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DESIGN A SINGLE PHASER BOOST RECTIFIER FOR POWER FACTOR IMPROVEMENT USING EMBEDDED SYSTEM

By

T.RENGASAMY

Reg No. : 0720105008

of

KUMARAGURU COLLEGE OF TECHNOLOGY
(AUTONOMOUS)
COIMBATORE – 641 006

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BONAFIDE CERTIFICATE

Certified that this project report titled "**DESIGN A SINGLE PHASER BOOST RECTIFIER FOR POWER FACTOR IMPROVEMENT USING EMBEDDED SYSTEM** " is the bonafide work of **Mr.T.RENGASAMY (0720105008)** who carried out the project work under my supervision. Certified further, that to the best of my knowledge the work reported herein does not form part of any other project report of dissertation on the basis of which a degree or ward was conferred on an earlier occasion on this or any other candidate.

HEAD OF THE DEPARTMENT — **GUIDE** 4/5/09

(Prof . K. Regupathy Subramanian) — (Mrs.V.SharmilaDeve)

The candidate with **University Register No 0720105008** was examined by us in Project Viva-Voce examination held on __6/05/09

INTERNAL EXAMINER — **EXTERNAL EXAMINER** 06.05.09

Block diagram consist of three main blocks,

- Diode Bridge rectifier
- Boost converter
- PIC Micro controller

1.5.2BRIDGE RECTIFIER

Generally, the bridge power factor correction (PFC) topologies also referred to as dual-boost PFC rectifiers, may reduce the conduction loss by reducing the number of semiconductor components in the line current path. When it is compared to the conventional boost rectifier one diode is eliminated from the line current path. However, the bridge boost rectifier has significantly larger common-mode noise than the conventional boost rectifiers. It will convert the AC main source to the DC source and it will give to the control unit for the boost up the voltage.

1.5.3 BOOST CONVERTER

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 inductor and capacitor combinations are often added to a converter's output to improve performance.

1.5.4 PIC MICROCONTROLLER

PIC Micro controller is used to control the chopper switch. There are three memory blocks in each of the PIC 16F877. The program memory and Data Memory have separate buses so that concurrent access can occur.

The PIC 16F877 devices have a 13-bit program counter capable of addressing 8K*14 words of FLASH program memory. Accessing a location above the physically implemented address will cause a wraparound. Each PIC16F877 instruction is a 14-bit word, divided into an OPCODE which specifies the instruction type and one or more operand which further specify the operation of the instruction.

1.6 METHODOLOGY

The proposed design is to be controlled by embedded processor. The embedded controller used to give the PWM pulses to the boost rectifier power module for the required output voltage level and improve the power factor. The PIC16F877A controller for generating the PWM pulses. Hi-Tech C program and MP lab software is used for writing program and debug the coding in the Embedded development environment. The PIC controller has inbuilt analog to digital converter.

CHAPTER 2

CIRCUIT DIAGRAM AND ITS OPERATION

2.1 CIRCUIT DIAGRAM

The general circuit diagram of the bridge less boost rectifier is shown in 2.1

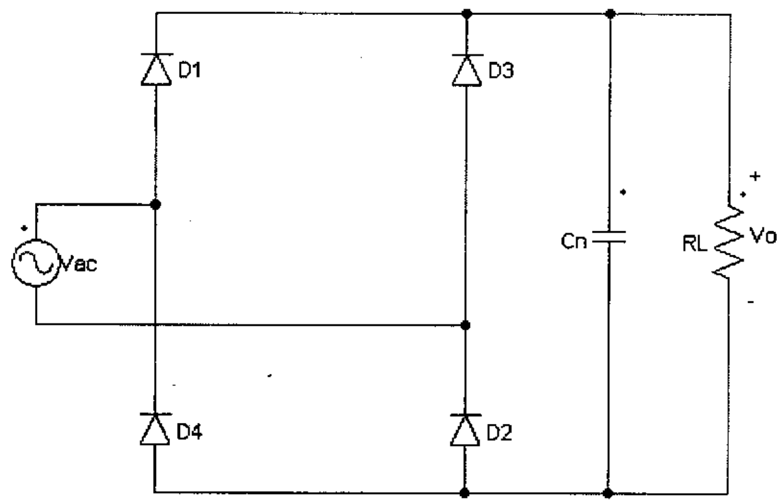


Fig 2.1 Circuit Diagram for Bridge Rectifier

2.2 OPERATION

- A high voltage AC supply is given to the rectifier, which is used to convert AC to DC.
- Then such converter DC supply is given as input to the boost converter.
- By using the boost converter it is eliminate the ripple and step up the input voltage.
- PIC micro controller is used to control the converter switch.
- It will reduce the input current harmonics and also improves the power factor in the system.

2.3 RECTIFIER

2.3.1 FULL-WAVE RECTIFICATION

Full-wave rectification converts both polarities of the input waveform to DC(direct current), and is more efficient. However, in a circuit with a non-center tapped transformer, four diodes are required instead of the one needed for half-wave rectification.

This is due to each output polarity requiring two rectifiers each, for example, one for when AC terminal 'X' is positive and one for when AC terminal 'Y' is positive. The other DC output requires exactly the same, resulting in four individual junctions.

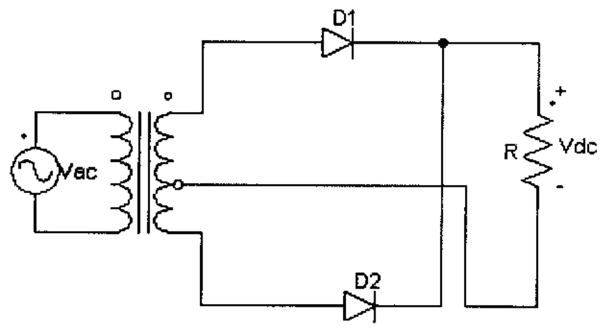


Fig 2.2 Full-wave rectifier

A full-wave rectifier converts the whole of the input waveform to one of constant polarity (positive or negative) at its output by reversing the negative (or positive) portions of the alternating current waveform. The positive (or negative) portions thus combine with the reversed negative (or positive) portions to produce an entirely positive (or negative) voltage/current waveform.

