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Synergistic Integration of Renewable Wind and Solar Energy with Advanced Distribution Grid for Electric Vehicle Charging and PMSM Motor Drive Applications

K.Kiranmaie, Kalintha Abhinav, Pendem Ramya, Mendu Snehanjani, Nallamekala Jyothsna

Department of Electrical and Electronics Engineering, Vasireddy Venkatadri Institute of Technology, Pedakakani, Namburu, India.

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ABSTRACT

This paper presents a framework for integrating renewable energy sources, such as wind and solar power, with an advanced distribution grid to power electric vehicles (EVs) and permanent magnet synchronous motors (PMSMs). The system uses wind turbines and solar panels to harness clean energy from the environment, and the generated renewable energy is integrated into the grid infrastructure through advanced power electronics and control systems. An innovative aspect of the system is the incorporation of onboard electric vehicle charging systems equipped with interleaved boost converters, which optimize the charging process of EVs while minimizing grid impact. This integration promotes the adoption of EVs and ensures their seamless integration into the existing grid infrastructure. MATLAB simulations are conducted to assess the performance and viability of the proposed system, evaluating key performance metrics such as energy efficiency, grid stability, and system reliability. The system employs optimization algorithms to maximize renewable energy resource utilization, minimize charging costs, and optimize the operation of PMSM motor drives. The insights from the simulations provide valuable guidance on the feasibility, scalability, and performance of the integrated system, demonstrating its potential to enhance energy sustainability, reduce greenhouse gas emissions, and improve grid resilience.

KEYWORDS: Renewable Energy Integration, Wind Energy, Solar Energy, Advanced Distribution Grid, Electric Vehicle Charging, PMSM Motor Drive, Energy Management, Energy Storage Systems

1. INTRODUCTION

The electric vehicle (EV) has gained popularity due to its potential to achieve zero fossil fuel consumption and reduce air pollution and global warming [1-2]. However, EVs require frequent charging using grid power, which poses several challenges [3-4]. Traditional methods like coal-fired power plants may not effectively reduce emissions, and the increasing penetration of EVs can negatively impact the local distribution grid [5-6]. Uncontrolled and unregulated charging can result in unexpected peak loads that exceed the capacity of the distribution grid. The distribution grid is also facing an increasing penetration of home photovoltaic (HPV) systems, which can cause voltage rise and line overload during noontime [7]. To address these challenges, integrating renewable energy sources such as wind power generation with solar photovoltaic (PV) systems presents a promising solution [8]. While solar PV systems generate power during daylight hours, wind turbines can produce electricity both day and night, providing a complementary source of renewable energy [9]. This combination of wind and solar energy can help mitigate the intermittency of renewable energy generation, thereby enhancing the reliability and stability of the grid. Energy storage units (ESUs) are typically deployed to mitigate the impacts of renewable energy integration, but adding ESUs to HPV systems incurs extra costs and may not be subsidized by the government or utility companies [10]. The idea of using the electric vehicle battery (EVB) as an energy storage system (ESS) has been proposed to mitigate the intermittency of PV systems. EVBs can act as an ESS, charging from solar PV when there is excess power and injecting power to the grid when needed [11]. This can help limit voltage rise problems at midday by taking power from HPV systems, contributing to the increase of HPV penetration in the distribution grid. Similarly, excess wind power generation can also be stored in EVBs during periods of low demand and injected into the grid during peak hours, providing additional flexibility and stability [12-14]. The concept of using EVB for supporting the electric grid during peak demands is also becoming increasingly attractive. Researchers have proposed optimal energy management strategies for using EV batteries at parking lots to reduce peak load based on demand response programs [15]. The proposed power management algorithm maximizes the load factor during daily operation of the EV parking lot considering arrival and departure times of EVs. Stored energy in EVBs can help stabilize the grid feeder during peak demand by injecting power to local feeders [16]. To further enhance the integration of renewable energy sources and address the challenges associated with electric vehicle (EV) charging, the utilization of onboard electric vehicle charging systems with interleaved boost converters can be employed [18-19]. Traditional charging methods often rely solely on grid power, leading to increased strain on the distribution grid and potential peak load issues. However, by integrating onboard charging systems with interleaved boost converters, EVs can efficiently utilize power from the grid for charging while minimizing grid impact. Interleaved boost converters are particularly effective in maximizing power transfer efficiency and reducing charging times [20]. By splitting the input current into multiple parallel branches, interleaved boost converters can handle higher power levels and reduce charging time compared to conventional charging methods [21]. Moreover, the integration of onboard electric vehicle charging systems with interleaved boost converters offers several advantages, including enhanced charging efficiency, reduced grid impact, fast charging, flexibility and adaptability, and scalability [22]. Incorporating onboard electric vehicle charging systems with interleaved boost converters into the transportation sector accelerates the adoption of electric vehicles and promotes the transition towards a cleaner and more sustainable transportation system [23]. By improving charging efficiency and reducing grid impact, interleaved boost converters play a crucial role in advancing the electrification of transportation and mitigating the environmental impacts of fossil fuel-powered vehicles. The study discusses the integration of electric vehicle (EV) charging and discharging systems (EVBs) with high voltage DC buses (usually 800V) [24-25]. The EVBs and ESS converters can be designed for unidirectional or bidirectional power flow, primarily taking power from PV arrays. The charging procedure for EVBs and ESS is controlled to minimize power draw from the grid. EVs use standard DC connectors to connect to the system. Recent research focuses on EVB applications in car parks or business buildings, but there is a research gap at the component level, particularly for residential PV applications [26]. To address this gap, a detailed design of a power conditioning system with a power control strategy for a solar powered EV charging/discharging system that supports power grids is proposed. The literature review on charging connectors shows that only CHAdeMO connector standard can be used for HPV-EVB systems without modifications, allowing bidirectional transfer of DC power directly from EVB to power conditioning system (PCS) [27]. The paper proposes the use of a fast DC charging connector to interface the HPV system with the EVB, presenting modes of operation and control system. The study suggests that using EVBs of less used cars to support residential solar PV can mitigate power fluctuations and reduce the burden on local power grids. This system can be part of a micro-grid or smart grid framework with a flexible control algorithm [28]. Additionally, the integration of permanent magnet synchronous motor (PMSM) drive applications in EVs enhances their efficiency and performance. PMSM drives offer high torque density, wide speed range, and improved efficiency, making them ideal for EV propulsion systems. By incorporating PMSM drives into EVs, vehicle manufacturers can achieve higher energy efficiency, longer driving range, and superior performance, further advancing the adoption and sustainability of electric transportation.

