

POWER FACTOR CORRECTION CONVERTER FOR AC DRIVES

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Abstract — In this paper deals with a power factor correction (PFC) converter for AC drives using pulse width modulation current control technique and also presents a topology for driving a three phase induction motor with a single phase AC supply is proposed. Single phase buck and boost DC-DC converter is used to obtain near unity power factor and to reduce the harmonic distortion in the main supply. The proposed scheme is simulated in MATLAB-2010-SIMULINK. In the proposed scheme VHDL coding was developed to generate the sinusoidal PWM gate signal of proposed PFC converter. A three phase, 415V, 0.5Hp, 3 phase induction motor is used as load for testing the developed hardware. The simulation and experimental result confirms that power factor has been increased for all loads.

Keywords- Variable Voltage Variable Frequency (VVVF) drive, Power factor correction (PFC) converters, Total harmonic distortion, SPWM, AC drives

I. INTRODUCTION

AC to DC converter is an integral part of any power supply unit in all the electronic equipment and also used as an interface between the utility with most of the power electronic equipment. Generally to convert AC into DC, bridge rectifier is used. To reduce the ripple in the DC output Voltage, a large filter capacitor is used at the output side of the rectifier. This filter will reduce the input power factor and distort the input Current waveform. In addition to the low power factor lower order harmonics influence the input supply waveforms. Variable Voltage Variable Frequency (VVVF) drive of an induction motor is widely used both in industrial and domestic applications. Especially in domestic applications a single-phase input and three-phase output inverters for motor drive have become popular. In AC systems, poor power factor causes to increases the Current loading on all wiring and components, thus leading to higher capital and operating costs, shortened equipment lifetime and higher utility bills. Power factor correction (PFC) converters holding an important area of study and research in power electronics [1].

The AC-DC converters provide stable DC voltage at the output with high input power factor [2]. PWM converter is one of the solutions for the problems of the converter circuit.[3] the control scheme of the converter circuit of the converter-inverter system.[4] the design method of the converter inverter system based on the loss of controllability and the output harmonic distortion. However, in designing high efficiency VVVF drive system for practical applications, it is the motor efficiency that should be taken into consideration [5].

The output of an uncontrolled converter can be controlled by controlling the performance of rectifiers [6] buck and boost converters provide regulated DC output Voltage at unity power factor and reduced Total harmonic distortion of input AC Current, these converters have found widespread use in various applications due to the advantages of high efficiency, high power density and inherent power quality improvement at AC input and DC output [7].

II. PROPOSED PFC CONVERTER

The proposed PFC converter consists of both buck and boost configurations. This converter consists of two switches one for buck mode and the other one for boost mode. The boost converter is most popular topology for PFC applications due to its current wave shaping ability. But it has some limitations due to higher DC output Voltage, high peak currents in the inductor and more conduction & switching losses. The power factor is high at high voltage gain in boost converter. So it is operated with large duty cycles.

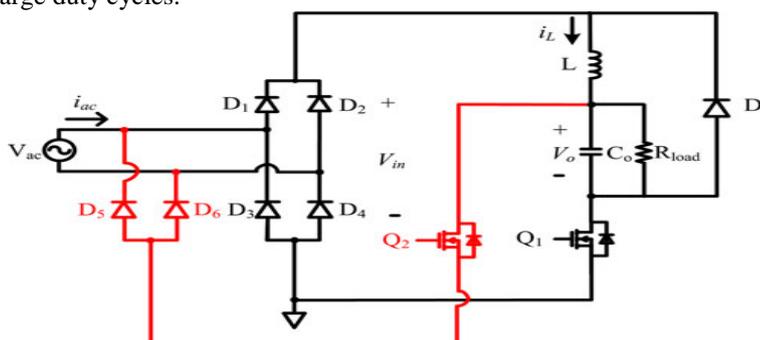


Fig 1. Basic Power circuit of proposed PFC converter

The buck converter has some merits. The output Voltage is regulated to a lower value than boost converter. The voltage stress across the switch is reduced. The large duty cycles will not allow the high inrush currents. Therefore, the efficiency of the buck converter is relatively high. In this improved buck PFC converter the demerits in both buck and boost topologies are eliminated. The rectified output of the bridge converter is a positive sine wave i.e. the Voltage increases from zero to maximum and again reduced to zero and so on. The input Voltage is boosted up when the input Voltage is less than a boundary level. If the input Voltage increases the boundary level, then the buck converter is operated and the pulse to boost converter is not given. The proposed converter is constructed by adopting both conventional topologies. This will increase the power factor and improve the overall performance of the system. The switching losses are reduced by reducing the voltage stresses on the switch.

2.1. BLOCK DIAGRAM

Block Diagram of the Proposed Scheme is Shown consist of diode bridge rectifier , Dc to Dc Converter, three phase inverter ,PFC Control , Three Phase Induction Motor as load, sine PWM gate pulse generator.

