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Power Factor Correction of Three Phase I.M Drive using PWM Boost Inverter

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Abstract: Induction motor are used approximately 85% of the industrial applications, due to their high reliability. When it goes to high speed the induction motor will be the better choice compared to the PMSM because we can easily control the field/flux building current. They are used vastly in HVAC, industrial, manufacturing plants, pumps in sewage and irrigation. They are also used in ceiling fan, mixer, pump, compressor, hydraulic power pack, drilling machine etc. They work mainly on the principle of induction. The boost inverters are applied in DC grid. They can also be inculcated in circuits which supply to both AC and DC loads. The boost inverters convert the low dc input signal into high ac output signal. The boost inverters are also applied in automobiles, buses, forklifts, motorcycles and bicycles, airplanes, boats, sub-marines etc. The boost-inverter topology is used as a building block for a single-phase grid-connected system offering low cost and compactness.

Keywords: HVAC, PMSM, VFDs, DC Grid.

I. INTRODUCTION

Induction motor is an AC electronic 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 motors rotor can be either wound type or squirrel-cage type. Three phase induction motors are widely used in industrial drives because they are rugged, reliable and economical. Although traditionally used in fixed-speed service, induction motors are increasingly being used with variable-frequency drives 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. In electrical engineering, the power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number in the closed interval of -1 to +1. A power factor of less than one means that the voltage and current waveforms are not in phase, reducing the instantaneous product of the two waveforms. Boost inverter is a system which converts a low level input signal into a high level output signal. Inverter is relevant because many equipments work on AC voltage and they are not able to work on DC voltage. They even include many domestic appliances like mixer, refrigerator etc.

II. POWER FACTOR

The power factor of an AC electrical power system is defined as the ratio of the real power flowing to the load to the apparent power in the circuit, and is a dimensionless number in the closed interval of -1 to +1. A power factor of less than one means that the voltage and current waveforms are not in phase, reducing the instantaneous product of the two waveforms. Real power is the circuit for performing work in a particular time. Apparent power is the product of the current and voltage of the circuit. Due to energy stored in the load and returned to the source, or due to a non-linear load that distorts the wave shape of the current drawn from the source, which is normally considered the generator. In an electric power system, a load with a low power factor draws more current than a load with a high power factor for the same amount of useful power transferred.

III. POWER FACTOR CORRECTION

Power factor is decreased mainly due to the presence of the Total Harmonic Distortion in an AC to DC converter. But when we connect an Induction Motor, the readings are taken of the speed and the torque as shown in Fig.1. When they do not reach the required speed or torque, values are added or subtracted (adjusted) to the dc rectifiers. These values are of voltage and frequency. The voltage and frequency producing a good speed and less torque as the time progress will be taken into consideration as shown in Fig.2.

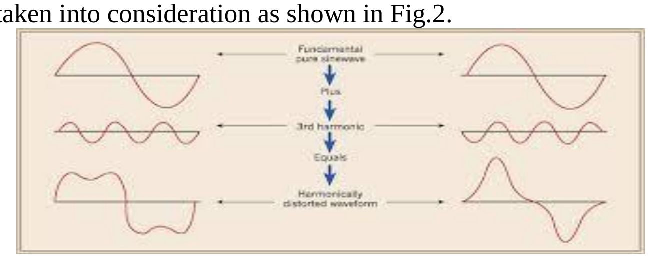


Fig.1. Total Harmonic Distortion.

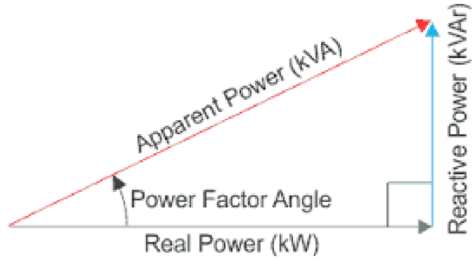


Fig.2. Power triangle.

