Single Phase Buck-Boost AC-AC Converter

A thesis Submitted to the Department of Electrical and Electronic Engineering in Partial Fulfillment of the Requirement for the Degree of

Master of Science in Engineering

By

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Abstract

AC voltage converters are widely used as one of the power electronics systems to control an output ac voltage, where a variable ac voltage is obtained from a fixed ac voltage, for power ranges from few watts up to fraction of megawatts. Phase angle control line commutated voltage controllers and integral cycle control of thyristors have been extensively employed in this type of regulators for many applications. Such techniques offer some advantages as simplicity and the ability of controlling large amount of power economically. However, they suffer from inherent disadvantages such as, retardation of the firing angle causes lagging power factor at the input side especially at large firing angles and high low order harmonic content in both of load and supply sides. Moreover a discontinuity of power flow appears at both input and output sides.

Solid-state switch based AC-AC PWM regulator similar to the DC-DC converters have been reported to alleviate the problems. They require a bi-directional freewheeling path across the load. As a result, only controlled freewheeling device could be used on the circuits. Also switches in the circuits require synchronized (current- sensed) switching to attain in phase input current to improve power factor.

In this thesis a single phase Buck-Boost AC-AC converter has been proposed where a single bi-directional switch has been used. We use the philosophy of half cycle to half cycle conversion individually and connecting the outputs to the load either in wired OR, or in differential mode. Such conversion has the advantage of input current being in phase with supply voltage without additional sensing and control circuits and the high frequency chopped input current can be made near sinusoidal with small input filter resulting in low input current THD and high power factor. The conversion is achieved by Buck-Boost conversion of each half cycle. Hence the AC-AC switch mode conversion proposed in this thesis provides step up/down output voltage. Also, such conversion is achieved with low input current THD, high input power factor, small input filter and high conversion efficiency.

Contents

List of Figures

List of Tables

CHAPTER-1

INTRODUCTION

1.1 Introduction

AC to AC voltage converters operate on the AC mains to regulate the output voltage. Part of the supply appears at the load while the semiconductor switches block the remaining portions. AC-AC phase-angle controlled or integral cycle controlled single and three phase voltage-controllers are widely used in low, medium and high power applications for controlling voltage across loads. The most common applications of voltage controllers are: industrial heating, on-load transformer connection changing, light controls, speed control of polyphase induction motors and ac magnet controls.

Conventional techniques have many drawbacks like the retardation of the firing angle causing lagging power factor at the input side, substantial low order harmonics in the supply voltages/currents and discontinuity of power flow to the load etc[1-3]. Solid-state switch based AC-AC PWM regulator similar to the DC-DC converters have been reported to alleviate the problems. They require a bi-directional freewheeling path across the load. As a result only controlled freewheeling device could be used on the reported circuits [4-20]. Also, switches in the circuits require synchronized (current-sensed) switching to attain in phase input current to improve power factor.

In this Thesis work a step-up/step-down AC-AC converter is reported which requires a single bi-directional switch and use the concept of Buck-Boost conversion. The conversion provides controllable step-down and step-up AC output maintaining low input current THD (Total harmonic distortion factor) and has high input power factor. The efficiency of the proposed AC-AC converter is variable with duty cycle of the control signal of the bi-directional switch. High efficiency is possible for a limited range of duty cycle.

1.2 Back ground and present state of the problem:

The ac voltage controller is used as one of the power electronic circuits to control an output ac voltage for power ranges from a few watts (as in light dimmers) up to fractions of megawatts (as in starting systems for large induction motors). Thyristor based On-off control and Phase-angle control have been traditionally used in these types of regulators. In on-off control, thyristor switches connect the load to the ac source for a few cycles of input voltage and then disconnect it for another few cycles. In phase control, thyristor switches connect the load to the ac source for a portion of each cycle of input voltage. The techniques offer advantages as simplicity and the ability of controlling a large amount of power economically [2] but is associated with problems like unregulated line voltages (in particular, long-term voltage sags) include equipment tripping, stalling, overheating, and complete process shut downs. These subsequently leads to lower efficiencies, higher power demand, higher cost for power, electromagnetic interference to control circuits, excessive heating of cables and equipment, and increased risk of equipment damage. The need for line voltage regulation remains a necessity to meet demands for high industrial productivity. There are several conditioning solutions to voltage regulation, which are currently available in the marketplace. Among the most common are tap-changing transformers, which are the types of voltage regulators used in today‟s power distribution systems. However, these methods have significant shortcomings. For instance, the tap-changing transformer requires a large number of thyristors, which results in highly complex operation for fast response. Furthermore, it has very poor transient voltage rejection, and only has an average response time. They also suffer from inherent disadvantages, such as retardation of the firing angle causing a lagging power factor at the input side. A discontinuity of power flow appears at both the input and output sides. Such ac–ac conditioners have slow response and need large input–output filters to reduce low-order harmonics from the respective waveforms [9]-[10].

Recent developments in the field of power electronics make it possible to improve the electrical power system utility interface. Line-commutated ac controllers can be replaced by pulse width modulation (PWM) ac chopper controllers, which have better overall performance. In this case, the input supply voltage is chopped into segments, and the output voltage level is decided by controlling the duty cycle of the chopper switching function. The advantages to be gained include nearly sinusoidal input–output current/voltage waveforms, better input power factor, better transient response, elimination of the low order harmonics and, consequently, smaller input–output filter parameters. Little attention has been given to the input power factor of ac chopper controllers. Researchers who deal with ac choppers have not considered the variation of the input power factor of such controllers [11]. Others insisted that the input power factor can be made to coincide with the load power factor and that it is independent of the duty cycle. In fact, this claim is not true from the practical and theoretical points of view due to the higher order harmonic contents in the line current resulting from the nature of the switching processes, in particular, at low values of duty cycle. Control by switching is often accompanied by extra losses due to the switching losses. The reduction in the number of switches is essential for control simplicity, cost, reliability, and high switching frequency with good efficiency [10].

In earlier AC switch mode circuits respectively in “Power Line Voltage Regulation by PWM AC Buck-Boost Voltage Controllers” and “AC Voltage Regulation By Ĉuk Switch Mode Power Supply” have been reported. Both worked with automatic voltage controller and used two switches in their ac-ac controller circuits. This thesis deals with a new configuration of a symmetrical PWM ac chopper voltage controller for single-phase systems. The proposed circuit employs only one bi directional switch. The proposed controller will be economical owing to a smaller number of controlled switches.

The concept of dc–dc converters may be extended to ac-ac converters because of their topological and functional similarities. In general, the use of fewer switches can reduce cost and improve reliability of a system. In this thesis a number of simple topologies of single-phase PWM ac–ac converters will be suggested which uses one switch per converter.

1.3 Review:

The review consists of two parts. The review of DC-DC converters and review of AC-AC converters. The review of DC-DC converter is compatible because the proposed work is derived from the circuits based on Buck-Boost conversion circuit of DC-DC converter.

1.3.1 Review of DC-DC Converter:

A DC converter can be considered as dc equivalent to an ac transformer with a continuously variable turns ratio. Like a transformer it can be used to step down or step up a dc voltage source. DC conversion is of great importance in many applications, starting from low power applications to high power applications. For low power levels, linear regulators can provide a very high-quality output voltage. For medium power levels, switching regulators are used. Switching regulators use power electronic semiconductor switches in On and Off states. Because there is a small power loss in those states, switching regulators has high efficiency.

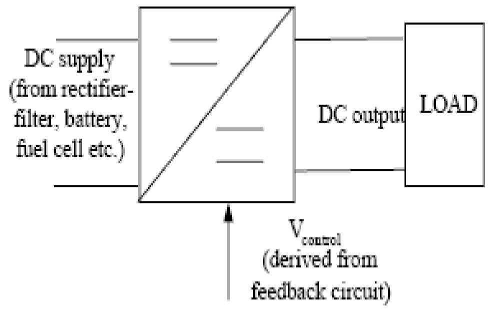

Fig1.1: General block diagram:

The functions of dc-dc converters are:

- Convert a DC input voltage into a DC output voltage.
- Regulate the DC output voltage against load and line variations.
- Reduce the AC voltage ripple on the DC output voltage below the required level.
- Provide isolation between the input source and the load (if required).
- Protect the supplied system and the input source from electromagnetic interference (EMI)

The DC-DC converter is considered as the heart of the power supply, thus it will affect the overall performance of the power supply system. The converter accepts DC and produces a controlled DC output.

1.3.2 Power Supply Types:

The two major power supply technologies that can be considered within a power supply system are:

- Linear voltage regulators.
- Pulse-width modulated (PWM) switching power supplies.

1.3.2.1 Linear Voltage Regulator:

The linear regulator is the original form of the regulating power supply. It relies upon the variable conductivity of an active electronic device to drop voltage from an input voltage to a regulated output voltage. The linear regulator wastes a significant amount of power in the form of heat. The linear power supply finds applications where its inefficiency is not important and also where low cost and a short design period are desired. The linear regulator is sometimes referred as dissipative regulator.

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Linear regulators can only produce output voltages lower than their input voltages and each linear regulator can produce only one output voltage. Each linear regulator has an average efficiency of between 35 and 50 percent; the losses are dissipated as heat. Linear regulators are step-down regulators only; that is, the input voltage source must be higher than the desired output voltage.

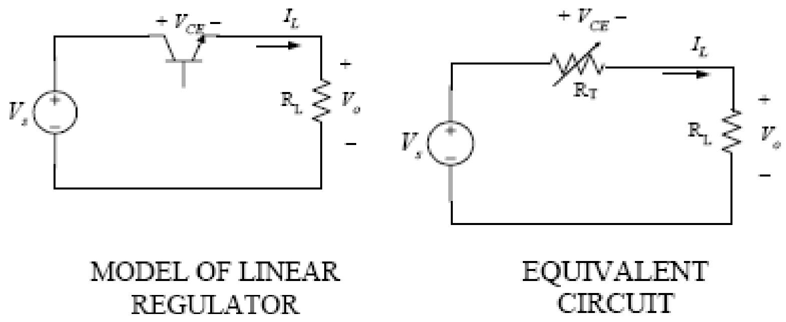


Fig: 1.2 linear voltage regulators

1.3.2.2 PWM Switch Mode Power Supply (SMPS):

A switching mode power converter (SMPC) is a power electronic system, which coverts one level of voltage into another level of voltage at load side by switching on and off of power switches. In DC to DC switching circuits, the power switches control the transfers of power from the input DC source to the load by means of connecting the power to the load for a predetermined duration. Switching power supply has a higher efficiency, less heat, and is smaller in size and weight in comparison with the linear voltage regulator. They are commonly found within portable products, aircraft and automotive products, small instruments, off-line applications, and generally applications where high efficiency and multiple output voltages are required.

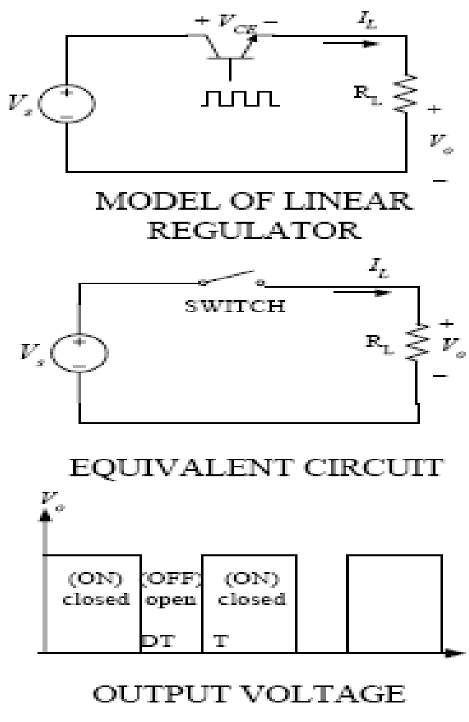


Fig 1.3: Switch Mode power supply

1.3.3 Types of switch DC-DC converter:

There are four basic topologies of switching regulators:

1. Buck regulator,
2. Boost regulator,
3. Buck Boost regulator,
4. Ĉuk regulator and
5. SEPIC regulator

In this thesis the Buck-Boost circuit is adopted for ac-ac conversion. Hence a basic operating principle of dc-dc Buck-Boost conversion is reviewed.

1.3.3.1 Buck-Boost Converter:

The buck, boost and buck-boost converters all transfers energy between input and output using the inductor, analysis being based on the voltage balance across the inductor. A buck-boost regulator provides an output voltage that may be less than or greater than the input voltage. The output voltage polarity is opposite to that of the input voltage.. this regulator is also known as an inverting regulator. A buck-boost converter comprises one inductor, one capacitor, a semiconductor switch and a diode.

1.3.3.1.1 Buck-Boost circuit and waveforms:

The circuit of the Buck-Boost DC-DC converter is shown in Figure:1.4 it consists of DC input voltage source Vs, energy transfer inductor L, controllable switch S, diode D, filter capacitor C, and the load. A buck-Boost regulator provides output voltage polarity reversal without a transformer. It has high efficiency. Under a fault condition of the transistor the di/dt of the fault current is limited by the inductor L and will be Vs/L. Output short-circuit protection would be easy to implement. But the input current is discontinuous and a high peak current flows through transistor Q.

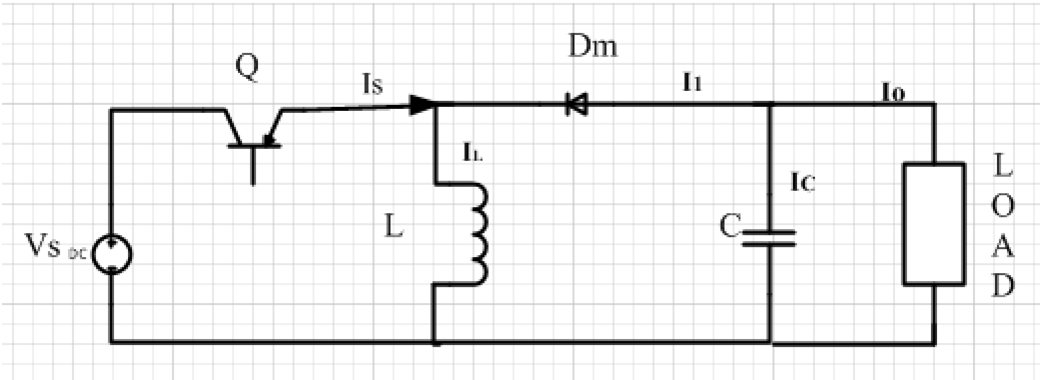


Fig 1.4: Schematic of a Buck-Boost converter.

1.3.3.1.2 The two operating states of a Buck-Boost converter:

The circuit operation of the Buck-Boost converter can be explained by two different modes.

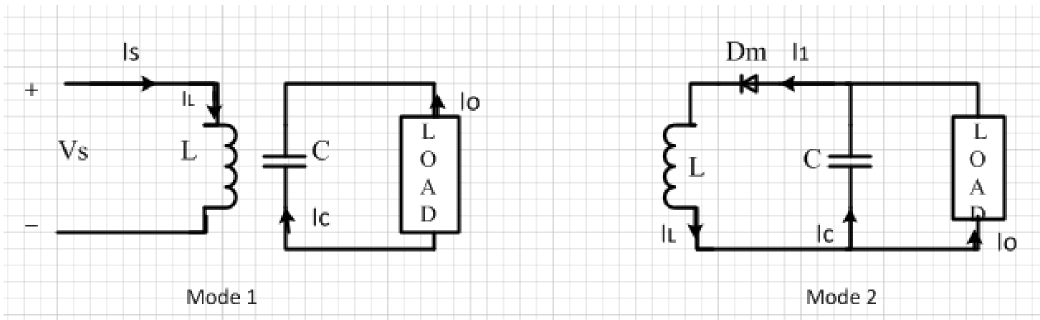


Fig 1.5: The two operating states of a Buck-Boost converter, switch On and Off stage

When the switch is on that is during mode 1, transistor Q is turned on and diode D is reversed biased. The input current which rises flows through inductor L and transistor Q and charges the inductor L. When the switch is Off that is during mode 2, transistor Q is switched off and the current, which was flowing through inductor L would flow through L,C,D and the load. The energy stored in inductor L would be transferred to the load and the inductor current would fall until transistor Q is switched on again in the next cycle. The wave forms for steady state voltages and currents of the buck-boost regulator are shown in Figure: for a continuous load current.

