Design and Simulation of Boost Converter for Constant Output Voltage

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ABSTRACT: After generation, to maintain the constant output voltage is one of the important tasks. Control of output voltage using DSP gives faster operation. The ripple content will be minimized and smooth output is achieved by slightly changing in the programme.

Keywords: Design of Boost Converter, By PWM Generation Method, With DLL Block

1. INTRODUCTION:

Some critical application like electrical drives can not tolerate failure of power supply as well as variation in load. Irrespective of situation like load variation and internal drive condition the drive performance at all time. For such application drive must be provided with the back-up supply arrangement. Batteries are used for back-up supply but to generate 600 V dc 48 batteries of 12 V is needed. The boost converter provides to use the lesser number of batteries and boosting the voltage up to the 600 V dc.

There are two methods for boosting the voltage namely, (i) Isolated or H-bridge dc-dc converter, (ii) Non isolated or convectional dc-dc boost converter. Isolated converter uses the full bridge topology which provides the isolation through the high frequency transformer. At the output side the fast recovery diodes for ac to dc conversion is used. The filter is also required for the ripple free dc output. The convectional boost converter has the only disadvantage that the rating of the component is quite higher than the H-bridge topology.

Control of output voltage is done by the DSP. It provides the fast and flexible control. The various quantity can be programmed and controlled to it's specify limit range. The non isolated converter project mainly designs for the back-up supply for the AC drives. The non isolated boost converter is also used in the photovoltaic solar cell, at the variable wind power .

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1.1 PROBLEM DEFINATION

Goal: It requires a constant 600V DC high power output with a 144 V DC input to supply power to a varying load.

Objectives: To design and implement a dc to dc converter with a regulated output voltage. The objectives are to design a converter with the following requirements:

1. Cost efficient DC-DC converter.
2. Remain within the allocated budget.
3. High power output.
4. 600 V DC output with varying 144 V DC input.
5. Output voltage tolerance within ±10 % of the output voltage.
6. The time taken for the steady state is as low as possible and programmable.

Constraints: The decided input voltage will vary between 144 ± 2.5% V and the permissible output voltage will be ± 5 percent of the stated regulated voltage of 600V DC. Thus, the dc –dc converter will be required to provide high power with a DC output voltage between 585-615V.

For high power, high step up voltage conversion the various kinds of power topologies is study from the different references. The conventional power topology is first referred [1]. The conventional topology for the no isolated dc to dc boost converter has the highest conversion ratio for a given duty cycle operation. Boost converter circuit is proffered for stepping up the voltage because of their low conduction loss and simplicity in design.

A 2 kW 100 kHz power converter, [3] describe new power topology for the boost converter. As the conventional topology uses the thyristor that is replaced by the IGBT and the MOSFET for the faster turn on and turn off.

The features of this topology are:

1) Fixed working frequency;
2) Usage of pulse width modulation (PWM) controlling techniques;
3) High efficiency;
4) No over voltage applied to power device;

The drawbacks are as follows:

1) Need of auxiliary power device for the turn off oscillator;
2) Over current through power device;

A comparison of various DC-DC converters and their application to power factor correction", [4] describe various buck-boost type converter was compared. As a result, it is found that the CSC converter has minimum components, while the stored energy large. For the higher efficiency this converter is used for the lower power rating. For the higher power rating

SEPIC or Luo converter is suitable in terms of lower transmission power.

In paper titled, "Novel high efficiency step-up converter", [6] describe a high efficiency high step-up converter is proposed, with the lower voltage stress on the power switch, power diode and capacitor. The circuit topology of the proposed converter consists of an energy clamp circuit and a voltage boost cell. The boost converter functions as an active clamp circuit to suppress the voltage spike on power switch during the turn-off transient period. The boost converter output terminal and fly back converter output terminal are serially connected to increase the output voltage gain with the coupled inductor. By serially connecting the secondary windings of the boost inductor, a high voltage gain is achieved with less voltage stress on the power devices, such as power MOSFETs and power diodes.

