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A Review on Power Electronic Converters and Control Mechanisms for Sustainable Microgrid-Based EV System

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ABSTRACT: The integration of Electric Vehicles (EVs) into microgrid-based renewable energy systems presents significant challenges related to power conversion, energy management, and system stability. Efficient power electronic converters and control strategies are essential for optimizing energy exchange between Renewable Energy Sources (RES), EVs, and the grid. This review examines various DC-DC converters, analysing their efficiency and impact on system performance. Additionally, it explores different control techniques, assessing their effectiveness in regulating power flow and ensuring stable operation. The findings highlight the role of converter design, and control approaches in enhancing the efficiency and reliability of microgrid-based EV systems. This study provides significance into emerging technologies and methodologies that support the uninterrupted integration of RES and EVs, contributing to the development of sustainable and resilient power infrastructure.

Keywords: Electric Vehicles (EVs), Renewable Energy Sources, Converters, Controllers and THD.

1. Introduction

EV systems are essential for tackling a variety of global issues, ranging from public health and environmental degradation to energy security and economic stability. A vital component of contemporary life, transportation makes it easier for people, products, and services to move about. It includes a range of modalities that enable us to connect over long distances and stimulate economic activity, such as automobiles, buses, trains, ships, and aircraft. Even while transportation is essential, the use of fossil fuels has a major negative influence on the environment [1-3]. However, as EVs have no exhaust emissions, they contribute to a smaller environmental impact overall. Therefore, switching to EVs, which emit fewer emissions, is regarded as a crucial step in achieving global climate objectives and lowering dependency on fossil fuels. Power management and energy-efficient technologies are major issues in the modern world. There has been a significant shift in vehicle mobility over the past several decades from fuel-based to electric [4-5]. Further, RES are increasingly crucial in today's world for a variety of environmental, economic, and social reasons. Their importance cannot be overstated, particularly as the world faces challenges related to climate change, energy security, and sustainable development. Unlike fossil fuels, RES like wind, solar, and hydropower produce little to no greenhouse gases during operation. This helps mitigate the effects of climate change by reducing the overall carbon footprint. By reducing greenhouse gas emissions, EVs help manage pollution issues. The vehicles are recharged overnight using the conventional EV charging method [6-7]. Therefore, to assure safe, effective, and dependable charging, a number of procedures must be followed while transferring energy from a charging station to an EV. By following this process, charging stations ensure that energy is safely and efficiently transferred from the grid to the EV. Nevertheless, the converters are crucial for enhancing the efficiency of EVs powered by PV systems. Conventional converters include SEPIC, Cuk, buck-boost, and interleaved converters, among others. These converters provide effective energy management and conversion [8-9]. Additionally, it supports advancements like V2G and regenerative braking, making electric cars more feasible, effective, and able to satisfy the demands of contemporary transportation. Although they have certain disadvantages, these converters in EVs are essential for effective energy management. The considerable volatility, high unpredictability, and obvious intermittent nature of solar power output have a detrimental effect on the power grid's capacity to operate consistently. When connected to the electrical grid, solar systems frequently need some level of energy storage to provide inertia [10]. Increased energy consumption, RES integration, aging infrastructure, and the requirement for greater environmental sustainability, dependability, and efficiency are some of these issues. Therefore, to ensure that the grid runs effectively, dependably, and sustainably, controllers are required. Using real-time data and clever decision-making algorithms, the Proportional-Integral (PI), Artificial Neural Network (ANN), Fuzzy - Proportional-Integral-Derivative (Fuzzy PID), and DC-DC controllers handle many grid components, including power generation, distribution, storage, and consumption [11-13]. For a microgrid to respond in real-time to changes in EV charging demand or grid conditions, controllers need to be fast enough to make decisions without introducing latency, which are challenging in certain systems. Moreover, various types of converters and controllers are available in electronics and EV applications [14-15]. So, identifying the best performance of converters and controllers is required for EV applications. Therefore, an analysis of converter techniques and controllers for EV systems was provided and addressed in this paper.

2. Review of Converters Techniques for EV

2.1 Buck-Boost Converter

A DC-DC converter that changes the input DC voltage by increasing or decreasing it is known as a buck-boost converter. It combines the features of both a buck converter and a boost converter. This makes it versatile, as it provides a regulated output voltage that is either higher or lower than the input voltage, depending on the system requirements. It is particularly useful in applications where the input voltage is varied significantly, such as in EVs with battery voltages that change as the battery discharges or fluctuates under load. The buck-boost converter's circuit design is seen in Figure 1.

