

Design and Performance Analysis of A Solar-Powered EV Charging Station for Campus Use

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Abstract: *The increasing adoption of electric vehicles (EVs) has led to growing demand for energy storage solutions. Conventional grid-connected charging stations rely heavily on grid electricity that is generated using fossil fuels, further reducing the benefits of electric mobility in terms of environmental sustainability and also increasing the demand on existing electricity grid. To address this issue, this work proposes the design and simulation of a solar-powered EV charging station that can be implemented in a university campus environment. The proposed system is an integration of a photovoltaic (PV) generation system and a battery energy storage system (BESS) that will offer green and sustainable electricity to charge EVs. The primary software that is used for the simulation is MATLAB/Simulink which is the software that will be used to simulate the behaviour of the PV system, battery system and EV charging load under varying solar and charging load. The performance indicators that are evaluated in the simulation are PV energy output, BESS state of charge (SOC), charging reliability, grid energy dependency, and carbon emissions reduction. Results indicate that the PV charging station can potentially provide a significant portion of campus EV charging load while avoiding unstable charging conditions. The use of BESS increases the charging reliability by balancing intermittent PV generation and charging demands. Further, the system is not highly dependent on the grid, and has considerable CO₂ reduction values, making it a viable and environmentally friendly alternative for campus EV charging systems.*

Keywords: Solar Photovoltaic (PV); Electric Vehicle Charging Station (EVCS); Battery Energy Storage System (BESS); MATLAB/Simulink Simulation; Renewable Energy Integration.

I. INTRODUCTION

Electric vehicles (EVs) have gained popularity all over the world due to the rapid shift towards sustainable transportation and clean energy systems. Electric mobility is becoming a popular theme among governments, industries, and research institutions as a tool to cut greenhouse gas emissions, lower reliance on fossil fuels, and enhance the quality of air in urban areas. Nevertheless, the large-scale implementation of EVs relies strongly on the presence of convenient, reliable, and long-term green charging networks. With the ongoing growth in the number of EVs on the road, the need to have an efficient charging system that can handle the rising energy demand has become a major concern to the current power systems [3], [13].

1.1 Growth of Electric Vehicles

Over the past years, electric cars have received a lot of interest as a viable alternative to traditional internal combustion engine cars. The quick spread of the EV market all over the world has been facilitated by technological advances in battery technologies, government subsidies, and increased environmental consciousness. Various nations are setting policies that promote the shift to electric mobility such as subsidies, taxation incentives and tightening of restrictions on emissions [14].



As EV adoption increases, the demand for charging infrastructure is also rising rapidly. Public charging stations, workplace chargers, and residential charging facilities are being developed to support the growing EV ecosystem. However, traditional charging systems that rely solely on the electrical grid may face challenges in handling the increasing load demand. Without proper infrastructure planning, large-scale EV charging could lead to significant stress on existing power distribution networks [11], [20].

1.2 Problems with Grid Charging

Although grid-powered charging stations are widely used, they present several challenges from both economic and environmental perspectives. One of the primary concerns is the high cost of electricity, particularly during peak demand periods. As EV charging demand grows, increased electricity consumption may result in higher operational costs for charging infrastructure operators and end users [6], [13].

Another major concern is the environmental impact associated with electricity generation. In many regions, grid electricity is still produced largely from fossil fuel-based power plants such as coal and natural gas. Consequently, charging EVs using grid electricity may indirectly contribute to greenhouse gas emissions, thereby reducing the environmental benefits associated with electric mobility [3], [18].

Additionally, large-scale EV charging may impose significant stress on existing power distribution systems. Sudden increases in electricity demand during peak charging periods can lead to grid instability, voltage fluctuations, and potential overloading of distribution transformers [11], [20]. These challenges highlight the need for alternative charging solutions that can reduce dependence on conventional grid electricity.

1.3 Solar-Powered EV Charging

The ability to incorporate renewable energy sources in charging infrastructure of EVs has a potential solution to most of the challenges posed by grid-based charging systems. Solar photovoltaic (PV) systems, among other renewable energy technologies, have become one of the most appropriate choices as it is widely available, can be scaled, and the cost of installation is declining [3], [15].

