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The Design and Implementation of Single Stage Zero Voltage Switching Converter with Boost Type Active Clamp

Md. Firoz Alam[1], Prof. Prabodh Khampariya[2]

[1]Research Scholar, Department of E&ESoE, SSSUTMS, Sehore (India)

[2]Assistant Professor, Department of E&ESoE, SSSUTMS, Sehore (India)

ABSTRACT

An ac to dc converter is an integral part of any power supply unit used in electronic equipment which from a major part of load on the utility. Generally, to convert line frequency ac to dc, a line frequency diode bridge rectifier is used. The efficiency of these converters can be improved by reducing the losses using soft switching techniques such as Zero Voltage Switching "ZVS", Zero Voltage Transition "ZVT" and Zero Current Switching "ZCS". The present work intends to study circuit techniques to improve the efficiency of the PFC stage by lowering the conduction losses and/or the switching losses. Operation of a ZVT converter has been discussed, in which the switching losses are minimized by using an additional auxiliary circuit incorporated in the conventional PWM boost converter. Finally, ZVT technique has been implemented in a single-phase active power factor correction circuit based on an ac-dc boost converter topology and operating in a continuous inductor current mode with peak current control method. A 160 W, 90 kHz ZVT PWM boost PFC converter has been simulated and simulation results are validated with reference results.

Keywords:- Alternating current, Direct current, Power system, Power voltage.

INTRODUCTION

In recent years, there has been growing interest in power electronics systems one reason for this is the increasing utilization of electrical and electronics equipment, not only for industrial, but also for commercial and residential applications. Another reason is interest in improving the system efficiency, besides the expansion of the application of renewable energies. This growing demand has favored the development of new power electronics devices, as well as novel power converter topologies, some of the areas where power electronics used:

1. GENERATION (Thermal, hydro, Nuclear, wind, solar and other)
2. INDUSTRIAL
3. DOMESTIC
4. TRANSPORT

Power electronics application broadly includes converters', inverters, choppers etc. The AC to DC converter (rectifier) is one of the most popular power electronics devices which are an efficient and convenient source of DC power [1].

A great portion of electrical and electronic devices currently in use is designed to operate using direct current (DC) power while, for reasons of distribution efficiency, most power is ultimately delivered to such devices as alternating current (AC) power. Therefore, the AC-DC front-end converter is needed to converter the AC power to the DC power in many electrical and electronic devices. Two-stage approach is widely used in the AC-DC front-end converters for high power application. Because of its continuous input current and simplicity, Continuous Conduction Mode (CCM) boost topology is the most popular for the power factor correction (PFC) stage [2].

II BUCK–BOOST CONVERTER

A non-isolated (transformer less) topology of the buck–boost converter is shown in Fig. 2.1 a. The converter consists of dc input voltage source V_S , controlled switch S, inductor L, diode D, filter capacitor C, and load resistance R. With the switch on, the inductor current increases while the diode is maintained off.

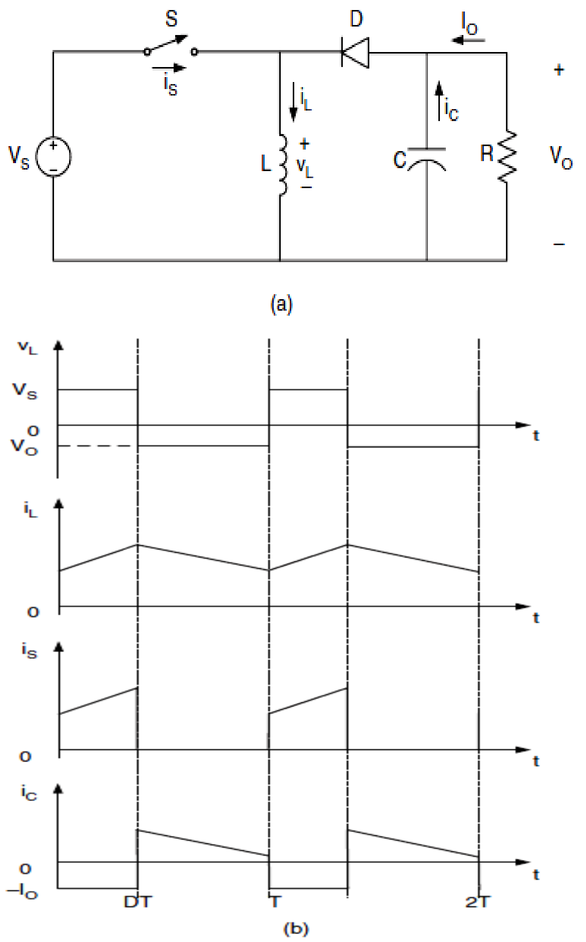

Figure 2.1: Buck-boost converter (a) circuit diagram (b) waveforms.

