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International Journal for Modern Trends in Science and Technology
Volume 10, Issue 03, pages 401-410.
ISSN: 2455-3778 online
Available online at: http://www.ijmtst.com/vol10issue03.html
DOI: https://doi.org/10.46501/IJMTST1003066

Smart Integration of Solar and Wind Microgrid Systems with Grid Infrastructure for Enhanced Electric Vehicle Charging and PMSM Drive Applications

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To Cite this Article
A.Sai Anusha, P.Kavya Sri, T.Gayathri, SK.Galib and U.Gopi Manikanta, Smart Integration of Solar and Wind Microgrid Systems with Grid Infrastructure for Enhanced Electric Vehicle Charging and PMSM Drive Applications, International Journal for Modern Trends in Science and Technology, 2024, 10(03), pages. 401-410.https://doi.org/10.46501/IJMTST1003066

Article Info
Received: 24 February 2024; Accepted: 21 March 2024; Published: 26 March 2024.

ABSTRACT

This paper proposes a smart integration framework for grid infrastructure and solar and wind microgrid systems to improve the charging of electric vehicles and the driving of Permanent Magnet Synchronous Motors (PMSMs). The framework aims to optimize renewable energy utilization and enhance the efficiency of electric vehicle charging and PMSM driving by coordinating grid infrastructure. It allows seamless integration with AC microgrid operations and incorporates bidirectional power flow capabilities, enabling efficient energy exchange. The framework also facilitates grid-to-vehicle (G2V) and vehicle-to-grid (V2G) energy transactions, which are crucial for maximizing renewable energy utilization. These transactions enable the microgrid to charge electric vehicles during periods of high renewable energy generation, reducing reliance on fossil fuels. Additionally, vehicle-to-grid (V2G) energy transactions allow the microgrid to tap into stored energy in electric vehicle batteries during peak demand periods, enhancing grid stability and reliability. The proposed framework has been validated through comprehensive simulations using MATLAB/Simulink, optimizing energy management, maximizing renewable energy utilization, and ensuring grid stability.

KEYWORDS: Solar and wind microgrid systems, Electric vehicles (EVs), Permanent Magnet Synchronous Motors (PMSMs), AC microgrid operations.

1. INTRODUCTION

The electric vehicle (EV) has grown in popularity owing to government, automaker, and environmentalist initiatives [1]. EVs seem hopeful for ending fossil fuel use, air pollution, and climate change. However, many issues remain, and EVs are meant to be charged periodically using grid energy. First, moving to electric cars may not lower pollution if grid energy came from coal-fired power stations. EVs with PMSM motors are more energy efficient and emit less even when charged with grid power. Second, as EVs expand, the local distribution system may suffer. People charge their electric cars at home after work. This strains the local distribution power system and causes voltage control, harmonic contamination, frequency changes, and other issues. [2]-[6]. A normal load increase is difficult for power providers to manage and prepare for. If charging is not correctly controlled, the distribution system may be overwhelmed by an unexpected demand increase. Thus, to handle EV charging demand, the distribution grid must be updated [4]. PMSM drives improve EV energy efficiency and minimise distribution grid load by optimising power usage during charging cycles. Meanwhile, distribution grid integration of house photovoltaic (HPV) systems is growing. If HPV systems push surplus energy back into the feeder at noon, when residences consume less power, the voltage might rise and the line may overload. [7], [8]. Standard technique requires energy storage units (ESU) to mitigate extremely penetrating HPV systems [9], [10]. HPV owners may be reluctant to invest in an ESU without government or utility support since it would add to their plans. [11]. Recent proposals include an energy storage system (ESS) based on electric vehicle batteries to minimise PV system intermittency [12–14]. PMSM drives in EVs have two benefits. They store extra HPV energy effectively during off-peak hours, decreasing distribution grid load, and they enable bidirectional energy transfer. As electricity demand grows, energy-vesting batteries (EVBs) can store solar power and release it back into the grid. EVBs powered by HPV systems may reduce midday voltage spikes. This increases HPV penetration in the distribution grid, which would otherwise be limited by high HPV penetration. Recent years have seen greater interest in using the EVB to support the electric grid during peak demand. Electric vehicle batteries and solar PV energy can reduce peak loads [15], [16]. PMSM drives enable efficient energy storage and retrieval in EV batteries, stabilising grid voltage and mitigating intermittent renewable energy fluctuations. An energy management strategy that uses electric car batteries in parking lots might reduce the requirement for peak load demand response algorithms [15]. Power management algorithm optimises load factor during daytime electric vehicle parking lot operation by taking into account EV arrival and departure periods. The authors of [16] improved commercial peak load management using EVs, battery systems, and solar modules. The optimal use of EV batteries for load balancing and peak shaving depends on PMSM drives. The published research focused on the impacts of charging stations at the office or parking lot, although all authors addressed the system level. Energy from EVBs may be injected into local feeders to stabilise the grid feeder during peak demand [17–20]. Figure 1 shows a conventional solar and wind charging infrastructure for electric automobiles that will supply grid ancillary services. Charging stations, solar and wind-powered parking garages, and commercial buildings with charging facilities may leverage this infrastructure. Micrograds with intermittent renewable energy may be powered by energy storage. Electric vehicle (EV) batteries may provide efficient microgrid storage after charging. Most personal automobiles remain in parking lots for 22 hours a day, making them idle assets. Electric cars can help micro-grid energy management by storing and recharging energy. Vehicle-to-grid (V2G) applications have several challenges in the general electricity grid, including regulation, EV requirements, and implementation in the near future [21]. Here, a microgrid V2G system may be created quickly. The Society of Automotive Engineers offers three electric car charging grades. Level 1 charging requires both the vehicle's built-in charger and a 120V household outlet. People who don't move more than 60 km per day and have all night to charge may utilise this slowest approach. Level 2 charging may be done using 220 V or 240 V and up to 30 A of power with EVSE at home or at a public station. Direct current quick charging is level 3. DC rapid charging stations can charge in 20–30 minutes with 90 kW at 200–450 V. EV energy storage requires quick power transfer, hence microwave grids employ DC fast charging for V2G design. Renewable power sources may be added via the DC bus. Most research has concentrated on V2G's usage in the power grid for control, peak shaving, valley filling, and spinning reserves [22]. V2G research on micro-grids to support variable renewable energy output is early. Most reported V2G works employ level 1 and level 2 ac charging [23]. AC charging systems' maximum power depends on the charger's rating. Another issue is that the distribution infrastructure is not equipped for two-way energy transfer. Technically sound charging station architectures for micro-grid vehicle-to-grid (V2G) technologies must be studied. A micro-grid facility design for DC quick charging stations with V2G capabilities is proposed in this study. Solar PV cells and wind turbines may be incorporated into the micro-grid over the same DC bus as EVs. New design allows off-board chargers for high-power bidirectional charging of electric cars. The suggested model is tested using MATLAB/Simulink simulations for G2V and V2G modes. To conclude, incorporating the Permanent Magnet Synchronous Motor (PMSM) drive for electric vehicle operation may boost economy and performance. PMSM drives provide great efficiency, torque density, and smooth operation. PMSM drives minimise energy use in electric cars, making them more sustainable. PMSM drives' bidirectional energy transmission between the vehicle and the grid supports grid stabilisation and renewable energy integration. PMSM drives are essential to vehicle electrification and a greener, more sustainable energy ecology.

