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A Review of Voltage Boosting Techniques for Step-up DC-DC Converter

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Abstract: Boost dc-dc converters are employed to uplifting the level of voltage from input to a higher output level. This paper presents a review on voltage boosting techniques and their application for step-up dc-dc converter. These boosting techniques comprise switched capacitor, voltage multiplier, multistage, magnetic coupling and switched inductor (voltage lifting). All of these techniques consider demerits and merits depending on applications in term of efficiency, reliability, cost, power density and complexity. Due to many difficult topologies and additional components, these techniques can not to define frame work of boost dc-dc converter. Therefore, boost dc-dc converter present clear picture to clarify several techniques of boosting up the voltage.

Keywords: Coupled Inductors, Multilevel Converter, Multi-Stage, Boost Dc-Dc Converter, Switched Capacitor, Switched-Inductor, Voltage Multiplier

I. INTRODUCTION

Switched-mode boost dc–dc converters specified with the enlargement of PWM (Pulse Width Modulation) step-up converter. Topologies of boost converters convert dc input voltage (lower level) in to higher level at output. At present several boost DC-DC converters are operable for miscellaneous power conversion, which depends on multifarious applications. These step-up converters are dextrous in industry with more attention and high demand such as transportation, medical, physics, military and many other applications. With increasing demand of high boost converters, various voltage boosting techniques are presented for multiple power applications.[1]

New techniques and topologies have desired features to boosting up the voltage gain and high power conversion, these features is reliability with high density of power, stability and efficiency [2]. Sometimes, some negative features can be generate due to power conversion which is cost, ripple, loss, Power Supply Rejection Ratio (PSRR) and Low Electromagnetic Interference (EMI).

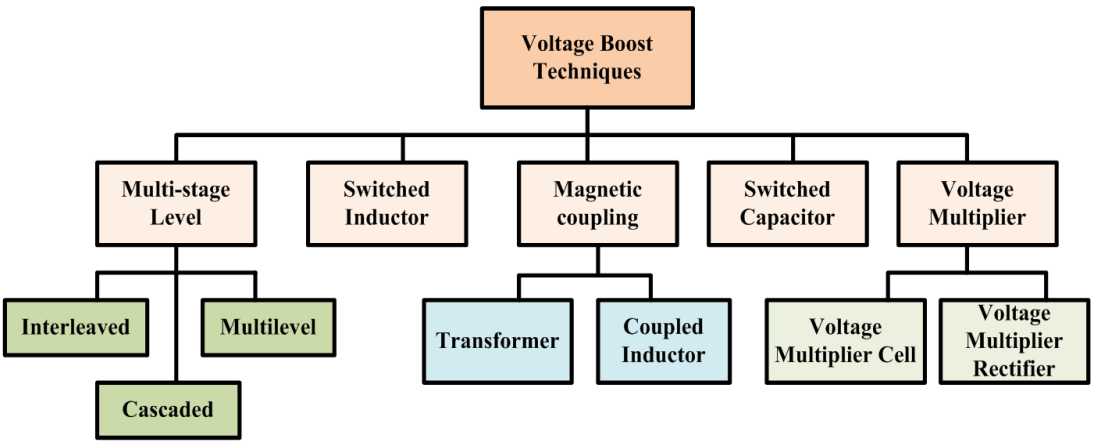

Fig. 1 Comprehensive classification of voltage boost techniques used for dc-dc converter

However, substantially boosting techniques can remove negative features. Voltage boosting applications have acute demand to obtaining high voltage conversion ratio for boost dc-dc converter using miscellaneous voltage boosting techniques such as, voltage multiplier, multistage level, coupled inductors etc. Multiple switching cells and switching topologies make a enormous number of topologies, which can be used to modification and combination of voltage boosting techniques. According to applications, these modification techniques can be employed.

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This review paper presents different voltage boost techniques, which have aim to providing for several boost power conversion and high voltage gain. Multifarious structure has been classified in section II of this paper.

II. VOLTAGE BOOST TECHNIQUES

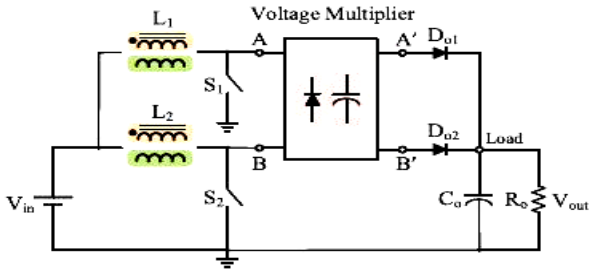
Voltage boosting techniques are categorized into groups which include by their sub-groups, so that each technique can understand more in depth. These sub-groups enumerate advantages and disadvantages and compare of these techniques has also been abbreviated. These booting techniques have been categorized which is depicted in Fig. 1 such as, multi-stage level, switched capacitor/inductor, magnetic coupling, voltage multiplier.

