SMART ENERGY MANAGEMENT SYSTEM FOR HYBRID RENEWABLE ENERGY BASED EV CHARGING STATION

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Abstract

The increasing adoption of electric vehicles (EVs) is a key strategy to reduce carbon emissions and promote sustainable transportation. However, as the number of EVs on the road continues to grow, there is a pressing need for efficient and reliable charging infrastructure. One promising solution is the integration of Hybrid Renewable Energy (HRE) systems at Electric Vehicle Charging Stations (EVCS), which can provide a sustainable and cost-effective energy supply for EV charging while reducing dependency on the grid.A Hybrid Renewable Energy-Based EV Charging Station combines multiple renewable energy sources such as solar, wind, Fuel cell and/or biomass with conventional power sources to ensure a stable and uninterrupted supply of energy. The key challenge, however, lies in managing the fluctuating and intermittent nature of renewable energy generation while meeting the consistent and often high energy demand from EVs. This is where an Energy Management System (EMS) plays a critical role. An Energy Management System (EMS) for a Hybrid Renewable Energy-Based EV Charging Station is designed to optimize the integration and distribution of energy from different sources. The EMS monitors and controls the power flow, ensuring efficient utilization of renewable energy, battery storage, and the grid. It also prioritizes energy sources based on availability, cost-effectiveness, and environmental impact, thus maximizing the use of clean energy and reducing operational costs.

Keywords : *Hybrid Renewable Energy, Maximum Power Point Tracking, Fuzzy Wind turbine*

I.INTRODUCTION

The rapid global shift toward sustainable transportation has spurred the development of innovative electric vehicle (EV) charging systems powered by renewable energy. Traditional EV charging stations often depend on grid electricity, which may still rely on fossil fuels, undermining the environmental benefits of electric mobility. To address this issue, integrating multiple renewable energy sources such as solar and wind power with fuel cell technology offers a hybrid solution that enhances reliability, efficiency, and sustainability. Solar and wind energy are among the most abundant and clean energy resources available. However, their intermittent and variable nature can pose challenges in meeting consistent energy demands. To overcome these limitations, the addition of a hydrogen fuel cell system acts as a complementary backup, storing excess energy and providing power during periods of low solar irradiance or wind speed.

The EMS is equipped with real-time monitoring and decision-making capabilities to handle the dynamic nature of energy production and consumption. It ensures that the charging station operates efficiently, reducing energy waste, enhancing system reliability, and providing a seamless user experience for EV owners. Additionally, the EMS can incorporate features such as demand-response management, load balancing, and predictive analytics to further optimize the charging station's performance. This introduction provides a framework for understanding the need and functionality of an Energy Management System in a Hybrid Renewable Energy-Based Electric Vehicle Charging Station. By integrating renewable energy sources with smart energy management, such systems can contribute to the larger goals of energy sustainability, reducing greenhouse gas emissions, and supporting the widespread adoption of electric mobility.

This introduction provides a framework for understanding the need and functionality of an Energy Management System in a Hybrid Renewable Energy-Based Electric Vehicle Charging Station. By integrating renewable energy sources with smart energy management, such systems can contribute to the larger goals of energy sustainability, reducing greenhouse gas emissions, and supporting the widespread adoption of electric mobility.

