IOSR Journal of Electrical and Electronics Engineering (IOSR-JEEE)
e-ISSN: 2278-1676,p-ISSN: 2320-3331, Volume 9, Issue 6 Ver. IV (Nov – Dec. 2014), PP 25-31
www.iosrjournals.org

Operating Three Phase Induction Motor Using Power Factor correction and controlled Technique

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Abstract: *This paper presents power factor correction control for three phase induction motor drive using pulse width modulation current controlled technique and also presents a topology for driving a three-phase induction motor with a single-phase ac supply. Single phase boost DC-DC converter is used to obtain near unity and to reduce harmonic distortion in the main supply. In the proposed scheme, UC3854 power factor corrector is used to improve the power factor and dsPIC30F2010 controller is used to generate PWM signals. A three phase, 415V, 1.5hp induction motor is used as load for testing the developed hardware. Textronics TDS2024B storage oscilloscope is used to store the gate pulses and waveforms. The experimental result showed that power factor has increased for all the loads when power factor correction (PFC) technique is used and when compared to without power factor correction (PFC) technique.*

Keywords: *Power factor correction boost converter, PWM inverter and three phase induction motor drive.*

I. Introduction

Induction motors are the most widely used motors for appliances, industrial control, and automation; hence, they are often called the workhorse of the motion industry. They are simple and most robust in construction without any mechanical commutator, and reliable. The role of static power converters in the motor control in industrial and domestic applications has grown rapidly in which power can be manipulated with high efficiency so in most of the applications AC machines are preferable to DC machines. The three-phase induction motors have some advantages in the machine efficiency, power factor, and torque ripples compared to their single-phase counterparts.

Though the precise control of single phase induction motor is less complex in comparison to the three phase induction motor, but when the torque requirement is considered then three phase induction motor is the best choice.Now a day's in the commercial and domestic applications a single-phase input and three-phase output inverters for motor drive have become popular.These motor drives are considered efficient as long as the power factor is above 0.85 and closer to 1.0 (unity).But in practical motor drives application the power factor is low.

Due to this low power factor in motor drives system following disadvantages occurs, large KVA rating of the machine, greater conductor size, large copper loss, poor voltage regulation, reduces the power handling capacity of the system. In this work power factor correction method is adopted to improve the power factor. This power factor correction circuit mainly contains DC-DC converter and pulse width modulation current controller. Here we are using a boost DC-DC converter for power factor correction circuit to improve the input power factor nearer to unity. The boost regulator gives continuous input current and it produces lowest level of conducted noise and gives best input current waveform. So, the boost converter is an excellent choice for a power factor correction circuit. In this work first i have converted single phase line voltage (AC) into DC. This DC is regulated by boost DC-DC converter and maintains a constant current waveform by using power factor correction circuit. DC is again converted to three phase AC and driving 3-phase induction motor using 16 bit High Performance Digital Signal Controller. The dsPIC30F2010 devices contain extensive Digital Signal Processor (DSP) functionality with high performance 16-bit microcontroller (MCU) architecture.

The developed hardware is tested on a 3-phase, 415V, 50Hz Induction motor. According to the requirement, a software program is written and is fed to the digital signal controller (dsPIC30F2010) for necessary action. The drive is operated under different loads (No Load, Half Load and Full Load) implementing with and without power factor correction Techniques. The input power factor is nearer to unity at all Loads using power factor correction technique.

The total harmonic distortion of three phase rotor currents has decreased and hence power factor increased for all the loads. Overall the performance of the drive is improved by using power factor correction technique when compared without power factor correction technique. The various graphs/waveforms are analyzed and studied on Digital Storage Oscilloscope.

II. Block Diagram And Its Explanation

2.1 System Overview

The block diagram of the proposed single phase to three phase power conversion and driving three phase induction motor is shown in figure 1. It has full bridge rectifier and filter capacitor, PFC circuit, full bridge inverter, control circuit. In the proposed work, rectifier bridge module KBPC3510 having 35 Amps and 1000V is used. The output of the rectifier is filtered by using two 1000μF, 250V capacitors which acts as filter capacitor.

The full bridge inverter has 2-FGA25N120ANTD-IGBT's switches with the snubber circuit to meet the requirement. A digital signal controller (dsPIC30F2010) is used to implement the core of the control function, which simplifies the hardware setup.