Solar-powered EV charging stations consist of photovoltaic panels converting solar energy into electricity that can be used to directly charge electric vehicles or stored in battery energy storage systems (BESS) for future use. Battery storage improves the system's reliability by reducing the impact of the weather and daily fluctuations in solar energy production [5], [9].

College campuses are the best places to establish solar-powered EV charging systems. Campuses characteristically possess large rooftop spaces, spaces that can be used to install PV systems, and predictable movement patterns of students, faculty and staff. Also, most EV charging demand on campuses is during the day, which coincides with the optimal time of solar energy production. These attributes render campuses as one of the most appropriate areas to implement and test solar-powered EV charging systems [1], [2].

1.4 Research Gap

A number of studies have investigated how to design and implement EV charging stations with renewable energy sources. A significant number of these studies target urban charging systems, commercial charging systems, or highway fast-charging systems. Although such systems are significant in large-scale EV adoption, they tend to be very dependent on grid electricity or hybrid power sources.

Existing research has also investigated photovoltaic-based charging stations; however, many of these studies emphasize general system design or economic feasibility without detailed simulation-based performance evaluation. In particular, limited research has been conducted on campus-specific EV charging systems that consider local mobility patterns, solar resource availability, and integrated battery storage.

Moreover, simulation models, including MATLAB/Simulink that has been extensively utilized to model renewable energy systems, have relatively few published studies using detailed MATLAB-based modeling of the performance of



solar-powered EV charging stations in campus contexts. The existing gap indicates the necessity of the widespread simulation-based method that assesses the behavior of the system in different conditions of solar and load variations.

1.5 Contributions of the Paper

In this paper, we attempt to close the gap by designing and analysing the performance of a solar-powered EV charging station for a campus environment. This research makes the following key contributions:

1. **Design of a solar photovoltaic powered EV charging system** suitable for campus environments, integrating photovoltaic generation, battery storage, and EV charging infrastructure.
2. **Development of a MATLAB/Simulink-based simulation model** describing the relationship between the PV system, battery energy storage system (BESS), electric vehicle (EV) charging load and the grid.
3. **Performance evaluation of the charging system under multiple operating scenarios** such as solar irradiance, EV charging load, and state of charge (SOC) of battery storage.
4. **Assessment of economic and environmental benefits** such as grid independence, increased charging availability and reduced carbon footprint with the integration of renewable energy.

The findings from this study offer insights into the potential and performance of solar-powered electric vehicle (EV) charging station in a campus setting and help build sustainable transportation energy systems.

II. LITERATURE REVIEW

The recent spike in electric vehicle (EV) adoption has increased the need for effective and green charging stations. Researchers around the globe have been debating some of the ways of integrating renewable energy with EV charging systems to reduce the dependence on the distribution network. Solar photovoltaic (PV) power has been found to be one of the most viable renewable energy sources to power EV due to its ubiquity and decreasing installation cost. Some studies have examined the design, performance and feasibility of solar charging stations of EV. In this section, we shall review previous studies regarding solar EV charging stations, combining photovoltaic and battery energy storage, and energy system modelling using MATLAB.

2.1 Solar EV Charging Systems

Photovoltaic-powered electric vehicle (EV) charging systems are the latest trend towards a sustainable solution for growing electric mobility. They utilise photovoltaic cells that convert the energy of the sun into electricity that is used to charge electric vehicles (EV) directly, or via a storage system.

The viability and functionality of solar-powered EV charging infrastructure in various settings have been explored in previous studies. Studies on PV-grid integrated EV charging stations have shown that integration of solar generation and grid support can greatly lower the costs of operation and carbon emission and provide reliable power supply [1]. Special systems usually include PV arrays, power electronic converters and EV charging units to provide clean electricity to charge vehicles [6], [12].

Research work carried out on solar EV charging systems implemented in universities setting has demonstrated encouraging outcomes. Indicatively, a study examining PV-charged EV charging in educational establishments pointed out that campuses are the best sites because of the open space and roofing that can be used to install photovoltaic systems [1]. Moreover, it is also found that campus charging demand generally coincides with daytime which is compatible with the solar energy generation patterns [2]. The attributes allow solar charging stations to be highly efficient and less grid dependent [3].