From the above papers the following conclusion arrived at:

1. For the higher voltage boost up and moderate current range the voltage conversion is doing in step. The voltage is increases in two or three step.
2. For the higher current and moderate voltage level the interleaved topology is chooses. So, the current rating of switches and inductor is minimized.
3. For the higher power level like 30 kW the three 10 kW cells are arranged in parallel.
4. After studying the various power topologies from the above paper, for the higher power application the IGBT is suitable device. For the frequency between 5 kHz to 10 kHz the switching looses in the IGBT is quite low.

Switched mode pulse width modulation (PWM) based dc-dc converters plays an important role in communication, automobile, computer and aerospace applications. The output voltage of dc-dc converter may fluctuate due to supply disturbance and load variances. The two general approaches to control output voltage fluctuations are voltage-mode control and current-mode control

In paper titled, "A family of PWM based sliding mode voltage controllers for basic DC-DC converters" [10] describes the various methods for controlling the output voltage to the constant value.

There is various method of controlling:

- Current control method
- Voltage control method
- Inner current and Outer voltage control method
- Sliding mode control method
- Closed loop control using PWM

2 DESIGN OF BOOST CONVERTER FOR CONSTANT 600V DC HIGH POWER OUTPUT WITH A 144 V DC INPUT TO SUPPLY POWER TO A VARYING LOAD.

Input Data:

f (Hz) = 6000; Vs (Volt) = 144; Vo (Volt) = 600

P (kW) = 30; T (µsec) = 166;

$$Io = P \div Vo$$
$$= 30000 \div 600$$
$$= 50A$$

$$D = \frac{outputvoltage - inputvoltage}{outputvoltage}$$
$$= \frac{v0 - vs}{vo}$$

$$D = \frac{600-144}{600} = 0.76$$

$$D = \frac{Ton}{Ton + Toff}$$
$$= \frac{Ton}{T}$$
$$Ton = TD$$
$$= 166 * 0.76$$
$$= 126.66 \mu s$$

$$VsIs = VoIo$$
$$Is = \frac{600 \div 50}{144}$$
$$= 208.33A$$

Taking 10% of Input current Ripple,

$$I = Is \pm \Delta I/2$$
$$I_2 = Is + \Delta I/2$$
$$= 208.33 + ((10\% \text{ of } Is)/2)$$
$$= 208.33 + 20.83/2$$
$$= 218.74A$$
$$I_1 = Is - \Delta I/2$$
$$= 208.33 - 20.833/2$$
$$= 197.9135A$$

Inductor calculation:

$$L = (Vs * D) \div (f * \Delta I)$$
$$= \frac{144*0.76}{6000*20.83}$$
$$L = 875.5 \mu H$$

Taking the ripple smoother, we take inductor 1.2times the value L =1050.6µH

So, the inductor needed is 1000µH, 238A.

Capacitor calculation:

If we take the variation at the output side is 5% of output voltage,

$$C = (Io * D) \div (f * \Delta Vo)$$
$$C = (50*0.76) \div (6000*300)$$
$$C = 211.11 \mu F$$

So, the minimum capacitor needed is 200 µF, 1200 V.

From the above calculations the following conclusion is arrived at,

1. While boosting the voltage from up to the 72 V to 600 V the duty cycle is quite large.
2. As the current is high so the larger size of inductor is used. Thus the cost is increase.
3. The rating of the IGBT is quite higher.
4. To maintain the switching loss within tolerable limit switching frequency set at 5 to 10 kHz