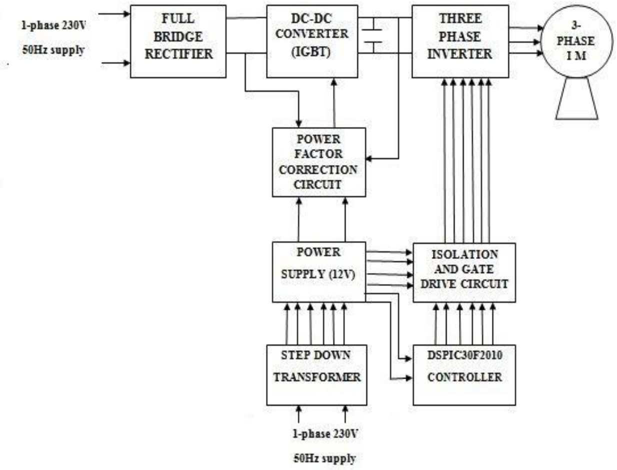


Fig1. Block diagram of the proposed system

2.2 Power Circuit Design

The power circuit contains full bridge rectifier, boost DC-DC converter with filter capacitors assembly, power factor correction circuit assembly and full bridge inverter assembly.

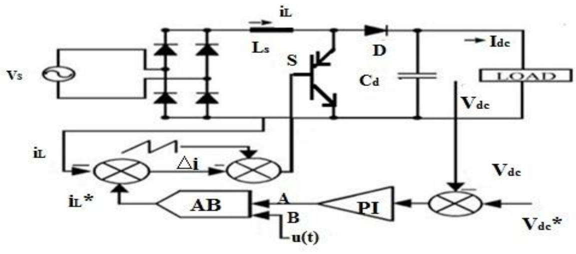


Fig2.PFC circuit employing PWM Current Controller

Single phase 230V, 50Hz AC supply is applied to the full bridge rectifier, followed by the DC-DC boost converter, the output of the DC-DC boost converter is given to the full bridge inverter which converts AC to DC is given to Induction Motor, In this work we are using Power Factor Correction (PFC) circuit to improve the Power factor. The output of the rectifier is taken as actual signal and output of the boost converter taken as a reference signal to the Power Factor Correction circuit. In this PFC method, the reference current and actual current are compared in the comparator an error signal is generated. This error signal is amplified and compared to a fixed frequency carrier wave to generate the pulses to the IGBT as shown in Fig.2.The energy that a switching power converter delivers to a motor is controlled by Pulse Width Modulated (PWM) signals applied to the gates of the switches. PWM signals are pulse trains with fixed frequency and magnitude and variable pulse width.

2.3 Control Circuit

The control circuit of the proposed scheme consists of a Digital signal Controller dsPIC30F2010.A Digital Signal Controller (DSC) is a single-chip, embedded controller that seamlessly integrates the control attributes of a Microcontroller (MCU) with the computation and throughput capabilities of a Digital Signal Processor (DSP) in a single core. The dsPIC DSC has the "heart" of a 16-bit MCU with robust peripherals and fast interrupt handling capability and the "brain" of a DSP that manages high computation activities, creating the optimum single-chip solution for embedded system designs. The dsPIC30F devices contain extensive Digital Signal Processor (DSP) functionality within high-performance 16-bit microcontroller (MCU) architecture. It also consists of two opto-coupler for isolating the control and power circuits.

In this work an optocoupler TLP250 is used to isolate the gate drive circuit and the IGBT-based power circuit. All six IGBTs of the power circuit are controlled by the PWM signals generated by the control circuit.

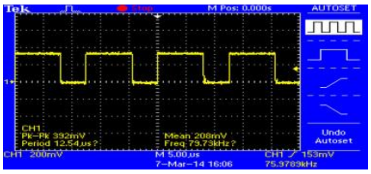
III. Experimental Setup And ITS Results

The proposed Power Factor Correction control system was implemented by integrated circuit UC3854 with boost converter. Control system was designed using digital signal controller (dsPIC30F2010) based pulse width modulation (PWM) inverter. C language is used to develop the program. The device is programmed using MPLAB Integrated Development Environment (IDE) tool. For execution of C-code, MPLAB compiler is used. In this work, I have used 415V, 50Hz, 3-Ph, 1.5 HP Induction motor. The hardware set is developed and tested in power electronics laboratory and the photograph of complete setup is shown in fig 3. The test is carried out on induction motor for different loads and voltages. For different loads and voltages, current drawn by the motor and voltages across all lines are noted and are tabulated.

Table 3.1, 3.3, 3.5 shows the output voltages, power and power factor for different loads without using the power factor correction technique (PFC). Table 3.2, 3.4, 3.6 shows the output voltages, power and power factor for different loads with using the power factor correction technique (PFC). The corresponding waveforms and gate pulses are shown in figures 3.1 – 3.16.

