Evaluating Conventional and Hybrid Buck-Boost Converters using Fuzzy Logic Decision-Making

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Abstract: In this paper, a novel hybrid Buck-boost AC-DC converter with a specific control approach is investigated. These converters are crucial in modern power electronics such as consumer electronic devices, renewable energy systems, and electric vehicles. Buck-boost controls output voltage over a wide input voltage range, used in AC to DC conversion. The architecture of the converter inherits the advantages of both boost and buck topologies, leading to enhanced reliability, efficiency, and compactness. This converter simply connects as a buck converter followed by a boost converter, where a common DC link is used to connect them. By modifying the switch of the converters, the voltage that connects to the load of the novel converter can be effectively controlled. The benefit of a novel Buck-boost converter is compared in this study, using a fuzzy approach, supporting decision-making (FASDM), with a conventional converter. FASDM provides a strong basis for comparing converters and considers key performance metrics like efficiency, THD and input PF. Also, it is the best approach for deciding which converter performs better under different operating situations, since it offers the best approach for decision-making. The results show that the performance metrics of the novel converter outweigh the traditional ones by getting a 0.5 final leaving and entering flow matrix of FASDM compared to -0.5 for a traditional converter, which means a lower performance operation. Our design can be used for faster charging of EV batteries, with lower harmonics.

Keywords: Active switching; Buck-boost converter; Fuzzy logic approach; THD; input PF; Efficiency

1 Introduction

A new circuit of a buck-boost AC to DC converter is used to generate the highly efficient output voltage. This converter combines both boost and buck converters to effectively alter the input voltage and generate a steady output voltage. The name novel or hybrid, refers to the mixture of these two converter types, utilizing the benefits of both to improve efficiency and performance [1]. When choosing and comparing different converter types, such as the new buck-boost converter, the fuzzy approach can be quite helpful. A more complete examination of converter performance is made possible by fuzzy logic, which accounts for uncertainty and imprecision in input factors including variable voltage levels, load situations, and operational efficiencies. By considering many factors like dependability, size, cost, efficiency, and lower losses with pure result, this strategy assists in choosing the best converter for a certain application [2].

The circuitry of the proposed buck-boost converter consists of an input filter, a switching circuit, and a rectifier. The capacitance block is used to control the switching of the converter. During switch activation, the input voltage is processed by the output filter, and during switch deactivation, the output voltage is maintained by the stored energy of the inductor and capacitor. The output filter is crucial for reducing high-frequency disturbances and generating a refined output voltage. Typically, it consists of an inductor and a capacitor linked in series with the load [3-6].

The comparison between the conventional and novel buck-boost converter in the literature review is still inadequate or sometimes missing. The evaluation of the buck-boost converter considers parameters are (IPF, THD, Efficiency, and the damping factor, which is responsible for the system stability. Determination of the damping factor in the open-loop control is executed randomly in this research paper. Furthermore, we use the new approach supporting fuzzy decision-making to validate this comparison. In conclusion, the hybrid buck-boost AC to DC converter is a versatile and efficient power conversion instrument. Its ability to continuously increase and decrease input voltage to maintain a constant output voltage even in the face of significant input fluctuations is one of its key features. It is more efficient than other converters because it makes use of effective switching circuits rather than transformers. It is ideal for applications where weight and space are constrained, such as automotive systems and portable electronic devices, because of its small size and lightweight. Using fuzzy approaches to decision-making enhances the ability to assess and select the optimal converter for a range of applications.

To overcome the aforementioned issues, this study proposes an alternate approach in which the damping loop is created by making minor adjustments and enhancing the system's transfer function. A high capacitance switching is introduced as a filter across the switching IGBT in parallel with the open-loop control, as per the suggested way. The parallel feedforward compensation (PFC) approach is the name given to this arrangement. This approach has been documented to produce good voltage characteristics with high margins of stability. In real-world AC-DC converter applications, design parameters such as efficiency and power factor often fluctuate due to environmental and system-level changes. This creates uncertainty in performance evaluation. To address this, we adopt fuzzy logic decision-making, which is well-suited for handling imprecision in multi-criteria systems. The unique methodology of fuzzy logic decision-making, which makes the process of choosing a high-performance converter easier, serves as further support for this. With improved efficiency, lower THD, and better PFC, the selected converter performs well. One of the applications that can be operated using this new converter as the supplier is electrical vehicle charging, which can be operated with high performance. It is worth mentioning that our work does not include a DC-DC converter because it is not widely used compared to AC-DC applications.

Table 1
Reviewing literature

No.	AC-DC	DC-DC	Original Converter	Novel Hybrid converter	Fuzzy Logic Decision-Making	Preference numbers
A	×	✓	✓	×	×	[6]
B	✓	×	✓	✓	×	[7] [5]
C	✓	×	✓	✓	×	[8]
D	×	✓	✓	✓	×	[9]
E	✓	×	✓	×	×	[10]
F	✓	×	✓	✓	✓	**Our work**

Fuzzy logic has proven effective in modeling and decision-making across a variety of nonlinear and uncertain systems. For instance, it has been applied in telesurgical robotics for accurate force control during tool–tissue interaction [11], in the modeling of shape memory alloy wire actuators with evolving fuzzy structures, and financial systems for dimension-reduced modeling of volatility surfaces using unsupervised learning techniques [12]. Additional studies have utilized fuzzy logic in modeling cognitive observation processes, integrated circuit behavior through active learning principles, and failure mode and effect analysis supported by similarity measures [13]. These works confirm the adaptability and strength of fuzzy approaches in uncertain and complex environments, supporting our decision to adopt a fuzzy logic-based evaluation method in converter performance assessment.