A. Multistage level

The first generic method to boosting up the voltage gain of step-up dc-dc converters is to employ various stages of the converter modules, which is connected in diverse ways. In this section, sub-groups of multistage level interleaved cascaded and multilevel converter topologies are depicted. In the voltage boosting techniques, voltage gain increases linearly or exponentially (often multiplicatively by number of stages) in pursuance of used topology.

1) Interleaved

Step-up power supplies are popular for creating higher dc voltages from low voltage inputs. As the power demands from these supplies increase, boosting techniques and topologies can be employed. Interleaved is a hopeful solution, due to its advantage of power distribution, fast transient response, voltage and inductor current ripple cancellation and passive component size reduction. Especially, when the converter work near 50% duty cycle for two phase interleaved boost converter, [4-5] Input current ripple will be reduce more.Fig. 3(b) depicted the general diagram of interleaved boost dc-dc converter with voltage multiplier modules and parallel input series and output boost converter are combined to increase the high voltage gain [3].



(a)

Interleaved boot dc-dc converter with coupled inductor has been presented [6], which increase the power level with reducing current ripple at input side

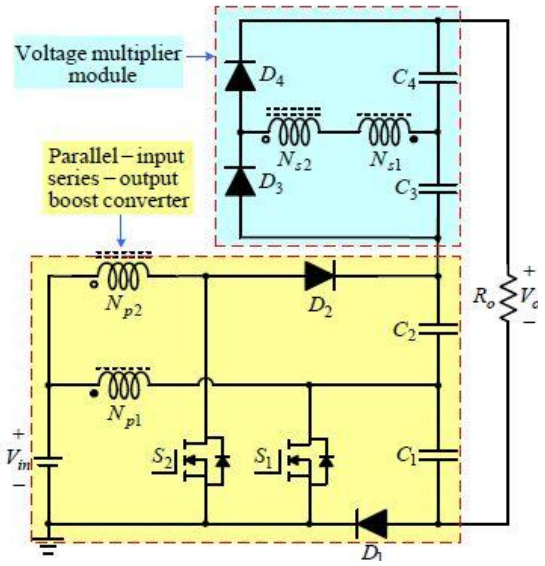


Fig. 2 (a) and (b) General framework of Interleaved dc-dc converter

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2) Cascaded

Cascading connection of converters is a convenient and straight forward approach to increasing gain of voltage. Fig. 3 shows the general diagram of cascaded boost dc-dc converter. [7].

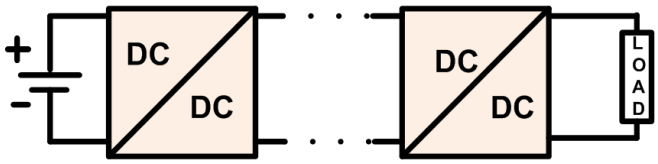
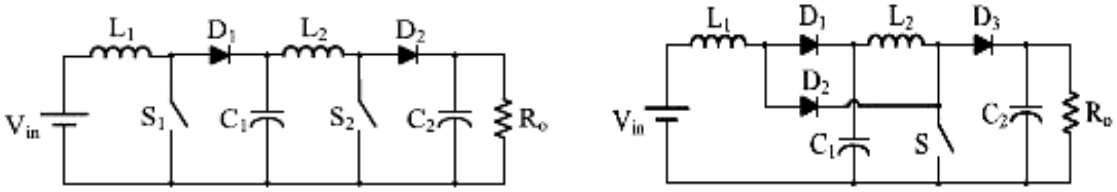


Fig.3 general diagram of cascades dc-dc boost converter

According to the related scheme, two or more boost converters can be connected in cascaded manner is called a quadratic group or different types of boost converters can be connected in cascaded manner is called a hybrid group.

