Comparison of Step Up DC-DC Converters for Renewable Applications

M.Devi[1], D.Kalaichelvi[2], J.Jayashree[3]
[1, 2, 3] Department of Electrical and Electronics Engineering
[1, 2, 3] CK College of Engineering and Technology

Abstract- *All renewable energy sources like solar, wind, fuel cell etc needs boost converter to step up the generated power. This paper proposes the comparison of the performance analysis of transformer based boost converter and transformer less boost converter and Capacitor Switched interleaved boost converter. The output voltage and efficiency of the three boost converters are analysed. Forward boost converter is analysed for transformer based boost converter. Capacitor switched boost converter is analysed for transformer less boost converter. For different input voltage the output voltage and the efficiency of the two boost converters are analysed.*

Keywords- Forward boost converter, Boost converter, capacitor soft switched interleaved boost converter,dc/dc power conversion, insulated-gate bipolar transistors (IGBTs), Capacitor soft switching, Output voltage, efficiency.

I. INTRODUCTION

Today power demand is increased, but the generation of power is not enough to meet the demand. The renewable sources are the only solution for the demand in future. The amount of power is produced from these sources are less. The produced power cannot be directly connect to the load. high-power dc/dc converters are required to boost (step up) the voltage of the generated power.

Forward converter is another popular switched mode power supply (SMPS) circuit that is used for producing isolated and controlled dc voltage from the unregulated dc input supply. It is a dc to dc converter that uses transformer windings to buck or boost the voltage (depending on the transformer ratio) and provide galvanic isolation for the load. It is generally more energy efficient and is used for applications requiring little higher power output.

The forward boost converter operates on the principle of boost converter[1]-[2]. The forward boost converter uses high frequency transformer. It reduces the size of the passive components, reduces the mass of the converter.

The large passive components used in high-power dc/dc boost converters, specifically the large boost inductor, comprise a major part of the mass of the converter. Higher frequency operation helps reduce the size of the passive components. The high-power insulated-gate bipolar transistors (IGBTs) used in these converters are commonly limited to hard-switching operation at about 30 kHz [3] or less, depending on the power level. The switching frequency limit exists to prevent overheating and failure of the IGBT. If soft switching is used, the switching losses are reduced, enabling these IGBTs to operate at frequencies up to 70 kHz [3], which can significantly reduce the masses of passive components in the converter without increasing the mass of the heat sink.

In resonant and quasi-resonant converters, the devices are turned off and/or on at zero voltage or zero current of a resonant mode [4]. Passive soft-switching methods [5] use only passive components to achieve zero-voltage or zero-current switching at a constant switching frequency. passive methods are designed for low-power boost converters using MOSFETs and hence focus on reducing the reverse-recovery losses (due to the boost diode) during turn-on of the switch rather than the more significant turn-off losses found in high-power converters using IGBTs. It is noteworthy that new silicon carbide (SiC) diodes have nearly zero reverse-recovery current and can be implemented as the boost diode to greatly reduce the turn-on losses of the switch [6]. Active soft-switching methods [7]–[9] use one or more auxiliary switches in addition to passive components to achieve zero-voltage or zero-current switching.

The capacitor switched regenerative boost converter circuit is simple, is highly efficient, operates effectively over the entire load range, requires no additional inductors, and straightforward control strategy, which was first introduced in [10]. The only additional components required are two IGBTs two diodes, and one capacitor. It reduces the turn off loss of the IGBT switch and increases the switching frequency of high-power boost converters without adding heavy extra inductors, so that the converter mass can be reduced. The efficiency can be improved.

The Interleaved boost converter is the parallel connection of two boost converters. It decreases the current rating of the switch. It can reduce the input current ripple, output voltage ripple, size of the passive components. The interleaved capacitor switched boost converter consist of two parallely connected capacitor switched boost converter. The three circuits are compared under same input voltage is applied and the performance of them are analysed.

