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Paper Authors

K .SRIKAR, B.LAKSHMANA NAYAK
Vikas College of Engineering & Technology, JNTUK;Vijayawada Rural, Krishna (DT); A.P, India.

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ANALYSIS OF POWER FACTOR CORRECTION USING BOOST CONVERTER FED INDUCTION MOTOR DRIVE

[1]K .SRIKAR, [2]B. LAKSHMANA NAYAK M.TECH., AMIE
[1]M-tech Student Scholar,Department of Electrical & Electronics Engineering,Vikas College of Engineering & Technology, JNTUK;Vijayawada Rural, Krishna (DT); A.P, India.
[2]Head of the Department & Associate Professor,Department of Electrical & Electronics Engineering,Vikas College of Engineering & Technology, JNTUK; Vijayawada Rural, Krishna (DT); A.P, India.

ABSTRACT: This paper researches a design a single phase rectifier with improved power factor by using the boost converter technique. The use of boost converter technique can improve the power factor. By designing the needs of the techniques, the overall Power Factor (PF) would be improved to the expectation. The low power factor is caused by non-linearity of the input current. Boost converter is one of method of re-shaping the input waveform to be same pattern with the sinusoidal input voltage. The connected controls that act as a Power Factor Correction (PFC) circuit. The proposed converters have been designed for induction motor drive achieving an improved power quality operation with low amount of total harmonic distortion (THD) of supply current at AC mains for a wide range of speed control at varying supply voltages.

Key words: Power Factor Correction (PF), AC-DC converter, Boost topology, Total Harmonic Distortion (THD), Induction motor.

I. INTRODUCTION

Traditionally, conversion of single phase to three phase system conversion has been done by various ways of switching processes with the help of power electronics devices [1]. It is somewhat common to have only a single phase power grid in domestic, commercial, manufacturing, and mainly in urban regions; however the variable speed drives may entreaty a three phase power grid. Single-phase to three-phase AC to DC to AC conversion usually employs a full bridge topology, which implicates many power switches, such a converter is represented here as conventional topology [2]. As conversion system includes various stages of conversion processes that defines distortion and generate harmonics on source line and load in system hence the input power factor become poor [3-5]. Now development in technologies causes various power factor improvement techniques are employed to overcome these power quality problems some of which the boost converter topology has been extensively used in various conversion applications [6]. Such that now a days AC to DC power supplies with power-factor correction (PFC) techniques is almost entirely implemented with boost topology, usually boost topology does not provide permissible value of higher power factor. So to overcome this problem, Dual Boost converter technique can be employed to overcome the performance of input characteristic of current and used to improve input power factor and reduces distortion in input current waveform. [7]. In this paper, a single phase to three-phase drive system composed of single-phase rectifiers along with dual boost converter to give boost output to three phase inverter to drive three phase induction motor along with speed control by using V/F method is proposed. The proposed system is perceived to operate where the single-phase utility grid is the unique option available [8-10]. As Compared to the conventional topology, the proposed system permits to reduce distortion in input currents and the total harmonic distortion (THD) of the system to increase fault tolerance of the system.

II. CURRENT SHAPING TECHNIQUE ON AC SIDE

An input-current waveform can be imposed by either active or passive methods. Passive methods have the advantage of simplicity, but the current waveform is generally load dependent. The maximum Power Factor that can be obtained in passive method is in the range 0.7 to 0.8 Active schemes offer possibilities for advanced control, such as current limiting and load-independent wave shape.Active devices provide a variety of ways to shape input current. Each of the basic ideas has several variations, leading to a large number of topologies and control schemes. Despite this variety, the methods seem to fall conveniently into two categories, boost-like topologies and buck–like topologies. One major difference between boost and buck topologies is the form of the energy storage. Boost topologies store energy in a source of constant voltage, such as a large capacitor. The buck-like methods store energy in a current source, such as a large inductor. Another difference is that boost PFC converters is active only if the output voltage is greater than the peak of the line voltage. Due to its simple implementation, the hysteresis technique is the most current control method for active input current wave shaping. The strength of the method lies in the fact it provides the tightest instantaneous current regulation using a simple control circuit. Using this method, the controller remains within a window whose size is a design parameter and fixes the maximum ripple of current.