1.1 Paper Contribution

This paper presents two main contributions: (1) the development of a novel hybrid buck-boost AC-DC converter topology that achieves improved efficiency and reduced ripple compared to conventional designs, and (2) the application of a fuzzy logic-based decision-making (FLDM) framework to evaluate and rank converter performance based on multiple criteria, including efficiency, total harmonic distortion (THD), input power factor (PF), and a robustness assessment using random damping factors. In practical AC-DC power applications, key performance parameters often vary due to load changes and environmental disturbances, introducing uncertainty into converter selection. To address this, the FLDM approach integrates imprecise and nonlinear criteria into a unified evaluation structure that enhances decision robustness and adaptability. The remainder of the paper is structured as follows: Section 2 presents the operating principles and structural modeling of both the conventional and novel converters; Section 3 details the FLDM methodology used for evaluation; Section 4 provides simulation results, comparison of results, and Section 5 concludes the paper with performance insights and recommendations for practical deployment.

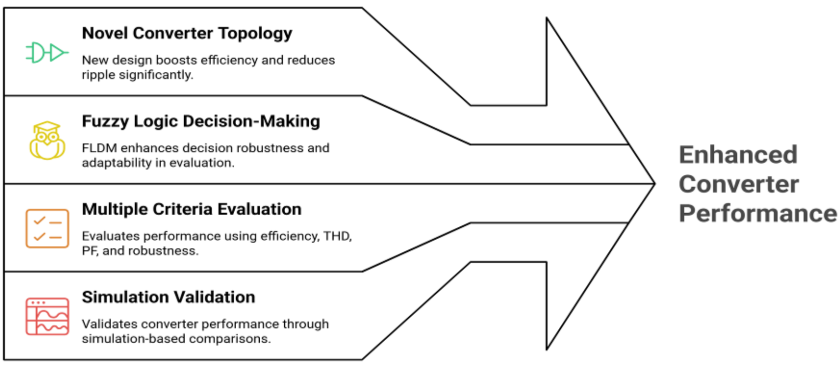

Figure 1
Paper contribution

2 Conventional and Novel Converters and their Control

A new buck-boost converter is presented that is more capable in terms of voltage conversion while maintaining the advantages of traditional converter schemes. This presents a superior solution to the issues of traditional buck-boost converters using optimized converter topology, which enables better performance during not just voltage step-down but also step-up operation. Fuzzy techniques are used for the selection of a converter that will guide the decision-making mechanism. In this way, they provide a more realistic characterization of the quality of a converter, as they include errors in input parameters and operation state. In some studies, for example, fuzzy logic is used to compare today's buck-boost converter with the traditional buck-boost converter because of a couple of parameters such as efficiency, voltage gain and reliability [14].

The optimal converter configuration will always be chosen for specific applications thanks to this enhanced decision-making ability. Regarding the new topology in electronic devices, by adding elements to improve the stability of the system, we add the switching capacity to make the system operation more efficient. Using a bridge rectifier rather than a transformer results in lower total costs and lighter weight. The design increases operating efficiency by eliminating hysteresis and minimizing potential energy losses caused by transformer magnetization. The conventional converter illustrated in Fig. 1 (a) includes the buck-boost converter without the switching block switching filter, but the novel modeling shown in Fig. 1(b) includes the switching blocking to increase the converter efficiency.

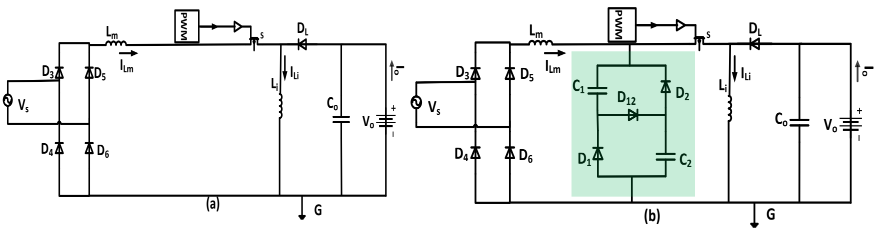

Figure 2
Buck-boost model (a) conventional converter (b) novel converter

The traditional buck-boost converter in Fig. 2(a) is a versatile power electrical device that can step up or step down voltage levels. It consists of an inductor, a diode, a switch, and an output capacitor. A consistent output voltage is made possible even in the presence of input disturbances by the energy that is stored in the inductor when the switch is on and released to the output when it is off. The buck-boost converter is ideal for applications with an AC input since it is currently used to adjust the input DC voltage. For the novel converter shown in Fig. 2(b), the switching capacitors C_1 and C_2 assist the charging operation of the buck-boost inductor L_i and output capacity C_o during both the positive and negative half cycles, as illustrated in Fig. 5 (a) and (b). Due to the reverse bias of D_{12} and the forward bias of D_1 and D_2, the capacitors are linked in parallel during the positive half cycle, which enables them to charge to half of the DC link voltage. On the other hand, because of D_{12} positive bias, C_1, and C_2 are linked in series with the DC link voltage during the negative half cycle shown in Fig. 5. The principles of energy conservation and charge balancing, in a steady state, are utilized to ensure the energy stored in the inductors and capacitors, remains steady throughout a complete cycle. Output voltage equations can be obtained by using this concept:

$$E_{Lm} = \frac{1}{2} L_m \, I_{Lm}^2 \tag{1}$$

$$E_{Lo} = \frac{1}{2} L_o \, I_{Lo}^2 \tag{2}$$

$$I_i T_{on} = I_O \, T_{off}, \, I_{lm} T_{on} = I_{lO} \, T_{off} \tag{3}$$

$$I_{lm} = \frac{V_i - V_c}{L_m} \, T_{on} \, , I_{lm} = \frac{V_i - 2V_c}{L_m} \, T_{off} \tag{4}$$

During the operation of the duty cycle, the output voltage will change with the PWM changing as the voltage gain with the duty cycle, as illustrated in Fig. 3.

