A

PROJECT REPORT ON

“POWER FACTOR CORRECTION USING BOOST CONVERTER FOR BLDC MOTOR”

GUIDED BY

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Gujarat Technological University, Ahmedabad

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BACHELOR OF ELECTRICAL ENGINEERING

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ABSTRACT

Power Factor, the ratio between the real or average power and the apparent power forms a very essential parameter in power system. It is indicative of how effectively the real power of the system has been utilized. With rapid development in power semiconductor devices, the usage of power electronic systems has expanded to new and wide application range that include residential, commercial, aerospace and many others. Power electronic interfaces e.g. switch mode power supplies (SMPS) have proved to be superior over traditional linear power supplies. However, their non-linear behaviour puts a question mark on their high efficiency. The current drawn by the SMPSs from the line is distorted resulting in a high Total Harmonic Distortion(THD) and low Power Factor(PF).Individually, a device with harmonic current does not pose much serious problem however when used on a massive scale the utility power supply condition could be detoriated. Other adverse effects on the power system include increased magnitudes of neutral currents in three-phase systems, overheating in transformers and induction motors etc. Hence, there is a continuous need for power factor improvement and reduction of line current harmonics. Development of new circuit topologies and control strategies for Power Factor Correction (PFC) and harmonic reduction has become still more essential with the introduction of strong technical IEC standards.

This project aims to develop a circuit for PFC using active filtering approach by implementing two boost converters arranged in parallel. It shall be based on an optimised power sharing strategy to improve the current quality and at the same time reduce the switching losses. The work initially involves simulation of basic power electronic circuits and the analysis of the current and voltage waveforms. It starts with simple circuits with a gradual increase incomplexity by inclusion of new components and their subsequent effect on the current and voltage waveforms. We focus on the objective of improving the input current waveform i.e. making it sinusoidal by tuning the circuits. All the simulation work is done in MATLAB Simulink environment and the results are attached.

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LIST OF SYMBOLS, ABBREVIATION AND NOMENCLATURE

Power Factor	PF
Metal Oxide Semiconductor Field Effect Transistor	MOSFET
Switch Mode Power Supply	SMPS
Diode	D
Capacitor	C
Inductor	L
Input current	I_{in}
Input Voltage	V_{in}
Power Factor Correction	PFC
Switching Period	T
Pulse Width Modulation	PWM
Over Voltage Protection	OVP
Under Voltage Lockout	UVLO
Zero Current Detection	ZCD
Integrated Circuit	IC
Power Factor	$\cos\phi$
Ground	GND
Multiplier	MULT

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CHAPTER 1
INTRODUCTION

1.1 POWER FACTOR:

Power factor is defined as the cosine of the angle between voltage and current in an ac circuit. There is generally a phase difference Ø between voltage and current in an ac circuit. cosØ is called the power factor of the circuit. If the circuit is inductive, the current lags behind the voltage and power factor is referred to as lagging. However, in a capacitive circuit, current leads the voltage and the power factor is said to be leading. In a circuit, for an input voltage V and a line current I,

VIcos Ø - the active or real power in watts or kW.
VIsinØ - the reactive power in VAR or kVAR.
VI - the apparent power in VA or kVA.

Power Factor gives a measure of how effective the real power utilization of the system. It is a measure of distortion of the line voltage and the line current and the phase shift between them.

$$\textbf{Power Factor} = \frac{\text{[illegible]}}{\text{[illegible]}}$$

Where, the apparent power is defined as the product of RMS value of voltage and current.

Power factor is an important measurement for two main reason , First, an overall power factor to of less than 1 means that an electrical supplies has to provide more generating capacity than actually is required.

For example, consider an office building drawing 200A at 400V. The supply transformer and back up UPS must be rated at 200A, 400V and 80KVA.but if the power factor of the load is only 0.6 then only 80KVA*0.6=48KVA of real power are being consumed. In other words, if the power factor were, the supply capacity (transformers cable, switchgear, UPS) can be considering smaller.

Since power factor is defined as W/VA, power factor is measured using a wattmeter. The wattmeter will measure true power and usually provide a direct measurement of volt-amperes as well as PF.

Linear loads with low power factor (such as induction motors) can be corrected with a passive network of capacitors or inductors. Non-linear loads, such as rectifiers, distort the current drawn from the system. In such cases, active or passive power factor correction may be used to counteract the distortion and raise the power factor. The devices for correction of the power factor may be at a central substation, spread out over a distribution system, or built into power-consuming equipment.

Benefits of power factor correction:

- Power factor correction reduces the reactive power in a system. Power consumption and thus power costs drop in proportion.
- Effective installation use an improved power factor means that an electrical installation works more economically. (Higher effective power for the same apparent power.)
- Improve voltage quality.
- Optimum cable dimensioning cable cross-section can be reduced with improvement of power factor (less current). In existing installation for instance, extra or higher power can be transmitted.
- Smaller transmission losses the transmission and switching devices carry less current, i.e only the effective power, meaning that the ohmic losses in the leads are reduced.

1.2 LINEAR SYSTEMS:

In a linear system, the load draws purely sinusoidal current and voltage, the current and voltage; hence the power factor is determined only by the phase difference between voltage and current.

i.e. PF=cosθ

In a purely resistive AC circuit, voltage and current waveforms are in step (or in phase), changing polarity at the same instant in each cycle. All the power entering the load is consumed. Where reactive loads are present, such as with capacitors or inductors, energy storage in the loads result in a time difference between the current and voltage waveforms. A linear load does not change the shape of the waveform of the current, but may change the relative timing (phase) between voltage and current

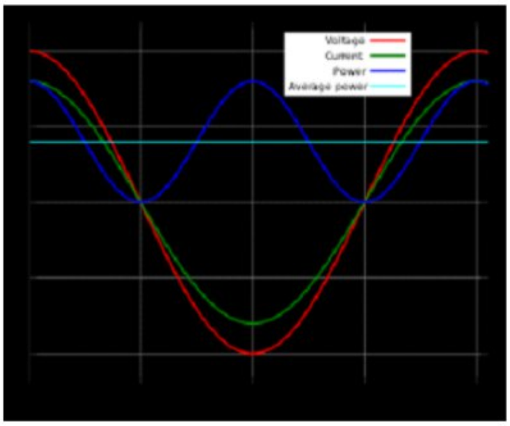


Fig.1.1: Purely resistive A.C Circuit

Inductive loads such as transformers and motors (any type of wound coil) consume reactive power with current waveform lagging the voltage. Capacitive loads such as capacitor banks or buried cable generate reactive power with current phase leading the voltage. Both types of loads will absorb energy during part of the AC cycle, which is stored in the device's magnetic or electric field, only to return this energy back to the source during the rest of the cycle.

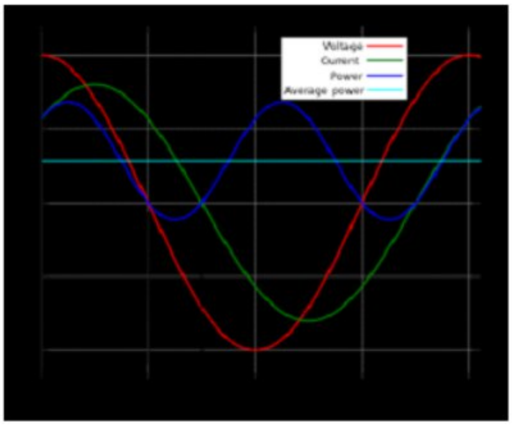


Fig.1.2: Inductive load waveform

1.3 NON-LINEAR CIRCUITS:

A non-linear load on a power system is typically a rectifier (such as used in a power supply), or some kind of arc discharge device such as a fluorescent lamp, electric welding machine, or arc furnace. Because current in these systems is interrupted by a switching action, the current contains frequency components that are multiples of the power system frequency. Distortion power factor is a measure of how much the harmonic distortion of a load current decreases the average power transferred to the load.

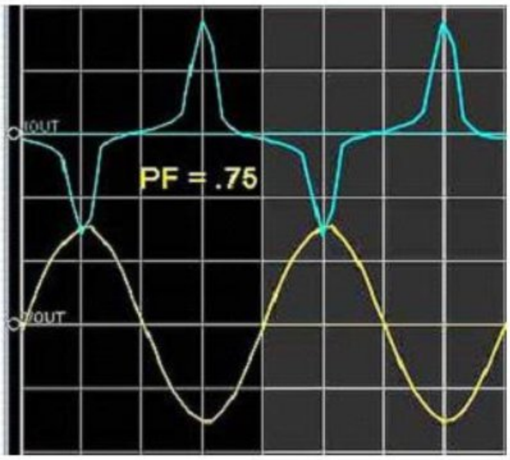


Fig.1.3: Voltage and current waveforms for Non-Linear loads

1.3.1 NON-SINUSOIDAL COMPONENETS:

Non-linear loads change the shape of the current waveform from a sine wave to some other form. Non-linear loads create harmonic currents in addition to the original (fundamental frequency) AC current. Filters consisting of linear capacitors and inductors can prevent harmonic currents from entering the supplying system. In linear circuits having only sinusoidal currents and voltages of one frequency, the power factor arises only from the difference in phase between the current and voltage. This is "displacement power factor". The concept can be generalized to a total, distortion, or true power factor where the apparent power includes all harmonic components. This is of importance in practical power systems that contain non-linear loads such as rectifiers, some forms of electric lighting, electric arc furnaces, welding equipment, switched-mode power supplies and other devices. A typical multimeter will give incorrect results when attempting to measure the AC current drawn by a non-sinusoidal load; the instruments sense the average value of a rectified waveform. The average response is then calibrated to the effective, RMS value. An RMS sensing multimeter must be used to measure the actual RMS currents and voltages (and therefore apparent power). To measure the real power or reactive power, a watt meter designed to work properly with nonsinusoidal currents must be used.

1.3.2 DISTORTION POWER FACTOR:

The distortion power factor describes how the harmonic distortion of a load current decreases the average power transferred to the load.

$$\text{Distortion power factor} = \frac{1}{\sqrt{1 + THD_i^2}} = \frac{I_{1,rms}}{I_{rms}}$$

THD_i is the total harmonic distortion of the load current. This definition assumes that the voltage stays undistorted (sinusoidal, without harmonics). This simplification is often a good approximation in practice. is the fundamental component of the current and is the total current - both are root mean square-values. The result when multiplied with the displacement power factor (DPF) is the overall, true power factor or just power factor (PF):

$$PF = \cos\varphi \frac{I_{1,rms}}{I_{rms}}$$

CHAPTER 2
HARMONICS

2.1 HARMONICS:

Switching converters of all types produce harmonics because of the non-linear relationship between the voltage and current across the switching device. Harmonics are also produced by -conventional equipment including:

1. Power generation equipment (slot harmonics).
2. Induction motors (saturated magnetics).
3. Transformers (over excitation leading to saturation)
4. Magnetic-ballast fluorescent lamps (arcing) and
5. AC electric arc furnaces. All these devices cause harmonic currents to flow and some devices, actually, directly produce voltage harmonics.

2.2 AFFECTS OF HARMONICS ON POWER QUALITY:

The contaminative harmonics can decline power quality and affect system performance in several ways:

1. Conductor loss and iron loss in transformers increase due to harmonics decreases the transmission efficiency and causes thermal problems.
2. The odd harmonics in a three phase system overload of the unprotected neutral conductor.
3. High peak harmonic currents may cause automatic relay protection devices to mis-trigger.
4. Excessive current in the neutral conductor of three-phase four-wire systems, caused by odd triple-n current harmonics (triple-*n*: 3^{rd}, 9^{th}, 15^{th}, etc.). This leads to overheating of the neutral conductor and tripping of the protective relay.
5. Telephone interference and errors in metering equipment.
6. The line RMS current harmonics do not deliver any real power in watts to the load, resulting in inefficient use of equipment capacity (i.e. low power factor).
7. Harmonics could cause other problems such as electromagnetic interference to interrupt communication, degrading reliability of electrical equipment, increasing product defective ratio, insulation failure, audible noise etc.

2.3 PROBLEM OF POWER FACTOR IN SINGLE PHASE LINE COMMUTATED RECTIFIERS:

Classical line commutated rectifiers suffer from the following disadvantages:

1. They produce a lagging displacement factor w.r.t the voltage of the utility.
2. They generate a considerable amount of input current harmonics.

These aspects negatively influence both power factor and power quality. The massive use of single-phase power converters has increased the problems of power quality in electrical system.

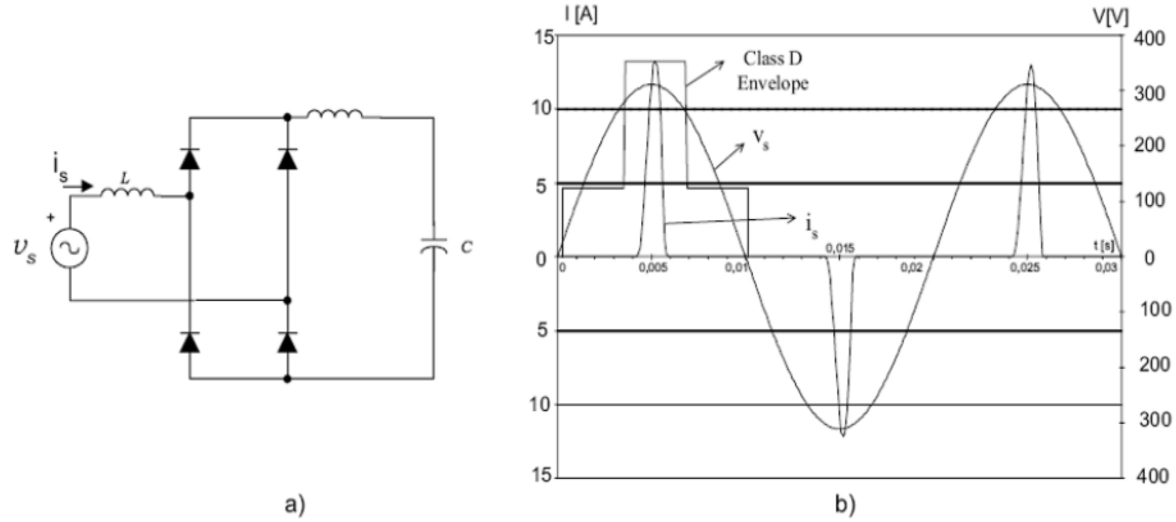


Fig.2.1: Single phase rectifier (a) circuit (b) waveforms of input voltage and current

2.4 STANDARDS FOR HARMONICS IN SINGLE PHASE RECTIFIERS:

The relevance of the problems originated by harmonics in single-phase line-commutated rectifiers has motivated some agencies to introduce some restrictions to these converters. Standardization activities in this area have been carried out for many years. As early as 1982, the International Electro-technical Committee-IEC published its standard IEC 555-2, which was also adopted in 1987 as European standard EN 60555-2, by the European Committee for Electro technical Standardization - CENELEC. Standard IEC 555-2 has been replaced in 1995 by standard IEC 1000-3-2, also adopted by CENELEC as European standard EN 61000-3-2.

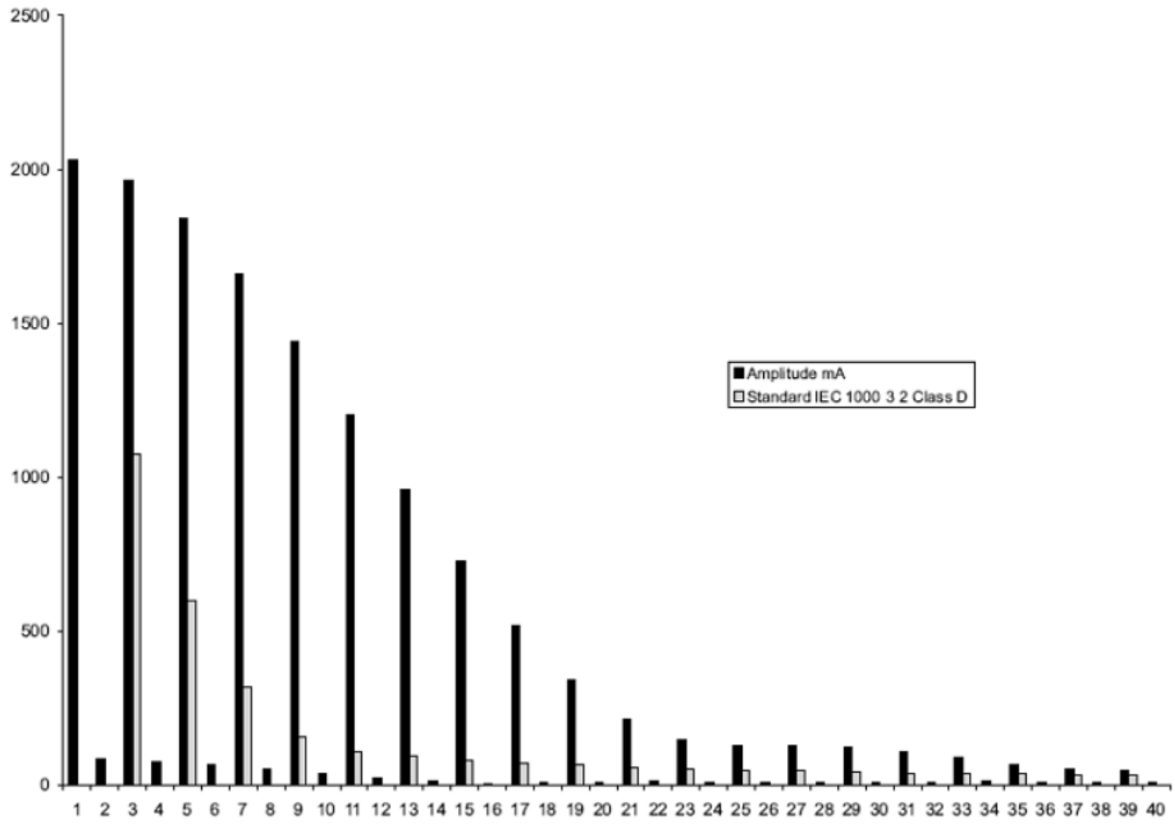


Fig.2.2: Input current harmonics produced by a single-phase diode bridge rectifier compared against IEC standards

Standard IEC 1000-3-2:

1. It applies to equipment with a rated current up to and including 16*Arms* per phase which is to be connected to 50Hz or 60 Hz, 220-240*Vrms* single-phase or 380-415*Vrms* three-phase mains.
2. Electrical equipments are categorized into four classes (A, B, C, and D), for which specific limits are set for the harmonic content of the line current.
3. These limits do not apply for the equipment with rated power less than 75W, other than lighting equipment.

