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Optimizing Renewable Energy With Electric Vehicles In Distributed Generation

Journal of Electrical Systems

Abstract*: -* Distributed generating systems that combine renewable energy sources with electric vehicles (EVs) offer a novel approach to grid stabilization and energy savings. In order to maximize the utilization of renewable energy sources, this research investigates how best to convert electric vehicles (EVs) into dynamic energy storage systems. When demand is strong, electric cars may store excess renewable energy and feed it back to the grid using vehicle-to-grid (V2G) systems and smart charging. This makes the system more dependable, which reduces the demand for conventional power sources, and also mitigates the issues associated with intermittent green energy. The integration of electric vehicles with renewable energy sources can be facilitated by state-of-the-art energy management techniques such as real-time demand-response systems and AI estimates. A more sustainable and decentralized energy future can be achieved more quickly, according to the report, by using this holistic approach. Furthermore, it demonstrates how beneficial it is to both the economy and the environment.

Keywords: Renewable Energy, Electric Vehicles, Distributed Generation, Smart Charging, Vehicle-to-Grid (V2G), Grid Stability, Energy Optimization, Demand Response, Sustainable Energy, AI-Driven Forecasting.

1. INTRODUCTION

Maximize energy utilization and improve grid performance, distributed generating systems must include electric vehicles (EVs) and renewable energy sources. The unreliability of renewable energy sources like wind and solar makes it difficult to guarantee a constant supply of power. Electric vehicles are a versatile energy asset because of their built-in battery storage systems and state-of-the-art charging infrastructure. They can store excess renewable energy and return it to the grid as needed. Together, renewable energy sources and electric vehicles improve the energy environment, strengthen the grid, and lessen our need for fossil fuels.

To get the most out of energy sharing, you need smart charging and V2G technologies that can expertly manage power flow. Energy systems are able to achieve real-time supply-and-demand balances with the help of demand-response systems and AI-powered projections, which reduces waste and increases profitability. By reducing transmission losses and increasing energy reliability, distributed production brings generation closer to the point of consumption. A novel approach to creating an environmentally friendly, decentralized, and dependable energy system is distributed generation, which combines renewable energy sources with electric vehicles (EVs).

One way to increase the adaptability of distributed generation systems is to convert electric vehicles (EVs) into mobile energy storage units. Bidirectional charging helps stabilize voltage variations and alleviates grid congestion by taking in extra green energy when demand is low and sending it back when demand is high. Thanks to this connection, decentralized energy markets are now a reality, allowing electric vehicle owners to exchange energy and boosting the usage of renewable power. How effectively renewable energy sources and electric vehicles collaborate will be significantly impacted by the advancements in smart grid infrastructure and battery technologies. A future energy system that is sustainable, efficient, and dependable can be built with this.

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2. REVIEW OF LITERATURE

Li et al. (2022) developed a multi-objective DEED model integrating EVs and wind energy to minimize both fuel costs and emissions. They used a self-adaptive multiple-learning harmony search algorithm, which improved convergence speed and reduced computation time. The study confirmed that EV participation helps flatten the load curve through vehicle-to-grid (V2G) interactions..

Pratapa, Tiwari, and Maurya (2022) explored the optimal allocation and operation of Distributed Generators (DGs) with configurable power factors in electric distribution networks that supply energy to electric vehicle (EV) charging stations. The study introduced a hybrid optimization framework that integrates network reconfiguration with a mixed metaheuristic approach. To enhance convergence performance and prevent premature stagnation in local optima, the authors combined genetic algorithm (GA) operators with the Artificial Gorilla Troops Optimizer (GTO).

