International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 6, June 2025)

Review of Solar and Motor-Based EV Drive with Grid Interaction

[1]Manish Kumar Chaudhary, [2]Mr. Sandeep Kumar Wasnik
[1]M.Tech Scholar, Dept. of Electrical and Electronics Engineering, SCOPE College of Engineering, Bhopal, India,
[2]Assistant Professor, Dept. of Electrical and Electronics Engineering, SCOPE College of Engineering, Bhopal, India

Abstract— Electric vehicles (EVs) are rapidly transforming the transportation sector, driven by the need for sustainable and energy-efficient mobility solutions. Integrating solar power with motor-based EV drive systems and grid interaction mechanisms presents a promising pathway for reducing dependency on fossil fuels and enhancing energy autonomy. This review explores recent advancements in solar-integrated EV drives, focusing on power electronics, motor control strategies, and bi-directional grid interfaces. It examines the technical challenges and solutions in implementing solar photovoltaic (PV) charging, motor drive efficiency, and vehicle-to-grid (V2G) systems. The analysis highlights how solar-EV-grid integration contributes to decarbonization, energy optimization, and smart grid evolution.

Keywords— Solar, Motor, EV Drive, Grid Interaction.

I. INTRODUCTION

The transition toward clean and sustainable transportation has become a global imperative, with electric vehicles (EVs) emerging as a pivotal solution to reduce greenhouse gas emissions and air pollution. While EVs themselves contribute to a cleaner environment by eliminating tailpipe emissions, their true environmental impact depends significantly on the source of electricity used for charging. Integrating renewable energy sources, particularly solar power, into EV charging systems not only enhances sustainability but also helps mitigate stress on conventional power grids. Solar-powered EV drive systems aim to harness sunlight through photovoltaic (PV) panels either mounted on vehicles or installed at charging stations, directly converting solar energy into electrical power for propulsion or storage.

Motor-based drive systems lie at the core of EV performance, governing the vehicle's torque, speed, and efficiency. Brushless DC motors (BLDC), permanent magnet synchronous motors (PMSM), and induction motors are commonly employed in modern EVs for their high efficiency and reliability. These motors must be carefully controlled through sophisticated power electronics and control algorithms to optimize energy use, especially when powered by intermittent sources like solar energy. Moreover, the synchronization between the motor drive and solar generation requires intelligent energy management systems to ensure smooth operation under variable irradiance conditions.

Another critical aspect of solar-EV systems is their interaction with the power grid. Vehicle-to-grid (V2G) and grid-to-vehicle (G2V) technologies enable bi-directional power flow, allowing EVs to serve as mobile energy storage units. During peak generation or low-demand periods, EVs can store excess solar energy and feed it back to the grid when needed, contributing to grid stability and energy efficiency. Smart charging and discharging mechanisms supported by power electronic interfaces, communication protocols, and control strategies are vital for seamless grid interaction. Such systems not only reduce electricity costs for EV owners but also enhance the flexibility and resilience of the electrical grid.

Recent research has explored several hybrid configurations that integrate solar panels with battery energy storage, motor drive controllers, and grid interfaces. These configurations are designed to maximize energy harvest, reduce conversion losses, and maintain the longevity of battery systems. Advancements in maximum power point tracking (MPPT) techniques, efficient DC-DC converters, and inverter technologies have further enabled the practical deployment of solar-EV-grid systems. The convergence of solar PV

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 6, June 2025)

technology, efficient motor control, and smart grid integration creates a highly sustainable transport-energy ecosystem.

However, the integration of solar energy and EV drives with grid systems presents certain challenges. These include space constraints for on-vehicle PV modules, the variability of solar irradiance, battery degradation due to frequent charge-discharge cycles, and the need for robust communication protocols between vehicles and grid infrastructure. Research continues to address these limitations through innovations in lightweight PV materials, adaptive energy management systems, and AI-based predictive control algorithms.

This review paper aims to comprehensively analyze the progress and challenges in solar and motor-based EV drive systems with grid interaction. It highlights the architecture, control strategies, component technologies, and operational outcomes of integrated systems. By examining both experimental and simulation-based studies, the review provides insights into the design considerations and performance metrics that define effective solar-EV-grid frameworks. The integration of clean energy with electric mobility and smart grids not only paves the way for carbon-neutral transportation but also supports broader goals of energy security and climate resilience.

