POWER FACTOR CORRECTION IN A SINGLE PHASE AC TO DC CONVERTER

A THESIS SUBMITTED IN PARTIAL FULFILLMENT OF THE
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CERTIFICATE

This is to certify that the thesis entitled "**Power factor correction in a single phase AC to DC converter**" submitted by **Smruti Ranjan Samal (Roll no. 10602001)** and **Sanjaya Kumar Dalai (Roll no. 10602007)**, in partial fulfillment of the requirements for the award of Bachelor of Technology in the Department of Electrical Engineering at National Institute of Technology, Rourkela (Deemed University) is an authentic work carried out by them under my supervision and guidance.

To the best of my knowledge, the matter embodied in the thesis has not been submitted to any other University/Institute for the award of any Degree or Diploma.

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ABSTRACT

Electronic equipments recently in use (PCs, TVs, and Telecommunication Equipments etc.) require power conditioning of some form, typically rectification, for their proper working. But since they have non-linear input characteristics and they are connected the electricity distribution network they produce a non-sinusoidal line current. Current of frequency components which are multiples of the natural frequency are produced that are otherwise called the line harmonics. With constantly increasing demand of these kind of equipments at a high rate, line current harmonics have become a significant problem. There has been an introduction of a lot of international standards which pose limitations on the harmonic content in the line currents of equipments connected to electricity distribution networks. This calls for measures to reduce the line current harmonics which is also otherwise known as **Power Factor Correction - PFC**.

There exist two kinds of power factor correction techniques – passive power factor correction and active power factor correction. In this thesis we tried to devise an active power factor correction method for improvement of the power factor. In this work the advantages of a boost converter is combined with that of the average current mode control to implement the technique. UC3854 was used to design the power factor corrector. This integrated circuit had all the circuits necessary to control a power factor corrector and was designed to implement the average current mode control.

CHAPTER 1

INTRODUCTION

1.1 INTRODUCTION :

An ideal single phase supply for domestic use is given by 230 V, 50 Hz which has a proper sinusoidal shape. However the power system has impedance which restricts the flow of current mainly due to magnetic flux effects in substation transformers and transmission lines. It is not possible to completely avoid this impedance or nullify its effect to a much lower level. This in turn results in the voltage difference between the substation supplying power and the consumer point (voltage being less at the consumer point). On the other front growth of consumer electronics has resulted in increase of mains driven electronic devices. These devices have mains rectification circuits which is the main cause of mains harmonic distortion. There would be a lot of such devices and they would be drawing reactive power from the same supply phase resulting in significant amount of reactive current flow and generation of harmonics.

Both of the above affect the power factor of the transmission system. The former relating to the impedance affects the displacement power factor while the latter one affects the distortion power factor of the system. Power factor reveals the electronic usage ratio which the household electronics consume, mainly focus on the degree of usage and waste. The better the power factor the better is the degree of power utilization and lesser is the waste. Hence it is always required to improve the power factor by some means or other and this project undertaken (Active Power factor Correction) is an attempt in this field. In later stages of this report it is explained how this method is adopted and various advantages of this method over its various counterparts. The project intends to combine the meritorious features of a boost converter along with the average current control method.

1.2 POWER FACTOR :

1.2.1 What is power factor

In simple terms, power factor can be defined as the ratio of real power to apparent power.

$$PF = \frac{P}{(\text{Vrms} \times \text{Irms})} \quad \text{or} \quad PF = \frac{\text{Watts}}{\text{V.A.}} \qquad \text{……(1.1)}$$

where P is the real input power and Vrms and Irms are the root mean square (RMS) voltage and current of the load. Correlating to the thesis work these can be considered as inputs given to the power factor corrector. The power factor is a number between 1 and 0. When the power factor is not equal to 1, it is an indication that the current waveform does not follow the voltage waveform. The closer the power factor is to 1 the closer the current waveform follows the voltage waveform.

Real power (watts) produces real work and is known as the energy transfer component. Reactive power is the power required to produce the magnetic fields (lost power) to enable the real work to be done. Reactive power comes into action when there is a mismatch between the demand and supply of power. Apparent power is the total power that is derived from the power company in order to supply the required power to the consumer. Although the active power is responsible for doing work, it is from apparent power only that the current flowing into the load can be determined.

In case the load is a pure resistance, only then the real power and the product of the RMS voltage and current will be the same i.e power factor will be 1. In any other case, the power factor will be below 1.

1.2.2 Forms of power factor

Power factor consists of two components :

- Displacement power factor
- Distortion power factor

The displacement power factor is related to the phase angle while the distortion power factor is related to the shape of the waveform.

$$\text{Power factor} = [\, I_{rms}(1) / I_{rms} \,] \times \cos(\text{Theta}) = Kd \times Kp \qquad \text{……(1.2)}$$

where $I_{rms}(1)$ is the current’s fundamental component and I_{rms} is the current’s RMS value. Theta is the phase angle displacement between the voltage waveform and the current waveform. Kd is called as the distortion power factor and Kp is known as the displacement power factor.

If the waveform of both current and voltage are purely sinusoidal, then power factor is calculated as the cosine of the phase angle between the voltage and current waveforms. However, in reality always a non-sinusoidal current is drawn by most of the power supplies. When the current is not sinusoidal and the voltage is sinusoidal, distortion power factor comes into play which usually is the case. This relationship is shown by equation 1.2.

Displacement power factor comes due to the phase displacement between the current and voltage waveforms. This displacement is caused by the presence of reactance in the power supply system. On the other hand harmonic distortion is responsible for distortion power factor. What happens in reality is the rms value gets increased without any increase in the amount of power drawn. With increase of these effects the power factor of the power supply system reduces. These have the effect of pulling the power factor below the value of 1.

1.2.3 Causes of low power factor

The power factor gets lowered as the real power decreases in comparison to the apparent power. This becomes the case when more reactive power is drawn. This may result from increase in the amount of inductive loads (which are sources of Reactive Power) which include - Transformers, Induction motors, Induction generators (wind mill generators), High intensity discharge (HID) lighting etc**.** However in such a case the displacement power factor is affected and that in turn affects the power factor.

The other cause is the harmonic distortion which is due to presence of the non linear loads in the power system. Due to the drawing of non-sinusoidal current there is further reduction in the power factor.

1.3 NON-LINEAR LOAD :

1.3.1 Non-linear loads

Generally, rectifiers that are used in power supplies, or in certain arc discharge device like fluorescent lamps, electric welding machines, arc furnaces constitute the non-linear load in a power system. The problem with this kind of equipments is other than current of fundamental frequency, current of frequencies which are multiples of power system frequency also flow through them. This is an outcome of regular interruption of current due to the switching action in the rectifiers. Due to the presence of this harmonic current the shape of the current waveform gets changed.

To convert AC input voltage into DC output voltage line frequency diode rectifiers are used. In relatively low power equipment that needs some kind of power conditioning, such as electronic equipment and household appliances, we make use of single phase diode rectifiers. In devices with higher power rating, three-phase diode rectifiers are used. In both of these cases, to smoothen out the ripple and obtain a more or less constant DC output voltage, a large filtering capacitor is connected across the rectifier. Due to this, the line current becomes non-sinusoidal. In most cases, the amplitude of odd harmonics of the line current is considerable with respect to the fundamental and cannot be neglected.

One can neglect the effect of a single low power nonlinear load on the network; however the combined effect of a significant number of nonlinear loads cannot be looked over. Increase in number of customer loads with electronic power supplies is synonymous to growth in the harmonic distortion.

1.3.2 Effect of non-linear loads

The non-linear loads result in production of harmonic currents in the power system. These harmonics in turn result in various undesirable effects on both the distribution network and consumers.

1) In transformers, shunt capacitors, power cables, AC machines and switchgear, they cause extra losses and overheating leading to their premature aging and failure.

2) In a three-phase four-wire system, excessive current flows in the neutral conductor. This is due to odd triple-n current harmonics (triple-n: 3rd, 9th, 15th, etc.)and eventually they cause tripping of the protective relay due to overheating of the neutral conductor.

3) By interaction with the system components resonances take place in the power system. This causes huge increase in amplitude of peak voltages and RMS currents.

4) The line voltage that gets distorted due to the harmonics may affect other consumers connected to the electricity distribution network.

5) The power factor gets reduced. Due to this the active power that is available is less than the apparent power supplied.

6) other effects include - telephone interference, extra audio noise, coggong and crawling of induction motors, errors observed in metering equipments.

1.3.3 Standards for line current harmonics

For limiting the line current harmonics in the current waveform standards are set for regulating them. One such standard was IEC 555-2, which was published by the International Electro-technical Committee in 1982. In 1987, European Committee for Electro-Technical Standardization – CENELEC, adopted this as an European Standard EN 60555-2. Then standard IEC 555-2 has been replaced by standard IEC 1000-3-2 in 1995. The same has been adopted as an European standard EN 61000-3-2 by CENELEC.

Hence, these limitations are kept in mind while designing any instrument. So that there is no violation and the negative effects of harmonics are not highly magnified.

CHAPTER 2

POWER FACTOR CORRECTION

2. POWER FACTOR CORRECTION :

2.1 What is Power Factor Correction (PFC)

Power factor correction is a modern concept which deals with increasing the degraded power factor of a power system by use of external equipments. The objective of this described in plain words is to make the input to a power supply appear as a simple resistor. As long as the ratio between the voltage and current is a constant the input will be resistive and the power factor will be 1.0. When the ratio deviates from a constant the input will contain phase displacement, harmonic distortion or both and either one will degrade the power factor.

In simple words, *Power factor correction (PFC) is a technique of counteracting the undesirable effects of electric loads that create a power factor (PF) that is less than 1.*

2.2 What is the need of PFC ?

Constant increasing demand of consumer electronics has resulted in that the average home has a huge variety of mains driven electronic devices. These electronic devices have mains rectification circuits, which is the dominant reason of mains harmonic distortion. A lot of modern electrical and electronic apparatus require to convert ac to dc power supply within their architecture by some process. This causes current pulses to be drawn from the ac network during each half cycle of the supply waveform. Though a single apparatus (a domestic television for example) may not draw a lot of reactive power or it cannot generate enough harmonics to affect the supply system significantly, but within a typical phase connection there may exist 100s of such devices connected to the same supply phase resulting in production of a significant amount of reactive current flow and current harmonics.

With improvement in semiconductor devices field, the size and weight of control circuits are on a constant decrease. This has also positively affected their performance and functionality and thus power electronic converters have become increasingly popular in industrial, commercial and residential applications. However this mismatch between power supplied and power put to use cannot be detected by any kind of meter used for charging the domestic consumers. It results in direct loss of revenues.

Furthermore 3-phase unbalance can also be created within a housing scheme since different streets are supplied on different phases. The unbalance current flows in the neutral line of a star configuration causing heating and in extreme cases cause burn out of the conductor.

The harmonic content of this pulsating current causes additional losses and dielectric stresses in capacitors and cables, increasing currents in windings of rotating machinery and transformers and noise emissions in many products, and bringing about early failure of fuses and other safety components. The major contributor to this problem in electronic apparatus is the mains rectifier. In recent years, the number of rectifiers connected to utilities has increased rapidly, mainly due to the growing use of computers.

Hence it has become very necessary to somehow decrease the effect of this distortion. Power factor correction is an extra loop added to the input of household applications to increase the efficiency of power usage and decrease the degree of waste.

2.3 Types of Power Factor Correction (PFC)

Power Factor Correction (PFC) can be classified as two types :

- Passive Power Factor Correction
- Active Power Factor Correction

2.4 Passive PFC

In Passive PFC, only passive elements are used in addition to the diode bridge rectifier, to improve the shape of the line current. By use of this category of power factor correction, power factor can be increased to a value of 0.7 to 0.8 approximately. With increase in the voltage of power supply, the sizes of PFC components increase in size. The concept behind passive PFC is to filter out the harmonic currents by use of a low pass filter and only leave the 50 Hz basic wave in order to increase the power factor.

Passive PFC power supply can only decrease the current wave within the standard and the power factor cannot never be corrected to 1. And obviously the output voltage cannot be controlled in this case.

