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A Review on the Renewable Sources Based Microgrid for Electric Vehicle Charging using various Emerging Technologies

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Abstract: This review examines the integration of renewable energy sources into microgrids for electric vehicle (EV) charging, leveraging emerging technologies such as the fuzzy logic and genetic algorithm. It addresses the challenges of scaling EV infrastructure, focusing on the potential of solar, wind, and bio-energy to enhance sustainability and grid independence. The paper discusses how fuzzy logic, genetic algorithm optimize energy management and maintenance. Overall, the study advocates for a holistic approach to develop efficient, resilient, and sustainable EV charging systems through the synergistic use of renewable microgrids and advanced technologies.
Keywords: solar power, fuzzy logic, genetic algorithm

I. INTRODUCTION

The global shift towards sustainable energy solutions has propelled the rapid development and deployment of renewable charging stations for electric vehicles (EVs). These charging stations, powered by renewable energy sources such as solar and wind, represent a crucial step in mitigating carbon emissions and reducing dependency on fossil fuels. In India, this transition towards renewable charging infrastructure has gained considerable traction, driven by escalating environmental concerns, ambitious clean energy targets, and the burgeoning demand for electric mobility. The surge in electric vehicle (EV) usage has led to a substantial increase in the demand for electric energy worldwide. The global electric vehicle market has experienced remark able growth, with the number of EV's on the road witnessing significant escalation. In 2010, the count of EVs was merely a few hundred, but by 2017, it had surged to approximately three million. By early 2019, this figure had doubled to around six million [7].

The rapid growth in demand for electric vehicles (EVs) and the subsequent increase in EV charging stations have prompted numerous research centers and energy providers to address the strain on local electricity grids. This strain arises from the expanding number of electric vehicles requiring charging. Photovoltaic sources have emerged as one of the most promising solutions to alleviate this pressure on local electricity networks. By harnessing solar energy, photovoltaic systems have the potential to bolster the EV charging infrastructure, offering a sustainable and renewable energy source to support the growing demand for electric vehicles [8].

Traditional charging stations can adversely impact the stability of the grid due to various issues, including harmonics, fluctuations, and voltage outages [9]. In contrast, the Resonant Current Injection (RCI) technology offers several advantages, such as high efficiency, low system cost, and straightforward arrangement [10]. Additionally, RCI requires fewer power conversion stages compared to alternating current (AC)-based facilities [11].

A. Latest Research in India

Recent research endeavors in India have focused on optimizing the efficiency and viability of renewable charging stations for EVs. Cutting-edge studies have delved into various aspects, including technological advancements, economic feasibility, and environmental impacts. Notably, a significant area of research has revolved around the integration of solar power into EV charging infrastructure. Studies have explored the optimal configuration and deployment strategies for solar-powered EV charging stations across diverse Indian cities. By analyzing factors such as solar irradiation levels, grid connectivity, and user demand patterns, researchers aim to develop robust models for designing and implementing efficient charging infrastructure. Furthermore, researchers have conducted techno-economic assessments to evaluate the viability and cost-effectiveness of solar EV charging stations in the Indian context.

These assessments consider factors such as installation costs, operational expenses, and potential revenue streams, providing valuable insights for policymakers, investors, and stakeholders. Moreover, environmental assessments have been conducted to quantify the carbon emissions reduction potential and environmental benefits of solar-powered EV charging stations. By comparing the environmental footprint of renewable charging infrastructure to conventional grid-based charging, researchers aim to highlight the role of solar EV charging in fostering sustainable transportation solutions.
Overall, the latest research endeavors in India underscore the growing momentum towards renewable charging infrastructure for electric vehicles. With ongoing innovation and collaboration between academia, industry, and government agencies, India is poised to play a pivotal role in shaping the future of sustainable mobility through renewable energy integration in EV charging.

II. VARIOUS EMERGING TECHNIQUES

A. Fuzzy Logic

The term fuzzy represents the things which are not clear. In the real world many times we find a situation where we can't determine whether the state is true or false, their fuzzy logic provides very valuable flexibility for reasoning. In this way, we can consider the inaccuracies and uncertainties of any situation. The simple diagram of fuzzy logic is as shown below:

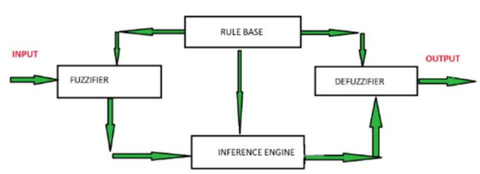

Figure 1 Fuzzy Logic Architecture

B. Genetic Algorithms

Algorithms with genetic elements, Friedberg (1958), endeavored to prompt learning by altering short FORTRAN software engineers, which prompted the improvement of GAs. Therefore, a software engineer with elite execution for a specific straightforward undertaking can be produced by making a suitable series of small changes to a machine code developer.
Challenges, limitations, and strength
Fuzzy logics

