# Performance Analysis of Three-Phase Asynchronous Motor with AC Direct and VFD

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*Abstract—* **This paper includes the performance analysis of three phase induction motor with three-phase AC direct and variable frequency drives (VFD). The comparison has been concluded with respect to various parameters. MATLAB-SIMULINK$^{TM}$ is used for the analysis.**

*Keywords— Pulse-width modulated inverter, diode rectifier, three-phase induction motor.*

## I. INTRODUCTION

VFD is variable frequency drive. VFD used to control the speed of electric induction motor. Induction motors are fixed speed motors which are used in most industries because of its reduced cost, reliability and rugged nature. The speed of the induction motor can be changed by various methods such as poles changing, voltage changing, connecting the resistance in rotor circuit etc., but the most efficient method is changing the supply frequency and voltage to the motor. Speed is directly proportional to the frequency of supply. The variable frequency drive (VFD) varies the frequency and hence varies the speed or torque of the induction motor as per the requirements of the load. As VFD provides the power efficient operation, smooth speed and torque control but also leads the harmonics in the system. Harmonics are generated due to use of power electronic switching devices. These harmonics affect the performance of the induction motor. This paper describes the effect of harmonics on motor performance and also how to improve the performance of induction motor by using appropriate LC filter with the help of MATLAB/Simulink. This paper has detail study of motor performance with different cases those showing performance of induction motor. First, we study the parameters when three phase induction motor is directly supplied by three phase AC supply. Then these parameters are compared with the parameters those are getting when same three phase induction motor is supplied by VFD without a filter. Then the performance is improved with the injection of LC passive filters in the system.

## II. PROCEDURE FOR FREQUENCY CONTROLLED INDUCTION MOTOR DRIVE

### A. Variable Frequency AC Motor Drive

The traditional variable-frequency drive (known as a volts-per-hertz (V/Hz) changes the motor's frequency and voltage using solid-state control units.
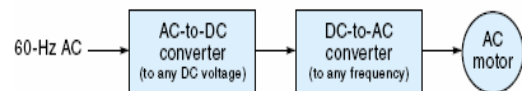


### B. Transistor Based Variable-Frequency Induction Motor Drives

The modern strategy for controlling the AC output of such a power electronic converters is the technique known as Pulse-Width Modulation (PWM), which varies the duty cycle of the converter switches at a high switching frequency to achieve a target average low frequency output voltage or current. In principle, all modulation schemes aim to create trains of switched pulses which have the same fundamental volt–second average as a target reference waveform at any instant. The major difficulty with these trains of switched pulses is that they also contain unwanted harmonic components which should be minimized.

Three main techniques for PWM exist. These alternatives are:

1. Switching at the intersection of a target reference waveform and a high frequency triangular carrier (Double Edged Naturally Sampled Sine-Triangle PWM).
2. Switching at the intersection between a regularly sampled reference waveform and a high frequency triangular carrier (Double Edged Regular Sampled Sine-Triangle PWM)).

### c. Variable frequency control of induction motor

This method is used to control the speed of an induction motor. The synchronous speed and therefore, the speed of the motor can be controlled by varying the supply frequency. The synchronous speed of an induction motor is given by the relation shown below.

Synchronous speed,

$$\text{Slip } S = \frac{N_s - N_r}{N_s}$$

$$\text{or, Slip } S = \frac{\omega_e - \omega_r}{\omega_e} = \frac{\omega_{sl}}{\omega_e}$$

or, rotor speed $N_r = N_s (1-s)$

Synchronous speed is given by $N_s = \dfrac{120 f}{p}$

## III  THREE PHASE INDUCTION MOTOR

Three phase induction motor is widely used in any kind of industry like automobile, cement, fertilizer, chemical, Yarn production etc. because of its simple and rugged construction. A three phase induction  motor is singly excited machine. Induction motor works on faraday law of electromagnetic induction. In this paper behaviour of an induction motor is studied when supplied with or without VFD by using MATLAB/Simulink.
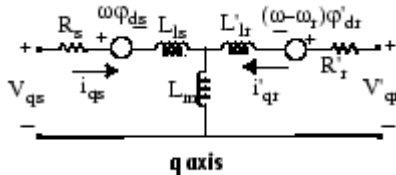