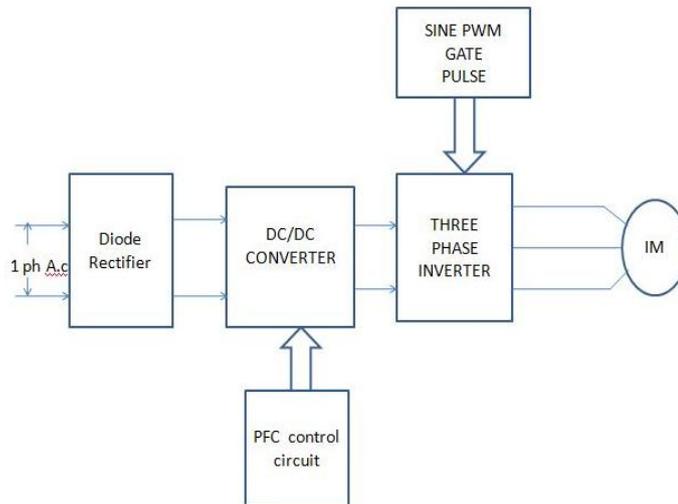


Fig 2. Block Diagram of Proposed PFC Converter

2.2 Pulse Generation

The inductor voltage is sensed and feed to a Zero Crossing Detector. The ZCD sense the zero current occurrences and produce the pulse and it is given to a R-S flip-flop. Control pulses are generated by comparing the saw-tooth waveform with the square wave which is produced by the o/p voltage feedback signal and buck/boost mode selection signal with the help of a transistor and voltage divider. The 'Q' output of the flip-flop is given to the two AND gates which are used to select the buck or boost converter to operate.

2.3 Constant ON time control

This is achieved with the help of an R-S flip flop. The pulse is maintained in high level up to the reset will become high.

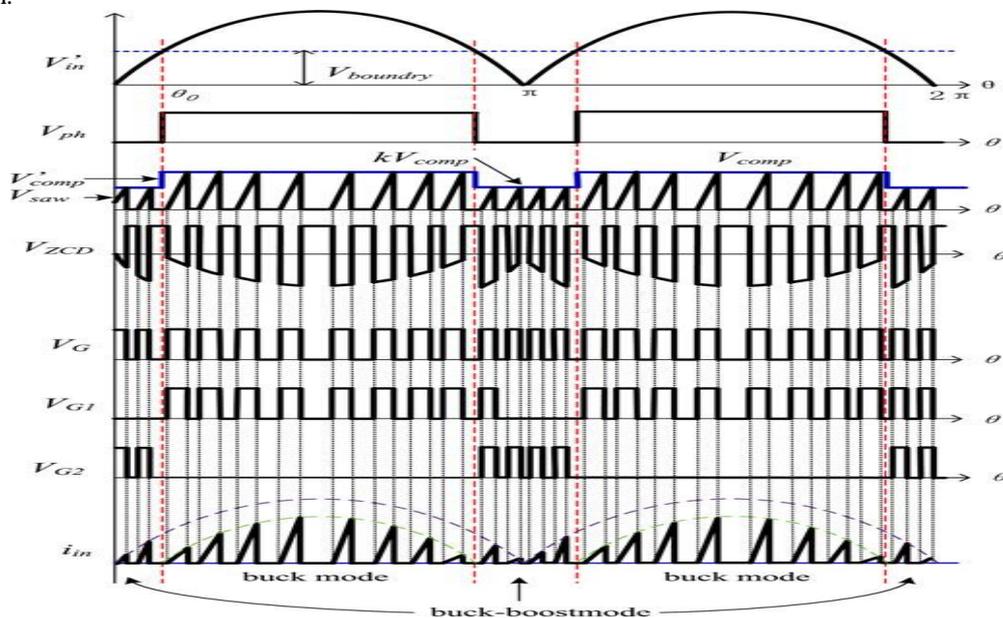


Fig.3 PFC control circuit waveforms for pulse generation

2.4. Mode 1 to Mode 6

In mode 1 the Boost converter is turned ON (Positive half cycle -raising). In the positive half cycle, if the voltage is less than the reference, then the boost converter mode is selected and the switch Q_2 is operated according to the output voltage level and the switch Q_1 is in OFF state. When switch Q_2 is turned ON, current direction is via $D_1 - L - Q_2 - D_6$. The energy is stored in the inductor. In Mode 2 the Boost converter is turned OFF (Positive half cycle- -rising). When the switch is turned OFF the energy stored in the inductor is supplied to the load. Now the devices in operation are $L - \text{LOAD} - D_0$. The capacitor C is used to maintain the output voltage level constant. Now the capacitor is charged. In Mode 3 Buck converter is turned ON (Positive half cycle – more than ref.). If the input voltage is more than the reference, then the buck converter is turned ON. The current direction is via $D_1 - L - \text{LOAD} - Q_1 - D_4$.