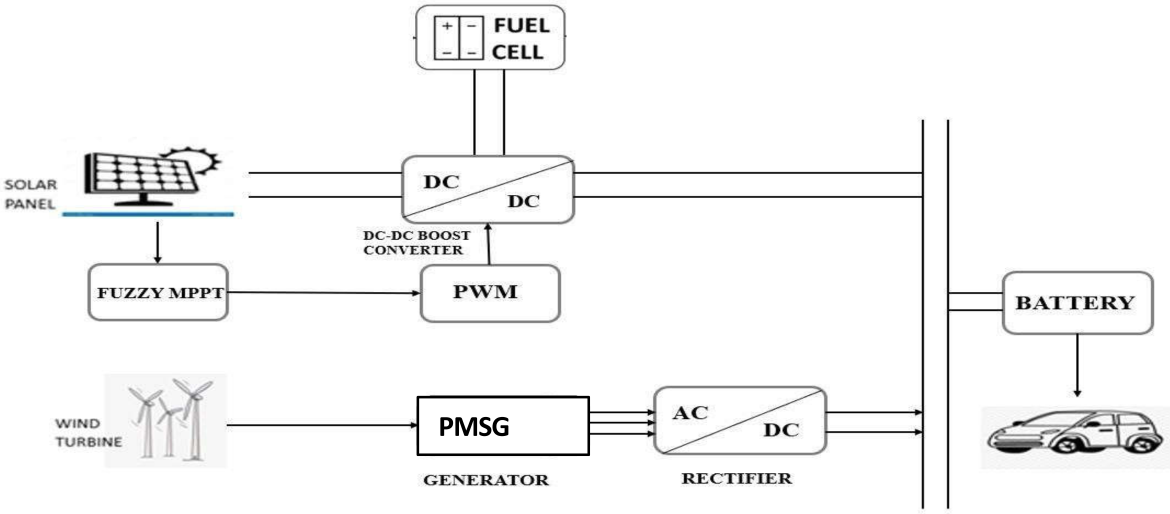
This hybrid configuration ensures continuous, off-grid EV charging capability while reducing greenhouse gas emissions and fossil fuel dependency. This paper explores the design and operation of a solar-wind-fuel cell hybrid EV charging station, focusing on intelligent energy management strategies to optimize power flow, maximize system efficiency, and ensure uninterrupted EV charging. Such a system represents a crucial step toward greener transportation infrastructure and a more resilient renewable energy ecosystem.

II. PROPOSED SYSTEM

The proposed model features a Electric Vehicle (EV) charging station designed with the energy sources of Solar, Fuel cell and Wind energy. In solar the fuzzy MPPT is used to give pulse to the boost converter. EV Charging Stations designed with solar, fuel cell and wind Energy are sustainable solutions that integrate renewable energy sources to charge electric vehicles (EVs). These stations combine solar panels, fuel cell and wind turbines to generate electricity, reducing dependence on the grid and lowering carbon footprints.

Fig.1. Proposed System Block Diagram

A hybrid renewable energy system combining fuel cell, solar, and wind sources offers a sustainable and reliable solution for battery charging applications. In the proposed architecture, the fuel cell and solar photovoltaic (PV) systems generate direct current (DC) power, each interfaced through individual DC-DC converters to regulate voltage and ensure compatibility with the common DC bus. The solar subsystem incorporates a Maximum Power Point Tracking (MPPT) algorithm to enhance power extraction under varying



irradiance conditions. In parallel, the wind turbine, which generates variable-frequency alternating current (AC), is connected to an AC-DC converter (rectifier with filter) to produce a stable DC output. All three sources converge at a centralized DC bus, from which power is directed to charge the battery through a suitable charge controller. This configuration not only ensures continuous energy availability by leveraging multiple sources but also improves power quality, battery life, and overall system efficiency.

The inclusion of intelligent control strategies enables source prioritization and power management, making the system ideal for off-grid or microgrid electric vehicle charging stations and other energy storage applications.

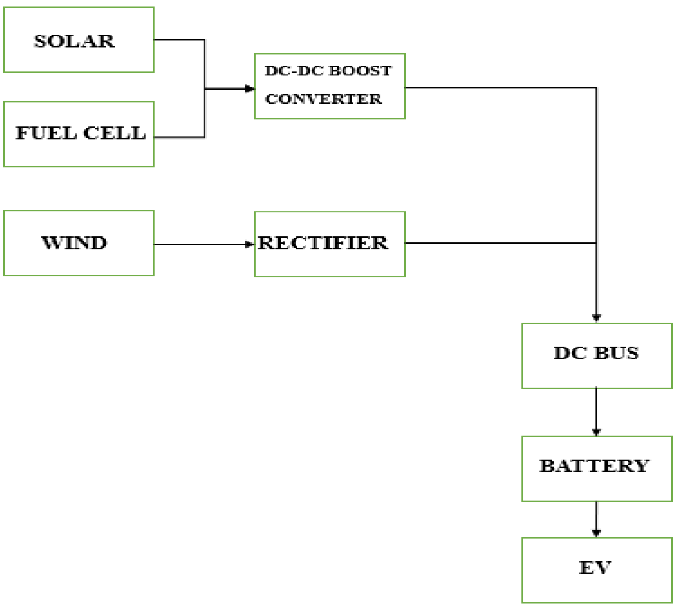


Fig.2. Proposed System Flowchart diagram

III. SIMULATION AND RESULTS

The simulation circuit of the proposed system is depicted below. The proposed topology is simulated in MATLAB. In this system, Electric Vehicle (EV) charging station designed with the energy sources of Solar, Fuel Cell and Wind energy, in solar the fuzzy MPPT is used to give pulse to the boost converter.