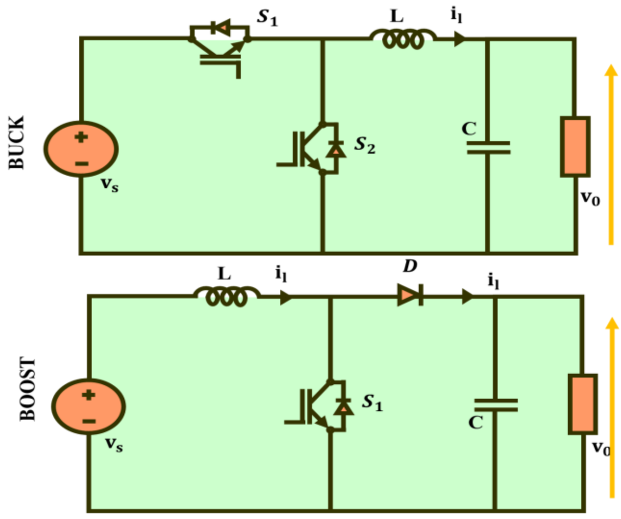

Figure 1: Buck-Boost Converter

In the former conduction mode, the current passing through the inductor emancipates tolerably, but it does not drop to zero before the switching cycle begins. In the later conduction stage, on the other hand, the internal current of the inductor decreases to zero. The following is the formula for the buck-boost converter c's output voltage V_{out},

$$V_{out} = \left(\frac{D}{1-D}\right) V_{in} \quad (1)$$

where V_{in} stands for the input voltage and D for the duty cycle. It is challenging to manage the buck-boost converter, necessitating careful attention to changes in load and input voltage. However, it only steps up voltage and are inefficient if the input voltage is close to or higher than the required output voltage. It does not provide isolation between input and output, which is required in certain safety-critical applications [5].

2.2 Cuk Converter

The Cuk Converter operates by transferring energy through an inductor and capacitor combination. Unlike other converters that operate through a direct switch mode, the Cuk Converter uses a combination of a capacitive and inductive energy storage, which allows it to either step up or step down the voltage while maintaining continuous current flow. It uses capacitors and inductors carefully to reduce switching losses and increase power conversion efficiency. The Cuk converter's reputation in the industry has been further enhanced by its increased use in a variety of power electronics applications, such as battery charging and electric automobiles, as a result of these exceptional qualities. The circuit diagram for the Cuk converter is displayed in Figure 2.

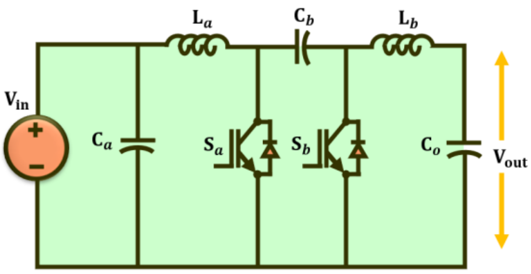

Figure 2: Cuk Converter

The Cuk Converter provides precise voltage regulation by adapting to varying input voltages, such as the fluctuating battery voltage in EVs. This ensures that sensitive components receive the required voltage for proper operation, even as the battery charge decreases or fluctuates. The general formula for the Cuk converter is as follows,

$$V_{out} = \left(\frac{D}{1-D}\right) V_{in} \quad (2)$$

Where, V_{out} is the output voltage, V_{in} is the input voltage, and D is the duty cycle of the switching transistor. Additionally, it provides continuous current, reducing ripple and improving battery life in EV systems. Moreover, Cuk converters are more complex and require more components, leading to higher costs and design difficulties [8].

2.3 SEPIC Converter

The SEPIC is a type of DC-DC converter that is capable of both step-up and step-down operations. It operates by transferring energy through a combination of inductors and capacitors, using a single inductor in the primary circuit and a capacitor to regulate the voltage. The SEPIC converter is capable of adjusting both higher and lower voltage levels while maintaining continuous power flow, with the added advantage of a non-inverting output. Figure 3 shows the circuit schematic for the SEPIC converter.

