HYBRID RENEWABLE ENERGY EV CHARGING STATION: SOLAR AND WIND INTEGRATION : A Review

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Abstract. The review comprehensively examines hybrid renewable energy systems that combine solar and wind energy technologies, focusing on their current challenges, opportunities, and policy implications. Despite the individual merits of solar and wind energy systems, their intermittent nature and geographical limitations have spurred interest in hybrid solutions that maximize efficiency and reliability through integrated systems. A critical analysis of available literature indicates that hybrid systems significantly mitigate energy intermittency issues, enhance grid stability, and can be more cost-effective due to shared infrastructure. The review identifies key challenges, such as system optimization, energy storage, and seamless power management, and discusses technological innovations like machine learning algorithms and advanced inverters that hold the potential for overcoming these hurdles. Importantly, the review elucidates the role of policy in accelerating the adoption of these systems by highlighting successful case studies of government incentives, public-private partnerships, and regulatory frameworks that have fostered investments in hybrid renewable energy systems. The study concludes with the outcomes obtained that signify the potential for hybrid renewable energy systems to not only meet but exceed future energy demands sustainably, provided there is concerted effort in research, investment, and policy making.

Keywords: Hybrid renewable energy systems, Solar and wind power Challenges ,Opportunities, Policy implications,

1 Introduction

As global awareness of climate change and its impacts intensifies, there is a compelling push towards sustainable transportation solutions to reduce carbon emissions and improve air quality. Electric vehicles (EVs) have emerged as a promising alternative to traditional internal combustion engine vehicles, offering significant environmental benefits through reduced greenhouse gas emissions and lower fossil fuel dependency. However, the accelerated adoption of EVs presents considerable challenges for existing power infrastructure, primarily due to the increased demand for electricity that accompanies widespread EV usage. Integrating renewable energy sources, such as solar and wind, into the EV charging ecosystem is vital for creating a sustainable and resilient transportation framework. This integration not only helps mitigate the environmental impact of EV charging but also enhances the efficiency and reliability of the power grid. The potential of renewable energy to contribute to EV charging systems is immense, offering a pathway to develop smart, sustainable, and decentralized energy solutions that align with the broader goals of reducing fossil fuel consumption and enhancing grid stability. Moreover, the transition from traditional charging methods to innovative technologies such as wireless power transfer (WPT) systems represent a significant step forward in facilitating user-friendly charging experiences. WPT eliminates the need for physical connections, thereby simplifying the charging process and making it more accessible. This paper delves into the various methods of integrating renewable energy with EV charging systems, assessing both grid-connected and wireless solutions. By addressing key technical challenges and exploring potential solutions, this study aims to provide insights that will guide future advancements in EV charging infrastructure while promoting green mobility initiatives. Integrating hybrid renewable energy systems (HRES) with electric vehicle charging stations (EVCS) offers a sustainable and efficient way to power EVs, reducing reliance on traditional grid power. HRES, combining sources like solar and wind power, can generate electricity on-site for charging, and even supply excess energy back to the grid. This approach addresses the intermittency of renewable energy while enhancing grid stability and promoting cleaner energy practices

Objectives: To develop an integrated system that utilizes renewable energy sources and the electrical grid to support electric vehicle (EV) charging infrastructure, thereby promoting sustainable and green mobility. • To assess the potential of various renewable energy sources (e.g., solar, wind) for EV charging applications. • To design a hybrid energy system that combines renewable sources with the grid for reliable and efficient EV charging. • To develop a smart energy management system for optimal utilization of renewable energy and grid power. • To evaluate the environmental and economic benefits of integrating renewables with EV charging infrastructure. • To analyze the impact of EV charging on the grid and propose solutions for minimizing peak demand and load fluctuations. • To explore energy storage options (e.g., batteries) to enhance the reliability and efficiency of the charging system. • To promote sustainable transportation by reducing the carbon footprint associated with EV charging.

Renewable Energy Sources with EV Charging: The integration of renewable energy sources into EV charging systems is a crucial strategy for promoting sustainable mobility and reducing dependence on fossil fuels. This combination not only supports the charging needs of growing EV populations but also contributes to cleaner energy generation, enhancing overall environmental sustainability.

