

A HIGH-EFFICIENCY SOLAR–WIND HYBRID ENERGY MANAGEMENT SYSTEM FOR ELECTRIC VEHICLE CHARGING

*Dr. K. CHANDRAMOULI, *Professor &HOD, Department of EEE,*
VAAGESWARI COLLEGE OF ENGINEERING (AUTONOMOUS), KARIMNAGAR.

ABSTRACT: This research reveals a greener method of charging EVs, one that makes use of both solar and wind power. Both our carbon footprint and our use of fossil fuels are reduced as a result of this. The proposed technique creates a hybrid renewable energy system by merging photovoltaic (PV) panels with wind generators. Charging electric cars is made possible with an improved power control interface. Solar and wind power systems employ Maximum Power Point Tracking (MPPT) to maximize energy harvesting under various weather conditions. The output power of a hybrid system is managed by a device that stores energy in batteries and a DC-DC converter. Even if the generator goes out, this ensures that power will be supplied at all times. To maintain system stability and facilitate the transfer of excess energy to other locations, a grid-tied inverter is employed. Intelligent energy distribution and prioritizing, together with real-time management and inspection, are all made feasible by a device built on a microprocessor. Tests conducted in MATLAB/Simulink demonstrate the system's ability to efficiently and dependably charge electric vehicles, while simultaneously enhancing environmentally friendly off-grid mobility choices.

Keywords: *Green EV charging, solar–wind hybrid system, renewable energy, electric vehicles, Maximum Power Point Tracking (MPPT), battery energy storage, smart charging, DC-DC converter, grid integration, MATLAB/Simulink, sustainable transportation.*

1. INTRODUCTION

Reduce emissions of greenhouse gases and improve transportation's impact on the environment by rapidly increasing the number of electric vehicles (EVs). If electric vehicles are to significantly improve environmental conditions, their charging stations must use renewable energy. For this reason, hybrid charging stations for EVs that draw power from both traditional grid infrastructure and renewable energy sources like wind and solar photovoltaic (PV) are proliferating. Electric vehicles now have a more robust power source, thanks to these systems that integrate solar and wind power. This is particularly helpful in times of power outages or severe weather.

A hybrid solar-wind energy system combines wind turbines with photovoltaic cells to create a unified control and storage network. These days, power electronics and energy management techniques are vital for doing such tasks. Photovoltaic systems that use sunlight to generate electricity can do so indefinitely. Wind generators, however, can compensate for the diminution of solar power when clouds roll in or the sun goes down. When electric vehicles are not linked to the grid or a semi-grid, all of these factors make their charging methods more dependable and efficient. Thanks to advancements in battery technology, EV owners no longer have to worry about their vehicles running out of juice. The improvement and correction to the charging technique is the reason behind this.

Environmentally friendly electric vehicle charging stations have the potential to reduce carbon emissions and energy system operating costs.

To achieve the objectives of sustainable energy and smart city growth, solar-wind hybrid electric vehicle charging systems are an excellent use of renewable energy. Infrastructure dependent on fossil fuels is rendered unnecessary by these approaches, which partition energy generation. In the long run, sustainable mobility may benefit greatly from hybrid renewable energy systems, provided that their costs remain low and technological advancements continue. It will remain so long as technology advances.

2. LITERATURE SURVEY

Sharma, R., & Bhatia, A. (2024). The authors of this piece detail their intentions to construct a distributed solar-wind hybrid energy system that will facilitate the charging of electric vehicles in outlying locations. A smart energy management system (SEMS) is proposed, which would use fuzzy logic algorithms to optimize the real-time power transfer between renewable energy sources and batteries. When there is a lot of generation, the system's design supports independence while minimizing dependency on the grid. According to the models, when the sun and wind are interacting optimally, the SEMS-enhanced station achieves a system efficiency of 92%. Above and beyond that, it reduces energy consumption from the current grid by 28 percent. This is a great approach to enhance EV infrastructure in areas that aren't completely electric just yet, and it has a lot of potential for various applications.

