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ANALYSIS OF FRONT-END CONVERTER WITH UNITY POWER FACTOR AND LOW INPUT CURRENT THD FOR TRACTION APPLICATION

***Devendra M. Sharma*[1] , *Sumit R. Patel*[2]**
1Students, M.E. (Electrical), Semester IV, Merchant Engineering College, Basna, Mehsana, Gujarat
Shramadevendra251@gmail.com
2Assistant Professor, Electrical Engineering, Merchant Engineering College, Basna, Mehsana, Gujarat
sumitpatel171188@gmail.com

Abstract — The work presented in this thesis deals with the simulation, design & development of the front-end converter. Here front-end converter is AC/DC or DC/AC converter at the front end of the system. A suitable PWM technique is employed in order to obtain the required output voltage in the line side of the inverter. SPWM technique has been used for providing triggering pulse to the FEC and Inverter both in which IGBT is used as switch. It is very accurate method as it is concern with the modulation of the amplitude and frequency. By changing Modulation index (ma) amplitude of the output voltage and current can be controlled. The main advantage of this approach is that the total harmonic distortion (THD) in line and phase voltage decrease as the value of the modulation index increased. The value of fundamental component in line and phase voltage is increased with the increase in modulation index. PWM is one of the best methods for the controlling the output voltage especially SPWM because it make it possible to control frequency and magnitude both in traction Induction motor. It is also used for the reduction of the harmonics from the system. FEC has advantage of drawing balanced supply even in the unbalance supply form Utility. Using Matlab simulink this operation will be shown with the details like THD analysis, output voltage, output current, triggering signals for switching. Total circuitry controlling will also be developed in the Matlab. The FEC prototype hardware results are nearly same as simulation results.

***Key Words**: Front-End Converter, Unity Power Factor, THD.*

I. INTRODUCTION

Traction means a driving force or an electric traction means a locomotion in which the driving force is obtained from electric motors. One of the practical application of the electricity which enters into everyday life of many of us, is its use trains, trolley buses, and tram cars in traction we have AC and DC drives. AC induction motor is referred as AC Drives; it offers advantages like low cost, low maintenance, smaller size and reliable operation. Some other prior application areas are fans & conveyer belts, robotics, overhead cranes, paper mills, textile mills, etc. In general for better control and lesser losses in motors. We need to adopted a advanced method which provides desired regulation and it have became more flexible after combining with power electronics; different kind of AC/DC, DC/AC and AC/DC/AC configurations are used to provide desired output of traction induction motor. Since it is very important to control output voltage of different electrical equipments. And for that control purpose FEC (front-end converter) are used at the front-end of the system.

II. FRONT END CONVERTER

Front end converters are becoming and interesting solution for power factor correction and low frequency current harmonic elimination in static power conversion systems. The term Front End Converter refers to the power converter system consisting of the line-side converter with active switches such as IGBTs, the dc link capacitor bank, and the load-side inverter. The line-side converter normally functions as a rectifier. But, during regeneration it can also be operated as an inverter, feeding power back to the line.

The line-side converter is popularly referred to as a PWM rectifier in the literature. This is due to the fact that, with active switches, the rectifier can be switched using a suitable pulse width modulation technique. The PWM rectifier basically operates as a boost chopper with ac voltage at the input, but dc voltage at the output. The intermediate dc-link voltage should be higher than the peak of the supply voltage. This is required to avoid saturation of the PWM controller due to insufficient dc link voltage, resulting in line side harmonics.

The required dc-link voltage needs be maintained constant during rectifier as well as inverter operation of the line side converter. The ripple in dc-link voltage can be reduced using an appropriately sized capacitor bank. The active front-end inverter topology for a motor drive application is shown in Figure for a constant dc-link voltage; the IGBTs in the line-side converter are switched to produce three-phase PWM voltages at a, b, and c input terminals. The line-side PWM voltages, generated in this way, control the line currents to the desired value. When dc link voltage drops below the reference value, the feed-back diodes carry the capacitor charging currents, and bring the dc-link voltage back to reference value.

