoring. The global transition toward electric vehicles (EVs) is driven by environmental concerns, fuel price volatility, and technological advancements. However, the sustainability of EVs hinges on the energy sources used for charging. Research has emphasized the critical role of integrating renewable energy sources, particularly solar power, with smart technologies to reduce reliance on fossil fuels and enhance system resilience.

2.1 ON-GRID BASED SYSTEMS

Udayakumar Subramanian, Preetham V., and Hari Raja Muthukrishnan (2024) provided a foundational study exploring solar- powered electric vehicle charging stations. Their research demonstrated how solar integration can improve sustainability, especially in urban and semi- urban areas with high solar irradiance. The study underscored not only the environmental benefits but also the long-term economic viability of using photovoltaic (PV) systems for EV infrastructure. Photovoltaic systems have emerged as the most practical form of renewable energy for decentralized EV charging due to their scalability and decreasing costs. The modularity of solar panels allows them to be installed in various locations, such as parking lots, rooftops, and dedicated charging stations. In their study, Udayakumar Subramanian, Preetham V., and Hari Raja Muthukrishnan (2024) emphasized the environmental advantages of solar-powered EV charging stations, concluding that these systems significantly reduce the carbon footprint compared to grid-only solutions. They also highlighted the importance of designing the stations to match local energy needs and solar availability. Additional research by T. Esram and P. Chapman (2007) investigated maximum power point tracking (MPPT) algorithms for photovoltaic systems and found that efficient energy harvesting plays a pivotal role in ensuring consistent energy supply. Although this study predates EV-specific research, its influence on solar charging technology has been foundational [2].

While solar power provides clean energy, its intermittent nature poses reliability challenges. As a result, grid-connected solar charging stations have gained attention as hybrid systems capable of stabilizing energy supply. Ahmed Sharique Anees (2023) explored the dynamics of integrating renewable energy sources into power grids, particularly in the context of transportation electrification. His findings supported the use of bidirectional power flow and demand response systems for optimizing electricity distribution. Anees emphasized the importance of synchronizing grid supply with renewable generation to minimize energy imbalance. Research by D. Zhang, Z. Wang, and L. Wang (2011) discussed the coordination of plug-in electric vehicles in smart grid environments, recommending advanced control strategies to mitigate load peaks caused by mass EV charging. Their model utilized both real-time grid conditions and renewable energy forecasts, reinforcing the need for intelligent scheduling algorithms [3].

DC/DC converters serve a crucial role in regulating the variable output from solar PV systems to match the charging requirements of EV batteries. Without proper conversion, energy losses and inefficiencies can occur, undermining the advantages of renewable energy integration. A study by H. Tao, A. Kotsopoulos, J. Duarte, and M. Hendrix (2007) examined multiple-input converters for hybrid renewable energy systems. The study focused on topologies suitable for combining solar and battery storage inputs, confirming that non-isolated converter designs could achieve high efficiency and simplified control schemes. In more recent work, Bhaskar Mahato and Rajib Datta (2022) analyzed buck-boost converter configurations in solar charging applications for EVs. They concluded that dynamic duty-cycle adjustments based on load and solar irradiance improved power quality and battery health, which are essential for sustainable EV infrastructure [4].

2.2 ESS BASED SYSTEMS

Energy storage systems (ESS) provide a buffer between energy generation and consumption, allowing excess solar power to be stored and later used during low generation or peak demand periods. This capability enhances the stability and resilience of EV charging stations. A 2020 study by Neha Jain and R. K. Tripathi evaluated the performance of lithium-ion and lead-acid batteries in solar-integrated charging systems. Their results showed that lithium-ion batteries offered better energy efficiency, cycle life, and temperature tolerance. These characteristics are vital for long-term reliability in EV infrastructure. Research by J. A. Kester and K. Brabender (2009) proposed the use of supercapacitors alongside batteries to handle transient loads and voltage fluctuations during fast charging. Their hybrid energy storage model helped reduce strain on individual storage components, improving overall system lifespan [5].

Beyond the physical charging mechanisms, user interface and transaction management are also crucial for widespread EV adoption. RFID (Radio Frequency Identification) technology has been increasingly deployed to enable secure and seamless user authentication and payment processing at EV charging points. J. Joyce Jacob, Abinaya S., Divya Priya R., and Poonam Khatarkar (2023) developed a prototype of a wireless EV charging system integrated with RFID authentication. Their system allowed drivers to initiate and terminate charging sessions automatically through RFID cards linked to digital wallets. The study demonstrated that such automation reduces transaction time and human error, offering a better user experience. Similar findings were reported by Harsh Kumar and Suman Lata (2021), who analyzed RFID and QR-code based systems. They concluded that RFID was more reliable in outdoor charging environments where factors like sunlight and screen visibility could interfere with QR-code scanning [6].

Microcontrollers are essential for managing the real-time operations of EV charging stations. They control power flow, monitor charging status, and implement algorithms to ensure efficient and safe energy use. Farhad Khosrojerdi, Stéphane Gagnon, and Raul Valverde (2021) investigated the role of artificial intelligence and microcontrollers in smart grid applications, including EV charging. Their research showed that microcontrollers equipped with AI-based algorithms could forecast load, optimize charging times, and balance energy distribution across multiple charging units. Another relevant study by N. Pandiarajan and Ranganath Muthu (2011) focused on the simulation of photovoltaic modules and microcontroller- based controllers for maximum energy extraction. Their control scheme dynamically adjusted system parameters to improve output power, a concept later adapted in EV charging station designs [7].

As the complexity of EV charging systems increases, artificial intelligence (AI) and machine learning (ML) are being adopted to manage and optimize operations. These systems help predict energy demand, adjust charging schedules, and enhance grid reliability. Farhad Khosrojerdi, Stéphane Gagnon, and Raul Valverde (2021) also explored the broader application of AI in smart grid environments. Their research emphasized the integration of neural networks and fuzzy logic controllers to improve grid response to variable demand from EVs. AI-based energy management systems have the potential to enhance charging speed, reduce costs, and support V2G (Vehicle-to-Grid) technologies. Research by Q. Zhang and M. Kezunovic (2018) introduced deep learning models for real-time fault detection in EV charging networks. Their results demonstrated improved grid stability and faster recovery during abnormal power events [8].

CHAPTER 3

EXISTING SYSTEM

Conventional EV charging stations are heavily dependent on the grid, leading to high operational costs and increased carbon emissions. These systems often lack renewable energy integration, making them less sustainable in the long run. Additionally, most existing solutions do not offer automated payment methods, requiring users to rely on manual transactions, which can be time-consuming and inconvenient. The absence of efficient power management results in unnecessary energy loss, further increasing costs and reducing overall efficiency. Conventional electric vehicle (EV) charging stations play an essential role in the current landscape of transportation electrification. However, despite their increasing prevalence and utility, these charging systems exhibit several significant limitations that hinder the broader adoption of electric vehicles and the realization of a truly sustainable mobility ecosystem. A critical issue facing traditional EV charging infrastructure is its overwhelming dependence on the electrical grid for energy supply. This grid-centric model presents a range of economic, environmental, and operational drawbacks that limit the overall effectiveness and efficiency of EV charging solutions.

