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Eco Friendly Power Source for Electric Vehicles Charging: A Hybrid Approach - A Review

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Abstract – *This review paper explores a hybrid approach to power electric vehicle charging stations, integrating multiple renewable energy sources to minimize environmental impact. The proposed system combines solar, wind, and grid power in an intelligent and adaptive manner to ensure a reliable and efficient energy supply for EV charging infrastructu.*

The review hybrid system employs advanced monitoring and control technologies to optimize the utilization of renewable energy sources. Solar panels harness energy from the sun, while wind turbines capture wind energy, both contributing to a clean and green power supply. Grid power serves as a backup and supplements the renewable sources during periods of low generation or high demand.

Smart energy management algorithms play a crucial role in dynamically balancing the energy mix based on real-time data such as weather conditions, energy demand, and grid availability. These algorithms prioritize renewable sources when conditions are favorable and seamlessly switch to grid power when needed, ensuring a continuous and stable charging infrastructure.

Keywords: **Eco friendly power source, electric vehicles, charging, hybrid approach, grid-to-meter energy efficiency, hybrid dynamical system**

I. Introduction

The global shift towards sustainable and eco-friendly transportation has led to a significant increase in the adoption of electric vehicles (EVs). As the demand for EVs continues to grow, the need for efficient and environmentally responsible charging solutions becomes paramount.

A. Charging Structure Design

The EV charging system design is developing a reliable and efficient charging station to meet the increasing power demand of EVs at the selected site and to supply power back into electricity grid or consume it by conventional load at the same site. However, an important issue that should be considered in this context, is that RES energy production depends on the location of installation, the seasonal variations, the daily weather change, the power grid stability issues (e.g. power quality and voltage variation) and the storage system capacity. Consequently, in this thesis, an integrated system design for a hybrid PV/grid/ storage system for EVs charging is implemented

The ESS can regulate the variations in solar energy production or the electricity grid and store energy during the periods of overproduction to supply the charging system at low production levels. In the modern charging systems, smart charging methods are employed to make the EV charging process follow the variables of power sources production [15, 16]. In this thesis, the charging station is designed considering the hierarchical control. The first level control and on-line energy management to maximize the PV power utilization rate, enhance the charging system capacities, reduce the cost of electricity purchase from the grid and minimize the grid stress resulting from simultaneous recharging of the large number of EVs is illustrated. By combining the electricity grid with the use of PV and ESS beside the implementation of the relevant control and energy management system (EMS), a positive impact of this combination on the charging process of EVs can be introduced.

B. EV charging power conversion: topologies

The EV chargers can be off-board or on-board as shown in Fig 1. Typically, the use of off-board chargers may reduce the total cost and the size of the vehicle. More recently, AC grids have been utilized to power EVs with embedded chargers [17].

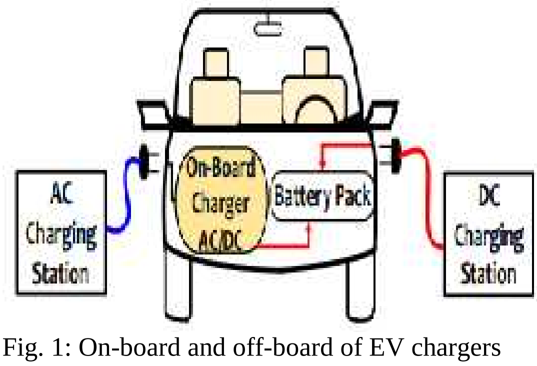

Fig. 1: On-board and off-board of EV chargers

The fast charger as an on-board option for an EV is hampered by the cost of the electronic components required for energy conversion, which increases the overall cost of EVs. However, on-board chargers cannot provide fast EV charging because of the power electronics high costs associated with the EV and the necessity to increase the capacity of the charger in the vehicle.

II. LITERATURE REVIEW

In recent years, the research landscape surrounding **Farshad Khalafian et.al. (2024) -** The design of a hybrid renewable islanded system capable of simultaneously supplying electrical and thermal energy is explored, utilizing wind systems and bio-waste units for energy generation. The incorporation of combined heat and power technology in the bio-waste unit enables the concurrent production of electricity and heat. Electric vehicles, operating with smart charging, consume electric energy. Compressed air energy storage is employed to align electric power generation and consumption patterns, enhancing energy efficiency and reducing planning expenses. [01].

Tripti Kunj et.al. (2024) - A system is constructed, consisting of a solar photovoltaic (PV) array, a battery energy storage (BES), a diesel generator (DG) set, and an electric vehicle (EV) charging station (CS). This setup facilitates continuous charging in islanded, grid-connected, and DG set connected modes. The primary function of the CS is to utilize the solar PV array and BES for charging the EV battery. Should the storage battery be depleted or the solar PV array is inactive, the CS intelligently switches to draw power from either the grid or the DG set. Furthermore, the system ensures that power drawn from the grid or DG set maintains a unity power factor even when subjected to nonlinear loading conditions [02].

