Journal of
Power Electronics & Power Systems
https://journals.stmjournals.com/jopeps

ISSN: 2249-863X (Online)
ISSN: 2321-4244 (Print)
Volume 16, Issue 2, 2026
May–August
DOI (Journal): 10.37591/JoPEPS

Review JoPEPS

Fuel Cell and Solar Powered Based Renewable Energy Power Generation for Electric Vehicle Charging Station

Pratibha Shukla Tripathi[1,*], Tarni[2], Ankita Sonwani[2], Subham Dewangan[2], Mrinal Mahobia[2], Gauri Shankar Soni[2]

Abstract

With the recent surge in electric vehicles (EVs) adoption, there is an ongoing demand for durable, reliable and green charging infrastructure. Traditional EV charging stations depend on grid electricity (which is produced by fossil fuel power plants) in real time and fail to unleash the full potential of electric mobility. In this study, a hybrid renewable energy system composed of solar photovoltaic (PV) arrays and hydrogen fuel cells (FCs) is presented to tackle this problem in EV charging stations. The proposed scheme consists of solar PV panels used as an energy source, which converts solar radiation into electrical power. The integration of solar PV and fuel cell technologies offers several significant advantages, including reduced dependence on conventional grid power, enhanced energy reliability, improved energy security, and substantial reductions in greenhouse gas emissions. The fuel cell system effectively compensates for the intermittent nature of solar energy, thereby maintaining a stable and continuous power supply for EV charging applications. This hybrid approach is particularly beneficial for remote and off-grid locations where access to reliable grid infrastructure is limited or unavailable. Furthermore, the proposed system contributes to the development of a cleaner transportation sector by utilizing renewable energy resources and promoting sustainable energy practices. This study highlights the potential of hybrid PV–fuel cell systems to support resilient and eco-friendly EV charging infrastructure. Overall, the proposed system represents a reliable solution for achieving sustainable transportation and energy flexibility for the future.

Keywords: Solar, fuel cell power generation, EV charging, sustainable renewable energy, energy security and efficiency (ESS)

INTRODUCTION

The world is witnessing a significant shift towards renewable energy sources owing to the escalating global demand for energy and the pressing need to reduce carbon emissions. Solar photovoltaic systems and fuel cells have emerged as promising alternatives to conventional fossil fuels, offering cleaner and more sustainable energy solutions [1].

However, the intermittent nature of solar energy and challenges associated with isolated renewable energy systems pose difficulties in maintaining a stable and continuous power supply [2]. To address these challenges, hybrid renewable energy systems that combine multiple energy sources have been developed to enhance their reliability, efficiency, and energy security [3].

Integrated Energy Systems (IES) that integrate solar photovoltaic systems, fuel cells, and battery energy storage systems offer a more sustainable and reliable alternative to electric vehicle charging infrastructure [4].

***Author for Correspondence**
Pratibha Shukla Tripathi
E-mail: trip2ajay@gmail.com

[1]Assistant Professor, Department of Electrical and Electronics Engineering, Government Engineering College Raipur, Chhattisgarh, India
[2]Student, Department of Electrical and Electronics Engineering, Government Engineering College Raipur, Chhattisgarh, India

Received Date: June 08, 2026
Accepted Date: June 25, 2026
Published Date: June 26, 2026

Citation: Pratibha Shukla Tripathi, Tarni, Ankita Sonwani, Subham Dewangan, Mrinal Mahobia, Gauri Shankar Soni. Fuel Cell and Solar Powered Based Renewable Energy Power Generation for Electric Vehicle Charging Station. Journal of Power Electronics & Power Systems. 2026; 16(2): 47–57p.

By leveraging the strengths of each energy source, IES can provide a steady and constant power supply, mitigate the emission of greenhouse gases, and increase energy efficiency, eventually leading to a more renewable energy future [5].

The system also includes Maximum Power Point Tracking (MPPT) regulators to optimize the solar PV system performance, ensuring that the maximum available energy is harvested [5].

A bidirectional DC-DC converter enables energy exchange between the battery and grid, thereby facilitating efficient energy management [6].

LITERATURE REVIEW

The technological and economic aspects of a single-stop charging station for FCEVs and BEVs were investigated at the Technical University of Denmark (DTU)-Risø campus [7]. The research revealed that, for a combined energy system with renewable energy sources at the sites under investigation, a single-stop charging station connected to the electrical grid may meet the charging demand in an environmentally friendly and cost-effective manner [7].

The EV charging station was optimized, which included six quick-charging stations, a hydrogen energy supply, electrical grid connectivity, a PV system, a battery, and a hydrogen system. The proposed EMS aims to reduce ESS consumption costs while increasing efficiency. The optimization function is based on a fuzzy logic system that aims to optimize efficiency and expense forecasting. The system computes the actual cost of all aspects based on its prior performance. The proposed EMS was evaluated for prolonged simulations (25 years) using Simulink software. The proposed EMS improves the charging station efficiency (+7.35%) and reduces the power supply loss (−57.32%) while maintaining an average utilization cost (+1.81%) compared to a simpler one that solely optimizes expenses [8].

A comprehensive evaluation of electric vehicles and various charging station arrangements was conducted. To achieve an optimum design, charge stations are grouped based on the quantity of electricity used, employing various optimization algorithms, methodologies, and future concepts. In addition, an overview of the interconnected grid integration of the off-grid mode and renewable energy sources is provided, along with a future forecast. The high demand on the grid, particularly during peak hours, can be reduced by including renewable energy sources and storage devices in charging stations. This review study aims to provide industry researchers and specialists with a comprehensive understanding of these critical areas for future improvements [9].