IV. RECTIFIER

Rectifier is the device which converts an input ac signal into an output dc signal. The ac signal is passed to the rectifier. A rectifier consists of four thyristors, a capacitor, an inductor and a resistor. During the positive half cycle of the signal, T1 and T4 are on and T2 and T3 are off. So a signal of positive half cycle appears on the load resistor. During the negative half cycle, the thyristors T2 and T3 will be on and T1 and T4 will be off. So this will also lead to the positive signal on resistor load. Now the output will be a pulsating dc. To avoid this, we put a capacitor in parallel to the load. So whenever there is a lowering signal at output, the capacitor produces the sufficient voltage to level the dc output. This voltage is already stored by the capacitor during the ac supply as shown in Fig.3.

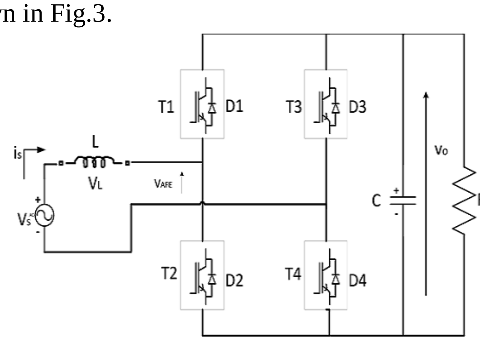


Fig.3.PWM Rectifier.

V. INVERTER

Inverter is an electronic device or circuitry that changes direct current into alternating current. The inverter does not produce any power, the power is provided by the DC source. A power inverter can be entirely electronic or may be a combination of mechanical effects or electronic circuitry. Static inverters do not use moving parts in the conversion process. An inverter can produce a square wave, modified sine wave, pulse width modulated wave or sine wave depending on circuit design as shown in Fig.4.

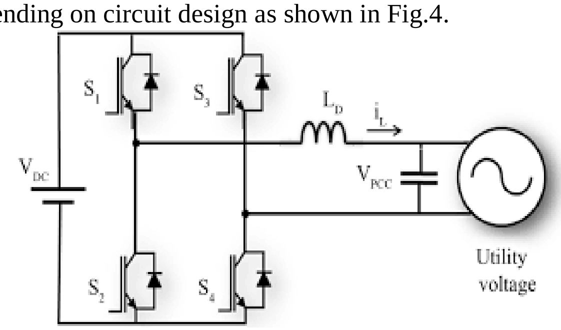


Fig.4. Inverter.

VI. INDUCTION MOTOR

An induction motor is an example of asynchronous AC machine, which consists of a stator and a rotor. This motor is widely used because of its strong features and reasonable cost. A sinusoidal voltage is applied to the stator, in the induction motor, which results in an induced electromagnetic field. A current in the rotor is induced due to this field, which creates another field that tries to align with the stator field, causing the rotor to spin. A slip is created between these fields, when a load is applied to the motor. Compared to synchronous speed, the rotor speed decreases at higher slip values. The frequency of the stator voltage controls the synchronous speed. The frequency of the voltage also controls the synchronous speed. The frequency of the voltage is applied to the stator through power electronic devices, which allows the control of the speed of the motor. The research is using techniques, which implement a constant voltage to frequency ratio. Finally, the torque begins to fall when the motor reaches the synchronous speed. Thus, induction motor synchronous speed is defined by following equation,

$$Ns = 120f/P \tag{1}$$

Where f is the frequency of AC supply, N is the speed of rotor; P is the number of poles per phase of the motor. By varying the frequency of control circuit through AC supply, the rotor speed will change as shown in Fig.5.

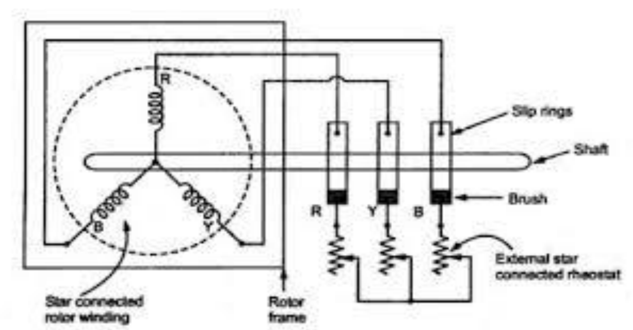


Fig.5. Induction motor.

