Control & Measuring Method for Three Phase Induction Motor with Improved Efficiency

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Abstract— Nowadays, three-phase induction motors are widely used on industrial and other types of processes. Therefore, accurate knowledge of an induction motor performance is very essential to have an idea of its operation conditions. This study is a sequel of a previous one, where Direct and Soft starting methods of three-phase motors has been simulated and compared. As in the previous study, the theory behind this one is based on representing the real motor by a set of equations and values in MATLAB, forming a corresponding idealistic motor in a way where all the physical effects are similar. The motor is started under three different frequencies in the VVVF method using supporting simulation of the current, torque, speed, efficiency and power factor curves. The results of the three starting methods are then discussed and compared. Then a review of induction motor fault has been presented. Faults like rotor broken bar, mass unbalance, stator faults, single phasing, crawling, bearing faults, etc. are discussed along with causes and effects.

Key words: Bearing Fault, Broken Rotor Bar, Construction Crawling, Induction Motor, Mass Unbalance Single Phasing Stator Fault

I. INTRODUCTION

Induction motor is a simple and wide used electromechanical energy conversion mean. It is the commonly used motor in industry more than 50% of the electrical energy is consumed by induction motors because of their advantages. The squirrel-cage induction motor is cheap. No slip ring and brushes are used as in the case of ac synchronous motor or commutator and brushes as in the case of dc motor. The motor design is simple and it is safely used in harsh environments. It is rugged because of lack of wiring in the rotor, and maintenance free. It has direct line start ability, and can withstand heavy overload for long time. The majority of the induction motor faults make their presence unexpectedly during operation. So, one may conclude about the main characteristics a diagnostic method should have, in order to be applied in real operating systems [6]. Induction motors condition monitoring is a very important process for immediate detection of the incipient faults. This prevents the spread of the faults up to risky degrees

And avoids catastrophic stop of the motor and relevant production line. Condition monitoring is important to maintain sustained operability of machinery. The ability to effectively and efficiently monitor the condition of industrial machines allows the user to have a clear understanding of any problems that may arise during machine operation. Condition monitoring has the clear advantage of offering the ability to perform just-in-time maintenance i.e. before failure occurs but only as necessary. This aspect allows companies to reduce downtime when repairing machinery and ensures that productivity does not suffer [7]. Expert Systems use measurement data and knowledge base to point out and explain reasons of fault. This approach is very effective if one knows all possibilities of faults [9].

II. THE GENERAL THEORY OF ELECTRICAL MACHINES

This theory is based on representative the real machine through a corresponding idealistic machine in a way anywhere all the physical effects are similar. This positive machine is symmetrical (has two poles and two phases) and has two pairs of identical windings on perpendicular axes in both of the stator and the rotor. The windings are fed by two AC currents that are shifted through 11 (90°) from each previous according to time as shown in figure 1. The idealistic machine is treated as a two poles machine because the magnetic flux distribution is repeated after each pair of poles, no matter how many poles there are in the real machine [2]. In the idealistic machine, the electrical and the geometrical axes are Identical. This property simplifies detecting the rotor's position with reference to the stator during transient state. This transient state has a very complicated physical effect, which makes it almost impossible to mathematically study the machine without applying some theories and assumptions. The complexity is caused by the nonlinearity of the magnetization curve and the elements of the machine, and their dependence to the currents passing through the windings. Another factor of the complexity is the non-sinusoidal curve of the windings electromagnetic force which alters according to the working system of the machine.

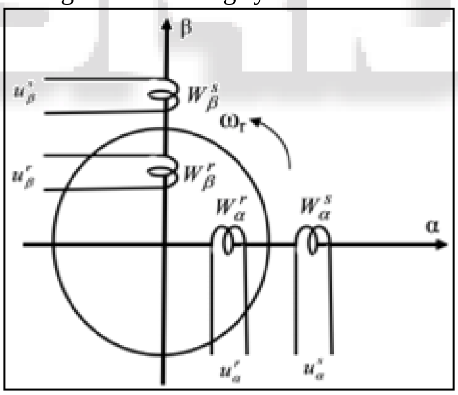

Fig. 1: The Ideal Machine Circuit

A. *Three Phase Drive System*

Three phase induction motors are more common employed in adjustable speed drives than three phase synchronous motor. When a three phase supply is connected to three phase stator winding, the speed of this rotating field, called synchronous speed is given by

- rpm......... (4)
- Where Ns = Synchronous Speed in rpm.
- f = Supply Frequency in Hz.
- P = No. of stator poles.
- Rotor cannot attain synchronous speed. It must run at a
- speed Nr less than Ns, Where
- Nr=Ns(1-s) .... (5)
- □m= ωs(1-s) ....(6)
- Where Nr =Rotor Speed in rpm

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- ωm= Rotor speed in rad/s
- s = slip

Three Phase Induction Motors are admirably suited to ful-fill the demand of loads requiring substantially a constant speed. Several applications however, need adjustable speeds for their efficient operation [5]. The various methods of speed control are as follows.

