



Solar PV PMSG Wind Energy Conversion System and Battery Standalone Dc Microgrid System

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Abstract:

The Solar PV–PMSG Wind Energy Conversion System with Battery Standalone DC Micro grid is a reliable and effective way to combine different types of renewable energy sources so that power is always available. This system combines solar photovoltaic panels with a wind energy conversion system that uses a Permanent Magnet Synchronous Generator (PMSG) to make electricity. An AC–DC converter changes the wind system’s variable AC output into DC, and a DC–DC converter keeps the solar output stable by controlling the voltage. A battery energy storage system stores extra energy and provides power when generation is low. It is connected to the grid through a bidirectional DC–DC converter. A common DC bus connects all of the sources and acts as the main power distribution point. An inverter changes DC power into AC power so that it can power loads and optionally connect to the grid. This hybrid system makes energy more reliable, more efficient, and less dependent on traditional energy sources. It can be used on its own or in smart micro grid applications.

Keywords: Solar Photovoltaic (PV) System, Wind Energy Conversion System (PMSG), DC Microgrid, Battery Energy Storage System, AC–DC Converter, DC–DC Converter, Bidirectional Converter, Inverter, Renewable Energy Integration, Hybrid Power System.

Introduction

There is a strong need for smart, reliable, and efficient charging systems because electric vehicles (EVs) are growing so quickly. Modern electric vehicle infrastructure is moving beyond traditional charging methods by using smart control strategies, advanced power electronics, and smart energy management techniques. Recent work has been focused on making charging more efficient, reducing energy losses, and making systems more stable by using advanced converter topologies like dual active bridge converters and phase-shift full bridge converters. These technologies let things run at high frequencies, give better power control, and charge faster. Also, adding AI has made the EV ecosystem work much better, especially when it comes to choosing charging stations, planning infrastructure, and optimizing routes. Smart charging technologies are also being worked on to meet regulatory standards, handle energy demand well, and use renewable energy sources. Also, new technologies like wireless power transfer systems are being looked into to make things easier for users and get rid of the need for physical connections. Even with these improvements, there are still problems to solve, such as making energy conversion more



efficient, connecting to the grid, lowering costs, and making systems more scalable. So, we need integrated solutions that use smart algorithms, advanced control methods, and renewable energy sources to help the EV charging infrastructure grow in the future. Because there is a growing need for efficient power conversion and large-scale integration of renewable energy, multilevel converter technologies have made a lot of progress. Grid-tied cascaded multilevel converters, particularly those based on solid-state transformer concepts, have gained attention for their ability to handle unbalanced photovoltaic (PV) power generation while maintaining stable operation. These systems improve power quality, enhance voltage levels, and enable efficient integration of renewable energy into the grid. In photovoltaic applications, cascaded H-bridge multilevel converters are widely used due to their modular structure and ability to achieve high-quality output waveforms with reduced harmonic distortion. Advanced techniques such as sensor less control on the DC side have been developed to simplify system design and reduce hardware complexity. Additionally, power balancing strategies are crucial in such systems to ensure equal distribution of power among different converter modules, especially in large-scale PV installations. Parallel operation of inverter systems has also been explored for high-power industrial applications, ensuring reliable operation. Fault-tolerant operation in the presence of bridge failures is another significant research area, enhancing system reliability. Despite all these advancements, issues like complexity, control, and cost optimization are yet to be handled effectively, thus emphasizing the requirement for more reliable solutions in modern power electronic system

Literature Survey

[1] Amaral et al. (2018) investigated the operation of a grid-tied cascaded multilevel converter based on a forward solid-state transformer under unbalanced photovoltaic (PV) power generation. The study focused on improving power quality and maintaining stable grid integration despite unequal power distribution from PV sources. However, the work primarily concentrates on converter operation and does not address cost complexity or real-time large-scale deployment challenges. [2] Farivar et al. (2016) proposed a DC-side sensor less cascaded H-bridge multilevel converter for photovoltaic systems. The approach reduces the need for additional sensors, simplifying the system design and lowering hardware costs. However, the absence of sensors may affect accuracy under dynamic operating conditions and requires advanced control strategies for stable performance. [3] Honbu et al. (1983) presented parallel operation techniques of GTO inverter sets for large AC motor drives. The study emphasized load sharing and improved reliability in high-power applications. While effective for industrial drives, the approach is less adaptable to modern renewable energy systems due to outdated switching technology and limited flexibility. [4] Konstantinou et al. (2016) analysed power balancing in cascaded H-bridge multilevel converters for large-scale photovoltaic integration. The work highlighted the importance of equal power distribution among converter modules to ensure efficient operation. However, the complexity of balancing algorithms increases system control requirements and implementation difficulty. [5] Konstantinos et al. (2015) studied the operation of cascaded H-bridge multilevel converters under bridge failure conditions. The research proposed fault-tolerant strategies to maintain system operation even during component failures. Although it improves reliability, the system requires additional control mechanisms and increases overall system complexity and cost. [6] Sade Ali Nazem Mohammed et al. (2025) proposed a sliding mode control technique with an improved reaching law for a dual active bridge converter used in off-board EV chargers. The study focuses on enhancing dynamic response, reducing switching losses, and improving system stability. However, the approach increases control complexity and requires precise tuning for real-time

