IJCTA, 8(4), 2015, pp. 1455-1462

High Voltage Gain Boost Converter Using Three Winding Coupled Inductor With three Stages of Switching Frequencies

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Abstract: In this Modern Era lot of DC-DC boost converters are designed to increase the efficiency and performance of the output power. While trying to increase the output power the generation of ripple current and voltage increase simultaneously. So the increases in ripples which will affect the output performance as well as the load connected to the output of the boost converter. Especially in PV system the output generated by the Distributed generator is not a constant one why because of the natural parameters such as temperature and irradiation. The main focus of this project is to achieve the output power requirement from the PV boost converter systems here the output voltage is 8 times achieved greater than that of the input voltage with lower amount of ripples in current as well as voltage due to the usage of Coupled Inductor instead of Isolation transformer. In this proposed project the two stages of Coupled inductor has been replaced in to the three stages of coupled inductor. Through these systems the voltage stress on the switches is lesser than that of two stages of coupled inductor based boost converters.

The Output voltage obtained is 450v from the input of 60v and the Output power is 2000 watts. Compare to the existing system the output power ratings of proposed system is two times increases.

Keywords: Boost Converter, High Voltage Gain, Load Capacitor, Soft Switching with different frequencies, stages of coupled inductor, Three winding Coupled Inductor.

1. INTRODUCTION

The conventional boost converter is normal applications ofStep-up boost converter in solar power application but not applicable in the high maximum demand on power sector for high voltage gain, mainly due to the high switching losses. When the duty cycle is unity getting high voltage gain in the boost converter circuit, in practical way, this high gain is limited in order to limit the I^2R loss in the boost inductor because of its intrinsic resistance [4].

The duty cycle of an isolation transformer, which is connected in open-loop condition of the controlled isolated dc–dc converter, is fixed at 50%. In the resultant of soft switching of all the power semiconductor switches can be always achieved by utilizing the leakage inductance [1]. The large duty ratios, high switch voltage stresses, output diode reverse recovery problem are still major main challenges in the step up and high power conversion with regulated efficiency [2]-[6].

The comparison is done based on how fast response it attained by using PI controller for high stable operation. For open loop it took 0.28s to achieve steady state the waveforms for output voltage, Output current, rotor speed, armature current, back emf, electromagnetic torque But for closed loop it took 0.03s to achieve steady state the waveform for output voltage and output current [2].

The techniques of soft switching and voltage clamping are responsibilities to cut the switching losses and conduction losses. The utilization of a low-voltage-rated power switch with a very small R_{DS}(on). So that the current change in the slew rate, the coupled inductor can be restricted by the outflow inductor, the current change

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time enables the power switch to turn ON with the ZCS properties easy, and the leakage inductor effects can alleviate the losses caused by the reverse-recovery of currents. Additional problems of the stray inductance energy and reverse-recovery currents within diodes in the conventional boost converter also solved, so here achieved in high-efficiency power conversion [3].

In the MPPT stage the mismatching of power can be occurs due to the change in irradiation under partial shading conditions. Power loss occurs in the Diode through reverse recovery voltage which reduces the efficiency of PV system [12].

The losses occurs in the switches can be reduced by means of using the low on-drop power semiconductor switches. In this circuit IGBT is used to turn ON and turn OFF easily through the gate pulse control. Since the High step up Buck or boost DC-DC converter operating in very high frequency at all occasions of proposed system to improve efficiency [5]-[8].

In this paper the two dc-dc converters are compared for to attain the fast charging in EV/HEV to extend the range of the electric drives. Some of the dc power distribution unit which deploy the bidirectional dc-dc charging operation and pass vehicle to connect with grid. In the grid connected applications of DG is helpful to inject the real and reactive component in to the grid to ensure harmonic filtering and load balancing [9]-[13].