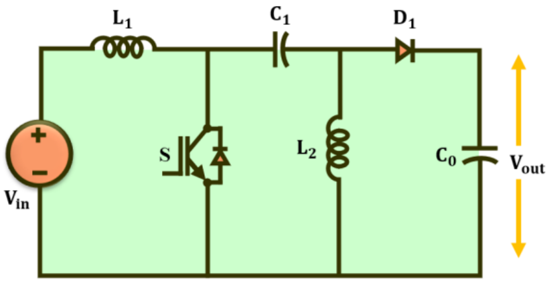

Figure 3: SEPIC Converter

The formula for the output voltage (V_{out}) of the SEPIC,

$$V_{out} = \left(\frac{D}{1-D}\right)\left(V_{in} + \frac{D}{1-D}\right) \quad (3)$$

This streamlined design method results in a more compact and lightweight converter with higher power density and enhanced reliability in a variety of applications. Without requiring a transformer or connected inductor, it achieves significant advantages while lowering switch-voltage stress and conduction losses. Its steady input current makes fuel cells and other renewable energy sources perfect.

SEPIC converters handles a wide range of input voltages, which makes them ideal for systems where the input voltage fluctuates significantly. Further, it provides a non-inverting output, which is useful for specific system designs. While SEPIC converters are efficient, results with lower efficiency, particularly at higher currents [8].

2.4 Hybrid Boost-Flyback Converter

High voltage gain gets achieved using the flyback converter with a coupled inductor, although leakage inductance reduces efficiency. In this instance, while the active switch is off, the boost converter acts as a clamping circuit. A hybrid boost-flyback converter is seen in Figure 4. Depending on the connected inductor's turn ratio, the voltage stress across the switch is lowered by less than half of the output voltage.

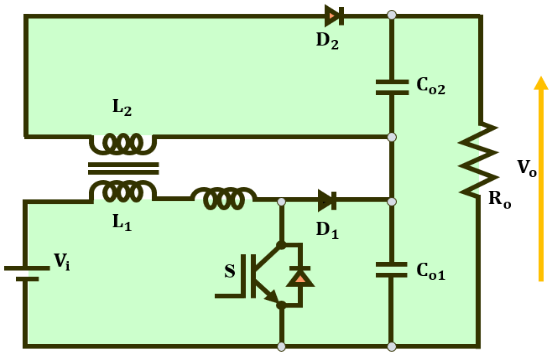

Figure 4: Hybrid Boost-Flyback Converter

Additionally, the output capacitor recycles the leakage energy by naturally clamping the voltage across the switch. To lower EMI levels, an extra input filter is used since the input current is irregular. The boost and flyback converters are integrated using many methods, such Voltage Multiplier Cells (VMCs). The output voltage, or the voltage across capacitor C_{o1}, then surpasses the voltage stress over the active switch. It allows for better handling of fluctuating input voltages and higher efficiency, especially in high-power applications. Moreover, it is more compact than using separate Boost and Flyback converters, saving space in EV applications [9]

3. Review of Controllers Techniques for EV

3.1 PI Controller

It combines two control actions proportional and integral to improve the system's performance in terms of stability, accuracy, and speed of response. The generated transfer function is placed through a transient analysis using step input to confirm the controller’s resilience. The PI controller is shown in Figure 5.

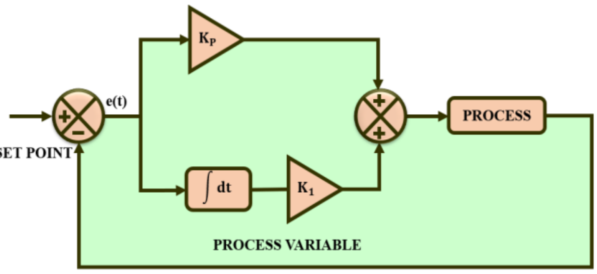

Figure 5: PI Controller

The voltage that is connected to a PI controller over a DC-link voltage is compared with the actual DC interface voltage. The total control output from a PI controller is often expressed as follows,

$$u(t) = k_p . e(t) + k_i . \int_0^t e(T)\, d \quad (4)$$

where k_i is the integral gain of PI controllers and k_p is the proportional gain of PI controllers. Although it results in an increased overshoot and settling time, an expansion of the proportional gain (k_p) reduces the rise in steady-state error and time. In a similar vein, increasing the required pick-up (k_i) decreases the relentless state error, but it is also the cause of overshoot and settling time.