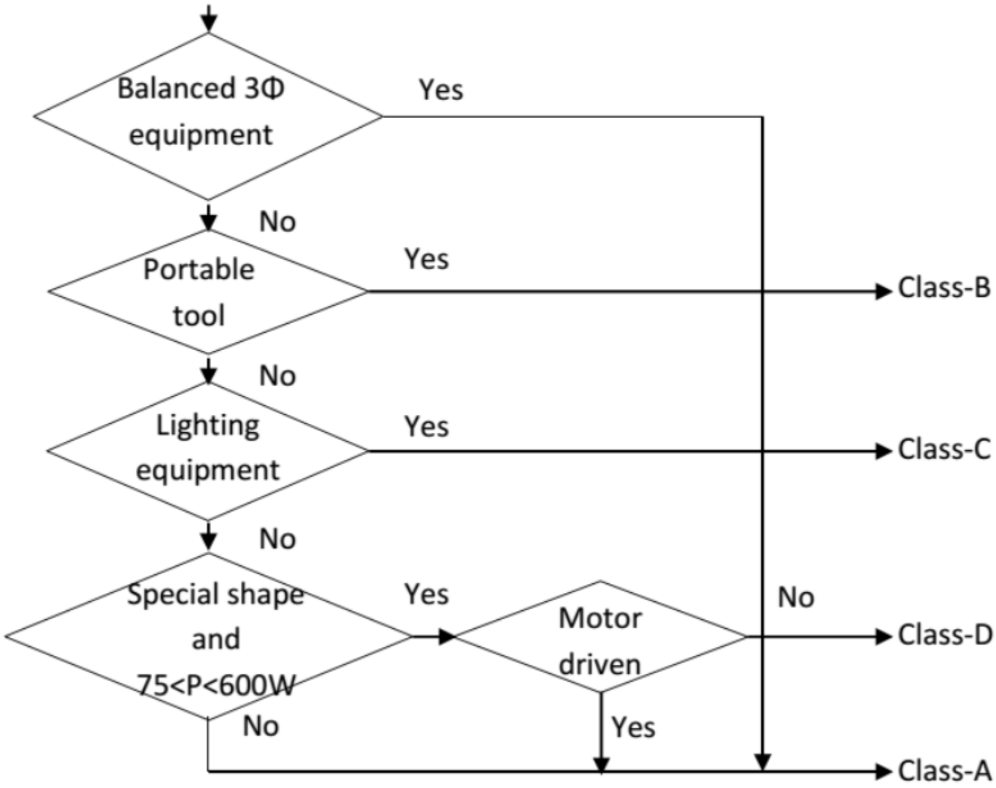


Fig.2.3: Flowchart showing the Classification of equipment under Standard IEC 1000-3-2

- CLASS-A:

It includes balanced three-phase equipments, household appliances, excluding the equipment identified as class-D. Equipment not specified in one of the other three classes should be considered as class-A equipment.

- CLASS-B:

It includes portable tools, and non-professional arc welding equipment.

- CLASS-C:

It includes lighting equipment (except for dimmers for incandescent lamps, which belong to class-A).

- CLASS-D:

Equipment with special line current shape i.e. includes equipment having an active input power less than or equal to 600w, of the following types:

1. Personal computers.
2. Personal computer monitors.
3. Television receivers.

The classification can also be represented using the flowchart: Fig: 2.3

CHAPTER 3
BOOST CONVERTER

3.1 GENERAL:

A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

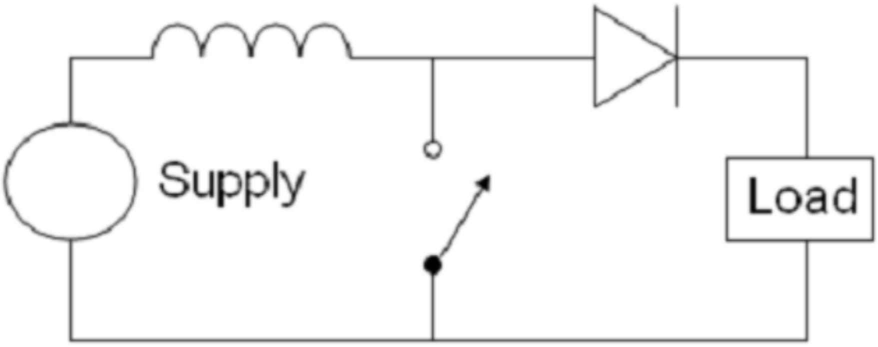


Fig.3.1: The basic schematic of a boost converter.

The switch is typically a MOSFET, IGBT, or BJT. Power can also come from DC sources such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it "steps up" the source voltage. Since power must be conserved, the output current is lower than the source current.

3.2 CIRCUIT ANALYSIS:

3.2.1 Operating Principle:

The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage.

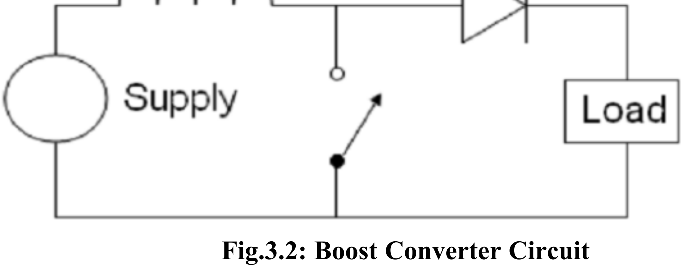


Fig.3.2: Boost Converter Circuit

When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.
The basic principle of a Boost converter consists of 2 distinct states

- in the On-state, the switch S (see figure 3.2) is closed, resulting in an increase in the inductor current;
- in the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.
- The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

3.3 WORKING PRINCIPLE OF A BOOST CONVERTER:

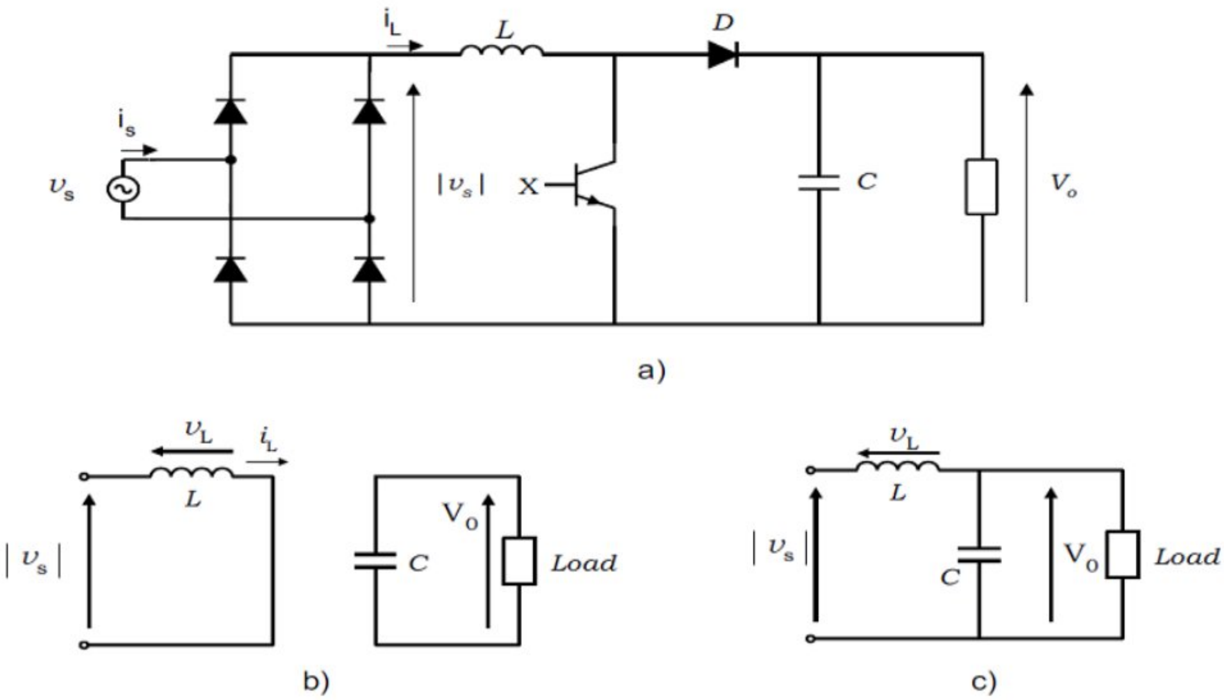


Fig.3.3: Figure representing the on and off states of a boost rectifier

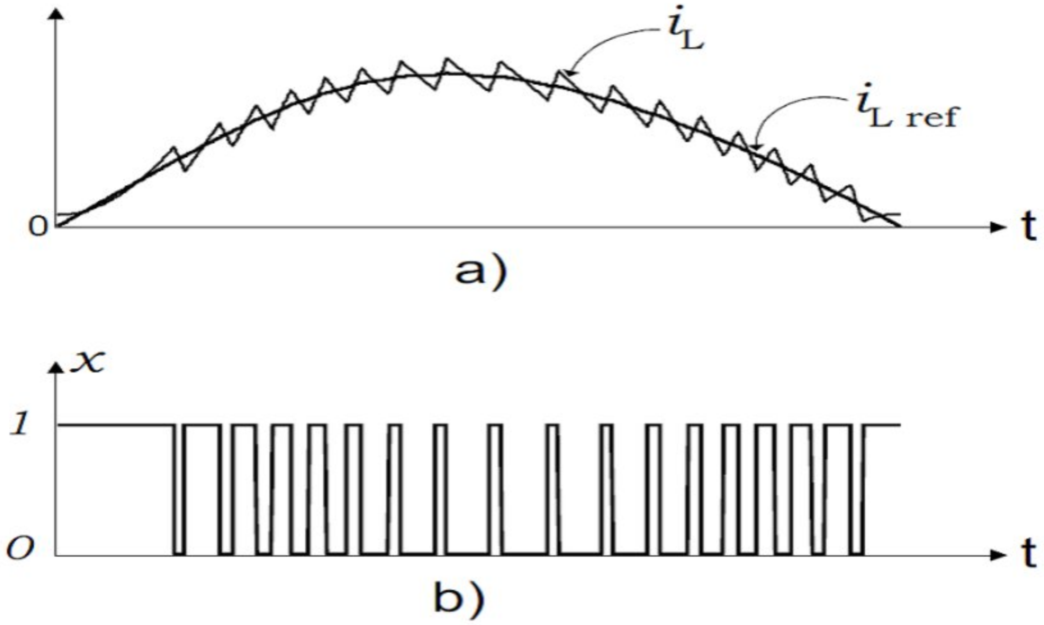


Fig.3.4: Behavior of inductor current (a) Waveforms (b) Transistor T gate drive signal x

The input current is(t) is controlled by changing the conduction state of transistor. By switching the transistor with appropriate firing pulse sequence, the waveform of the input current can be controlled to follow a sinusoidal reference, as can be observed in the positive half wave in Fig.3.4 (a,b). This figure shows the reference inductor current iLref, the inductor current i, and the gate drive signal x for transistor. Transistor is ON when x = 1 and it is OFF when x =0. The ON and OFF state of the transistor produces an increase and decrease in the inductor current iL.

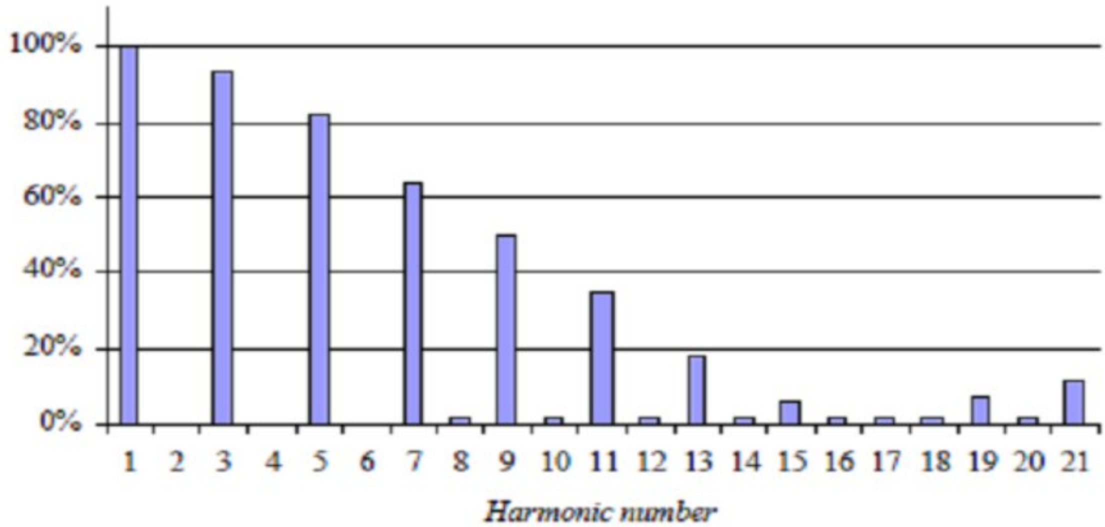


Fig.3.5: Harmonic content of the current waveform obtained from a rectifier circuit

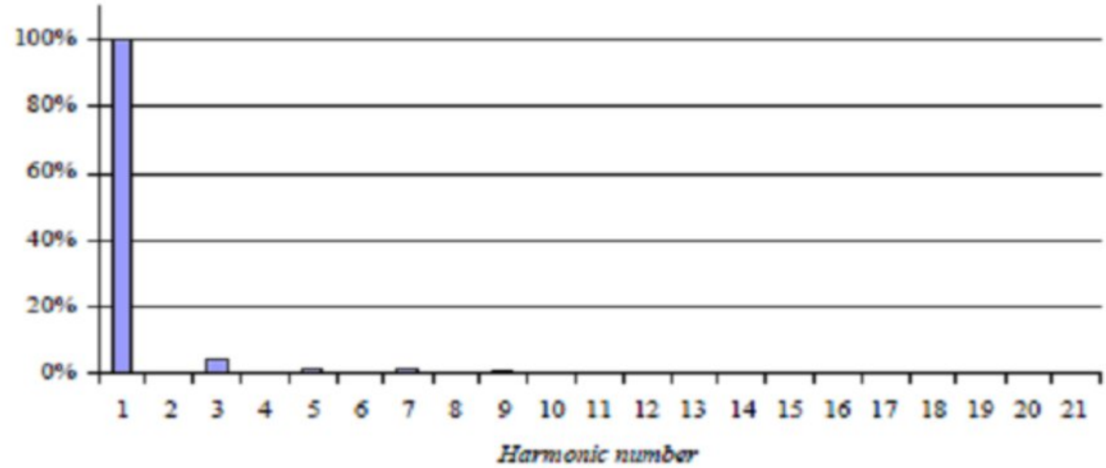


Fig.3.6: Harmonic content of the current waveform of a boost PFC converter

As can be clearly seen, the higher order harmonics are considerably reduced in the line current by using a boost converter.

CHAPTER 4
POWER FACTOR CORRECTION

4.1 INTRODUCTION:

The attention devoted to the quality of the currents absorbed from the utility line by electronic equipment is increasing due to several reasons. In fact, a low power factor reduces the power available from the utility grid, while a high harmonic distortion of the line current causes EMI problems and cross-interferences, through the line impedance, between different systems connected to the same grid. From this point of view, the standard rectifier employing a diode bridge followed by a filter capacitor gives unacceptable performances. Thus, many efforts are being done to develop interface systems which improve the power factor of standard electronic loads.

An ideal power factor corrector (PFC) should emulate a resistor on the supply side while maintaining a fairly regulated output voltage. In the case of sinusoidal line voltage, this means that the converter must draw a sinusoidal current from the utility; in order to do that, a suitable sinusoidal reference is generally needed and the control objective is to force the input current to follow, as close as possible, this current reference. The most popular topology in PFC applications is certainly the boost topology, shown in Fig.1 together with a generic Controller.

A diode rectifier effects the ac/dc conversion, while the controller operates the switch in such a way to properly shape the input current ig according to its reference. The output capacitor absorbs the input power pulsation, allowing a small ripple of the output voltage VL.

The boost topology is very simple and allows low-distorted input currents and almost unity power factor with different control techniques. Moreover, the output capacitor is an efficient energy storage element (due to the high output voltage value) and the ground-connected switch simplifies the drive circuit. The main drawbacks of this topology are:

- start-up over currents, due to the charge of the large output capacitor;
- lack of current limitation during overload and short circuit conditions, due to the direct connection between line and load;
- difficult insertion of a high-frequency transformer for insulating the input and output stages;
- Output voltage always greater than peak input voltage.

In spite of these limitations, many PFC's based on the boost topology have been proposed in the literature. Various control strategies have also been implemented. In the following, the most popular control techniques are reviewed and compared, in order to highlight advantages and drawbacks of each solution, also referring to the availability of commercial control IC's.

4.2 Types of Power Factor Correction (PFC):

Power Factor Correction can be classified as two types:

1. Passive Power Factor Correction
2. Active Power Factor Correction

4.2.1 Passive Power Factor Correction:

In Passive PFC, in addition to the diode bridge rectifier, passive elements are introduced to improve the nature of the line current. By using this, power factor can be increased to a value of 0.7 to 0.8 approximately. As the voltage level of power supply increases, the sizes of PFC components increase. The idea of passive PFC is to filter out the harmonic currents by use of a low pass filter and only allow the 50 Hz power frequency wave to increase the power factor.

Advantages of Passive PFC:

- It has a simple structure.
- It is reliable and rugged.
- The cost is very low because only a filter is required.
- The high frequency switching losses are absent and it is not sensitive to noises, and surges.
- The equipment used in this circuit don't generate high frequency EMI.

Disadvantages of Passive PFC:

- For achieving better power factor the size of the filter increases.
- Due to the time lag associated with the passive elements it has a poor dynamic response.
- The voltage cannot be regulated and the efficiency is low.
- Due to presence of inductors and capacitors interaction may take place between the passive elements and the system resonance may occur at different frequencies.
- Although by filtering the harmonics can be filtered out, the fundamental component may get phase shifted thus reducing the power factor.
- The shape of input current is dependent upon what kind of load is connected.

4.2.2 Active Power Factor Correction:

An active PFC is a power electronic device designed to control the amount of power drawn by a load and obtains a power factor as close as possible to unity. Commonly any active PFC design functions by controlling the input current in order to make the current waveform follow the supply voltage waveform closely (i.e. a sine wave). A combination of the reactive elements and some active switches increase the effectiveness of the line current shaping and to obtain controllable output voltage. The switching frequency differentiates the active PFC solutions into two classes.

- **Low frequency active PFC**:

Switching takes place at low-order harmonics of the line-frequency and it is synchronized with the line voltage.

- **High frequency active PFC:**

The switching frequency is much higher than the line frequency. The power factor value obtained through Active PFC technique can be more than 0.9. With a suitable design even a power factor of 0.99 can be achieved easily. Active PFC power supply can detect the input voltage automatically, supports 110V to 240V alternative current, its size and weight is smaller than passive PFC power supply.

Advantages of Active PFC:

- The weight of active PFC system is very less.
- The size is also smaller and a power factor value of over 0.95 can be obtained through this method.
- It reduces the harmonics present in the system.
- Automatic correction of the AC input voltage can be obtained.
- It is capable of operating in a full range of voltage.

Disadvantages of Active PFC:

- The layout design is somewhat more complex than passive PFC.
- It is very expensive since it needs PFC control IC, high voltage MOSFET, high voltage
- ultra-fast choke and other circuits

4.3 Review of PFC Control Techniques:

In the following, we will refer to the boost PFC, even if many of the discussed control techniques can also be used with other topologies.

