International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 6 Issue 12, December 2025

A Comprehensive Review on Solar PV Based Multifunctional EV Charging Systems

Varun Bachle[1] , Devendra Sharma[2]
Research Scholar, Department of Electrical and Electronics, TIT&S BHOPAL (MP)[1]
Associate Professor Department of Electrical and Electronics TIT &S BHOPAL (MP)[2]

Abstract: *This review paper presents an analysis of solar photovoltaic (PV) based multifunctional electric vehicle (EV) charging systems, focusing on converter topologies, control strategies, and energy-management techniques. Recent studies highlight the use of bidirectional DC–DC converters, such as SEPIC, to enable efficient G2V, V2G, and V2H operations while supporting residential loads under variable solar conditions The reviewed implementation demonstrates a unified charger capable of MPPT without a separate DC–DC converter, seamless grid/islanded switching, active filtering, and robust dc-link control using SOGI-FLL and sliding-mode techniques .An Implementation of Solar PV Overall, the review identifies key advancements and existing gaps in designing cost-effective, reliable, and multifunctional PV-integrated EV charging infrastructures.*

Keywords: *Single phase grid system, Photovoltaic (PV) system, electric vehicle (EV) charger, BD-SEPIC (bidirectional-SEPIC) converter.*

1. Introduction

According to a new IEA report, the world's renewable power capacity is predicted to grow significantly over the remainder of this decade due to favourable economic conditions and supportive policies. Global additions are expected to eventually equal the combined power capacity of the US, China, the EU, and India. The Renewables 2024 report, the IEA's signature annual publication on the renewable energy sector, reveals that the global renewable energy sector is expected to expand by over 5500 gigawatts (GW) between 2024 and 2030. This increase is nearly three times the rate observed between 2017 and 2023. Based on market patterns and existing government policy settings, the paper projects that China will build about 60% of the world's renewable capacity between now and 2030. This would increase China's share of the world's renewable power capacity from a third in 2010 to almost half by the end of this decade. India is expanding at the quickest pace among major economies, while China is adding the largest amounts of renewable energy. Due to the development of new, big solar power plants and a rise in rooftop solar installations by businesses and families, solar photovoltaics (PV) alone is expected to account for a staggering 80% of the expansion in worldwide "renewable capacity between now and 2030". Despite persistent difficulties, the wind industry is also expected to rebound, as shown by the fact that its growth rate doubled from 2024 to 2030 when compared to 2017 to 2023. In almost every nation, wind and solar photovoltaics are now the most affordable ways to add additional power generating [3] .

Due to these developments, about 70 nations—which together own 80% of the world's renewable power capacity—are on track to meet or exceed their present renewable goals by 2030. The analysis predicts that worldwide renewable capacity will reach 2.7 times its 2022 level by 2030, which is not entirely consistent with the ambition of over 200 nations to triple global renewable capacity this decade at the COP28 climate change summit in December 2023. However, according to IEA research, governments can completely reach the tripling objective if they use short-term chances to act. This encompasses the development of ambitious strategies in "the forthcoming round of Nationally Determined Contributions under the Paris Agreement", and the enhancement of international collaboration to reduce the exorbitant financing costs in emerging and developing economies, which are impeding the expansion of renewable energy in high-potential regions like Africa and Southeast Asia. The pace of renewable energy is outpacing the ability of national governments to establish goals. According to "IEA Executive Director Fatih Birol", this is mostly due to the fact that renewable energy sources are now the most affordable way to build new power plants in almost every nation in the world, not merely because of initiatives to reduce emissions or improve energy security. The findings of this report indicate that the expansion of renewable energy sources, particularly solar, will revolutionise electricity systems worldwide during the current decade. Global renewable energy capacity is expected to reach about 5500 gigawatts by 2030, which is almost equivalent to the combined power capacity of the US, China, EU, and India. Half of the world's power consumption is anticipated to be met by renewable sources by 2030. The forecast indicates that the proportion of global electricity generation that is solely comprised of wind and solar PV is expected to double to 30% by the conclusion of this decade. The study does, however, stress how urgently governments must step up their efforts to safely incorporate these variable renewable energy sources into electricity grids[2] .