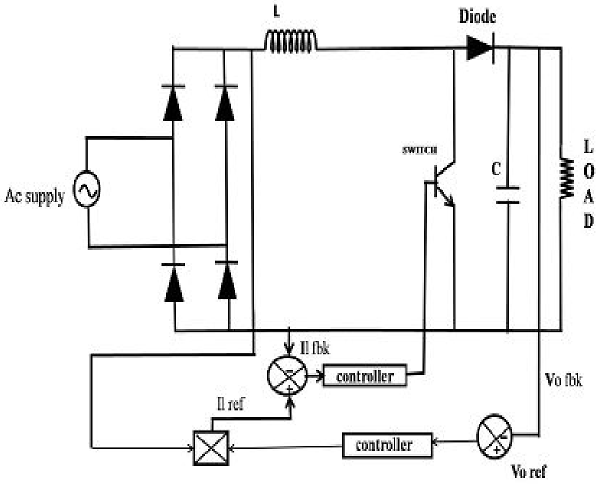

Fig.1. A single-phase front-end diode-rectifier input-current wave shaping circuit controlled by hysteresis technique.

III. DESIGN AND ANALYSIS OF UNCONTROLLED RECTIFIER

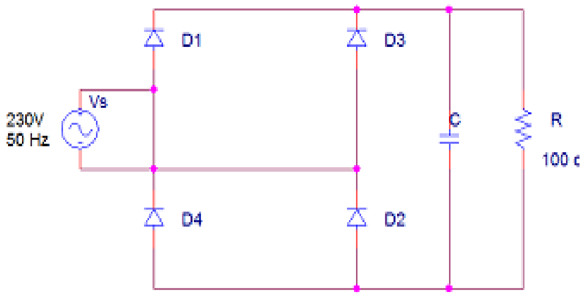

Fig.2. A Single-phase full wave diode bridge rectifier with capacitive filter

Rectification is the process of conversion of alternating input voltage to direct output voltage. Rectifier converts ac power into dc power. In diode–based rectifiers, the output voltage cannot be controlled. Hence the diode bridge rectifiers are known as uncontrolled rectifiers. A Capacitor C directly connected across the load serves to smoothen out the dc output value. The smoothing capacitor converts the full wave rippled output of the rectifier into a smooth DC output voltage. There are two important parameters to consider when choosing a suitable smoothing capacitor and these are its Working Voltage, which must be higher than the no-load output value of the rectifier and its Capacitance Value, which determines the amount of ripple that will appear superimposed on top of the DC voltage.

A. DESIGN OF OUTPUT FILTER CAPACITANCE

Capacitor across the load offers direct short circuit to ac components and dc stored in the form of energy in capacitor. It allows almost constant dc output voltage across the load. The capacitor filter is designed for the supply voltage of 230*√2 and 50Hz

$$C = \frac{1}{4fR}\left[1 + \frac{1}{\sqrt{2}RF}\right] \quad (1)$$

For the above design specification table the output filter capacitor is designed using the equation (1). The values are substituted in the above equation (1) and the capacitance value is obtained as 757µF.The power factor is the ratio of the Real power to the apparent power. In the input side of the diode bridge rectifier the power factor is measured using the equation (2)

$$\mathrm{PF} = \frac{P}{S} \quad (2)$$

P is real power
Q is reactive power
S is apparent power
The apparent power is given us

$$S = \sqrt{P^2 + Q^2} \quad (3)$$

IV DESIGN AND ANALYSIS OF ACTIVE POWER FACTOR CORRECTION CIRCUIT

The boost topology is used in this simulation. The Active Power Factor Correction is used to shape the input current in phase with the input voltage. They will improve the input Power Factor nearer to the unity. A boost converter is supplied with 230V rms, 50H Hz, ac source. The aim is to control the rectifier input current, by controlling the gate pulses applied. The values of the inductor and capacitor are designed using the equation (4) and equation (5) respectively.

