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COMPREHENSIVE REVIEW OF DC-DC CONVERTERS IMPLEMENTED WITH DIFFERENT CONTROL ALGORITHMS FOR ACHIEVING HIGH-EFFICIENCY

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Abstract

In this article, a comprehensive review of DC-DC converters implemented with different control algorithms for achieving high efficiency is presented. The brief literature review will enable us to find an efficient converter and its corresponding algorithm. To overcome the energy deficiency problem, renewable energy resources such as fuel cells and solar cells play an important role. In renewable energy applications, high-efficiency DC-DC converters act as a challenging factor in providing better-regulated output. The output voltage of the converters can be controlled by linear or non-linear controllers. The traditional controllers (PI/PID) are used to reduce oscillations and to improve the loop gain. Non-linear controllers like fuzzy controllers and sliding mode controllers provide fast transient and stable steady-state responses, even though variations are present in input, reference, and output voltages. The detailed description of the converters and controllers is discussed with suitable diagrams and expressions.

Index Terms: DC-DC Converter, Fuzzy Controller, PI Controller, PID Controller, Sliding Mode Controller.

1. INTRODUCTION

The applications of power electronic converters are uninterrupted power supplies, electric vehicles, smart grids, photovoltaic systems, and numerous industrial goods and applications. In most power electronics topologies, power switches are used and controlled by pulse width modulation techniques. Various power converter topologies are used, such as DC-DC, DC-AC, or AC-DC, based on the applications. In numerous industrial and technological products, switched-mode DC-DC converters are broadly used and implemented. In different applications, different types of DC-DC boost converters such as buck-boost, flyback, boost, Cuk, buck, sepic, etc. are employed [1].

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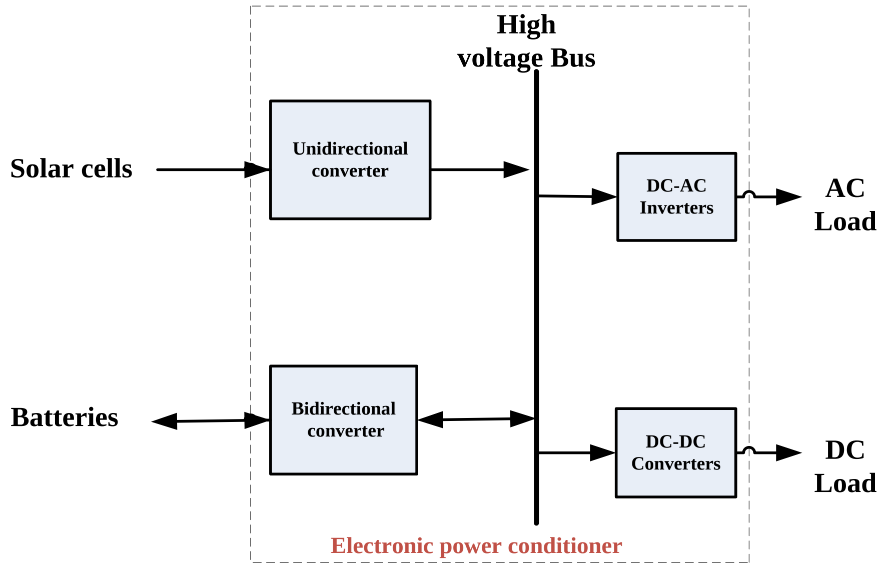

Fig 1: Architecture of power distribution system [2]

The architecture of the power distribution system contains the Electronic Power Conditioner (EPC) unit depicted in Fig. 1, which combines a unidirectional converter, a bidirectional converter, inverters, and converters. The unidirectional and bidirectional converters obtain inputs from solar cells and batteries. The inverters and converters get their input from the high-voltage bus. The output of the electronic power conditioner unit is provided to the load [2]. Dual-active-bridge (DAB) converters include several fundamental and significant features, such as symmetric structure, bidirectional power transmission capacity, and easy zero-voltage switching operation without the need for additional components. Dual-active-bridge converters are used in distributed generating systems, DC microgrid systems, uninterrupted power supply systems, and aviation power systems. [2]. In energy processing applications, DC-DC switching converters are widely used. Efficiency is the most valuable parameter in battery-operated applications to minimize losses. A simple modulation technique known as phase shift modulation is applied to control the power transfer in the converter topology [2].

Table 1 describes the comparison of different DC-DC converters. The hybrid converter operated with the input of 380 V produces an output of 95-190 V. The converter achieved an efficiency of 96.8 % with a power of 1200 W [3]. The filter-based converter gained an efficiency of 94 % with a power of 150 W. The converter functioned with a voltage of 40-60 V and obtained an output of 400 V with a frequency of 60 kHz [4]. The power controller-based converter operates with an input of 100 V, and it also produces an output of 20-30 V. The converter frequency is 2.5 kHz with a power of 476 W and achieves an efficiency of 94% [5]. The converter which is implemented using phase shift control obtained an efficiency of 92 %, from the 125 W. The converter also produces an output of 50 V from an input of 200 V and a frequency of 20 kHz[6]. The phase shift modulation-based converter has obtained an output of 50-60 V from the input of 30-70 V with a frequency

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of 40 kHz [7]. The AC/DC converter with the matrix principle attained an efficiency of 96.1 % from the 2200 W power. The converter also results in an output of 200 V from the input of 236.3 V with a frequency of 20 kHz [8]. The converter which works under artificial intelligence attained an output of 40 V and an efficiency of 92.7 %. The converter is implemented with a frequency of 50 kHz, an input of 100-140 V, and an output of 40 V [9]. The converter operated with the triple phase shift modulation reached the efficiency of 98 % from the 1000 W power. The converter functions with an input of 200 V and produces an output of 160-230 V [10]. The converter which works under the input serial and output parallel-based approach obtained an output of 50 V from the input of 150 V. The converter attained an efficiency of 94 % from the 600 W power [11].

