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COMPARATIVE REVIEW ON HIGH GAIN TRANSFORMERLESS DC-DC CONVERSION TOPOLOGIES

Keerthana. K, PG Scholar[1]/EEE, Dr. V. Geetha Professor and Head[2],

Department of EEE,
Government College of Engineering, Salem, India

Abstract: DC-DC Converters with voltage enhancing capabilities are widely used among high power conversion applications. This paper deals with the survey of several CCM (continuous conduction mode) operated DC – DC step-up converters using boosting techniques, switched capacitor and inductor techniques and voltage multiplier cells. Several topologies are being proposed using both active and passive components. The converters may also have smaller and large number of components that increase the gain of the system. Voltage stress and losses may also be reduced. These converters are suitable for renewable energy applications, electric vehicles and other micro inverting applications.

***Index Terms* – Continuous input Current, Coupled Inductor, High Voltage gain, Switched Capacitor, Voltage Stress**

I. INTRODUCTION

Renewable energy resources like wind and solar are an alternative, clean, and sustainable solution for the shortage of fossil fuels. The energy produced from renewable sources is of lower voltage. In order to use these resources for higher voltage applications, the power electronics converters are interfaced between the source and the load side. Most often, DC-DC converters are used to increase the efficiency and voltage gain of the system.

The DC-DC converters are of two types. They are Isolated and non-isolated. In the isolated type, Galvanic isolation between the converter is made by transformer. This type of converters is preferred for high power applications because of their galvanic isolation. Preferably-isolated type of converters are mostly used in renewable energy resources, fuel celled vehicles and in other applications. The interfaced converters may differ in techniques and topologies to increase the output level of the system. Several Techniques include Voltage multiplier cells, Voltage doubler network, Switched Capacitor, Switched Inductors and other diode capacitor cells for boosting the output Voltage.

Quasi Z- Source Network and coupled inductors are used to overcome the disadvantage of energy transferring between the windings in isolation [1]. The proposed Active Switched Inductor Step-up 2 Cell (ASL-SU2C) has good efficiency with lower count of passive components [2]. The proposed Switched Capacitor Inductor Network (SCLN) has lower components count and it reduces the control complexity of the converter [3]. To reduce the effects of Electro Magnetic Interference (EMI) because of high amount of input current ripple a non-isolated DC-DC Converter is proposed [4]. Active capacitor Inductor Network Converter (ACLNC) with simple structure is proposed [5]. Switched capacitor cells and coupled inductor are merged to increase the voltage gain ratio [6]. Higher gain can be achieved between zero to fifty duty cycle ratios [7]. The derived topology is suitable for interfacing photovoltaic panels with DC link voltage in micro inverter applications [8]. Voltage stress in converter is simplified to enhance conversion and to facilitate voltage matching between fuel cell and battery [9]. Both inductors having same magnitude reduces current stress on the battery [10]. Converter with lower component count, concise structure, easily controllable circuit higher efficiency is achieved [11]. A novel Predictive control (MPC-MPPT) algorithm is proposed [12]. Higher voltage gain with lower duty cycle is achieved [13]. Higher voltage gain with minimal number of components with inverting capability is achieved [14]. Common grounding is provided between input and output to avoid electromagnetic interference [15]. Switching and Conduction losses are reduced while operating converters with lower duty ratios. This further enhances the gain of the system.

The further discussion in this paper is as follows: Section II presents an overview of Voltage gain techniques used in converters. Voltage gain Comparison of Converters have been presented in Section III. The proposed work is mentioned in Section IV.

II. OVERVIEW OF VOLTAGE GAIN TECHNIQUES USED IN CONVERTERS

A new step-up DC-DC Converter is presented in [1]. Conventional boost converter is integrated with Auxiliary Capacitor and Coupled inductor in which the auxiliary capacitor in series serves as voltage source. It reduces voltage stress across the switches and diodes. Reduction in Voltage stress increases the efficiency of the system. As, the current is continuous it will further increase the life time of fuel cell and PV [1]. A New High Gain converter with Active Switched inductor and Passive Switched Capacitor is proposed by [2]. Active switched inductor and Passive switched Capacitor Network is combined with normal boost converter. Here, the current flow between the switched capacitor and inductor increases the voltage gain. Higher efficiency is achieved with lower number of components and with simple structure. The Output voltage is thirteen times greater than the input voltage [2].