2. SYSTEM CONFIGURATION

The system configuration for integrating renewable energy sources with electric vehicle (EV) charging infrastructure involves the strategic placement of solar photovoltaic (PV) systems and wind turbines to capture and generate clean energy. These renewable energy sources complement each other, with solar PV systems generating power during daylight hours and wind turbines producing electricity both day and night, thereby mitigating the intermittency of renewable energy generation and enhancing grid reliability. Energy storage units (ESUs), often in the form of battery storage systems like lithium-ion batteries, are employed to store excess energy generated by solar and wind systems during periods of low demand or high generation, ensuring a reliable and continuous power supply for EV charging. Additionally, the integration of onboard electric vehicle charging systems with interleaved boost converters optimizes charging efficiency, minimizes grid impact, and reduces charging times. This approach enables EVs to efficiently utilize power from the grid while mitigating strain on the distribution grid. The system also incorporates permanent magnet synchronous motor (PMSM) drive applications in EVs to enhance their efficiency, torque density, and overall performance, further advancing the adoption and sustainability of electric transportation

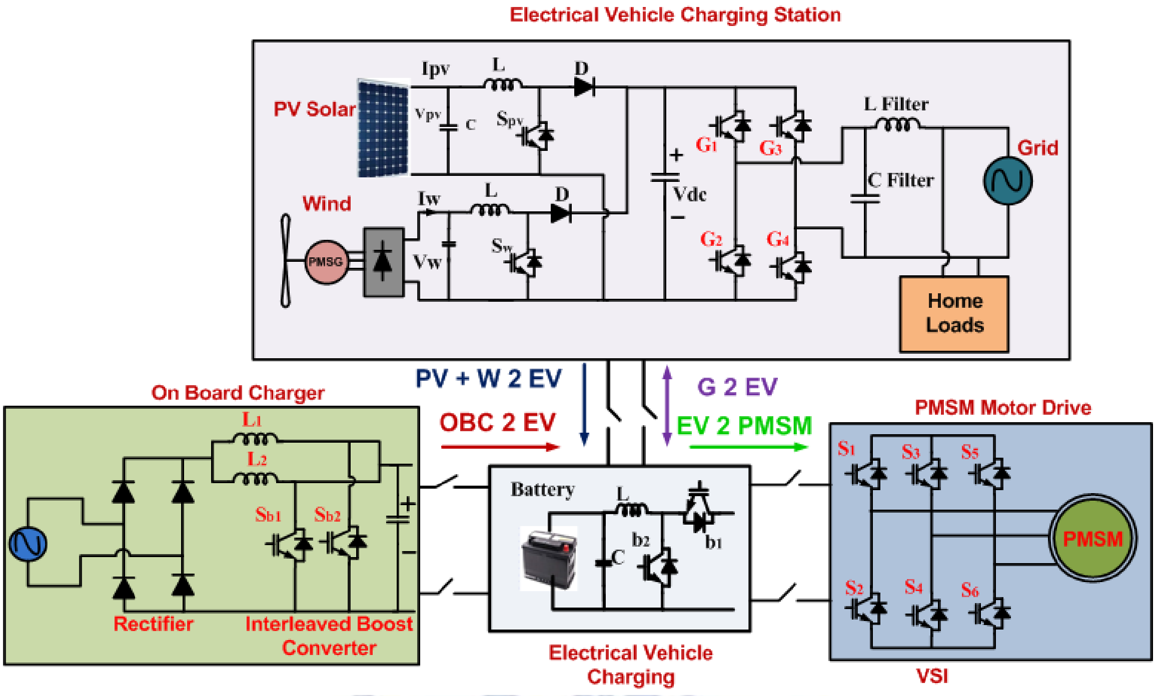


Fig .1 system configuration of an Advanced Distribution Grid for Electric Vehicle Charging