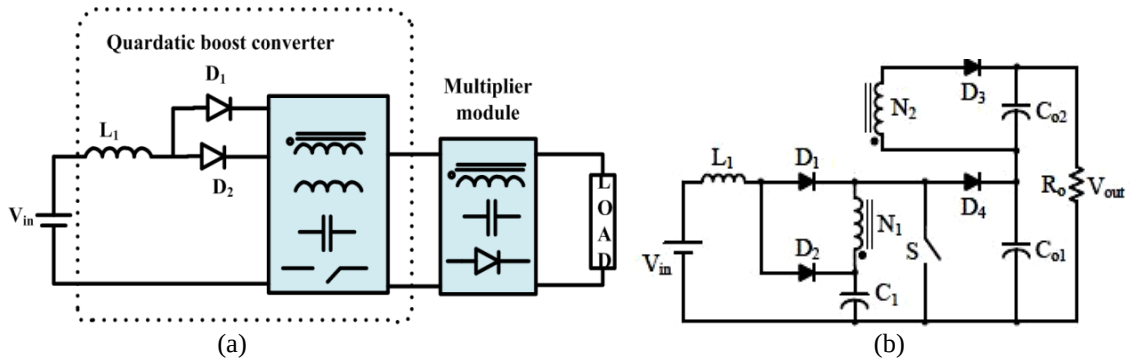
a) Quadratic boost- Fig. 4(a) demonstrated a cascaded sep-up dc-dc converters, which consist of two boost converters in cascaded manner. Thus, voltage stress on the first stage is comparatively low at high frequency. Whilst second stage can be operated to decrease the switching loss at low frequency. Single switch quadratic boost converter has been presented [9], which follows to make the system easier and lifting up the voltage gain via gradually increasing duty ratio.



(a) (b)

Fig. 4 Quadratic dc-dc converter (a) Two cascaded boost converters. (b) Quadratic boost

b) Hybrid boost- Fig. 5(a) depicted with generic diagram of hybrid cascaded converter. To achieve high voltage gains, quadratic converters are combined with multiplier modules, see [17], where first stage is considered a quadratic boost converter and in the second stage, a coupled inductor module is included with a series connection of output capacitors.



(a) (b)

Fig .5 Hybrid cascaded dc–dc converters. (a) General layout of the quadratic hybrid cascaded converter. (b) Example of quadratic-based hybrid cascaded converters

3) Multilevel

Multilevel converters are useful in high voltage and high power applications, [10] due to more attention in industry. In effect, these converters are not support to remove magnetic components but it can also reduce size, cost and weight of converters. From the supply (input voltage) point of view, multilevel converters have two parts: multilevel dc-dc converters with multiple dc source and single dc source. Structures of multilevel dc-dc converters for single DC source are required in motor traction, EV (electrical vehicle), which is presented in Fig. 6(a) and multilevel dc-dc converters with cascaded connection for multiple DC source are employed in multifarious distributed energy system in Fig. 6(b).

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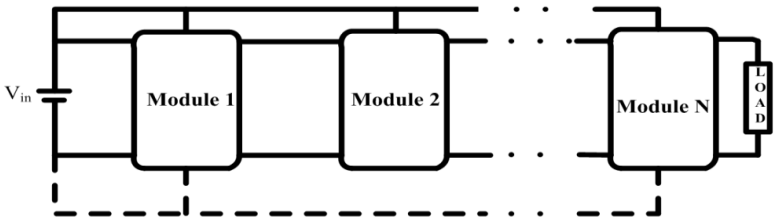
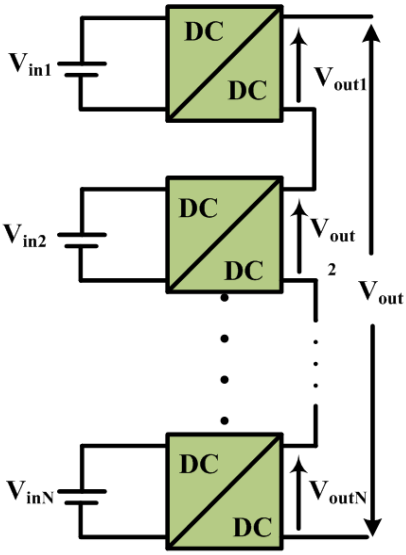


(a)



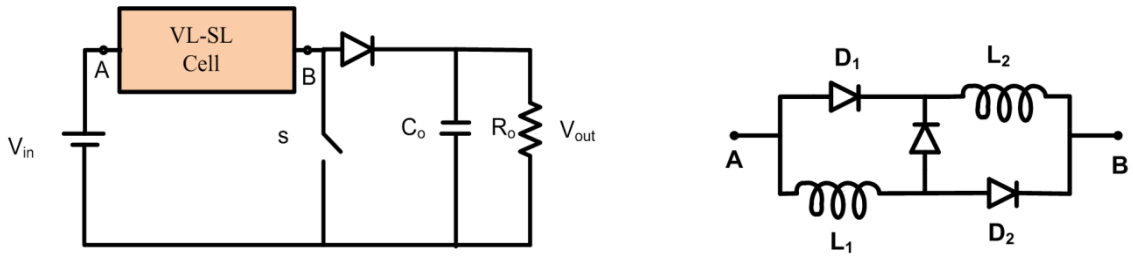
(b)

Fig. 6 General structure multilevel modular dc–dc converters (a) for single dc source (b for multiple dc source)

To instate high conversion ratio, zero current-switching modular structure multilevel converter have been presented [11-12].

