Simulation Based Study on Renewable Energy-Based Generation for Electric Vehicle Charging Station for Rural Area

Pratibha Shukla Tripathi 1 , Ajay Tripathi 2 , Govind Sahu 3

1 Research scholar, Department of Electrical Engineering, Kalinga University, Naya Raipur-492101,

2 Professor, Department of Mechanical Engineering, Government Engineering College, Raipur-492015,

3 Assistant professor, Department of Mechanical Engineering, Government Engineering College, Raipur-492015

Abstract:

Many villages and localities have connected with the main grid, although the quality of the supply is quite unreliable. Despite electricity requirements traveling in rural areas are costlier due to unviability of petrol pumps causing blackmarking of patrols at very backward areas. Which can be mitigated by promoting the use of electric vehicles for their daily requirements which will help for their economic and environmental stability. This study focused on the MATLAB based study for stabilizing electrical vehicle charging station at rural areas depended on the renewable energy-based resources only.

Keywords: Non-conventional Energy, Hybrid System, Electric Vehicle, MATLAB Simulation.

1. INTRODUCTION

Renewable energy sources have become in substantial demand, and their importance is recognized around the world. Renewable energy is defined as energy derived from naturally existing sources that can self-renew (Infield and Freris, 2020). Renewable energy is derived from recyclable sources such as sunlight, wind, water movement, and geothermal heat, and its availability is unbounded (Alghurayed et.al., 2022). India has enormous renewable energy potential, but it has yet to be completely realized. The country's major energy issue, as well as the imports of fossil resources, are constraining economic progress (Ramachandra and Hegde, 2014). As more fossil fuels are burnt in power plants to meet energy demand, the availability of these fuels is fast depleting. The Earth's limited resources, like coal, oil, and natural resources, are running out due to the depletion of nonrenewable sources. This overuse harms the environment, raises expenses, and forces people to rely on restricted resources. It is necessary to move to sustainable, renewable energy sources, such as solar and wind power.

Due to the growing issue of non-renewable resource scarcity, electric vehicles are being launched as an alternative to gasoline and diesel-powered automobiles. Electric vehicles (EVs) are predicted to be a major component of future transportation systems. A number of countries have released roadmaps aimed at facilitating the adoption of EVs on the road. However, the most popular way to charge an electric vehicle (EV) is to plug it into a power supply at home. Because charging an EV demands a substantial quantity of electricity, the supply system in the home or office must be modified to accommodate EV charging. Furthermore, the supply system becomes contaminated as a result of the vast number of harmonics in the current drawn by EVs, which affects the local office and household load (Verma and Singh, 2019). Furthermore, many public places, such as parking lots, malls, and businesses, allow electric vehicles to be charged. As a result, vehicle charging is considered to take place in both residential and commercial settings. When an electric automobile is plugged in, it normally starts charging until it is completely charged. However, adopting such a charging approach may result in the transformer's maximum capacity not being achieved due to power consumption (Khushalani et al., 2017). For the most part, electricity has been generated using traditional, non-renewable energy sources such as coal, natural gas, and oil. EV charging stations may be readily deployed by linking them into the existing grid, eliminating the need for significant infrastructure upgrades. This contradicts the major goal of transitioning to electric vehicles in order to reduce carbon emissions and promote greener transportation.

As the world struggles with environmental deterioration and climate change, the use of renewable energy in infrastructure for electric vehicles becomes increasingly important. Electric vehicle (EV) charging stations powered by renewable energy sources are an important step toward developing a more environmentally friendly and sustainable transportation ecology. Renewable Energy (RE) sources are recommended for charging EVs for a variety of reasons, including lower energy prices and environmental considerations. Utility system disturbances can be reduced by integrating energy storage and renewable energy sources (Hamidi et al. 2013).

Rural electrification is key requirements for the developments of villages and India as well. After 1989, focused programs and schemes for electrifying rural areas in India were launched, with the primary goal being household electricity for the most basic domestic requirements. In India, village electrification is nearly completed; yet, constant electricity delivery remains a challenge. It is extremely difficult to meet the load requirement using traditional generation. Furthermore, due to rising fuel costs, limited stockpiles, polluting nature, and the requirement for long transmission lines with losses, traditional electricity generation is not a better option for the future. As a result, the trend of distributed generation using renewable energy sources such as PV, hydro, solar, wind, biomass, and biogas has increased during the previous decade. Such systems can provide a low-cost alternative to power supply for isolated rural loads. These renewables can be integrated with diesel/biogas sets to construct hybrid power systems, which improves supply conditions and increases generation. Such hybrid setups can be operated in a standalone or grid-interactive mode, or they can be coupled to generate electricity for local demands and transfer power between microgrids (Ahadi et al., 2018, 8. Akbas et al., 2022). The transportation in the rural region are also costlier due to scarcity of petrol/diesel pumps in the villages. The local villagers acquire fuels from the black-markets at more price or carries their own fuels for long periods of time arising the chances of accident. To overcome the above-mentioned issue the villages should be promoted to use more and more electric vehicles and for their charging requirements a separate off-grid should be installed in the villages or in the wards for more populated villages by the local governments. On-site solar photovoltaic (PV) installations were among the first and most prevalent ways to integrate renewable energy into EV charging.

