

Review Paper on Performance Improvement of High Gain DC-DC Boost Converter

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Abstract - DC-DC converters with voltage boost capability are widely used in a large number of power conversion applications, from fraction-of-volt to tens of thousands of volts at power levels from milliwatts (mW) to megawatts (MW). The literature has reported on various voltage boosting techniques in which fundamental energy storing elements (inductors and capacitors) and/or transformers in conjunction with switch(es) and diode(s) are utilized in the circuit. These techniques include switched capacitor (charge pump), voltage multiplier, switched inductor/voltage lift, magnetic coupling and multi-stage/-level, and each has its own merits and demerits depending on application, in terms of cost, complexity, power density, reliability, and efficiency. To meet the growing demand for such applications, new power converter topologies that use the above voltage boosting techniques, as well as some active and passive components, are continuously being proposed. The permutations and combinations of the various voltage boosting techniques with additional components in a circuit allow for numerous new topologies and configurations, which are often confusing and difficult to follow. Therefore, to present a clear picture on the general law and framework of the development of next generation step-up dc-dc converters, this paper aims to comprehensively review and classify various step-up dc-dc converters based on their characteristics and voltage boosting techniques.

Key Words: Switched mode step-up dc-dc converter, PWM boost converter, voltage multiplier, voltage lift, switched capacitor, switched inductor, coupled inductors, transformer, multistage converter, multilevel converter.

1. INTRODUCTION

Switched mode step-up dc-dc converters originated with the development of Pulse Width Modulated (PWM) boost converters. Step-up dc-dc topologies convert lower dc voltage levels to higher levels by temporarily storing the input energy and then releasing it into the output at a higher voltage level. Such storage can occur in either magnetic field storage components (single inductor/coupled inductor) or electric field storage components (capacitors) through the use of various active or passive switching elements (power switches and diodes).

With the introduction of semiconductor switches in the 1950s, step-up dc-dc converters achieved steady performance advancements and their use accelerated through the 1960s when semiconductor switches became commercially available with allied manufacturing technologies [1]. The rise of the aerospace and telecommunication industries further extended the research boundaries of boost converters, especially in applications where efficiency, power density, and weight were of major concern. Efficiency has steadily improved since the late 1980s owing to the use of power Field Effect Transistors (FETs), which are able to switch more efficiently at higher frequencies than power Bipolar Junction Transistors (BJTs) while incurring lower switching losses and requiring a less complicated drive circuit. In addition, the FET replaces output rectifying diodes through the use of synchronous rectification, whose "on resistance" is much lower than and further increases the efficiency of the step-up dc-dc converter, which requires a higher number of diodes for voltage boosting [1]-[3].

The voltage step-up capability of a PWM boost dc-dc converter is enabled by an inductor at the input side that can operate either with a continuous current—in so-called Continuous Conduction Mode (CCM)—or including a zero current state in Discontinuous Conduction Mode (DCM). In general, CCM operation is more prevalent owing to the load dependent voltage gain, high current ripple, and low efficiency of DCM operation. However, the higher stability characteristics of the boost converter and smaller inductor implementation in DCM mean that, occasionally, DCM operation of step-up dc-dc converters is preferable [4]-[5].

Each topology has its own advantages and disadvantages and should be selected based on the application and its requirements, e.g., isolated/nonisolated, unidirectional/bi-directional, voltage-fed/current-fed, hard/soft switched, or with/without minimum phase characteristics.