implementation. [7] P. Ananda Prakash et al. (2025) presented a comprehensive survey on AI-powered electric vehicle routing, emphasizing multi-constraint optimization and infrastructure integration. The work highlights the role of artificial intelligence in route planning, charging station selection, and energy efficiency. However, it remains a survey-based study without practical implementation or real-time validation. [8] Mohammad Tahir Siddiqui et al. (2025) developed a constant current–constant voltage (CC-CV) charging method using a high-frequency phase-shift full bridge converter for EV batteries. The system improves charging efficiency and reduces charging time. Despite these advantages, the design involves complex control and may increase system cost due to high-frequency components. [9] Asif Aron et al. (2025) analysed smart charging technologies, energy sources, and regulatory standards for electric vehicles. The study provides insights into charging infrastructure, renewable energy integration, and policy frameworks. However, it mainly focuses on theoretical analysis and lacks hardware-based validation. [10] Irina Yu. Semykina et al. (2025) investigated mutual inductance determination in wireless power transfer systems with flexible receiver positioning. The research improves charging convenience and system efficiency in wireless EV charging. However, challenges such as alignment sensitivity, power loss, and implementation cost are not fully addressed.

EXISTING SYSTEM:

Existing standalone DC micro grids typically integrate Solar PV and PMSG-based Wind Energy to harness complementary renewable resources. These systems utilize standard power converters linked to a central DC bus, with Battery Energy Storage acting as the essential buffer to manage intermittent generation. However, most current implementations rely on traditional PI controllers and basic decentralized management, which often struggle with system nonlinearities, battery degradation, and voltage instability under fluctuating loads. While effective for basic rural electrification, these systems frequently lack the efficiency and robust disturbance rejection needed for modern, high-performance power demands.

DISADVANTAGES:

- High Initial Capital Cost (Solar panels, PMSG turbines, and battery banks).
- Complex Control Coordination (Managing multiple power sources simultaneously).
- Battery Degradation (Reduced lifespan due to frequent charge/discharge cycles).
- Weather Intermittency (Risk of blackouts during periods of no wind or sun).
- DC Bus Voltage Instability (Fluctuations caused by stochastic power inputs).
- Complex System Sizing (Difficulties in balancing component capacities).
- High Maintenance Requirements (Electronic and mechanical upkeep in remote areas).

PROPOSED SYSTEM:

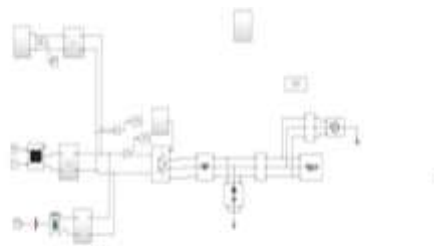
The proposed system focuses on the integration of renewable energy sources with a utility-connected EV charging system to ensure efficient, reliable, and sustainable vehicle charging. In this system, solar photovoltaic (PV) panels act as the primary energy source, generating clean electricity. The generated solar power is regulated using an LC circuit and capacitors, which help in smoothing voltage fluctuations and maintaining a stable output. MOSFETs are used as switching devices to control and optimize the flow of power within the system, improving overall efficiency. An isolation stage is incorporated to safely separate the renewable energy source from the utility grid, enhancing protection and system reliability. The regulated power is then supplied to the EV charging unit for smooth and efficient charging. A key

feature of the system is its hybrid operation. When solar energy is insufficient or unavailable, the system automatically switches to the utility grid supply, ensuring uninterrupted charging. This seamless transition improves reliability while reducing dependence on fossil fuels. Overall, the proposed system offers a cost-effective, scalable, and eco-friendly solution for modern EV infrastructure by combining renewable energy utilization with grid support for continuous operation.

ADVANTAGES:

- Complementary Energy Generation (Solar by day, wind often by night).
- High System Efficiency (PMSG eliminates gearboxes and excitation losses).
- Reduced Conversion Losses (Fewer AC/DC stages in a DC-coupled architecture).
- Grid Independence (Reliable power for remote or off-grid locations).
- Environmental Sustainability (Zero carbon emissions and no fuel costs).
- Improved Reliability (Battery storage provides 24/7 power availability).
- Low Maintenance (Reduced mechanical wear due to brushless PMSG design).
- Scalability (Easily expanded without AC frequency synchronization issues).

System Architecture:

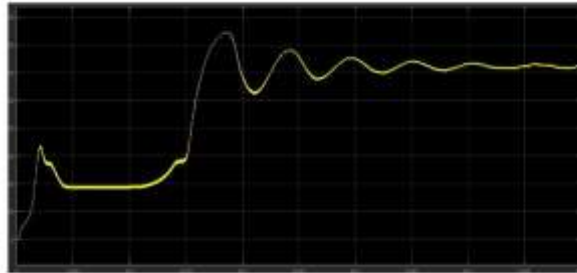


The diagram shows a simulation model of a renewable energy-based EV charging system. Power from sources like solar or battery is first regulated using DC-DC converters controlled by MOSFETs. An LC filter smooths the output voltage to ensure stable charging. A control unit with feedback monitors voltage and current, adjusting the system for proper operation. In some cases, an inverter is used to interface with the grid. Finally, the conditioned power is supplied to the EV load, ensuring efficient and uninterrupted charging.