Switched Inductor and switched capacitor networks are merged in a single switch dc – dc converter topology to achieve ultra-gain in [3]. This converter achieves a maximum gain of twenty-five times more than the given input. The analysis and performance of the converter shows that this would be suitable for grid connected PV systems. By considering the obtained output results, this converter can be used for both single phase and three phase applications [3]. A New High gain topology is proposed in [4] by combining boost converter and SEPIC converter with a diode capacitor network to reduce stress across the switch. As it produces low switching voltage, the efficiency of the system is increased. The maximum voltage gain is obtained at higher duty ratio. This converter is suitable for renewable energy applications having low input dc voltage [4].

A Novel High Step-up Converter with Active Coupled Inductor is proposed in [5]. In addition, with the two coupled inductors it also has a lossless clamped circuit which suppresses the voltage spikes caused by the leakage inductance and it also recycles the leakage energies of the inductor to improve efficiency. High voltage gain can be achieved with reduced magnetic size. This converter is proposed for sustainable energy system [5]. A New high gain Converter based on Switched Capacitor and Coupled Inductor is proposed in [6]. Here, the secondary winding of the inductor acts as the controlled voltage source. As, the coupled inductor increases the voltage of the switched capacitor, the gain of the system is further increased. As the leakage inductance is much smaller than the magnetizing inductance, operation of mode 1 and 4 are short. So, mode 1 and 4 are neglected [6].

A New topology of the converter is presented in [7] with the combination of boost, super lift Luo Converter and with the Voltage doubler circuit. This converter achieves ten times voltage gain at fifty percent duty cycle. The voltage and current stress of this converter are low [7]. A Non-isolated step-up DC-DC Converter is presented in [8]. The existing system is modified with a diode and capacitor branch. This in turn reduces the severe voltage stress and EMI generation. This paper shows the efficient transfer of energy to the output by both magnetic coupling and a charge pump mechanism. Soft diode commutations are achieved by shaping the capacitor charging and discharging current through the leakage inductance of the coupled inductor. This system achieves a voltage gain of nine times more than the given input [8].

Dual Switch Step-up Converter is proposed in [9]. The Conventional boost converter is modified with dual switch and with dual inductor in order to maintain high gain ratio. This converter achieves a high voltage gain with lower duty cycle ratios. This converter can be used in batteries in fuel cell powered vehicles [9]. A High Gain Converter with Switched Inductor is proposed in [10]. This converter maintains voltage gain with lower duty ratio. This converter is suitable for renewable energy applications particularly for PV [10].

Hybrid Gain DC-DC Converter is proposed in [11]. Three Voltage booster module is integrated with a single voltage source. These three-boost module consists of an active switch, a coupled inductor, diodes and capacitors. By clamping the voltage across the switch voltage spikes are reduced and recycling of leakage energy in inductor increases the efficiency of the converter. This converter is suitable for fuel cell power systems and PV systems [11]. A New gain is achieved by Model Predictive Control based MPPT Algorithm is proposed in [12] to operate with fixed and adaptive size. This system is suited for both normal and weather changing conditions. Here, Sensor is replaced by observer in order to reduce the cost of the system [12].

A hybrid quasi switched topology is proposed in [13] to increase the voltage gain. Voltage gain is achieved with lower duty cycle which further reduces the voltage stress and conduction losses of the switches. This reduction in stress increases the efficiency. This converter is suitable for lower power step-up applications [13]. A High gain Non-isolated DC-DC Converter is proposed in [14]. This converter combines the fundamental interleaved boost converter with diode capacitor stages. The Capacitors of Cockcroft Walton – voltage Multiplier cells are energized through the inductors of the interleaved structure [14].

The proposed converter in [15] utilizes two switched capacitor networks with the combination of quasi switched boost network for increasing the voltage gain. Common grounding eliminates the problem of EMI and Leakage Current. It maintains lower voltage stress across the switches [15].