3. MODE OF SYSTEM OPERATION

Electric vehicle charging stations and renewable energy sources like wind turbines and solar photovoltaic (PV) systems work together to power the system. Unlike wind turbines, which create power 24/7, solar photovoltaic systems only use sunshine during the day. The intermittency of renewable energy sources may be reduced by combining solar and wind power output. This results in a more constant and stable power supply for electric vehicle charging. The system uses energy storage units (ESUs) to deal with changes in renewable energy production and changes in the demand for charging electric vehicles. During times of high generation or low demand, these ESUs store the extra energy, usually in the form of lithium-ion batteries. Energy storage units (ESUs) provide a constant power supply for electric vehicle charging by storing excess energy, even in periods of low or high demand or renewable energy output. Electric vehicles may have their charging efficiency maximised using interleaved boost converters, reducing grid strain. The energy stored in ESUs may be effectively transformed into the voltage and current needed to charge electric vehicles by use of these converters. The technology improves charging efficiency by reducing load on the distribution grid and charging times via this method of management. Smart grid interaction between EVs and the power grid is also made possible by the system, which considers things like renewable energy production patterns and grid load. When charging takes place at the most efficient periods, supply and demand are balanced, and renewable energy sources are used to their fullest potential while non-renewable sources are minimised. By interacting with the grid in this way, electric vehicles may help achieve grid stability and sustainability goals while making optimal use of grid electricity. Electric vehicles' performance and economy are both improved by using permanent magnet synchronous motor (PMSM) driving applications. PMSM motors are a boon to electric vehicle development since they outperform conventional motors in terms of efficiency and torque density. The integration of PMSM drive applications into the system further improves the eco-friendliness of EVs, which in turn encourages their broad use and decreases dependency on fossil fuels. Sustainable, efficient, and dependable electric mobility is made possible by the integrated system's coordinated operation, which makes use of renewable energy production, energy storage, an optimised charging infrastructure, and cutting-edge motor technology. The system helps move us towards a greener, more sustainable energy future by maximising the use of renewable energy and improving the way electric vehicles are charged.

1. The grid is integrated with renewable energy sources to supply electricity for charging electric vehicles.

A sustainable and advanced method of powering transportation is the integration of renewable energy sources into the grid for the charging of electric vehicles (EVs) as shown in fig.2. Solar photovoltaic (PV) systems and wind turbines are strategically placed to create power using the natural resources of sunshine and wind. Optimising the performance of these renewable energy sources is greatly assisted by the Perturb and Observe (P&O) and Maximum Power Point Tracking (MPPT) algorithms. These algorithms dynamically modify the operational parameters of the sources to guarantee they function at their maximum power output. Combining the output of wind turbines and solar photovoltaic (PV) systems, which generate electricity all day long, can create a steady and dependable power source for charging electric vehicles. Grid-tie inverters allow for the seamless integration of renewable energy into the current electrical system by distributing the generated power to charging stations throughout the network. Advanced algorithms that carefully manage the power flow and prioritise renewable energy sources whenever possible control the charging of electric vehicles. To maximise the use of renewable energy resources, EV charging is optimised at times of low grid demand or periods of high renewable energy output. By reducing transportation's environmental impact and successfully balancing supply and demand, this serves to ease pressure on the grid. The integration of bidirectional charging capabilities enables grid-to-vehicle and vehicle-to-grid operations. Grid-to-vehicle (G2V) charging allows EVs to draw power from the grid, supplementing their onboard battery storage. This functionality is particularly useful during peak renewable energy generation periods, when excess energy can be stored in EV batteries for later use. Vehicle-to-grid (V2G) operation enables EVs to discharge stored energy back into the grid when needed. During periods of high demand or low renewable energy production, EVs can serve as distributed energy resources, providing valuable energy storage and grid stabilisation services. Improving the stability and dependability of the grid relies heavily on energy storage technology like lithium-ion batteries. During periods of abundant renewable energy production, these systems store the extra energy and release it when demand is high or output is low. They provide a reliable and consistent power source for charging electric vehicles (EVs) by acting as a buffer against variations in renewable energy production or grid circumstances. All things considered, the integrated system is a huge step forward in terms of environmentally friendly transport networks. Utilising energy storage systems, streamlining charging processes, and utilising renewable energy sources together provide a comprehensive strategy for addressing the growing demand for electric mobility in a way that promotes environmental sustainability and grid resilience