2. MATLAB SIMULATION

Simulation is the process of creating a model or representation of a real-world system in order to understand, assess, forecast, or enhance its behavior. MATLAB is an abbreviation for "matrix laboratory". The term "MATLAB simulation" refers to the use of MATLAB software to build, evaluate, and conduct system or process simulations. MATLAB's extensive set of integrated functions, toolboxes, and visualization tools facilitate the creation and analysis of simulations in a wide range of areas, including power systems, control systems, signal processing, and many more. In their research work, Eng. Abdulmajeed M Alsaiari et al. provide a MATLAB simulation of a stand-alone electric vehicle charging station powered by photovoltaic energy. A system that includes a solar array with a boost converter, an energy storage system buck controller to regulate the electric vehicle's charging process, and a bidirectional controller to maintain DC bus voltage stability has been presented. The data show that, under all PV changes, the electric car battery charges exactly and steadily. Furthermore, the charging and discharging procedures of the energy storage battery work flawlessly to store and recover from changes in PV energy (Alghurayed et.al., 2022).

Gourav Prakash Shirsat discusses the various equipment necessary to configure a grid-connected electric vehicle charging station that uses renewable energy. The study provides insight into the configuration of a grid-connected EV charging station that is linked with a renewable energy system. To obtain the results of the simulation model, MATLAB/SIMULINK is employed to simulate a charging station for electric vehicles connected to the grid using renewable energy sources (Shirsat, 2019).

Arunesh Kumar Singh et al. use MATLAB to examine working MPPTs using various methods such as the P&O algorithm and fuzzy logic. To address the issue of fluctuating environmental conditions while meeting power requirements, this study proposed a hybrid non-conventional energy system that combines various energy sources, such as fuel cells (FC), photovoltaic (PV), and battery systems, to deliver continually and optimal electrical power (Khatoon et. al., 2022).

Simulation is an important tool in many fields because it can recreate real-life situations in an environment of control. Engineers may develop, test, and refine complicated systems or processes without having to create expensive physical prototypes. MATLAB may help you save time and money by analyzing performance, identifying potential problems, and optimizing designs before they go into production by creating virtual models. Simulation allows for the exploration of scenarios that would otherwise be too risky, costly, or impracticable to test in the actual world. Furthermore, simulation aids understanding of dynamic system behavior under various conditions. Simulating different operational settings, loads, and inputs can help predict how a system would react. Finally, because of its ability to improve learning and comprehension in a range of applications, improve performance, increase safety, and expedite innovation, simulation is critical in the technical field.

3. PROBLEM IDENTIFICATION

Electric vehicles (EVs) have gained popularity in recent years due to their lower greenhouse gas emissions and less dependence on fossil fuels. However, charging electric vehicles could have a substantial impact on the electricity system. But the villages suffer from the scarcity of electricity at sufficient quantity which as major challenges for the adoption of electrical vehicles for rural areas. Renewable energy systems are one possible way to mitigate these issues. Renewable energy systems can be used to charge electric vehicles in areas without a local grid. This study presents a new approach to creating a renewable energy charging station that includes wind turbines, a solar system, and an energy storage system in order to reduce the need of diesel generators in isolated settlements. The proposed technique would improve the efficiency of standard EV charging stations. The study's main focus is on the efficient utilization of electricity from the renewable based resources. The charging station’s infrastructure is optimized and modeled.

4. PROPOSED METHODOLOGY

To solve the above-mentioned issues, a shift to hybrid power systems that incorporate different sources such as renewables and storage technologies is commonly suggested.

Hybridization can improve system dependability, increase energy resilience, and help to create a more sustainable and flexible power infrastructure.

Keeping this in mind, a "off-grid renewable energy-based generation for electric vehicle charging station" is proposed. The fundamental idea is to transition to a power system that is independent of the grid and runs on energy from renewable sources. A solar-wind hybrid system is suggested to provide power for electric vehicles. The primary goal is to remove reliance on the grid and optimize the use of renewable energy sources for EV charging purposes.

4.1 Solar Power Generation

Solar power generation entails turning sunlight into electricity using photovoltaic cells or solar panels. These cells capture and convert sunlight into direct current. The technology is also used by an MPPT (Maximum Power Point Tracker) converter that employs the perturb and observe algorithm (P&O), which assists the solar power generating system in adjusting the angle of operation of solar panels to ensure the generation of the maximum potential output power. The DC current is then sent through a DC-DC converter.

