Analysis of Stresses on the Performance of Induction Motor Under Various Disturbances

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ABSTRACT

Induction Motor is a most popular drive in Industrial application due to its various characteristic. Better performance of Induction Motor depends on the quality power in un-disturbances condition. But the performance of power system is dynamic and the continuous disturbances take place in power system as well as in the Induction Motor. In Induction Motor most of the faults takes place at stator side like open fault, short circuit, transient fault etc. In general the performance of Induction Motor changes due to various faults and transient and hence it is necessary to make the analysis of such fault and their stresses on the Induction Motor. This paper deals with analysis of stresses on Induction motor due to disturbances and faults at stator side. The Propose analysis to do assessment under open-circuit and short-circuit conditions. A generalized dynamic model of a three-phase squirrel cage induction motor will be developed by following reference projects. The model will be developed using d and q variables in a synchronously rotating reference frame. The model will predict performance of the motor during open-circuit and short-circuit conditions. The simulation results will be obtained from squirrel cage induction motor for low hp. The proposed system has been developed using MATLAB/SIMULINK..

Keywords

Modeling, Induction motor (IM), open-circuit (OC), short-circuit (SC)

1.INTRODUCTION

Induction motor are commonly controlled by contactors, which are electromagnetic switches that are highly sensitive to voltage depressions and momentary service interruptions. During start-up and other severe transient operations induction motor draws large currents, produces voltage dips, oscillatory torques. The Voltage depressions caused by faults on the system affect the performance of induction motors, in terms of the production of both transient currents and transient torques. It is often desirable to minimize the effect of the voltage dip on both the induction motor and more importantly on the process where the motor is used. Large torque peaks may cause damage to the shaft or equipment connected to the shaft. Some common reason for voltage depressions are lightning strikes in power lines, equipment failures, accidental contact power lines, and electrical machine starts. Despite being a short duration between 10 milliseconds to 1 second event during which a reduction in the RMS voltage magnitude takes place, a small reduction in the system voltage can cause serious consequences.

In order to investigate such problems, the d, q axis model has been found to be well tested and proven to be reliable and accurate. [1-3] describes the basic concept of dynamic modeling of the machine. Dynamic behavior of the machine may be analyzed using any one of following the reference frames:

a) Stationary reference frame
b) Rotor reference frame
c) Synchronous reference frame

[4-5] the dynamic behavior of IM can be described using dynamic model of IM. The dynamic model considers the instantaneous effects of varying voltages/currents, stator frequency and torque disturbance. In this project the dynamic model of IM is derived by using d and q variables in a synchronously rotating reference frame and also the dynamic performance of IM under open circuit and short circuit fault conditions for both low and high power machines.

Now a day Matlab/Simulink is a very useful tool for modeling electrical machine and it may be used to predict the dynamic behavior of the machines [12-14]. In this paper Matlab/Simulink based modeling is proposed using any one reference frame as mentioned above.

2. MATHEMATICAL MODELING

Three-phase to two phase Transformation

[A dynamic model for the three-phase induction machine can be derived from the two-phase machine if the equivalence between three and two phase is established. The equivalence is based on the equality of the mmf produced in the two-phase and three-phase winding and equal current magnitudes. The d and q axes mmf are found by resolving the mmfs of the three phases along the d and q axes.

$$\begin{bmatrix} i_{qs} \\ i_{ds} \\ i_o \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\theta_c & \cos\left(\theta_c - \frac{2\pi}{3}\right) & \cos\left(\theta_c + \frac{2\pi}{3}\right) \\ \sin\theta_c & \sin\left(\theta_c - \frac{2\pi}{3}\right) & \sin\left(\theta_c + \frac{2\pi}{3}\right) \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix}\begin{bmatrix} i_{as} \\ i_{bs} \\ i_{cs} \end{bmatrix} \quad (1)$$