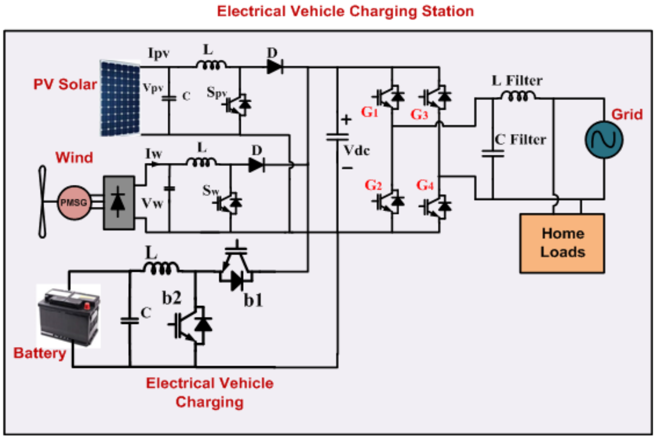


Fig.2 renewable energy sources integrated with grid system

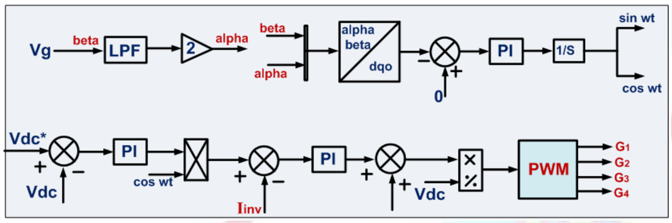


Fig.3 controller design of renewable energy sources integrated with grid system

1. **Maximum Power Point Tracking (MPPT)**:
   - The MPPT algorithm aims to maximize the power output of renewable energy sources like solar PV systems and wind turbines.
   - One common MPPT algorithm is the Perturb and Observe (P&O) method, which adjusts the operating point of the system and observes the resulting change in power output.
2. **Power Output of Solar PV Systems**: The power output (P_{PV}) of a solar PV system can be calculated using the formula:

$$P_{PV} = A \times G \times \eta_{PV}$$

Where:

- A is the area of the solar panels (m²),
- G is the solar irradiance (W/m²), and
- η_{PV} is the efficiency of the solar PV system.

3. **Power Output of Wind Turbines**: The power output (P_{wind}) of a wind turbine can be calculated using the formula:

$$P_{wind} = \frac{1}{2} \times \rho \times A \times v^3 \times \eta_{wind}$$

Where:

- ρ is the air density (kg/m³),
- A is the swept area of the wind turbine rotor (m²),
- V is the wind speed (m/s), and
- η_{wind} is the efficiency of the wind turbine.

4. **Boost Converter Output Voltage**: The output voltage (V_{out}) of a boost converter can be calculated using the formula:

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

where:

- D is the duty cycle of the converter (unitless), and
- V_{in} is the input voltage (V).

5. **Battery Charging Power**: The power ($P_{battery}$) delivered to charge the battery can be calculated using the formula:

$$P_{battery} = V_{battery} \times I_{battery}$$

where:

- $V_{battery}$ is the battery voltage (V), and
- $I_{battery}$ is the charging current (A).

6. **Energy Stored in Batteries**: The energy stored ($E_{battery}$) in the battery can be calculated using the formula:

$$E_{battery} = V_{battery} \times C_{battery}$$

Where:

- $C_{battery}$ Is the battery capacity (Ah).

2. Convenient on-board charging for electric vehicles.

Electric vehicle (EV) onboard charging systems start by obtaining alternating current (AC) power from outside sources, including charging stations or outlets that are linked to the grid. A rectifier converter is used to ensure that this AC power is compatible with the vehicle's battery system. In order to charge the electric vehicle's battery pack, this converter converts the incoming alternating current (AC) electricity to direct current (DC). In order to charge the battery pack, the DC voltage may need to be boosted after conversion. Interleaved boost converters are useful in this situation. The DC voltage is effectively increased with little current ripple because of the parallel operation of these converters, which distribute the effort over numerous stages.

Charging performance is enhanced, and power transmission is made smoother by operating in an interleaved fashion. The electric vehicle's BMS and battery pack get the enhanced DC voltage output from the interleaved boost converters. The BMS, which has sophisticated monitoring and control functions, keeps an eye on and regulates the charging process to ensure its effectiveness and safety. Optimal charging speed and protection of the battery cells from overcharging, over current, and overheating are achieved via charging algorithms included in the BMS, which control the charging current and voltage. Efficiency and less grid impact are two major benefits of this onboard charging system as shown in fig.4. The technology reduces power losses and energy consumption while charging electric vehicles by effectively transforming alternating current (AC) electricity from outside sources into direct current (DC) power. Both the charging process and the grid are made more efficient as a result of this, especially during times of high demand. To summaries, rectifier converters and interleaved boost converters work together to promote sustainability and energy savings in transportation via dependable and efficient electric car charging.