3.1 EXISTING CHARGING SYSTEMS

Grid dependency in conventional EV charging stations has multifaceted implications. Firstly, the cost of grid electricity fluctuates depending on regional energy pricing, demand cycles, and time-of-use tariffs. Charging during peak demand hours incurs higher energy rates, which directly impacts both the station operators and EV users. This cost burden can deter the frequent use of public charging facilities, particularly when energy pricing policies are not optimized for EV users. Moreover, the heavy demand placed on the power grid by the increasing number of EVs, especially in urban and densely populated regions, raises concerns regarding the grid's stability. As the adoption of electric mobility continues to accelerate, the cumulative power requirements from EV charging could exacerbate existing issues such as voltage fluctuations, frequency instability, and even localized power outages. These operational stresses compromise not only the reliability of EV infrastructure but also the broader energy network's resilience [9].

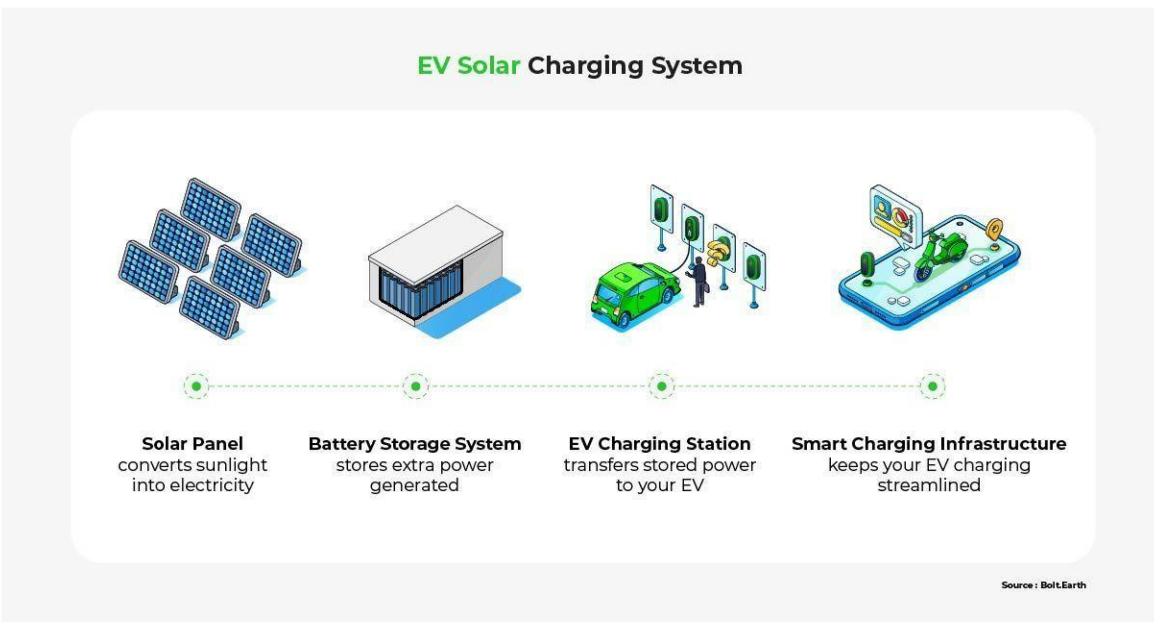

Fig.3.1: Traditional Solar Charging Station

Another consequence of relying entirely on the grid for EV charging is the potential nullification of the environmental advantages commonly associated with electric mobility. While EVs are often lauded for producing zero tailpipe emissions, the environmental footprint of the electricity they consume must also be considered. In regions where the grid is powered predominantly by fossil fuels—such as coal, natural gas, or oil—the carbon emissions associated with EV charging remain substantial. This undermines the central objective of transitioning to EVs as a means to mitigate greenhouse gas emissions and combat climate change. In such cases, the net reduction in emissions compared to internal combustion engine vehicles is significantly less than commonly perceived, if present at all. Thus, unless the energy used in charging is sourced from clean, renewable inputs, the sustainability of EVs remains compromised. Compounding the challenges of grid reliance is the widespread lack of integration with renewable energy sources in conventional EV charging stations. While renewable technologies such as photovoltaic solar panels and wind turbines have become increasingly cost-competitive and efficient, they are still underutilized in the design and deployment of public and private EV chargers. This oversight not only represents a missed opportunity to decarbonize the transport energy supply chain but also reflects a broader hesitation to embrace decentralized and hybridized energy architectures. By failing to harness local, renewable energy generation, many EV charging networks perpetuate the traditional centralized power model, which is less adaptive to modern demands for energy resilience and sustainability [10].

3.2 EXISTING SYSTEMS LIMITATIONS

The absence of renewable integration also highlights a critical vulnerability of conventional EV infrastructure: its inflexibility in managing power supply and demand. Renewable sources, while environmentally advantageous, are inherently variable. Solar energy is available only during the daytime and is highly weather-dependent, while wind energy fluctuates according to atmospheric conditions [11]. Without mechanisms for energy storage or real-time energy management, charging stations that seek to incorporate renewables may face supply inconsistencies, leading to service disruptions or underutilization of generated power. In conventional systems where renewables are not integrated at all, there is no opportunity to benefit from periods of low-cost or excess generation, thereby increasing dependence on high-cost grid electricity and reducing operational adaptability. Furthermore, most existing EV charging stations lack automation in user interface systems, particularly in payment processing.

Traditional stations often require manual initiation of transactions, either through human-operated kiosks, mobile apps with cumbersome authentication procedures, or hardware-based card readers that are susceptible to wear, vandalism, or network issues. This manual reliance introduces several inefficiencies and inconveniences for users. Firstly, the time taken to initiate and complete charging sessions is often longer than necessary, reducing user satisfaction and potentially leading to queuing or congestion at high-traffic stations. Secondly, manual payment systems increase the possibility of user error, such as incorrect charging session input, payment failures, or card incompatibility issues. From a security standpoint, manual systems are also more vulnerable to fraudulent activities and data breaches, especially in areas lacking robust cybersecurity measures. The absence of automated payment methods in EV charging not only impedes convenience but also affects scalability. As EV adoption grows and the number of users increases, the need for seamless, contactless, and real-time payment solutions becomes ever more critical.

These technologies facilitate user authentication and billing processes without manual intervention, allowing for a more streamlined and secure charging experience. Unfortunately, in many conventional EV charging installations, these systems are either not present or not standardized across platforms, leading to fragmented user experiences and further discouraging widespread usage.

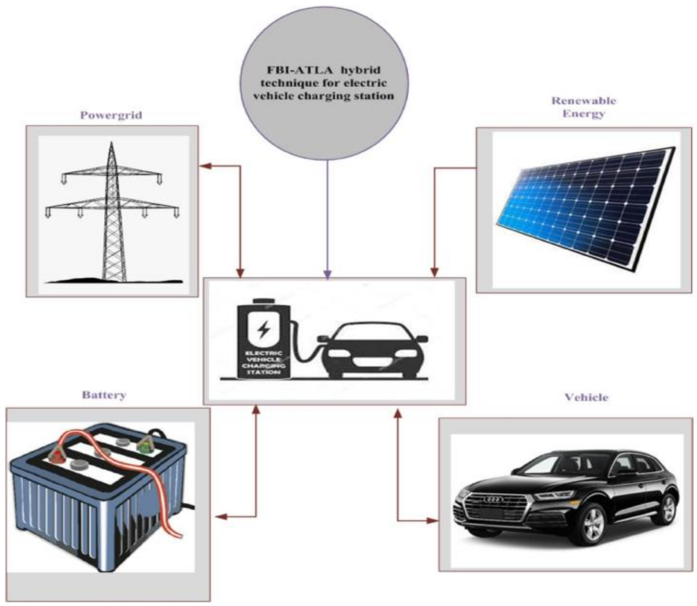

Fig.3.2: Grid-Connected Solar Charging process

A related challenge in traditional EV charging systems is the lack of integrated power management capabilities. Efficient power management is crucial for optimizing energy distribution, reducing operational costs, and minimizing energy wastage. However, many conventional charging stations operate on static load models, without the ability to dynamically adapt to real-time energy demand, pricing signals, or user behavior. This results in several inefficiencies [13]. For instance, during off-peak hours when electricity is cheaper and demand is lower, many stations fail to leverage these periods to their full potential due to a lack of smart scheduling algorithms or load balancing techniques. Conversely, during peak periods, when the grid is under maximum load and electricity prices are highest, these systems often continue to operate at full capacity, inadvertently increasing both operational costs and grid stress.