The following is a MATLAB simulation of solar power generation, which generates DC power from solar energy.

<Figure 1>

A simulation of the pulse generator subsystem of the solar power generation system is provided below. This pulse generator has an MPPT that employs the P&O algorithm. The PWM generator controls the switching device of the boost converter.

<Figure 2>

Below is a simulation of the solar power generation system's DC-DC Boost Converter Subsystem.

<Figure 3>

The graph of solar power generation derived using MATLAB Simulink is shown below.

<Figure 4>

4.2 Wind Power Generation

Permanent Magnet Synchronous Generator (PMSG) wind turbines are utilized for wind power generation because they are efficient, reliable, and can operate at different speeds, making them suited for a wide range of wind conditions. The least wind speed needed to generate power is 4m/s. As the wind moves the turbine blades, the rotor in a PMSG creates power directly. Because the wind power generation system generates alternating current, it is routed via a diode rectifier which converts it to direct current before passing through a DC-DC converter. The wind power production system is also utilized by the MPPT converter, which employs the perturb and observe algorithm (P&O) to assure maximum power generation.

<Figure 5>

The modeling of a subsystem for generating three-phase electrical power from wind energy is shown below. Electricity is generated using a permanent magnet synchronous generator (PMSG) wind turbine.

<Figure 6>

A simulation of subsystems is provided below. Figure 7 depicts the connection of a universal bridge that functions as a rectifier and an RC filter that acts as a filter, allowing us to obtain filtered DC power. Figure 8 depicts the modeling of a DC-DC boost converter.

<Figure 7>

<Figure 8>

Figure 9 depicts the P&O algorithm used by the MPPT to generate wind electricity. Figure 10 depicts the simulation of the MPPT subsystem, which is used to generate pulses that are fed into the boost converter's switch, in this case an IGBT.

<Figure 9>

<Figure 10>

The torque that is given to the PMSG is calculated as the torque generated by wind turbine here is in P.U. thus, to calculate the actual torque we calculate the base torque using the power and the angular speed calculated by the tip speed ratio and the power torque equation.

$$T_a = \frac{T_{pu}}{T_b} \qquad T_b = \frac{P}{w} \qquad TSR = \frac{wr}{v}$$

Where,

Ta = Actual Torque, Tb = Base torque, P = Power, w = Rotational speed in radians/sec, r = rotor radius, v = speed of relative wind

The ratio of the input and the output voltage of the Boost converter helps us to find the duty cycle.

$$\frac{V_{out}}{V_{in}} = \frac{1}{(1 - D)}$$

Where, Vout= Output voltage of boost converter Vin= input voltage D= duty cycle of the boost converter.

The graph of the wind power generation obtained from the MATLAB Simulink model is given below.

<Figure 11>

4.3 Hybrid Power Generation

To create a hybrid system with a solar and wind power source, the two above mentioned simulations are connected in parallel. Hybrid systems offer numerous benefits that boost productivity, dependability, and sustainability by integrating two or more energy sources. By diversifying the power sources and minimizing reliance on a single supply, they first provide increased energy security. Hybrid systems can make use of variable climatic circumstances and provide a more consistent energy output by merging complementary sources such as wind and solar. By doing this, the system's total performance is improved in addition to resource utilization.

<Figure 12>

The power is calculated simply by the formula given below.

$$P = VI$$

Where, P= Power of the system,

V= Voltage,

I= Current.

5. RESULTS

Case 1: When the % utilization of solar energy and wind eneegy will be 70% and 30% respectively.

<Table 1>

The percentage contribution of solar and wind power sources to total power generation is shown in the above table. This proportion of the contribution is ideal for areas where wind and solar energy have equal capacity to meet demand as an alternative source of electricity generation. The hybrid system graphs for the aforementioned % contributions from each source, derived from the MATLAB Simulink model, are provided below.

<Figure 13>

The hybrid generation system was designed to create 150 kW of power, but we ended up generating about 180kW to ensure the dependability of the charging station by accounting for some additional demand.

Case 2: When the % utilization of solar energy and wind eneegy will be 10% and 90% respectively.

<Table 2>

The percentage contribution of solar and wind power sources to total power generation is shown in the above table. In situations like coastal regions or onshore regions where wind has a significant potential to create power, this percentage contribution is ideal. Below is a graph of the hybrid system derived from the MATLAB Simulink model for the aforementioned percentage contribution of each source.

<Figure 14>

Case 3: When the % utilization of solar energy and wind eneegy will be 90% and 10% respectively.

