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Review

A Review on Non-Isolated Multiport Boost &Luo Converters for Non-Conventional Energy Applications

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Abstract: Due to increased understanding in the use of renewable energy resources, several techniques are being built for harvesting full energy from non-conventional sources. Power electronic converters play a significant role in the conversion process. Research on multiport converters increased due to awareness in the use of multiple sources as input, especially employing any renewable energy sources with a storage device. In this paper, different Non isolated multiport boost & Luo converters are presented. The main objective is to concentrate on the non-isolated topologies which provide reliable output. Various non-isolated topologies and boost circuits are provided with their merits and demerits. The Comparative statements on converters are discussed. This review helps us to carry out to design new multiport topologies.

Keywords: *Boost Converter, Luo Converter, Non isolated converter, Multiport converter, Renewable energy*

1. Introduction

Global warming is the buzzing word in the society, Due to the effect of fossil fuels there is a drastic changes in the environmental condition. In order to overcome the above factor, Renewable energy sources will be the replacement for the above problem. As the renewable energy sources are unreliable, intermittent. Several technologies are proposed nowadays to grasp maximum amount of energy from the available resources. The use of the Renewable energy resources is increased year by year, which is shown in Figure.1

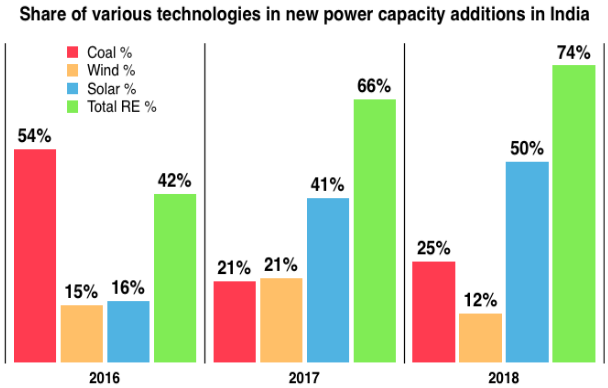

Figure 1. Increase in the use of Renewable energy usage up to 2018 in India

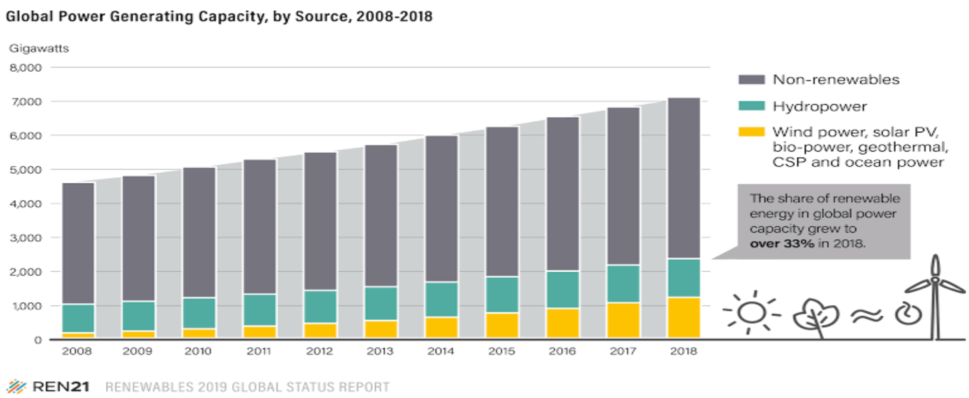

Figure 2. Global Renewable Energy usage report 2019

The Figure.2 shows the Global Renewable energy usage & the increased rate of use year by year. India is planned to cross the 175GW renewable energy mark by 2022. Around 30GW, renewable capacity, which includes 18GW solar, and 10GW wind under implementation. We can expect our Renewable energy sector will cross 100GW mark by this year. The rate of increasing in the rate of renewable energy will reduce the Global warming. The installed capacity and target for the Indian government is given in Table.1

Table 1. Installed Capacity and Target of Installation of Renewable Energy Resources in 2022

RES	Total Installed Capacity (GW)	Target (GW)
Power from Wind	34.046	60
Power from Solar	21.651	100
Power from Bio mass	8.701	10
Power from Waste	0.138	-
Power from Small Hydro	4.486	5
Total	69.022	175

Figure 3 shows the basic block diagram of Energy conversion process from renewable energy sources.