Advantages of Passive PFC :

- It has a simple structure.
- It is reliable and rugged.
- In this equipments used don’t generate high-frequency EMI.
- Only the construction of a filter is required which can be done easily. Hence the cost is very low.
- The high frequency switching losses are absent and it is insensitive to noises and surges.

Disadvantages of Passive PFC :

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

2.5 Active PFC

An active PFC is a power electronic system that is designed to have control over the amount of power drawn by a load and in return it obtains a power factor as close as possible to unity. Commonly any active PFC design functions by controlling the input current of the load in order to make the current waveform follow the mains voltage waveform closely (i.e. a sine wave). A combination of the reactive elements and some active switches are in order to increase the effectiveness of the line current shaping and to obtain controllable output voltage.

The switching frequency further 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 reached easily. Active PFC power supply can detect the input voltage automatically, supports 110V to 240V alternative current, its dimension and weight is smaller than passive PFC power supply which goes against the traditional view that heavier power supply is better.

Advantages of Active PFC :

- The weight of such a system is very less.
- The dimension is also smaller and a power factor value of over 0.95 can be obtained through this method.
- Diminishes the harmonics to remarkably low values.
- By this method automatic correction can be obtained for the AC input voltage.
- It is capable of operating in a full range of voltage.

Disadvantages of Active PFC :

- The layout design is bit more complex.
- Since it needs PFC control IC, high voltage MOSFET, high voltage U-fast, choke and other circuits; it is highly expensive.

In this thesis a method of active power factor correction is proposed. It makes use of a boost converter that uses average current control method discussed in the next section.

CHAPTER 3

CURRENT MODE CONTROL

3. CURRENT CONTROL MODE :

3.1 What is Current control mode

Current mode control uses the load current as feedback to regulate the output voltage. In this approach there is direct control over the load current whereas output voltage is controlled indirectly, hence it is called "current-mode programming".

In this control a functional block using local feedback is formed to create a voltage-to-current converter. By using this voltage-to-current converter block inside an overall voltage feedback loop, a voltage regulator can be produced where the control voltage sets the load current rather than the switch duty cycle (as in the voltage mode programming in which duty cycle is varied as it is directly proportional to the control voltage). Figure 3.1 is a block diagram of the concept.

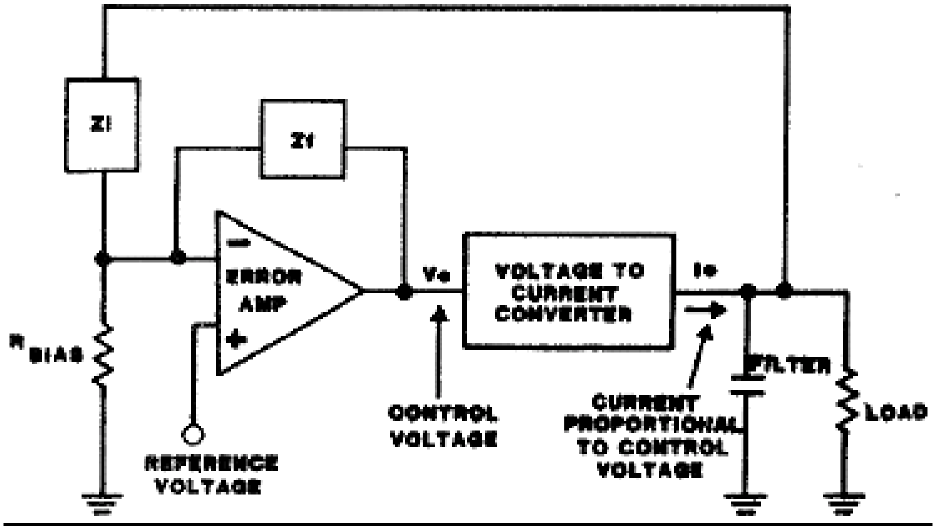

Fig 3.1 : Block diagram of an ideal current mode converter

3.2 Purpose of Current Mode Control

The current-mode approach offers the following advantages :

- Since the output current is proportional to the control voltage, the output current can be limited simply by clamping the control voltage.

- The energy storage inductor is effectively absorbed into the current source. A simpler compensation network can stabilize the control-to-output transfer function.
- When this is applied in higher power applications, parallel connection is used for the power stages. The power stages can be made to share equal current by connecting them to a common bus. This is possible because the output current is proportional to the control voltage.
- Last is the automatic feed forward from the line voltage. This particular feature is actually more readily attained in voltage-mode converters by a technique known as "ramp compensation". In fact, in current-mode converters perfect feed forward is obtained only by a particular value of slope compensation.

3.3 Basics of Current Mode Control

It is a general fact that a constant voltage would be maintained when a constant current flows through a fixed resistor. But when the load resistor changes to maintain the same constant voltage, the current level has to change as the load resistance varies. That is exactly what current mode control of switching power converters is all about. The idea behind the current mode control is to create a voltage-controlled ideal current source. This current source is designed in such a way that it maintains a constant voltage at the output of the power converter regardless of load current changes.

This approach is implemented through two control loops. A current control loop (inner loop) monitors the information about inductor current and thus creates the voltage-controlled current source. The other loop is a voltage loop (outer loop) that would monitor the output voltage of the converter constantly and then program the controlled current source so as it regulates the output voltage at a given set point.

3.4 Ideal vs. Real Current Mode Control

However if we consider reality, there is no existence of an ideal voltage-controlled current source. It is required that the inner current loop senses the inductor current information and afterwards uses it to turn-on or/and turn-off the power converter switches. But this process of sensing the current information has time delays associated with itself and due to it minimum on-time and/or off-time constraints come into picture.

Limitations are imposed by these constraints on the output voltage range that can be generated by a power converter at a given switching frequency and input voltage.

To add to this any sudden change in the load current of the converter would relatively slow down its response as the inner current loop has a limited bandwidth. Additionally, it suffers from inherent instabilities, generally referred to as sub-harmonic oscillation. If adequate compensation is done to account for these instabilities, it slows down the response to any sudden change in input voltage. These imperfections change the concern from "seeking ideal performance" to "seeking the best trade-offs for a given application". This calls for design of different current mode schemes those which can offer the best trade-off for different applications.

3.5 Types of Current Mode of Control

There are various types of current control schemes. Generally a scheme would be named based on the type of inductor current information being sensed and/or how the information is used to control the power switches.

The various current mode control schemes are – average current control, peak current control, hysteresis control, borderline control, valley current control, emulated current control.

Out of those many number of schemes average current mode control is being used in the undertaken project. Hence in this thesis this current control scheme is described and a comparison with another commonly used current control scheme i.e. peak current mode control.

3.6 Peak Current Mode Control (PCMC)

In peak current mode control, the active switch is turned on with constant switching frequency, and turned off when the upslope of the inductor current reaches a level set by the outer loop. When the power switch is on it senses the peak inductor current information, then uses it to turn off the switch. Controlling the turn-off event of the power switch is commonly referred to as "trailing edge modulation". PCMC offers faster response to load and line changes, simpler loop compensation requirements, as well as inherent peak current limit protection as compared to the conventional voltage mode control.

On the other hand, it suffers from sub-harmonic oscillation at duty cycles higher than 50%. By use of ramp compensation which has a slope greater than one-half of the inductor current down-slope these sub-harmonic oscillations can be damped. However, this compensation technique may affect this scheme’s response to ant sudden change in load. A time delay is required to sense the peak inductor current somewhat correctly when the switch is in on state. Hence power converters which utilize PCMC would have a minimum on-time limitation. This results in imposing a limit on the minimum output voltage that can be generated by the converter at a given input voltage and switching frequency.

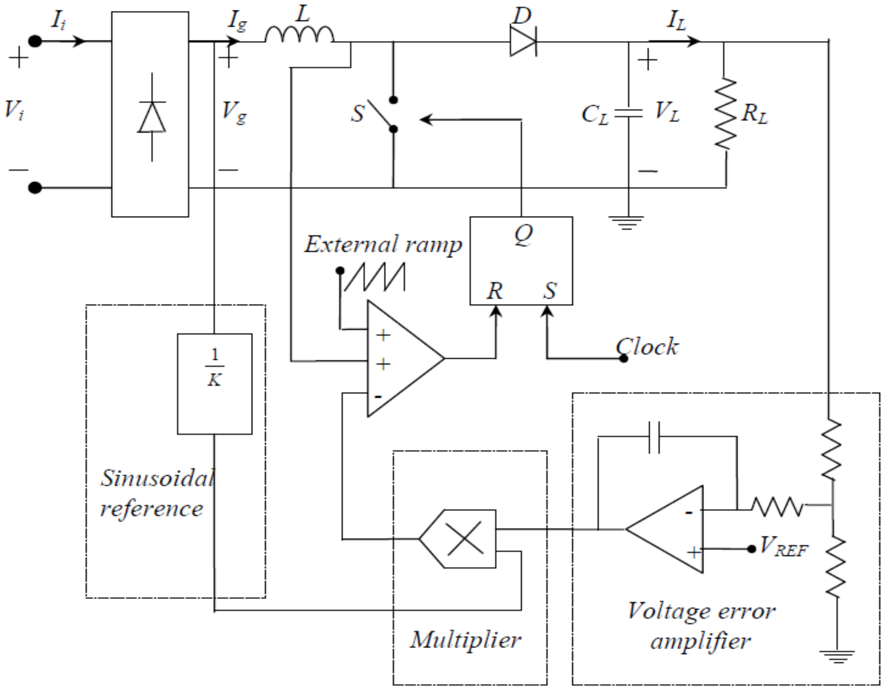

Fig 3.2 : Scheme of peak current controller

The above figure represents the scheme of peak current controller along with a typical input.

Advantages of peak current control :

- It operates with a constant switching frequency.
- A current transformer can sense the switch current and thus losses due to the sensing resistor can be avoided.
- Any kind of compensation network or current error amplifier is need not be used along with it.
- Possibility of a true switch current limiting.
- Response speed and the reliability shows improvement.

Disadvantages of peak current control :

- Sub-harmonic oscillations come into existence at duty cycles greater than 50%, calling for the need of a compensation ramp.
- There is input current distortion and it increases with increase in line voltages or with light load. It further worsens with the use of a compensation ramp.
- The control can be affected by commutation changes and are highly sensitive to their presence.

3.7 Average Current Mode Control (ACMC)

In this current mode control scheme the inductor current is sensed and filtered by a current error amplifier and the output from it drives a PWM modulator. By doing this extra step the inner current loop minimizes the error between the average input current and its reference. This latter is obtained in the same way as in the peak current control.

Average Current Mode Control is typically a two loop control method (inner loop, current; outer loop, voltage) for power electronic converters. The main distinguishing feature of ACMC, as compared with peak current mode control, is that ACMC uses a high gain, wide bandwidth Current Error Amplifier (CEA) to force the average of one current within the converter, typically the inductor current, to follow the demanded current reference with very small error, as a controlled current source.

Below in Fig 3.3 the scheme for average current mode control is shown. This technique of average current mode control overcomes the problems of peak current mode control by introducing a high gain integrating current error amplifier (CEA) into the current loop.

The gain-bandwidth characteristic of the current loop can be tailored for optimum performance by the compensation network around the CA. Compared with peak current mode control, the current loop gain crossover frequency, can be made approximately the same, but the gain will be much greater at lower frequencies.