1) Stator Voltage Control
2) 2.Frequency Control
3) 3.Constant V/f Control
4) 4.Vector Control
5) 5.Changing the stator poles

In this paper three phase squirrel-cage induction motor with open loop voltage fed inverter is modelled MATLAB/SIMULINK software. The tested motor has the Following characteristics:

B. Dynamic Model for the IM

Let us first consider the stator circuit. The resistance R_s of the stator winding is (for all practical purposes) equal in all three phases. From the law of induction it follows that the part of the stator voltage which is not dissipated in the stator resistance will build up a flux in the stator winding. Hence, with v_s^s as the stator voltage space vector, the following relation must hold:

$$v_s^s - R_s i_s^s - \frac{d\psi_s^s}{dt} = 0$$

Where i_s^s and ψ_s^s are the space vectors for stator current and stator flux linkage respectively. The rotor circuit, with winding resistance R_r, can be treated in a similar way. Suppose that the rotor is observed from a coordinate system (rotor coordinates) which rotates with the same speed as the rotor ω_r. Let us denote rotor coordinates with superscript "r". As the coordinate system is rotor-fixed, there will be no induced voltage due to the rotation, so the same relation as for the stator must hold, but with "s → r":

$$v_r^r - R_r i_s^s - \frac{d\psi_r^r}{dt} = 0 \qquad (4.7)$$

Here v_r^r, i_r^r and ψ_r^r are the rotor voltage, current, and flux space vectors respectively. But the rotor winding is short-circuited, so $v_r^r = 0$. Now, let us transform i_r^r and ψ_r^r to stationary coordinates. This is a αβ transformation using the rotor position $\theta_r = \int \omega_r \, dt$:

$$i_r^s = e^{j\theta_r} i_r^r, \quad \psi_r^s = e^{j\theta_r} \psi_r^r \qquad (4.8)$$

Equation (4.7) is transformed as

$$0 - R_r e^{-j\theta_r} i_r^s - \frac{d\left(e^{-j\theta_r}\psi_r^s\right)}{dt} = 0 \Rightarrow$$

$$-R_r e^{-j\theta_r} i_r^s - \left(-j\omega_r e^{-j\theta_r}\psi_r^s \frac{d\left(e^{-j\theta_r}\psi_r^s\right)}{dt}\right) = 0 \Rightarrow$$

$$j\omega_r \psi_r^s - R_r i_r^s - \frac{d\psi_r^s}{dt} = 0 \qquad (4.9)$$

The induction motor is thus described by the following equations:

$$\frac{d\psi_s^s}{dt} = v_s^s - R_s i_s^s \qquad (stator)$$

$$\frac{d\psi_r^s}{dt} = j\omega_r \psi_r^s - R_r i_r^s \qquad (rotor) \qquad (4.10)$$

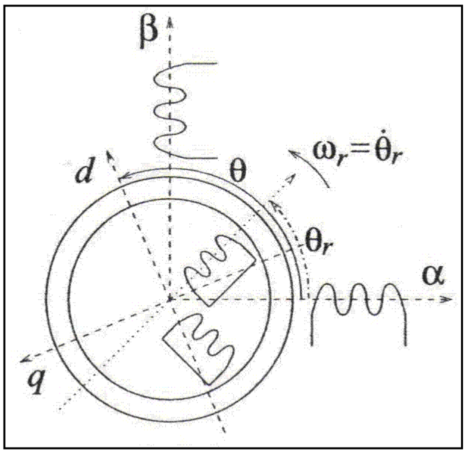

Fig. 2: Induction machine

Let us now find a relation between the stator and rotor flux linkages. The rotor winding is referred to the stator, i.e., the rotor winding is represented by coils in the α and β directions, cf. (Fig. 9). Assuming linear magnetic conditions, the air gap flux ψ_α^s can then be expressed as