In recent years, the rate of curtailment has been steadily increasing, with several countries already experiencing a 10% increase in the amount of renewable electricity generation that is not utilised. Increasing the flexibility of the electricity grid is one way that nations should solve this. Larger shares of generation from renewable sources would be made possible by a concerted effort to address policy uncertainties, streamline permitting procedures, build and modernise 25 million kilometres of electrical grids, and reach 1500 GW of storage capacity by 2030, as noted in a previous IEA analysis. The percentage of final energy consumption that comes from renewable sources is expected to rise from 13% in 2023 to over 20% by 2030, driven mostly by the enormous expansion of renewable power. The report's special chapter on renewable fuels highlights the need for specific policy assistance to decarbonise hard-to-electrify industries, since they are currently falling behind. According to the paper, meeting global climate objectives will need not just increasing the deployment of renewable energy but also dramatically boosting "the uptake of sustainable biofuels, biogases, hydrogen, and e-fuels". These fuels are expected to account for less than 6% of the world's energy supply by 2030 since they are still more costly than their fossil fuel equivalents.

The manufacturing status of renewable technology is also examined in the paper. By the end of 2024, the world's solar production capacity is predicted to exceed 1100 GW, more than double the anticipated demand. Module costs have more than halved since early 2023 as a consequence of this supply glut, which is focused in China, but it also means that many manufacturers are suffering significant financial losses. By 2030, it is anticipated that solar PV production capacity in the US and India would treble, contributing to global diversification, given the increased emphasis on industrial competitiveness on a worldwide scale. However, the cost of manufacturing solar panels is twice as high in India and three times more in the United States than in China. The paper suggests that authorities should examine important concerns like job development and energy security when determining how to balance the increased costs and advantages of local production.

1.1 The state of global EV charging infrastructure

The majority of charging still takes place at home or at work, and there are 10 times as many private chargers as public ones. But as more EVs are on the road, more public charging stations are required to accommodate the widespread adoption of EVs, particularly in crowded locations with less access to home charging. Globally, the number of public charging stations quadrupled to more than 5 million between 2022 and 2024. In China, where there is now one public charging station for every ten EVs, two-thirds of the increase since 2020 has occurred.

There are now about 200,000 public charging stations in the US, a 20% increase. Additionally, the quantity of fast and ultra-rapid chargers increased. In 2024, there were 2 million fast chargers (22 kW to 150 kW) worldwide, and the number of ultra-speed chargers (> 150 kW) increased by more than 50%. According to the IEA, in order to meet anticipated EV sales under existing policy, public charging infrastructure must increase ninefold worldwide by 2030. Smart charging and vehicle-to-grid (V2G) are emerging as viable solutions to assist balance demand; experiments are now underway in China, Australia, the UK, and other countries. To make EVs adaptable grid resources, top manufacturers work together to develop standards.

1.2 Importance of public EV charging infrastructure

India has more than 12,000 public charging stations in existence as of February 2024. Twenty to 150 EVs per charging station is a commonly used standard. India will require approximately 4 million charging stations due to the government's objective of 30% electric vehicle sales by 2030, which is equivalent to approximately 80 million electric vehicles (EVs). Currently, there are more than "1.3 million electric vehicles on Indian roads".

EV adoption is hampered by the present ratio of 32 EVs per charging station, claims JMK Research and Analytics. Though its viability relies on having a permanent parking spot, which varies depending on socio-geographical conditions, home charging is still a popular choice. Indian customers are equally receptive to home and public charging, particularly for electric four-wheelers (E4Ws), according a McKinsey poll. However, EV sales are often deterred by the lack of adequate public infrastructure.

Decarbonising freight and transportation requires the strategic placement of rapid chargers for heavy-duty and commercial vehicles. To provide improved accessibility, the government's updated FAME II rules now require one charging station per three miles in urban areas and every twenty-five kilometres on highways. Strong public infrastructure is required for top-up charging, as seen by the increasing demand for E4Ws, particularly in shared mobility (such as fleets and taxis). "Electric two- and three-wheelers (E2Ws and E3Ws)" are driving the gig economy's growth, which emphasises the need for more easily accessible charging stations.

1.3 Challenges hindering EV charging infrastructure

India's charging infrastructure still lags below international norms, even with legislative initiatives under FAME II to lower regulatory hurdles and provide subsidies. A small number of states, such as Maharashtra, Delhi, and Karnataka, have a large number of operational public charging stations and enjoy beneficial state-specific EV laws. The public charging station to EV ratio is less than the suggested 1:20 even in these states.

Charging station location and kind are complicated issues that rely on a number of variables, including geography, EV type, and urbanisation trends. Public electric vehicle (EV) charging stations necessitate a substantial amount of land, a reliable electricity supply, and elevated operational and maintenance expenses, in contrast to petroleum stations. Home charging is less expensive, but because of limited residential space and worries about grid reliability, its long-term sustainability is dubious.