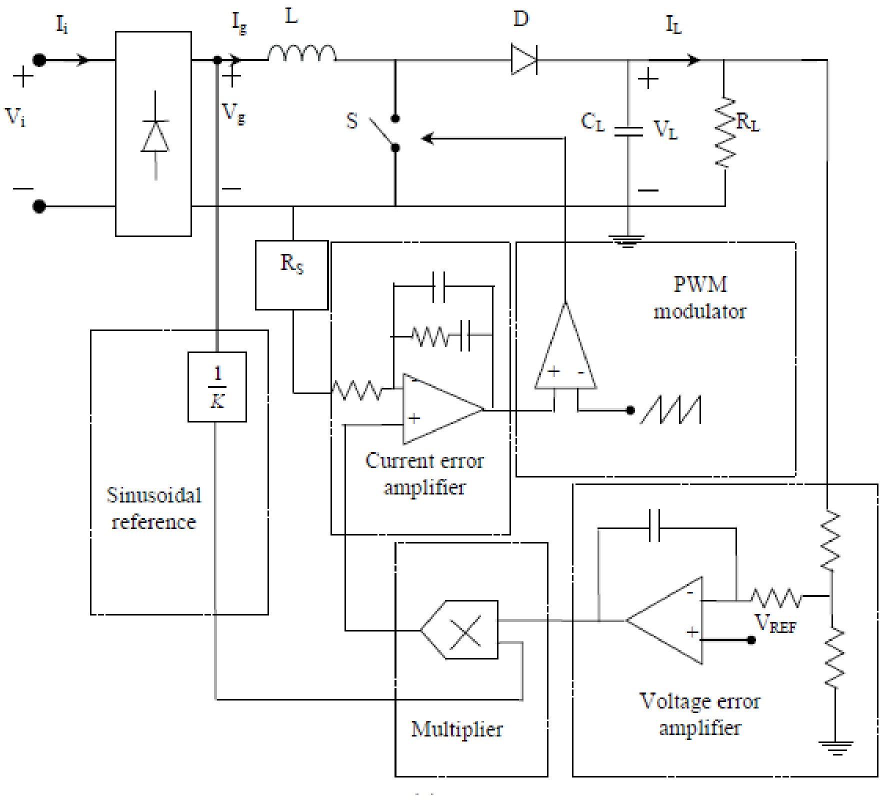

Fig 4.3 Scheme of Average current mode control

Advantages of average current mode control :

- It also operates with a constant switching frequency.
- In this case any compensation ramp is not required.
- Since the current is filtered the control is less sensitive to commutation noises unlike peak current mode control.
- 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.

Disadvantages of average current mode control :

- The inductor current needs to be sensed which is not easy.
- In this current mode control scheme a current error amplifier is needed. For this error amplifier a compensation network needs to be designed in addition, and that must account for different converter operating points

Out of the above two methods the average current mode control is to be implemented in the project due to its superiority over the peak current mode control.

CHAPTER 4

BOOST CONVERTER

4. BOOST CONVERTER :

4.1 What is a boost converter

It is a type of power converter in which the DC voltage obtained at the output stage is greater than that given at the input. It can be considered as a kind of switching-mode power supply (SMPS). Although it can be formed in different configurations, the basic structure must have at least two semiconductor switches (generally a diode and a transistor) and one energy storing element must be used.

4.2 Operating Principle

The inductor has this peculiar property to resist any change of current in them and that serves as the main principle which drives a boost converter. The inductor acts like a load (like resistor) when it is being charged and acts as a source of energy (like battery) when it is discharged. The rate of change of current decides the voltage that is built up in the inductor while it is being discharged. The original charging voltage is not responsible for this and hence it allows different input and output voltages.

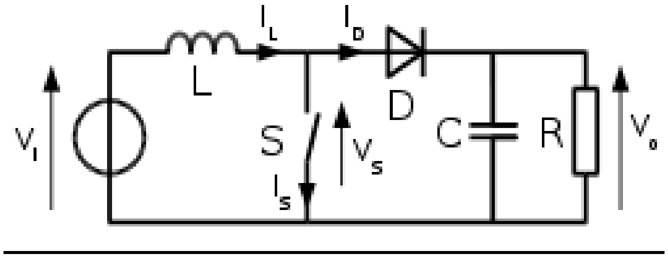

Fig. 4.1 : Boost converter schematic

The Boost converter assumes two distinct states (Fig 4.2) :

- The On-state, in which the switch S in Fig 4.1 is closed, and then there is a constant increase in the inductor current.

- The Off-state, in which the switch S is made open and the inductor current now flows through the diode D, the load R and the capacitor C. In this state, the energy that has been accumulated in the inductor gets transferred to the capacitor.
- The input current and the inductor current are the same. Hence as one can see clearly that current in a boost converter is continuous type and hence the design of input filter is somewhat relaxed or it is of lower value.

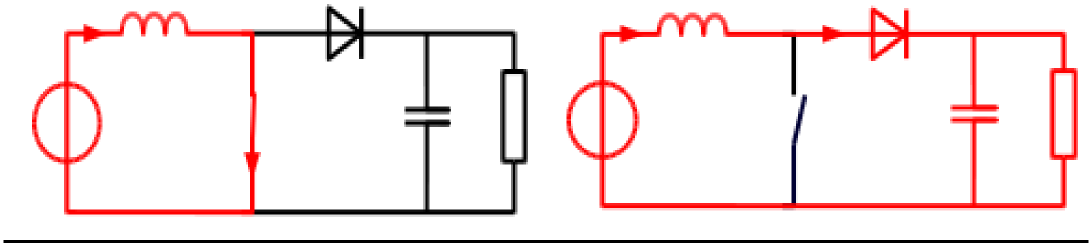

Fig 4.2 : The two states of a boost converter that change with change in state of the switch

4.3 Circuit analysis for Continuous mode

During continuous mode of operation of a boost converter, the inductor current (I_L) never becomes zero during a commutation cycle.

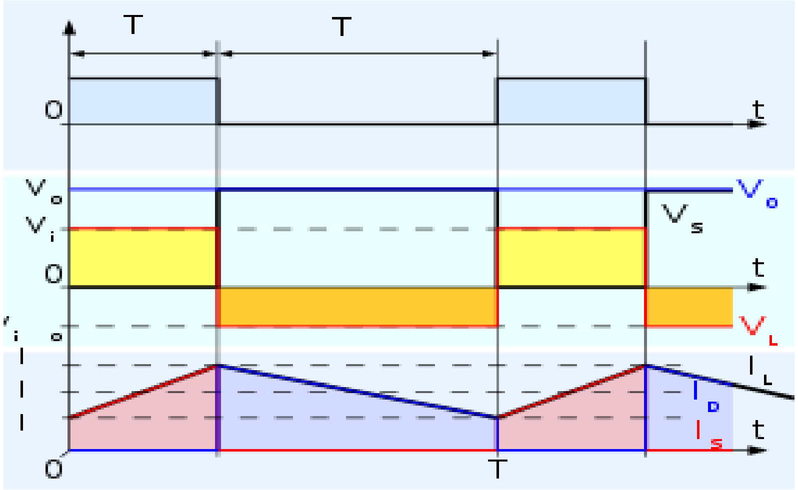

Fig 4.3 : Current and voltage waveforms while a boost converter operates in continuous mode.

The switch S is closed to start the On-state. This makes the input voltage (V_L) appear across the inductor, and that causes change in inductor current (I_L) during a finite time period (t) which is given by the formula:

$$\frac{\Delta I_L}{\Delta t} = \frac{V_i}{L}$$

When the On-state reaches its end, the total increase in I_L is given by:

$$\Delta I_{L_{On}} = \frac{1}{L}\int_0^{DT} V_i dt = \frac{DT}{L} V_i$$

Where D is known as the duty cycle i.e. the ratio of time period for which the switch is On and the total commutating time period T. Therefore D has a value between 0 (that indicates S is never on) and 1 (that indicates S is always on).

When the switch S is made open the converter operates in Off-state. During that time period the load serves as a path for the inductor current. If voltage drop in the diode is neglected or assumed to be zero, and the capacitor is taken to be large enough for maintaining a constant voltage, the equation of I_L is given by:

$$V_i - V_o = L\frac{dI_L}{dt}$$

During the time period for which the converter remains in Off state, the change in I_L is given by:

$$\Delta I_{L_{Off}} = \int_0^{(1-D)T} \frac{(V_i - V_o)\,dt}{L} = \frac{(V_i - V_o)\,(1-D)\,T}{L}$$

As we consider that the converter operates in steady-state conditions, the amount of energy stored in each of its components has to be the same at the beginning and at the end of a commutation cycle. In particular, the energy stored in the inductor is given by:

$$E = \frac{1}{2}LI_L^2$$

Therefore, the inductor current has to be the same at the beginning and the end of the commutation cycle. This can be written as

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = 0$$

Substituting $\Delta I_{L_{On}}$and $\Delta I_{L_{Off}}$by their expressions yields:

$$\Delta I_{L_{On}} + \Delta I_{L_{Off}} = \frac{V_i D T}{L} + \frac{(V_i - V_o)(1-D)T}{L} = 0$$

This can be written as:

$$\frac{V_o}{V_i} = \frac{1}{1-D}$$

which in turns reveals the duty cycle to be :

$$D = 1 - \frac{V_i}{V_o}$$

From the above expression it is observable that the output voltage is always greater than the input voltage (as D is a number between 0 and 1), and that it increases as D increases. Theoretically it should approach infinity as D approaches 1. For this reason boost converter is also known as step-up converter.

4.4 Circuit analysis for Discontinuous mode

The only difference in the principle of discontinuous mode as compared to the continuous mode is that the inductor is completely discharged at the end of the commutation cycle. In this node of operation before the switch in the circuit is opened the inductor current value reaches zero. This kind of case happens when the energy to be transferred is very small and the process of transfer requires a time period less than the commutating time period.

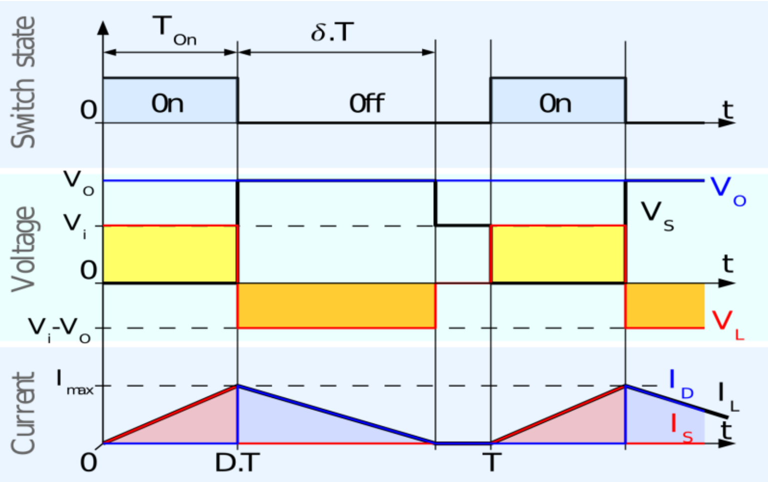

Fig 4.4 : Waveforms of current and voltage in a boost converter operating in discontinuous mode

As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$ (at *t* = *DT*) is

$$I_{L_{Max}} = \frac{V_i DT}{L}$$

During the off-period, I_L falls to zero after δ*T*:

$$I_{L_{Max}} + \frac{(V_i - V_o)\,\delta T}{L} = 0$$

Using the two previous equations, δ is:

$$\delta = \frac{V_i D}{V_o - V_i}$$

The load current I_o is equal to the average diode current (I_D). As can be seen on figure 4, the diode current is equal to the inductor current during the off-state. Therefore the output current can be written as:

$$I_o = \bar{I_D} = \frac{I_{L_{max}}}{2}\delta$$

Replacing I_{Lmax} and δ by their respective expressions yields:

$$I_o = \frac{V_i D T}{2L} \cdot \frac{V_i D}{V_o - V_i} = \frac{V_i^2 D^2 T}{2L\left(V_o - V_i\right)}$$

Therefore, the output voltage gain can be written as flow:

$$\frac{V_o}{V_i} = 1 + \frac{V_i D^2 T}{2 L I_o}$$

In comparison to the output voltage expression for the continuous mode, this expression is much more complicated. Furthermore, in discontinuous operation, the output voltage gain not only depends on the duty cycle, but also on the inductor value, the input voltage, the switching frequency, and the output current.

The Active PFC method proposed in this thesis deals with the continuous mode of operation for its simplicity and easy design process.

CHAPTER 5

ACTIVE POWER FACTOR CORRECTION

5. ACTIVE POWER FACTOR CORRECTION :

5.1 Requisites of Active PFC

A boost regulator is considered to be the best choice for designing the power stage of the active power factor corrector. This is because of the continuity of the input current in a boost converter, production of best input current waveform and the lower level of conducted.

However the high output voltage required in a boost converter accounts as one of its disadvantage. When design is done for a particular voltage range, the output voltage is required to be greater than the highest expected peak input voltage. For power factor correction, the input current in a boost regulator should be made proportional to the input voltage waveform by some forcing technique or programming.

