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Speed Control of Induction Motor using AC-AC and DC-DC Buck-Boost

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Abstract: This paper compares a new type of AC-AC converter which can operate as traditional inverting buck-boost converter with DC-DC buck-boost converter. AC-AC converter generally consists of six bidirectional voltage blocking switches and six unidirectional current switches, thus its acts as AC-AC converter .Depending on the input inductor values the output voltage changes and thus acts as buck-boost .While DC-DC have only switch with less complications. Pulse width can be varied to make it work in either buck-boost mode. In this paper we compare output voltages of both the circuits. And this output voltage is given to induction motor to control its speed. Single phase induction motor are mainly used in applications as washing machine and vacuum cleaners, water pumps as well as many industrial applications. Induction motor is known for its constant speed maintenance but its disadvantage is controlling its speed. Generally to control its speed cyclo converters are used .Due to commutation problem and less immune to shoot through voltage problem. AC-AC buck-boost is designed with input inductor and two capacitors. This output voltage compared with DC-DC converter in Boost mode and graphs are plotted .Thus DC-DC converter has more output voltage and less switching complication unlike AC-AC converter and proved in experimental results as provided.

Keywords: *Induction motor, AC-AC, DC-DC, Openloop, Buck-Boost converter*

1. INTRODUCTION

Generally induction motor are widely used in many applications. Single phase induction motors are used extensively for smaller loads such as house hold appliances like fans, ac, refrigerator and blowers, tool drives, pump drives and even in many industrial applications. Common methods to control single phase induction motor is v/ f control or frequency control. Changing the number of stator poles. Controlling supply voltage. Adding rheostat in the stator circuit. With invention of power electronics thyristors has become widely used to control speed of induction motor with high efficiency. Cyclo-converters are traditionally used for speed control. This purposed AC-AC converter has less commutation problem and reliability compared to cyclo converters so speed control of induction motor is done using.

This AC-AC converter. And even DC-DC converter is used to control the speed of induction motor by inverting the output of circuit .In industries AC-AC power converters are generally uses thyristors for power controlling to get desired output voltage .However the main disadvantage is its low power factor and harmonic distortions and low efficiency. For AC-AC conversions with different frequencies and voltages, the use of indirect ac–ac converters with dc-link and matrix converters have been advanced because they can obtain higher power factor and efficiency, and smaller filter requirements. For applications in which only voltage regulation is needed, the direct pulse width modulation (PWM) AC–AC converters are more preferred because they can reduce the size and cost of converter. All of these direct PWM ac–ac converters in are obtained from their dc–dc counterparts, where all the unidirectional switches are replaced with bidirectional devices. However, each topology has its own limitations. The buck-boost topology can do step up and step down voltages with reversed phase angle .More over this both topologies have disadvantages high voltages stress across switches there are discontinuous input and output currents in case of buck-boost converters.

All of the direct PWM AC–AC converters have a common commutation problem, which occurs because compared to the ideal situation in which the complementary switches do not have any overlap or dead-time; however, practically there exists a small overlap or dead-time owing to different time delays of gating signals and limited speed of switching devices. During the overlap time between complementary switches, either a short-circuit of voltage source (or capacitor) occurs or two capacitors with different voltages become in parallel to each other both of which results in current spikes which may damage the switching devices. During the dead time, there is no current path for the flow of inductor current or two inductors become in series resulting in voltage spikes which may also damage the switching devices. To solve this commutation problem, the PWM dead-times are intentionally added in switching signals to avoid overlap time, and then bulky and lossy *RC* snubbers are used to protect switching devices from voltage spikes or dedicated Safe-commutation strategies are implemented To provide continuous inductor current path during dead-time. These PWM dead-times not only reduce the quality of output Voltage, but also limit the maximum obtainable voltage gain and switching frequency .In switching cell structure and coupled inductors are used to solve commutation problem in conventional buck, boost and buck–boost converters.

These direct PWM ac–ac converters typically employed IGBTs, and therefore, cannot obtain benefits of using MOSFETs (such as low switching loss, resistive conduction voltage drop, and fast switching speed, etc.) because of following reasons; They are hard-switched ac–ac converter, and the body diodes of bidirectional switches also conduct same amount of current as the active switches. Therefore, the poor reverse recovery problem of MOSFETs body diodes prevents their use in these hard-switched ac–ac converters.

To overcome the drawbacks of existing PWM AC-AC converters, a direct AC-AC converter is proposed with inverting buck-boost mode. The purposed converter uses the same number of passive components has single non-inverting buck or boost converter. The proposed converter is immune from shoot-through of voltage source (or capacitors) even when all switches are turned on simultaneously, which enhances its reliability and it does not need PWM dead time which results in high-quality output voltage. Even though it uses six unidirectional current conducting bidirectional voltage blocking switches, only two of them are switched at high frequency in each half-cycle during any operating mode, resulting in smaller switching losses. In the proposed converter, no current flows through body diodes of switches, and therefore, it uses power MOSFETs with fast recovery diodes in series, which decreases switching losses and poor reverse recovery problem of MOSFETs body diodes is also avoided. The noninverting buck–boost modes of proposed converter are suitable for applications with both step-up and step-down demand while the inverting buck–boost mode can also be utilized in DVR application to compensate both voltage sags and swells.

