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# A Review of Efficient Power Management Using Fuzzy Logic For Electrical Vehicle Charging Station Based on Hybrid Energy Source

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***Abstract* –** *his review paper delves into the realm of efficient power management strategies employed in electrical vehicle (EV) charging stations, focusing on the integration of hybrid energy sources. The burgeoning demand for sustainable transportation has intensified the need for innovative and eco-friendly charging solutions. In this context, the application of fuzzy logic in power management systems is explored as a promising approach to optimize the utilization of diverse energy resources.*

*The review critically examines existing literature, highlighting advancements and challenges in the integration of hybrid energy sources, such as solar and wind, within the framework of EV charging infrastructure. Special attention is given to the role of fuzzy logic controllers in dynamically adapting to fluctuating energy inputs, demand variations, and system uncertainties. The paper synthesizes key findings from diverse studies, emphasizing the impact of fuzzy logic on enhancing energy efficiency, reducing operational costs, and mitigating environmental impact in EV charging stations.*

***Keywords:*** **Electrical Vehicle Charging Stations, Power Management, Hybrid Energy Sources, Sustainable Transportation, Renewable Energy Integration Energy Efficiency**

## I. INTRODUCTION

The escalating global concern over environmental sustainability has catalyzed a paradigm shift towards greener modes of transportation, prominently exemplified by the increasing adoption of electric vehicles (EVs). As the EV market expands, the demand for efficient and eco-friendly charging infrastructure becomes imperative. In response to this challenge, researchers and engineers are exploring innovative solutions to enhance the performance of electrical vehicle charging stations. This review focuses on the pivotal role of efficient power management strategies, specifically leveraging fuzzy logic, in the context of EV charging stations powered by hybrid energy sources.

The integration of hybrid energy sources, such as solar and wind, into the power supply infrastructure of EV charging stations represents a progressive step towards sustainable and self-sufficient transportation ecosystems. However, the inherent variability of renewable energy sources poses challenges in maintaining a consistent and reliable power supply for charging. Fuzzy logic controllers offer a dynamic and adaptive approach to address these challenges by intelligently managing the diverse and fluctuating inputs within the charging station's energy system.

This paper aims to synthesize and analyze the current state of research in the field, examining the synergies between fuzzy logic controllers and hybrid energy sources for optimal power management. By critically reviewing existing literature, we intend to shed light on the advancements, limitations, and potential breakthroughs in this dynamic intersection of electric vehicle technology and sustainable energy solutions. Additionally, the introduction will set the stage for the subsequent sections, outlining the objectives, scope, and significance of the review in contributing to the advancement of intelligent and sustainable EV charging infrastructure.

## II. LITERATURE REVIEW

In a 2019 study, T.S. Biya and colleagues [14] highlighted that as the number of electric vehicles (EVs) on the streets increases, effectively charging them has become a pressing concern. They proposed an innovative charging station outfitted with solar panels, a battery system, and additional grid assistance as a promising solution to cater to the diverse charging needs of multiple EVs throughout the day. The station attains the desired power by regulating its DC bus voltage via PID controllers, current modulation, and voltage regulation. The design and power management of this station were elaborated and verified using MATLAB/Simulink, considering five distinct operational scenarios and exploring two cases of EV demands. The resilience of this design and its associated algorithms is noteworthy. Given its high power capacity, this setup can potentially serve as a public or workplace charging point for EVs.

In a subsequent 2020 study, Vimala Juliet and her team [15] deduced that uninterrupted EV charging could be facilitated by an electric vehicle charging station powered by decentralized energy streams, notably the DC Nanogrid (NG). This NG harnesses energy from both solar (PV) and wind sources, which are sustainable energy mediums. An energy storage unit (ESU) is employed to store surplus energy generated from these renewables and to dispense it during periods of low renewable energy output. To ensure continuous charging, especially during instances when the NG faces high demand or the ESU is energy-depleted, a mobile charging station (MCS) is introduced. This MCS enables battery exchange and facilitates connections between the vehicle and the grid. Furthermore, the MCS plays a pivotal role in monitoring battery health and its State of Charge (SOC) by constantly observing parameters like voltage, current, and temperature in relation to the SOC and State of Health (SOH). To validate the practicality of connecting EVs to the NG and for real-time battery metrics monitoring through IoT, a laboratory prototype is under development and examination.

