IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 3, June 2025

Impact Factor: 7.67

Design and Simulation of Solar-Wind Hybrid EV Charging System using MATLAB

Ninad Rajurkar[1], Aditi Ambekar[2], Bhimrao D. Dabhade[3]

Dr. Rahul Agrawal[4], Dr. Sunil Magan More[5], Harshal Shelar[6]

Final Year Student, Department of ElectricalEngineering[1, 2]

Professor, Head of Electrical Engineering Department[4]

Assistant Professor, Department of Electrical Engineering[3, 5, 6]

Guru Gobind Singh College of Engineering & Research Centre, Nashik, Maharashtra, India

Abstract: *This report outlines a comprehensive MATLAB-based simulation of a hybrid electric charger that integrates both solar and wind energy sources. The system is designed to charge a 48V, 24Ah battery using power generated by photovoltaic panels and a wind turbine. To enhance energy conversion efficiency, a Maximum Power Point Tracking (MPPT) controller is employed. This controller dynamically adjusts the input parameters to extract the maximum possible energy from each renewable source. The simulation covers several key components of the system, including the power output from solar and wind generators, the battery charging process, and the system's overall energy efficiency. By leveraging both solar and wind inputs, the system delivers a more consistent and dependable power supply, even under variable weather conditions. The MPPT controller is essential in this setup, as it fine-tunes energy capture to ensure optimal performance. Simulation results reveal the battery's charging behavior under fluctuating environmental inputs and assess the MPPT's performance in managing energy flow. The analysis underscores the viability of solar-wind hybrid systems in promoting sustainable power solutions, especially in applications such as electric vehicle charging. This project demonstrates that combining multiple renewable sources can serve as a high-efficiency, environmentally friendly alternative to conventional energy systems.*

Keywords: Solar-wind hybrid system, renewable energy, electric vehicle charger, MATLAB modeling, photovoltaic panels, wind energy, 48V battery, MPPT controller

I. INTRODUCTION

As the worldwide shift toward renewable energy accelerates, hybrid solar and wind power systems offer an eco-friendly and dependable option for supporting electric vehicle (EV) charging networks. With the rise in EV adoption, there is an increasing demand for clean and consistent energy sources to power these vehicles [8]. This project aims to model a hybrid energy system that combines solar photovoltaic (PV) panels, wind turbines, an AC-DC rectification unit, and battery storage to deliver stable and efficient EV charging [9, 10].

System Components and Design:

The hybrid energy system is composed of several essential components that work in unison to optimize the use of renewable energy sources:

- **Solar Photovoltaic (PV) Panels:** These panels capture sunlight and convert it into direct current (DC) electricity. They operate most effectively when solar irradiance, temperature, and panel positioning are optimal, supplying energy primarily during daylight hours [10].
- **Wind Turbine:** Designed to harness the wind's kinetic energy, the wind turbine generates mechanical energy, which is then converted into electricity. This allows for energy production even in the absence of sunlight, such as during nighttime or overcast conditions.

- **AC to DC Rectifier:** Wind turbines typically produce alternating current (AC), which must be converted to direct current (DC) for compatibility with storage systems and electric vehicle (EV) charging infrastructure. A rectifier handles this conversion.
- **Energy Storage Battery:** To manage fluctuations in renewable energy availability, the system includes a battery unit that stores surplus electricity generated by the solar and wind sources. This ensures a consistent energy supply during periods of low generation.
- **Charge Controller and Energy Management System:** The charge controller safeguards the battery by regulating charge levels, preventing both overcharging and deep discharge. Meanwhile, the power management system coordinates energy distribution across the solar panels, wind turbine, and battery to maximize efficiency and reliability.

Simulation and Performance Analysis:

- This hybrid system simulation examines multiple key aspects such as power production, storage performance, and charging dependability. The evaluation model takes into account:
- **Renewable Energy Resources:** Solar and wind energy data are assessed to forecast the system's electricity generation capacity.
- **Electric Vehicle Charging Needs:** Different levels of EV charging demand are simulated to evaluate how effectively the system can supply power [3, 4].
- **Battery Efficiency:** The charging and discharging processes are closely observed to ensure consistent performance and extended battery life.
- **System-Wide Efficiency:** The combined use of photovoltaic panels, wind turbines, and battery storage is fine-tuned to achieve optimal use of renewable energy sources.