1) *Challenges:* Fuzzy controllers provide the benefit of allowing specialists to apply their qualitative understanding of operations. Experts, however, find designing fuzzy controllers using their heuristic approach difficult.
2) *Limitations:* The accuracy of these systems is harmed since they rely on incorrect data and inputs. There is no one-size-fits-all approach to solve the problem with FL. Because the results are frequently erroneous, it is not commonly recognized.
3) *Strength:* FL enables enhanced and more efficient machine control while also lowering costs. Although FL has been criticized for being imprecise, the conclusions are acceptable, especially when dealing with faulty inputs. FL is essential for forecasting future events. FL is adaptable, taking into account both natural knowledge and direct computation, execution, and translation.

C. Genetic Algorithms

1) *Challenges:* Gas are a randomized heuristic inquiry strategy in which the population contains rival arrangements established through transformation and intersection. Moreover, GA is vital and uncomplicated because the upsides of the well-being aim capability are used for streamlining. Besides, GA may not merge to a worldwide ideal, notably in populaces with numerous individuals and execution pointers. GAs require earlier information, which is based on learning and inferred wellness functions: new rules are developed based on the training instances and trends found in prior search phrases. The challenge must be set up in such a manner that future generations are encouraged to pick better genes, and the parameters must be chosen to reflect the fitness function. Since the well-being evaluation is computationally demanded, GAs are sluggish. Because they depend on the examined issue, determining chromosomal representation of parameters, domain, and range is problematic.
2) *Limitations:* Because development based on wellness capacities cannot provide consistent enhancement reaction times, the employment of continuous GAs is limited. FL is used to show frameworks that are difficult to show due to ambiguous quality boundaries.
3) *Strength:* GA tackles a multi-objective enhancement issue and arranges the progressively considering the changing remote climate. GAs is faster and consume less memory while looking through a vast region.

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III. LITERATURE REVIEW

Himabidu N et al. [1], in their research work has mentioned that the diminishing reserves of fossil fuels and escalating environmental concerns have prompted the exploration of clean and sustainable energy alternatives, utilizing renewable sources. Additionally, the surging demand for oil and the consequential rise in carbon emissions have created significant opportunities for the widespread adoption of Electric Vehicles (EVs) globally, leading to a burgeoning EV market. Incorporating photovoltaic (PV) technology into EV charging infrastructure can notably diminish carbon footprints compared to traditional grid-based charging methods. The integration of solar power and EV charging stands as one of the most effective strategies for sustainable development within the EV market.

Recent data indicates a significant uptick in EV usage across various cities in India, underscoring the pressing need for the expansion of charging infrastructure in this densely populated nation. To address this challenge, a two-pronged approach is proposed. Firstly, the development of theoretical demand models and stochastic models for EV traffic and resource utilization patterns. Secondly, a comprehensive analysis is conducted to determine the optimal configuration and techno-economic viability of Solar- powered EV Charging Stations (EVCS) within microgrids across four diverse Indian cities: Shillong, Bengaluru, Jaipur, and Kashmir, each characterized by varying solar radiation conditions. The conceptual view of microgrid is shown below

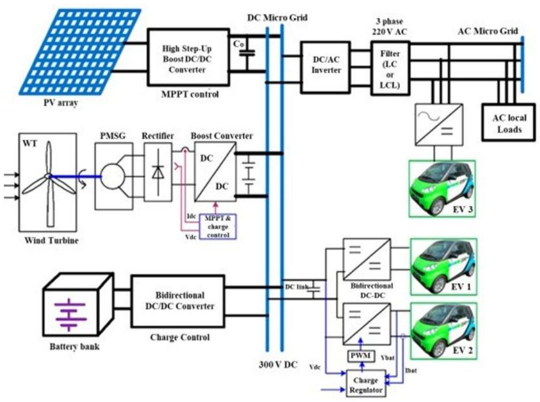

Figure 2 Conceptual view of microgrid [1]

Gilsung Beyon et al. [2], in their research work has mentioned that This paper introduces a novel Energy Management Strategy (EMS) tailored for a DC distribution system within buildings. With the rise in DC loads and the emergence of DC output distribution energy resources (DERs) like photovoltaic (PV) systems and fuel cells, DC distribution systems are gaining prominence. Their advantages include seamless integration of DERs and Electric Vehicles (EVs), decreased conversion losses between DC sources and loads, and avoidance of reactive power issues. This makes them highly suitable for industrial and commercial buildings equipped with DERs and EVs.