II. PROPOSED CIRCUIT

A. FORWARD BOOST CONVERTER

The forward converter energy is transferred directly between the primary and secondary sides. It consists of a fast switching device 'S' along with its control circuitry,a transformer with its primary winding connected in series with switch 'S'to the input supply and a rectification and filtering circuit for the transformer secondary winding. The load is connected across the rectified output of the transformer-secondary.

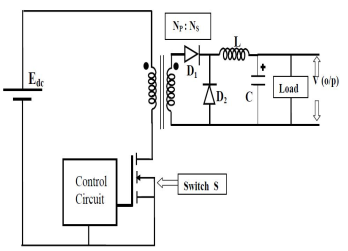

Figure 1. Circuit diagram of forward converter

When switch 'S' is turned on, input dc gets applied to the primary winding and simultaneously a scaled voltage appears across the transformer secondary. Dotted sides of both the windings are now having positive polarity.Diode 'D1', connected in series with the secondary winding gets forward biased and the scaled input voltage is applied to the low pass filter circuit preceding the load.

When switch 'S' is turned off, the primary as well as the secondary winding currents are suddenly brought down to zero. Current through the filter inductor and the load continues without any abrupt change.

B. CAPACITOR SWITCHED SOFT SWITCHING BOOST CONVERTER

Capacitor switched regenerative circuit is used to reduce the stress on the switch, ripples on the output voltage and current and reduces the switching loss on the switch. Capacitor switched regenerative circuit consist of two IGBT switches, two diodes and one capacitor.

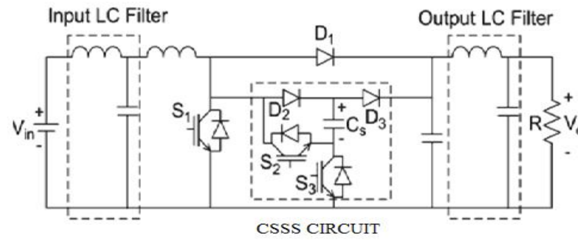

Figure 2. Capacitor switched soft switching boost converter

In high-power IGBT-based dc/dc boost converters, the switch turn-off loss is generally greater than the turn-on loss. The high value of turn-off losses in an IGBT can be explained by the significant current tail following the rapid rise of the voltage across the switch during turn-off. The turn-on loss, however, can be significantly reduced by reducing or eliminating the reverse-recovery current of the boost diode. This can now be easily achieved by using silicon carbide (Sic) diodes, since they exhibit virtually zero reverse-recovery current. Thus, the proposed capacitor-switched regenerative circuit focuses on reducing the significant turn-off losses in high power boost converters so that high switching frequencies can be achieved without exceeding the thermal limits of the IGBT.

The proposed regenerative circuit is shown in Fig. 2. The idea is to charge the capacitor Cs at one turn-off event and discharge it at the next turn-off event. With this operation, the voltage rise across the switch is slowed down, the current tail of the switch is reduced at each turn-off, and virtually all of the energy used to accomplish this is returned to the output circuit.At the first turn-off of S1, shown in Fig. 3, auxiliary switch S3 is on and auxiliary switch S2 is off so that current flows through D2 and S3 to charge the capacitor Cs from 0 V to the output voltage (Vout). This charging action slows down the voltage rise across switch S1, thus greatly reducing the losses while the current in S1 falls quickly.

At the next turn-on, both S2 and S3 are off, thus, the operation of S1 at turn-on is unaffected by the circuit. When S1 is on and Cs is charged up to Vout, Cs does not discharge through D3 and the body diode of S3 because the voltages at the anode and cathode of D3 are equal, not letting D3 conduct.

At the next turn-off of S1 (Fig. 5), S2 is on and S3 is off; thus, the current flows through S2 and D3 to discharge the capacitor. Again, this action greatly slows down the voltage rise across S1 and reduces the current tail through S1. All the energy stored in the capacitor is transferred to the output of the circuit, leading to a very efficient operation. Note that diode D1 conducts when S1 is off, in exactly the same manner as diodeD1 in the hard-switched converter. Overall, the proposed converter operates in the same manner as the hard switched converter except at turn-off of S1 when the auxiliary circuit is active.