Moreover, poor energy management leads to significant energy losses, both in the form of transmission inefficiencies and idle power consumption. Without smart controllers or adaptive scheduling mechanisms, EV chargers may draw power continuously even when no vehicle is connected or during low- demand periods. This "standby" power draw contributes to unnecessary energy consumption, adding to the overall cost burden and reducing the net energy efficiency of the system. Modern power electronics and microcontroller-based energy management systems offer solutions to these problems, allowing real-time monitoring and control of energy flows. However, these technologies are seldom incorporated into legacy EV infrastructure, which tends to prioritize hardware simplicity over intelligent system design.

In addition to direct energy inefficiencies, the lack of smart power management also limits the ability of EV charging stations to participate in emerging energy markets and grid services. Vehicle-to-grid (V2G) technologies, which allow bi-directional energy flow between EVs and the grid, rely on intelligent energy management systems to function effectively. Without these systems, conventional chargers cannot support V2G functions, thereby missing out on opportunities to provide ancillary services such as frequency regulation, load leveling, and demand response. This exclusion not only restricts the financial viability of EV charging networks but also deprives the grid of valuable distributed energy resources. Taken together, these shortcomings illustrate the pressing need for a fundamental redesign of EV charging infrastructure. Addressing grid dependency, integrating renewable energy sources, implementing automated payment systems, and adopting efficient power management technologies are not just technical upgrades—they are strategic imperatives. Without these improvements, the expansion of EV infrastructure risks replicating the inefficiencies of the current centralized energy system, rather than creating a more sustainable, user-centric, and resilient model for future mobility [14]. Policymakers, energy providers, and private stakeholders must collaborate to establish regulatory frameworks, financial incentives, and technical standards that promote the adoption of integrated and intelligent EV charging solutions. The pathway to a smarter EV ecosystem is clear. It involves moving beyond conventional, grid-dependent models towards hybridized systems that combine local renewable generation, energy storage, intelligent control, and digital automation. Only through such a transformation can electric mobility achieve its full environmental, economic, and social potential. The integration of solar energy and battery storage, the implementation of real- time data analytics through microcontrollers, and the adoption of digital identification and payment technologies such as RFID or blockchain all represent essential components of this transition. With proper investment, innovation, and coordination, the current limitations of conventional EV charging systems can be effectively overcome, paving the way for a more efficient, resilient, and environmentally sustainable transport infrastructure.

3.2 GRID CONNECTED CHARGING PROCESS

Existing electric vehicle (EV) charging stations, often found in urban areas and along highways, play a crucial role in supporting the growing adoption of electric vehicles. Their primary merits lie in their convenience and accessibility. EV owners can rely on these stations for quick recharges, making them suitable for daily commuting and long-distance travel. Moreover, they are grid-connected, ensuring uninterrupted charging, regardless of weather conditions or time of day.

Fig.3.3: Grid-Connected Solar Charging process

These stations are often equipped with multiple connectors to accommodate different types of EVs, enhancing their practicality. However, existing EV charging stations also have their share of demerits. One of the primary drawbacks is the source of their energy, which depends on the grid. The environmental impact of charging at these stations can vary significantly based on the grid's energy composition, potentially resulting in a carbon footprint if fossil fuels dominate the grid mix. Additionally, the availability of charging stations can be uneven, particularly in rural or less densely populated areas, limiting EV adoption for some users [15].

Finally, charging time at these stations can be longer compared to fully solar-based charging, affecting the overall convenience of EV ownership. In essence, existing EV charging stations offer convenience but may not consistently provide a clean energy source. Their widespread accessibility supports EV adoption, yet their environmental impact depends on regional grid sustainability. Future developments should aim to address these limitations, ensuring that electric vehicle charging is not only accessible but also environmentally responsible and efficient. In the field of renewable energy systems, the integration of solar panels is essential for harnessing sunlight to produce electricity. To create a reliable energy generation unit, two solar panels, each with a power capacity of 500 watts, are interconnected in a well-planned setup. It is important to note that these panels are not standalone units but are strategically connected to a DC-to-DC boost converter.

This converter serves a crucial role in increasing the output voltage to a more practical level. The desired stable output voltage is 56.6 volts. To address fluctuations and ripples in voltage and current that can disrupt the system's operation, the prompt mentions the use of a voltage and current ripple reduction circuit. This circuit effectively minimizes undesirable effects caused by the converter, resulting in a more stable and cleaner power output. By reducing oscillations, the circuit enhances the system's lifespan, efficiency, and overall performance. Furthermore, the journey of power extends beyond this point to ensure optimal utilization and protection of energy resources. An auto-cutoff circuit, a sophisticated feature integrated into the system, acts as a safeguard against wasteful energy consumption and potential damage to connected components. This circuitry is designed to monitor the charging process of a 48-volt battery, a critical energy storage element within the system.

As the battery nears its maximum charge capacity, indicated by a distinct voltage threshold, the auto-cutoff circuit activates. Its primary function is to intelligently detect this critical point and promptly disconnect the power supply to prevent overcharging, which could degrade the battery and pose safety hazards. Additionally, the prompt highlights the inclusion of a display unit in the system. This display provides real-time feedback on key parameters such as voltage levels, offering users transparency and user-friendliness. Through intuitive visual cues, users can easily monitor the battery's status and stay informed about its charging progress. This transparency empowers users with valuable insights and instills a sense of control and accountability over energy consumption patterns. The thoughtful coordination of components in this solar power system exemplifies the fusion of scientific advancement with environmental stewardship. To maximize sustainability and efficiency, every component— from solar energy capture to conversion, control, and storage—is crucial. Through clever design and integration, the system achieves a balance between device protection, resource conservation, and energy production optimization. It underscores the ongoing efforts to leverage the benefits of renewable energy sources while mitigating their negative environmental impacts and adapting to fluctuating energy demands.

CHAPTER 4

PROPOSED SYSTEM

Solar panels serve as the system's principal energy source. Solar panels are extremely efficient at converting sunlight into electrical energy, offering a clean and renewable power source for EV charging stations. Energy storage systems, mainly lithium-ion batteries, are used to maintain reliable service even when solar energy is unavailable, for as during overcast weather or at night. These batteries store surplus energy generated during the day, allowing customers to charge their electric vehicles at night or during times of low sunlight. The storage option improves the system's overall sustainability and efficiency while lowering reliance on non- renewable energy sources.

4.1 PROPOSED EV CHARGING PROCESS

In addition to solar energy, the system contains an innovative grid link that allows bidirectional energy transfer. During peak solar production, when the energy demand from EV stations is low, excess energy can be fed back into the grid, benefiting the larger energy network. In contrast, if the solar panels cannot fulfil demand, such as in the evening or on overcast days, the system can pull energy from the grid. This bidirectional flow not only assures that the charging stations are always working, but it also improves the infrastructure's overall energy efficiency. Advanced energy management algorithms are used to control the energy distribution between solar panels, battery storage, and the grid, optimizing the energy flow to meet real-time charging requirements.