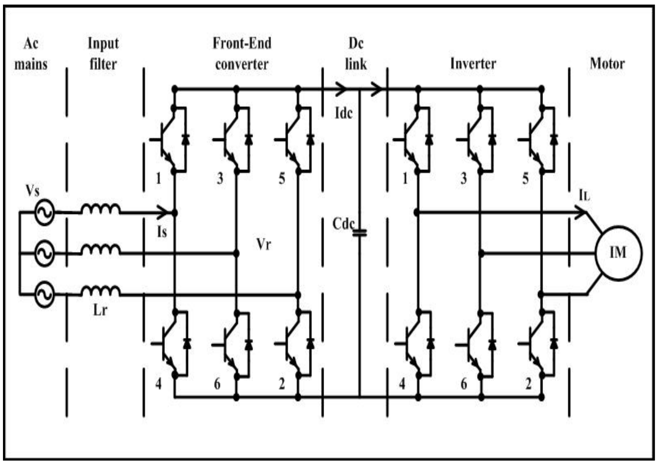

Figure:1 Basic Circuit Diagram of Front End Converter.

III. Pulse Width Modulation Technique

Pulse width modulation is a technique in which a fixed input dc voltage is given to the inverter and a controlled ac output voltage is obtained by adjusting the on and off periods of the inverter components. This is most popular method of controlling the output voltage and this method is termed as pulse width modulation technique. PWM is an internal control method and it gives better result than an external control methods. There are number of PWM methods for variable frequency voltage-sourced inverters. A suitable PWM technique is employed in order to obtain the required output voltage in the line side of the inverter. A Sinusoidal Pulse Width Modulation technique is also known as the triangulation, sub oscillation, sub harmonic method is very popular in industrial applications. In this technique a high frequency triangular carrier wave is compared with the sinusoidal reference wave determines the switching instant. When the modulating signal is a sinusoidal of amplitude Am, and the amplitude of triangular carrier wave is Ac, then the ratio m=Am/Ac, is known as the modulation index. It is to be noted that by controlling the modulation index one can control the amplitude of applied output voltage.

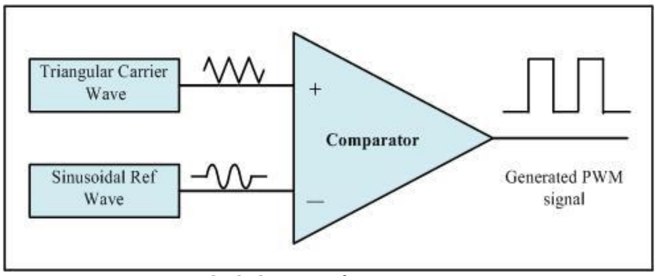

Figure:2 Block diagram of Basic PWM Generator.

For wide variation in drive speed, frequency of the applied AC voltage needs to be varied over a wide range. The applied voltage also needs to be varying almost linearly with the frequency. The harmonic content in the output of the inverter can be reduced by employing pulse width modulation (PWM).

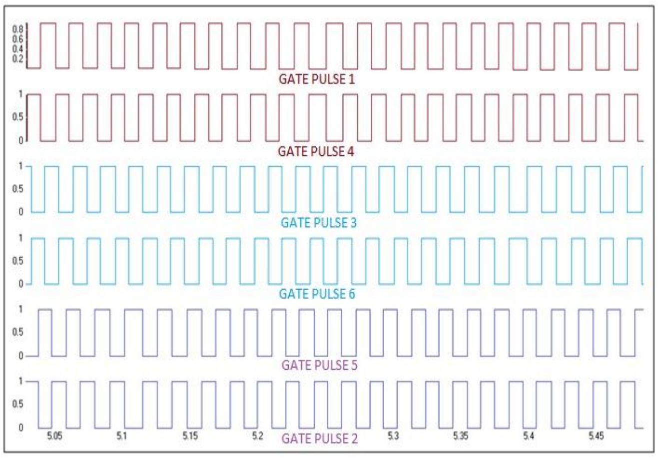

Figure:3 PWM generated signal.