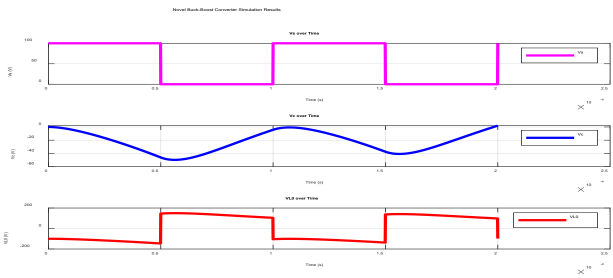

Figure 3
Duty cycle with the voltage gain

$$V_c = \frac{V_i}{(2-D)}, \, and \, V_o = \frac{-V_c \, D}{(1-D)} \tag{5}$$

The output voltage regarding the power passing through the converter, as the analysis of the current passing through the capacitance and inductance will be in equation (6).

$$V_o = \frac{\frac{-V_i}{(2-D)} D}{(1-D)} = \frac{-V_i \, D}{(2-D)(1-D)} \tag{6}$$

As a result, this approach verifies the output voltage equation that is derived from volt-second balancing and duty cycle analysis. Numerous approaches yield identical results due to the reverse diode, indicating the precision and resilience of the analysis for the innovative Buck-Boost AC to DC converter. It doesn't happen with the 2-D conventional converter since the input circuit lacks a capacitance switch.

$$V_{oc} = \frac{V_i \, D}{(1-D)} \tag{7}$$

As illustrated voltage gain in Fig. 4, the output voltage gains of the novel converter are less than the traditional converter due to the capacitance-blocking switching filter because of this, the output voltage will have a higher performance at step-down operation.

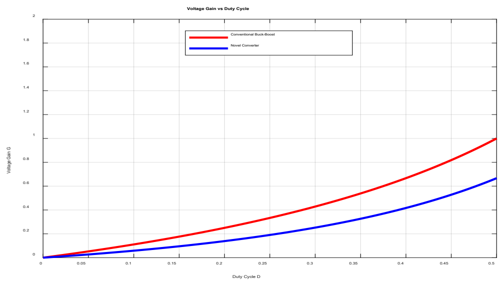

Figure 4
Voltage gains of both converter

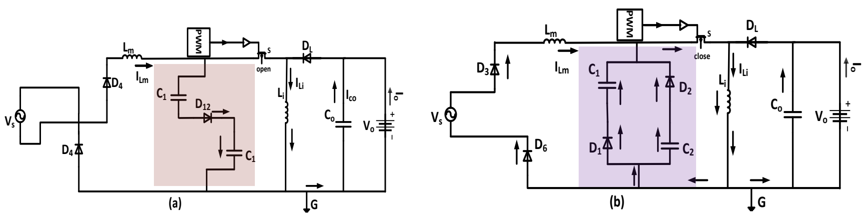

Figure 5
Passing currents in (a) Positive state operation, (b) Negative state operation

At high-duty cycles, such as 5%, 10%, 30% and 50%, any converter's efficiency typically decreases due to magnetization losses and a loss of hysteresis. The suggested architecture may lead to a more efficient converter than traditional ones since it may achieve the same voltage gain at a lower duty cycle. To analyze the stability of the system, the transfer function of the converter should include the zeroes and poles of the system, and the phase margin to determine which system can reach stability faster than the other. An open loop was used to create the transfer function of the system.

$$\eta_C = \frac{P_o}{P_i} = \frac{v_o}{|v_i|}\frac{(1-D)}{D} \tag{8}$$

$$\eta_N = \frac{P_o}{P_i} = \frac{v_o}{|v_i|}\frac{(2-D)(1-D)}{D} \tag{9}$$

$$THD = \frac{\sqrt{\sum_{N=2}^{\infty} V_N^2}}{V_1} \quad and \quad IPF = \frac{V_i\, I_i}{V_{rms}\, I_{rms}} \cos \emptyset \tag{10}$$

$$\eta_N = \eta_C(2 - D) \tag{11}$$

As compared to the conventional and the new type of converter, in comparison to the other converter, the new converter operates at a high degree of efficiency. The performance and stability of the new converter will be enhanced, and there will be less ripple loss because it has a lower voltage gain than the conventional converter. To analyze the stability of the system, the transfer function of the converter which can include the zeroes and poles of the system, and the phase margin to determine which system can reach stability faster than the other, as illustrated in Fig.6 we used the open loop to create the transfer function of the system.

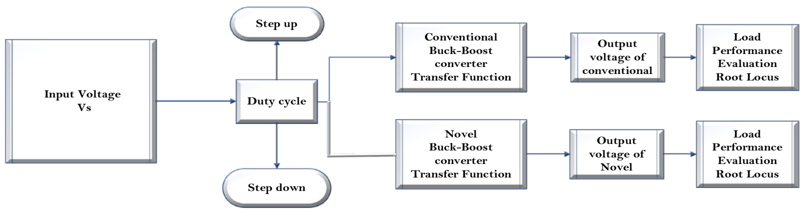

Figure 6
Transfer function block diagram

The transfer function of both converters can give us the Bode diagram of the converter to show the system stability with the parameters of the converter. For the conventional converter, the transfer function that is responsible for the system's stability is as the following with the ripple,

$$H_{conv} = \frac{-D}{L*C*S^2+R*C*S+(1-D)^2} \tag{12}$$

$$\Delta i_L = \frac{V_{in}\,D\,(1-D)}{L*F_S} \quad and \quad \Delta i_C = \frac{i_o\,D}{F_S\,C} \tag{13}$$

The novel converter has a switching capacitance with increasing it is stability as compared to the other converter.

$$H_{novel} = \frac{-D}{S^2\frac{(2-3D)(L_m+L_i)C_{total}}{R}+S\frac{(2-3D)(L_m+L_i)}{R}+2-3D+D^2} \tag{14}$$

$$\Delta i_{Lnovel} = \frac{V_{in}\,D\,(1-D)}{(L_m+L_i)*F_S}, and\ \Delta i_{Cnoval} = \frac{i_o\,D}{F_S\,C_{total}} \tag{15}$$

Regarding the equations and the analysis of both converters, the results and the stability of the system can be shown in the following curves, which indicate that the novel converter reaches system stability faster than the other converter.