Table 1: Comparison Of Different Converters With Their Efficiency

Ref	Converters	Input voltage(V)	Output voltage(V)	Switching frequency(kHz)	Rated power(W)	Efficiency (%)
[3]	Hybrid converter	380	95-190	50	1200	96.8
[4]	Filter based converter	40-60	400	60	150	94
[5]	Power controller-based converter	100	20-30	2.5	476	94
[6]	Converter with phase shift control	200	50	20	125	92
[7]	Converter with phase shift modulation	30-70	50&60	40	NA	NA
[8]	Matrix-based AC/DC converter	236.3	200	20	2200	96.1
[9]	Artificial intelligence-based converter	100-140	40	50	140	92.7
[10]	Converter with triple phase shift	200	160-230	20	1000	98
[11]	ISOP (input serial output parallel) converter	150	50	20	600	94
[12]	Q-capability converter	20-40	36	20	100	95.8
[13]	Converter for generation system	100-140	40	50	140	92.5
[14]	IPOP (input parallel output parallel) converter	270	0-270	100	1400	96.84
[15]	High-frequency converter	400	320-480	10	5600	95.5
[16]	GaN-based converter	200	50	1000	186	93.4
[17]	Converter with zero voltage switching	300 & 200	20 & 28.8	200	1000 & 200	86.37 & 92.27
[18]	Single- stage single-phase converter	200	156	25	500	90.6
[19]	Converter with multiple phase shift	50	30-50	8	125 & 250	86
[20]	Fuel cell-powered converter	25	350	100	550	90
[21]	zcs-based dc-dc boost converter	20	350	1	350	93.33

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The converter produced an output of 36 V from the input of 20–40 V and a frequency of 20 kHz [12]. The converter that applies to the generation system results in an output of 40 V from the input of 100–140 V. The converter is operated with a frequency of 50 kHz and reaches an efficiency of 92.5% [13]. The input-to-output parallel-based converter, operated with a frequency of 100 kHz, produced an output of 0-270 V from the input of 270 V. The converter achieved an efficiency of 96.74% from the 1400 W power [14]. The high-frequency-based converter reached an efficiency of 95.5% from the 5600 W power. The converter obtained an output of 320–480 V from the input of 400 V with a frequency of 10 kHz [15]. The converter was designed using GaN, resulting in an output of 50 V and an efficiency of 93.4%. The converter is operated with an input of 200 V and a frequency of 1000 kHz [16]. The soft switching-based converter achieved an efficiency of 86.37 and 92.27% from the power of 1000 and 200 W. The converter results in an output voltage of 20 and 28.8 V from the input voltage of 300 and 200 V [17]. The single-stage single-phase converter functioned under an input voltage of 200 V, producing an output of 156 V. The converter is operated with a frequency of 25 kHz and reaches an efficiency of 90.6% from the 500 W power [18]. The converter with the multiple phase shift technique attained an efficiency of 86% from the power of 125 and 250 W. The converter is operated with an input of 50 V and produces an output of 30–50 V [19]. The fuel cell-powered converter achieved an efficiency of 90% from the power of 550 W. The converter produced an output of 350 V from the input of 25 V with a frequency of 100 kHz [20]. The zcs-based dc-dc boost converter functioned using an input of 20 V and produced an output of 350 V. The converter reached an efficiency of 93.33% with a power of 350 W and a frequency of 1 kHz [21].

2. DC-DC CONVERTERS WITH HIGH-EFFICIENCY

Based on the efficiency, DC-DC converters are classified into various types, such as two-port and multi-port converters, as depicted in Fig. 2.

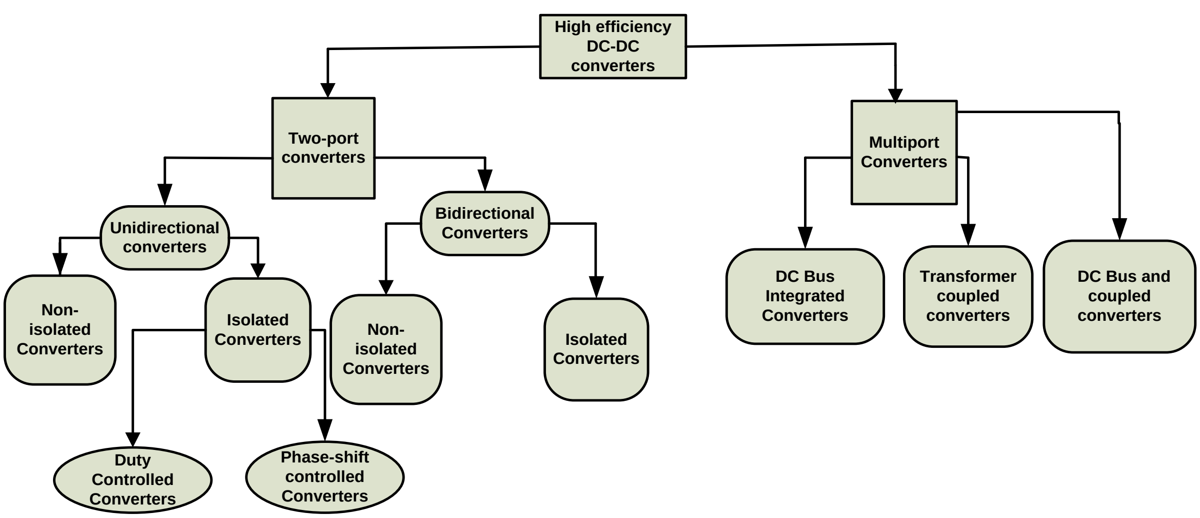

Fig 2: Classification of High-efficiency DC-DC converters [2]

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The high-efficiency DC-DC converters are classified into two-port converters and multiport converters. If the input or output source terminals are two, then it is known as a two-port converter. If the input or output source terminals are more than two, they are known as multiport converters. The two-port DC-DC converters are classified into non-isolated converters and isolated converters.