Sinusoidal PWM (SPWM) is affecting in reducing lower order harmonics while varying the output voltage and gone through many revisions and it has a history of three decades. Some of the following constraints for slow varying sinusoidal voltage be considered as the modulating signal are:

(1) The peak magnitude of the sinusoidal signal is less than or equal to the peak magnitude of the carrier signal. This ensures that the instantaneous magnitude of the modulating signal never exceeds the peak magnitude of the carrier signal.
(2) The frequency of the modulating signal is several orders lower than the frequency of the carrier signal. For example 50 Hz for the modulating signal and 20 KHz for the carrier signal. Under such high frequency ratio's the magnitude of the modulating signal will be virtually constant over any particular carrier signal time period.
(3) A three phase Sine-PWM inverter would require a balanced set of three sinusoidal modulating signals along with a triangular carrier signal of high frequency.

IV. SIMULTION RESULTS

Here we prepare the simulation of front-end converter with controlled and uncontrolled mode with their appropriate results; the controllable converter can be operated as a rectifier as well as an inverter too. The switching pulse of Inverter is provided by the PWM generator. The simulation of the proposed circuit is prepared with uncontrolled diode rectifier in line side and inverter controlled with six pulse pwm generator at load side. IGBT is used here as switch and to triggering that we can apply the pwm generator. The Capacitor is connected in parallel for removing fluctuations from the DC Bus Voltage. And there related waveforms are given below. Nominal fixed load torque of 11.9 N-m is given to the motor. The output speed of the motor will given in angular terms (ωm) hence to get the rpm a gain (block) speed converter is used uses the below expression for converting speed.

$$rpm = \frac{\omega m * 60}{2 * \pi}$$

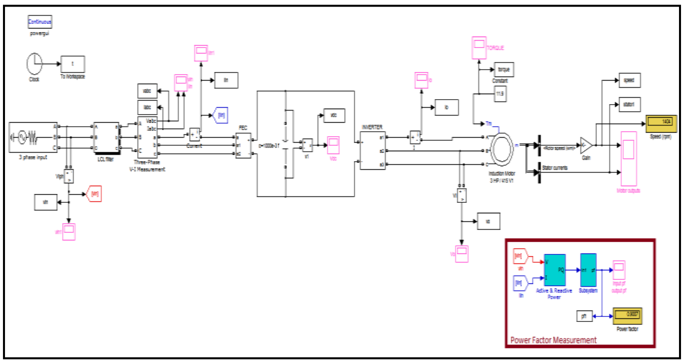

Figure:4 Simulation of The Proposed Circuit (uncontrolled).

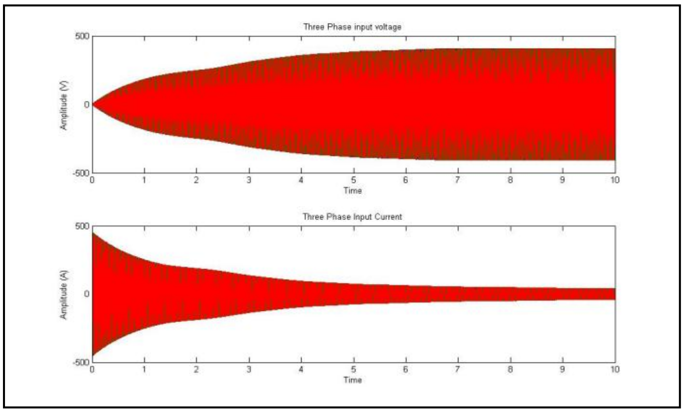

Figure:5 Input output voltage and current.

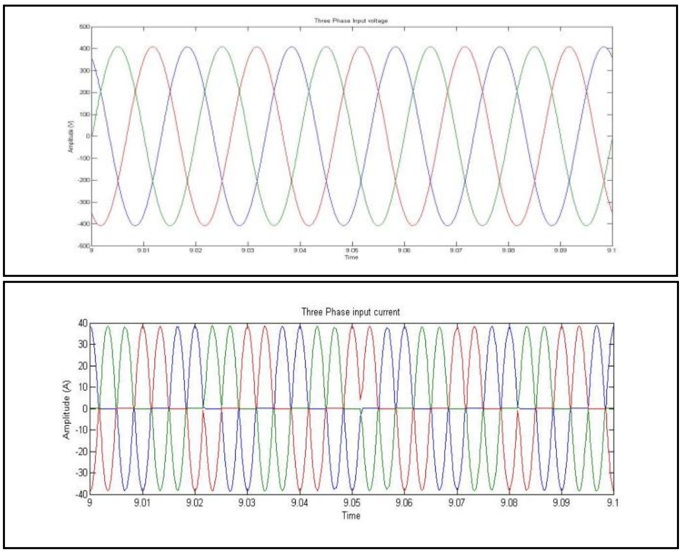

Figure:6 Input output voltage and current.