Fig. 1 Circuit Diagram of Induction Machine

$$V_{qs} = R_s i_{qs} + \frac{d}{dt}\varphi_{qs} + \omega\varphi_{ds}$$

$$V_{ds} = R_s i_{ds} + \frac{d}{dt}\varphi_{ds} - \omega\varphi_{qs}$$

$$V'_{qr} = R'_r i'_{qr} + \frac{d}{dt}\varphi'_{qr} + (\omega - \omega_r)\varphi'_{dr}$$

$$V'_{dr} = R'_r i'_{dr} + \frac{d}{dt}\varphi'_{dr} - (\omega - \omega_r)\varphi'_{qr}$$

$$T_e = 1.5\,p(\varphi_{ds}i_{qs} - \varphi_{qs}i_{ds})$$

## IV  AC-DC-AC CONVERTER

This  converter  is  basically a combination of  Bridge Rectifier, a LC Filter and a DC-AC PWM IGBT Inverter.  A 60 Hz, voltage source feeds a 50 Hz, 50 kW load through an AC-DC-AC converter. The 600V, 60 Hz voltage obtained at the secondary of the Wye/Delta transformer is first rectified by a six pulse diode bridge. The filtered DC voltage  is applied to an IGBT two-level inverter generating 50 Hz. The Pulse Width Modulation (PWM) in the IGBT Inverter  at a 2 kHz carrier frequency. sample time of 4 us is Descritized in the circuit.
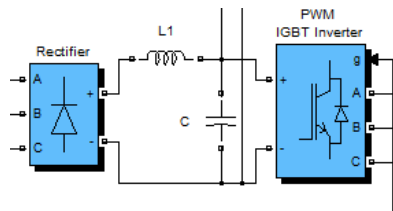


Fig. 2 AC-DC-AC Converter

## V  THREE PHASE RECTIFIER

Full-wave bridge rectifiers are used, employing either silicon junction diodes or thyristors. Because of the arduous operating conditions in a power station and the need for maximum reliability and life.
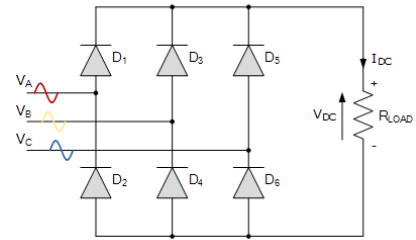


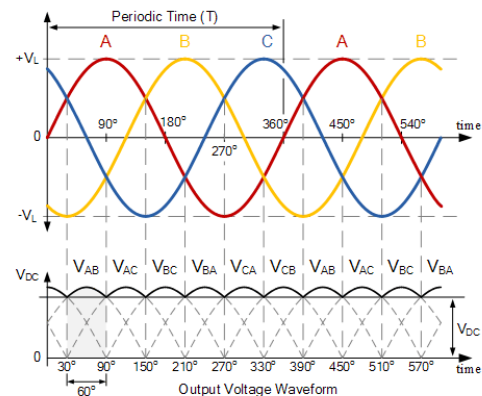Fig. 3 Three Phase Full Wave Rectifier with R Load



Fig. 4 Output voltage waveform of Three phase Rectifier

## VI  PWM IGBT INVERTER

The dc to ac converters more commonly known as inverters, depending on the type of the supply source and the related topology of the power circuit, are classified as voltage source inverters (VSIs) and current source inverters (CSIs).
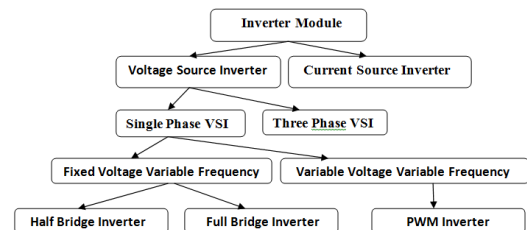