2.3.2 PEAK LOSS

An aspect of most rectification is a loss from peak input voltage to the peak output voltage, caused by the threshold voltage of the diodes (around 0.7 V for ordinary silicon p-n-junction diodes and 0.1 V for Schottky diodes). Half-wave

To further reduce this ripple, a capacitor-input filter can be used. This complements the reservoir capacitor with a choke and a second filter capacitor, so that a steadier DC output can be obtained across the terminals of the filter capacitor. The choke presents a high impedance to the ripple current.

2.4 APPLICATIONS

A rectifier diode (silicon controlled rectifier) and associated mounting hardware. The heavy threaded stud helps remove heat.

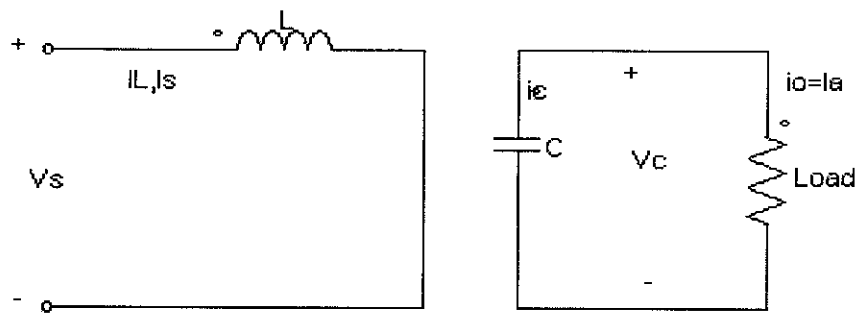
The primary application of rectifiers is to derive usable DC power from an AC supply. Virtually all electronics requires a DC supply but mains power is AC so rectifiers find uses inside the power supplies of virtually all electronic equipment.

Converting DC voltage from one level to another is much more complicated. One method of such DC-to-DC conversion is to first convert to AC (using a device called an inverter), then use a transformer to change the voltage, and finally rectify it back to DC.

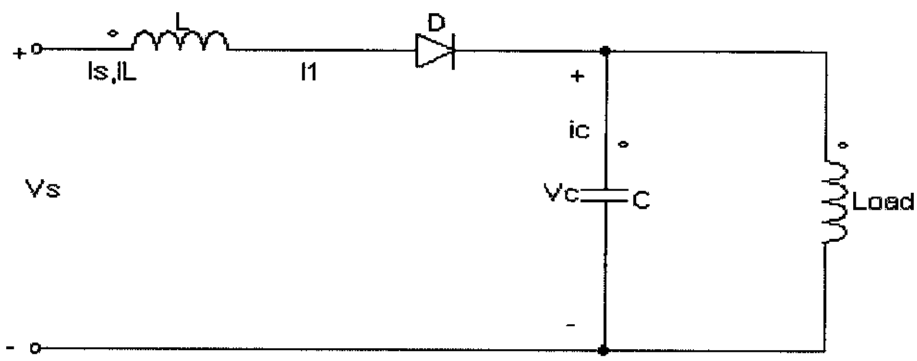
Rectifiers also find a use in detection of amplitude modulated radio signals. The signal may or may not be amplified before detection but if unamplified a very low voltage drop diode must be used.

When using a rectifier for demodulation the capacitor and load resistance must be carefully matched. Too low a capacitance will result in the high frequency carrier passing to the output and too high will result in the capacitor just charging and staying charged.

3.2 OPERATING PRINCIPLE



Mode 1



Mode 2

Fig 3.2 Modes of Operation of Boost Converter

The basic principle of a Boost converter consists of two modes of operation. mode1 begins when switch S closed at t = 0.the input current, which rises, flows through inductor L and switch S. mode 2 begins when switch S opened at t = t_1.the current that was flowing through switch S would now flow through L, C, load, and diode D. the inductor current falls until switch S is turned on again in the next cycle. The energy stored in inductor L is transferred to the load.

3.2.1 CONTINUOUS MODE

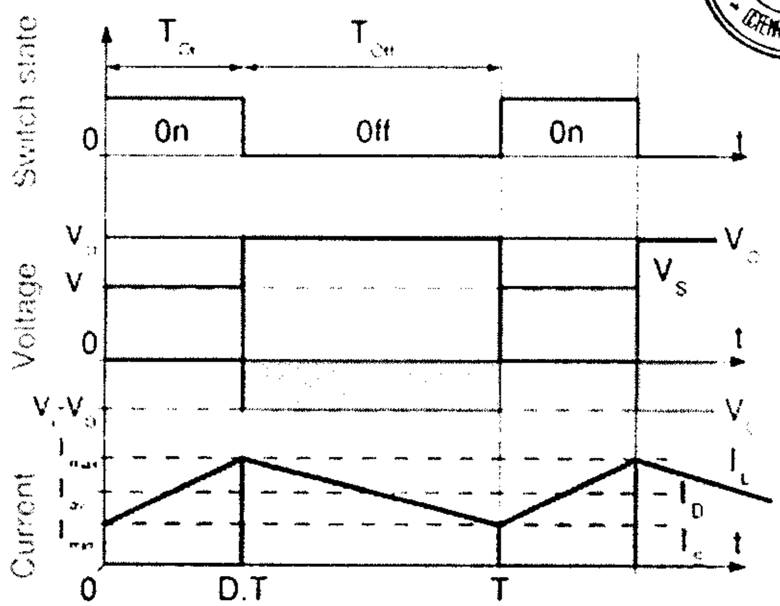


Fig 3.3 Waveforms of current and voltage in a boost converter operating in continuous mode.

