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Evaluation on Various Dc-Dc Non-isolated Maximized Voltage Gain Converter Topology

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***Abstract*—A complete review on different dc-dc non isolated ,high output voltage gain converter's topology are explained in detail.Each topology contains some merits and demerits that has been elaborated.These converter's topology can achieve high voltage gain ratio for a low range of duty ratio such that it can be applicable to PV grid connected power systems. The minimization in switch and capacitor voltage stresses is also observed.This category of converters are simple in structure with use of light weighted components that reduces the manufacturing cost.The non isolated type of converters are hence suitable for low to medium power applications.Finally a proper comparison is determined among these topology on the basis of various parameters.**

***Index Terms*— maximized gain, minimum switch stress, low capacitor stress, non-isolated converter.**

I. INTRODUCTION

The photovoltaic(PV) cell plays a major role in today's electricity generation among all other renewable sources but it's output voltage is very less.A classical boost converter maximizes the output voltage from a low input voltage.But due to it's demerit this converter can't be used for high voltage applications Ref. [1].In past few years various newly derived non-isolated dc-dc converters have been implemented to overcome the boost converter demerits.These category of converters not only provides a high output voltage gain over a low range of duty ratio but also shows reduction in capacitor voltage stresses and switch stresses.The non isolated type of dc-dc converters contains non complex structure with light weighted components that lowers the manufacturing cost and are highly efficient. Hence they are applicable in low to medium power level applications Ref. [3].This paper delivers a detailed discussion on the derived non isolated dc-dc converter topologies. The merits and demerits of each converter is explained followed by basic circuit diagram and voltage gain expression for the better understanding.A comparative analysis is done among different converters on the basis of various parameters that gives an idea about the performance of these converters for future work.These converters are also compared on the basis of their capacitor stress voltages and output gain expressions theoretically.

II. CLASSICAL BOOST CONVERTER

A classical boost converter presented in Fig.1 that maximizes the output voltage(V_0) from a low input voltage (V) for any duty ratio, non complex structure and continuous input current. Equation (1) is the

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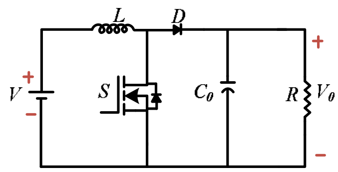
expression of output voltage that shows the dependency of duty ratio(α) on output voltage.Hence to obtain a higher voltage gain the range of duty ratio must be increased that is practically not feasible as the converters efficiency is compromised Ref. [1].The control of boost converter is practically very difficult to achieve if the duty ratio range is increased.Also the switch and capacitor voltage stresses are some common demerits of this converter Ref. [2] that concludes that boost converter can't be used in high power applications.



$$V_0 = \frac{V}{(1-\alpha)} \quad (1)$$

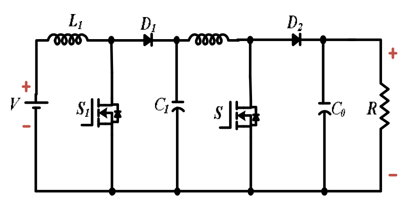
Fig.1.Boost converter

III. ORGANIZATION OF NON-ISOLATED DC-DC MAXIMUM VOLTAGE GAIN CONVERTERS

The demerits of classical boost converter are compensated by these derived non isolated category of converters.This section provides a detailed discussion on various non isolated type of dc-dc converters along with their merits,demerits and basic structure.

A. Cascaded Boost Converters

The cascading structure is a common approach to step up the output voltage(V_0) of boost converter Ref.[3].Fig.2 shows the cascaded boost converter that is formed by cascading two boost converters. Equation(2) is the expression of output voltage.This structure step up the input voltage step by step in order to maximize the output voltage.Also there is reduction in duty ratio range($\alpha_2>\alpha>\alpha_1$) at every stage.The switch stresses are hence minimized increasing the efficiency of converter Ref.[2].The continuous input current is also one of the merit of cascaded boost converter.So these converters can be used in high power density applications Ref.[3].This converter contains some demerits that are increase switch losses due to multiple switches,heavy and bulky structure due to large number of components and difficulty in control due to wide range of duty ratio($\alpha_2>\alpha>\alpha_1$).Due to the mentioned demerits of cascaded boost converters they are not widely used in high power applications.



$$V_0 = \frac{V}{(1-\alpha_1)(1-\alpha_2)} \quad (2)$$

Fig.2.Cascaded Boost converter

B. Quadratic Boost Converters

The limitations of cascaded boost converter can be fulfilled by quadratic boost converters Ref.[3].This quadratic boost converter are formed by replacing a diode D_2 in place of switch S_1 in Fig.2 that provides a simplified structure and good performances Ref.[4]. Fig.3 shows the basic quadratic boost converter that maximizes the output voltage at a low range of duty ratio.Equation(3) is the output voltage expression of this converter.Maximized output voltage gain at low duty ratio, non complex structure,continuous input current,low switch losses,high efficiency and proper control schemes are some of the most significant merits of quadratic boost converters.These converters are therefore widely used in high power density applications.Instead of having above mentioned merits the voltage stress across switch and capacitors are the main issue in such converters.The quadratic boost converters contains high voltage stresses in the capacitors and switches that increases the size and cost of components.