III. SIMULATION OUTPUT

The forward boost converter and capacitor switched soft switching boost converter are simulated for transformer based boost converter and transformerless boost converter. The DC input is given to both circuits. The output voltage and efficiency of the two circuits are compared. The input is given to the circuit is 24V and it is stepped up into 48V. The outputs of the two converters are same.

A. FORWARD BOOST CONVERTER

The circuit diagram of the forward boost converter shown in fig 4. The input voltage of 24V DC is applied to the forward boost converter. The transformer is used to transfer the energy. In FBC circuit the multiple outputs can be taken.

The efficiency is calculated for different values of input voltage. The output voltage is 48V.For multiple output the transformer winding are added depending upon the requirement.

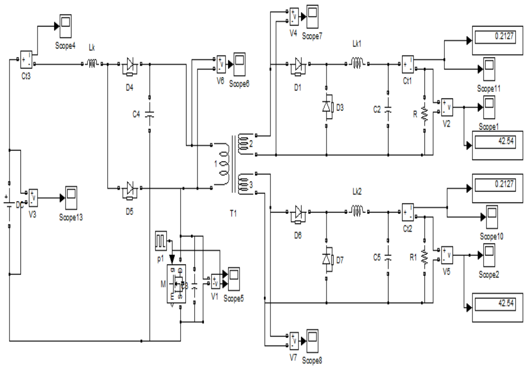

Figure 4. Forward boost converter circuit diagram

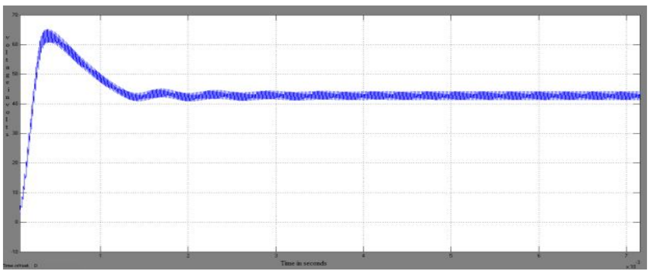

Figure 5. output voltage waveform of forward boost converter circuit

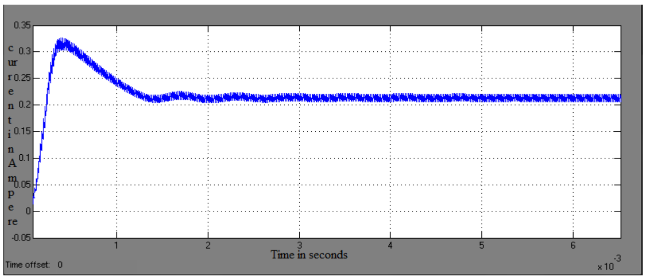

Figure 6. Output current waveform of forward boost converter circuit

Figure 5 and figure 6 shows the output voltage and output current waveform of the forward boost converter. It contains ripples. The FBC output voltage and current contains more ripples when AC input voltage is applied. There are different input voltage is applied to the FBC circuit and efficiency is calculated.

B. CAPACITOR SWITCHED SOFT SWITCHING BOOST CONVERTER

Figure 7 shows the circuit diagram of CSSBC. Figure 14 shows the capacitor switched soft switching circuit, which is added in the boost converter. In this boost converter the soft switching method is used to turn on and turn off the switches. The soft switching method is used to reduce the switching loss. During turn off the energy is diverted to the capacitor,The voltage stress across the switch is reduced.

