Efficiency Comparison of variousDC to DC Boost Converters for Application of Energy Harvesting

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Abstract— in this paper deals with different types of dc to dc energy conversion scheme for proposed in order to reduce the input current ripples, to reduce the output voltage ripples and to reduce the size of passive components with high efficiency for high power applications. The proposed converter is compared with other topologies, such as conventional boost converter (BC), multi-device boost converter (MDBC), ZVS boost converter and ZVT- ZCT boost converters in order to examine its performance.Interleaving techniques are widely used to reduce input/output ripples, to increase the efficiency and to increase the power capacity of the boost converters. A new snubber cell is developed in order to increase the power density and the efficiency in pulse width modulation (PWM) converters and to decrease the EMI noise. The developed snubber cell provides main switch both to turn on with zero- voltage transition (ZVT) and to turn off with zero-current transition (ZCT). The converter incorporating this snubber cell operates with soft switching (SS) in a wide range of line and load voltages. Also, all semiconductor devices in the converter operate with SS. There is no additional voltage stress in the main components, and the stresses of the auxiliary components are negligible. The new converter has a simple structure, low cost, and ease of control as well. The overall efficiency of the new converter has reached a value of 99% at nominal outputpower.

Keywords: conventional boost converter (BC), multi-device boost converter (MDBC), ZVS boost converter, snubber cells and ZVT- ZCT boost converters

I. INTRODUCTION

Renewable energy resources have the wide role in the field of power electronics research. The photovoltaic cells which give a very low output voltage are used in most of theapplications.The DC-DC boost converter has to be connected with the renewable energy source in order to increase the available voltage for various high voltage applications. Different topologies have been introduced to achieve a very high voltage gain which doesn't include the method of increasing the duty cycle. By combining switched inductors, coupled inductors with the classical boost converter, a high frequency transformer or switched capacitors with high step up ratio and a low voltage stress can be obtained.

The input electrolytic capacitors have an effect in this topology that the input current ripple decreases the maximum output power, thereby decreasing the work-span of the capacitor. A high efficiency and a high step up conversion can be achieved by using active clamp dual boost converters and active clamp full bridged boost converters. there are many number components and isolated sensors or feedback controllers are equipped in this topology. So it is very expensive one.

The interleaved voltage doublers has been introduced which has the ability to share the current and lower active switch stress. The voltage gain is not high, the diode voltage stress remains very high. The proposed topology uses an input- parallel output- series configuration in order to achieve a higher voltage gain without adopting an extreme large duty cycle.The proposed converter cannot only achieve high step-up voltage gain with reduced component count but also reduces the voltage stress of both active switches and diodes to reduce both switching and conduction losses.

II. SYSTEM MODELS

1. *Basic Boost Converter:*

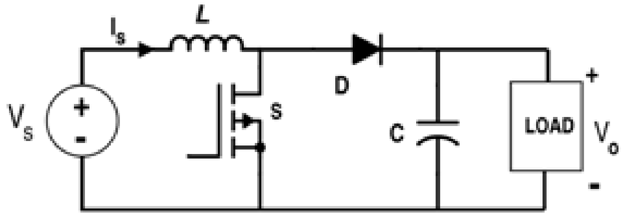


Fig. 2.1 Basic boost converter

A Boost converter is a switch mode DC to DC converter in which the output voltage is greater than the input voltage. It is also called as step up converter. The name step up converter comes from the fact that analogous to step up transformer the input voltage is stepped up to a level greater than the input voltage. By law of conservation of energy the input power has to be equal to output power (assuming no losses in the circuit).