VII. CONTROL STRATEGY OF SINGLE PHASE PWM RECTIFIER

The input AC voltage is applied to the controlled rectifier and the output must be DC voltage. The basic operation of voltage source rectifier consist of keeping the dc link voltage desired reference value Voref. The output of DC link voltage is measured and compared with the generate reference voltage. This voltage error signal generated by comparison is used to switch ON and OFF the values of the voltage source rectifier. The control includes a voltage controller, typically a proportional integrative controller which controls the amount of power required to maintain the DC link voltage constant. The voltage controller is given the amplitude of the source current. For this reason, the voltage controller output is multiplied by a sinusoidal signal with the same phase and frequency than Vs, in order to obtain the input current reference as shown in Fig.6. The fast current controller controls the input current, so the high input power factor is achieved. This controller is used for hysteresis with a PWM modulator.

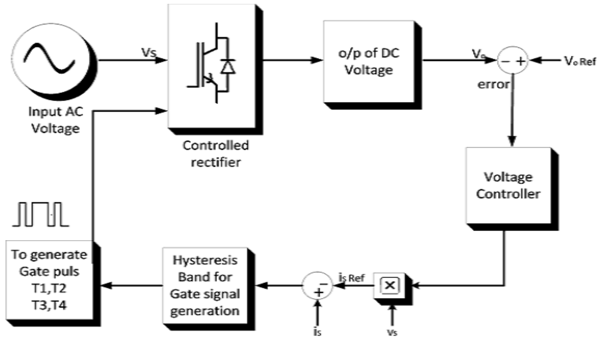


Fig.6. Block diagram of single phase PWM rectifier.

VIII. PULSE WIDTH MODULATION

It is a modulation technique used to encode a message into a pulsating signal. Its main use is to allow the control of power supply to the electrical devices. The average value of voltage fed to the load is controlled by turning the switch between supply and load on and off at a fast rate. The longer the switch is on compared to the off period, the larger the power supplied to the load. The PWM switching frequency has to be much higher than that would affect the load, which is to say that the resultant waveform perceived by the load must be as smooth as possible. The frequency at which the power supply must switch can vary greatly depending on load and application as shown in Fig.7. Pulse Width Modulation play a very important role in saving the power in a system. They also help in changing the reactive power into active power thus reducing the power factor to a greater extend.

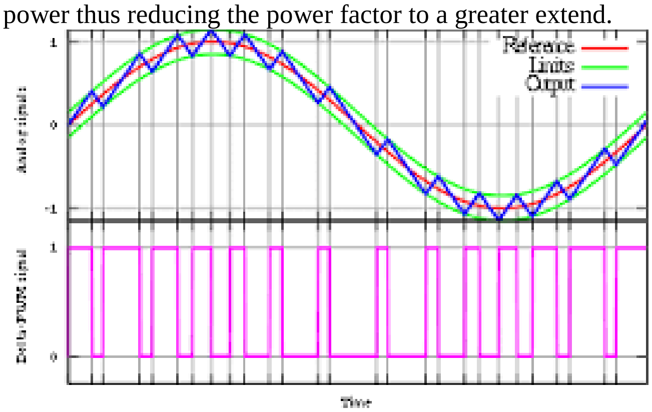


Fig.7. Pulse Width Modulation.

IX. CONTROL STRATEGY OF INDUCTION MOTOR

A. Open Loop

In this type of control, the desired value of speed and torque are set. When the original value of the speed and torque do not reach the desired value, there is some decrease in power factor due to the presence of Total Harmonic Distortion, Eddy current etc. To decrease the closeness of speed and torque to the desired value, we need to provide a voltage and frequency which uplifts the power factor to maximum. So we test different frequency and voltage. From the output values of different speed and torque we get the most suitable input voltage and frequency. Then we apply them as inputs.

B. Closed Loop

Power electronics interface such as three phase SPWM interface using constant voltage loop volts/hertz control scheme is used to control the motor. According to the desired output speed, the amplitude and frequency of the reference (sinusoidal) signals will change. In order to maintain constant magnetic flux in the motor, the ratio of the voltage amplitude to voltage frequency will be kept constant. Hence a closed loop proportional integral controller is implemented to regulate the motor speed to the desired set point. The closed loop speed control is characterized by the measurement of the actual motor speed, which is compared to the reference speed while the error signal is generated. The magnitude and polarity of the error signal correspond to the difference between the actual and required speed. The PI controller generates the corrected motor stator frequency to compensate for the error, based on the speed error.