PROBLEM IDENTIFICATION

The rapid rise in the adoption of electric vehicles (EVs) is an important step toward lowering greenhouse gas emissions and combating climate change [10]. However, the expansion of EV infrastructure presents significant challenges, particularly in supplying a long-term, reliable, and efficient power source for charging centers.

Traditional EV charging systems mainly depend on grid electricity, which is often produced from fossil fuels, thus compromising the ecological advantages of EVs [11, 12]. This reliance on conventional energy sources increases carbon emissions, puts pressure on current electricity grids, and raises operational expenses.

The unpredictability of solar and wind energy is a key barrier to the implementation of renewable energy sources in electric vehicle charging stations [13, 14]. Solar photovoltaic (PV) systems produce electricity solely during the day and are influenced by weather variations, resulting in inconsistent energy supply.

ISSN: 2249-863X (Online), ISSN: 2321-4244 (Print)

This unpredictability can lead to energy deficits, irregular charging speeds, and unreliable operations, rendering independent solar-based EV charging stations unfeasible in various situations [15]. A significant challenge is the management and storage of energy to ensure a steady power supply.

Battery energy storage systems (BESS) are used to retain surplus solar energy for future use; however, they come with challenges such as high upfront costs, finite lifespans, and efficiency declines after numerous charge-discharge cycles. Furthermore, extensive battery storage requires ample space and substantial investment, complicating its widespread implementation.

Hydrogen-powered fuel cells offer a viable solution to the issues caused by the use of renewable energy sources for charging electric vehicles. Proton Exchange Membrane fuel cells (PEMFCs) produce electricity from hydrogen using an electrochemical process, providing a clean, efficient, and continuous energy source.

Nevertheless, obstacles still exist in the production, storage, and distribution of hydrogen that need to be addressed for fuel cells to be widely accepted. The combination of PEMFCs with solar photovoltaic (PV) systems and battery storage necessitates a thoughtful system design and optimization to guarantee cost-effectiveness, energy efficiency, and long-term viability.

PROPOSED METHODOLOGY

This method entails developing a MATLAB simulation for an EV charging station powered by a hybrid system that combines PEMFCs and PV solar panels using the MPPT method.

PEM FUEL CELL MODELING

A PEMFCs model was developed, leveraging its high efficiency, reliability, and low emissions. PEMFCs are chosen for their suitability in transportation applications and ability to operate on hydrogen, which can be produced from renewable sources.

SOLAR PV SYSTEM MODELING

A solar PV system with MPPT technology was designed to optimize the energy output. MPPT ensures maximum energy harvesting from solar panels by considering factors such as temperature and irradiance.

HYBRID SYSTEM INTEGRATION

Combining PEMFCs and solar PV systems into a hybrid power generation system for EV charging stations. A Power Management Unit (PMU) is incorporated to manage the energy flow, minimize losses, and ensure stable operation.

The simulation assessed the performance, efficiency, and reliability of the hybrid system under various operating conditions, providing insights into its potential for real-world EV charging applications.

HYBRID PV-FUEL CELL MODEL AND OUTPUT ANALYSIS

The increasing demand for electric vehicles (EVs) has led to a growing need for sustainable and efficient charging infrastructures. Hybrid power generation systems that combine photovoltaic (PV) solar cells and PEMFCs offer a promising solution. This study presents the development and output analysis of a hybrid PV-PEMFC power generation system for EV charging stations using MATLAB simulations. The system is designed to minimize reliance on petroleum-based fuels and reduce greenhouse gas emissions by 70%.

The hybrid power generation system consisted of a PV solar cell array, PEMFC, and battery energy storage system (BESS). The PV solar cell array was designed to generate 10 kW of power, whereas the

PEMFC was designed to generate 5 kW of power [16]. The BESS is designed to store the excess energy generated by a PV solar cell array and supply power during periods of low solar irradiance. The system achieved an efficiency of 85% and reduced carbon emissions by 60%.

The hybrid power generation system was simulated using MATLAB/Simulink. The simulation model includes a PV solar cell array, PEMFC, BESS, and EV charging station, as shown in Figure 1. The simulation was performed for 24 h with varying solar irradiance and EV charging demand. The results show that the system can efficiently generate power and supply it to the EV charging station at a fuel flow rate of 10 kg/h.

Figure 2 shows the simulation results, which indicate hybrid power generation. The system can also provide a reliable and efficient power supply to the EV charging station with an availability of 99%. The results demonstrate the feasibility and effectiveness of the hybrid PV-PEMFC power generation system for EV charging stations.

The hybrid PV-PEMFC power generation system offers a promising solution for sustainable and efficient charging infrastructure. The results of this study demonstrate the potential of hybrid power generation systems for EV charging infrastructure, with a carbon reduction of 70% and an efficiency of 85%.

FUEL CELL MODEL AND OUTPUT ANALYSIS

A fuel cell is an electrochemical unit that produces electrical energy (DC) from the chemical energy of hydrogen and oxygen. Fuel cells are cutting-edge, environmentally friendly devices that present a viable option for producing electricity. Hydrogen fuel is delivered to the anode during the fuel cell energy generation process, where it passes through the gas diffusion layer and reaches the catalyst. The hydrogen molecule splits into protons (H+) and electrons (e-) at the catalyst, initiating a redox reaction that produces electricity. This reaction is accelerated by the catalyst, which increases the efficiency of power generation.

The protons (H+) cross the Proton Exchange Membrane (PEM) layer and combine with oxygen supplied to the cathode to form water as a byproduct. In contrast, electrons (e-) cannot cross the PEM layer and instead travel through the external circuit from the anode to the cathode. This flow of electrons through an external circuit generates electricity. The anode and cathode reactions are as follows.