CALCULATION OF THE DIFFERENT RATING OF THE CAPACITOR AND INDUCTOR

Table-1.1: Calculation of the Different Rating of the Inductor and Capacitor

Lmin (µH)	Lneed (µH)	F (kHz)	P (kW)	C (µF)	Vs (v)	Vo (v)	Delta (D)
9.406	11.2872	5	30	326.666	12	600	0.98
36.864	44.2368	5	30	320	24	600	0.96
141	169.2	5	30	306.66	48	600	0.92
304	364.8	5	30	293.33	72	600	0.88
1050	1260	5	30	253.33	144	600	0.76
14.11	16.932	5	20	217.75	12	600	0.98
55.301	66.3612	5	20	213.312	24	600	0.96
211.989	254.3869	5	20	204.424	48	600	0.92
456.237	547.4844	5	20	195.536	72	600	0.88
1576	1891.2	5	20	168.872	144	600	0.76
28.23	33.876	5	10	108.84	12	600	0.98
110.636	132.7632	5	10	106.624	24	600	0.96
424.105	508.926	5	10	102.181	48	600	0.92
912.771	1095.3252	5	10	97.738	72	600	0.88
3153	3783.6	5	10	84.41	144	600	0.76
56.47	67.764	5	5	54.42	12	600	0.98
221.27	265.524	5	5	53.312	24	600	0.96
848.211	1017.8532	5	5	51.09	48	600	0.92
1825	2190	5	5	48.86	72	600	0.88
6306	7567.2	5	5	42.205	144	600	0.76
4.704	5.6604	10	30	163.33	12	600	0.98
18.432	22.1184	10	30	160	24	600	0.96
70.656	84.7882	10	30	153.33	48	600	0.92
152	182.4	10	30	146.665	72	600	0.88
525	630	10	30	126.66	144	600	0.76
7.05	8.46	10	20	108.875	12	600	0.98
27.6505	33.1806	10	20	106.656	24	600	0.96
105.9945	127.1934	10	20	102.212	48	600	0.92
228.118	273.7416	10	20	97.768	72	600	0.88
788	945.6	10	20	84.436	144	600	0.76
14.115	16.938	10	10	54.42	12	600	0.98
53.318	63.9816	10	10	53.312	24	600	0.96
212.052	254.4624	10	10	51.09	48	600	0.92
456.385	547.662	10	10	48.869	72	600	0.88
1576	1891.2	10	10	42.205	144	600	0.76
Lmin (µH)	Lneed (µH)	F (KHZ)	P (KW)	C (µF)	Vs (v)	Vo (v)	Delta
28.235	33.882	10	5	27.21	12	600	0.98
110.635	132.762	10	5	26.656	24	600	0.96
424.105	508.926	10	5	25.545	48	600	0.92
912.5	1095	10	5	24.43	72	600	0.88
3153	3783.6	10	5	21.102	144	600	0.76
2.352	2.8224	20	30	81.665	12	600	0.98
9.216	11.0592	20	30	80	24	600	0.96
35.328	42.3936	20	30	76.665	48	600	0.92
76	91.2	20	30	73.33	72	600	0.88
262.5	315	20	30	63.33	144	600	0.76
3.52	4.224	20	20	54.43	12	600	0.98
13.825	16.59	20	20	53.328	24	600	0.96
52.997	63.5964	20	20	51.106	48	600	0.92
114.059	136.8708	20	20	48.884	72	600	0.88
394	472.8	20	20	42.218	144	600	0.76
7.0575	8.469	20	10	27.21	12	600	0.98
26.659	31.9908	20	10	26.656	24	600	0.96
106.026	127.2312	20	10	25.545	48	600	0.92
228.192	273.8304	20	10	24.434	72	600	0.88
788	945.6	20	10	21.102	144	600	0.76
14.1175	16.942	20	5	13.605	12	600	0.98
53.3175	63.981	20	5	13.328	24	600	0.96
212.052	254.4624	20	5	12.772	48	600	0.92
456.2	547.44	20	5	12.21	72	600	0.88
1576.5	1891.8	20	5	10.551	144	600	0.76

3.SIMULATION OF BOOST CONVERTER

Simulation of boost converter under different operating conditions like, steady state condition, reduced supply voltage, step change in load. First the simulation is done on the full scale version then down scale version has been simulated. In this the simulation done with the DLL block and program of DLL block can directly used for the DSP programming after some modification.