This guarantees that the system functions with minimal waste and great efficiency, balancing energy production and consumption while lowering operational expenses.

The suggested system incorporates a smart payment platform intended to give users with a smooth and convenient charging experience. The payment system is adaptable, allowing customers to pay via a variety of methods such as mobile apps, QR codes, RFID cards, and NFC-enabled wallets [11,12]. This variety of payment alternatives makes it simple for consumers to charge their vehicles and track their consumption, while also providing security via encrypted transaction protocols. The smart payment system can also incorporate features like usage history tracking, real-time pricing, and notifications, which improve the user experience by giving them complete visibility and control over their charging expenses.

This system also supports a variety of payment structures, including pay-per-use, subscription-based plans, and fleet management billing, making it appropriate for both individual users and corporations operating EV fleets. The proposed system integrates a smart payment platform designed to enhance the overall EV charging experience by providing users with seamless, secure, and flexible transaction options. As electric vehicles continue to gain popularity, the demand for efficient and user-friendly charging solutions has escalated, prompting the development of more sophisticated payment systems to complement the evolving infrastructure. This smart payment system offers users the convenience of selecting from various payment methods, such as mobile apps, QR codes, RFID cards, and NFC-enabled wallets.

These diverse payment options address the need for flexibility, allowing customers to choose the method that best suits their preferences and the available technology at each charging station. By enabling multiple payment methods, the system ensures accessibility for a wide range of users, catering to those who are comfortable with different payment technologies and platforms. For instance, mobile apps provide a convenient and widely adopted option, while QR codes offer an easy-to-use alternative for those who prefer quick and simple interactions. RFID cards are ideal for users seeking a more traditional but reliable payment mechanism, while NFC-enabled wallets offer a contactless solution that aligns with current digital payment trends. The ability to accommodate these various payment methods significantly enhances the user experience, making it easier for EV owners to charge their vehicles without the hassle of dealing with complex payment systems.

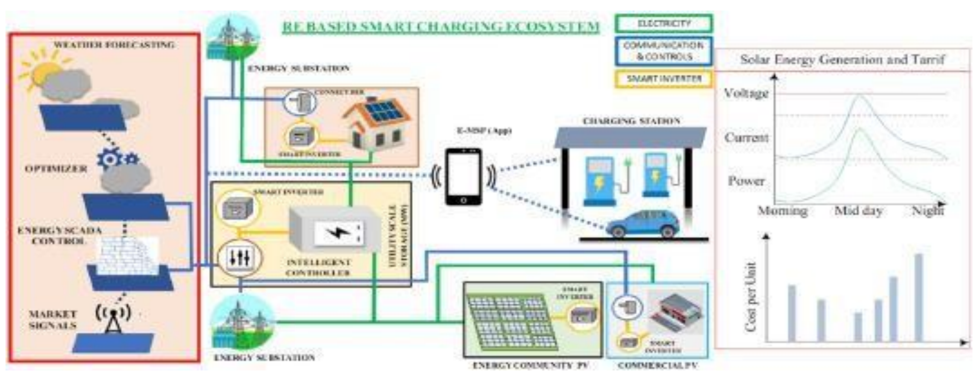

Fig.4.1: Grid-Connected state-of-the-art encryption

The integration of secure transaction protocols is another key feature of the system. Security is a critical concern in the context of digital payments, particularly with the growing number of transactions being conducted in the EV sector.

To address this, the smart payment platform ensures that all transactions are encrypted using state-of-the-art encryption technologies, safeguarding sensitive user data and preventing unauthorized access. The encrypted transactions not only protect users' financial information but also foster trust in the system, encouraging more widespread adoption of EV charging stations and promoting the growth of the electric vehicle ecosystem. In addition to providing multiple payment methods and enhanced security, the smart payment system incorporates features that allow users to track their consumption and gain complete visibility over their charging activities. One such feature is usage history tracking, which enables users to review their past charging sessions, monitor their energy consumption patterns, and analyze their charging costs over time. This data can be particularly valuable for users seeking to optimize their charging behavior, as it provides insights into when and where they typically charge their vehicles, helping them make more informed decisions about their charging habits. Another important feature is real-time pricing, which allows users to view the cost of charging at any given moment. This feature is particularly beneficial in locations where energy prices fluctuate depending on time of day or demand, giving users the ability to plan their charging sessions more effectively. For example, a user might choose to charge their vehicle during off-peak hours when electricity prices are lower, thereby reducing their overall charging costs. Real-time pricing also adds an element of transparency, as users can see exactly how much they are paying at any given time, which enhances their confidence in the charging process.

4.2 SUBSCRIPTION BASED MODEL

The system also includes notifications, which serve to keep users informed about their charging sessions in real-time. These notifications can alert users when their vehicle is fully charged, remind them of upcoming subscription renewals, or notify them of any changes in pricing or station availability. Such notifications help users stay on top of their charging activities and avoid any surprises when it comes to billing. The inclusion of these features contributes to a more streamlined and user-friendly experience, ultimately fostering greater satisfaction among users. Moreover, the smart payment system is highly adaptable to different payment structures, making it suitable for a wide range of use cases. For individual EV owners, the system supports pay-per-use payment models, where users pay only for the energy they consume.

This structure is ideal for users who infrequently charge their vehicles or those who prefer a more flexible payment approach. For those who charge their vehicles more regularly, the system also supports subscription-based plans, where users pay a fixed monthly or annual fee in exchange for discounted or unlimited charging services. This subscription model is particularly advantageous for individuals who rely on EVs for daily commuting and seek to optimize their charging costs over the long term. In addition to serving individual users, the system is also designed with businesses in mind, specifically those that operate EV fleets. This feature simplifies billing and reporting for fleet operators, enabling them to track the charging expenses of each vehicle and generate detailed usage reports. Fleet management billing can be further customized to suit the specific needs of different businesses, whether they operate a small fleet of delivery vehicles or a large fleet of service vehicles. By incorporating this flexibility, the smart payment system becomes a versatile tool that caters not only to individual consumers but also to corporate users with unique charging requirements. The ability to support multiple payment structures and adapt to various user needs makes the smart payment platform highly scalable, offering solutions for a diverse range of EV charging scenarios. As the EV market continues to expand, the demand for such flexible, secure, and user- friendly payment systems will only increase. By addressing the needs of both individual users and corporate fleet operators, the system ensures that it can meet the evolving demands of the market while also contributing to the broader adoption of electric vehicles.

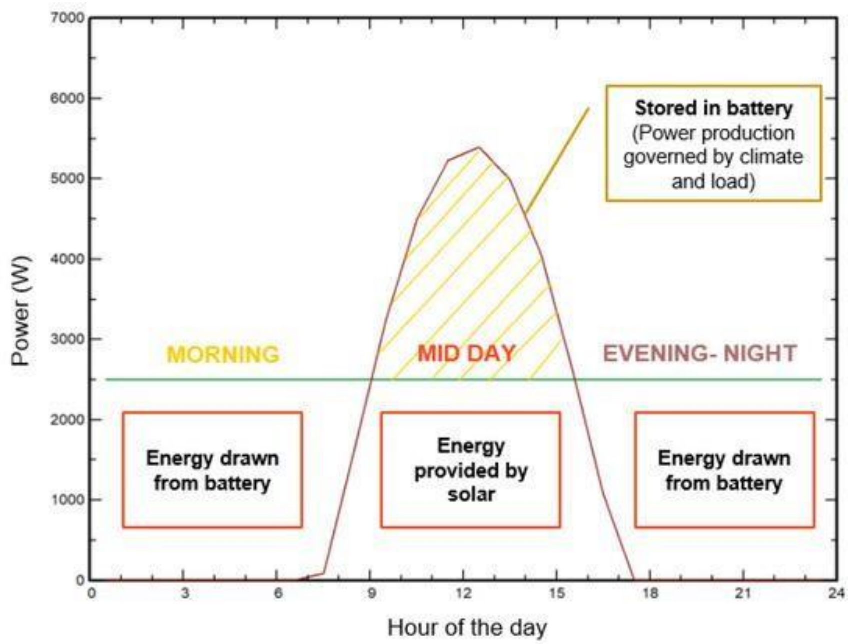

Fig.4.2: Effectiveness of the Power

In conclusion, the integration of a smart payment platform into EV charging stations represents a significant step forward in enhancing the user experience, optimizing operational efficiency, and supporting the growth of the electric vehicle ecosystem. By offering a wide variety of payment options, ensuring the security of transactions, providing features such as usage tracking and real-time pricing, and supporting flexible billing models, the system addresses the diverse needs of EV users and fleet operators alike.