Moreover, the study of the design and deployment of stand-alone solar ev charging stations that can be independent of the primary power supply has been examined in a few studies. These systems usually come with PV arrays, battery storage units and inverters that can be used to provide continuous charging. These systems have been analysed in



performance terms to show that solar energy will be able to supply a significant part of the EV charging load under favourable solar conditions and help to achieve significant savings in the emission of greenhouse gases and operation costs [2], [3].

2.2 PV–Battery Energy Storage Systems

The use of battery energy storage systems (BESS) is crucial in improving the efficiency and effectiveness of solar-powered EV charging systems. Solar power is intermittent and weather-dependent, which means that solar energy needs to be stored in batteries as a buffer to the excess solar energy generated during sunrise and to store energy during nights and cloudy days.

Battery energy storage systems provide multiple services to EV charging. Firstly, they offer energy storage, enabling the system to store excess solar energy during the day and release it during peak charging times or low solar production [5]. This helps to maintain a reliable and consistent energy source for EV charging [7], [9].

Second, battery storage helps achieve **load balancing** within the charging station. During peak charging periods, multiple electric vehicles may require simultaneous charging, resulting in increased load demand. The battery system can supply additional power to support these peak loads, thereby reducing the burden on the electrical grid [5], [7].

Several studies have examined the performance of PV–battery integrated EV charging systems and have demonstrated that such configurations significantly enhance system reliability. Research analyzing solar-powered EV charging infrastructure equipped with battery storage has shown that BESS can reduce grid electricity consumption and improve overall system efficiency [2], [5]. In addition, battery storage systems help mitigate fluctuations in solar energy generation caused by variations in irradiance, cloud cover, and seasonal changes [19].

Next-generation battery technologies, like lithium-ion batteries, are commonly adopted in EV charging infrastructure because of the higher energy density, longer life cycle and efficiency than the conventional battery technologies [5], [6]. The combination of BESS and PV can allow EV charging systems to operate more reliably and effectively harness PV energy [2], [7].

2.3 MATLAB-Based Energy System Simulation

Simulation tools play an important role in analyzing the performance of renewable energy systems before practical implementation. Among the various simulation platforms available, MATLAB and its Simulink environment are widely used for modeling, simulation, and analysis of power systems and renewable energy technologies.

MATLAB provides a flexible platform for modeling photovoltaic systems, battery storage units, and power electronic converters [19]. Researchers frequently use MATLAB/Simulink to develop detailed models that simulate the behavior of PV modules under varying solar irradiance and temperature conditions [1], [2]. These models allow researchers to evaluate system performance, optimize design parameters, and analyze energy flow within renewable energy systems [16], [17].

MATLAB is not only used for PV modeling, but it is also frequently employed to design control algorithms for energy management systems in renewable energy systems. For instance, maximum power point tracking (MPPT) algorithms can be developed in MATLAB to maximise the power output of photovoltaic systems under varying weather conditions [4]. Likewise, we can develop battery management strategies to control battery charging and discharging, thus enhancing battery performance and longevity [5], [6].

A number of studies have employed MATLAB simulation models for solar-powered EV charging stations [1], [2]. These include PV power generation, energy storage, EV charging loads and grid interconnections. The simulations allow researchers to assess various system metrics including power output, battery SOC, charging capacity, and grid reliance [7], [9]. MATLAB simulations also allow researchers to simulate a range of operating scenarios, such as different levels of solar radiation, charging load and system parameters, to provide insights into system performance and optimisation [19].



2.4 Research Gap

Although significant research has been conducted on EV charging infrastructure and renewable energy integration, several gaps remain in the existing literature. Many studies focus primarily on large-scale urban charging networks or commercial charging stations designed for public transportation systems. These systems often rely heavily on conventional grid electricity, which limits the environmental benefits associated with electric mobility.

Additionally, while photovoltaic-based EV charging systems have been explored in previous studies, many of these investigations emphasize general system design or economic feasibility without considering the specific characteristics of campus environments. University campuses possess unique operational features such as predictable mobility patterns, concentrated charging demand, and availability of suitable solar installation areas, which require tailored charging system designs.

Furthermore, although MATLAB/Simulink has been widely used for modeling renewable energy systems, relatively few studies have applied detailed MATLAB-based simulation frameworks to analyze solar-powered EV charging stations specifically designed for campus use. Comprehensive simulation studies that integrate PV generation, battery storage systems, EV charging loads, and grid interaction within a unified MATLAB environment remain limited.