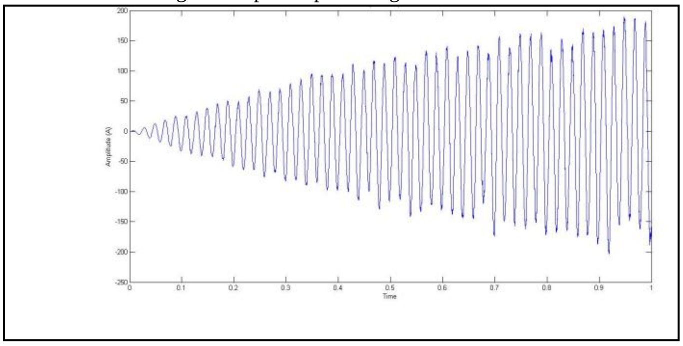

Figure:7 Output Current.

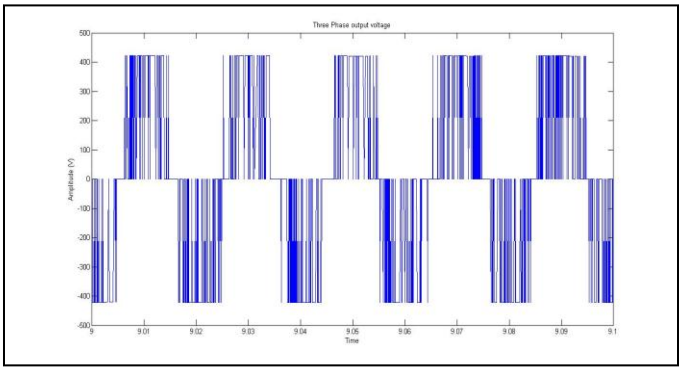

Figure:8 Output Voltage.

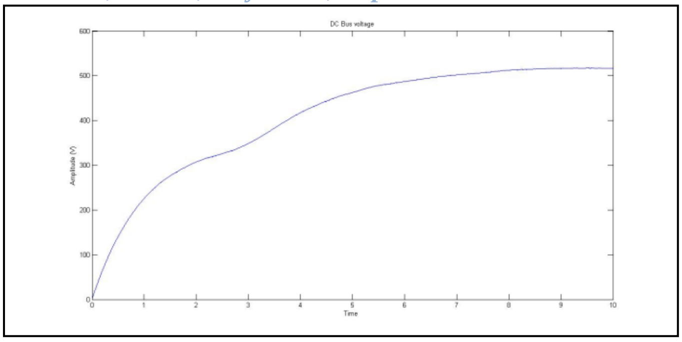

Figure:9 DC link voltage.

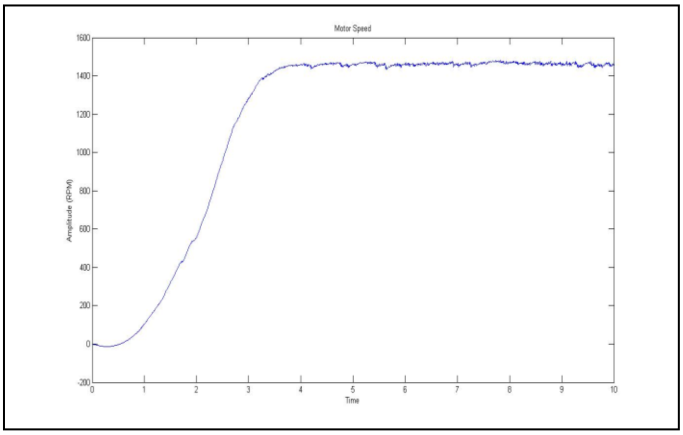

Figure:10 Motor Speed.