II. LITERATURE SURVEY

Keshari et al. (2024) proposed a novel electric vehicle (EV) drive system based on a switched reluctance motor (SRM) integrated with a bidirectional grid interaction feature. The paper emphasizes the dual-mode operation—driving and charging—using a unified converter topology. The bidirectional grid interface supports both vehicle-to-grid (V2G) and grid-to-vehicle (G2V) operations, enabling better utilization of power flow between the EV and the power grid. The design ensures optimal energy management and supports ancillary services such as peak shaving and frequency regulation. The work also presents control strategies that enhance the overall efficiency and reduce hardware complexity. Through simulation and hardware results, the system demonstrates promising performance in terms of torque ripple reduction and charging efficiency. This study marks a significant contribution toward realizing smart and flexible EV-grid systems [1].

Khaligh and D'Antonio (2019) provided a comprehensive overview of high-power on-board chargers (OBCs), analyzing global trends and technological evolution in EV charging. The authors discussed various converter architectures, control methods, and component-level advancements influencing charger performance. Their review highlights how the transition to high-power (≥20 kW) on-board chargers supports faster charging while presenting thermal and EMI challenges. They also examined trends such as wide-bandgap (WBG) semiconductors and wireless power transfer integration. This work is instrumental in contextualizing the infrastructure requirements for solar-integrated EVs, where high-power OBCs ensure compatibility with distributed PV sources and reduce dependence on grid transformers. The findings reinforce the need for efficient, compact, and thermally robust charging systems in modern EV architecture [2].

Yilmaz and Krein (2013) delivered a foundational review of battery charger topologies and infrastructure requirements for plug-in hybrid and electric vehicles. Their work outlines classifications of chargers (on-board/off-board, conductive/inductive) and various charging levels, including Level 1, 2, and DC fast charging. The study focuses on power electronics configurations such as single-phase, multi-phase, and isolated vs. non-isolated converters. They emphasized the growing relevance of bidirectional converters in supporting V2G operations. Though dated, this paper remains vital in understanding the evolution of EV charger design, particularly in solar-assisted systems where decentralized power input is variable and integration requires flexible power management. The groundwork laid here continues to inform the design of advanced EV-grid-solar interactions today [3].

Yuan et al. (2021) conducted an in-depth review of bidirectional on-board chargers (BOBCs), which are essential for achieving V2G functionality in EVs. The paper systematically categorized BOBC architectures based on their levels of integration and operational modes. It evaluates

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 6, June 2025)

performance metrics such as power density, cost, and thermal performance while comparing various control strategies for grid synchronization. The authors also addressed challenges in meeting grid codes and ensuring secure communication between EVs and utility systems. In solar-EV-grid systems, such bidirectional chargers play a central role by enabling EVs to function as energy sources during peak demand. This review is particularly useful for researchers aiming to build intelligent, grid-interactive EVs with embedded renewable energy support [4].

Sun et al. (2023) proposed a multiport PV-assisted bidirectional charger tailored for SRM-based EVs, supporting not just G2V and V2G but also vehicle-to-load (V2L) functionality. The system features an integrated electric drive and charging converter with multi-source input support, improving energy availability and operational flexibility. By incorporating PV input and MPPT control, the charger efficiently utilizes solar energy, reducing grid dependency. The architecture allows simultaneous motor driving and charging from renewable sources, making it ideal for off-grid and hybrid operation scenarios. Their experimental results validate high efficiency and rapid switching between modes. This research aligns with current efforts to decentralize EV energy supply chains and maximize clean energy use in transportation [5].

Cai and Zhao (2021) introduced a dual-function integrated converter for SRM-based EVs, capable of supporting both traction and battery charging. Their design removes the need for a dedicated charger, reducing system size, cost, and complexity. The system uses a reconfigurable topology where power electronics components are shared between driving and charging modes. The controller manages power flow seamlessly, maintaining battery protection and maximizing energy conversion efficiency. This research is pivotal for solar-integrated EVs where component minimization and cost-efficiency are crucial. Their findings also indicate improved thermal management and reduced total harmonic distortion, making it suitable for compact EV platforms like scooters and urban vehicles [6].

Subramanian and Peter (2020) designed a hybrid energy storage system (HESS) that combines lithium-ion batteries with supercapacitors to enhance EV energy management. The paper proposes an energy distribution controller that dynamically allocates load between the battery and supercapacitor based on driving conditions and regenerative braking events. This setup helps manage peak power demands and prolongs battery life. In the context of solar-powered EVs, such hybrid systems are valuable because they mitigate the variability in solar output and smoothen energy supply to the motor drive. The integration of HESS also supports fast energy injection to the grid during V2G operation. Their study reflects how smart energy storage configurations complement solar and grid-interactive EV architectures [7].