The two-port non-isolated converters are boost, buck-boost, buck, and Cuk converters. These converters provide good power factor correction. The two-port isolated converters are single-switch forward, flyback,full-bridge, two-switch forward, and push-pull converters. These converters provide high voltage gain. The isolated converters are classified into duty-controlled converters and phase-shift-controlled converters. The duty-controlled converters keep the switching frequency constant and regulate the output voltage.

The full-bridge converter is one of the duty-controlled converters that provides high power capability and low-voltage device stress. The converter practices the phase shift technique known as phase-shift-controlled converters. The full-bridge resonant transition converter is one of the phase-shift-controlled converters that is used to obtain high voltage gain. The good-isolated bidirectional converter is a dual-active bridge converter because of its better power-handling capability and simple topology. [2].

The two-port isolated unidirectional converter is depicted in Fig. 3 [22]. The two-port non-isolated bidirectional converter is depicted in Fig. 4 [23]. The non-isolated two-port converters with a bidirectional flow provide high efficiency, soft switching, and a high conversion ratio [24].

The multiport converters are classified into three types: Transformer-coupled converters, DC bus integrated converters, and an integration of transformer-coupled converters and a DC bus. In the DC bus integrated converter, sources are combined at the DC bus without magnetic coupling. In these converters, source voltages are similar at the DC bus or may be different when connected to the transformer. The transformer-coupled converters are magnetically coupled and improve reliability.

The combination of a transformer-coupled converter and a DC bus has an isolation technique due to the magnetic connection. The three-port(3P) converter with integration of the DC bus is depicted in Fig. 5 [25]. The three-port converter(3P) with magnetic coupling and bus integration is depicted in Fig. 6 [26].

Since these converters have fewer magnetics, they provide a high power density [26].

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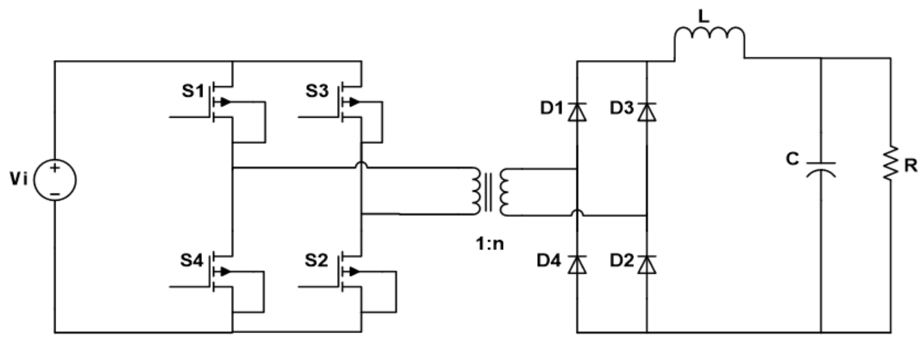

Fig 3: Two-port isolated unidirectional converter[22]

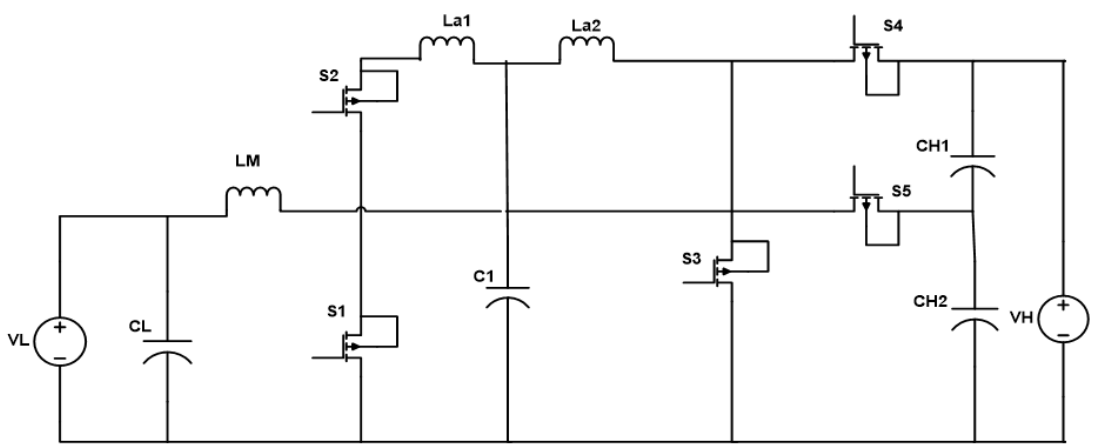

Fig 4: Two-port non-isolated bidirectional converter [23]

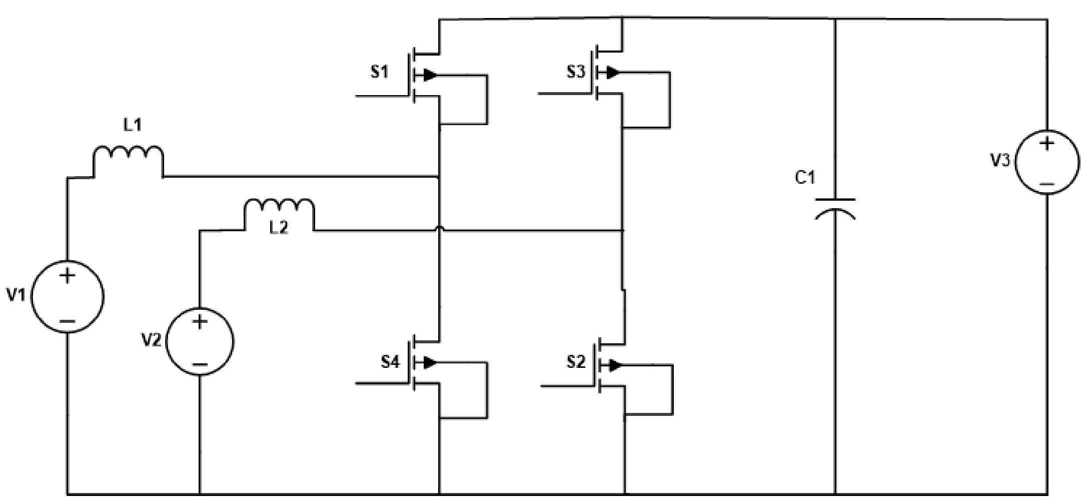

Fig 5: Three-port converter with integration of dc bus [25]