A. Design of Boost Inductor

$$L = \frac{V_S K}{f \Delta I} \quad (4)$$

B. Design of Boost Capacitor

$$C = \frac{I_0 K}{f \Delta I} \quad (5)$$

In order to shape input current a sinusoidal ref current is generated with its amplitude proportional to (2 P_O/V_m). And the input current wave form is switched between ±0.1 of the reference current by hysteresis current control technique. The I_{ref} is generated using the equation (10). The output voltage v_O is compared with the V_{ref} and the output of this is given to the voltage controller. The generated Iref is multiplied with the output of the voltage controller. This product output is compared with the inductor current I_L. The output of this comparator is given to the current controller.

The pulse for the switch is generated in this manner. The outer voltage loop should be slow whereas inner current loop should be fast to get an effective unity Power Factor action.

$$V_{in} = V_m sin\omega t \tag{6}$$

$$I_{rms} = \frac{P_0}{V_{rms}} \tag{7}$$

$$I_{rms} = \frac{P_o}{\frac{V_m}{\sqrt{2}}} = \frac{\sqrt{2}\,P_o}{V_m} \tag{8}$$

$$I_m = \sqrt{2}\,I_{rms} = \sqrt{2} * \frac{\sqrt{2}\,P_o}{V_m} = \frac{2\,P_o}{V_m} \tag{9}$$

$$I_{ref} = I_m\, sin\omega t = \left(\frac{2P_O}{V_m}\right)\left(\frac{V_{in}}{V_m}\right) \tag{10}$$

V. INDUCTION MOTOR

An asynchronous motor type of an induction motor is an AC electric motor in which the electric current in the rotor needed to produce torque is obtained by electromagnetic induction from the magnetic field of the stator winding. An induction motor can therefore be made without electrical connections to the rotor as are found in universal, DC and synchronous motors. An asynchronous motor's rotor can be either wound type or squirrel-cage type.Three-phase squirrel-cage asynchronous motors are widely used in industrial drives because they are rugged, reliable and economical. Single-phase induction motors are used extensively for smaller loads, such as household appliances like fans. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives (VFDs) in variable-speed service. VFDs offer especially important energy savings opportunities for existing and prospective induction motors in variable-torque centrifugal fan, pump and compressor load applications. Squirrel cage induction motors are very widely used in both fixed-speed and variable-frequency drive (VFD) applications. Variable voltage and variable frequency drives are also used in variable-speed service.In both induction and synchronous motors, the AC power supplied to the motor's stator creates a magnetic field that rotates in time with the AC oscillations. Whereas a synchronous motor's rotor turns at the same rate as the stator field, an induction motor's rotor rotates at a slower speed than the stator field. The induction motor stator's magnetic field is therefore changing or rotating relative to the rotor. This induces an opposing current in the induction motor's rotor, in effect the motor's secondary winding, when the latter is short-circuited or closed through external impedance. The rotating magnetic flux induces currents in the windings of the rotor; in a manner similar to currents induced in a transformer's secondary winding(s). The currents in the rotor windings in turn create magnetic fields in the rotor that react against the stator field. Due to Lenz's Law, the direction of the magnetic field created will be such as to oppose the change in current through the rotor windings. The cause of induced current in the rotor windings is the rotating stator magnetic field, so to oppose the change in rotor-winding currents the rotor will start to rotate in the direction of the rotating stator magnetic field. The rotor accelerates until the magnitude of induced rotor current and torque balances the applied load. Since rotation at synchronous speed would result in no induced rotor current, an induction motor always operates slower than synchronous speed. The difference, or "slip," between actual and synchronous speed varies from about 0.5 to 5.0% for standard Design B torque curve induction motors. The induction machine's essential character is that it is created solely by induction instead of being separately excited as in synchronous or DC machines or being self-magnetized as in permanent magnet motors. For rotor currents to be induced the speed of the physical rotor must be lower than that of the stator's rotating magnetic field (n_s); otherwise the magnetic field would not be moving relative to the rotor conductors and no currents would be induced. As the speed of the rotor drops below synchronous speed, the rotation rate of the magnetic field in the rotor increases, inducing more current in the windings and creating more torque. The ratio between the rotation rate of the magnetic field induced in the rotor and the rotation rate of the stator's rotating field is called slip. Under load, the speed drops and the slip increases enough to create sufficient torque to turn the load. For this reason, induction motors are sometimes referred to as asynchronous motors. An induction motor can be used as an induction generator, or it can be unrolled to form a linear induction motor which can directly generate linear motion.

