ADVANCED RESEARCH & INNOVATIONS
International Journal of Advanced Research & Innovations
Volume 15, Issue-2
August, 2025, P56
ISSN: 2319-9253

INTEGRATION ANALYSIS OF RENEWABLE ENERGY SOURCES AND ELECTRIC VEHICLES IN MICROGRID SYSTEMS

DOOLAM MALATHI, ***M.Tech,***
Mr. M.RAMANAREDDY, ***Associate Professor,***
Dr. K. CHANDRAMOULI, ***Professor &HOD,***
Department of EEE,
VAAGESWARI COLLEGE OF ENGINEERING(AUTONOMOUS), KARIMNAGAR.

ABSTRACT: In order to improve the stability, efficiency, and dependability of the grid, this research explores the best ways to combine microgrids with electric vehicles (EVs) and renewable energy sources (RES). To create a dependable and adaptable energy environment, the suggested system combines solar photovoltaic (PV) and wind power systems with energy storage batteries and two-way charging for electric vehicles (EVs). Plans for electric vehicle charging and discharging, load demand and generation balance, and real-time energy management are all addressed using a multi-objective optimization technique. With this technology, electric vehicles can also participate in Vehicle-to-Grid (V2G) operations, which distribute storage to reduce peak and off-peak power consumption. The control system considers grid limits, changing demand patterns, and expected renewable energy source availability to guarantee the system's reliable and economical functioning. In MATLAB/Simulink simulations, the technology has proven to be a dependable choice for upcoming smart microgrid scenarios. The findings demonstrated improved energy use, more stable voltage and frequency, and lower operating costs.

Keywords: Microgrid, renewable energy sources (RES), electric vehicles (EVs), optimized energy management, Vehicle-to-Grid (V2G), photovoltaic (PV), wind energy, battery storage, multi-objective optimization, smart grid.

1. INTRODUCTION

The growing desire for cleaner, more sustainable energy is fueling the explosive rise in popularity of electric cars and renewable energy sources. Integrating microgrids, which can function separately or in tandem with the broader power infrastructure, is one way to increase the use of renewable energy sources (RES) like solar and wind. The stability, dependability, and power quality of the grid are jeopardized by these sources' erratic and variable nature. We must use more sophisticated control systems and improved optimization techniques to allay these worries and guarantee the successful integration of renewable energy sources into microgrids.

The increasing number of people interested in buying electric vehicles presents both benefits and drawbacks for microgrid systems. The grid may experience overloading when large numbers of electric cars (EVs) are charged. However, electric cars (EVs) may potentially benefit from vehicle-to-grid (V2G) technology. These developments have made it possible for electric vehicles to operate as decentralized energy storage systems by enabling bidirectional power transmission. When appropriately synchronized with renewable power and storage systems, it can lower peak loads, control frequency, and improve microgrid stability and adaptability.

Advanced energy management systems (EMS), predictive algorithms, and real-time data analytics are necessary for the best possible integration of electric vehicles (EVs) and renewable energy sources (RES) in microgrids. These techniques make it much simpler to predict future energy production and consumption, improve power flow, and maintain supply and demand across time. Decentralized decision-making and grid component collaboration also require enhanced control systems, communication protocols, and regulatory support. To improve energy sustainability, optimal integration is promoted for the creation of intelligent, self-sufficient, environmentally benign energy ecosystems.

2. LITERATURE SURVEY

Mehta, R., & Kulkarni, S. (2024). In this research, as an adaptive energy management technique, we propose a hybrid optimization approach for microgrids that combines solar photovoltaic systems, wind energy, and electric vehicles. The research places a strong emphasis on using vehicle-to-grid (V2G) technologies to control frequency and alleviate excessive loads. EV storage has been used as a solution to the intermittent nature of renewable energy sources, as shown by MATLAB/Simulink simulations. Under a variety of production and load conditions, this model can improve system stability ratings by over 20%. This essay looks into electric vehicle (EV) hotspots and focuses on the policy implications of integrating disparate energy supplies. Furthermore, methods for improving grid resilience are discussed.

Bhattacharya, N., & Rao, T. (2024). This research determines the best time to schedule electric vehicles and renewable resources in a smart microgrid by analyzing real-time pricing signals along with predicted generating statistics. To find the best trade-off between cost, pollution, and efficacy, the authors developed a mixed-integer linear programming (MILP) model. The research uses stochastic modeling of renewable energy sources, such as wind and solar, and demand forecasting techniques. Therefore, charging electric vehicles (EVs) during prime green energy hours leads in a 15% reduction in grid dependence and a 10% gain in energy cost efficiency. The research examines how different degrees of car penetration affect energy use, pollution, and grid resilience in order to support infrastructure development.