Input power (P_{in}) = output power (P_{out})

Since$V_{in} < V_{out}$ in a boost converter, it follows then that the output current is less than the input current. Therefore in boost converter$V_{in} < V_{out}$ and $I_{in} > I_{out}$

The main working principle of boost converter is that the inductor in the input circuit resists sudden variations in input current. When switch is OFF the inductor stores energy in the form of magnetic energy and discharges it when switch is closed. The capacitor in the output circuit is assumed large enough that the time constant of RC circuit in the output stage is high. The large time constant compared to switching period ensures a constant output voltage $V_o(t) = V_o$(constant)

The boost converter can be operated in two modes

a) **Continuous conduction mode** in which the current through inductor never goes to zero i.e. inductor partially discharges before the start of the switching cycle.

b) **Discontinuous conduction mode** in which the current through inductor goes to zero i.e. inductor is completely discharged at the end of switching cycle.

In continuous conduction mode when switch in ON the diode will be open circuited since the n side of diode is at higher voltage compared to p side which is shorted to ground through the switch. Hence the boost converter can be redrawn as follows during this state the inductor charges and the inductor current increases. The current through the inductor is given as

$$I_L = (1/L) * \int V * dt$$

Assume that prior to the opening of switch the inductor current is $I'_{L,off}$. Since the input voltage is constant

$$I_{L,off} = (1/L) * \int (Vin) * dt + I'_{L,off}$$

Assume the switch is open for t_{on} seconds which is given by $D*T_s$ where D is duty cycle and Ts is switching time period. The current through the inductor at the end of switch on state is given as

$$I_{L,on} = (1/L) * Vin * D * Ts + I'_{L,on}$$

Hence $\Delta I_L = (1/L)*V_{in}*D*T_s$.

When switch in OFF the diode will be short circuited and the boost converter circuit can be redrawn as follows the inductor now discharges through the diode and RC combination. Assume that prior to the closing of switch the inductor current is $I''_{L,off}$. The current through the inductor is given as

Note the negative sign signifies that the inductor is discharging. Assume the switch is open for t_{off} seconds which is given by $(1-D)*T_s$ where D is duty cycle and T_s is switching time period. The current through the inductor at the end of switch off state is given as

$$I'''_{L,off} = -(1/L) *(V_{in}-V_{out})*(1-D)*T_s + I''_{L,off}$$

In steady state condition as the current through the inductor does not change abruptly, the current at the end of switch on state and the current at the end of switch off state should be equal. Also the currents at the start of switch off state should be equal to current at the end of switch on state. Hence

$$I'''_{L,off} = I_{L,on}, \text{ also } I''_{L,off} = I''_{L,off}$$

Using the equations 1 and 2 we get

$$(1/L) *V_{in}*D*T_s = -(1/L) *(V_{in}-V_{out})*(1-D)*T_s$$

$$V_{in}*D = -(V_{in}-V_{out})*(1-D)$$

$$V_{in}* (D-1+D) = V_{out}*(1-D)$$

$$V_{out}/V_{in} = 1/ (1-D)$$

Since D < 1 $V_{out} > V_{in}$. Assuming no losses in the circuit and applying the law of conservation of energy

$$V_{out}*I_{out} = V_{in}*I_{in}$$

This implies $I_{out}/I_{in} = (1-D)$, Thus $I_{out} < I_{in}$. As the duty cycle increases the output voltage increases and output current decreases. But due to parasitic elements in the lumped elements resistor, inductor, capacitor the step up ratio Vout/Vin decreases at higher duty cycles and approaches zero at unit duty cycle.

$$I_L = (1/L) \int V_L * dt$$

In discontinuous conduction modethe inductor drains its stored energy completely before completion of switching cycle.The inductor in discontinuous mode drains all the current which it piled up in charging interval of same switching cycle. The current through the inductor is given as

$V_{in}*D*T_s = -(V_{in}-V_o)*\delta*T_s$(negative sign signifies that the inductor is discharging)

$$V_{out}/V_{in} = (D+ \delta)/ \delta$$

and the ratio of output to input current from law of conservation of energy is $I_{out}/I_{in} = \delta/ (D+ \delta)$.

Applications of Boost converter are used in regulated DC power supplies.They are used in regenerative braking of DC motors. Low power boost converters are used in portable device applications.As switching regulator circuit in highly efficient white LED drives.Boost converters are used in battery powered applications where there is space constraint to stack more number of batteries in series to achieve higher voltages.