When the switch is turned off, the diode provides a path for the inductor current. Note the polarity of the diode which results in its current being drawn from the output. The buck–boost converter waveforms are depicted in Fig. 3.10b. The condition of a zero volt–second product for the inductor in steady state yields

$$V_S DT = -V_O(1-D)T$$

Eq 2.1

Hence, the dc voltage transfer function of the buck–boost converter is

$$M_V \equiv \frac{V_O}{V_S} = -\frac{D}{1-D}$$

Eq 2.2

The output voltage VO is negative with respect to the ground. Its magnitude can be either greater or smaller (equal at D = 0.5) than the input voltage as the converter's name implies. The value of the inductor that determines the boundary between the CCM and DCM is

$$L_b = \frac{(1-D)^2 R}{2f}$$

Eq 2.3

The structure of the output part of the converter is similar to that of the boost converter (reversed polarities being the only difference). Thus, the value of the filter capacitor can be obtained from Eq..

2.2 Flyback Converter

A PWM flyback converter is a very practical isolated version of the buck–boost converter. The circuit of the flyback converter is presented in Fig. 2.2The inductor of the buck–boost converter has been replaced by a flyback transformer. The input dc source VS and switch S are connected in series with the primary transformer. The diode D and the RC output circuit are connected in series with the secondary of the flyback transformer. Figure 3.11b shows the converter with a simple flyback transformer model. The model includes a magnetizing inductance Lm and an ideal transformer with a turns ratio n = N1/N2. The flyback transformer leakage inductances and losses are neglected in the model. It should be noted that leakage inductances, although not important from the principle of operation point of view, affect adversely switch and diode transitions. Snubbers are usually required in flyback converters. Refer to Fig. 3.11b for the converter operation. When the switch S is on, the current in the magnetizing inductance increases linearly. The diode D is off and there is no current in the ideal transformer windings. When the switch is turned off, the magnetizing inductance current is diverted into the ideal transformer, the diode turns on, and the transformed magnetizing inductance current is supplied to the RC load. The dc voltage transfer function of the flyback converter is

$$M_V \equiv \frac{V_O}{V_S} = \frac{D}{n(1-D)}$$

Eq 3.19

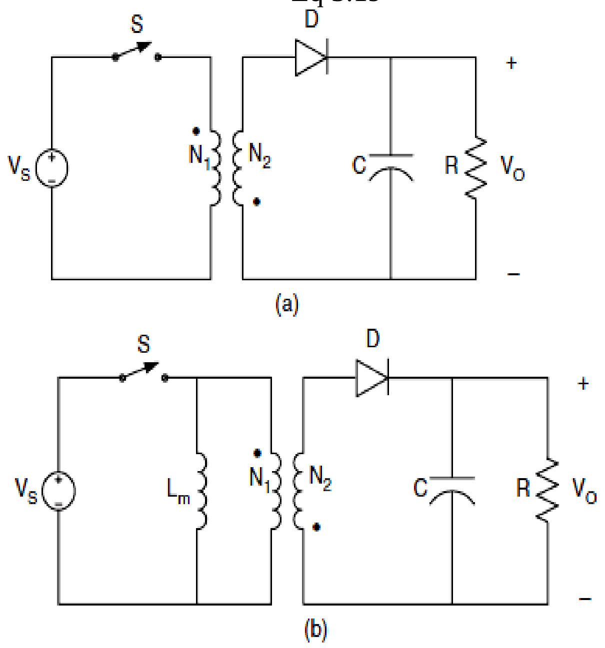

Figure 2.2: Flyback converter (a) circuit diagram (b) circuit with a transformer model showing the magnetising inductance L_m.

