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POWER FACTOR CORRECTION FOR NON LINEAR LOADS USING PARALLEL BOOST CONVERTERS

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Abstract—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. 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 in complexity 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 Power results are attached herewith.

Keywords: Inductor, Capacitor, Diodes, Source voltage,

I. INTRODUCTION

1.1Power 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. cos Ø 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 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

1.2harmonics

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) Magnetic-ballast fluorescent lamps (arcing) and
4) AC electric arc furnaces.
All these devices cause harmonic currents to flow and some devices, actually, directly produce voltage harmonics.

1.3 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.

2 TYPES OF POWER FACTOR CORRECTORS

2.1 PASSIVE PFC

Harmonic current can be controlled in the simplest way by using a filter that passes current only at line frequency(50 or 60 Hz).Harmonic currents are suppressed and the non-linear device looks like a linear load. Power factor can be improved by using capacitors and inductors i.e. passive devices. Such filters with passive devices are called passive filters.

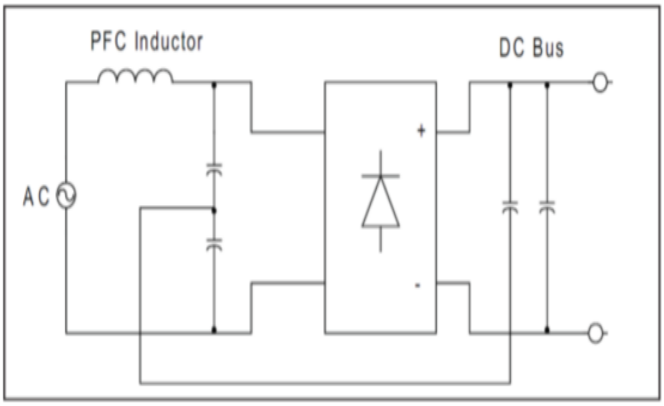


Fig 2.1 : A passive PFC circuit[2]

Disadvantage :They require large value high current inductors which are expensive and bulky. A passive PFC circuit requires only a few components to increase efficiency, but they are large due to operating at the line power frequency

2.2 ACTIVE PFC

An active approach is the most effective way to correct power factor of electronic supplies. Here, we ace a boost converter between the bridge rectifier and the main input capacitors. The converter tries to maintain a constant DC output bus voltage and draws a current that is in phase with and at the same frequency as the line voltage.

3 Role of dc-dc converters:

Power electronic converters are essentially required when we need to convert electricity from one form to other. They form an interface between the source and load side.
In the last several years, the massive use of single phase power converters has increased the problems of power quality in electrical systems.
High-frequency active PFC circuit are preferred for power factor correction. Any DC-DC converters can be used for this purpose, if a suitable control method is used to shape its input current or if it has inherent PFC properties.
The DC-DC converters can operate in Continuous Inductor Current Mode – CICM, where the inductor current never reaches zero during one switching cycle or Discontinuous Inductor Current Mode - DICM, where the inductor current is zero during intervals of the switching cycle.
In CICM, different control techniques are used to control the inductor current. Some of them are (1) peak current control (2) average current control (3) Hysteresis control (4) borderline control. The average mode control technique is specifically developed for PFC boost converters and is analysed here.

3.1 WORKING PRINCIPLE OF A BOOST CONVERTER

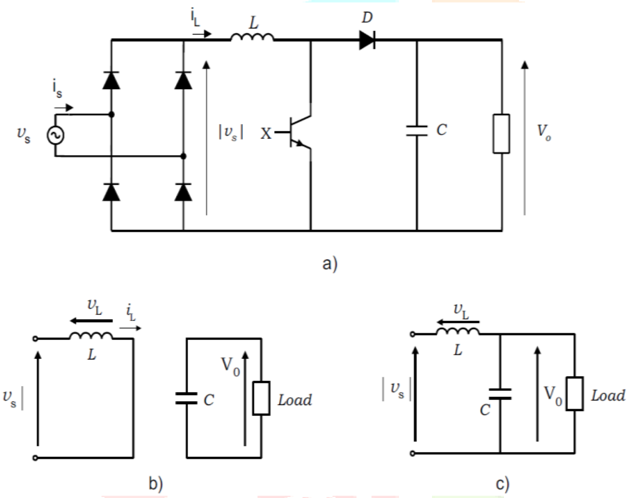


Fig3.1: Figure representing the on and off states of a boost rectifier

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. This figure shows the reference inductor current i_L ref , the inductor current i_L, 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 i_L