When a boost converter operates in continuous mode, the current through the inductor (I_L) never falls to zero. Figure3.4 shows the typical waveforms of currents and voltages in a converter operating in this mode. The output voltage can be calculated as follows, in the case of an ideal converter (i.e using components with an ideal behavior) operating in steady conditions:

During the On-state, the switch S is closed, which makes the input voltage (V_i) appear across the inductor, which causes a change in current (I_L) flowing through the inductor during a time period (t) by the formula:

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

At the end of the On-state, the increase of I_L is therefore:

$$\Delta I_{L_{On}} = \int_0^{D \cdot T} \frac{V_i}{L} dt = \frac{V_i \cdot D \cdot T}{L}$$

This can be written as:

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

This in turns reveals the duty cycle to be

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

From the above expression it can be seen that the output voltage is always higher than the input voltage (as the duty cycle goes from 0 to 1).

3.2.2 DISCONTINUOUS MODE

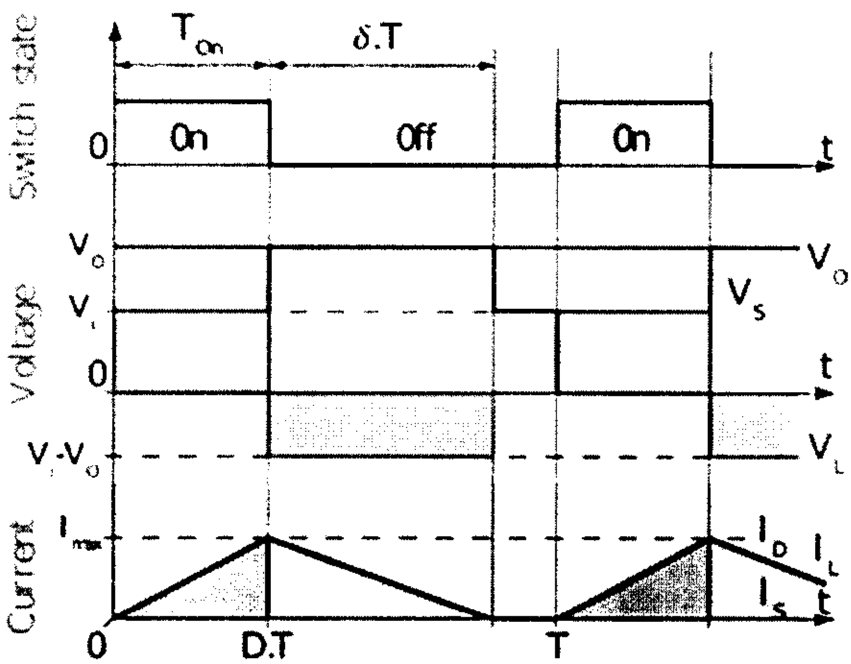


Fig 3.4 Waveforms of current and voltage in a boost converter operating in discontinuous mode.

In some cases, the amount of energy required by the load is small enough to be transferred in a time smaller than the whole commutation period. In this case, the current through the inductor falls to zero during part of the period. The only difference in the principle described above is that the inductor is completely discharged at the end of the commutation cycle. Although slight, the difference has a strong effect on the output voltage equation. It can be calculated as follows: As the inductor current at the beginning of the cycle is zero, its maximum value $I_{L_{Max}}$(at t=D.T) is

$$I_{L_{Max}} = \frac{V_i \cdot D \cdot T}{L}$$

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

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

Using the two previous equations, δ is:

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

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

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

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

Therefore, the output voltage gain can be written as:

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

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

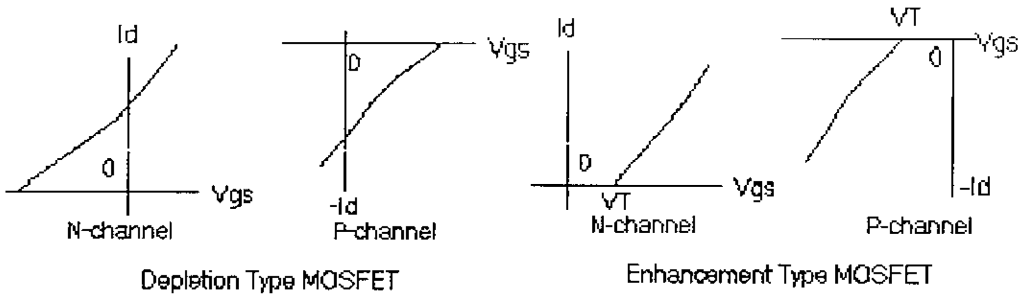


Fig 3.5 The steady state characteristics of different types of MOSFET

N-channel enhancement type MOSFETS are the most popular for use in power switching circuits and applications. The drive voltage or voltage applied between gate and source to switch the MOSFET ON must exceed a threshold value V_T 4V although values of 10 - 12V.