Feng et al. (2019) presented an innovative SRM drive for plug-in electric vehicles (PEVs) incorporating a bridgeless interleaved boost converter (BLIL) that also supports power factor correction (PFC). The system is designed for dual-mode operation—driving and battery charging—via a single-stage conversion. Their work improves charging efficiency while complying with grid harmonics standards. The PFC function ensures that during grid charging, power is drawn in a sinusoidal manner, reducing stress on utility infrastructure. Such innovations are essential when EVs are powered partly through solar and partly through the grid. The modular and compact nature of their design enables efficient onboard integration, particularly relevant for low- to mid-range EVs operating in smart city environments [8].

Chang and Liaw (2011) proposed an integrated SRM drive system using a three-phase power module capable of handling both propulsion and charging. The design eliminates the need for separate converter circuits, thereby saving space and cost. The charging operation is achieved by reconfiguring the inverter topology, utilizing the same hardware used in drive mode. This early research laid the groundwork for many of today's multifunctional drive/charge topologies in SRM-based EVs. Although the paper predates the current solar-EV-grid boom, its influence is visible in later converter designs that emphasize dual functionality, compact size, and system cost-efficiency—all vital elements for solar-integrated EV solutions [9].

International Journal of Recent Development in Engineering and Technology
Website: www.ijrdet.com (ISSN 2347 - 6435 (Online) Volume 14, Issue 6, June 2025)

Cheng et al. (2020) introduced a novel SRM powertrain for plug-in hybrid electric vehicles (PHEVs) capable of multiple driving and onboard charging modes. Their design integrates two motor drives with charging capabilities, ensuring flexibility in energy intake and distribution. The system supports grid-connected operation, enabling both G2V and V2G functionalities. With coordinated control, the architecture can draw power from various sources—including PV systems—enhancing its adaptability in hybrid renewable environments. The dual-mode operation allows intelligent energy routing and efficient power sharing between motors and battery modules. This work strongly supports the paradigm of integrating EVs with distributed solar resources and smart grids to optimize both mobility and energy ecosystems [10].

III. Challenges

1. Variability of Solar Energy

- Solar photovoltaic (PV) output is inherently dependent on weather conditions, time of day, and geographic location.
- This intermittency poses challenges in ensuring continuous and reliable power for EV charging and motor drive.
- Energy fluctuations require complex power conditioning circuits and energy management strategies.

2. Complexity in Power Electronics Integration

- Designing a single power converter for both motor drive and charging functions (bidirectional) increases circuit complexity.
- The system must switch efficiently between charging (G2V) and discharging (V2G) modes without significant losses.
- Heat dissipation, electromagnetic interference (EMI), and compactness are difficult to manage simultaneously.

3. Battery Management and Degradation

- Frequent charging-discharging cycles, especially in V2G scenarios, accelerate battery wear and reduce lifespan.
- Maintaining battery health while supporting solar input and grid interaction requires advanced battery management systems (BMS).
- Thermal management and charge balancing are also critical challenges.

4. Grid Synchronization and Standards Compliance

- Bi-directional interaction with the grid (G2V and V2G) must meet regional grid codes, frequency stability, and power factor requirements.
- Synchronizing multiple EVs with distributed generation can introduce voltage fluctuations or harmonic distortion into the grid.
- Secure and real-time communication between EVs and utility systems is still evolving.

5. Control Strategy Complexity

- Intelligent control is needed to manage multi-source inputs (solar + grid), hybrid energy storage, and drive power demand.
- Coordinated control must balance real-time motor operation with solar availability and grid commands.
- Adaptive and predictive algorithms (often using AI) are required but computationally intensive.

6. Energy Storage Integration

- Combining lithium-ion batteries with supercapacitors or alternative storage introduces compatibility and sizing challenges.
- Optimal energy flow between storage units and the motor drive system demands precise energy management.
- Cost and weight constraints limit storage capacity in compact EVs.

7. Communication and Cybersecurity Issues

- Grid-interactive EVs and solar systems depend on secure, real-time data exchange (e.g., for V2G transactions).
- Lack of standard protocols and weak cybersecurity frameworks can lead to data breaches or system manipulation.
- Integration with smart grids and IoT-based systems increases the cyber-attack surface.