Strong charging infrastructure is essential as the demand for charging heavy-duty vehicles rises due to the electrification of public buses and medium- and heavy-duty commercial vehicles. Significant hazards are associated with long-distance mobility due to the lack of public charging facilities in rural regions and the irregular power supply that puts strain on the system. Numerous charging regulations and space restrictions prevent widespread electrification of public transportation, especially buses, even in metropolitan areas.

2. Literature Review

(Pillewar et al., 2022) This study examines the process of charging an EV battery using a multifunctional EV charger that is powered by a solar photovoltaic array. Included in the multipurpose EV charger are two converters, one of which is bilingual. The first is a DC-DC converter (BDDC), while the second is "a voltage source converter (VSC)". The EV battery charger's operation is controlled such that the system is powered by grid energy or photovoltaics. vehicle with grid connectivity (V2G). The purpose of the technique is to improve grid stability in the event of a power outage. During periods of high load, vehicle-to-home, or V2H, is also activated. In order to regulate the DC-link voltage, this system now features a PI control mechanism. A method for controlling the bidirectional battery converter's DC-link voltage was added to the system via an API. The EV battery is charged in buck mode by the bidirectional DC-DC converter, and it is discharged in boost mode. Because "a voltage source converter (VSC)" is used as an active power filter, the total harmonic distortion (THD) of the grid current is within the IEEE 519 standard. MATLAB/Simulink is used to simulate and test the different modes of operation.

(Jagadeesh & Indragandhi, 2023) In the realm of power electronics, the introduction of converters has led to a paradigm shift. DC/DC converters have recently become a viable technology for both low- and high-power applications, mostly using alternative energy sources. In renewable energy systems like hydro, solar photovoltaic (PV), fuel cells (FC), and wind, the DC/DC converter is essential for power conversion. In order to satisfy the system's specifications, its primary function is to adjust the current and voltage levels. The single-ended primary-inductor converter (SEPIC), CUK, and ZETA are all thoroughly examined in this article in a number of stages, including increasing efficiency, attaining cost-effective operation, and reducing switching losses. The operating modes of each converter and a comparison of efficiency and output power are also included in this research. This essay contrasts the incorporation of FC and solar PV technologies into different converters.

(Jain & Bhullar, 2024) The World Health Organisation (WHO) has brought attention to the global effect of air pollution, which has helped to promote the development of environmentally friendly and emission-free modes of transportation like electric vehicles (EVs). Global EV sales are predicted to reach 14 million units by 2025, a 43% increase from 2019 to 2020. However, EVs have disadvantages including costly batteries, short lifespans, unreliability, a low driving range, and lengthy charging times. It is becoming more and more common to include "renewable energy sources (RESs)" including wind, solar, and biomass into EV charging infrastructure. Reduced fuel expenses, simpler installation, reduced pressure on the power grid, and financial savings are some advantages of PV solar-powered EV charging. On-board and hybrid charging systems include advantages such better communication protocols, quicker charging, and less weight. Although on-board chargers transmit more energy, they are more costly and challenging to combine with charging stations. Public, fast, induction, and residential charging stations are examples of off-board charging solutions. To extend battery life, advanced charge management systems may optimise charging. In order to improve efficiency and user experience, it is advised that future research focus on the creation of complex control algorithms, wireless charging integration, fast-charging infrastructure expansion, material innovation, compatibility with a wide range of vehicles, and grid interface optimisation. This study discusses the charging of electric cars in both independent and grid-connected photovoltaic systems and explains the several ways these systems may operate. In addition, a concise explanation of the power capacities, specifications, and numerous types of EV chargers is provided. Scholars who want to learn more about EV charging stations are likely to find the research and comparisons in this article to be helpful resources.

(Ika Putri et al., 2022) A battery charging system that combines solar and a septic converter is presented in this article. It is possible to overcome the limitations of photovoltaic systems, which rely on temperature and solar radiation, and guarantee energy availability to the load by using batteries as energy storage. The load may be powered by the battery when there is little solar irradiation. To modify the necessary voltage for battery charging, a SEPIC converter is used. By utilising a microprocessor to adjust the duty cycle, the SEPIC converter's output voltage is kept constant. Based on the outcomes of the experimental testing, it is feasible for this PV system to function effectively when equipped with a SEPIC converter. It is possible to charge batteries in an optimum manner. In order to preserve the battery's lifespan, this system is further outfitted with an automated feature that disconnects the battery after it is completely charged.