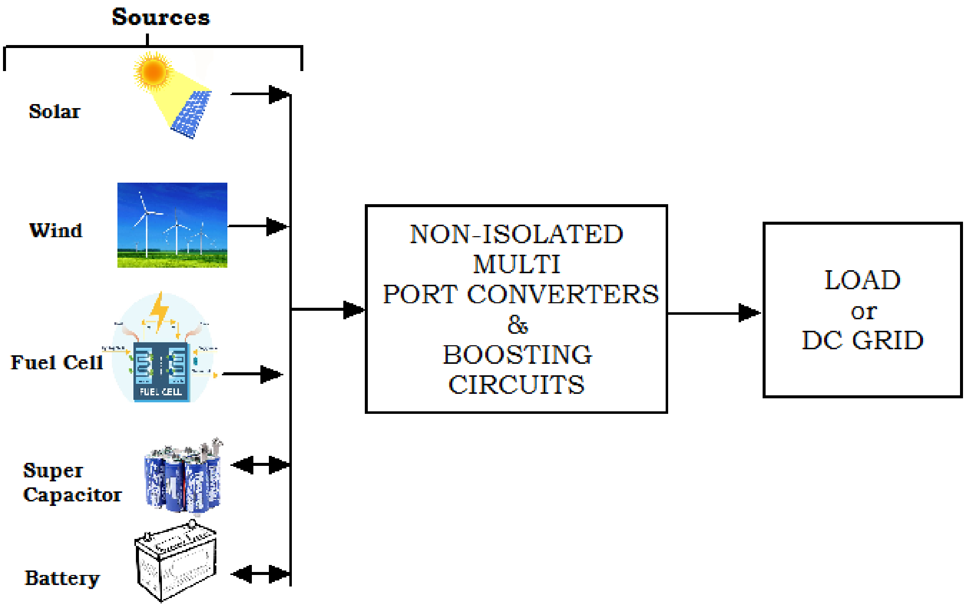

Figure 3. Energy Conversion Process using non-conventional energy

The power electronic converters act as a bridge to convert the Nonconventional resources to electrical energy. The energy storage systems are used in this mechanism to boost network stability. For this application, different types of batteries & super capacitors are used. Bidirectional energy flow is obtained by using these energy storage devices. The Classification of the multiport converters is shown in Figure.4

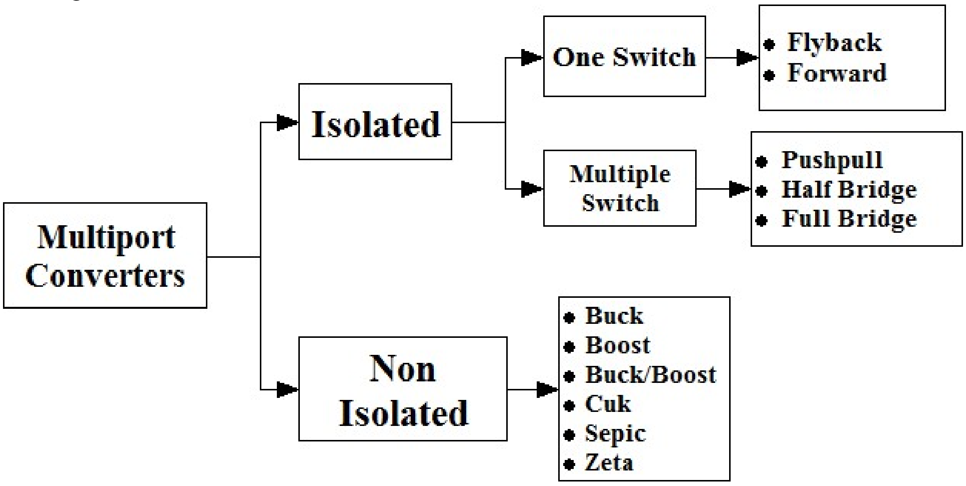

Figure 4. Classification of multiport converters

Table 2. Comparison Isolated and Non-isolated multiport converter

Topology	Isolated	Non-Isolated
Isolated Transformer	Required	Not Required
Switching loss	More	Less
Ripple Content	High	Low
Size	High	Low
Noise Filtering capability	Strong	Less
Circuit	Complex	Simple

The size and cost of the isolated multiport converters are increased due to big transformer present in the converter. The loss due to leakage is more hence it increases the losses in the switching device and converter efficiency is also affected. Whereas in non-isolated multiport converter, the circuit is simple and the number of switches used is less, it helps in reducing ripple content. A small comparison of isolated and non-isolated converter is given in Table 2.

In Section 2 various multiport Topologies are presented, section 3 explains the different types of DC-DC Boost topology for renewable energy system. Section 4 describes the Luo Converter topology for renewable energy system.

2. Topologies of Non Isolated Converters

The family of non-isolated converters is derived from various dc to dc converters i.e., step down (buck), step up (boost), step down and up (buck boost) converters in different configurations. In [1], bidirectional switching cells create a bidirectional power flow by charging and discharging the batteries. Those topologies are performed by integrating multiple boost converters where the efficiency of the converter becomes less, where the soft switching is not able to employ. Due to topological limitations, there is limited amount of power flow in the circuit. The topologies of coupled inductors are used to increase the converter's voltage gain. In [2] a single stage power conversion with low device operating count is executed but reconfigurable, operating this types of converter in different modes is difficult. This will combine input and output port of multiport converters which gives better efficiency when compared with the reconfigurable and capacitive coupled ports. The Representation of Different multiport converters are shown from Figure 5 to Figure 10.