The input voltage of 24V DC is applied to the boost converter with CSSS circuit. The output of the circuit will be 48V. The frequency used for main switch on the boost converter is 125 kHz. Two IGBTs are used as switching device in CSSS circuit.capacitor is used to reduce the voltage stress across the switch during turn off. The frequency of 60 kHz is used for both auxillary switches of CSSS circuit. The main switch and auxiliary switch is turned on and turned off at zero voltage to reduce the stress across the switch.

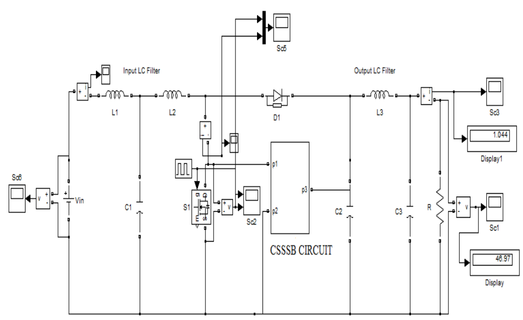

Figure 7. Boost converter with capacitor switched soft switching circuit

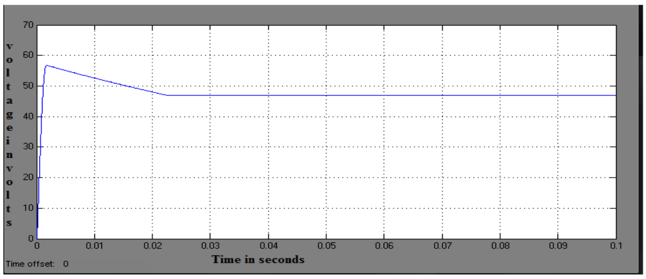

Figure 8. Output voltage of capacitor switched soft switching boost converter

Figure 3 shows the switching signals for S1, S2, S3 switches applied by using the pulse generator. The main switch is applied with frequency of 125 kHz and the auxillary switches are applied with 60 kHz. The soft switching method is used so high frequency is applied; it reduces the size of the capacitor and converter size by reducing the switching loss and stress.

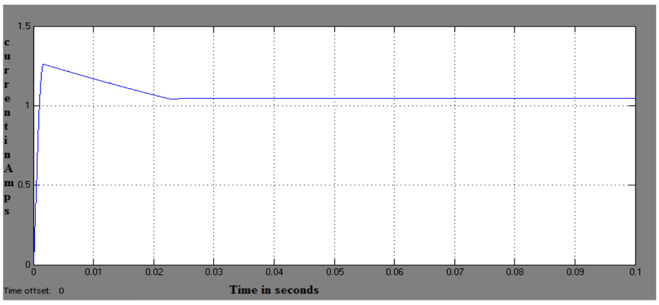

Figure 9. Output current of capacitor switched soft switching boost converter

Figure 8 shows the voltage across and current through the main switch. Figure 9 and figure 10 shows that the ripples present on the output voltage and output current are less compared to the forward boost converter.

During turn off the switch the stress across the main switch is reduced by diverting the energy to the CSSS circuit. The output voltage and output current of CSSBC contains ripples are less compared to the forward boost converter by using the soft switching method for switching the switches of the circuit.

C. INTERLEAVED CAPACITOR SWITCHED BOOST CONVERTER

The fig.11 shows the interleaved capacitor switched boost converter circuit diagram. The interleaved capacitor switched boostconverter consist of two parallely connected capacitor switched boost converter.

The input voltage of 24V DC is applied to the Interleaved boost converter with CSSS circuit. The output of the circuit will be 48V. The frequency used for main switch on the boost converter is 125 kHz. Two IGBTs are used as switching device in CSSS circuit.capacitor is used to reduce the voltage stress across the switch during turn off. The frequency of 60 kHz is used for both auxillary switches of CSSS circuit. The main switch and auxiliary switch is turned on and turned off at zero voltage to reduce the stress across the switch.