Innovative EV Charging System Utilizing Solar and Wind Energy. This section introduces a novel hybrid charging approach for electric vehicles (EVs) that leverages both solar and wind energy to overcome the limitations of current charging methods. Recognizing the importance of reliable charging infrastructure for long-distance EV travel, a hybrid renewable energy system was proposed and modelled using MATLAB-Simulink. The model evaluates the performance of solar and wind energy components under varying environmental conditions [1, 5]. The solar panel's behaviour was assessed at different levels of solar irradiance, while the wind turbine's output was examined under multiple loading scenarios. The results, based on an analysis of hourly EV energy demands compared to renewable energy generation, show that the system can adequately meet charging requirements. Furthermore, incorporating battery swapping significantly reduces charging time. This sustainable charging solution not only supports the broader use of EVs but also contributes to environmental conservation by lowering emissions. [3]

II. METHODOLOGY

The system is simulated in MATLAB using discrete time steps to monitor and adjust power generation, Maximum Power Point Tracking (MPPT), and Battery State of Charge (SOC) dynamics. This ensures that power is efficiently harnessed from solar panels and wind turbines while keeping track of battery storage levels [2].

2.1 Block Diagram of the Simulation

This Figure no. 01 shows a hybrid energy system using both solar and wind power to charge a lithium-ion battery.

The solar panel directly produces DC power, which is sent to an MPPT (Maximum Power Point Tracking) unit. MPPT helps extract the maximum power from the panel. The output goes to a buck-boost converter which adjusts the voltage before charging the battery [11].

The wind turbine generates mechanical energy, which is converted to AC electricity by a PMSG (Permanent Magnet Synchronous Generator). This AC power is passed through an uncontrolled bridge rectifier, converting it to DC power. This DC power also goes through its own MPPT unit and buck-boost converter, similar to the solar path.

Both power sources charge a Li-ion battery (48V, 24A), which stores energy for later use.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 3, June 2025
Impact Factor: 7.67

