DC-DC BOOST CONVERTERS - A LITERATURE REVIEW

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Abstract: In recent years, as a consequence of fast paced populace and industrialization, we can see a steady increase in the energy performance in all the fields. But the warehouse of energy resources such as fossil fuels etc are getting lesser and lesser. These energy resources are safer to use and are non-renewable. The consumption of fossil fuel has certain disadvantage that by its dissipation greenhouse wastes are collected in the atmosphere which is the major cause of global warming and climatic alterations. In this scenario renewable resources like solar cells, fuel cells, wave energy and tidal energy are becoming more acceptable alternate energy sources in distribution system. The hazard of collapse of fossil fuels can be conquered to a great extent as the renewable energy source can be taken as an alternate because it is available in excessive in nature. But the voltage delivered by such renewable energy sources are unstable and very low to be utilised for commercial purposes. So they are combined with high gain dc-dc converters to get a high output voltage. The high output voltage obtained from the dc-dc converter is then assembled to the inverter for high ac power production.

Keywords: Voltage Multiplier Cell, Interleaved Boost Converter, coupled inductor, Switched capacitor.

1. INTRODUCTION

In Commercial and Industrial applications, it is required to convert a constant dc voltage into variable voltage dc. A dc-dc converter can be considered as the dc equivalent of an AC transformer with varying turns ratio. The basics of boost converters are given in [2] to understand the basic working principle which deals with time domain studies, filter design, duty cycle derivation, signal stability analysis etc

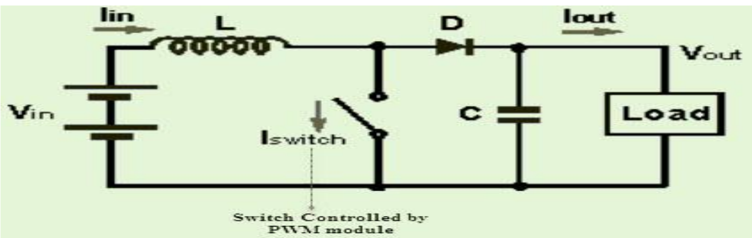

Figure1: Basic Boost converter circuit [23]

The basic boost converter circuit consist of inductor, MOSFET as a power switch, diode, capacitor and a resistive load. Square wave is given as input to the MOSFET gate. MOSFET acts as a switch. It conducts and the inductor stores energy in the magnetic field. During the falling edge of the square wave, MOSFET gets turned off. The sudden current fall causes the production of back emf. Here the input voltage and the back emf comes in series with each other and get added. The boost converters require large duty cycles to produce high voltages which in turn causes high conduction loss in MOSFET and the reduction in converter efficiency.

2. VOLTAGE BOOSTING METHODS

Literature survey reveals that there are so many methods to boost voltage level with high efficiency. The methods include switched capacitor, Voltage multiplier cells, switched inductor for voltage lift, magnetic coupling and multistage level. This paper makes a review of different topologies making use of these various methods.

Recently many applications are concentrated on battery power and low voltage storage elements. Hence the demand for efficient, high gain dc-dc boost converters are increasing day by day. Typical applications are photovoltaic array, fuel cell stack, renewable energy systems, Electric vehicles, home dc appliances etc., uninterrupted power supply [3]-[5]. Converters with high static gain, high efficiency, less weight, volume and cost is required for these applications. In order to get high efficiency, the crucial stage for these converters are the voltage boosting stage due to the operation with high input current and high output voltage.

2.1 Switched Capacitor technique

A switched capacitor is an electronic circuit which utilises the movement of charges into and out of capacitors when switches are opened and closed. It is an effective method for obtaining high gain [6]. The main advantage is that the energy stored in the magnetic elements is very less by which weight, size and cost for the inductors are substantially reduced, less conduction loss for the power supply. and improved efficiency. The main drawback of the switched capacitor technique is the pulsating input current. Many other converters based on switched capacitor technique is discussed [6]-[8]. Many high voltage gain converter topologies have been developed which utilises the combination of conventional boost converters with switched capacitor-inductor technique.[4][5][9]. [24] suggests a system which can be used in distribution system which facilitates the storage of high voltage in grid system. Here the switched inductor in the second stage provides high gain.