Sankar and Chatterjee (2022) proposed a multi-objective optimization framework for the optimal placement of renewable distributed generation (RDG) units in electric distribution systems characterized by a high penetration of plug-in hybrid electric vehicles (PHEVs)**.** The study incorporated a stochastic PHEV demand model that considers several random behavioral and operational factors influencing charging patterns. Using the Multi-Objective Artificial Hummingbird Algorithm (MOAHA), the authors achieved an optimal trade-off between economic and technical objectives, such as minimizing energy losses and improving voltage profiles. Validation on standard IEEE test systems demonstrated that the proposed method effectively enhances system reliability and operational efficiency, offering a robust approach for future smart distribution networks integrating RDGs and PHEVs.

Hmingthanmawia et al. (2022) examined the economic dispatch (ED) problem in systems with large-scale electric vehicle (EV) integration. The study focused on cost minimization and loss reduction, considering both Grid-to-Vehicle (G2V) and Vehicle-to-Grid (V2G) interactions. To address the stochastic nature of renewable generation and EV charging demand, the authors compared several optimization algorithms for effective resource scheduling. Simulation outcomes showed that the proposed optimization techniques significantly reduced operational costs and system losses, confirming that EVs can enhance grid flexibility and performance.

Asaad, Ali, and Mahmoud (2022) focused on determining optimal placement of renewable energy sources and EV charging stations **within** smart microgrids**.** Their multi-objective optimization framework aimed to minimize total costs, including infrastructure development, energy production, and charging costs**,** while also reducing energy not supplied (ENS)**.** A weighted-sum optimization approach was used to balance economic and technical criteria such as voltage regulation, power balance, and EV charging rates. Simulation studies on a solar–wind–EV microgrid demonstrated improved system profitability and reliability under optimal configurations.

Zhang, X., & Li, Y. (2022). Variations in voltage have the potential to impact power quality due to the extensive network of charge stations for electric cars (EVs) and renewable energy sources. Maintaining good voltage management in a distribution network using basic reactive power control modes is not an easy task. By expanding the conventional distribution network architecture to include alternative energy sources and EVs, this research develops a multi-objective optimization model. Reducing line loss and stabilizing voltage variation while increasing the margin of static voltage stability is the objective. In certain instances, the optimal outcomes can be achieved by adjusting the model parameters to incorporate various forms of machinery and environmental factors. To determine which algorithm is most suited for a given task, the TOPSIS judgment procedure should be applied to compare how well each algorithm fits the refined model. The developed model demonstrated its ability to deliver superior reactive power control strategies in a comparison test.

Huang, P., Lovati, M., Zhang, X., & Bales, C. (2021). In order to develop more efficient clusters, this essay argues for a unified control strategy that makes use of energy storage, electric vehicles (EVs), and energy sharing. Genetic algorithms are able to manage the building cluster and the synchronization of electric vehicle charging and discharging by analyzing data from renewable energy sources and projected 24-hour electricity demand. The process of charging and uninstalling electric vehicles has been modeled. Using a cluster of actual buildings in Ludvika, Sweden, the control method has been validated. In comparison to conventional controls, the results demonstrate that coordinated control can reduce daily power costs by 36% while increasing the cluster-level green self-consumption rate by 19%.

Engelhardt, J., Zepter, J. M., Gabderakhmanova, T., & Marinelli, M. (2021). This research demonstrates various methods for handling energy in a novel design using multiple batteries that does not require a power converter. In these systems, the busbar matrix is utilized to establish direct connections between the battery lines and other DC components. The energy management system uses a two-tiered control structure. Solar panels and electric vehicle rapid chargers are examples of DC microgrid components that are assigned to battery strings at the first level. The second tier regulates power flow to and from the regional distribution system. A more sophisticated control that bases its actions on forecasts is pitted against a simpler droop control. By lowering grid contact and battery cycles, improved control makes self-sufficiency easier. Monte Carlo models accurately depict the unpredictable nature of electric vehicle charging using real photovoltaic readings from different months. However, it may hasten the battery's aging process by bringing it closer to its charge thresholds.