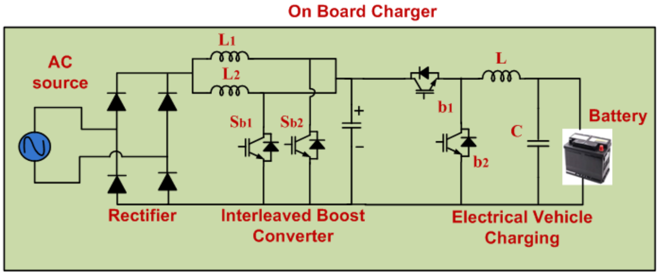


Fig.4 on-board electric vehicle charging with interleaved boost converter

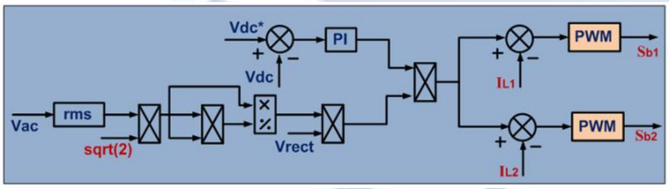


Fig.5 control design of on-board electric vehicle charging with interleaved boost converter

1. **Rectifier Converter Output Voltage (V_{dc}):** The output voltage of the rectifier converter depends on the input AC voltage and the rectification method. For a full-wave rectifier, the output DC voltage can be approximated as:

$$V_{dc} = \frac{V_{ac} \times \sqrt{2} - V_{diode}}{2}$$

Where:

- V_{ac} is the input AC voltage (rms),
- V_{diode} is the voltage drop across the diodes in the rectifier.

2. **Interleaved Boost Converter Output Voltage (V_{out}):** The output voltage of the interleaved boost converter can be calculated using the formula:

$$V_{out} = \frac{D \times V_i}{1 - D}$$

Where:

- D is the duty cycle of the converter (unitless),
- Vin is the input voltage (V).

3. **Charging Power ($P_{battery}$):** The power delivered to charge the EV battery pack can be calculated using the formula:

$$P_{battery} = V_{battery} \times I_{battery}$$

Where:

- $V_{battery}$ is the battery voltage (V),
- $I_{battery}$ is the charging current (A).

4. **Battery Charging Efficiency (η):** The efficiency of the charging process can be calculated as the ratio of the power delivered to the battery pack to the power input from the grid:

$$\eta = \frac{P_{battery}}{P_{grid}} \times 100\%$$

Where:

- P_{grid} is the power input from the grid (W).

5. **Energy Losses (P_{loss}):** The power losses in the charging system can be calculated as the difference between the power input from the grid and the power delivered to the battery pack:

$$P_{loss} = P_{grid} - P_{battery}$$

3. Electric vehicle battery to PMSM motor drive

The operation of an electric vehicle (EV) battery to Permanent Magnet Synchronous Motor (PMSM) drive system involves several key components working together seamlessly as shown in fig.6. At the heart of the system is the high-voltage battery pack, typically comprising lithium-ion cells, which serves as the primary energy storage unit for the vehicle. The battery pack supplies direct current (DC) electricity to power the vehicle's drive train and accessories. Before reaching the motor, the DC output from the battery undergoes conversion in a power electronics unit, which typically includes a DC-DC converter and an inverter. The DC-DC converter steps down the battery's high voltage to a level suitable for powering auxiliary systems within the vehicle, such as lights and air conditioning. Meanwhile, the inverter is responsible for converting the DC voltage into alternating current (AC) necessary for driving the PMSM motor. This AC output is then supplied to the PMSM motor, which serves as the primary propulsion system for the electric vehicle. The PMSM motor, with its permanent magnets and synchronous operation, efficiently converts the electrical energy into mechanical motion, driving the wheels of the vehicle and providing the desired torque and speed. Through this integrated system, electric vehicles can achieve smooth and responsive performance while maximizing energy efficiency and minimizing environmental impact.

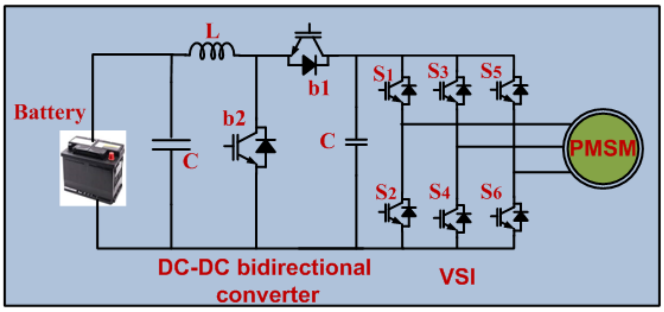


Fig.6 PMSM drive with electric vehicle battery system

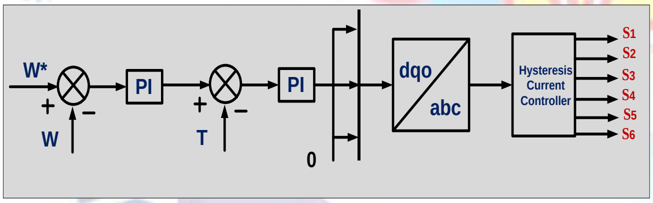


Fig. 7 Control design of PMSM drive with electric vehicle battery system

1. **Battery Voltage ($V_{battery}$):** The voltage of the battery pack can be calculated as the product of the number of cells (N_{Cell}) and the voltage per cell (V_{Cell}):