3.1 SIMULATION OF 30kw BOOST CONVERTER WITH PWM GENERATION METHOD

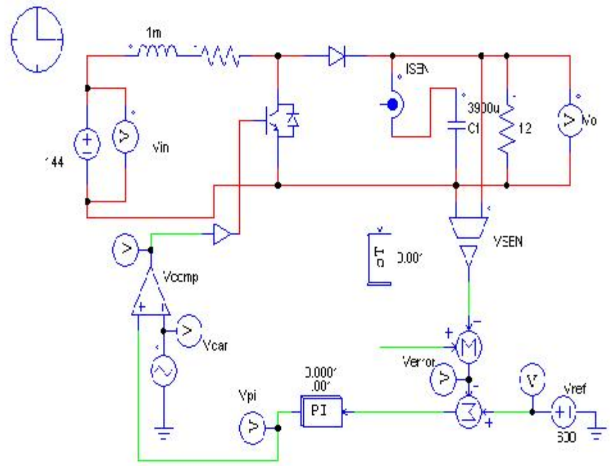

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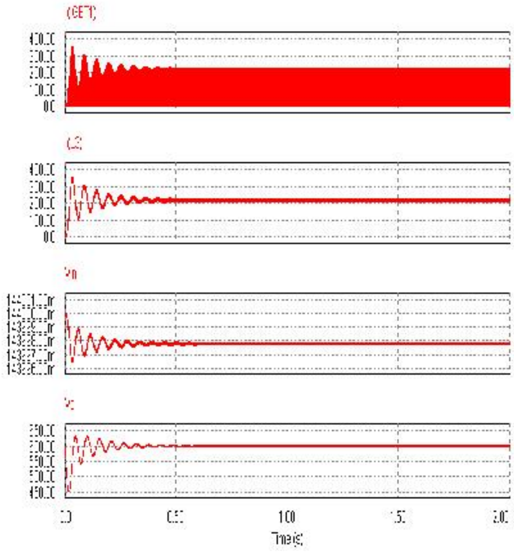
Fig 3.1 shows the simulation of boost converter and the waveform are shown below the fig 3.2 shows the output voltage waveform which can be steady state after 0.5 sec.



(a) IGBT current: X- axis: 1div = 0.5sec, Y- axis: 1div = 100Amp (b) Inductor current: X- axis: 1div = 0.5sec, Y- axis: 1div = 100Amp (c) Input voltage: X- axis: 1div = 0.5sec, Y-axis: 1div = 0.000001Vn (d) Output voltage: X- axis: 1div = 0.5sec, Y- axis: 1div = 50V

Fig:3.2 simulation result of the PWM generation method

3.2 SIMULATION OF 30KW BOOST CONVERTER WITH DLL BLOCK

For the simulation the power rating has been choose to be 30 kW. The corresponding inductor value is taken for the steady state condition and the simulation is done.