$$V_0 = \frac{V}{(1-\alpha)^2} \quad (3)$$

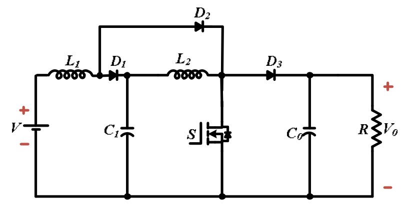


Fig.3.Quadratic Boost converter

C. New Quadratic Boost Converters

To overcome the demerits of basic quadratic boost converters a set of newly derived quadratic converters are developed Ref.[5].The output voltage gain of such converters are same as classical quadratic boost converters.However these converters are developed by replacing the quadratic boosting cell structure Ref.[5] in place of the single inductor L in a classical boost converter that is presented in Fig.4.The quadratic boosting cell as shown in Fig.5 contains two diodes(D_1,$D2$), two inductors ($L_1$and L_2) and a capacitor C.When the switch is active the parallel charging of inductors takes place that is presented in Fig.4.1 and when switch is off then their serial discharging takes place, increasing the output voltage gain as shown in Fig.4.2.Also there is a reduction in stress voltage across the capacitor in the boosting cell. Equation(4) shows the output voltage expression of this converter.These newly derived quadratic boost converters gives high output voltage at a low range of duty ratio, low switch losses, high efficiency and reduced capacitor voltage stresses as compared to conventional quadratic boost converters.But the discontinuous input current and switch stress are the main limitation of such converters.

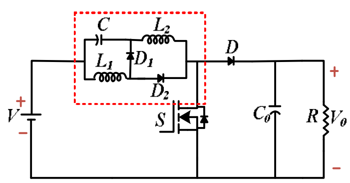


Fig.4.New quadratic boost converter

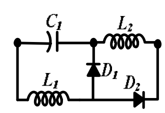


Fig.5.Boosting cell

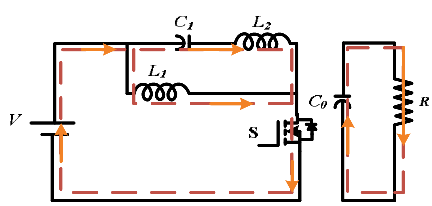


Fig.4.1.New quadratic boost converter during on mode

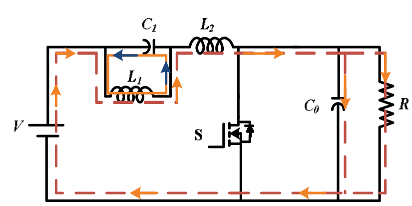


Fig.4.2 New quadratic boost converter during off mode

$$V_0 = \frac{V}{(1-\alpha)^2} \tag{4}$$

D. New Boost Converter Topology

These converter is basically developed by extending the basic quadratic boosting cell Ref.[5] and replacing them in place of the single inductor L in the classical boost converter as shown in Fig.7.The output gain of such converters are very high at a low range of duty ratio along with reduction in capacitor stress voltages Ref.[6].Fig.6 shows the extended structure of boosting cell.By adding another capacitor C_2 , inductor L_3 and two diodes (D_3,D_4) to the boosting cell in Fig.5, the extended boosting cell structure is formed that is presented in Fig.6.These converters show a dependency ofboosting cell on the output voltage gain over a range of duty ratio.Equation(5) gives the output voltage gain expression of this converter.This newly derived boost converter contains the following merits over other converters:

a) Reduced voltage stresses across each capacitor that minimizes the size and cost of capacitors
b) Maximized output voltage gain for a low dutyratio
c) As per the application the output voltage can be maximized by altering the quadratic boosting cells

The discontinuous input current,switch stress and power losses due to extra components are main drawbacks of this converter.

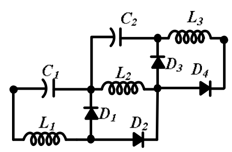


Fig.6.Extended quadratic boosting structure(n=2)

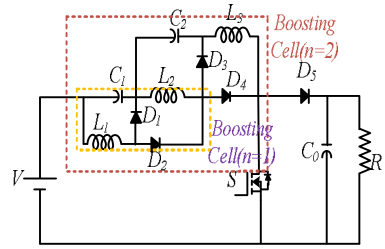


Fig.7.New boost converter with extended quadratic boosting cell(n=2)

$$V_0 = \frac{V}{(1-\alpha)^3} \tag{5}$$

E. New Multi Device Boost Converter With CLD Cell

The basic shortcoming of new quadratic boost converter is the switch stress that can be compensated by addition of a CLD(capacitor-inductor-diode) cell in basic multi-device boost converter Ref.[7].This cell consist of two diodes, an inductor and two capacitor that step up the output voltage and reduce the stress voltage across the MOSFET switch. Fig.8 presents the multi-device boost converter structure with basic CLD cell. Equation(6) shows the output gain voltage expression of the converter where n is the number of switch.This converter presents the maximized output voltage gain for low range of duty ratio,minimized switch stress and high efficiency as compared to other topology.Also the CLD cell is compact in size due to which the cost of components are minimized.Power losses across the switches are the main drawback of this converter.