PI controllers are relatively simple to understand and implement, making them an attractive choice for many control systems. Further, it provides quick response, while the integral term ensures long-term accuracy. Moreover, in cases of large errors, the control signal overshoots or is too large, leading to instability or an increased overshoot.

3.2 ANN Controller

ANN is one AI method that uses the human nervous system as its model. Each of its effective processing units, known as neurons, is connected to the others. Figure 6 depicts the architecture of the ANN controller.

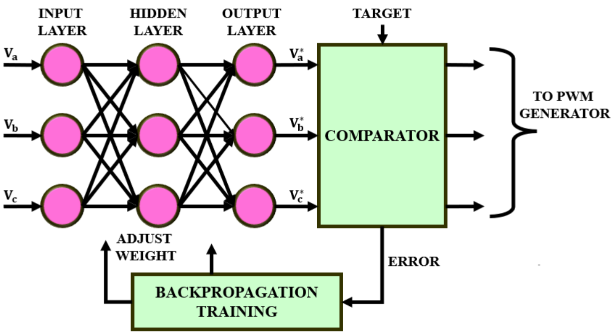

Figure 6: Architecture of ANN

Input, hidden, output are the different layer types. Data must be normalized before being supplied into the input layer, which is typically the case with data-driven fault detection methods. Using the feature scaling of the following, which guarantees that every value falls inside the range [0, 1], is one such technique.

$$x' = \frac{x - \min(x)}{\max(x) - \min(x)} \quad (5)$$

The following hidden layers are displayed in order to progressively transform the input data's information into higher representations,

$$h_1 = \sigma(W_{1x} + b_1) \quad (6)$$

The hyper parameters d and nh_l are established before neural networks are trained. σ, a nonlinear activation function, makes the previously described transformation nonlinear. It is defined as,

$$\sigma(x) = \max(0, x) \quad (7)$$

Without the activation function, the output of the last hidden layer is transformed as follows,

$$h_s = W_s h_d + b_s \quad (8)$$

Additionally, the SoftMax layer determines the values of each output neuron using the SoftMax function of the following form,

$$y_j = \frac{\exp(h_{s,j})}{\sum_{j=1}^{nh_z} \exp(h_{s,j})} \quad (9)$$

The label with the greatest output value is then selected by the network to give the input data a predicted label. From output to input during the training phase, memory-based intelligence is provided via the backward sweep and back propagation. It adjusts their parameters to optimize system performance, such as controlling energy flow between the grid, EVs, and other components in the microgrid. However, it requires large amounts of historical or real-time data for training [10].

3.3 Fuzzy PID Controller

Smart grid systems frequently employ PID controllers because of their capacity to handle many subsystems in a stable, effective, and responsive manner. Energy storage, power flow, voltage, and frequency are all managed by a PID controller in a smart grid, ensuring grid stability and optimal performance. By combining fuzzy logic's robustness in managing uncertainties and nonlinearities with the precision of PID controllers, it provides improved stability, efficiency, and reaction times. Figure 7 illustrates the fuzzy PID controller.

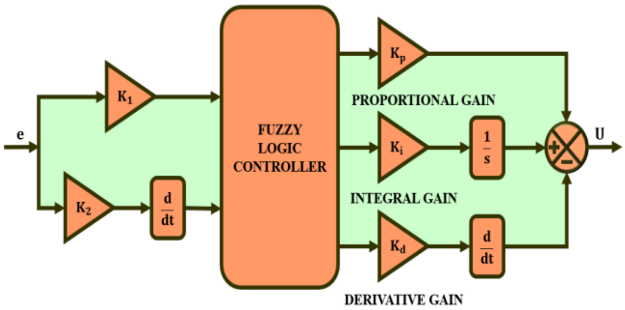

Figure 7: The fuzzy PID controller

Furthermore, the time variations (e) of the slave and master clocks are considered control inputs. This adaptability helps manage unpredictable disturbances and nonlinearities in smart grid scenarios. It handles nonlinearities in a microgrid-based EV system better than traditional PID controllers. Further, it helps smooth out fluctuations in these disturbances, improving system stability. Nevertheless, requires defining fuzzy rules and membership functions, which is time-consuming and require expertise. Additionally, the PID parameters themselves need to be appropriately tuned for optimal system performance [12].