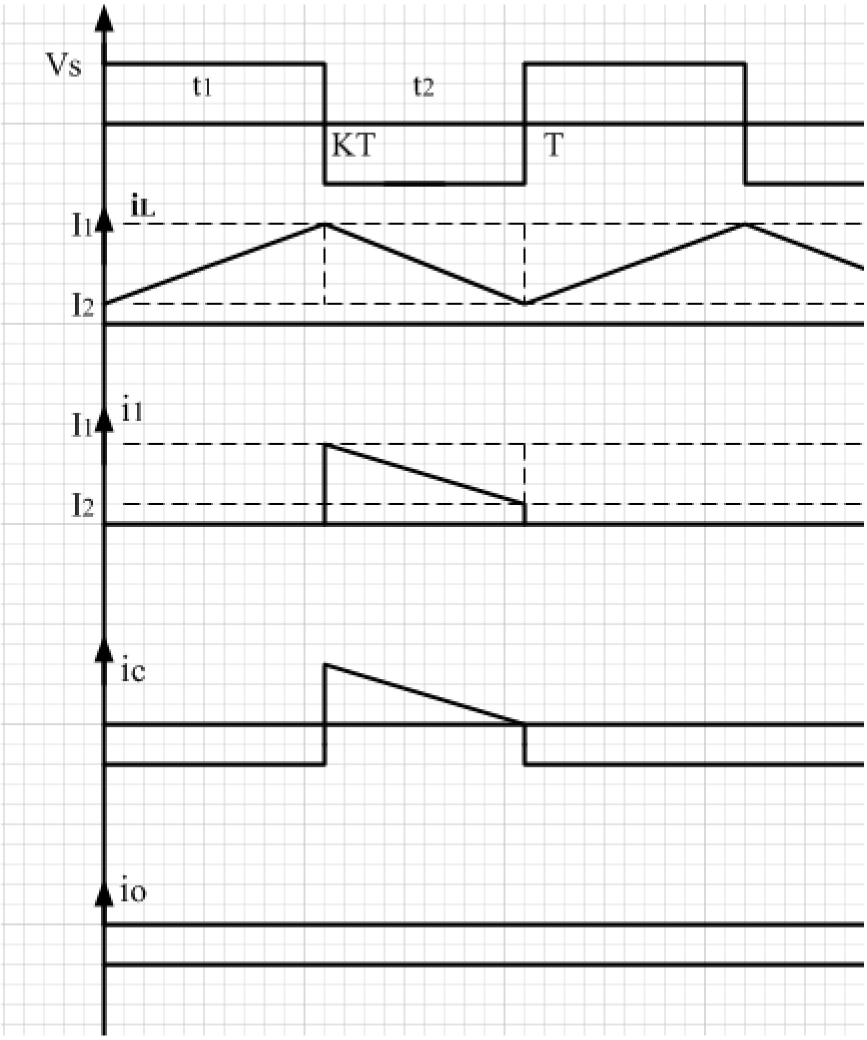


Fig 1.6: Buck-Boost converter waveforms

Assuming that the inductor current rises linearly from I1 to I2 in time t1

$$Vs = L\frac{I2 - I1}{t1} = L\frac{\Delta I}{t1}$$

Or

$$t1 = \frac{\Delta IL}{Vs}$$

And the inductor current falls linearly from I2 to I1 in time t2

$$Vo = -L\frac{\Delta I}{t2}$$

Or

$$t2 = -\frac{\Delta I L}{Vo}$$

Where $\Delta I = I2 - I1$ is the peak-to-peak ripple current of inductor now from the above equation we can write

$$\Delta I = \frac{\text{Vs t1}}{\text{L}} = -\frac{\text{Vo t2}}{\text{L}}$$

Substituting $t1 = kT$ and $t2 = (1-k)T$, the average output voltage is

$$Vo = -\frac{Vs\,k}{1-k}$$

1.3.4 Advantages of an SMPS:

Switch mode power supplies have following advantageous features:

- Isolation between the source and the load
- High power density resulting reduction of size and weight
- Controlled direction of power flow
- High conversion efficiency
- Input and output waveforms with low total harmonic distortion for small filters and
- Controlled power factor if the source is an ac voltage.

1.3.5 Review of AC voltage Regulators:

1.3.5.1 AC voltage controller circuit:

AC voltage controllers (ac line voltage controllers) are employed to vary the RMS value of the alternating voltage applied to a load circuit by introducing thyristors between the load and a constant voltage ac source. The RMS value of alternating voltage applied to a load circuit is controlled by controlling the triggering angle of the thyristors.

In brief, an ac voltage controller is a type of thyristor power converter which is used to convert a fixed voltage, fixed frequency ac supply to obtain a variable voltage ac at the output load. The RMS value of the ac output voltage and the ac power flow to the load is controlled by varying (adjusting) the trigger angle „α"

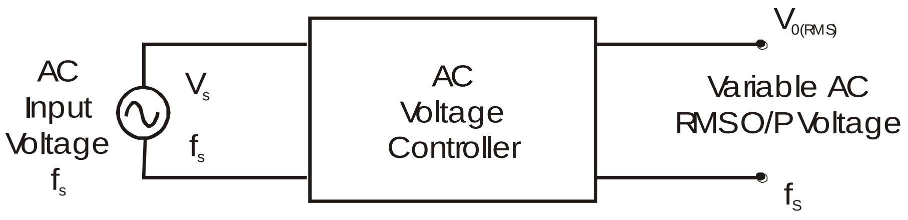


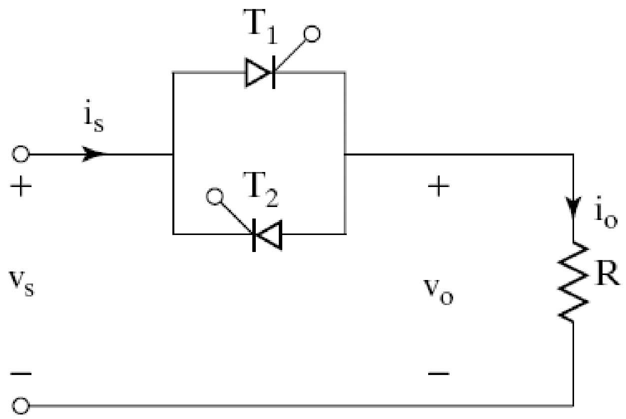
Fig 1.7: Model of AC voltage controller

There are two different types of thyristor control which are used in practice to control the ac power flow

- On-Off control
- Phase control

1.3.5.1.1 ON-OFF CONTROL TECHNIQUE (INTEGRAL CYCLE CONTROL):

The basic principle of on-off control technique is explained with reference to a single phase full wave ac voltage controller circuit shown in Fig:1.8. The thyristor switches T_1 and T_2 are turned on by applying appropriate gate trigger pulses to connect the input ac supply to the load for „n"number of input cycles during the time interval t_{on}. The thyristor switches T_1 and T_2 are turned off by blocking the gate trigger pulses for „m"number of input cycles during the time interval t_{off}. The ac controller ON time t_{on} usually consists of an integral number of input cycles.



R=R_L= Load Resistance

Fig1.8: Single phase full wave AC voltage controller circuit

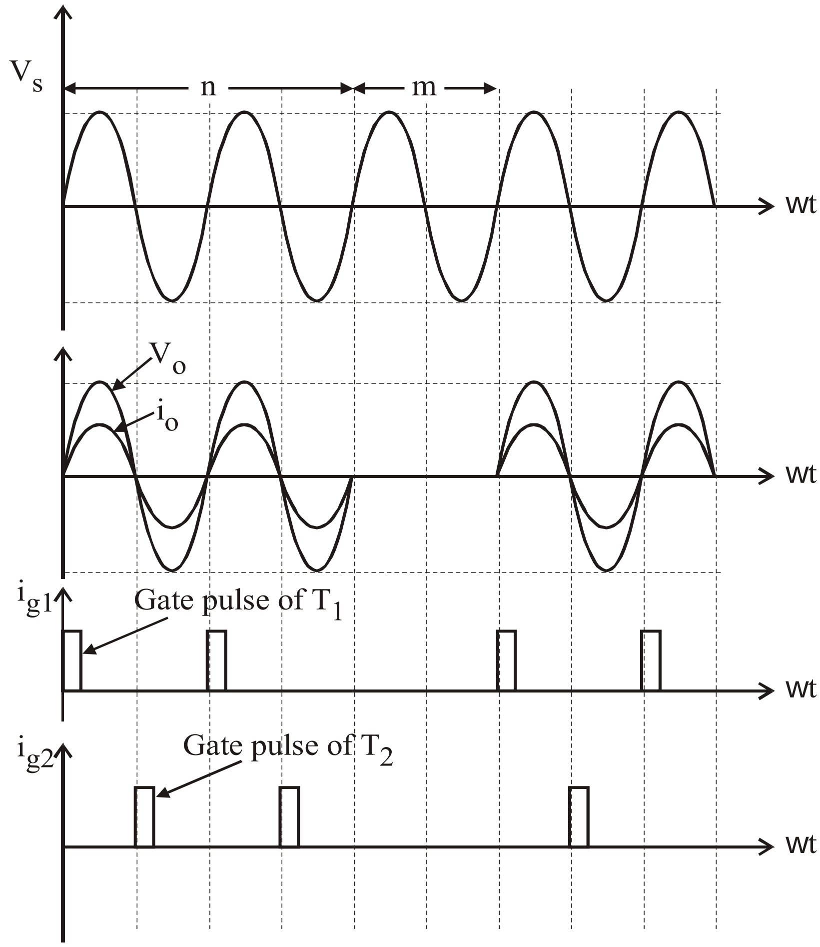


Fig.1.9: Waveforms of Single phase full wave AC voltage controller circuit

This type of control is used in applications which have high mechanical inertia and high thermal time constant (Industrial heating and speed control of ac motors). Due to zero voltage and zero current switching of thyristors, the harmonics generated by switching actions are reduced.

For a sine wave input supply voltage,

$$v_s = V_m \sin \omega t = \sqrt{2} V_S \sin \omega t$$

$$v_s = RMS\ value\ of\ input\ ac\ supply = \frac{v_m}{\sqrt{2}} = RMS\ phase\ supplt\ voltage$$

If the input ac supply is connected to load for „n" number of input cycles and disconnected for „m" number of input cycles, then

$$t_{ON} = n \times T, \qquad t_{OFF} = m \times T$$

$$Where, T = \frac{1}{f} = input\ cycle\ time\ (time\ period) and$$

$$f = input\ supply\ frequency.$$

$$t_{on} = controller\ on\ time = n \times T.$$

$$t_{OFF} = controller\ off\ time = m \times T.$$

$$T_0 = Output\ time\ period = (t_{on} + t_{off}) = (nT + mT)$$

1.3.5.1.2 PRINCIPLE OF AC PHASE CONTROL

The principle of ac phase control technique is explained with reference to a single phase half wave ac voltage controller (unidirectional controller) circuit shown in the Figure1.10.

The half wave ac controller uses one thyristor and one diode connected in parallel across each other in opposite direction that is anode of thyristor T_1 is connected to the cathode of diode D_1 and the cathode of T_1 is connected to the anode of D_1. The output voltage across the load resistor „R" and hence the ac power flow to the load is controlled by varying the trigger angle „α".

The trigger angle or the delay angle „α" refers to the value of ωt or the instant at which the thyristor T_1 is triggered to turn it ON, by applying a suitable gate trigger pulse between the gate and cathode lead.

The thyristor T_1 is forward biased during the positive half cycle of input ac supply. It can be triggered and be made to conduct by applying a suitable gate trigger pulse only during the positive half cycle of input supply. When T_1 is triggered it conducts and the load current flows through the thyristor T_1, the load and through the transformer secondary winding.

Assuming T_1 as an ideal thyristor switch it can be considered as a closed switch when it is ON during the period $\omega t=\alpha$ to π radians. The output voltage across the load follows the input supply voltage when the thyristor T_1 is turned-on and when it conducts from $\omega t=\alpha$ to π radians. When the input supply voltage decreases to zero at $\omega t=\alpha$, for a resistive load the load current also falls to zero at $\omega t=\pi$ and hence the thyristor T_1 turns off at $\omega t=\pi$. Between the time period $\omega t=\pi$ to 2π, when the supply voltage reverses and becomes negative the diode D_1 becomes forward biased and hence turns ON and conducts. The load current flows in the opposite direction during $\omega t=\pi$ to 2πradians when D_1 is ON and the output voltage follows the negative half cycle of input supply.

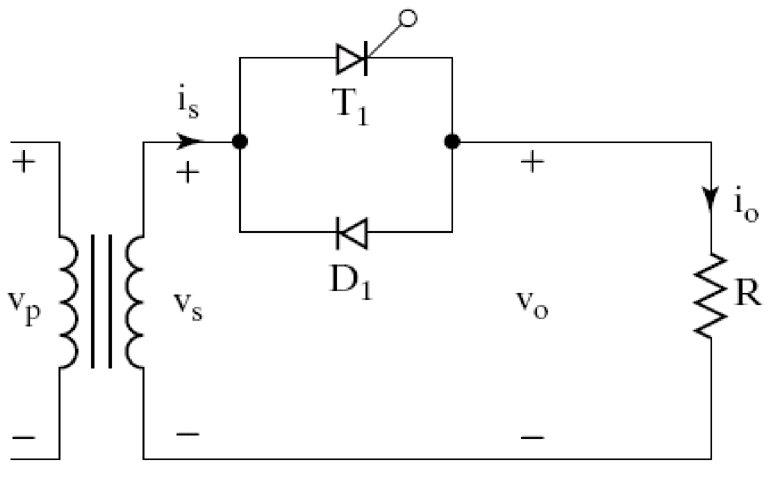


Fig.1.10: Half-wave AC phase controller (Unidirectional Controller)

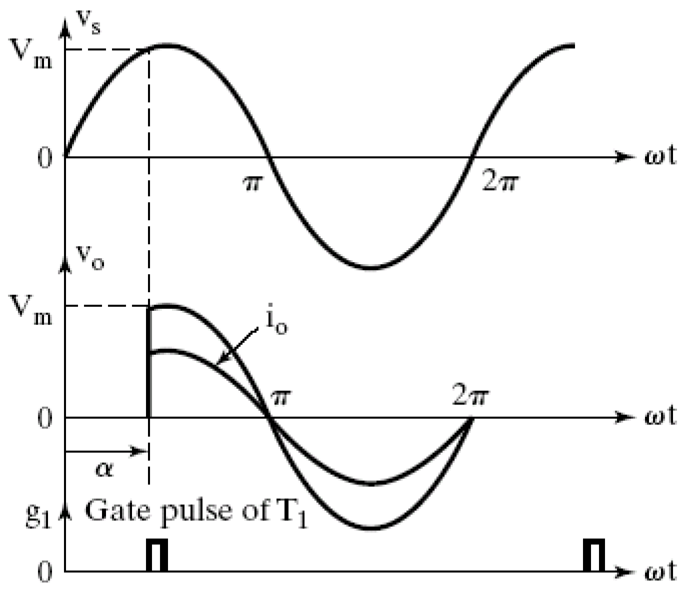


Fig.1.11: Waveforms of Half-wave AC phase controller

Equations:

Input AC supply voltage across the transformer secondary winding.

$$v_s = V_m \sin \omega t$$

$$V_s = V_{in(rms)} = \frac{V_m}{\sqrt{2}} = RMS\ value\ of\ secondary\ voltage.$$

Output Load Voltage

$$V_0 = V_L; for\ \omega t = 0\ to\ \alpha$$

$$V_0 = V_L = V_m sin\omega t; for\ \omega t = \alpha\ to\ 2\pi$$

Output Load Current

$$i_0 = i_L = \frac{V_0}{R_L} = \frac{V_m sin\omega t}{R_L}; for\ \omega t = \alpha\ to\ 2\pi$$

$$i_0 = i_L = 0; for\ \omega t = 0\ to\ \alpha$$

We can show that,

$$Output\ RMS\ voltage\ V_{0(rms)} = V_{i(rms)}\sqrt{\frac{t_{on}}{T_0}} = V_s\sqrt{\frac{t_{on}}{T_0}}$$

Where $V_{i(rms)}$ is the RMS input supply voltage = V_s.

Phase controlled AC-AC voltage controller has following two circuits for single phase and three phase voltage controls:

- Full wave Phase controlled single phase AC-AC voltage controller
- Full wave Phase controlled three phase AC-AC voltage controller

1.3.5.1.2.1 Full wave Phase controlled single phase AC-AC voltage controller:

Single phase full wave ac voltage controller circuit using two SCRs or a single triac is generally used in most of the ac control applications. The ac power flow to the load can be controlled in both the half cycles by varying the trigger angle „α".

The RMS value of load voltage can be varied by varying the trigger angle „α". The input supply current is alternating in the case of a full wave ac voltage controller and due to the symmetrical nature of the input supply current waveform there is no dc component of input supply current i.e., the average value of the input supply current is zero.

A single phase full wave ac voltage controller with a resistive load is shown in the figure below. It is possible to control the ac power flow to the load in both the half cycles by adjusting the trigger angle „α". Hence the full wave ac voltage controller is also referred to as to a bi-directional controller.