Table 2

Items: Components of the converter

Components	Symbols	Values
Inductors	Lm	10 mH
	Lo	10 mH
Capacitors	C1	470 µF
	C2	470 µF
	C0	2200 µF
Resistor	RL	500 Ω
Frequency	FS	50 khz

Based on the findings presented in Fig. 7, which shows the system stability for the traditional and novel buck-boost converter. This frequency response indicates the output transfer function gain, which provides insights into the stability and performance of the converters over a range of frequencies. For the conventional converter, the bode plot shows the gain margin and the phase margin which is lower than the novel converter, the system will appear to the system stable but with lower performance compared to the other converter because the novel converter typically has a higher gain margin and phase margin which indicating better stability and performance over the range of frequency.

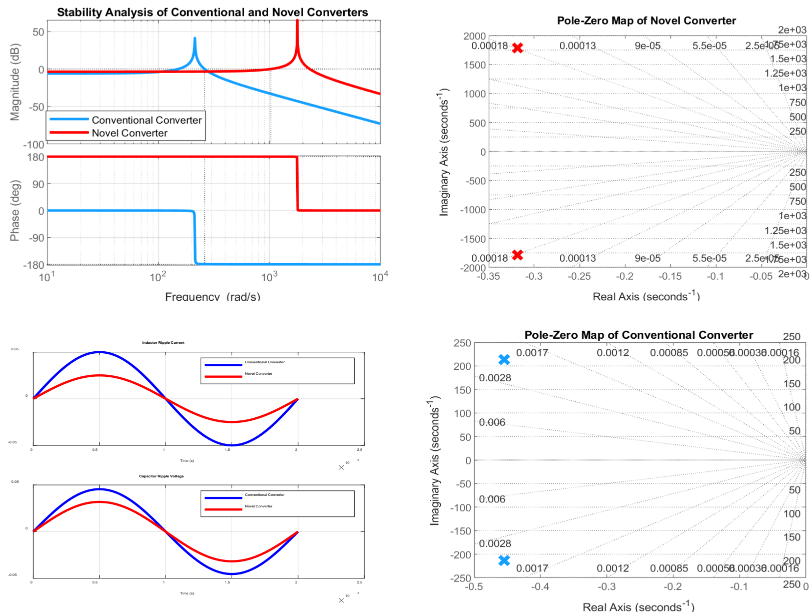

Figure 7

The frequency response of the system gains output transfer function and Pole-zero plot

Regarding the pole-zero plot shown in Fig. 7, which indicates the pole-zeros for the conventional converter in the left half of the s-plane that indicating the system stability, but the novel converter shows pole and zeros more spread out, which makes the system more complex but potentially a more stable and responsive system. The system will be operating with a good output without distribution of the sinusoidal wave, indicating the system will working with a lower loss. Therefore, both converters shown the ripple of the system in Fig. 7 the converter that works with lower ripple indicated better stability, for the conventional converter the ripple current in inductance is 0.050 A and for the novel converter shown has 0.025 A, for the ripple voltage in case the conventional converter is operating the ripple voltage of the capacitor around 0.0455 V but for novel converter across the capacitors are 0.0318 V regarding to that the frequency output of the conventional is 1.07 Khz and the novel will be 0.63 Khz, however, the novel converter has the lower ripple current, voltage, and output frequency switching, then the novel converter demonstrates better performance which can lead to improved stability and efficiency in applications requiring precise voltage regulation.

The Nyquist plot is shown in Fig. 8, the real part of the system transfer function against its imaginary part as the frequency varies, which is useful for analyzing stability. The Nyquist result shows a complex with the real part of the frequency response but the novel, converter has a wider dB than the other converter in this case, it has better performance because has a higher gain margin which makes the novel converter less susceptible to becoming unstable and has a wider range of operating conditions. The step response of both converters, as illustrated in Fig. 8, indicates that the novel converter has a much faster response than the other converter and a smaller overshoot with a lower settling time. In this case, the input voltage will change much faster than the conventional converter with high performance.

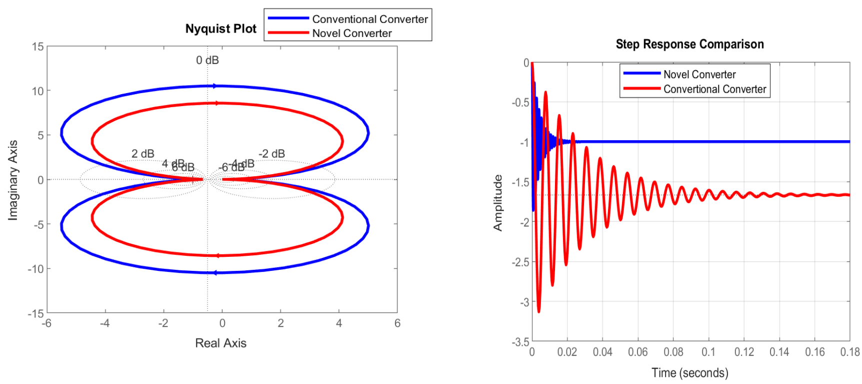

Figure 8

The Nyquist plot of both converters and the step response plot of both converters

3 Comparison of Conventional and Novel Converters Using (FLDM)

Fuzzy decision-making has found applications in a wide range of areas, including supply chain management, banking, engineering, and healthcare. In the face of financial uncertainty, it aids in evaluating investment prospects and enhances engineering system controls. It supports diagnostic and treatment planning in the healthcare sector as well as demand forecasting and inventory control in supply chain management [15-18]. Moreover, its versatility allows for more in-depth research due to its capacity to adjust to different situations. A recent study has highlighted the use of FLDM in sustainable energy systems and smart energy management [19], showcasing its relevance in addressing contemporary challenges. When evaluating parameters like THD, Efficiency, and PF, fuzzy decision-making is a helpful technique for combining them. These factors may be given different weights and trade-offs. Decision-makers can weigh the benefits and drawbacks of many options while taking into consideration the interdependencies and complexity of these factors, thanks to fuzzy logic. As a result, judgments are more well-informed and balanced and consider both objective and subjective evaluations, which is an aspect that is frequently critical in technical and operational settings. All things considered, FLDM improves decision-making in an increasingly complex world by offering more flexibility and precision. It is difficult to determine whether the converter is superior because MATLAB takes a while to display changes in THD, efficiency, and IPF with different duty cycles. The intermediate duty cycle value of 50% and the safety factor – the Q value in charge of regulating the system's stability – can be found using the fuzzy FLDM concerning the efficiency, THD, and IPF equations.