2. SYSTEM CONFIGURATION

The integrated system configuration combines solar and wind power generation with electric vehicle (EV) charging infrastructure to promote sustainable development and grid stability. Solar photovoltaic arrays are installed on rooftops of charging stations, parking garages, and commercial buildings, providing clean, environmentally friendly power. Wind turbines are strategically erected to harness wind energy during low solar irradiance or at night. Energy-vesting batteries (EVBs) are integrated with EVs, acting as efficient storage devices for surplus energy generated from renewable sources. EVBs store excess energy during low demand or high renewable energy production, releasing it back into the grid or charging EVs during peak demand periods. This bidirectional energy flow capability enhances grid stability and supports the widespread adoption of electric vehicles. This approach maximizes the benefits of renewable energy sources, promotes energy efficiency, and advances the transition towards a more sustainable and resilient energy ecosystem.

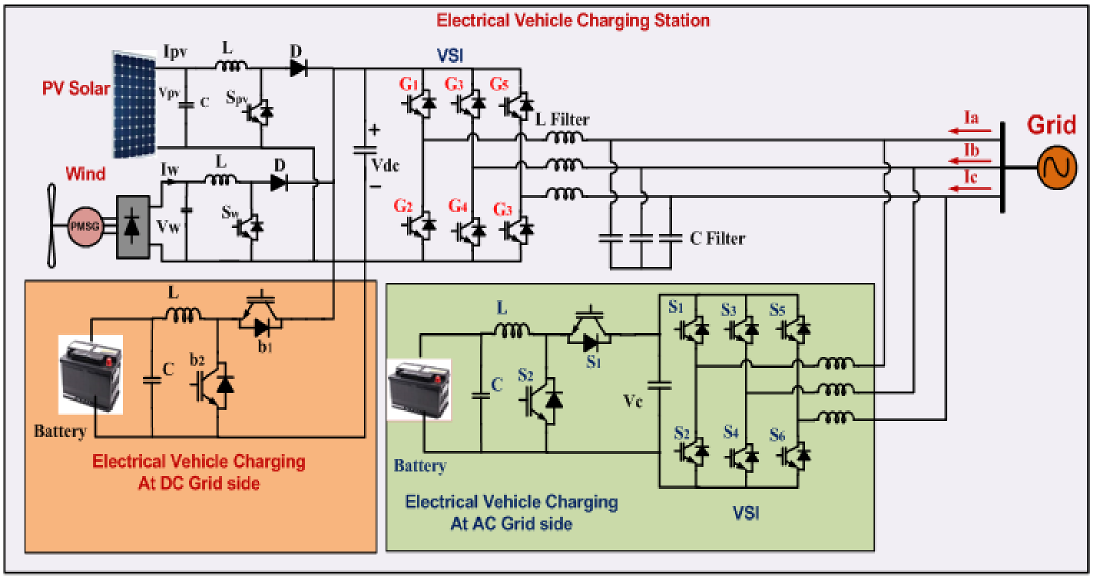


Fig.1 system configuration of AC–DC microgrid electric vehicle charging station

3. DESIGN AND IMPLEMENTATION OF SYSTEM CONFIGURATION

1. Solar MPPT boost converter

Solar power is a crucial solution for combating climate change and reducing greenhouse gas emissions. It offers a clean alternative to traditional fossil fuels and is cost-effective as shown in fig.2. Boost converter technology is essential for maximizing the efficiency and reliability of solar power systems, converting direct current output from solar panels into alternating current suitable for homes and businesses. This technology not only enhances the performance of solar power systems but also contributes to the integration of renewable energy into the broader electricity grid. The Perturb and Observe (P&O) maximum power point tracking (MPPT) algorithm works with boost converter technology to get the most power out of solar panels by constantly changing their operating points. This algorithm dynamically tracks changes in solar irradiance and temperature, ensuring solar panels operate at their maximum power point under varying environmental conditions. This fine-tuning of voltage and current levels enhances system efficiency and reliability. The combination of boost converter technology and the P&O MPPT algorithm facilitates the widespread adoption of solar power for various applications, including electric vehicle (EV) charging systems. Solar power supports the electrification of transportation, reducing dependence on fossil fuels and mitigating harmful emissions. As governments, businesses, and individuals prioritize sustainability and environmental stewardship, the integration of solar power with innovative technologies like boost converters and MPPT algorithms represents a crucial step towards a cleaner, more sustainable energy future.

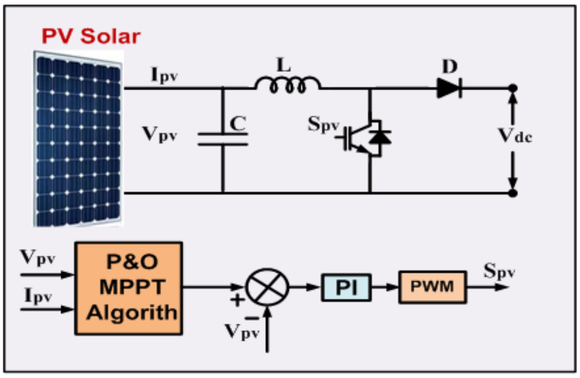


Fig.2 solar PV boost converter system

- **PV Panel Output Power (P):**

$$P = V_{PV} \times I_{PV} \quad (1)$$

Where:

V_{PV} = Voltage output from the solar panel array

I_{PV} = Current output from the solar panel array