In positive Half Cycle

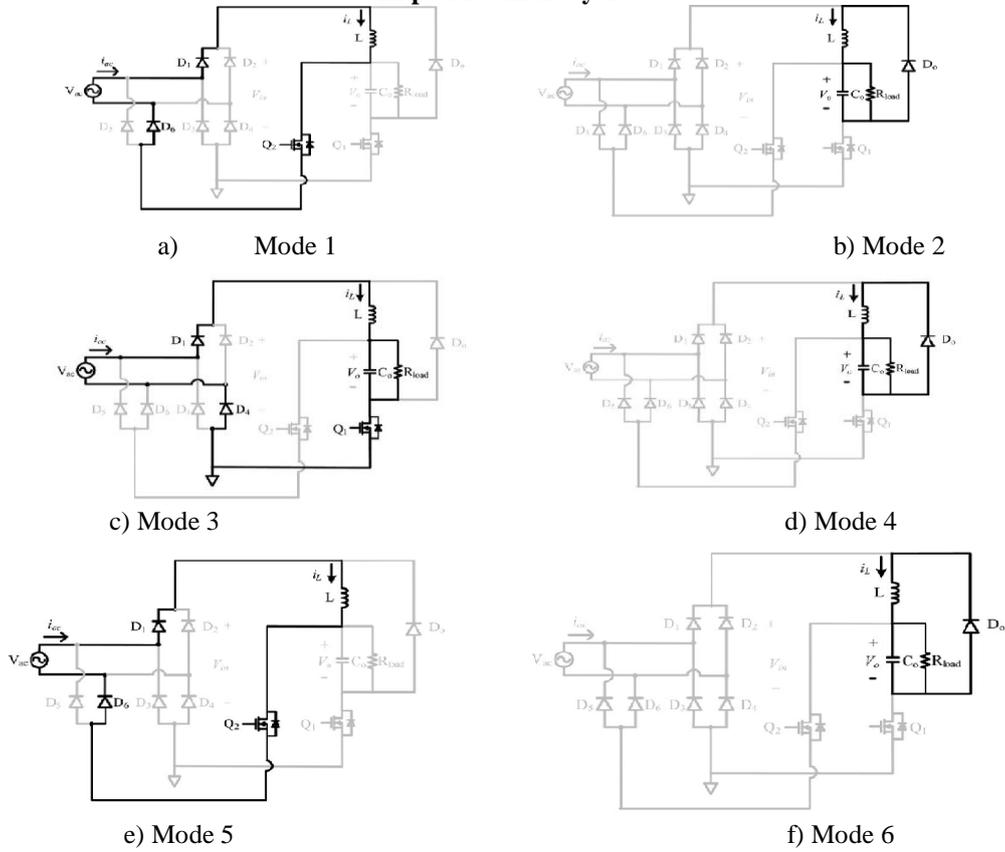


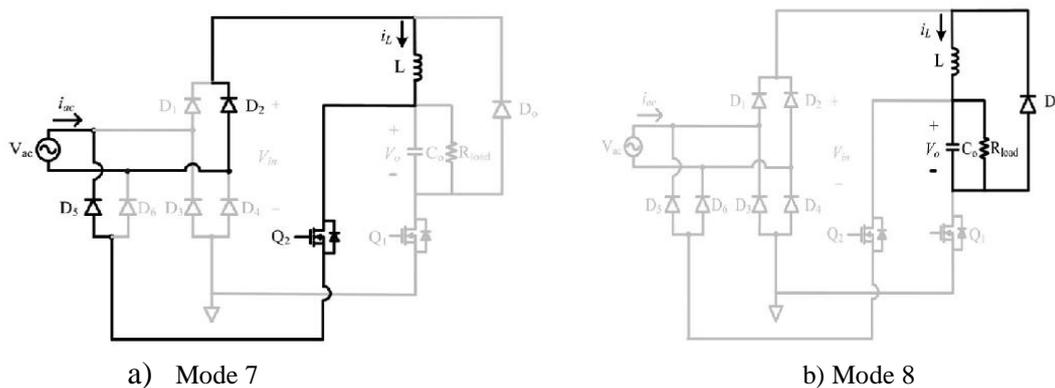
Fig. 4. Different Operating Modes of Converter Circuit in positive half cycle

In Mode 4 Buck converter is turned OFF (Positive half cycle – more than ref.) if the output voltage is more than the level, then the buck converter is turned OFF. The current direction is via $L - \text{LOAD} - D_0$. In the mode 5, the mode1 operation is repeated and in mode6, the mode 2 operation is repeated i.e. the boost converter is in operation.

2.5. Mode 7 to Mode 12

The modes 7 to 12, the input voltage is in negative half cycle of sine wave. The operations are same as that of the positive half cycle but the diodes in conducting will not be the same. The operation is illustrated in Fig.5.