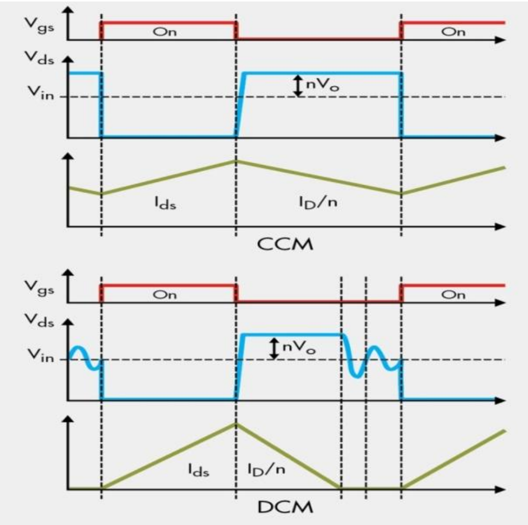


Fig. 2.2 Basic boost converter continuos and discontinuous mode wave form

2. Snubber Circuit

The snubber is a circuit which snubs or limits the switching voltage amplitude and its rate of rise (dv/dt). Hence it reduces the power dissipation in power electronic switching networks.Advantages of snubber circuit are to reduces the voltage and current amplitude.It limits the rate of rise of voltage and current. To reduces the power dissipation in switching networks and reduce EMI by damping voltage and current ringing

The snubber Circuit shows a simple power switching network with a power semiconductor switch and resistive load. When the power semiconductor is switching on or off, the device voltage and current are large, resulting in high power dissipation across the device with high energy loss. The ideal wave forms of switch voltage, current and power is shown in figure during switching operation.

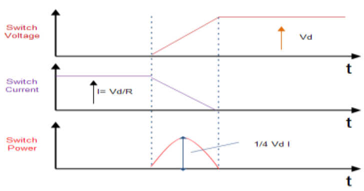


Fig. 3.1voltage and current wave form

When the switch is open to interrupt the current flow in resistive load, there will be a linear variation of switch voltage and current as shown in the wave form. The resultant peak power dissipation is 1/4 of product of maximum of voltage and maximum current which is very high in high voltage switching circuits. If the load is inductive then the power dissipation is appreciably large, because inductance to prolong current flow.

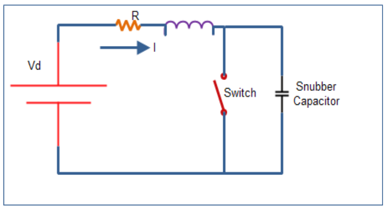


Fig. 3.2 Basic boost converter with snubber capacitance

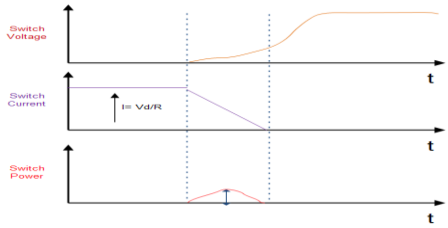


Fig. 3.3snubber voltage and current wave form

This turn off losses can be minimized with the snubber capacitor connected across the semiconductor switch as shown in figure. As the switch opens, current is diverted in to the snubber capacitor, which is initially uncharged. The current diversion slows the buildup of switch voltage, and as a result current drops to a low value before the switch voltage has increased significantly. This slow increase in switch voltage produces a substantial reduction in the switching energy loss. With this arrangement of sunnbers and power semiconductor switches we can attain high frequency of operation and low switching losses.

When the switch is closed at the start of its conduction angle, the snubber capacitor discharges through the closed switch. The discharge current is usually limited by placing a small resistor in series with snubber capacitor as shown in figure b. This gives the basic RC snubber circuit with time constant T= RC.