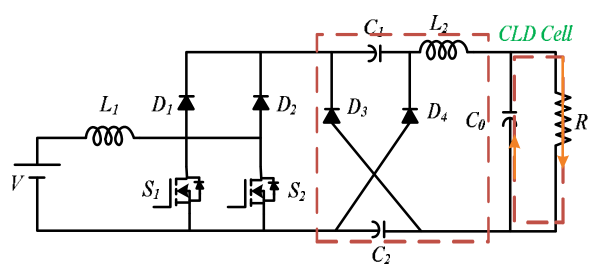


Fig.8.New Multi device boost converter with CLD(capacitor-inductor-diode) cell

$$V_0 = \frac{V(1+n\alpha)}{(1-n\alpha)} \tag{6}$$

IV. THEORETICAL COMPARISON

This section describes the theoretical comparison between various dc-dc non isolated converters on the basis of output voltage gain and capacitor stress voltages.The Table I gives the information about the number of components like switches,capacitors,inductors and diodes used in different converters.Hence it gives an idea about performance of each topology.The Table II shows that the highest voltage gain is obtained in new boost converter topology.Whereas in new multi device boost converter CLD cell topology the voltage stress across switch is minimal as compared to others for the same value of input voltage(V), duty ratio(α),switching frequency(f) and output power(P)gives the information about the number of components like switches,capacitors,inductors and diodes used in different converters.Hence it gives an idea about performance of each topology.

TABLE I. COMPARISON ON THE BASIS OF DIFFERENT PAREMETERS BETWEEN THE DIFFERENT DC-DC CONVERTERS

	Parameters comparison				
Converter	***Switch***	***Capacitor***	***Inductor***	***Diode***	***f***
Boost	1	1	1	1	*f*
Cascaded Boost	2	2	2	2	*f*
Quadratic boost	1	2	2	3	*f*
New Quadratic boost	1	2	2	3	*f*
New boost converter	1	3	3	5	*f*
Multi device boost	2	3	2	4	*2f*

TABLE II. COMPARISON ON THE BASIS OF OUTPUT VOLTAGE GAIN AND CAPACITOR STRESS VOLTAGES

Converter	V_{C1}	V_{C2}	V_{C3}	Voltage Gain
Boost	–	–	–	$V_0 = \frac{V}{(1-\alpha)}$
Cascaded Boost ($\alpha_1=\alpha_2$)	$V_{C1}=\frac{V}{(1-\alpha)}$	$V_{C2}=\frac{V}{(1-\alpha)^2}$	$V_{C3}=\frac{V}{(1-\alpha)^3}$	$V_0=\frac{V}{(1-\alpha_1)(1-\alpha_2)}=\frac{V}{(1-\alpha)^2}$
Quadratic Boost	$V_{C1}=\frac{V}{(1-\alpha)}$	$V_{C2}=\frac{V}{(1-\alpha)^2}$	–	$V_0 = \frac{V}{(1-\alpha)^2}$
New Quadratic Boost	$V_{C1}=\frac{V\alpha}{(1-\alpha)}$	$V_{C2}=\frac{V}{(1-\alpha)^2}$	–	$V_0 = \frac{V}{(1-\alpha)^2}$
New Boost	$V_{C1}=\frac{V\alpha}{(1-\alpha)}$	$V_{C2}=\frac{V\alpha}{(1-\alpha)^2}$	–	$V_0 = \frac{V}{(1-\alpha)^3}$
Multi Device with CLD Cell	–	$V_{C2}=\frac{V_0}{(1+n\alpha)}$	$V_{C3}=\frac{V_0}{(1+n\alpha)}$	$V_0 = \frac{V(1+n\alpha)}{(1-n\alpha)}$

V. CONCLUSION

The paper explains the shortcomings of classical boost converter and possible derived topology to overcome the demerits of boost converter.The converters structure ,merits and demerits are explained in detail.Eventually a theoretical comparison is presented among the converters on the basis of various parameters that gives an idea about their performance.Hence based on the study of different dc-dc non isolated converters some following conclusion are obtained:The non isolated dc-dc converters are simple in structure, reliable, highly efficient and applicable for low to medium power applications.These converters mainly maximizes the output voltage gain for a low duty ratio range.

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