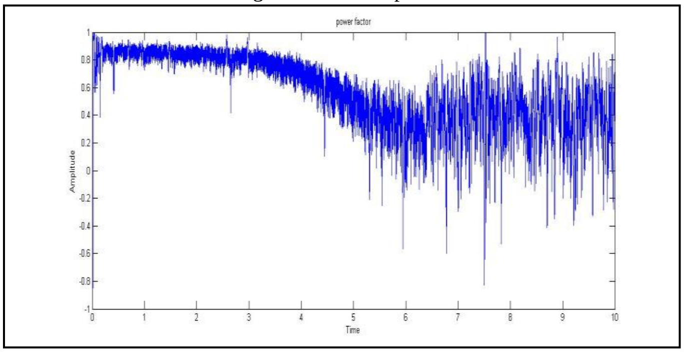

Figure:11 Power Factor for uncontrolled system.

MODULATION INDEX	THD I/P CURRENT	THD O/P CURRENT	THD I/P VOLTAGE	THD O/P VOLTAGE
0.2	3.71	19.99	24.59	149.08
0.4	3.74	14.88	25.23	110.45
0.6	3.98	2.93	26.69	119.23
0.8	3.89	2.38	26.38	60.52
1	3.86	3.83	26.35	18.28

Table1: THD analysis of uncontrolled system.

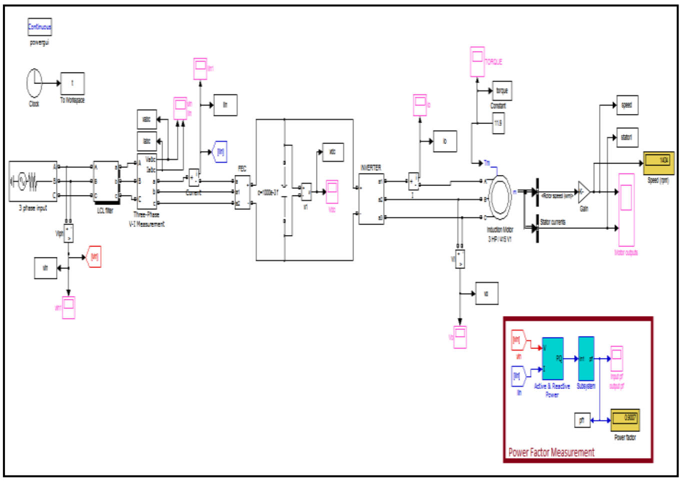

Figure:12 Simulation of The Proposed Circuit (uncontrolled).

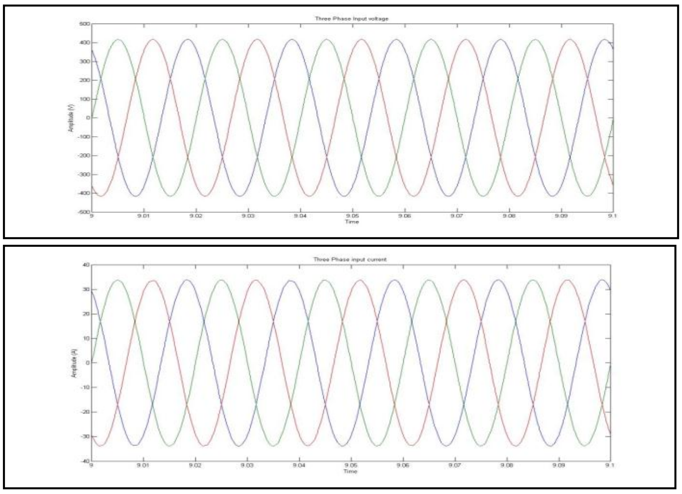

Figure:13 Input output voltage and current.