- **Perturbation in Voltage** (ΔV) **or Current** (ΔI)**:**

$$\Delta V = Step\ Size \times Sign\ of\ Power\ Chnage$$

$$\Delta I = Step\ Size \times Sign\ of\ Power\ Chnage$$

The step size is a small increment or decrement applied to the voltage or current.

- **Instantaneous Power** $(P_{instaneous})$**:** $P_{instantneous} = V_{PV} \times I_{PV}$ (2)
- **Power Change (ΔP):** $\Delta P = P_{instantneous} - P_{Previous}$

Where

$P_{Previous}$ is the previous value of instantaneous power.

- **Duty Cycle (D):**

$$D = \frac{V_{out}}{V_{in}} \quad (3)$$

Where:

V_{out} = Output voltage of the boost converter

V_{in} = Input voltage of the boost converter

2. Wind power generation with P and O MPPT boost converter

Converting the Permanent Magnet Synchronous Generator's (PMSG) alternating current (AC) output to direct current (DC) is an essential step in incorporating it into a renewable energy system as shown in fig.3. A rectifier that converts alternating current (AC) into direct current (DC) using pulses is used for this purpose. In order to get the produced power ready for DC-based applications, the rectifier circuit utilises diodes to guarantee a unidirectional flow of energy. After that, a DC-to-DC boost converter is used to raise the voltage level while keeping the output steady, using the converted DC voltage as input. The boost converter now has an MPPT algorithm attached to it, which stands for Perturb and Observe. To maximise power production, this algorithm continuously monitors the PMSG's power output and adjusts the operating voltage or current accordingly. The total performance and efficiency of the renewable energy system are improved via this iterative optimisation process. There are many advantages to combining a PMSG with an AC-to-DC rectifier and a DC-to-DC boost converter that are equipped with the P&O MPPT algorithm. These include efficient power conversion from AC to DC, energy harvesting, and overall performance and dependability.

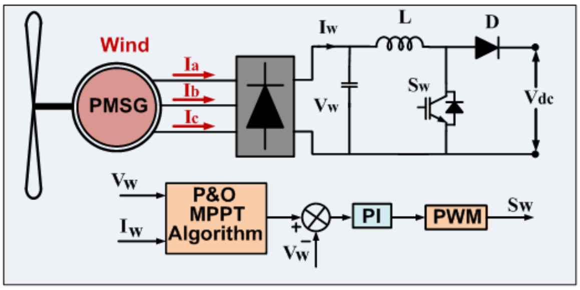


Fig.3 wind power generation system

1. AC to DC Rectifier:

The output voltage (V_{DC}) of the rectifier can be calculated using the peak AC voltage (*V*AC,peak) and the voltage drop across the diode (V_{diode}):

$$V_{DC} = V_{AC,Peak} - V_{diode} \quad (4)$$

2. DC to DC Boost Converter:

The output voltage (V_{out}) of the boost converter is given by:

$V_{out} = \frac{V_{in}}{1-D}$ (5)

Where:

V_{in} is the input voltage.

D is the duty cycle of the boost converter.

3. Perturb and Observe (P&O) MPPT Algorithm:

The change in power (ΔP) is calculated as:

$\Delta P = P_{new} - P_{old}$ (6)

The change in voltage or current (ΔV or ΔI) is then calculated based on the sign of (\Delta$P$):

$\Delta V = Step\ Size \times Sign(\Delta P)$ (7)

$\Delta I = Step\ Size \times Sign(\Delta P)$

3. Battery Charger Configuration

In a bidirectional DC-DC converter designed for electric vehicle (EV) charging applications, the operation is tailored to efficiently manage energy flow between the EV battery and the grid or charging station as shown in fig.4. This converter is equipped with separate switches, namely S1 for charging (buck mode) and S2 for discharging (boost mode), allowing for versatile operation and effective battery management.