1.1 VARIOUS TOPOLOGIES OF STEP-UP DC-DC CONVERTERS

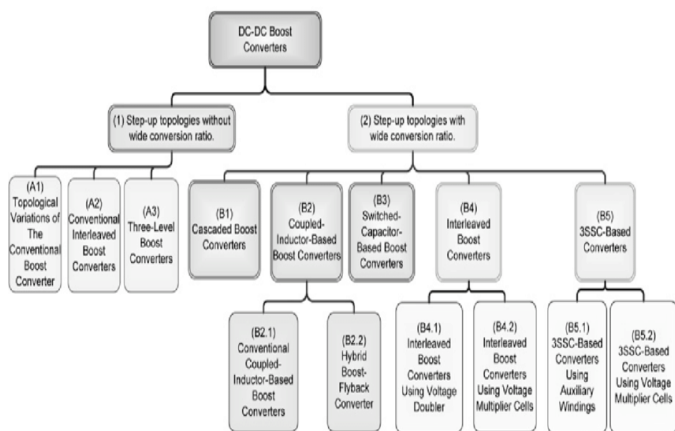


Fig 1: Various technique for step up converter.

A. Voltage Multiplier Cell: The circuits of Voltage multiplier are easy to apply in any circuit as they are popular for high boost application. The circuit diagram of VMC in DC-DC converters is shown in Fig. 2. The cells which consists capacitors and diodes are as shown in Fig. 2 (b) to Fig. 2 (d) are known as switched/diode-capacitor voltage multiplier. Some of the VMC placed vertically as shown in Fig 2 (c). As shown in Fig. 2 (b) to Fig. 2 (d) the performances of the VMCs are alike and the ratios of voltage gain are similar: $(1 + D) / (1 - D)$, in this D denotes a duty ratio. For achieving the zero current switching (ZCS) situation in VMC a small inductor is used as shown in Fig. 2 (d). This raises the efficiency of the circuit and decreases the losses in the power.

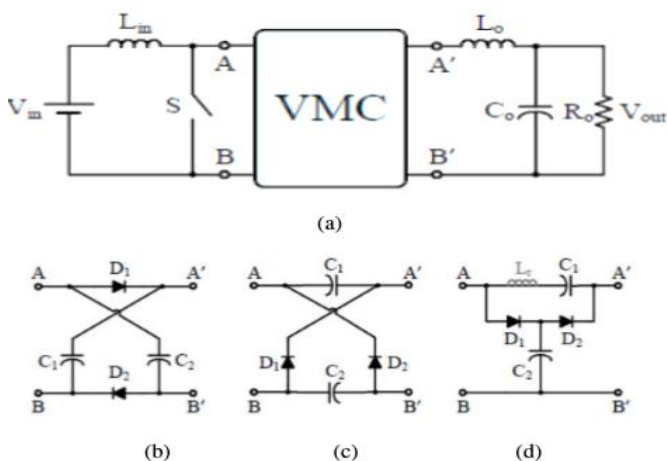


Fig2: Voltage multiplier cell

B. Voltage Multiplier Rectifier: In this, the group of voltage multipliers is referred. This consists of different arrangements of capacitors and diodes. They are recognized as voltage multiplier rectifiers in Fig. 3 and can be used as a converter of output stage with AC or input as pulsating DC.

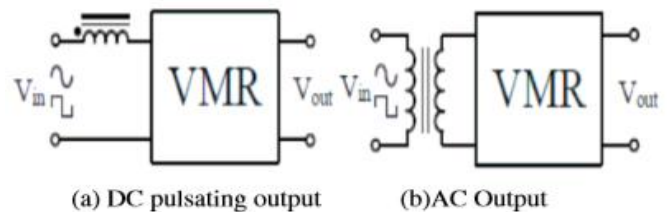


Fig 3 – Voltage Multiplier Rectifier.

Half Wave: The wide group of half-wave voltage multiplier rectifiers is presented in Fig. 4. This can be used for joined inductors and insulated transformers secondary side as well as it is used in converters integrated with coupled inductors and transformer. In multi-stage converters and DC-DC converters based on the transformer, Greinacher Voltage Doubler Rectifier (G-VDR) is used as shown in Fig. 4 (a). The disadvantage of this type of VMR is that the voltage stress on output capacitor and diode is high. Fig. 4 (b) shows an enhanced form of the G-VDR that was just presented. As compared to output voltage the voltage stresses are half; this permits for the consumption of lesser voltage rating apparatuses than in conventional VMRs which in turn leads to great efficiency and low power loss. The combination of one inverted and one normal G-VDR forms the Greinacher Voltage Quadrupler Rectifier (G-VQR) as shown in Fig. 4 (c). The neutral point terminal is provided by this VMR which is required for transformer-less inverters based on the half bridge.