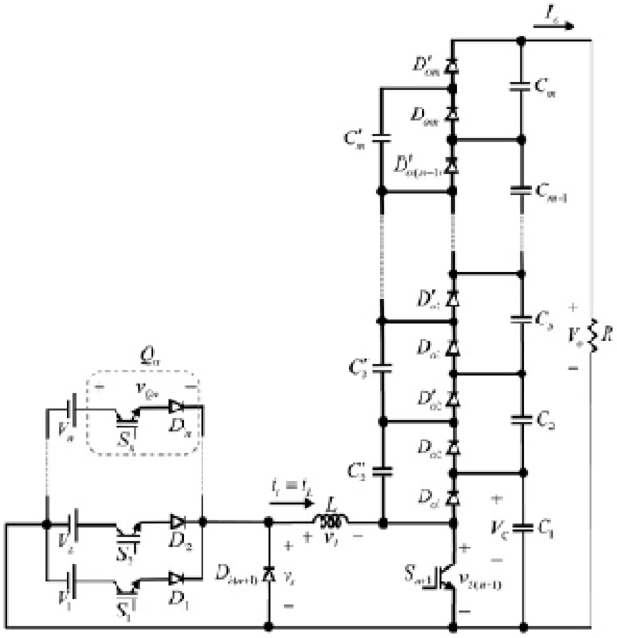

Figure 5. Multi Input - output DC-DC Converter

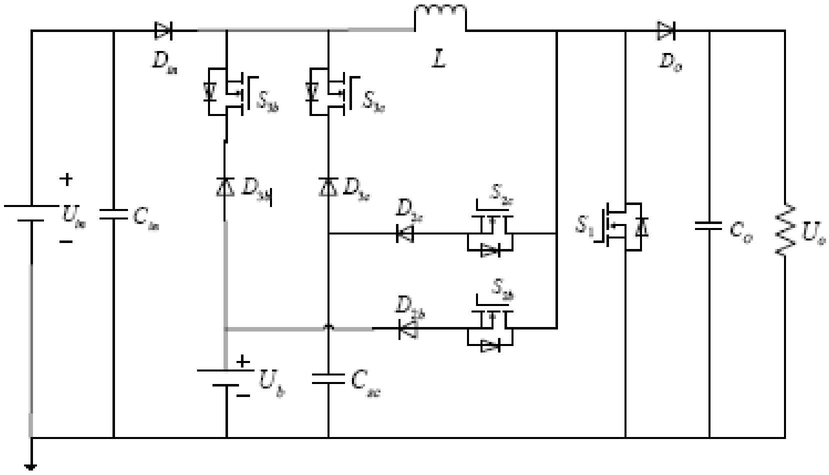

Figure 6. Non-isolated Four port DC - DC Converter

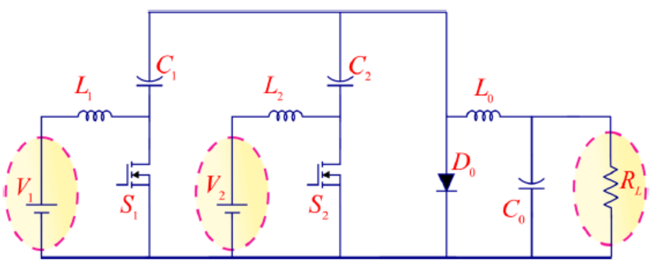

Figure 7. Three port DC-DC Cuk Converter

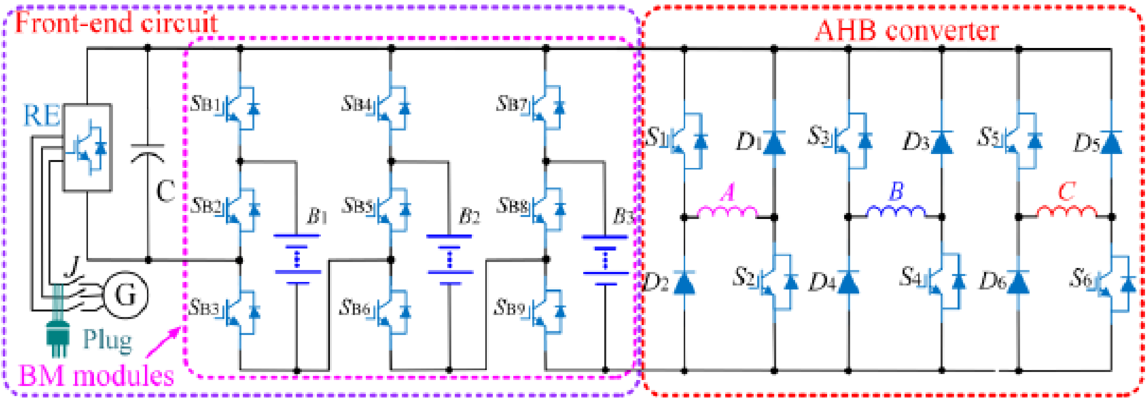

Figure 8. Cascaded multiport converter for 3 phase SRM

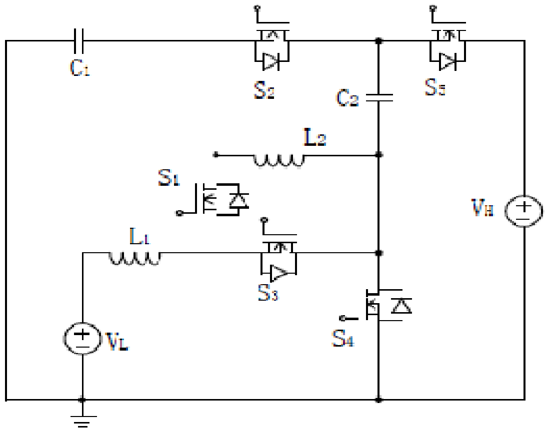

Figure 9. Bidirectional step up/down converter with high step up ratio

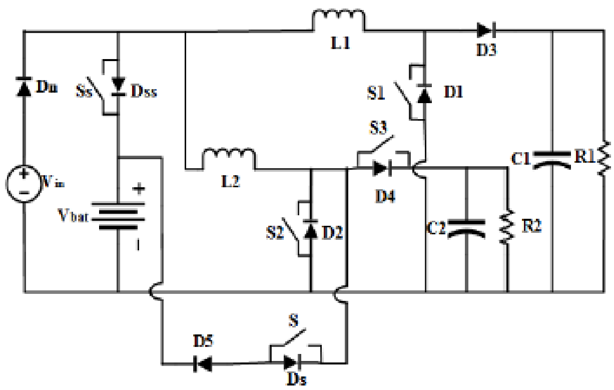

Figure 10. Bidirectional Non inverting Buck boost converter

A topology for multi input- output (MIMO) is suggested in [3] and corresponding circuit diagram is depicted in Figure.5. It gives output at different voltage levels. This converter operates without transformer & having high switching frequency. Different Input source at different voltage levels with continuous input current is analyzed. The drawback observed in the structure is unidirectional power flow. The equation relating voltage of input and output is expressed in the following equation,

$$V_o = \frac{m}{1-D_{n+1}}[D_1V_1 + \sum_{j=2}^{n}(D_j - D_{j-1})V_j \quad (1)$$

Assuming an analogous resistance related to the input impedance in series is equal to

$$V_o = \frac{1}{\frac{1-D_{n+1}}{m}+\frac{mR_{ESR}L}{(1-D_{n+1})R}}[D_1V_1 + \sum_{j=2}^{n}(D_{j-}D_{j-1})V_j \quad (2)$$

The converter operates in three modes where the bidirectional power flow is implied. The MPPT is employed in the photo voltaic cells with single stage transformation. The Circuit diagram is shown in Figure.6. It has single output port and three input ports. The design and model of four-port dc – dc converter and its controller are described in [5]. It has two half bridges where each bridge is controlled by two independent PWMs. The simulation