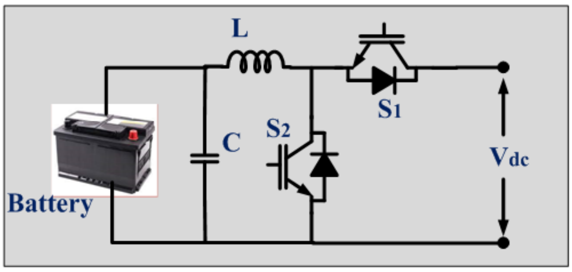


Fig. 4. Battery charger configuration

Buck Mode (charging):

Buck mode is a mode where the switch S1 is closed to enable EV battery charging. This mode steps down the input voltage from the grid or charging station to a suitable level for charging the battery. The duty cycle (D) of the converter regulates the ratio of output voltage to input voltage, allowing the converter to efficiently regulate charging voltage and minimize losses. It also ensures high efficiency by carefully managing the energy transfer process.

Output Voltage (V_0) : $V_{out} = D \times V_{in}$

Duty Cycle (D): $D = \frac{V_{out}}{V_{out}+V_{diode}}$ (8)

Boost Mode (Discharging):

In boost mode, the switch S2 is closed to enable the EV battery's discharging, allowing the converter to step up the battery voltage for energy back to the grid or charging station. The converter's duty cycle (D), which matches the output voltage to the input voltage and ensures compatibility with grid or charging station requirements, enables this bidirectional energy flow. This operation allows the EV battery to contribute power to the system.

Output Voltage (V_0) :

$V_0 = \frac{V_{in}}{1-D}$ (9)

Duty Cycle (D):

$D = \frac{V_{out}}{V_{out}+V_{diode}}$ (10)

d. Efficiency and Energy Transfer:

Efficiency is crucial in the operation of a bidirectional DC-DC converter, as it minimizes energy losses during charging and discharging cycles, enhancing the overall effectiveness of an electric vehicle (EV) charging system. Factors such as switching losses, conduction losses, and component selection affect the converter's efficiency. The energy transfer process in the converter is characterized by the power flow between the EV battery and the grid or charging station. The converter optimizes this process by adjusting the duty cycle and controlling voltage levels to match the requirements of the battery and external power source. This ensures reliable and effective operation of EV charging systems, promoting sustainable energy management and widespread adoption of electric vehicles.

- **Efficiency:** The efficiency (η) of the bidirectional converter can be calculated using the following formula:

$\eta = \frac{P_{out}}{P_{in}} \times 100\%$ (11)

Where:

P_{out} is the output power.

P_{in} is the input power.

- **Energy Transfer:** The energy transferred (E) during a charging or discharging cycle can be calculated using the formula:

$E = \int_{t_1}^{t_2} P(t)\, dt$ (12)

Where:

$P(t)$ is the power at time t.

4. Electric vehicle battery to PMSM motor drive

Electric vehicle (EV) drive systems include not only the main parts shown in Figure 5, but also a number of other important parts that work together to provide the best possible performance and operation. The high-voltage battery pack, with its main energy reservoir usually made of lithium-ion cells, is at the heart of the system. This battery pack is the engine that drives the electric motor and gearbox, among other parts. The direct current (DC) output of the battery is transformed before it reaches the motor in a power electronics unit, which typically includes an inverter and DC-DC converter. The inverter changes direct current (DC) into alternating current (AC), which the permanent magnet synchronous motor (PMSM) needs, and the DC-DC converter regulates the high voltage of the battery to run ancillary systems like lighting and air conditioning. The primary means of moving the vehicle forward is the permanent magnet synchronous motor (PMSM) motor, which efficiently transforms electrical energy into mechanical motion and transmits the necessary torque and speed to the wheels. Strategies that absorb and recycle energy during deceleration, such as regenerative braking, are used to further optimise efficiency. Also, by keeping an eye on important metrics like temperature and battery charge, the BMS makes sure the battery pack is healthy and lasts as long as possible. Superior energy efficiency, little environmental impact, and responsive and smooth road performance are all possible thanks to the careful integration and control of various systems and components in electric cars.

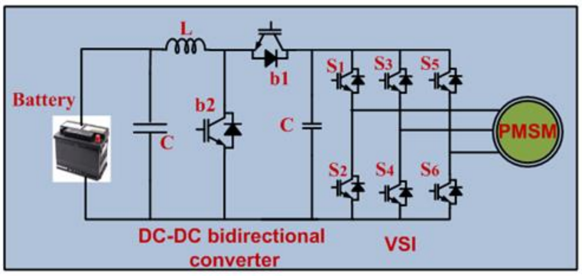


Fig.5 PMSM drive with electric vehicle battery system

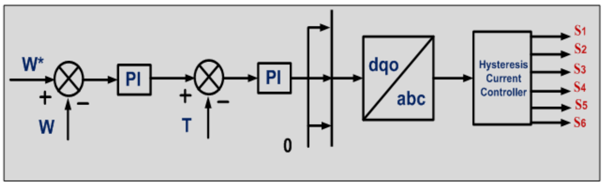


Fig. 6 Control design of PMSM drive with electric vehicle battery system

1. DC-DC Converter Efficiency (η_{DC-DC}): $\eta_{DC-DC} = \frac{P_{out,DC}}{P_{in,DC}} \times 100\%$ (13)

Where:

$P_{out,AC}$ is the output power of the DC-DC converter.