2.3 CCM Shaping Technique

Like other power electronic apparatus, the core of a PFC unit is its converter, which can operate either in DCM or in CCM. As shall be discussed in the next section, the benefit from DCM technique is that low-cost power supply can be achieved because of its simplified control circuit. However, the peak input current of a DCM converter is at least twice as high as its corresponding average input current, which causes higher current stresses on switches than that in a CCM converter, resulting in intolerable conduction and switching losses as well as transformer copper losses in high power applications. In practice, DCM technique is only suitable for low to medium level power application, whereas, CCM is used in high power cases. However, a converter operating in CCM does not have PFC ability inherently, i.e. unless a certain control strategy is applied, the input current will not follow the waveform of line voltage. This is why most of the research activities in improving PF under CCM condition have been focused on developing new current shaping control strategies. Depending on the system variable being controlled (either current or voltage), PFC control techniques may be classified as current control and voltage control. Current control is the most common control strategy since the primary objective of PFC is to force the input current to trace the shape of line voltage. To achieve both PFC and output voltage regulation by using a converter operating in CCM, multi-loop controls are generally used. Figure 2.3 shows the block diagram of ac–dc PFC.

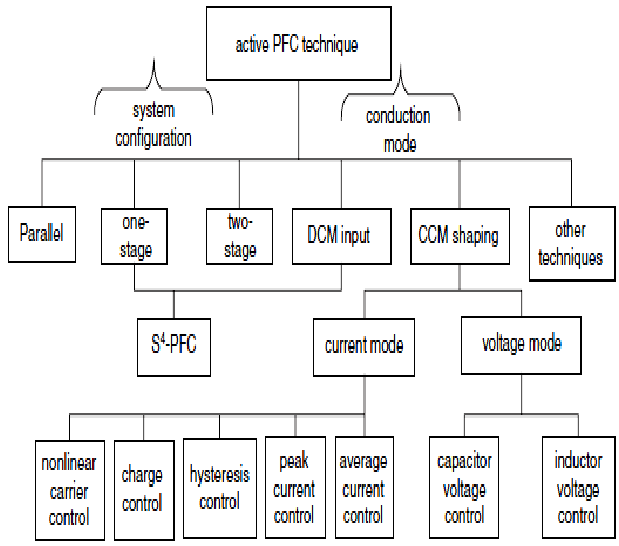

Figure 2.3: Overview of PFC techniques.

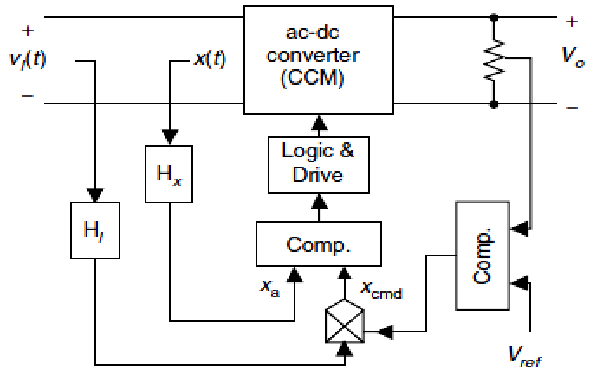

Figure 2.4: Block diagram of PFC converter with CCM shaping technique.

For a converter with CCM shaping technique, where, Hl is a line voltage compensator, Hxis a controlled variable compensator, and x(t) is the control variable that can be either current or voltage. Normally, in order to obtain a sinusoidal line current and a constant dc output voltage, line voltage vl(t), output voltage Vo, and a controlled variable x(t) need to be sensed. Depending on whether the controlled variable x(t) is a current (usually the line current or the switch current) or a voltage (related to the line current), the control technique is called "current mode control" or "voltage mode control," respectively. In Fig. 4.14, two control loops have been applied: the feed forward loop and the feedback loops. The feed forward loop is also called "inner loop" which keeps the line current to follow the line voltage in shape and phase, while the feedback loop (also called "outer loop") keeps the output voltage to be tightly controlled. These two loops share the same control command generated by the product of output voltage error signal and the line voltage (or rectified line voltage) signal.

III MODELING OF ZVS BOOST CONVETER

A high-efficiency single-stage soft-switching converter for universal line voltage applications with a boost type of active-clamp circuit used to achieve ZVS operation of the power switches. The topology for the above mentioned boost type ac-dc converter is sh own in figure 3.1 below.

