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Simulation and Comparison of Basic Boost Converter and Two-Stage DC-DC Step-Up Converter

KEYWORDS: Boost converter, DC-DC Step Up Converter, Two Stage Conversion.

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ABSTRACT A DC-to-DC converter is a device that accepts a DC input voltage and produces a DC output voltage. Typically the output produced is at a different voltage level than the input. DC-DC Converter has widely been used in Switched-Mode Power Supply and DC drives. In this paper, comparison between basic boost converter and the novel topology two stage DC-DC step-up converter is given. In simple boost converter boost ratio is limited. For solving this problem two-stage conversion is used. Two-Stage DC-DC converter is the novel topology used for converting a 24V DC input supply into 135V DC. The full-bridge topology is used for Step-up the DC voltage. The simulation of boost converter and Two-stage DC-DC converter can be done with MATLAB and PSIM respectively.

I. INTRODUCTION

The DC-DC Converter converts the given voltage to the required value of voltage by load and desired it to the load. Fig.1 shows the block diagram of DC-to-DC Power conversion. The system consists of the dc source, dc-to-dc converter and the load. The dc source provides arbitrary dc voltage to the dc-to-dc converter. The dc-to-dc converter then converts the given dc voltage to the value required by the load and delivers it to the load. The load is an application system that operates with a fixed voltage and eventually consumes electrical power.

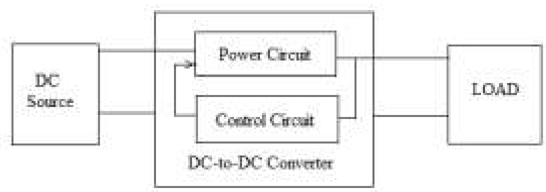

Fig. 1 Block diagram of DC-to-DC Power conversion

The characteristic features of DC source, DC-to-DC converter and the load are given below:

1) DC source with Non-ideal characteristics:

The voltage level of the dc source could vary with time, as is the case with batteries, fuel cells and other standalone dc sources. The change in the voltage could occur either gradually or abruptly, depending on the characteristics and condition of the dc source. A rectified ac source is often used as a substitute for the dc source. For this case, the rectified ac source could contain a considerable amount of ac components, known as ac ripple. In addition, the output of the rectifier ac source could be corrupted with various noises. Accordingly, the dc source represents any non-ideal source whose voltage can be varied, polluted with ac ripples and noises and switched from one value to another.

2) DC-to-DC converter as voltage source:

The DC-to-DC converter receives an arbitrary voltage from the non-ideal source and is required to provide a fixed dc voltage for the load. To altering the voltage level, the dc to dc converter should have capacity of maintaining its output constant at the presence of the variation, ac ripple component and abrupt change in the input voltage. The dc-to-dc converter should function as an ideal voltage source powered by a non-ideal voltage source and programmed to produce the required dc voltage for the load. DC-to-DC converter is more complicated in structure and functions. They divide into two blocks: Power circuit

Control circuit

Power circuit alters the level of the input voltage into a desired value using various circuit components. Control circuit provides the necessary signals for the power circuit to execute its function. All the power circuit employs the common electronics components to perform dc-to-dc power conversion.

3) Load as Dynamic current sink:

The load of a dc-to-dc converter can be any electronics equipment or system operating with a fixed dc voltage. The load draws the current from dc-to-dc converter to meet its power requirement load current fluctuate depending on operational conditions of the load.

There are basic three topologies: buck, boost and buck-boost converter. The buck (step-down) converter is used to decreases a given input dc voltage. The boost (step-up) converter is used to increases a given input DC voltage. The buck-boost (inverting Step-up/down) Converter inverts the polarity of a given input dc voltage and can increase or decrease the input voltage magnitude. These converters have one active switch and one passive switch performing the switching action in the converter. The active switch is directly controlled by an external control signal. It is usually implemented with a bipolar or a field-effect transistor. The passive switch is indirectly controlled by the state of the active switch and the circuit condition. It is usually implemented by a diode. Two switches can be combined into one network with three terminals a, p, and c, which stands for active, passive, and common, respectively. This three-terminal network is called the PWM-switch. Since all other elements of the converters are supposed to be linear, the PWM-switch is the only nonlinear element and therefore responsible for the nonlinear behavior of the converters. The

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active and the passive switch operate like a single-pole double-throw switch. During the time interval dT, the passive switch is off and the active switch is on, and the active terminal is connected to the common terminal. During time interval d'T, the active switch is off and the passive switch is on, and the passive terminal is connected to the common terminal. T, is the switching period of the active switch, d stands for the duty ratio as the ratio of the on-time of the active switch and the switching period and d' = 1 - d for the continuous conduction mode[7].