$P_{in,DC}$ is the input power to the DC-DC converter.

2. Inverter Efficiency ($\eta_{inverter}$):

$\eta_{inverter} = \frac{P_{out,AC}}{P_{in,DC}} \times 100\%$ (14)

Where:

$P_{out,AC}$ is the output power of the inverter.

$P_{in,DC}$ is the input power to the inverter.

3. Motor Efficiency (η_{Motor}):

$\eta_{Motor} = \frac{P_{out,Mechanical}}{P_{in,Electrical}} \times 100\%$ (15)

Where:

$P_{out,Mechanical}$ is the mechanical output power of the motor.

$P_{in,Electrical}$ is the electrical input power to the motor.

4. Torque (T) - Current (I) Relationship for PMSM: $T = k_{torue} \times I$ (16)

Where:

k_{torue} is the torque constant of the PMSM.

5. Mechanical Power ($P_{Mechanical}$):

$P_{Mechanical} = T \times \omega$ (17)

Where:

ω is the angular velocity of the motor.

6. DC-AC Conversion Power Losses: $P_{Loss,DC-AC} = P_{in,DC} - P_{out,AC}$ (18)

7. DC-DC Conversion Power Losses: $P_{Loss,DC-DC} = P_{in,Battery} - P_{out,DC}$ (19)

4. CONTROL SYSTEM

A. Off-Board Charger Control

In the implemented constant current control strategy for the battery charger circuit, a Proportional-Integral (PI) controller plays a pivotal role in regulating the charge/discharge process effectively. The strategy commences by assessing the reference battery current against zero to ascertain the polarity of the current signal, thereby discerning between charging and discharging modes. Once the mode is established, the reference current is compared with the measured current, generating an error signal that reflects the deviation from the desired battery current. This error signal is then fed into the PI controller, which comprises both proportional and integral components. The proportional component promptly responds to changes in the error signal, providing a rapid initial adjustment, while the integral component integrates the error over time to eliminate any residual steady-state error. Consequently, the PI controller produces control signals that adjust the switching pulses for S1/S2 accordingly. Throughout the charging process, S2 remains inactive, while during discharging, S1 is deactivated. As shown in fig.7 this control strategy ensures precise and efficient regulation of the battery charge/discharge process, optimizing performance and safeguarding the battery's health and longevity.

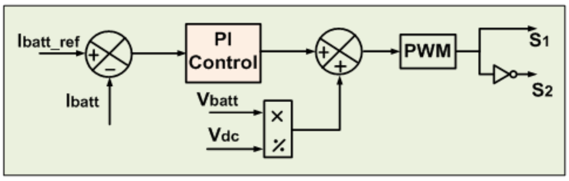


Fig. 7. Constant current control strategy for battery charger

B. Inverter Control

In the proposed cascade control strategy implemented in synchronous reference frame for the inverter controller, a sophisticated approach is adopted to ensure precise regulation and enhanced performance. The conventional standard vector control, depicted in Fig. 8, employs four Proportional-Integral (PI) controllers arranged in a nested loop structure. This control architecture comprises two outer voltage control loops and two inner current control loops, each serving a specific purpose. The outer voltage control loops operate on the d-axis and q-axis, where the d-axis loop governs the DC bus voltage while the q-axis loop regulates the AC voltage magnitude by adjusting the reactive current. Within each outer loop, there exists an inner current loop responsible for controlling the active AC current on the d-axis and the reactive current on the q-axis. Additionally, dq decoupling terms, represented by wL, and feed-forward voltage signals are introduced to enhance performance during transient conditions. These features contribute to the robustness and effectiveness of the control strategy, allowing for precise and dynamic control of the inverter's operation in synchronous reference frame.

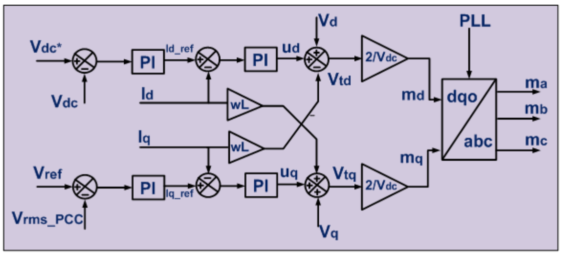
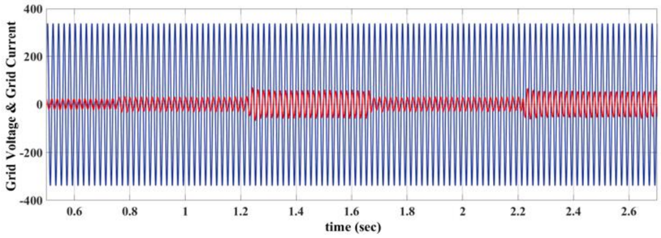