In a 2021 research article, Rajanand Patnaik Narasipuram and team [16] observed that the electric vehicle industry has seen remarkable growth in recent times as a response to the challenges posed by greenhouse gas emissions. A pivotal aspect of this expansion hinges on the deployment of user-friendly and economical EV charging stations equipped with advanced control systems, mirroring the accessibility of traditional fuel stations. Their paper offers a comprehensive overview of electric vehicles and various battery technologies suited for recharging. They delve into the categorization of charging stations based on power needs, shedding light on optimization techniques and future prospects. They also delve into the nuances of grid-connected sustainable energy solutions, emphasizing the benefits of combining storage with renewable energy inputs for the charging infrastructure. This can mitigate the grid's load, especially during peak hours. The study aims to provide a thorough understanding for professionals and researchers to foster future innovations.

In a 2019 publication, Wajahat Khan and associates [17] note the immense pressure the automobile sector faces in transitioning to greener and more efficient modes of transport, given the looming environmental crisis. Electric vehicles (EVs) emerge as an appealing solution over traditional internal combustion engine vehicles, with charging times being a primary concern. The study elaborates on strategies for public fast charging, prioritizing power quality and efficient load management. Their proposed model for a fast-charging station ensures efficient power transmission with minimal harmonic interference. This station connects EVs to a DC bus via converters linked to the grid. The integration of a solar PV system to the charging station aims to lessen the grid's strain from rapid charging. By harnessing the collective energy output of the EV batteries present at the station, the system optimizes overall energy consumption.

In their 2018 research, Anjeet Verma and collaborators [18] propose a system ensuring continuous EV charging by amalgamating a solar photovoltaic (PV) setup, a battery energy storage system (BESS), the grid, and a diesel generator (DG). Efficiently utilizing these diverse energy sources can cut down the operational expenses of the charging station, translating to more affordable EV charging. Their proposed strategy prioritizes solar PV and BESS energy. When these resources are depleted, the system taps into the grid and eventually resorts to a DG if necessary. This approach is cost-effective, considering the varying costs of electricity derived from these sources. They also introduce a unique voltage source converter (VSC) that offers several advantages, including cost reductions, reactive power compensation, and better power flow management. This charging station is designed to accommodate both AC and DC power for EV charging. Leveraging solar PV and BESS power, the station ensures a consistent 220V and 50Hz output for AC charging, maintaining a harmonious distortion and an optimal power factor.

In their 2020 research, Parag K. Atri and team [19] offer an exhaustive analysis of various maximum power point tracking (MPPT) methods suitable for solar charge controller setups, integrating different converter structures. The examined system consists of a PV panel, a DC-to-DC converter, a charge controller, and a battery. They compared several MPPT approaches, such as Perturb and Observe (P&O), Incremental Conductance (IC), and Fractional Open Circuit Voltage (FOCV) through MATLAB simulations. They underscored that this kind of solar charger is versatile enough to cater to different electric vehicles, including vehicles like golf carts. The study intricately breaks down the functionalities of the solar battery charger.

C. Chellaswamy and associates, in their 2018 paper [20], introduced a solar and wind energy-based charging mechanism, abbreviated as SWCM, to recharge battery packs meant for electric vehicles (EVs). This eco-friendly charging station draws its power from both wind turbines and solar photovoltaic (PV) modules. Notably, the deployment of the SWCM aids in lowering $CO_2$ and CO emissions by reducing dependency on fossil fuels for electricity generation. The research employed both a single diode model and analytical modelling for simulating wind energy generation. The entire simulation model of the proposed SWCM was crafted in MATLAB-Simulink.