2. STRUCTURE OF CIRCUIT DIAGRAM

In this generalized circuit diagram of 3 stages of coupled inductor based DC-DC boost converter with three switches for each stage by three different switching frequencies. The switching frequencies applied to the switches with switching points from (0-120), (120-240), (240-360) and three diodes connected in each stage coupled inductor. The coupled inductor output is connected to the output capacitor C_o which is to be parallel to the Load resistance R_L which aredenoted in the above Fig 1.

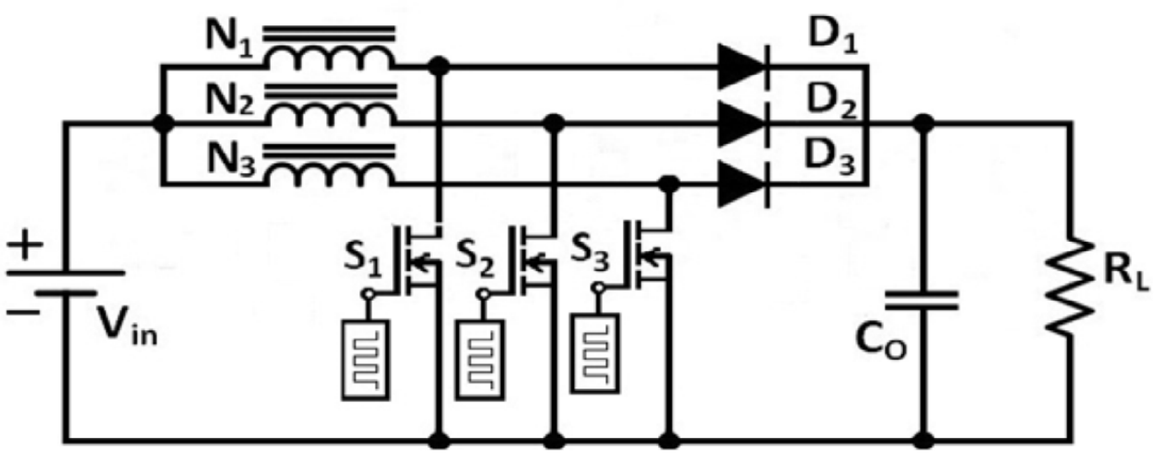


Figure 1: High gain DC-DC proposed boost converter

3. MODE OF OPERATION

Here have a four mode of operation in this circuit with equvalent circuit and mode of equations are properly discussed below and the all modes Operation in the circuit waveforms are mentioned in Fig 2.

MODE: 1($t = t_0 – t_1$ for $S_{1,}$ $t = t_2 – t_3$ for $S_{2,}$ $t = t_3 – t_4$ for S_3)

In this mode N_1 is the first inductor which get charging from 0-50% through the switch S_1 is at ON status with the switching frequency of 20KHZ switching pointsfrom 0-120 and other two switches is at OFF status. During this mode N_2 having 50% of charge and starts discharge to the load R_L through the diode D_2 and load capacitor c_o .N_3 already get charged fully through previous conduction duration (mode 4) so the energy stored is going to discharge to the load R_L and C_o starts charges again.