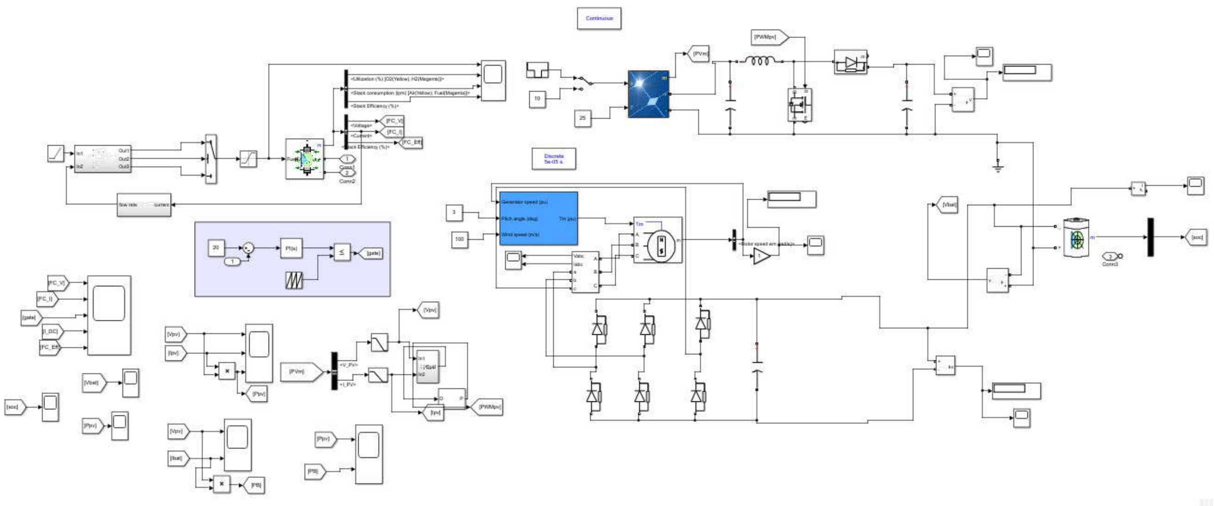


Fig.3. Simulation

The proposed System consists of Solar array, Boost Converter, Fuzzy Wind turbine with PMSG and Rectifier MPPT and a Battery is used to charging a electric vehicle and the battery used is Lithium-ion battery. Solar PV modules provide maximum voltage while operating at maximum power points. There will always be a particular operating point where the highest power can be drawn. It is necessary to track that point. Here the PWM pulse is given to the boost converter by Fuzzy MPPT controller. Wind turbine converts the wind kinetic energy into electrical power through its blades, which capture wind energy and cause the rotor to rotate, driving a generator to produce electricity. The output of DC-DC Boost converter and the PV array is shown in figure .The figure shows the solar voltage, solar current, Solar power and the Boost Voltage. The values of voltage and current are measured and verified using voltage and current measurement blocks in Simulink model. The simulation is made to run for period of 10 sec. It can be observed that the power is maintained constant throughout the time. Thus, the MPPT tracks the maximum power from the solar panel at standard temperature condition.