   $$V_{battery} = N_{Cell} \times V_{Cell}$$

2. **DC-DC Converter Efficiency ($\eta_{Converter}$):** The efficiency of the DC-DC converter, which steps down the battery voltage for auxiliary systems, can be calculated as the ratio of the output power (P_{out}) to the input power (P_{in}):

   $$\eta_{Converter} = \frac{P_{out}}{P_{in}} \times 100\%$$

3. **Inverter Efficiency ($\eta_{inverter}$):** The efficiency of the inverter, which converts DC to AC for the PMSM motor, can be calculated similarly as the ratio of output power (P_{out}) to input power (P_{in}):

   $$\eta_{iinverter} = \frac{P_{out}}{P_{in}} \times 100\%$$

4. **Power (P_{motor}):** The power delivered to the PMSM motor can be calculated using the formula:

   $$P_{motor} = V_{inverter} \times I_{motor}$$

   Where:

- $V_{inverter}$ is the voltage supplied by the inverter to the motor (V), and
- I_{motor} is the current drawn by the motor (A).

5. **Torque (T_{motor}):** The torque produced by the PMSM motor can be calculated using the formula:

   $$T_{motor} = \frac{P_{motor}}{\omega_{motor}}$$

   Where:

- ω_{motor} is the angular velocity of the motor (rad/s).

6. **Speed (ω_{motor}):** The angular velocity of the motor can be calculated as:

   $$\omega_m = \frac{2\pi N}{60}$$

   Where:

- N is the rotational speed of the motor (rpm).

4. RESULTS AND DISCUSSION

1. Simulation results for different variations of renewable sources and integrated grid conditions

The simulation results offer valuable insights into the performance and impact of different configurations of renewable energy sources and their integration with the grid as shown in fig.8. They analyze variations of solar photovoltaic systems and wind turbine designs, providing data on factors influencing energy generation. These findings aid in selecting the most efficient renewable energy solutions. The simulation of grid integration scenarios assesses the implications of renewable energy penetration on grid stability and reliability. It explores different levels of integration, storage capacity, and demand response strategies, revealing potential benefits of increased renewable energy penetration in enhancing grid resilience. The simulations also highlight the importance of distributed generation and microgrid configurations in bolstering grid resilience under extreme conditions, such as natural disasters or equipment failures. These findings underscore the significance of renewable energy integration in reducing dependency on centralized infrastructure and mitigating climate change impacts. The simulation results contribute to a deeper understanding of the environmental, economic, and operational implications of renewable energy integration, informing policy decisions and investment strategies for a more sustainable and resilient energy future.

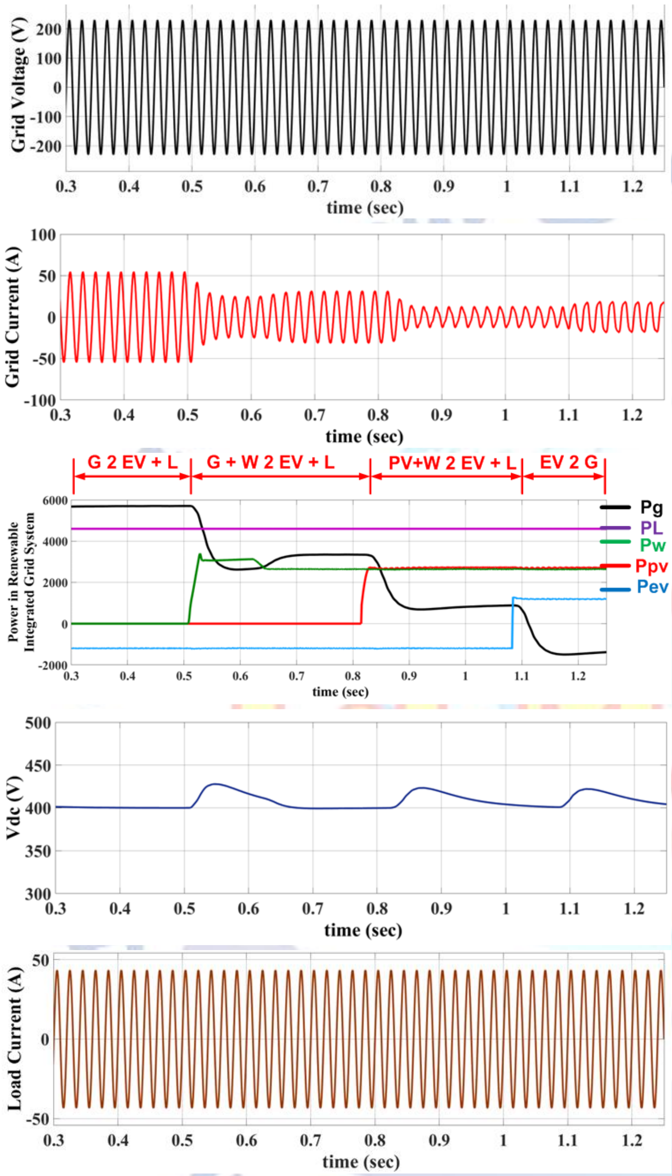
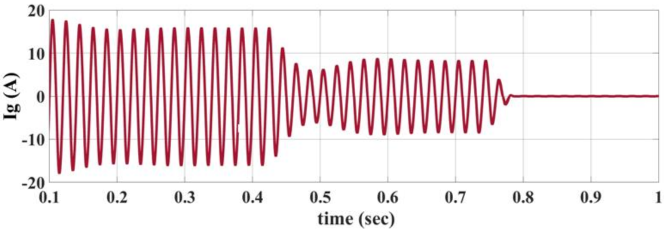