Synchronous Speed:

The rotational speed of the rotating magnetic field is called as synchronous speed.

$$Ns = \frac{120 \text{ x } f}{P} \quad \text{(RPM)} \qquad (11)$$

Where, f = frequency of the supply
P = number of poles

Slip:

Rotor tries to catch up the synchronous speed of the stator field, and hence it rotates. But in practice, rotor never succeeds in catching up. If rotor catches up the stator speed, there won’t be any relative speed between the stator flux and the rotor, hence no induced rotor current and no torque production to maintain the rotation. However, this won't stop the motor, the rotor will slow down due to lost of torque, and the torque will again be exerted due to relative speed. That is why the rotor rotates at speed which is always less the synchronous speed.

The difference between the synchronous speed (Ns) and actual speed (N) of the rotor is called as slip.

$$\% \text{ slip} \quad s = \frac{Ns - N}{Ns} \text{ x } 100 \qquad (12)$$

VI. MATLAB/SIMULINK RESULTS

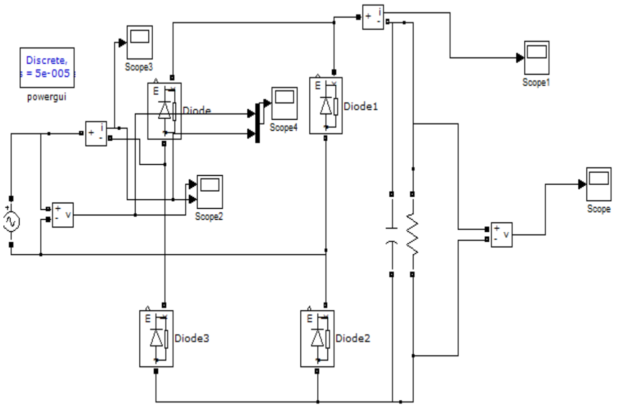

Fig.3.MATLAB/SIMULINK circuit of Full bridge diode rectifier

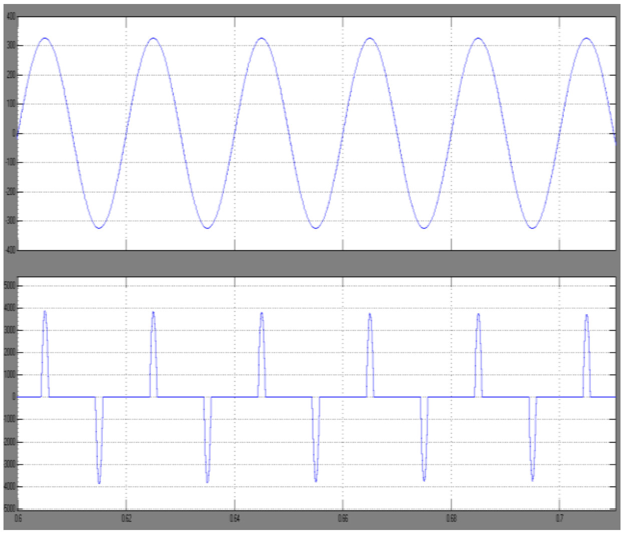

Fig.4 Input voltage and Current waveform of the full bridge diode rectifier

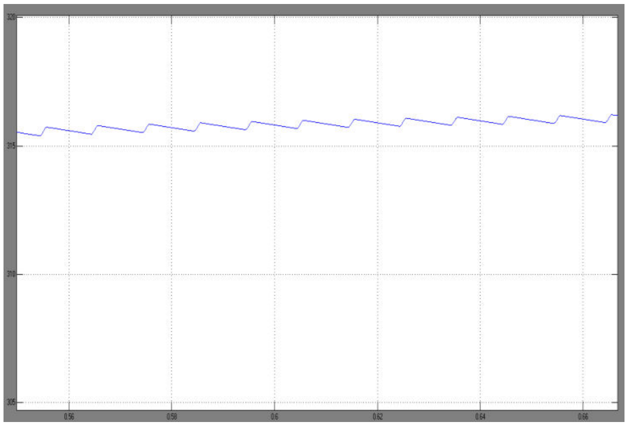

Fig.5 Output voltage waveform of the full bridge diode rectifier

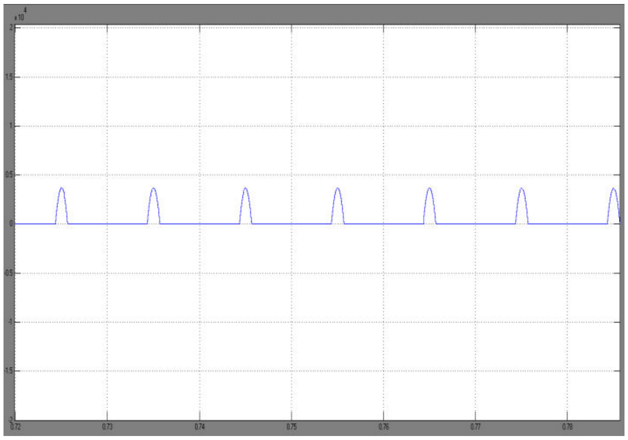

Fig.6 Output Current waveform of the full bridge diode rectifier

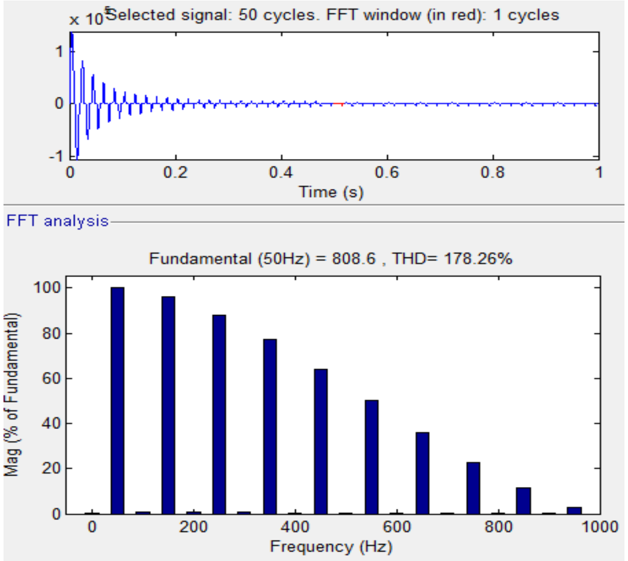

Fig.7 FFT and THD analysis of input current

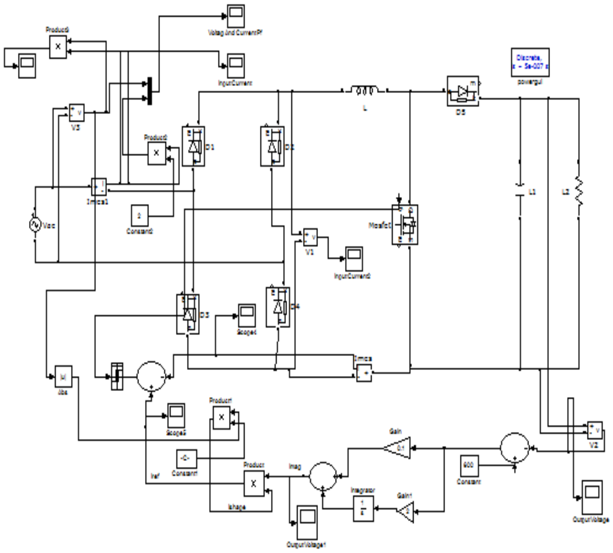

Fig.8 MATLAB/SIMULINK circuit of Full bridge diode rectifier with closed loop controller