The current $\dot{I}_{o}$ represents the imbalances in the a, b and c phase current and can be recognized as the zero-sequence component of the current. Equation can be expressed in a compact form by

$$i_{qdo} = [T_{abc}] i_{abc}$$

(2)

$$i_{qdo} = [i_{qs} \quad i_{ds} \quad i_o]^t$$

(3)

$$i_{abc} = [i_{as} \quad i_{bs} \quad i_{cs}]^t \quad (4)$$

The zero- sequence current, $\dot{I}_{o}$, does not produce a resultant magnetic field. The transformation from two-phase currents to three-phase currents can be obtained as

$$[T_{abc}]^{-1} = \frac{2}{3}\begin{bmatrix} \cos\theta_c & \sin\theta_c & 1 \\ \cos\left(\theta_c - \frac{2\pi}{3}\right) & \sin\left(\theta_c - \frac{2\pi}{3}\right) & 1 \\ \cos\left(\theta_c + \frac{2\pi}{3}\right) & \sin\left(\theta_c + \frac{2\pi}{3}\right) & 1 \end{bmatrix} \quad (5)$$

This transformation could also be thought of as a transformation from three (abc) axes to three new (qdo) axes; for uniqueness of the transformation from one set of axes to another set of axes, including unbalances in the abc variables requires three variable such as the dqo.

$$T^{s}_{abc} = \frac{2}{3}\begin{bmatrix} 1 & -\frac{1}{2} & -\frac{1}{2} \\ 0 & -\frac{\sqrt{3}}{2} & \frac{\sqrt{3}}{2} \\ \frac{1}{2} & \frac{1}{2} & \frac{1}{2} \end{bmatrix} \qquad (6)$$

$$\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} = \frac{2}{3}\begin{bmatrix} 1 & \frac{1}{2} & -\frac{1}{2} \\ 0 & \frac{\sqrt{3}}{2} & -\frac{\sqrt{3}}{2} \end{bmatrix}\begin{bmatrix} V_a \\ V_b \\ V_c \end{bmatrix} \qquad (7)$$

$$\begin{bmatrix} V_d \\ V_q \end{bmatrix} = \frac{2}{3}\begin{bmatrix} \cos\theta c & \sin\theta c \\ -\sin\theta c & \cos\theta c \end{bmatrix}\begin{bmatrix} V_\alpha \\ V_\beta \end{bmatrix} \qquad (8)$$

3. SIMULINK MODEL OF INDUCTION MOTOR

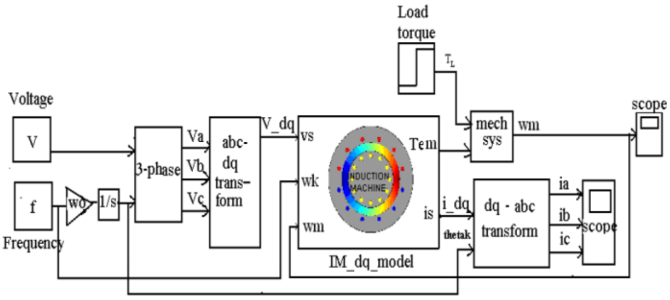


Fig.1 Block diagram of induction motor model in the arbitrary frame

4. INDUCTION MOTOR UNDER SHORT CIRCUIT CONDITIONS

[6] When a three phase short circuit fault occurs electrically close to the motor no electrical energy can enter or leave the motor. It is obvious that current can still flow in both the stator and rotor windings, thus torque can be produced. The energy stored in the magnetic field can therefore be dissipated either as mechanical energy or as heat due to copper losses in the motor. As the fault is applied, there is a large negative torque transient associated with the transient current of a typical magnitude of 9 p.u. It is not uncommon for motors to have a maximum reverse torque impulse of up to 15 p.u [12 13]. This torque impulse reaches its maximum within few cycles, but decays rapidly. Since the flux decays rapidly, clearing of the fault and the subsequent re- establishment of the supply voltage produces transients of the same order as at startup. However if many motors are left connected to the system their combined effect could lead to a voltage depression due to large currents, and all the motors might not be able to accelerate back to full speed.