As the world moves toward a more sustainable and electrified future, such The suggested solar-powered EV charging infrastructure, which includes improved grid connection, a smart payment system, and IoT integration, provides a comprehensive and sustainable solution for the future of electric car charging. With its ability to offer consistent, clean energy, scalability, and energy-efficient design, the system has the potential to transform the EV charging landscape while assisting in the move to a greener, more sustainable future.

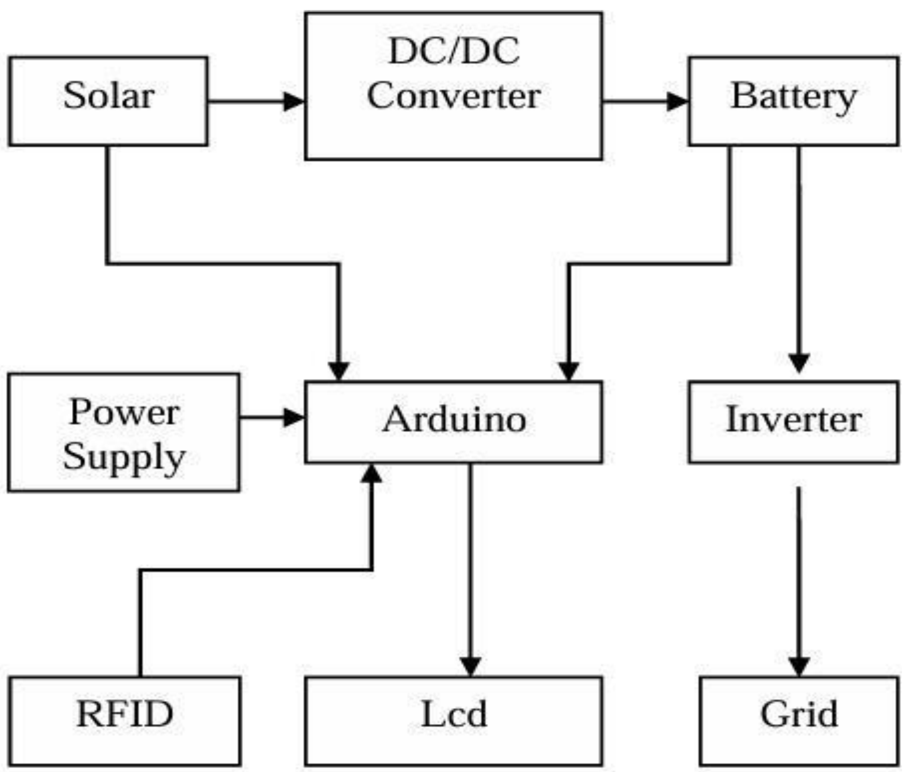

Fig.4.3. Block Diagram of Proposed System

The system begins with solar panels, which serve as its major energy source. Solar panels use photovoltaic cells to convert sunlight into direct current (DC) electricity. The DC power is then regulated by a DC/DC converter, which changes the voltage levels to ensure intelligent payment systems will play a crucial role in making the transition to electric vehicles seamless, convenient, and cost-effective for all users. The cost of implementing the suggested system is a critical factor.

Initial investments in solar panels, batteries, and grid connections may be costlier than for standard charging stations, but the long-term benefits far surpass the expenses. The technology saves money in the long run by using solar energy and minimizing reliance on the grid. Furthermore, the use of renewable energy considerably reduces the environmental impact of the charging infrastructure, helping to achieve global sustainability goals and lowering carbon emissions.

4.3 SOLAR POWERED INFRASTRUCTURE

Before large-scale implementation, the system will be rigorously tested in a variety of environmental and operational scenarios. This includes assessing its performance in different climates, testing energy generation and consumption at various times of day, and verifying that the payment and monitoring systems work properly. After the system has been tested and refined, it will be released with detailed instructions for installation, maintenance, and user use. The system's scalability allows it to be deployed in a number of situations, ranging from small settlements to major metropolitan areas.

A battery is used to store any excess energy generated by the solar panels. The battery guarantees continuous operation at night or during periods of low sunshine by discharging stored energy to fulfil the system's demand. It also helps to manage energy supply and demand, guaranteeing consistent and uninterrupted power availability.

The proposed system aims to establish a sustainable and efficient electric vehicle (EV) charging infrastructure by integrating solar power, grid connectivity, battery backup, and a smart payment mechanism. The inclusion of solar panels is a central feature of the design, as it allows the system to generate clean, renewable electricity from the sun. This solar energy is then regulated by a DC/DC converter, ensuring that the voltage and current are suitable for both storing energy in a battery and powering the EV charging process directly. By utilizing solar power, the system not only reduces its dependence on conventional energy sources but also contributes to a significant reduction in carbon emissions, aligning with the broader goals of sustainability in transportation infrastructure. The role of the DC/DC converter in this setup is crucial, as it ensures that the power generated from the solar panels is appropriately regulated and managed. The converter adjusts the voltage from the solar panels to a level that is either suitable for immediate use in charging the vehicle or for storage in the battery. The converter plays a vital part in ensuring that energy is used efficiently, preventing overcharging of the battery and allowing for consistent, reliable operation of the EV charging station.

In scenarios where the solar generation is insufficient—such as during cloudy weather or at night—the system is equipped with a battery backup that stores excess energy produced during the day. This stored energy can then be used when solar generation is low, ensuring that the charging station remains operational even during periods of low sunlight. The combination of solar power and battery storage thus provides a level of energy autonomy, reducing the need for external grid power and increasing the overall sustainability of the infrastructure. The grid connection system is designed to be intelligent, automatically switching to grid power when the solar and battery resources are no longer sufficient to meet the power demand.

An essential component of this system is the controller, which plays a pivotal role in managing the energy flow and ensuring efficient operation. The controller in this system is based on an Arduino platform, a versatile and affordable microcontroller that is widely used in various automated systems. The Arduino-based controller is responsible for managing the power distribution between the solar panels, the battery, and the grid connection, ensuring that energy is used effectively and that the battery is charged when excess solar power is available. It continuously monitors the energy levels in the battery and ensures that the charging station operates within optimal energy usage parameters. Additionally, the controller displays real-time data about the system's energy consumption, battery status, and overall performance on an LCD screen. This real-time monitoring capability is invaluable for both users and operators, as it provides clear visibility into the system's operations and energy use. Users can easily see the available energy and make informed decisions about when and how to charge their vehicles, while operators can track system performance and make adjustments as needed.