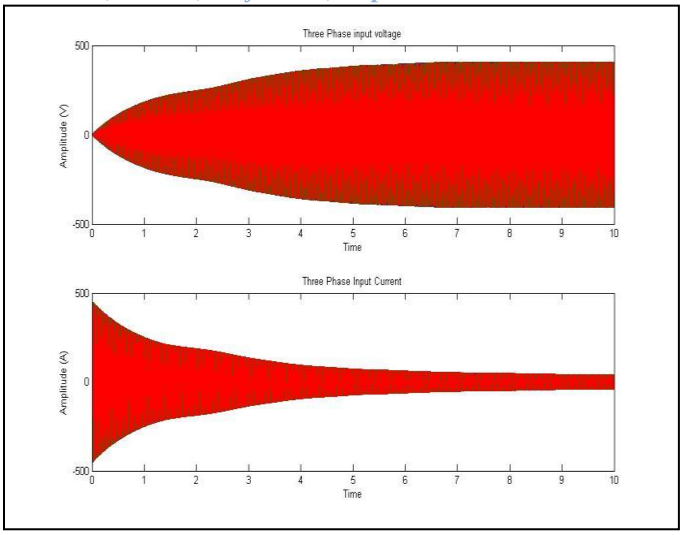

Figure:14 Input output voltage and current.

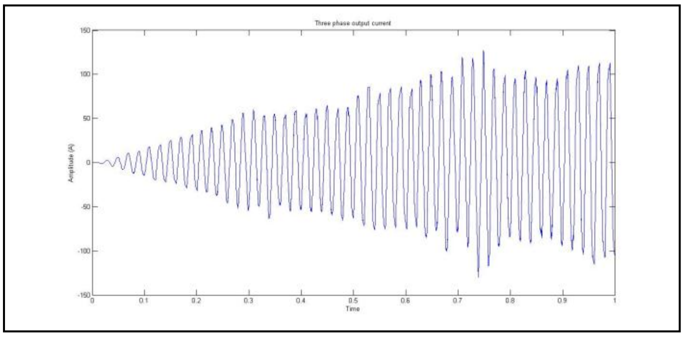

Figure:15 Output Current.

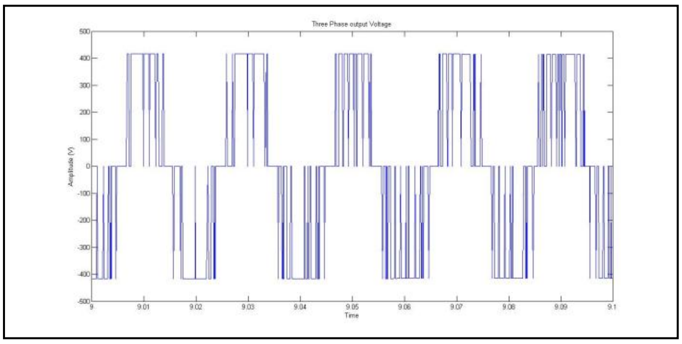

Figure:16 Output Voltage.

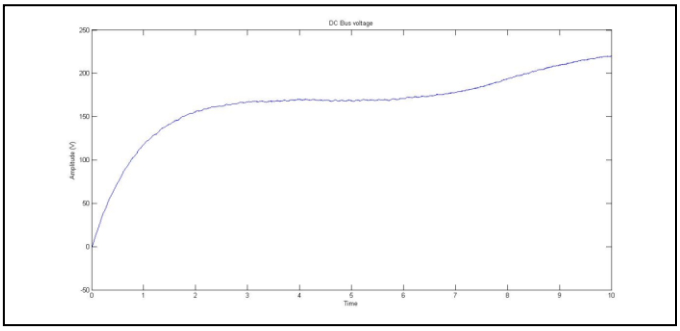

Figure:17 DC link voltage.

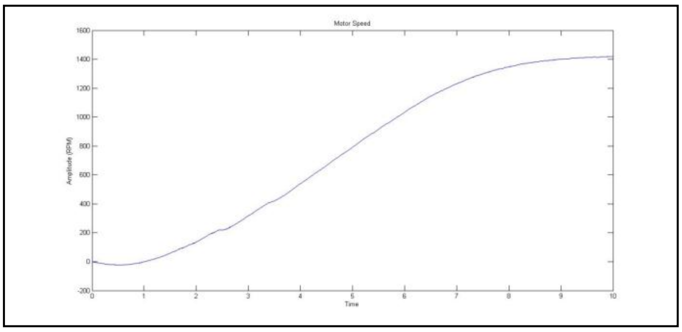

Figure:18 Speed of Motor.