IX. MATLAB/SIMULATION RESULT

Simulation results of this paper is as shown in bellow Figs.8. to 14.

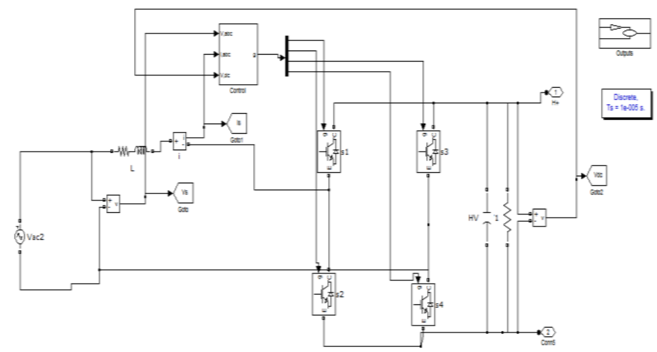
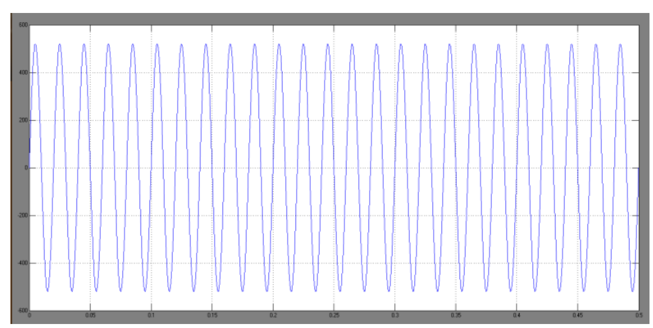
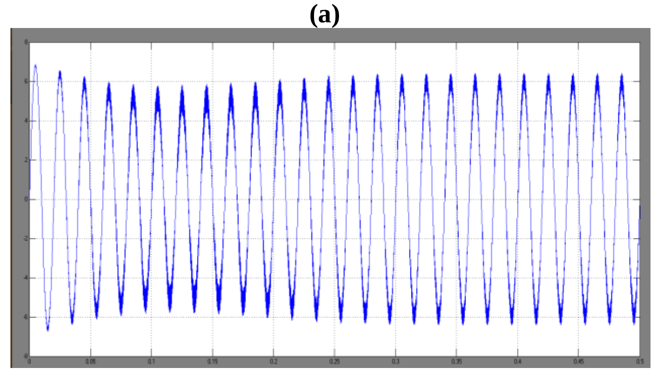


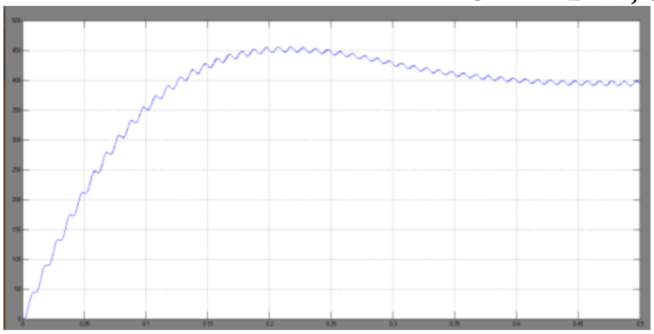
Fig.8. Matlab/simulation circuit of Single phase Rectifier.



(a)



(b)



(c)

Fig.9. Simulation result of single phase PWM rectifier. (a) Result of source voltage and source current, (b) Result of source current, (c) Result of DC link voltage.

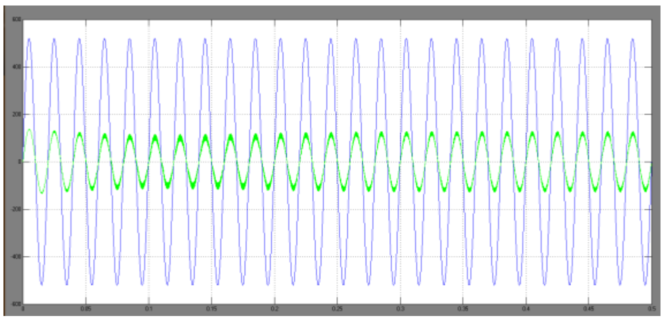


Fig.10. Simulation waveform of power factor.