Maldonato, F., & Hadachi, I. (2021). Renewable energy and electric vehicle (EV) powered virtual power plants (VPPs) are the focus of this research, which investigates the potential applications of reinforcement learning control approaches in such systems. The project's overarching goal is to enhance energy delivery models by repurposing EVs as portable power storage for households or for storing excess renewable energy (RE2V). Including electric vehicles in virtual power plants, particularly in microgrids, improves their reliability and facilitates the balancing of supply and demand. The research demonstrates the versatility of machine learning methods for modeling energy grid networks. This allows for the continuous improvement of an open, linked energy system and encourages its evolution.

Liu, L., Zhang, Y., Da, C., Huang, Z., & Wang, M. (2020). In order to organize charging stations for EVs and distributed generation in a manner that complements active distribution networks with a high concentration of EVs and DG, this article proposes a two-level programming strategy. The upper echelons of management want the power supply company to maximize its annual profit, while the lower echelons employ proactive management techniques to maximize their chances of success. The Monte Carlo simulation approach is used to create electric car charging load profiles; however, the K-means++ clustering algorithm is employed to decrease the quantity of photovoltaic outputs and load situations. Utilizing an advanced harmonic particle swarm optimization approach, the two-level model is addressed. The suggested model has several positive effects on society and the environment, including higher yearly revenues, less system power losses, less voltage fluctuations, and easier distribution generation and charging station planning for electric vehicles. Verification was carried out on three different test systems: the IEEE-33 node, the PG&E-69 node, and a genuine 30-node distribution network in a specific location.

Huang, Z., Fang, B., & Deng, J. (2020). In order to construct interdependent energy systems, this research demonstrates a multi-objective optimization strategy for distribution networks that makes use of EVs equipped with vehicle-to-grid (V2G) capabilities. The goal of the approach is to reduce power losses and voltage fluctuations in distribution networks, making them safer and more cost-effective. A reduction in the load peak-valley difference is achieved by the implementation of time-of-use pricing, synchronized charging and discharging of electric vehicles, and reactive power compensation. By keeping all EVs in sync, power losses, voltage fluctuations, and strain on the power grid can be significantly mitigated. The outcomes of the 33-node test case simulation conducted by IEEE demonstrate that this has the potential to enhance the distribution system's safety while also reducing costs.

3. ELECTRICAL GRID

Energy can be transferred from generators to homes and businesses through the electrical network. The four parts are marketing, distribution, transmission, and generation. Typically, there is just one direction for the flow of conventional electricity, from generation to consumption. There is now a two-way flow of energy thanks to developments in RES, DG, and EVs (electric cars).

Unidirectional : Power flows in just one way over a network, we say that it is unidirectional. The energy flux is shown in Figure 1. Production, transportation, distribution, and, finally, sale to the consumer are all parts of the process.

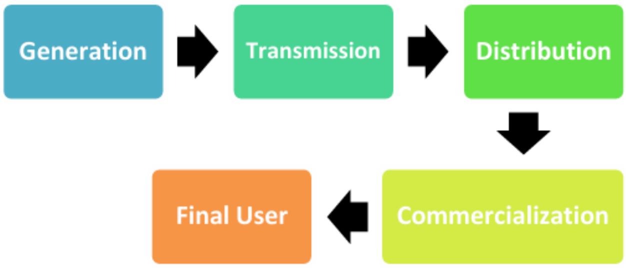

Fig: 1 Unidirectional Diagram

Bidirectional : Power can go in either way through a network, we say that it is bidirectional. Because smart grids allow for bidirectional energy transfer, the V2G concept makes it possible for end users to generate their own energy using electric vehicles (EVs) and distributed generation (DG). On top of that, they can try selling the distribution network their extra things.

From traditional generation to transmission, distribution, and finally to consumers, Figure 2 depicts the commercialization process and the flow of power over smart grids.