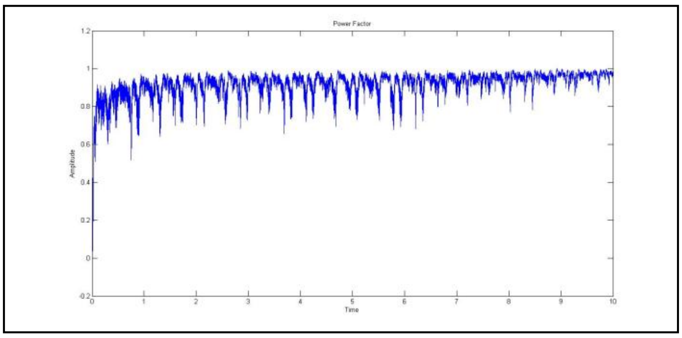

Figure:19 Power Factor for uncontrolled system.

MODULATION INDEX	THD I/P CURRENT	THD O/P CURRENT	THD I/P VOLTAGE	THD O/P VOLTAGE
0.2	0.13	9.79	13.35	8.59
0.4	0.11	13.28	38.33	190.11
0.6	0.28	5.28	47.64	44.99
0.8	1.03	3.96	29.68	33.41
1	1.14	3.73	23.86	178.9

Table2: THD analysis of controlled system.

V. HARDWARE MODLE

In part of hardware side we prepare the prototype model of front-end converter. Where the gating pulses for the controlled rectifier are generated through the PIC Microcontroller. The main controlling unit of the project is the microcontroller. And that's controlled PIC are given to the opto coupler -mosfet driver -mosfet and from that finally we get the required output.

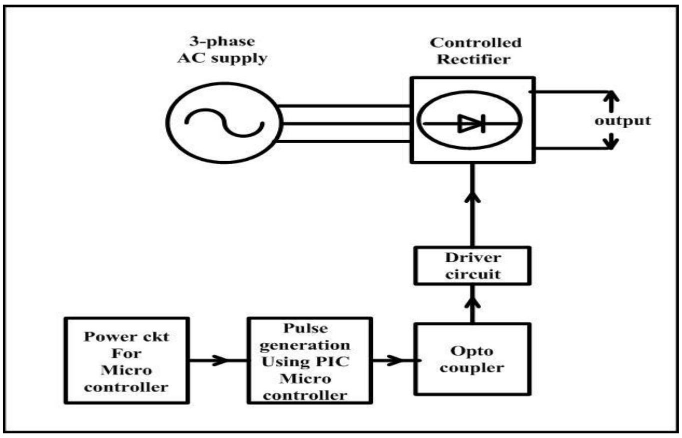

Figure 20: Basic Block for hardware implementation.

Hardware Detail

- PIC Microcontroller Board
- Optocoupler (4N25)
- Driver IC IR2109
- N-Channel MOSFET (IRF250N)

PIC Microcontroller Boar

The Microcontroller board based on the PIC 16F777. It has 40 pin digital input/output pins. It is Mid Range Family microcontroller and it has 35 instructions. The 5 I/O ports and 17 Interrupts. The 14 A/D input channels. Where we can change the output of controlled rectifier with a potentiometer connected to a 10-bit ADC channel (AN1) determines the frequency. The microcontroller uses the ADC results to calculate the PWM duty cycle and thus, the frequency and the amplitude of the supply is change.

Figure 21: PIC Microcontroller board.

Figure 22: PWM pulse from PIC Microcontroller board.

Optocoupler

There are many situations where signals and data need to be transferred from one subsystem to another within a piece of electronics equipment, or from one piece of equipment to another, without making a direct ohmic electrical connection. Often this is because the source and destination are (or may be at times) at very different voltage levels, like a microprocessor which is operating from 5V DC but being use to control a triac which is switching 240V AC.

Figure 23: Practical circuit of optocoupler.

Figure 24: Result of optocoupler.

Driver IC IR2109

IR 2109 High and Low side Driver device for driving the MOSFET .It is capable of up to 600v at a current rating of 2A at fast switching speeds. This device is required to drive the high side MOSFET in the circuit designated HO, due to the fast that the gate to source voltage must be higher than the drain voltage , which is the highest voltage in the system. This device utilizes a bootstrapping capacitor to maintain a voltage difference of approximately 10v above the drain to source voltage.