The FLDM approach considers three primary objectives: minimizing THD, maximizing input PF, and maximizing efficiency. These are treated as competing objectives in a fuzzy environment, and the solution corresponds to the converter with the best outranking flow score. The approach avoids traditional gradient-based optimization, relying instead on preference-based ranking for practical decision-making.

4 Simulation Results

4.1 Steps of the Fuzzy Decision-Making Approach

Multiple steps are involved in the fuzzy decision process to determine which converter is best. We can use the best converter for a variety of tasks, such as PV systems and EV battery charging, based on the fuzzy decision's result [20].

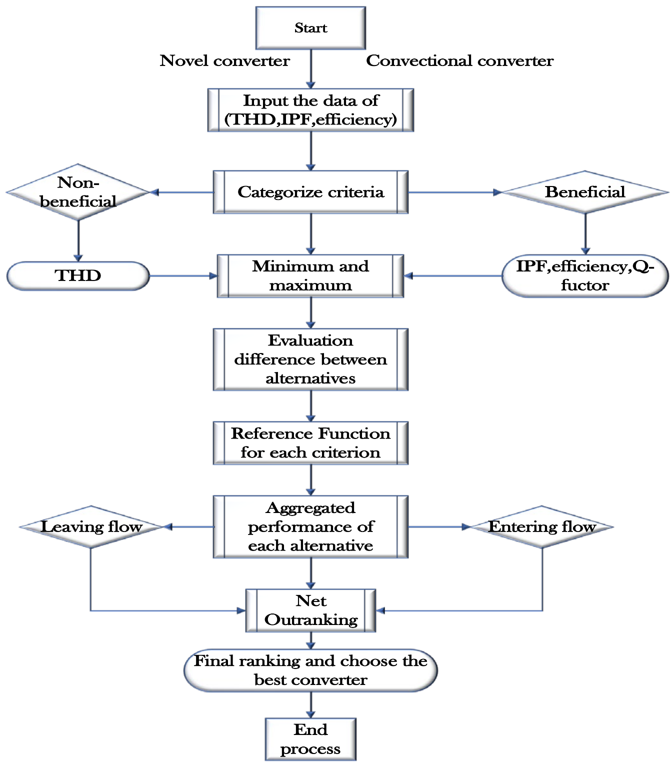

Figure 9
Flowchart for fuzzy decision-making process

There are a lot of steps to reach and select the best converter by using this approach. All the steps are indicated in the flowchart, which has all the details of the algorithms that are used for solving and selecting the best rank. The flowchart, as illustrated in Fig. 9, includes all the steps of this approach to choose the high-performance converter. After the calculation was made, we took the two files for each converter and put them as the comparison items.

The algorithm proceeds as follows: (1) Normalize THD, IPF, and efficiency; (2) Identify beneficial/non-beneficial criteria; (3) Apply the reference function; (4) Calculate aggregated performance; (5) Derive outranking flow and final decision.

4.2 The Values of THD, IPF, and Efficiency

The three crucial components (efficiency, THD, and IPF) that influence the converters' performance after calculations determine the two values of the buck-boost converter with the original circuit and the new converter, as shown in Fig. 10 and Table 3.

Table 3
Comparison of converters

Types	Efficiency	IPF	THD %
Conventional Converter	0.8987	0.8076	35.175
Novel Converter	0.9019	0.8376	30.3625

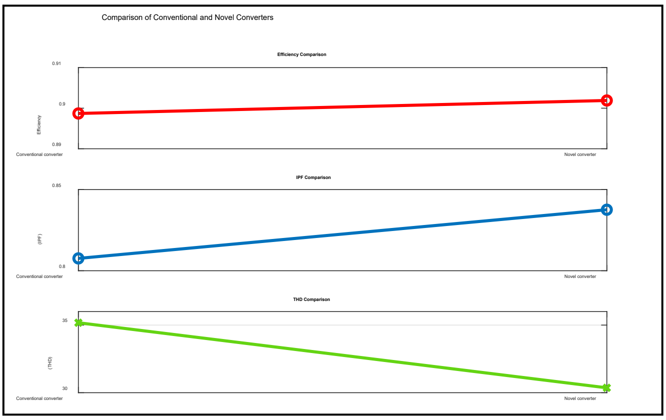

Figure 10
Output metrics of converters

To determine the safety factor or damping factor, I will use Q=0.8, the medium value for both converters, which shows that the system is functioning in a good, stable manner.

4.3 Criteria Categorization and Outranking Flow Analysis

There are a lot of steps to consider in the analysis of FMSDM. The equations that are used for the analysis are indicated in Table 4.