3.4.2 OPERATING PRINCIPLE OF N-CHANNEL ENHANCEMENT MOSFETS

A simplified diagram of an N-channel enhancement MOSFET is shown in figure 6.2. Drain and source connections are made to higher conduction high doped regions. The metal gate is electrically isolated from the P-type substrate by a layer of non-conducting silicon oxide (SiO2). When a positive voltage is applied to the gate with respect to the source an electric field will be created pointing away from the base and across the P-region directly under the base. The electric field will cause positive charges in the P-region to move away from the base inducing or enhancing a N-region in its place. Conduction can then take place between the N+(drain) N(enhanced region) N+(source)

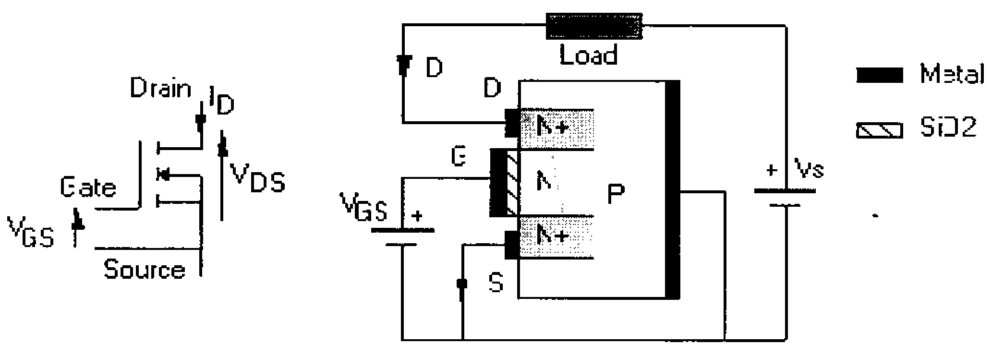


Fig 3.6 Simple model of an N-channel enhancement type MOSFET

In practice, a fairly large current in the order of 1 - 2A can be required to charge the gate capacitance at turn ON to ensure that switching times are small. Due to gate leakage current, nano-amps are needed to maintain the gate voltage once the device is ON.

3.4.3 MOSFET SWITCHING CHARACTERISTICS

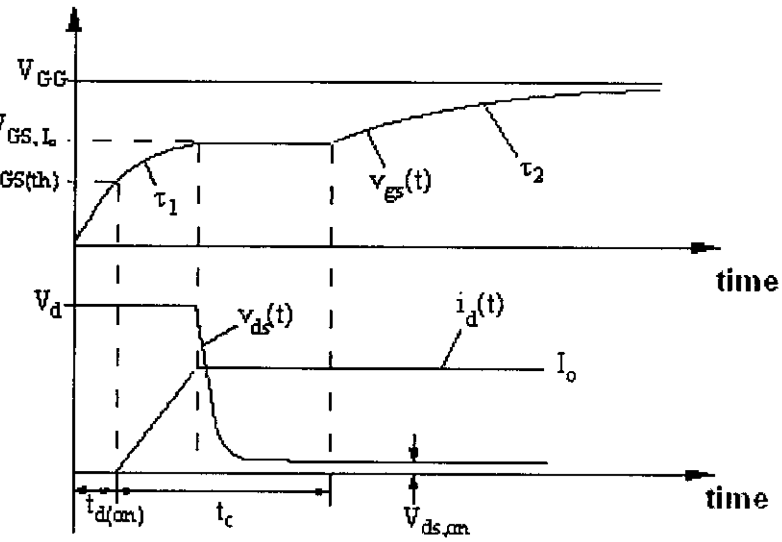


Fig 3.7 Turn-on Characteristics of the MOSFET

The turn-off of the MOSFET involves the inverse sequence of events that occurred during turn-on. This is shown in Fig 3.8. The turn-off process is initiated by applying a step gate voltage of -VGG.

During turn-on and turn-off, the instantaneous power loss in the MOSFET occurs primarily during the crossover time tc indicated in figures. 10 and 11 where p (t) = VDS ID is high. Since the junction capacitance doesn't vary with temperature, the switching power losses in the MOSFET are independent of the junction temperature. In fact, the turn-off losses are somewhat lower than the turn-on losses since the rate of change of voltage during turn-off is controlled by the output capacitance of the MOSFET.

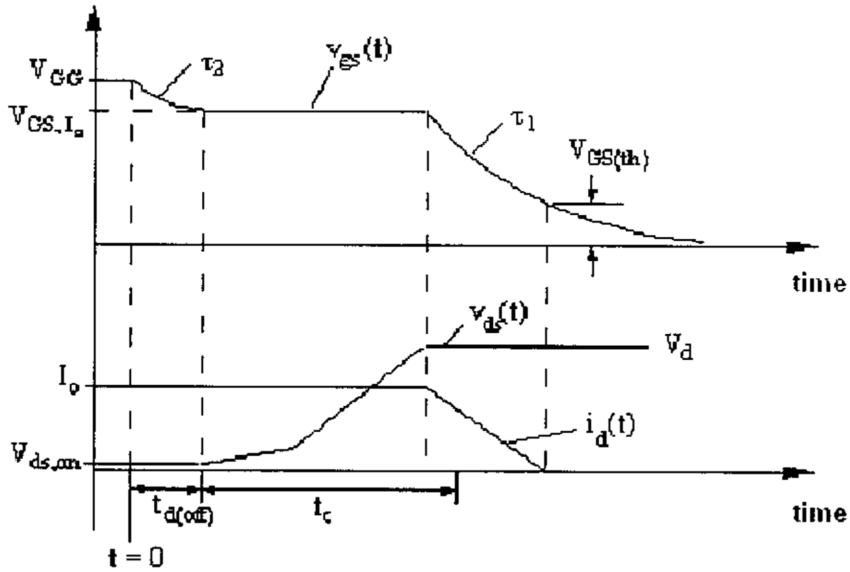


Fig. 3.8 Turn-off Characteristics of the MOSFET

For the conduction losses, the instantaneous power on-state dissipation in the MOSFET is given by,

$$P_c = I_c^2 r_{ds}$$

The on-state resistance has several components and it varies with the junction temperature. Thus, the conduction losses will also vary with the junction temperature. Notice here that the current computed for conduction losses is the RMS current flowing in the MOSFET.