The study delved into the intricacies of different wind turbine metrics under two distinct load scenarios and analyzed the I-V and PV traits of the solar panel under varying sunlight intensities. This system integrates unidirectional DC-DC converters for the PV modules and wind turbine, and bidirectional DC-DC converters for the charging points. Moreover, to connect the system to the grid and equilibrate load requirements, a three-phase bidirectional DC-AC inverter is used. Based on the outcomes, the team ascertained that the proposed renewable charging mechanism is apt for EV charging, promising a cleaner environment.

## III. METHOD

Electric electrical vehicle (EV) charging stations powered by hybrid energy sources, the integration of a method based on fuzzy logic serves as a sophisticated and adaptive approach to optimize power management. Fuzzy logic controllers (FLCs) play a pivotal role in dynamically adjusting the charging process by considering the inherent uncertainties and variability associated with renewable energy inputs.

The method begins with the deployment of sensors and monitoring devices to capture real-time data on energy production from hybrid sources, such as solar panels and wind turbines. Fuzzy logic, a computational paradigm inspired by human reasoning and decision-making processes, is then employed to interpret this data and make intelligent decisions regarding power distribution and charging priorities.

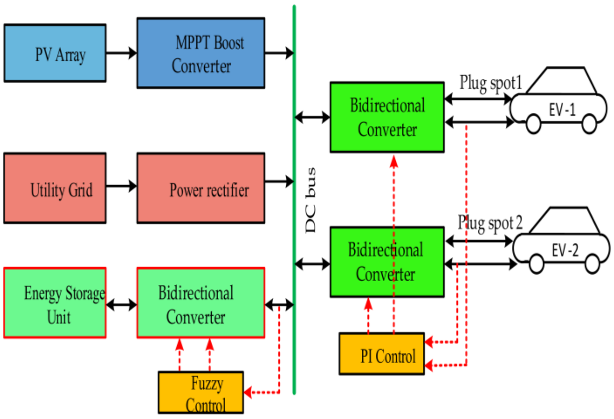


Figure 1: Fuzzy logic based management system

The fuzzy logic system incorporates linguistic variables, membership functions, and a set of rules that encapsulate expert knowledge about the charging station's operation. These rules enable the FLC to assess factors such as energy availability, grid demand, and charging requirements. By employing fuzzy inference mechanisms, the controller can dynamically adjust charging rates, allocate power among different charging stations, and manage energy storage systems.

This method ensures robust adaptability to changing environmental conditions and demand fluctuations, thereby maximizing the utilization of renewable energy while maintaining a reliable and efficient charging infrastructure. Additionally, the fuzzy logic-based approach contributes to the longevity of battery life by optimizing charging profiles based on the state of charge and health of the batteries.

## IV. CONCLUSION

In n conclusion, the integration of fuzzy logic-based methods for power management in electrical vehicle (EV) charging stations, particularly those reliant on hybrid energy sources, presents a promising avenue for addressing the dynamic challenges associated with sustainable transportation infrastructure. This review has underscored the significance of incorporating fuzzy logic controllers (FLCs) to enhance the efficiency, adaptability, and environmental sustainability of EV charging systems.

The dynamic nature of renewable energy inputs, such as solar and wind, poses inherent challenges in maintaining a consistent and reliable power supply for EV charging. Fuzzy logic, with its ability to handle uncertainties and variations, proves to be a valuable tool in optimizing the utilization of hybrid energy sources. The fuzzy logic-based approach enables intelligent decision-making, considering factors such as real-time energy production, grid demand, and charging requirements.

Through a comprehensive analysis of the existing literature, this review has highlighted the key contributions of fuzzy logic-based methods, including improved energy efficiency, reduced operational costs, and minimized environmental impact. These advancements are critical for fostering the widespread adoption of electric vehicles by addressing the infrastructure challenges associated with charging.

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