Table 4
Key points Equations

	Beneficial criterion Non-beneficial criterion	Reference function	Aggregated performance	Leaving-with entering-outranking flow
A	$I_{ij} = \frac{N_{ij} - \text{Min}(N_{ij})}{\text{Max}(N_{ij}) - \text{Min}(N_{ij})}$	$f_{ij}(\text{A},\text{B}) = 0 \quad If \quad R_{Aj} \leq R_{Bj}$	$\partial(\text{A},\text{B}) = \frac{\left[\sum_{j=1}^{n} M_j f_j(\text{A},\text{B})\right]}{\sum_{j=1}^{n} M_j}$	$\emptyset^{+} = \frac{1}{N-1} \sum_{B=1}^{N} \partial(\text{A},\text{B}) \qquad A \neq B$
B	$I_{ij} = \frac{\text{Max}(N_{ij}) - N_{ij}}{\text{Max}(N_{ij}) - \text{Min}(N_{ij})}$	$f_{ij}(\text{A},\text{B}) = R_{Aj} - R_{Bj} \quad If \quad R_{Aj} > R_{Bj}$	-	$\emptyset^{-} = \frac{1}{N-1} \sum_{B=1}^{N} \partial(\text{B},\text{A}) \qquad A \neq B$

Must categorize each of your decision criteria – THD, PFC, Efficiency, and Safety Factor – as advantageous or ineffective to determine which option is best. For each criterion, this categorization establishes whether a greater or lower value is preferred. Beneficial criteria are the higher values that are regarded as better or more desirable in beneficial criteria [21]. Increasing the weight of these variables leads to improved performance or decision-making. Typical examples are profit, efficiency, and performance ratings. Use the following formula to standardize data in decision-making models while normalizing favorable criteria. This ensures that the highest value gets the best score, making the criterion beneficial regarding point A in Table 3. The non-beneficial criteria, lower values are acceptable or preferred. In this instance, lowering the value leads to better performance or a more intelligent decision. Expenses, risks, and dangerous emissions are among the instances. By using the formula, the normalizing process for non-beneficial criteria is reversed. The formula ensures that the lowest value is rewarded with the highest normalized score, making the criterion non-beneficial in point B. Calculating the variations in evaluation between the options. This procedure compares each alternative to the others according to each criterion, assisting in the identification of advantages and disadvantages in comparison to the competition. This stage gives a clear picture of how each option performs by calculating the differences between the normalized values of alternatives for both non-beneficial and beneficial criteria. These distinctions are crucial for prioritizing options and advancing toward the choice that best satisfies the goals of the decision-making process. When making fuzzy decisions, evaluating the distinctions between options is the first step toward identifying the reference function. This function shows the degree to which option A is preferred over option B for a given criterion j. Typically, the computation uses the normalized data of the alternatives to evaluate the performance difference between them. Using the reference function to calculate the relative preference or dominance of one option over another allows decision-makers to rank the options based on both positive and non-beneficial variables, as shown in Table 3, points A and B. The preference values from every criterion are combined into a single score for each alternative in the aggregated performance. This is achieved by averaging or summing the reference function values, weighted by the importance of each criterion, to allow for a final comparison and ranking of possibilities. Aggregated performance function ∂(A, B), which is shown in Table 3. The matrix of the aggregation of both converter and outranking is shown in points (16) and (17) and Fig. 11 covers all the steps and values of the comparison process.

$$\partial(A,B) = \begin{bmatrix} - & 0.25 \\ 1.25 & - \end{bmatrix} \tag{16}$$

$$\emptyset(A) = \begin{vmatrix} 0.125 & 0.625 \\ 0.625 & 0.125 \end{vmatrix} = \begin{bmatrix} -0.5 \\ 0.5 \end{bmatrix} \begin{bmatrix} 2 \\ 1 \end{bmatrix} \tag{17}$$

Criteria / Path Planning Algorithms	Duty Cycle	Efficiency	Power Factor Correction	Total Harmonic Distortion	Safety Factor / Damping	Conventional Buck-boost	Novel Buck-boost Converter	Max, Min	Normalized Values (Conventional)	Normalized Values (Novel)	Reference Function	Weight	Results
Duty Cycle	0.5											0.5	
Efficiency		0.8987				0.8987	0.9019	(0.9019, 0.8987)	(0.8987 - 0.8987) / (0.9019 - 0.8987) = 0	(0.9019 - 0.8987) / (0.9019 - 0.8987) = 1	1	0.5	0.25
Power Factor Correction			0.8076			0.8076	0.8376	(0.8376, 0.8076)	(0.8076 - 0.8076) / (0.8376 - 0.8076) = 0	(0.8376 - 0.8076) / (0.8376 - 0.8076) = 1	1	0.5	
Total Harmonic Distortion				35.175		35.175	30.3625	(35.175, 30.3625)	(35.175 - 35.175) / (35.175 - 30.3625) = 0	(35.175 - 30.3625) / (35.175 - 30.3625) = 1	1	0.5	
Safety Factor / Damping Factor					0.8	0.8	0.8	(0.8, 0.8)	#DIV/0!	#DIV/0!	1	0.5	

final results				
Comparison Matrix	**Conventional Buck-boost Converter**	**Novel Buck-boost Converter**	**Performance Function**	**Leaving Flow**
Conventional Buck-boost Converter	–	0.25	0.125	0.125
Novel Buck-boost Converter	1.25	–	0.625	0.625
Entering Flow	0.625	0.125	–	–
Final Matrix	**Leaving Flow**	**Entering Flow**	**Result**	**Rank**
Conventional Buck-boost Converter	0.125	0.625	-0.5	Low Performance
Novel Buck-boost Converter	0.625	0.125	0.5	High Performance

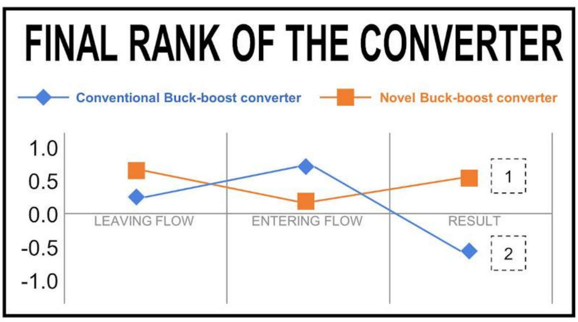

Figure 11
Results of the rank comparisons

The final calculation is to choose the best rank by using the flow outranking process. The departing outranking flow shows how much an option outranks others, and the entering outranking flow shows how much an alternative is outranked when making hazy decisions. The distinction between them, referred to as the net outranking flow, helps identify which choices work better overall. Net outranking flow for each alternative, Leaving Outranking Flow (LOF), and Entering Outranking Flow (EOF) to get the final matrix of outranking.