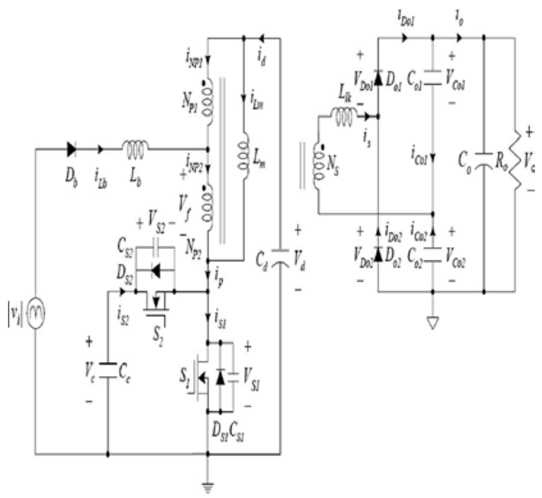

Figure 3.1: Circuit diagram of proposed single stage soft switching converter.

3.1 ZVS Boost converter model

An integration of above listed components is expressed in the complete schematic of ZVS single stage boost type Active clamp circuit shown below in Figure 3.1.

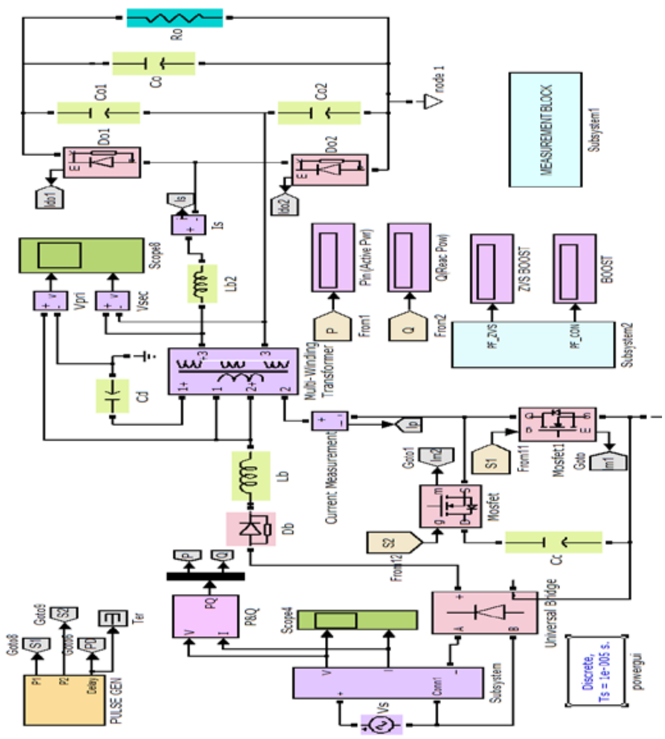

Figure 3.2: Proposed ZVS single stage Boost converter.

3.2 Simulation Configuration Used

The simulation model used is circuit model is simulated in Simulink using "ODE 45" in discrete simulation mode with a sampling period of 10 µsec and variable step sizes for a duration of 0.8 sec.

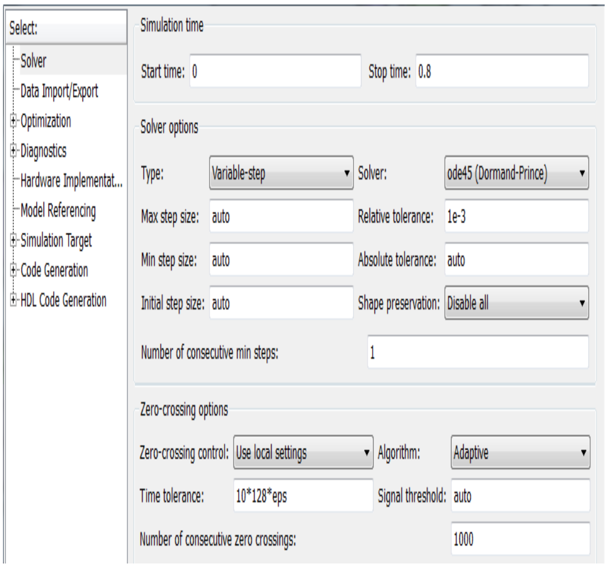

Figure 3.3: Configuration settings used.

The modeling of the boost type converter discussed in this section was done based on the proposals of Choi et al [11]. The proposed converter circuitry is modeled in MatlabV-7.12, with configuration parameters shown above in Figure 3.2.

IV RESULTS AND DISCUSSION

The simulation model prepared in the previous unit for a single stage zero voltage switching boost type active clamp circuitry was simulated using simulink. The The results obtained are validated with reference to the selected reference Choi et al [11] and are presented in the current section along with a discussion and analysis for the obtained waveforms. The Converter model developed is simulated for an input voltage of 230 Vrms. The simulation result waveforms obtained are summarized.