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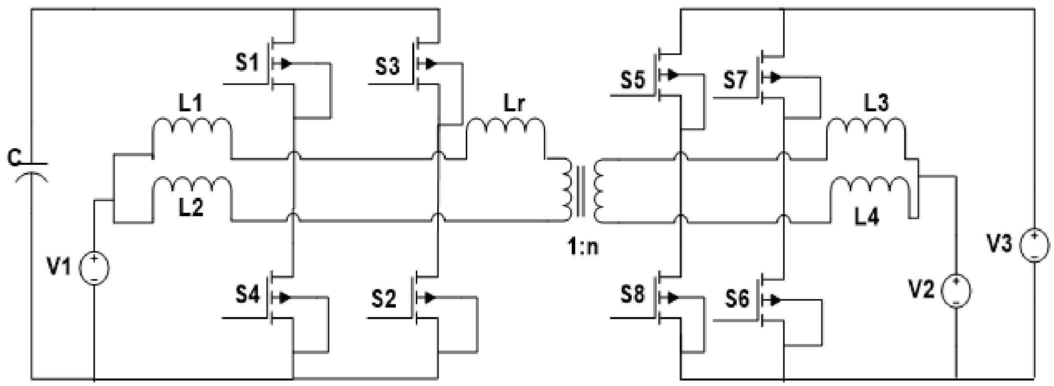

Fig 6: Three-port converter(3P) with magnetic coupling and bus integration [26]

Table 2: Comparison Of The Voltage Gain Of Different Converters

Ref.	Converter	Features	Voltage gain	Duty ratio
[27]	Current-fed boost converter	High conversion ratio,Low voltage stress,High efficiency and power density	$\frac{V_o}{V_i}=\frac{N}{2(1-D)}$	D>50%
[28]	Dual-inductor boost converter	High voltage gain,High-frequency, High-efficiency and low voltage stress	$\frac{V_o}{V_i}=\frac{2N}{(1-D)}$	D>50%
[29]	Active switched-inductor converter	High efficiency,Low voltage stress and self-voltage balancing	$\frac{V_o}{V_i}=\frac{3+D}{1-D}$	NA
[30]	High-efficiency DC-DC Converter	High efficiency, High voltage gain and reduced switching stress	$\frac{V_o}{V_i}=(1+n_3)+\frac{1}{1-D}+\frac{D}{1-D}n_2$	NA
[31]	Multiphase DC-DC converter	High efficiency, Operates in synchronous and continuous mode	$M=\frac{DR_o}{R_o+Dr_{fc}}$	NA
[32]	PWM full-bridge converter	Minimise circulating current,Reduce switching losses and improve power efficiency	$\frac{V_o}{V_i}=ND$	D<50%
[33]	Isolated DC-DC converter	High voltage gain and High efficiency	$\frac{V_o}{V_i}=\frac{n(2-D)}{(1-D)}$	D>50%
[34]	Auxiliary power unit-based converter	Voltage regulation and error cancellation	$\frac{V_d}{V_b}=\frac{n}{2(1-D)}$	D>50%
[35]	Energy harvesting converter	Good charging characteristics and better power quality	$\frac{V_{dc}}{V_b}=\frac{1}{1-D}$	NA
[36]	Quadratic high gain converter	Reduce switching stress, Improve the efficiency and voltage gain	$\frac{V_o}{V_i}=\frac{(5-4d+d^2)}{(1-d)^2}$	52.15%
[37]	High efficiency AC-DC converter	High efficiency, High power density and high power factor	$\frac{V_o}{V_i}=\frac{2n}{1-D}$	NA

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Table 2 describes the comparison of the voltage gain of different converters. The converter topologies and their duty ratios are also depicted. Based on the values of duty ratio D, number of turns ratio N, and the resistance value R_o the voltage gain of the converter can be determined.

3. OPTIMIZATION OF CONVERTERS USING THE CONTROLLERS

The controllers are used for the optimization of converters, which are classified based on linear and non-linear modes, as depicted in Fig. 7. In the linear mode, traditional controllers such as PI (proportional integral) and PID (proportional integral derivative) controllers play an important role in the optimization of converters. In the non-linear mode, fuzzy logic controllers, sliding mode controllers, etc. provide better-optimized output from the converter [38].