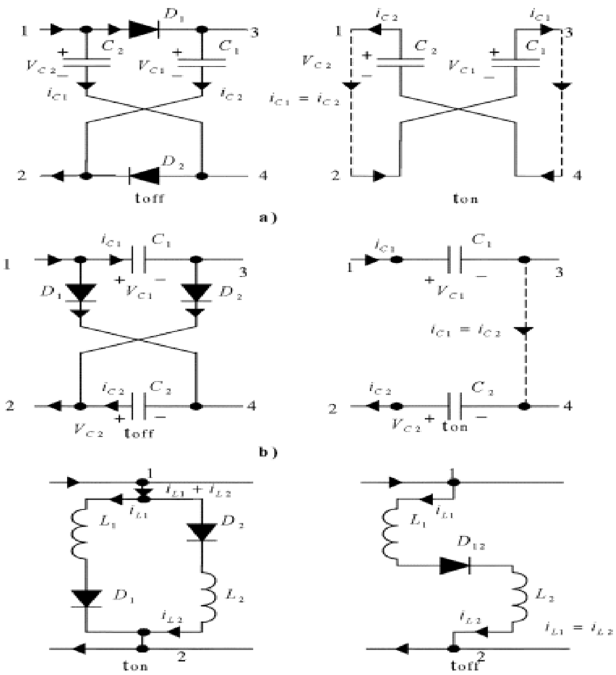

Figure 1. Switching topologies of the step-up structures [6]

2.2 Voltage Lift Converters

It is the most effective voltage boosting technique which uses the performance of energy storing elements such as capacitors and inductors. Capacitor is charged and Step by step increase of the input voltage charges the capacitor more and more and deliver high voltage to load. Figure 2 shows the basic circuit of voltage lifting method.

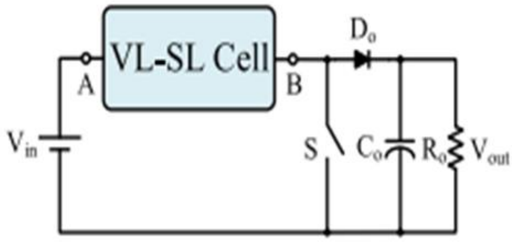

Figure 2: Voltage lifting basic circuit [12]

As the number of capacitors is increased, the voltage can be re-lifted, triple-lifted and quadruple lifted. A boost converter is proposed using this technique [10]. The main advantages are reduced output voltage, reduced complexity due to the lack of additional switches, high efficiency, low cost. [11] uses a combination of coupled inductors and voltage lift cell. The main advantages are high voltage conversion ratio is obtained through inversely coupled inductors and voltage lift cell.

2.3 Voltage multiplier technique

A voltage multiplier cell (VMC) includes a number of of capacitors and diodes for attaining high voltage gain. It can be placed in the converter in two ways. 1. Place it after the switch by which the voltage stress across the switch is highly reduced. The second method is to place the VMC in the output stage of the transformer. Figure.2 shows the placement of VMC in step up converter.

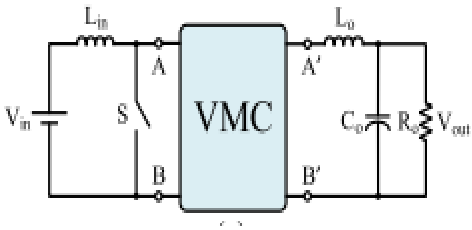

Figure 2: Placement of VMC in step up converter [12]

A conventional boost converter coupled with a voltage multiplier cell (VMC) is suggested. [4][13] proposes a boost converter having a power switch, a three -winding inductor, and a voltage multiplier unit. A high voltage gain can be achieved by avoiding the need of high duty cycle. A step- up DC-DC converter providing high gain which uses three inductors which are coupled to each other and a voltage multiplier system are proposed to obtain high output voltage [15]. Here the number of active switches required is only one which avoids the need of high duty cycle. To reduce the voltage stress on the power switch and diodes, the secondary windings turns ratio is increased. Hence low rate switches can be selected. A network which cancels out the ripples is proposed [15]. The proposed network includes capacitors and coupled inductors and it achieved both the merits of the interleaved boost converter and input current ripple cancellation. A standard boost converter using voltage multiplier cell is introduced in [15][16]. A high voltage gain is attained by this topology.