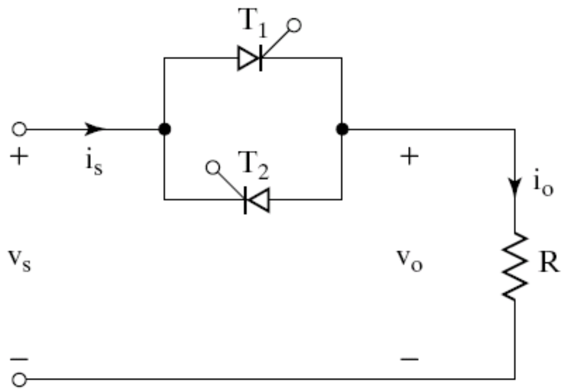


Fig.1.12: Single phase full wave ac voltage controller (Bi-directional Controller) using SCRs

In Fig.1.12 the thyristor T_1 is forward biased during the positive half cycle of the input supply voltage. The thyristor T_1 is triggered at a delay angle of α ($0 \le \alpha \le \pi$ radians). Considering the ON thyristor T_1 as an ideal closed switch the input supply voltage appears across the load resistor R_L and the output voltage V_0=Vs during ωt=α to π radians. The load current flows through the ON thyristor T_1 and through the load resistor R_L in the downward direction during the conduction time of T_1 from ωt=α to π radians.

At ωt=π, when the input voltage falls to zero the thyristor current (which is flowing through the load resistor R_L) falls to zero and hence T_1 naturally turns off. No current flows in the circuit during ωt=π to (π+α).

The thyristor T_2 is forward biased during the negative cycle of input supply and when thyristor T_2 is triggered at a delay angle (π+α), the output voltage follows the negative half cycle of input from ωt=(α+α) to 2π. When T_2 is ON, the load current flows in the reverse direction (upward direction) through T_2 during ωt = (π+α) to 2π radians. The time interval (spacing) between the gates trigger pulses of T_1 and T_2 is kept at π radians or 1800. At ωt=2π the input supply voltage falls to zero and hence the load current also falls to zero and thyristor T_2 turn off naturally.

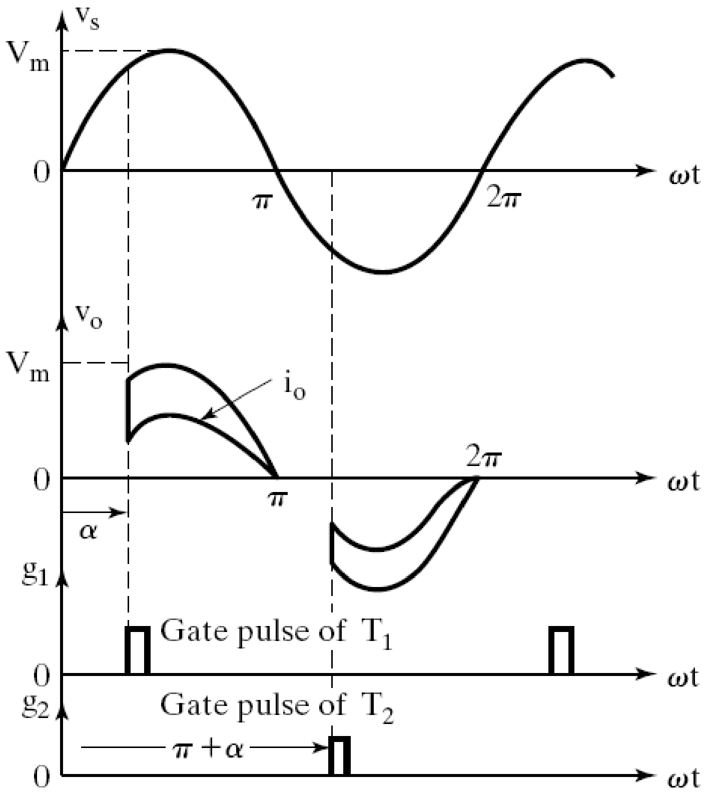


Fig1.13: Waveforms of single phase full wave ac voltage controller

EQUATIONS:

Input supply voltage

$$v_S = V_m \sin \omega t = \sqrt{2} V_S \sin \omega t \,;$$

Output voltage across the load resistor R_L;

$$v_O = v_L = V_m \sin \omega t \;;$$

For $\omega t = \alpha$ to π and $\omega t = (\pi + \alpha)$ to 2π

Output load current

$$i_O = \frac{v_O}{R_L} = \frac{V_m \sin \omega t}{R_L} = I_m \sin \omega t \;;$$

For $\omega t = \alpha$ to π and $\omega t = (\pi + \alpha)$ to 2π

1.3.5.1.2.2 Full wave Phase controlled three phase AC-AC voltage controller:

The circuit of a three-phase, three-wire ac regulator (termed as ac to ac voltage converter) with balanced resistive (star-connected) load is shown in Fig. 1.14. It may be noted that the resistance connected in all three phases are equal. Two thyristors connected back to back are used per phase, thus needing a total of six thyristors The thyristors are fired in sequence (Fig. 1.15), starting from 1 in ascending order, with the angle between the triggering of thyristors 1 & 2 being (one-sixth of the time period T=60^0 of a complete cycle). The line frequency is 50 Hz, with 1/f=T=20ms. The thyristors are fired or triggered after a delay of α from the natural commutation point. The natural commutation point is the starting of a cycle with period, (1/6T=60°) of output voltage waveform, if six thyristors are replaced by diodes. The output voltage is similar to phase-controlled waveform for a converter, with the difference that it is an ac waveform in this case. The current flow is bidirectional, with the current in one direction in the positive half, and then, in other (opposite) 3 direction in the negative half. So, two thyristors connected back to back are needed in each phase. The turning off of a thyristor occurs, if its current falls to zero. To turn the thyristor on, the anode voltage must be higher than the cathode voltage, and also, a triggering signal must be applied at its gate.

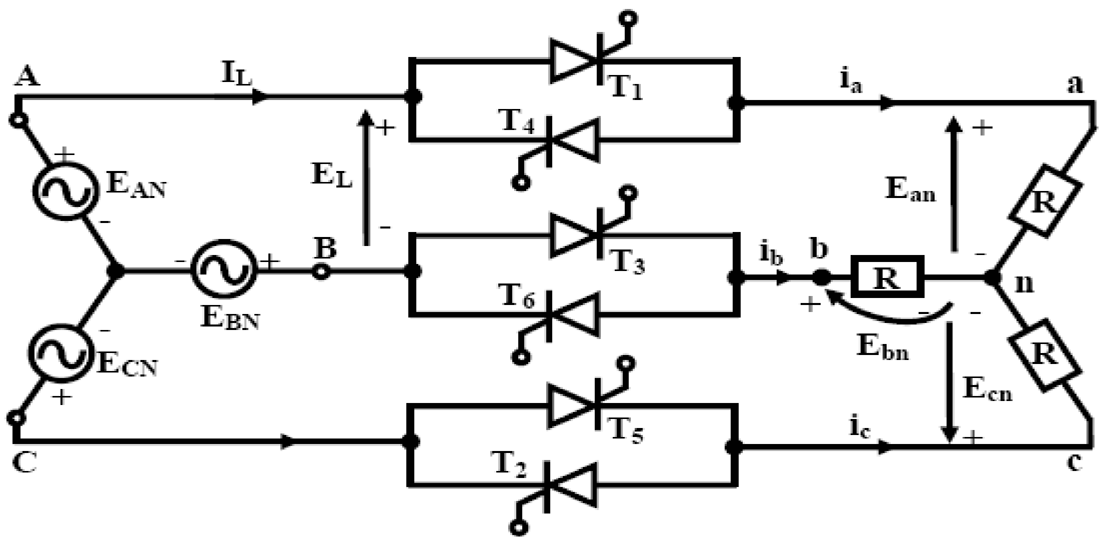


Fig.1.14 Three-phase, three-wire ac regulator

The procedure for obtaining the expression of the rms value of the output voltage per phase for balanced star-connected resistive load, which depends on range of firing angle, as shown, is described. If E_s is the rms value of the input voltage per phase, and assuming the voltage, E_{AN} as the reference, the instantaneous input voltages per phase are,

$$e_{AN} = \sqrt{2}E_s \sin \omega t,$$

$$e_{BN} = \sqrt{2}E_s \sin(\omega t - 120^0) \text{ and}$$

$$e_{CN} = \sqrt{2}E_s \sin(\omega t + 120^0)$$

Then, the instantaneous input line voltages are,

$$e_{AN} = \sqrt{6}E_s \sin(\omega t + 30^0),$$

$$e_{BN} = \sqrt{6}E_s \sin(\omega t - 90^0) \text{ and}$$

$$e_{CN} = \sqrt{6}E_s \sin(\omega t - 150^0)$$

The waveforms of the input voltages, the conduction angles of thyristors and the output voltage of one phase, for firing delay angles (α) of (a) 60° and (b) 120^0 are shown in Fig. 1.15 For $0 \le \alpha \le 60°(\pi/6)$, immediately before triggering of thyristor 1, two thyristors (5 and 6) conduct. Once thyristor 1 is triggered, three thyristors (1, 5 and 6) conduct. As stated earlier, a thyristor turns off, when the current through it goes to zero. The conditions alternate between two and three conducting thyristors. At any time only two thyristors conduct for $60^0 \le \alpha \le 90^0$.Although two thyristors conduct at any time for $90^0 \le \alpha \le 150^0$, there are periods, when no thyristors are on. For $\alpha \ge 150^0$, there is no period for which two thyristors are on, and the output voltage becomes zero at $150^0 \le \alpha \le \pi$. The range of delay angle is $0^0 \le \alpha \le 150^0$.

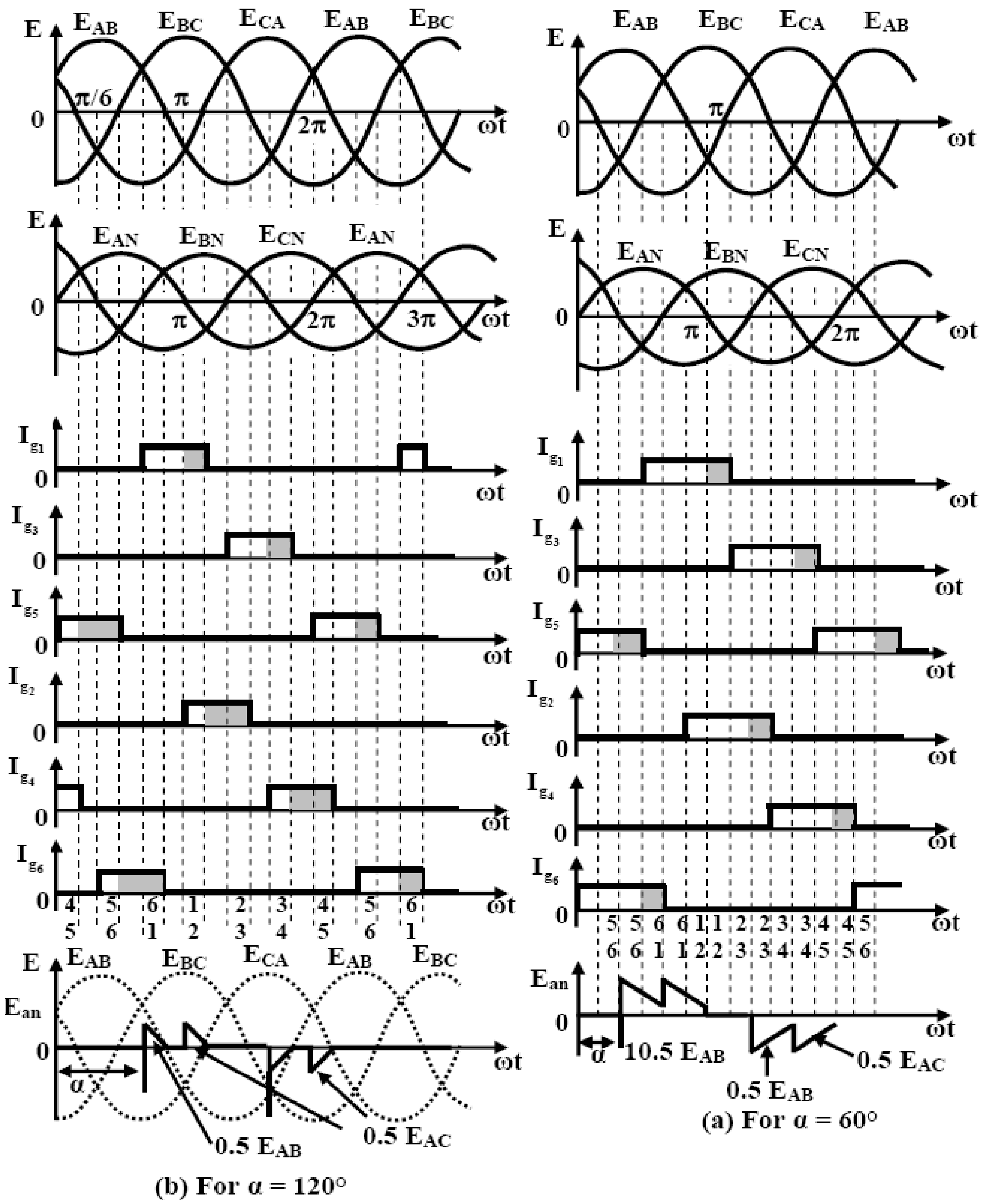


Fig.1.15 Waveforms for three-phase three-wire ac regulator

1.4 OBJECTIVES AND METHODOLOGY

1.4.1 OBJECTIVES

The input currents of ac phase controlled voltage controllers are non-sinusoidal and require large filters to make them sinusoidal. Switch mode design of ac voltage controllers will reduce the input filter size. Efforts are continuing to improve the present switch mode ac-ac voltage regulators or find better circuit topologies having good power quality.

A new single phase ac-ac voltage controller circuit topology based on buck-boost converter is investigated in this research work. The topology has a single bi-directional switch at the front end of the converter in contrast to synchronized switching of two unidirectional switches for ac-ac conversion. Synchronized switching of unidirectional switches is problematic in implementation as regard to the gate pulse generation for various loads in continuous and discontinuous conduction modes. Single switch implementation eases this problem. Switching regulator configuration allows the reduction of filter size of both the input and output sides of the converter and is expected to provide step-up/ step-down voltage regulation at acceptable high efficiency and with good power quality.

1.4.2 METHODOLOGY

The new ac-ac buck-boost regulator circuit is derived from its counterpart topology used for dc-dc conversion. The input to the regulator is ac and the switch used is a bi-directional switch, which is made of a unidirectional switch combined with four diodes. It is envisaged that ac-ac conversion by the buck-boost topology using a single bi-directional switch is possible by the philosophy of half cycle to half cycle conversion individually and connecting the outputs to the load either in wired OR, or in differential mode. Such conversion has the advantage of input current being in phase with supply voltage without additional sensing and control circuits and the high frequency chopped input current can be made near sinusoidal with small input filter resulting in low input current THD and high power factor. In the wired OR connection to the load both half cycles appear at the output load. In the differential connection average dc of the individual outputs are cancelled out and the load voltage lower than the expected peak to peak is available. In the differential mode of connection two quadrant operation of single switch converter in each positive and negative cycle of the supply voltage is necessary because path for current flow from load to source is necessary when the switch is OFF. Reducing the number of control switch makes the design simple, cost effective and reliable. Input current distortion to the circuit is in acceptable range and the circuit exhibit good performance in respect to input power factor, input current THD and efficiency in a given range of duty cycle. The proposed circuit is simulated using spice simulator and the performance of circuit is investigated in terms of efficiency and power quality.

1.5 OUTLINES OF THE THESIS:

This thesis consists of three chapters. Chapter-1 deals with introduction to SMPS, review of DC and AC voltage regulators. Objective of the thesis and methodology are also included in chapter-1.

Chapter-2 includes the study of proposed AC-AC Buck-Boost regulator. AC Buck-Boost regulator with a ac-ac voltage conversion topology with a bi-directional switch has been proposed and studied. Principle of operation of the proposed circuit, simulation, step by step function of the circuit and comparison table of THD, power factor, output voltage control with various values of duty cycle and corresponding waveforms are highlighted in this chapter. Differential mode of output connection is also described with waveforms.

Chapter-3 concludes the thesis with summary, achievements and suggestion on future works.

CHAPTER-2

Single Phase Single Switch Buck-Boost AC-AC Voltage Regulator

2.1 INTRODUCTION

AC Buck-Boost voltage regulator is a modified version of the dc-dc Buck-Boost converter to work with ac voltage as input and ac voltage as output. This regulator provides output voltage less or greater than the input voltage.

2.2 SINGLE PHASE AC-AC CONVERTER TECHNOLOGIES:

AC voltage controllers are used in application requiring variable output voltage. Conventionally Phase Angle Control (PAC) and integral cycle control of thyristors are used for their simplicity and ability to handle large amount of power economically. Power factor is lagging in phase angle control and leading in extinction angle control. However, they suffer from inherent disadvantages such as; retardation of the firing angle cause lagging power factor at the input and high low order harmonics content at load and supply sides. Moreover a discontinuity of power flow takes place at input and output sides.

Voltage sensitive appliances need regulated stable voltage sources. Series voltage controllers are commonly used to supply such sensitive equipment. Series voltage controllers with unipolar matrix chopper and serial transformer for adding the compensating voltage and input transformer with tap changer are used to step-up and step-down AC voltage for stabilization. The weight and volume of this controller are large because of an input transformer with thyristor tap switches. In order to solve this problem several other solutions of series AC voltage controllers are also available.