Fig. 5 Classification of Three Phase Inverter

Power Inverters are the Basic Electronic Circuits which is used  to convert the DC to AC. The Inverter input may be from rectified AC input or DC source. The categories with which we can giving switching to the inverter is square wave and pulse width modulated technique.
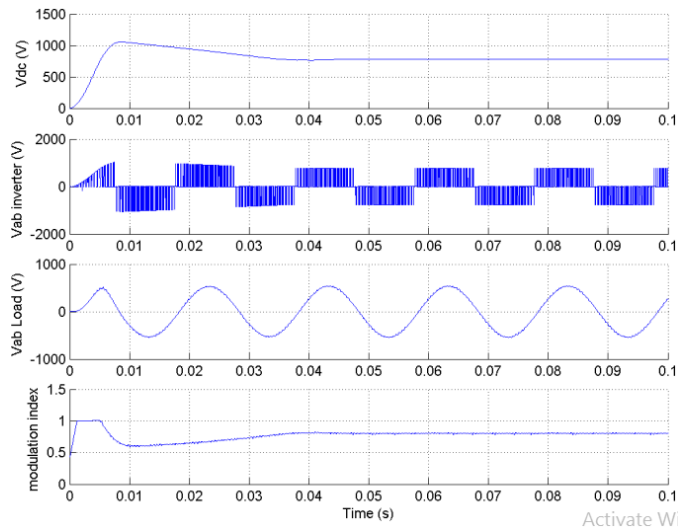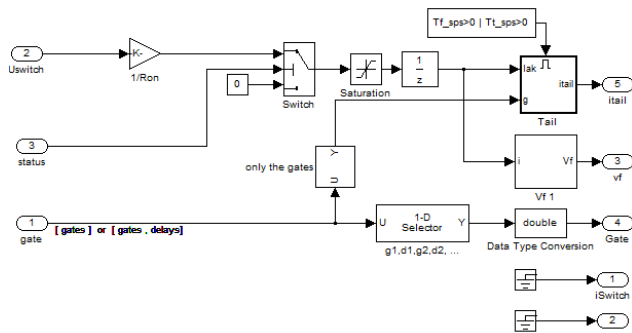
Fig. 6 Output waveforms of Three Phase Inverter



Fig. 7 Discrete IGBT

The main Advantages of PWM converter is the value of the load, the PWM inverter corrects the output voltage by changing the width of the switching frequency of the oscillators. The main drawback of this inverter is the harmonic voltages of fifth, seventh and other non- triplen odd multiple fundamental frequency distort the output voltage.
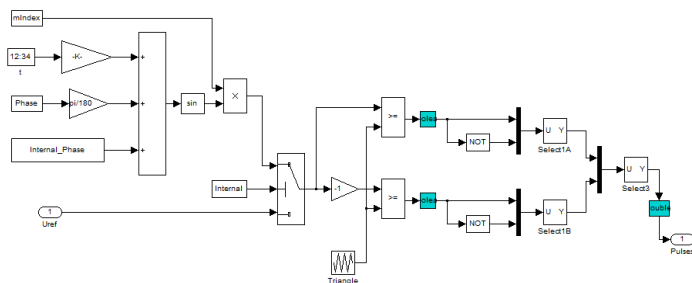


Fig. 8 Discrete PWM Generator

The PWM Generator block generates pulses for carrier-based pulse width modulation (PWM) converters using two-level topology. The block can be used to fire the forced-commutated devices (FETs, GTOs, or IGBTs) of single-phase, two-phase, three-phase, two-level bridges, or a combination of two three-phase bridges.