To design such a converter a feedback loop must be implemented to control the input current. Either peak current mode control or average mode control may be used in these cases. As discussed earlier peak current mode control has a low gain and a wide bandwidth current loop which is the reason for its unsuitability for a high performance power factor corrector, since there is a significant error between the programming signal and the current. This results in distortion and a power factor worsens more.

In average current mode control, to make the input current track the programming signal with less error an amplifier is used in the feedback loop around the boost power stage. This is the advantage of average current mode control and it is what makes active power factor correction possible.

5.2 High power factor control circuit

A block diagram of a boost power factor corrector is shown in Fig 5.1. The power circuit of a boost power factor corrector is the same as that of a dc to dc boost converter. A diode bridge is used to rectify the AC input voltage ahead of the inductor. The capacitor generally used for this conversion is kept at the output of the converter and even if any capacitor value is used in the input bridge, its value is very less and it is only used to control any noise.

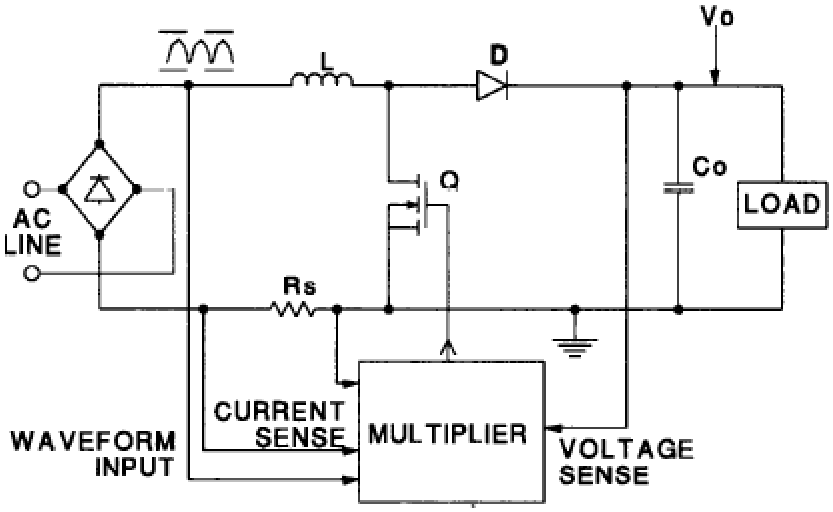

Fig 5.1 : Basic configuration of a high power factor control circuit

A constant voltage is obtained at the boost converter output but the input voltage by some programming forces the input current to be a half wave. The power obtained by the output capacitor is in the form of a sine wave which has a frequency equal to twice that of the line frequency and is never constant. This is illustrated in the Fig 5.2.

In the figure below, the voltage and current that goes into the power factor corrector are indicated by the top waveform. The second waveform shows the power that flows into and out of the capacitor in periods of its charging and discharging. When the input voltage is higher than the voltage of the capacitor energy is stored in the capacitor. When the input voltage drops below the capacitor voltage, to maintain the output power flow the capacitor starts releasing energy. The third waveform in the figure indicates the charging and discharging current. This current appears as if it is the second harmonic component and is different in shape as compared to the input current. Flow of energy reverses direction continuously and that in turn results in a voltage ripple which is shown as the fourth waveform. Since the voltage ripple is generated due to storage of reactive energy it is displaced by 90 degrees relative to the current waveform above it. Ripple current of high frequencies are generated due to the switching of the boost converter. The rating of the output capacitor should be such that it can handle the second harmonic ripple current as well as the high frequency ripple current.

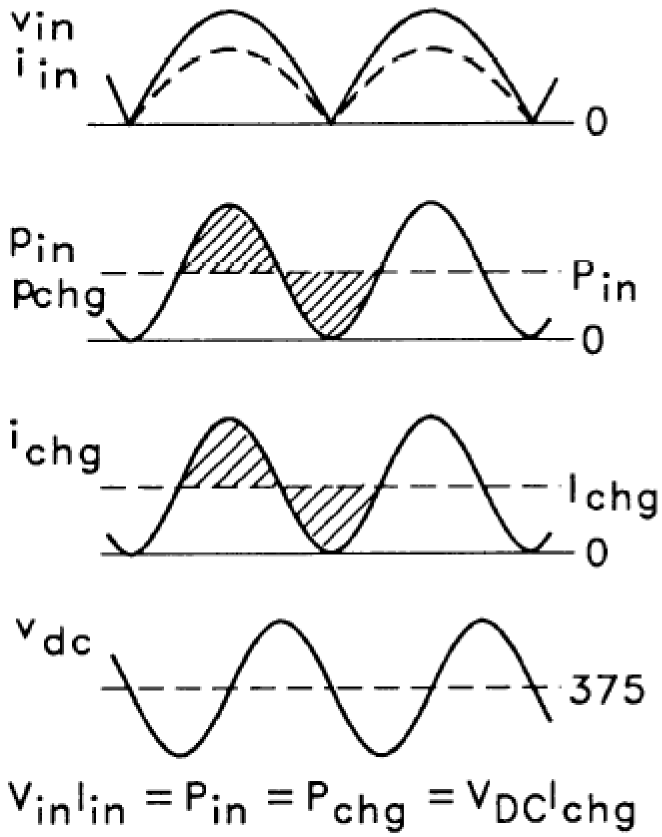

Fig 5.2 : Pre-regulator waveforms

5.3 Control circuit for Active Power Factor Corrector

The active power factor corrector is required to control both the input current and the output voltage. The rectified line voltage programs the current loop in order to make the converter input appear as resistive. Average amplitude of the current that is used as a programming signal is changed to achieve control over the output voltage. The rectified line voltage is multiplied with the output of voltage error amplifier by an analog multiplier.

This produces the current programming signal and provides it the shape of the input voltage and average amplitude which helps control the output voltage.

Figure 5.3 is a block diagram which shows the basic control circuit arrangement necessary for an active power factor corrector. The output of the multiplier is the current programming signal and is called Imo for multiplier output current. A rectified line voltage is shown as the multiplier input.

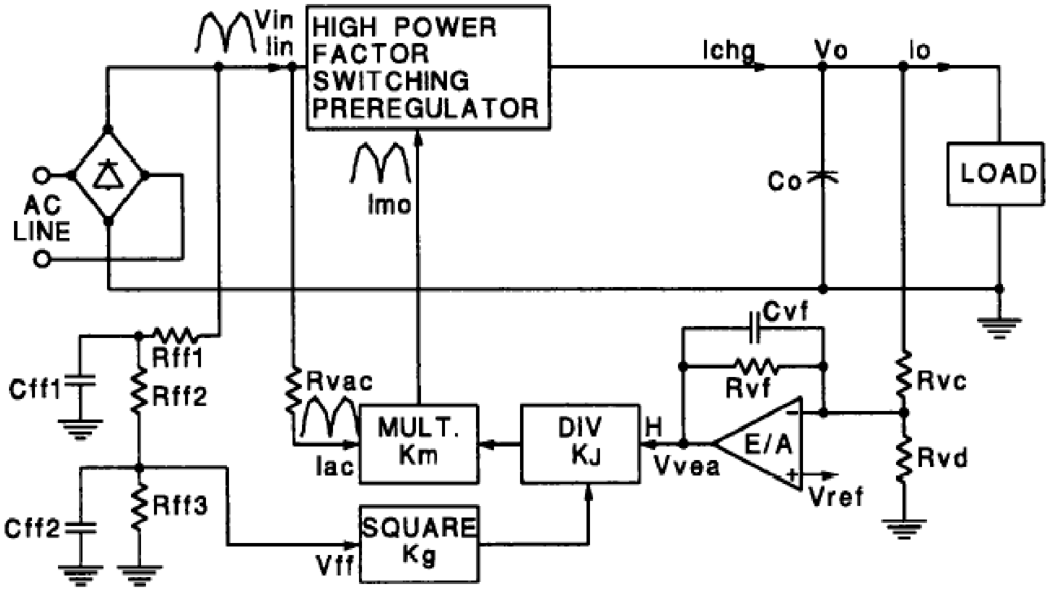

Fig 5.3 : Basic control circuit arrangement necessary for an active power factor corrector

Figure 5.3 has a squarer as well as a divider along with the multiplier in the voltage loop. The divider divides the output of the voltage error amplifier by the square of the average input voltage. The resulting signal is then multiplied by the rectified input voltage signal. The voltage loop gain is maintained at a constant value due to the presence of the combination of these blocks. Otherwise the gain would have varied with change in square of the average input voltage (called feed forward voltage, Vff). This voltage only is squared by which the output of voltage error amplifier is later divided.

For increasing the power factor to the maximum value possible, the rectified line voltage and the current programming signal must match as closely as possible. The bandwidth of the voltage loop should be maintained at a lower value than the input line frequency, failing which huge distortion is produced in the input current. However on the other hand for fast transient response of the output voltage the bandwidth needs to be made as large as possible. In case of wide input voltage ranges, the bandwidth needs to be as close as possible to line frequency. This is achieved by the action of the squarer and divider circuits which help maintain the loop gain constant.

These circuits that maintain constant loop gain convert the output of voltage error amplifier into a power control. Hence, now the power delivered to the load is controlled by this output of the voltage error amplifier. Here we consider an example. Suppose that the voltage error amplifier output is constant and then we double the input voltage. As the programming signal depends on the input voltage it will also get doubled. Then it will get divided by square of the feed forward voltage, which is equal to four times the input now. This results in reducing the input current to half of its original value. Since the input voltage is doubled, a factor of two is associated with it. Then it gets multiplied with half of the input current. This results in no change in the input power and it remains same as before. The output of the voltage error amplifier, then, controls the input power level of the power factor corrector. This can be used to limit the maximum power which the circuit can draw from the power line.

Provisions can be made for clamping the output of the voltage error amplifier at some value which would correspond to some maximum power level. Then as long as the input voltage is within its defined range, the active power factor corrector will not draw more than that amount of power.

Keeping all these in mind, an approach for correction of power factor is proposed in the next section.

CHAPTER 6

PROPOSED DESIGN

6. PROPOSED DESIGN :

6.1 Design procedure for the power factor corrector

For designing the proposed method of power factor correction, a power factor corrector of output rated at 200 W is taken. Although the design is developed for 200 W rating, the control circuit remains more or less the same for output ranging from 50 W to 5000 W. Although the power stage design varies, the design process is the same for all ratings.

1. Specifications:

Determination of the operating requirements for the active power factor corrector.

Pout (max) : 200W

V_{in} range : 80-270Vac

Line frequency range : 47-65Hz

Output voltage : 400Vdc

2. Selection of **switching frequency** :

The switching frequency must be high enough to minimize the size of power circuit and reduce distortion. On the other hand it should be less for greater efficiency. Compromising between the two factors the value is selected as 100 KHz.

3. Inductor selection:

The inductor is selected from the value of maximum peak current which flows through it when the input voltage has minimum value.

A. Maximum peak line current. Pin = Pout(max)

$$Ipk = \frac{\sqrt{2} \times Pin}{Vin\,(\,min\,)}$$

Ipk=1.41 x200/80=3.53 amps

B. Ripple current.

Ripple current is usually assumed to about 20% of the peak inductor current. In this case it is arbitrarily selected to be 22% of it.

I’ = 0.22 x Ipk

I’ = 0.22 x 3.53 = 0.8 amps peak to peak

C. Determination of the **duty factor** at Ipk where Vin(peak) is the peak of the rectified line voltage at low line.

$$D = \frac{Vo - Vin(peak)}{Vo}$$

D = (400-113)/400 = 0.71

D. Calculation of the **inductance**. fs is the switching frequency.

$$L = \frac{Vin \times D}{fs \times \Delta I}$$

L = (113x.71)/(100,000x0.8) = 1.0028 mH. Rounding up to 1.0mH.

4. Selection of **output capacitor**. With hold-up time, the equation below was used. Typical values for Co are 1uF to 2uF per watt. At is the hold-uptime in seconds and V1 is the minimum output capacitor voltage.

$$Co = \frac{2 \times Pout \times \Delta t}{Vo^2 - V1^2}$$

Co = (2x200x34msec)/(400^2-350^2) = 360uF

5. Selection of **current sensing resistor**.

This is required to sense the inductor current. Sense resistor is the least expensive method and is suitable for low power applications. Keeping the peak voltage across the resistor at a low value. 1.0V is a typical value for Vrs.