(M et al., 2021) This study outlines a multifunctional EV charger that uses solar photovoltaic arrays to charge the batteries of electric vehicles. Two converters make up a multipurpose EV charger: a voltage source converter (VSC) and a bidirectional DC-DC converter (BDDC). The EV battery charger's functioning is controlled so that it may be powered by the grid or photovoltaic cells. Vehicle to house (V2H) and vehicle to grid (V2G) operations are employed to increase grid stability during peak demand hours and islanding mode of operation, respectively. This system has a PI control mechanism to regulate the DC-link voltage from the bidirectional battery converter. When the EV battery is being charged, the bidirectional DC-DC converter operates in buck mode; when the battery is being discharged, it operates in boost mode. Using a voltage source converter (VSC), the charging system functions as an active power filter, and the grid current's total harmonic distortion (THD) is within the IEEE 519 standard. MATLAB/Simulink is used to simulate and test the different modes of operation.

(K & Chengaiah, 2024) Because of changes in the global climate, environmental concerns have gained the most attention in recent decades. More than 22.9% of all carbon dioxide emissions come from the transport sector, making it a significant contributor. Due to growing fuel prices and carbon emissions from fossil fuels, the majority of cars now operate on petrol or diesel, which is neither practical or sustainable. In order to solve these problems, electric vehicles (EVs) provide a compelling substitute for automobiles with internal combustion engines that run on electricity. Vehicle charging using renewable energy makes sense, making it a clean energy source from beginning to finish. Energy conversion is a key component of electric cars. Alternating current (AC) and direct current (DC) may be transformed into one another during the energy conversion process. DC-to-DC conversion, which calls for DC-to-DC converters, is used in EV rapid charging applications. In order to provide end-to-end clean energy, this study analyses the Buck-Boost and Single-Ended Primary Inductance Converters (SEPIC) using PV as input for EV charging applications. A MATLAB/SIMULINK environment is used to simulate a 5-by-5 PV system with Buck-Boost, SEPIC converters using the particle swarm optimisation approach. According to the simulation's findings, SEPIC's output ripples are negligible, facilitating EV batteries' efficient and seamless charging.

(Sagar et al., 2023) It is the goal of this endeavour to ensure that the residential energy is supplied without interruption and the EV battery is charged. In order to meet the needs of EVs, home loads, and the grid, a domestic electric vehicle (EV) charger that is linked to the grid and powered by a solar photovoltaic (PV) array is given. Using a photovoltaic array, the charger is able to function independently, supplying home loads with electricity and charging without interruption. Nonetheless, the grid-connected mode of operation is offered in the event that the PV array is not available or is not generated enough. A bidirectional AC-DC conversion utilising the grid and a DC-DC conversion using solar are two of the technologies we are deploying in this project to charge EV batteries and provide electricity to residential loads. The household supply and EV charger are not disrupted as the charger autonomously connects and disconnects from the grid.

3.PV System and Control Technique

This section gives an overview of photovoltaic (PV) systems, including how they function, the many kinds of PV modules and solar array layouts, and the main benefits of solar photovoltaic technology. It also talks about Maximum Power Point Tracking (MPPT) and how it works to improve efficiency. Also, for efficient power management and integration, the basics, uses, advantages, and how bidirectional AC–DC and bidirectional DC–DC converters function are spoken about.

3.1 PV Arrays

The fundamental components of a solar array are many linked PV modules, which together form a bigger power producing unit. Since a single PV module has a limited capacity, multiple modules are often linked in series or parallel to form a PV array in order to fulfil higher power needs. An array may be flexibly formed from different sizes to meet the demands of a variety of applications, ranging from big PV power plants to tiny residential systems.
The ability to scale is one of PV arrays' benefits. The output of an array can be adjusted by adjusting the number of modules in accordance with the power requirements. Consequently, the traditional power grid can be reduced by reducing the reliance on a large-scale power source during the day with the appropriate configuration of a PV array in an industrial power project, which is determined by the power requirements. Angle, orientation, and shading considerations should also be made while installing PV arrays in order to ensure that each module receives enough sunshine to produce its maximum power.
The problems of energy storage and grid connectivity must also be taken into account while developing PV arrays. It is possible to maximise the use of electricity by feeding surplus power created during the day back into the grid, which is what many PV arrays do. Energy storage batteries can be employed to store diurnal electricity for nighttime use in off-grid scenarios. Flexible power use is made possible by solar arrays, whether they are off-grid or on the grid.