Applications of DC to DC convertersare used extensively for diverse applications in the healthcare (bio life science, dental, imaging, laboratory, medical), communications, computing, storage, business systems, test and measurement, instrumentation, and industrial equipment industries. They are used in Used in electric motor drives, in Switch mode DC power supplies e.t.c

3. Interleaved Boost Converter With Parallel-Input Series-Output Connection

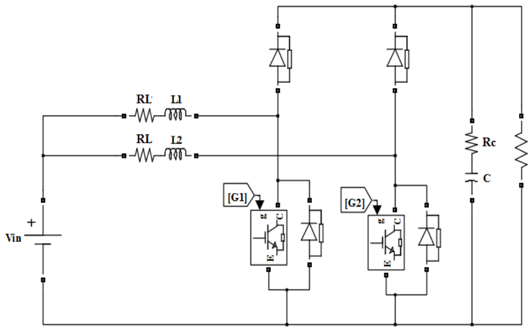


Fig. 3.1phase interleaved boost converter

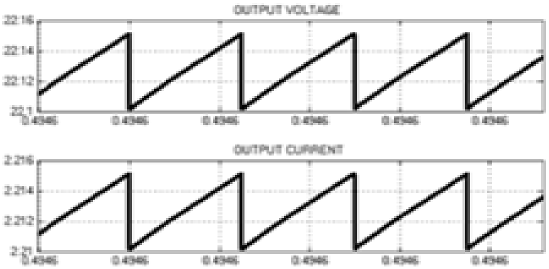


Fig 3.2 Output voltage and output current of Basic interleaved boost converter

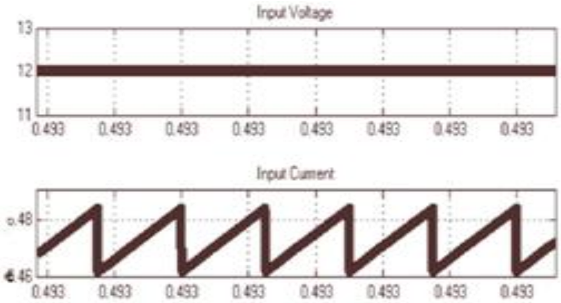
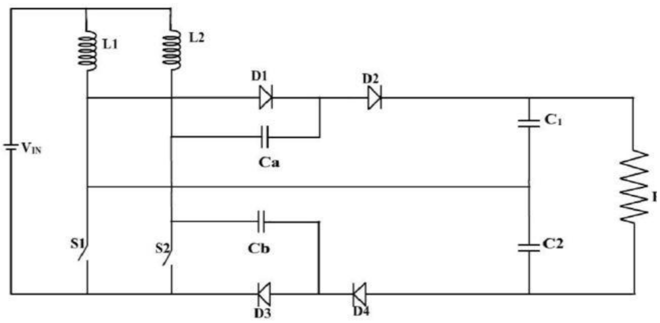


Fig 3.3 voltage and input current of basic interleaved boost converter

4. The Quadrupler Boost Converter



(b)

Fig. 4.1Quadrupler boost converter

The proposed converter topology, has some drawbacks like the presence of pulsating output period which is seen in currently used high step up dc-dc converters. Moreover the main goal is to have a high voltage gain, which can be obtained with a duty cycle greater than 0.5 and the continuous conduction mode (CCM). Apart from this, if the duty cycle is less than 0.5 or the converter is operated in discontinuous conduction mode (DCM), there won't be any transfer of energy from the inductors to the blocking capacitors, output capacitors and load side. Hence, high voltage gain is achieved without an extra circuitry which involves the process of uniform currentsharing.