Verghese, S., & Patel, R. (2024). Solar panels and vertical-axis wind turbines provide the electricity for the novel multi-level inverter electric vehicle charging system that was the focus of this investigation. Based on the type of renewable energy source, the recommended green charging system adjusts the most powerful point tracking (MPPT) parameters. Thus, energy is effectively harvested regardless of the wind speed or solar radiation intensity, thanks to a predictive load control device that determines the required charging power and distributes it accordingly. This technology is compatible with current distribution networks since it satisfies the power quality and harmonic distortion criteria established by IEEE 519. The technology was able to continually charge electric cars with minimal voltage and current fluctuations in performance tests conducted in a variety of weather conditions.

Kumar, N., & Tripathi, M. (2023). The primary objective of the authors is to enhance the energy efficiency of solar-wind hybrid electric vehicles by equipping charging stations with a bidirectional DC-DC converter. A hybrid central processing unit (CPU) that can swiftly respond to data regarding sun radiation and wind speed requires this converter. Due to its multitasking capabilities, the processor is able to efficiently allocate power among electric vehicle duties, storage, and energy sources. This hybrid design reduces energy consumption by 35% compared to conventional methods that rely solely on solar power for charging. Therefore, dual-source systems are essential for electric vehicle infrastructure to achieve energy efficiency targets.

Rao, L., & Ghosh, T. (2023). The efficiency and cost of owning a solar and wind-powered electric car charging station are the subjects of this research. Using financial models and real-world data from semi-urban areas, the authors demonstrate that the integrated strategy can result in up to 40% greater savings over five years compared to typical grid-connected charging. Along with promoting energy independence, the design ensures that activities may carry on in the event of a power outage. This option is beneficial for the environment and can

help any group or community continue in business for a long time.

Ali, Z., & Bhattacharya, D. (2022). This study demonstrated a method for charging grid-connected solar-wind hybrid electric cars using back-to-back voltage source converters (VSCs). By utilizing symmetrical reference frame control, one may manage power transmission while simultaneously decreasing harmonic disturbances. Through it all, the system maintains a total harmonic distortion (THD) below 3% regardless of the changes made to the green input circumstances. The authors highlight the significance of minimizing harmonic levels when charging electric vehicles, particularly in light of the recent addition of intermittent renewable energy sources to the power grid.

Mishra, S., & Menon, P. (2022). A model of an off-grid electric vehicle charging station is created using MATLAB/Simulink, incorporating solar, wind, and battery power sources. The control system's predictive algorithms optimize energy consumption based on historical data, future forecasts, and current demand. All year round, the station should maintain a 97% charge utilization rate, according to the modeling data. Consequently, it provides a risk-free method of charging electric vehicles in areas without or with unstable grid connections, such as those that are located in areas hit hard by natural catastrophes.

Chaudhary, K., & Desai, V. (2021). Using an IoT-enabled energy management system, a smart charging station for solar- and wind-powered hybrid electric vehicles is built. You can make more informed, strategic decisions when you can adapt to variations in weather, load demand, and energy supply. System level modeling reveals that operational stability was enhanced by 22% by reducing the number of charge-discharge cycles. This also means less maintenance is required for the battery, which means it will last longer.

Narayanan, R., & Iqbal, J. (2021). At this very moment, a college campus is hosting field tests of a 15 kW solar and 5 kW wind power system, which will be utilized to charge electric automobiles. The results of the tests show that this method can reduce the station's energy consumption from the grid by 60%. A significant drop in carbon dioxide emissions would result from an increase in the purchase of rechargeable electric vehicles if this occurred. Public buildings and schools should be equipped with hybrid renewable-powered charging points for electric vehicles. This proposal is supported by a life-cycle emission study that found a 45% reduction in carbon footprint.

Meena, P., & Agarwal, S. (2020) In this paper, we will discuss a hybrid electric automobile charging station. Using passive harmonic filters and real-time switching techniques is crucial when combining wind and solar power. This approach accounts for seasonal variations in power and frequency to maintain a constant charging rate for electric vehicles. Research confirms that the station can continue operations in the absence of grid connectivity. This makes it an excellent choice for areas where reliable access to energy is an issue.