A. Find $tIpk(max) = Ipk + \frac{\Delta I}{2}$

Ipk(max) = 3.54+0.4 = 3.94 amps peak

B. Calculating **sense resistor** value.

Rs = Vrs / Ipk(max)

Rs = 1.0/4.4 = 0.227 ohms. Choosing 0.25 ohms.

C. Calculation of the actual **peak sense voltage**.

$Vrs(pk) = Ipk(max) \times Rs$

$Vrs(pk) = 4.4 \times 0.25 = 1.1V$

6. Setting up independent peak current limit. **Rpk1** and **Rpk2** are the resistors in the voltage divider. Choosing a peak current overload value, Ipk(ovld). A typical value for Rpk1 is 10K.

$Vrs(ovld) = Ipk(olvd) \times Rs$

$= 4.9 \times 0.25 = 1.225$ V

$Rpk2 = Vrs(ovld) \times Rpk1 / Vref$

$Rpk2 = (1.4 \times 10K) / 7.5 = 1.64K$.

7. Multiplier setup. The operation of the multiplier is given by the following equation. Imo is the multiplier output current, Km=1 , Iac is the multiplier input current, Vff is the feedforward voltage and Vvea is the output of the voltage error amplifier.

$Imo = Km \times Iac \times (Vvea-1) / vff^2$

A. Feedforward voltage divider. Changing Vin from RMS voltage to average voltage of the rectified input voltage. At Vin (min) the voltage at Vff should be 1.414 volts and the voltage at Vffc, the other divider node, should be about 7.5 volts. The average value of Vin is given by the following equation where Vin(min) is the RMS value of the AC input voltage:

$Vin(av) = Vin(min) \times 0.9$

The following two equations are used to find the values for the Vff divider string. A value of 1Megohm is usually chosen for the divider input impedance. The two equations must be solved together to get the resistor values.

$vff = 1.414v = Vin(av) \times Rff3 / (Rff1 + Rff2 + Rff3)$

$Vnode = 7.5V = Vin(av) \times (Rff2 + Rff3) / (Rff1 + Rff2 + Rff3)$

Rff1=910K, Rff2=91K, and Rff3=20K

B. Rvac selection. Maximum peak line voltage is found out.

$Vpk(max) = a \times Vin(max)$

$Vpk(max) = 1.414 \times 270 = 382$ Vpk

Dividing by 600 microamps, the maximum multiplier input current.

Rvac = Vpk(max) / 600E-6

Rvac = (382) / 6E-4 = 637K. Choosing 620K

C. Rb1 selection. This is the bias resistor. Treating this as a voltage divider with Vref and Rvac and then solving for Rb1. The equation becomes:

Rb1 = 0.25 Rvac

Rb1=0.25Rvac=155K. Choosing 150K

D. Rset selection. Imo cannot be greater than twice the current through Rset. Finding the multiplier input current, Iac, with Vin(min). Then calculating the value for Rset based on the value of Iac just calculated.

$$Iac(\min) = \frac{Vin(pk)}{Rvac}$$

Rset = 3.75 / (2 x Iac (min))

Rset = 3.75V / (2x182pA) = 10.3Kohms. Choosing 10 Kohms

E. Rmo selection. The voltage across Rmo must be equal to the voltage across Rs at the peak current limit at low line input voltage.

Rmo = Vrs (pk) x 1.12/2 x Iac(min) = 15.7KHz

: Rmo=(1.1x1.12)/(2x182E-6)=3.39K.

8. Oscillator frequency. Calculate Ct to give the desired switching frequency.

Ct = 1.25 / Rset x fs

Ct = 1.25 / (10K x 100K) = 1.25nF.

9. Current error amplifier compensation.

A. Amplifier gain at the switching frequency.

Calculate the voltage across the sense resistor due to the inductor current downslope and then divide by the switching frequency. With current transformers substitute (Rs/N) for Rs.

The equation is:

Delta Vrs =(400x0.25)/(0.001 x100,000)=1.0Vpk

This voltage must equal the peak to peak amplitude of Vs, the voltage on the timing capacitor (5.2 volts). The gain of the error amplifier is therefore given by:

Gca = Vs/ delta Vrs

Gca = 5.2/1.0=5.2

B. Feedback resistors. Setting Rci equal to Rmo.

Rci = Rmo

Rcz = Gca x Rci

Rcz=5.2x3.39K=17.628Kohms

C. Current loop crossover frequency

$$fci = \frac{Vout \times Rs \times Rcz}{Vs \times 2\pi L \times Rci}$$

Fci = (400 x 0.25 x 20K) / (5.2 x 2 x pie x 0.001 x 3.9K) = 15.7KHz

D. Ccz selection. Choose a 45 degree phase margin. Setting the zero at the loop crossover frequency.

$$Ccz = \frac{1}{2\pi \times fci \times Rcz}$$

Ccz=1/(2xpiex15.7x17.7K)=572pF

Choosing 580pF.

E. Ccp selection. The pole must be above fs/2.

$$Ccp = \frac{1}{2\pi \times fs \times Rcz}$$

Ccp=1/(2~x 100Kx17.7K)=89.9pf. Choosing 90pF.

10. Harmonic distortion budget. Deciding on a maximum THD level. Allocating THD sources as necessary. The predominant AC line harmonic is third. Output voltage ripple contributes 1/2% third harmonic to the input current for each 1% ripple at the second harmonic on the output of the error amplifier. The feedforward voltage, Vff, contributes

1% third harmonic to the input current for each 1% second harmonic at the Vff input to the UC3854.

3% third harmonic AC input current is chosen. as the specification. 1.5% is allocated to the Vff input and 0.75% is allocated to the output ripple voltage or 1.5% to Vvao. The remaining 0.75% is allocated to miscellaneous nonlinearities.

11. Voltage error amplifier compensation.

A. Output ripple voltage. The output ripple is given by the following equation where fr is the second harmonic ripple frequency:

$$Vo(pk) = \frac{Pin}{2\pi fr \times Co \times Vo}$$

Vo(pk) = 200 /(2~100 x 360E-6 x 400) = 2.21Vac

B. Amplifier output ripple voltage and gain. Vo(pk) must be reduced to the ripple voltage allowed at the output of the voltage error amplifier. This sets the gain of the voltage error amplifier at the second harmonic frequency.

The equation is:

$$Gva = \frac{\Delta Vvao \times \%Ripple}{Vo(pk)}$$

For the UC3854 Vvao is 5 -1 = 4V

Gva = (4 x 0.015) / 2.21 = 0.0271

C. Feedback network values. Find the component values to set the gain of the voltage error amplifier. The value of Rvi is reasonably arbitrary.

Choosing Rvi=511K

$$Cvf = \frac{1}{2\pi \times fr \times Rvi \times Gva}$$

Cvf=1/(2x3.14x100x511x2.21)=.1149uF

D. Setting DC output voltage.

$$\mathrm{Rvd} = \frac{\mathrm{Rvi} \times \mathrm{Vref}}{\mathrm{Vo} - \mathrm{Vref}}$$

Rvd = (511K x 7.5) / (400 - 7.5) = 9.76K. Choosing 10.0K.

E. Finding **pole frequency**.
fvi = unity gain frequency of voltage loop.

$$\mathrm{fvi}^2 = \frac{\mathrm{Pin}}{\Delta\mathrm{Vvao} \times \mathrm{Vo} \times \mathrm{Rvi} \times \mathrm{Co} \times \mathrm{Cvf} \times (2\pi)^2}$$

Fvi = sqrt(200 / (4 x 400 x 511K x 360E-6 x .1149E-6 x 39.5))
= 12.1Hz

F. Finding **Rvf.**

$$\mathrm{Rvf} = \frac{1}{2\pi \times \mathrm{fvi} \times \mathrm{Cvf}}$$

Rvf = 1 / (2 x 12.1 x 47E-9) = 114.47K. Choosing 120K.

12. Feed forward voltage divider capacitors. These capacitors determine the contribution of Vff to the third harmonic distortion on the AC input current. Determine the amount of attenuation needed. The second harmonic content of the rectified line voltage is 66.2%. %THD is the allowed percentage of harmonic distortion budgeted to this input from step 10 above.

Gff = %THD / 66.2%

Gff = 1.5 / 66.2 = 0.0227

Using two equal cascaded poles. Find the pole frequencies. fr is the second harmonic ripple frequency.

fp = sqrt (Gff) x fr.

fp=0.15xl00=15Hz

13.Select Cff1 and Cff2.

$$\mathrm{Cff1} = \frac{1}{2\pi \times \mathrm{fp} \times \mathrm{Rff2}} \qquad \mathrm{Cff2} = \frac{1}{2\pi \times \mathrm{fp} \times \mathrm{Rff3}}$$

Cff1 = 1 / (2 x 3.14 x 15 x 91K) = 0.116uF

Cff2 = 1 / (2 x 3.14 x 15 x 20K) = 0.53uF

6.2 Inductor design for the Boost converter

$I_m = I_0 + I' =$ 5.5 A

$E = 0.5 * L * I_m^2 = 15.125 * 10^{-3}$ joules

$A_p = Aw * Ac = 2E/(K_w * K_c * I * B_m)$

[$B_m = 0.2$ for ferrite, $J = 3\ A/mm^2$, $K_w = 0.6$, $Kc = 1$]

$= 84.02 * 10^{-9}\ m^4 = 8.4\ mm^4$

Proper choice of core E 65/32/13

$A_c = 2.66\ cm^2$, $A_w = 5.37\ cm^2$, $A_p = 14.284\ cm^4$

No. of turns :

$N = L * I_m / (A_c * B_m) = 103.33 = 104$ turns (approx.)

Wire gauge :

$A = I_0 / J$

$= 5 / 3 = 1.6667\ mm^2$

For this **SWG 16** is a proper choice ($a = 2.075\ mm^2$)

Cross check :

The inequality **$\underline{A_w K_w > aN}$** has to be satisfied.

So,

$A_w K_w = 322.2\ mm^2$

$aN = 215.8\ mm^2$

Hence the inequality is satisfied, which means that the windings will fit into the available window area.

Air gap length :

$l_g = u_0 N^2 A_c / L = 3.615\ mm$

As has been described earlier, the design process can be adopted for an output power ranging from 50 W to 5000 W. In this thesis another design is done for 250 W output power. The circuit diagram for the design of 250 W is shown in the figure below. All the value of the components labeled below, are for the 250 W output power design.