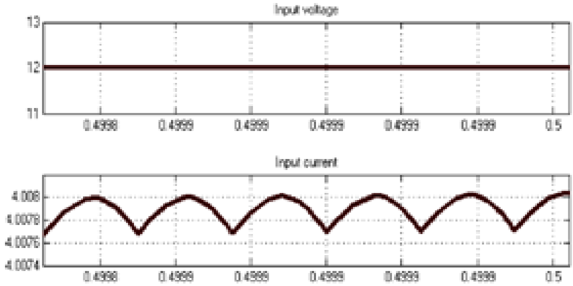


Fig 4.1Input voltage and input current of Quadrupler DC-DC converter

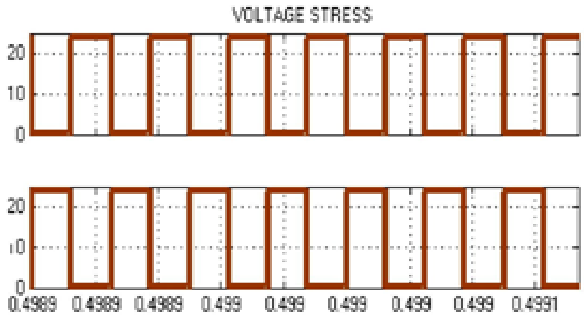


Fig. 4.2 Voltage stress across switch in quadrupler DC-DC converter

Fig.4.3 Output voltage and input current of Quadrupler DC-DC Converter

These problems can only be solved by using soft-switching (SS) techniques realized by snubbercells. Basically, the root causes of the switching losses are due to simultaneous change of the voltage and the current during switching, reverse recovery of the diode, and discharge of the parasitic capacitor.

The overall performance of Pulse Width Modulation (PWM) converters can be improved by using soft-switching techniques. These techniques allow operation at higher switching frequencies resulting in higher power densities without penalizing the efficiency. There are two main soft- switching approaches. They are the Zero-Current Switching (ZCS) and the Zero-Voltage Switching (ZVS). The MOSFET's present better performance under ZVS. This is because under ZCS the capacitive turn-on losses increase the switching losses and the Electromagnetic Interference (EMI). On the other hand, Insulated Gate Bipolar Transistors (IGBT's) present better results under ZCS which can avoid the turn -off losses caused by the tail current. The ZCS techniques proposed in the literature have some drawbacks such as significant voltage stress on the main diode, which increases the conduction losses, and the presence of the resonant inductor in series with the main switch, which increases the magnetic losses. In order to have the advantages of both ZVS and ZCS technique and to eliminate their disadvantages better choice is to have a converter with both ZVS and ZCS, where a transition period is created for switching on and off the switches. This type of converters is known as Zero Voltage Transition-Zero Current Transition (ZVT –ZCT) converters.

5. SOFT SWITCHING CONDITION FOR ZVT-ZCTCONVERTER

The control signal of the auxiliary transistor is applied; the parasitic capacitor of the main switch must be discharged completely, and then anti parallel diode of the main switch can be turned on. The turn on of the main switch is carried out when the body diode is in the on state, so that the main switch will be turned on under ZVS and ZCS with ZVT.

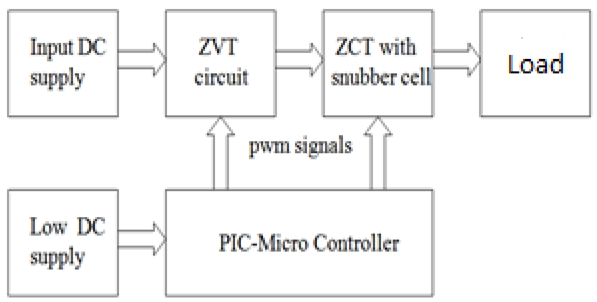


Fig. 1.Proposed ZVT-ZCT PWM Boost converter.

The main switch conducts the input current in the on state. When the auxiliary switch turns on, the resonance current increases and becomes greater than the input current, and the body diode of the main switch turns on. The control signal of the main switch is removed while the main diode is in the on state and turn off with ZCT isprovided.

The rise rate of the current is limited because of the Lsb snubber inductance connected serially to the auxiliary switch. So, the turn on of the auxiliary switch is provided with ZCS. The resonance is formed when the auxiliary switch is on state and its body diode D2 turns on. In order to turn off the auxiliary switch with ZCS, the control signal has to be removed when the diode conducts.