2. BUCK-BOOST AC-AC CONVERTER

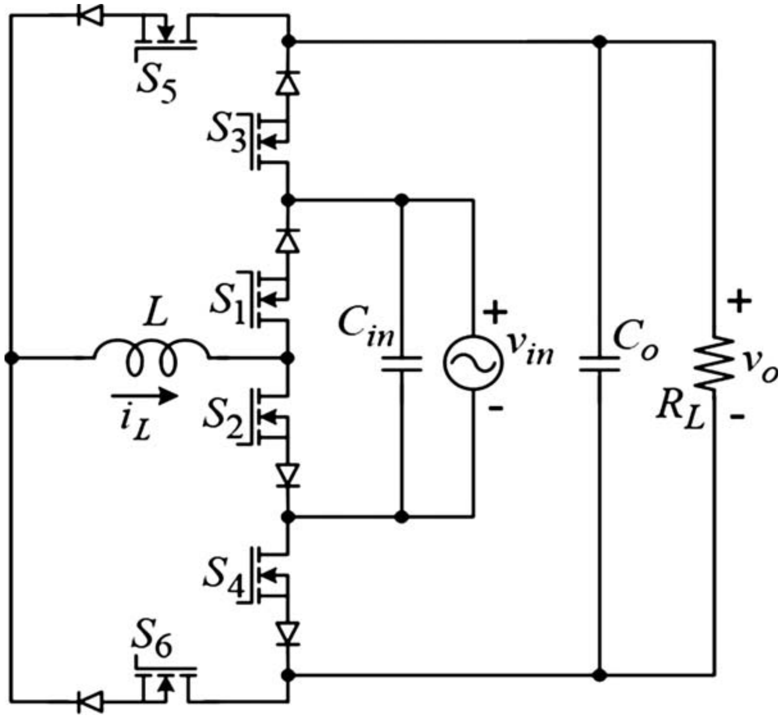

Figure 1: Circuit topology of AC-AC converter

Fig. 1 shows the circuit topology of the proposed ac–ac converter with six unidirectional current and bidirectional voltage blocking switches S1 − S6 , one inductor L, and two input and output filter capacitors Cin and Co. The six unidirectional current switches can be realized by series combination of power MOSFETs with external recovery diodes, as shown in Fig.1 In this figure, body diodes of MOSFETs are not shown as they never conduct, and thus, their reverse recovery problem is completely removed. For high power applications, it can either use six reverse blocking IGBTs (RB-IGBTs) or six IGBTs (without body diode) with external fast recovery diodes in series. The proposed converter can operate as traditional noninverting buck and boost converters with voltage gain of D and 1/ (1 − D), respectively. By using six switches, it can combine the functionality of eight switches noninverting buck–boost converter shown in Fig. 2(*a*), and four switches inverting buck–boost converter shown in Fig. 1(*c*). Therefore, it can be used as noninverting buck–boost converter to replace the traditional inverting buck–boost converter in various AC-AC conversion applications.

2.1. Commutation study of purposed converter and inverting buck-boost mode operations

There are three flow paths in circuit which causes short circuit of input voltage output voltage and direct parallel connection of both of them All of the other possible closed paths for the flow of current, when all gating signals are high, contain the inductor L in series which avoids the current overshoot. This immunity from shoot-through problem increases the reliability of the proposed converter as it has no commutation problem, and also the PWM dead-times in gating

Signals are not needed, which increase quality of output voltage. The switching sequence of the proposed converter during inverting buck–boost mode operation and key waveforms are shown in Fig. 11. For

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vin > 0, switches S_2 , S_4 , S_5 are always turn on and S_1 , S6are always turn off, while switch S_3 is switched at high frequency. Fig. 12 shows the equivalent circuits of the proposed converter for vin > 0. The circuit shown in Fig. 12(*a*) is during DT interval in which switch S3 is turned on and the input energy is stored in inductor L. The switch S_4 is also turned on; however, its external series diode becomes reverse biased because of inverse voltage ($v_{in} + v_o$) across it. Therefore, no current flows through switch S4 during this interval, as shown in Fig. 12(*a*). Applying KVL, we get $v_L = v_{in}$. (7) During (1 − D)T interval as shown in Fig. 12(*b*), switch S3 is turned off while S4 conducts in this interval as its series diode becomes forward biased due to the action of free-wheeling inductor current(L). Energy stored in this inductor is released to load in this interval. Applying KVL yields $v_L = - v_o$.

For vin < 0, switches S_1 , S_3 , S_6 are always turn on while switches S_2, S_5 are always turn off, and S_4 becomes high frequency switch. The operation for $v_{in} < 0$ is the same as explained for $v_{in} > 0$, with only difference is that now the switch S_4 acts the same as S_3 (for $v_{in} > 0$), and vice versa. The equivalent circuits during this half-cycle are shown in Fig. 13(*a*) and (*b*). By applying volt–second balance condition on inductor L from (7) and (8), the gain in this buck–boost mode is given by From (9), it can be concluded that the voltage gain of the proposed ac–ac converter in this operation mode is the same as that of inverting buck–boost ac–ac converter.

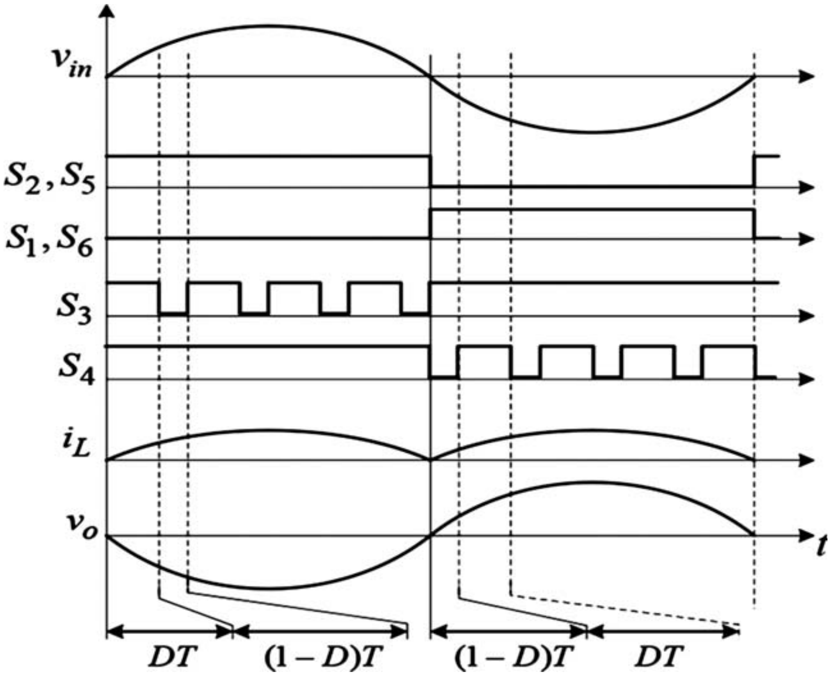

Figure 2: Key operational waveforms during inverting buck–boost mode

Simulation for Buck-boost is shown in Fig : 2 and output waveform for respective switches are shown in figures (3,4,5,6,7) with given input voltage as $V_{in} = 50$, L = 4*e*-3 and output voltage as $V_o = 187.1$. This open loop operation can be performed with different input voltages and respective output voltages are noted. By varying inductor value different modes of operations are seen.