6.3 Circuit Diagram

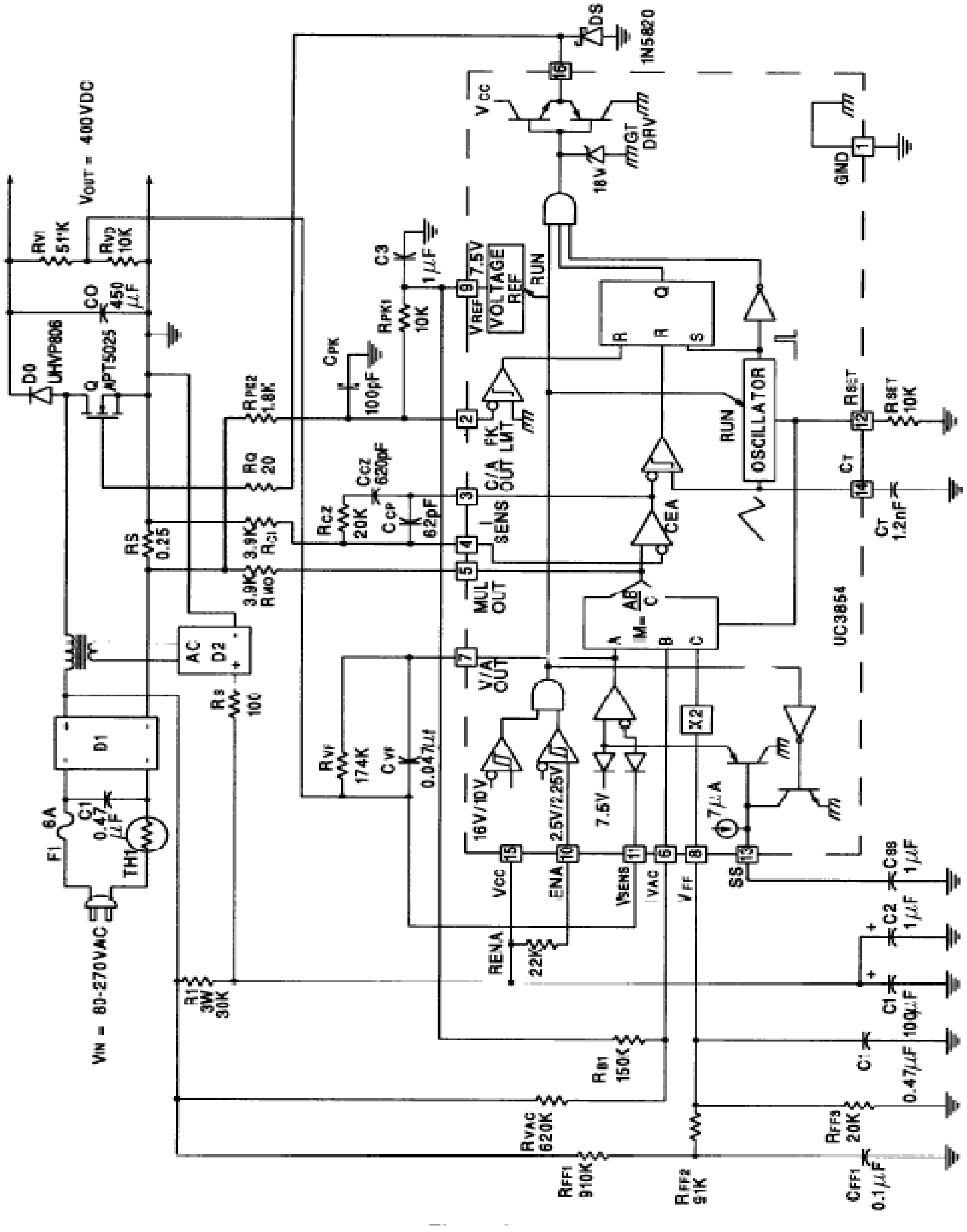

Fig 6.1 : Complete schematic of 250 W power factor regulator

CHAPTER 7

SIMULATION RESULTS

7. SIMULATION

7.1 Powersim (PSIM) software

PSIM is a simulation software specifically designed for power electronics and motor drives. With fast simulation and friendly user interface, PSIM provides a powerful simulation environment for power electronics, analog and digital control, magnetics, motor drives, and dynamic system studies.

The PSIM simulation environment consists of the PSIM circuit schematic, the simulation engine, and the waveform processing program SIMVIEW. The PSIM schematic program provides interactive and user-friendly interface for circuit schematic entry and editing. SIMVIEW is the waveform display and post-processing program for PSIM. It provides a powerful environment to display and analyze simulation results.

All the simulations that has been carried out in the thesis, is done in this PSIM software.

7.2 Few Passive PFC methods

7.2.1 Rectifier with AC side inductor

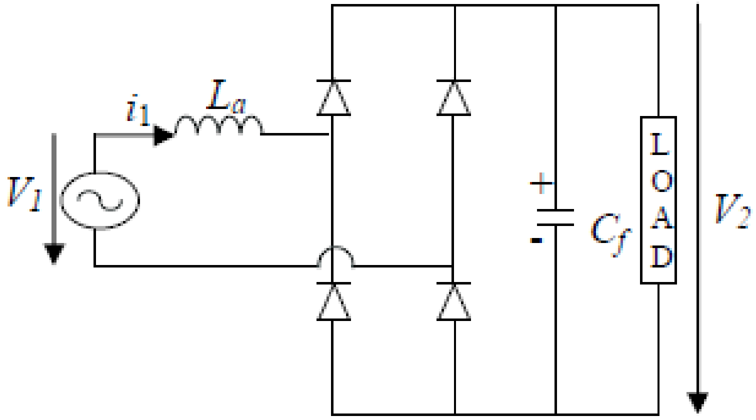

Fig 7.1 : Circuit showing passive PFC done with inductor on the AC side

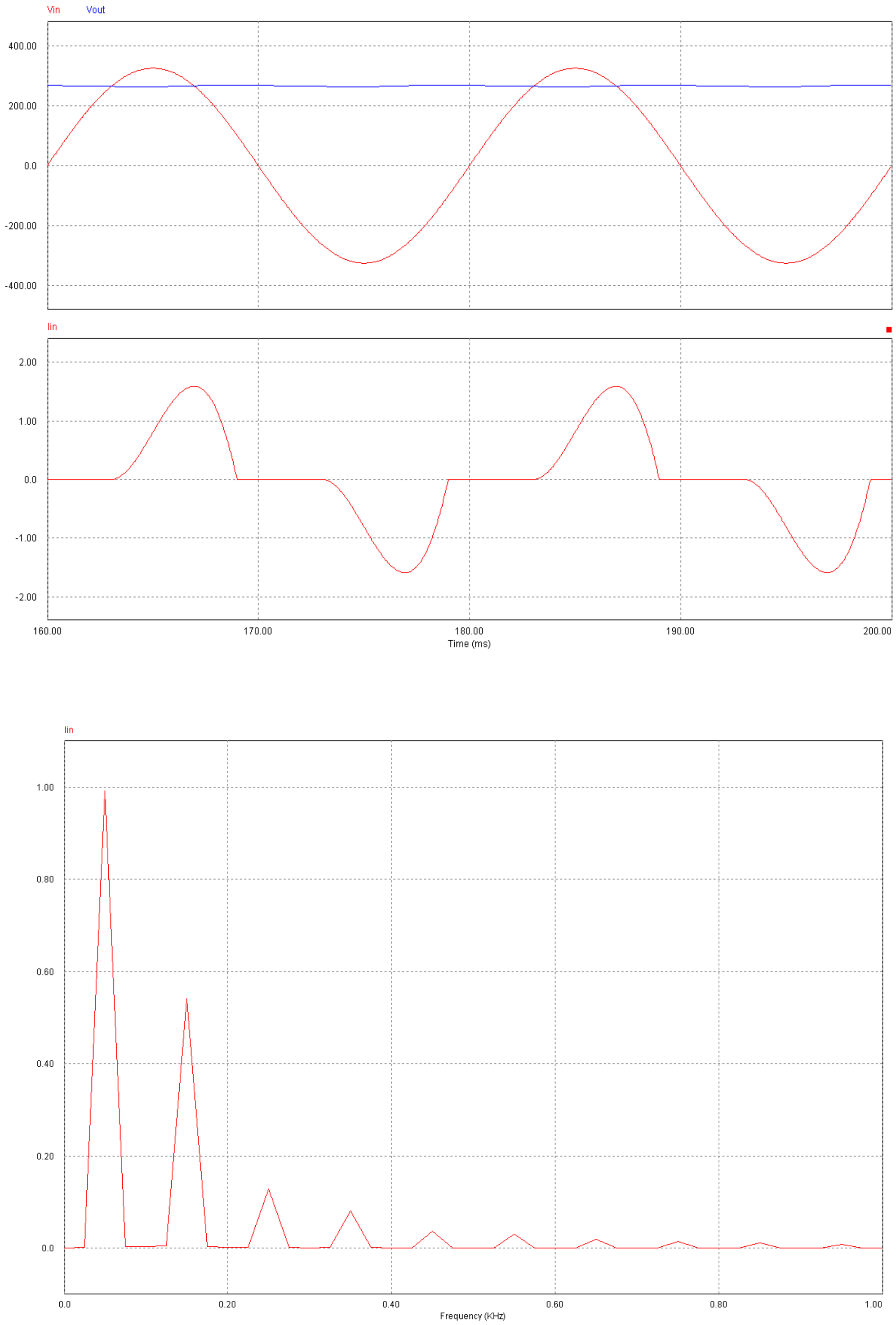

Fig 7.2 : Input voltage, input current and line current harmonics for inductor used in rectifier side, where L = 100 mH, C = 500 uF and R = 500 ohms