8. Cost and Infrastructure Barriers

- Solar integration in EVs (on-vehicle PV or solar charging stations) adds to the overall system cost.
- Bidirectional chargers and smart inverters are more expensive than traditional chargers.
- Widespread infrastructure deployment (solar stations, bidirectional chargers) remains economically and logistically challenging.

9. Thermal and Space Management

- Combining motor drives, charging systems, and solar interfaces within a single platform increases space constraints.
- High-power converters and batteries generate significant heat, requiring effective thermal design.
- Compact EVs face greater difficulty integrating all these systems without compromising performance or safety.

IV. CONCLUSION

The integration of solar energy with motor-based electric vehicle (EV) drive systems and bidirectional grid interaction presents a transformative approach toward sustainable and energy-efficient transportation. While significant progress has been made in power electronics, control strategies, and system architecture, several challenges such as solar variability, battery degradation, system complexity, and grid compliance still need to be addressed. Nevertheless, the combination of renewable energy sources with intelligent motor drives and smart grid connectivity holds immense potential for reducing fossil fuel dependence, enabling vehicle-to-grid services, and supporting the future of clean mobility. Continued research and innovation are essential to optimize performance, enhance reliability, and make these systems more economically viable for widespread adoption.

References

1. A. Keshari, D. Raveendhra, B. N. Raju, P. Chaturvedi, U. R. Reddy and P. B. Bobba, "Switched Reluctance Motor-based EV Drive with Bidirectional Grid Interaction," *2024 IEEE 4th International Conference on Sustainable Energy and Future Electric Transportation (SEFET)*, Hyderabad, India, 2024, pp. 1-8, doi: 10.1109/SEFET61574.2024.10717965.
2. A. Khaligh and M. D'Antonio, "Global Trends in High-Power On-Board Chargers for Electric Vehicles," in IEEE Transactions on Vehicular Technology, vol. 68, no. 4, pp. 3306–3324, April 2019.
3. M. Yilmaz and P. T. Krein, "Review of Battery Charger Topologies, Charging Power Levels, and Infrastructure for Plug-In Electric and Hybrid Vehicles," in IEEE Transactions on Power Electronics, vol. 28, no. 5, pp. 2151–2169, May 2013.
4. J. Yuan, L. Dorn-Gomba, A. D. Callegaro, J. Reimers and A. Emadi, "A Review of Bidirectional On-Board Chargers for Electric Vehicles," in IEEE Access, vol. 9, pp. 51501–51518, 2021.
5. Q. Sun, H. Xie, X. Liu, F. Niu and C. Gan, "Multiport PV-Assisted Electric-Drive-Reconstructed Bidirectional Charger with G2V and V2G/V2L Functions for SRM Drive-Based EV Application," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 11, no. 3, pp. 3398–3408, June 2023.
6. J. Cai and X. Zhao, "An On-Board Charger Integrated Power Converter for EV Switched Reluctance Motor Drives," in IEEE Transactions on Industrial Electronics, vol. 68, no. 5, pp. 3683–3692, May 2021.
7. G. Subramanian and J. Peter, "Integrated Li-Ion Battery and Super Capacitor based Hybrid Energy Storage System for Electric Vehicles," 2020 IEEE International Conference on

Electronics, Computing and Communication Technologies (CONECCT), Bangalore, India, 2020, pp. 1–6.

8. C. Feng, J. Wu, Q. Sun, H. Wu and L. Zhang, "An Integrated BLIL Boost Converter-based Switched Reluctance Motor Drive for PEV Applications with PFC Charging Function," 2019 22nd International Conference on Electrical Machines and Systems (ICEMS), Harbin, China, 2019, pp. 1–5.
9. H.-C. Chang and C. -M. Liaw, "An Integrated Driving/Charging Switched Reluctance Motor Drive Using Three-Phase Power Module," in IEEE Transactions on Industrial Electronics, vol. 58, no. 5, pp. 1763–1775, May 2011.
10. H. Cheng, Z. Wang, S. Yang, J. Huang and X. Ge, "An Integrated SRM Powertrain Topology for Plug-In Hybrid Electric Vehicles With Multiple Driving and Onboard Charging Capabilities," in IEEE Transactions on Transportation Electrification, vol. 6, no. 2, pp. 578–591, June 2020.