Fig.8 different power variation of Advanced Distribution Grid for Electric Vehicle Charging

2. Simulation results for on-board electric vehicle charging

Onboard electric vehicle (EV) charging system simulation findings, including DC-DC interleaved boost converters, provide light on how efficient and effective this technology is. These simulations provide a thorough grasp of the functioning of onboard charging systems, their effects on EV operation, grid interaction, and energy efficiency as a whole by evaluating a wide range of factors and situations as shown in fig.9. Under various settings, the simulation evaluates the speed and efficiency of onboard charging systems that use DC-DC interleaved boost converters. In order to charge the vehicle's battery, these converters are essential for effectively increasing the voltage from the battery. Scientists can find the best setup for transferring power efficiently with minimal losses by playing around with factors like duty cycle, number of interleaved converters, and switching frequency. Manufacturers may utilise these insights to improve the design of onboard charging systems for electric vehicles, making them more user-friendly and lowering charging times and energy usage. When it comes to controlling peak demand and maintaining grid stability, models also examine the effects of onboard charging systems with DC-DC interleaved boost converters on the grid. Considerations including charging schedules, grid congestion, and renewable energy integration are part of the analysis of how EVs using these converters interact with the grid during charging events. Simulations shed light on the potential of onboard charging systems to alleviate power grid strain and optimise electrical resource utilisation via the examination of smart charging methods and demand response enabled by interleaved boost converters. Onboard charging systems that use renewable energy sources, such solar panels built into the car, may also be considered in these models. The amount of solar energy that goes into charging, its impact on the vehicle's overall efficiency, and its interactions with the grid may be better understood by modelling the production and consumption of energy by electric vehicles equipped with integrated solar panels and DC-DC interleaved boost converters. These findings provide valuable information for designing environmentally friendly electric vehicle charging systems that make use of renewable energy sources to lessen our reliance on fossil fuels and cut down on emissions, all while improving grid integration and stability