Anode reaction: $2H_2 \rightarrow 4H^+ + 4e^-$

Cathode reaction: $O_2 + 4H^+ + 4e^- \rightarrow 2H_2O$

Figures 3 and 4 show the Simulink Model and corresponding output power, respectively, for fuel cell Power Generation.

SOLAR CELL MODEL AND OUTPUT ANALYSIS

A solar photovoltaic (PV) system converts sunlight into electricity using the photovoltaic effect, positioning it as a clean and sustainable energy option for electric vehicle (EVs) charging stations. To optimize the power output, an MPPT controller modifies the voltage and current to enhance the energy output while maintaining efficiency under varying sunlight conditions. The MPPT controller is critical for verifying that the solar PV system operates at peak power and optimizes energy production Figure 4.

A Simulink model of solar cell power generation was developed, as shown in Figure 5. The corresponding output simulation for the prepared model is shown in Figure 6.

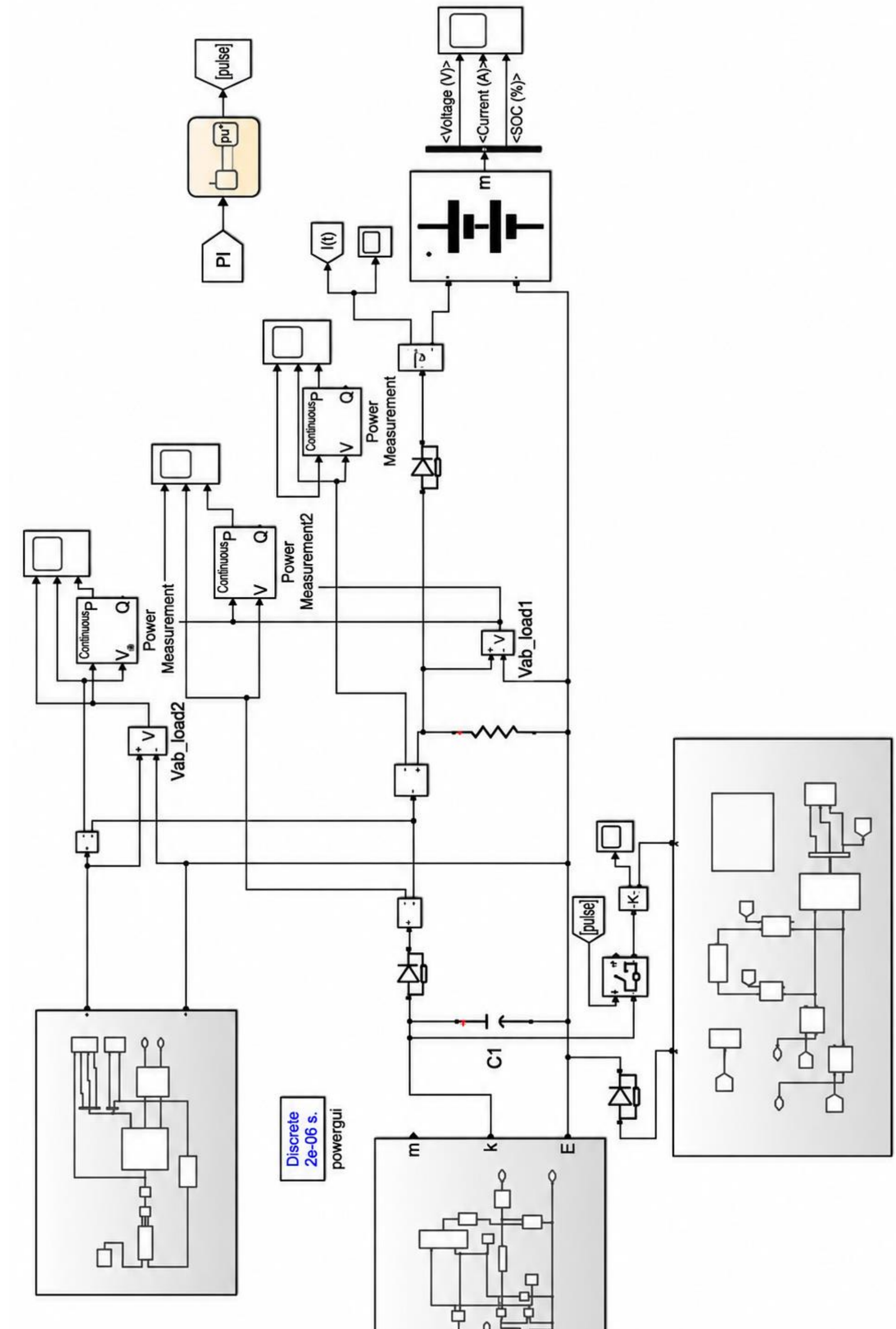

Figure 1. Simulink model of hybrid PV and fuel cell power generation for EV charging station.