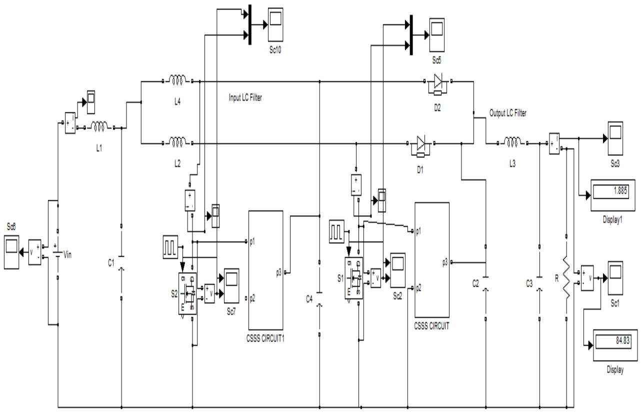

Figure 10. Interleaved Capacitor Switched Boost converter circuit

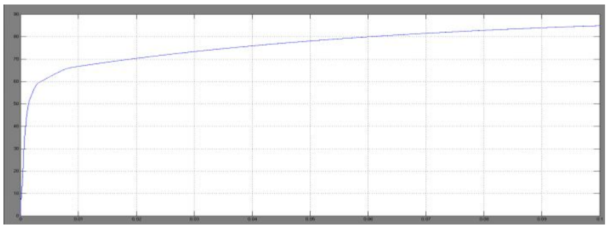

Figure 11. Output voltage of Interleaved capacitor switched boost converter

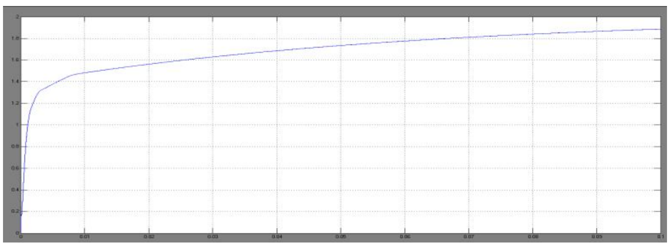

Figure 12. Output current of Interleaved capacitor switched boost converter

Figure 12 and figure 13 shows that the ripples present on the output voltage and output current are less compared to the Capacitor soft switching boost converter.

D. EFFICIENCY

The efficiency is calculated for CSSSBC circuit and FBC circuit for different values of input voltage. The results of them are compared. The efficiency is given by

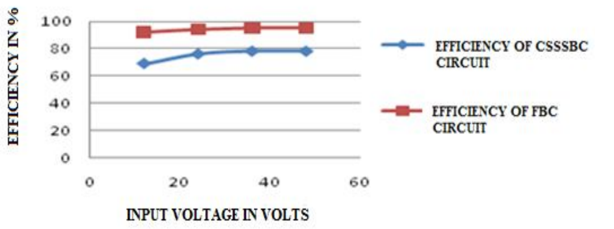

Figure 13.

The efficiency graph is plotted for the values listed in table. The efficiency of the CSSSBC is higher than the FBC circuit.

IV. CONCLUSION

This paper presents the comparison of transformer based converter, forward converter and transformerless boost converter, capacitor switched soft switching boost converter, and interleaved capacitor switched boost converter for renewable applications. The simulation is done for CSSSBC circuit and FBC circuit of same input voltage. The simulation result indicates that the ripples on the output voltage and output current of CSSSBC are less compared to the forward boost converter circuit.

The ripples present on the output voltage and current of interleaved boost converter are less than the capacitor switched soft switching boost converter.

The efficiency is improved in the capacitor switched soft switching boost converter compared to the forward converter due to reduced switching loss.

REFERENCES

[1] M. H. L. Chow, Yim-Shu Lee and C. K. Tse, "Single-stage single-switch isolated PFC regulator with unity power factor, fast transient response, and low-voltage stress," in IEEE Trans. on Power Electronics, vol.15, no.1, pp. 156-163, 2000.

[2] Youhao Xi and P. K. Jain, "A forward converter topology with independently and precisely regulated multiple outputs," in IEEE Trans. on Power Electronics, vol.18, no. 2, pp. 648-658, March 2003.