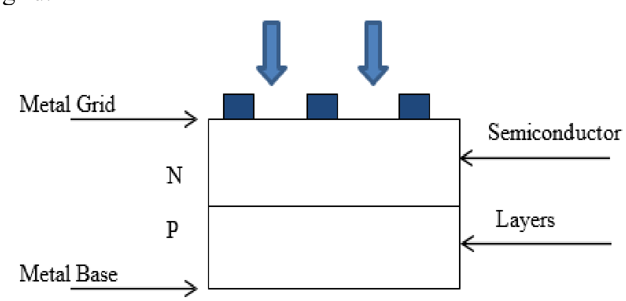

Figure 0.1 Structure of a PV cell

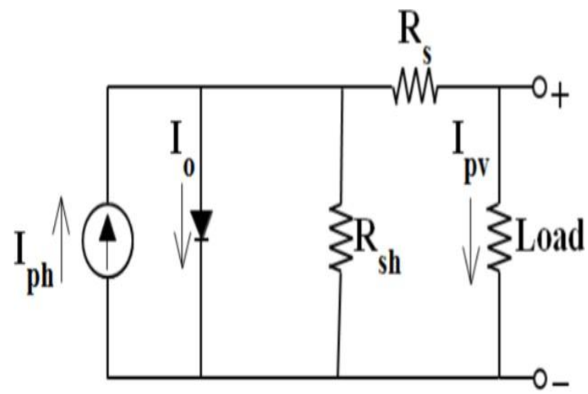

Figure 0.2 Simplified circuit diagram of a solar PV cell

4.Proposed Methodology

4.1 PV based multifunctional EV charger

Certain components are involved in this suggested system, as shown by the block diagram in the figure 4.1.

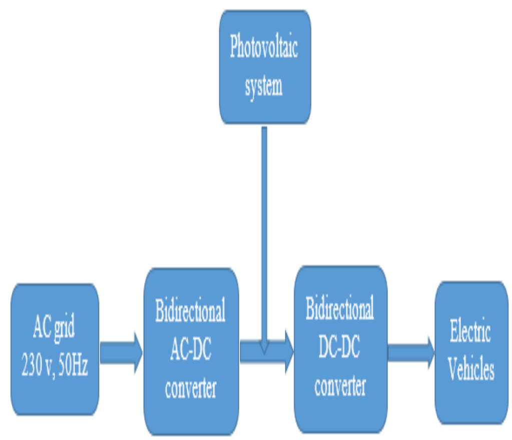

Figure 0.1 block diagram of PV based multifunctional EV charger

4.2 Role of PV array system

A multipurpose EV charger relies less on fossil fuels and the grid by using a photovoltaic (PV) system as its main power source to charge electric cars using clean, renewable energy produced by sunshine. The charger's use of solar energy lessens the strain on the main electrical grid, especially during periods of high demand when solar output is at its maximum.

4.2.1 Role of MPPT

The purpose of "the Maximum Power Point Tracking (MPPT) system" in a multipurpose EV charger is to maximise the power that can be obtained from a

International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 6 Issue 12, December 2025

photovoltaic (PV) power source by modifying the electrical load (such as the battery charger) to correspond with the operating point of the power source. In order to charge the battery of an electric car or power DC loads more effectively, this makes sure that the PV system, which may be incorporated into the charging station, produces the maximum energy possible under various weather and vehicle movement circumstances.

4.2.2 Hysteresis Controller

One method for controlling a voltage source inverter is hysteresis control, which generates switching pulses for the inverter by instantly comparing the reference current and the grid current. Fig. 4.2 shows a hysteresis current controller arrangement. What separates the referent current from the real grid current is the error signal, e. emin and emax are the lower and upper bounds corresponding to the error signal's minimum and maximum values, respectively. The hysteresis band is the region of error signals (emin − emax) where the inverter's output current is regulated. As shown in Fig. 4.3, this enables the current to be maintained within the upper and lower hysteresis band limitations.