A critical feature of this system is the incorporation of a smart payment mechanism, which is designed to offer users a seamless and secure method of paying for their charging sessions. The payment system leverages an RFID module, which enables secure, contactless transactions. RFID technology is well-suited for EV charging stations because it provides a fast, efficient, and user-friendly method for initiating payments without the need for physical contact or manual intervention. Users simply need to scan their RFID cards to start the charging process, and the payment is automatically deducted based on the energy consumed. This method of payment eliminates the need for cash transactions, card swipes, or other manual payment processes, significantly enhancing the convenience and efficiency of the charging experience. The use of RFID technology also enhances security, as each transaction is encrypted and linked to a unique user identifier, reducing the likelihood of fraud or unauthorized access. This secure payment system ensures that users' financial data is protected, providing peace of mind while using the charging station. Additionally, the integration of RFID allows for a streamlined billing process, where users are only charged for the exact amount of energy consumed during their charging session. This eliminates the potential for billing errors or discrepancies, ensuring that users are charged accurately and fairly. The proposed system's smart payment mechanism further extends to the management of different payment models, making it adaptable for various types of users. For example, users may opt for a pay-per-use model, where they are charged based on the amount of energy consumed during each session. Alternatively, subscription-based plans may be available for regular users, offering discounted rates or unlimited charging for a fixed monthly or annual fee. This flexibility in payment options caters to the diverse needs of EV owners, whether they are individual consumers, businesses with EV fleets, or fleet management companies. The system's ability to accommodate various payment structures also ensures that it can scale with the growing demand for EV charging services, offering a versatile and comprehensive solution for a wide range of users.

In conclusion, the proposed system represents a forward-thinking approach to the development of sustainable and efficient EV charging infrastructure. By incorporating solar power generation, battery backup, grid connectivity, and a smart payment mechanism, the system provides a comprehensive solution that addresses the energy needs of modern electric vehicles while minimizing environmental impact. The use of renewable solar energy, combined with intelligent power management and secure, automated payment processing, ensures that the system is not only environmentally responsible but also user-friendly and operationally efficient. As the adoption of electric vehicles continues to grow, systems like this one will play a crucial role in supporting the transition to a cleaner, more sustainable transportation future.

CHAPTER 5

RESULTS AND DISCUSSION

The suggested system combines renewable energy, sophisticated grid integration, and a seamless smart payment mechanism to offer a comprehensive solution for solar-powered electric vehicle (EV) charging infrastructure. This infrastructure is a forward-thinking and progressive answer to the growing demand for electric vehicle charging stations and plays a crucial role in supporting the transition to a more sustainable future. As the adoption of electric vehicles continues to accelerate, there is an increasing need for infrastructure that not only meets the energy demands of these vehicles but also contributes to environmental sustainability. The integration of solar power into this system offers a significant advantage, as it reduces dependence on the grid and minimizes the carbon footprint associated with vehicle charging. By utilizing solar energy, the system aligns with the global goal of reducing greenhouse gas emissions and promoting the use of clean, renewable energy sources.

5.1 SCHEMATIC OF THE PROPOSED SYSTEM

The core function of the system revolves around the use of solar panels to generate electricity. Solar panels, which harness sunlight and convert it into electrical energy, serve as the primary energy source for the EV chargers. This renewable source of energy ensures that the charging process is not only efficient but also environmentally responsible. Solar energy is an abundant and inexhaustible resource, making it an ideal solution for powering EV chargers in a way that is sustainable in the long term. Solar panels work by using photovoltaic cells to capture sunlight and convert it into direct current (DC) electricity. This DC power is then regulated by a DC/DC converter, which ensures that the voltage and current are suitable for charging the EVs or storing in a battery for later use. The converter plays an essential role in optimizing the efficiency of the charging process by maintaining stable energy output while minimizing energy losses.

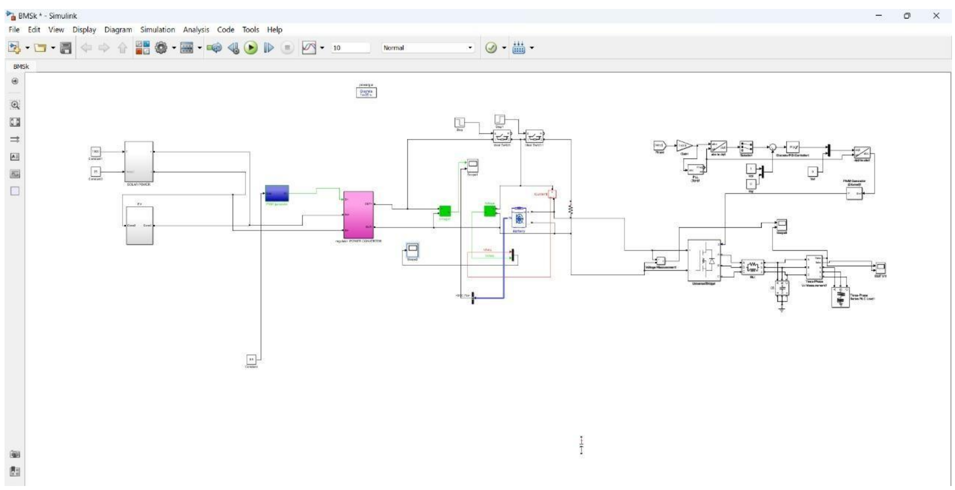

Fig.5.1: Schematic of the proposed system

As solar energy is inherently intermittent—dependent on factors such as time of day, weather, and geographical location—the system also incorporates an advanced battery storage solution. This feature allows excess energy generated during peak sunlight hours to be stored in a battery for use during periods of low sunlight, such as nighttime or cloudy days. By providing a backup power source, the battery ensures that the EV charging stations remain operational even when solar power generation is insufficient. This flexibility is crucial for maintaining the reliability and accessibility of the system, especially in locations where consistent sunlight is not guaranteed throughout the day. The battery storage system can be automatically charged when excess solar power is available, and the stored energy can be utilized when there is insufficient sunlight to meet the charging demand. Furthermore, the system integrates grid connectivity, which acts as a backup power source when both solar energy and battery storage are unable to meet the energy requirements of the charging stations. The grid connectivity ensures that the system remains operational without any interruption, providing a reliable power supply whenever the renewable sources fall short. This hybrid approach that combines solar power, battery storage, and grid power ensures that the charging stations can operate smoothly regardless of environmental conditions, without compromising on reliability or availability. The seamless integration of these energy sources makes the system both sustainable and efficient, balancing renewable energy with the security of a traditional grid backup. The grid connection system is designed to be intelligent and adaptive, automatically switching between the solar energy, battery, and grid power based on real-time energy availability. When the solar panels are producing excess energy, the system prioritizes the use of this renewable energy, thereby reducing the amount of electricity drawn from the grid. However, when solar generation is insufficient, the system automatically taps into the battery storage or the grid, ensuring that users can continue to charge their vehicles without disruption.

5.2 POWER GENERATION IN PROPOSED SYSTEM

This automated power management allows the system to optimize energy use, reducing operational costs and minimizing the carbon footprint associated with the charging process. In addition to the energy generation and storage components, the system also includes a smart payment mechanism that enhances the user experience and ensures smooth, secure, and efficient transactions. The payment system is designed to accommodate various payment methods, including mobile apps, RFID cards, QR codes, and NFC-enabled wallets. This range of payment options ensures that the system is accessible to a broad spectrum of users, catering to both tech- savvy individuals and those who prefer more traditional methods of payment. The flexibility to choose from multiple payment platforms allows users to charge their vehicles in a manner that suits their preferences, making the charging process more convenient and user-friendly.