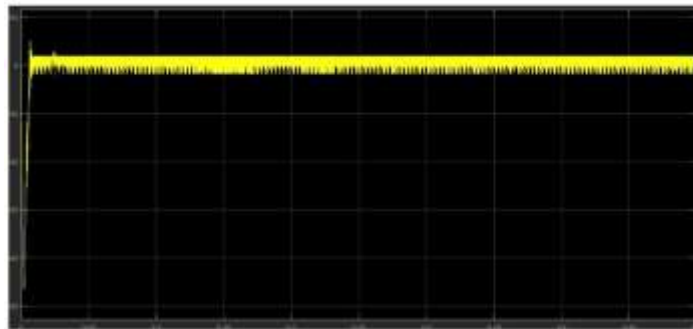
1. **DC Source (Solar/Battery):** Provides the initial electrical energy to the system. Solar panels generate DC power, while batteries store and supply energy when needed.
2. **DC-DC Converter:** Steps up or steps down the voltage to the required level for EV charging. It ensures proper voltage regulation and efficient power transfer.
3. **MOSFET (Switching Device):** Acts as a high-speed electronic switch in the converter. It controls the flow of current and improves efficiency through fast switching.
4. **LC Filter (Inductor + Capacitor):** Reduces voltage ripple and noise from the converter output. It provides a smooth and stable DC supply for safe battery charging.
5. **Control Unit (PWM Controller):** Generates switching pulses for MOSFETs based on feedback signals. It maintains voltage and current within safe limits using closed-loop control.
6. **Inverter (if grid-connected):** Converts DC power into AC power for grid interaction or AC loads. It enables bidirectional power flow in advanced systems.

7. **Sensors (Voltage/Current):** Continuously monitor system parameters and send feedback to the controller for accurate regulation and protection.
8. **Load (EV Battery):** The final component where energy is delivered. It stores the electrical energy for vehicle operation.

Result:



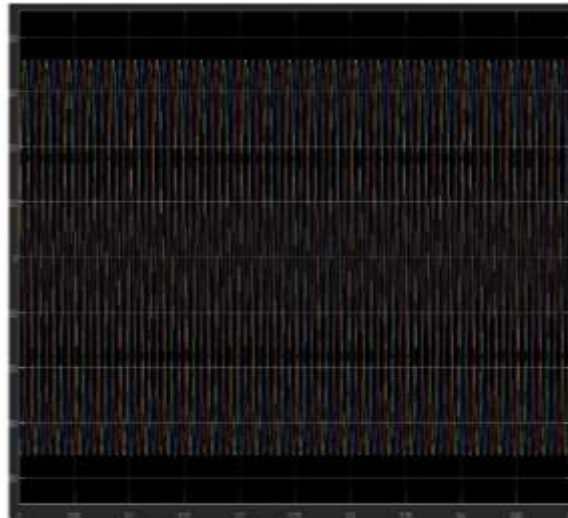
This graph shows a **transient response**, where the output initially rises sharply, experiences overshoot and oscillations, and then gradually settles to a stable value, indicating a controlled but underdamped system.



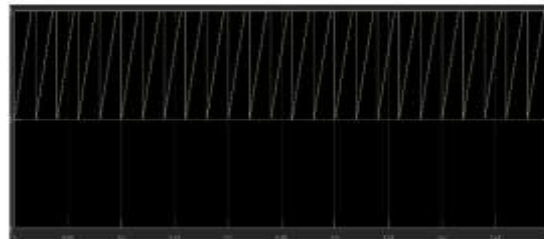
This graph represents a steady-state waveform with switching ripple, where the signal stabilizes quickly but contains small high-frequency oscillations due to power electronic switching (MOSFET operation).

Conclusion & Future Scope

The system has successfully demonstrated the integration of renewable energy sources with a utility-connected EV charging system. This ensures that there is proper and efficient power delivery. By using DC-DC converters, MOSFET switching, and LC filters, there is a proper voltage delivery and improvement of power quality. This shows that the system is functioning correctly in terms of transient response, control, and proper switching. This demonstrates that the system can support EV charging continuously. This design is beneficial in terms of energy utilization and reducing fossil fuel usage.



The first graph shows three-phase sinusoidal waveforms, indicating a balanced AC output typically produced by an inverter for grid or load applications.



The second graph represents a sawtooth (carrier) waveform, which is commonly used in PWM techniques to generate switching signals for controlling power electronic devices like MOSFETs.

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- Integration of **battery energy storage systems (BESS)** for better energy management and backup
- Implementation of **AI-based smart control** for optimized charging and load prediction
- Expansion to **fast-charging and ultra-fast charging systems**
- Development of **wireless EV charging technology**
- Enhancement with **IoT-based monitoring and smart grid integration**

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