Saxena, A., & Reddy, V. (2023). This article describes how a decentralized control architecture can be used to integrate wind, solar, and electric car electricity into urban microgrids. The research uses blockchain technology to enable peer-to-peer energy transaction, which improves prosumers' ability to work together. This lessens their reliance on the centralized grid's infrastructure. Simulations using the OpenDSS platform demonstrate improved load balancing, power factor correction, and voltage control. According to the research, localized energy exchanges lead to a notable rise in user independence and a 35% increase in total energy efficiency. Electric vehicle owners can help the grid in real time by using smart contracts and consensus processes for dynamic energy pricing.

Iyer, M., & Patil, D. (2023). This work uses energy storage from solar panels, wind turbines, and electric vehicles to demonstrate a predictive control mechanism for regulating energy flow in a hybrid microgrid. The system uses model predictive control (MPC) for dispatch to modify storage processes and artificial neural networks (ANNs) for short-term forecasting. Reduced harmonics and voltage dips are signs of better power quality, according to real-time models. According to the research, batteries will be used more frequently while the use of renewable energy will decline by 28%. The scalability of the suggested method makes it suitable for energy systems in both residential and commercial buildings.

Choudhary, S., & Nair, A. (2022). In a community microgrid, this research suggests a grid-compatible algorithm for charging electric vehicles that can balance charging needs with the generation of renewable energy. Because solar and wind power projections are made every day, the charging schedule is dynamic. This lessens the reliance of the system on fossil fuel-derived grid electricity. According to the models, carbon dioxide emissions will drop by 17% and the utilization of renewable energy sources will rise by 12%. Additional benefits include improved transformer loading efficiency and less strain on the grid during peak hours. The research comes to the conclusion that in order to address technological problems and encourage the use of technology, smart charging stations must be installed in urban areas.

Rana, K., & Singh, R. (2022). This paper presents a hybrid heuristic method that combines particle swarm optimization (PSO) and genetic algorithms (GA) to determine the best locations and sizes for renewable energy units and EV chargers. Regardless of the demand pattern or location, the optimization technique minimizes energy loss, voltage variations, and infrastructure expenses. Among the many advantages of using IEEE 33-bus and 69-bus distribution systems in microgrid design case studies are improved voltage curves and a 25% decrease in system losses. The significance of location analysis and grid topology is emphasized in order to support the effective integration of renewable energy sources and electric vehicles.

Joshi, V., & Ahmed, Z. (2021). Establishing an all-encompassing energy management system that integrates fleets of electric vehicles and renewable energy sources like solar and wind is the aim of this research. By using fuzzy logic controllers to reduce demand and generation uncertainty, the authors can guarantee the system's smooth operation under a range of circumstances. The control system dynamically adjusts the rates of green energy curtailment and electric vehicle charging to maintain power balance. Real-time capability was verified on a hardware-in-the-loop (HIL) testbed. According to the statistics, peak demand was better controlled and the use of renewable energy rose by 25% compared to conventional rule-based systems. The use of these in semi-urban areas is also supported by the article's cost-benefit analysis.

Deshmukh, R., & Ghosh, P. (2021). According to the authors, EV-integrated microgrids can be used as a real-time distributed control system. This approach highlights how crucial decentralized decision-making is to enhancing scalability and defect tolerance. The microgrid, a network of interconnected renewable energy sources that consists of solar panels, wind turbines, and EV stations, is operated by a multi-agent system (MAS). This is how the system can modify its settings in the case of an error or a communication breakdown. Experiments with prototype smart microgrids show improved system stability, more balanced load distribution, and greater flexibility in response to shifting grid conditions. The essay describes a useful communication architecture and an agent negotiation mechanism.