Drawback: The outputs voltages are less compare to DC-DC and there are some disadvantages of higher voltage stress across the switches, discontinuous input output current from the simulation there are some ripples in the output sine wave and also it is difficult to design feedback for this converter as all the switches need to control to maintain controlled output voltage.

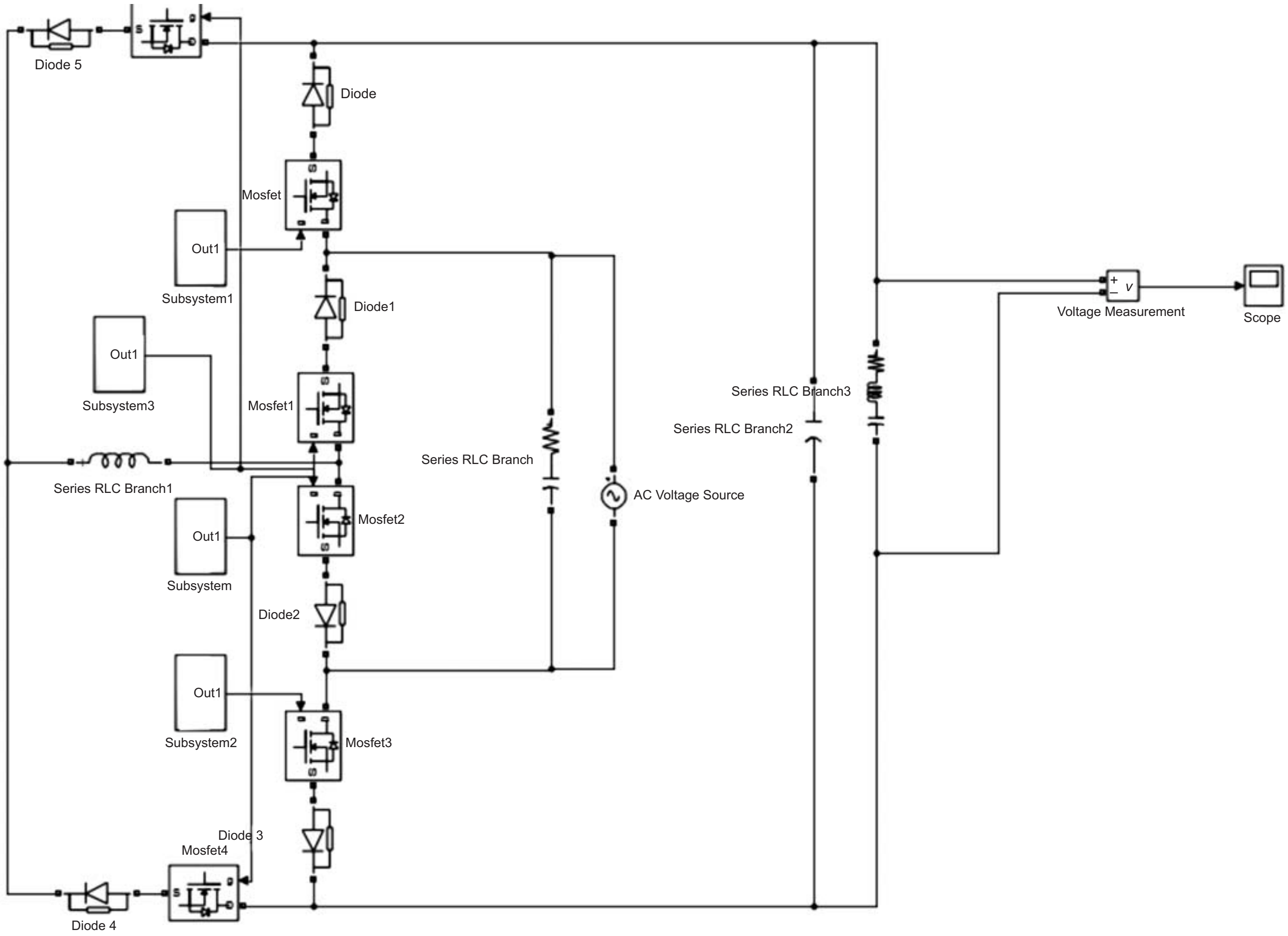

Figure 3: Simulation for AC-AC Buck-Boost converters

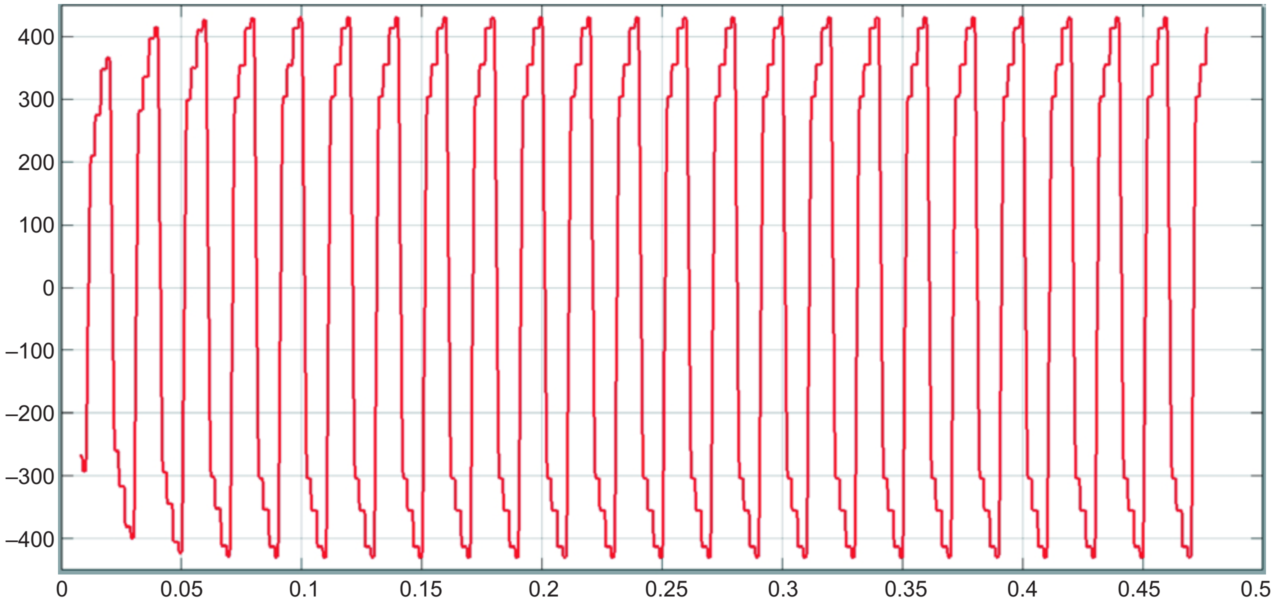

Figure 4: Final output for AC-AC circuit

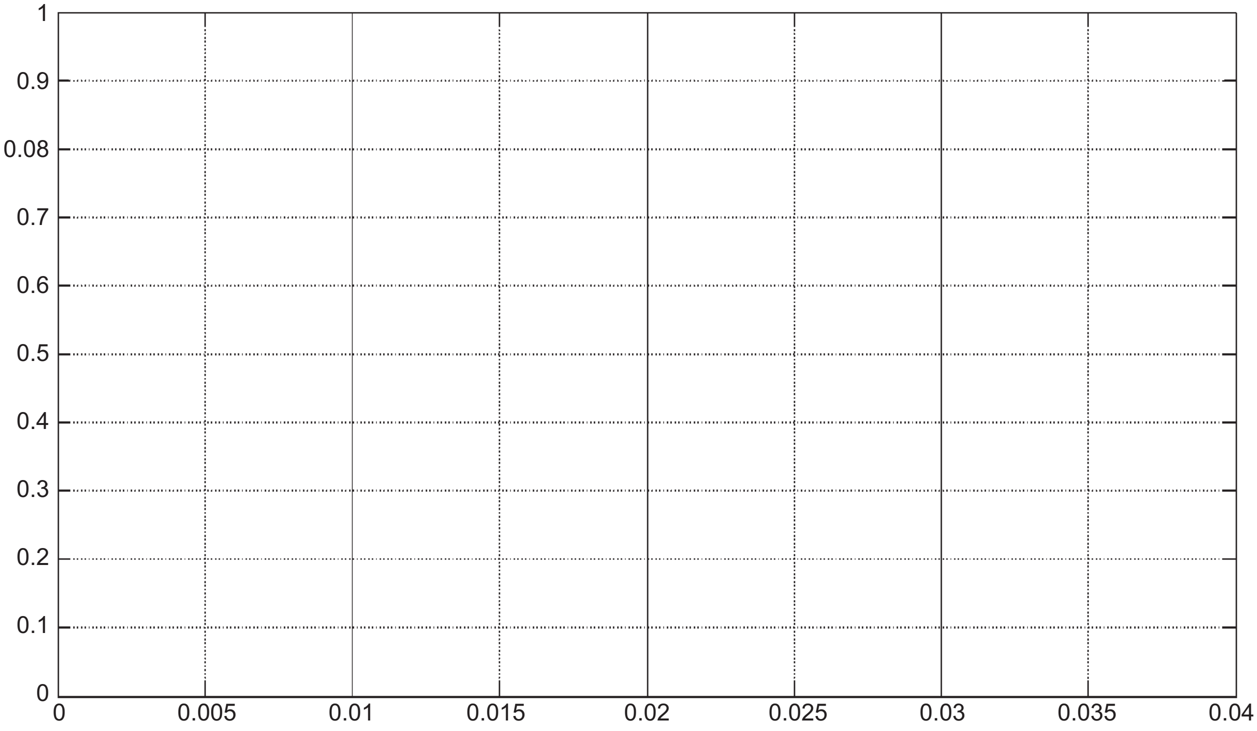

Figure 5: Trigger pulses for *s*2, *s*5 switches