results are obtained. It exhibits the properties of power flow between the source & load and vice versa. A three port converter is designed with cuk topology is shown in Figure.7. This converter works in two modes where it achieves bidirectional power flow. The converter produce continues current and voltage in output port. The Comparative analysis of the multiport converters is given in Table 3

Table.3 List of key parameters in non isolated topologies

References	No of switches & Diodes	No of Inductors	No of Capacitors	Switching Frequency	Key points	Efficiency
[6]	n+1	1	m	10kHz	Unidirectional power flow, High voltage gain with less duty cycle value	92
[7]	n+m+1	1	m	10kHz	By adding number of loads, number of input voltage source is increased, Controller design is complex	86
[8]	6	2	3	20KHz	Cost is high Bus sharing is shown Increased input currents	94
[9]	10	3	10	164KHz (Resonant frequency)	Narrowed operation ranges	94
[10]	3	2	3	100 KHz	EDLC & Fuel cell is used, Cost is high	93
[11]	4	2	4	100 KHz	Both unidirectional and bidirectional converter is analyzed Circuit is simple operation range is narrow	96.8
[12]	4	3	4	100 KHz	Volume of circuit is more due to increased	97

					number of inductors	
[13]	6	1	1	80KHz	Output is unidirectional Bidirectional switches allowed in two mode only	95
[14]	7	2	4	100 KHz	Capacitive coupling is utilized Number of switches is more	96.6
[15]	3	3	2	10KHz	Allow power flow between two port Slow switching devices is used	90
[16]	8	2	2	110KHz	Switching loss is more	97
[17]	5	2	2	100 KHz	Very low output gain	92

3. Topologies of Non Isolated Boost Converters

There are many types of Boost converters, which can be incorporated with the multiport topology to obtain the Combination of various renewable energy resources. The List of Boost converter is given in Figure.11.