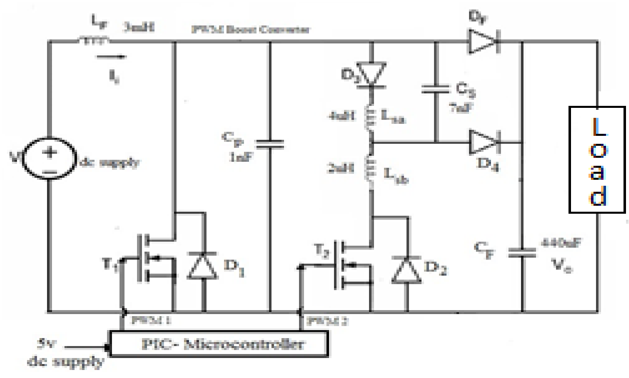


Fig. 2. Pulse signal of the proposed ZVT-ZCT PWM Boost converter.

he value of the Lsasnubber inductance should be greater than the value of the Lsb snubber inductance for the turn on of D2.

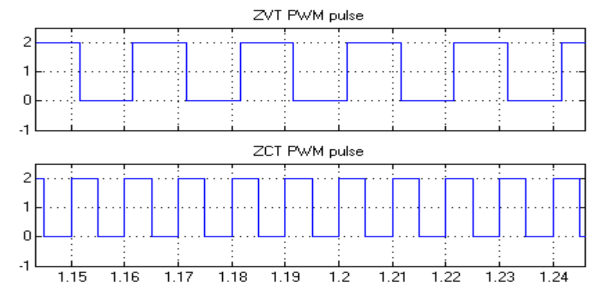


Fig. 3. Pulse signal of the proposed ZVT-ZCT PWM Boost converter.

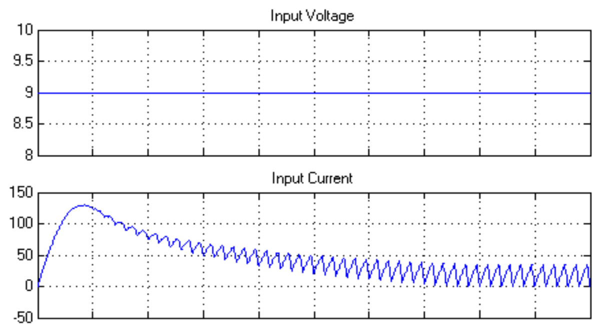


Fig. 4. Input voltage/current of the proposed ZVT-ZCT PWM boost converter fed PMDC motor

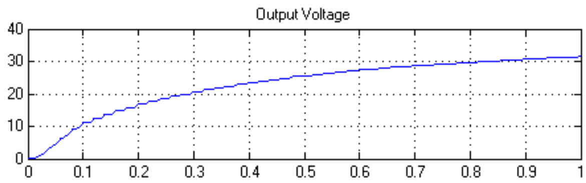


Fig. 5.Output voltage of the proposed ZVT-ZCT- PWM boost converter.

The input and output voltage and current waveform of ZVT-ZCT PWM boost converter. The circuit can boost the input voltage of 9V dc to 34V dc. The snubber circuit in ZVT-ZCT PWM boost converter provides soft switching for both main and auxiliary switches and thus reduces the switching losses and the efficiency is increased to 98%.The load chosen for simulation is stepper motor load.

The conduction time of the auxiliary transistor is very short. The auxiliary switch is turned on under near ZCS and is turned off with perfect ZCT due to the removal of drive signal while the internal diode is conducting. The peak current through the auxiliary switch in the ZCT interval is lower than the ZVT interval. This is because of the losses in the resonance circuit. From the waveforms, it is seen that the auxiliary switch is not subjected to any voltage stress.

In the ZVT interval, the voltage across the snubber capacitor starts to increase when the resonance is started withtheturnonoftheauxiliarytransistor.