4.3.1 Peak Current Control:

As we can see, the switch is turned on at constant frequency by a clock signal, and is turned off when the sum of the positive ramp of the inductor current (i.e. the switch current) and an external ramp (compensating ramp) reaches the sinusoidal current reference. This reference is usually obtained by multiplying a scaled replica of the rectified line voltage v_g times the output of the voltage error amplifier, which sets the current reference amplitude. In this way, there reference signal is naturally synchronized and always proportional to the line voltage, which is the condition to obtain unity power factor.

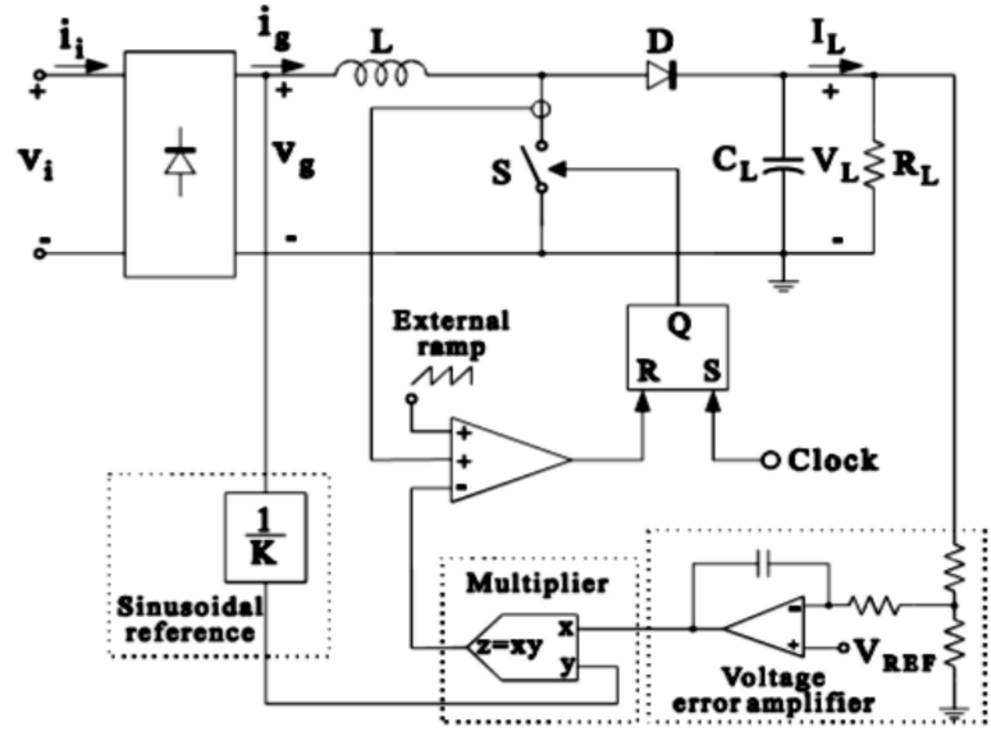


Fig.4.1: Circuit diagram of peak current control scheme

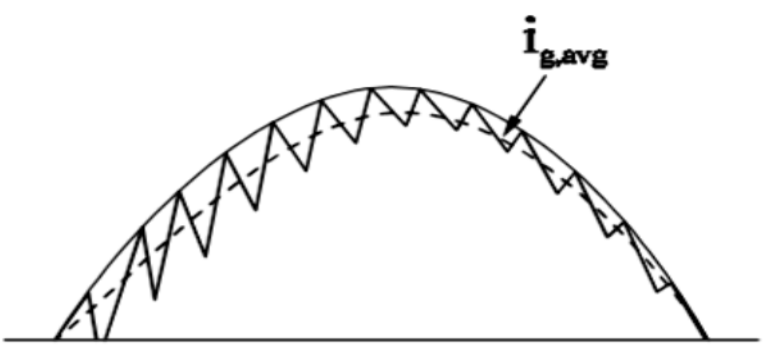


Fig.4.2: Peak current control

As Fig. 4.1 reveals, the converter operates in Continuous Inductor Current Mode (CICM), this means that devices current stress as well as input filter requirements are reduced. Moreover, with continuous input current, the diodes of the bridge can be slow devices (they operate at line frequency). On the other hand, the hard turn-off of the freewheeling diode increases losses and switching noise, calling for a fast device.

Advantages:

- Constant switching frequency.
- Only the switch current must be sensed and this can be accomplished by a current transformer, thus avoiding the losses due to the sensing resistor.
- No need of current error amplifier and its compensation network.
- Possibility of a true switch current limiting.

Disadvantages:

- Presence of sub harmonic oscillations at duty cycles greater than 50%, so a compensation ramp is needed.
- Input current distortion which increases at high line voltages and light load and is worsened by the presence of the compensation ramp.
- Control more sensitive to commutation noises.

The input current distortion can be reduced by changing the current reference wave shape, for example introducing ADC offset, and/or by introducing a soft clamp. These provisions are discussed in and. In it is shown that even with constant current reference, good input current waveforms can be achieved. Moreover, if the PFC is not intended for universal input operation, the duty-cycle can be kept below 50% so avoiding also the compensation ramp.

4.3.2 Average Current Control Scheme:

Another control method, which allows a better input current waveform, is the average current control represented in Fig.4.3 Here the inductor current is sensed and filtered by a current error amplifier whose output drives a PWM modulator. In this way the inner current loop tends to minimize the error between the average input current i_g and its reference. This latter is obtained in the same way as in the peak current control. The converter works in CICM, so the same considerations done with regard to the peak current control can be applied.

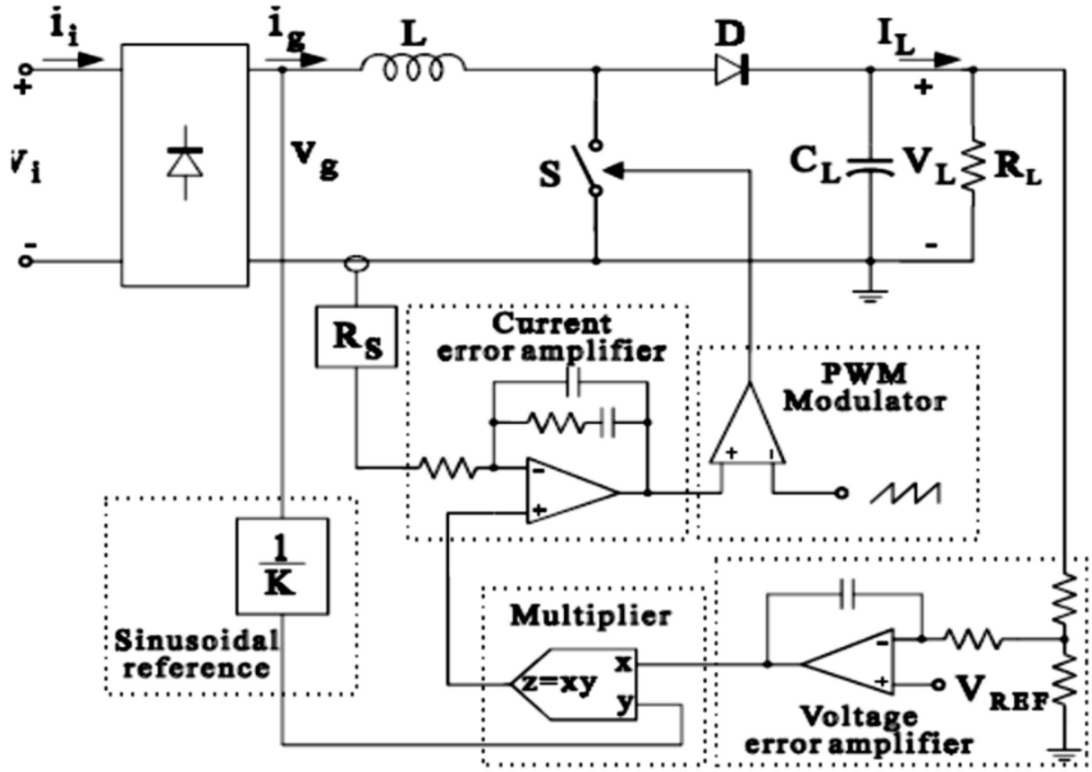


Fig.4.3: Circuit diagram of average current control scheme

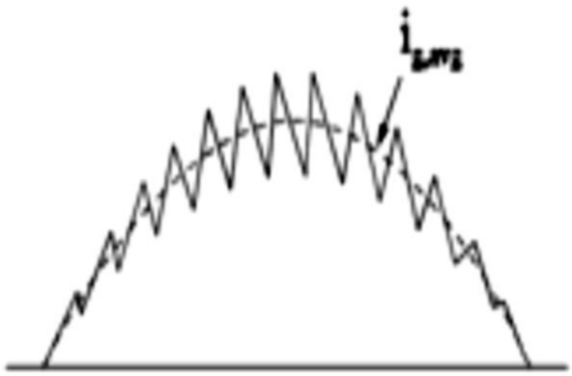


Fig.4.4: Average current control

Advantages:

- Constant switching frequency.
- No need of compensation ramp.
- Control is less sensitive to commutation noises, due to current filtering.
- Better input current waveforms than for the peak current control since, near the zero crossing of the line voltage, the duty cycle is close to one, so reducing the dead angle in the input current.

Disadvantages:

- Inductor current must be sensed.
- A current error amplifier is needed and its compensation network design must take into account different converter operating points during the line cycle.

4.3.3 Hysteresis Current control:

Fig. 4.5 shows this type of control in which two sinusoidal current references I_{Pref}, I_{Vref} are generated, one for the peak and the other for the valley of the inductor current. According to this control technique, the switch is turned on when the inductor current goes below the lower reference I_{Vref} and is turned off when the inductor current goes above the upper reference I_{Pref}, giving rise to a variable frequency control. Also with this control technique the converter works in CICM.

Advantages:

- No need of compensation ramp.
- Low distorted input current waveforms.

Disadvantages:

- Variable switching frequency.
- Inductor current must be sensed.
- Control sensitive to commutation noises.

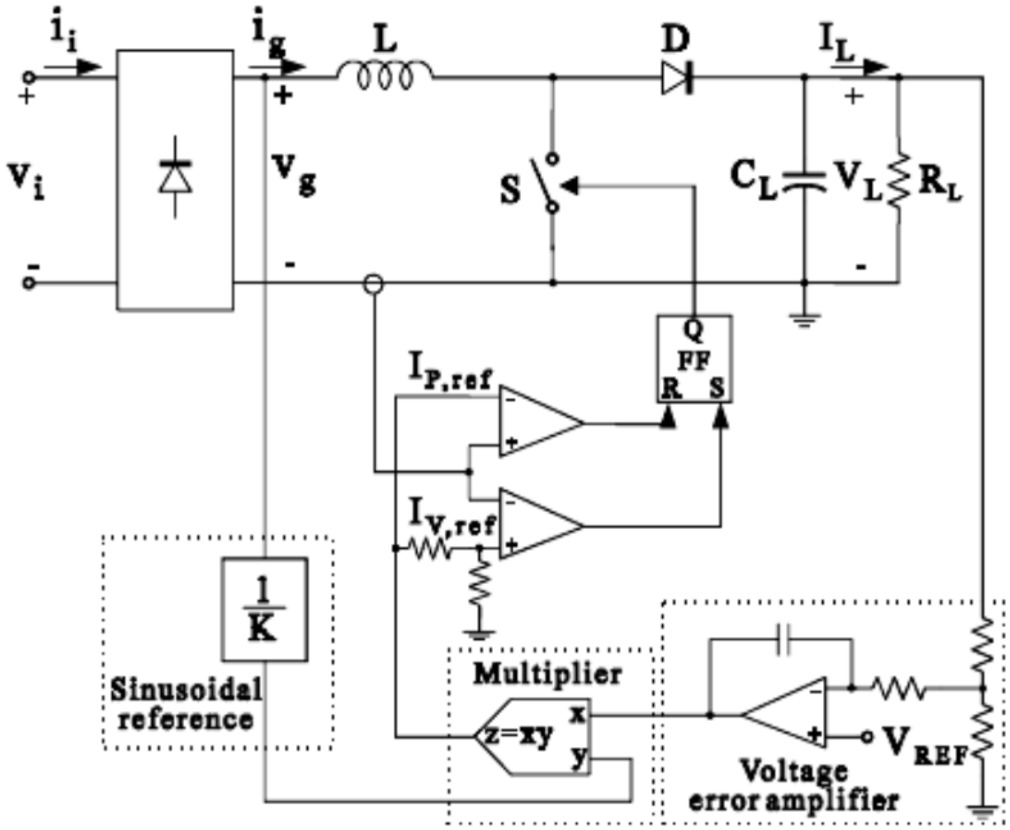


Fig.4.5: Circuit diagram of Hysteresis current control scheme

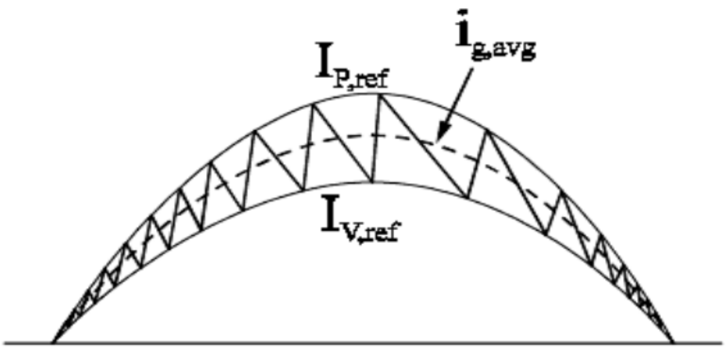


Fig.4.6: Hysteresis current control

4.3.4 Borderline Control:

In this control approach the switch on-time is held constant during the line cycle and the switch is turned on when the inductor current falls to zero, so that the converter operates at the boundary between Continuous and Discontinuous Inductor Current Mode (CICM-DICM). In this way, the freewheeling diode is turned off softly (no recovery losses) and the switch is turned on at zero current, so the commutation losses are reduced. On the other hand the higher current peaks increase device stresses and conduction losses and may call for heavier input filters (for some topologies).

This type of control is a particular case of hysteretic control in which the lower reference I_{Vref} is zero anywhere.

The principle scheme is shown in Fig. 4.8the instantaneous input current is constituted by a sequence of triangles whose peaks are proportional to the line voltage. Thus, the average input current becomes proportional to the line voltage without duty-cycle modulation during the line cycle. This characterizes this control as an "*automatic current shaper*" technique. Note that the same control strategy can be generated, without using a multiplier, by modulating the switch on-time duration according to the output signal of the voltage error amplifier. In this case switch current sensing can be eliminated.

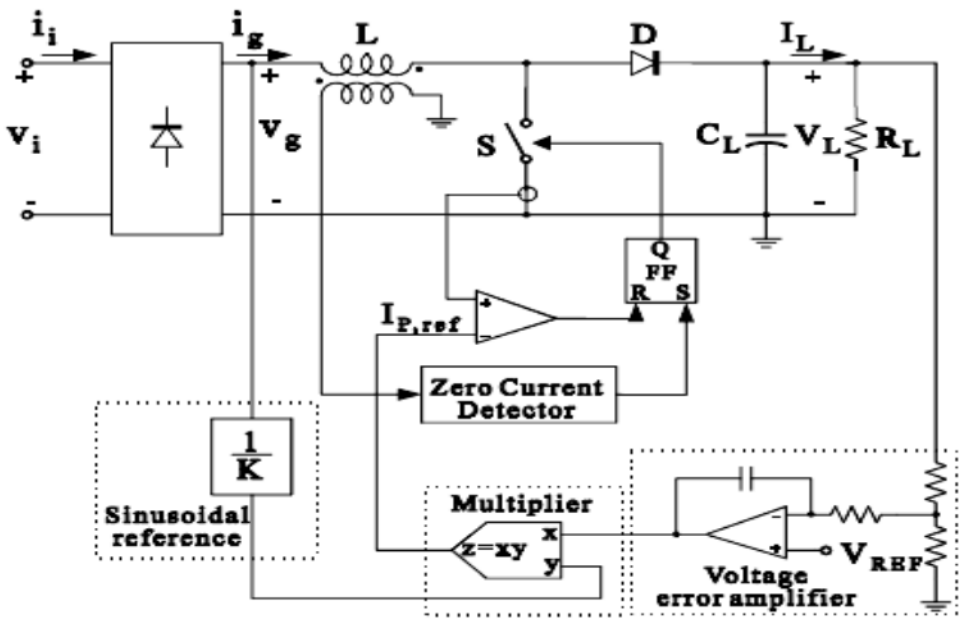


Fig.4.7: Circuit diagram of borderline control scheme

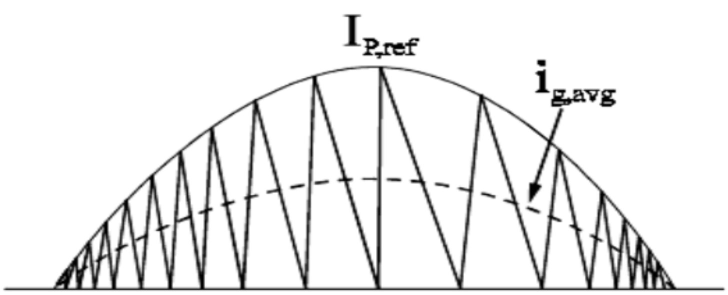


Fig.4.8: Borderline control

Advantages:

- No need of a compensation ramp.
- No need of a current error amplifier.
- For controllers using switch current sensing, switch current limitation can be introduced.

Disadvantages:

- Variable switching frequency.
- Inductor voltage must be sensed in order to detect the zeroing of the inductor current.
- For controllers in which the switch current is sensed, control is sensitive to commutation noises.

4.3.5 Discontinuous Current PWM Control:

With this approach, the internal current loop is completely eliminated; so that the switch is operated at constant on-time and frequency (see Fig.4.9). With the converter working in discontinuous conduction mode (DCM), this control technique allows unity power factor when used with converter topologies like flyback, Cuk and Sepic. Instead, with the boost PFC. This technique cause some harmonic distortion in the line current.