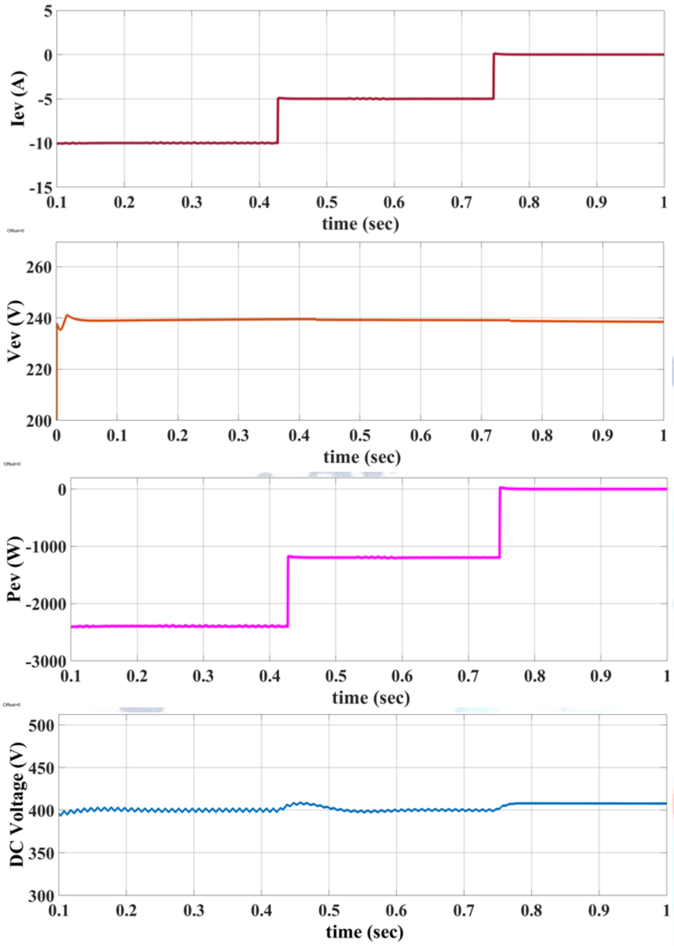


Fig.9 different variation of on-board electric vehicle charging

3. Simulation results for the electric vehicle to PMSM drive application

Important insights into the efficiency and performance of electric vehicle (EV) to Permanent Magnet Synchronous Motor (PMSM) driving applications have been uncovered by simulation findings as shown in fig.10. These models examine motor torque, speed, and power production in various driving scenarios, including acceleration, cruising, and regenerative braking. To maximize energy efficiency and driving range while assuring smooth and responsive vehicle performance, simulations assist optimize control algorithms and operating strategies by adjusting aspects including battery state of charge, vehicle load, and driving profile. They also assess how grid integration and power consumption are affected by PMSM drive applications. Taking into account variables like charging infrastructure, grid demand, and renewable energy integration, researchers examine the energy consumption trends of electric vehicles using PMSM drives throughout the charging and driving cycles. By exploring the potential for demand response and smart charging techniques, simulators help us determine the optimal use of EV-PMSM drive systems, preventing grid overload and maximising power efficiency. To further improve the performance and dependability of EV-PMSM drive systems, simulations may further investigate the possibility of using sophisticated control algorithms and power management techniques. Vehicle propulsion, battery management, and external grid infrastructure interactions may be modelled to find areas for improvement and new developments.

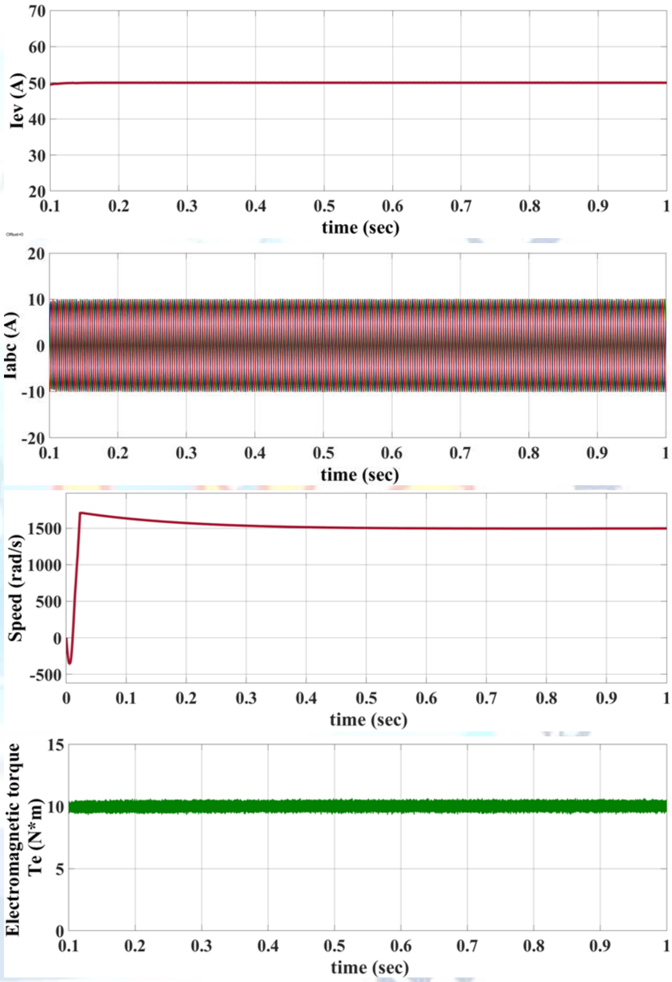


Fig.10 simulation results of PMSM drive application with electric vehicle battery

5. CONCLUSION

The integration of renewable energy sources like solar photovoltaic systems and wind turbines with electric vehicle (EV) charging infrastructure is a promising solution to address challenges related to EV charging and grid stability. This approach mitigates the intermittency of renewable energy generation, enhancing grid reliability and stability. Energy storage units (ESUs), including EV batteries (EVBs), balance supply and demand by storing excess energy and injecting it into the grid when needed. The use of EVBs as energy storage systems (ESS) is cost-effective and supports renewable energy integration. Onboard EV charging systems with interleaved boost converters improve charging efficiency, reduce grid impact, and accelerate EV adoption. The integration of permanent magnet synchronous motor (PMSM) drive applications further enhances EV efficiency, performance, and sustainability. Recent research has focused on designing solar-powered EV charging and discharging systems for residential PV applications. Fast DC charging connectors and advanced control systems facilitate bidirectional power transfer between HPV systems and EVBs, contributing to grid stability and reducing power fluctuations

Conflict of interest statement

Authors declare that they do not have any conflict of interest.

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