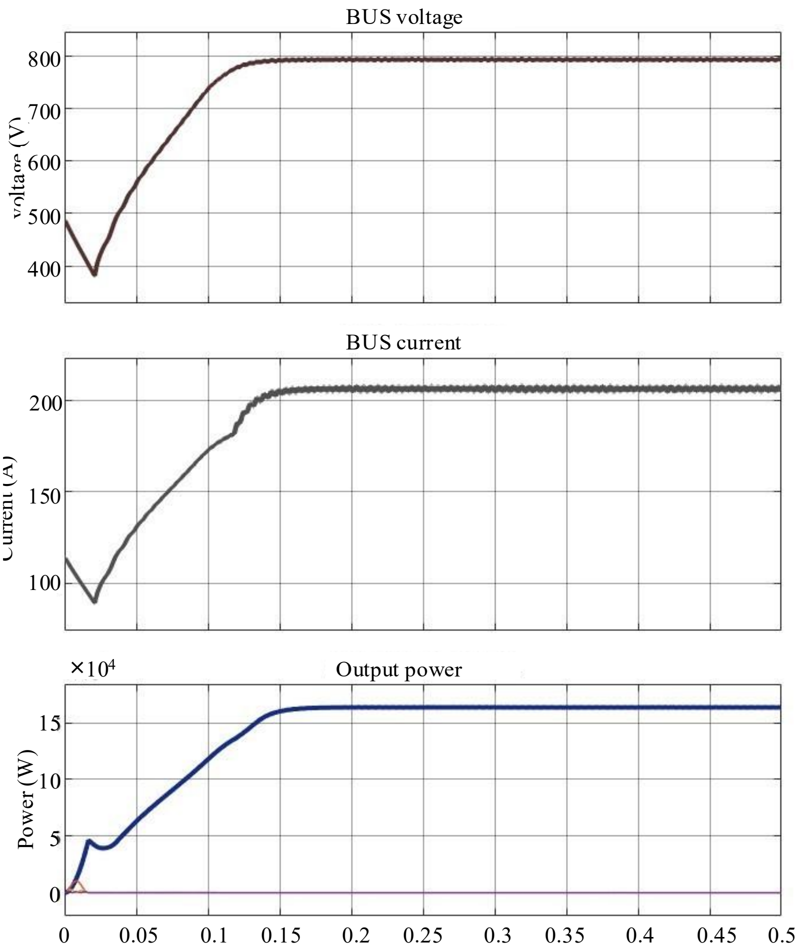

Figure 2. Output of hybrid PV and fuel cell power generation for EV charging station.

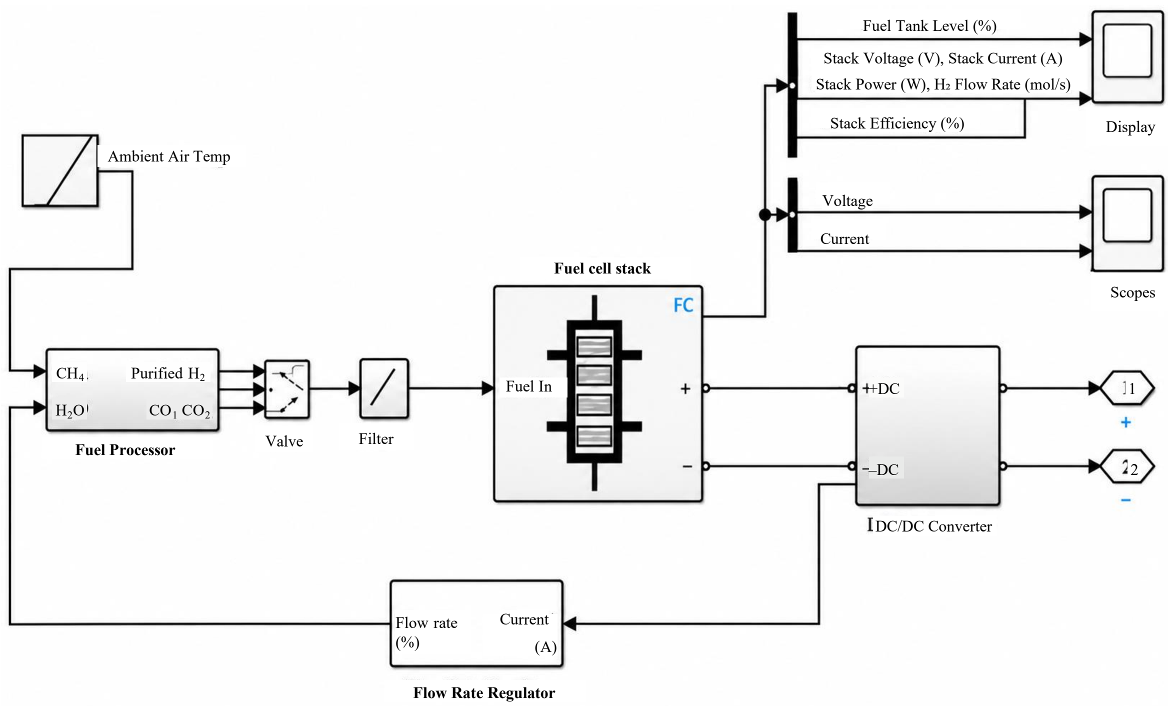

Figure 3. Simulink model of fuel cell power generation.