4 TYPES OF MODES

4.1 VOLTAGE MODE CONTROL

The voltage-mode control scheme shown in Fig.2.Here the converter output voltage that is to be regulated is sensed and fed back through a resistive voltage divider. It is then compared with precision external reference voltage, Vref in a **voltage error amplifier**. The error amplifier produces a control voltage that is compared to a constant-amplitude **sawtooth waveform**. The **comparator or the PWM Modulator** produces a **PWM signal** that is fed to drivers of controllable switches in the dc-dc converter. The duty ratio of the PWM signal depends on the value of the control voltage. The frequency of the PWM signal is the same as the frequency of

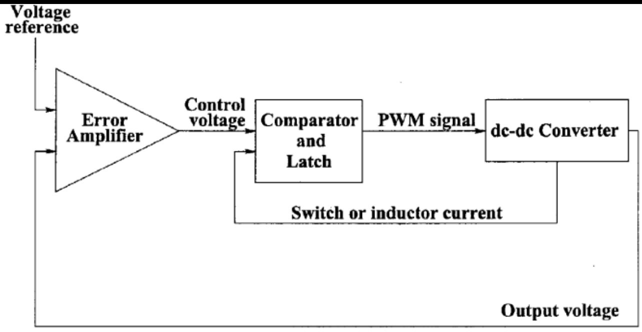


Fig 4.1 : Schematic diagram for voltage mode control

4.2 CURRENT MODE CONTROL

Signals in current form have a natural advantage over voltage signals. Voltage being an accumulation of electron flux, is slow in time as far as control mechanism is concerned. This led to the development of a new area in switch mode power supply design, i.e. the current mode control. Here, the averaged or peak current of magnetic origin is employed in the feedback loop of the switch mode power converters. It has given new avenues of analysis and at same time introduced complexities in terms of multiple loops.

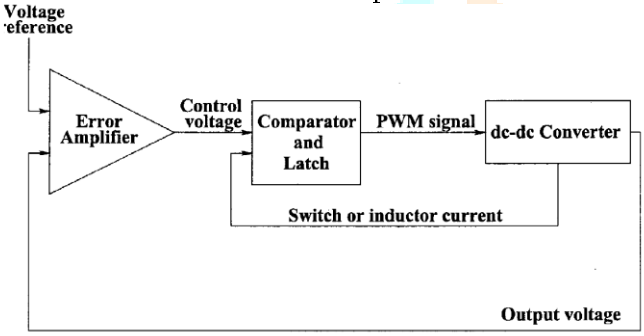


Fig 4.2: Schematic diagram for current mode control

4.3 AVERAGE CURRENT MODE CONTROL

Average current mode control(ACMC) is a two loop control method, inner loop being the current and the outer loop being the voltage loop for power electronic converters. This control method has many applications in the higher switching frequency, lower power segment upto 10kW, at higher switching frequency and above, but this too is subject to change.

It is frequently being used for the control of DC/DC converters and single phase Power factor correctors.

Average current mode control has the following advantages over peak current mode control:

1) An external compensation ramp is not required.
2) Increased DC closed loop gain at low frequencies.
3) Improved immunity to noise in the sensed current signal.
4) The increased current loop DC gain at low frequencies is especially useful for single phase PFC applications using boost derived topologies. This is because here it is desirable that he average rather than the peak of the inductor current follows sinusoid