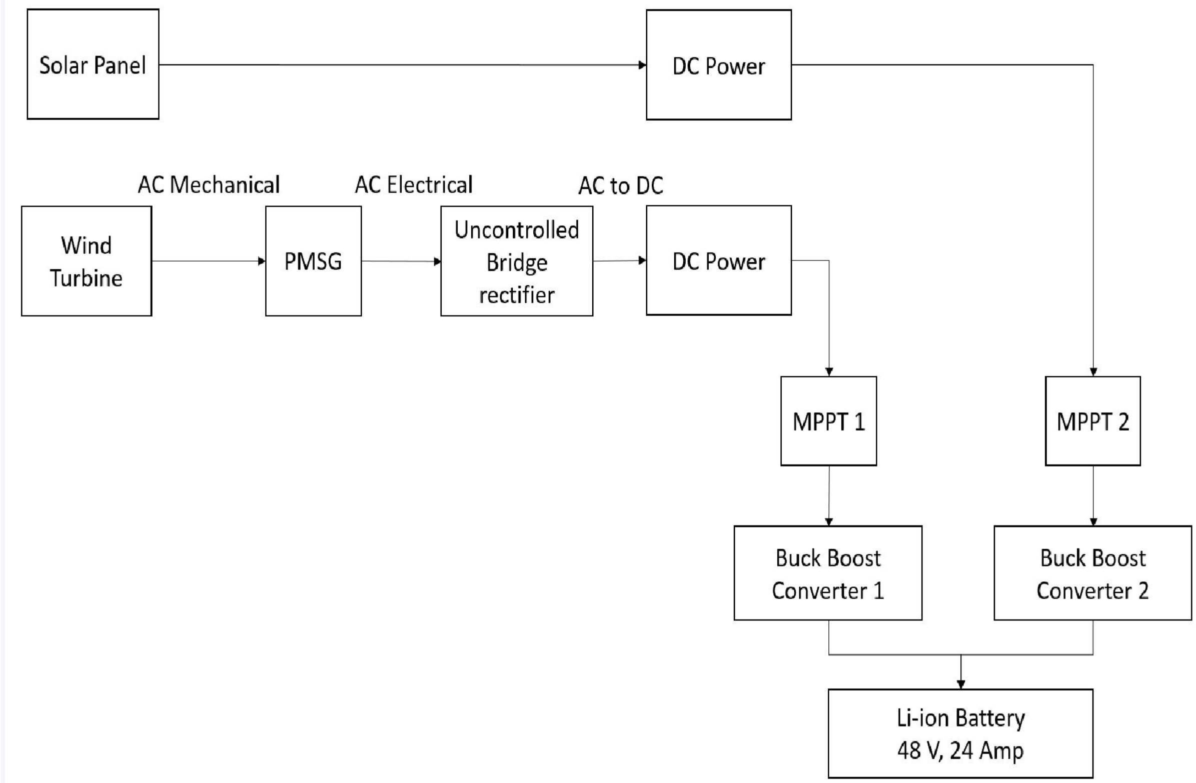

Figure no. 01 - Block Diagram of the Simulation

2.3 System Description

A hybrid charging setup utilizes both solar and wind energy to effectively recharge a battery. By drawing power from these renewable sources, it helps maintain a steady and reliable energy supply.

Solar Module

This Simulink model represents a small solar power system using 8 solar panels arranged in a series-parallel combination. The panels are connected such that 4 panels are in series, and 4 of these series strings are connected in parallel.

Solar Panel Configuration:

Each solar panel has the following ratings:

- Voc (Open Circuit Voltage) = 21 V
- Isc (Short Circuit Current) = 2.3 A
- Vmp (Voltage at Maximum Power) = 18 V
- Imp (Current at Maximum Power) = 1.9 A

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 3, June 2025
Impact Factor: 7.67

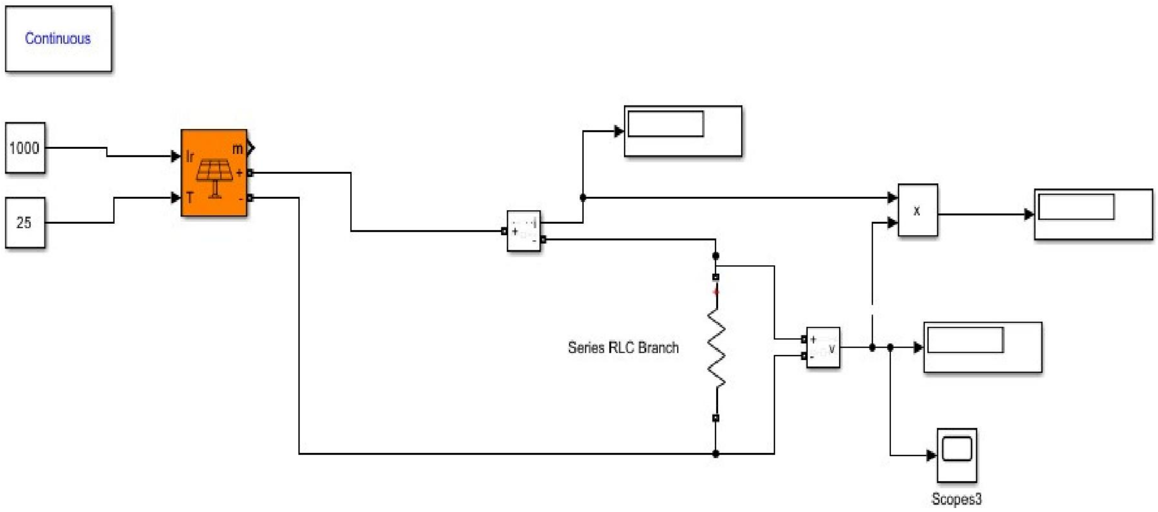

Figure no.02 - Simulation of Solar Module

Working of this Model:

The solar panel block is powered with input irradiance (1000 W/m²) and temperature (25°C)z

The output current and voltage from the panel array go through a Series RLC Branch (resistor, inductor, capacitor in series) to simulate a load or power line.

The measured voltage and current are then multiplied to get power.

A scope is connected to monitor the waveform or output in real time.

Wind Module

This Simulink model illustrates a wind energy conversion system (WECS) that integrates a three-phase wind turbine connected to a Permanent Magnet Synchronous Machine (PMSM), serving as the generator.