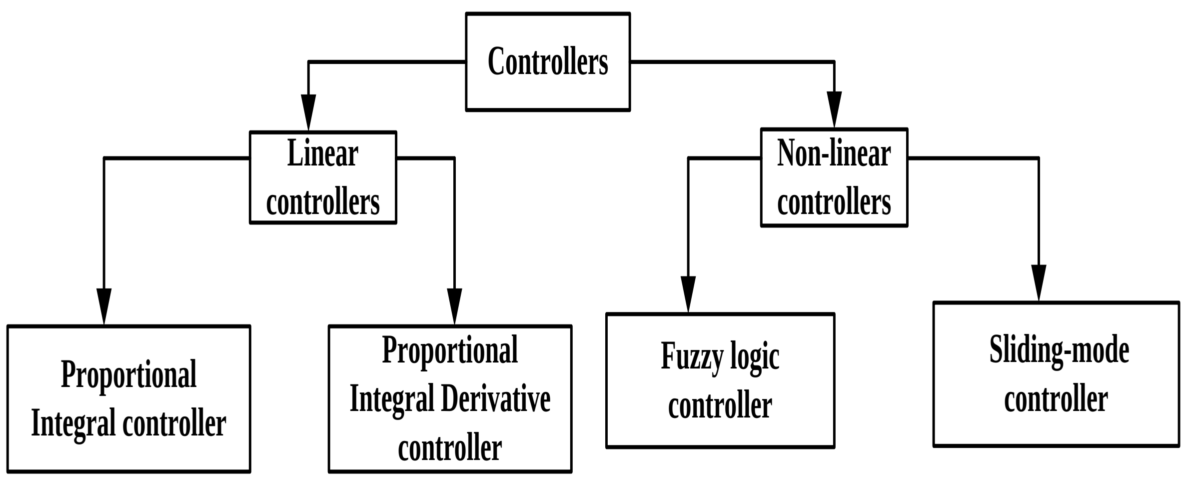

Fig 7: Classification of Controllers

Table 3 describes the comparison of linear and non-linear controllers. The linear PI and PID controllers apply only to one operating point. [38]. The majority of control applications employ and make use of proportional-integral-derivative /proportional-integral (PID/PI) control methods. Heuristic techniques like Ziegler-Nichols, particle swarm optimization (PSO), genetic algorithms (GA), and simulated annealing are used to determine the parameters of PI/PID controllers. Analytic techniques like frequency response, Bode plot, and root-locus technique are used, as well as intelligent techniques like neural networks and fuzzy logic [39]. In the PI and PID controllers, k_p, k_i, and k_d are the constants. In the sliding mode controller, I_{d1} is the reference inductor current, and K_{P1} and K_{I1} are positive constants [40]. In fuzzy logic controllers, e(V) and d{e(V)} are the error value and change in error value [41].

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Table 3: Comparison Of Linear And Non-Linear Controllers

Ref	Controllers	Expressions	Features
[38]	Proportional Integral controller	$U = k_p + k_i \int_0^t edt$	Achieve stable steady-state response
[38]	Proportional Integral Derivative controller	$U = K_p + K_i \int_0^t edt + K_d \frac{de}{dt}$	Provides transient response
[41]	Fuzzy Logic controller	$e(V) = V_{out} - V_{ref}$ $d\{e(V)\} = e(V)_2 - e(V)_1$	Based on the general knowledge of the system,Provides quick transient response and have stable response
[40]	Sliding mode controller	$\sigma_1 = iL_1 - id_1$ $i_{d1} = -k_{p1}(V_o - V_d) - K_{I1}\int (V_o - V_d)dt$	Improve transient response,provides stability analysis

Table 4: Comparison of the Different Converters and Controllers

Ref	Converters	Input voltage(V)	Output voltage(V)	Controllers	Switching frequency (KHz)
[41]	DSP based converter	20	12	PID and Fuzzy controller	150
[42]	Hysteresis-based hybrid converter	5	20	PI with Sliding mode controller	infinite
[40]	Cascade boost converter	5-3.3	30	Sliding mode controller	NA
[43]	Unified PWM converter	24	48	Sliding mode controller	200
[44]	Two-stage converter	5-3.3	20	Sliding mode controller	NA
[45]	Neural network-based converter	24	15	Neural network-sliding mode controller	20
[46]	Converter with non-singular terminal	12	24	Disturbance observer-based Sliding mode controller	40
[47]	Buck converter with control	110	48	RBITSMC-Robust Backstepping Integral Terminal sliding mode controller	20
[48]	High-frequency converter	3	1.5	FPGA-based sliding mode controller	4000
[49]	PWM-based boost converter	6	12	Adaptive sliding mode controller	200
[50]	Non-minimum phase converter	24	48	Integral sliding mode controller	100
[51]	Boost converter with control	24	36-48	Disturbance observer-based integral Sliding mode controller	100
[52]	POESLL converter	4-5.5	12	Adaptive estimator-based sliding mode control	20

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The Table 4 describes the comparison between the controllers. The hysteresis-based hybrid converter implemented using PI and sliding-mode controller produces an output of 20 V from the input of 5 V [42]. The cascade boost converter was designed using a sliding-mode controller that produced an output of 30 V from the input of 5 – 3.3 V [40]. The unified PWM-based converter operated with a frequency of 200 kHz produces an output of 48 V from the input of 24 V [43]. The two-stage converter functioned with the sliding-mode controller produces an output of 20 V from the input of 5-3.3 V [44]. The converter functioned using a neural network produced an output of 15 V and operated with a frequency of 20 kHz [45]. The non-singular terminal-based converter was designed using the disturbance observer-based sliding mode controller that operates with a frequency of 40 kHz. The converter functioned with an input of 12 V producing the output of 24 V [47]. The Robust Backstepping Integral Terminal sliding mode controller-based buck converter produced an output of 48 V from the input of 110 V. The converter is operated with a frequency of 20 kHz [46]. The high-frequency-based converter was designed using an FPGA-based sliding-mode controller that produces an output of 1.5 V from the input of 3 V. The converter is operated with a frequency of 4000 kHz [48].

The boost converter with the PWM technique is implemented using the adaptive sliding-mode controller and produces an output of 12 V from the input of 6 V [49]. The non-minimum phase converter implemented using the integral sliding-mode controller operates with the input of 24 V and produces the output of 48 V with a frequency of 100 kHz [50]. The control-based boost converter operated with a frequency of 100 kHz produced an output of 36-48 V from the input of 24 V. The converter was functioned using the disturbance observer-based integral sliding mode controller [51]. The POESLL (positive output elementary super lift Luo) converter was designed using the adaptive control and obtained an output of 12 V from the 4-5.5 V and the frequency is 20 kHz [52]. The KY boost converter with the output of 36 V was implemented with the adaptive vector reference control method for obtaining the low ripple [53]. The multi-phase converter produces an output of 12 V from an input of 44 V. The digital current controller is used to detect the current level of the converter accurately [54]. The quadratic boost converter working with a switching frequency of 20 kHz is implemented with a fixed current-mode controller to increase the performance characteristics and stability [55]. The current-fed boost converter operated with the frequency of 150 kHz produces an output of 200 V from the input of 16-22 V. The novel converter is used for achieving a high conversion ratio and ripple reduction [27]. The dual-inductor-based boost converter achieves a maximum efficiency of 95.58 % with a 600 W output power. The converter is used for high-voltage applications with low-voltage ripples [28]. The three-phase AC-DC converter applicable for auxiliary power units achieved an efficiency of 97.6 % for a 6-kW load.