[3] Powerex CM150DU-12F Datasheet. [Online]. Available: http://www.pwrx.com.

[4] Y.-C. Chuang and Y.-L. Ke, "High-efficiency and low-stress ZVT–PWM DC-to-DC converter for battery charger," IEEE Trans. Ind. Electron.,vol. 55, no. 8, pp. 3030–3037, Aug. 2008.

[5] J.-M. Kwon, W.-Y. Choi, and B.-H. Kwon, "Single-switch quasi-resonant converter," IEEE Trans. Ind. Electron., vol. 56, no. 4, pp. 1158–1163, Apr. 2009.

[6] M. R. Amini and H. Farzanehfard, "Novel family of PWM soft-singleswitched DC–DC converters with coupled inductors," IEEE Trans. Ind Electron., vol. 56, no. 6, pp. 2108–2114, Jun. 2009.

[7] M. M. Hernando, A. Fernandez, J. Garcia, D. G. Lamar, and M. Rascon,"Comparing Si and SiC diode performance in commercial AC-to-DC rectifiers with power-factor correction," IEEE Trans. Ind. Electron., vol. 53, no. 2, pp. 705–707, Apr. 2006.

[8] C.-M. Wang, "A new family of zero-current-switching (ZCS) PWM converters," IEEE Trans. Ind. Electron., vol. 52, no. 4, pp. 1117–1125, Aug. 2005.

[9] T. Wu, Y. Lai, J. Hung, and Y. Chen, "Boost converter with coupled inductors and buck–boost type of active clamp" IEEE Trans. Ind. Electron., vol. 55, no. 1, pp. 154–162, Jan. 2008.

[10] QCJ. Marshall and M. Kazerani, "A novel lossless snubber for boost converters," in Proc. IEEE Int. Symp. Ind. Electron., Montreal, Canada, Jul. 9–13, 2006, pp. 1030

[11] Bor-Ren Lin and Chien-Lan huang, " Interleaved ZVS Converter With Ripple-Current Cancellation" IEEE Trans.Ind.Electron.,vol.55, no.4,pp.1576-1585,Apr.2008.

[12] Gustavo A.L.Henn, R.N.A.L. Silva, Paulo P.Praca,Luiz H.S.C.Baretto and Dermercil S.Oliveira ,"Interleaved-Boost Converter With High voltage gain",IEEE Trans. Power Electron.vol.25, no.11,Nov.2010.

[13] Doo-Yong Jung,Young-Hyok Ji,Sang-Hoon Park, Yong-Chae Jung and Chung-Yuen Won ,"Interleaved soft Switching boost converter for photovoltaic power generation system",IEEE Trans.Power Electron.vol.26,

no.4,Apr.2011.

BIBILOGRAPHY

M.Devi received the Bachelor degree in Electronics and Communication Engineering from Mailam Engineering College affiliated to Anna University. She obtained her Master degree in Power Electronics and Drives in Adhiparasakthi Engineering College at Melmaruvathur. Presently Working as Assistant Professor in CK College of Engineering and Technology. Her area of interest includes DC to DC converters, Multilevel Inverters and Power converters.

D.Kalaichelvi received her Bachelor degree in electrical and Electronics Engineering. She obtained her Master degree in Power Systems. Presently she is working as Assistant Professor in CK College of Engineering and Technology. Her area of Interest includes Power Converters and FACTS devices.

J. Jayashree is working as AssistanceProfessor in the dept of EEE at CK College of Engineering and Technology. She received BE in EEE Madurai Kamaraj University, Madurai. ME Embedded system Engineering from GKM Engineering College Chennai. She has been teaching for the past 11 years, and guided more than 100 BE,10 ME students for their projects. She has published 10 papers in national and international journals. She is a Member of IEEE, ISTE, His research interests are in the areas of Embedded system, Digital electronics, and Wireless System.