CHAPTER 4
SIMULATION STUDY

4.1 INTRODUCTION TO MATLAB

MATLAB is a high-performance language for technical computing. It integrates computation, visualization, and programming in an easy-to-use environment where problems and solutions are expressed in familiar mathematical notation.

Typical uses include

1. Math and computation
2. Algorithm development
3. Data acquisition Modeling, simulation, and prototyping
4. Data analysis, exploration, and visualization
5. Scientific and engineering graphics
6. Application development, including graphical user interface building

SIMULINK is a software package for modeling, simulating, and analyzing dynamic systems. It supports linear and nonlinear systems, modeled in continuous time, sampled time, or a hybrid of the two. Systems can also be multi rate, i.e., have different parts that are sampled or updated at different rates. As MATLAB and SIMULINK are integrated, we can simulate, analyze, and revise our models in either environment at any point. Thus using SIMULINK, MATLAB models have been created for Cascaded multi level inverter and its triggering circuit and their simulation results have been obtained.

4.2 SIMULINK MODEL

The simulation model of the boost mode operation for harmonics reduction is developed by the MATLAB/SIMULINK software. The simulation model of boost mode operation for harmonic reduction is shown in Fig.4.1

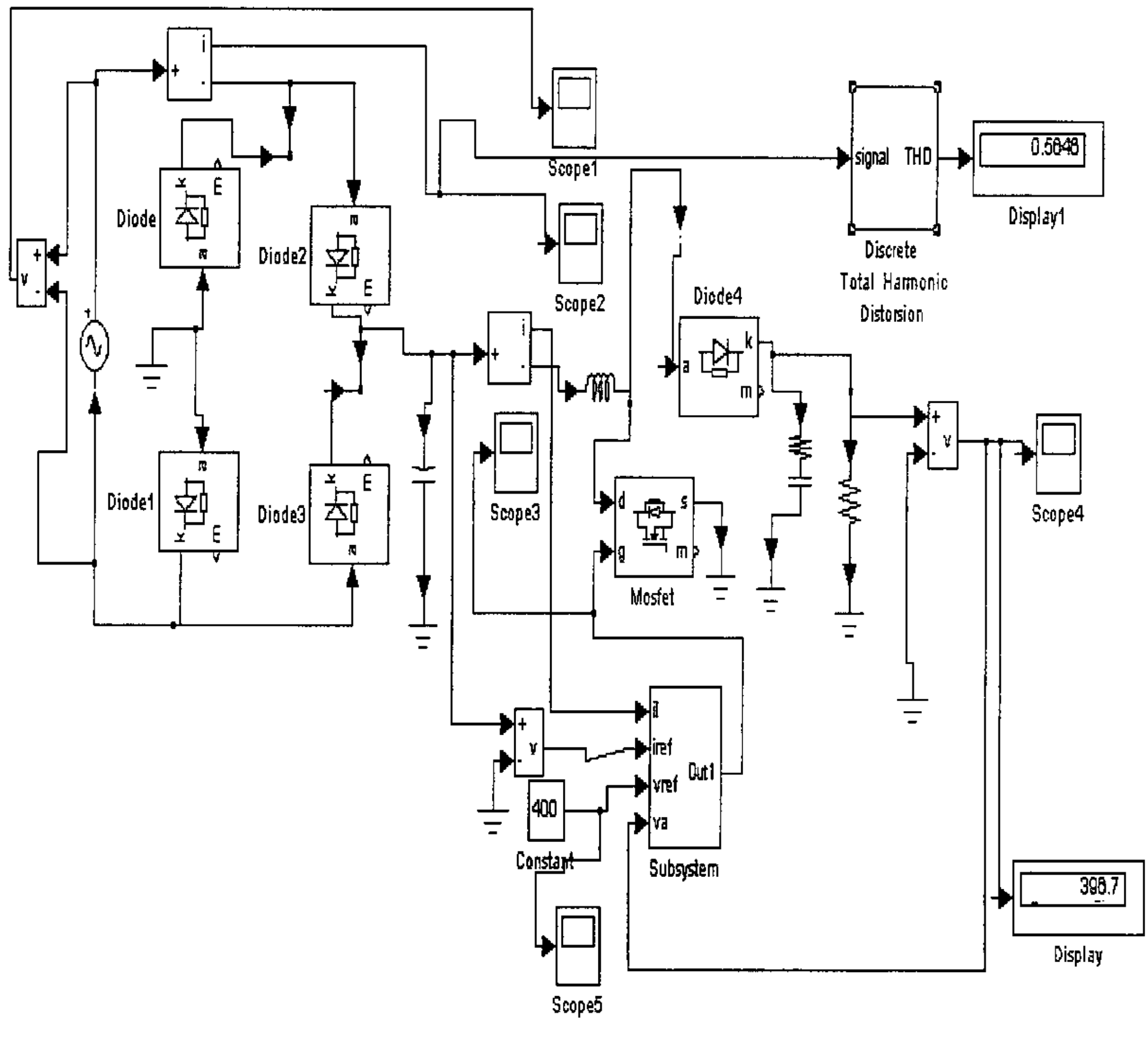


Fig.4.1 Simulation Model of boost mode operation for harmonics reduction

4.3 INPUT VOLTAGE

The simulated model of the boost rectifier where it's input voltage is fed from 220V AC, this wave form is shown in fig 4.2