The implementation of a well-designed EMS from an economic standpoint can result in reduced energy costs for buildings and offer benefits to participants engaged in energy management. This paper identifies pertinent components for the DC distribution system and proposes a real-time decision-making algorithm aimed at minimizing operational costs. Additionally, it outlines an EV service model within the EMS, designed to incentivize EV owners to participate in battery discharging activities. To validate the efficacy of the proposed algorithm, computer simulations and economic analyses are conducted. The findings demonstrate that the proposed EMS not only reduces energy costs but also incentivizes EV owners, making it a viable solution for DC distribution buildings.

Furthermore, the environmental benefits of PV-powered EVCS are rigorously evaluated and compared. The findings unders core the significant impact of solar irradiation levels and feed-in-tariff (FIT) prices on the optimal configuration and investment efficiency of EVCS in each urban area. Notably, Kashmir, boasting high solar irradiation conditions, emerges as particularly suited for investment in solar EVCS infrastructure compared to the other cities.

Hong Liu et al [3]. In their research work has mentioned that his paper delves into the complexities associated with the intermittent nature of renewable energy sources such as wind and photovoltaic (PV) systems, which often generate variable power outputs. These fluctuations, when overlaid on the conventional load curve, result in what is termed a 'load belt', introducing significant variability into the grid's load profile. Moreover, with the rapid proliferation of electric vehicles (EVs), the power grid faces additional challenges due to the varying charging demands, potentially exacerbating peak load periods and grid congestion.

In response to these challenges, the paper aims to devise a controlled EV charging strategy that effectively manages the peak-valley difference in grid demand, taking into consideration the regional variability of wind and PV power generation. To achieve this objective, the authors develop a sophisticated probabilistic model to capture the stochastic nature of wind and PV power outputs. This model provides insights into the expected variability and uncertainty associated with renewable energy generation, crucial for devising robust grid management strategies. Building upon this probabilistic framework, the paper proposes a method for assessing the peak-valley difference of the stochastic load curve. By quantifying the variations in grid demand over time, this approach lays the foundation for designing effective pricing mechanisms that incentivize controlled EV charging during off-peak periods, thereby optimizing grid utilization and reducing peak load stresses.

Furthermore, the paper introduces a two-stage peak-valley price model tailored specifically for controlled EV charging. This pricing model aims to strike a balance between encouraging EV owners to charge their vehicles during periods of low grid demand (valley price) while discouraging charging during peak demand periods (peak price). The development of an optimization model, leveraging genetic algorithms, facilitates the determination of optimal start and end times for valley pricing, as well as the corresponding peak-valley price differentials. In conclusion, the paper presents a comprehensive framework for optimizing grid operations through controlled EV charging, leveraging insights from renewable energy generation patterns. Through computational analysis and simulation, the effectiveness and feasibility of the proposed approach are demonstrated, highlighting its potential to enhance grid stability, minimize congestion, and promote efficient utilization of renewable energy resources.

D Stuborne et al. [4] in their research work has mentioned that in recent years, electric vehicles (EVs) have garnered considerable attention as an environmentally sustainable and cost-effective alternative to conventional internal combustion engine vehicles. This shift aims to reduce dependence on fossil fuels and lower greenhouse gas emissions. However, numerous challenges persist in achieving widespread adoption. One notable challenge is the potential strain on the electrical grid caused by simultaneous charging of a large number of EVs. Various solutions have been proposed in recent literature to address peak demand from EVs and related grid issues. One such solution involves implementing EV charging strategies, facilitated by aggregation agents, to mitigate grid impact while ensuring service quality. These strategies rely on smart grid technologies like smart meters, Information and Communication Technologies (ICTs), and energy storage systems (ESSs). ESSs, in particular, play a crucial role in the broader smart grid paradigm and can enhance the integration of next-generation EV fast charging stations by providing peak shaving and power quality functions, ultimately reducing charging times. This paper provides an overview of different types of EV charging stations according to international European standards and examines storage technologies for their integration into smart grids. Furthermore, it delves intothedetailedimplementationofaprototypeEVfastchargingstationequippedwithanESS, developed and currently operational at ENEA (Italian National Agency for New Technologies, Energy, and Sustainable Economic Development) labs. Extensive experimental testing has been conducted on this prototype system within a smart grid environment, facilitated by a custom communication protocol developed by researchers. Results from these tests demonstrate the system's effective performance in implementing peak shaving functions, thereby minimizing its impact on the main distribution grid and making it highly compatible with a nearly zero-impact network.