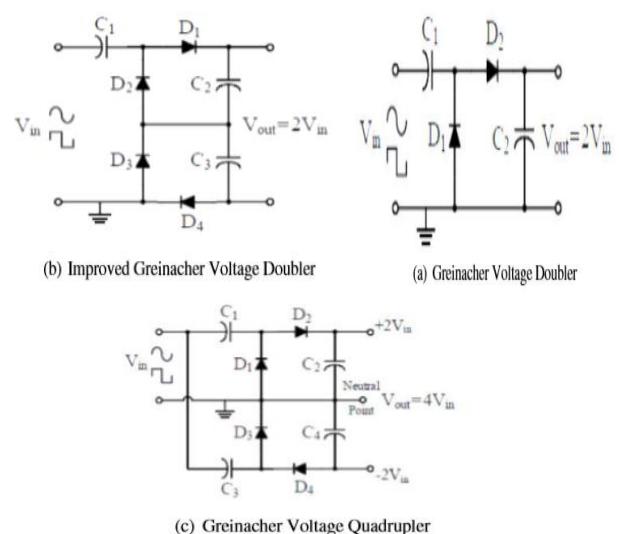


Fig 4- Various Half wave voltage multiplier rectifier

Full Wave: The converters based on a transformer at the output stage uses VMRs of the Full wave which is one of the independent boosting voltages. The generalized and basic structure groups of odd and even voltage multiplier are shown in Fig. 5 In Fig. 5 (a) the VMR is known as voltage double rectifier full bridge, reduces the voltage stresses of output capacitors that is reduces the one-half voltage and it is used for different DC-DC converters. Due to voltage stresses are balanced on both diodes and capacitor, in recent DC-DC converters by the VMR was known as quadrupled voltage rectifier as shown in Fig.5(b).

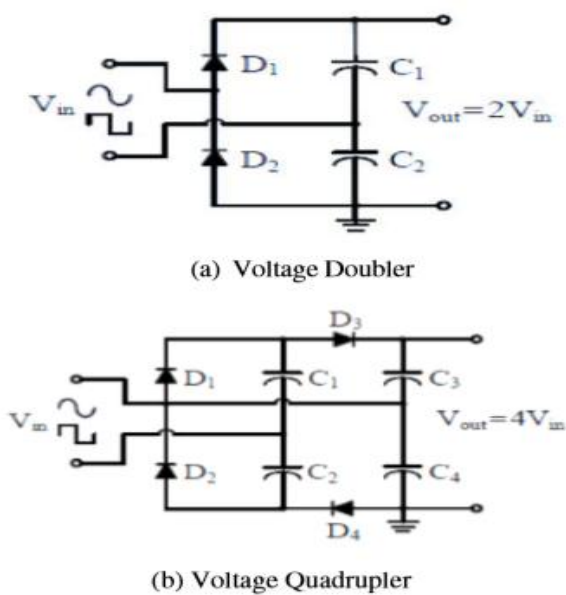


Fig 5- full-wave voltage multiplier rectifiers

C. Switched Inductor and Voltage Lift: For increasing the level of voltage in DC-DC converters, one of the methods is Voltage Lift (VL). This method is based on capacitor charging to a definite voltage, for example, input voltage and the output voltage is stepped up (lifting voltage) with the capacitor charged to the accepted voltage level. By iterating this process with the addition of extra capacitors to produce so-called triple-lift, quadruple-lift and re-lift, circuits, there is an improvement in output voltage level. The capacitor diode VL circuit with n-stage is used in the circuit of multiple-lift for increasing the voltage lift.