These flows help in ranking the alternatives by showing which ones perform better relative to the others based on the overall criteria evaluation. Based on the most recent evaluation results of fuzzy decision support approaches, the new back boost converter performs better than the original converter. Because of this, the novel converter's new switching capacitance allows the load to operate with minimal ripple. However, because the damping factor varies, the comparison may be evaluated using codes, and the new converter performs better in the assessment that follows. Use the closed-loop control for both converters even though the damping factor is random to get the precise value for the safety factor or damping factor, the process operation of this random to choose the best value of the damping Q factor that gives the best converter as the following flowchart as illustrated in Fig.12 and results in Fig. 13.

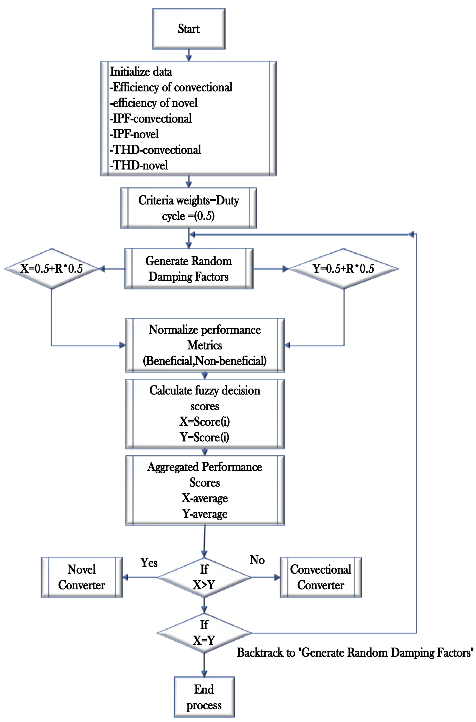

Figure 12
The process to choose the best converter in case the damping factor is random

Regarding the process above, this can be implemented to choose the specific value of the damping factor that makes the novel converter work with high performance as compared to the other. By using the closed-loop control, the system will generate the main damping factor that makes the system's operation stable.

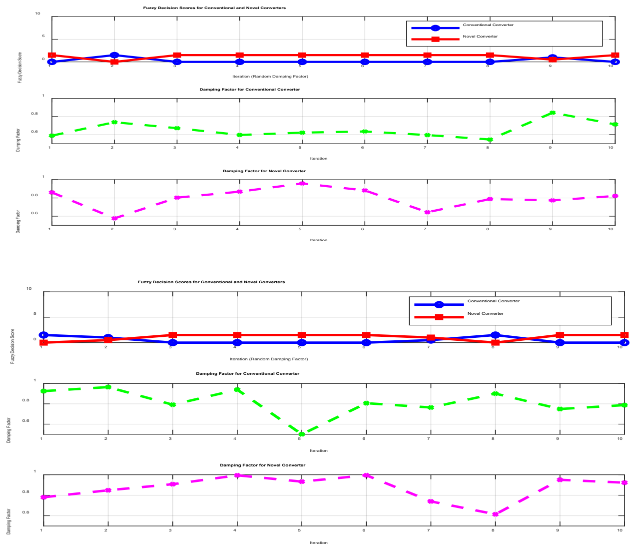

Figure 13

Other results for the performance with random Q-factor

To validate the efficiency of the suggested approach for both converters. Other simplifying presumptions were applied in the theoretical study. Some instances of ideal component behavior include modelling the input voltage waveform as a rectified sinusoid and simulating the output voltage as a pure DC source by using a large output capacitor to eliminate ripple effects. With the provided data values, as shown in Fig. 14 MATLAB was used to model both the standard and converters.

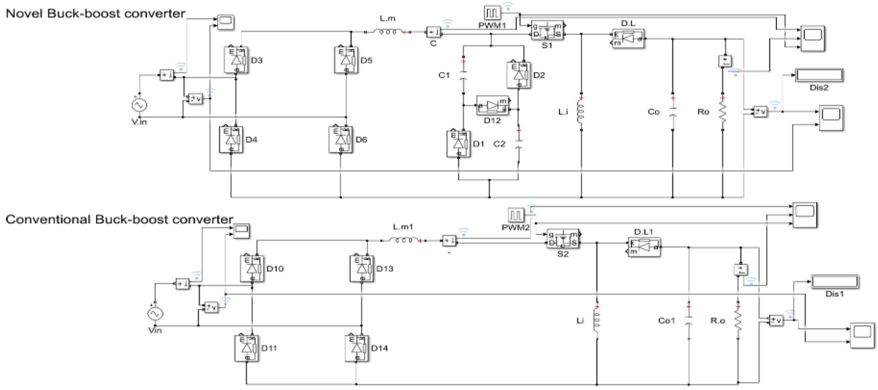

Figure 14
MATLAB simulation of converters factor

Regarding Fig. 15, the input inductance has a high issue and is unstable at the beginning of the operation of the converter, because of the overshoot occurring at the first operation of the converter. To solve this issue by using filters or closed-loop control operation will minimize the overshoot as illustrated in Fig. 16.