III. Comparison of Voltage Gain of Converters

3.1 Comparison of conversion Parameters

Table 1: Comparison of Components, Voltage Stress and Voltage Gain of the Converters

Converter Topologies	Components Used					Voltage Stress	Voltage Gain
	Switches (S)	Diodes (D)	Inductors (L)	Capacitors (C)	Coupled Inductor(L)		
[1]	1	4	-	5	1	Low	$(1+N_{sp})/(1-2D)$
[2]	2	2	3	3	-	Low	$(1+3D)/(1-D)$
[3]	1	4	2	3	-	-	$(2-D)/(1-D)^2$
[4]	1	4	2	4	-	Low	$(3+D)/2(1-D)$
[5]	2	2	-	2	2	-	$C6/(1-D)$
[6]	1	3	-	3	1	Low	$(N_{sp}+2)/(1-D_y)$
[7]	1	6	3	6	-	-	$(3-D)/(1-D)^2$
[8]	2	3	-	4	1	Medium	$2+n(1+D)$
[9]	2	1	2	1	-	Low	$(1+D)/(1-D)$
[10]	2	7	2	3	-	Low	$(3-D)/(1-3D)$
[11]	1	5	-	5	1	Low	$2(1+n)/(1-D)$
[12]	2	3	2	2	-	Low	$(1+D)/(1-D)$
[13]	2	4	2	4	-	-	$2(1-D)/(1-3D+D^2)$
[14]	2	6	2	6	-	-	$N/(1-D)$
[15]	2	6	1	5	-	-	$4/(1-2D)$

3.2 Coupled Inductor

The Coupled inductor has two or more windings in a same core. It transfers energy from primary winding to secondary winding. Coupled inductor is similar to transformer. In transformer Voltage gain can be increased by increasing the turns ratio. But on the other side larger turns ratio will produce larger leakage reactance which will reduce the efficiency of the system and increase the voltage stress across the switches. By selecting appropriate turns ratio of the coupled inductor, the voltage gain can be improved. Leakage inductance in coupled inductor causes voltage spikes but it can be suppressed by employing clamp circuits.

Table 2: Comparison of Voltage Gain of Coupled Inductor Topologies

Topologies	Voltage Gain	Number of times Voltage Gained
[1]	$(1+N_{sp})/(1-2D)$	8.4
[5]	$C6/(1-D)$	10
[6]	$(N_{sp}+2)/(1-D_y)$	15.2
[8]	$2+n(1+D)$	9
[11]	$2(1+n)/(1-D)$	11.11

3.3 Switched Capacitor

Switched capacitor Circuits have the ability to obtain high static voltage gain and it also has the ability to reduce voltage stress across the switches. Sometimes, Switched Capacitor network combines with other voltage enhancing techniques to increase the efficiency of the system.

Table 3: Comparison of Voltage Gain of Switched Capacitor Topologies

Topologies	Voltage Gain	Number of times Voltage Gained
[2]	$(1+3D)/(1-D)$	13
[3]	$(1+3D)/(1-D)$	16.25 for 20 V: 14.4 for 45 V
[6]	$(N_{sp}+2)/(1-D_y)$	15.2
[13]	$2(1-D)/(1-3D+D^2)$	5.5
[15]	$4/(1-2D)$	7.14

IV. Conclusion

This review comes up with a comparative analysis of techniques involved for further improving the voltage gain of the converter. Voltage conversion ratio differences have been showed between coupled inductor and switched capacitor topologies. Other gain techniques also produce voltage conversion ratio nearly equal to that of both coupled inductor and switched capacitor cells. Efficiency can be increased further by efficient utilization of leakage energies in coupled inductor. Model Predictive Control method produces efficient output for Solar Photovoltaic systems. Effects of Electro Magnetic Interferences have also been reduced. The converters are mostly suitable for fuel cell vehicles and for utility grid DC bus applications.

REFERENCES

[1] Wu. G, Ruan .X and Ye. Z, "Non-isolated high step-up DC-DC converter adopting auxiliary capacitor and coupled inductor," in Journal of Modern Power Systems and Clean Energy, vol. 6, no. 2, pp. 384-398, March 2018.