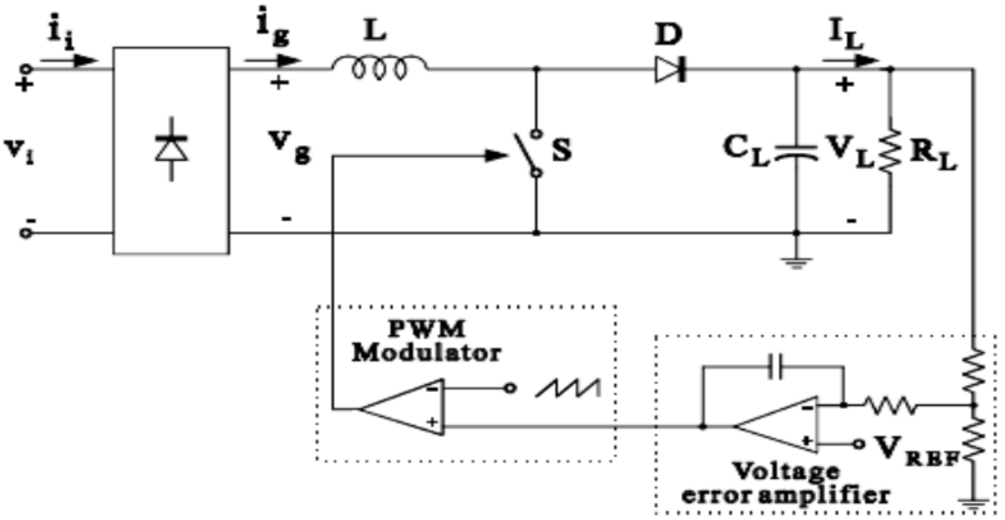


Fig.4.9: Discontinuous current PWM control

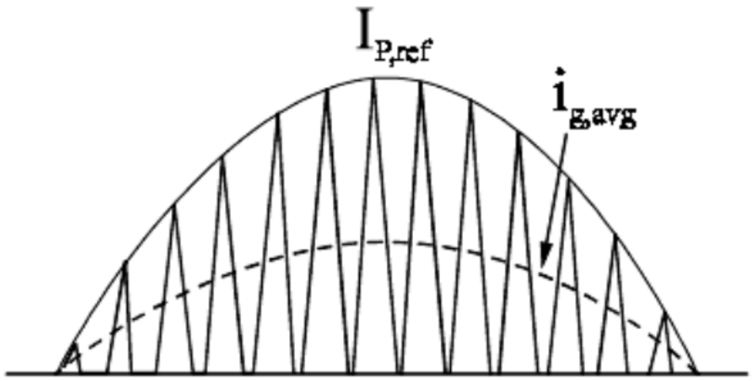


Fig.4.10: Discontinuous current PWM control waveform

Advantages:

- Constant switching frequency
- No need of current sensing
- Simple PWM control

Disadvantages:

- Higher devices current stress than for borderline control.
- Input current distortion with boost topology.

CHAPTER 5
SOFTWARE DISCRIPTION

5.1 Simulation & Result of Boost Circuit Without PFC:

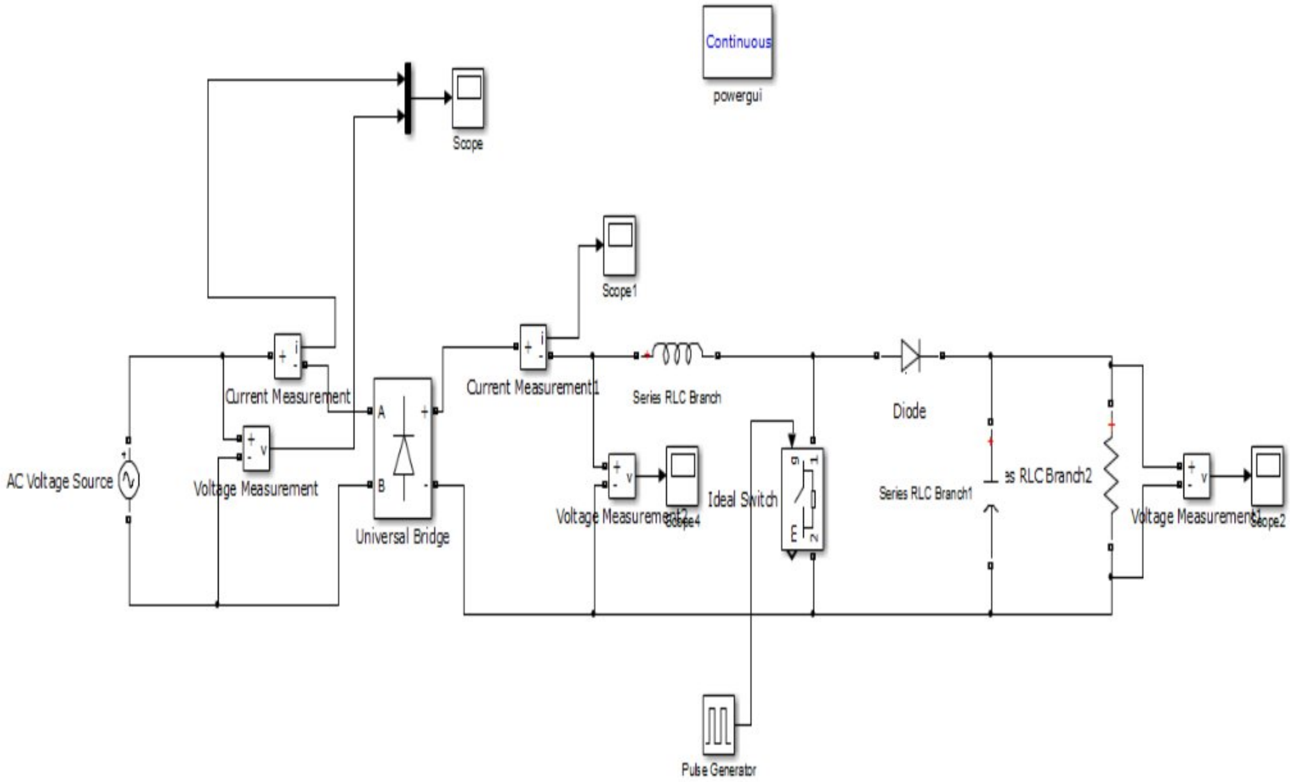


Fig.5.1: Boost circuit without PFC

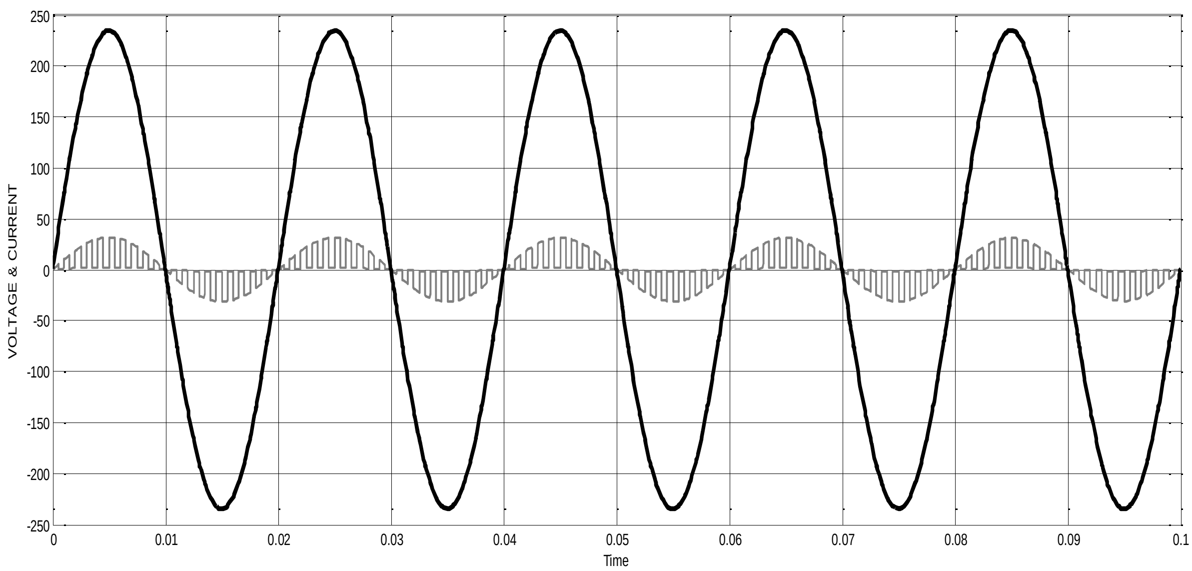


Fig.5.2: Boost circuit without PFC waveform

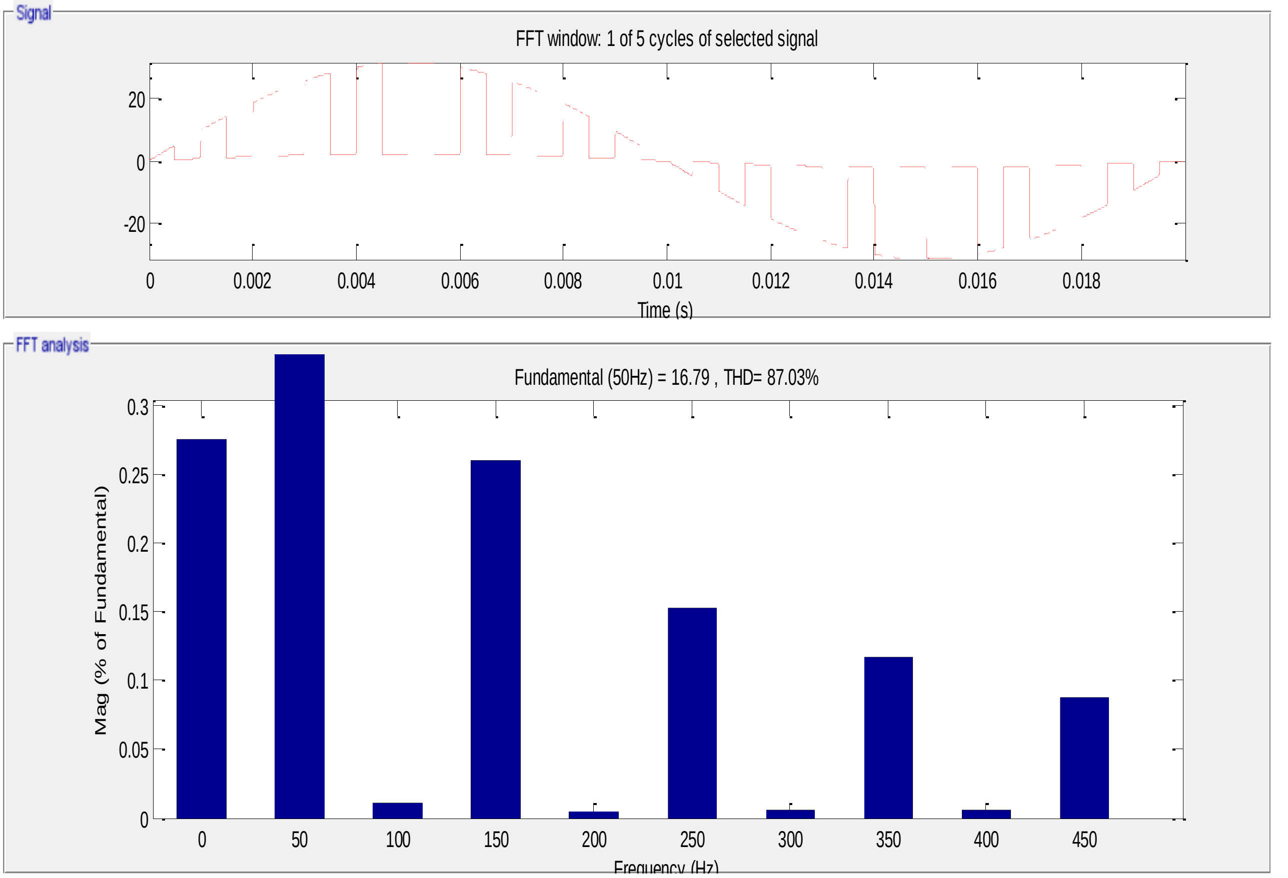


Fig.5.3: Harmonics Analysis without PFC

Here 230v, 50Hz, single phase AC supply is given to the rectifier. Now the rectifier rectifies it to DC and then it is given to the circuit of step up chopper. In this circuit a large inductor L in series, when the switch is on the current passes through switch, rectifier and inductor and energy is stored into inductor till the switch remains ON. When the switch is OFF the inductor current could not die down instantaneously. This current is forced to flow through diode and load till the switch is OFF. The current tends to decrease the polarity of emf induced in inductor is reversed, as a result voltage across the load which exceeds the source voltage Vs (Vo>Vs) in this manner this circuit acts as a step up chopper and energy stored in L is released to the load. Here the capacitor absorbs the input power pulsation allowing a small ripple of output voltage of inductor.

5.2 Simulation of Boost Circuit With PFC:

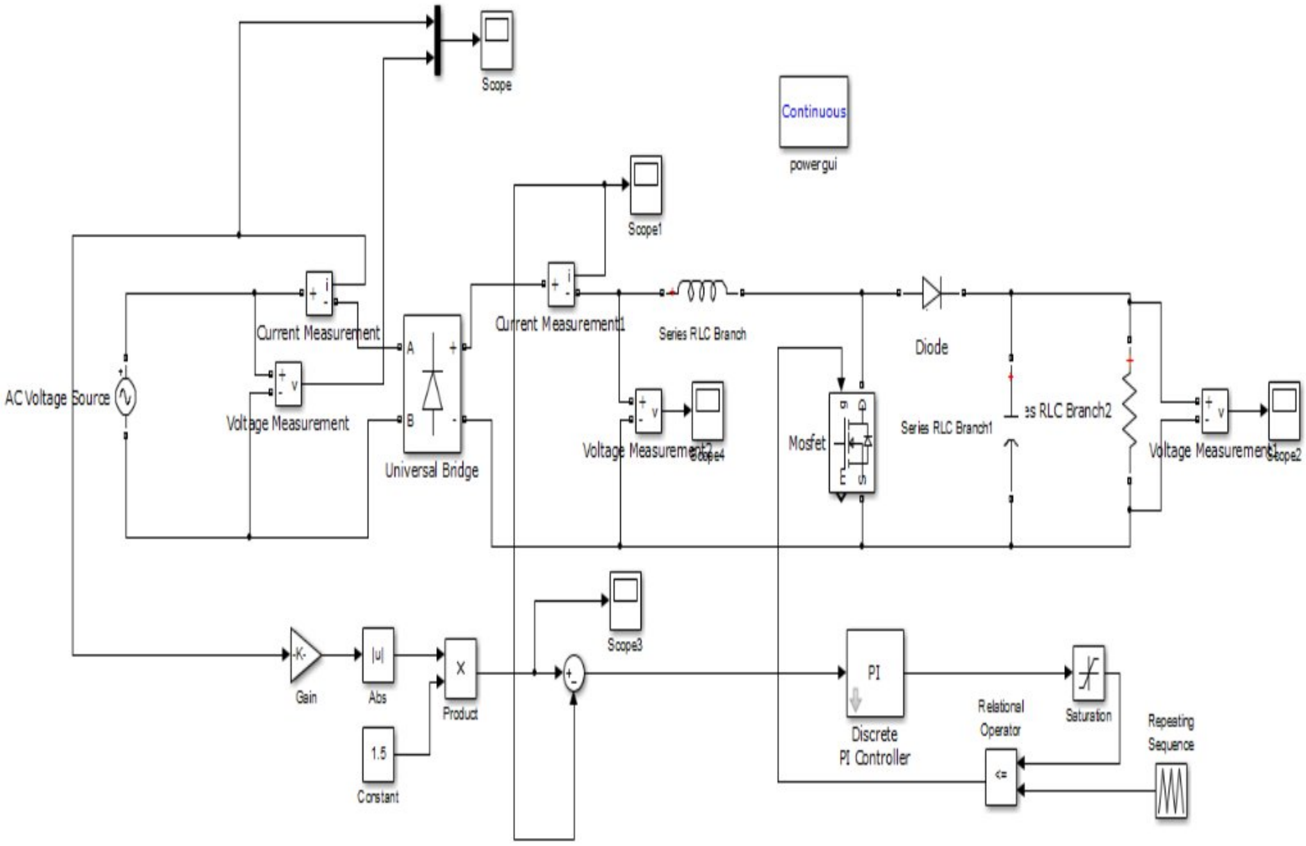


Fig.5.4: Boost circuit with PFC

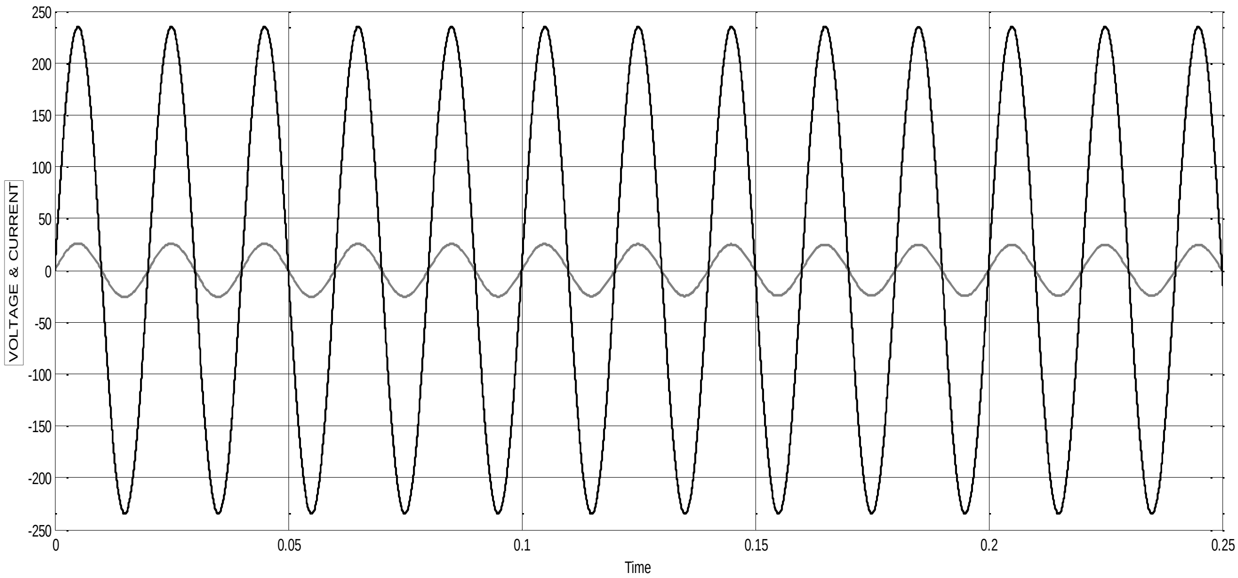


Fig.5.5: Boost circuit waveform with PFC

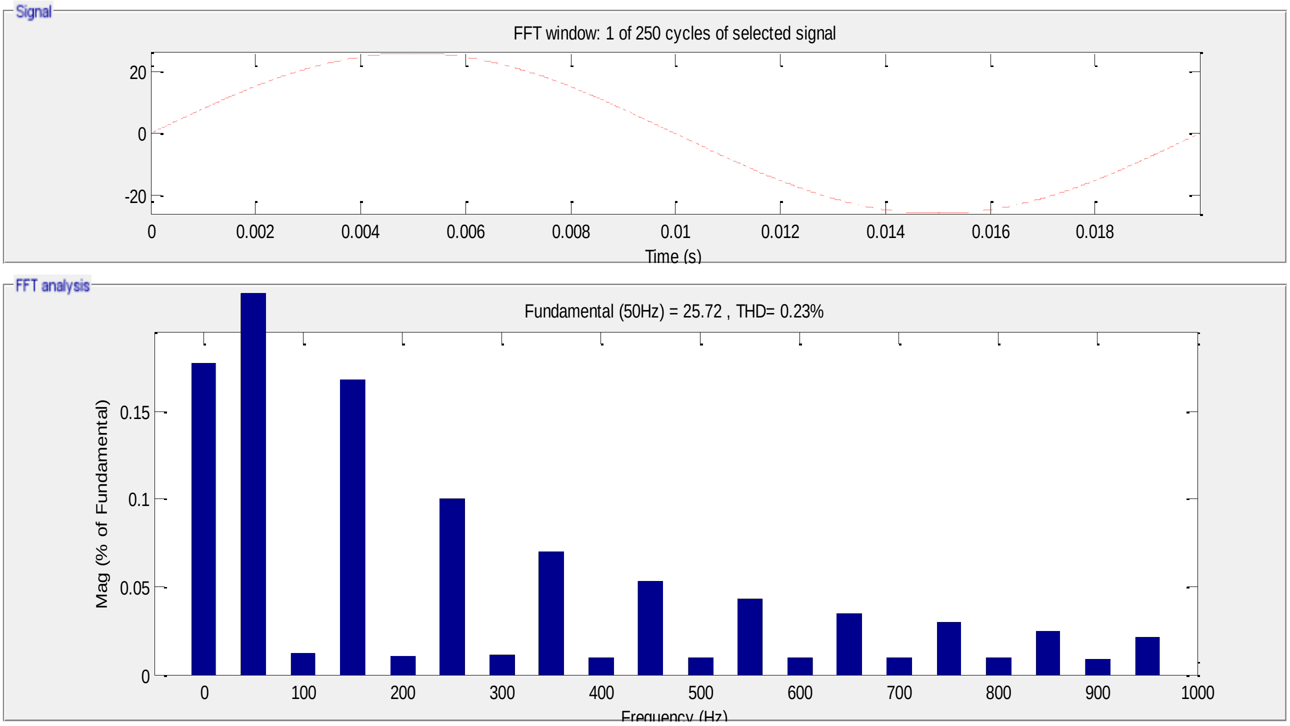


Fig.5.6: Harmonics Analysis with PFC

Here, We can see that from the Harmonics analysis, by applying the power factor correction technique, the THD level is taken less than 5% which is in the range of the standard. As well as the Harmonics content in the supply of the BLDC Motor is become less. So the overall power required for the Motor is become less with the help of power factor correction using Boost converter.