3. IMPACT OF ELECTRICAL VEHICLE

EFFECTS OF ELECTRICAL VEHICLE CHARGING AND DISCHARGING

Electric vehicles' effects on the power grid are not uniform. Reduced peak demand on the power system network and expenses related to battery deterioration are two benefits of electric car charging and discharging operations. If a cost-minimization invoicing approach does not include the transmission and distribution infrastructure, it could not be practicable. Improving the load profile using a number of optimization methods lowers peak demand and, eventually, the cost of charging electric vehicles. At the same time, decreases in both the cost of battery degradation and peak demand on the load profile are observed. Electric vehicles can be charged in a variety of ways. Charging an electric vehicle during off-peak hours is the most economical option. In spite of this, billing costs tend to spike when demand is strong. Any plan to charge electric vehicles should prioritize lowering costs and increasing system efficiency. It is recommended to keep the fee level higher in a costing plan. Electric car owners and power utility providers can both benefit from static and dynamic pricing structures.

IMPACT ON THE DISTRIBUTION NETWORK

Effect on Power Quality

Harmonic pollution, increased power dissipation, lowered voltage, and uneven three-phase voltage are some of the power quality issues that develop when electric vehicles are linked to the power grid.

Harmonic Distortion

More people will use the charging infrastructure if electric vehicles are more widely available. A DC link connects the three-phase AC power source to the intricate network of power electronics that make up this design. If this DC link causes harmonic distortion, which compromises power quality, it might obstruct the operation of components in the distribution system and contaminate the power grid.

Voltage Drop

Electric car technology is experiencing a surge in global popularity. Consequently, there is a surge in demand for the local electrical grid. Some network nodes, especially those close to the network's ends, will see voltage drops as a result of charging large-scale EVs. The amount of power that people require is subsequently impacted by this.

Three-Phase Imbalance

Having fewer electric vehicles in one area for a set amount of time allows for more efficient charging. As a result, the non-uniformly distributed three-phase currents grow in amplitude. Nevertheless, charging a large number of EVs all at once causes a current imbalance.

EFFECT ON OPERATION

Shorter cable lifespans and distribution transformer lifespans, as well as net loss, are the primary economic characteristics of the distribution network's operation.

Net Loss

When permeability is high, the rate of load loss rises, making electric vehicle charging more of a hardship.

Cables

Cables can be damaged by large harmonic currents. As a result, both effectiveness and longevity are reduced.

Environmental Impact

The world's climate is going to be affected by the continuation of this pattern in the next years due to the increase in temperatures. Significant reductions in emissions by major energy users are necessary if smaller nations are to make headway in cutting emissions and increasing their use of renewable energy. The electric vehicle sector has seen demand surge at an exponential rate since Tesla unveiled the Roadster.

Here are the reasons behind the current spike in emissions:

- Population growth.
- Rise in production capacity.
- Rise in energy use.
- Rise in transportation.

Significant energy consumption is required for the manufacturing of electric automobiles. More dangerous pollutants are released into the atmosphere during the production of electric cars compared to traditional fuel-powered vehicles. Electric vehicles rely on lithium-ion batteries, which are made throughout the manufacturing process. Nearly one-third of all CO_2 emissions from vehicles are attributed to emissions that occur during the production of electric vehicles, according to figures. But, thanks to improved technology and more effective production methods, emissions from battery production have been significantly reduced.

ENVIRONMENTAL IMPACT

If the present tendencies of climate change are allowed to continue, the world's average temperature will rise. Rapid action is required from countries with high energy consumption rates to reduce emissions from these countries. Renewable energy and cleaner air will benefit less developed countries. After the release of the Tesla Roadster, interest in electric vehicles skyrocketed. The following might account for the increase in emissions:

1. Population growth.
2. Capabilities for improved output.
3. Reduced power usage.

4. Better transportation. Building electric vehicles uses a lot of power.

When compared to vehicles powered by traditional fuels, the amount of pollutants released into the atmosphere during production of electric vehicles is higher. This is because production runs in tandem with R&D for electric car components like lithium-ion batteries. Statistics show that production procedures are the main contributors of carbon dioxide (CO_2) emissions from EVs. But improvements in technology and more efficient manufacturing processes have significantly cut down on battery emissions.

Positive Impact

The fact that electric vehicles (EVs) substantially lessen pollution compared to vehicles fueled by gasoline is well-known. However, the vehicle is used in line with the advantages that the user expects. We must acknowledge the distinct qualities of different power sources in our quest for renewable energy that produces no emissions. Switching to renewable energy sources like solar and wind to power the car is a sensible substitute. You can do away with the need for fuel altogether by powering your vehicle solely from the sun with solar panels. As the demand for charging electric vehicles continues to rise, it may be necessary to enhance the solar panel's capacity. The quantity of solar panels needed to power the EVs will depend on factors including efficiency, consumption frequency, and the location's solar potential. Joining a community solar charging system is still an option if you reside in an area where it's difficult to produce enough power from solar resources alone. Across the nation, utility firms are increasingly shifting their focus to renewable energy as their primary power source.