4. Review of Optimization Techniques for EV

4.1 Particle Swarm Optimization (PSO)

PSO is a nature-inspired optimization algorithm based on the social behavior of birds flocking or fish schooling. Its simplicity, effectiveness, and versatility make it a popular choice for resolving intricate optimization issues in smart grids. PSO is used in smart grids to improve performance and optimize a variety of functions. The damping ratio of an eigenvalue is determined by its real and imaginary components.

$$\zeta(Z = Re + j.Im) = \frac{|Re|}{\sqrt{(Re^2+Im^2)}} \qquad (10)$$

There are p operating points for microgrids, yet there are m eigenvalues. Reactive power imbalances are another issue with this work. These are based on,

$$\Delta Q = \sum_{j=1}^{n-1} \left| \frac{n_j.Q_j - n_{j+1}.Q_{j+1}}{Q_N} \right| \qquad (11)$$

where n_j, n, Q_j, and Q_N represent the jth converter's reactive power droop coefficient, base reactive power, number of microgrid converters, and reactive power of the jth converter, respectively. It adapts well to dynamic and changing environments, which is ideal for EV applications where operating conditions change frequently. However, it requires careful tuning of its parameters, such as inertia weight, cognitive coefficient, and social coefficient. These parameters significantly influence the algorithm's performance. Improper tuning is led to poor performance, and finding the right parameters are time-consuming [13].

4.2 Genetic Algorithm Optimization (GAO)

GAO is a type of evolutionary algorithm that mimics the process of natural selection. It is part of a broader category of algorithms called evolutionary computing, which mimics biological processes to solve complex computational problems. It is often applied in optimization problems, including those related to EV systems, to enhance performance, reduce energy consumption, and optimize various system parameters. The population evolves over multiple generations. The fitness function evaluates the quality of each individual in the population. Each individual (chromosome) in the population is represented as a string of binary values, depending on the problem.

$$Population = \{X_1, X_2, \dots, X_N\} \qquad (12)$$

Where, N is the size of the population and X_1represents an individual solution.

The fitness function is typically problem-specific and can either be maximized or minimized.

$$Fitness\ of\ individual\ X_i = f(X_i) \qquad (13)$$

Where, $f(X_i)$ is the objective function that needs to be optimized. Each individual is given a probability of selection proportional to its fitness,

$$P(X_i) = \frac{f(X_i)}{\sum_{i=1}^{N} f(X_i)} \qquad (14)$$

Where, $P(X_i)$ is the probability of selecting individual X_i based on its fitness.

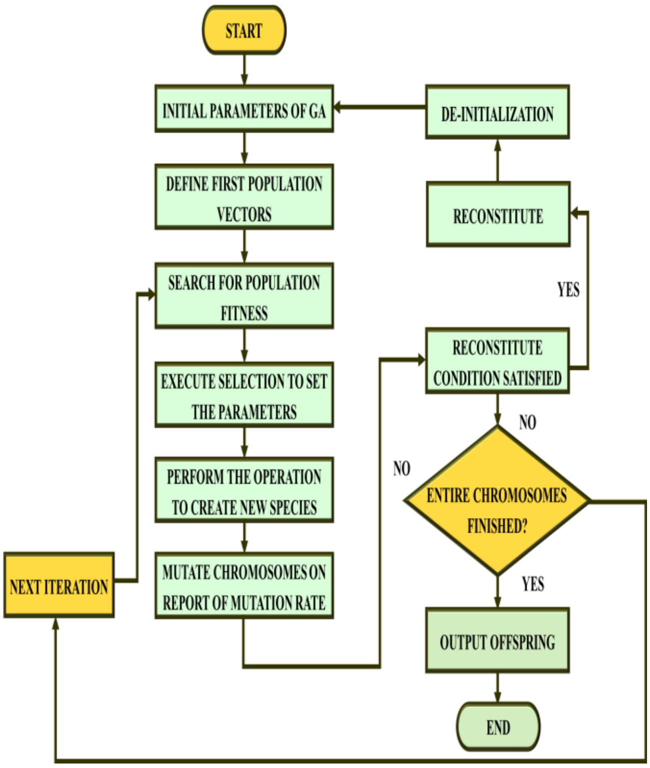

Figure 8: Flow chart for GAO

Figure 8 shows the flow diagram of the GAO. The overall success of GAO depends on properly defining the fitness function, selecting good genetic operators, and setting appropriate algorithm parameters. It explores a large search space and avoid local optima, making it more likely to find global solutions. Since GAO works on a population of solutions, it is inherently parallelizable, meaning it is implemented in parallel computing environments to speed up the optimization process. However, it takes a long time to converge to an optimal solution, especially if the problem is very complex [15].