In negative Half Cycle



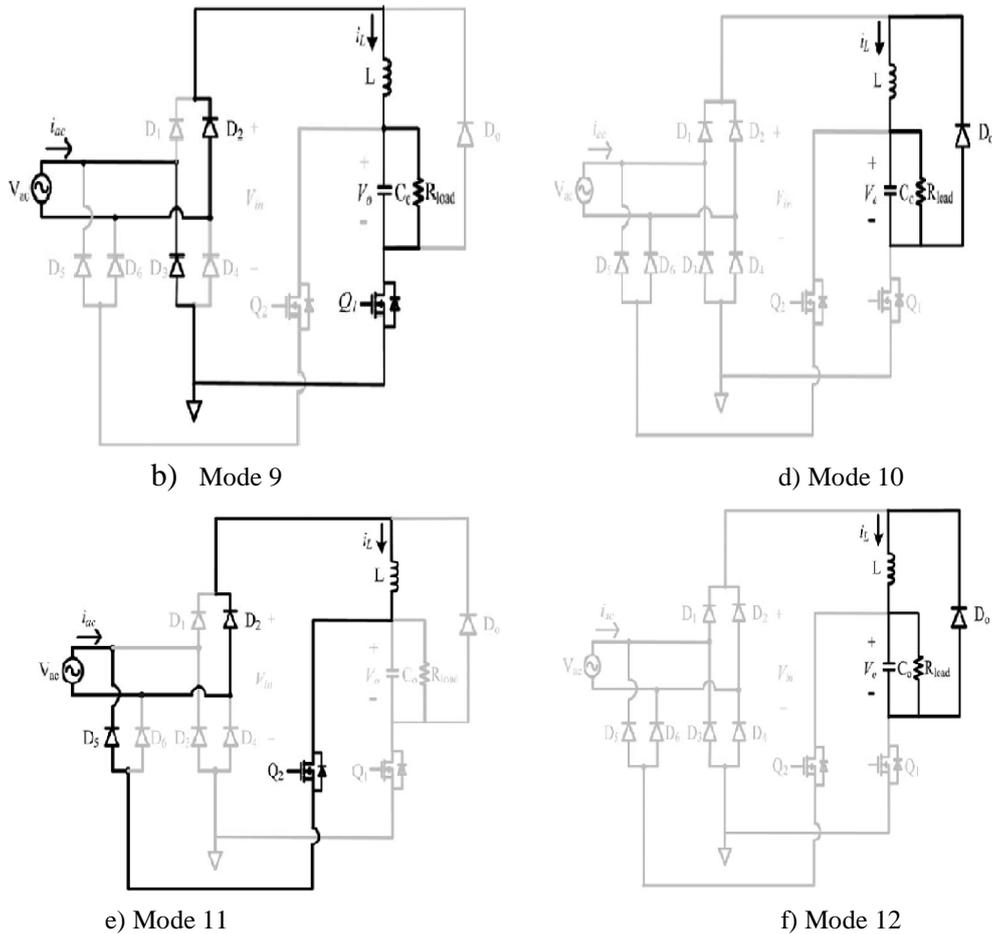


Fig. 5. Different Operating Modes of Converter Circuit in negative half cycle

2.6. SINE- PWM INVERTER

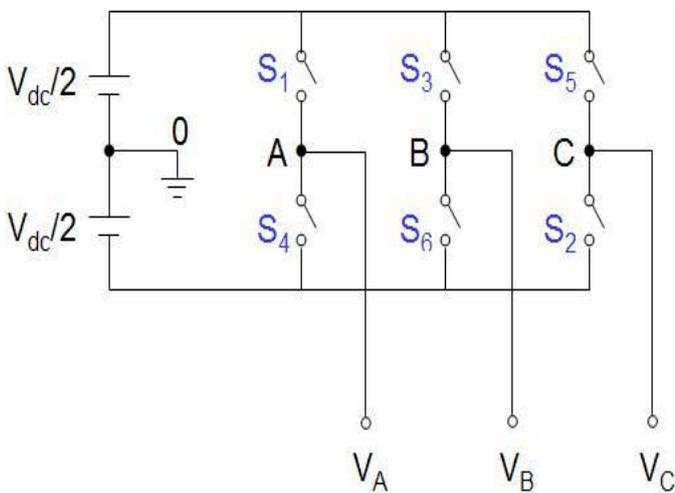


Fig. 6 Three-phase VSI Inverter.

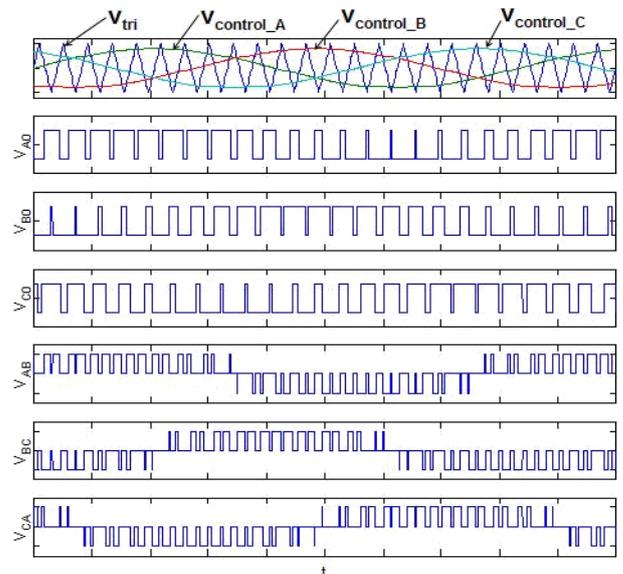


Fig. 7 Output Waveforms Of Three-Phase Inverter

III SIMULATION AND RESULTS

3.1 MATLAB simulation model of WITHOUT PFC

Table 1 Simulation Results of WITHOUT PFC Converter

Sl. No.	C	AC motor load	PF	I/P voltage Vm	Input current A	Output current A	THD %
1	1000e-6	0.5 HP	0.4611	325.269	1.663	0.367	97.86

MATLAB Simulation of Proposed PFC converter with AC Motor load

Fig 11 shows the Simulation Model Of Proposed Converter With Three phase AC induction motor load . Proposed Scheme consist of Single Phase Bridge Rectifier, PFC control circuit, three phase inverter ,three phase induction motor. Power factor correction control circuit subsystem simulation is Shown In Fig12