4. INDUCTION MOTOR UNDER OPEN CIRCUIT CONDITIONS

[6] When the .motor is open-circuited the rotor windings carry the current to maintain the mmf and hence the flux in the motor. Once the fault has been cleared, the motor can be reconnected to the supply.

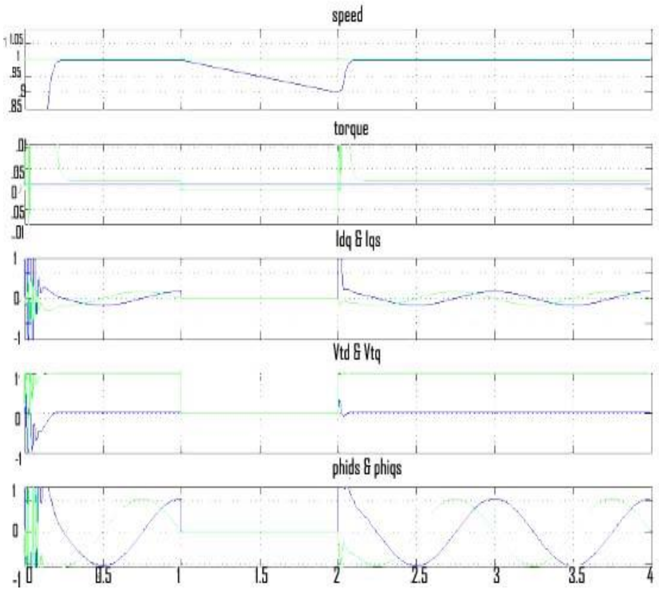
If the motor terminals are disconnected from the supply, once again no energy can enter or leave the magnetic field via the electrical terminals. Further as there is no current in the stator, torque cannot be produced, thus energy cannot be transferred to the mechanical load. At that instant when the stator current is interrupted, the net mmf in the motor must remain constant. This mmf balance is achieved by an instantaneous increase in the current in the rotor windings which results in energy decay due to the resistance in the rotor.

Fig.2 Dynamic performance of 3-hp induction machine during a Short-circuit fault [p.u]

5. SIMULATION RESULTS

This paper presents the modeling of the IM and its performance under different fault conditions of the machine. The effect of electrical torque, speed, current due to sudden change in applied voltage for low hp induction machines are analyzed. This analysis is carried through matlab/simulink software environment.

Dynamic performance of Induction machine during a 3-phase short-circuit fault:



The dynamic performance of the 3-hp induction machines is shown, respectively in fig 2 during a short-circuit (SC) fault at the terminals.

Dynamic performance of Induction machine during an open-circuit fault:

The dynamic performance of the 3hp induction machine is shown, respectively in fig 3 during a open-circuit (OC) fault at the terminals.

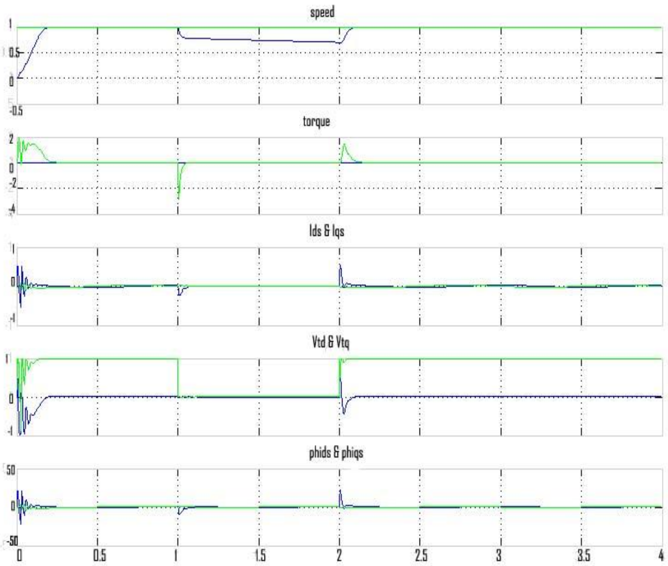


Fig. 3 Dynamic performance of 3-hp induction machine during A Open-circuit fault [p.u]

6. REFERENCES

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