4.3 Wolf Colony Algorithm (WCA)

WCA is a nature-inspired algorithm based on the hunting behavior of humpback whales. It has been widely used in various optimization problems, including those in EV systems. In EV applications, WCA is used for tasks such as energy management, battery optimization, charging scheduling, V2G optimization, and controller tuning. It is used to solve complex optimization problems by simulating the way whales hunt for food in the ocean, offering a unique way of searching for solutions in a multidimensional search space. The other wolves will continue to attack if the leader wolf doesn't shift, though, until they are less than d_{near}, which gets stated as follows:

$$d_{near} = \frac{1}{D \times W} \times \sum_{d=1}^{D} max_d - min_d \quad (15)$$

where max_d and min_d are the maximum and minimum distance, and ω is the distance factor. The wolf colony then divides up the prey according to the principle that tougher work would provide greater rewards as a consequence. The least suitable M wolves are so removed. In order to preserve population diversity, M new intelligent wolves are created at random at the same time. The WCA's flow diagram is displayed in Figure 9.

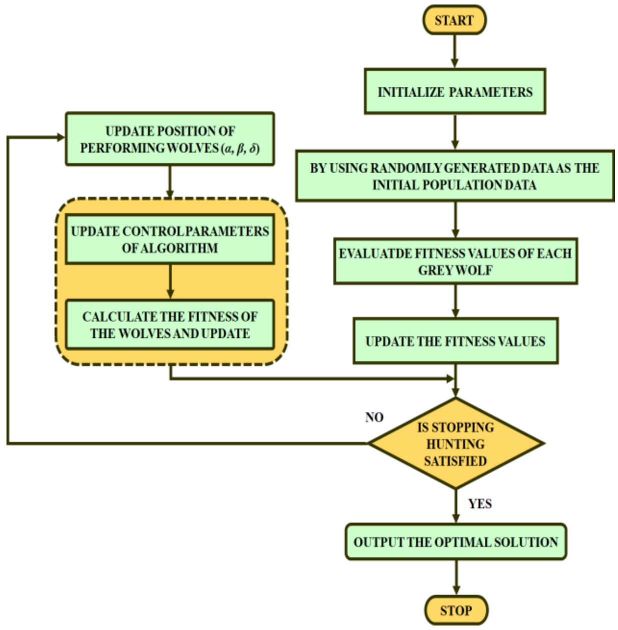

Figure 9: Flow chart for WCA

It is capable of optimizing highly nonlinear and complex systems without needing detailed gradient information. Further, it helps the algorithm effectively explore the solution space while focusing on areas that yield better results, making it more efficient than other algorithms in terms of solution accuracy and speed. However, it works well for small to medium-sized optimization problems, it faces scalability issues when applied to large, high-dimensional problems, such as fleet management or large-scale charging infrastructure optimization [14].

5. Comparative Analysis

This section's overview of the advantages and drawbacks of different converters, and controllers for the research potential. Table 1 presents a comparison of the several converter and control methods applied to the microgrid-based EV system.

Table 1: Comparative Analysis of converters and controllers for EVs

SL. NO	Author/Year of Publication	Methodology	Advantages	Limitations
1	H. Wang et al [2024] [4]	DC/DC converter is discussed in this paper for fuel cell EV.	It enhances energy efficiency, reduce energy consumption, and lower operating costs.	It computationally expensive, time-consuming, and require significant expertise to avoid overfitting, underfitting, or inefficient training.
2	P. -E. Velázquez-	Interleaved DC–DC buck-boost converter	It balances the load from the grid, optimize the use of renewable energy, and	It needs to be fast enough to make decisions without introducing

	Elizondo et al [2022] [6]	presented for increasing efficiency.	manage battery state-of-charge effectively.	latency, which is challenging in certain systems.
3	R. Kushwaha et al [2022] [8]	This paper proposes a Cuk–SEPIC converter for EV charging systems.	It ensures stable operation even under changing conditions.	Poor initialization can lead to suboptimal performance or convergence issues.
4	B. Sah et al [2022] [10]	A fuzzy logic and ANN-based intelligent controller for a vehicle-to-grid system	It improves efficiency by continuously adjusting to new patterns or demands.	It increases maintenance complexity and the cost of system operation.
5	M. A. Fkirin et al [2022] [12]	Fuzzy-PI controller is proposed for positioning control system.	It prevents excessive load on the microgrid and ensures optimal charging rates that align with grid stability.	The fuzzy logic system requires defining fuzzy rules and membership functions, which can be time-consuming and require expertise.