For these reason, a Two-Stage Step-Up Converter must be used when the output voltage is higher than the input voltage. Two-Stage Step-Up converter is the connection of full-bridge controlled Inverter and full-bridge diode rectifier through

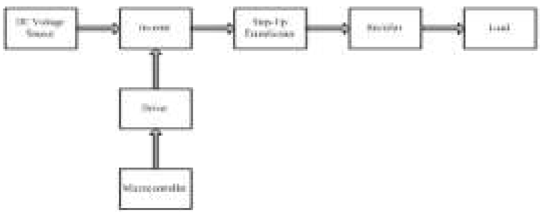

Fig. 2 Block diagram of Two-stage DC-DC step-up converter

step-up transformer. A two-stage DC-DC step-up converter is a full-bridge converter and this full-bridge converter is used to convert 24V DC into a constant output voltage 135V DC.

Fig. 2 shows the block diagram of Two-stage DC-DC Converter.

In conventional boost converters, output voltage is not much higher than the input voltage. In order to solve these problems a two-stage step-up converter is used. The novel converter has the advantages of easy control, high efficiency, fast dynamic response, and so on[5].

II. BASIC BOOST CONVERTER

In basic boost converter, the output voltage is greater than the input voltage. In boost converter, switch is connected in parallel with the voltage source. The circuit of boost converter using power MOSFET is shown in fig. 3.

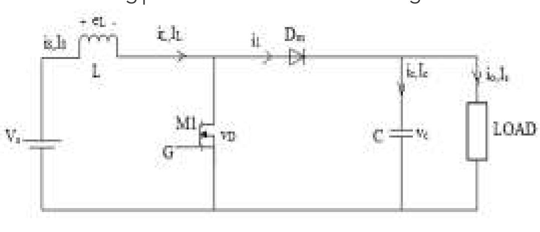

Fig. 3 Basic boost converter

In mode-1 transistor is switched on and mode-2 transistor is switched off. Mode-1 begins when transistor M1 is switched on. The input current flows through L and transistor M1. The operation of mode-1 shown in below fig. 4.

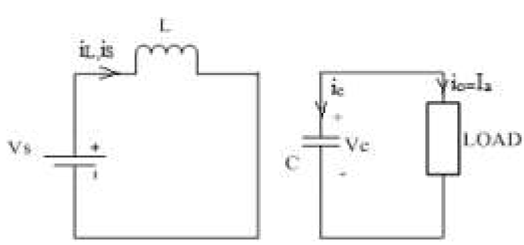

Fig. 4 Mode-1 Operation

Mode-2 begins when the transistor M1 is switched off. The current was flowing through L, C, Load and diode Dm. The operation of mode-1 is shown in fig. 5. The inductor current falls until transistor M1 is turned on again for the next cycle.

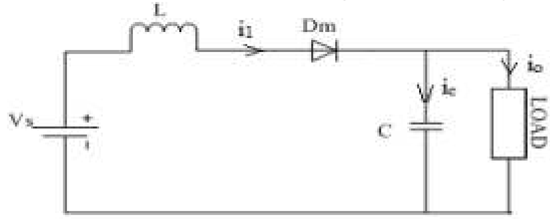

Fig. 5 Mode-2 Operation

A boost converter can step up the output voltage without transformer. Due to a single transistor, it has a high efficiency. The input current is continuous. However, a high peak current has to flow through the power transistor. The output voltage is very sensitive to change in duty cycle and it might be difficult to stabilize the converter[1].

Voltage Gain: Apply volt-sec balance on inductor.

$$V_o = \frac{V_S}{1-d}$$

Current Ripple: In each sub-period the rate of change of current is constant.

$$\delta I_L = \frac{V_S d T_S}{L}$$

Voltage Ripple: The charging and discharging current of the capacitor decides voltage ripple.

$$\delta V_o = \frac{\delta Q}{C} = I_o \frac{dT_s}{C}$$

$$\frac{\delta V_o}{V_o} = \delta_v = \frac{dT_s}{RC}$$

Input Current: The average of the inductor current is the same as the average source current.

$$I_S = \frac{I_o}{1-d}$$

The important features of the boost converter are:

1. The gain is more than unity (hence boost converter).
2. The gain is independent of the switching frequency so long as T<< RC. However this design inequality is a function of load.
3. The output voltage ripple percentage is dependent on the load on the converter. The output ripple has a first order roll-off with the switching frequency.
4. The input current is continuous. Therefore the boost converter is less sensitive to the dynamic impedance of the source compared to the buck converter.