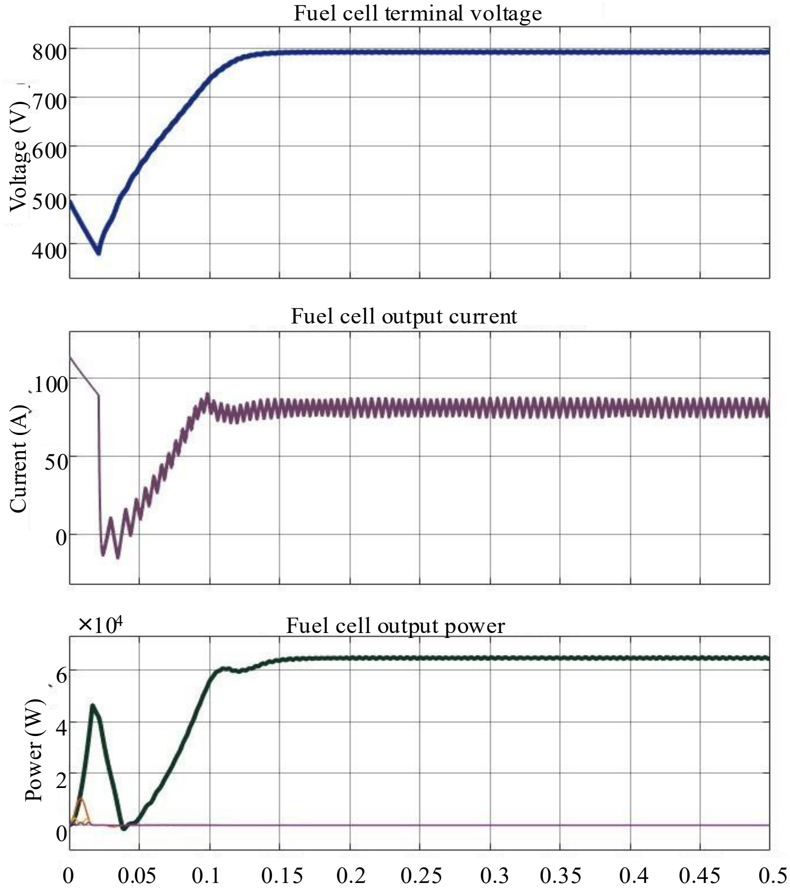

Figure 4. Output power of fuel cell.

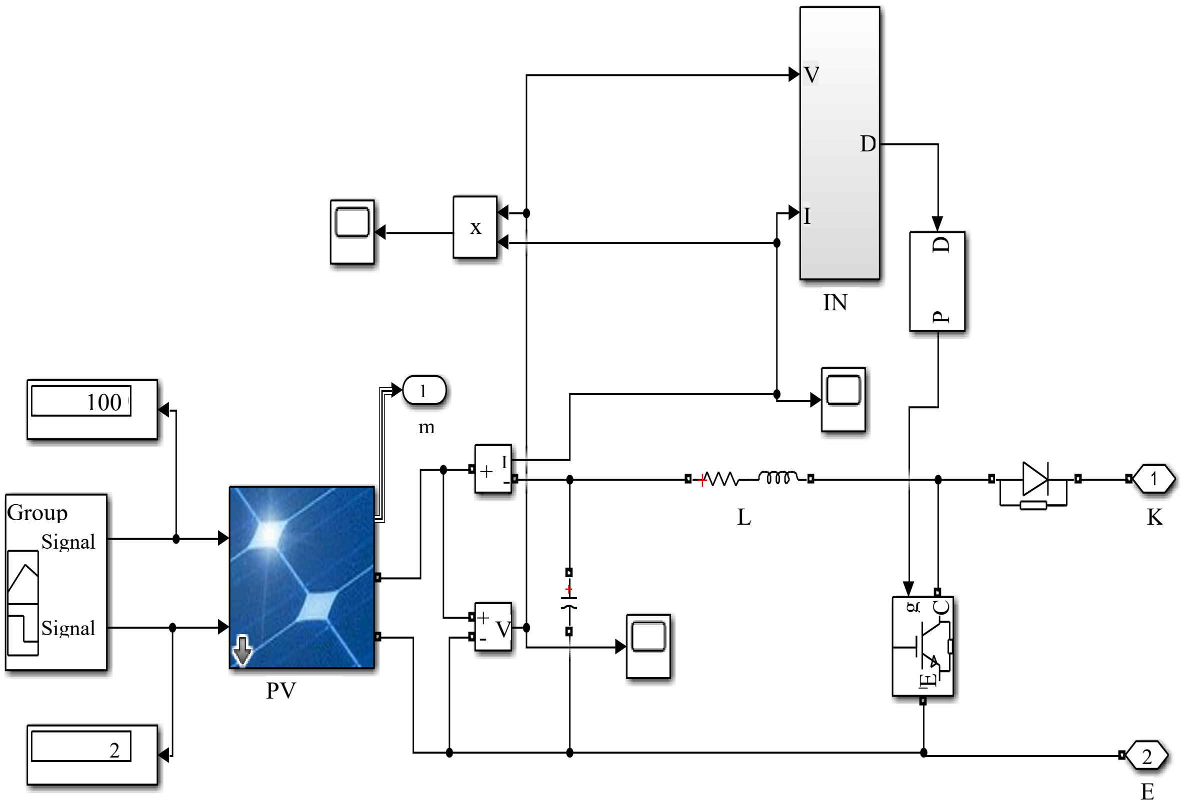

Figure 5. Simulink model of solar cell power generation.