The objectives of the converter are increasing the power density, reduces the number of power devices [56]. The LC type bridge converter obtained the output voltage of 100-300 V from the input of 120 V. This converter is used to increase the voltage gain and also applicable for transportation system [57]. The push-pull converter works under the duty ratio of 0.6 produces the output of 380 V. This converter achieves the zero-current-

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switching to achieve the maximum efficiency [58]. The six-phase dual-interleaved converter is used to achieve high efficiency and high-power density. This converter is analysed using the large-signal and small-signal averaged models [59]. The SEPIC converter functioned using the 20 kHz frequency produces the output of 200 V. The purpose of the converter is to increase the stability and safety of the system [60]. The active switched -inductor converter achieves the high voltage gain and high efficiency. This converter attained an output power of 200 W from the output of 380 V [29]. The high-efficiency converter operated with a frequency of 100 kHz produces the output of 400 V. This converter is used to obtain high voltage gain and also reduces the switching stress [30]. The converter which is applicable for auxiliary power units achieved a maximum efficiency of 99.5% from the 5kW power. In this converter, voltage and current control modes are implemented for the smooth transitions [31]. The full-bridge converter implemented with a zero -voltage switching produces the output of 350 V. The converter attained an efficiency of 94 % with a frequency of 60 kHz [32]. The review article describes the level-1 and level-2 converter topologies which is used for AC chargers. This article also explains about various types of voltage equalizers [61].

The inductor-based flyback converter achieved a soft-switching condition with an output power of 20 W. The converter attained an efficiency of 91% with a frequency of 40 kHz [62]. The converter applicable for fuel cell produced the output power of 300 W with a frequency of 70 kHz. The converter obtained the output voltage of 400 V from the input of 18-60 V [63]. The voltage lift-based converter produced the power of 200 W and attained a maximum efficiency of 93 %. The converter is operated with an input of 24 V and produces an output of 200 V. This converter is used to increase the voltage gain and efficiency [33]. The conventional boost converter which is applicable for adapter produces the output power of 60 W. The converter is operated with a frequency of 20 kHz and its duty ratio is 0.946 [64]. The current-fed push-pull converter is suitable for an auxiliary power unit operated with an input of 12 V. The converter obtained the power of 100 W with a frequency of 30 kHz [58]. The boost converter which is used in the electric scooter is operated with a frequency of 20 kHz. The H-bridge inverter is functioned with a voltage of 200 V [65]. The review article describes the various power conditioning topologies that apply to propulsion systems. The converter is implemented with a hybrid modulation technique for reducing the switching losses of the inverter [66]. The reconfigurable converter functioned with a frequency of 100 kHz and produced the power of 2500 W. The converter is operated with an input of 378.8 V and produces an output of 600 V [67]. The conventional buck-boost converter implemented using the linear and non-linear controllers provides better performance characteristics. The linear PID controller and non-linear Fuzzy controller attain regulated output voltage and better settling time response [68].

The converter-based PI controller is operated with the input of 20 V. The converter is functioned with a frequency of 20 kHz [69]. The Cuk converter which is applicable for aerospace implemented using a Fuzzy logic controller. The converter is functioned with a frequency of 100 kHz [70]. The review article briefly explains the various voltage-

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boosting methods with their topologies. This article also describes the different applications of step-up converters [71]. The conventional boost converter introduces a non-linear control for achieving the stabilized output voltage. The converter is analysed based on the numerical and experimental results [72]. The converter with adaptive controller obtained the high voltage gain and also maintained the low voltage stress in power devices. The controller design is done based on the state-space model [73]. The multilevel converter provides a high step ratio which applies to medium-voltage and high-voltage. In this converter, the PI controller is used for maintaining energy stability and current detection [74]. The bidirectional converter operated with a frequency of 50 kHz attained a maximum efficiency of 95.61 % and 96.38 % in buck and boost modes. The converter is implemented with zero-voltage switching to achieve high efficiency [75]. The resonant converter operated with the frequency of 81 kHz produces an output of 404 V. The converter is implemented with zero-current switching and zero-voltage switching to achieve maximum efficiency [76].

The hybrid converter functioned with an input of 30 V and attained an efficiency of 97.5%. The converter is implemented with a frequency of 100 kHz and the output power is 300 W [77]. The dual half-bridge converter with trajectory controller provides high efficiency and high voltage conversion ratio. The converter produces the output power of 800 W with the voltage range of 200-145 V [78]. The non-inverting converter operated with the frequency of 25 kHz achieves the high efficiency and large bandwidth. The magnetic coupling and modelling of converter are described and analysed [79]. The grid-based converter attained the high efficiency using a power conversion method. The converter is employed with a power of 250 W and the frequency is 50 kHz [80]. The module-integrated converter achieved the high efficiency and quick system response. The converter produced the output power of 200 W. The converter is employed with PI controller to obtain the stabilized output voltage [81]. The asymmetric-based converter attained the maximum efficiency of 90 % with a rated power of 600 W [82]. The converter with ultra-capacitor provides good controlling technique and fast transient response. The working of the converter is analysed and verified using the simulation and experimental results [83]. The synchronous converter obtained the power of 2500 W with the input of 400 V. The converter produced the output of 12 V [84].