7.2.2 Rectifier with inductor on the DC side

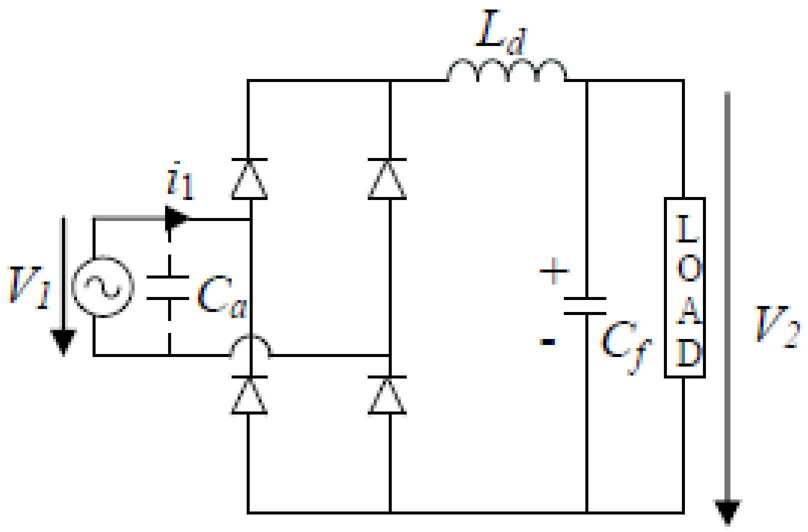

Fig 7.3 : Schematic showing passive PFC by use of inductor in the DC side

7.2.3 Rectifier with series-resonant band-pass filter

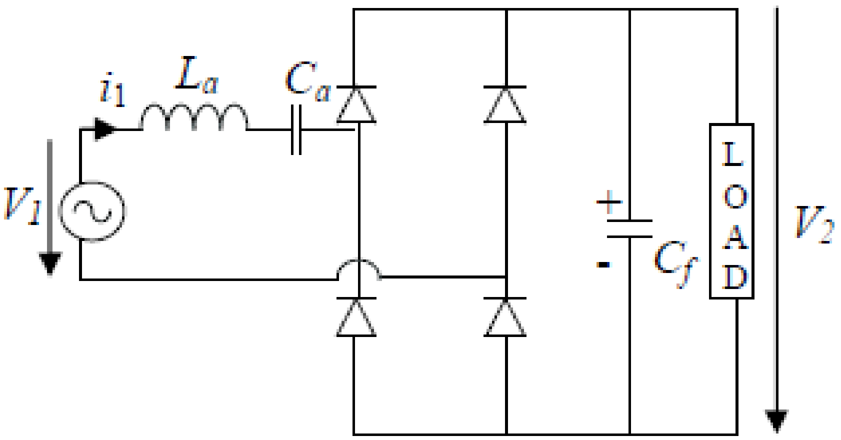

Fig 7.4 Schematic showing passive PFC by using series-resonant band-pass filter

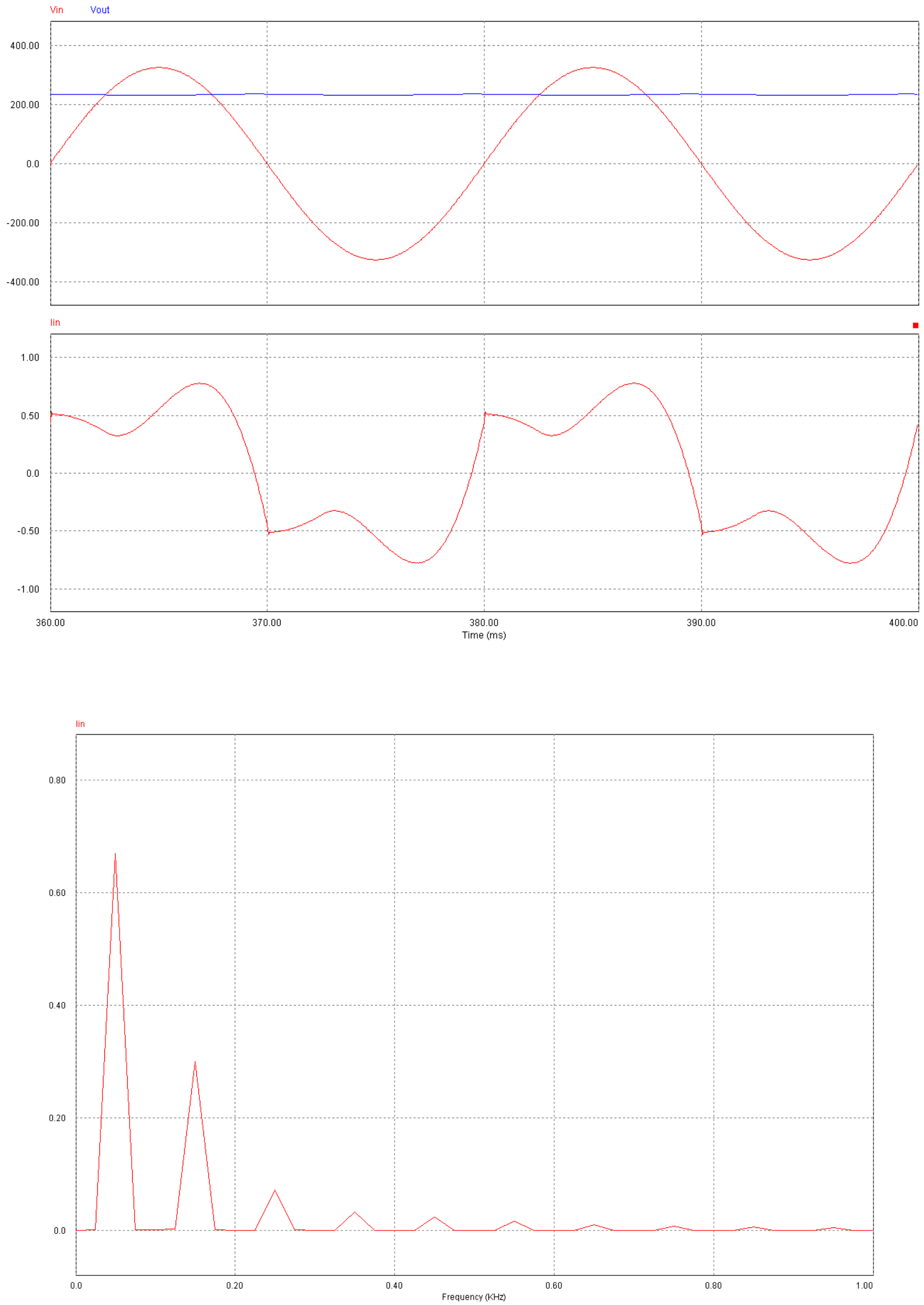

Fig 7.5 : Input voltage, input current and line current harmonics for inductor used in the DC side, where L = 100 mH, C = 500 uF, R = 500 ohms and Ca = 5 uF

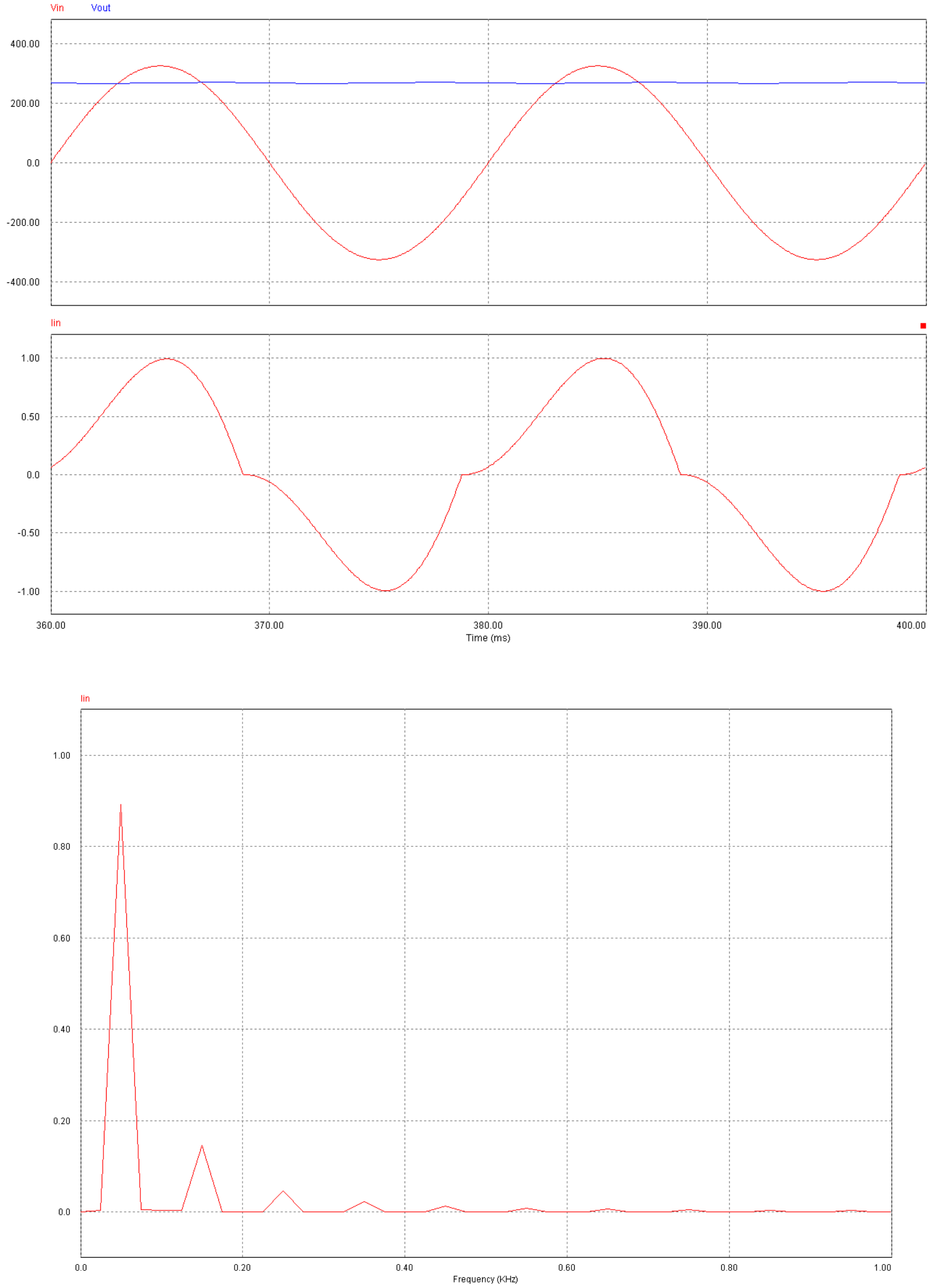

Fig 7.6 : Input voltage, input current and line current harmonics for a series-resonant band-pass filter used in the rectifier, where L = 100 mH, C = 500 uF, R = 500 ohms and Ca = 5 uF

7.3 Peak Current mode Control

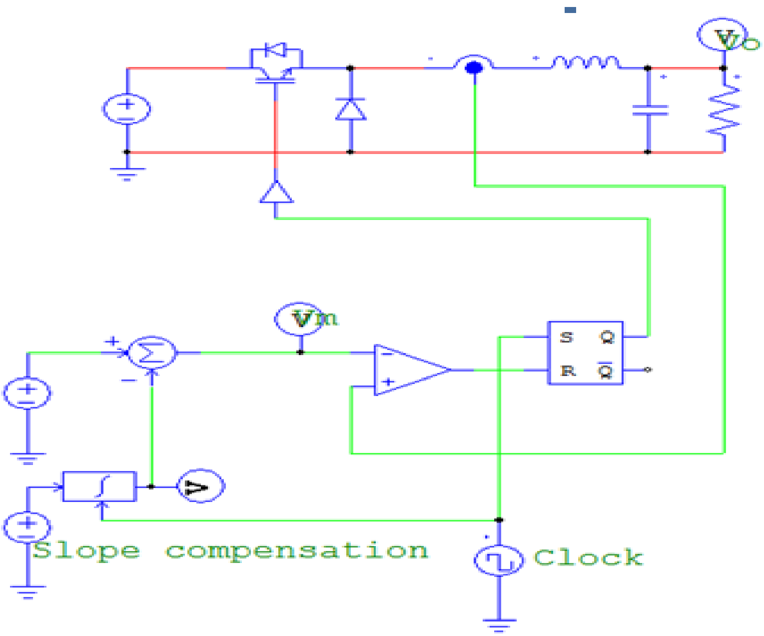

Fig 7.7 : PSIM model of peak current mode control with slope compensation

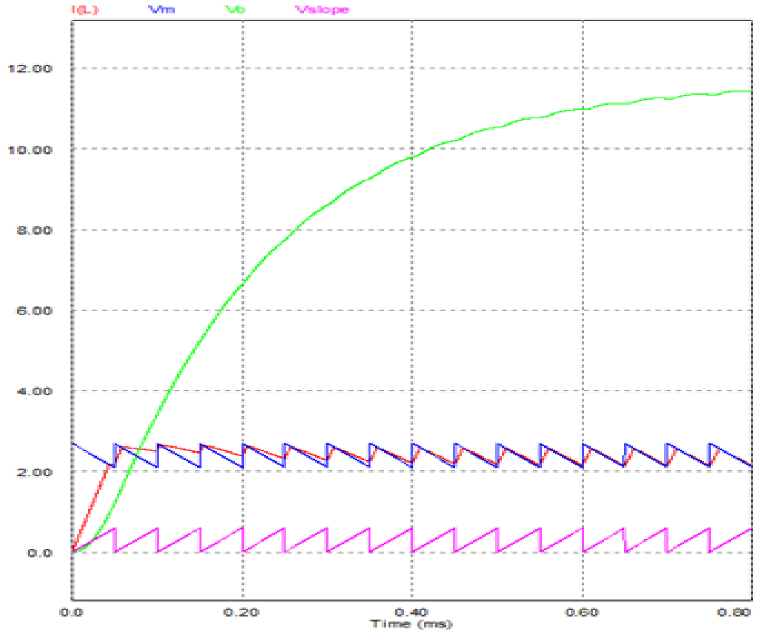

Fig 7.8 : Input and output waveforms obtained from peak current mode control

7.4 Average Current mode Control

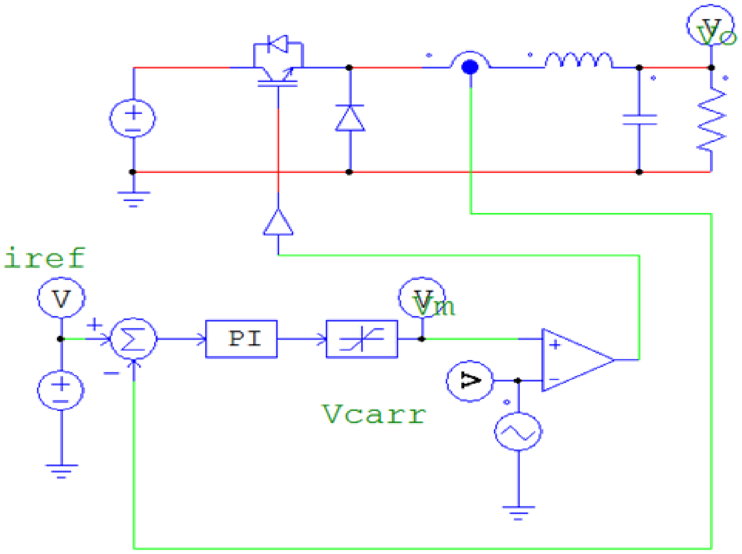

Fig 7.9 : PSIM model showing average current mode control

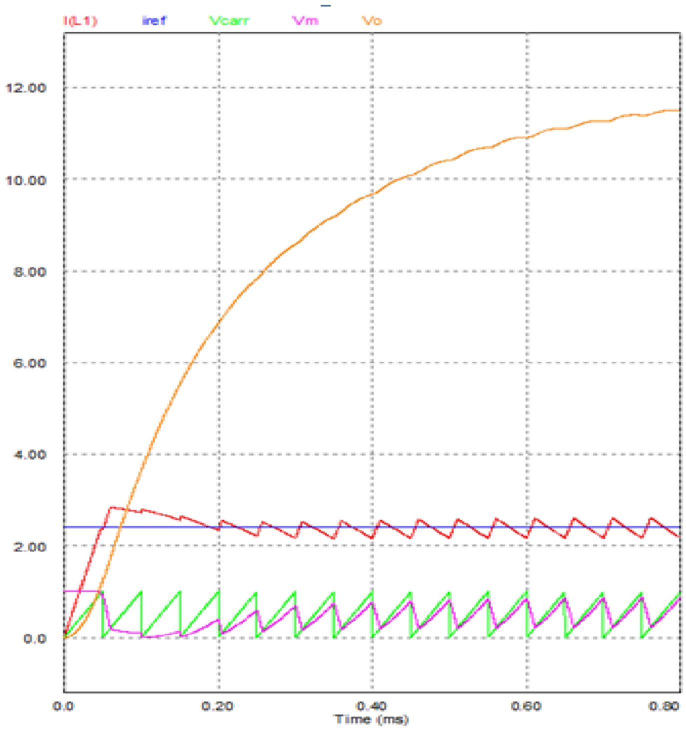

Fig 7.10 : Input and Output waveforms obtained by average current mode control

7.5 Simulation Results for the Power Factor corrector

Ratings of the active power factor corrector :