In step-up DC-DC converters, the VL cells can use the VL techniques. In Fig. 6, Voltage Lift Switched Inductor (VL-SL) is shown. In a step-up DC-DC converter a particular placement of these cells is shown in Fig 6(a). The firstly introduced a basic SL cell is shown in Fig. 6(b). The magnetization of inductors, when placed in parallel and demagnetized in series, is conducted in SL cell. For reducing the weight and size of converters the inductors are included into single core as both inductors have the

same operational condition and equal inductance value. The Fig.6(c) represents the basic VL circuit. Recently in the elementary VL cell small resonant inductor, less than 1 μH is introduced. This gives the benefit of high efficiency and simple structure for DC-DC converters. In an SL cell, the VL cell is implemented in order to produce self-lift SL cell as shown in Fig 6 (d). The double self-lift SL cell is produced by implementing capacitor and diode to the self lift as shown in Fig. 6 (e).

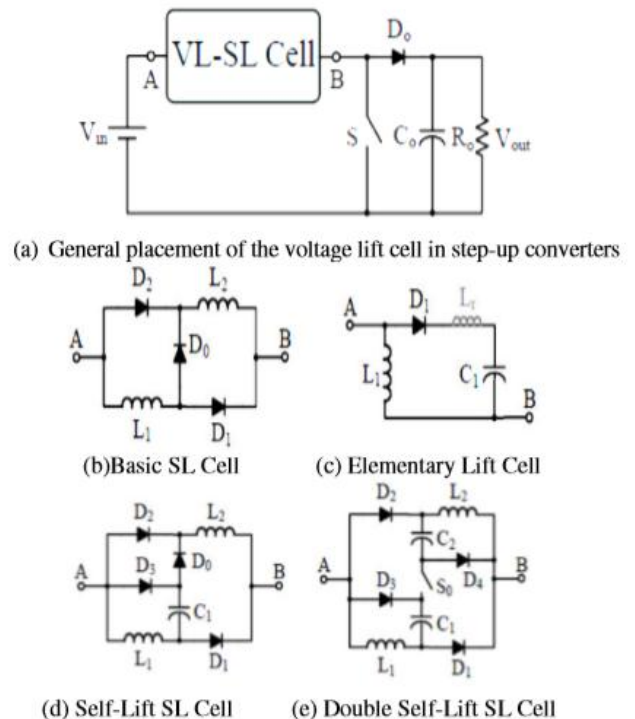


Fig 6- Switched Inductor and Voltage Lift

3. CONCLUSION

The ongoing technological progress in high voltage step-up dc-dc converter has five primary drivers—energy efficiency, power density, cost, complexity, and reliability—all of which also influence each other to some extent. This view facilitates quick selection between related alternatives for special load and application requirements. Each voltage boosting technique has its own unique features and suitable applications, and there is no onsize-fits-all solution. Nevertheless, it is generally not fair to permanently favor any particular technique or solution. The converter topology and control method, which was seen as complex and inefficient a decade back, has now become a key solution for many industries and applications. In this manner, new topologies based on different and often merged voltage boosting techniques will continue to appear in order to meet and improve the performance of different applications.

ACKNOWLEDGEMENT

It gives me great pleasure to acknowledge my guide, **Prof. S. Y. Gadgune** for helping me with his valuable suggestions and for being a constant source of help and guidance. His timely help made it possible to complete the work.

I would like to thank **Prof. L. S. Patil**, Head of Department, **Prof. M. C. Butale** P. G. Coordinator and **Dr. G. V. Ghewade**, Principal, Padmabhooshan Vasandraodada Patil Institute of Technology, Budhgaon and the entire staff members of Electrical Engineering Department for their kind co-operation and help. I also take this opportunity to thank our colleagues who backed our interest by giving suggestions and all possible help.

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