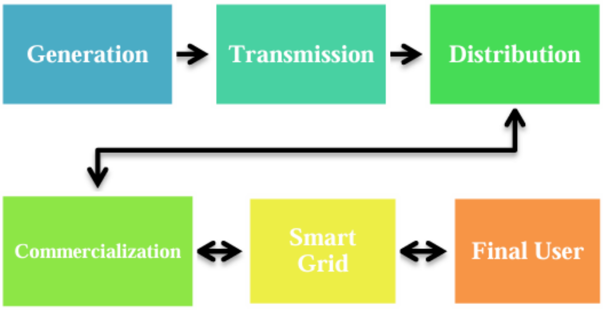

Fig: 2 Bidirectional Diagram.

Hybrid electric vehicles (HEVs) and plug-in hybrid electric cars (PHEVs) have a special kind of bidirectionality that should be acknowledged. This is relevant to the changeover from an electric motor to a turbine powered by gasoline. The main source of internal bidirectionality issues affecting electric vehicles is short-circuit problems in batteries.

4. SMART GRID

Connecting power lines has become more easier thanks to the digital grid. The data and information are analyzed to automate and manage processes remotely, which improves the energy source's reliability, efficiency, and sustainability.

The fact that clients can influence the network's operation is a defining characteristic of intelligent networks. With the use of smart meter technology, customers can see their energy usage, cost, and incentives in real time. They are free to decide for themselves how much power they want to use and what options are available to them. Smart grids also make use of distributed generation units. Since the network is capable of quickly fixing itself, you shouldn't be worried about any possible problems. There are a number of ways in which the smart grid differs from the conventional electrical grid, as shown in Table 1.

Table 1. The smart grid and the traditional grid are compared.

Characteristics	Conventional Grid	Smart Grid
Communication	Uni-directional	Bi-directional

Monitoring control	Manual	Autonomous and intelligent
Inclusion of smart	Limited	Throughout
Sensors and meters	Passive	Active
Consumer participation	Centralized	Distributed
Power generation	Manual	Self-healing

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5. DISTRIBUTED GENERATION

The distribution networks that rely on renewable energy sources for distributed generation have had a profound impact on the bidirectionality of energy supply. Unlike power plants that generate electricity from a central location, distributed generators may necessitate that the customer be physically near the plant.

Solar and small-scale wind power are suitable for this topic because of their rapid expansion, although the DG can consider numerous energy sources.

WIND GENERATION: Allows for the generation of renewable, pollution-free power, wind energy is gaining prominence. This energy may be used wisely and in close proximity to client requirements, making it suited for smart grids in distributed generation. It is difficult to predict the output of wind power since, like solar energy generation, it is dependent on meteorological conditions. There are the same problems with intermittent power that there are with solar energy.

- Fluctuation in voltage.
- Fluctuation in frequency.
- Increase in the level of failure.
- Voltage rise problem

6. ELECTRIC VEHICLE

Move people or goods, electric vehicles (EVs) convert electrical energy into mechanical energy. To generate propulsion, one can use wheels or propellers powered by rotary engines. Also, magnetic levitation trains are only one example of how non-rotating motor types including linear motors, inertial motors, and magnetic systems can be used to generate motion. There are two main kinds of electric vehicles, distinguished by the power sources they use: plug-in and non-plug-in. Table 2 displays the car's category, acronym, and brief description.

Type	Abbreviation	Description
Electric Vehicle	BEVoVE	One term for a car that runs on batteries is a "pure electric." There is no internal combustion engine; instead, it has an electric motor or motors. Electric devices that run on batteries mostly draw power from the power grid. Personal belongings

Hybrid Electric Vehicle	HEV	It also has an electric motor or motors in addition to a combustion engine. A combination of an internal combustion engine and an electric motor drive the wheels of the vehicle. The electric motor is the only power source for some car manufacturers, while for others it is just an accessory. As cruising speed drops, the vehicle's heat engine and energy recovery system begin to automatically replenish the batteries. No connection could be made.
Plug-in Hybrid Electric Vehicle	PHEV	It combines a combustion engine with abattery and an electric motor, unlike HEVs, they have larger capacity batteries that have to be charged by connectingthem to the electrical network.(Pluggable)
Range Extended Electric Vehicle	REEVo EREV	A gasoline engine may be there, but it is not what drives the vehicle. When the batteries die, it turns into a generator instead. The two things can be unrelated.
FuelCell Electric Vehicle	FCEV	They have electric motors as their only propulsion system and run on hydrogen fuel cells instead of batteries. Connection cannot be established.