Table 2: Comparison of performance

Converters	Efficiency %
SEPIC Converter [8]	87.78
Buck-Boost Converter [5]	92.56
Cuk Converter [8]	96.12
Hybrid Boost-Flyback Converters [9]	98.45

The efficiency performance of a comparison evaluation of different controllers is shown in Table 2. It accomplishes 87.78% for the SEPIC converter [8], 92.56% for the Buck-boost converter [5], 96.12% for the Cuk converter [8], and 98.45% for the Hybrid boost-flyback converters [9].

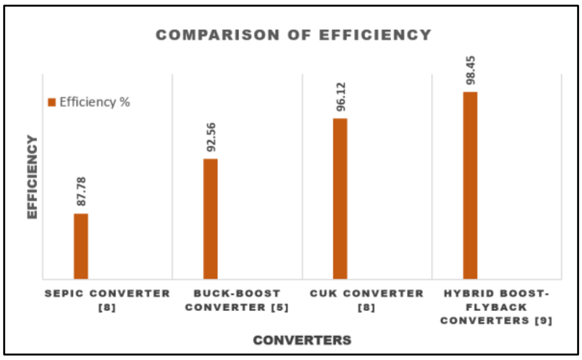

Figure 10: Comparison of Efficiency

The efficiency of various converter techniques is compared in Figure 10. The Hybrid Boost-Flyback Converter is the best choice for high-power applications and EV systems.

Table 3: Comparison of performance

Controllers	THD %
PI[11]	5.72
ANN[10]	3.95
Fuzzy PID[12]	2.14

The THD performance of a comparative examination of several controllers is shown in Table 3. The THD of the ANN [10], the PI [11], and the Fuzzy PID [12] converters is 3.95%, 5.72%, and 2.14%, respectively. In this case, it demonstrates the Fuzzy PID controller attained the lowest THD values and high performance.

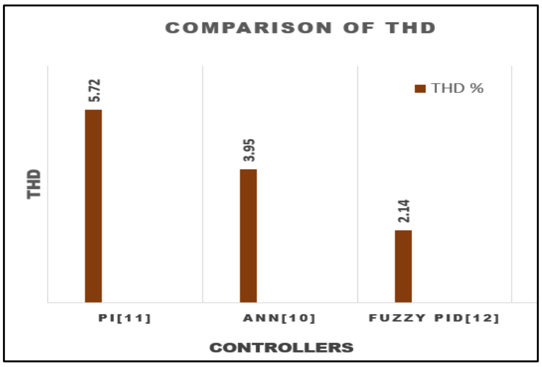

Figure 11: Comparison of THD

A comparison of multiple THD value controllers is shown in Figure 11. Conversely, alternative controllers such as PI, ANN, and Fuzzy PID are shown to have THD values of 5.72%, 3.95%, and 2.14%, respectively.

6. Conclusion

The converters and controllers play a vital role in optimizing the performance, efficiency, and sustainability of electric vehicles. Hence, a comprehensive review of converters and control strategies is discussed in this paper for a sustainable microgrid-based EV system. The results highlight their crucial role in enhancing the overall performance, efficiency, and sustainability of EV systems. Therefore, this review analyzed and compared earlier controllers and converters. Further, the efficiency is achieved by the GAO approach, and the hybrid boost-flyback converter earned the maximum efficiency. Moreover, the Fuzzy PID controller received the minimum value of THD, which achieves the best efficiency.

Reference

1. Tehseen Ilahi, Tahir Izhar, Saeed Mian Qaisar, Umar Tabrez Shami, Muhammad Zahid, Asad Waqar, Ahmad Alzahran, 2023, "Design and Performance Analysis of Ultra-Wide Bandgap Power Devices-Based EV Fast Charger Using Bi-Directional Power Converters", in IEEE Access, Vol: 11, pp. 25285-25297.

2. Salvatore D'Arco, Santiago Sanchez, Jon Are Suul, 2024, "Multi-Hardware-in-the-Loop Laboratory Testing of Power Converters and Intelligent Electronic Devices for Large-Scale Power System Applications", in IEEE Open Journal of Power Electronics, Vol: 5, pp. 1520-1533.