Ahad Hamednia et.al. (2023) - An optimization problem to determine the optimal balance between trip duration and charging expenses. This problem is subsequently converted into a hybrid dynamical system, wherein distinct functions and state/control vectors model the dynamics during driving and charging phases. To enhance computational efficiency, we suggest representing driving dynamics in a spatial domain, allowing decisions to be made based on the traveled distance. Meanwhile, charging dynamics are depicted in a temporal domain, where decisions are based on a normalized charging time. The effective charging time is represented as a scalar variable, concurrently optimized with the optimal state and control trajectories for both driving and charging phases. The algorithm's efficacy is evaluated on a route with varied terrain, considering two charging options along the way. The outcomes reveal a 44% reduction in total trip time (inclusive of driving and charging durations) compared to a scenario without active battery heating/cooling [03].

Ijaz Ahmed et.al. (2023) – Efforts toward environmentally sustainable transportation have gained paramount importance, driven by the depletion of natural resources and escalating levels of pollutant emissions. Plug-in electric vehicles (PEVs) emerge as a promising solution, offering both economic and environmental advantages. However, the proliferation of PEVs, coupled with the self-interested behavior of users, poses challenges to power grids, given the information asymmetry between charging demand and supply [04].

Venkatesh Boddapat et.al. (2022) - The design of Electric Vehicle Charging Stations (EVCS) for various locations in Denmark was carried out by leveraging the existing renewable energy resources. The system, which included photovoltaic (PV) panels, wind turbines, battery storage, and distributed generation (DG), underwent mathematical modeling. Using the HOMER optimization tool, the design and performance were thoroughly analyzed to evaluate the technical parameters and economic aspects of the projects **[05].**

Abhinav K. Gautam et.al. (2022) - As per the review, there is a growing interest among researchers in exploring the design features of powertrains and Energy Management Systems (EMSs) for hybrid and electric vehicles. Various powertrain and EMS topologies have been proposed to address control objectives such as reducing fuel consumption, minimizing emissions, preserving Energy Storage System (ESS) charges, and enhancing drivability and vehicle performance. The development of energy management techniques involves a trade-off between optimality and execution **[06].**

Mehrdad Ehsani et.al. (2021) - Electric and hybrid electric vehicles (EV/HEV) are promising solutions for fossil fuel conservation and pollution reduction for a safe environment and sustainable transportation. The design of these energy-efficient power trains requires optimization of components, systems, and controls. Controls entail battery management, fuel consumption, driver performance demand emissions, and management strategy. The hardware optimization entails powertrain architecture, transmission type, power electronic converters, and energy storage systems. In this overview, all these factors are addressed and reviewed. Major challenges and future technologies for EV/HEV are also discussed. Published suggestions and recommendations are surveyed and evaluated in this review. The outcomes of detailed studies are presented in tabular form to compare the strengths and weaknesses of various methods. Furthermore, issues in the current research are discussed, and suggestions toward further advancement of the technology are offered. This article analyzes current research and suggests challenges and scope of future research in EV/HEV and can serve as a reference for those working in this field **[07].**

Mehrdad Ehsani et.al. (2021) -The primary drivers for transitioning to modern Electric Vehicle (EV) and Hybrid Electric Vehicle (HEV) technologies are improved fuel efficiency, drivability, and reduced emissions. Unlike conventional and EV powertrains, HEV powertrains are more intricate in both architecture and control due to their reliance on two or more power sources. This complexity arises from the need for optimal dynamic power distribution among these sources to achieve optimal fuel economy. [17].

Imran Rahman et.al. (2020) - The field of Electrification of Transportation has undergone significant transformations in the past decade. The success of integrating smart grid technology and renewable energy relies heavily on the widespread adoption of Plug-in Hybrid Electric Vehicles (PHEVs) to achieve a pollution-free transportation industry. A crucial performance indicator for hybrid electric vehicles is the State-of-Charge (SoC), which must be improved for the progress of charging stations through the application of computational intelligence methods. Through computational experiments, the results have been obtained to maximize the highly non-linear fitness function, estimating the performance of both techniques in terms of the best fitness value and computation time **[08].**

Van-Binh Vu et.al. (2020) - A hybrid charging system integrating both inductive and conductive methods for electric vehicles is introduced. The key advantage of this innovative system lies in its ability to optimize the utilization of on-board power electronics and magnetic components during two charging modes. Consequently, the hybrid charger minimizes component counts and simplifies system complexity. To attain this objective, a meticulously designed set of three coils enhances power transfer while adhering to electromagnetic emission constraints. The paper elucidates the design and functionality of the proposed coupler coils, offering a detailed discussion. Experimental validation of the hybrid charger's feasibility is conducted using a 3-kW laboratory prototype, tested under various operating load conditions. The findings presented in this paper serve as a foundational exploration for future investigations into hybrid charger systems tailored for electric vehicle applications, paving the way for further studies in this domain **[09].**

Salman Habib et.al. (2020) - This paper investigates contemporary requirements, recent advancements, and challenges associated with power electronics converters to propose potential improvements in Electric Vehicle (EV) charging solutions. The development in power converter designs plays a crucial role in enhancing EV charging technologies for electric transportation. The focus of this document is on global standards that facilitate the widespread deployment of EVs, conducting a thorough analysis of both frontend and back-end converter topologies, highlighting their respective challenges and advantages.