Fig. 8. Inverter control system

5. SIMULATION RESULTS AND DISCUSSION

1. Different variation power in mocrogrid system

A hybrid AC/DC grid is suggested in this research as a novel method of charging electric vehicles. Faster charging times and better grid integration are two benefits of the system's flexible and efficient design for charging electric automobiles. This technology integrates AC and DC grids to overcome the shortcomings of the existing charging infrastructure and encourage the broad use of electric cars. DC networks, which combine renewable energy sources with AC grids, can reliably power electric cars. In addition to improving grid stability, this hybrid technology permits bidirectional power transmission, which opens the door for vehicle-to-grid capabilities. When taken as a whole, the suggested approach addresses all of the issues with electric car charging infrastructure. Optimal energy flow and storage for electric cars can be achieved at the DC grid level, and the system can effectively manage peak demand and alleviate pressure on the AC grid level as well. A long-term answer to transportation issues, this integrated strategy improves charging dependability and efficiency for electric vehicles. Figure 9 displays the results of the simulations that demonstrate the distinct power fluctuations in the AC microgrid and the DC microgrid systems. According to the results, the suggested method minimises energy waste while maximising performance by balancing the power distribution between the two grids. A more environmentally friendly transportation future may be within reach with the help of this cutting-edge technology, which may completely alter the landscape of electric car charging infrastructure. The system can generate 18 kW of solar electricity and 40 kW of wind power, with a total load capacity of 58 kW. In order to make the most of energy storage and utilisation during times of peak demand, the system is equipped with a 50 kWh battery storage capacity. The combination of smart grid technologies and renewable energy sources increases the microgrid system's overall efficiency and reliability. With its ability to go in both directions, from the electric car to the grid, and vice versa, this electric vehicle offers more options for energy management and may help ease the burden on the central power system. The smart charging features of the system also let customers plan charging sessions for times when energy usage is lower, so they may save even more money.



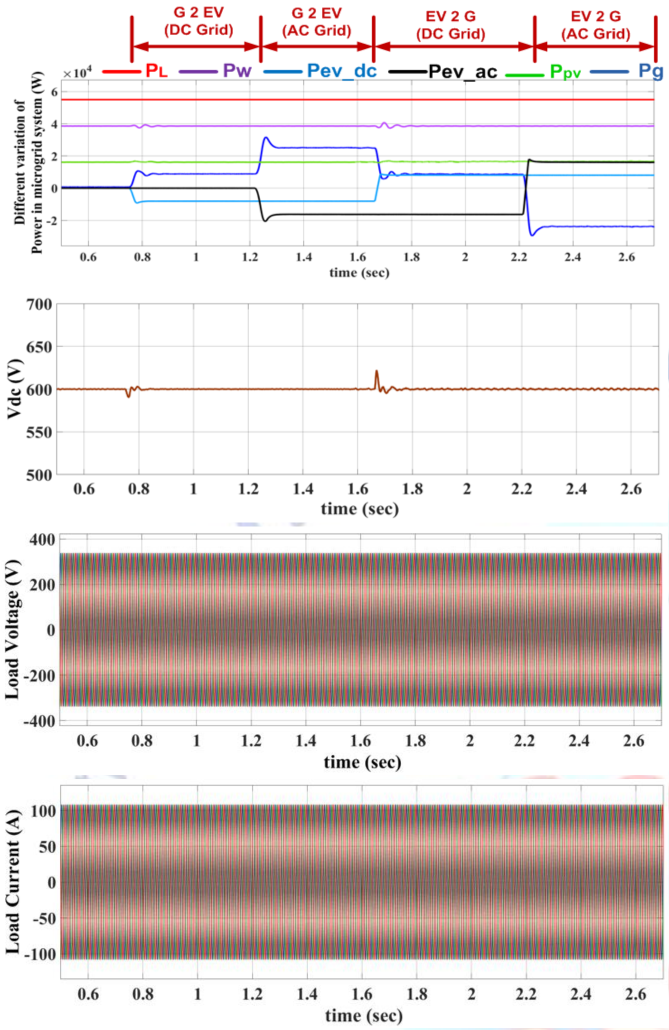


Fig.9 simulation results of different variation power in AC-DC microgrid system

2. different speed variation of PMSM drive application

The Permanent Magnet Synchronous Motor (PMSM) drive in an electric vehicle (EV) battery system is a complex system that uses power electronics to convert the battery's direct current (DC) into the required alternating current (AC) as shown in fig.5. An inverter facilitates this conversion by converting the battery's DC power into three-phase AC power. The PMSM drive's control system, equipped with sensors, monitors key parameters like motor speed, position, and current, providing real-time feedback to the control algorithm. The control algorithm regulates the frequency, voltage, and phase angle of AC power supplied to the motor, allowing for precise control of the motor's speed, torque, and direction of rotation. The motor rotates when it receives power and control signals from the PMSM drive, generating rotational motion that is transferred through the motor's mechanical components to the vehicle's wheels. The PMSM drive continuously adjusts its control signals based on feedback from the motor sensors, ensuring optimal performance, efficiency, and reliability. This closed-loop control system ensures smooth acceleration, deceleration, and overall vehicle operation. As shown in fig.10 simulation results shows different speed variation of PMSM drive under various load conditions, demonstrating the effectiveness of the control system in maintaining consistent performance. Additionally, the PMSM drive's ability to quickly respond to changes in operating conditions highlights its suitability for use in electric vehicles requiring dynamic and precise control of motor functions.