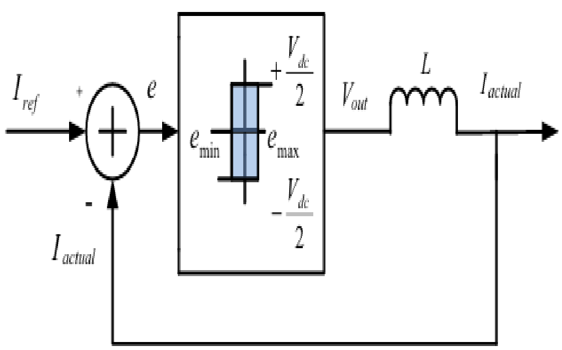

Figure 0.2 Configuration of hysteresis current controller

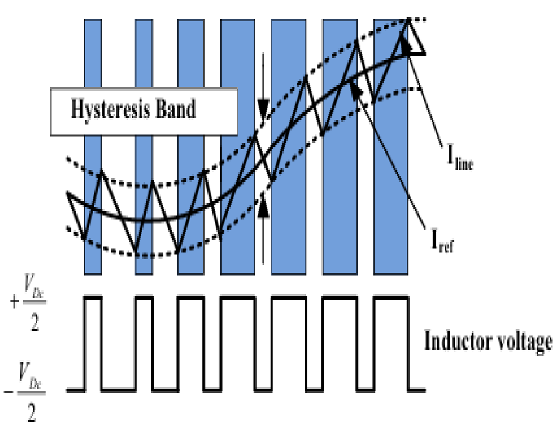

Figure 0.3 Hysteresis current controller operational waveform

4.3 SEPIC Converter

Single-ended primary-inductor converter is referred to as SEPIC. In essence, a SEPIC is a kind of dc-to-dc converter that produces a steady voltage at the output side while permitting a range of dc voltage at the input side. This kind of converter is very similar to Cuk and buck-boost converters, which produce an output voltage that is equal to, higher than, or less than the input voltage. The SEPIC converter employs the same buck-boost converter capabilities. Some benefits of a SEPIC converter over a buck-boost converter include high efficiency, the capacitor separating the input and output sides, and "the input and output voltages" having the same polarity.

4.4 Operating principle of bidirectional SEPIC converter

The topology of a SEPIC converter typically consists of "a power switch (MOSFETs), a diode, two inductors (L1, L2)", and two capacitors (C1, C2). This type of converter is unidirectional, but it can be made bidirectional by substituting a bidirectional switch (MOSFET) for the unidirectional switch (Diode), as illustrated in Figure 4.4. The converter operates as a boost converter in mode two and as a buck converter in mode one, "assuming continuous conduction mode (CCM)".

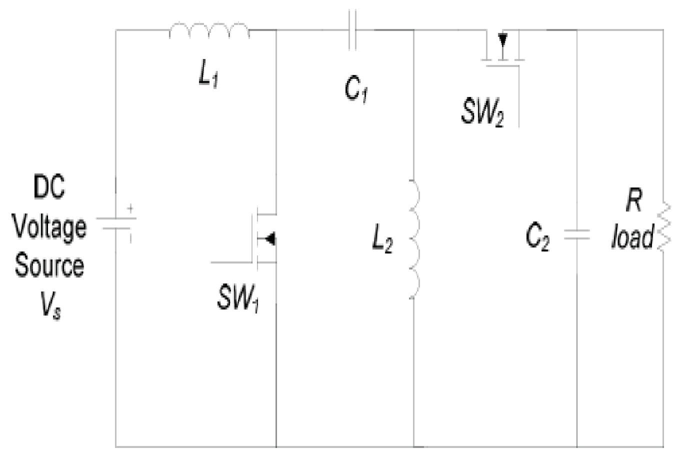

Figure 0.4 Basic DC-DC bidirectional SEPIC converter

4.4.1 Buck mode

In this mode, a voltage stepdown action occurs and the SEPIC converter behaves like a buck converter. SW1 will transition to the ON state, whereas SW2 will transition to the OFF state. As seen in Figure 4.5, the input current begins to flow via inductors and a capacitor, with inductors

IJEASM
International Journal of Engineering Applied Science and Management
ISSN (Online): 2582-6948
Vol. 6 Issue 12, December 2025

L1 and L2 being charged by sources Vs and Vc1, respectively.

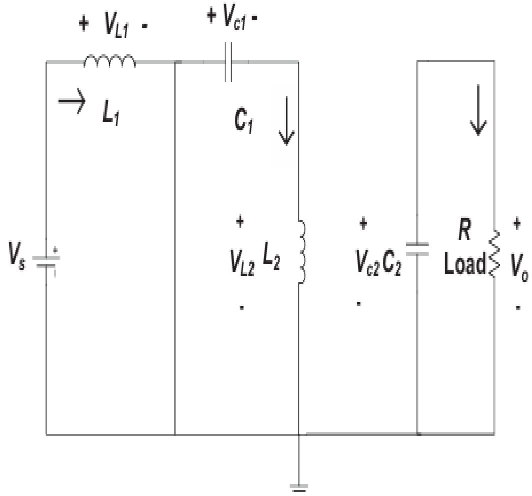

Figure 0.5 DC-DC bidirectional SEPIC converter at buck mode

4.4.2 Boost mode

The boost mode specifies how this converter operates in reverse power flow. SW1 changes from an ON to an OFF state at this time, and SW2 changes from an OFF to an ON state. Through the inductor and load, the capacitors C1 and C2 begin to discharge, as seen in Figure 4.6.