3.2.1 SIMULATION OF 30KW BOOST CONVERTER WITH STEADY STATE CONDITION

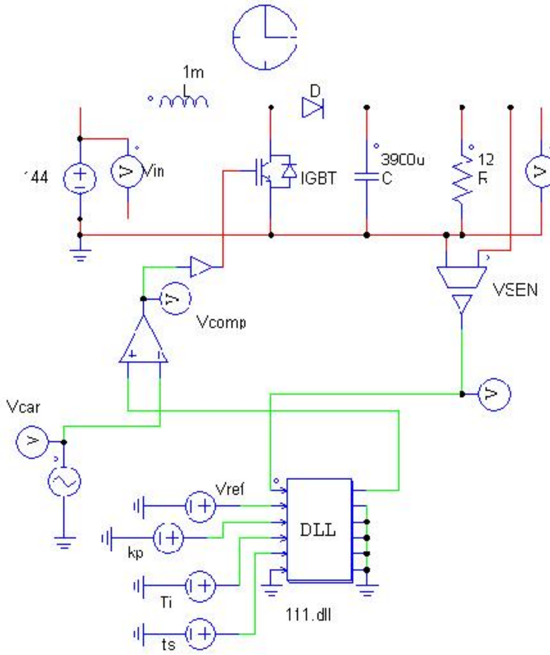


Fig.3.3 simulation of 30 kw boost converter with steady state conditiom

Fig. 3.3 shows the simulation of boost converter and the waveform are shown below. The Fig. 3.4(a) shows the output voltage waveform which can be steady state after 0.25 sec. the peak observed in Fig.3.4(a) is quite higher and it can be reduce by boosting the voltage slightly slower. After steady state the peak-peak voltage is observed to be 5V. Fig. 3.4(b) shows the input current flowing through the inductor has the average value of 200 A. The first peak observed is quite higher and hence to control this peak initially the reference voltage is slowly incremented by programming to the desired voltage rating. The load current is shown in Fig. 3.4(c) which is constant and the peak-peak variation observed in the load current is quite low, the average value is 200 A. Fig. 3.4(d) shows the IGBT's current waveform which is pulsating and the peak is the same as the inductor current.

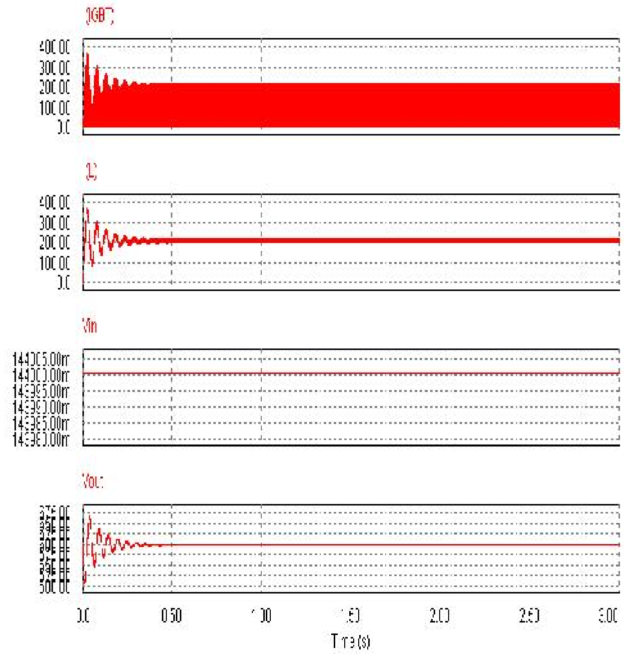


Fig:3.4 simulation result in steady state condition

(a) IGBT current: X- axis: 1div = 0.5sec, Y- axis: 1div = 100Amp
(b) Inductor current: X- axis: 1div = 0.5sec, Y- axis: 1div = 100Amp
(c) Input voltage: X- axis: 1div = 0.5sec, Y- axis: 1div = 0.000001V
(d) Output voltage: X- axis: 1div = 0.5sec, Y- axis: 1div =25V

3.2.2 SIMULATION OF BOOST CONVERTER WITH VARYING LOAD

The boost converter works properly even when the load is suddenly chancing, the simulation is shown in Fig. 3.3. Here, for changing the load there is 1 kΩ resistance is connected across the load. The 0.5 Hz frequency square wave is given for the varying the load from 12 Ω to 1 kΩ.

Fig. 3.5(a) shows the output voltage variation when the load is changing. When the positive pulse is given the 12Ω are parallel connected to 1 kΩ and the voltage remains constant at 600 V. when this 12 Ω is disconnected the load current gets down and the voltage start to incrementing but its steady state after the time taken for the RC time constant at the output.Again when the load is connected to its normal rating the deep is observed which can be reduced by using the lower value of capacitor.