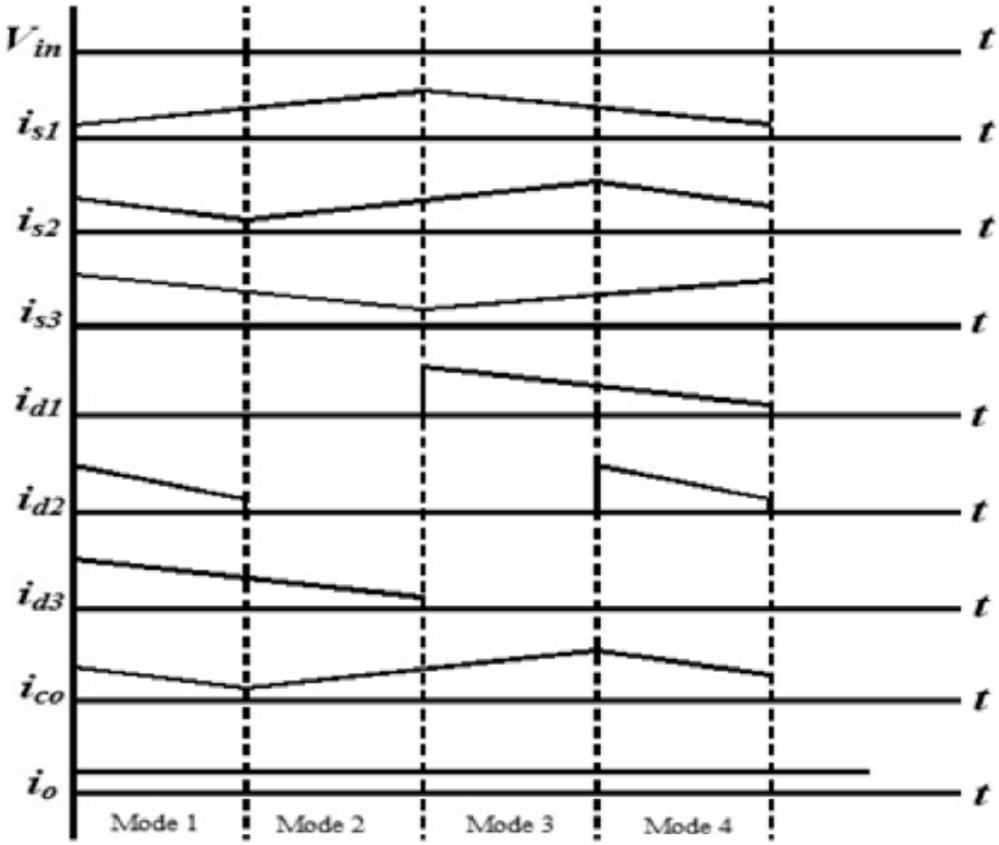


Figure 2: all modes of Operation in the circuit

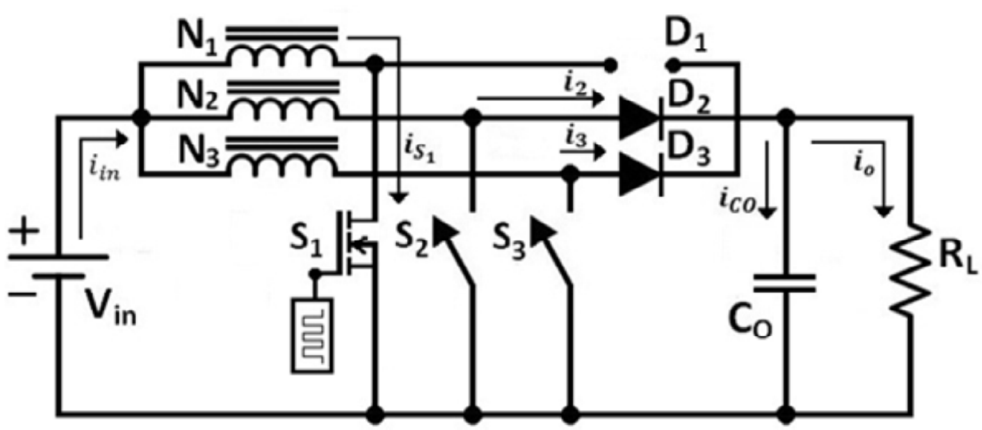


Figure 3: Equivalent circuit of mode 1 for proposed converter

Here the following voltage equations are mentioned from the Equivalent circuit of mode 1 for proposed converter,

$$V_{in} + L_2 \frac{d_{i2}}{dt} + L_3 \frac{d_{i3}}{dt} + L_m \left[\frac{d_{i2}}{dt} + \frac{d_{i3}}{dt} \right] = I_o R_L \tag{1}$$