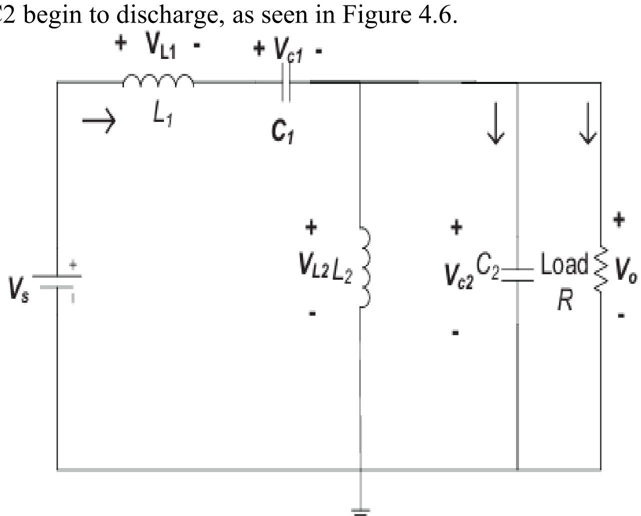

Figure 0.6 Bidirectional SEPIC converter at boost mode

4.5 Advantages of SEPIC converter

Compared to boost converters and other DC-DC converter types, "SEPIC (Single-Ended Primary Inductor Converter) converters" have a number of benefits. Here are a few main advantages:

Output Voltage Range: The output voltage of SEPIC converters might be equal to, greater than, or less than the input voltage. This adaptability renders them appropriate for applications in which the input voltage is subject to significant fluctuations. Contrarily, boost converters are only capable of increasing voltage, which restricts their use in situations when the input voltage may exceed the intended output. **Isolation from Input Voltage:** Better control and noise immunity may result from a SEPIC converter's output voltage not being directly connected to the input voltage. In battery-powered systems where voltage dips are possible, this is very helpful.

Simplicity in Design: Compared to more complicated converters that can need many inductors or transformers, SEPIC converters are easier to build since they just need one inductor and a few passive parts.

Lower Ripple Current: SEPIC converters may have reduced output ripple currents as a consequence of their design. This is advantageous in precise analogue devices or sensitive applications that necessitate output voltage stability, such as the operating of RF circuits.

5. Conclusion

This review highlights the technological progress and research advancements in solar PV-based multifunctional electric vehicle (EV) charging systems. A detailed analysis of recent literature shows a strong shift toward integrating renewable energy with EV charging to reduce grid dependency, enhance energy sustainability, and support vehicle-to-grid (V2G) and vehicle-to-home (V2H) functionalities. Studies demonstrate the increasing adoption of bidirectional converter topologies—particularly SEPIC, buck–boost, and advanced DC–DC structures that enable efficient bidirectional power flow, improved dynamic response, and stable charging performance even under fluctuating solar irradiation conditions

References

[1] M. F. Akhtar, S. R. S. Raihan, N. A. Rahim, M. N. Akhtar, and E. A. Bakar, "Recent Developments in DC-DC Converter Topologies for Light Electric Vehicle Charging: A Critical Review," *Applied Sciences*, vol. 13, 2023.

[2] Aminuddeen and S. Bhandari, "Electric Vehicle Battery Charger Using PV Array with FOPID Controller," *CEUR Workshop Proceedings*, 2021.

[3] S. Anusha and K. Nagabhushanam, "Designing of Multifunctional EV Charger Based on Solar PV Array," *ShodhKosh: Journal of Visual and Performing Arts*, vol. 5, no. 7, 2024.

[4] B. Balavidyasri and D. J. Subrahmanyam, "Controlling of Solar Based Electric Vehicle Charging Station Through Intelligence Controller for G2V and V2G Modes," *IJRASET*, vol. 12, no. 8, 2024.

[5] P. Chaithanyakumar, S. Ashok, S. Nikhil, M. Vikram, and G. Harish, "PV Array-Based Off-Board Electric Vehicle Battery Charger," *JETIR*, vol. 11, no. 3, 2024.