4.1 Switch Voltage and Boost Inductor Current

The voltage appearing across the switching devices of active clamp circuitry and the boost inductor current are shown in figure below

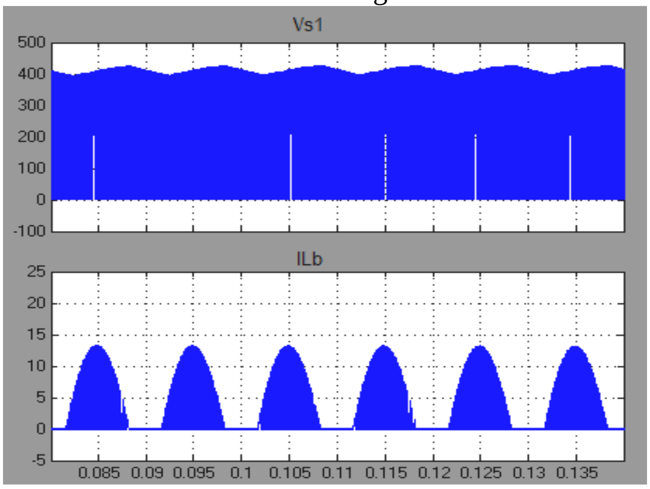

Figure 4.1: Active clamp Switch Voltage and Boost Inductor Current.

4.2 Switch Voltage and Transformer Primary Current

The voltage appearing across the switching devices of active clamp circuitry and the transformer primary current are as shown in figure (a) and (b)

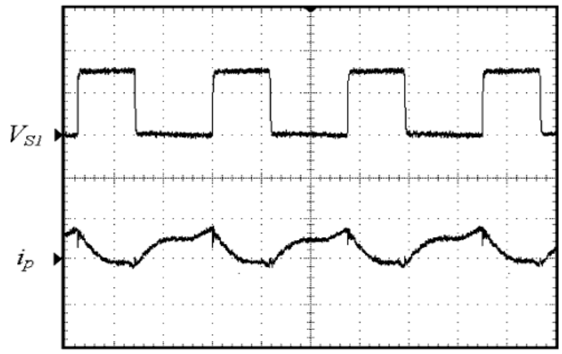

Figure 4.2: Switch Voltage & Transformer Primary Current (a) Reference (b) Simulation Results.

4.3 Active Clamp Voltage and Current

The active clamped voltage and current shown in below for switch S_1, S_2. The Voltage appear across

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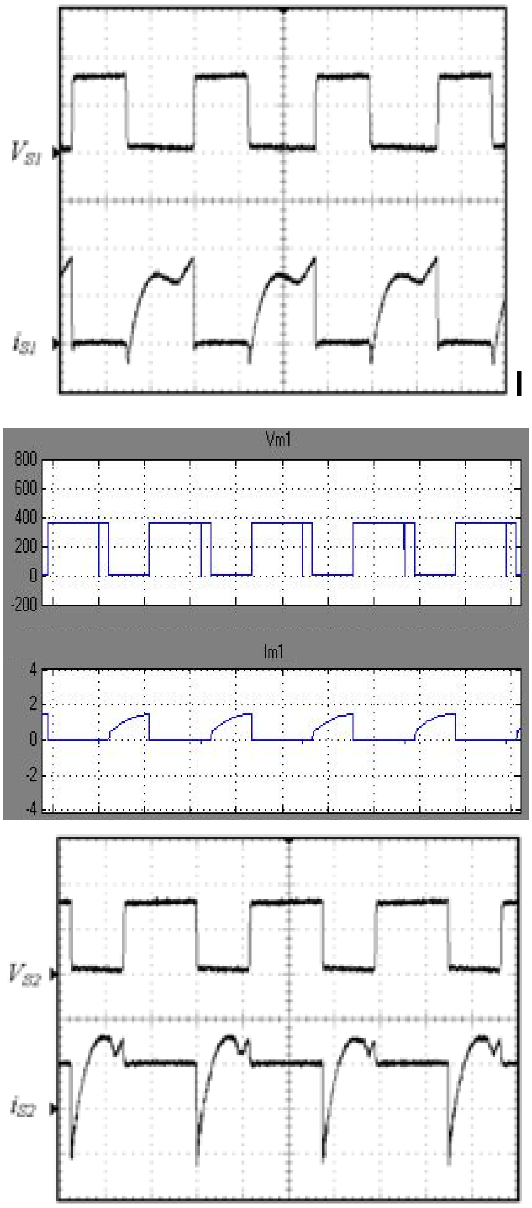
Switch S_1, S_2 and Current Flowing trough it is shown in below waveform