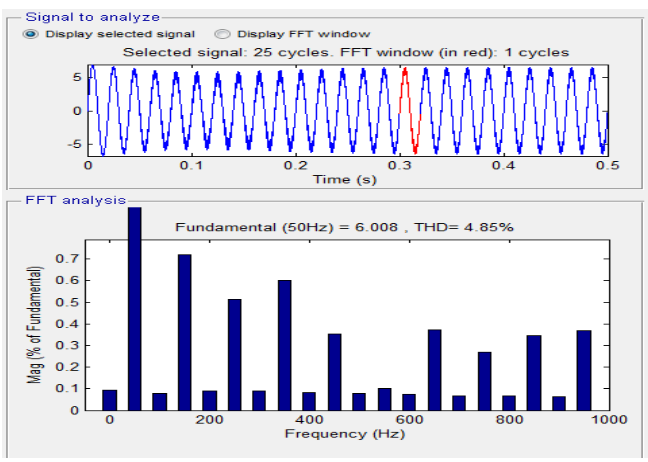


Fig.11. Input current THD result.

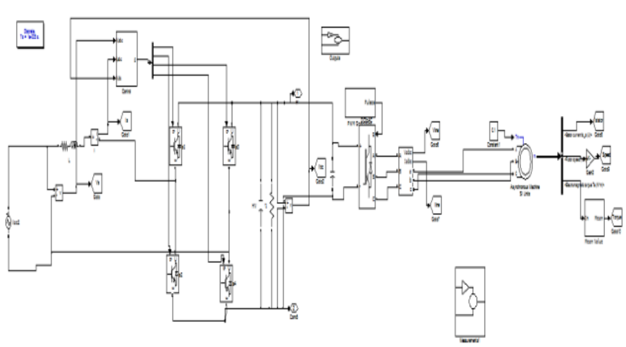


Fig.12.Matlab/Simulation circuit for single phase inverter.

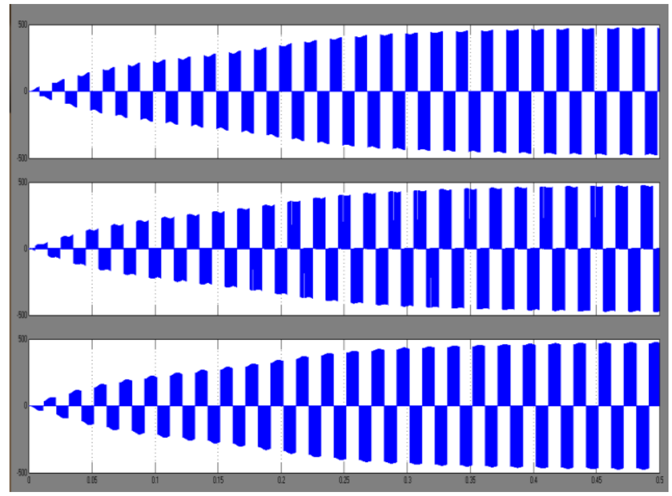


Fig.13. Simulation waveform of line voltage.

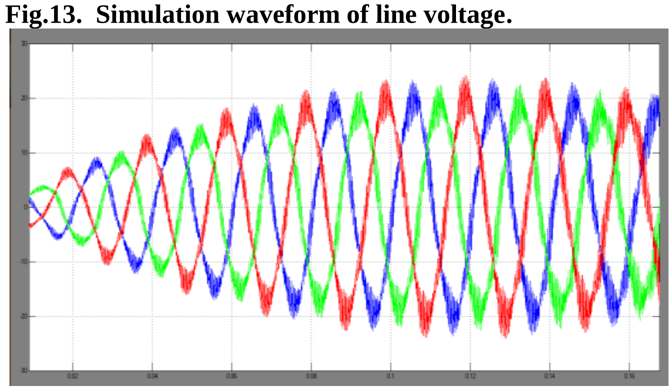


Fig.14. Simulation waveform of line current.

X. CONCLUSION

The study of the power factor is done by connecting an induction motor at the load terminal. The power factor is corrected with the help of the open loop system. From the study of power factor, error signals are analyzed. The apt input voltage and frequency are taken for the apt speed and torque output. The THD and the eddy current are also studied from the output.

XI. REFERENCES

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