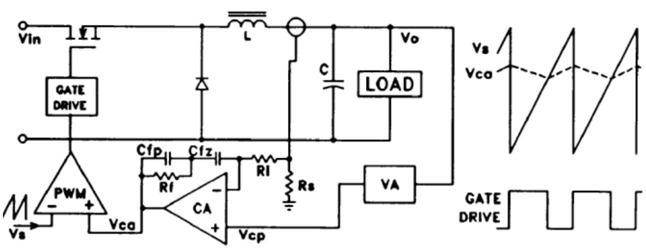
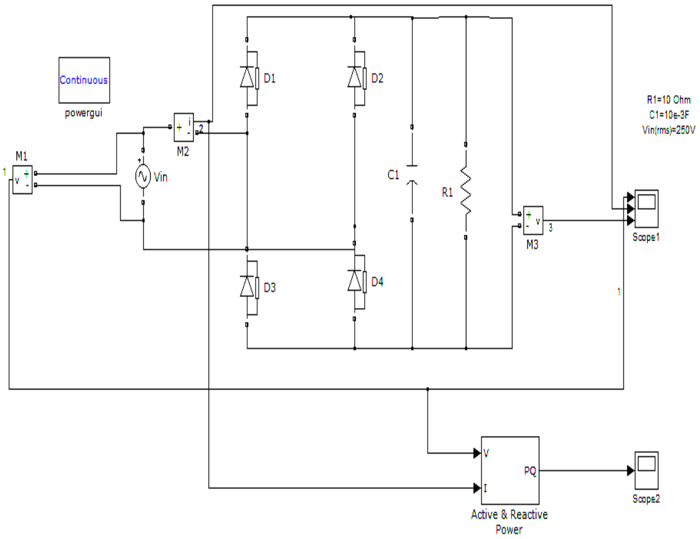


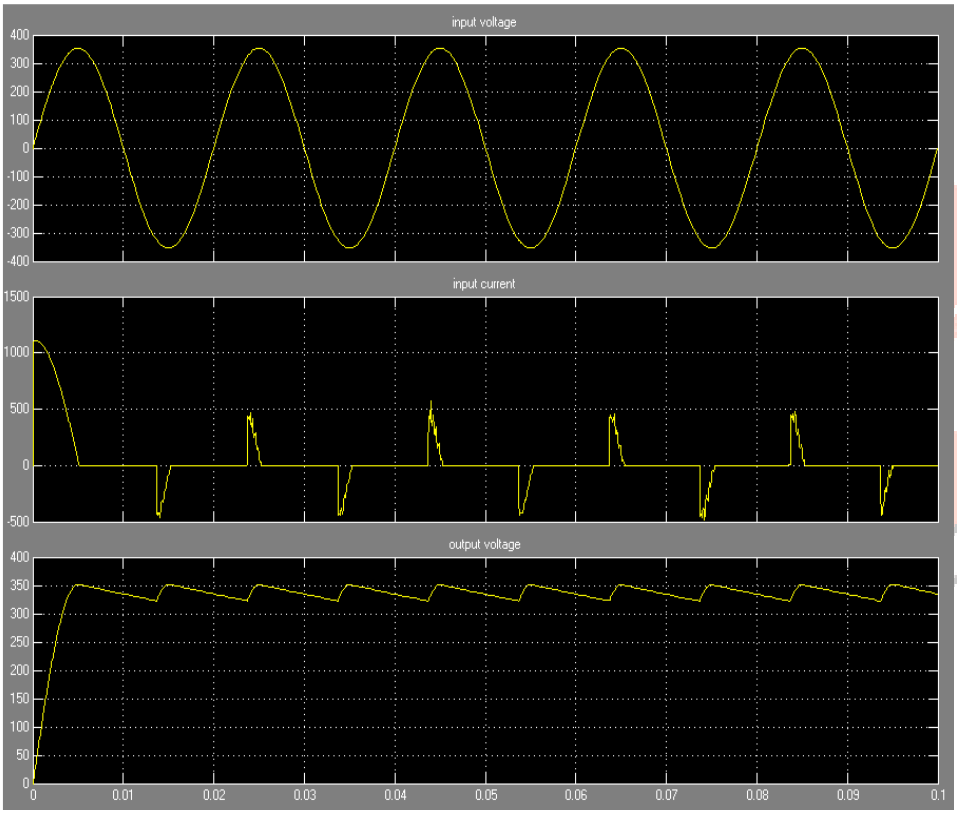
Fig 4.3: Average current mode control circuit and waveforms

1) MODEL AND SIMULATION RESULTS FOR A RECTIFIER CIRCUIT WITHOUT PFC CIRCUIT:

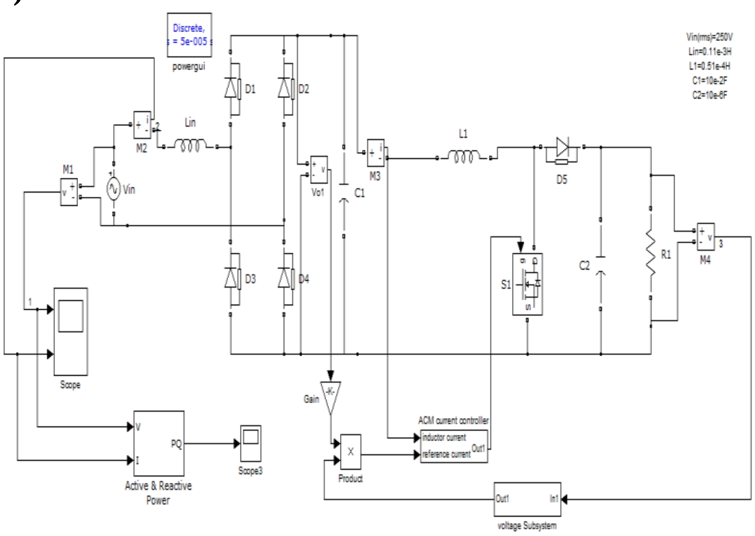
1A) MODEL:



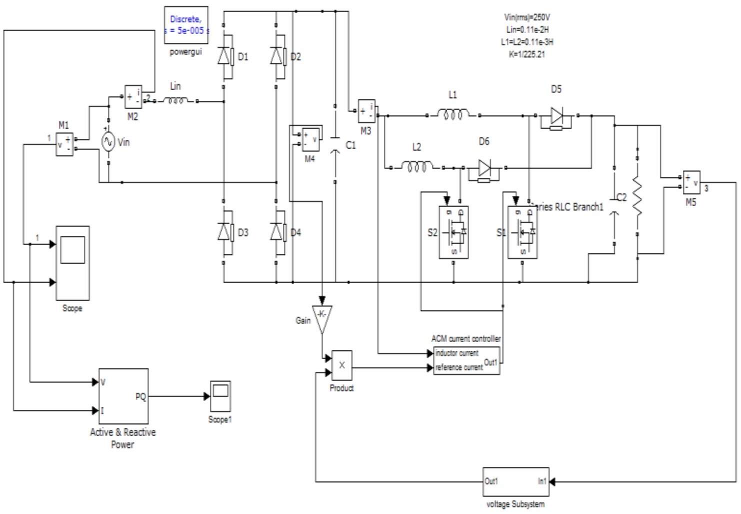
1B) SIMULATION RESULT:



2)MODEL AND SIMULATION RESULTS FOR PFC CIRCUIT HAVING A BOOST CONVERTER:



3)MODEL AND SIMLATION RESULTS FOR A PFC CIRCUIT WITH A PARALLEL BOOST CONVERTER:



5 CONCUSION:

The main objective throughout the project has been to improve the input Power Factor with simultaneous reduction of input current harmonics.
Simulations were initially done for elementary rectifier circuits without employing any PFC circuit. These simulations included circuits with and without source side inductors and capacitors. The changes in the input current waveform were observed and studied.
A PFC circuit having a parallel boost converter i.e. two boost converters arranged in parallel was designed. The control strategy was based on average current mode control due to its relative advantages over voltage mode control and peak current mode control.
The key points that were taken into account while designing were:
1) Placing the two poles at origin and somewhere near the switching frequency.
2) Placing the zero at half the crossover frequency.
3) Gain of the inner current control loop should be in accordance to the switching frequency of the PWM modulator.
Calculation of Power Factor was done base on active and reactive power measurement with the inbuilt MATLAB block for the same.
For the purpose of comparison and to validate the improvement in power factor, Power factor and THD (Total Harmonic Distortion) for three circuits:
CIRCUIT 1) Rectifier Circuit only without any PFC.
CIRCUIT 2) Rectifier Circuit with a single boost converter for PFC.
CIRCUIT 3) Rectifier Circuit with a parallel boost converter.

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