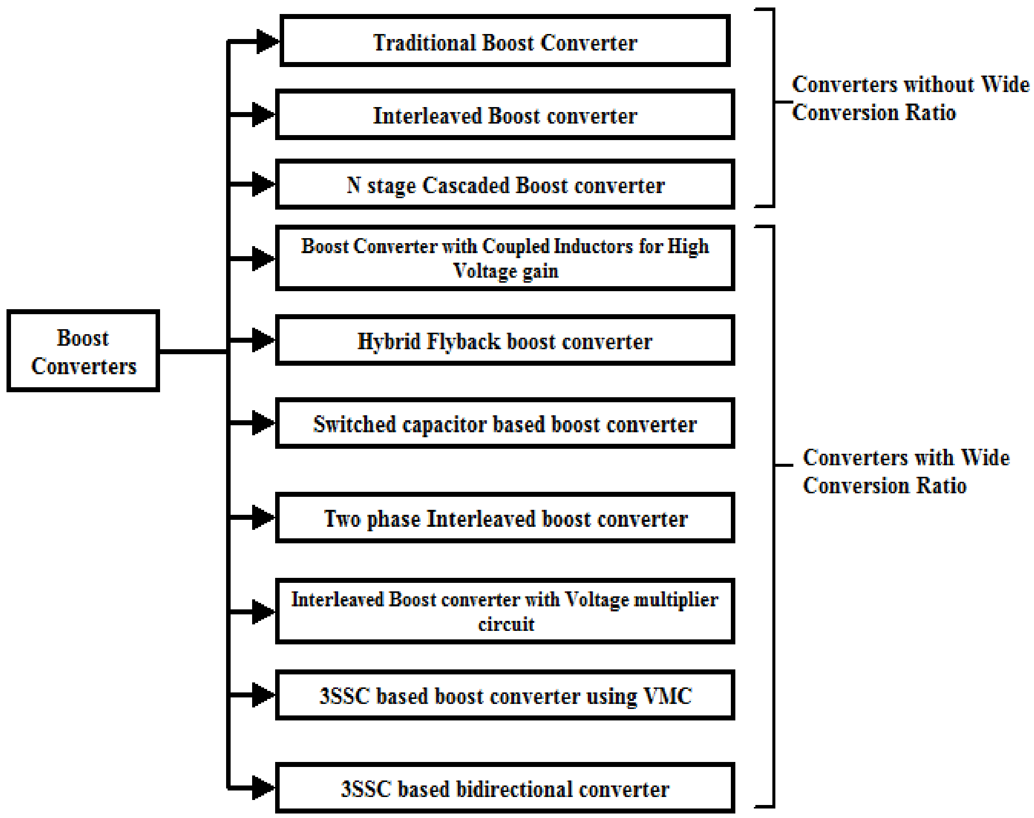

Figure 11. Types of step up (Boost) Converters

In [18] working and modes of operation of traditional step up (Boost Converter) are presented. The Gain of the converter is given by

$$G_v = \frac{V_o}{V_i} = \frac{1}{1-D} \tag{3}$$

The converter efficiency is expressed by

$$\eta = \frac{1}{(1+R_L/((1-D)^2.R_o))} \tag{4}$$

Where, R_o= represent the load resistance in ohms, V_i represents the converter input voltage in volts , V_o represents the converter output voltage, D represents the converter duty cycle, and R_L represents the internal resistance of the inductor in ohms.

The Gain and efficiency of the converter depends on R_L, D & R_o. The voltage conversion efficiency is reduced when the duty cycle is high, thus the traditional boost converter is used for low & medium power applications and corresponding circuit diagram is depicted in Figure.12