CHAPTER 6
HARDWARE DISCRIPTION

6.1 Block diagram of hardware:

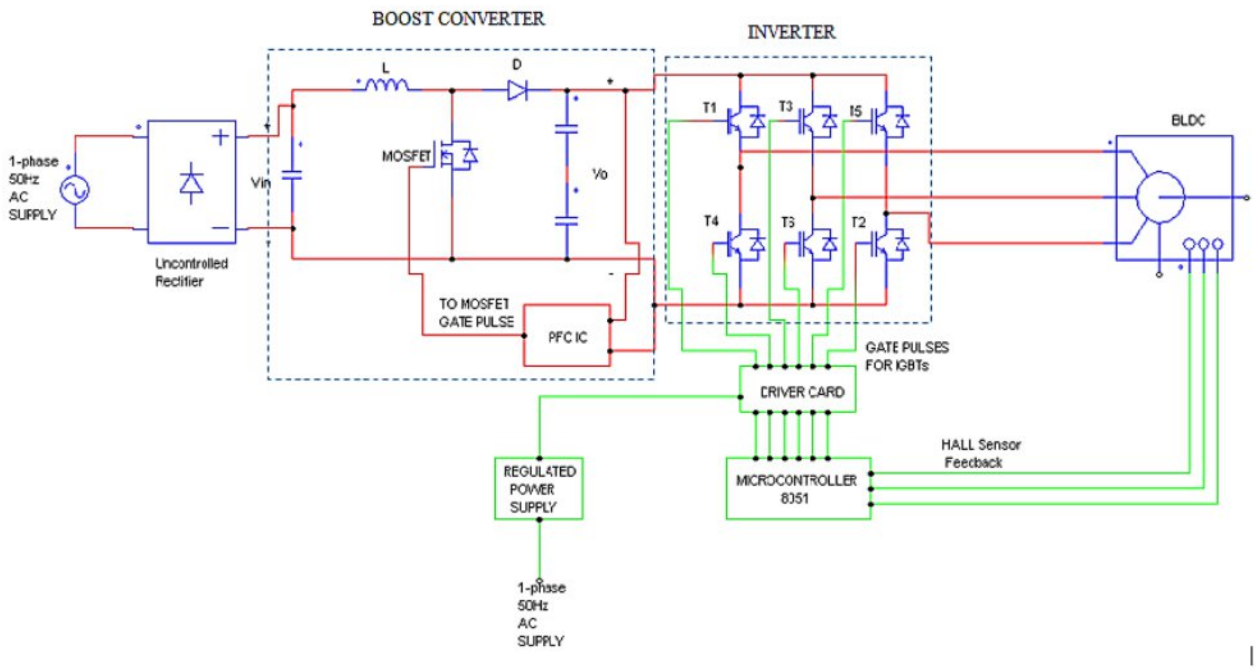


Fig.6.1: Block diagram of Hardware

6.2 Components of hardware:

6.2.1 Uncontrolled rectifier:

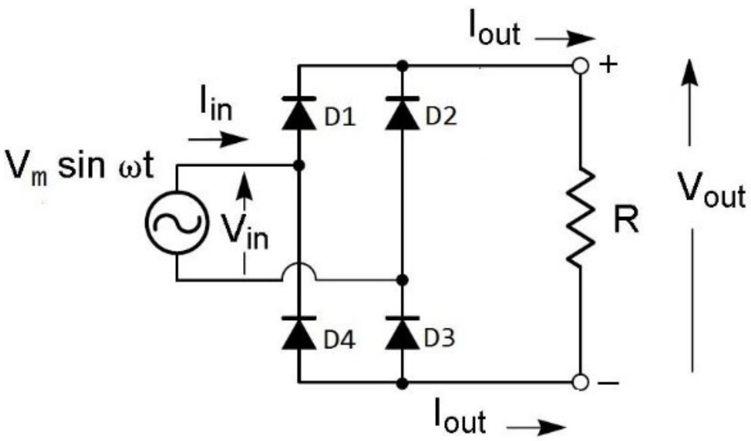


Fig.6.2: Full wave bridge rectifier

"Circuits that are used to convert the Alternating Current (AC) input power into a Direct Current (DC) output power is known as rectifier circuits. The output parameters of a controlled rectifier can be easily controlled with the help of semiconductor switches. A single phase full wave bridge rectifier consists of four diodes connected to form a closed loop called “bridge”.

In a full wave bridge rectifier two diodes will be conducting for each half cycle. The rest of the diodes will be reverse biased. During the positive half cycle of the supply, diodes D1 and D2 are forward biased and will be conducting. Diodes D3 and D4 are reverse biased and will not be conducting.

During the negative half cycle of the supply diodes D3 and D4 are forward biased and will be conducting. Diodes D1 and D2 are reverse biased and will not be conducting. During both the half cycles the current flowing through the load is unidirectional. Hence the voltage developed across the load is also unidirectional. The output voltage contains voltage ripples that can be controlled by connecting a capacitor in parallel to the load.

6.2.2 Regulated power supply:

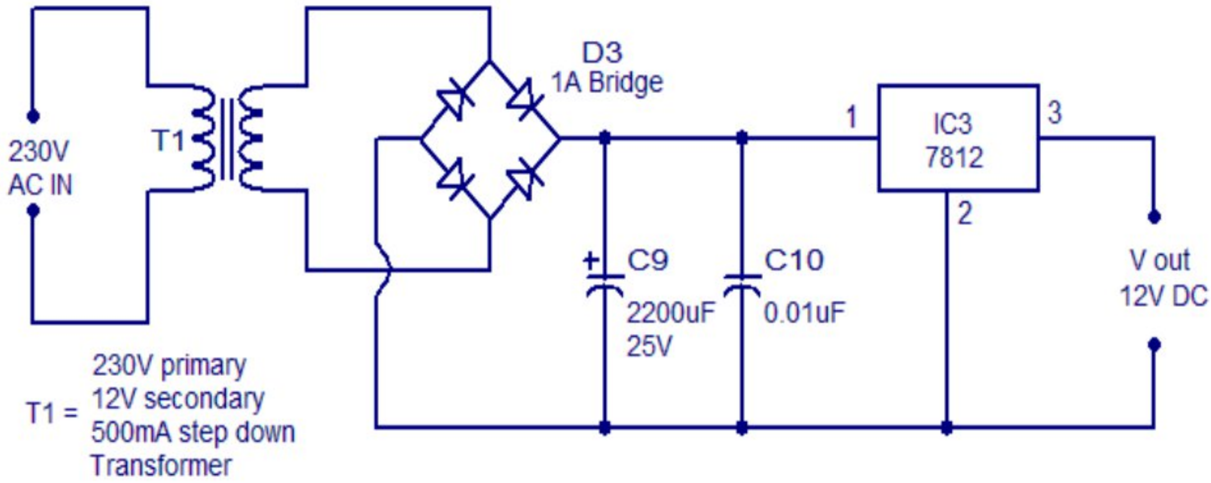


Fig.6.3: 12 V regulated power supply

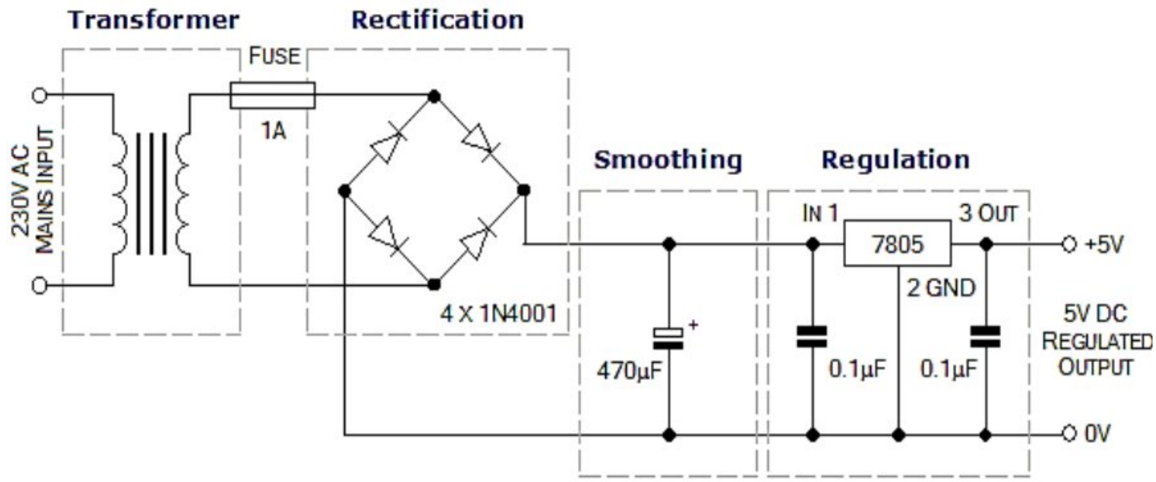


Fig.6.4: 5 V regulated power supply

A regulated power supply is an embedded circuit; it converts unregulated AC into a constant DC. With the help of a rectifier it converts AC supply into DC. Its function is to supply a stable voltage (or less often current), to a circuit or device that must be operated within certain power supply limits. The output from the regulated power supply may be alternating or unidirectional, but is nearly always DC.

6.2.3 Three phase Inverter:

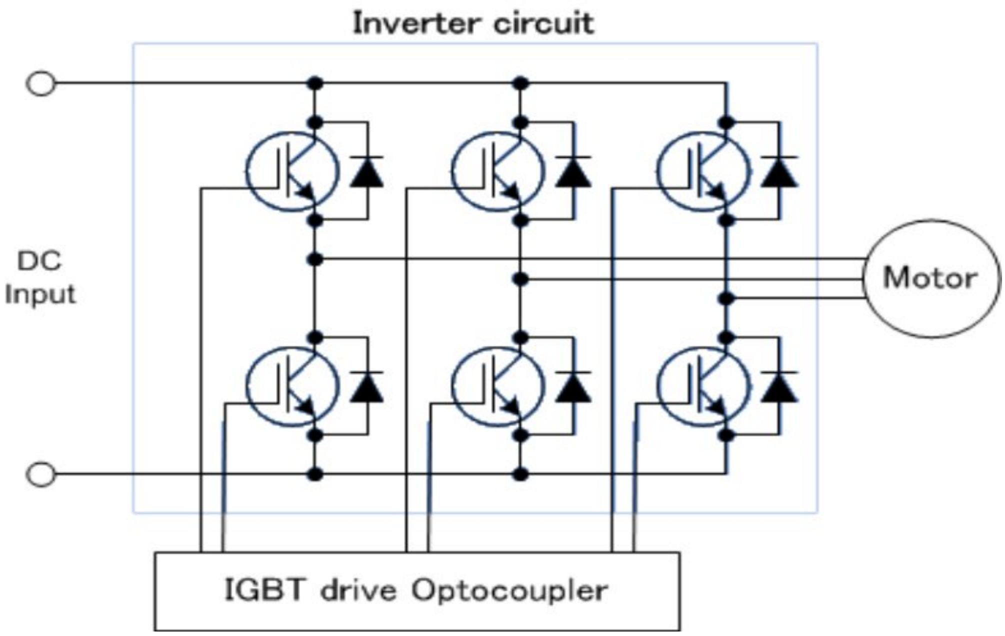


Fig.6.5: 3-Phase inverter

Three-phase inverters are used for variable-frequency drive applications and for high power applications such as HVDC power transmission. A basic three-phase inverter consists of three single-phase inverter switches each connected to one of the three load terminals. For the most basic control scheme, the operation of the three switches is coordinated so that one switch operates at each 60 degree point of the fundamental output waveform. This creates a line-to-line output waveform that has six steps. The six-step waveform has a zero-voltage step between the positive and negative sections of the square-wave such that the harmonics that are multiples of three are eliminated as described above. When carrier-based PWM techniques are applied to six-step waveforms, the basic overall shape, or envelope, of the waveform is retained so that the 3rd harmonic and its multiples are cancelled.

6.2.4 Driver Circuit:

In electronics, a driver is an electrical circuit or other electronic component used to control another circuit or component, such as a high-power transistor, liquid crystal display (LCD), and numerous others.

They are usually used to regulate current flowing through a circuit or is used to control the other factors such as other components, some devices in the circuit. The term is often used, for example, for a specialized integrated circuit that controls high-power switches in switched-mode power converters. An amplifier can also be considered a driver for loudspeakers, or a constant voltage circuit that keeps an attached component operating within a broad range of input voltages.

Typically the driver stage(s) of a circuit requires different characteristics to other circuit stages. For example in a transistor power amplifier, typically the driver circuit requires current gain, often the ability to discharge the following transistor bases rapidly, and low output impedance to avoid or minimize distortion

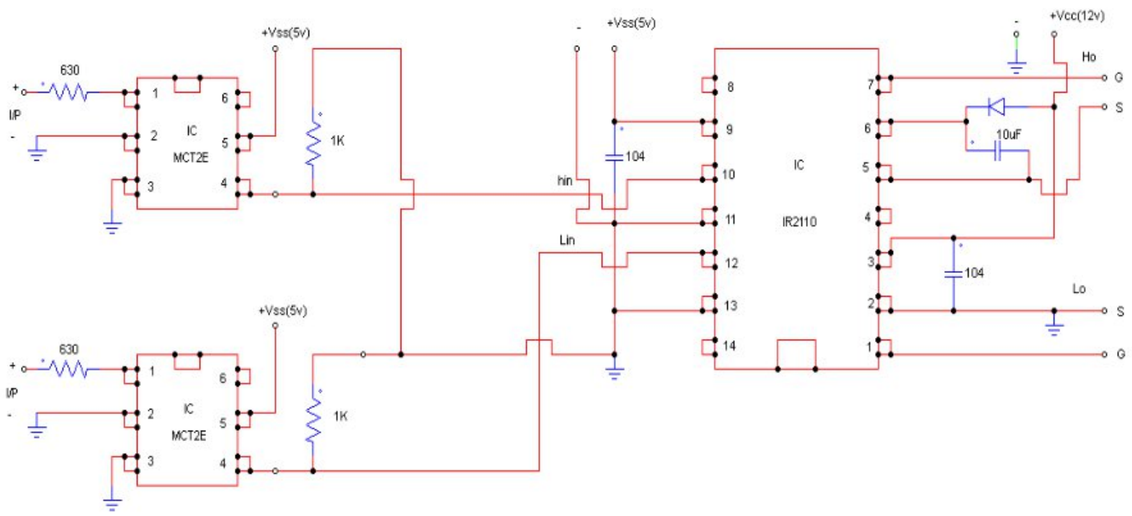


Fig.6.6: Driver circuit

6.2.5 BLDC Motor:

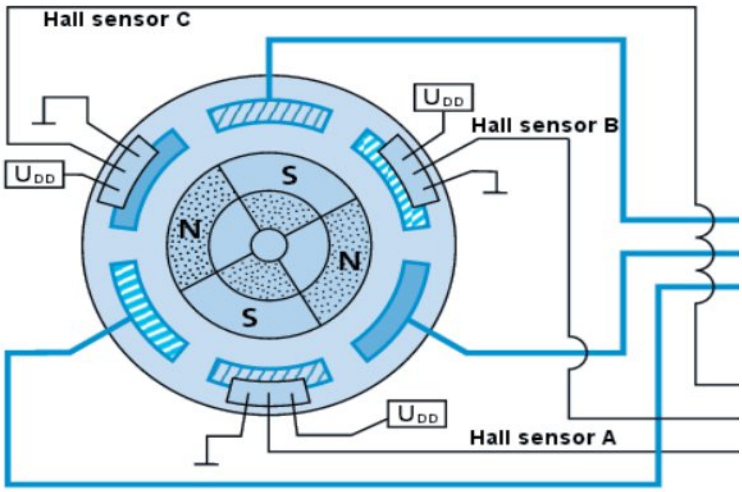


Fig.6.7: BLDC motor

Brushless DC electric motor (BLDC motors, BL motors) also known as electronically commutated motors (ECMs, EC motors) are synchronous motors that are powered by a DC electric source via an integrated inverter/switching power supply, which produces an AC electric signal to drive the motor. In this context, AC, alternating current, does not imply a sinusoidal waveform, but rather a bi-directional current with no restriction on waveform. Additional sensors and electronics control the inverter output amplitude and waveform (and therefore percent of DC bus usage/efficiency) and frequency (i.e. rotor speed).

