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Fault Diagnosis in Induction Machines for Internal Fault Identification Scheme

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Abstract: In this paper, a mathematical model of the three-phase induction motor drives in abc reference frame is described. A computer simulation of the motor drive is provided which utilized Lab VIEW software. This simulation can be conveniently used to study the level of the 'Fault Tolerant System' parameters like current, voltage, torque, speed and also simulate the three phase Induction Motor for diagnosis of the short circuit and normal case using Laboratory virtual Instrumentation Engineering Workbench (LabVIEW).

***Index Terms*: Three Phase Induction Motor, Fault Diagnosis System.**

I. INTRODUCTION

Some of the recent research activities in the area of electric motor drives for applications (such as textile and production industry etc.) are focused on looking at various motor and drive topologies. Researchers feel that the concept of a fault-tolerant motor drive has now reached a level where it is feasible to be used in practice by the help of recent technological advances and developments in the area of power electronics and motor control.

In the active redundancy system, either motor drive unit may sustain the function. Although the complexity of the circuit and the cost increase due to the multiple and independent controllers, even if one of the motor drive segments is partially or completely out of order, the remaining motor drive or the stand-by motor drive can continue to operate and may provide sufficient power for the safe shutdown procedure. A high performance and complete fault tolerant system can be obtained if all of the components in the motor drive system and all are made fault-tolerant individually. Switched Reluctance (SR) motors are inherently fault-tolerant. However, they have significantly less torque density and efficiency than their PM ac counterparts, hence are not preferred in this study. An alternative fault-tolerant motor configuration for PM ac motors can be obtained by separating the three-phase windings and driving each motor phase from a separate single-phase inverter . It is evident that this new configuration doubles the number of power devices. However, the device voltage ratings are reduced since the devices withstand the phase voltage rather than the line voltage. As a result, the switching losses of the inverter will be reduced, in turn reducing the heat sink requirements, which also mean less weight.

Although there is a marginal advantage in increasing the number of phases of the motor under open circuit fault, there is no overall benefit since the complexity of the drive circuit increases, where in reducing the reliability. Therefore, a three-phase PMAC motor configuration is selected. It should be emphasized here that, in the event of the failure of one motor phase, the reduction of the developed average torque can be compensated for by overrating each phase of the motor by a fault-tolerant factor, which is a function of the number of phases. Over the years the monitoring was done on a theoretical basis and finding out the fault was not accurate enough but as the years went by the LabVIEW software came into existence. Till now this software has been used in connection with only one motor and this practice has not been feasible enough and the outcome was partial and the full potential of the system cannot be obtained. This shortcoming has been a setback for many industries in many areas, basically the financial sector and has led to heavy financial loses owing to the non-functionality of the machines being used for the production purposes. Hence this has been a serious issue waiting to be dealt with.

II. DYNAMIC MODEL OF INDUCTION MACHINE

In order to obtain a general dynamic model for the BSTM and BTPM motors, the three-phase abc modeling approach is used in this paper. Since the rotor of a PMAC motor has high receptivity, the effects of the stator currents on the total flux distribution may be ignored under the normal operating conditions. Therefore, a network consisting of a winding resistance, an equivalent winding inductance, can model the three phase star-connected PMAC motor and a back emf source per phase, all connected in series. In this work, it is assumed that the stator resistances of all the windings are equal and the self and the mutual Inductances are constant. Therefore, the voltage equations in the matrix form of a three-phase PMAC motor are expressed as:

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$$\begin{bmatrix} v_1 \\ v_2 \\ v_3 \end{bmatrix} = \begin{bmatrix} R & 0 & 0 \\ 0 & R & 0 \\ 0 & 0 & R \end{bmatrix} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} + \begin{bmatrix} L & 0 & 0 \\ 0 & L & 0 \\ 0 & 0 & L \end{bmatrix} \frac{d}{dt} \begin{bmatrix} i_1 \\ i_2 \\ i_3 \end{bmatrix} + \begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} \quad -(1)$$

Here v_1, v_2, and v_3 are the phase voltages; R is the winding resistance; i_1, i_2, and i_3 are the line currents; L is the equivalent winding inductance; and e_1, e_2, and e_3 are the back emfs of the phases and the electromagnetic torque is given by:

$$T_e = \frac{1}{w_r}(e_1 i_1 + e_2 i_2 + e_3 i_3) - \;(2)$$

Here W_r is the angular speed of the rotor.

$$T_e - T_l = J\frac{dw_r}{dx} \quad -(3)$$

Here T_l is the load torque; J is the inertia of the motor and the connected load.