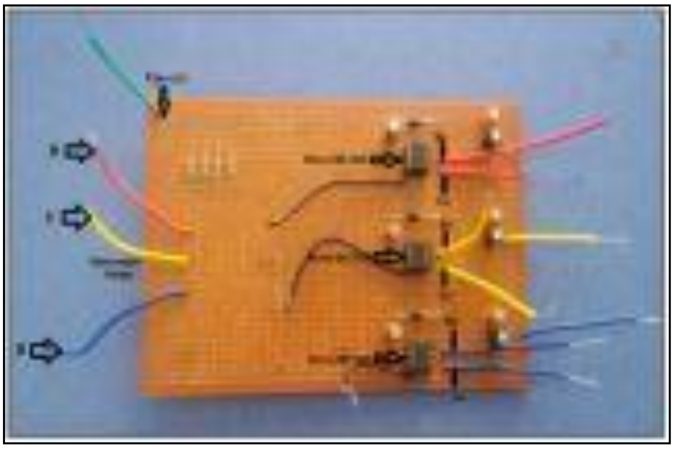

Figure 25: Driver circuit board with IR2109.

Figure 26: Results of MOSFET Driver circuit with High and Low signal.

MOSFET (IRF250N) Based Rectifier

MOSFET utilizing higher processing techniques to achieve really low on-resistance (0.075Ω) per silicon area and it's have a benefit of fast switching speed and ruggedized design. It's Voltage rating VDSS is up to 200V, current rating is 30A and operating temperature is 175o c. The use of heat sinks is important for the MOSFET based rectifier. It is provides an reasonable method to increase the performance of power MOSFET and easily to move heat away from the device in order to maintain a lower device temperature and safe the device from excessive temperature.

Figure 27: Experimental results of rectifier circuit board using MOSFET.

Figure 28: Experimental results of rectifier circuit board using MOSFET.

VI.CONCLUSION

Generally there are different control strategies to operate the traction motor as load. But with different strategy we always try to get the maximum output, and for that we included power electronics in the system. With a help of power electronics we can convert the AC/DC, DC/AC power at controllable mode. Earlier the AC is converted to fixed DC through uncontrolled rectifier using power diodes; a capacitor is used to filter the distortion and the pure DC is fed to an inverter for converting fixed DC to variable AC. Now a day controllable switch in converter is used as it is actively participating in the switching time. On the other hand a front – end converter is controllable device in line side converter for controlling the regular dc input in dc link. Front End Converter working in bidirectional mode which can fed the power back to the grid. Moreover if any kind of harmonic is present in the DC link than it will not be fed back into the grid when bidirectional power flow through FEC is considered. The controlled technique i.e. switching will however inject some harmonics. The Front End Converter is used here for solves the problem of poor power factor and it also help to achieve the better THD profile especially in controllable switching modes. So to solve the same problem we prepare the prototype model of the FEC. FEC contains two circuits one is control circuit and another is power circuits and each circuits contains some other sub circuit. The PIC microcontroller 16F777 generated the PWM signals and its given to the opto-coupler specially for the protection purpose and that given to the driver and with the help of that we can found the high and low signals for MOSFET triggering. And it to controlled output of rectifier.

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Devendra M. sharma is a research student pursuing M.E in Power System Engineering from Merchant Engineering College, Basna (Guj) India. The degree of B.E. (Hons) secured in Electrical Engineering from L. C. Institute of Technology, Bandu (Guj), India in 2011.

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Mr. Sumit R. Patel was born in Mehsana, Gujarat, India in 1988. He received the degree of B.E. (First Class) in Electrical Engineering from L. C. Institute of Technology, Bandu (Guj), India in 2010 and the degree of M. E. (Hons.) in Power System Engineering is secured from Merchant Engineering College, Basna (Guj) India in 2014.
He is presently working as Assistant Professor in Electrical Engg. Department at Merchant Engineering College, Basna (Guj) India, where he is engaged in teaching and his research area includes Electrical Drives, Controlled Power Converters using PWM techniques, Application of AI in switching control, Power System & Power Electronics.