Electric vehicles' inner workings reveal who is responsible for the transfer of power. There are three modes listed below.

Vehicle To Vehicle o V2V: It allows a group of EVs, like those in a community or public parking lot, to link up with the local network of bidirectional chargers. An aggregator is the controller in a V2H system that controls the amount of energy that is sent to the network. The broker establishes a V2V network by connecting different V2H systems, such as those in a parking garage. Both kinds of controllers make it possible for all vehicles to talk to each other and for energy to be transferred to the grid or other vehicles that need it. Priorities can be set up using this configuration. After all the linked cars have been charged, any extra power can be transmitted back to the grid.

Vehicle To Home o V2H: Hooked up to a home's electrical grid, electric vehicle (EV) batteries can be charged and discharged with the help of a bidirectional converter. Driving an electric car to a specified outlet at home is the quickest and easiest way to charge the vehicle. A bidirectional converter is typically used in vehicle-to-home

(V2H) connections, which connect an EV to a home's electrical grid. Either the area power grid or renewable energy sources close to the recharge location could supply the energy. The electrical network requires an operator. Through the links between the electric vehicle and the electrical grid, this person will be in charge of controlling the energy resource as needed.

Vehicle To Grid o V2G: The principles of Vehicle to Home (V2H) and Vehicle to Vehicle (V2V) enabled the establishment of a comprehensive networked system, which in turn facilitated the Vehicle to Grid (V2G) network. With vehicle-to-grid (V2G) technology, EVs may draw electricity from the grid, store it, and then send it back when they need it. Additionally, V2Gs are required to follow the worldwide standard ISO 15118, which details the protocol for electric vehicle communication with the charging and discharging network.

Fig. 3 A variety of electric vehicle (EV) layouts are shown in Figure 3 that allow for bidirectional mobility.

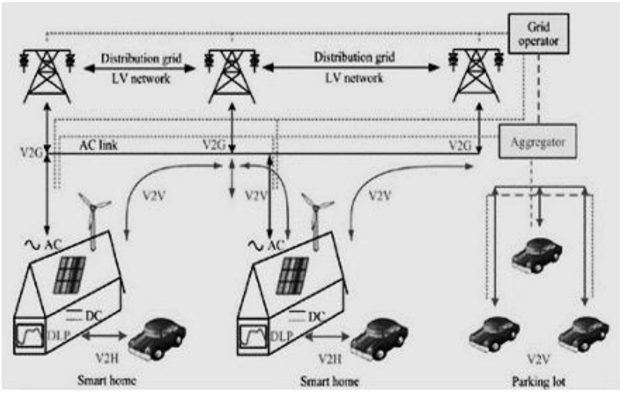

Fig: 3 Bi-directional EV settings (V2G, V2V y V2H).

7. RESULT AND DISCUSSIONS

As shown in Figure 4, the majority of the papers that were reviewed concentrated on voltage and active power, while a smaller percentage dealt with energy and battery state of charge (SOC), reactive power, efficiency, electric vehicle penetration, and frequency.