6.2.6 Dual Channel Rotary Speed Encoder:

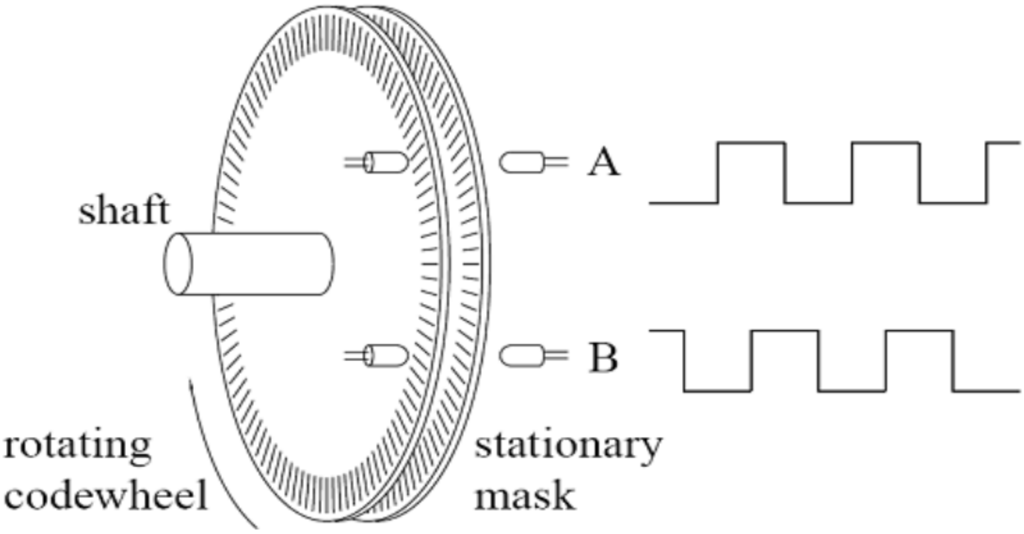


Fig.6.8: Rotary speed encoder

A rotary encoder, also called a shaft encoder, is an electro-mechanical device that converts the angular position or motion of a shaft or axle to an analog or digital code. There are two main types: absolute and incremental .The two output wave forms are 90 degrees out of phase, which is what quadrature means. These signals are decoded to produce a count up pulse or a countdown pulse. For decoding in software, the A & B outputs are read by software, either via an interrupt on any edge or polling, and the above table is used to decode the direction.

6.3 Schematic Diagram of PFC:

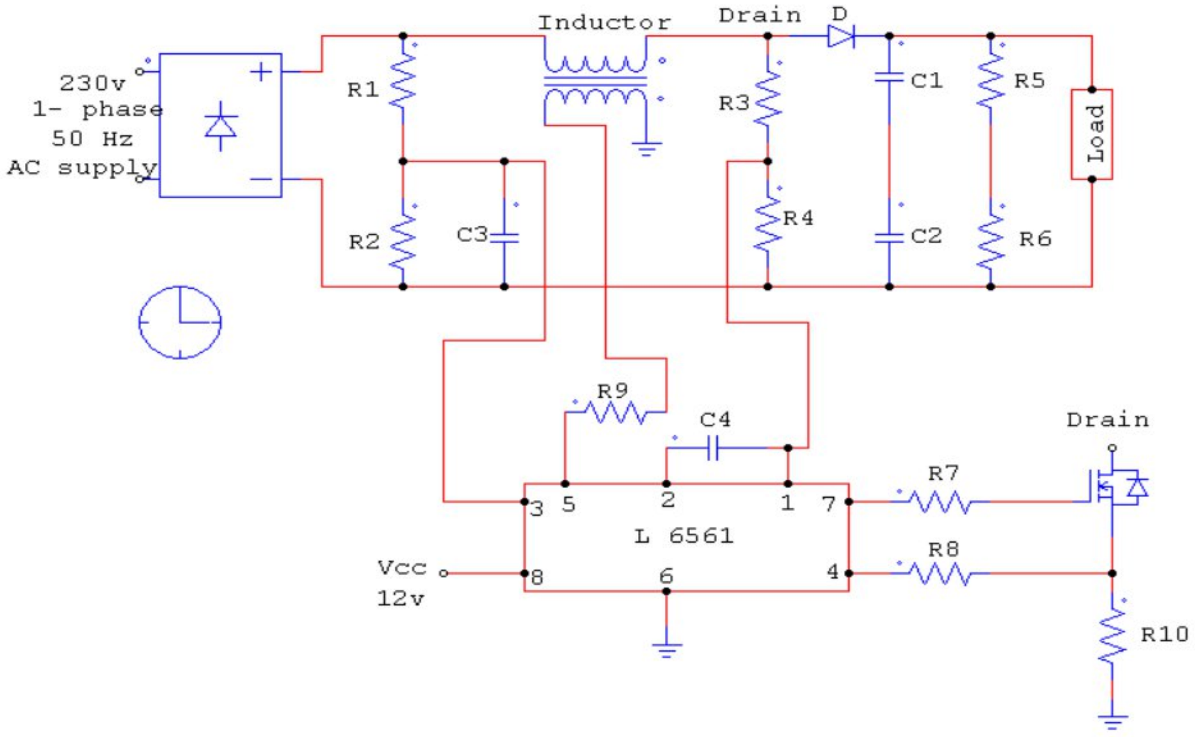


Fig.6.9: Schematic diagram of PFC

6.4 Hardware Photographs with Waveform:

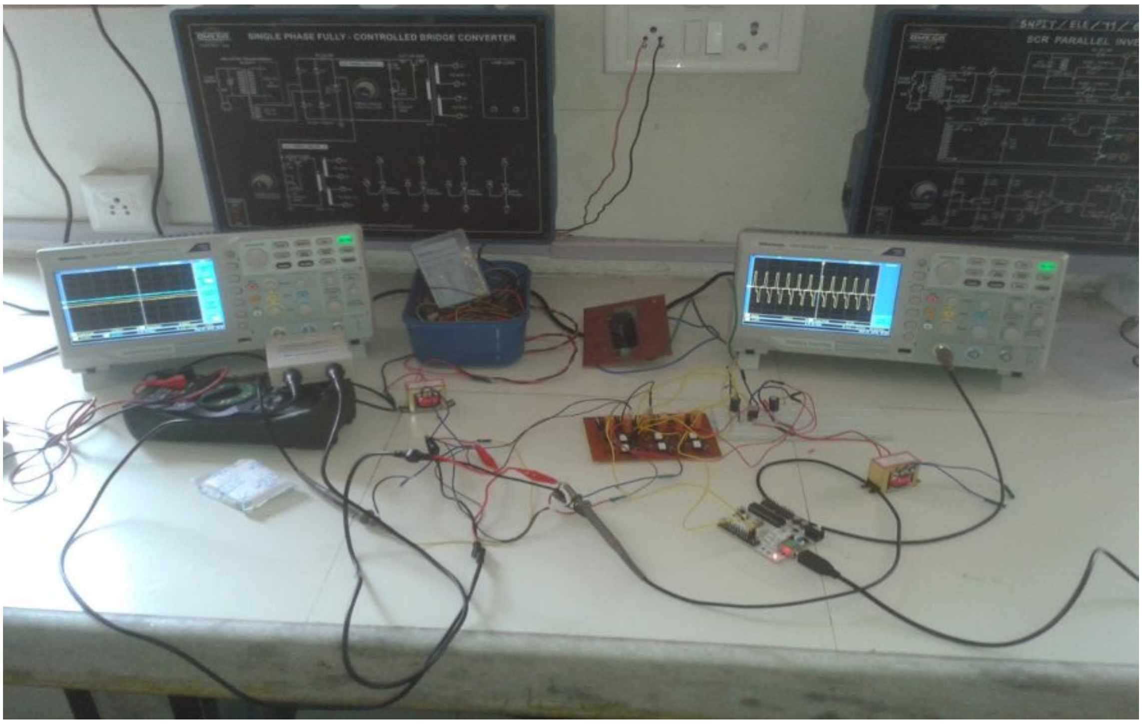


Fig.6.10: Without PFC Circuit on Breadboard

Fig.6.11: With PFC on Breadboard with Bulb Load

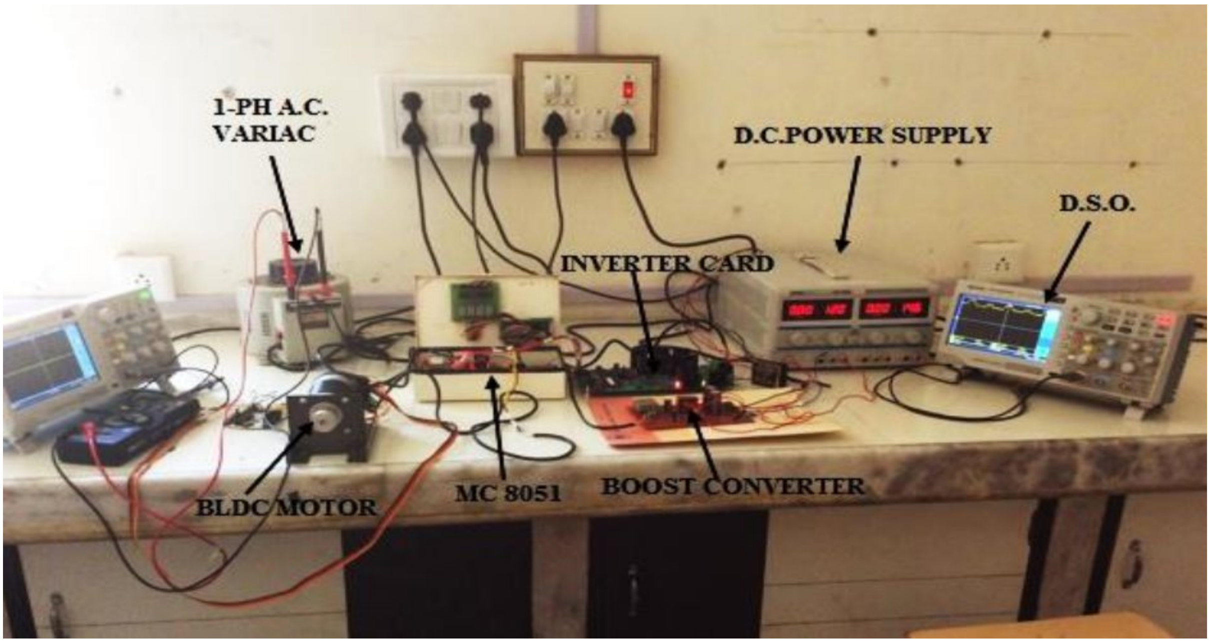


Fig.6.12: Final Hardware of PFC with Speed Control

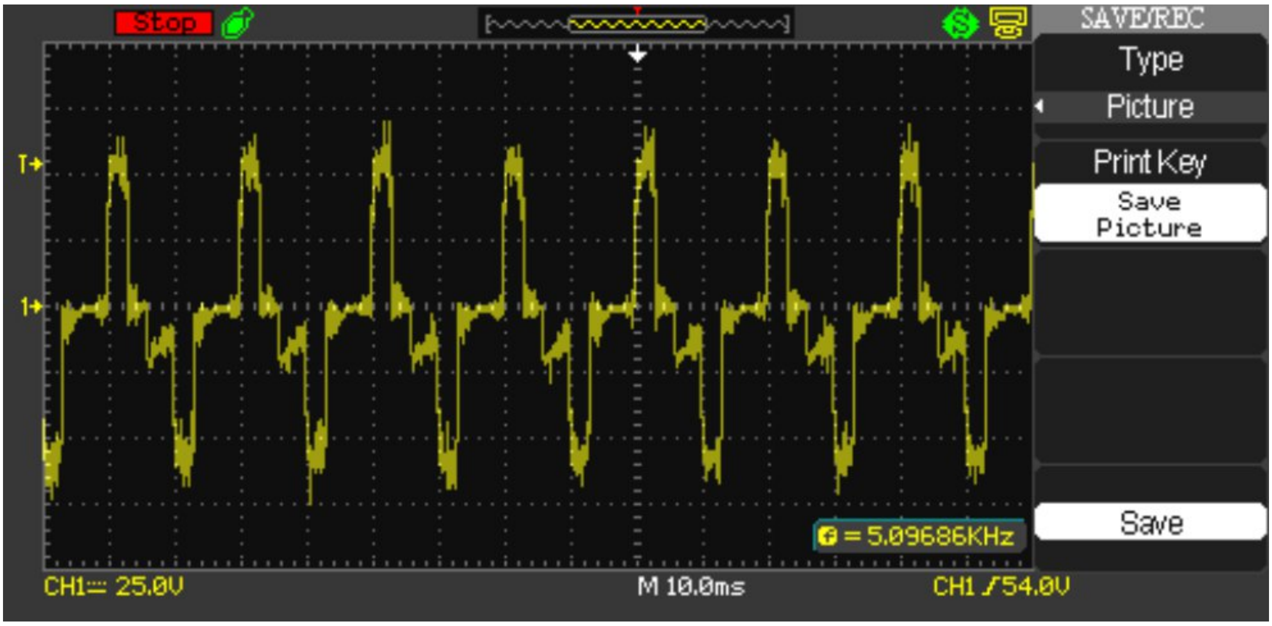


Fig.6.13: Current Waveform without PFC

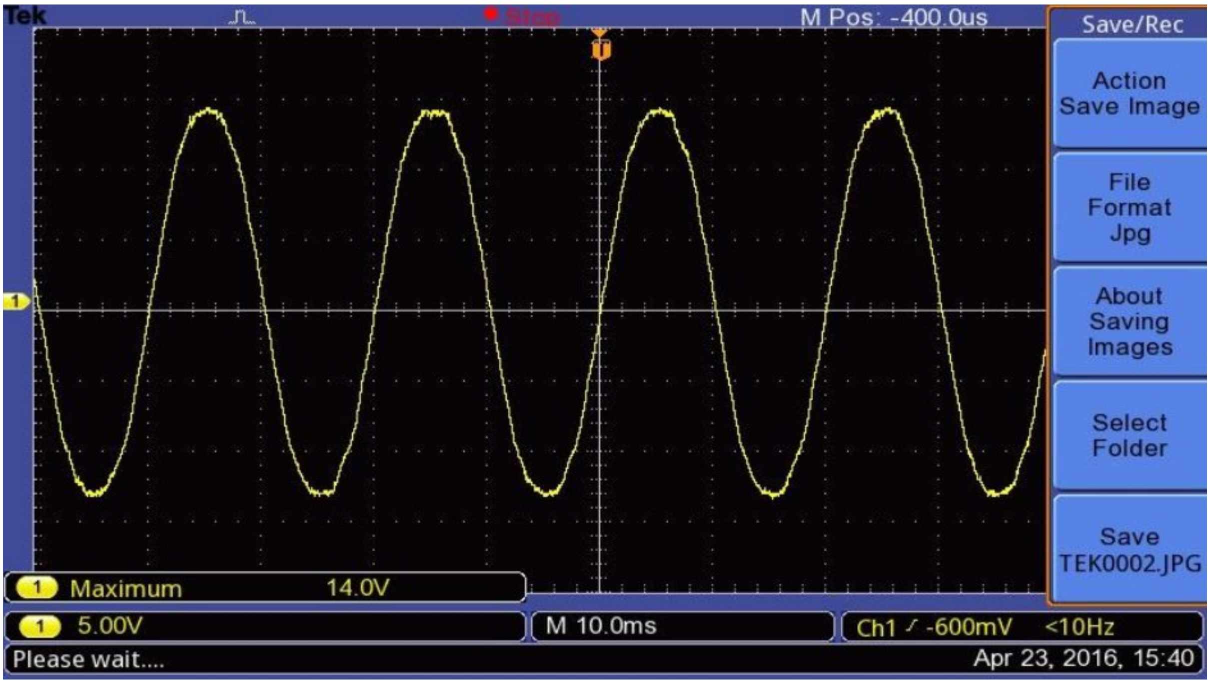


Fig.6.14: Voltage Waveform without PFC

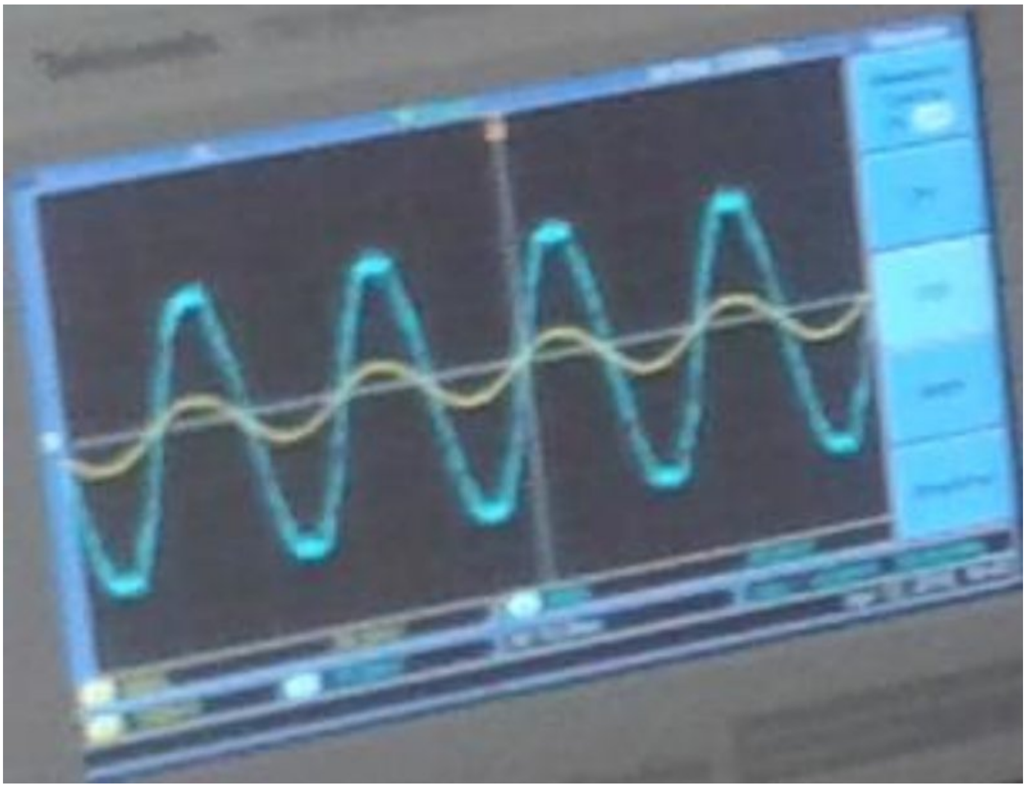
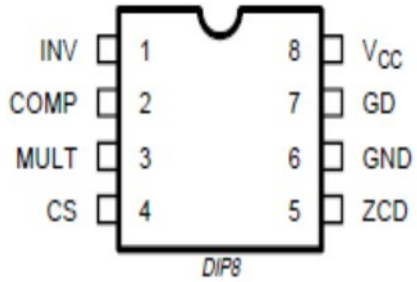


Fig.6.15: Voltage & Current Waveform with PFC

CHAPTER 7
COMPONANT DESCRIPTION

7.1 Power Factor correction I.C: L6561:

Features:

- Very precise adjustable output over voltage protection
- Micro power start-up current (50µA TYP)
- Very low operating supply current (4mA TYP.)
- Internal start-up timer
- Current sense filter on chip
- Disable function
- 1% Precision (@ Tj = 25°C)internal reference voltage
- Transition mode operation
- Totem pole output current:±400mA
- Dip-8/SO-8 Packages