The AC controllers with thyristor technology can be replaced by PWM AC chopper controller which has important advantages. The recent developments in the field of power electronics made it possible to improve the electrical power system utility interface. Line commutated AC controllers can be replaced by PWM AC chopper controllers, which have better overall performance. The advantages to be gained include nearly sinusoidal input output current/voltage waveforms, better input power factor, better transient response, elimination of the low order harmonics and small input–output filter. Control by switching is accompanied by extra losses due to the switching losses. The reduction in the number of switches is essential for control simplicity, cost, reliability, and high switching frequency with good efficiency.

In this thesis a single bidirectional switch is used which chops the ac in both the positive and negative cycle at a high frequency and by utilizing Buck-Boost conversion principle step up/step down regulated output voltage is obtained with reduced circuit components.

2.3 PROPOSED CIRCUIT CONFIGURATION

Figure 2.1 shows the proposed circuit for a singe phase switched mode PWM AC voltage Buck-Boost converter. This circuit has two Buck-Boost conversion paths for the positive and negative cycles. To perform Buck-Boost conversion in positive and negative half cycles of the input voltage, the power switch Q of the converter has a bridge diode connection (D1-D4) across it. The circuit output connection is made by wired OR connection of +ve and –ve Buck-Boost conversion.

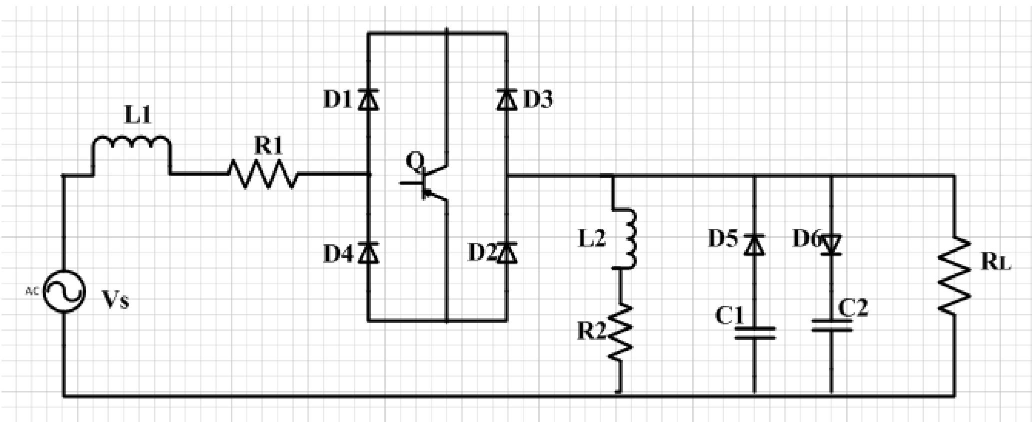


Fig. 2.1: Proposed Circuit of AC-AC voltage controller using Buck-Boost topology

Controlling the duty cycle of the proposed AC-AC converter results in variable AC output voltage with good input power factor, input current THD and efficiency. For getting a particular output voltage having good power factor, THD of input currents and efficiency, proper design in the choice of the circuit elements and the duty cycle of the switching pulse is necessary.

2.3.1 PRINCIPLE OF OPERATION

In Figure 2.2 the basic concept of AC-AC buck-boost converter has been shown. Two bidirectional switches are required to buck-boost both the positive and negative cycle. In the proposed circuit only one bidirectional switch is used which operate in buck-boost mode separately for positive and negative cycle of the supply.

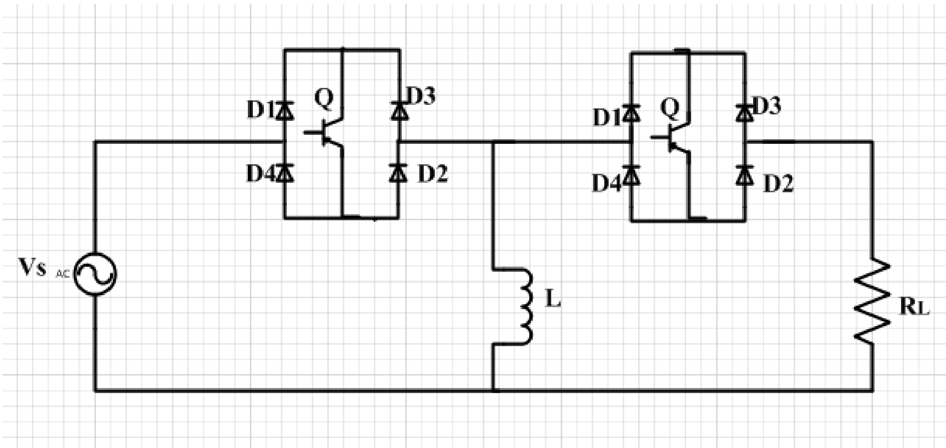


Fig.2.2: Basic AC-AC PWM Buck-Boost converter.

2.3.2 OPERATION OF THE PROPOSED CIRCUIT:

According to the ON-OFF conditions of the bi-directional switch in the positive and negative half cycle of the supply the circuit of the proposed configuration have four states .These four states are presented in Figure 2.3.

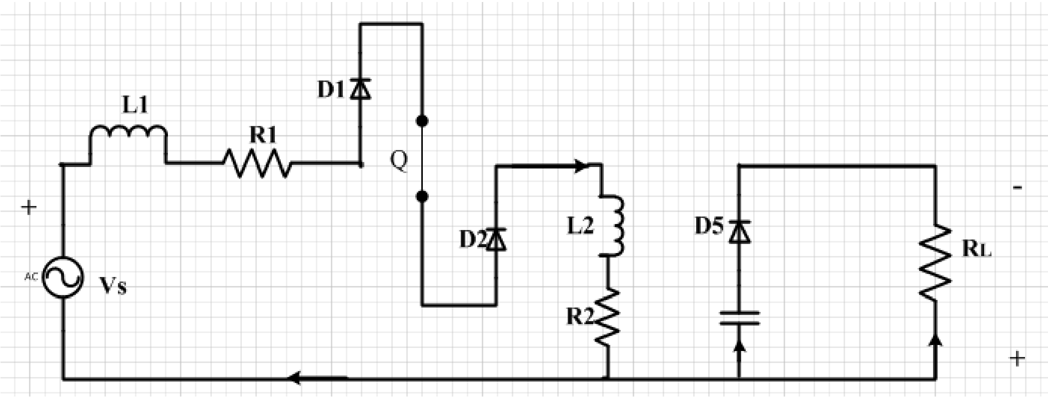


Fig. 2.3(a). State 1: Circuit when the bidirectional switch is ON during the positive half cycle of the AC supply

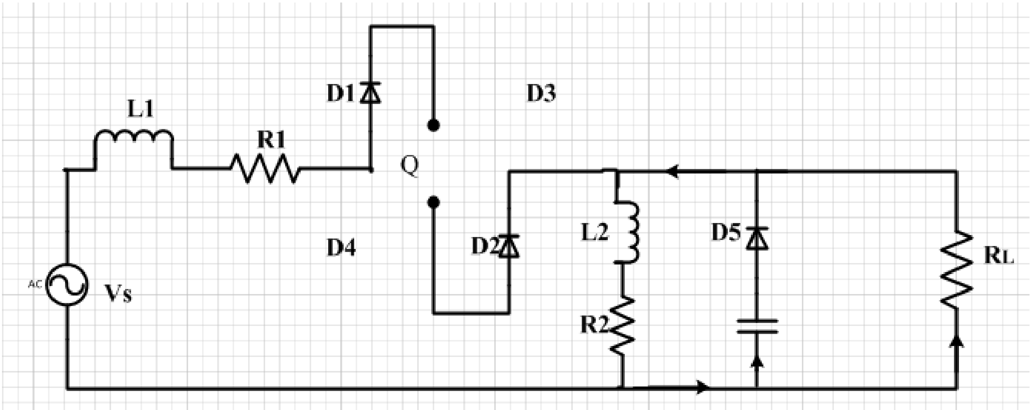


Fig. 2.3(b). State 2: Circuit when the bidirectional switch is OFF during the positive half cycle of the AC supply

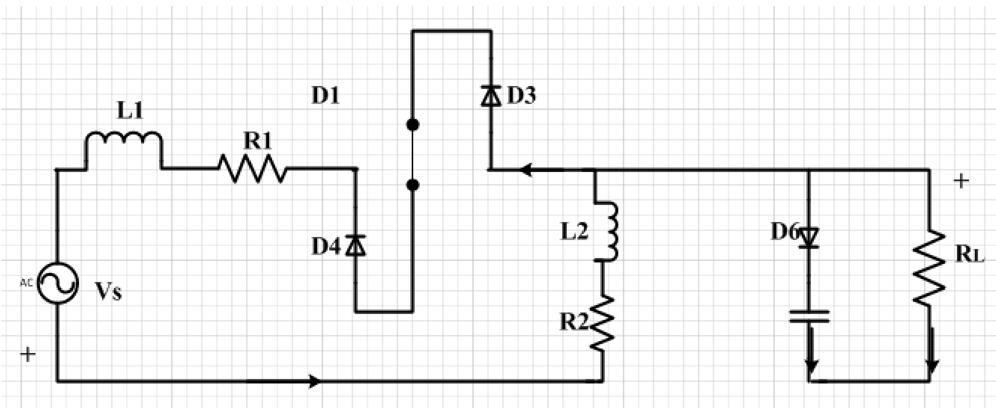


Fig.2.3(c). State 3: Circuit when the bidirectional switch is ON during the negative half cycle of the AC supply

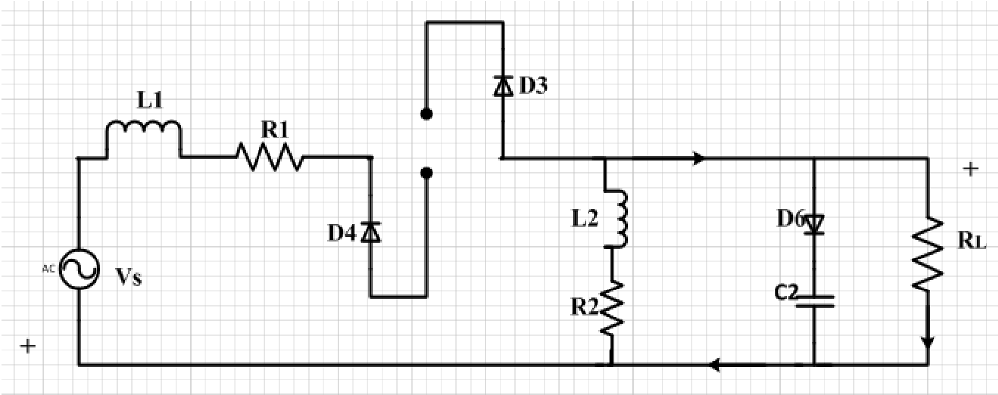


Fig. 2.3(d). State 4: Circuit when the bidirectional switch is OFF during the negative half cycle of the AC supply

In the positive half cycle of the supply the circuit perform buck-boost conversion according to state 1 and state 2 when the power switch in ON and OFF respectively. In the negative half cycle of the supply, Buck-Boost conversion is performed by state 3 and 4 while the power switch is ON and OFF respectively.

For the positive cycle of the input ac signal, the output of the buck-boost conversion is across the capacitor C2 and for the negative half of the input signal the output of the buck-boost conversion is across the capacitor C1.The load resistor R in parallel with the capacitor C1 and C2 is connected differentially across the terminals to get desired AC output.

2.3.3 Simulation of proposed Buck-Boost ac-ac regulator without input filter:

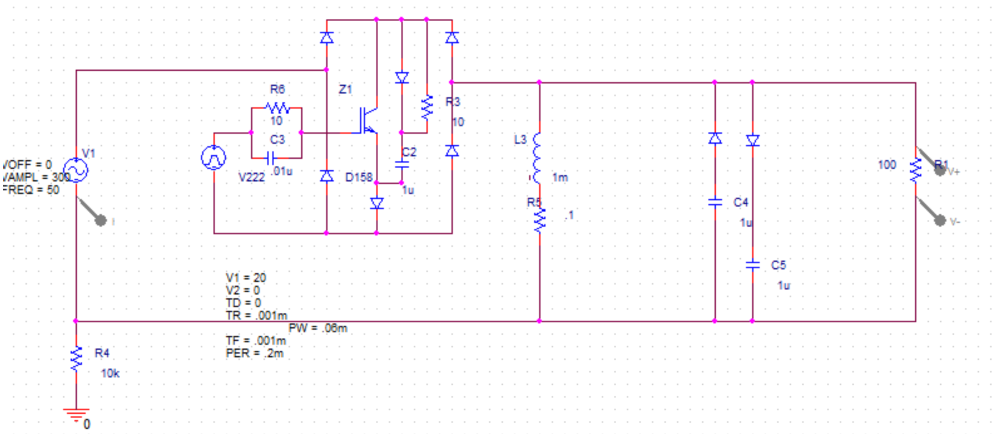


Fig.2.4: Simulation Circuit of proposed Buck-Boost AC-AC Regulator without input filter

The bi-directional switch of Fig.2.4 consists of an IGBT(Z_1) and four diodes. It also has snubber circuit consisting of a diode, a capacitor and a resistor across it as shown in the figure 2.4. At the gate of the IGBT parallel R-C is provided for ensuring fast switching of the IGBT. For performance study following expressions have been used for calculation of output power, input power, input power factor and efficiency of the converter at different duty cycle,

P_{input}= AVG(-I(V1)*V(V1:+,V1:-)

PF= AVG(I(V1)*V(V1:+,V1:-))/ RMS(I(V1)*V(V1:+,V1:-)

P_{output}= AVG(-I(R1)*V(R1:2,R1:1))

Efficiency=$\frac{Poutput}{Pinput}$%

= (AVG(I(R1)*V(R1:1,R1:2))/ AVG(-I(V1)*V(V1:+,V1:-)))*100

The THD of the input current and Spectrum of the input current are obtained from ORCAD simulation output file. Simulation is carried out for duty cycle of 0.3, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65 and 0.7. Typical output-Input voltages, Input current, Spectrum of input current and power factor are shown in Fig 2.5 to 2.16 for different duty cycles. The results are tabulated in table 2.1.