The quasi converter employed with model predictive control provides high efficiency. The controller of this converter enhances the accuracy and steady-state performance [85]. The parallel input-based converter provides the regulated output voltage with constant duty cycle. The converter produced the output of 0.9-1.8 kV from the input of 300 V. The converter is functioned with a frequency of 200 kHz [86]. The three-level converter which is applicable for automotive and high-power applications operated with a frequency of 32 kHz. The converter is employed with an integral back stepping controller and optimised through genetic algorithm [87]. The dual-input hybrid converter attained the maximum efficiency and high voltage conversion ratio. The converter is operated with a frequency of 20 kHz. The converter is analysed and modelled using the transfer functions and small-signal model [88]. The converter with zero-voltage switching employed with the PI

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controller provides the better regulated voltage. The converter is employed with a frequency of 40 kHz and produces the output of 200 V [89]. The multistage converter operated with a frequency of 50 kHz produces the output of 650 V. The converter also produced the power of 500 W. The PI controller is used for better voltage regulation [90].

The converter with a switched capacitor achieved an efficiency of 80 %. The switching losses of the converter are reduced using the gate drive circuit. The controller is employed for detecting the oscillations of the gate drive and to regulate the output [91]. The converter with ultra-voltage gain produced an output power of 500 W and an output of 650 V. The converter is implemented with a switching frequency of 50 kHz [92]. The converter with the point of load attained an efficiency of 86.8 %. The converter functions with an input of 12 V and obtains an output of 1.3 V [93]. The multilevel converter and dual-active bridge converter are used for high-voltage DC transmission and medium-voltage DC transmission. This article provides a comparative study in terms of magnetic and semiconductor devices, and efficiency [94]. The isolated converter achieved the maximum efficiency of 99.3 % from the output of 100 kW. The converter is employed with a frequency of 16 kHz and produces a voltage range of 850 V [95]. The adaptive control-based converter obtained an efficiency of 85.5 % [96]. The hybrid bridge converter attained an efficiency of 94 % with the power of 1000 W [97]. The soft bidirectional converter produced the power of 300 W and achieved the efficiency of 98 % [98]. The quadruple converter achieved an efficiency of 96.5 % from the power of 2500 W [99]. The converter with voltage control obtained the power of 1200 W and attained an efficiency of 96 % [100]. The twin-bus converter produced the power of 50 W and reached the efficiency of 98.3 % [101]. The converter with split-capacitor attained the efficiency of 98 % and obtained the power of 3000 W [102]. The predictive control-based converter reached the efficiency of 90 % [103]. The converter with high gain produced the power of 100 W and achieved the efficiency of 93.6 % [104]. The dynamic converter attained the efficiency of 86 % with a rated power of 100 W [105]. The converter with phase shift produced the power of 1000 W and reached the efficiency of 95.5 % [106]. The efficient converter achieved the efficiency of 98.3 % with a power of 1000 W [107]. The converter with Hybrid Bridge produced the power of 500 W and attained the efficiency of 97.9 % [108].

4. RESULTS AND DISCUSSION

From the literature review of this article, many authors described the various parameters like high efficiency, high power density, low voltage ripples, and high voltage conversion ratio. From Table 5 and Table 1, the graphical representations are depicted. Fig.8 describes the graphical depiction of input and output voltage. The Fig.9 defines the graphical depiction of year and efficiency. The Fig.10 labels the graphical representation of frequency and power. Fig.11 designates the graphical depiction of year and power. Fig.12 describes the graphical representation of output voltage and efficiency. The input varies from 20 V to 400 V. The output varies from 20 V to 400 V. The duration of the year varies from 1996 to 2022. The power varies from 50 Watts to 100000 watts.

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Table 5 depicts the different converters, rated power, year, and their efficiency values.The matrix inductor-based converter achieved a high efficiency of 99.3 % from the rated power of 400 W. Also, this converter attains zero-voltage switching and high-power density. The LLC resonant converter and composite converter achieved an efficiency of 98.7 %. Even though the matrix inductor-based converter achieves high efficiency, it faces the great challenges of better voltage regulation, fast transient response, and stable steady-state response. The above challenges can be overcome by implementing suitable control algorithms like fuzzy controllers, sliding-mode controllers, genetic algorithms, particle swarm optimization, etc.

Table 5: Comparison of Different Converters with Power and Efficiency

Ref	Converter	Power (watts)	Year	Efficiency (%)
96	Converter with adaptive control	-	2006	85.5
97	Hybrid bridge converter	1000	2022	94
98	Soft bidirectional converter	300	2008	98
99	Quadruple converter	2500	2018	96.5
88	Three-level converter	700	2014	95
100	Converter with voltage control	1200	2018	96
25	Multiport converter	1000	2006	90
101	Twin-bus converter	50	2011	98.3
102	Split-capacitor based converter	3000	2021	98
103	Predictive control-based converter	-	2018	90
104	High gain converter	100	2018	93.6
105	Dynamic Converter	100	2018	86
106	Converter with phase shift	1000	2015	95.5
107	Efficient Converter	1000	2017	98.3
108	Converter with hybrid-bridge	500	2021	97.9
109	Efficiency based converter	2000	2012	93.5
110	New resonant converter	2500	2014	96
111	Wide range converter	10000	2023	98.4
112	SEPIC based converter	160	2021	96.3
113	Matrix inductor-based converter	400	2020	99.3
114	High voltage converter	3504	2017	94.55
115	Tapped-inductor based converter	1000	2005	97
116	AI-based converter	800	2023	98
117	Multiple output converter	100	2015	95
118	Two-input buck converter	300	1998	97
119	Voltage-fed converter	500	2014	92.4-boost 91.7-buck
120	Converter with hybrid control	80	2021	96.1
121	PWM based converter	-	2000	90
122	LLC resonant converter	10000	2023	98.7
123	Wide-range converter	500	2016	95
124	Z-source converter	100	2018	89
58	Push-pull converter	500	2021	96.2
29	Active switched-based converter	200	2022	97.3
27	Current-fed converter	400	2010	93.2
125	Full-bridge converter	1000	2008	92
126	Power-density converter	100000	2007	98
127	Quadratic boost converter	120	2019	94.5
128	Transformer-less converter	200	2022	98.24
129	Composite converter	10000	2016	98.7
130	High power converter	100000	1996	95
131	Interleaved converter	400	2020	96.7