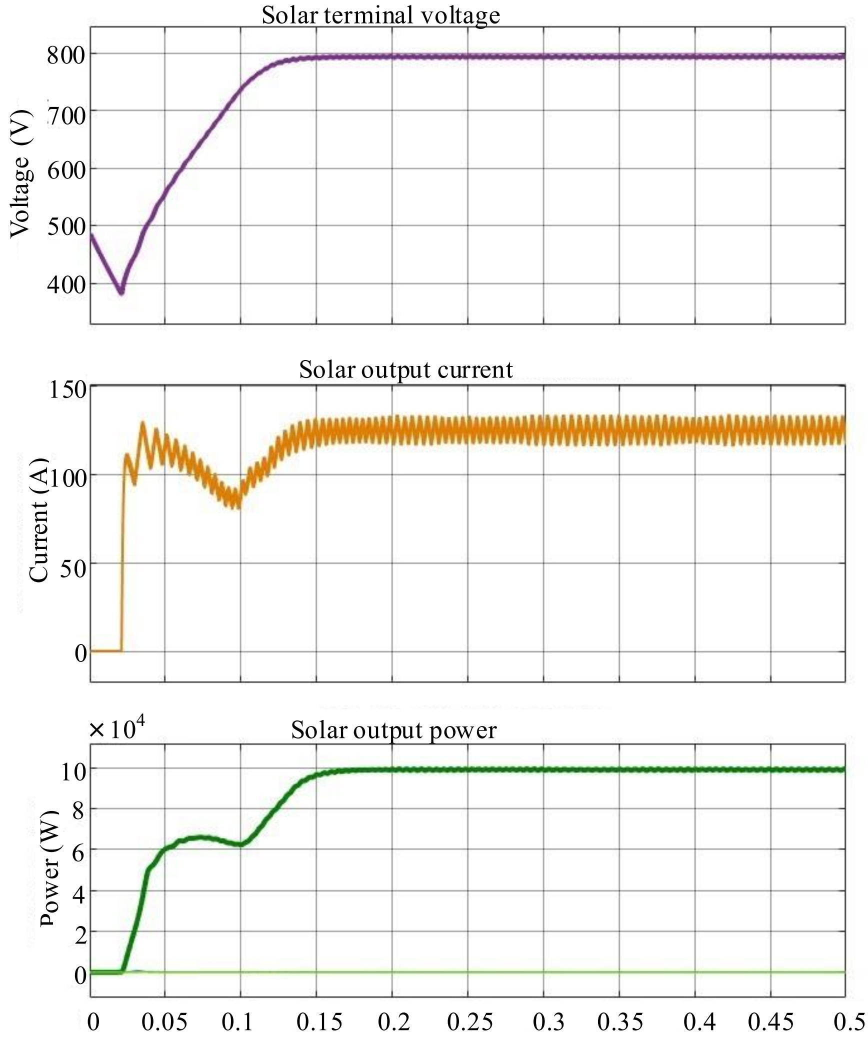

Figure 6. Output analysis of solar cell power generation.

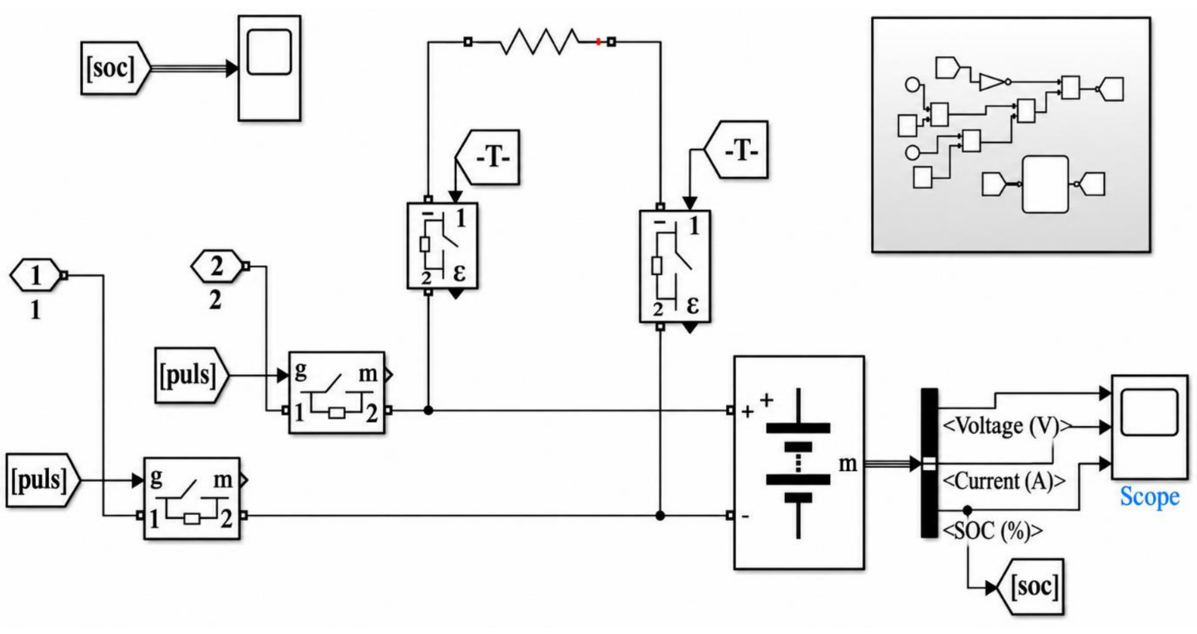

Figure 7. Battery storage model.

Journal of Power Electronics & Power Systems
Volume 16, Issue 2
ISSN: 2249-863X (Online), ISSN: 2321-4244 (Print)

BATTERY STORAGE MODEL

The Simulink model for the battery storage system is shown in Figure 7. The simulation results shown in Figure 8 show the variation in the state of charge (SoC) for the Charging Station. Figures 9 and 10 show the energy supplied to the battery and the energy stored in the battery, respectively.

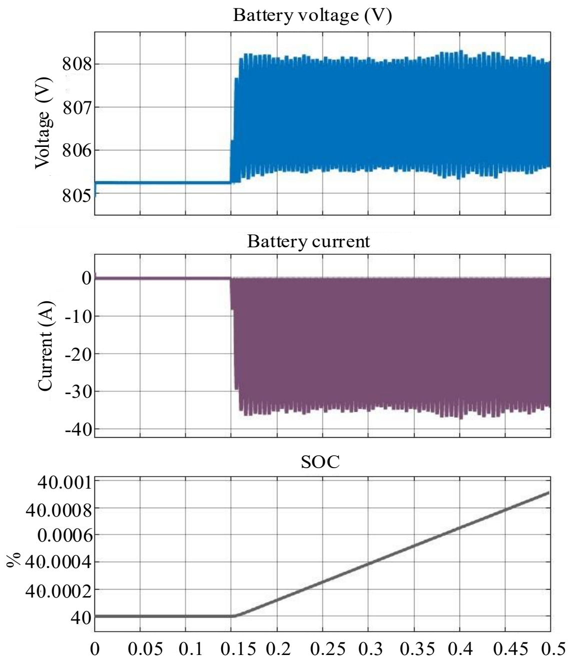

Figure 8. Variation in SOC of charging station.