- **Maximum output power = 250 W**
- **Range of voltage input : 80-270 V AC (rms)**
- **Operating frequency range : 47-65 Hz**
- **Output Voltage = 400 V**
- **Load Resistance = 643 ohms**
- **Inductor value = 1 mH**
- **Output capacitor = 450 uF**

Table 7.1 : Simulation results for the 250 W power factor corrector

Line Voltage, Vin (in V)	Output Voltage, Vout (in V)	Efficiency (in %)	Power Factor	Total Harmonic Distortion (in %)
For no value of inductance on the input side				
180	401.066	95.5	0.980856	19.78
190	401.066	96.0	0.978924	19.78
200	401.064	95.8	0.977540	21.46
210	401.062	95.65	0.976316	23.55
220	401.058	95.46	0.975302	22.5
230	401.053	95.36	0.974539	22.89
240	401.046	95.25	0.974022	22.12
250	401.039	95.31	0.973789	23.23
For an inductance of value 0.1 mH in the input side				
180	401.105	97.78	0.980346	3.31
190	401.105	97.77	0.978714	3.01
200	401.104	97.74	0.977193	2.77
210	401.105	97.62	0.975871	2.62
220	401.098	97.69	0.974744	2.52
230	401.092	97.67	0.973961	2.35
240	401.089	97.65	0.973376	2.37
250	401.078	97.61	0.973088	2.38

As can be seen from the simulation results and the curves obtained though there is no significant improvement in the power factor of the circuit there is an improvement in the efficiency of the converter by using a small inductor on the input supply side. Also the total harmonic distortion is reduced to an acceptable range (less than 6 %). Most importantly, the input current waveform is more sinusoidal kind and ripple free.

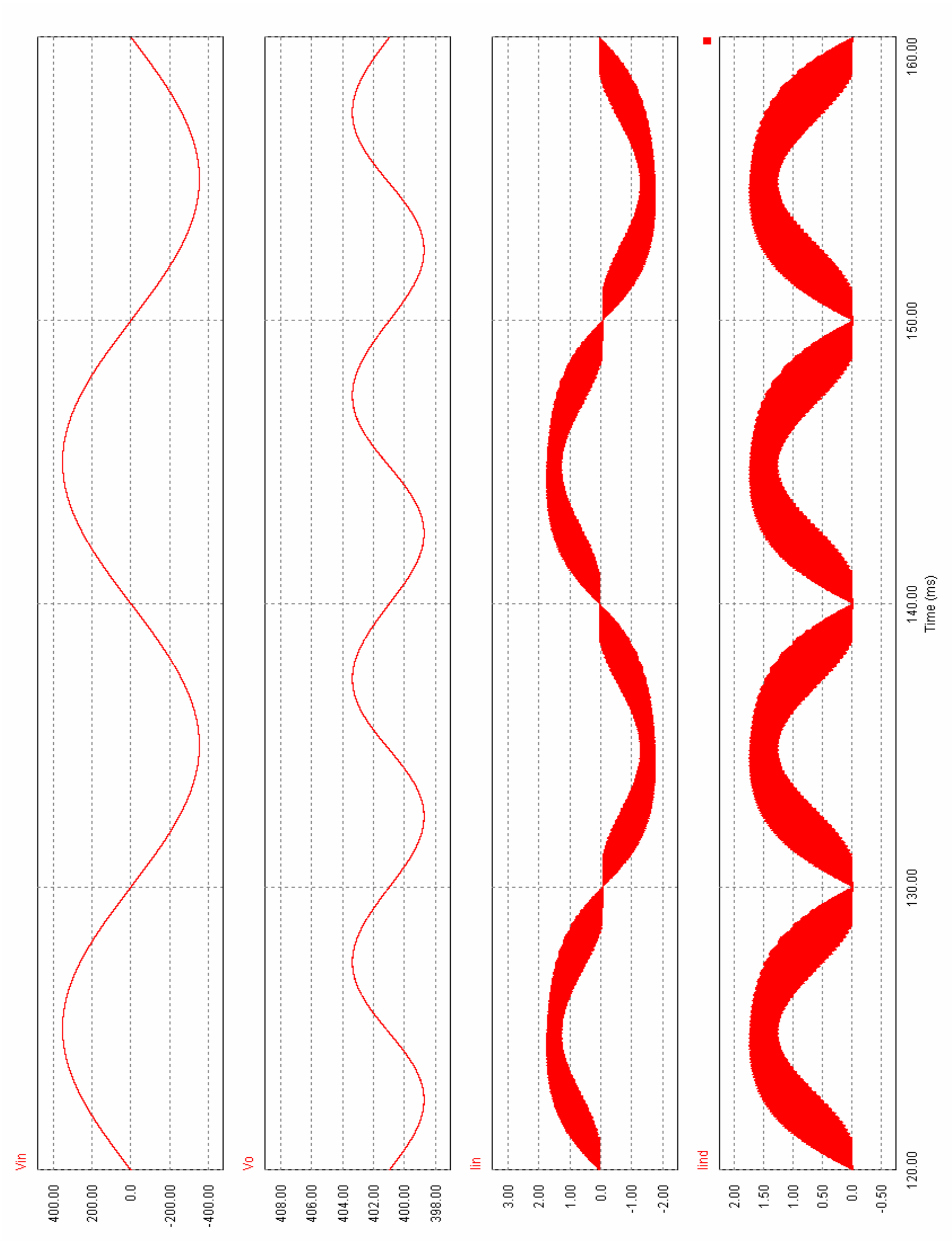

Fig 7.11 : a) Input voltage, b) output voltage, c) Input current and d) Inductor current waveform when the supply voltage is 230 V rms and the output power is 250 W

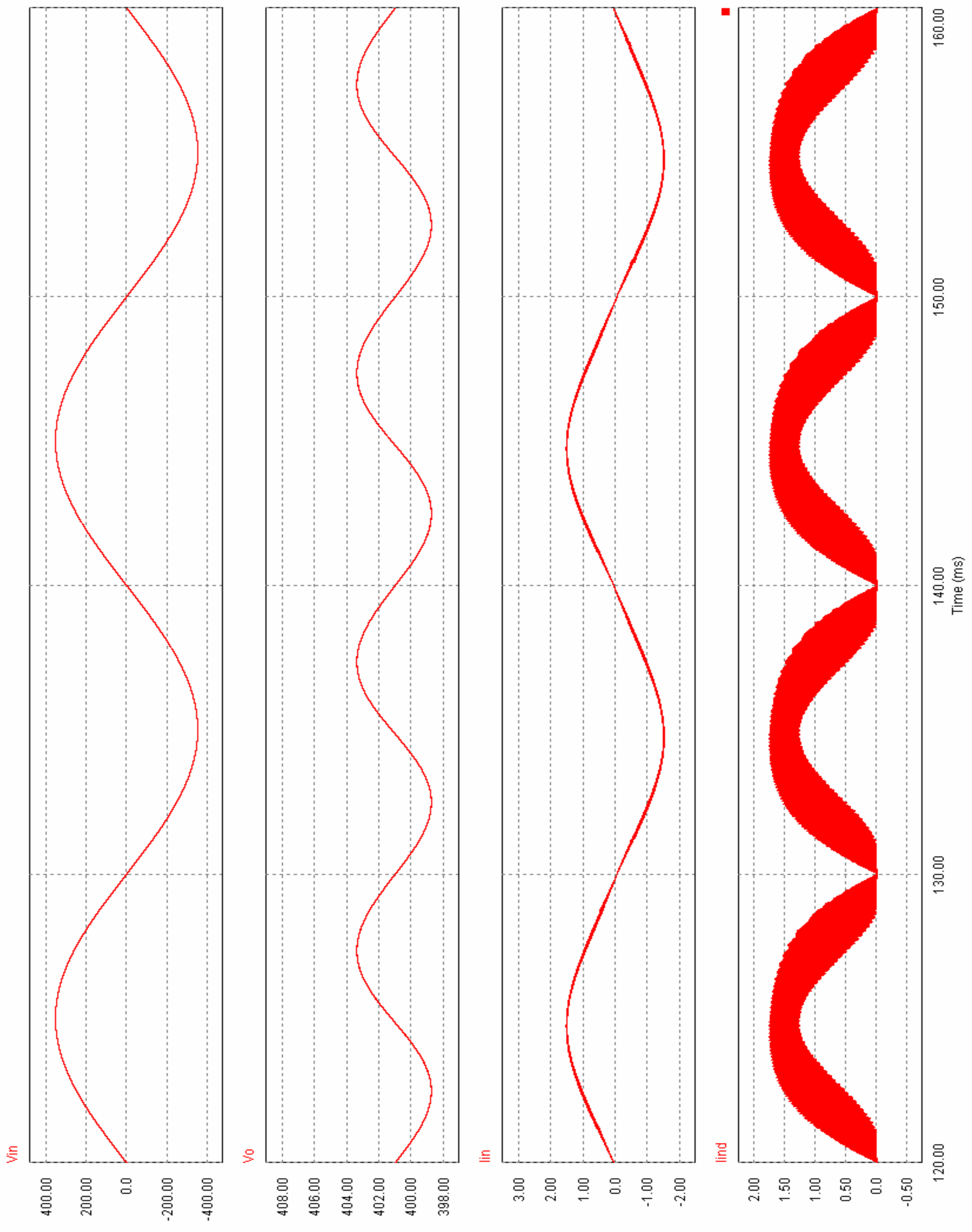

Fig 7.12 : a) Input voltage, b) output voltage, c) Input current and d) Inductor current waveform when the supply voltage is 230 V rms and the output power is 250 W and an inductance value of 0.1 mH is provided in the input side

Table 7.2 : Comparison between simulation results for power factor corrector of different output rated power

Rated output power (in W)	Output Voltage, Vout (in V)	Efficiency (in %)	Power Factor	Total Harmonic Distortion (in %)
For no value of inductance on the input side				
200	405.6	92.16	0.910131	20.69
250	401.053	95.36	0.974539	22.89
1000	405.29	95.96	0.982727	23.52
For an inductance of value 0.1 mH in the input side				
200	406.01	92.59	0.963321	7.7
250	401.092	97.67	0.973961	2.35
1000	404.789	94.25	0.981657	2.94

CHAPTER 8

CONCLUSION

8. CONCLUSION :

To comply with different standards the harmonic current needs to be reduced by some technique. Development of such a technique is known as power factor correction (PFC). Power factor correction counter balances the unwanted effects caused by the non-linear loads which account for the low power factor of the system.

This technique can be of two types – Passive and Active, depending upon whether active switches are used or not.

In this thesis an active power factor correction technique is proposed. The proposed approach makes use of UC3854 to design the power factor corrector. This integrated circuit contains the circuits necessary to control a power factor corrector. The UC3854 is designed to implement average current mode control (but is flexible enough to be used for a wide variety of power topologies and control methods too).

The power factor can be improved to about 98 % by implementation of this technique. The use of an inductor on the input side improves the performance of the power factor corrector. Design of the power control circuit was done for three values of output rated power – 200 W, 250 W and 1000 W. For all the designs the power factor corrector performed in an appreciable manner increasing the power factor to approximately 98 %.

8.1 Future work

Through this thesis analysis of such an active power factor corrector was done by simulations. As a further step, the hardware can be designed and the simulation results can be compared with the results obtained in practical set of conditions.

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