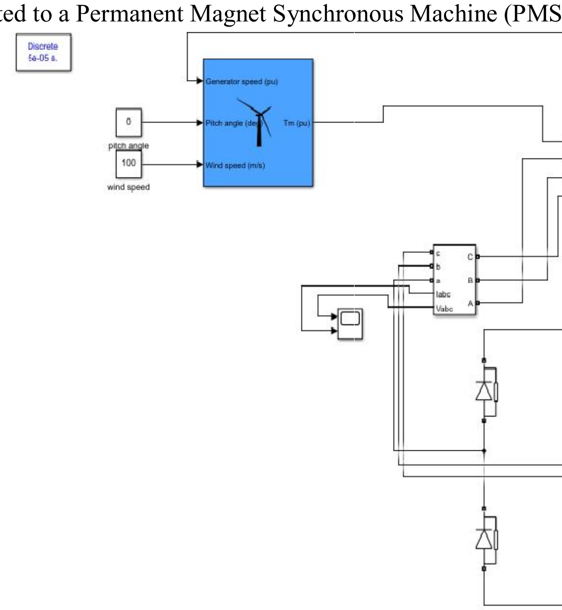

Figure no.03 - Simulation of Wind Module

DOI: 10.48175/IJARSCT-27558

Working Explanation:

Wind Turbine Block (Blue Block):

This system is a three-phase wind turbine that operates using an input wind speed of 100 meters per second and a pitch angle set to 0 degrees. Based on these inputs, it determines the mechanical torque (Tm) and the rotational speed of the rotor, which are then used to power the generator.

Mechanical to Electrical Conversion:

The mechanical torque produced by the turbine is transferred to the shaft of a Permanent Magnet Synchronous Machine (PMSM), which operates in generator mode. In this mode, the machine transforms the mechanical input into three-phase alternating current (AC) electricity. This electrical output is then routed to a three-phase power monitoring system, which enables observation of line voltages and current flow.

Power Electronics – Three-Phase Bridge Rectifier:

The AC power generated is directed into a three-phase bridge rectifier that operates without control elements, utilizing six diodes. This setup converts the AC into a pulsating direct current (DC). Since no active switching components are involved, the rectifier functions in an uncontrolled mode.

Output Monitoring:

The rectified DC voltage is measured and displayed on "Display 2," typically showing a value close to 440 volts.

Electrical power output is monitored on "Display 1," which records an output of approximately 1.8 kilowatts, indicating efficient conversion of wind energy to electrical energy.

Load Connection

A resistive component is connected to the DC output to draw and use the generated power. To minimize voltage ripple and ensure a more stable DC supply, a capacitor is also included in the circuit.

III. RESULT & DISCUSSION

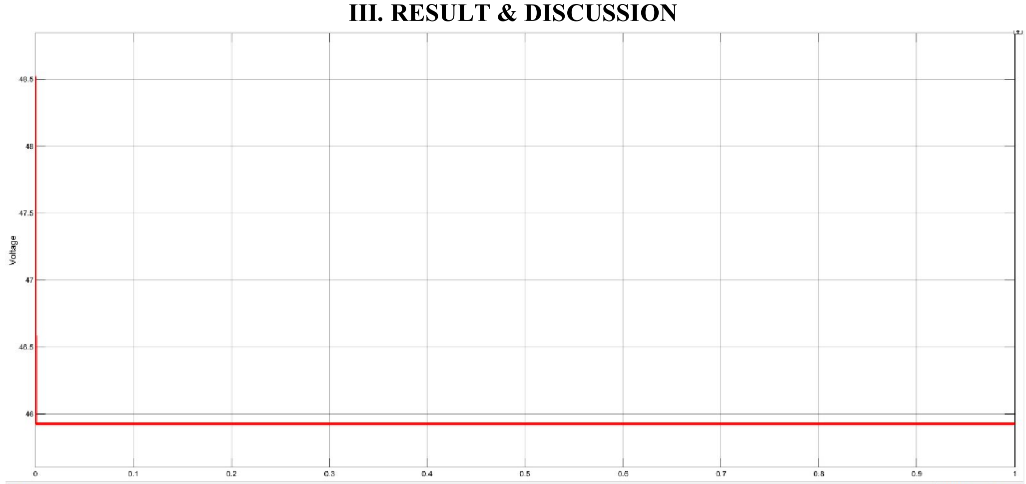

Figure no. 06 - DC Power form Solar Panel at 600 IR and 25 T

The graph (Figure no. 06) illustrates the DC voltage output of a solar panel functioning under standard testing conditions, specifically with a solar irradiance of 600 watts per square meter and an ambient temperature of 25°C. The y-axis represents the voltage, while the x-axis denotes time in seconds. The chart depicts a stable voltage output, indicating consistent energy production by the panel. This direct current is fed into a Maximum Power Point Tracking (MPPT) controller, which enhances the efficiency of energy extraction. The optimized power output from the MPPT is subsequently used to charge an electric vehicle (EV) battery. Voltage data is captured every millisecond to ensure accurate monitoring of the system's performance.