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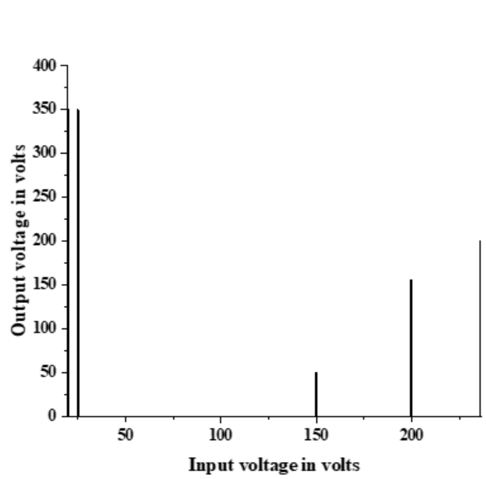

Fig 8: Graphical representation of input and output voltage

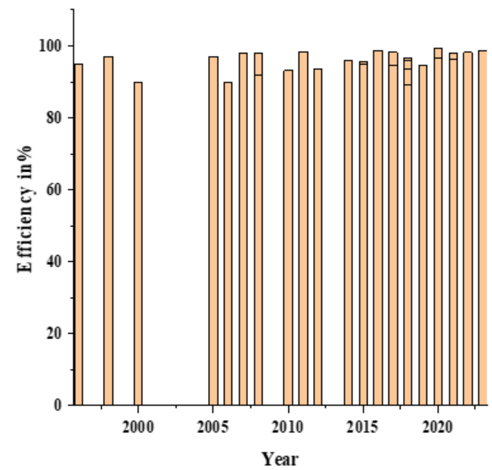

Fig 9: Graphical representation of year and efficiency

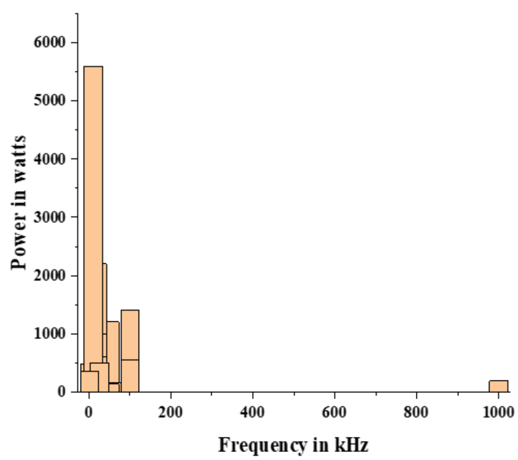

Fig 10: Graphical representation of frequency and power

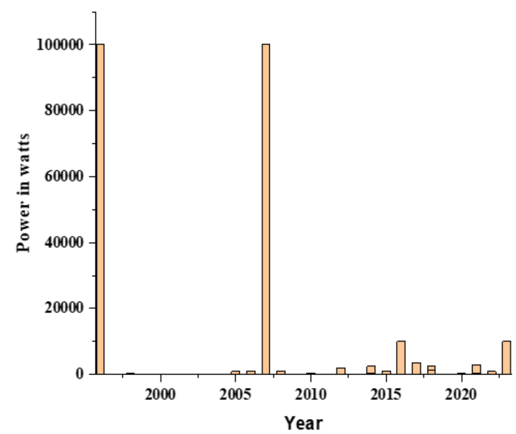

Fig 11: Graphical representation of year and power

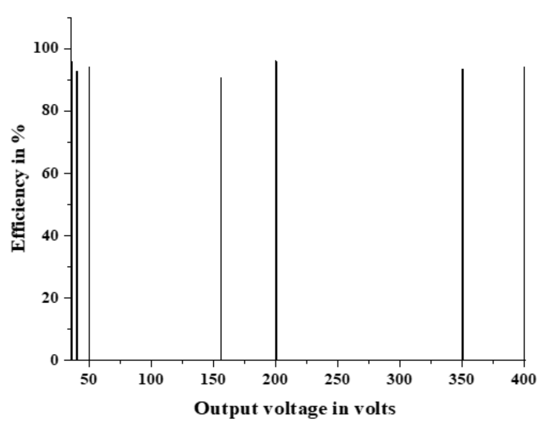

Fig 12: Graphical representation of output voltage and efficiency

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5. CONCLUSION

This article reviewed the different DC-DC converters with various control algorithms for predicting the most efficient converter. In this article, the various classifications of DC-DC converters are briefly discussed, along with their voltages and frequency parameters. The two-port converters deliver high voltage gain and non-pulsating input current. In addition to achieving high efficiency and power density, the multiport converter also lessens device stress. These converters establish better reliability and flexibility because of the design of the converter topology. The different controllers, such as linear and non-linear controllers, that are necessary for the regulation of converters are listed and compared with their voltages and switching frequencies. Since the high-voltage bus has several advantages and also enhances semiconductor device techniques, high-efficiency DC-DC converters have become more important than other converters. From the brief literature review, the authors infer that matrix inductor-based boost converters achieved a high efficiency of 99.3% at a rated power of 400 W. Also, this converter attains zero-voltage switching and high-power density with a frequency range of 300 KHz to 1 MHz. Even though the matrix inductor-based converter achieves high efficiency, it faces the great challenges of better voltage regulation, fast transient response, and stable steady-state response. The above challenges can be overcome by implementing suitable control algorithms like fuzzy controllers, sliding-mode controllers, genetic algorithms, particle swarm optimization, etc.

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