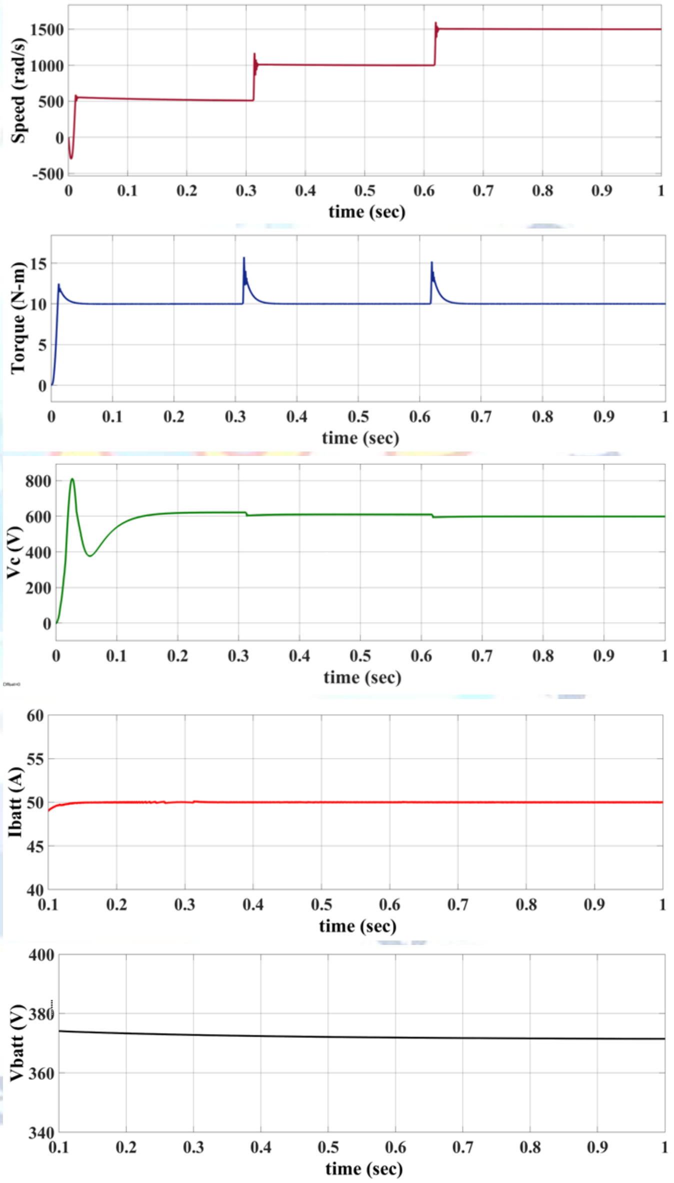
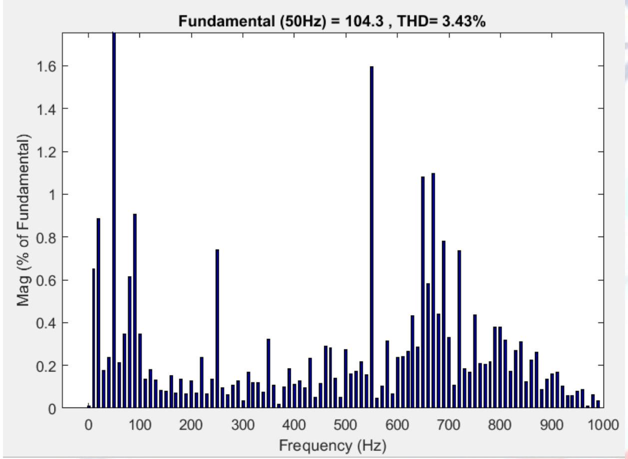


Fig.10 simulation results of different speed variation PMSM drive

3. Total harmonic distortion

The grid current THD is 3.47%, indicating that the current waveform is relatively clean with minimal harmonic distortion. This low THD value ensures efficient operation of the grid-connected system and compliance with power quality standards. Additionally, a low grid current THD helps prevent overheating of equipment and reduces the risk of power outages caused by harmonic distortion. Overall, maintaining a clean current waveform is crucial for the stability and reliability of the grid-connected system.



6. CONCLUSION

The widespread adoption of electric vehicles (EVs) is a promising solution for reducing fossil fuel usage, air pollution, and combating climate change. However, this transition presents challenges to the local distribution grid, such as voltage regulation issues, harmonic contamination, and frequency variations. To address these issues, updating and reinforcing the distribution grid is crucial. Integrating renewable energy sources like solar and wind power into charging infrastructure can enhance sustainability and resilience. Energy storage units (ESUs) and electric vehicle batteries (EVBs) can store excess energy from renewable sources, reducing reliance on conventional power plants. Vehicle-to-grid (V2G) technology allows EVs to consume energy and contribute to grid stabilization and peak demand management. Micro-grid facilities with V2G functionality and rapid charging stations can improve energy management and grid stability, especially in areas with high EV penetration. The integration of EVs, renewable energy sources, and advanced grid technologies holds great potential for transforming the energy landscape towards a more sustainable and resilient future.

Conflict of interest statement

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

REFERENCES

[1] Viet T. Tran, Md. Rabiul Islam, D. Sutanto, K. M. Muttaqi " A solar power EV charging or discharging facility to support local power grids" Proc. 53th IEEE Ind. Appl. Soc. Annu. Meeting Conf., Portland, OR, USA, Sept. 2018, pp. 1–7.

[2] K. Clement-Nyns, E. Haesen, and J. Driesen, " The Impact of charging plug-in hybrid electric vehicles on a residential distribution grid," IEEE Trans. Power Syst., vol. 25, no. 1, pp 371–380, Feb. 2010.