Where $L_m = L_{k2} = L_{k3}$ (2)

$$V_{in} + L_1 \frac{d_{is1}}{dt} + L_m \frac{d_{i1}}{dt} \tag{3}$$

Where $L_m = L_{k1}$ (4)

MODE: 2 ($t = t_1 - t_2$ for $S_{1,}$ $t = t_3 - t_4$ for $S_{2,}$ $t = t_0 - t_1$ for S_3)

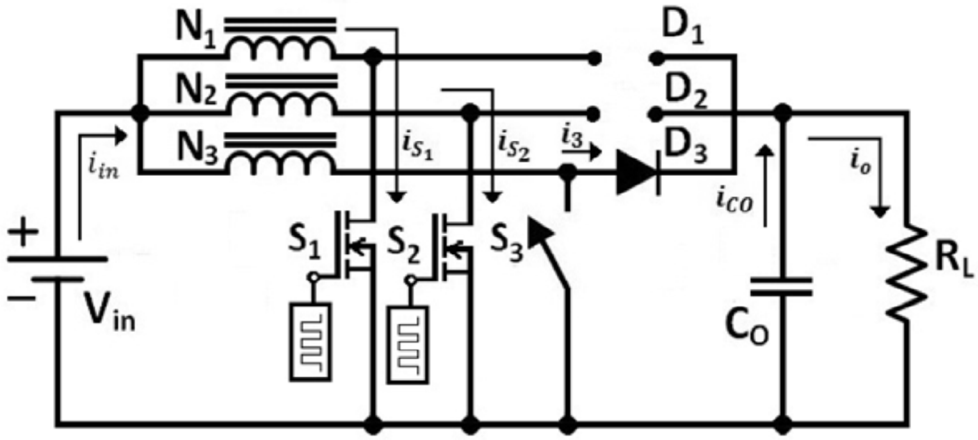


Figure 4: Equivalent circuit of mode 2 for proposed converter

In this mode 2 N_1 starts charging from 50% to 100% due to switch S_1 is at conduction for few seconds and got to saturation condition with frequency of 20KHZ switching points from 0-120.N_2 starts charging from 0-50% through the switch S_2 is atON status and starts conducting with the switching frequency of 30KHZ switching points from120-240 and other two at OFF status. N3 already have 50% of stored energy and starts discharge to the load R_L through the load capacitor C_o and diode $D2$.

Here the following voltage equations are mentioned from the Equivalent circuit of mode 2 for proposed converter,

$$V_{in} + L_3 \frac{d_{i3}}{dt} + L_m \left[\frac{d_{i1}}{dt} + \frac{d_{i2}}{dt} \right] + V_{OC} = I_O R_L \tag{5}$$

Where $L_m = L_{k1} = L_{k2}$ (6)

$$V_{in} = L_1 \frac{d_{is1}}{dt} + L_2 \frac{d_{is2}}{dt} + L_m \left[\frac{d_{i1}}{dt} + \frac{d_{i2}}{dt} \right] \tag{7}$$

Where $L_m = L_{k1} = L_{k2}$ (8)

MODE: 3($t = t_2 - t_3$ for $S_{1,}$ $t = t_4 - t_0$ for $S_{2,}$ $t = t_1 - t_2$ for S_3)