Thus a systematic study integrating solar PV generation, battery energy storage systems and MATLAB simulation modelling is required to determine the functionality of EV charging stations in campus settings. The solution to this research gap will offer useful information on the viability, stability and sustainability of EV charging infrastructure that is powered by renewable energy and specific to academic campuses.

Author	System Studied	Methodology	Key Contribution
Kassem et al. (2025)	PV-grid integrated EV charging station	Simulation-based system design and optimization	Demonstrated optimal sizing of PV systems for EV charging infrastructure and evaluated cost-effectiveness in university environments
Ahmad et al. (2024)	Solar-powered EV charging station with battery storage	Experimental monitoring and performance analysis	Evaluated system performance under real operating conditions and highlighted the benefits of battery storage for energy reliability
Ghosh (2025)	Solar-powered EV infrastructure (BEV and FCEV systems)	Comprehensive literature review	Analyzed the potential of integrating solar energy into EV infrastructure and emphasized sustainability benefits and renewable integration

Table 1. Summary of Previous Research on Solar-Powered EV Charging Systems

III. SYSTEM ARCHITECTURE

production, energy storage, and EV charging infrastructure to enable reliable and sustainable EV charging services on a campus setting. The system will be engineered to use the solar photovoltaic (PV) energy as the main power source together with a battery energy storage system (BESS) and optional grid support to ensure that the charging activity will not be unstable on different conditions.

The architecture will allow a conversion, storage, and distribution of solar panel generated electrical energy effectively. The PV system produces electricity during prime sunlight periods which could be directly utilized to recharge electric



vehicles or stored in the battery system to be used later. The battery storage system or grid connection may supplement the solar energy production when the demanded energy is not enough to charge the EVs.

3.1 Overall System Components

The solar-powered EV charging station presented will be made up of various essential components that will collaborate to provide an efficient energy production, conversion, and use.

Solar Photovoltaic (PV) Array

The charging station's primary source of power is the photovoltaic (PV) array. The PV effect is the conversion of the sun's rays into direct current (DC) electricity by solar panels. The power output of the PV system is dependent on the solar radiation, PV efficiency, temperature and orientation of the panels.

Maximum Power Point Tracking (MPPT) Charge Controller

The MPPT charge controller maximises the output power of the photovoltaic (PV) system under different environmental conditions. The controller optimises the voltage and current of the PV system to increase the power output of the PV system [4].

DC-DC Converter

The DC-DC converter regulates the voltage generated by the PV array and stabilizes the power supplied to the DC bus. This component ensures efficient energy transfer between the PV array, battery storage system, and other electrical components.

Battery Energy Storage System (BESS)

The energy storage system stores the excess PV energy generated during the day time. This energy can then be used when PV production is low or when EV charging demand is higher than instantaneous PV production. BESS increases system reliability and ensures the constant supply of charge.

Inverter

The inverter converts DC electricity produced by the PV system or battery storage system into alternating current (AC) electricity that is used by the EV charging station. It also ensures sufficient regulation of voltage and frequency for safe charging.

EV Charging Unit

The electric vehicle (EV) charging unit transforms the electricity in the charging station to the electric car battery. The proposed charging system is Level-2 AC because this is the most suitable for the campus environment when the electric cars spend more than 4 hours in the parking lot [6], [12].

Grid Connection

An optional grid connection is included to provide backup power when both solar generation and battery storage are insufficient. The grid connection improves system reliability and ensures uninterrupted charging services.

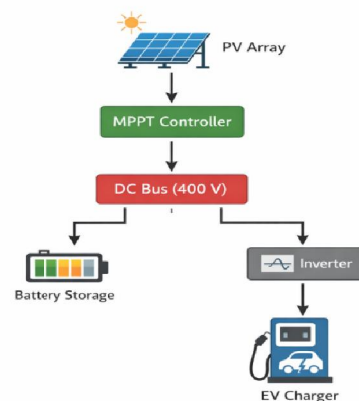


Figure 1: Architecture of Solar-Powered EV Charging Station



Component	Specification
PV System Capacity	7.4 kWp
Battery Storage Capacity	34.56 kWh
Inverter Rating	6 kW
Charging Type	Level-2 AC Charging
DC Bus Voltage	400 V

Table 2. System Specifications of the Proposed Solar-Powered EV Charging Station.