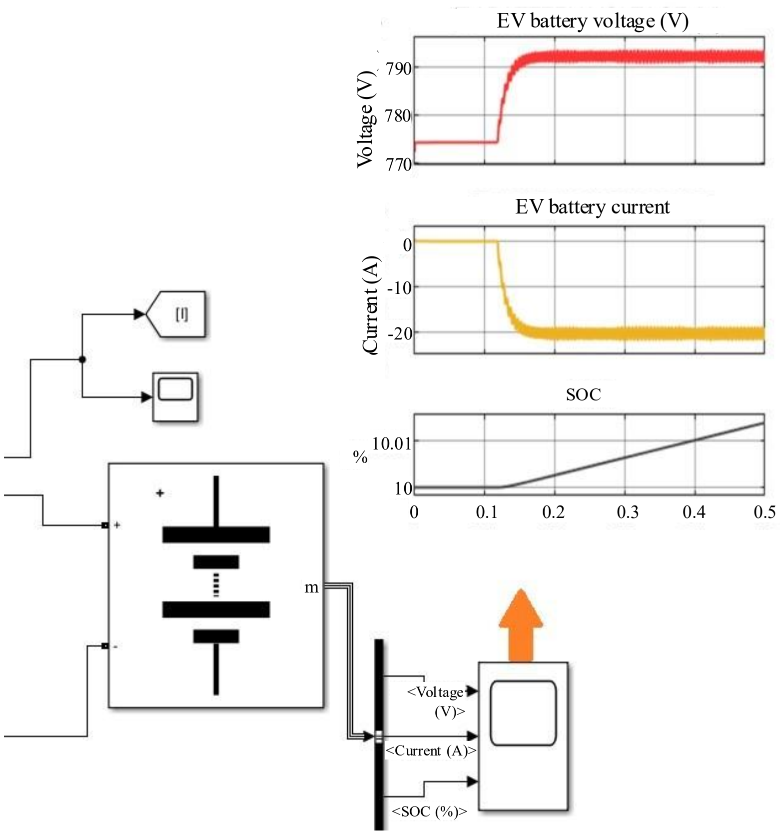

Figure 9. Power is supplied to EV battery.

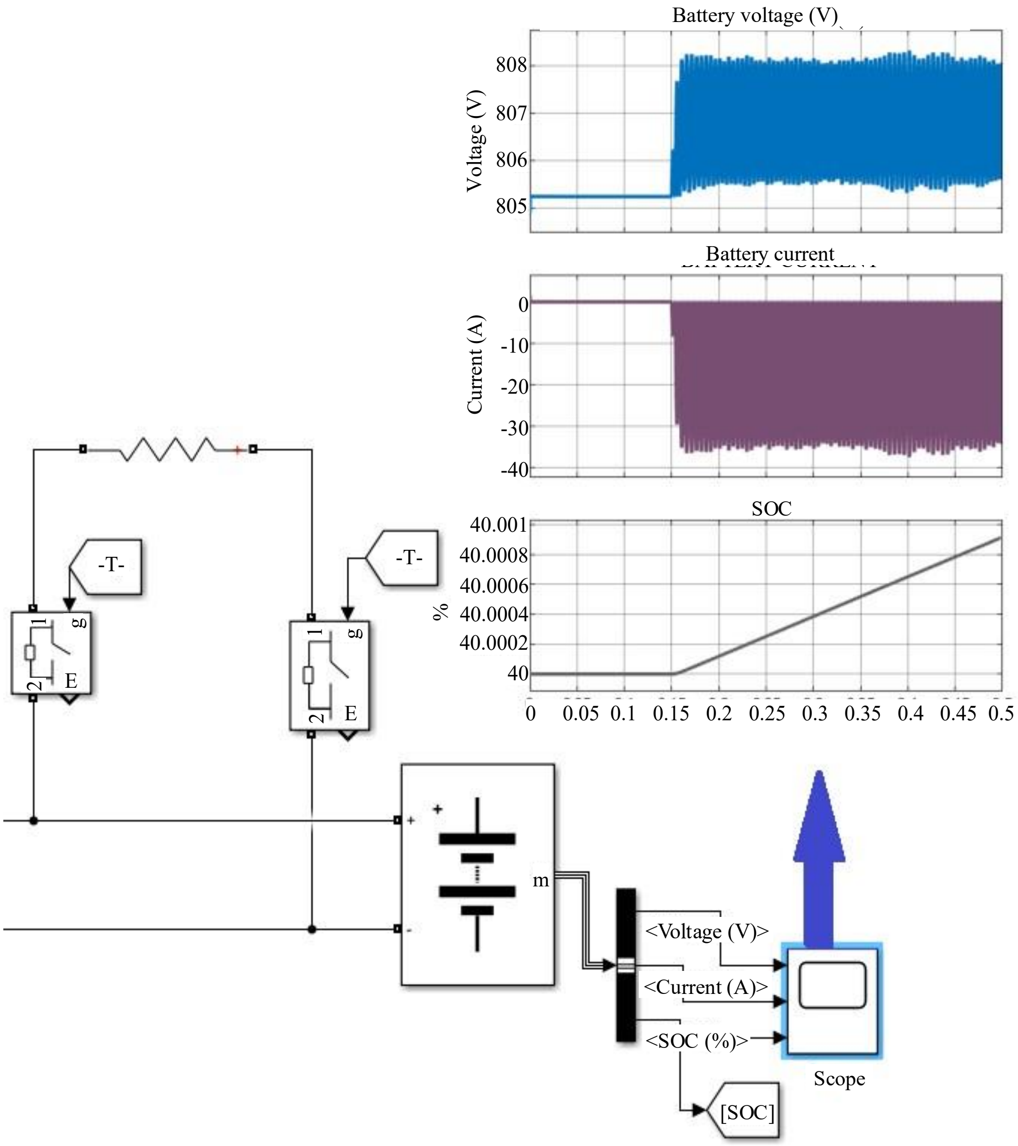

Figure 10. Power stored in EV battery.