I have observed the gate pulse and output voltage waveforms using DSO and they are given in the following figures

Gate pluses for different loads



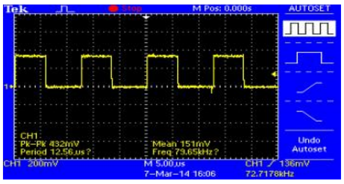


Fig 3.1 Gate pulse at No load   Fig 3.2 Gate pulse at 1kg load

3.1 Experimental result for without power factor correction technique and with power factor correction technique at No load with 1480 rpm speed.

Table 3.1Experimental result for without power factor correction technique

SL.No	Input voltage (volts)	Rectifier output voltage (volts)	Output voltage (volts)			Output power (watts)	Power factor (cosϕ)
			V_a	V_b	V_c		
01	40	42	27	26	30	71.6	0.89
02	60	63	44	43	48	195	0.88
03	80	85	68	69	74	335	0.87
04	100	105	98	97	106	437	0.84
05	120	117	128	127	133	652	0.81
06	140	138	152	151	158	792	0.8

Input and output voltage waveforms for without power factor correction technique as shown in below figures 3.3 and 3.4

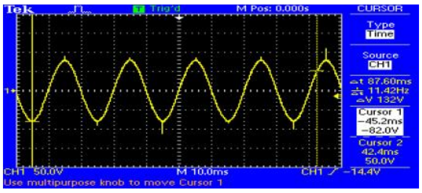


Fig 3.3 Input voltage waveform at No load for without PFC technique

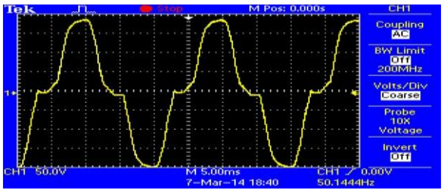


Fig 3.4 Output voltage waveform at No load- for without PFC technique

Table 3.2 Experimental result for with power factor correction technique

SL.No	**Input voltage (volts)**	**Rectifier output voltage (volts)**	**Boost converter output voltage (volts)**	**Output voltage (volts)**			**Output power (watts)**	**PFor(cosϕ)**
				V_a	V_b	V_c		
01	40	41	48	27	26	31	70	0.97
02	60	62	75	43	44	49	187	0.96
03	80	83	102	66	67	72	325	0.95
04	100	102	128	98	97	106	415	0.94

05	120	114	145	126	123	134	612	0.92
06	140	137	182	147	144	156	755	0.91

Input and output voltage waveforms for with power factor correction technique as shown in below figures 3.5 and 3.6.

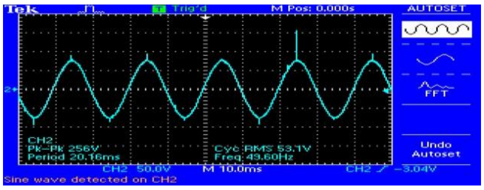


Fig 3.5 Input voltage waveform at No load for with PFC technique

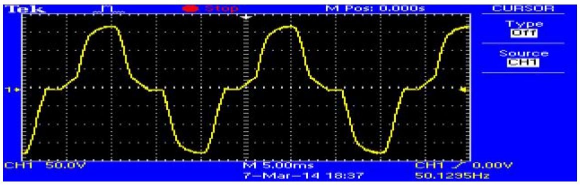


Fig 3.6 Output voltage waveform at No load-load- for with PFC technique.

The table 3.1 and 3.2 shows experimental results for without PFC and with PFC technique at no load condition. From the table3.1 considering one input voltage i.e.100V. After the rectification that voltage is 105V, output power consumption is 437W with corresponding power factor 0.84. From the table 3.2 considering that same input voltage i.e. 100V, the rectification voltage is changed to 128V after using PFC technique with boost converter, the corresponding power and power factor are changed to 415W and 0.94 respectively. 3.2 Experimental result for without power factor correction technique and with power factor correction technique at 1kg load with 1380 rpm speed.

Table 3.3 Experimental result for without power factor correction technique

SL.No	Input voltage (volts)	Rectifier output voltage (volts)	Output voltage (volts)			Output power (watts)	Power factor (cosΦ)
			V_a	V_b	V_c		
01	40	43.8	26	25	33	130	0.85
02	60	63.4	42	41	48	250	0.83
03	80	82.2	68	69	74	399	0.8
04	100	104	92	93	101	450	0.79
05	120	115	125	127	133	719	0.77
06	140	138	168	167	174	835	0.8

Input and output voltage waveforms for without power factor correction technique as shown in below figures 3.7 and 3.8.