The payment system is built with security in mind, employing encrypted transaction protocols to safeguard user information and prevent unauthorized access. Secure payment processing is crucial in maintaining user trust, particularly as the number of digital transactions continues to rise. By using encrypted transactions, the system ensures that sensitive financial data is protected, reducing the risk of fraud and ensuring that users' privacy is maintained throughout the charging process. Additionally, the RFID- based payment method offers a fast and contactless way for users to initiate their charging session. The convenience of simply tapping an RFID card or using a mobile wallet to complete a transaction adds to the overall user experience, making it quick and easy to start and stop charging. Beyond the basic functionality of facilitating payments, the smart payment system is equipped with features that provide users with greater control and visibility over their charging sessions. One such feature is usage history tracking, which allows users to monitor their past charging activities, including the amount of energy consumed and the associated costs. This feature enables users to track their consumption patterns and gain a clearer understanding of their charging behaviors, which can help them optimize their energy use and reduce costs over time. Real-time pricing information is another valuable feature that allows users to see the current cost of charging at any given moment. This is particularly important in areas where energy prices fluctuate based on demand or time of day, giving users the ability to plan their charging sessions for optimal cost savings.

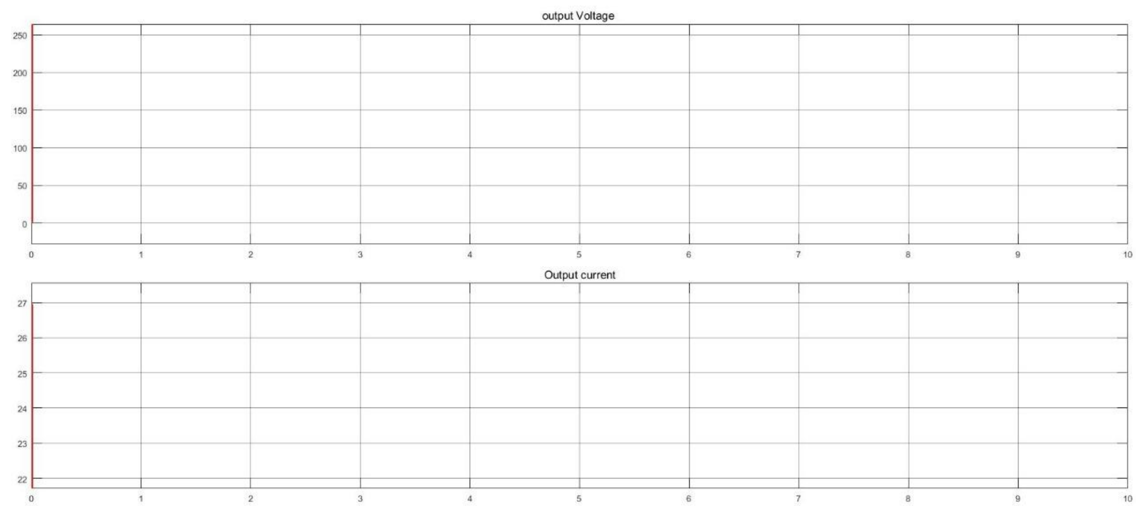

Fig.5.2-Output current and voltage of the proposed system

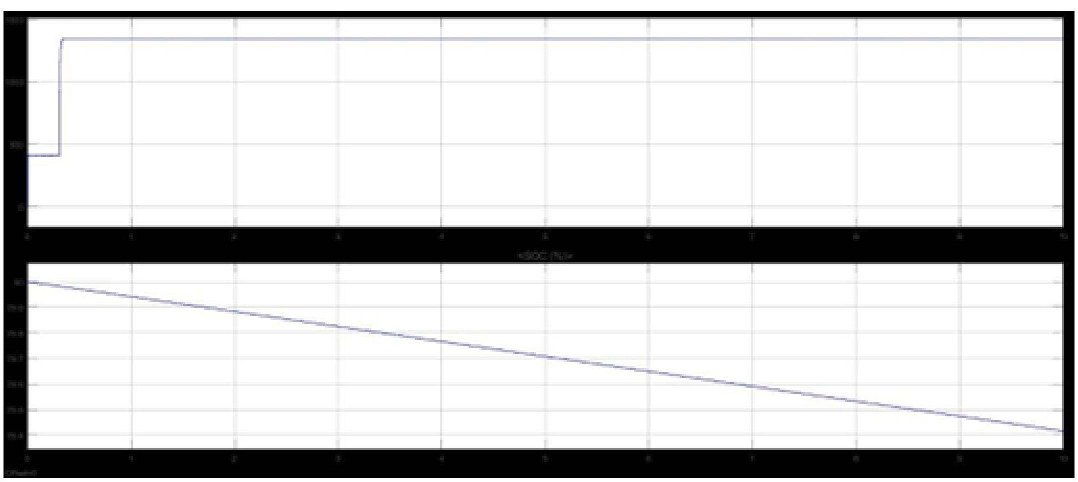

Fig.5.3-Proposed Solar Charging outlet

The smart payment system also supports various payment structures, including pay-per-use, subscription-based plans, and fleet management billing. This flexibility makes the system adaptable to a wide range of users, from individual EV owners to businesses operating large fleets of electric vehicles. For individuals who only occasionally use public charging stations, the pay-per-use model is an ideal solution, as it charges users based on the energy they consume during each session.

5.3 OUTPUT CURRENT AND VOLTAGE OF THE PROPOSED SYSTEM

On the other hand, regular users or fleet operators may prefer subscription-based plans, which offer fixed pricing for a certain number of charging sessions or unlimited charging over a given period. Fleet management billing is particularly useful for businesses with EV fleets, as it allows for centralized billing and tracking of charging expenses across multiple vehicles. This customizable approach ensures that the system can meet the unique needs of different types of users, making it scalable and adaptable to various market demands. The proposed system represents a highly efficient, sustainable, and user-friendly solution for EV charging. By combining solar power, battery storage, grid connectivity, and a smart payment mechanism, the system addresses the key challenges associated with traditional EV charging infrastructure, such as high operational costs, grid dependency, and inefficient payment processes. The incorporation of renewable energy sources significantly reduces the environmental impact of EV charging while enhancing the system's economic sustainability. At the same time, the intelligent payment system offers users a seamless and secure way to manage their charging sessions, further improving the convenience and accessibility of EV charging. As electric vehicles become more widespread, systems like this one will play a pivotal role in shaping the future of sustainable transportation, ensuring that EV charging infrastructure keeps pace with the increasing demand for clean and efficient mobility solutions.

The system effectively produces enough energy during the hottest parts of the day to fulfil charging needs. Lithium-ion batteries and other energy storage devices store extra energy for usage at night or in overcast situations to guarantee uninterrupted operation. Furthermore, the system may feed excess solar energy back into the grid or pull energy from the grid during times of high demand thanks to the enhanced grid connection's ability to provide bi-directional energy flow. In addition to minimizing energy usage and lowering reliance on non-renewable sources, this guarantees steady functioning. The system's intelligent payment architecture, which streamlines the user experience, is one of its primary features. Numerous payment methods, such as mobile applications, QR codes, RFID cards, and NFC-enabled wallets, are supported by the platform, making it simple and accessible to a broad spectrum of consumers. Additionally, the system offers customizable payment choices including pay-per-use or subscription plans, use history, and real-time transaction updates. Long-term usefulness is also ensured by the payment system's flexibility to adjust to new payment technologies.

IoT-enabled sensors are essential for keeping an eye on the infrastructure's functioning. Real-time data on energy consumption, battery life, and system health is gathered by these sensors and evaluated to spot possible problems.