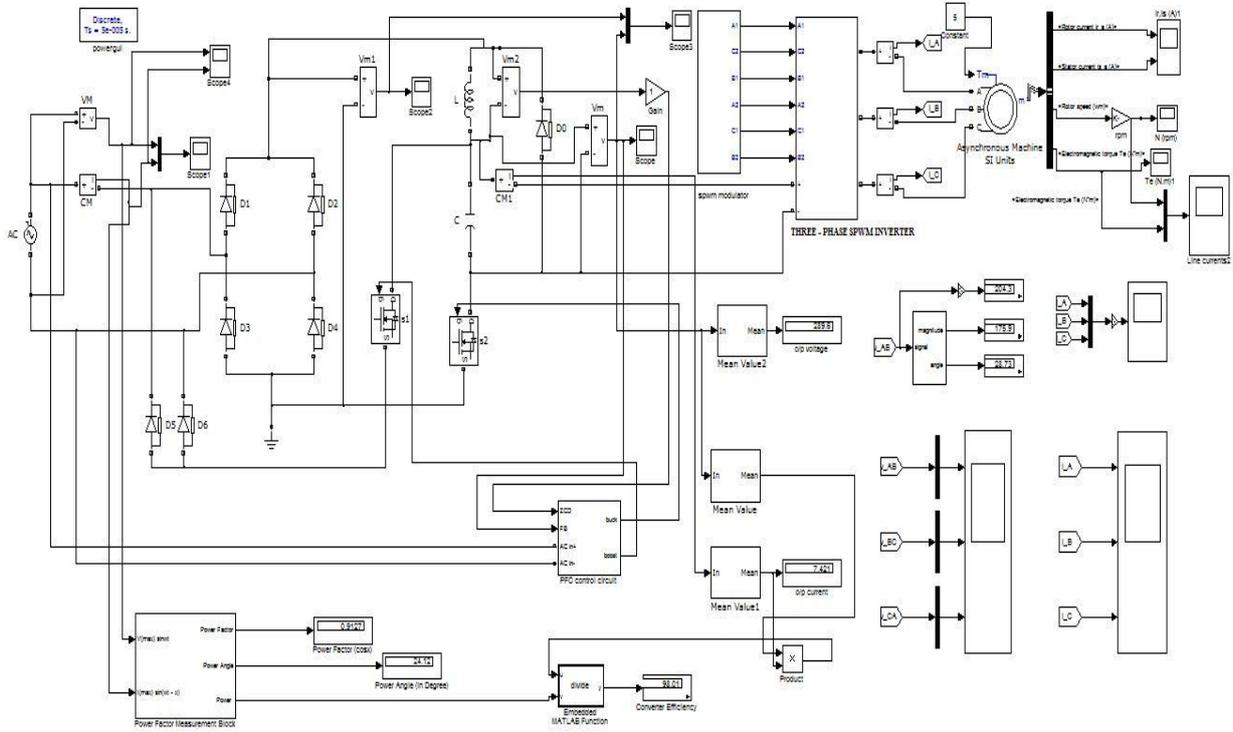


Fig 11. MATLAB model of proposed PFC converter with 3 phase AC motor load- Power circuit

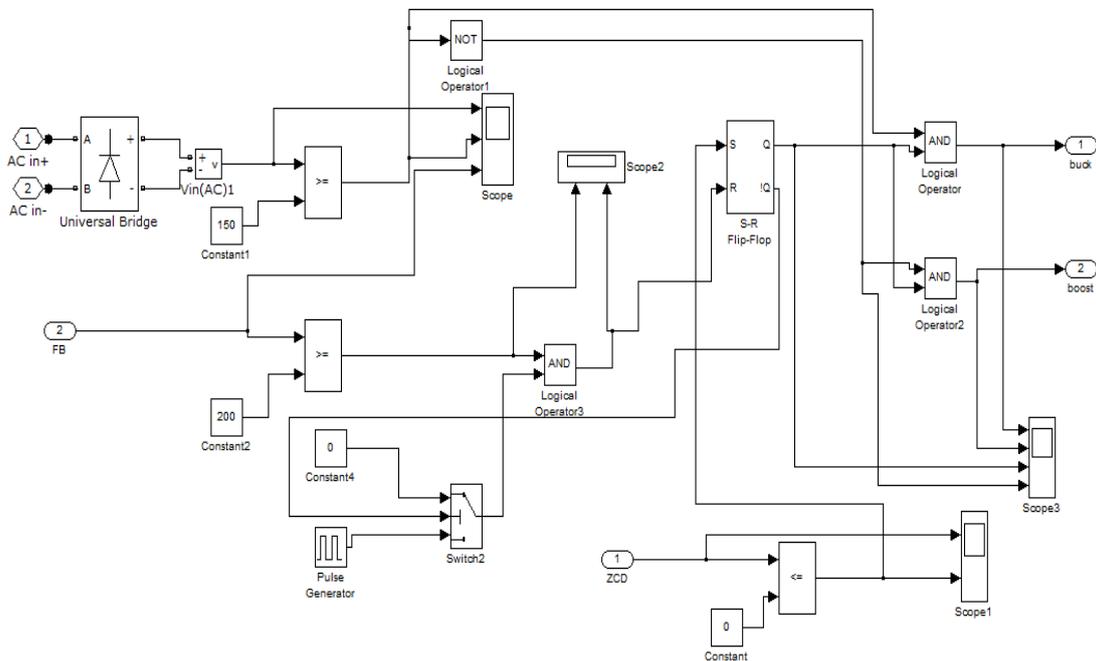


Fig 12 . MATLAB model of Power Factor Correction control circuit

Input voltage & Current waveforms

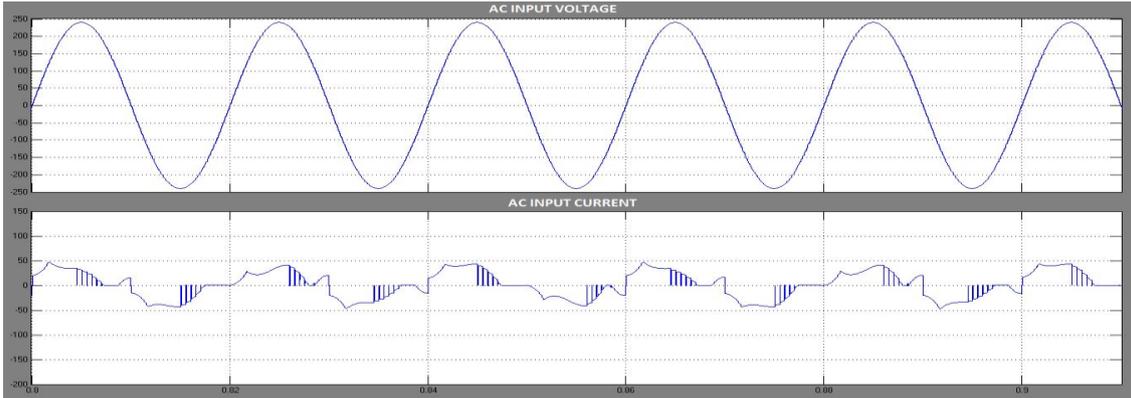


Fig. 13 AC input Voltage and input Current waveform . Input power factor is 0.9299