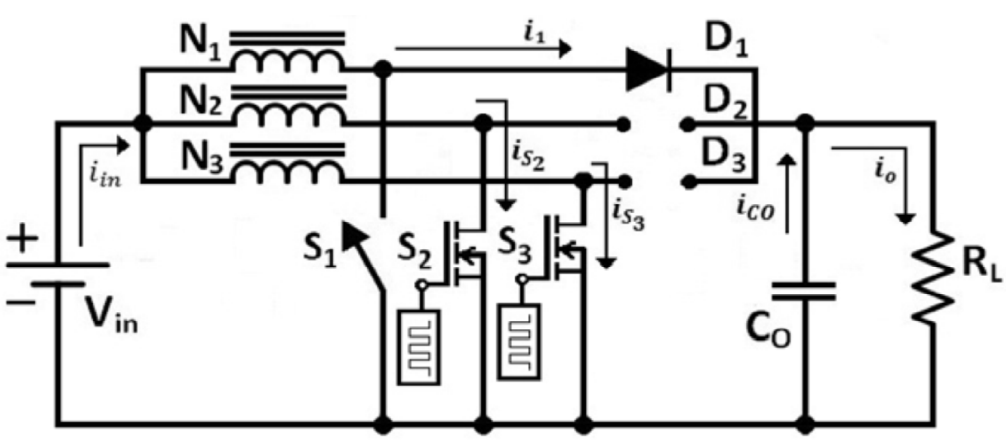


Figure 5: Equivalent circuit of mode 3 for proposed converter

In this mode 3 N_2 starts charging from 50%-100% due to the saturation of previous mode switch S_1 from conduction mode with frequency of 20KHZswitching points from 0-120and N_3starts charging from 0-50%through switch $S_2$with frequency of 30KHZ switching points from 120-240 other switches are at OFF status. During this mode $N_1$is fully charged through the previous conduction duration (mode 2) so full energy of $N1$ is discharged to the load R_L through Diode $D1$ and charges from load capacitor $C_o$also get discharged.

Here the following voltage equations are mentioned from the Equivalent circuit of mode 3 for proposed converter,

$$V_{in} + L_1 \frac{d_{i1}}{dt} + L_m \frac{d_{i1}}{dt} + V_{OC} = I_O R_L \tag{9}$$

Where $L_m = L_{k1}$ (10)

$$V_{in} = L_2 \frac{d_{is2}}{dt} + L_3 \frac{d_{is3}}{dt} + L_m \left[\frac{dis_2}{dt} + \frac{dis_{-3}}{dt} \right] \tag{11}$$

Where $L_m = L_{k2} = L_{k3}$ (12)

MODE: 4($t = t_3 - t_4$ for S_1, $t = t_1 - t_2$ for S_2, $t = t_3 - t_4$ for S_3)

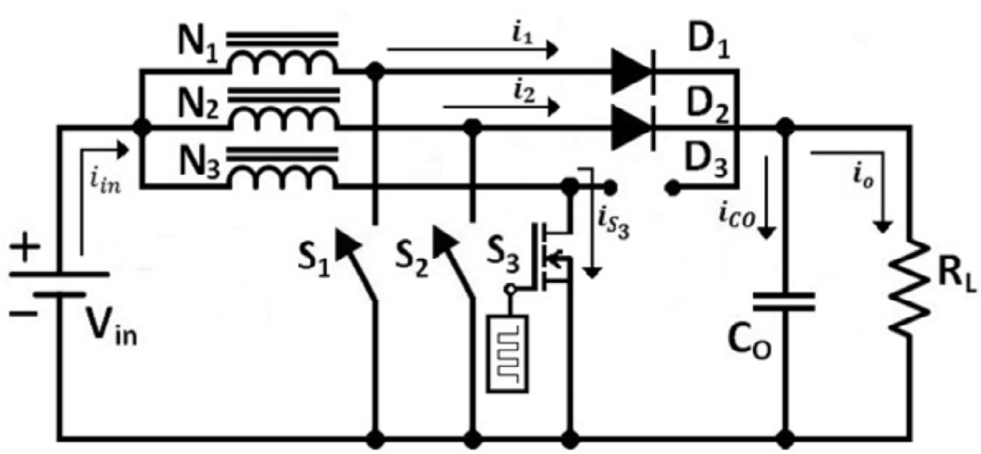


Figure 6: Equivalent circuit of mode 4 for proposed converter

In this mode 4 N_3starts charging from 50%-100% through the previous mode switch S_3saturation with the frequency of 40KHZ switching points from 240-360 and stored energy of N_1 is fully discharged to load R_L through Diode $D_1$and N_1 is ready to charge again from 0%.The stored energy of N_2 is at 50% initially through switch $S2$ with frequency of 30KHZswitching points from 120-240 and starts discharge to the load RL through the Diode $D2$ and N_2ready to starts from 50% onwards due to previous mode switch S_1 saturated from conduction mode with frequency of 20KHZ.