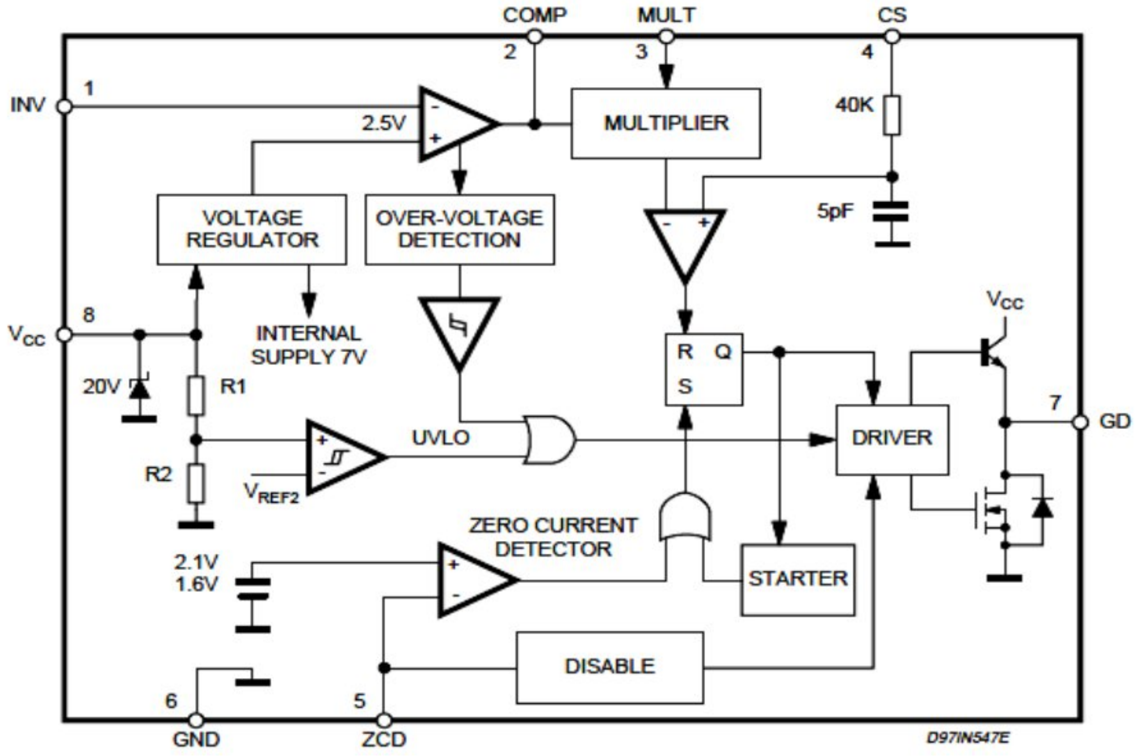


Fig.7.1: Block diagram of L6561

Pin Descriptions:

No.	Name	Function
1	INV	Inverting input of the error amplifier. A resistive divider is connected between the output regulated voltage and this point, to provide voltage feedback.
2	COMP	Output of error amplifier. A feedback compensation network is placed between this pin and the INV pin.
3	MULT	Input of the multiplier stage. A resistive divider connects to the pin the rectified mains. A voltage signal, proportional to the rectified mains, appears on this pin.
4	CS	Input to the comparator of the control loop. The current is sensed by a resistor and the resulting voltage is applied to this pin.
5	ZCD	Zero current detection input. It is connected to GND, the device is disable.
6	GND	Current return for driver and control circuits.
7	GD	Gate driver input. A push pull output stage is able to drive the power MOS with peak current of 400mA(source and sink).
8	V_{CC}	Supply voltage of driver and control circuits.

Device Blocks Description:

Supply Block:

A linear voltage regulator supplied by Vcc generates an internal 7V rail used to supply the whole integrated circuit, except for the output stage which is supplied directly from Vcc. In addition, ab and gap circuit generates the precise internal reference (2.5V±1% @ 25°C) used by the control loop to ensure a good regulation.

The under voltage lockout (UVLO) comparator with hysteresis used to enable the chip as long as the Vcc voltage is high enough to ensure a reliable operation.

Error Amplifier and Overvoltage Detector Block:

The Error Amplifier (E/A) inverting input, through an external divider connected to the output bus, compares partition of the boosted output DC voltage, Vo, with the internal reference, so as to maintain the pre- regulator output DC voltage constant.

The E/A output is used for frequency compensation, usually realized with a feedback capacitor connected to the inverting input. The E/A bandwidth will be extremely low because the output of the E/A must be constant over a line half-cycle to achieve high PF.

The dynamics of the E/A output is internally clamped so that it can swing between 2V and 5.8V in order to speed up the recovery after the E/A saturates low due to an overvoltage or saturates high because of an over current.

The device is provided with a two-level overvoltage protection (OVP), realized by using the pin connected to the E/A output.

In case of overvoltage, the output of the E/A will tend to saturate low but the E/A response is very slow, so it will take a long time to go into saturation. On the other hand, an overvoltage must be corrected immediately. Hence a fast OVP detector, based on a different concept, is necessary.

In steady state condition, the current through R1 is equal to the current in R2 because the compensation capacitor does not allow DC current to flow (neither does the high-impedance inverting input of the E/A):

$$\mathbf{I_{R1,R2}} = \frac{\square\square\square\ \square.\square}{\square\ \square} = \frac{\square.\square}{\square\ \square} \qquad (7.1)$$

When the output voltage rises because of a step load change, the current in R1 builds up as well but the current through R2, fixed by the internal 2.5V reference, does not because of the E/A slowness. The current in excess will then flow through the feedback capacitor and enter the low-impedance E/A output, where it is sensed. In case, a two-step procedure can occur.

When the current in excess reaches about 37mA, the output voltage of the multiplier is forced to decrease thus the energy drawn from the mains is reduced. This slows down the rate of rise of the output voltage. In some cases, this "soft braking" action is able to prevent the output voltage from exceeding the regulated value too much.

If the output voltage further increases despite the soft braking, so that the current entering the E/A reaches 40mA, a "sharp braking" takes place. The output of the multiplier is pulled to ground, thus turning off the output stage and the external MOSFET. Also the internal starter is switched off. The internal current comparator is provided with hysteresis, thus the pull-down will be released and the output stage are enabled as the current entering the E/A falls approximately below 10μA.

Dynamic and Static OVP operation:

This dynamic OVP, with its combination of soft and sharp braking, is effective to handle most of load changes but does not provide a complete protection. In fact it is sensitive to output voltage variations (whence the appellative "dynamic") and cannot reveal a steady overvoltage, which is likely to occur in case of load disconnection.

The above mentioned concept of the E/A saturation is effective to achieve a "static" OVP. If the overvoltage so long that the output of E/A goes below 2.25V (the E/A is in linear dynamics up to 2.5V), the protection is activated. Besides turning off the output stage and the external MOSFET, it disables some internal blocks reducing the quiescent current of the chip to 1.4mA (typ). The operation of the device isre-enabled as the E/A output goes back into its linear region.

Zero Current Detection, Triggering and Disable Block:

As the circuit is running, the signal for ZCD is obtained with an auxiliary winding on the boost inductor. Of course, a circuit is needed that turns on the external MOSFET at start-up since no signal is coming from the ZCD. This is realized with an internal starter, which forces the driver to deliver a pulse to the gate of the MOSFET, producing also the signal for arming the ZCD circuit. The repetition rate of the starter is greater than 70 ms (@ 14 kHz) and this maximum frequency must be taken into account at design time.

Disable Block:

The ZCD pin is used also to activate the Disable Block. If the voltage on the pin is taken below 150 mV the device will be shut down. As a result, its current consumption will be reduced. To re-enable the device operation, the pull-down on the pin must be released.

Multiplier Block:

The multiplier has two inputs: the first one takes a partition of the instantaneous rectified line voltage and the second one the output of the E/A. If this voltage is constant (over a given line half-cycle) the output of the multiplier will be shaped as a rectified sinusoid too. This is the reference signal for the current comparator, which sets the MOSFET peak current cycle by cycle.

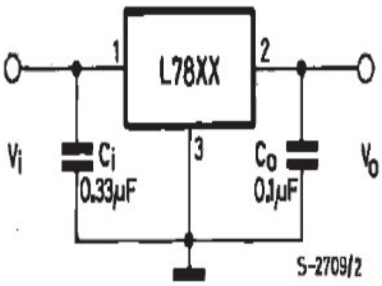
Current Comparator and PWM Latch:

The current comparator senses the voltage across the current sense resistor (Rs) and, by comparing it with the programming signal delivered by the multiplier, determines the exact time when the external MOSFET is to be switched off. The PWM latch avoids spurious switching of the MOSFET which might result from the noise generated. The output of the multiplier is internally clamped to 1.7V,(typ.) thus current limiting occurs if the voltage across Rs reaches this value.

Driver:

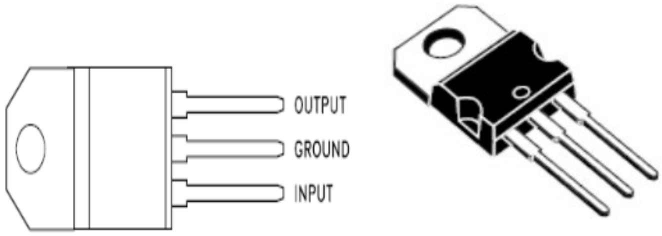
A totem pole buffer, with 400mA source and sink capability, allows driving an external MOSFET. An internal pull-down circuit holds the output low when the device is in UVLO conditions, to ensure that the external MOSFET cannot be turned on accidentally.

7.2 Voltage Regulator: -L7812:



Features:

- Output current 1.5A
- Output voltages of 5,5.2,6,8,8.5,9,12,15,18,24v
- Thermal overload protection
- Short circuit protection
- Output transition soak protection



Description:

These regulators can provide local on-card regulation, eliminating the distribution problems associated with single point regulation. Each type employs internal current limiting, thermal shut down and safe area protection, making it essentially indestructible. If adequate heat sinking is provided, they can deliver over, an output current. Although designed primarily as fixed voltage regulators, these devices can be used with external components to obtain adjustable voltage and currents.

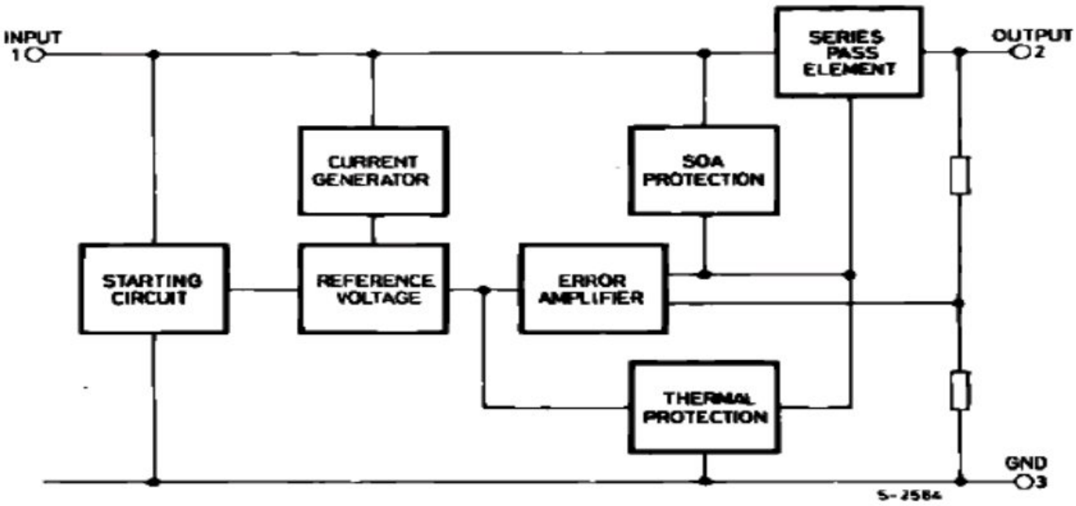
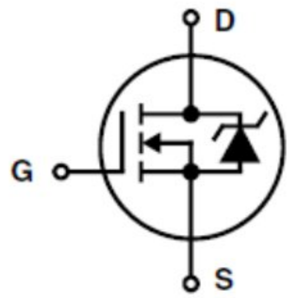
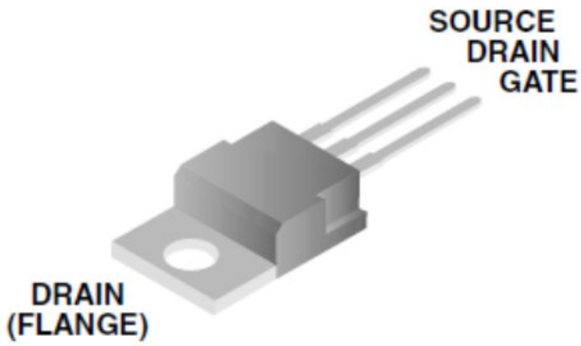


Fig.7.2: Internal block diagram of voltage regulator

7.3 MOSFET: -IRF840:





TYPE	V_{DSS}	$R_{DS(ON)}$	I_D
IRF840	500 V	0.850Ω	8A

Features:

- 8A, 500V
- $R_{DS(ON)}$= 0.850Ω
- Single Pulse Avalanche Energy Rated
- SOA is Power Dissipation Limited
- Nanosecond Switching Speeds
- Linear Transfer Characteristics
- High Input Impedance
- Related Literature
  - TB334 “Guidelines for Soldering Surface Mount Components to PC Boards”

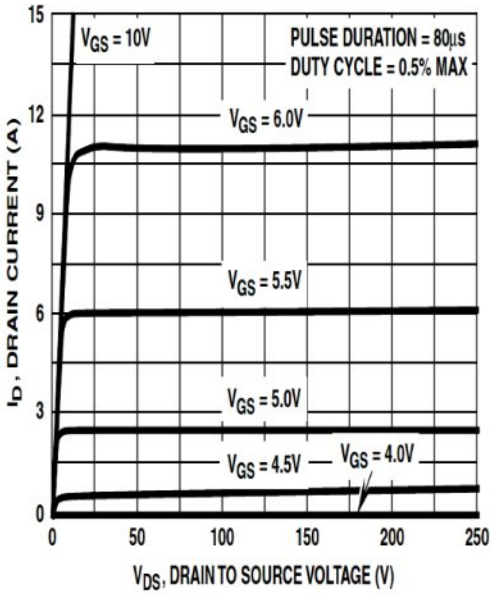
Description:

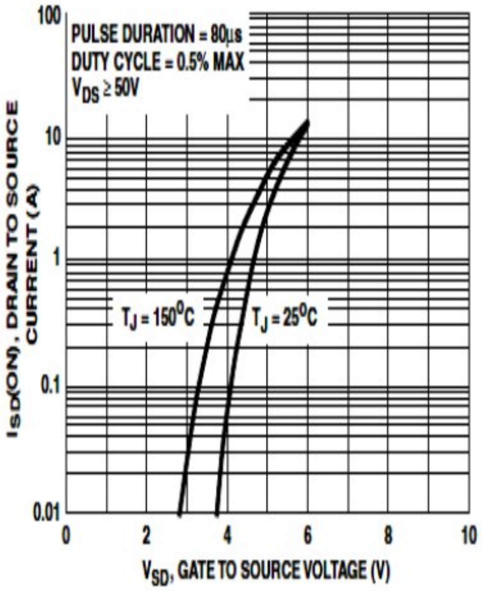
This power MOSFET is designed using the company’s consolidated strip layout based [MESH OVERLAY] process. This technology matches and improves the performances compared with standard parts from various sources.

Application:

- High current switching
- Uninterruptable power supply (UPS)
- Dc/dc converters for telecom industrial and lighting equipment.

Characteristics of MOSFET:



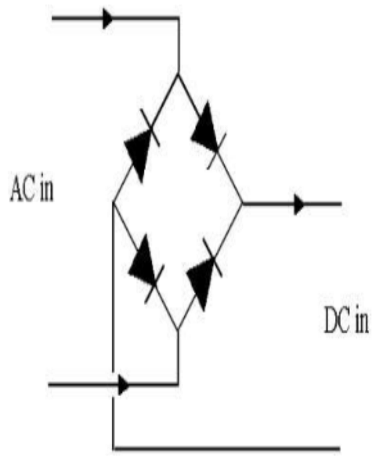


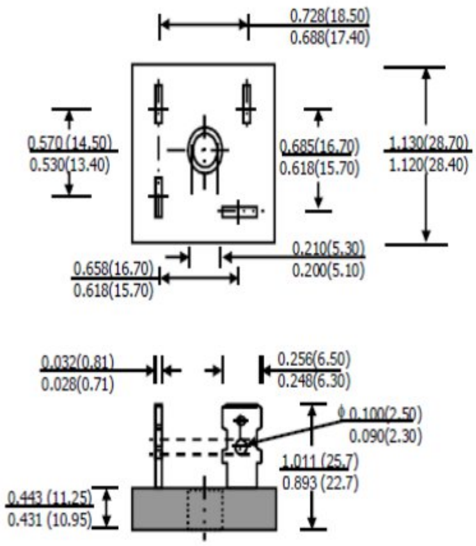
Output characteristics Transfer characteristics

7.4 Bridge Rectifier:-KBPC3510:

FEATURES:

- low cost
- This series is UL recognized under component index, file number E127707
- High forward surge current capability
- Ideal for printed circuit board
- High isolation voltage from case to leads





Dimensions in inches and (millimeters)

7.5 Inductor:

Specification:

- Ferrite core transformer
- Primary -1000 turns (wires 10*0.2mm)
- Secondary -100 turns
  27 AWG (0.15mm)
- Primary inductance-0.8mh
- Current -1 Amp

A First approximation of the inductor value L can be obtain with the following equation:

$$? = \frac{?^{?}?? * ?}{? * ?\% * ?_{??? \; ??} * ?} \quad ?? - ?\frac{\sqrt{?} * ?_{??}}{?_{???}}?? \qquad (7.2)$$

Where,

P_{out} = 40 watt

V_{in} = 85 to 265 Vdc

T = 1/f

f = 50 Hz

V_{out} = 200 to 400 Vdc

η > 90%

1% = Ratio of allowable pk–pk ripple current to peak current to peak current to peak current inductor (20 to 40%)

The inductor selection is somewhat iterative and is determined based on the peak current, operation mode, ripple current, output ripple voltage, component stress and losses. As the design equation will show, most of these parameters move in opposite directions, working against each other, and optimizing the inductor design will require some trade-offs. It is up to the circuit designer to prioritize which parameters is more crucial to satisfy the design requirements.

7.6 Output Capacitor:

Specification:

- Capacitance : 220 µF
- Voltage : 250 Vdc
- Tolerance : 20 %
- Temperature : 105ºC
- Lead type : Radical snap
- Dimensions (D*L) : 25*35 (MM)

The output capacitor is picked based on its capacitance value, voltage &rms current rating. The voltage rating is dictated by the output voltage of the pre-converter circuit. The capacitance value depends on the level of output voltage ripple allowed and on the hold up time in brownout condition.

The level of output ripple is typically set by the secondary stage input requirement Vout-Vripple must be greater than the minimum required input voltage of the second stage.

Typical power supplies require a minimum hold up time in case of loss of the power mains during which the supply must be able to sustain its load output 20 ms of hold up time is accepted standard in the industry. The minimum capacitance required for a 20 ms hold up time can be calculated as:

$$[\text{illegible}] = \frac{[\text{illegible}] * [\text{illegible}] * [\text{illegible}]}{[\text{illegible}]} \qquad (7.3)$$

Where ,

T_{hold} = minimum hold up time, 20 ms

V_{out} = 200 to 400 Vdc

V_{out} = 375 Vdc

7.7 Current Transformer:

CT characteristic:

- Potted with compound & better isolated, betterresis-rush
- High temp rise, corrosion proof
- Small volume, beautiful exterior
- Wide range in linearity, better consistency

Usage: medical treatment, apparatus instrument, communication etc.