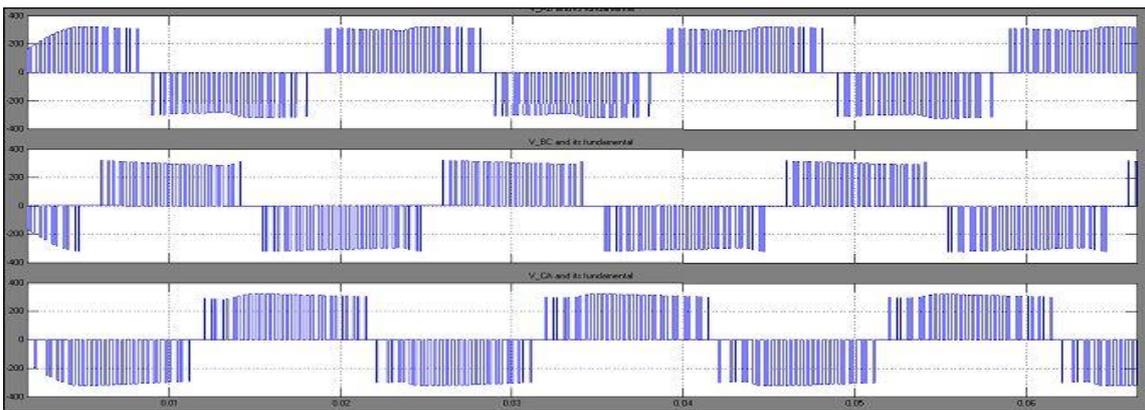


Fig. 14 Input Voltage wave forms at the AC motor terminals.

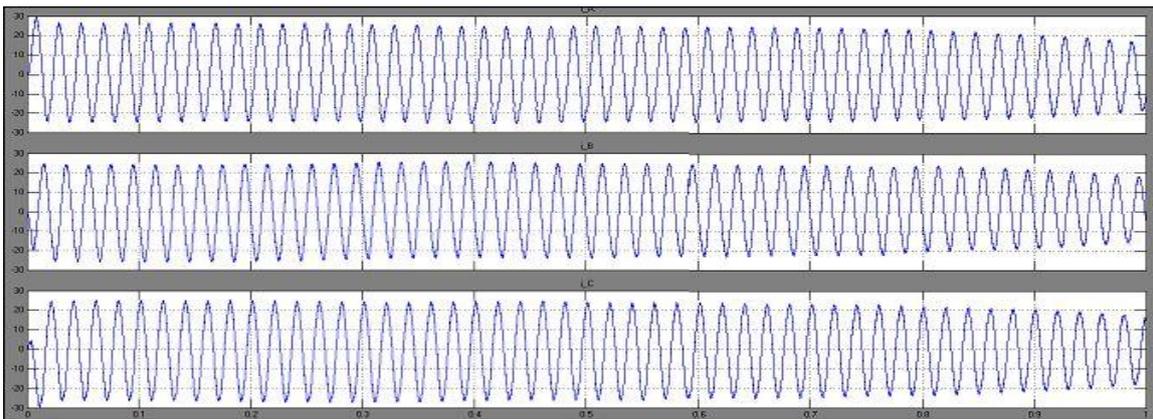


Fig. 15 Input Current waveforms of three phase AC induction motor

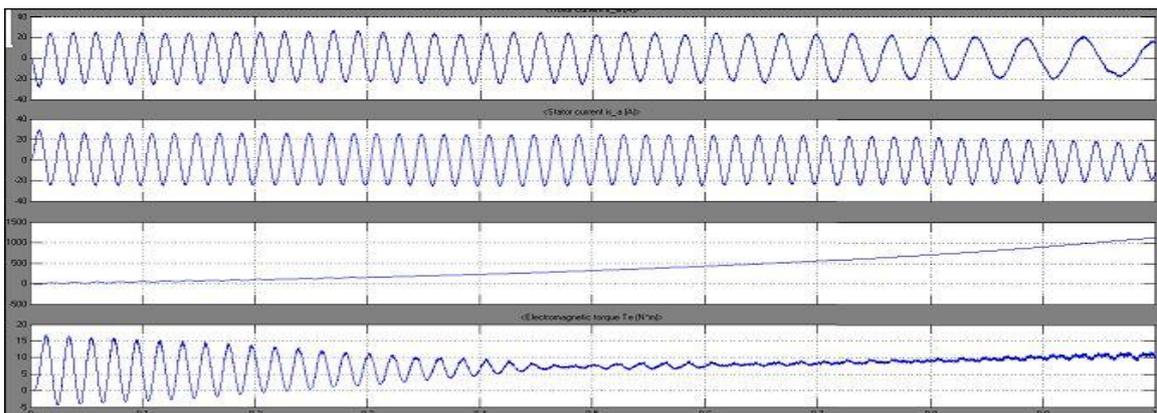


Fig. 16 Stator Voltage ,Stator Current ,Rotor Speed , Electro Magnetic Torque

FFT Analysis

The FFT Analysis of proposed scheme with 3 phase induction motor load . THD value for the above circuit model is 46.74%