Here the following voltage equations are mentioned from the Equivalent circuit of mode 4 for proposed converter,

$$V_{in} + L_1 \frac{d_{i1}}{dt} + L_2 \frac{d_{i2}}{dt} + L_m \left[\frac{di_1}{dt} + \frac{di_2}{dt} \right] = I_O R_L \tag{13}$$

Where $L_m = L_{k1} = L_{k2}$ (14)

$$V_{in} = L_3 \frac{d_{is3}}{dt} + L_m \frac{d_{i3}}{dt} \tag{15}$$

Where $L_m = L_{k3}$ (16)

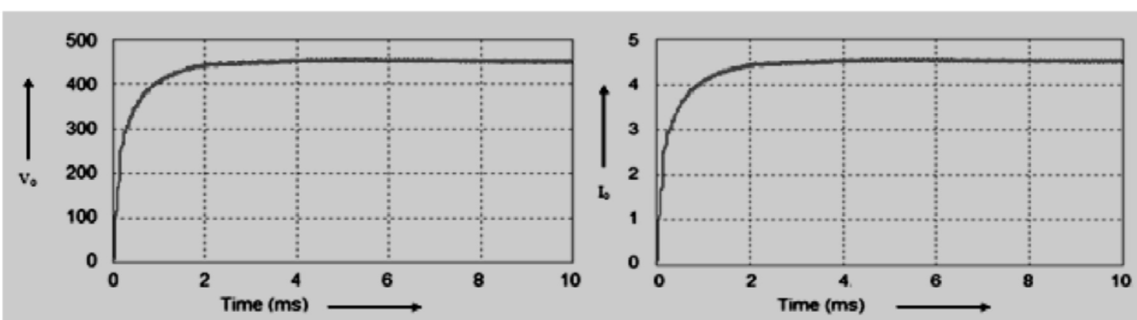
Table 1
Design Consideration of Proposed Converter System

S.no	*Parameter*	*Existing [4]System Values*	*Proposed System Values*
1.	Input voltage	60v	60v
2.	Capacitor	C_1 = 30uf/300v,C_2 = 30uf/600v	C_o=30uf/600v
3.	Diodes	0.7v	0.7v
4.	Switching Frequency of Switch 1	45 KHZ	20 KHZ
5.	Switching Frequency of Switch 2	45 KHZ	30 KHZ
6.	SwitchingFrequency of Switch 3	–	40 KHZ
7.	Load resistance	400 Ω	100 Ω
8.	Self-inductance	10 μH	10μH
9.	MutualInductance	5μH	9μH
10.	Turn's ratio (n2: n1) (n3: n2: n1)	1:1	1:1:1
11.	Output voltage	600 V	450 v
12.	Output power	900 W	2000 W
13.	Output current	1.5 amps	4.5 amps

The above table1 which has explains the detailed analysis of the existing system and improved power rating of proposed system through three stages of coupled inductor with different operating switching frequencies.