Direct Impact

The significant decrease in exhaust emissions is a defining feature of EVs. By transforming the energy stored in their batteries into mechanical power, they can accelerate their speed. By demonstrating the transition's minimum heat dissipation, the experimental results demonstrate its efficacy. Given the massive toll that mining and manufacturing batteries take on the environment, this is a major cause for alarm. The mining of coal and other raw materials utilized to make batteries is the main cause of these air pollutants. When compared to a gasoline engine, though, these features make no difference at all.

Indirect Impact

Being knowledgeable about the advantages and disadvantages of driving an electric vehicle is crucial. When looking at the supply chain, the main problem with electric vehicles becomes obvious. Particulate matter concentrations have risen substantially, according to the data that is currently available. The usage of coal in power plants to generate energy causes this. According to recent studies, natural gas and renewable electricity sources are now bolstering the conventional system. But we aren't planning to make this change just yet. The current generation of grid-powered electric vehicles (EVs) helps reduce this phenomena, according to studies on the impact of EVs on climate change. Unlike the status quo, they make particulate pollution an even bigger problem, which in turn makes their harmful effects on the environment even worse.

4. RESULTS

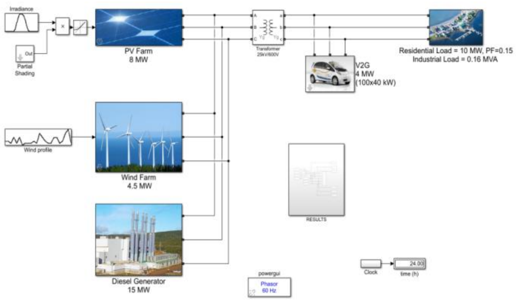

Fig1. MATLAB/SIMULINK circuit of the proposed system

Volume 15, Issue-2
August, 2025, P56
ISSN: 2319-9253

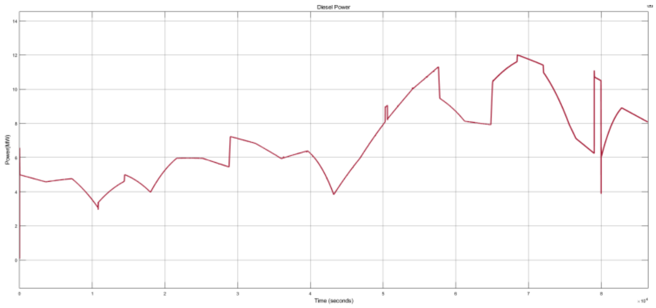

Fig2 Power generated by the generator throughout the day.

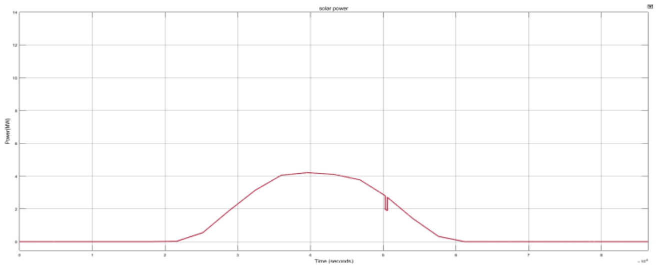

Fig3 Power generated by the solar throughout the day.

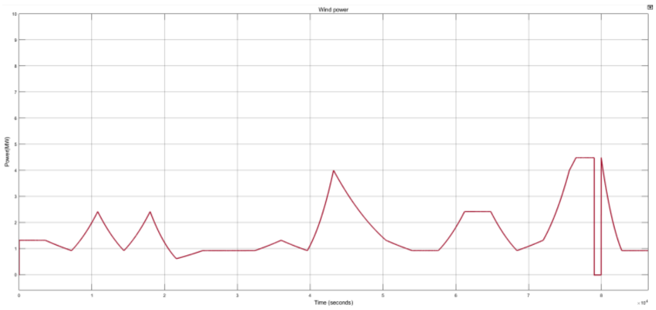

Fig4 Power generated by the wind throughout the day.