III. TWO-STAGE DC-DC STEP-UP CONVERTER

Conversion of 24V DC to 135V DC is not possible with direct DC-DC converter (Boost converter) because direct DC-DC conversion is not capable of stepping up to such a high voltage. Therefore, the conversion is done with two stages.

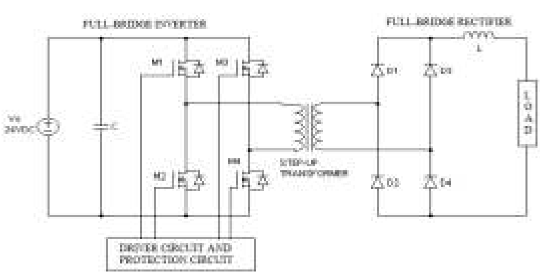

Fig. 6 Two stage DC-DC step-up converter

The two-stage DC-DC step-up converter is shown in Fig. 6.The 24V DC from the source is given to the capacitor.

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Capacitor is use to give the constant DC supply to the full-bridge Inverter.

MOSFET is mainly employed in full bridge inverter because MOSFETs are preferred to for lower voltage rating and higher switching frequency. MOSFET is a controlled device which is used in full bridge inverter. Therefore, this inverter is known as a full bridge controlled Inverter. Copper sheet bus bars are use for connections instead of wires. Copper sheet bus bars can reduce the wire inductance and high voltage spikes. The driver circuit is used to gives the gate pulses required for MOSFETs.

The constant output of the capacitor is given to the full bridge inverter and it converts 24V DC into 24V AC. The 24V AC is given to the step up transformer and then the 24V AC is stepped up to 135V AC. The output of the transformer is given to the uncontrolled full bridge rectifier and rectifier is use to convert 135V AC into 135V DC. In the rectifier diode used as a switch and it is an uncontrolled device. The inductance of minimum value is used to smoothen the output current of uncontrolled full-bridge rectifier.

The two-stage step-up DC/DC converter has following advantages[5]:

1) All MOSFETs are Pulse Width Modulation (PWM)-controlled. All switches have a common source potential. The control circuit is simple and reliable.

2) This converter is used for higher boost ratio. Boost ratio means output voltage to the input voltage ratio of boost converter.

IV. SIMULATION AND RESULT

1) Basic Boost Converter

Simulation of basic boost converter is done with MATLAB/Simulink as shown in fig. 7. In the simulation, MOSFET as an active switch and diode is a passive switch. The components are arranged as per the figure. In MATLAB gate pulses applied with the help of pulse generator. The main parameters for simulation of boost converter are as follows:

TABLE I
CIRCUIT PARAMETERS FOR BOOST CONVERTER

Description	Value
Input voltage	24V DC
Switching frequency	100kHz
Duty ratio	0.8
Resistance R	10mΩ
Inductance L	100 μH
Capacitance C	200 μF
Load resistance	6Ω

The simulated waveform of gate pulse applied to MOSFET is shown in fig. 8 and waveform of output voltage is shown in fig. 9. In boost converter, 24V DC is applied as a input supply and by changing the duty ratio of the gate pulse, output voltage would be changed.

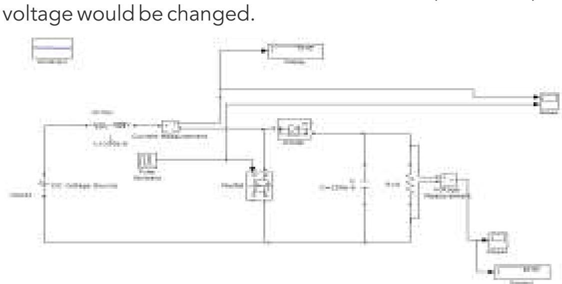

Fig. 7 Simulation of basic boost converter

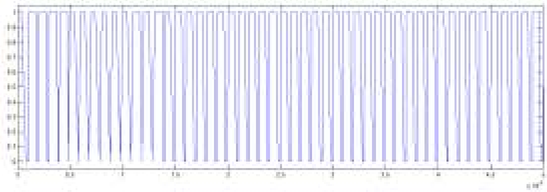

Fig. 8 Gate pulse of basic boost converter

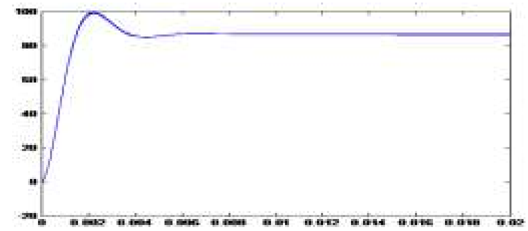

Fig. 9 Output voltage of basic boost converter [Vo=87 V DC]