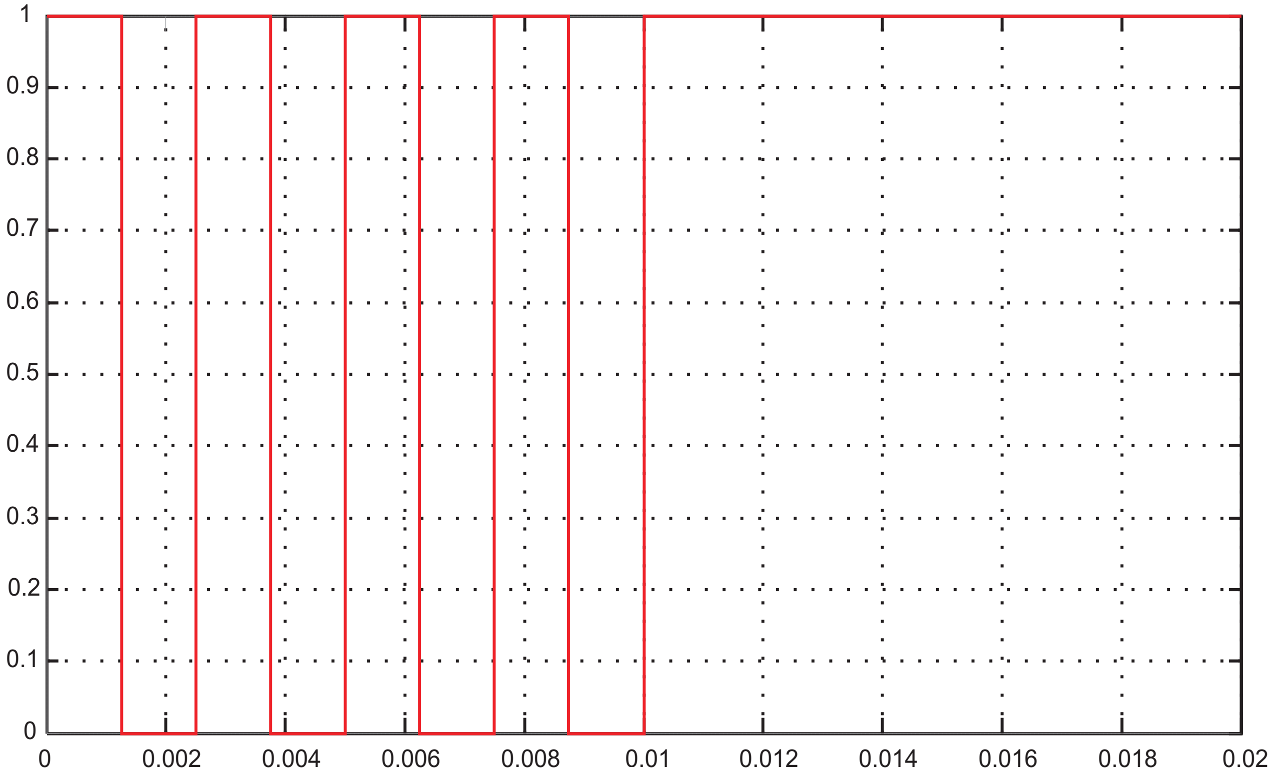

Figure 6: Trigger pulses for *s*3 switch

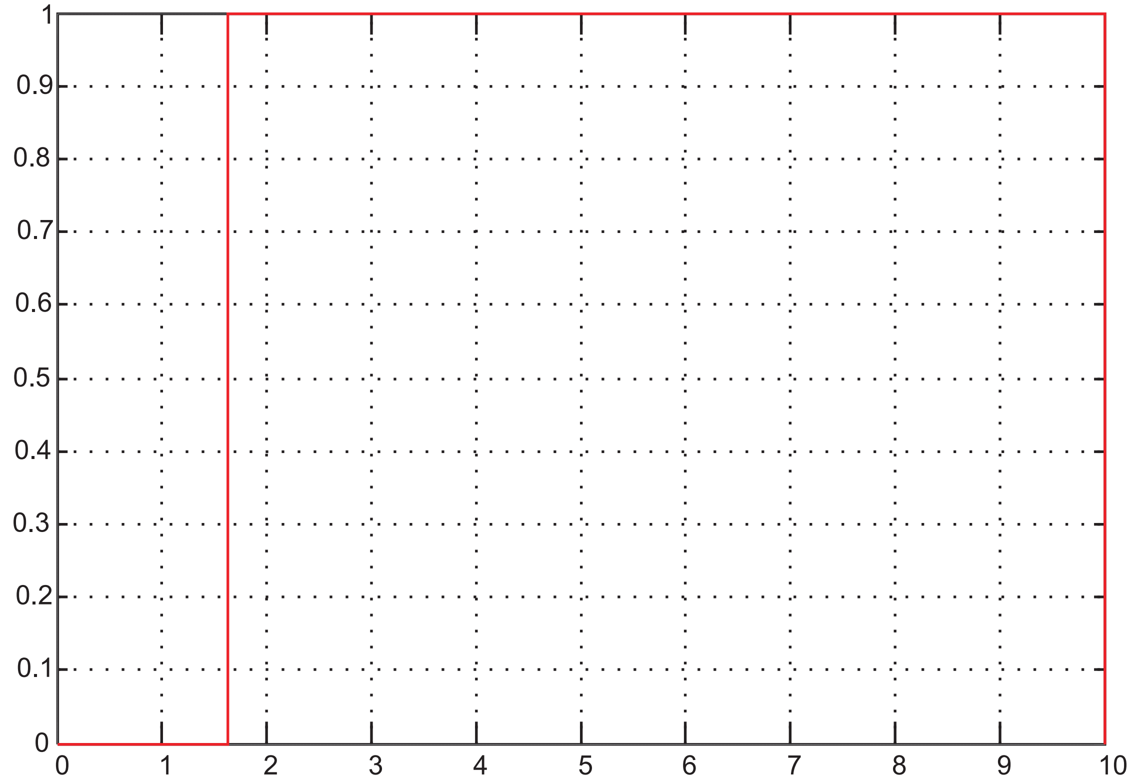

Figure 7: Trigger pulses for $s1$, $s6$ switches

Table 1
Electrical Specifications of the Proposed ac–ac Converter

S.No.	*Specifications*	*Values*
1.	Output voltage	187.1v
2.	MOSFET (S1 −S6)	47N60CFD
3.	Diode (D1 − D6)	RHRG3060
4.	Inductance	4*e*-3
5.	Input capacitor(Cin)	1.5*e*-6
6.	output capacitor(Co)	4.5*e*-6

Table 2
Plot for o/p voltage with L = 4*e*-3

V_{in}	V_o
50	187.1
100	401.7
150	616.3
180	745.1
200	830.9
220	916.8

3. BUCK-BOOST DC-DC CONVERTER

The main application of step up and step down (Buck-Boost) is regulated DC supply. The cascade connection both step up and step down is combine in this converter. When the switch is close the input provides energy to the inductor and diode act as reverse bias. When the switch is open, the energy which is stored in inductor is transferred to the output. No energy is supplied by the input in this interval. In the study state analysis the output capacitor is assumed to be high which results constant output voltage.

Table 3
Electrical Specifications of the Proposed DC-DC Converter

S. No.	*Specifications*	*Values*
1.	Output voltage	722.6v
2.	Diode	RHRG3060
3.	Switch	47N60CFD
4.	Capacitor	47*e*-6
5.	Inductor	1*e*-3
6.	Input voltage	150*v*