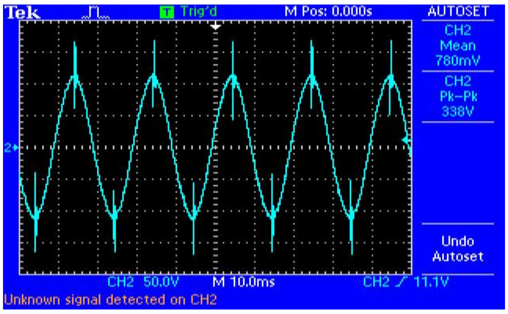


Fig 3.7 Input voltage waveform at 1kg load- For without PFC technique

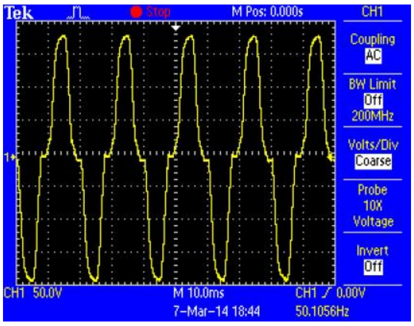


Fig 3.8 Output voltage waveform 1kg load for without PFC technique

Table 3.4 Experimental result for with power factor correction technique

SL.No	Input voltage (volts)	Rectifier output voltage (volts)	Boost converter output voltage (volts)	Output voltage (volts)			Output power (watts)	PF (cosΦ)
				V_a	V_b	V_c		
01	40	42.3	49	25	26	31	115	0.96
02	60	62.5	72.9	43	44	49	230	0.95
03	80	81	94	66	67	72	372	0.92
04	100	102	115	102	97	108	405	0.91
05	120	125	150	124	123	134	677	0.9
06	140	138	181	167	166	174	797	0.89

Input and output voltage waveforms for with power factor correction technique as shown in below figures 3.9 and 3.10.

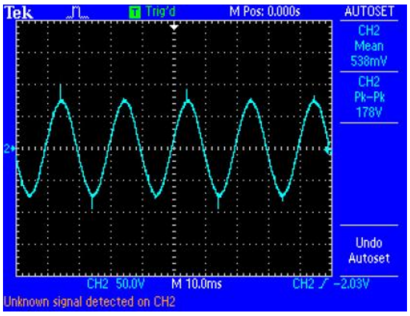


Fig 3.9 Input voltage waveform at 1kg load for with PFC technique

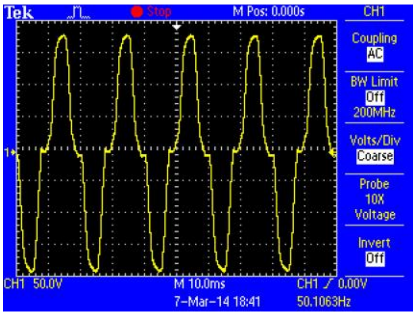


Fig 3.10 Output voltage waveform 1kg load for with PFC technique

The table 3.3 and 3.4 shows experimental results for without PFC and with PFC technique at 1kg load condition. From the table3.3 considering one input voltage i.e.100V. After the rectification that voltage is 104V, output power consumption is 450W with corresponding power factor 0.79. From the table 3.4 considering that same input voltage i.e. 100V, the rectification voltage is changed to 115V after using PFC technique with boost converter, the corresponding power and power factor are changed to 405W and 0.91 respectively. 3.3Experimental result for without power factor correction technique and with power factor correction technique at 2kg load with 1300 rpm speed.

Table 3.5 Experimental result for without power factor correction technique

SL.No	Input voltage (volts)	Rectifier output voltage (volts)	Output voltage (volts)			Output power (watts)	Power factor (cosϕ)
			V_a	V_b	V_c		
01	40	42	27	25	33	144	0.83
02	60	61	42	41	48	295	0.81
03	80	82	69	69	76	456	0.77
04	100	104	92	93	101	550	0.76
05	120	115	125	127	133	749	0.73
06	140	138	168	167	172	874	0.7

Input and output voltage waveforms for without power factor correction technique as shown in below figures 3.11 and 3.12.