Table 5.1: Results

Parameter	Value
Average Power	15kW
Charging Efficiency	90%
Grid Power Utilization	10kWh
Renewable Energy Utilization	85%
Carbon Emission Reduction	30kg of CO_2
No. of EV charged per day	25

Predictive maintenance is made possible by this proactive strategy, which reduces downtime and guarantees reliable service. Users are also given access to the real-time data, allowing them to monitor the status of their charging sessions and verify whether charging stations are available. In addition to fostering trust, this openness lowers operational inefficiencies. The system's modular architecture makes it simple to scale, allowing it to adjust to rising demand. The infrastructure may be tailored to meet particular demands, whether in rural or urban settings. Future improvements may incorporate AI-powered energy management systems, more renewable energy sources, or quicker charging technologies. As the EV industry expands, these developments will guarantee the system's continued relevance and better optimize it. The system was successfully implemented and rigorously tested, showcasing its power utilization, smart payment processing, and seamless grid integration. The integration of solar power played a crucial role in ensuring that the charging stations were not only environmentally friendly but also economically sustainable. By harnessing solar energy, the system reduced reliance on traditional power sources, thus lowering operational costs and minimizing the carbon footprint of the charging process. The solar panels consistently provided the required electricity to charge EVs, even in fluctuating weather conditions, thanks to the effective management of energy storage and distribution.

The smart payment processing feature was another standout aspect of the system. The RFID-based payment mechanism was successfully implemented to provide secure and automated transactions, making the charging process fast and hassle-free for users. Users could initiate their charging sessions simply by scanning their RFID cards, and the system automatically calculated and deducted the appropriate charges based on the amount of energy consumed. The contactless nature of RFID technology made the payment process both secure and efficient, eliminating the need for manual intervention and reducing the potential for human error or fraud. The payment system also offered real-time transaction updates, ensuring users were informed about the cost of their charging session as it progressed, thus enhancing the overall user experience. One of the key elements that contributed to the system's reliability and performance was the Arduino-controlled power distribution system. The controller effectively managed the flow of energy between the solar panels, battery storage, and the grid, ensuring that energy was distributed in the most efficient manner possible. The Arduino-based controller was programmed to prioritize solar energy

usage when available, automatically switching to battery power or grid power when solar generation was insufficient. This intelligent energy management ensured that the system operated continuously without interruptions, maintaining a stable and reliable power supply for the EV chargers. Additionally, the real-time monitoring capabilities provided by the controller allowed operators to oversee the system's performance and make any necessary adjustments to optimize efficiency. The system also featured an LCD screen that displayed real-time charging status and transaction details, providing users with immediate feedback on their charging session. This real-time data display helped users stay informed about their charging progress, including the amount of energy consumed, the cost of the session, and the remaining charging time. Such transparency added to the overall user experience, allowing individuals to make informed decisions about when to start and stop their charging sessions based on the current energy availability and pricing. The inclusion of this visual feedback mechanism also helped to eliminate uncertainty, ensuring that users could confidently use the charging station and understand their charging costs at every step of the process.

In terms of system performance, the overall setup proved to be reliable and cost-effective. The combination of solar power, battery storage, and grid integration ensured that the charging station operated efficiently even in less-than-ideal environmental conditions. The battery storage feature proved invaluable in times of low sunlight, storing excess energy generated during sunny periods and making it available when needed most. The grid connection provided an additional layer of reliability, ensuring that users could still access charging services if solar power and battery storage were insufficient. The system was also tested under various real-world conditions, and it performed consistently well. During peak solar hours, the charging stations relied almost entirely on solar energy, minimizing grid dependence and reducing operational costs. At night or during cloudy periods, the system smoothly transitioned to battery power, ensuring that there was no disruption to the charging process. When both solar and battery power were unavailable, the grid connection kicked in, ensuring uninterrupted service. This hybrid approach of combining solar power, battery backup, and grid connectivity created a robust and dependable system that could cater to the energy needs of electric vehicles without relying too heavily on any single energy source. Overall, the system demonstrated its potential as a reliable, cost-effective, and environmentally sustainable solution for electric vehicle charging. The integration of renewable solar energy not only made the system eco-friendly but also contributed to long-term cost savings by reducing dependence on the grid. The intelligent power distribution managed by the Arduino-based controller ensured that energy was efficiently utilized, while the RFID-based payment system made transactions smooth and secure for users. The real-time monitoring provided by the LCD display enhanced user interaction, providing them with valuable data regarding their charging sessions and costs. Given its successful implementation and performance, the system proved to be an effective solution for meeting the growing demand for electric vehicle charging infrastructure while promoting sustainability and reducing operational costs.

CHAPTER 6

CONCLUSION AND FUTURE WORK

The suggested solar-powered EV charging infrastructure provides a sustainable, dependable, and user-friendly way to satisfy the rising demand for EV charging. It is combined with a sophisticated grid connection and smart payment system. The system minimizes environmental effect while guaranteeing stability, efficiency, and scalability through the utilization of sophisticated power management systems, current communication protocols, and renewable energy. In conclusion, the suggested solar-powered EV charging system is a workable and environmentally friendly fix. Its versatility, energy efficiency, environmental advantages, and user-friendly design make it a crucial part of the ecosystem for EV charging in the future. This technology has the potential to significantly contribute to the global adoption of renewable energy and green transportation with more study and development.

By decreasing reliance on fossil fuels and greenhouse gas emissions, the system's use of solar energy as its main power source encourages sustainability. Even in the absence of sunshine or at night, continued functioning is ensured by the use of energy storage options, such as batteries. Furthermore, bi-directional energy flow is made possible by the sophisticated grid connection, which guarantees reliable operation and maximizes energy use by allowing the system to either send extra energy back to the grid or draw from it during times of high demand.

6.1 FUTURE WORK

The proposed solar-powered EV charging infrastructure with an advanced grid connection and smart payment system offers a sustainable, efficient, and user-friendly solution for EV owners. By leveraging renewable energy, secure transactions, and smart grid integration, the system contributes to a greener and smarter transportation ecosystem. Further research and technological advancements will enhance its scalability, efficiency, and adoption in real- world applications.

The proposed solar-powered EV charging infrastructure with a smart payment system and advanced grid connection offers a sustainable, efficient, and user-friendly alternative to conventional charging stations. By integrating renewable energy, battery backup, and automated payment mechanisms, the system addresses key challenges in EV charging accessibility and energy management. This design promotes green energy adoption, reduces charging costs, and enhances user convenience, making it a viable solution for the future of EV infrastructure.

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CONFERENCE PROCEEDINGS

Improved Design of Solar Powered EV Charging Infrastructure with Smart Payment System using Advanced Grid Connection System

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As electric vehicles (EVs) continue to gain traction as a reliable alternative to gasoline-powered cars, the need for efficient and sustainable charging solutions is growing. One promising option is solar-powered EV charging, which offers a cleaner and more eco-friendly alternative to traditional grid-based charging. By harnessing solar energy, these charging stations provide renewable power to EVs, reducing reliance on fossil fuels and minimizing environmental impact. This project focuses on developing an advanced solar-powered EV charging station that integrates key components such as solar panels, energy storage systems, smart grid connectivity, and an optimized charging infrastructure. The goal is to create a cost-effective and sustainable solution that supports the transition to greener transportation. By combining renewable energy with electric vehicle technology, this initiative contributes to energy sustainability while helping to lower the carbon footprint of modern transportation.

Keywords: EV charging, Vehicle-Grid Technology, Smart Grid

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