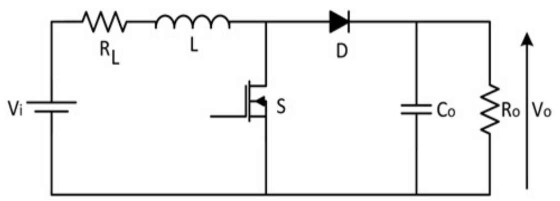

Figure 12. Traditional Boost converter

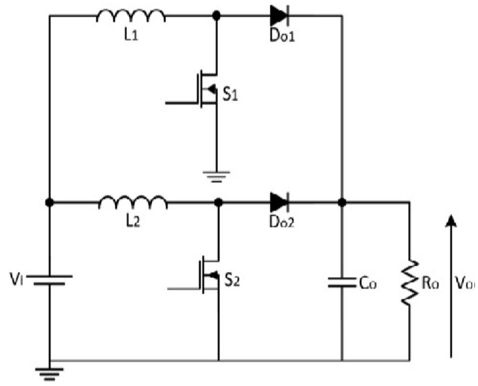

Figure 13. Interleaved Boost Converter

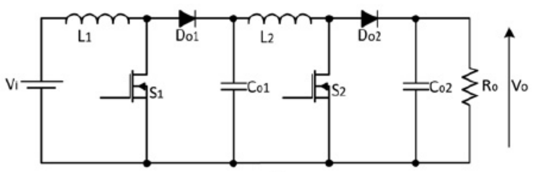

Figure 14. Cascaded Boost converter

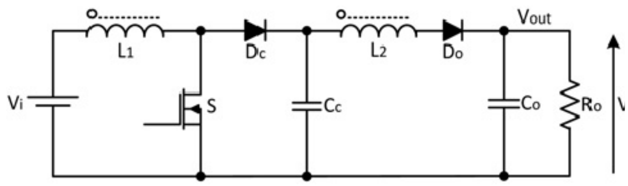

Figure 15. Boost Converter with Coupled Inductor

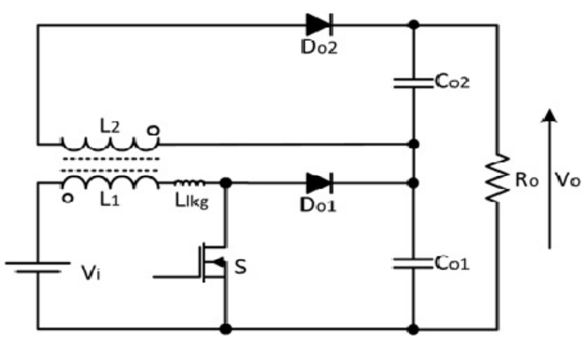

Figure 16. Hybrid Flyback Boost Converter

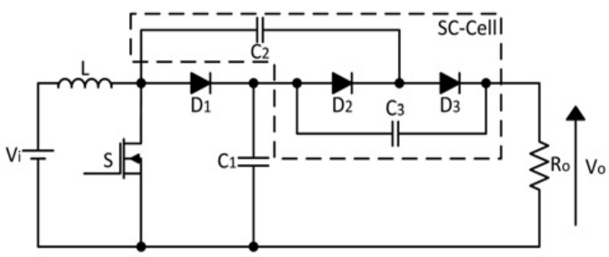

Figure 17. Switched Capacitor based Boost Converter

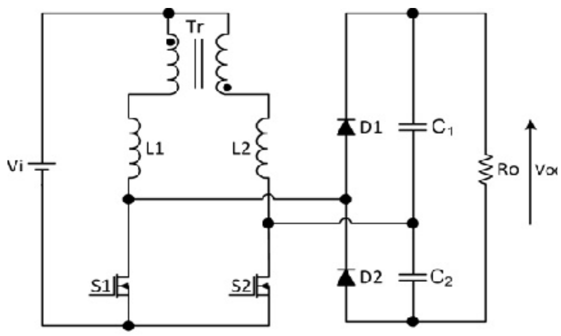

Figure 18. Two phase Interleaved Boost Converter with Voltage Doubler

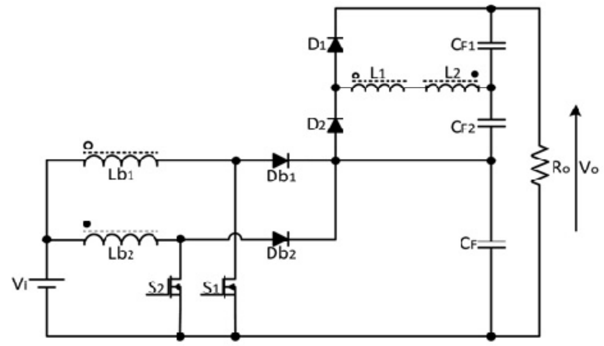

Figure19. Interleaved Boost converter with Voltage multiplier circuit

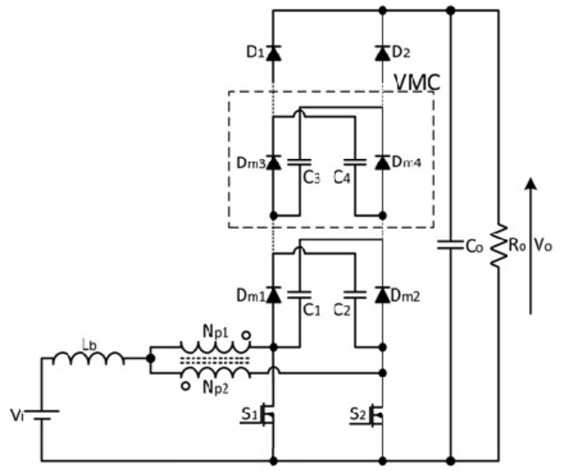

Figure 20. 3SSC based boost converter using Voltage multiplier circuit

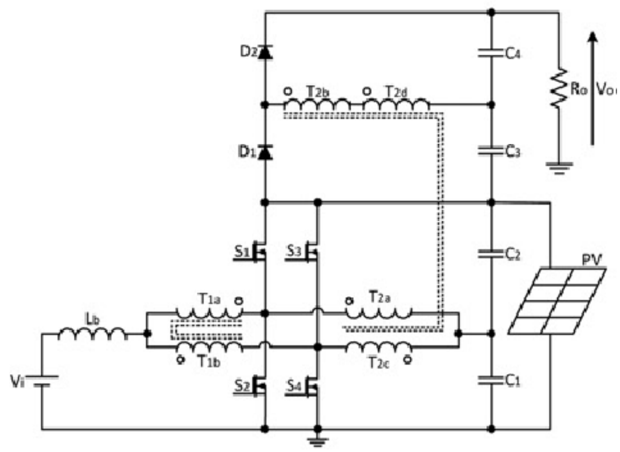

Figure 21. 3SSC based bidirectional converter

In [19], working and modes of operation of two phase Interleaved boost converter with maximum conversion ratio model is presented. The Interleaving in the boost converter is used to increase the efficiency of the filter elements and reduce their size and corresponding circuit diagram is depicted in Figure.13. This form of converter is recommended for enhanced ripple current conversion performance & power density. The working and mode of operation of voltage multiplier cell with Interleaving boost converter topology is presented in [20]. This topology is not recommended for high power application because voltage stress in the switches is equal to voltage at load end and also the efficiency of the converter reduced due to reverse recovery current of the diodes.

In [21], high conversion ration Cascaded boost converter is presented and it is shown in Figure.14. The boost converter doesn't extend to systems needing high voltage gain. These types of converter are used to ensure large conversion ratio & minimized current ripple. The working and mode of operation of single-switch-quadratic-boost converter topology is presented in [22] and it is obtained by replacing switch with diode. The Converter has more number of components which reduces the converter efficiency.

The modified version of the cascaded boost converter is depicted in Figure.15. A clamping circuit is implemented because of the leakage and the combined inductors to reduce the voltage stress around the main switches. The average voltage in the active switch is equal to the amount of input voltage and voltage along the inductance L_1. Due to high voltage across the diode, the cost of semiconductors become high. Hence it is preferred for increased step up efficiency and low voltages.