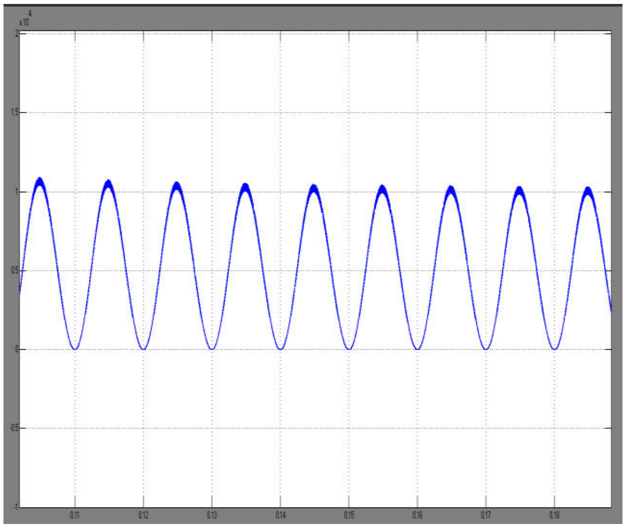

Fig.9 Input voltage waveform

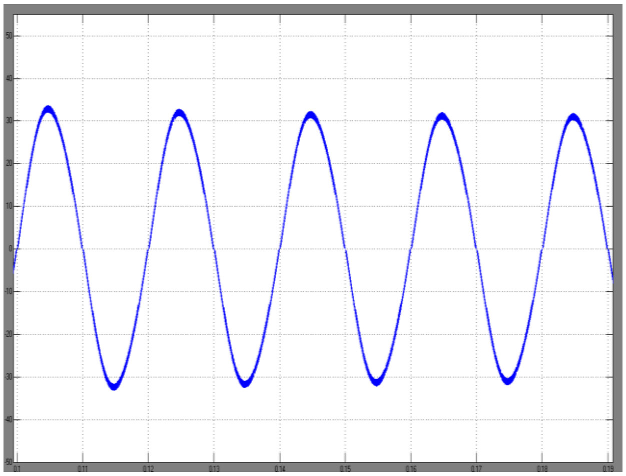

Fig.10 Input current waveform

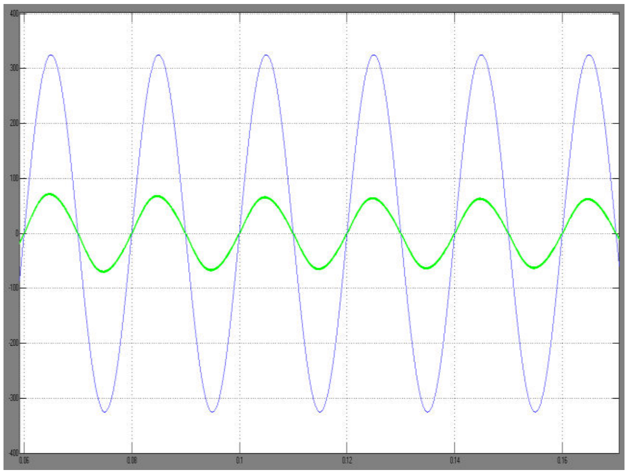

Fig.11 Power factor angle between voltage and current

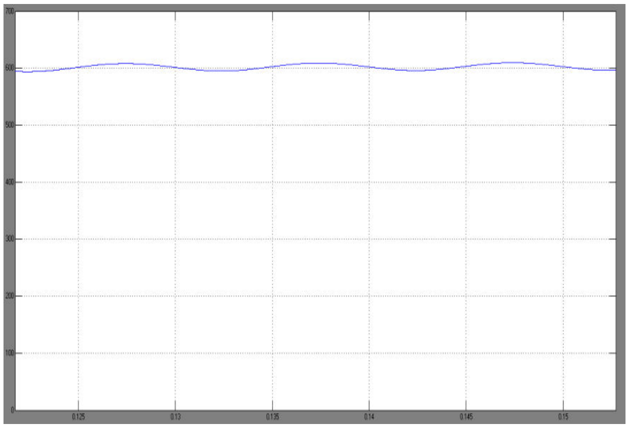