IJARSCT
International Journal of Advanced Research in Science, Communication and Technology
International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal
ISSN: 2581-9429
Volume 5, Issue 3, June 2025
Impact Factor: 7.67

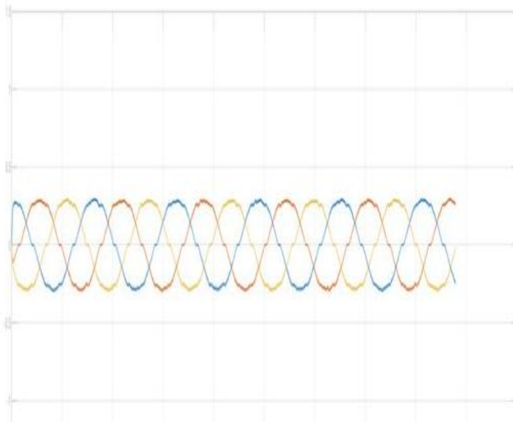

Figure no. 07- AC Sinusoidal Waveform from Wind Turbine

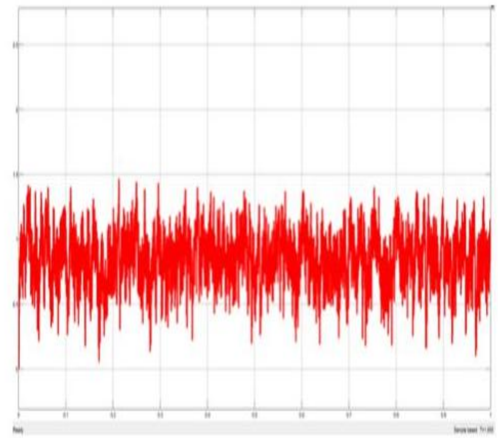

Figure no. 08 - DC Power from Wind Turbine

Wind turbines generate three-phase AC power, as shown in the sinusoidal waveform. To convert this AC into DC, an uncontrolled bridge rectifier is used. The rectifier consists of six diodes arranged in a three-phase bridge configuration, allowing current to flow in only one direction. This conversion results in a pulsating DC output, which can be further smoothed using capacitors or filters. The rectified DC power can then be stored in batteries or used in DC applications like electric vehicle charging.

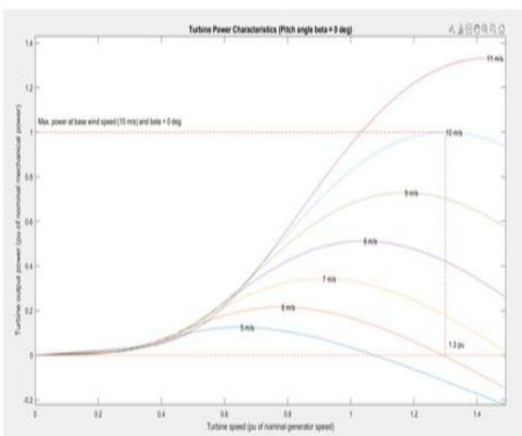

Figure no. 09 - Turbine Power Characteristics at Base Speed 10 ms

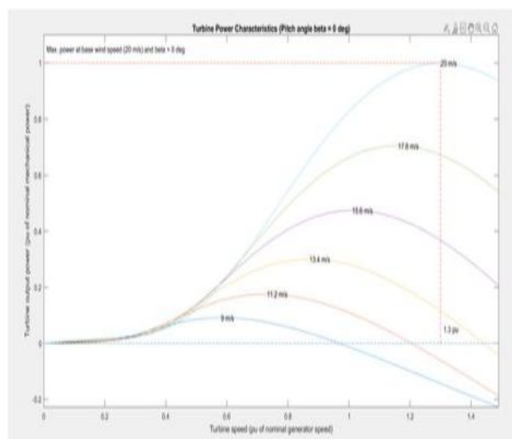

Figure no. 10 - Turbine Power Characteristics at Base Speed 20 ms

The two graphs show how the power output of a wind turbine changes at different wind speeds—10 m/s and 20 m/s.