The Figure.16 shows the Hybrid fly back boost converter, here half of the output voltage depends on turns ratio of the coupled inductor, hence voltage stress is reduced. The reverse recovery problem is mitigated and the voltage stress across the diode is reduced. An additional Input filter is needed due to input current and reduce EMI levels.The switched capacitor based boost converter is shown in Figure.17, In this the voltage gain is twice that of conventional boost converter which is proven in [23], here the Inductor used is large hence it is not preferred for high power applications.

A two phase interleaved boost convert with Voltage doubler circuit is given in [24]. The Circuit diagram is show in Figure.18,It has an autotransformer of ratio of unity turns. The residual gain from the circuit is enhanced due to the presence of Voltage doubler. The biggest downside found in this converter is the inclusion of an external transformer and one inductor per step that reduces the circuit's cost and measurements.

The Interleaved configuration is shown in Figure.14 is modified and added with a Voltage multiplier circuit which is depicted in Figure.19. The input voltage on the active switches is responsible for the voltage stress. A three state switching cell boost converter is analyzed in [34], The representation is shown in Figure.20

This Converter comprises of two diodes and capacitors & also operated in high efficiency for wide load range. The VMC increases the static gain of the converter. The Converter shown in Figure.21 is a 3SSC bidirectional converter which is used for renewable energy applications. This type of converter has many magnetic circuits with cores. The high voltage gain is observed when duty cycle is greater than 50%. The Comparative statement of the Boost Converters is given in Table.4.

Table 4. List of key parameters in Boost non-isolated topologies

Ref	No of Switches	Static Gain	Duty Cycle Range	No of Diodes	No of Capacitors	No of Inductors	Operating Frequency	Auxiliary transformer
26	1	(1/(1-D)	0<D<1	1	1	1	f_o	-
27	N	(1/(1-D)	0<D<1	N	1	N	$N*f_s$	-
28	N,N>1	$(1/(1-D)^N$	0<D<1	N	N	N	f_s	-
29	1	((n+1)-D)/(1-D)	0<D<1	2	2	2	f_s	-
30	1	((1+n-D)/(1-D)	0<D<1	2	2	2	f_s	-
31	1	(N/(1-D))	0<n<1	2N+1	2N+1	1	f_s	-

32	2	(4/1-D)	0<D<1	2	2	2	$f_s/2$	-
33	2	(2.nV+1)/1-D)	0.5<D<1	2V+2	2V+2	2	$f_s/2$	-
34	2	((V+1)/1-D)	0.5<D<1	2V+2	2V+2	1	$f_o/2$	1 (2Windings)
35	4	(1/1-D)+(2.n/1-D+α)	0<D<1	2	4	1	$f_o/2$	2 (6Windings)

4. Luo Converters

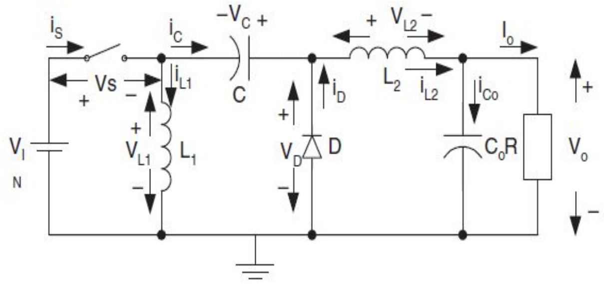

Figure 22. Positive Luo Converters (Voltage Lift)