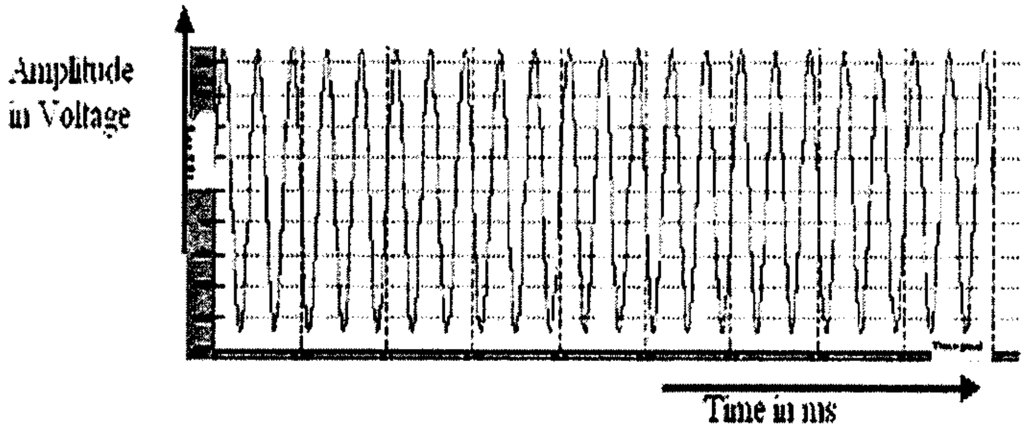


Fig 4.2 Wave form for input voltage

4.4 INPUT CURRENT

The simulated model of the boost rectifier where its input current is fed from 220V AC, this wave form is shown in fig 4.3.

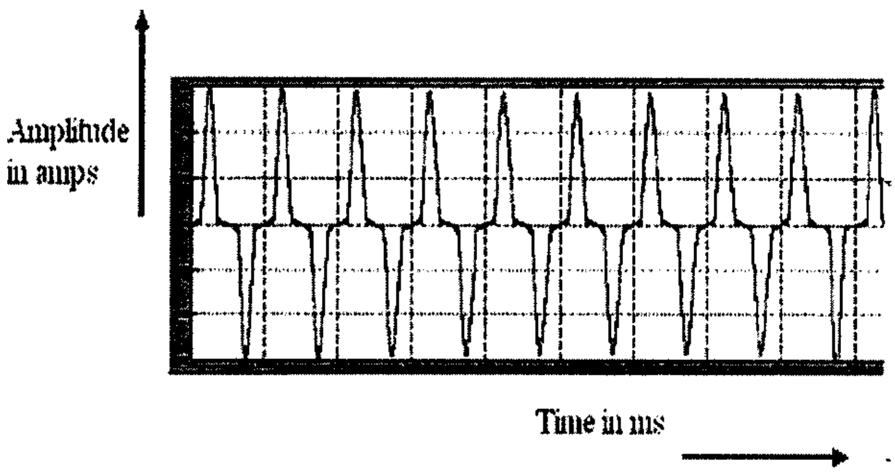


Fig4.3 Wave form for input current

CHAPTER 5

HARDWARE DISCRIPTION

5.1 CIRCUIT DIAGRAM

The complete experimental set-up of the proposed scheme shown in Figure 6.1 consists of a 230V ac source, Boost chopper using a MOSFET, PIC microcontroller (PIC16F877A) and an opto-coupler. The dc-dc converter consists of inductor of value 1000mH, a MOSFET (IRF840), capacitor of value 100μF and a power diode (IN5819) ,IR2112 gate driver. The 230V AC source given to the bridge rectifier which converts AC to DC fed to the boost chopper.