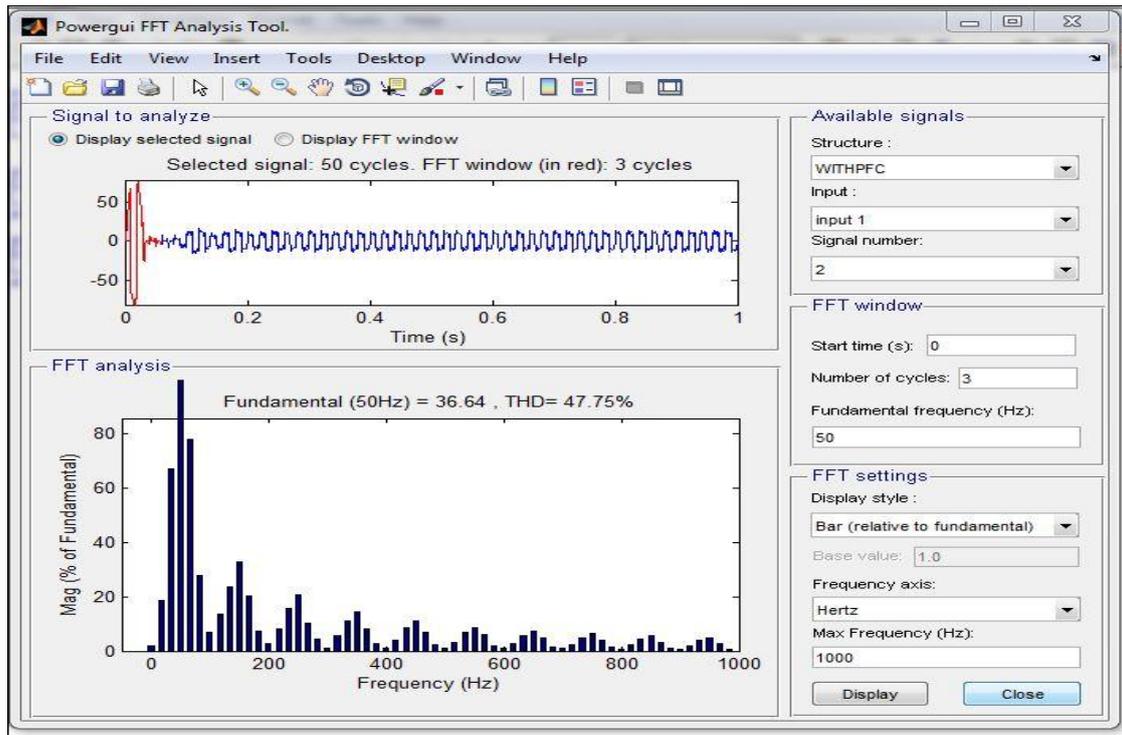


Fig.17 FFT Analysis .

TABLE 2 Simulation Results of WITH PFC

Sl. No.	C	AC motor load	Input PF	I/P voltage Vm	Input current A	Output current A	THD %
1	1000e-6	0.5 HP	0.9299	325.269	0.734	0.872	46.11

TABLE 3 Comparison Table of WITH PFC and WITHOUT PFC

Sl. No.	Converter	Input Voltage Vm	INPUT current (A)	Load current (A)	Input PF	THD (%)
1	WITHOUT PFC	325.69	1.663	0.367	0.4711	97.21
2	Proposed (WITH PFC)	325.69	0.734	0.872	0.9299	46.11

The simulation results of WITH PFC and WITHOUT PFC are shown in table 3. From comparison table the input power factor has improved from 0.4711 to 0.9299 using the proposed PFC converter .

IV HARDWARE IMPLEMENTATION

The proposed power factor correction converter hardware is designed and constructed to drive a 0.5 HP, 1380 rpm, 50 HZ Three phase a AC induction motor load. In the proposed scheme VHDL coding was developed to generate the sinusoidal PWM gate signal of proposed PFC converter. A 3 phase AC Squirrel cage induction Motor is used as load

4.1 Hardware Set-up of the proposed PFC Converter (WITH PFC)

The Hardware Set-up of Power Factor Correction Converter for AC motor load. The Input power factor is measured by using Hioki power quality analyzer.