## VII   LC FILTER

A PWM sequence of pulses contains a useful base frequency and a set of high-frequency harmonics which are not required for common control purposes and all together produce electrical noise. Electrical noise is always undesirable for the electromagnetic compatibility reasons. Moreover, some of the high-frequency harmonics of the PWM are harmful for the electrical machines, basically because of two phenomena: reflections in a long cable and the rather low high-frequency impedance of the electrical machine via its phases through the bearings to the ground.
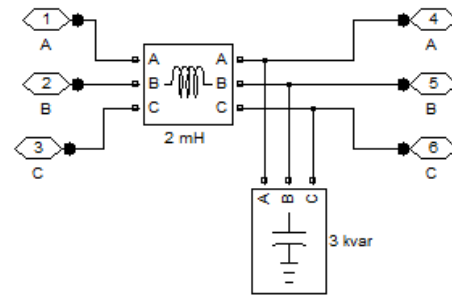


Fig. 9 LC Passive Filter

## VIII   SIMULATION AND RESULTS

In this Simulation circuit model Three phase Induction motor fed by VFD system. Variable frequency Drive system made up of PWM Inverter. A 50 Hz, voltage source feeds a 5HP Induction motor  through an AC-DC-AC converter. The 600V, 50 Hz voltage obtained at secondary of the Wye/Delta transformer is first rectified by a six pulse diode bridge. The filtered DC voltage is applied to an IGBT two-level inverter generating 50 Hz. The IGBT inverter uses Pulse Width Modulation (PWM) at a 2 kHz carrier frequency. The circuit is discretized at a sample time of 2 us.
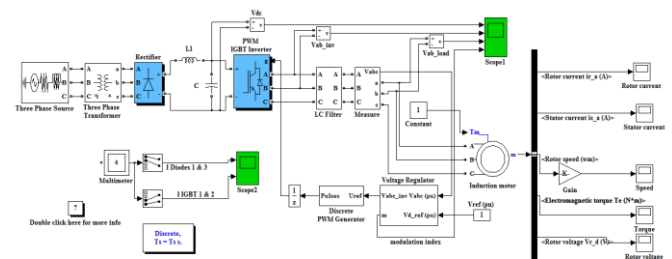


Fig. 10   Simulation circuit of three phase induction motor when supplied by VFD with filter
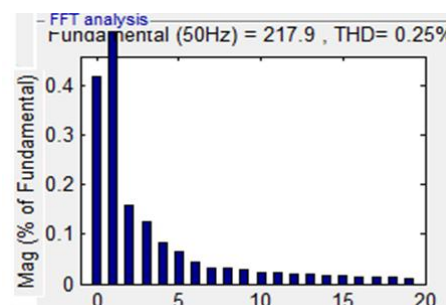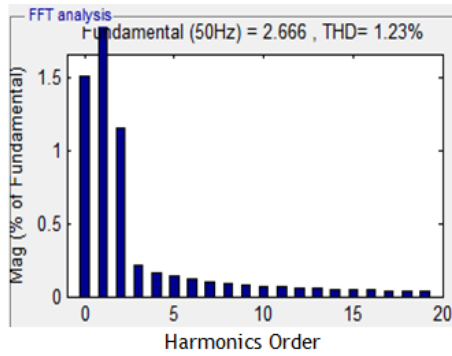


Fig. 11   THD in Voltage Waveform

Fig. 12  THD in current when induction motor
is supplied by VFD with filter

## IX  CONCLUSION

Induction motor works very efficiently when we operate it with Direct three phase AC voltage source. But the thing is, we need to control the speed of IM. In that case VFD is used to control the speed. But VFD made up of Power Electronics switching devices so it injects peaky rotor current, Oscillations in Torque which results additional heating, power losses that affects power stability of IM. To improve the rotor current waveform, an appropriate LC filter is connected after the VFD Converter. After LC Filter Rotor current of IM improves. Torque oscillations are damped and VFD Converter output waveform becomes more sinusoidal.

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