Types of Renewable Energy Sources Solar Energy: • Photovoltaic (PV) Systems: Solar panels can be installed on rooftops of parking spaces, charging stations, or nearby structures. This harnesses sunlight to generate electricity, which can be used directly for charging EVs or stored in batteries for later use. • Benefits: Solar energy is abundant and widely available, especially in sunny regions, making it an ideal source for powering charging stations. Wind Energy: • Wind Turbines: These can be deployed in areas with sufficient wind resources to generate electricity that can support EV charging infrastructure. • Benefits: Wind energy can complement solar generation, particularly in areas where wind patterns differ from solar availability, allowing for more consistent energy supply throughout the day and night. • Hydropower: Large-scale hydroelectric facilities can provide a stable source of renewable energy that can be linked to the grid and used for powering EV charging stations. Users can access the data through a user-friendly interface, enabling them to monitor system performance in real-time and make informed decisions regarding maintenance and optimization

Integration with Charging Infrastructure: Targeting renewable energy sources with EV charging stations involves several components: Smart Grids: • The use of smart grid technologies allows for dynamic management of energy flows between renewable sources, charging stations, and the power grid. They can optimize the use of available renewable energy, balancing supply and demand efficiently. Energy Storage Systems: • Battery storage systems can be combined with renewable energy sources to store excess energy generated during peak production times (e.g., sunny or windy days) for use during off-peak times or high-demand periods. This enhances the reliability of EV charging stations by ensuring the availability of power when needed.

2. Literature Review

Itie Goswami et al. (2020) This work presents an energy management strategy for multi-power mixed (VV) vehicles, of which the fuel cell (FC) is the main source of energy, and the batteries and super capacitors (SC) are the second most powerful. Electric cars draw the energy they need from fuel cells, while auxiliary energy is used to compensate for power shortages during high-speed or overpower during braking. The use of secondary energy efficiency has proven to be effective in improving vehicle performance, significantly reducing hydrogen consumption, and bringing reliability and reliability to the operation of the entire system. The proposed strategy regulates the distribution of power to various energy sources in the best possible way to meet power needs.Matlab / Simulink are used as a simulation platform.

T.Porselvi et al. (2019) introduced the amount of power supply, which is highly reliable for electric vehicle steering systems. Batteries, solar photovoltaic power supplies, and super capacitors play an important role in this long-lasting power supply. The main power source is the battery, which connects to the super capacitor during transient processes such as overload and start-up.To purchase mixed electric vehicles, hybrid energy storage systems (HESS) with super capacitors and batteries are widely used to improve the charging and discharging characteristics of the batteries, thereby increasing the power of immediate discharge. To reduce energy loss in a hybrid battery storage system, a bidirectional DC / DC converter should be used with a flexible conversion solutions.technology. Initially, the power received from the PV sequence was used to charge the super capacitors and batteries. When PV cannot provide enough power to charge the EV, it can use battery power and super capacitors. With the help of MATLAB software, you can also compare the performance of existing and non-super capacitors systems.

Zheng Guan et al. (2019) research on hybrid power sources that combine batteries and super capacitors is a hot spot in the field of electric vehicle research. Batteries have a high energy density, and super capacitors have high density. To moderately control the output power of both and make the electric car run more efficiently, it conducted a detailed analysis of how hybrid energy systems work and proposed energy management strategies based on speed and energy Logical level control. In the world of MATLAB / SIMULINK simulation, the power supply of electric vehicles and control strategies are proposed. The simulation results show that the super capacitors waveform can accurately track the current deer, and the proposed control strategy can normally divide the output of the battery and the super capacitors to meet the energy output according to different power requirements.

Amir Rezaei et al. (2018) Energy management of hybrid plug-in (HEV) vehicles is usually divided into two parts: heavy power modes and power maintenance methods. This paper presents the best adaptive laws for a variety of adaptive energy reduction strategies (ECMS) under the heavy-duty hybrid plug-in method. To implement the best law, a special ECMS adapter, called Capture Energy Saving Opportunity (CESO) was selected. CESO has been used in hybrid and hybrid vehicles in a maintenance free manner. Here, by introducing the rules governing the best sports, CESO's strategy extends to how power is consumed in hybrid vehicles.