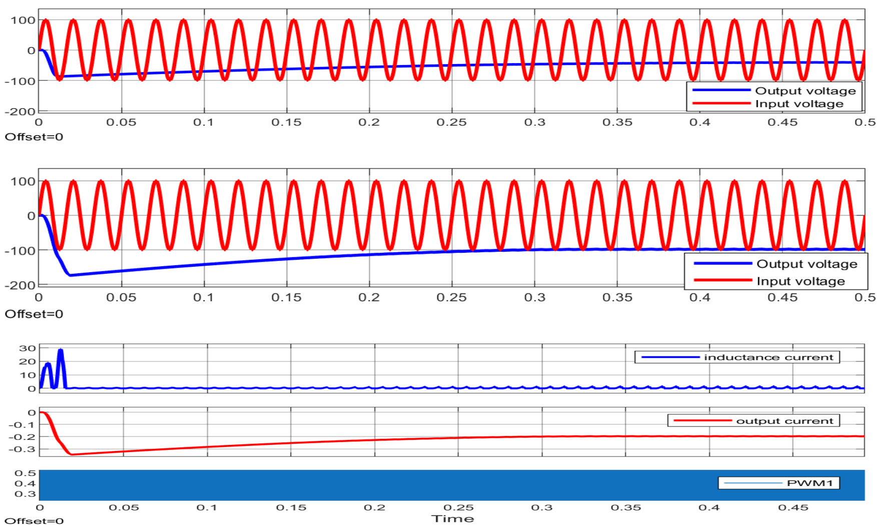

Figure 15
Output voltage at D=30 and D=60 for the conventional converter with currents and PWM

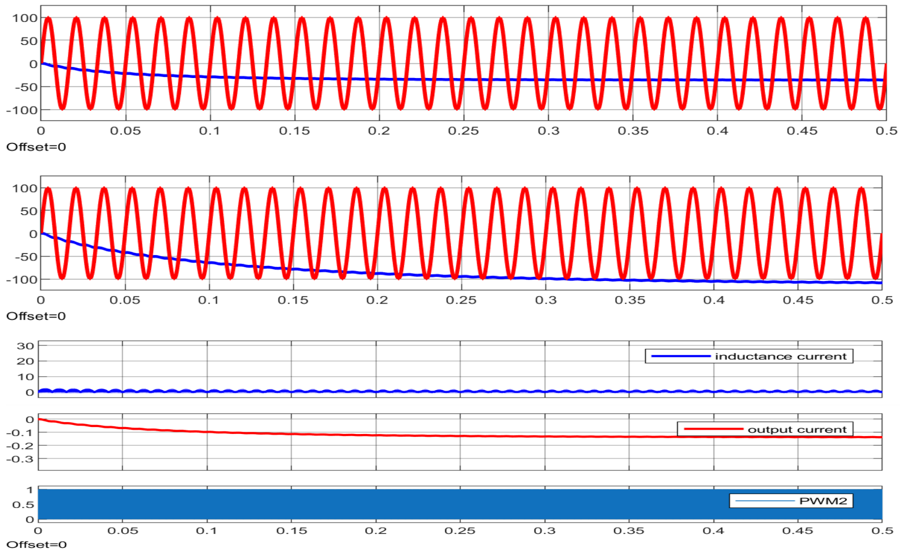

Figure 16
Output voltage at D=30 and D=70 for a new converter with currents and PWM

To ensure a valid comparison, both converters were simulated using identical input parameters and passive component values, differing only in topology and control. The novel converter demonstrates improved output voltage performance compared to the conventional design. Once steady-state values are achieved, a fuzzy decision-making approach is applied to support the comparison. Based on the analysis, the novel converter is well-suited for electric vehicle (EV) charging applications, enabling higher efficiency and faster battery charging. By setting the duty cycle above 0.5, the output voltage exceeds the input, allowing the converter to effectively supply the EV system. The operation of this configuration is illustrated in Fig. 17.

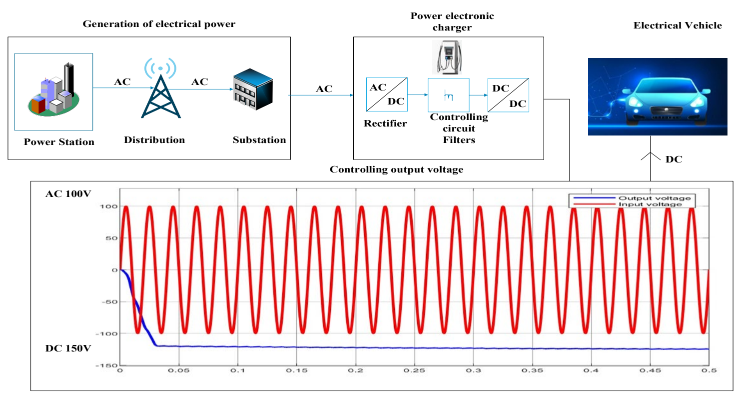

Figure 17
System operation with EV

Conclusions

In this article, we tested new technology and made comparisons between the converters, to select the best for use as a supply, to load devices, such as electric vehicles. Performance indicators such as efficiency, THD and IPF metrics increased significantly in the novel converter built, with an original topology combining buck and boost functionalities.

The application of the fuzzy logic approach, enabled a systematic analysis of uncertainties in both converter systems, leading to a more reliable and flexible comparison. Simulation results demonstrated that under varying operating conditions, the novel converter consistently outperformed the conventional design, by achieving a lower THD and higher efficiency. This improvement is primarily attributed to its enhanced switching-capacitor topology, which minimizes power losses and stabilizes output voltage under fluctuating inputs. Additionally, the novel converter proves highly suitable for electric vehicle charging applications, particularly where compact and efficient power delivery is required.

The fuzzy decision-making approach proved to be a valuable tool in selecting the optimal converter, as it enabled the simultaneous evaluation of multiple performance factors such as efficiency, stability and effectiveness under uncertain operating conditions. The proposed fuzzy decision-making approach significantly enhanced the converter selection process by accommodating multiple performance criteria under varying and uncertain conditions.

Beyond improving decision accuracy, it established a flexible framework suitable for a wide range of operational scenarios. This adaptability makes it particularly effective for control structures involving filters and switching capacitors.

The simulation results, covering both steady-state and transient responses, further validate the reliability and efficiency of the novel converter, when evaluated using this method.

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