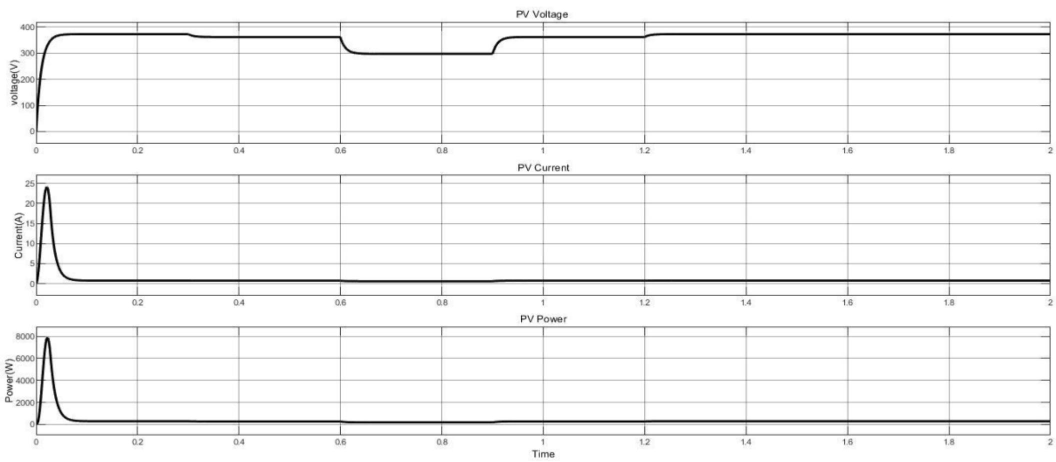


Fig.4. Solar Array & Boost Converter output Waveforms

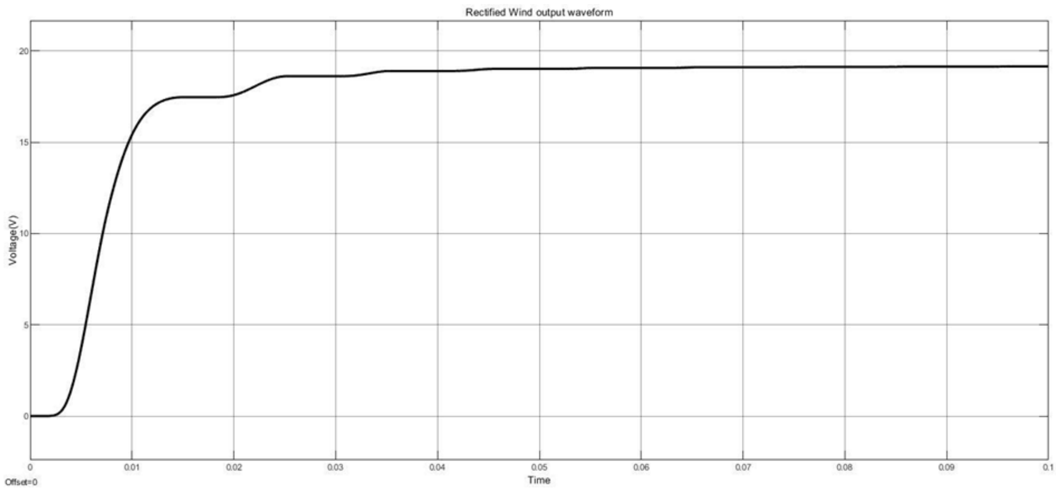


Fig.5.Rectified Wind output Waveforms

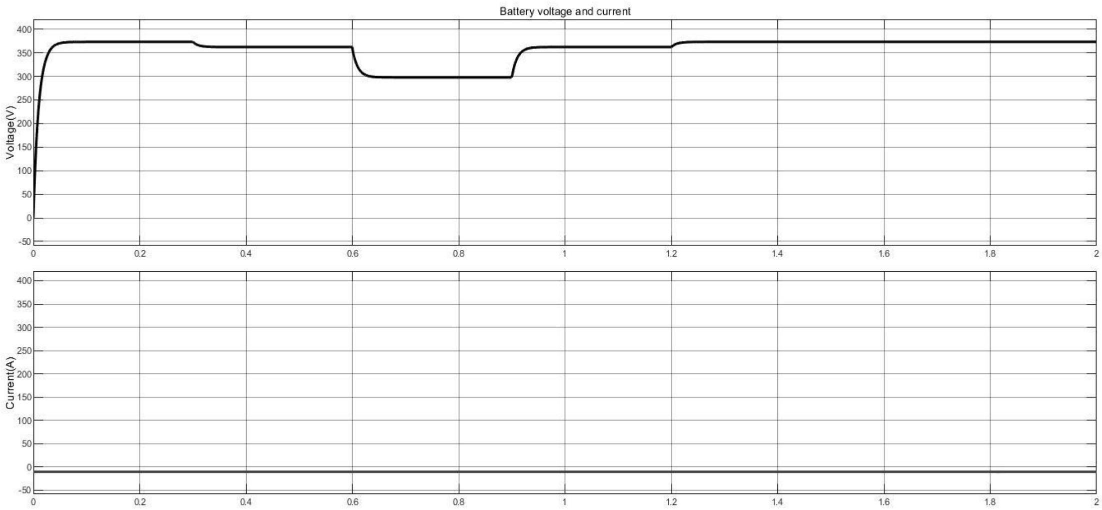


Fig.6. Battery voltage and current output Waveforms

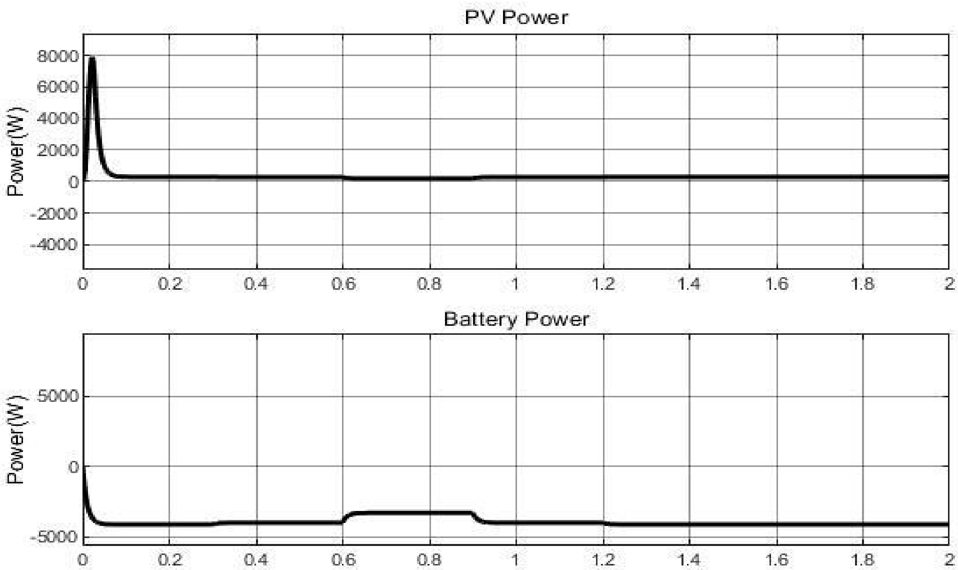


Fig.7 . Battery and PV Power output Waveforms

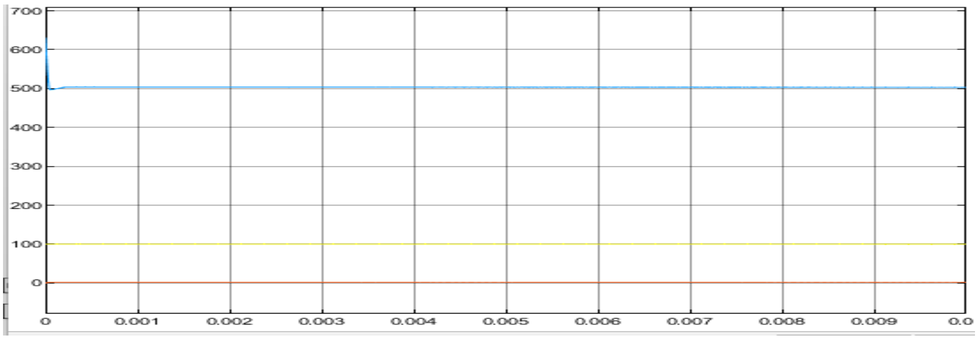


Fig.8.SOC output Waveforms

IV. CONCLUSION

The integration of renewable energy sources such as solar and wind for EV charging stations offers a sustainable and efficient solution for powering electric vehicles. Effective energy management systems (EMS) play a critical role in optimizing the use of these intermittent energy sources, ensuring reliability, cost-efficiency, and environmental sustainability. Hybrid solar, fuel cell and wind systems complement each other, providing a more consistent energy supply. Energy management ensures maximum utilization of renewable resources, reducing dependency on grid power and fossil fuels. Smart controllers and battery management systems ensure efficient energy flow and storage.

Energy storage solutions mitigate the variability of renewable energy, enabling uninterrupted EV charging even during unfavourable weather conditions. Renewable energy-based EV charging stations represent a pivotal step toward sustainable transportation. By leveraging energy management systems, these stations can ensure reliable operation, economic feasibility, and a reduced environmental footprint, making them a cornerstone of the future green energy ecosystem.

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