B. Switched Inductor

Voltage lift technique is auxiliary and significant way. This technique is extensively used in boost dc-dc converters to up-lifting the voltage level of output, due to charging a capacitor to a certain input voltage and then after the charging, boost up the output voltage. Fig. 7(a) and 7(b) shows the general frame work of voltage lift cells in boost dc to dc converter and basic SL-cell respectively [13-14].



(a) (b)

Fig. 7 Voltage lift cells (a) general structure of VL-SL in boost converter (b) basic switched inductor cell

C. Magnetic coupling

Magnetic coupling is one well known most popular method of voltage boosting techniques to uplifting voltage which is employed in both isolated and non-isolated boost dc-dc converters. In this sub-section, the inductor coupling as well as transformer based boost techniques are demonstrated.

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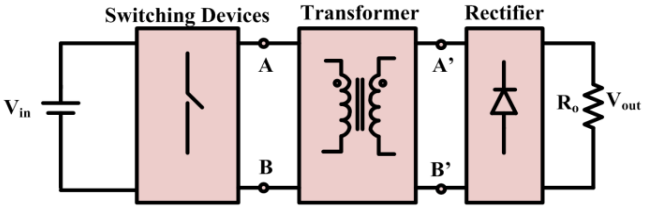
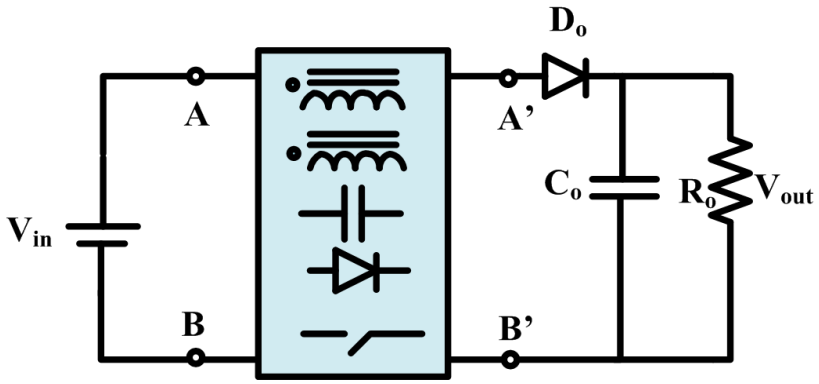


(a)

From isolated converter point of view, transformer based converter have great work for high boost ability [15]. To provide discontinuity in dc-dc converter isolated transformer is expected. Fig. 8(a) demonstrates a basic structure of transformer based converters, in which input port of transformer is followed by the switching device and output port is connected with rectifier. There are divided in several parts according to switching devices like half/full bridge, push/pull and forward/ flyback is depicted in Fig 8(b-d).

In Fig. 8(e), basic structure coupled inductor dc-dc boost converter is depicted. Second part of magnetic coupling is coupled inductor. Coupled inductors are precious components of non-isolated converter, which firstly store the energy in one part and then in other cycle power the load. Various application do not desire for isolation because, coupled inductor is enough to provide auxiliary and profitable boosting techniques in converter instead of isolation [16-17].



(b)

Fig. 8 (a) basic structure of transformer based converters (b) basic structure coupled inductor dc-dc boost converter

D. Switched Capacitor

SC (switched capacitor) is general and efficient way of voltage boost techniques, which is applied in numerous applications. SC circuits are prevalent technique based on cell structure. The combine switched boost converter with switched capacitor (SC) provide large conversion ratio due to high boost up capability [18] with the result that technique can eliminate voltage stress and spikes of active switches and output diodes [19], which is demonstrated in Fig. (8) Consequently, power losses are reduced and efficiency is enhanced.