IV. MATHEMATICAL MODELING

This section describes the mathematical models for the analysis of the proposed solar-driven EV charging station. They represent the PV power generation, energy storage characteristics of the batteries, EV charging load, and the energy balance of the system. These models are incorporated into the MATLAB/Simulink simulation to assess the system performance under various operating conditions.

PV System Model

Electrical power of a photovoltaic system varies with the solar irradiance, panel efficiency, and effective surface area of the PV modules. The power of the PV system can be given as:

$$P_{PV} = \eta_{PV} \times A \times G$$

Where:

- η_{PV} = PV module efficiency
- A = surface area of the photovoltaic panel
- G = solar irradiance (W/m²)

The required photovoltaic system capacity can be estimated using the following equation:

$$P_{PV} = \frac{E_{load}}{H_{avg} \times \eta_{system}}$$

Where:

- E_{load} = daily EV charging energy demand
- H_{avg} = average solar irradiance
- η_{system} = overall system efficiency

This equation helps determine the appropriate PV system size required to meet the charging demand.

Battery Energy Storage Model

The battery energy storage system (BESS) stores the excess power during high solar power production and delivers power during low PV power. The required capacity of the battery is:

$$C_{battery} = \frac{E_{load} \times Autonomy}{DoD}$$

Where:

- $Autonomy$ = backup duration of the system
- DoD = depth of discharge of the battery

The battery system improves system reliability and ensures continuous EV charging even during periods of reduced solar irradiance.



EV Charging Load Model

The EV charging demand depends on the number of vehicles connected to the charging station, the charging power, and the charging duration. The total energy demand for EV charging can be expressed as:

$$E_{EV} = N \times P_{charge} \times t$$

Where:

- N = number of EVs being charged
- P_{charge} = charging power of each EV
- t = charging duration

This model helps estimate the total charging energy required within a given time period.

Energy Balance Equation

The overall energy balance within the charging station can be represented as:

$$P_{PV} + P_{grid} + P_{battery} = P_{EV} + Losses$$

Where:

- P_{PV} = power generated from the photovoltaic system
- P_{grid} = power supplied by the electrical grid
- $P_{battery}$ = battery charging/discharging power
- P_{EV} = power required for EV charging
- **Losses** = system losses due to conversion and transmission

This equation makes sure that the overall power of the PV system, battery storage and grid connection can meet the EV charging demand and system losses.

Parameter	Value
PV Efficiency	18–20 %
Solar Irradiance	800–1000 W/m ²
Battery Depth of Discharge (DoD)	60%
EV Charging Power	3–7 kW
DC Bus Voltage	400 V

Table 3. Key simulation parameters used in the MATLAB model of the solar-powered EV charging station.

V. MATLAB / SIMULINK MODELING AND SIMULATION

MATLAB/Simulink is used to model the proposed solar powered electric vehicle (EV) charging station. The model includes the solar power generation system, battery storage, EV charging load and grid interactions to investigate the behaviour of the system under various conditions.

The MATLAB/Simulink model represents the dynamic interaction between the major components of the charging system and enables evaluation of power flow, battery behavior, and charging demand over the simulation period.



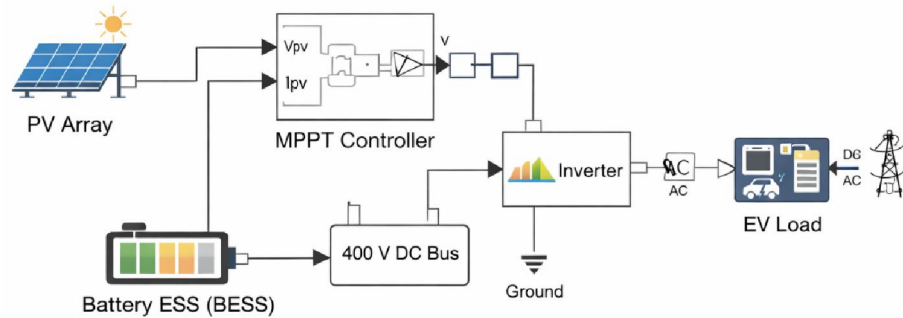


Figure 2: MATLAB Simulink Model of the EV Charging System

The overall simulation model consists of several interconnected blocks representing the key components of the charging infrastructure, including:

- Photovoltaic (PV) array model
- Maximum Power Point Tracking (MPPT) controller
- Battery energy storage system (BESS)
- EV charging load model
- Grid connection

Photovoltaic model takes input parameters such as solar irradiance and temperatures and produces voltage, current and power output. The MPPT controller is used to make the PV system work to the optimal power point so as to use the maximum amount of solar energy under different environmental conditions [4].