[2] Salvador M. A, Lazatin T. B and Coelho R. F, "High Step-Up DC–DC Converter with Active Switched-Inductor and Passive Switched-Capacitor Networks," in IEEE Transactions on Industrial Electronics, vol. 65, no. 7, pp. 5644-5654, July 2018.

[3] Kumar G. G, Sundaramoorthy. Karthikeyan. V and Babaei. E, "Switched Capacitor–Inductor Network Based Ultra-Gain DC–DC Converter Using Single Switch," in IEEE Transactions on Industrial Electronics, vol. 67, no. 12, pp. 10274-10283, Dec. 2020.

[4] Saravanan. S and Babu N. R, "Design and Development of Single Switch High Step-Up DC–DC Converter," in IEEE Journal of Emerging and Selected Topics in Power Electronics, vol. 6, no. 2, pp. 855-863, June 2018.

[5] Liu .H .C and Li. F, "Novel High Step-Up DC–DC Converter with an Active Coupled-Inductor Network for a Sustainable Energy System," in IEEE Transactions on Power Electronics, vol. 30, no. 12, pp. 6476-6482, Dec. 2015.

[6] Wu. G, Ruan .X and Ye. Z, "High Step-Up DC–DC Converter Based on Switched Capacitor and Coupled Inductor," in IEEE Transactions on Industrial Electronics, vol. 65, no. 7, pp. 5572-5579, July 2018.

[7] Rahimi. T, Ding. L, Gholizadeh .H, Shahrivar. R. S and Faraji. R, "An Ultra High Step-Up DC–DC Converter Based on the Boost, Luo, and Voltage Doubler Structure: Mathematical Expression, Simulation, and Experimental," in IEEE Access, vol. 9, pp. 132011-132024, 2021.

[8] Spiazzi. G, Biadene. D, Marconi. S and Bevilacqua. A, "Non-isolated high step-up DC-DC converter with minimum switch voltage stress," 2017 IEEE Southern Power Electronics Conference (SPEC), 2017, pp. 1-6.

[9] Wu .X, Shi. W and Du. J, "Dual-Switch Boost DC–DC Converter for Use in Fuel-Cell-Powered Vehicles," in IEEE Access, vol. 7, pp. 74081-74088, 2019.

[10] Bao. D, Kumar A, Pan .X, Xiong .X, Beig. A. R and Singh. S. K, "Switched Inductor Double Switch High Gain DC-DC Converter for Renewable Applications," in IEEE Access, vol. 9, pp. 14259-14270, 2021.

[11] Shen, Chih-Lung, Hong-Yu Chen, and Po-Chieh Chiu. 2015. "Integrated Three-Voltage-Booster DC-DC Converter to Achieve High Voltage Gain with Leakage-Energy Recycling for PV or Fuel-Cell Power Systems" *Energies* 8, no. 9: 9843 -9859.

[12] Abdel-Rahim. O and Wang .H, "A new high gain DC-DC converter with model-predictive-control based MPPT technique for photovoltaic systems," in CPSS Transactions on Power Electronics and Applications, vol. 5, no. 2, pp. 191-200, June 2020.

[13] Zhu .X, Zhang. B and Jin. K, "Hybrid No isolated Active Quasi-Switched DC-DC Converter for High Step-up Voltage Conversion Applications," in IEEE Access, vol. 8, pp. 222584-222598, 2020.

[14] Meraj .M, Bhaskar M. S, Reddy B. P and Iqbal. A, "Non-Isolated DC–DC Power Converter with High Gain and Inverting Capability," in IEEE Access, vol. 9, pp. 62084-62092, 2021.

[15] Avneet Kumar, Yi Wang, Xuewei Pan, Sajid Kamal, Xiaogang Xiong, Rui Hong Zhang, Danyang Bao., "A High Voltage Gain DC–DC Converter with Common Grounding for Fuel Cell Vehicle," in IEEE Transactions on Vehicular Technology, vol. 69, no. 8, pp. 8290-8304, Aug. 2020.