3. Zhipeng Qi, Md Biplob Hossain, Md Rabiul Islam, Md Ashib Rahman, Raad Raad. 2024, "Advancement in Converter Topology, Control, and Power Management: Magnetic Linked Power Converter for Emerging Applications", in IEEE Access, Vol: 12, pp. 101228-101246.

4. Hanqing Wang, Jianlong Xu, Yaxu Sun, Pengfei Du, Yawen Lei, 2024, "Theoretical Comparison, Real-Time Emulation, and Experiment Validation of DC/DC Converter for Fuel Cell Electric Vehicle", in IEEE Access, Vol: 12, pp. 56824-56835.

5. Seyfettin Vadi, Fethi Batincan Gurbuz, Seref Sagiroglu, Ramazan Bayindir, 2021, "Optimization of PI Based Buck-Boost Converter by Particle Swarm Optimization Algorithm", in IEEE Access, pp. 295-301.

6. Pedro-Enrique Velázquez-Elizondo, Ismael Araujo-Vargas, Ilse Cervantes, Kevin Cano-Pulido, Marco-Antonio Hernández-Nochebuena, 2022, "A 32 kW Power-Dense Six-Phase Dual-Interleaved DC–DC Buck-Boost Converter with Three Interphase Transformer", in IEEE Access, Vol: 10, pp. 130880-130893.

7. Vasileios Boglou, Christos–Spyridon Karavas, Athanasios Karlis, Konstantinos G. Arvanitis, Ilias Palaiologou, 2023, "An Optimal Distributed RES Sizing Strategy in Hybrid Low Voltage Networks Focused on EVs' Integration", in IEEE Access, Vol: 11, pp. 16250-16270.

8. Radha Kushwaha, Bhim Singh, Vinod Khadkikar, 2022, "An Isolated Bridgeless Cuk–SEPIC Converter-Fed Electric Vehicle Charger", in IEEE Transactions on Industry Applications, Vol: 58, No: 2, pp. 2512-2526.

9. Feng Zhang, Yunxiang Xie, Yanshen Hu, Gang Chen, Xuemei Wang, 2020, "A Hybrid Boost–Flyback/Flyback Microinverter for Photovoltaic Applications", in IEEE Transactions on Industrial Electronics, Vol: 67, No: 1, pp. 308-318.

10. Bikash Sah, Praveen Kumar, Sanjay Kumar Bose, 2021, "A Fuzzy Logic and Artificial Neural Network-Based Intelligent Controller for a Vehicle-to-Grid System", in IEEE Systems Journal, Vol: 15, No: 3, pp. 3301-3311.

11. Srishail K. Bilgundi, R. Sachin, H. Pradeepa, H. B. Nagesh, MV Likith Kumar, 2022, "Grid Power Quality Enhancement Using an ANFIS Optimized PI Controller for DG", in Protection and Control of Modern Power Systems, Vol: 7, No: 1, pp. 1-14.

12. Mohamed A. Fkirin, Manal Abd-Elazim Khira, 2023, "Enhanced Antenna Positioning Control System Using Adapted DC Servo Motor and Fuzzy-PI

Controller”, in IEEE Access, Vol: 11, pp. 102661-102668.

13. Habib Kraiem, Aymen Flah, Naoui Mohamed, Majed Alowaidi, Mohit Bajaj, Shailendra Mishra, 2021, “Naveen Kumar Sharma, Sunil Kumar Sharma, "Increasing Electric Vehicle Autonomy Using a Photovoltaic System Controlled by Particle Swarm Optimization”, in IEEE Access, Vol: 9, pp. 72040-72054.

14. Xiaowen Zhang, Shuqing Zhang, Wei Dong, Kainan Wang, 2022, “A Novel Time Synchronization Method for Smart Grid Based on Improved Wolf Colony Algorithm-Cuckoo Search Optimized Fuzzy PID Controller ”, in IEEE Access, Vol: 10, pp. 116959-116971.

15. Debabrata Mazumdar, Pabitra Kumar Biswas, Chiranjit Sain, Taha Selim Ustun, 2024, “GAO Optimized Sliding Mode Based Reconfigurable Step Size Pb&O MPPT Controller With Grid Integrated EV Charging Station”, in IEEE Access, Vol: 12, pp. 10608-10620.