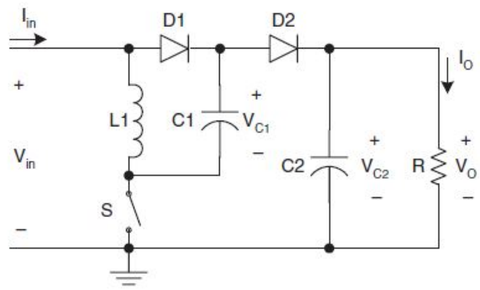

Figure 23. Positive output Super Lift Luo Converters

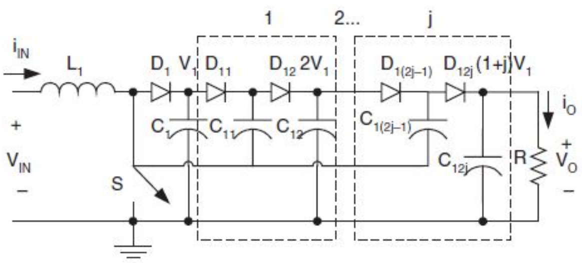

Figure 24. Positive Cascaded multi series Boost Converters

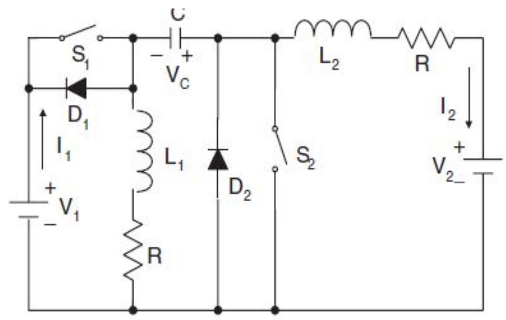

Figure 25. Multi Quadrant Luo Converters

4.1. Voltage Lift Luo Converters

The Voltage lift converters are obtained from basic Luo, cuk&Sepic converters to increase the output voltage. The Voltage lift uses the Arithmetic progression to improve the Converter voltage. The basic elementary circuit of the Voltage lift converter is shown in Figure.22. The output voltage is given by

$$V_o = \frac{1}{1-K} V_{in} \quad (4)$$

4.2. Super Lift Luo Converters

In this Super lift converter, the Voltage transfer gain is increased by geometric progression. It has High Power density and Efficiency. The basic Positive output super lift luo Converter is shown in Figure.23. The Output Voltage transfer gain is given by

$$G = \frac{V_o}{V_{in}} = \frac{2-k}{1-k} \qquad (5)$$

4.3. Positive Output Cascaded Boost Converter (Multi-series)

The above Super lift converters are a bit complex. Positive output Cascaded Luo converter with simpler structure can obtain the same Voltage gain. The First three stages of the Converter is represented in Figure.24. It can be increased further by adding the stages for enhanced voltage gain. The output Voltage of the Converter is given by

$$V_o = \frac{1+j}{1-k} V_{in} \qquad (6)$$

Table 5.Switching status of Multiple output Luo Converters

Switch or Diode	Mode A (QI)		Mode B (QII)		Mode C (QIII)		Mode D (QIV)	
	State-on	State-off	State-on	State-off	State-on	State-off	State-on	State-off
Circuit	Circuit 1				Circuit 2			
S_1	ON				ON			
D_1				ON				ON
S_2			ON				ON	
D_2		ON				ON		

4.4. Multiple Output Luo Converters

This Converter is obtained by combination of positive and negative output luo converter, which is similar to the Choppers. The representation of the converter is shown in Figure.25. This Converter will operate in all four quadrants which is preferred for motoring applications. The modes of operation of the converter are given in Table 5. The Resonant boost converters are now used for renewable applications with proper ZVS and ZCS techniques.

A Good Boosting Circuit must possess the following advantages

- Electromagnetic interference (EMI)
- The output response should be stable
- Low total harmonic distortion (THD)
- Transients must be less
- High power density for reduction of size and weight
- Lower Losses
- High conversion efficiency
- High switching frequency
- Controlled power factor if the source is an AC voltage

5. Conclusion

In this paper various non-isolated boost Converter topologies are analyzed. The main objective of the multiport converters is to carry out single stage power conversion by integrating different sources. Here Non isolated Converters has typical Boosting Circuits to enhance the Voltage Levels, As for as the review is concern the Boosting Circuits must be well efficient to adapt the renewable energy resources. This paper also compares the efficiency & key points of the non-isolated topologies for future research. The focus of this paper is on non-isolated multiport converters, which provide better performance in terms of domestic power operation. The bidirectional power flow in this type of converter gives impact in the maximum use of Renewable energy resources. This Multiport Converters will play a key role in Electric vehicles, charging stations etc.

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