The battery energy storage system is designed such that it models the dynamics of charging and discharging and the battery state of charge (SOC) over the course of the simulation. The battery will store surplus solar energy at times of maximum production and release power when solar energy is less or the demand to charge power is higher.

The EV charging load is modeled based on the **number of vehicles, charging power, and charging duration**. In a typical campus environment, charging demand exhibits peak periods during **morning arrival hours and afternoon departure hours**, which are incorporated into the simulation load profile.

An **energy management algorithm** is implemented to prioritize renewable energy utilization. The control logic follows a hierarchical energy flow strategy:

1. Solar power is used as the primary energy source for EV charging.
2. When solar generation is insufficient, the battery energy storage system supplies additional power.
3. If both solar and battery energy are insufficient, the electrical grid provides backup power.

This control strategy ensures efficient utilization of renewable energy while maintaining reliable EV charging operations [7], [9].

VI. SIMULATION SCENARIOS AND RESULTS

The proposed solar-powered EV charging station is assessed in terms of its performance using MATLAB/ Simulink simulations under various operating conditions. Simulation framework examines the relationship between photovoltaic generation of power, battery energy storage, EV charging demand and grid support.

To evaluate the robustness of the system, several operating scenarios are considered:

- **Normal sunny day conditions**, representing optimal solar irradiance levels.



- **Cloudy weather conditions**, representing reduced solar generation.
- **High EV charging demand**, where multiple vehicles require charging simultaneously.
- **Low solar irradiance conditions**, representing early morning or late evening hours.

These scenarios allow the evaluation of system performance in terms of solar energy utilization, battery behavior, and grid dependency under realistic operating environments.

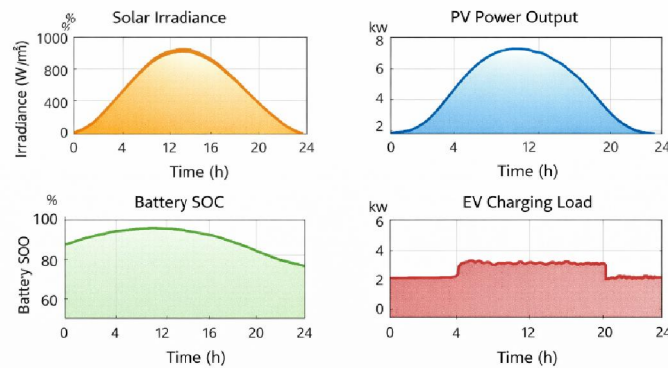


Figure 3: Solar Irradiance, PV Power Output, Battery SOC, and EV Charging Load

Figure 3 presents the combined simulation results including solar irradiance, photovoltaic power output, battery state of charge (SOC), and EV charging demand over the simulation period. The results illustrate the relationship between solar energy availability and the charging system operation.

During peak sunlight hours, the photovoltaic system produces higher power output, which is used to charge electric vehicles and store excess energy in the battery storage system. As solar irradiance decreases, the battery discharges to maintain the EV charging demand. This behavior ensures continuous charging availability while minimizing reliance on the electrical grid.

The findings indicate that when solar PV generation is combined with battery storage, it can greatly enhance system reliability and provide the opportunity to efficiently use renewable energy in the charging station [2], [5], [7].

Metric	Value
Solar Energy Utilization	~85%
Grid Dependency	~15%
Charging Efficiency	~90%
Average EV Energy Demand	25–35 kWh/day

Table 4. System Performance Metrics

VII. ECONOMIC AND ENVIRONMENTAL ANALYSIS

The economic viability of the proposed solar-powered EV charging station is assessed based on the cost of capital of the key system components such as photovoltaic panels, battery energy storage systems, inverters, and EV charging infrastructure. The cost of the renewable energy systems, especially in the beginning, may be quite expensive but the operational costs are going to be saved and minimizing electricity use in the grid enhances the economic feasibility of the system.