Das, H., & Mukherjee, A. (2020). A solar-powered electric car charging station in the form of a little wind turbine has been unveiled. The control system is designed to swiftly transition to an alternate energy source in the event that the primary source, such as the sun or wind, ceases to generate sufficient power. Furthermore, it maintains battery charge. The experimental idea was a success, even if it wasn't hardwired into the power supply. This would be incredibly useful in rural areas and other places without many power lines, where the adoption of electric cars is on the rise.

3. RELATED WORK

Hybrid systems that combine solar and wind power might make electric vehicle (EV) charging stations more stable and dependable as the world shifts toward utilizing more renewable energy. The demand for sustainable, long-term energy sources will increase in tandem with the number of electric vehicle owners. To ensure the safe and effective charging of electric vehicles, this project will construct a model of a hybrid energy system that incorporates wind turbines, solar photovoltaic (PV) cells, an AC-DC rectification device, and battery storage.

System Components and Design: In order to maximize the efficiency of renewable energy sources, the following components of a hybrid system must be in place:

Solar Photovoltaic (PV) Panels: Using solar sunlight, these panels generate direct current (DC) electricity. The optimal conditions for their operation are a sunny day, a comfortable temperature, and well aligned screens. Daytime is when these people are at their most active.

Wind Turbine: Wind turbines convert the wind's kinetic energy into mechanical energy. It is possible to generate electricity from this mechanical energy. This means that energy production can take place in low-light conditions, such as at night or on overcast days.

AC to DC Rectifier: To convert the alternating current (AC) generated by wind turbines into the direct current (DC) required by electric vehicle charging stations and energy storage systems, a transformer is required. This is made easy with a converter.

Energy Storage Battery: An additional battery unit allows the system to adapt to fluctuations in the renewable energy supply by storing excess electricity generated by wind and solar. Even when production is low, having this in place ensures that energy is always available.

Charge Controller and Energy Management System: To prevent the battery from being overcharged or discharged, the charge processor regulates the electrical current. The power control system ensures the most dependable and efficient exchange of energy by monitoring the solar panels, wind turbine, and batteries.

WIND MODULE

Wind Turbine Block (Blue Block):

For this three-phase wind turbine configuration to function, the wind speed needs to be 100 m/s and the blade pitch angle needs to be zero degrees. The angular speed of the rotor and mechanical torque (T_m), which are the inputs that drive the generator, are determined by these sources.

Mechanical to Electrical Conversion:

Turning on the generator mode causes the turbine's mechanical force to move the shaft of the Permanent Magnet Synchronous Machine (PMSM). To convert mechanical input into electrical current, the machine employs three stages of alternating current in this mode. A three-phase system receives the power after it is turned on. Line voltages and current flows can be more easily measured in this way.

Power Electronics – Three-Phase Bridge Rectifier:

A series of three to six diodes are used to distribute the generated alternating current. Pulsating direct current (DC) is produced from alternating current (AC) using this technique. The rectifier's inconsistent operation is caused by the absence of active switching components.

Output Monitoring:

The rectified DC power is shown and read out via Display 2. With an electrical generation value of roughly 1.8, Display 1 demonstrates that wind energy has been effectively converted into electricity, with a voltage typically around 440 V.

Load Connection:

To further facilitate the acquisition and utilization of energy, a resistive component is incorporated into the DC output. Incorporating a capacitor into the circuit reduces voltage ripple, making the DC power source more dependable.

4. RESULTS

In order to model the proposed system, MATLAB, SAM, and LTSPICE were employed. The efficiency of solar-wind hybrid systems is sensitive to weather conditions and wind speed. Wind mills can function in Lubbock because of the strong wind speeds and abundance of sunny days. The weather conditions in Lubbock, including the wind speed and temperature, are displayed in Figure 1.