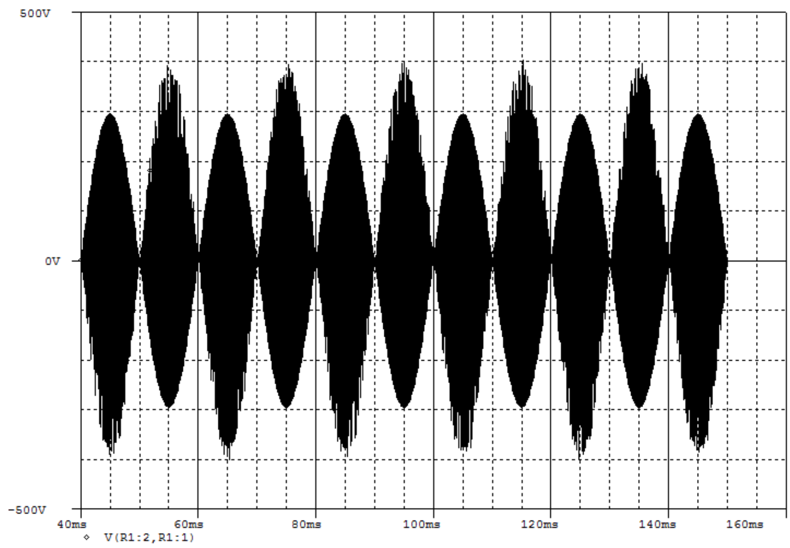


Fig. 2.5: Output voltage for Duty cycle D= 0.3

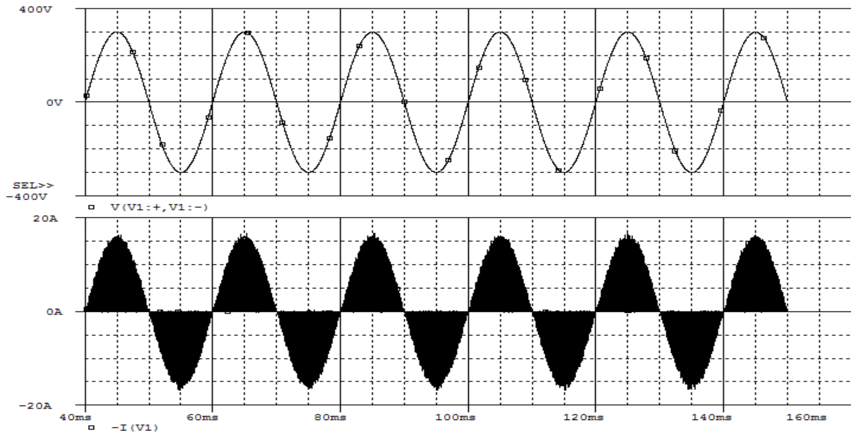


Fig. 2.6: Input voltage and Input current for Duty cycle D=0.3

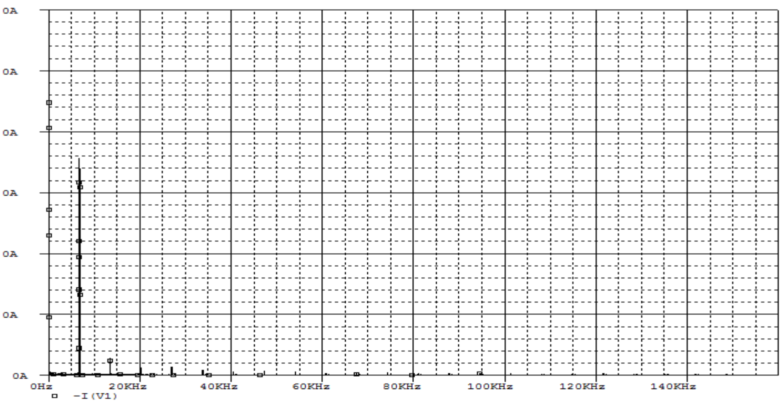


Fig. 2.7: Frequency Spectrum of Input current of fig 2.6

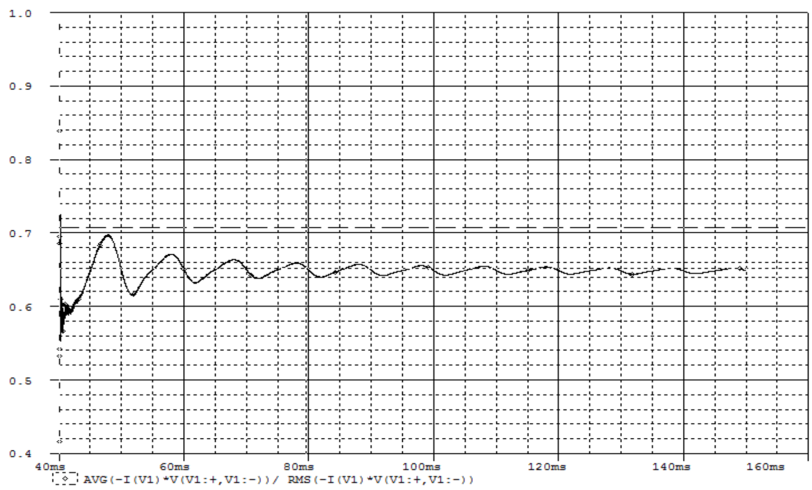


Fig. 2.8: Trace of power factor for duty cycle D=0.3

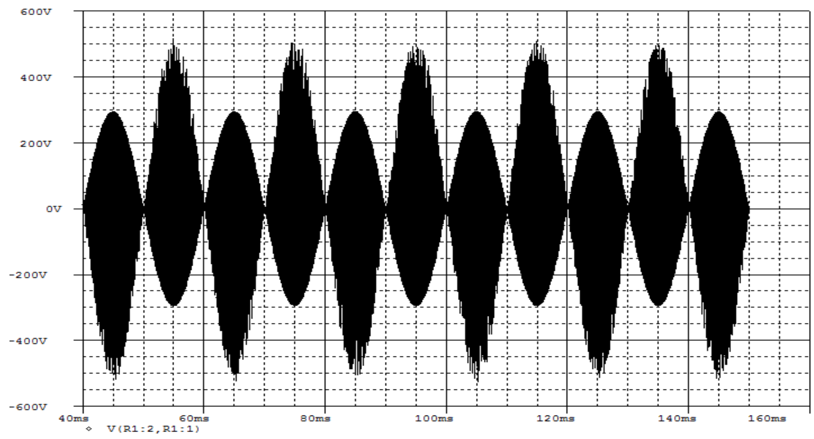


Fig. 2.9: Output voltage for Duty cycle D=0.4

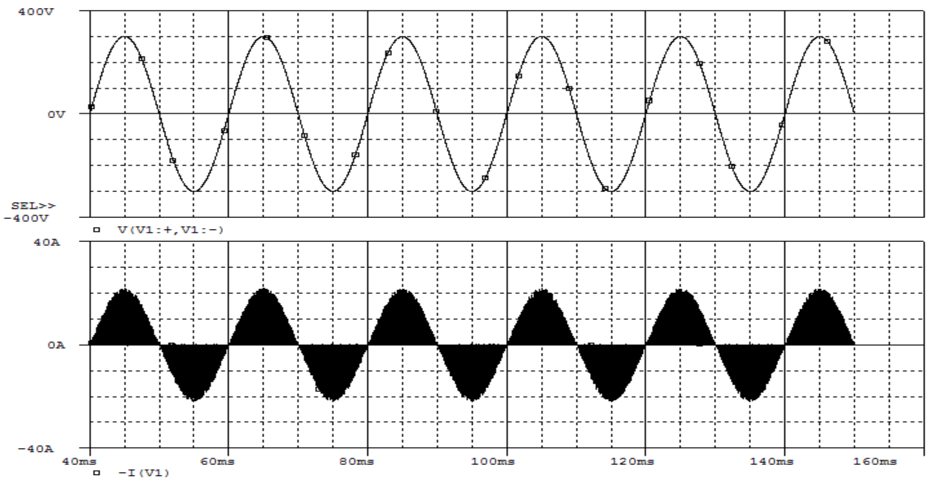


Fig. 2.10: Input voltage and input current for Duty cycle D=0.4

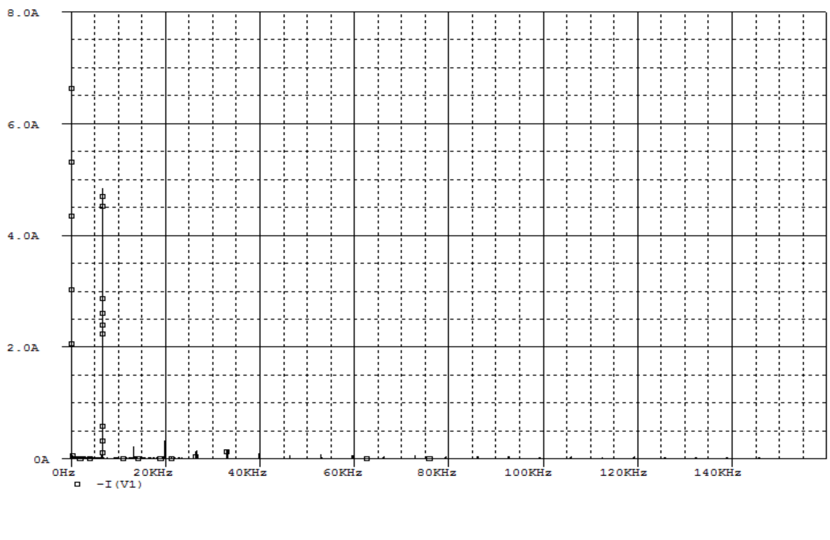


Fig. 2.11: Frequency Spectrum of input current of fig. 2.1

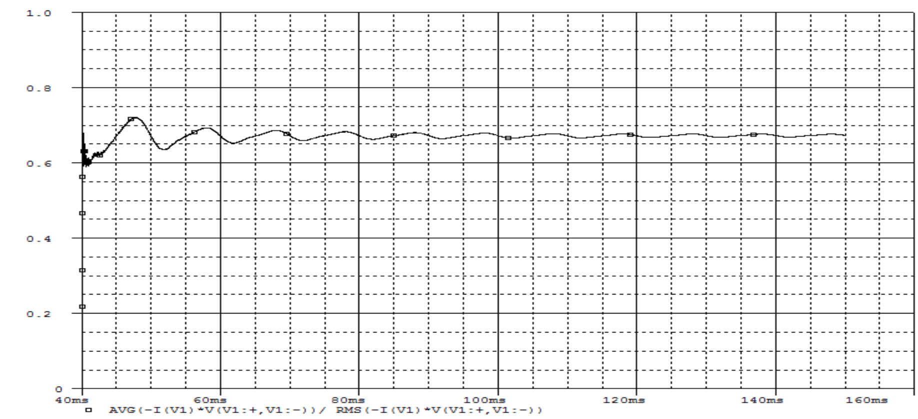


Fig. 2.12: Trace of power factor for duty cycle D=0.4

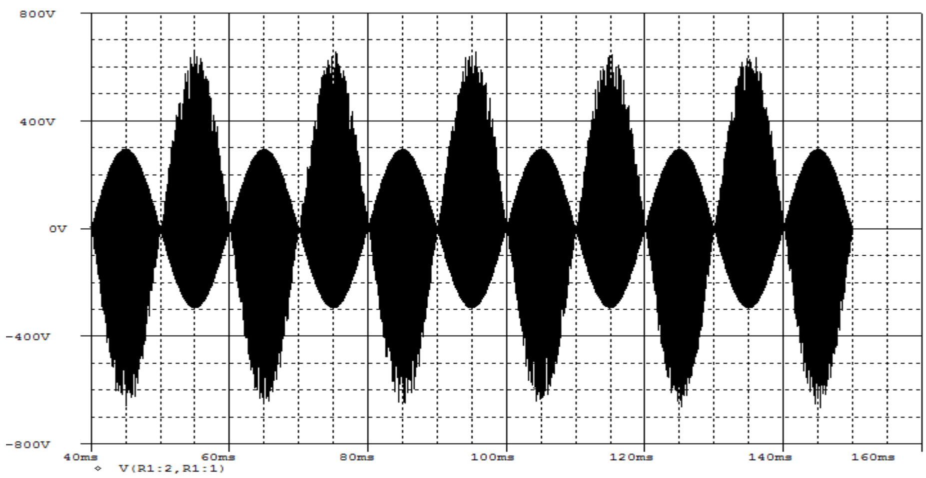


Fig. 2.13: Output voltage for duty cycle D=0.4

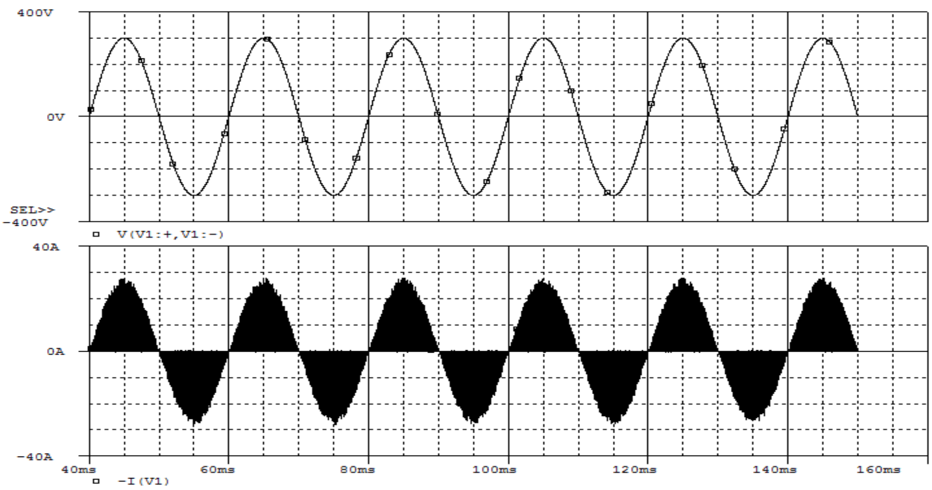


Fig. 2.14: Input volage and input current for Duty cycle D=0.5

2.4.

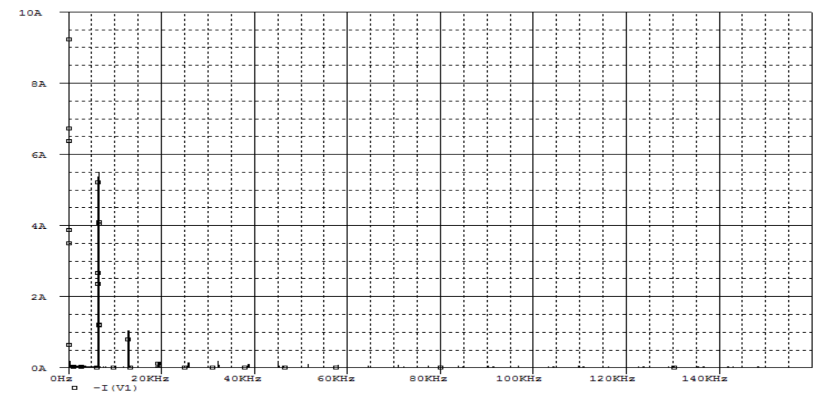


Fig. 2.15: Frequency Spectrum of the input current of fig. 2.14

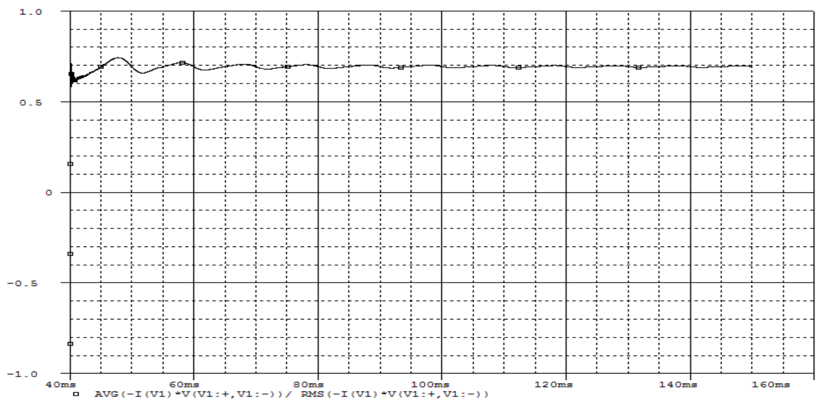


Fig. 2.16: Trace of power factor for duty cycle D=0.5

The total simulation result of the proposed Buck-Boost AC-AC converter without input filter has been shown in table 2.1. The maximum voltage gain of the circuit is 1.68 and the efficiency of the circuit is not satisfactory. Moreover, the input power factor of the proposed circuit is not very good and the input current THD is very high. That is why, we included a small input filter to the proposed Buck Boost AC-AC converter and simulated it. The simulation result of the proposed Buck Boost AC-AC converter with input filter has been shown in figure 2.18 to 2.33 and in table 2.2 to 2.4.

Table 2.1: Performance of Proposed Buck-Boost AC-AC Converter without Input Filter

Duty cycle	Input voltage rms (v)	Output voltage rms (v)	Input current rms (amp)	Output current rms (amp)	Input pf	Input power(kw)	Output power (kw)	Efficiency (%)	THD of input current (%)
0.3	212	184	15	1.8	0.65	2.9	0.68	23	71
0.4	212	219	20	2.2	0.68	4.1	0.96	23.5	63
0.45	212	233	22	2.3	0.68	4.5	1.1	24.2	61
0.5	212	250	25	2.5	0.7	5.2	1.2	23.8	59
0.55	212	273	28	2.7	0.7	5.8	1.5	25.4	52
0.6	212	294	33	2.9	0.7	7	1.7	24.6	48
0.65	212	324	39	3.2	0.73	8.5	2.1	24.6	43
0.7	212	356	43	3.5	0.74	9.5	2.5	26.5	43

2.3.4 Simulation of proposed Buck-Boost ac-ac regulator with input filter:

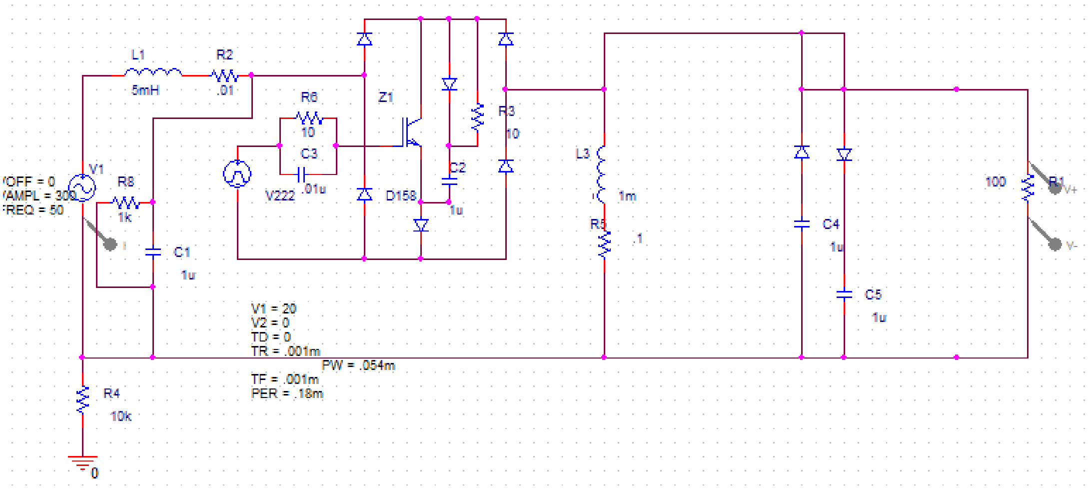


Fig.2.17: Simulation Circuit of proposed Buck-Boost AC-AC Regulator with input filter

In Fig. 2.17 a filter circuit is added at the input to shape the input current. The filter circuit consists of one inductor of 5mh added in series with a resistor of 10 mΩ and one capacitor of 1uf added in parallel with a resistor of 1kΩ. The bi-directional switch of Fig.2.6 consists of an IGBT(Z_1) and four diodes. It also has snubber circuit consisting of a diode, a capacitor and a resistor across it as shown in the figure 2.17. At the gate of the IGBT parallel R-C is provided for ensuring fast switching of the IGBT. For performance study following expressions have been used for calculation of output power, input power, input power factor and efficiency of the converter at different duty cycle,

P_{input}= AVG(-I(V1)*V(V1:+,V1:-))

PF= AVG(I(V1)*V(V1:+,V1:-))/ RMS(I(V1)*V(V1:+,V1:-))

P_{output}= AVG(-I(R1)*V(R1:2,R1:1))

Efficiency= $\frac{Poutput}{Pinput}$%

= (AVG(I(R1)*V(R1:1,R1:2))/ AVG(-I(V1)*V(V1:+,V1:-)))*100

The THD of the input current and Spectrum of the input current are obtained from ORCAD simulation output file. Simulation is carried out for duty cycle of 0.3, 0.4, 0.45, 0.5, 0.55, 0.6, 0.65 and 0.7. Typical output-Input voltages, Input current, Spectrum of input current and traces of Input Power-output power and power factor-efficiency are shown in Fig. 2.18 to 2.33 for different duty cycles. Harmonic components of input current of above as obtained from output file of ORCAD simulation are provided in Table 2.2 and 2.3 respectively. Performance analysis result is provided in table 2.4 and a comparison is made with and without input filter AC-AC controller in table 2.5. The results tabulated in table 2.4 are graphically presented in Fig. 2.34 to 2.38.