Simulation result:

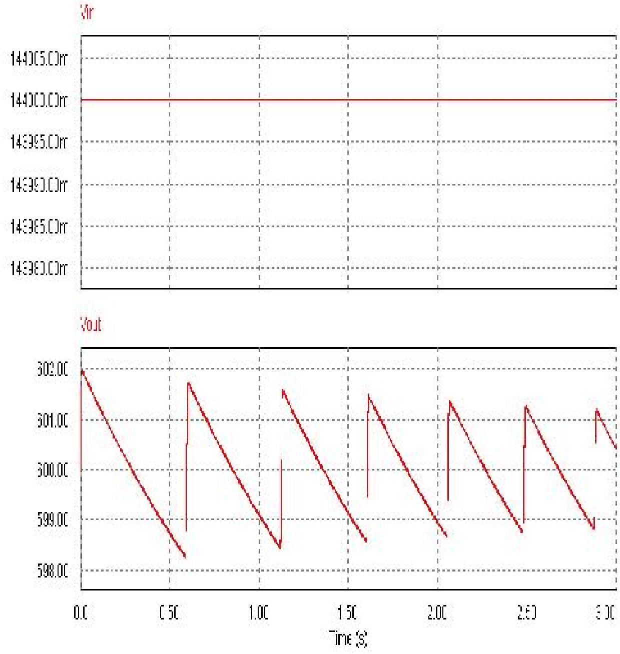


Fig. 3.5 Simulation result for Boost converter with varying load
(a) Input voltage: X- axis: 1div = 0.5sec, Y- axis: 1div = 0.000005V
(b) Output voltage: X- axis: 1div = 0.5sec, Y- axis: 1div =1V

3.2.3 SIMULATION OF BOOST CONVERTER WITH REDUCE I/P AND LOAD

The boost converter has operated on the battery supply, when the battery gets discharge and its voltage start reducing so this simulation is carried out based on the reduction in the supply voltage of boost converter. Fig. 3.6 shows the simulation of boost converter with input voltage is reduced up to the 120 V.

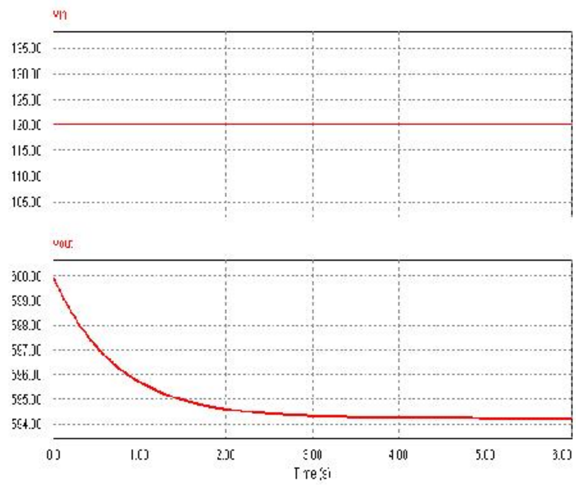


Fig. 3.6 Simulation results for Boost converter with reduce input voltage and load
(a) Input voltage: X- axis: 1div = 0.1sec, Y- axis: 1div = 5V
(b) Output voltage: X- axis: 1div = 0.1sec, Y- axis: 1div = 1V

3.2.4 SIMULATOIN OF BOOST CONVERTERWITH LOW I/P VOLTAGE AND VARING LOAD

The output voltage is shown in Fig.3.7(a) where it can be constant to the 582 V which is acceptable within the range of ±5 % of output voltage variation.

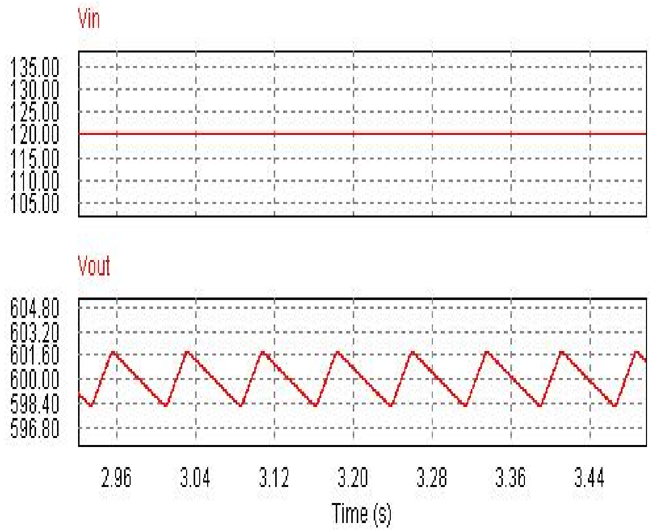


Fig.3.7 Simulation result of Boost converter with low I/P voltage and varying load
(a) Input voltage: X- axis: 1div = 0.08sec, Y- axis: 1div = 5V
(b) Output voltage: X- axis: 1div = 0.08sec, Y- axis: 1div = 1.6V