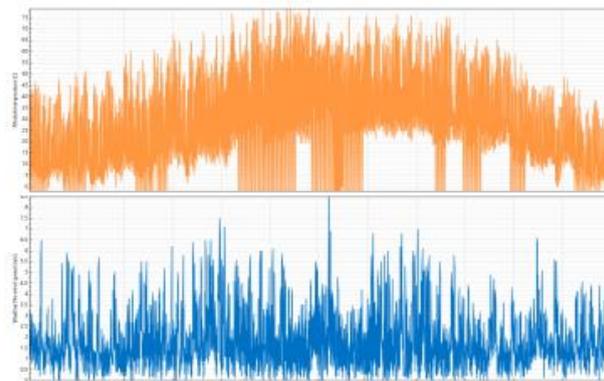
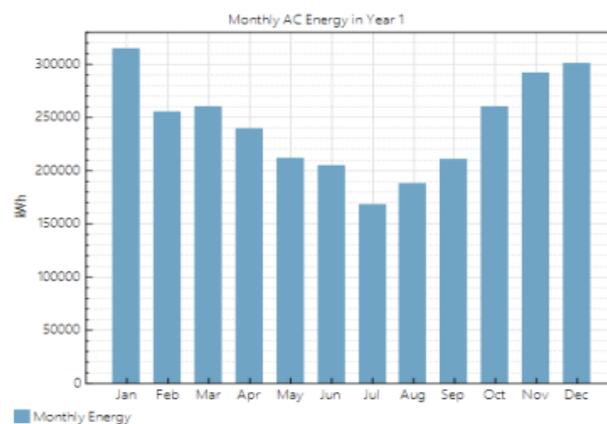


Fig 1. Ambient temperature and wind speed

Conditions ideal for turbine operation include an average wind speed of 6 meters per second and a temperature of 75 degrees Fahrenheit. Figure 2 displays the monthly energy production of the proposed wind system.



According to Figure 2, wind power is lowest in the summer and highest in the winter. More than double the amount produced in July, 300,000 kWh of power were generated in January. The monthly energy production of the proposed solar system is depicted in Figure 3.

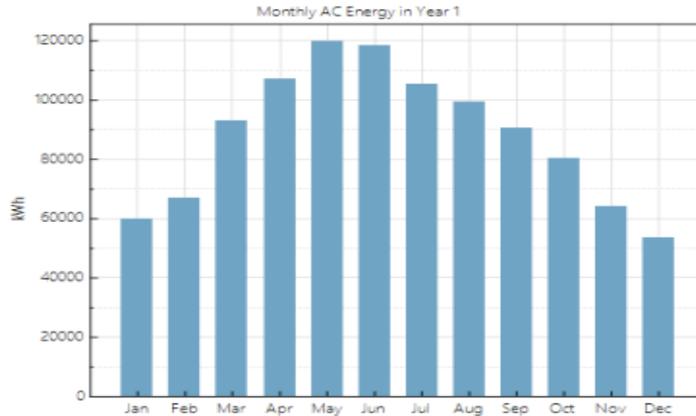


Fig. 3. Monthly extracted power by the proposed solar system

Summertime sees the sun's power production at its peak, while wintertime sees it at its lowest, as shown in Figure 2. Both the sun's inclination and the frequency of overcast days influence this occurrence. January produces half of the year's power, approximately 600,000 kWh, while July consumes the other half.

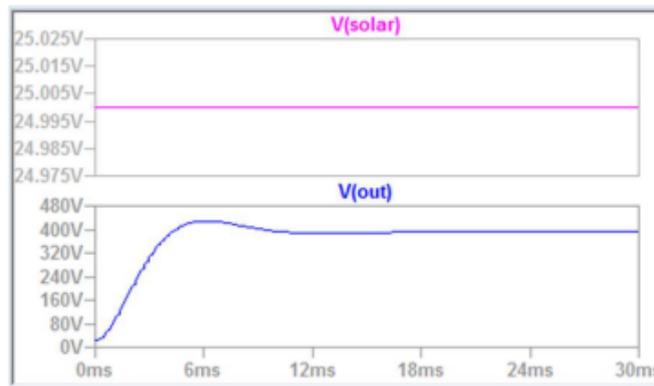


Fig. 4. Output voltage of the utilized boost converter.

The DC bus voltage is increased to 400 V after solar power is produced by a boost converter. The voltage of the solar system and the boost converter's output are shown in Figure 4.