[6] R. I. Putri, S. Nata, and B. Priyadi, "Battery Charging Control Using Photovoltaic with SEPIC Converter," *IJFTE*, vol. 1, no. 1, 2022.

[7] I. Jagadeesh and V. Indragandhi, "Solar Photovoltaic Based Hybrid CUK, SEPIC, ZETA Converters for Microgrid Applications," *E-Prime*, vol. 6, 2023.

[8] A. Jain and S. Bhullar, "Operating Modes of Grid Integrated PV-Solar Based Electric Vehicle Charging System: A Comprehensive Review," *E-Prime*, vol. 8, 2024.

[9] J. K. and C. Chengaiah, "Evaluation of PV-based Buck-Boost and SEPIC Converters for EV Charging Applications," *Trends in Renewable Energy*, vol. 10, no. 2, 2024.

[10] R. Kalyan, M. V. Subbaiah, B. S. Charan, K. M. Reddy, and D. P. S. Babu, "Modelling and Control of SEPIC and BIDC Converter Based Off-Board EV Battery Charger Using PV Array," *JEET*, vol. 4, no. 2, 2022.

[11] A. B. Kancherla, N. B. Prasad, and D. R. Kishore, "Solar Energy EV Charging System Using Integrated Zeta-Luo Converter," *Journal of Engineering and Applied Science*, 2024.

[12] B. A. Kumar, B. Jyothi, A. R. Singh, M. Bajaj, R. S. Rathore, and M. Berhanu, "A Novel Strategy Towards Efficient and Reliable Electric Vehicle Charging," *Scientific Reports*, vol. 14, 2024.

[13] P. V. Kumar, P. V. Prasad, and E. V. Sagar, "Multifunctional EV Charger with Bidirectional SEPIC Converter for Low Current Ripple," *IJEEE*, vol. 11, no. 10, 2024.

[14] J. M. Kumbhare and S. G. Kadwane, "A Grid-Tied Solar Photovoltaic Based Off-board Electric Vehicle Charger in G2V and V2G Mode," *AIP Advances*, 2024.

[15] R. K. Lenka, A. K. Panda, R. Patel, and J. M. Guerrero, "PV Integrated Multifunctional Off-Board EV Charger with Improved Grid Power Quality," *IEEE Transactions on Industry Applications*, 2022.

[16] H. M., T. Thomas, and I. S. Induja, "A Solar PV Array Based Multipurpose EV Charger," *IJAERS*, vol. 8, no. 9, 2021.

[17] B. Makode, "PV Based Standalone Microgrid System for EV Charging Station: A Review," *IJRT*, vol. 11, no. 4, 2023.

[18] D. B. Mesquita, J. L. Silva, H. S. Moreira, M. Kitayama, and M. G. Villalva, "A Review and Analysis of Technologies Applied in PV Modules," 2019.

[19] P. V. Kumar, P. V. Prasad, and E. V. Sagar, "ANFIS Based Grid Connected Renewable Source Bidirectional SEPIC Converter Multifunctional EV Charger," *JISEM*, vol. 10, no. 29s, 2025.

[20] K. M. P., R. S., D. M. N., D. G. S., and S. M. R., "Solar-Powered Grid-Integrated Electric Vehicle Charging with Bidirectional Energy Flow System," *IJCRT*, vol. 12, no. 1, 2024.

[21] P. R. Pillewar, S. N. Patil, and M. G. Unde, "An Implementation of Solar PV Array Based Multifunctional Electric Vehicle Charger," *Materials Today: Proceedings*, vol. 69, 2022.

[22] G. Prashanth and K. Vani, "Electric Vehicle Solar PV Battery Charger Based on SEPIC Converter and BIDC with FOPID Controller," *IJARST*, vol. 13, no. 3, 2023.

[23] K. M. Reddy, P. S. Babu, R. Kalyan, B. Saicharan, and M. V. Subbaiah, "Off-Board Electrical Vehicle Battery Charger Using PV Array," *Journal of Engineering Sciences*, vol. 14, no. 4, 2023.

[24] V. Sagar, K. Anusha, Ankith, and T. Pranay, "An Implementation of Solar PV Array Based Multifunctional EV Charger," *Journal of Engineering Sciences*, vol. 14, no. 6, 2023.

[25] P. Shameem and L. Suresh, "Simulation Studies on Developed Solar PV Array Based Multipurpose EV Charger Using SMC and ANFIS," *IRJET*, vol. 9, no. 7, 2022.