The study further explores charging topologies, encompassing integrated chargers, frontend (AC-AC), and back-end (AC-DC) converters. It presents quantitative design specifications for various topologies. The research delves into multiple sub-areas within power electronic converters, providing a comprehensive analysis of their role in electrifying transportation systems. This paper is expected to be a valuable addition and a significant source of information for researchers investigating power converter topologies in EV charging systems **[10].**

Sajib Chakraborty et.al. (2019) - The research encompasses both AC-DC and DC-DC converter architectures tailored for Fast Charging Stations (FCHARs). Following a meticulous examination, the Multidevice Interleaved DC-DC Bidirectional Converter (MDIBC) emerges as the optimal topology for high-power Battery Electric Vehicles (BEVs) and Plug-in Hybrid Electric Vehicles (PHEVs) with a power rating exceeding 10 kW. This selection is substantiated by its advantageous features, including low input current ripples, minimal output voltage ripples, low electromagnetic interference, bidirectionality, high efficiency, and reliability.

On the contrary, pinpointing a singular optimal candidate for low-power electric vehicles below 10 kW presents challenges. Nevertheless, the Sinusoidal Amplitude Converter, Z-Source DC-DC converter, and boost DC-DC converter with resonant circuit demonstrate suitability for low-power BEVs and PHEVs. Their merits include soft switching, noise-free operation, low switching loss, and high efficiency.

The paper concludes by exploring the potential integration of wide band gap semiconductors (WBGSs) in DC-DC converters for BEVs, PHEVs, and FCHARs. It outlines a future research roadmap for WBGSs, encompassing the modeling of emerging topologies and detailed design of control systems for BEV and PHEV powertrains. This comprehensive analysis serves as a valuable resource for researchers and solution engineers in the automotive industry, aiding in the selection of an appropriate converter topology to enhance the projected power density growth **[11].**

III. METHOD

A hybrid approach to eco-friendly power sources for electric vehicle (EV) charging typically involves combining multiple renewable energy sources and energy storage systems to optimize efficiency and reliability. Here are several components and methods that can be integrated into a hybrid approach:

Solar Power

- Solar Panels: Install solar panels in charging stations or nearby areas to harness energy from the sun.
- Solar Tracking Systems: Implement tracking systems that follow the sun's movement to maximize energy capture.

Solar power is a renewable energy source that harnesses the energy of the sun to generate electricity or heat. This form of energy is considered environmentally friendly and sustainable because it relies on the sun, which is an abundant and inexhaustible resource. Solar power can be harnessed through various technologies, with the two primary methods being photovoltaic (PV) systems and solar thermal systems.

Fig 2 Solar power

Wind Power

- Wind Turbines: Install small-scale wind turbines to harness wind energy, especially in locations with consistent wind patterns.
- Vertical Axis Wind Turbines (VAWT): VAWTs can be more suitable for urban environments and are less affected by changes in wind direction.

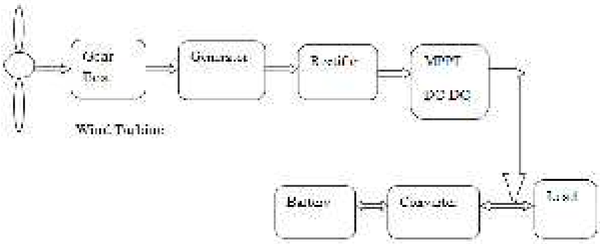

Fig 3 Wind Power

IV. CONCLUSION

In this paper has provided a A hybrid approach to powering electric vehicle charging stations, integrating both renewable and conventional energy sources along with energy storage solutions, presents a balanced and effective strategy. This approach addresses the challenges associated with the intermittent nature of renewable energy while promoting sustainability and reducing the overall environmental impact of electric transportation. As technology continues to advance, further refinements in hybrid systems are likely, contributing to a more efficient and sustainable future for EV charging.

Diverse Energy Sources:

A hybrid approach typically involves combining renewable energy sources such as solar and wind with conventional sources or energy storage systems. This diversity helps overcome the intermittent nature of renewable sources, ensuring a more consistent and reliable power supply for EV charging.

Reliability and Consistency:

Incorporating conventional power sources, such as the electrical grid or backup generators, provides reliability and consistency in charging, especially during periods of low renewable energy generation. This ensures that EV users have a dependable charging infrastructure regardless of weather conditions or time of day.

Energy Storage Integration:

Hybrid systems often include energy storage solutions like batteries. These batteries can store excess energy generated during peak renewable production times and release it during periods of low production, contributing to a more stable and continuous power supply for EV charging.

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