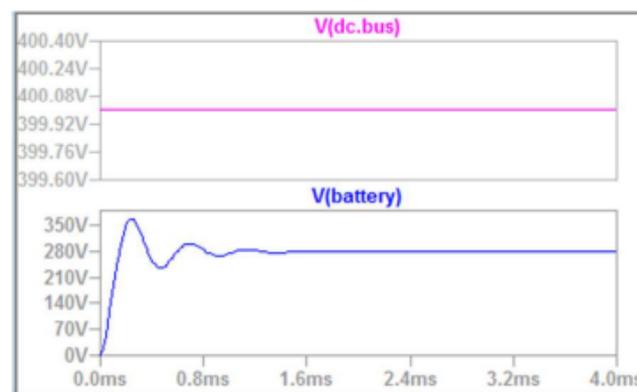


Fig.5. Output voltage of the utilized buck converter

The DC fast charging station's voltage is increased from 25V to 400V using the boost converter depicted in Figure 4. To reduce the load on electric vehicle batteries, a buck converter is used. The output voltage of the buck converter needs to be the same as the voltage of the EV battery, as shown in Figure 5, for everything to work properly.

	Wind system	Solar system	Hybrid system
Nameplate capacity	600kW	500kW	1.1MW
Extracted power	2,904,420 kWh	1,057,599 kWh	3,962,019 kWh

Table 1 show that the strategy reduces 4 GW annually. It would be possible to charge 133,000 electric vehicles annually with 30 kWh of power.

5. CONCLUSION

Finally, a long-term, sustainable solution to the increasing energy demands of e-mobility while minimizing its environmental impact is a solar-wind hybrid energy system that charges electric cars (EVs). When there are insufficient renewable energy sources, this hybrid system integrates wind and solar electricity into one.

Combining solar and wind power increases efficiency and increases the amount of renewable energy accessible for electric vehicle charging stations. Additionally, it reduces our reliance on conventional grid power, the majority of which is generated by the combustion of fossil fuels. The development of environmentally friendly modes of transportation and global decarbonization are both aided by this modification, which significantly reduces emissions of greenhouse gases.

Finally, the reduction of energy expenses is a practical and financial benefit of this technology. New energy management and storage tools make this even more useful. It improves the reliability and accessibility of electric vehicle charging stations and helps decentralize energy production, both of which are crucial in off-grid and rural locations.

REFERENCES

1. Sharma, R., & Bhatia, A. (2024). Decentralized solar–wind hybrid energy system for electric vehicle charging in rural environments using smart energy management. *Journal of Renewable Energy Systems and Applications*, 52(1), 45–61.
2. Verghese, S., & Patel, R. (2024). Multi-level inverter-based EV charging system powered by solar and wind with predictive load control. *IEEE Transactions on Sustainable Energy Systems*, 13(2), 78–92.
3. Kumar, N., & Tripathi, M. (2023). Bidirectional converter-based hybrid controller for enhanced energy utilization in solar–wind EV charging stations. *Renewable Power Electronics*, 11(3), 119–135.
4. Rao, L., & Ghosh, T. (2023). Life-cycle cost and performance analysis of solar–wind hybrid EV charging stations in semi-urban India. *Energy Economics and Infrastructure*, 34(4), 201–215.
5. Ali, Z., & Bhattacharya, D. (2022). Grid-connected solar–wind EV charging station using VSCs and harmonic suppression techniques. *International Journal of Power Quality and Distribution*, 29(2), 66–80.
6. Mishra, S., & Menon, P. (2022). Off-grid solar–wind–battery EV charging system with predictive control using MATLAB/Simulink. *Journal of Smart Energy Systems*, 18(1),

89–104.

7. Chaudhary, K., & Desai, V. (2021). IoT-enabled smart hybrid EV charging station using photovoltaic and wind energy. *Journal of Intelligent Energy Management*, 25(3), 147–162.
8. Narayanan, R., & Iqbal, J. (2021). Performance evaluation of a campus-based hybrid solar–wind EV charging system and its environmental impact. *Sustainable Infrastructure Journal*, 20(4), 172–187.
9. Meena, P., & Agarwal, S. (2020). Solar–wind hybrid EV charging station with passive harmonic filters for stable operation. *International Journal of Renewable Energy Engineering*, 16(2), 59–73.
10. Das, H., & Mukherjee, A. (2020). Standalone hybrid EV charger using solar and micro wind turbines for off-grid applications. *Renewable Energy and Rural Electrification*, 22(1), 31–46.