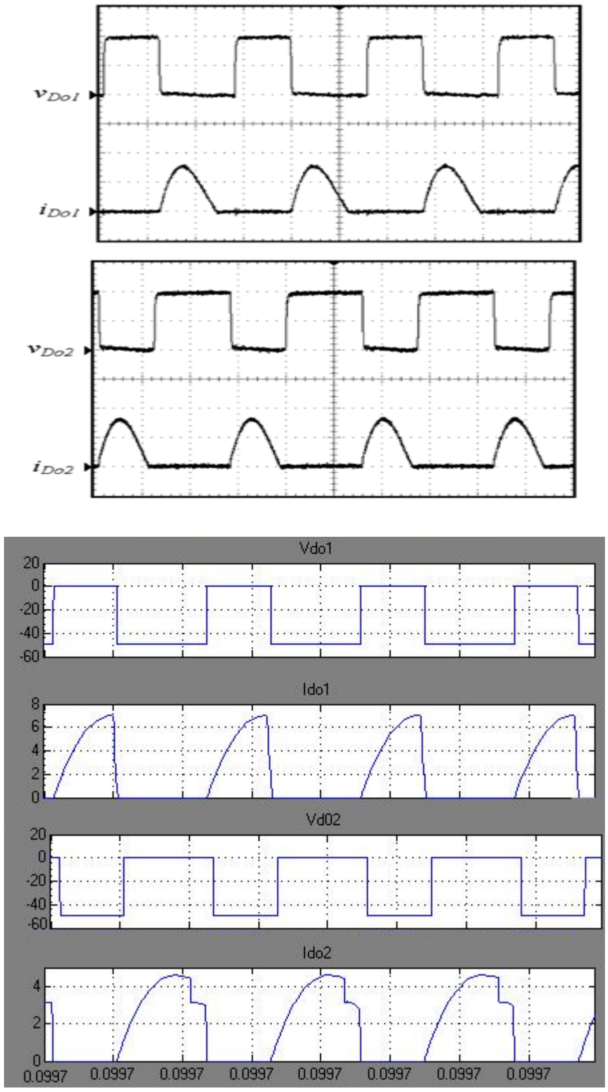


(a) Reference (b) Obtained results

Figure 4.3: Active clamp voltage and current switch S_1 and S_2.

4.3 Voltage Doubler Rectifier Voltage

Voltage Doubler Rectifier means it improve the quality of DC Output side voltage. The voltage appears across Diode D1, D2 and current flowing through it shown in below

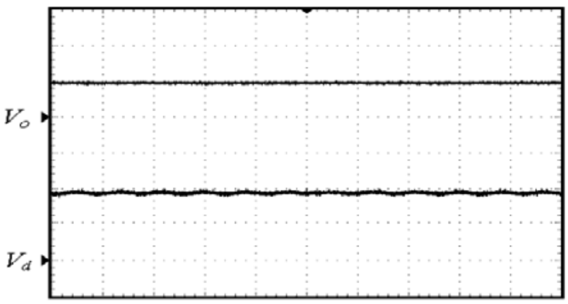


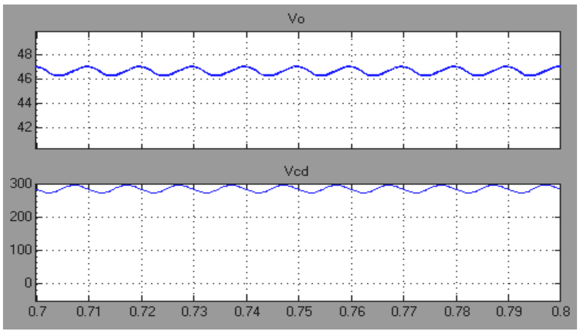
(a) Reference results (b) Obtained results

Figure 4.4: Voltage Doubler rectifier voltage and current Diode Do_1 and Do_2.

4.4 Output and DC Link Voltage

The Output voltage across the load terminal and DC link Voltage across the DC Link Capacitor is shown in below





(a) Reference results (b) Obtained results

Figure 4.5: Output voltage DC Link Capacitor Voltage.