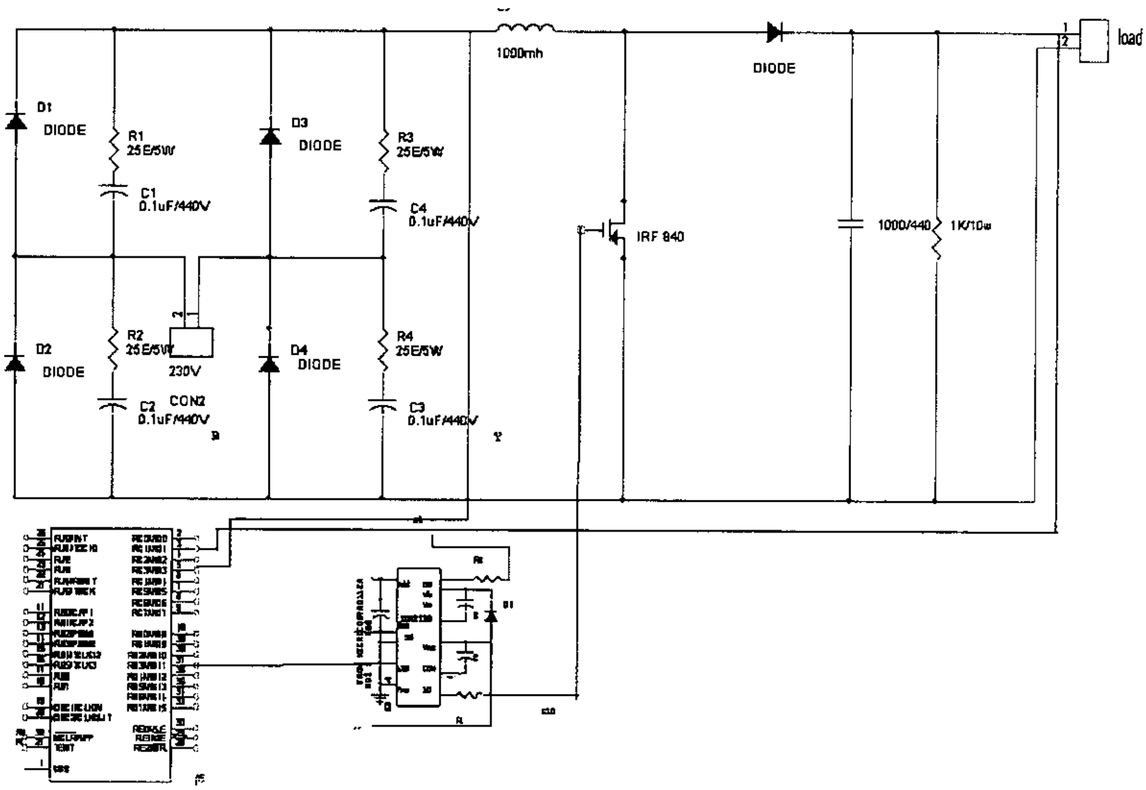


Fig 5.1 Hardware circuit

5.2 OPTOCOUPLER

An Optocoupler involves a LED and a phototransistor, separated so that light may travel across a barrier but electrical current may not. When an electrical signal is applied to the input of the opto-isolator, its LED lights, its light sensor then activates, and a corresponding electrical signal is generated at the output. Unlike a transformer, the opto-isolator allows for DC coupling and generally provides significant protection from serious overvoltage conditions in one circuit affecting the other. The optocoupler is used in the circuit for voltage isolation between the PIC microcontroller which generates the gate pulses and the MOSFET in the chopper circuit.

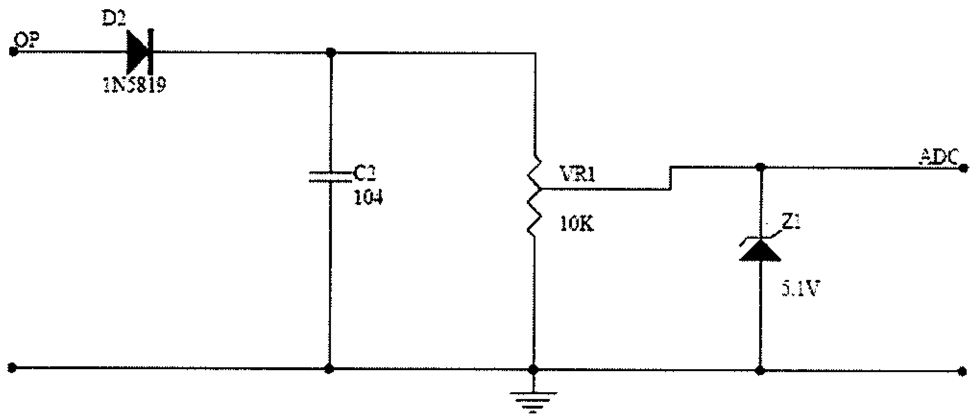


Fig 5.2 Optocoupler

This circuit depicts the potential divider used in the feedback loop of the chopper circuit. A zener diode is used in the divider circuit. A Zener diode is a type of diode that permits current in the forward direction like a normal diode, but also in the reverse direction if the voltage is larger than the breakdown voltage known as "Zener knee voltage" or "Zener voltage". A reverse-biased Zener diode will exhibit a controlled breakdown and allow the current to keep the voltage across the Zener diode at the Zener voltage. A diode with a Zener breakdown voltage of 5.1 V will exhibit a voltage drop of 5.1V if the reverse bias voltage applied across it is more than its Zener voltage. So this ensures that the voltage does not exceed the limit thus preventing damage to the microcontroller.

5.3 EXPERIMENTAL RESULTS

The controller for producing variation in the duty cycle has been constructed using the PIC microcontroller. For the closed loop operation of the proposed scheme an analog feedback circuit has been fabricated using the potential divider and an opto-coupler. By adjusting the duty cycle, the input current harmonics are minimized. Hence the input current and input voltage are in phase therefore power factor is improved.

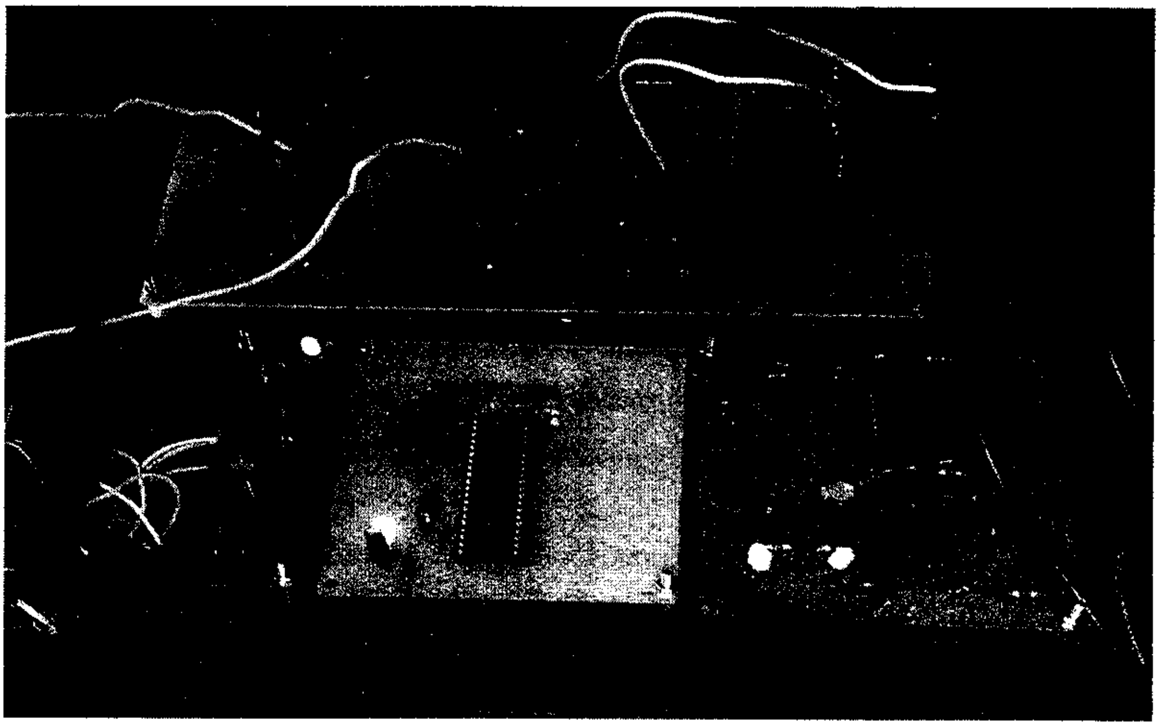


Fig 5.3 Hardware circuit

INPUT VOLTAGE IN AC	OUTPUT VOLTAGE IN DC
25	50
50	100
75	150

Table 5.1 output of the hardware

6.2.3 Memory Organization

The organization of memory in PIC 16F877 is shown in the following table.