Based on the system configuration and expected solar energy generation, the estimated **payback period** of the proposed charging station is approximately **5–8 years**, depending on local electricity tariffs, solar resource availability, and EV charging demand. The integration of solar photovoltaic generation reduces operational electricity costs while improving energy independence from the conventional power grid [1], [3].

In order to test the economic performance of the system, the Levelized Cost of Charging (LCOC) is estimated. LCOC is defined as the average price of supplying one unit of electrical power to charge EVs throughout the system life. This may be formulated as:

$$LCOC = \text{Total Energy Delivered} / \text{Total System Cost}$$

Where:

- **Total System Cost** includes the installation cost of PV modules, battery storage systems, inverters, and EV charging equipment.
- **Total Energy Delivered** represents the total electrical energy supplied to EVs during the operational lifetime of the system.

Besides its economic benefits, the proposed system has its own environmental benefits. The charging station minimizes the emission of greenhouse gases related to traditional power generation by substituting grid electricity with renewable energy sources such as solar energy.

The reduction in carbon dioxide (CO₂) emissions can be estimated using the following equation:

$$CO_{2,saved} = E_{solar} \times EF_{grid}$$

Where:

- E_{solar} = total energy generated from the solar PV system
- EF_{grid} = emission factor of grid electricity (kg CO₂ per kWh)

The results indicate that utilizing solar energy for EV charging can significantly reduce carbon emissions while supporting sustainable transportation and renewable energy adoption within campus environments [3], [18].

VIII. DISCUSSION, CONCLUSION, AND FUTURE WORK

Discussion

The simulation results from the MATLAB/Simulink model show the effectiveness of the proposed solar powered EV charging station to campuses. The integration of photovoltaic energy production and a battery energy storage system enable the charging station to be highly efficient in terms of using sustainable energy and to be able to provide reliable charging.

The findings show that when the sun is shining and there is high solar irradiance, the photovoltaic system can produce enough energy to support a large percentage of the EV charging. The surplus energy generated during sunny periods is stored in the battery energy storage system, which can be used during periods of low solar power output [5]. This helps to ensure consistent EV charging during variable solar output [2], [7].

In addition, the battery system also increases the system's reliability and reduces the need for grid energy. The energy storage system offers an uninterrupted supply of charging and balances the energy supply and demand by storing the excess energy produced and releasing it when it is less [5], [9]. Overall, the results of the simulation show that the proposed system can be effective to incorporate renewable energy in EV charging systems [1], [2].

Conclusion

This paper gave the design and performance evaluation of a solar powered EV charging station that could be used on the campus. The proposed system is a combination of photovoltaic power production, battery energy storage, and EV charging infrastructure to offer a sustainable and reliable solution to charging [1], [2], [5].



The system operation under varying conditions was studied via mathematical modeling and simulations using MATLAB/Simulink. The results demonstrate that the PV system can meet a substantial portion of the EV charging demand, with the battery energy storage system improving the overall system performance by compensating for the intermittency in the PV system.

By using renewable energy it is possible to cut down the reliance on the grid and the carbon emission that is caused by traditional electricity production [3], [18]. Also, the proposed system offers economic advantages, such as decreased electricity usage and a decent payback time [1], [2]. Comprehensively, the research validates the claim that EV charging stations powered by the sun can be an effective and efficient way of sustaining electric mobility in campuses [1], [2], [3].

Future Work

Despite the promising performance of the proposed system, there are a number of opportunities on how to improve and expand it further. Future studies can be aimed at updating vehicle-to-grid (V2G) technology, through which electric vehicles can provide stored energy to the grid when it is in high demand [18].

One more prospective developmental change is the application of energy management systems based on artificial intelligence to streamline the development of energy between solar production, battery storage, and EV charge loads. Algorithms based on AI have the potential to increase the efficiency of the system by forecasting demand in charging and optimizing power flow [7], [8].

In addition, the charging process could be tracked and managed in real-time, by adopting IoT-based smart charging systems [8]. These may improve energy efficiency, user convenience and smart energy management initiatives in smart campuses [10], [11].

Lastly, future research can consider machine learning-based EV demand forecasting models to forecast charging patterns and better plan the system. These innovations may increase the efficiency, scalability, and sustainability of solar-charging EV infrastructure further.

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