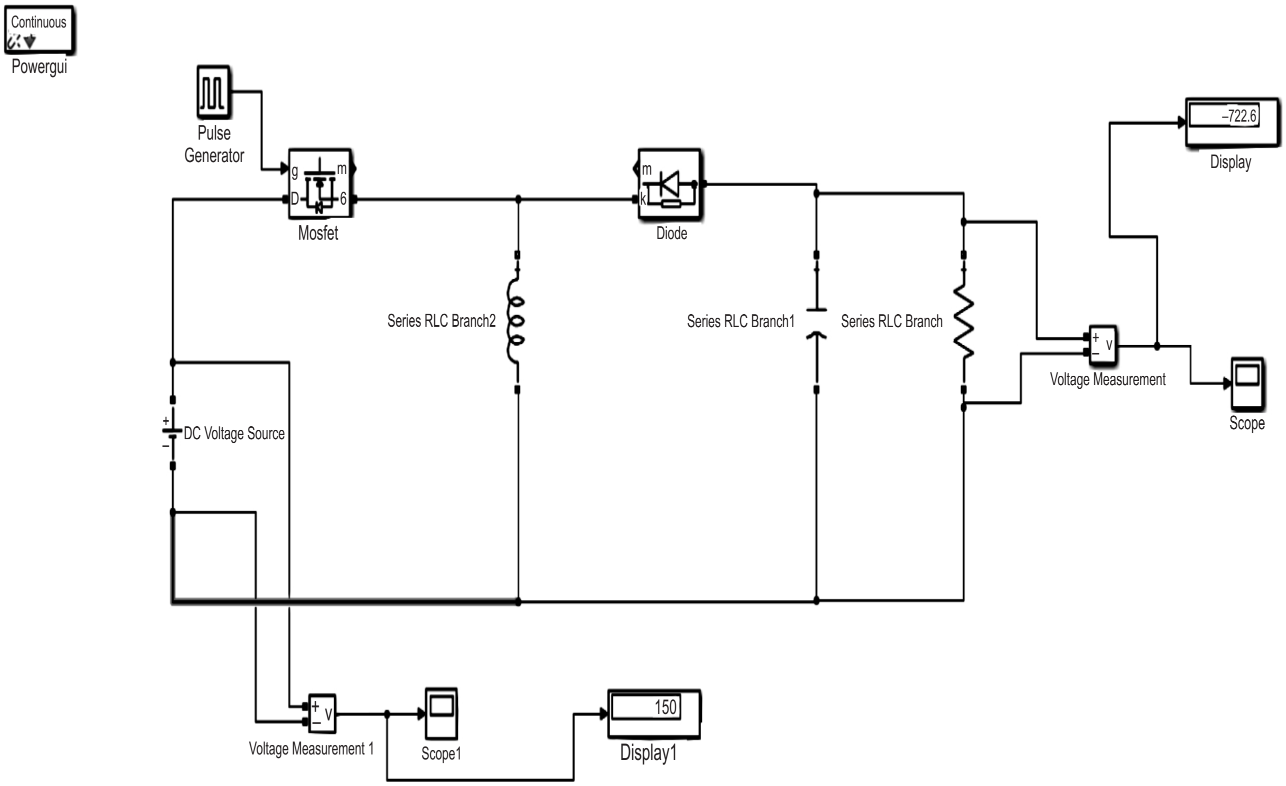

Figure 8: DC-DC Buck-Boost convereter

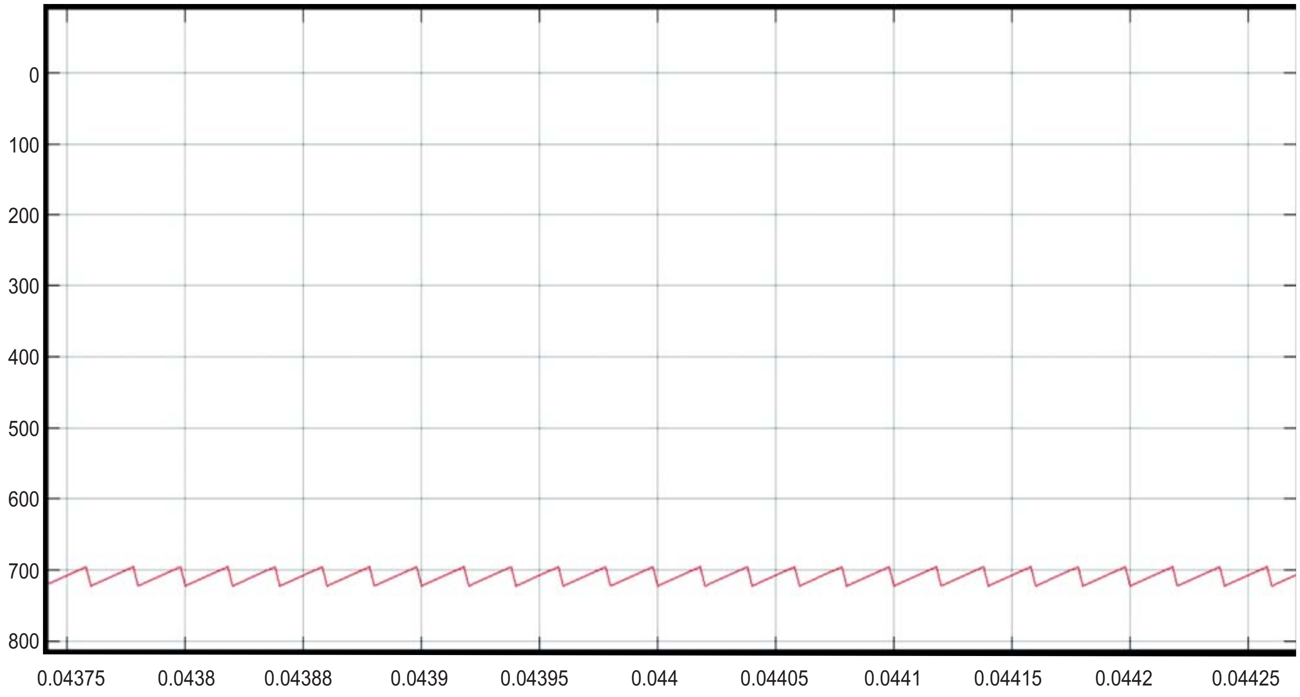

Figure 9: Output for DC-DC Circuit

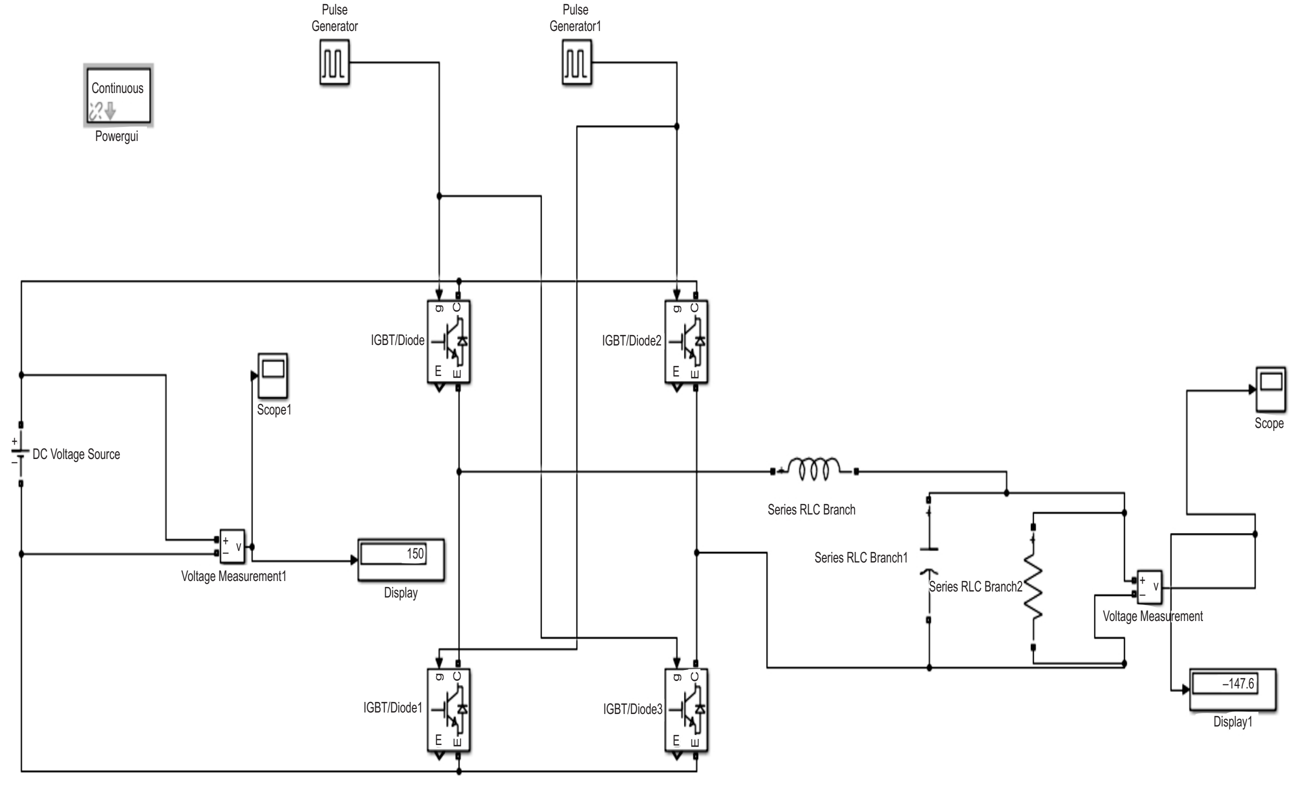

Figure 10: Inverter circuit For DC TO AC

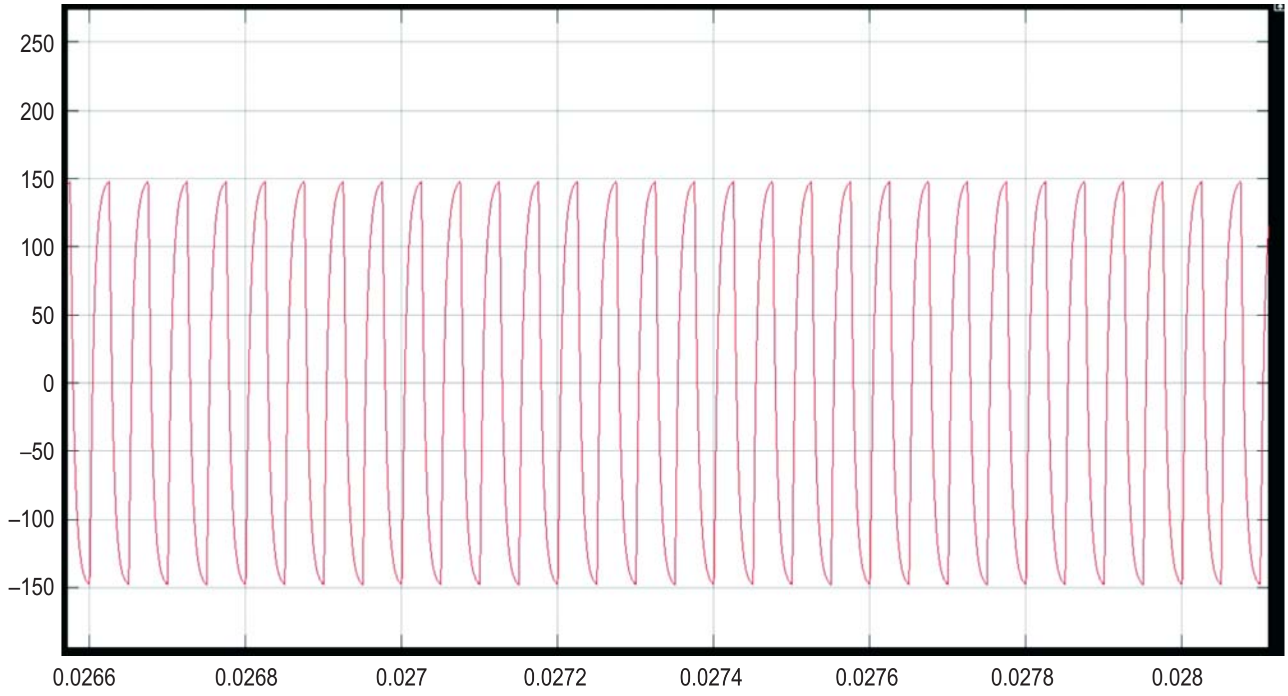

Figure 11: Output of inverter circuit

Table 3
DC-DC Output Voltage For 90 Pulse Width

V_{in}	V_o
50	240.6
100	481.6
150	722.6
200	936.6
220	1060

As DC-DC buck-boost converter has one switch with less switching stress is easy to control and maintain closed loop the respective output voltage as shown in the table (III).Dc output source can be inverted using inverter circuit as shown in fig 10 with less voltage loss thus for 150v input in boost mode operation after inversion 720v will be the output voltage from this conclusion we state that output voltage is more compared with AC-AC converter.

4. COMPARISON OF AC-AC AND DC-DC

Thus from the simulation outputs and graphs we can conclude that DC-DC converter has constant duty cycle with respect to gain compared to AC-AC converter and it is even possible to design feedback in DC-DC converter unlike AC-AC.