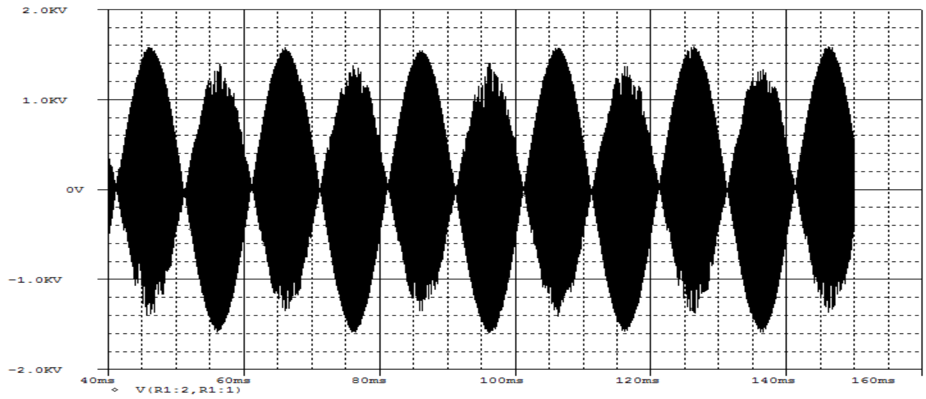


Fig 2.18: Output voltage for duty cycle D=0.3

In Figure 2.18 the output voltage of the buck-boost converter has been shown of Duty cycle 0.3. The average value of the output voltage is zero and the rms value is 268 V so it is an AC voltage.

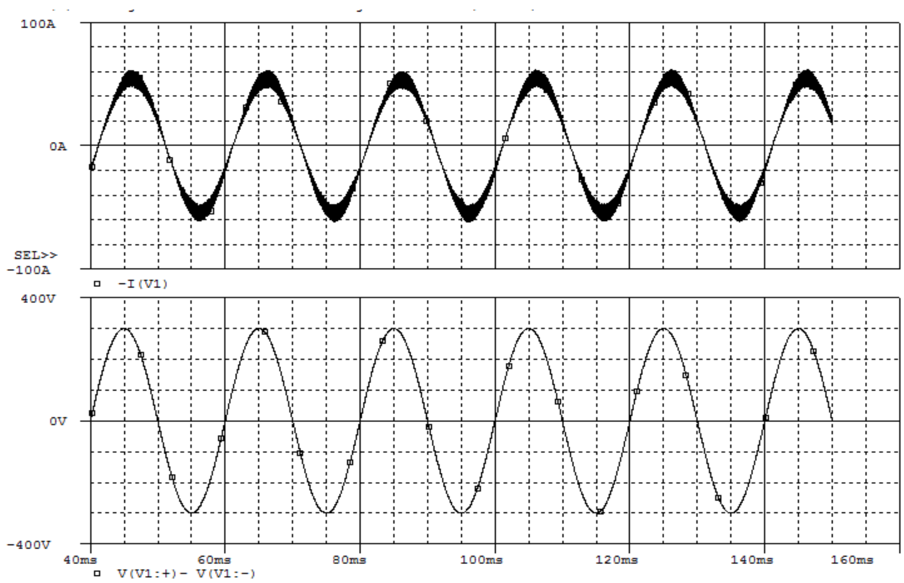


Fig 2.19: Input current and Input voltage for duty cycle D=0.3

From figure 2.19 it has been shown that the input current is continuous sinusoidal wave with a phase difference of 36.87 degree.

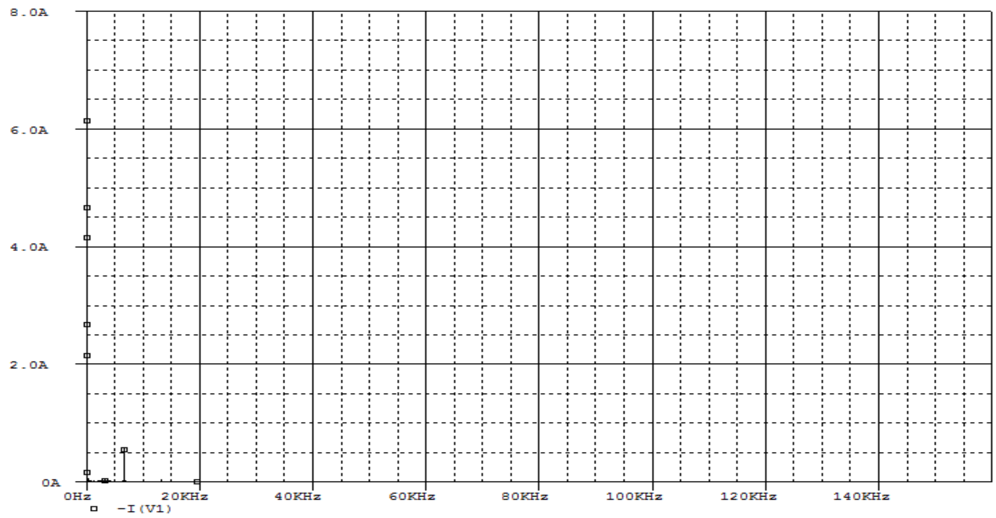


Fig 2.20: Frequency Spectrum of Input current for duty cycle 0.3.