2.4 Magnetic Coupling Technique

Since the foremost feature of the renewable energy sources are their low output voltage, they are combined with high gain dc-dc converters to get a high output voltage [1]. A non-isolated step up dc to dc converter is introduced. A regenerative snubber circuit recycles the leakage current to the output side. Soft switching conditions are used here. The high output voltage thus obtained is then assembled to the inverter for ac power production. In a standard boost converter as the voltage conversion ratio increases, the duty ratio also increases. So in an attempt to meet the high voltage requirement, high duty ratio is required by the conventional boost converter. In such a circumstance it is very difficult to get high efficiency. The ordinary boost converters face with certain disadvantages like the high conduction losses, diode reverse recovery problem which in sequence decreases the efficiency and low power level. Boost converters combined with coupled inductors are a good remedy for the above mentioned problems. Wisely selecting the turns ratio of the coupled inductors, the duty ratio can be minimised and hence the voltage stress on the switch. A few papers in the literature concerns with the boost converters with coupled inductors combined with transformer which has turns ratio of greater than one. High gain is obtained with these converters without using high duty ratio and more components [4][5][9] .Practical coupled inductor acquires huge measure of leakage inductance because there exists a non-ideal coupling between primary and secondary. The power switches are affected by the voltage stress which is a result of the leakage inductance. The paper [16] has been proposed as a solution. But the active clamp topologies were complex. For applications utilizing high input current, an interleaved boost converter comprising of coupled inductors is proposed [17] in the literature.

2.5 Interleaved technique

In interleaving method, the frequency of a phase is lower than the effective switching frequency. The switching losses are substantially reduced by the interleaving method as the input current is divided into various phases. An interleaved converter with voltage multiplier cell is introduced [18]. The voltage gain range can be increased by adjusting the turns ratio of the coupled inductor. The main limitations of this converter is hard switching operation of the MOSFET switch and large current stress through the clamp capacitors. An interleaved converter [19] is recommended in the literature. The energy stored in the inductance is gathered together in a clamp capacitor. The clamp diode is acitng as the discharging path for the leakage current. Thus the clamp operation is done efficiently. A high gain interleaved dc-dc converter having two multiplier cell is introduced in the literature [20]. But the main drawback found is that the system is so bulky as it consists of so many power capacitors and power diodes. Non-isolated converters using voltage multiplier cells and switched capacitor method have been suggested [25] which can provide high voltage gain having less turns ratio at very low duty cycle. In this topology the size of component can be effectively reduced. In dc- dc converters the power switches are affected by voltage spikes due to the presence of leakage energy. As a solution to this problem snubber circuit utilizing active clamp network is brought forward [22].

3 COMPARISON OF DIFFERENT VOLTAGE BOOSTING METHODS

Table 1: Comparison of different voltage boosting methods.

Voltage boosting Method	Advantage	Disadvantage	Application Field
Switched Capacitor	High gain, fast response,high conversion ratio	Pulsating input current	Energy harvesting,power electronic applications
Voltage Lift	Low voltage stress on semiconductor devices, high voltage conversion	Complex circuit, reduced efficiency,	Renewable energy applications

	ratio, high power density. Less ripples in output voltage		
Voltage Multiplier	High voltage gain, Reduces the stress on main switch.Compact circuit, can be integrated with interleaved converters, modular structure	Need multiple sections for high voltage applications, high voltage stress on components	X-Ray, Laser, Plasma research
Magnetic Coupling	High voltage gain,applicable to isolated and non-isolated converters.	Unwanted voltage spikes across the switches. leakage inductance.	Renewable energy generators,grid applications
Multistage (Interleaved)	High gain, reduction of switching loss, increased power density, reduced input and output ripples.	Complex Structure, High stress on semiconductor devices, additional current loops required.	Renewable energy systems, high power applications

Conclusion

This paper makes a literature review of different dc-dc boost converter topologies presented in many international journals, IEEE transactions and some conference papers. Different topologies were studied for understanding the operations, converter techniques, advantages and disadvantages. The study makes a reveal of the best topologies which gives high gain, high efficiency and less ripples which are considered as the main factors in many applications like photovoltaic cells, Hybrid electric vehicles, Renewable energy systems etc.

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