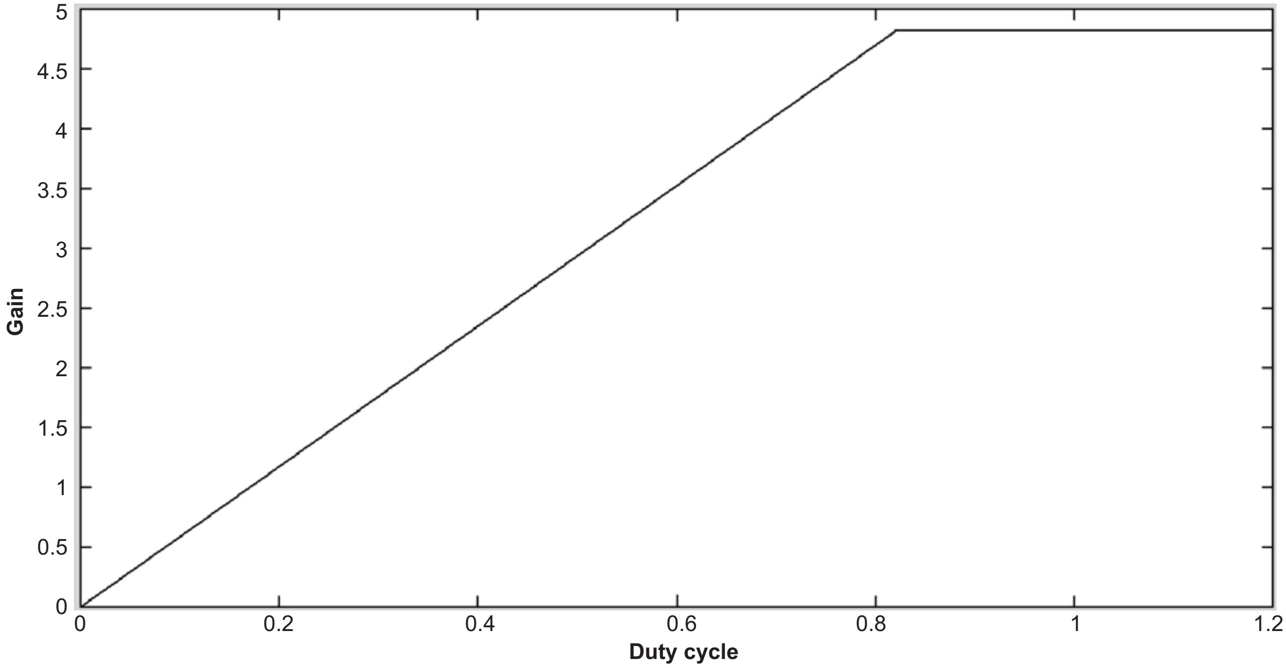

Figure 12: DC-DC Gain v/s Duty cycle

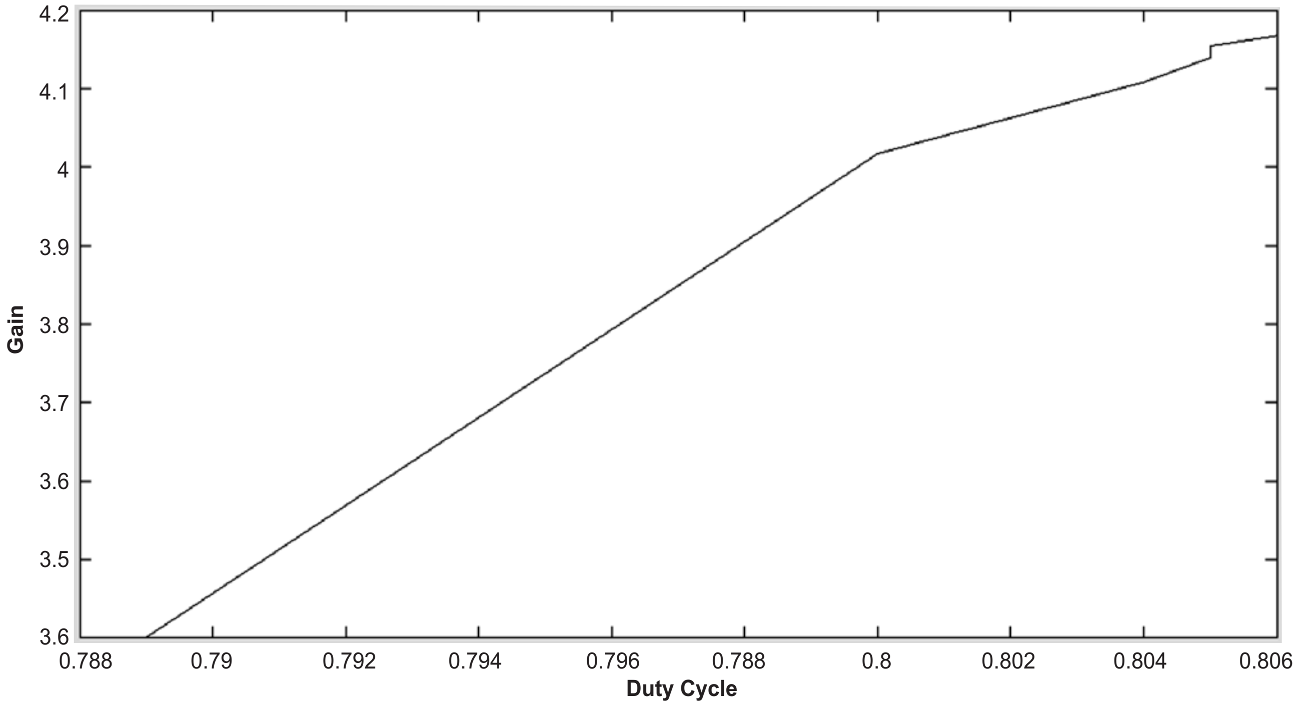

Figure 13: AC-AC Gain v/s Duty cycle

In AC-AC converter there are six switches that are need to be controlled to make feedback and even voltage stress across switches is higher. Because of this reasons we go for DC-DC converter with inverting output that gives accuracy compared with AC-AC converter.

5. CONCLUSION

In this paper, thus it is shown that DC-DC has slightly more output voltage i.e inverted with more efficiency and output is fed to induction motor to control the speed in open loop system while in AC-AC due to some voltage stress across switches and also difficulty in designing closed loop path we go for DC-DC converter. Output voltage in AC-AC converter is less than DC-DC converter which is seen from the table II and table 3 .

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