Fig.12 Output voltage

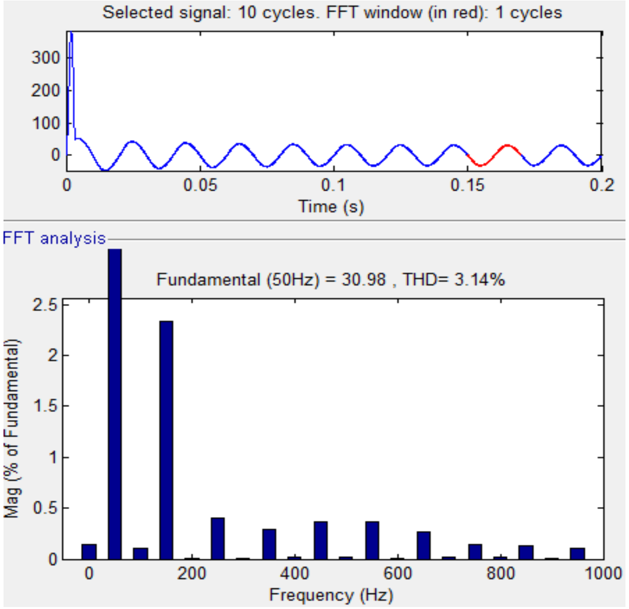

Fig.13 Source current THD

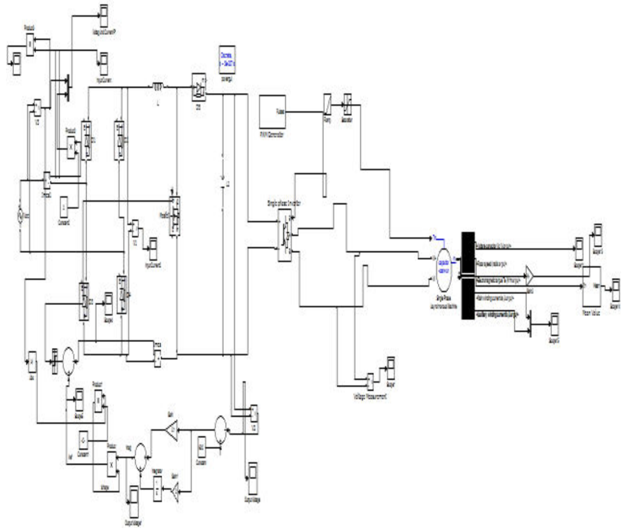

Fig.14 MATLAB/SIMULINK circuit of Full bridge diode rectifier with closed loop controller fed induction motor drive