4.5 Input Voltage & Current

The Input Voltage and Current from the AC source at 9000Hz frequency is shown in below. The Voltage waveform is pure sinusoidal and current is chopped in nature at 90K. As is evident the Current is in exact phase with the voltage wave.

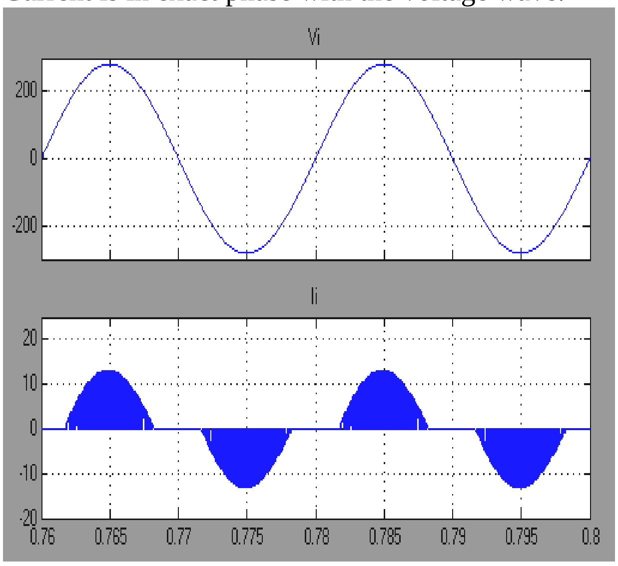
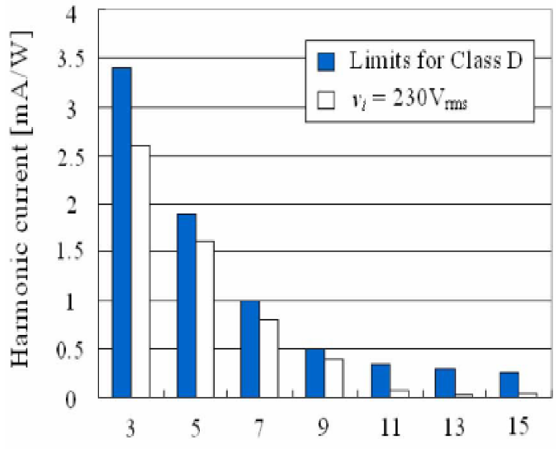
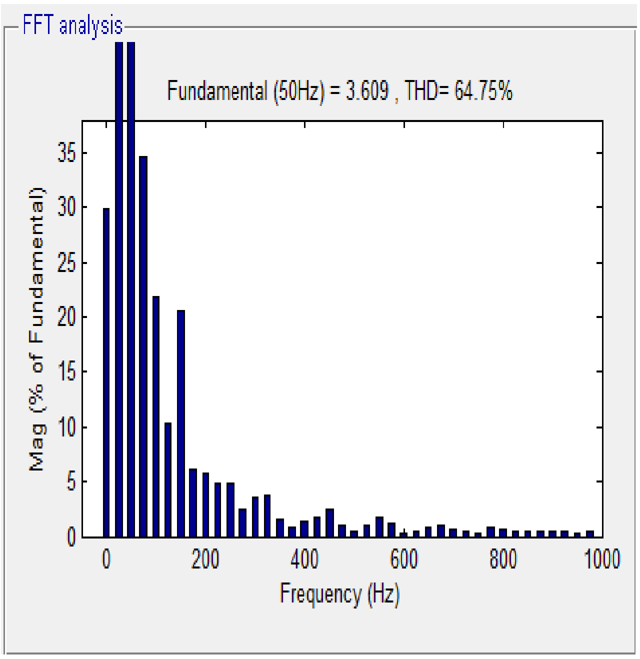


Figure 4.6: Input Voltage & Current.

The current waveform obtained from the simulation is compared for THD and the results are displayed below in Figure 4.6.





(a) Reference results (b) Obtained results

Figure 4.7: FFT Analysis of Supply Current.

V CONCLUSION

1. A simple and effective boost converter is proposed which has many advantages like: - power factor correction.

Less number of semiconductor devices are used.

2. Easy control techniques.

As the power factor plays very important role in power system so it is very necessary to improve power factor. By using this converter output power factor is corrected and thus harmonics are reduced.

VI FUTURE SCOPE

1. Hardware verification of simulated techniques can be implemented.
2. The work can be verified using Fuzzy-logic or using multilevel converters.

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