DEVICE	PROGRAM FLASH	DATA MEMORY	DATA EEPROM
PIC 16F877	8K	368 Bytes	256 Bytes

Table-6.1 Memory of PIC 16F877

6.2.4 Peripheral Features

- Timer0: 8-bit timer/counter with 8-bit prescaler
- Timer1: 16-bit timer/counter with prescaler
- Timer2: 8-bit timer/counter with 8-bit period register, prescaler and postscaler
- Two Capture, Compare, PWM modules

  Capture is 16-bit, max resolution is 12.5 ns,

  Compare is 16-bit, max resolution is 200 ns,

  PWM max. resolution is 10-bit
- 10-bit multi-channel Analog-to-Digital converter

These are all some of the important features of the peripherals available in PIC16F77A Microcontroller.

6.2.7 Analog-To-Digital Converter (A/D) Module

The Analog-to-Digital (A/D) Converter module has five inputs for the 28-pin devices and eight for the 40/44-pin devices. The conversion of an analog input signal results in a corresponding 10-bit digital number. The A/D converter has a unique feature of being able to operate while the device is in Sleep mode. To operate in Sleep, the A/D clock must be derived from the A/D's internal RC oscillator. The A/D module has four registers. These registers are:

- A/D Result High Register (ADRESH)
- A/D Result Low Register (ADRESL)
- A/D Control Register 0 (ADCON0)
- A/D Control Register 1 (ADCON1)

The ADCON0 register controls the operation of the A/D module. The ADCON1 register configures the functions of the port pins. The port pins can be configured as analog inputs or as digital I/O.

R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	R/W-0	U-0	R/W-0
ADCS1	ADCS0	CHS2	CHS1	CHS0	GO/$\overline{\text{DONE}}$	-----	ADON
bit 7							bit 0

bit 7-6 ADCS1:ADCS0: A/D Conversion Clock Select bits

ADCON1 <ADCS2>	ADCON0 <ADCS1:ADCSO>	Clock Conversion
0	00	Fosc/2
0	01	Fosc/8
0	10	Fosc/32
0	11	F_{RC} (clock derived from the internal A/D RC oscillator)
1	00	Fosc/4
1	01	Fosc/16
1	10	Fosc/64
1	11	F_{RC} (clock derived from the internal A/D RC oscillator)

Table 6.2 A/D Conversion Clock Select bits

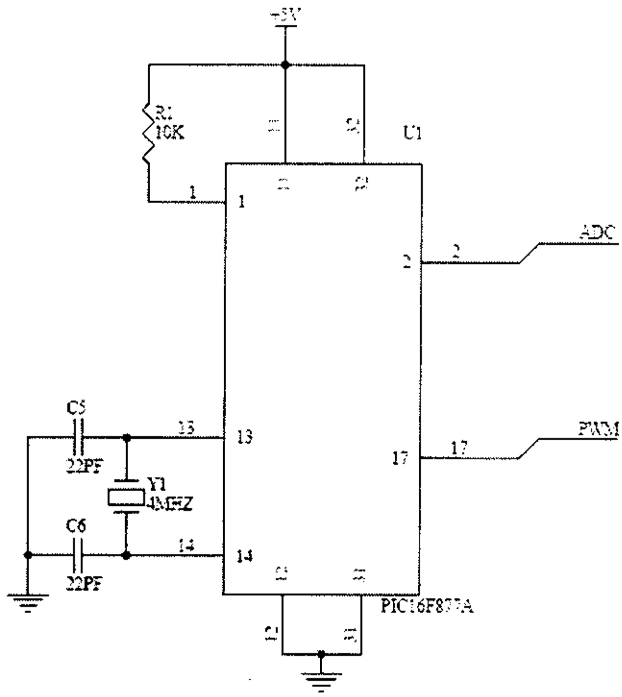


Figure 6.3.PIC circuit for triggering MOSFET of the Boost Chopper

CHAPTER 7

CONCLUSION

7.1 CONCLUSION

This project presents a harmonics reduction control method in the power utility systems, a method for the improvement of power factor and also step up the output voltage, by using the bridge boost rectifiers. The proposed methods are simple, robust, and easy to design and achieve input current control performance that can meet even the most stringent harmonic current limits for air-borne application. The methods are most suitable for UPS application which creating the pulsated current to the utility systems.

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APPENDIX

MICROCONTROLLER PROGRAM

```
#include<lcd.h>
void mc_init();
void pwm_init();
void main()
{
mc_init();
delay(100);
lcd_init();
delay(100);
pwm_init();
delay(100);

while(1)
        {
        if(RC4==0)
                {
                while(RC4==0);
                CCPR1L=CCPR1L+10;
                if(CCPR1L>250)
                        CCPR1L=250;
                }if(RC5==0)
                {
                while(RC5==0);
                CCPR1L=CCPR1L-10;
                if(CCPR1L<10)
                        CCPR1L=10;
                }
        }
```