1. At 10 m/s (Figure no. 09): The turbine power increases as the turbine speed rises, reaching a peak before slightly declining. This indicates that at this wind speed, the turbine generates a moderate amount of power, which is suitable for normal operation.

2. At 20 m/s (Figure no. 10): The power output is much higher because the wind energy is stronger. The curve follows a similar trend but reaches a much greater maximum power compared to the 10 m/s case.

Overall, as wind speed increases, the turbine generates more power, but there is a limit beyond which efficiency may decrease.

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429

Volume 5, Issue 3, June 2025

Impact Factor: 7.67

State of Charge

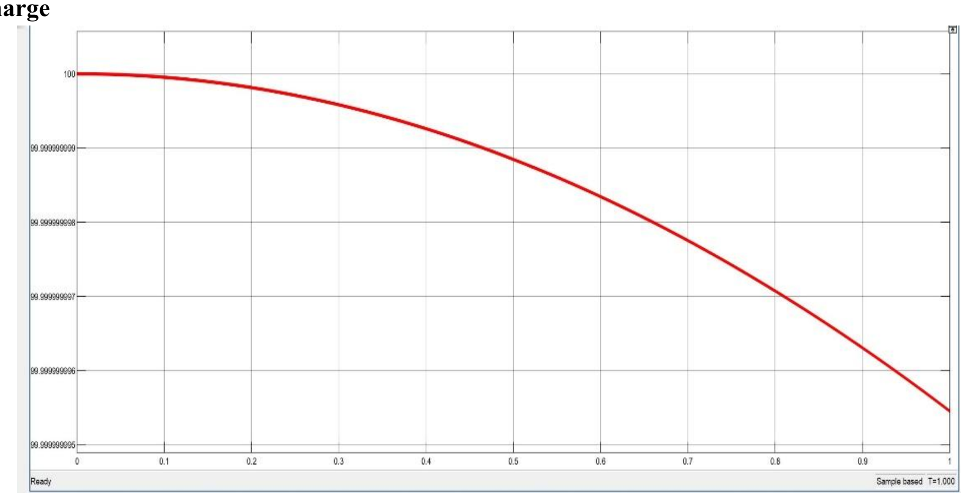

Figure no. 11 - Graph of SOC

The graph (Figure no. 11) illustrates the output from a MATLAB Simulink simulation, which tracks the State of Charge (SOC) of a battery over a given period. SOC is an important metric that shows how much charge remains in a battery, usually expressed as a percentage. In the graph, the vertical axis shows the SOC values, beginning near 100%, while the horizontal axis likely indicates time in seconds or possibly sample index values. The SOC decreases progressively, following a non-linear trend. This suggests the battery is undergoing discharge under a certain load, and the varying rate of decline implies that the discharge process is influenced by factors such as current draw, temperature, or the battery's internal resistance. These simulation results are valuable for studying how a battery performs under specific operating conditions. Such insights are especially important in fields like electric transportation, renewable energy systems, and portable electronic devices. By examining how the SOC changes, engineers can develop more efficient energy management systems and enhance the overall performance and durability of batteries.

IV. CONCLUSION

We developed a hybrid energy system that integrates solar and wind power to generate direct current (DC) electricity. This combination of renewable energy sources ensures a stable and environmentally friendly power supply, making it particularly beneficial for remote or off-grid areas. The solar setup includes eight photovoltaic (PV) panels arranged in a series-parallel configuration, optimizing both voltage and current to enhance energy storage and efficiency. Meanwhile, the wind component consists of a turbine connected to an AC generator, with the output being converted to DC via a basic, cost-effective bridge rectifier.

The dual-source design allows for complementary energy production—solar panels operate most efficiently during daylight, while wind turbines are often more effective at night or under cloudy conditions. This balance promotes uninterrupted power availability. Additionally, the system supports global sustainability efforts by reducing greenhouse gas emissions and promoting clean energy usage. It presents a practical solution for rural electrification, emergency backup power, and other applications requiring independent energy systems.