$$\psi_\alpha^s = L_m i_m^s, \quad i_m^s = i_s^s + i_r^s \qquad (4.11)$$

Where L_m is the mutual inductance between the stator and the rotor, which is also called the magnetizing inductance, and i_m^s, is the magnetizing current. The stator flux is the sum of the air gap flux and the stator leakage flux, the latter which under linear magnetic conditions is proportional to the stator current only. Similar reasoning for the rotor flux yields

$$\psi_s^s = L_m i_m^s + L_{sl} i_s^s$$

$$\psi_r^s = L_m i_m^s + L_{rl} i_r^s \qquad (4.12)$$

Where L_{sl} and L_{rl} are the stator and rotor leakage inductances, respectively. The leakage inductances are typically 10% of L_m or less. Alternatively, with $L_s = L_m + L_{sl}$ and $L_r = L_m + L_{rt}$ as the stator and rotor self-inductances, respectively, the relations can be expressed as

$$\psi_s^s = L_s i_s^s + L_m i_r^s$$

$$\psi_r^s = L_m i_s^s + L_r i_r^s \qquad (4.13)$$

Combining (4.12) with (4.10), assuming constant inductan-ces, yields

$$v_s^s - R_s i_s^s - L_{sl}\frac{d i_s^s}{dt} - L_m \frac{d i_m^s}{dt} = 0$$

$$j\omega_r \psi_r^s - R_r i_r^s - L_{rl}\frac{d i_r^s}{dt} - L_m \frac{d i_m^s}{dt} = 0$$

C. Total Harmonic Distortion

Total Harmonic distortion is the important method to calculate the order of harmonics present in the voltage or current waveform. It is also useful in analyzing the quality of

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ac output voltage or current. Non sinusoidal wave quality can also be observed through Total harmonic distortion (THD). The total harmonic distortion is a measurement of the harmonic distortion and is described as the ratio of rms value of all harmonic components to the rms value of fundamental component. Total Harmonic distortion is defined as summation of all the harmonic content of current with respect to fundamental component of current [4]

III. PROPOSED APPROACH

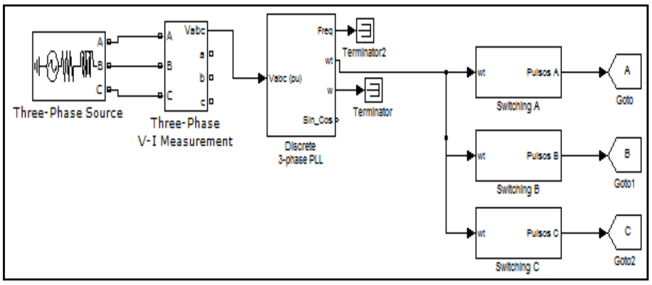

Fig. 3: Simulation diagram

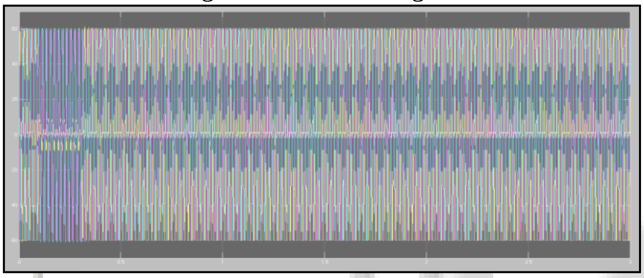

Fig. 4: Simulation of Induction Machine start

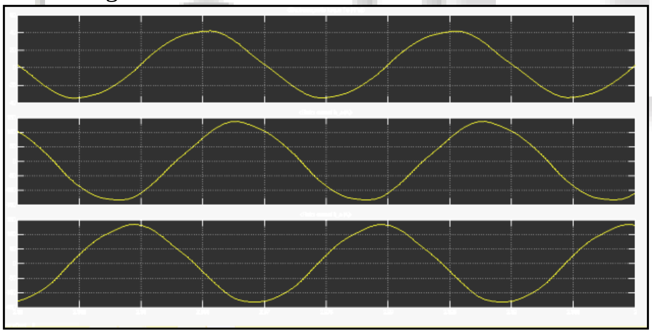

Fig. 5:

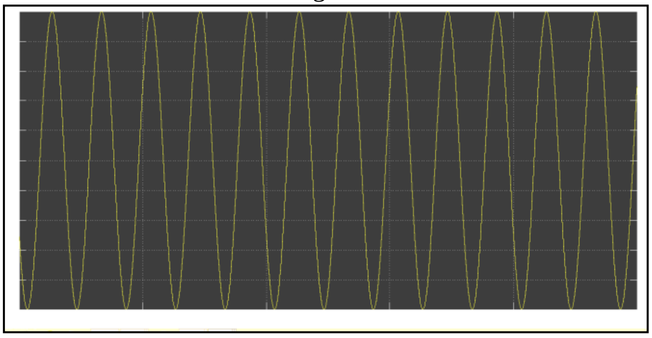

Fig. 6:

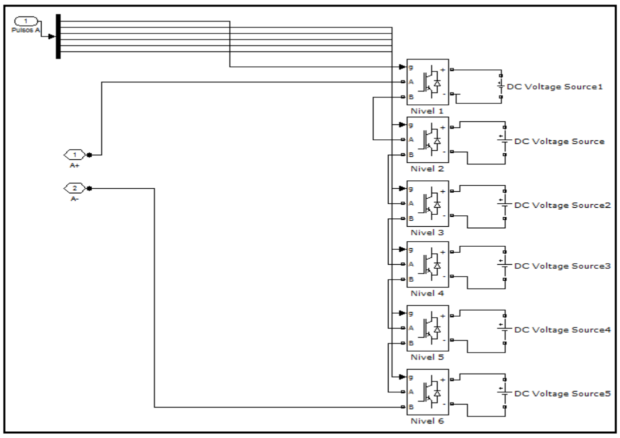

Fig. 7: IM Sub. 1

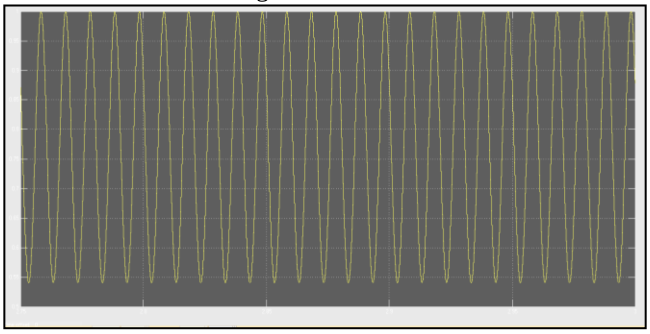

Fig. 8: Main Simulink Model

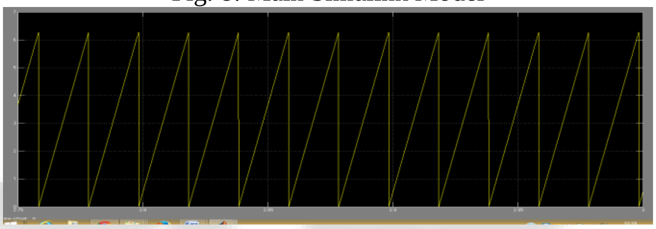

Fig. 9:

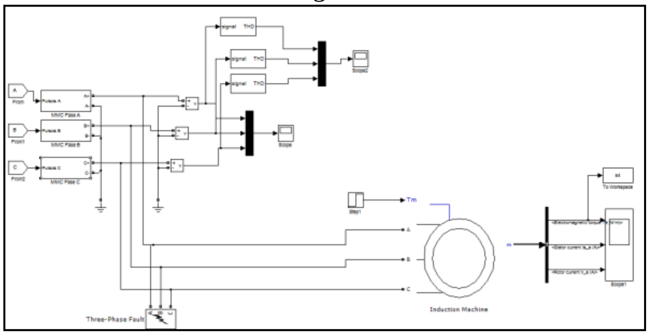

Fig. 10: Three-Phase Induction Machine (IM main)

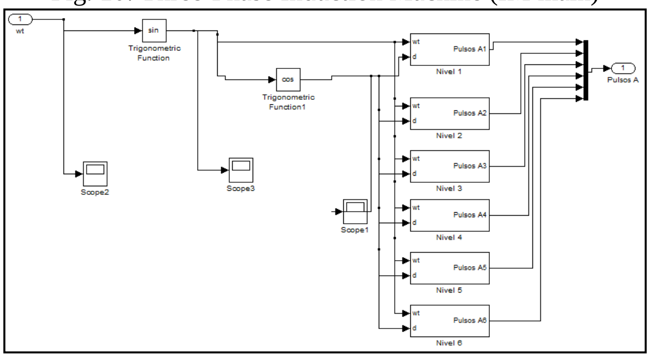

Fig. 11: Three-Phase Induction Machine (IM main)

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