3.2.5 SIMULATION OF BOOST CONVERTER USING RECTIFIRE

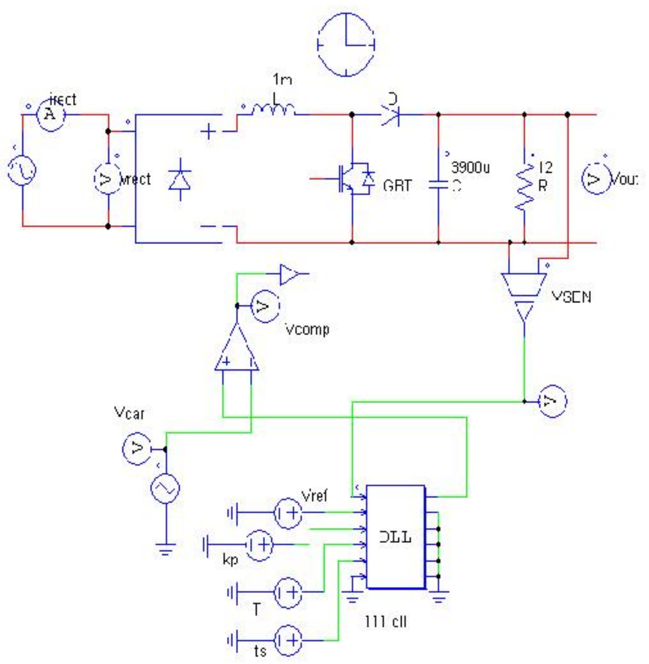


Fig:3.8 Simulation of Boost converter using rectifier

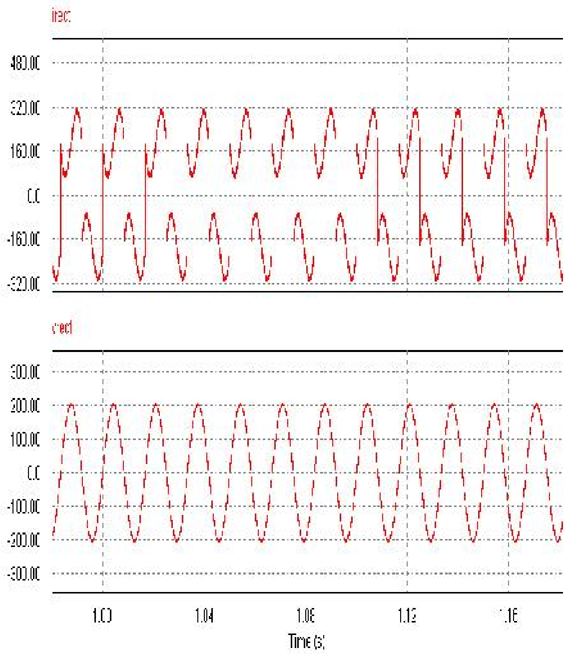


Fig:3.9 Simulation result of Boost converter using rectifier

In fig.3.9 easily show the wave form of the current and voltage and also observe the current wave form is getting non-linear so need a power factor correction for getting a linear wave form.

CONCLUSION:

From the above experiment the following conclusions arrived at.

- The output voltage remains constant and ripple content will remain within tolerable limit.
- To get steady state condition after changing in load it will take some time.
- Using DSP as the controlling parameter response gets faster.
- The line and load regulation of this converter is good.
- It is quite cheaper than the isolated dc-dc boost converter.

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