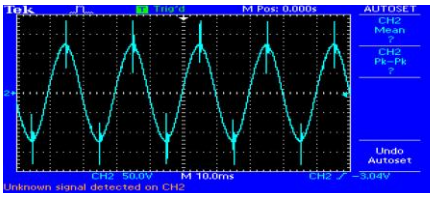


Fig 3.11 Input voltage waveform at 2kg load-for without PFC technique

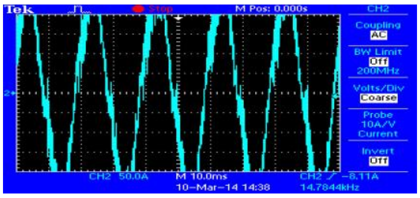


Fig 3.12Output voltage waveform 2kg load-for without PFC technique

Table 3.6 Experimental result for with power factor correction technique

SL.No	Input voltage (volts)	Rectifier output voltage (volts)	Boost converter output voltage (volts)	Output voltage (volts)			Output power (watts)	Power factor (cosϕ)
				V_a	V_b	V_c		
01	40	41	46	24	26	31	126	0.93
02	60	62	74	45	44	49	280	0.92
03	80	82	100	74	67	72	424	0.90
04	100	106	130	113	97	108	515	0.89
05	120	127	151	155	123	134	705	0.88
06	140	137	183	167	168	172	832	0.89

Input and output voltage waveforms for with power factor correction technique as shown in below figures 3.13 and 3.14.

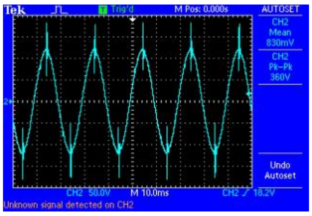


Fig 3.13 Input voltage waveform at 2kg load for with PFC technique

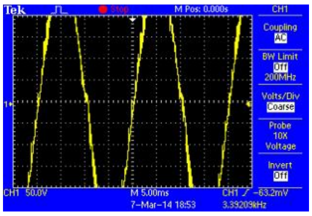


Fig 3.14 Output voltage waveform 2kg load for with PFC technique

The table 3.5 and 3.6 shows experimental results for without PFC and with PFC technique at 2kg load condition. From the table3.5 considering one input voltage i.e.100V. After the rectification that voltage is 104V, output power consumption is 550W with corresponding power factor 0.76. From the table 3.6 considering that same input voltage i.e. 100V, the rectification voltage is changed to 130V after using PFC technique with boost converter, the corresponding power and power factor are changed to 515W and 0.89 respectively.

Input and output voltage waveforms for with power factor correction technique as shown in below figures 3.15 and 3.16.

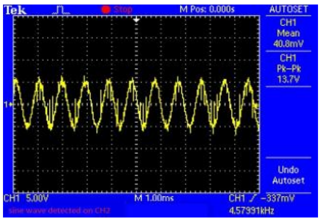
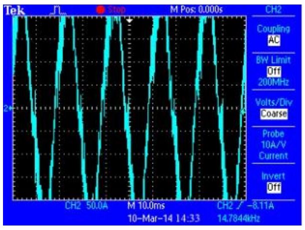


Fig 3.15 Input voltage waveform at 3kg for load-with PFC technique



3.16 Output voltage waveform 3kg load-for with PFC technique

Fig3.Photograph of complete experimental setup

IV. Conclusion

Operating a three phase induction motor using power factor correction technique with single phase supply has been presented. The developed power factor correction circuit hardware setup is tested on a three phase 1.5hp, 415V, and 50Hz induction motor with loading in power electronics laboratory. The induction motor drive is runs at different loads and voltages implementing without power factor correction technique and with power factor correction technique. For different loads and voltages, power, power factor and voltages across all lines are noted and are tabulated in experimental setup and result chapter.

From the experimental setup and results chapter it is clear that total harmonics distortion of the three phase rotor current has decreased hence power factor has increased for all the loads when power factor correction (PFC) technique is used and when compared to without power factor correction (PFC) technique. Overall the performance of the drive is improved by using PFC technique compared to without PFC technique.

The developed system is useful for domestic, commercial applications and remote areas where three phase supply is not available easily.

APPENDIX

The following defines the nomenclature and system parameters used in this paper :

A. Motor parameters and nomenclature :

50Hz, 415V, 1.5hp, 3-phase, 4-pole induction machine.

B. PFC parameter:
UC3854 IC
C. Inverter parameters :
Vin : lnput voltage 230V
C1, C2 : DC bus capacitors 1000µF , 250V each
Q1,Q2: IGBTs **FGA25N120ANTD** 1200V, 25A

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