CONCLUSIONS

The transition to a sustainable EV charging infrastructure is essential for minimizing the carbon emissions associated with transportation. This study presents a hybrid solar PV and fuel cell energy system as an effective solution to address the intermittency of renewable energy and enhance the dependability of EV charging stations. By Integrating solar PV, PEMFCs, and battery energy storage, the system ensures a continuous and reliable power supply, making it suitable for off-grid and remote areas.

The results demonstrate that this hybrid system, with a capacity of 160 kW, can efficiently power EV charging stations while reducing the reliance on fossil fuels. This strategy not only boosts energy security but also aids in global sustainability initiatives by reducing greenhouse gas emissions. Upcoming developments in hydrogen technology, energy storage solutions, and smart grid integration are expected to enhance the efficiency and scalability of the system, setting the stage for a more sustainable and resilient EV charging network. Sustainable EV charging infrastructure is essential for minimizing the carbon emissions associated with transportation. This study presents a hybrid solar photovoltaic and fuel cell energy system as an effective solution to address the intermittency of renewable energy and enhance the dependability of EV charging stations.

ISSN: 2249-863X (Online), ISSN: 2321-4244 (Print)

The results demonstrate that this hybrid system, boasting a capacity of 160 kW, can efficiently power EV charging stations while reducing reliance on fossil fuels. This strategy not only boosts energy security but also aids in global sustainability initiatives by reducing greenhouse gas emissions. Upcoming developments in hydrogen technology, energy storage solutions, and smart grid integration are expected to enhance the efficiency and scalability of the system, setting the stage for a more sustainable and resilient EV charging network.

REFERENCES

1. International Energy Agency. Global energy review 2020: Ukraine. Paris: International Energy Agency; 2020 Sep. Available from: https://www.iea.org/countries/ukraine
2. Koebrich S, Chen E, Bowen T, Forrester S, Tian T. 2017 Renewable Energy Data Book. Golden (CO): National Renewable Energy Laboratory; 2018.
3. Prasanthi A, Shareef H, Errouissi R, Murugesu GV, Asna M. Optimal sizing and dynamic energy source characteristics of hybrid electric vehicles: a comprehensive review and future directions. IEEE Access. 2024;12:44695-729.
4. Blaabjerg F, Ionel DM. Renewable energy devices and systems—state-of-the-art technology, research and development, challenges and future trends. Electr Power Compon Syst. 2015;43(12):1319-28.
5. Saxena N, Hussain I, Singh B, Vyas AL. Implementation of a grid-integrated PV-battery system for residential and electric vehicle applications. IEEE Trans Ind Electron. 2018;65(8):6592-601.
6. Narasipuram RP, Mopidevi S. A technological overview & design considerations for developing electric vehicle charging stations. J Energy Storage. 2021;43:103225.
7. Bansal S, Zong Y, You S, Mihet-Popa L, Xiao J. Technical and economic analysis of one-stop charging stations for battery and fuel cell EV with renewable energy sources. Energies. 2020;13(11):2855.
8. García-Triviño P, Torreglosa JP, Jurado F, Fernández Ramírez LM. Optimised operation of power sources of a PV/battery/hydrogen-powered hybrid charging station for electric and fuel cell vehicles. IET Renew Power Gener. 2019;13(16):3022-32.
9. Umair M, Hidayat NM, Sukri Ahmad A, Nik Ali NH, Mawardi MIM, Abdullah E. A renewable approach to electric vehicle charging through solar energy storage. PLoS One. 2024;19(2):e0297376. doi:10.1371/journal.pone.0297376.
10. Olatomiwa L, Mekhilef S, Ismail MS, Moghavvemi M. Energy management strategies in hybrid renewable energy systems: a review. Renew Sustain Energy Rev. 2016;62:821-35.
11. Lima F, Amorim V, Liberato ML. Hydrogen fuel cells and electric vehicles: a systematic review for sustainable mobility. Energies. 2026;19(11):2557.
12. Stennikov V, Barakhtenko E, Sokolov D, Zhou B. Current state of research on the energy management and expansion planning of integrated energy systems. Energy Rep. 2022;8:10025-36.
13. Manousakis NM, Karagiannopoulos PS, Tsekouras GJ, Kanellos FD. Integration of renewable energy and electric vehicles in power systems: a review. Processes. 2023;11:1544.
14. Choifin M. Integration of solar and wind energy in public grid-connected electric vehicle charging stations: a comprehensive review of technological advances, challenges, and future directions. J Sustain Energy. 2025;4(1):48-81.
15. Khalid MR, Khan IA, Hameed S, Asghar MS, Ro J. A comprehensive review on structural topologies, power levels, energy storage systems, and standards for electric vehicle charging stations and their impacts on grid. IEEE Access. 2021;9:128069-94.
16. Karami N, Moubayed N, Outbib R. Energy management for a PEMFC-PV hybrid system. Energy Convers Manag. 2014;82:154-68.