[3] K. Qian, C. Zhou, M. Allan, and Y. Yuan, " Modeling of load demand due to EV battery charging in distrbution systems," IEEE Trans. Power Syst., vol. 26, no. 2, pp 802–810, May 2011.

[4] M. Yilmaz and P. T. Krein, " Review of the impact of vehicle-to-grid technologies on distribution systems and utility interfaces," IEEE Trans. Power Electron., vol. 28, no. 12, pp. 5673-5689, Dec. 2013.

[5] A. Dubey and S. Santoso, "Electric vehicle charging on residential distribution systems: impacts and mitigations," IEEE Access, vol. 3, pp. 1871-1893, Sept. 2015.

[6] H. Farzin, M. Moeini-Aghtaie, and M. Fotuhi-Firuzabad, " Reliability studies of distribution systems integrated with electric vehicles under battery-exchange mode" IEEE Trans. Power Deliver., vol. 31, no. 6, pp 2473–2482, Dec. 2016.

[7] M. R. Islam, M. F. Rahman, and W. Xu, "Advances in Solar Photovoltaic Power Plants," Green Energy and Technology Series, Springer-Verlag GmbH, Heidelberg, Germany, Jun. 2016.

[8] A. Woyte, V. V. Thong, R. Belmans, and J. Nijs, "Voltage fluctuations on distribution level introduced by photovoltaic systems," IEEE Trans. Energy Convers., vol. 21, no. 1, pp 202–209, Mar. 2006.

[9] S. Sikkabut, P. Mungporn, C. Ekkaravarodome, N. Bizon, P. Tricoli, B. Nahid-Mobarakeh, et al., "Control of High-Energy High-Power Densities Storage Devices by Li-ion Battery and Supercapacitor for Fuel Cell/Photovoltaic Hybrid Power Plant for Autonomous System Applications," IEEE Trans. Ind. Appl., vol. 52, no. 5, pp. 4395-4407, Oct. 2016.

[10] S. Abedlrazek and S. Kamalasadan, "Integrated PV capacity firming and energy time shift battery energy storage management using energy oriented optimization," IEEE Trans. Ind. Appl., vol. 52, no. 3, pp. 2607–2617, May/Jun. 2016.

[11] S. Barcellona, L. Piegari, V. Musolino, and C. Ballif, ‘‘Economic viability for residential battery storage systems in grid-connected PV plants,'' IET Renew. Power Gener., vol. 12, no. 2, pp. 135–142, Feb. 2018.

[12] M. J. E. Alam, K. M. Muttaqi, and D. Sutanto, "Effective utilization of Available PEV Battery Capacity for Mitigation of Solar PV impact and Grid Support With Integrated V2G Functionality," IEEE Trans. Smart Grid, vol. 7, no. 3, pp. 1562-1571, May 2016.

[13] Nupur Saxena et al, "Implementation of a Grid-Integrated PV-Battery System for Residential and Electrical Vehicle Applications", IEEE Trans. Ind. Electron., vol. 65, no. 8, pp. 6592-6601, Aug. 2018.

[14] N. Liu, Q. Chen, X. Lu, J. Liu, and J. Zhang, “A charging strategy for PV-based battery switch stations considering service availability and self-consumption of PV energy,” IEEE Trans. Ind. Electron., vol. 62, no. 8, pp. 4878–4889, Aug. 2015.

[15] I. Sengor et al., “Optimal Energy Management of EV Parking Lots Under Peak Load Reduction Based DR Programs Considering Uncertainty,” IEEE Trans. Sustain. Energy, vol. 10, no. 3, pp. 1034–1043, Jul. 2019.

[16] [K. Mahmud et al., “Peak-Load Management in Commercial Systems With Electric Vehicles,” IEEE Systems Journal, vol. 13, no. 2, pp. 1872–1882, Jun. 2019.

[17] [F. Marra et al., “EV charging facilities and their application in LV feeders with photovoltaics,” IEEE Trans. Smart Grid, vol. 4, no. 3, pp. 1533–1540, Sep. 2013.

[18] F. Marra et al., “Improvement of local voltage in feeders with photovoltaic using electric vehicles,” IEEE Trans. Power Syst., vol. 28, no. 3, pp. 3515–3516, Aug. 2013.

[19] U. C. Chukwu and S. M. Mahajan, “V2G parking lot with PV rooftop for capacity enhancement of a distribution system,” IEEE Trans. Sustain. Energy, vol. 5, no. 1, pp. 119-127, Jan. 2014.

[20] Q. Chen, N. Liu, C. Hu, L. Wang, and J. Zhang, “Autonomous energy management strategy for solid-state transformer to integrate PV-assisted EV charging station participating in ancillary service”, IEEE Trans. Ind. Inf., vol. 13, no. 1, pp. 258-269, 2017.

[21] C. Shumei, L. Xiaofei, T. Dewen, Z. Qianfan, and S. Liwei, “The construction and simulation of V2G system in micro-grid,” in Proceedings of the International Conference on Electrical Machines and Systems, ICEMS 2011, 2011, pp. 1–4.

[22] S. Han, S. Han, and K. Sezaki, “Development of an optimal vehicle-togrid aggregator for frequency regulation,” IEEE Trans. Smart Grid, vol. 1, no. 1, pp. 65–72, 2010.

[23] M. C. Kisacikoglu, M. Kesler, and L. M. Tolbert, “Single-phase on-board bidirectional PEV charger for V2G reactive power operation,” IEEE Trans. Smart Grid, vol. 6, no. 2, pp. 767–775, 2015