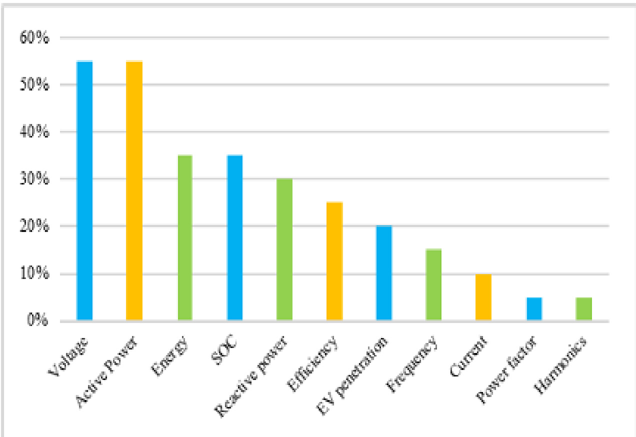

Fig: 4 Bar chart, metric evaluation

Voltage articles frequently cover the topics of overvoltage and undervoltage. The majority of studies that have looked at ESSs as a potential solution to voltage issues have used these terms. Still, energy and SOC (State of Charge) are key components of ESS. A large number of electric vehicles (EVs) on the road can help with reactive power and voltage issues. The problem of harmonics, which is associated with electric car technology, may still arise, though. An intelligent grid maximizes energy, voltage, active power, reactive power, power factor, and frequency through the coordinated efforts of several energy sources, such as electric vehicles (EVs), energy storage systems (ESS), bidirectionality, vehicle-to-grid (V2G) technologies, and distributed generation (DG).

There are two broad types of environmental implications that electric vehicles (EVs) have, according to the research. The most noticeable difference is between the direct emissions produced by electric vehicles and those of conventional vehicles. The environment benefits more from the use of an electric vehicle than from a conventional car. The bulk of the articles reviewed for this research provide credence to this view. On the other hand, you could say that the energy comes from the traditional network that charges the electric car. On rare occasions, power plants would burn coal or other potentially harmful materials to create energy. As a result, the majority of the articles I've read don't explain the indirect emissions caused by driving an electric vehicle.

A consensus was achieved to include electric vehicles (EVs) and energy storage systems (ESS) into networks that already use wind and solar power. We did this to make the system more efficient and less harmful to the environment. In addition to stabilizing electrical factors like voltage and frequency, the ESS may help reduce the unpredictable nature of renewable energy sources like wind and solar power.

Discuss a topic of contention concerning the vehicle-to-grid (V2G) paradigm and the relative merits of bidirectional and unidirectional communication as it pertains to EVs. Specific charging levels for electric vehicle equipment are outlined in the SAE J1772 standard. Similarly, it was contended that the V2G concept is not relevant outside of public, private, and commercial settings, as opposed to residential and office settings (level 1). This suggests that the idea of vehicle-to-grid (V2G) was developed to facilitate the deployment of large fleets of electric vehicles. Due to battery degradation during charging and discharging cycles, the operational lifespan of electric cars is limited, making bidirectional communication crucial for the V2G notion. This proves the concept is flawed and calls for further investigation in studies that don't specifically label it as an EV problem.

8. CONCLUSION

Grid stability, sustainability, and energy economics are all improved by deploying electric vehicles (EVs) to augment distributed generation's renewable energy sources. We can lessen our dependency on fossil fuels by storing and effectively harnessing excess energy from renewable sources like solar and wind in electric vehicles (EVs). Thanks to vehicle-to-grid (V2G) technology and innovative charging procedures, electric vehicles can now store energy while on the go. This allows them to contribute to the grid's power during times of high demand and take advantage of moments of low demand. Collaborating in this way makes it easier to reduce carbon emissions by making energy more reliable and saving money for both utilities and consumers. Problems with grid integration, infrastructure development, and getting regulatory approval must be resolved in order for the project to be executed successfully. Keeping supply and demand in a healthy equilibrium requires cutting-edge optimization techniques, real-time energy management systems, and demand-response mechanisms. For electric cars (EVs) and renewable energy (RE) to reach their full potential, lawmakers, utilities, and EV makers must work together to build smart networks. To secure a future where healthy energy is quickly and easily transitioned to, ongoing research and investment in innovative technologies are crucial.

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