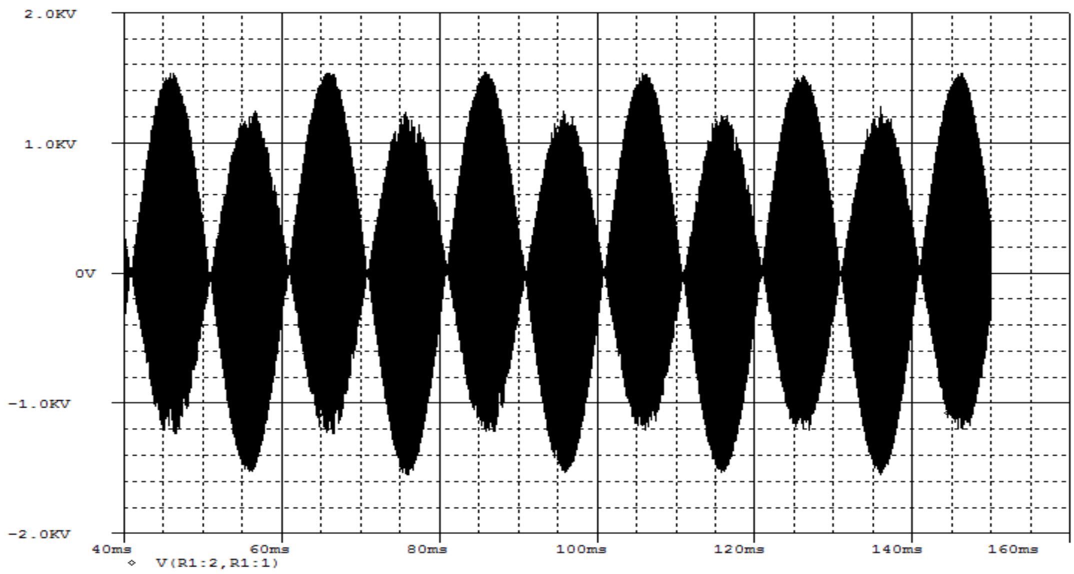


Fig2.21: Output voltage for duty cycle D=0.4

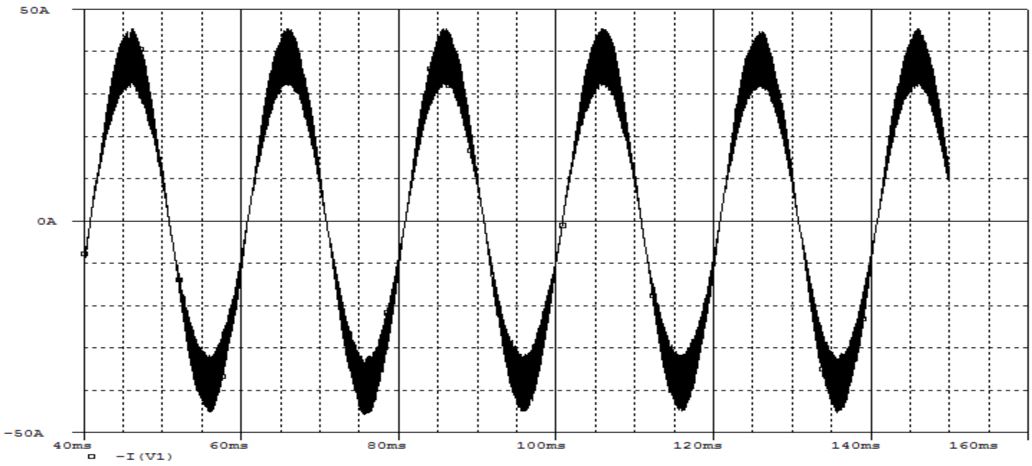


Fig 2.22: Input current for duty cycle D=0.4

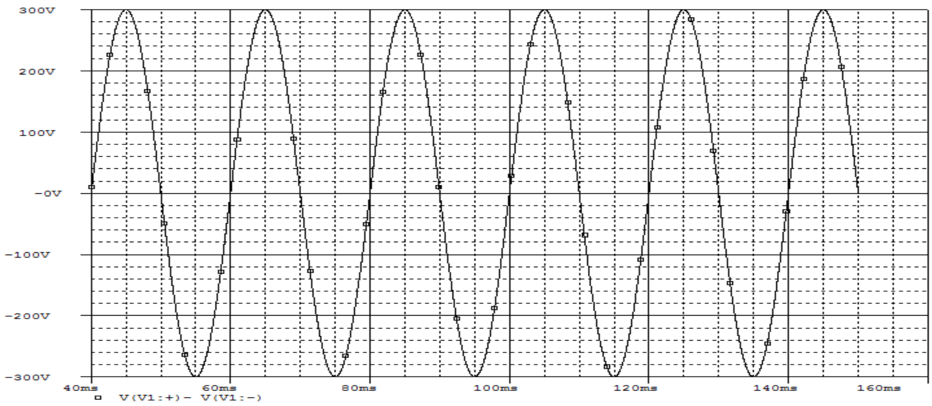


Fig 2.23: Input voltage for duty cycle D=0.4

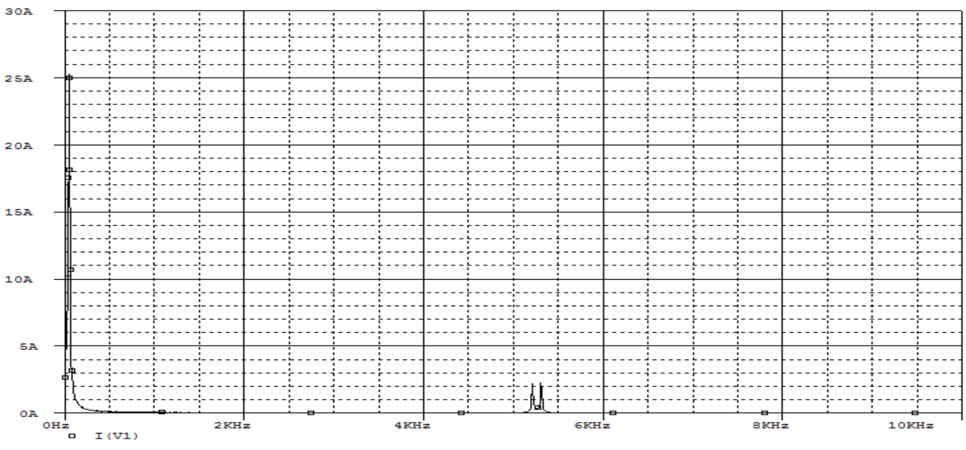


Fig 2.24: Frequency Spectrum of Input current for duty cycle 0.4

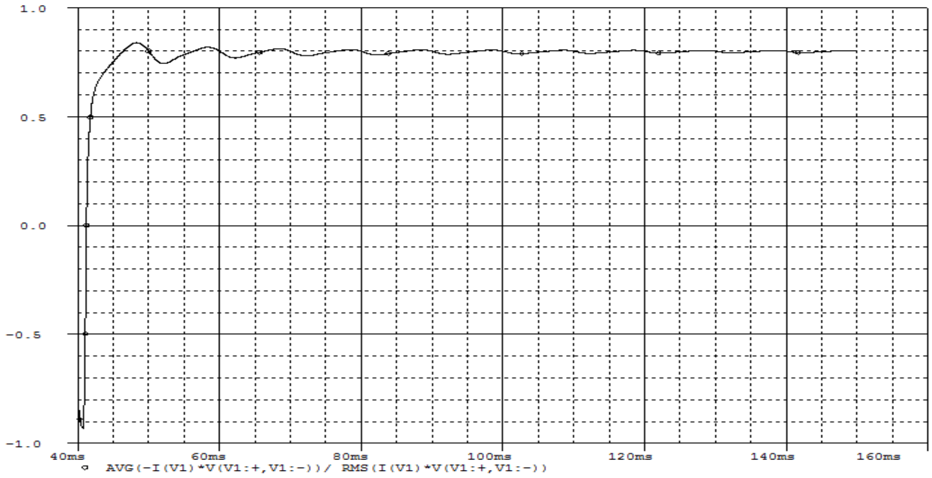


Fig 2.25: Trace of Power factor for duty cycle D=0.4

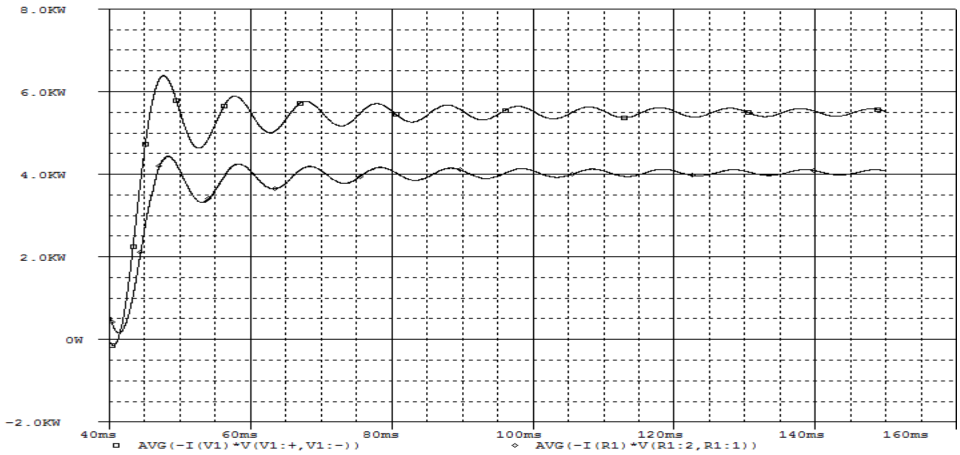


Fig 2.26: Trace of Input and output Power for duty cycle D=0.4

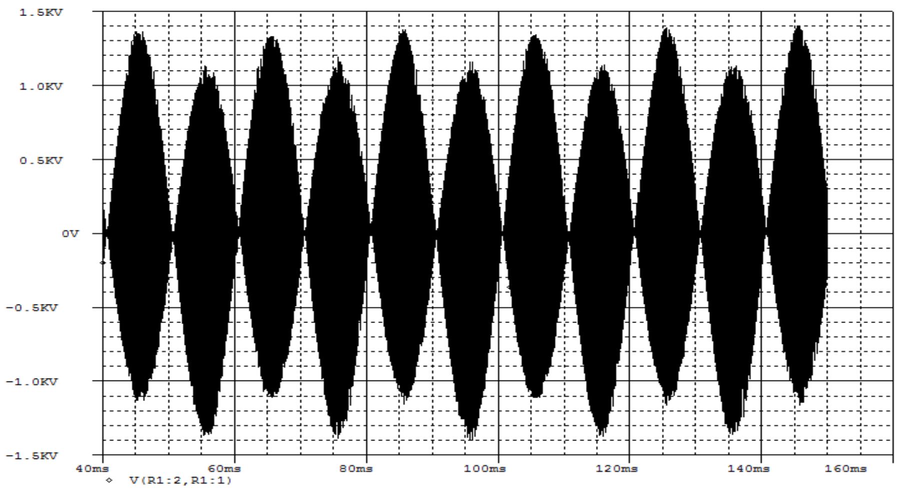


Fig 2.27: Output voltage for duty cycle D=0.5

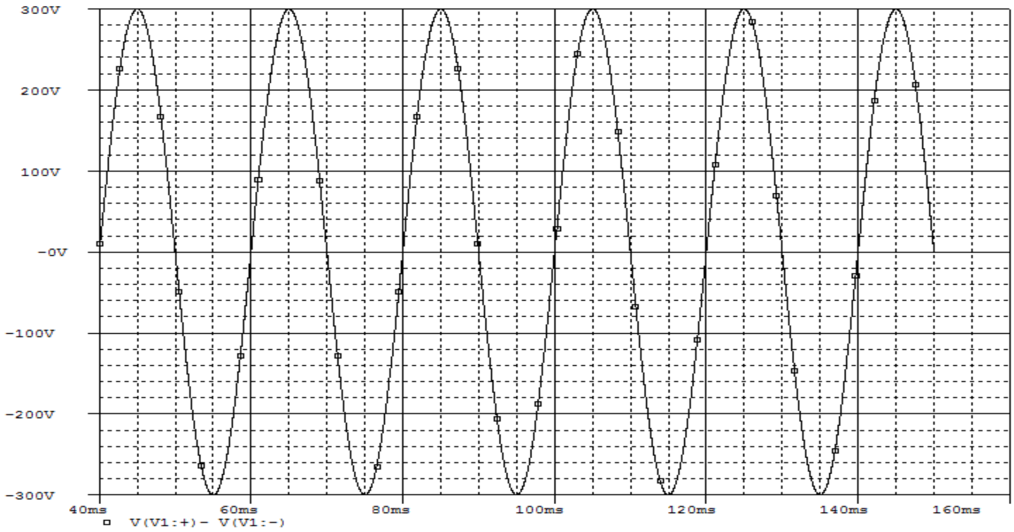


Fig 2.28: Input voltage for duty cycle D=0.5

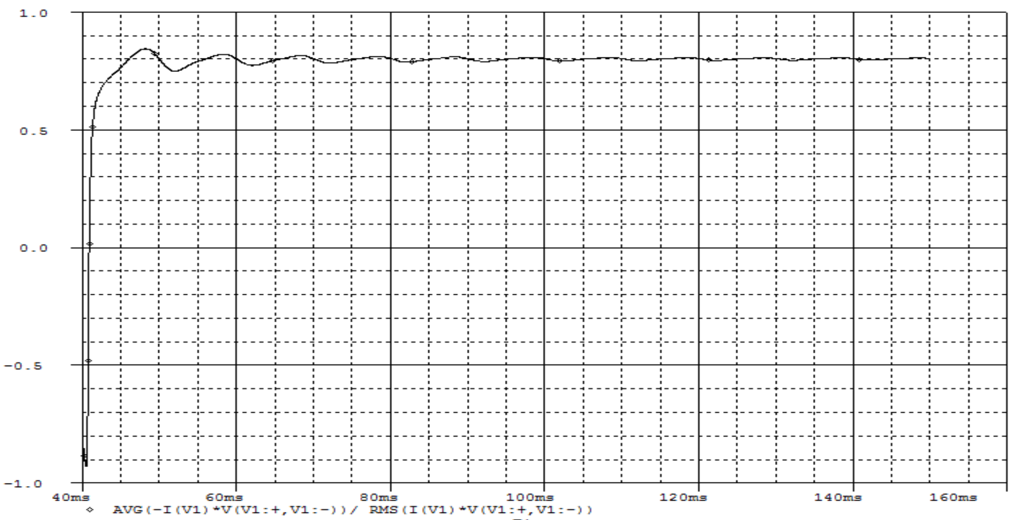


Fig2.29: Trace of Power factor for duty cycle D=0.5

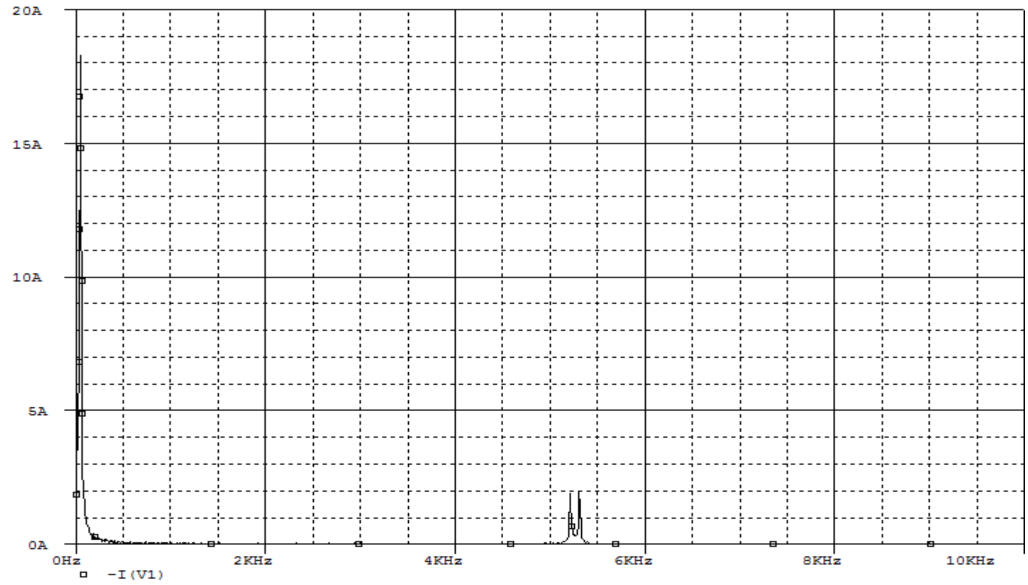


Fig 2.30: Frequency Spectrum of Input current for duty cycle 0.5

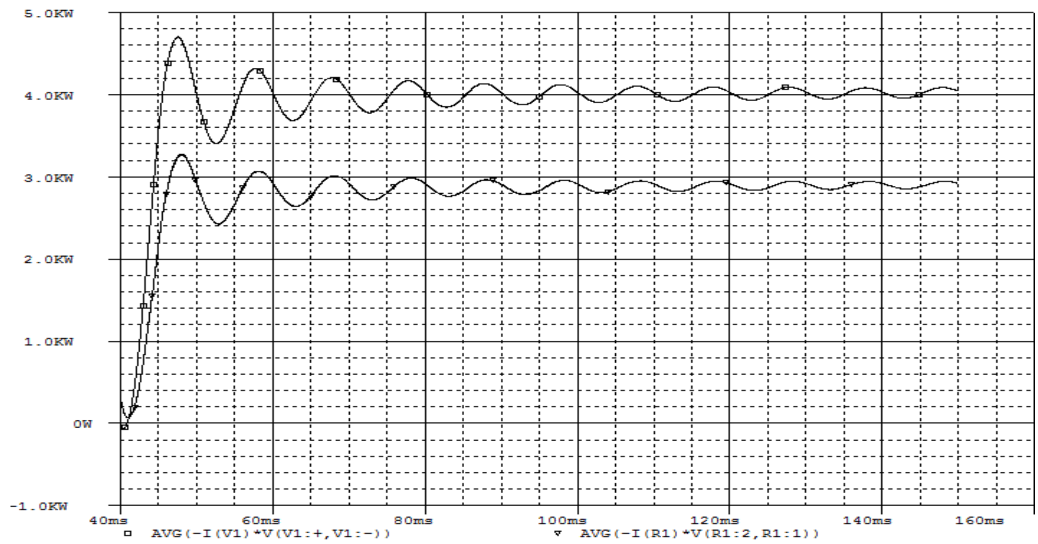


Fig 2.31: Trace of Input and output Power for duty cycle D=0.5

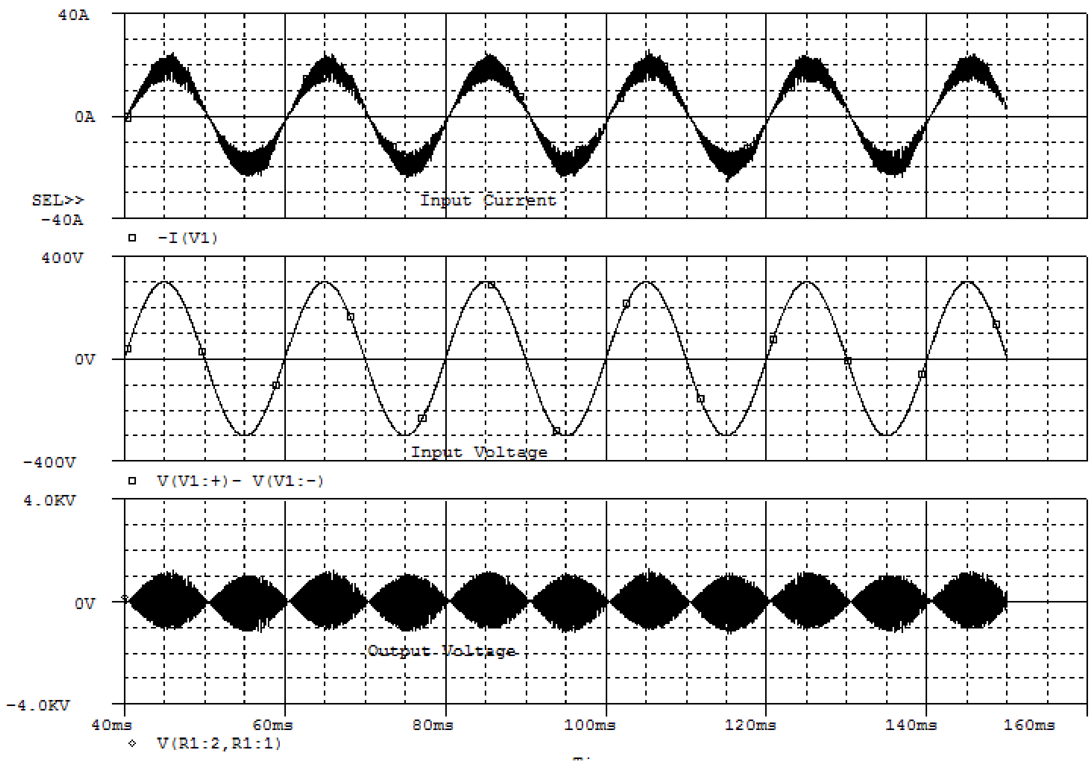


Fig 2.32: Trace of Input current, Input voltage and Output voltage for duty cycle 0.6

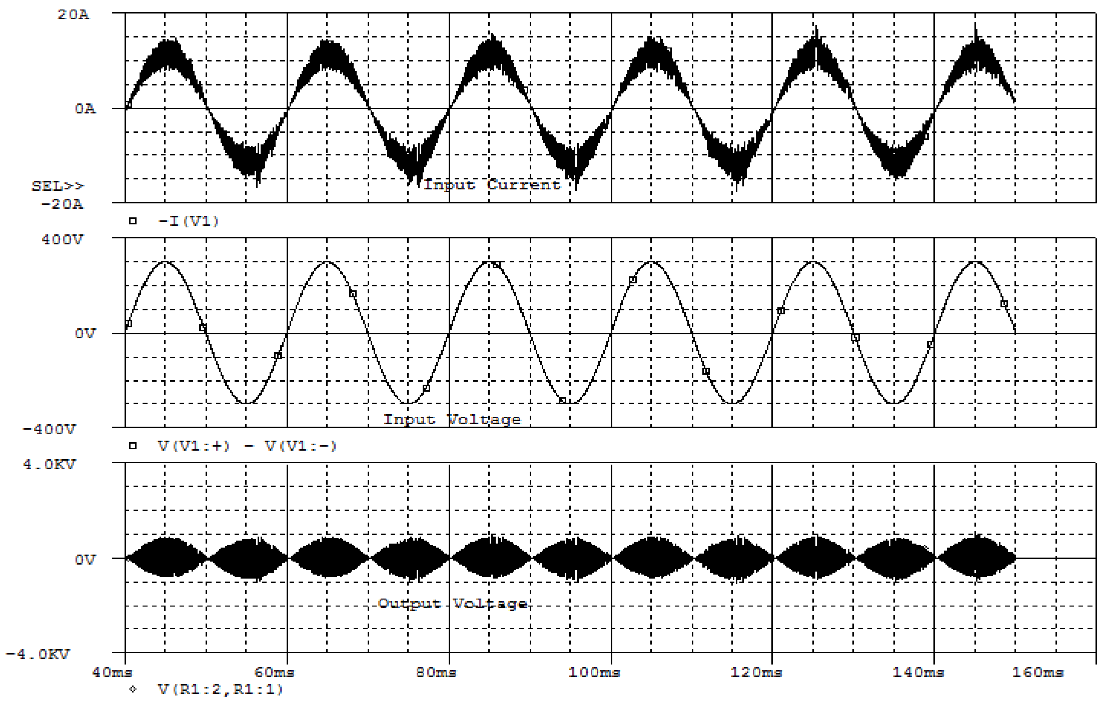


Fig 2.33: Trace of Input current, Input voltage and Output voltage for duty cycle 0.7

Table 2.2: Spectrum of Input current for duty cycle D=0.4

Harmonic Number	Harmonic Frequency	Normalized Magnitude of Fourier Series
1	50	1.0
2	100	.003
3	150	.004
4	200	.0005
5	250	.002
6	300	.003
7	350	.003
8	400	.001
9	450	.003
10	500	.001
11	550	.002
12	600	.001
13	650	.004
14	700	.001
15	750	.003
16	800	.001
17	850	.002
18	900	.00006
19	950	.002
20	1000	.0007
21	1050	.0004
22	1100	.001
23	1150	.003
24	1200	.003
25	1250	.001
26	1300	.002
27	1350	.002
28	1400	.002
29	1450	.011
30	1500	.036
31	1550	.047
32	1600	.052
33	1650	.025
34	1700	.008
35	1750	.004
36	1800	.001
37	1850	.006
38	1900	.001
39	1950	.006
40	2000	.0018

TOTAL HARMONIC DISTORTION = 8.6

Table 2.3: Spectrum of Input current for duty cycle D=0.5

Harmonic Number	Harmonic Frequency	Normalized Magnitude of Fourier Series
1	50	1
2	100	.0008
3	150	.005
4	200	.003
5	250	.001
6	300	.003
7	350	.003
8	400	.001
9	450	.002
10	500	.0005
11	550	.002
12	600	.001
13	650	.001
14	700	.0007
15	750	.002
16	800	.0017
17	850	.002
18	900	.0017
19	950	.001
20	1000	.0004
21	1050	.0009
22	1100	.0007
23	1150	.001
24	1200	.0008
25	1250	.001
26	1300	.003
27	1350	.05
28	1400	.0057
29	1450	.057
30	1500	.0009
31	1550	.0026
32	1600	.002
33	1650	.001
34	1700	.0008
35	1750	.0016
36	1800	.0005
37	1850	.001
38	1900	.001
39	1950	.00058
40	2000	.0017

TOTAL HARMONIC DISTORTION = 8.2

Table 2.4: Performance of Proposed Buck-Boost AC-AC Converter with Input Filter

Duty cycle	Input voltage rms (v)	Output voltage rms (v)	Input current rms (amp)	Output current rms (amp)	Input pf	Input power(kw)	Output power (kw)	Efficiency (%)	THD of input current (%)
0.3	212	268	8.5	2.7	0.8	2.04	1.44	70	8
0.4	212	350	13	3.5	0.82	3.12	2.45	78	8.6
0.45	212	385	16	3.8	0.82	3.84	2.96	77	8
0.5	212	438	19	4.4	0.83	4.56	3.84	84	8.2
0.55	212	476	23	4.8	0.83	5.52	4.53	82	7.8
0.6	212	518	27	5.2	0.83	7.92	6.61	83	7.2
0.65	212	575	33	5.7	0.83	7.92	6.61	83	6.8
0.7	212	702	50	7.0	0.83	12	9.86	82	6.6

Table 2.5: Comparison of Circuit with and without Input filter

Duty Cycle	Proposed Circuit Without Input Filter				Proposed Circuit with Input filter			
	Voltage Gain	THD%	pf	η%	Voltage Gain	THD%	pf	η%
0.3	0.87	71	0.65	23	1.26	8	0.8	70
0.4	1.03	63	0.68	23.5	1.65	8.6	0.82	78
0.45	1.1	61	0.68	24.2	1.82	8	0.82	77
0.5	1.2	59	0.7	23.8	2.1	8.2	0.83	84
0.55	1.3	52	0.7	25.4	2.25	7.8	0.83	82
0.6	1.4	48	0.7	24.6	2.44	7.2	0.83	83
0.65	1.53	43	0.73	24.6	2.7	6.8	0.83	83
0.7	1.68	43	0.74	26.5	3.3	6.6	0.83	82

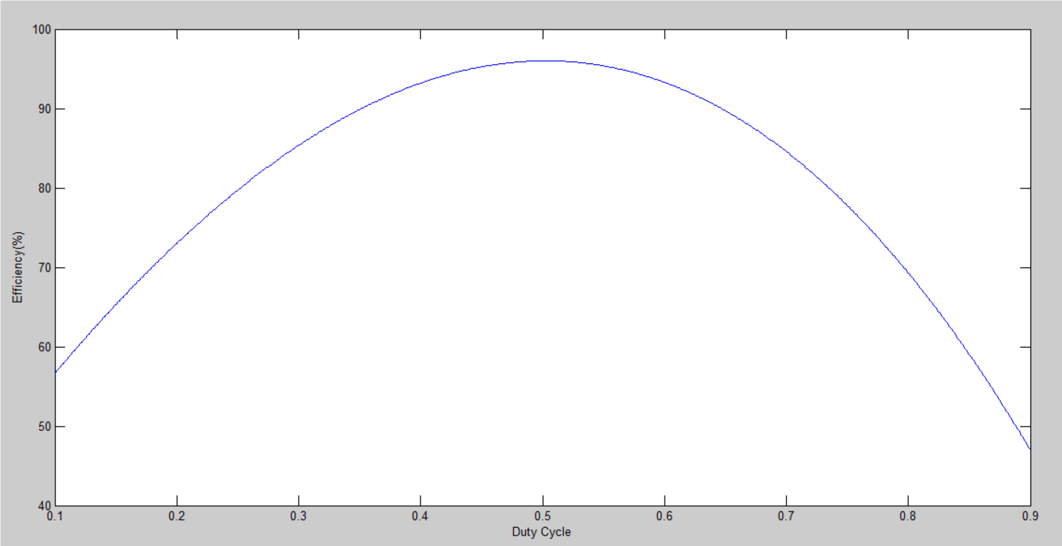


Fig 2.34: Trace of Duty cycle Vs Efficiency for Time Period 0.2 ms and Switching frequency 5 KHz with input filter

In Figure 2.34 it has been shown that when we vary the duty cycle we get a parabolic curve for efficiency. We get efficiency more than 80% for a certain range of duty cycle.