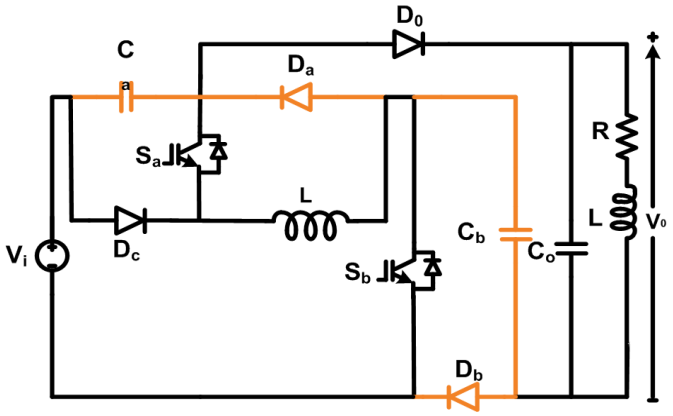


Fig. 9 Switched boost converter with SC

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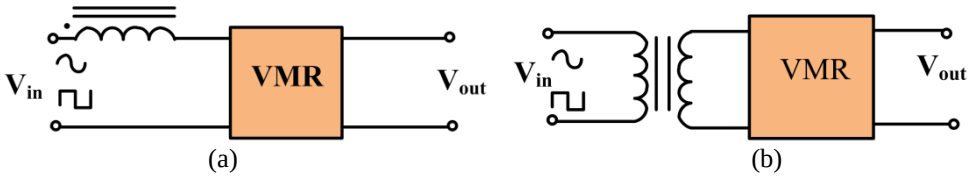
E. Voltage multiplier

Voltage multiplier structure is a simple and efficient, which consists a set of capacitor and diodes to achieve voltage at output, it can be shown in Fig. 10. During structural approach they are separated in two groups.

- Voltage multiplier cell (VMC), which is included in the middle of the diagram after the main switch to alleviate voltage stress.
- Voltage multiplier rectifier, which take place at the output of transformer and coupled-inductor-based structures to rectify AC (alternating current) or pulsating DC (direct current) voltage .

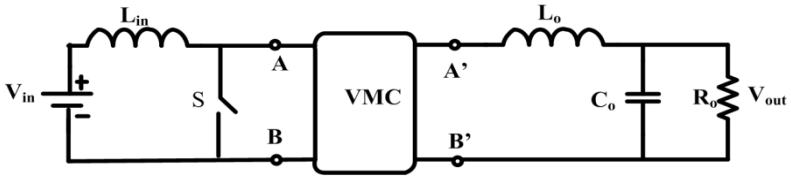
a) Voltage multiplier rectifier- VMR circuits can be at output side of a dc-dc converter along with AC and DC inputs they are also represents a VMRs.



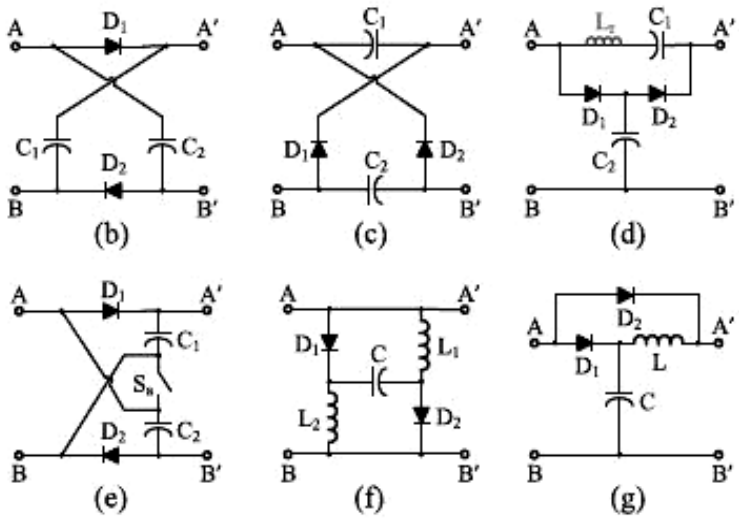
(a) (b)

Fig.10 General view of the placement of VMRs (a) at dc pulsating output and (b) at ac output

b) Voltage multiplier cell:- voltage multiplier structures are legendary for boosting up applications and can be implemented with simply switching structure. Fig. 11(a) demonstrates few general vasiculations, which represents as VMCs. VMC can be referred with some cells, they consists passive components (diodes and capacitors) see Fig. 11(b).



(a)



(b)

Fig.11(a) Generic diagram of voltage multiplier cells in step-up dc-dc converters.
(b)–(g) several voltage multiplier cells

VMCs have also auxiliary switches in these cells with passive components [21]. Many voltage multiplier has been presented with hybrid implementations in [20]. When proposed circuits combined with multiple VMC they can generally provide high voltage gain with low stress.

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III. CONCLUSION

This paper has demonstrated a review on voltage boosting techniques and their applications for step-up dc-dc converter. Different voltage boosting techniques have its own specific characteristics and suitable applications. New topologies with different techniques can be merged and improve the performance for required applications. To decide the most convenient boosting techniques, these paper help to provide a clear image for desired applications. These review paper has various solutions for next generation of power conversion system and clarify about several topology with different techniques.

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