1) Two-Stage DC-DC Step-Up Converter

In Two stage DC-DC step-up converter, full-bridge topology is used. Full-bridge controlled Inverter and full-bridge uncontrolled Rectifier is in this full-bridge topology. Simulation of this two stage DC-DC step-up converter is done with PSIM and it is shown in fig. 10. MOSFETs are used as a switch in the Inverter because Inverter is a controlled device and MOSFET is a controlled switch. MOSFET is a voltage controlled switch. By changing the turn ON and OFF time, Output voltage is controlled. In PSIM, comparator is used to compare the two waveforms. With the help of comparator, compare the triangular and direct current waveform. And the output of comparator is given to gate of MOSFETs. Full-bridge Inverter is used to convert 24V DC into 24V AC. This 24V AC is given to the step-up transformer and stepped up 24V AC to 135V AC. Secondary side of the transformer is connected with full-bridge rectifier. Rectifier is used to convert 135V AC into 135V DC.

In order to smoothen the output current of the uncontrolled full-bridge rectifier the inductance of minimum value is used.

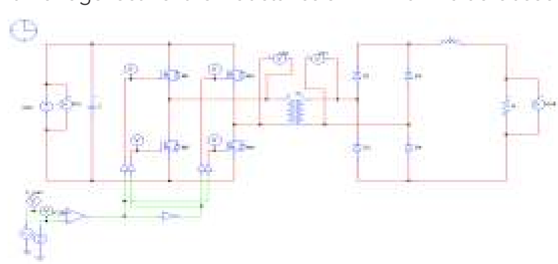

Fig. 10 Simulation of Two stage DC-DC step-up converter

The main parameters for simulations are as follows:

TABLE II
VALUE OF PARAMETERS FOR TWO STAGE DC-DC CONVERTER

Desciption	Value
Input voltage	24V DC
Switching frequency	5kHz
Duty ratio	0.8
Tranformer turns Ratio	1/8
Inductance L	1uH
Capacitance C	1uF
Load R	1Ω

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The simulated waveforms of switch voltage for Two-stage DC-DC converter stage.

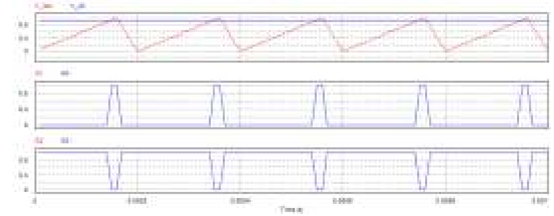

Fig. 11 Gate Pulses of Two stage DC-DC step-up converter

The simulated waveform of Input voltage.

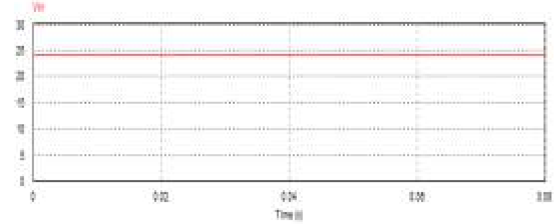

Fig. 12 Input voltage waveform of Two Stage DC-DC Step-up converter [Vin=24V DC]

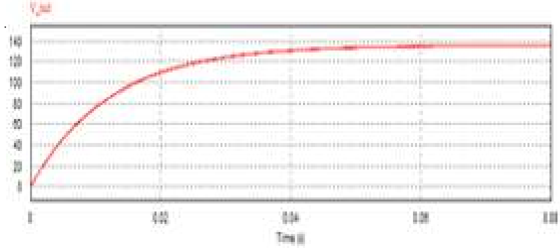

Fig. 13 Output voltage waveform of Two Stage DC-DC Step-up converter [Vout=135V DC]

V. CONCLUSION

This paper gives comparison between two converters. In simple Boost converter, voltage step-up up to certain limit. For higher boost ratio boost converter is not useful. Two stage DC-DC step-up converter is the solution for this problem. Two stage DC-DC step-up converter is used for wide range between input and output. Two stage DC-DC step-up converter is simulated using PSIM and with the help of this two-stage DC-DC step-up converter, convert 24V DC into 135V DC. The novel converter has the advantages of high power density, high efficiency, high utilization of transformer, easy control. Therefore, this novel converter is suited for applications where the input voltage is significantly lower than the output voltage, in the area of electrical vehicle power supplies, industrial application, etc.

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