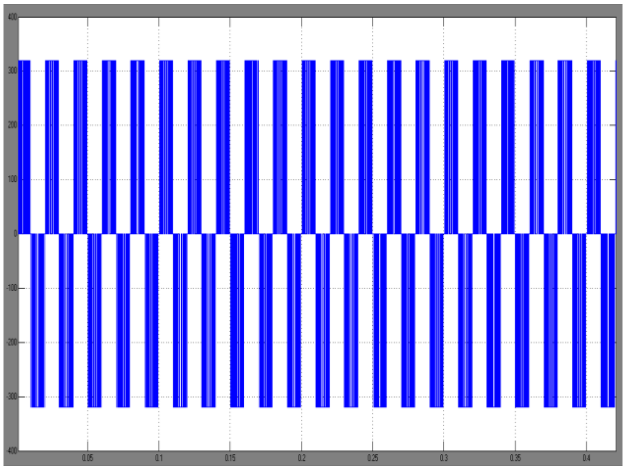

Fig.15 Inverter output voltage

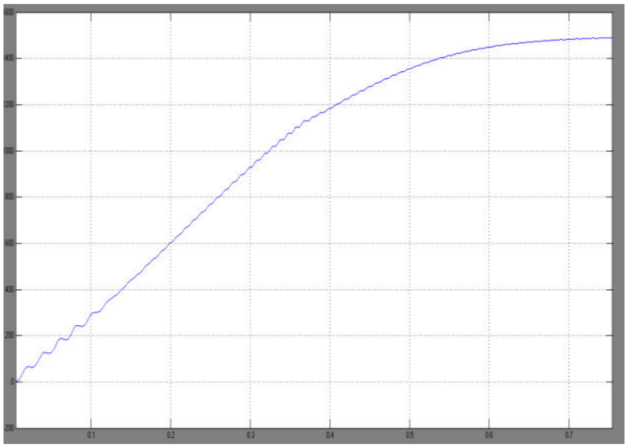

Fig.16 Induction motor speed waveform

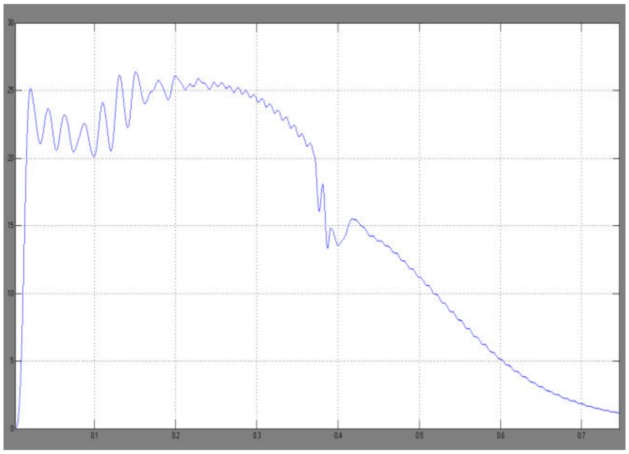

Fig.17 Induction motor torque waveform

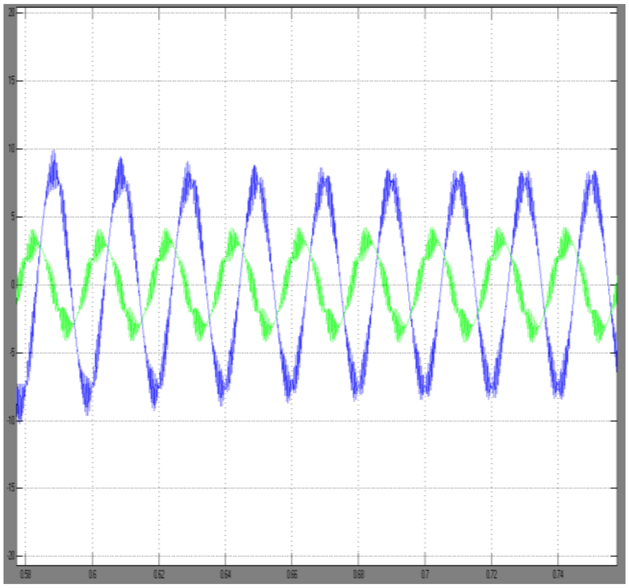

Fig.18 main and auxiliary winding currents

VII. CONCLUSION

The Power Factor Correction with boost converter is simulated with MATLAB Simulink. In this paper conventional converter, Boost converter using border line Control is discussed. It is noticed that the power Factor is better for Boost Converter Circuit. The operation and the working of the boost converter fed induction motor drive has been validated and the motor is completely utilized and also we have a good range of speed control using simulation results verified.

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