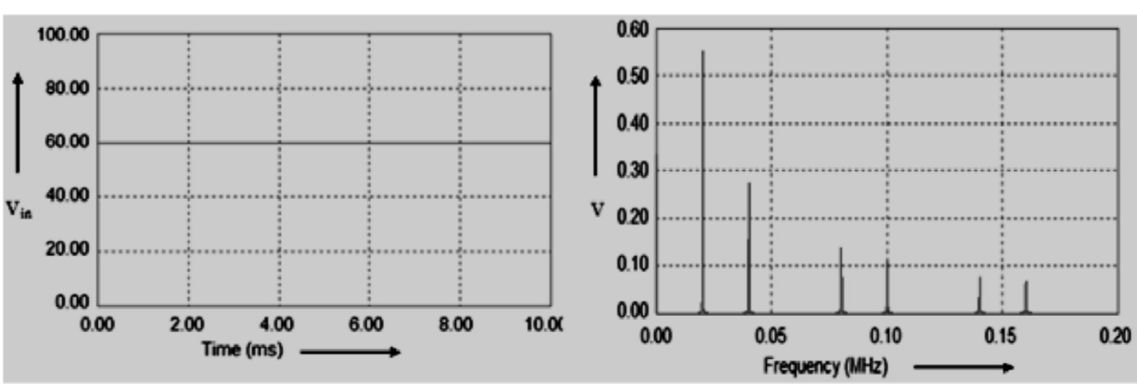
4. SIMULATIONS & RESULTS

The analysis of DC-DC high step up coupled inductor based boost converter to obtain the high voltage gain for the required output voltage ratings of PV power applications. With the help of modified 3 stages of coupled inductor for to increase the voltage gain and reduces the voltage stress across the switches to avoid the ripple current and voltages. The simulated output voltage and output current waveforms from this circuit are mentioned in below fig 7, input voltage and FFT response of switches S_1, S_2, S_3 with the frequencies of 20khz, 30khz, 40khz are mentioned in fig 8 & fig 9.



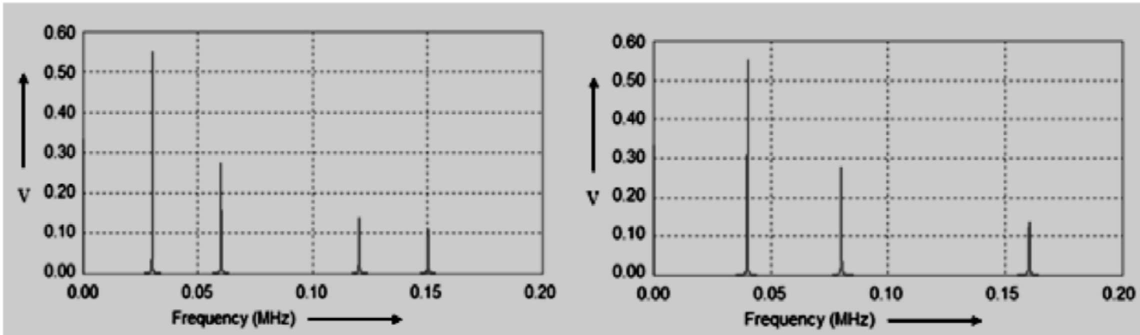
(a) (b)

Fig 7: (a) Output Voltage Waveform (b) Output Current Waveform



(a) (b)

Fig 8: (a) Input Voltage Waveform (b) FFT Response of Switch S_1 at 20 kHz



(a) (b)

Fig 9: (a) FFT Response of Switch S_2 at 30kHz (b) FFT Response of Switch S_3 at 40kHz

5. CONCLUSION

In this paper the DC-DC high step up coupled inductor based boost converter for to increase the voltage gain and attain the steady state within 3ms by modifying the three stages of coupled inductor instead of two stages and adjusting the turn's ratio from 1:2 to 1:1:1.Usage of different switching frequencies to the three different staged switching activities of coupled inductor. Thus the high efficiency converter topology provides required output for the PV system. In future work of this paper is to add this boost converter output to inverter circuit for the purpose of Ac loads in standalone PV based Domestic applications.

The Output voltage obtained is 450v from the input of 60v and the Output power is 2000 watts. Compare to the existing system the output power ratings of proposed system is two times increases, these analysis can be done through graphical response in PSIM Software.

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