REFERENCES

[1] Haiying Li, Hao Liu, Aimin Ji, Feng Li, Yongli Jia "Design of a hybrid solar-wind powered charging station for electric vehicles" College of Metallurgy and Energy Hebei United University Tangshan, China.(2013)

[2] Kishan Bhushan Sahay and Ayushi Yadav,"Implementation of MPPT Technique in PV Array For a Varying Load by Modeling and Simulation"IEECON 2018, Krabi, Thailand

[3] C. Chellaswamy1, V. Nagaraju2, R. Muthammal3 "Solar and Wind Energy Based Charging Station for Electric Vehicles" ISSN (Print) : 2320 – 3765 ISSN (Online): 2278 – 8875 (2018)

DOI: 10.48175/IJARSCT-27558

IJARSCT

International Journal of Advanced Research in Science, Communication and Technology

International Open-Access, Double-Blind, Peer-Reviewed, Refereed, Multidisciplinary Online Journal

ISSN: 2581-9429 Volume 5, Issue 3, June 2025 Impact Factor: 7.67

[4] Rohaan George Thomas, Department of Mechanical Engineering Birla Institute of Technology & Science Pilani,Pilani, India,"On-grid system evaluation for EV charging stations using renewable sources of energy"(2020)

[5] Birudala Venkatesh Reddy & Prof. Ch. Chengaiah "A Solar-Wind based EV Charging Station Model using MATLAB Simulink" doi:10.1088/1755-1315/1382/1/012003

[6] S.Jadisha Rajesh and Dr.Ananthi Christy ,"CHARGING ELECTRIC VEHICLE THROUGH HYBRID SOLAR WIND RENEWABLE ENERGY SOURCES", ISSN:0975-3583,0976-2833 VOL12,ISSUE05,2021.

[7] Sunil Magan More, Dr. Brajesh Mohan Gupta, "A Review of Battery Thermal Management System for Electric Vehicles", J.ElectricalSystems20-10s(2024):5079- 5096, Journal Name: Journal of Electrical Systems, ISSN: 1112-5209, Journal url: https://journal.esrgroups.org/jes/ Scopus link: https://www.scopus.com/sourceid/19700186890 Indexing: Scopus/ESCI, Scope: Multidisciplinary URL: https://journal.esrgroups.org/jes/article/view/6199/4356 (Scopus Indexed Journal)

[8] Sunil Magan More, Dr. Brajesh Mohan Gupta, presented paper in IEEE Conference on "Design & Development of Battery Management System for Electric Vehicles to Minimize Various Faults", Second IEEE International Conference on Computational and Characterization Techniques in Engineering & Sciences, CCTES-2024, November 15-16, 2024, Integral University, Dasauli, Bas-ha Kursi Road, Lucknow – 226026. Conference website page: https://cctes.iul.ac.in/ Paper Status: Accepted & Presented in IEEE Conference CCTES-2024 (IEEE Indexed Conference)

[9] Sunil Magan More, Dr. Brajesh Mohan Gupta, Presented paper in International Conference on "Review on Battery Thermal Management Systems for Electric Vehicles", Multillingul International Conference on Multidisciplinary Studies & Innovative Technologies, Venue: YMCA Connaught place New Delhi, MSIT-2024, Date 28 August 2024, ISBN 978-93-91535-93-3, www.conferenceworld.in (International Conference)

[10] R. Tharwin Kumar *, C. Christober Asir Rajan "Integration of hybrid PV-wind system for electric vehicle charging: Towards a sustainable future", https://doi.org/10.1016/j.prime.2023.100347 Received 4 September 2023; Received in revised form 6 October 2023; Accepted 3 November 2023, 2772-6711/© 2023 The Author(s). Published by Elsevier Ltd. This is an open access article under the CC BY license (http://creativecommons.org/licenses/by/4.0/). e-Prime - Advances in Electrical Engineering, Electronics and Energy journal homepage: www.elsevier.com/locate/prime.

[11] Priyanshu Singla 1, Shakuntla Boora, Poonam Singhal, Nitin Mittal, Vikas Mittal & Fikreselam Gared, "Design and simulation of 4 kW solar power-based hybrid EV charging station" Scientific Reports | (2024) 14:7336 | https://doi.org/10.1038/s41598-024-56833-5