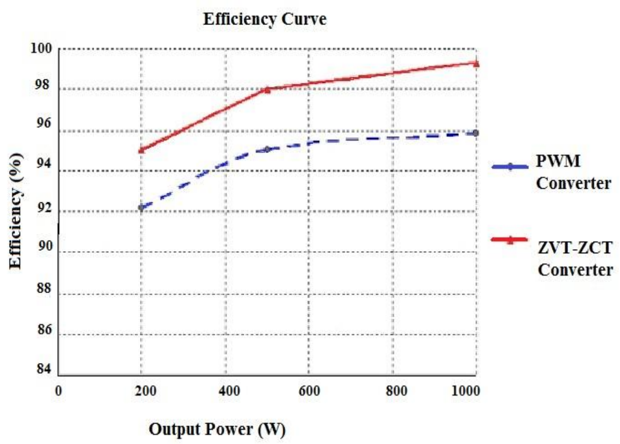


Fig.6. Efficiency curves of the HS converter andtheproposed SSconverter.

III. SIMULATION/EXPERIMENTAL RESULTS

the performances of the three different converter topologies and it shows that the best topology is pwmzvt –zct with snubber cell DC-DC converter the comparison is shown in the below Graphs

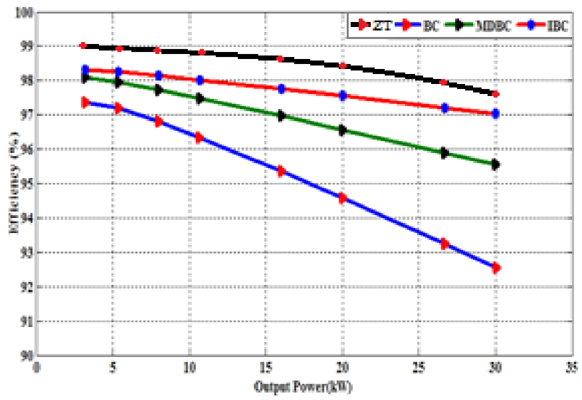


Fig.7: The comparative efficiency betweenDC/DC converters at load change

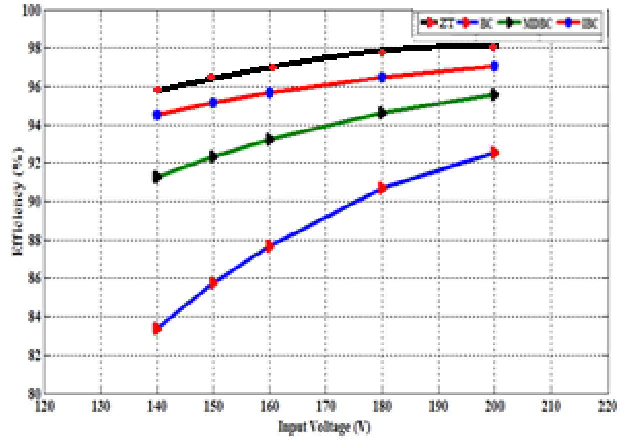


Fig.8: The comparative efficiency between DC/DC converters at input voltage change

IV. CONCLUSION

In this paper, a novel transformer-less adjustable voltage dc–dc converter with high voltage gain and reduced voltage stress is compared with the other topologies. Also the voltage stress across the switch is reduced and also the stress across the diode is reduced. The topology discussed here gives a very high voltage gain without using an extreme large duty cycle. Apart from the high voltage gain, the converter reduces the voltage stress of the two active switches and diodes. This makes easier to choose lower voltage rating MOSFETs and diodes in order to reduce both switching and conduction losses. The operation principle is comparison with the new high step-up converter topologies are presented in this paper.

V. FUTURE SCOPES

Future developments include using Nano Diodes which can operate in Tetra Hz frequency range and design a Single Power Electronic Device for converter circuits. Instead of using IGBT/MOSFT switches a better choice to use monolithically integrated AlGaN/GaN lateral field effect rectifiers (L-FER) and a normally off transistor switch. The L -FER exhibits no reverse recovery current associated with the turn off transient because of its unipolar nature. Thus it can further reduce the losses in the proposed ZVT-ZCT Boost converters used in different energy harvesting applications. The topology can be cumulated with an interleaved zero voltage and current method for future expansion.

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