CHAPTER 8
CONCLUSION

The power factor correction for the speed control of BLDC motor can be achieved by the boost converter and the distortion factor can be reduced.

In the speed control of BLDC motor at initial condition, the hall sensor senses the rotor position and according to the hall sensor sequence the phases are excited in clockwise and anti-clockwise direction respectively and the motor rotates according to the switching sequence.

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Semester : Semester 8

PPR Details

Time Interval : -

Periodic Progess Report : First PPR

Project : Power Factor Correction Using Boost Converter For The Brushless Dc Motor

Status : Reviewed (Freeze)

1. What Progress you have made in the Project ?

Finding the circuit parameter for over hardware of PFC.

2. What challenge you have faced ?

PFC IC.

3. What support you need ?

No

4. Which literature you have referred ?

IEEE Standard papers, Report and Thesis.

Comments

Comment by Internal Guide :

NA

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

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Discipline : BE

Semester : Semester 8

PPR Details

Time Interval : 0 days, 0 hours, 4 minutes, 9 seconds

Periodic Progess Report : Second PPR

Project : Power Factor Correction Using Boost Converter For The Brushless Dc Motor

Status : Reviewed (Freeze)

1. What Progress you have made in the Project ?

Now we are testing the basic circuit without PFC IC.

2. What challenge you have faced ?

Value of Inductor and desired output is not obtained.

3. What support you need ?

No

4. Which literature you have referred ?

IEEE Standard papers, Report and Thesis.

Comments

Comment by Internal Guide :

NA

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

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Semester : Semester 8

PPR Details

Time Interval : 0 days, 0 hours, 3 minutes, 22 seconds

Periodic Progess Report : Third PPR

Project : Power Factor Correction Using Boost Converter For The Brushless Dc Motor

Status : Reviewed (Freeze)

1. What Progress you have made in the Project ?

Now I am Testing on final PFC circuit with PFC IC.

2. What challenge you have faced ?

Manufacture of Inductor is difficult.

3. What support you need ?

No

4. Which literature you have referred ?

IEEE Standard papers, Report and Thesis.

Comments

Comment by Internal Guide :

NA

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

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Semester : Semester 8

PPR Details

Time Interval : 0 days, 0 hours, 3 minutes, 12 seconds

Periodic Progess Report : Forth PPR

Project : Power Factor Correction Using Boost Converter For The Brushless Dc Motor

Status : Reviewed (Freeze)

1. What Progress you have made in the Project ?

I am making our final circuit on PCB.

2. What challenge you have faced ?

Soldering is difficult.

3. What support you need ?

No

4. Which literature you have referred ?

Youtube videos for soldering.

Comments

Comment by Internal Guide :

NA

Comment by External Guide :

None

Comment by HOD :

None

Comment by Principal :

None

Comment by University Admin :

None

GTU Innovation Council

Patent Drafting Exercise (PDE)

FORM 1 THE PATENTS ACT 1970 (39 OF 1970) & THE PATENTS RULES, 2003 APPLICATION FOR GRANT OF PATENT	(FOR OFFICE USE ONLY) Application No: Filing Date: Amount of Fee paid: CBR No:__________________

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3. Title of Invention/Project:

Power Factor Correction Using Boost Converter For The Brushless Dc Motor

4. Address for correspondence of applicant/authorized patent agent in india

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5. Priority particulars of the application(S) field in convention country

Country	Application No.	Filing Date	Name of the Applicant	Title of the Invention
N/A	*N/A*	*N/A*	*N/A*	*N/A*

6. Particulars for filing patent co-operation treaty (pct) national phase Application

International application number	International filing date as alloted by the receiving office
N/A	N/A

7. Particulars for filing divisional application

Original(First) Application Number	Date of filing of Original (first) application
N/A	N/A

8. Particulars for filing patent of addition

Original(First) Application Number	Date of filing of Original (first) application
N/A	N/A

9. DECLARATIONS:

(i) Declaration by the inventor(s)

I/We, the above named inventor(s) is/are true & first inventor(s) for this invention and declare that the applicant(s). herein is/are my/our assignee or legal representative.

Date : 29 - May - 2016

	Name	Signature & Date
1	Vyas Bhargav Prahladbhai	_______________
2	Bhargav Haresh Indreshbhai	_______________
3	Limmachiya Miteshkumar Jentilal	_______________
4	Patel Meghakumari Nareshbhai	_______________
5	Jogani Harikrushan Ramesh Bhai	_______________

(ii) Declaration by the applicant(s) in the convention country

I/We, the applicant (s) in the convention country declare that the applicant(s) herein is/are my/our assignee or legal representative.applicant(s)

(iii) Declaration by the applicant(s)

I/We, the applicant(s) hereby declare(s) that:-

- ☑ I am/We in possession of the above mentioned invention.
- ☑ The provisional/complete specification relating to the invention is filed with this aplication.
- ☑ The invention as disclosed in the spcification uses the biological material from India and the necessary permission from the competent authority shall be submitted by me/us before the grant of patent to me/us.
- ☑ There is no lawful ground of objection to the grant of the patent to me/us.
- ☑ I am/we are the assignee or the legal representative of true & first inventors.
- ☑ The application or each of the application,particulars of each are given in the para 5 was the first applicatin in the convention country/countries in respect of my/our invention.
- ☑ I/we claim the priority from the above mentioned applications(s) filed in the convention country/countries & state that no application for protection in respect of invention had been made in a convention country before that date by me/us or by any person
- ☑ My/Our application in india is based on international application under Patent Cooperation Treaty (PCT) as mentioned in para 6
- ☑ The application is divided out of my/our application(s) particulars of which are given in para 7 and pray that this application may be treated as deemed to have been filed on ____________under section 16 of the Act.
- ☑ The said invention is an improvement in or modification of the invention particulars of ehivh are given in para 8.

10. Following are the attachments with the application:

- ☑ (a) Provisional specification/Complete specification
- ☑ (b) Complete specification(In confirmation with the international application) / as amended before the international Preliminary Examination Authority (IPEA),as applicable(2 copies),No.of pages.....No.of claims.....

- ☑ (c) Drawings (In confirmation with the international application)/as amended before the international Preliminary Examination Authority(IPEA),as applicable(2 copies),No.of sheets....
- ☑ (d) Priority documents
- ☑ (e) Translations of priority documents/specification/international search reports
- ☑ (f) Statement and undertaking on Form 3
- ☑ (g) Power of Authority
- ☑ (h) Declaration of inventorship on Form 5
- ☑ (i) Sequence listing in electronic Form
- ☑ (j) .... Fees Rs.XXX in Cash /Cheque/Bank Draft bearin No.XXX Date: XXX on XXX Bank.

I/We hereby declare that to the best of my /our knowledge, information and belief the fact and mtters stated herein are correct and I/We request that a patent may be granted to me/us for the said invention.

Dated this **29** day of **May** , **2016**

	Name	Signature & Date
1	Vyas Bhargav Prahladbhai	______________
2	Bhargav Haresh Indreshbhai	______________
3	Limmachiya Miteshkumar Jentilal	______________
4	Patel Meghakumari Nareshbhai	______________
5	Jogani Harikrushan Ramesh Bhai	______________

FORM 2
THE PATENTS ACT, 1970
(39 OF 1970)
&
THE PATENTS RULES, 2003
PROVISIONAL SPECIFICATION

1. Title of the project/invention :

Power Factor Correction Using Boost Converter For The Brushless Dc Motor

2. Applicant(s) :

Vyas Bhargav Prahladbhai (Indian)

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Jogani Harikrushan Ramesh Bhai (Indian)

Address : Electrical Engineering , Vidyabharti Trust, Institute Of Technology & Research Centre, Umrakh-Bardoli , Gujarat Technologycal University.

3. Preamble to the description :

The following specification describes the invention.

4. Description :

a. Field of Application / Project / Invention :

power elecronics,micro controller,,machine

b. Prior Art / Background of the Invention / References :

1.1 POWER FACTOR:

Power factor is defined as the cosine of the angle between voltage and current in an accircuit. There is generally a phase difference Ø between voltage and current in an accircuit. cos Ø is called the power factor of the circuit. If the circuit is inductive, thecurrent lags behind the voltage and power factor is referred to as lagging. However, in acapacitive circuit, current leads the voltage and the power factor is said to be leading.In a circuit, for an input voltage V and a line current I,
VIcos Ø –the active or real power in watts or kW.
VIsin Ø- the reactive power in VAR or kVAR.
VI- the apparent power in VA or kVA.
Power Factor gives a measure of how effective the real power utilization of the system is.It is a measure of distortion of the line voltage and the line current and the phase shiftbetween them.

Power Factor=
Where, the apparent power is defined as the product of rms value of voltage and current.

c. Summary of the Invention/Project :

4.2.1 PEAK CURRENT CONTROL:
The basic scheme of the peak current controller is shown in Fig., together with a typical input current waveform.

Fig.4.2.1 Peak Current control

As we can see, the switch is turned on at constant frequency by a clock signal, and is turned off when the sum of the positive ramp of the inductor current (i.e. the switch current) and an external ramp (compensating ramp) reaches the sinusoidal current reference. This reference is usually obtained by multiplying a scaled replica of the rectified line voltage vg times the output of the voltage error amplifier, which sets the current reference amplitude. In this way, the reference signal is naturally synchronized and always proportional to the line voltage, which is the condition to obtain unity power factor.

As Fig. reveals, the converter operates in Continuous Inductor Current Mode (CICM); this means that devices current stress as well as input filter requirements are reduced. Moreover, with continuous input current, the diodes of the bridge can be slow devices (they operate at line frequency). On the other hand, the hard turn-off of the freewheeling diode increases losses and switching noise, calling for a fast device. Advantages and disadvantages of the solution are summarized hereafter.
4.2.1.1 ADVANTAGES:
1.Constant switching frequency;
2.Only the switch current must be sensed and this can be accomplished by a current transformer, thus avoiding the losses due to the sensing resistor;
3.No need of current error amplifier and its compensation network;
4.possibility of a true switch current limiting.

4.2.1.2 DISADVANTAGES:
1.Presence of sub harmonic oscillations at duty cycles greater than 50%, so a compensation ramp is needed;
2.Input current distortion which increases at high line voltages and light load and is worsened by the presence of the compensation ramp [4-5];
3.Control more sensitive to commutation noises.

The input current distortion can be reduced by changing the current reference wave shape, for example introducing a dc offset, and/or by introducing a soft clamp. These provisions are discussed in [4] and [5]. In [6] it is shown that even with constant current reference, good input current waveforms can be achieved. Moreover, if the PFC is not intended for universal input operation, the duty-cycle can be kept below 50% so avoiding also the compensation ramp. Available commercial IC's for the peak current control are the ML4812 (Micro Linear) [3] and TK84812 (Tokyo).

d. Objects of the Invention/Project :

This project aims to develop a circuit for PFC using active filtering approach by implementingtwo boost converters arranged in parallel. It shall be based on an optimised power sharingstrategy to improve the current quality and at the same time reduce the switching losses.The work initially involves simulation of basic power electronic circuits and the analysis of thecurrent and voltage waveforms. It starts with simple circuits with a gradual increase incomplexity by inclusion of new components and their subsequent effect on the current andvoltage waveforms. We focus on the objective of improving the input current waveform i.e.making it sinusoidal by tuning the circuits.All the simulation work is done in MATLAB Simulink environment and the results are attachedherewith.

e. Drawing(s) :

f. Description of the Invention :

BOOST CONVERTER

3.1 GENERAL:
A boost converter (step-up converter) is a power converter with an output DC voltage greater than its input DC voltage. It is a class of switching-mode power supply (SMPS) containing at least two semiconductor switches (a diode and a transistor) and at least one energy storage element. Filters made of capacitors (sometimes in combination with inductors) are normally added to the output of the converter to reduce output voltage ripple.

Fig.3.1: The basic schematic of a boost converter.

The switch is typically a MOSFET, IGBT, or BJT . Power can also come from DC sources such as batteries, solar panels, rectifiers and DC generators. A process that changes one DC voltage to a different DC voltage is called DC to DC conversion. A boost converter is a DC to DC converter with an output voltage greater than the source voltage. A boost converter is sometimes called a step-up converter since it “steps up” the source voltage. Since power ( ) must be conserved, the output current is lower than the source current.

3.2 CIRCUIT ANALYSIS:
3.2.1 Operating Principle:
The key principle that drives the boost converter is the tendency of an inductor to resist changes in current. In a boost converter, the output voltage is always higher than the input voltage.

Fig.3.2: Boost Converter Circuit

When the switch is turned-ON, the current flows through the inductor and energy is stored in it. When the switch is turned-OFF, the stored energy in the inductor tends to collapse and its polarity changes such that it adds to the input voltage. Thus, the voltage across the inductor and the input voltage are in series and together charge the output capacitor to a voltage higher than the input voltage.
The basic principle of a Boost converter consists of 2 distinct states
1.in the On-state, the switch S (see figure 1) is closed, resulting in an increase in the inductor current;
2.in the Off-state, the switch is open and the only path offered to inductor current is through the fly back diode D, the capacitor C and the load R. This result in transferring the energy accumulated during the On-state into the capacitor.
3.The input current is the same as the inductor current as can be seen in figure 2. So it is not discontinuous as in the buck converter and the requirements on the input filter are relaxed compared to a buck converter.

3.3 WORKING PRINCIPLE OF A BOOST CONVERTER

Fig. 3.1: Figure representing the on and off states of a boost rectifier

Fig.3.3:Behavior of inductor current[2] (a) Waveforms (b) Transistor T gate drive signal x

The input current is(t) is controlled by changing the conduction state of transistor. By switching the transistor with appropriate firing pulse sequence, the waveform of the input current can be controlled to follow a sinusoidal reference, as can be observed in the positive half wave in Fig.3.2(a,b). This figure shows the reference inductor current iLref, the inductor current iL, and the gate drive signal x for transistor. Transistor is ON when x = 1 and it is OFF when x =0. The ON and OFF state of the transistor produces an increase and decrease in the inductor current iL.

Fig.3.4: Harmonic content of the current waveform obtained from a rectifier circuit

Fig.3.5: Harmonic content of the current waveform of a boost PFC converter

As can be clearly seen, the higher order harmonics are considerably reduced in the line current by using a boost converter.

g. Examples :

h. Unique Features of the Project :

Na

5. Date & Signature :

Date :29 - May - 2016

Sign and Date
Vyas Bhargav Prahladbhai

Sign and Date
Bhargav Haresh Indreshbhai

Sign and Date
Limmachiya Miteshkumar Jentilal

Sign and Date
Patel Meghakumari Nareshbhai

Sign and Date
Jogani Harikrushan Ramesh Bhai

6. Abstract of the project / invention :

Power Factor, the ratio between the real or average power and the apparent power forms a veryessential parameter in power system. It is indicative of how effectively the real power of thesystem has been utilized.With rapid development in power semiconductor devices, the usage of power electronic systemshas expanded to new and wide application range that include residential, commercial, aerospaceand many others. Power electronic interfaces e.g. switch mode power supplies (SMPS) haveproved to be superior over traditional linear power supplies. However, their non-linear behaviourputs a question mark on their high efficiency. The current drawn by the SMPSs from the line isdistorted resulting in a high Total Harmonic Distortion(THD) and low Power Factor(PF).Individually, a device with harmonic current does not pose much serious problem however whenused on a massive scale the utility power supply condition could be detoriated. Other adverseeffects on the power system include increased magnitudes of neutral currents in three-phasesystems, overheating in transformers and induction motors etc.Hence, there is a continuous need for power factor improvement and reduction of line currentharmonics. Development of new circuit topologies and control strategies for Power FactorCorrection (PFC) and harmonic reduction has become still more essential with the introductionof strong technical IEC standards.

Drawing Attachments :

FORM 3
THE PATENTS ACT, 1970
(39 OF 1970)
&
THE PATENTS RULES, 2003
STATEMENT AND UNDERTAKING UNDER SECTION 8

1. Declaration :

I/We, Vyas Bhargav Prahladbhai ,
Bhargav Haresh Indreshbhai ,
Limmachiya Miteshkumar Jentilal ,
Patel Meghakumari Nareshbhai ,
Jogani Harikrushan Ramesh Bhai

2. Name, Address and Nationality of the joint Applicant :

Vyas Bhargav Prahladbhai (Indian)
Address :Electrical Engineering , Vidyabharti Trust, Institute Of Technology & Research Centre, Umrakh-Bardoli , Gujarat Technologycal University.

Bhargav Haresh Indreshbhai (Indian)
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Limmachiya Miteshkumar Jentilal (Indian)
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Patel Meghakumari Nareshbhai (Indian)
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Jogani Harikrushan Ramesh Bhai (Indian)
Address :Electrical Engineering , Vidyabharti Trust, Institute Of Technology & Research Centre, Umrakh-Bardoli , Gujarat Technologycal University.

Here by declare :
(i) that I/We have not made any application for the same/substantially the same invention outside India.
(ii) that the right in the application(s) has/have been assigned to,

Name of the Country	*Date of Application*	*Application Number*	*Status of the Application*	*Date of Publication*	*Date of Grant*
N/A	*N/A*	*N/A*	*N/A*	*N/A*	*N/A*

(iii) that I/We undertake that up to the date of grant of patent by the Controller , I/We would keep him inform in writing the details regarding corresponding application(s) for patents filed outside India within 3 months from the date of filing of such application.

Dated this **29** day of **May** , **2016**

3. Signature of Applicants :

Sign and Date
Vyas Bhargav Prahladbhai

Sign and Date
Bhargav Haresh Indreshbhai

Sign and Date
Limmachiya Miteshkumar Jentilal

Sign and Date
Patel Meghakumari Nareshbhai

Sign and Date
Jogani Harikrushan Ramesh Bhai

To
The Controller of Patent
The Patent Office, at **Mumbai.**

Joganí Harikrishna

Bhargav Haresh. I.

Patel Megha. N.

Vyas Bhargav. P.

Limmachiya Mitesh. J.

The Business Model Canvas

Designed for:

Designed by:

Date:

Version:

Key Partners

- Financial Institution
- Customer service
- Social Networks
- Organization
- Distributors

Key Activities

- Hardware
- Testing
- Design
- Programming

Key Resources

- Measuring equipments
- People
- Software
- Display Devices

Value Propositions

- Innovative
- Safety
- Performance
- Individually
- Better P.f
- Control speed

Customer Relationships

- Maintanance
- Good Services

Channels

- Direct setting
- Retailers
- Social Media
- Online Networks

Customer Segments

- Industrialists
- Salesman
- Students
- Automobile Companies
- Distributers
- Market

Cost Structure

- Initial cost
- Marketing
- Transportation
- Salary of employee
- Licence

Revenue Streams

- Asset sale
- Fees
- Real time Market
- Subscription
- Fixed prices
- Advertising

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