D. Karabelli et al. [5], in their research work has mentioned that the increasing prevalence of Electric Vehicles (EVs) presents a significant challenge for battery manufacturers and recyclers when it comes to end-of-life management. Manufacturers require access to critical materials to produce battery systems, making the recycling of end-of-life EV batteries crucial for maintaining a steady supply of these materials and closing the material cycle within a circular economy framework. However, the resource consumption per cell, and consequently its chemistry, is subject to constant change due to disruptions in supply or significant increases in the costs of specific raw materials, coupled with higher performance expectations for EV batteries. This study aims to examine the projected evolution of dominant cell chemistries of Lithium-Ion Batteries (LIBs) until 2030, followed by an assessment of raw material availability. This analysis is conducted through research studies and expert surveys defining scenarios to predict battery chemistry evolution and its implications for a circular economy. Our findings will include discussionsontheanticipatedglobale-mobilitydemandby2030andthesustainabilityimpactof Nickel-Manganese-Cobalt (NMC) based cathode chemistries. Estimations beyond 2030 remain highly uncertain due to the possible market penetration of innovative technologies currently undergoing research, such as solid-state Lithium-Ion and/or sodium-based batteries.

Omar Hofez et al. [6] in their research work has mentioned that intricate process of designing an Electric Vehicle Charging Station (EVCS) with the primary objective of minimizing its lifecycle costs, all the while considering the environmental impact of its operations. It undertakes a comprehensive examination of various energy sources that can power the EVCS, ranging from renewable energy technologies to diesel generation. Realistic data pertaining to the physical attributes, operational dynamics, and economic aspects of these energy sources are meticulously incorporated into the analysis.

A significant focus of the study is to address the pervasive concern known as "range anxiety," which refers to the apprehension felt by EV owners about the distance their vehicles can travel before needing to recharge. To alleviate this concern, the research investigates the optimal design of an EVCS specifically situated along highways, treating it as an isolated Microgrid. By isolating the EVCS in this manner, the study aims to provide insights into the unique challenges and opportunities associated with such a setup. Moreover, the paper extends its analysis to consider scenarios where the EVCS is connected to the larger electrical grid, functioning as a smart energy hub. This allows for a more comprehensive evaluation of the economic viability and environmental implications of grid-connected EVCS compared to their isolated counterparts. In determining the charging demand of the EVCS, the study utilizes real-world drive data, ensuring that the analysis is grounded in practical insights derived from actual usage patterns. Furthermore, the research conducts a thorough economic assessment to compare the financial implications of operating a grid-connected EVCS versus an isolated one.

A key aspect of the study involves identifying the optimal break-even distance for a grid-connected EVCS to become a financially viable option. This analysis provides valuable insights into the economic thresholds that must be met for grid-connected EVCS to be considered feasible and sustainable in real- world settings. Overall, through its comprehensive analysis and empirical insights, this paper contributes to the ongoing discourse surrounding the design and operation of EV charging infrastructure, shedding light on critical considerations related to cost-effectiveness, environmental sustainability, and the integration of renewable energy sources in the transportation sector.

IV.CONCLUSION AND FUTURE SCOPE

In conclusion, this review paper has examined the latest research on the life cycle assessment (LCA) of solar energy in India. Through a comprehensive analysis of recent studies, we have gained valuable insights into the environmental impacts, energy efficiency, and sustainability of solar power systems across their life cycle stages. The reviewed literature highlights the significance of conducting LCAs to assess the holistic environmental footprint of solar energy deployment in India, considering factors such as manufacturing, installation, operation, and end-of-life management. Despite the rapid growth of solar energy in India and its potential to mitigate greenhouse gas emissions, challenges remain, including the need for improved data accuracy, methodology standardization, and policy support for sustainable practices. Furthermore, the review underscores the importance of considering regional variations, technological advancements, and socio-economic factors in LCA studies to provide comprehensive and context-specific insights. Moving forward, continued research efforts, collaboration between academia, industry, and policymakers, and the integration of LCA findings into decision-making processes will be essential for promoting the sustainable development and adoption of solar energy in India.

The future scope of research on the life cycle assessment (LCA) of solar energy in India holds promising avenues for advancement. Firstly, there is a pressing need to refine LCA methodologies tailored to the Indian context, climatic variations, and resource availability. This entails developing robust life cycle inventory databases specific to the Indian solar industry to enhance the accuracy and reliability of LCA findings. Secondly, integrating emerging technologies like next- generation photovoltaic materials, energy storage systems, and smart grid technologies into LCA studies is imperative to assess their environmental impacts and sustainability implications accurately. Moreover, expanding the scope of LCA studies to encompass broader sustainability indicators, including social and economic aspects, would provide a holistic understanding of solar energy systems' overall sustainability performance. Additionally, addressing gaps in knowledge and data availability related to the end-of-life management of solar panels is crucial, necessitating exploration of recycling and disposal options and their environmental and economic implications. Interdisciplinary collaboration and stakeholder engagement will be paramount for advancing research in this field, fostering partnerships between academia, industry, government, and non-profit sectors to address complex sustainability challenges and drive positive change in India's solar energy sector.

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