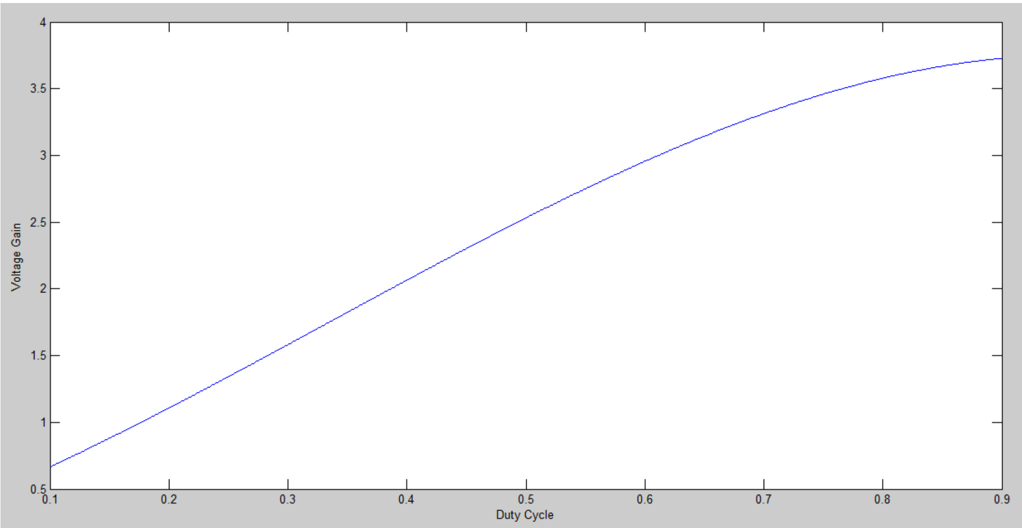


Fig 2.35: Trace of Duty cycle Vs Voltage gain for Time Period 0.2 ms and Switching frequency 5 KHz with input filter

In Figure 2.35 it is depicted that when we increase the Duty Cycle then the Voltage Gain of the buck-boost circuit will increase almost linearly.

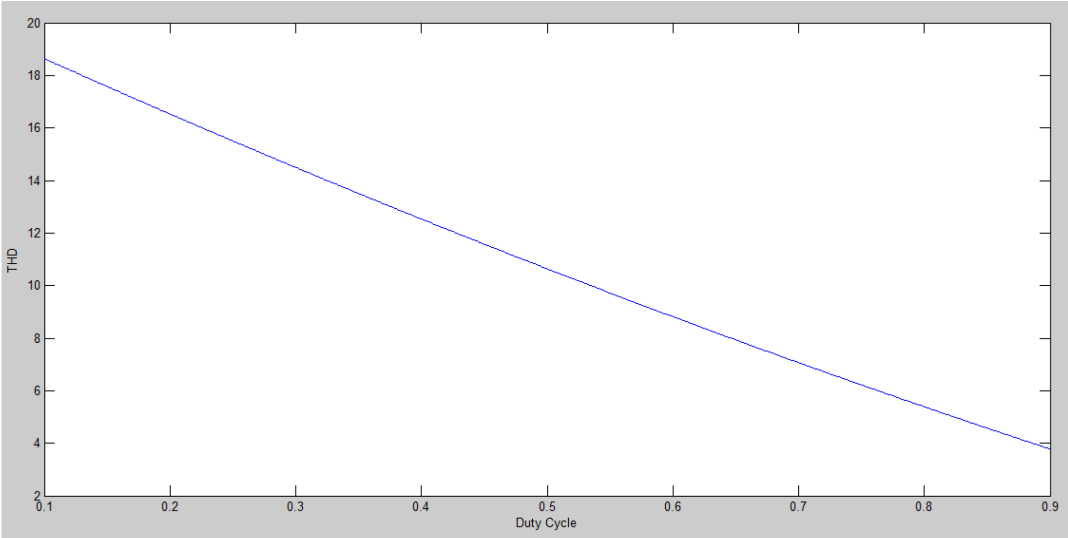


Fig 2.36: Trace of Duty cycle Vs THD for Time Period 0.2, Switching frequency 5 KHz with input filter

In Figure 2.36 it has been shown that for a particular Switching frequency when we increase the Duty Cycle then the Total Harmonic Distortion (THD) of the input current will decrease.

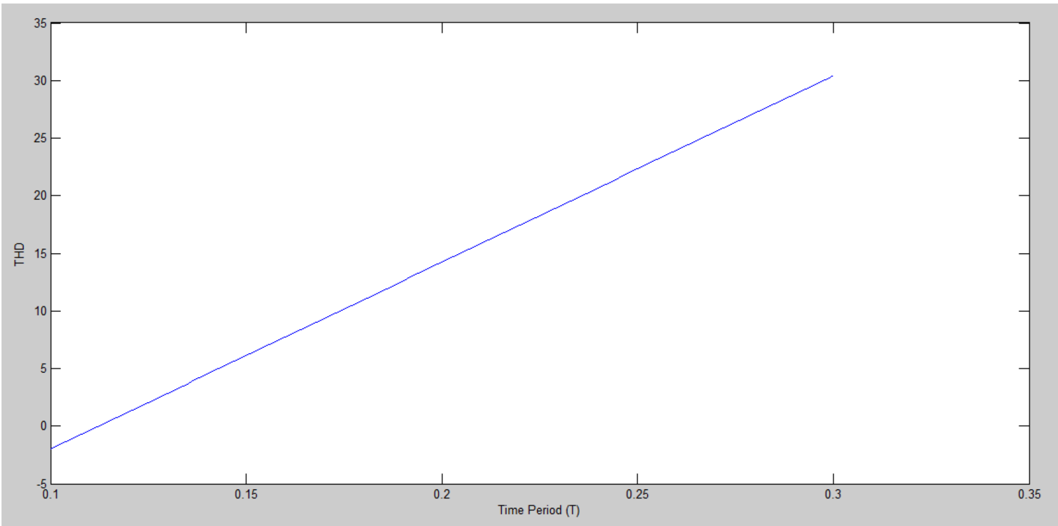


Fig 2.37: Trace of Time period Vs THD for duty cycle 0.5 with input filter

In Figure 2.37 it is depicted that when we increase the Time Period that means if we decrease the Switching frequency then the THD of the input current will increase linearly.

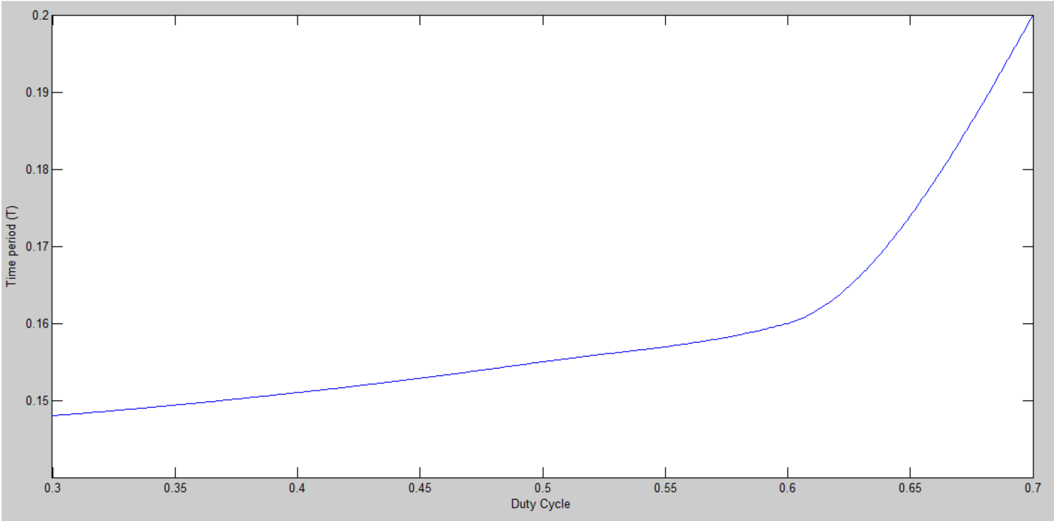


Fig 2.38: Trace of Duty Cycle Vs Time period with input filter

In Figure 2.38 it has been shown the relationship between the Duty Cycle and the Time Period for the average efficiency of 80% and average THD of 7.5 based on the Data Table 2.3. From figure 2.34 we see that only for a selective range of Duty Cycle we get efficiency 80% or above but Duty Cycle outside that selective range efficiency rapidly decreases. Again from figure 2.36 and figure 2.37 we see that for a particular Switching frequency if we increase Duty cycle than THD of the input current decreases and for a particular Duty Cycle if we increase Time period that means if we decrease the Switching frequency than THD of the input current increases respectively. So it is impossible to get a high efficiency with a low THD at the same time for a wide range of Duty cycle. But we can achieve this by following the trace of figure 2.38 for example if the Time period of the pulse is 0.15 ms that is if Switching frequency is 6.66 KHz than we have to select Duty cycle between 0.35 to 0.4 to get an average efficiency of 80% with a THD of 7.5 only, by the same way if the Time period is 0.2 ms that means Switching frequency 5 KHz than we have to select Duty Cycle 0.7 to achieve an efficiency of 80% with a THD of 7.5 only. Again if the Duty cycle is 0.6 than we have to select Switching frequency 6.25 KHz that means Time period as 0.16 ms to achieve an efficiency of 80% with a THD of 7.5. Thus we can control the output voltage of the buck-boost converter by varying the Time period or the Duty cycle.

CHAPTER-3

CONCLUSION AND RECOMMANDATIONS

3.1 CONCLUSION:

AC voltage controllers are widely used to obtain variable AC voltage from fixed AC source. Triacs or thyristors are usually employed as the power control elements of such controllers. Such techniques offer some advantages as simplicity and ability of controlling large amount of power economically. However, delayed firing angle causes discontinuity and plentiful harmonics in load current. This type of pollution decreases the quality of voltage and current of power system and is one of the most important considerations in domestic, industrial and commercial applications today. The harmonic currents generated by the power electronics related equipment flow through the utility system and cause various power quality problems. Most of the power switches have different operating conditions, thus they generate different order and different amplitude harmonics. Voltage sags is one of the most important power quality problems affecting domestic, industrial and commercial customers. Voltage sag is the momentary decrease or increase in the rms voltage magnitude, usually caused by faults or sudden loading on the power system. Equipment used in modern industrial plants is becoming more sensitive to voltage fluctuations as the complexity of the equipment increase. Increasing use of loads supplied by electronic power converters has led to growing problems in the quality of power supplies. Computers, adjustable speed drives and automated manufacturing processes are very susceptible to voltage sags and brief outages. An essential feature of efficient electronic power processing is the use of semiconductor devices in a power supply in switch mode (to achieve low losses) to control the transfer of energy from source to load through the use of pulse width modulated techniques. Inductive and capacitive energy storage elements are used to smooth the flow of energy while keeping losses at a low level. As the frequency of switching increases, the size of the capacitive elements decreases in a direct proportion. Because of their superior performance they are replacing conventional linear power supplies.

In this thesis a new scheme for single phase AC-AC Buck-Boost converter is proposed that has low input current THD and good input power factor. It also has acceptable efficiency for selective range of duty cycle. The proposed circuit does not require any additional control scheme to reduce harmonics. Based on the results obtained from simulation, the proposed circuit can be considered for AC-AC conversion with low harmonic distortion, high input power factor and acceptable range of efficiency. The circuit is investigated and reported with low switching frequency which is desired for its applicability in medium and high power applications. As a starting work towards obtaining a practical light weight, efficient and reliable AC to AC voltage regulator the proposed Buck-Boost converter show promising aspects.

3.2 RECOMMENDATION OF FUTURE WORK:

The proposed AC-AC Buck-Boost regulator may be implemented practically in laboratory in future. For the proposed circuit to obtained a good efficiency we have to vary both the duty cycle and switching frequency manually, but it is also possible to make an automatic control technique which can be done in future.

RFERENCES:

[1] Muhammad H. Rashid "Power Electronics: Circuits, Devices, and Applications" Third Edition

[2] Mohan, Undeland, Robbins "Power Electronics: Converters, Applications and Design"

[3] Bimal K. Bose "Modern Power Electronics and AC Drives"

[4] N.H. Malik, "Analysis and performance characteristics of three-phase thyrode ac voltage controllers" IEEE Trans. On Power Electronics, vol. 4, no. 3, 1989.

[5] Ahmet Altintas, "A Study on Power Quality Improvement in PWM Controlled AC Voltage Controller", Sulayman Demirel Universitesi, Fen Bilimleri Enstiti Dergesi, 12-I, pp.58-64

[6] K.A. Nabil A. Ahmed and M. Sakui, "A new configuration of single phase symmetrical PWM ac chopper voltage controller" IEEE Transactions on industrial electronics, vol. 46, no. 5, pp. 942-953, 1999.

[7] Z. Fedyczak; M. Jankowshi; P. Szczesniak; "A comparison of basic properties of single phase serial ac voltage controllers using bipolar pwm chopper" European Conference on Power Electronics and Applications, Dresden, 2005.

[8] Sasitharan Subramanian and Mahesh Kumar Mishra, " Interphase AC-AC Topology for Voltage Sag Supporter" IEEE Transactions on power Electronics, vol. 25, no. 2, February 2010.

[9] M.E. Balci, M.H. Hocaoglu. "Efficts of Source voltage harmonic distortion on power factor compensation in triac controlled ac chopper circuits" IEEE PEDS, 1119-1204. 2005

[10] Do-Hyun Jang; Gyu-Ha Choe, "Step-up/down ac voltage regulator using transformer with tap changer and PWM AC chopper" IEEE Transaction on Industrial Electronics,vol.45, no. 6,pp.905-911, 1998.

[11] G. Zinoviev; M. Ganin; E. Levin; A. Obufov; V. Popov; " New class of buck-boost ac-ac frequency converters and voltage controllers" IEEE Trans. On Power Electronics, vol.11,no. 2, pp.311-317,2000.

[12] L.C. Fang Zheng Peng and F. Zhang, "Simple topologies of pwm ac-ac converters" IEEE power Electronics Letters, col. 1 no. 1, 2003.

[13] M. Narendra Kumar, P. Sujata, K.S.R. Anjaneyulu, "Experimental Verification of four switch PWM AC chopper fed single phase Induction Motor", Journal of Theoritical and Applied International Technology,2005-2009 JATIT ,pp. 13-18.

[14] Ahmet ALTINTAS, "A new method for power quality improvement in classical AC/AC voltage controllers using PWM technique", Scientific Research and Essays vol. 5(10), May 18, 2010, pp. 1075-1083