<Table 3>

The percentage contribution of solar and wind power sources to total power generation is shown in the above table. This percentage contribution is ideal for places like desert regions with high insolation levels where solar energy has a lot of potential to produce electricity. Below is the hybrid system graph, which was created using the MATLAB Simulink model and represents the aforementioned % contribution from each source.

<Figure 15>

Case 4: When the % utilization of solar energy and wind eneegy will be 10% and 10% respectively.

<Table 4>

In the event that unfavorable weather prevents solar and wind energy sources from generating the necessary quantity of power—such as during foggy and rainy seasons—the above table shows the percentage contribution of these sources to total power generation. Below is the hybrid system's graph, which was created using the MATLAB Simulink model.

<Figure 16>

<Figure 17>

The total number of EVs which can be charged utilizing electricity produced in various scenarios is shown in the following figure. In cases 1, 2, and 3, the total power generated is 180 kW, but in case 4, the total power created is roughly 37 kW.

An electric car typically requires 10–15 kW of power to completely charge. Thus, if we consider cases 1, 2, and 3, we can roughly charge 13 EVs, and if we consider case 4, we can roughly charge 3 EVs in unfavorable weather.

6. CONCLUSION

It has been concluded that depending solely on one non-conventional resource for supply at charging stations is not ideal. Hybrid systems offer numerous of advantages that augment efficiency, dependability, and sustainability by merging two or more energy sources. First off, by minimizing reliance on a single resource through diversification of power sources, they provide increased energy security. This is especially important when there could be supply changes or disruptions. A further significant benefit is increased energy efficiency. Hybrid systems are capable of taking advantage of different climatic circumstances and guaranteeing a more consistent energy supply by combining complimentary sources such as solar and wind. This improves system performance overall and maximizes the use of available resources.

Additionally, by incorporating renewable energy sources, reducing greenhouse gas emissions, and encouraging a cleaner energy mix, hybrid systems support environmental sustainability. This is in line with international initiatives to tackle climate change and move toward a cleaner, more sustainable energy system.

ACKNOWLEDGEMENT

The authors are very grateful Principal Government Engineering College, Raipur, Chhattisgarh for providing facilities to carried out this work.

NOMENCLATURE

Subscripts

kW	Killo Watt
EVs	Electric Vehicles
PV	Photovoltaic
RE	Renewable Energy
VIPV	Vehicle Integrated Photovoltaics
FC	Fuel cells
MPPT	Maximum Power Point Tracker
DC	Direct Current
AC	Alternating Current
PWM	
PMSG	Permanent Magnet Synchronous Generator

REFERENCES

1. Infield, D., & Freris, L. (2020). Renewable energy in power systems. John Wiley & Sons..
2. Alghurayed, A. M., Alshehri, A. H., Albalawi, T. A., & Alsaiari, A. M. (2022). MATLAB Simulation of an Electric Vehicle Charging Station Supplied by Photovoltaic Energy. International Journal of Applied Engineering Research, Volume 17(3), 283-289.
3. Ramachandra, T. V., & Hegde, G. (2014, September). Scope for distributed renewable energy systems in South India. In 2014 IEEE Global Humanitarian Technology Conference-South Asia Satellite (GHTC-SAS), 45-50.
4. Verma, A., & Singh, B. (2019, September). Control and implementation of renewable energy based smart charging station beneficial for EVs, home and grid. In 2019 IEEE Energy Conversion Congress and Exposition (ECCE), 5443-5449.
5. Khushalani, B., Alluri, P., Kasani, V. S., & Solanki, J. (2017, September). Coordinated charging strategies for plug-in hybrid electric vehicles. In 2017 North American Power Symposium (NAPS), 1-5.
6. Hamidi, A., Weber, L., & Nasiri, A. (2013, October). EV charging station integrating renewable energy and second-life battery. In 2013 International Conference on Renewable Energy Research and Applications (ICRERA), 1217-1221.
7. Ahadi, A., Sarma, S., Moon, J. S., Kang, S., & Lee, J. H. (2018). A robust optimization for designing a charging station based on solar and wind energy for electric vehicles of a smart home in small villages. Energies, 11(7), 1728.
8. Akbas, B., Kocaman, A. S., Nock, D., & Trotter, P. A. (2022). Rural electrification: An overview of optimization methods. Renewable and Sustainable Energy Reviews, 156, 111935.
9. Shirsat, G. P. (2019). Simulation of grid connected EV charging station with renewable energy source. International Journal of Advanced Trends in Computer Science and Engineering, 8(1.4), 415-419.
10. Khatoon, S., Jalil, M. F., Singh A. K. and Pushpender, “Real Time Simulation based MPPT for Hybrid System”, Advances and Applications in Mathematical Sciences, Volume 21, Issue 12, October 2022.