K. Chaudhari et al. (2018) Energy storage systems (ESSs) are often used to manage renewable energy (RES) characteristics. Proper control strategies are needed to preserve power balance among RES, demand, and ESS. The traditional control system for vigor storage systems (HESS) utilizes high/low power steering systems for power generation and ESS power distribution. This paper proposes a new DCbased photo catalytic system for heating with battery and super capacitor (SC) as HESS. The new control strategies utilize the power of non-electrical in the system to improve the overall HESS process. Compared to conventional control strategies, the advantages of the proposed control strategy are the recovery of fast DC voltage and efficient power distribution between the battery and the SC.

3. Methodology

In a hybrid Micro grid, the photovoltaic system is usually controlled to operate at maximum point-to point xtraction mode (MPPT). The energy storage system operates in the form of a power supply or a constant power supply. To provide frequent support and to prevent power ctuations, this section offers dual SM monitoring strategies and high performance.

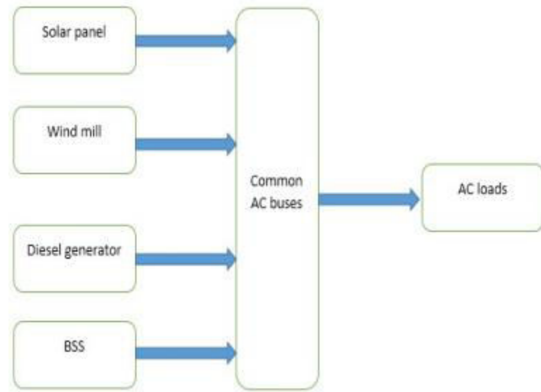

Fig. 1: Block Diagram of system

The effectiveness of a dual power generation system for automatic street lighting lies in the seamless integration and intelligent operation of its various components. This section details how solar and wind energy sources are combined, how energy is managed, and the logic governing the automatic lighting control.The core principle of the hybrid system is to leverage the complementary nature of solar and wind resources. Solar panels generate electricity during daylight hours, with peak production typically around midday. Wind turbines, conversely, can generate power day and night, and their output is dependent on wind speed, which often varies independently of solar irradiance. In many geographical locations, periods of low solar insolation (e.g., cloudy days, winter months) often coincide with higher wind speeds,and vice-versa. This natural complementarity ensures a more consistent and reliable power supply than either source could provide individually. The electrical outputs from both the solar panels (via their charge controller) and the wind turbine (via its charge controller) are fed into a common DC bus, which then charges the battery bank.This parallel connection allows for continuous energy harvesting from whichever source is available and productive, maximizing the overall energy capture and minimizing periods of insufficient generation

4. Conclusion

The Integrating EV charging with renewable energy sources and the grid promotes sustainable mobility by reducing greenhouse gas emissions and enhancing energy efficiency. Utilizing smart grid technology enables real-time management of energy use, dynamically allocating power from renewables and the grid. EVs can also serve as energy storage, supplying excess power back to the grid during peak demand. This approach not only lowers operational costs and dependency on fossil fuels but also fosters innovation and job creation in green technologies. Ultimately, this integration supports a resilient energy infrastructure, advancing the transition to electric vehicles and a cleaner environment.

Advantages • Reduced Carbon Footprint: Using renewable energy like solar or wind to charge EVs minimizes greenhouse gas emissions compared to fossil fuel-based electricity. • Energy Cost Savings: Renewable sources can lower electricity costs for EV charging, especially during peak grid prices. • Grid Stability and Demand Management: Combining grid and renewables allows load balancing and peak shaving, reducing stress on the power grid. • Enhanced Energy Security: Diversifying energy sources reduces dependence on non-renewable fuels and increases energy resilience. • Support for Smart Grids: Integration facilitates smart charging strategies, demand response, and vehicle-to-grid (V2G) services. • Promotion of Sustainable Mobility: Encourages the adoption of green transportation by providing cleaner and more efficient charging infrastructure.

Applications • Residential EV Charging: Home solar panels paired with grid backup for sustainable and cost-effective vehicle charging. • Public Charging Stations: Solar- or wind-powered EV charging stations in urban areas and highways to provide green mobility options. • Workplace Charging: Integration of renewable energy systems with workplace chargers to support employee EVs sustainably. • Fleet Charging: Electric bus and delivery fleets charging via renewable energy sources to reduce operational emissions. • Smart Grid and V2G Systems: Utilizing EVs as energy storage units that can supply power back to the grid when needed. • Remote or Off-grid Locations: Using renewable energy-based EV charging systems in areas without reliable grid access.winning.

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