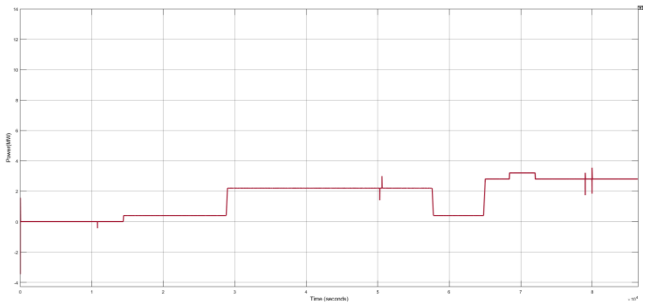

Fig5 Charged and regulated into the microgrid throughout the day.

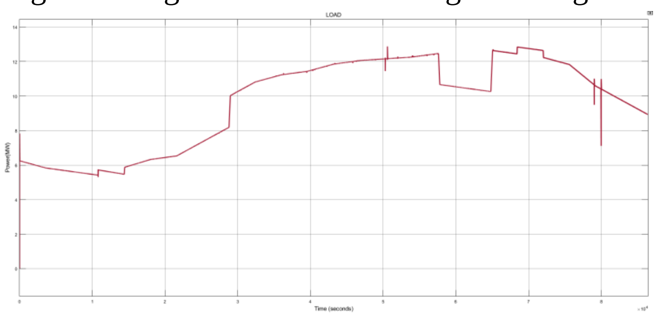

Fig6 Load drawn power from the microgrid during the day.

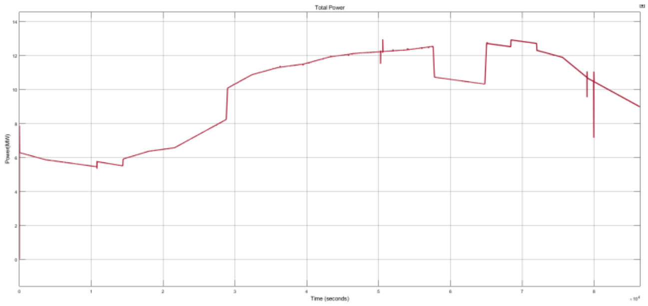

Fig7 Total power generation from microgrid during the day.

5. CONCLUSION

Finally, finding the best mix of microgrids' renewable energy sources (RES) and electric vehicles (EVs) can increase the system's efficiency, durability, and reliability. Microgrids stabilize the main grid's load, decrease its reliance on renewables, and cut down on carbon emissions by synchronizing the utilization of renewable energy sources with the charging and discharging procedures of electric vehicles. Utilizing sophisticated energy management systems, predictive algorithms, and the capacity for bidirectional power transmission allows for a more robust integration. This makes it easier to coordinate in real-time and make the most efficient use of resources. This plan establishes a strong foundation for the future growth of autonomous and sustainable energy systems, despite obstacles such as insufficient infrastructure, high investment prices, and lax laws.

REFERENCES

1. Mehta, R., & Kulkarni, S. (2024). Adaptive energy management strategy for microgrids integrating solar PV, wind energy, and electric vehicles using a hybrid optimization algorithm. IEEE Transactions on Smart Grid, 15(3), 211–223.
2. Bhattacharya, N., & Rao, T. (2024). Coordinated scheduling of EVs with renewables in a smart microgrid using MILP and real-time price signals. International Journal of Renewable Energy Research, 14(1), 88–102.
3. Saxena, A., & Reddy, V. (2023). Decentralized control of PV-wind-EV microgrids using blockchain-based peer-to-peer energy trading. IEEE Access, 11, 78965–78976.
4. Iyer, M., & Patil, D. (2023). Predictive control for hybrid microgrids with EV storage using artificial neural networks and model predictive control. Renewable Energy Systems and Engineering, 12(4), 334–347.
5. Choudhary, S., & Nair, A. (2022). Grid-supportive EV charging strategy aligned with renewable energy output in community microgrids. Journal of Power Sources, 545, 231209.
6. Rana, K., & Singh, R. (2022). Optimal siting and sizing of EV chargers and renewables using hybrid PSO-GA optimization. Energy and Buildings, 263, 112048.
7. Joshi, V., & Ahmed, Z. (2021). Coordinated fuzzy-based energy management for microgrids with renewable generation and EV fleets. Smart Energy Systems Journal, 9(2), 112–123.
8. Deshmukh, R., & Ghosh, P. (2021). Real-time distributed control for EV-integrated microgrids using multi-agent systems. IEEE Systems Journal, 15(2), 1885–1895.