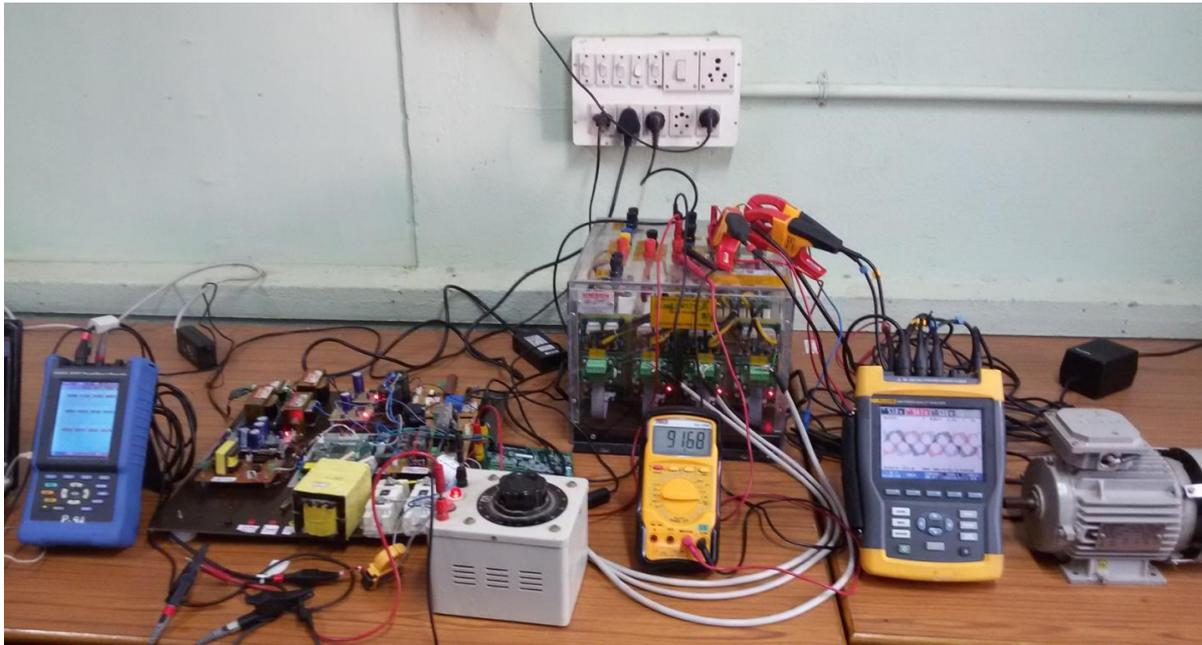


Fig. 18. Hardware Set-up of Power Factor Correction Converter for AC motor load

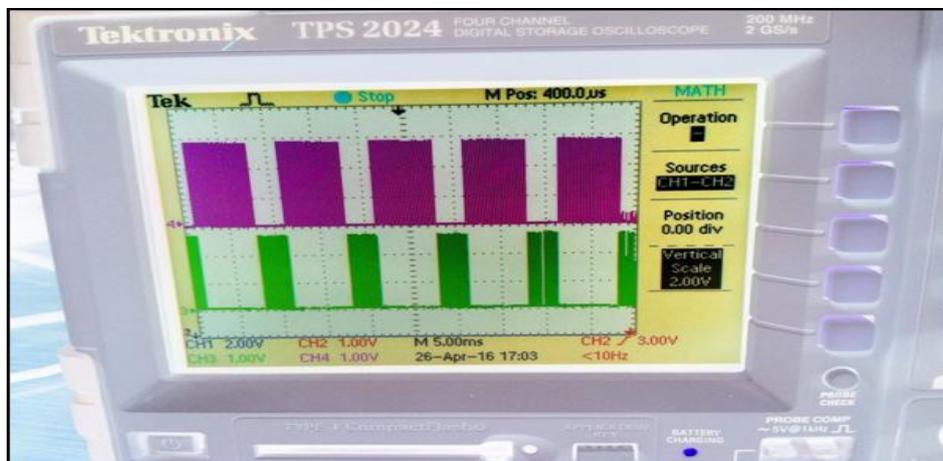


Fig 19 input Voltage and input Current waveform of single phase AC mains with proposed converter

Ch1: Buck converter pulse $30^\circ - 150^\circ$ Ch2: Buck converter pulse $0^\circ - 30^\circ$ & $150^\circ - 180^\circ$
 Ch3: ZCD output ,AC sine wave as reference Carrier frequency 10kHz and Reference Frequency 50 Hz

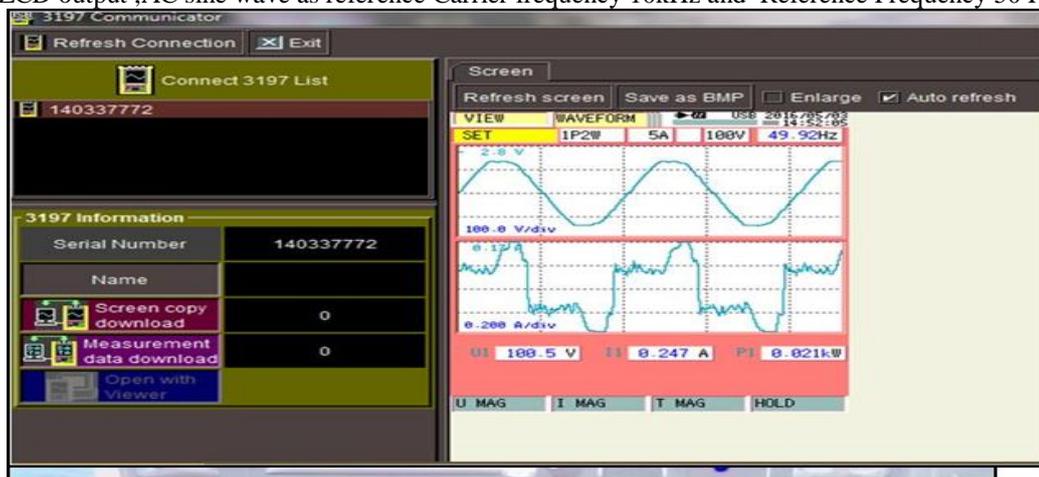


Fig. 20. Input voltage and Current Waveforms of single phase AC mains with proposed converter (Hioki Power Analyzer)

Table 4 Hardware Results of proposed converter

AC INPUT VOLTAGE (V)	INPUT CURRENT (AMPS)	DC OUTPUT VOLTAGE (VOLTS)	INVERTER OUTPUT VOLTAGE MODULATION INDEX =0.95			INPUT POWER FACTOR	THD %
			V RY	VYB	VBR		
110.8	0.296	91.60	53.69	53.69	53.52	0.829	3.2
100.5	0.247	69.52	40.3	40.6	40.2	0.828	3.3
94.9	0.223	65.88	38.26	38.46	38.16	0.824	3.5
90.4	0.205	63.19	36.16	36.95	36.95	0.818	3.6
80.1	0.167	56.73	33.13	33.26	32.99	0.797	3.9

Result

From the results it can be concluded that the input power factor is improved up to 0.829 for the input voltage range 8 to 100V AC. In the simulation it is improved up to 0.9299 for the input voltage range of 90 to 230V AC. Due to some dv/dt and di/dt protection problems the input voltage is applied up to 110V. So that the power factor is not able to improve as it is in the simulation.

V. CONCLUSION

The power factor correction converter has been developed for Variable Voltage and Variable Frequency (VVVF) drive (three phase induction motor as load.) The Input Power factor of the single phase AC input mains supply has been nearly unity using proposed PFC Technique. The developed power factor correction hardware circuit setup is tested on a three phase 0.5HP, 415V, and 50Hz induction motor load. The three phase induction motor drive is runs at different loads and voltages implementing with power factor correction technique .The input power factor is improved to nearly unity at all loads proposed PFC Technique. .The developed system is useful for domestic, commercial applications and remote areas where three phase supply is not available easily.

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