If the stator windings of the three-phase motor are symmetrically displaced, the ideal back emf equations of the BSPM motor can be given by

$$\begin{bmatrix} e_1 \\ e_2 \\ e_3 \end{bmatrix} = \begin{bmatrix} E_m \sin(\theta_e) \\ E_m \sin(\theta_e - 2\pi/3) \\ E_m \sin(\theta_e - 4\pi/3) \end{bmatrix} - (4)$$

In Eqns. 4 and 5, *Em* is the maximum value of the back emfs that can be given by

$$E_m = k_e w_r \quad -(5)$$

Where k_e is the back emf constant, and θ_e is electrical rotor position that is given by:

$$\theta_e = p\theta_r = p\int w_r dt \quad -(6)$$

Here θr is the mechanical rotor position and p is the number of pole pairs of the motor.

$$v_1 = v_a - v_b \quad -(7)$$

$$v_3 = \left(\frac{v_a + v_b + v_c}{3}\right) - \left(\frac{e_1 + e_2 + e_3}{3}\right) - (8)$$

The terminal voltage V_a is determined by the switching states of the phase, which can be either $\pm Vdc/2$. For the star-connected PMAC motor, it is always true that the summation of the line currents equals to zero. Therefore, when all three phases conduct current, the floating star-point voltage of the motor can be easily derived from the three-voltage equation

Similarly, if only two of the phases (say Phase 1 and 2) are conducting currents, the floating star-point voltage of the motor can be derived as:

$$v_3 = \left(\frac{v_a + v_b}{2}\right) - \left(\frac{e_1 + e_2}{2}\right) - (9)$$

$$T_e - T_i = J\frac{dw_r}{dx} \quad -(10)$$

III. ROTATION IN AC MACHINES

3.1 Introduction

The principle of rotating magnetic fields is the key to the operation of most three-phase ac motors, such as conventional synchronous, permanent magnet synchronous, and induction motors. The rotating magnetic field is usually developed in the stator of an ac motor in order to produce mechanical rotation of the rotor. The rotor field is made to follow this rotating stator field by being attracted and repelled, hence the free rotating rotor follows the rotating field in the stator. However, a rotating magnetic field in three-phase ac motors is probably most difficult to understand since it cannot be visualized easily unless particular tools are used. Furthermore, unlike the gradually varying sinusoidal voltage, (in additional difficulty arises when an ac motor is driven by an inverter that provides only programmed step voltages (high or low) to the motor windings. The classic DC motor design generates an oscillating current in a wound rotor, or armature, with a split ring commutator, and either a wound or permanent magnet stator. A rotor consists of one or more coils of wire wound around a core on a shaft; an electrical power source is connected to the rotor coil through the commutator and its brushes, causing current to flow in it, producing electromagnetism. The commutator causes the current in the coils to be switched as the rotor turns, keeping the magnetic poles of the rotor from ever fully aligning with the magnetic poles of the stator field, so that the rotor never stops (like a compass needle does) but rather keeps rotating indefinitely (as long as power is applied and is sufficient for the motor to overcome the shaft torque load and internal losses due to friction, etc.).

Many of the limitations of the classic commutator DC motor are due to the need for brushes to press against the commutator. This creates friction. At higher speeds, brushes have increasing difficulty in maintaining contact. Brushes may bounce off the irregularities in the commutator surface, creating sparks. (Sparks are also created inevitably by the brushes making and breaking circuits through the rotor coils as the brushes cross the insulating gaps between commutator sections. Depending on the commutator design, this may include the brushes shorting to-gether adjacent sections and hence coil ends momentarily while crossing the gaps.

IV. SIMULATION OF AC MOTOR USING LABVIEW

The programs in Lab VIEW applications are called Virtual Instruments (VI).

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Similar to a subroutine used in the C language, any VI in Lab VIEW can be used as a sub-VI in the block diagram (where the programming is done) of a high-level The sub-VIs can also be called from the inside of another sub-VI, and there is no limit to the number of sub-VI used in Lab VIEW. This hierarchical nature provides a very flexible and powerful programming environment. A number of sub-VIs is implemented in this study. The "motor" sub-VI consists of four-computation subsection. Finally, the section four solves the differential equations (Equation.1) and computes the electromagnetic torque of the motor (Equation.2) is shown in figure 1 and 2. The "motor" sub-VI is customized and six inputs and four outputs are defined, which are used to link to the other sub-VIs in the program. One of the inputs is the array of the inputs for the switching signals, which are used to link the control signals of the power devices in the inverter. The parameters of the motor and the calculation interval are the other two inputs in the sub- VI. In order to set the initial values at the top-level VI, the final step values of the currents and the rotor position also provided as the inputs to the "motor" sub VI. An input signal named "mode" is defined to select a Induction motor to be simulated.

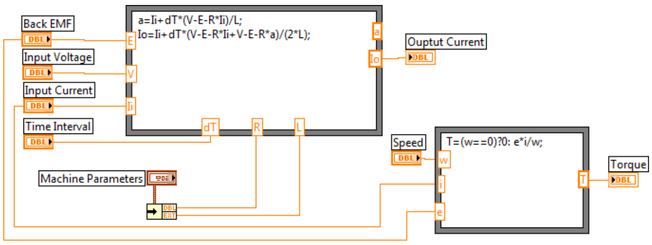

Figure 1: Schematics of Simulation of Motor Phase A in LabVIEW

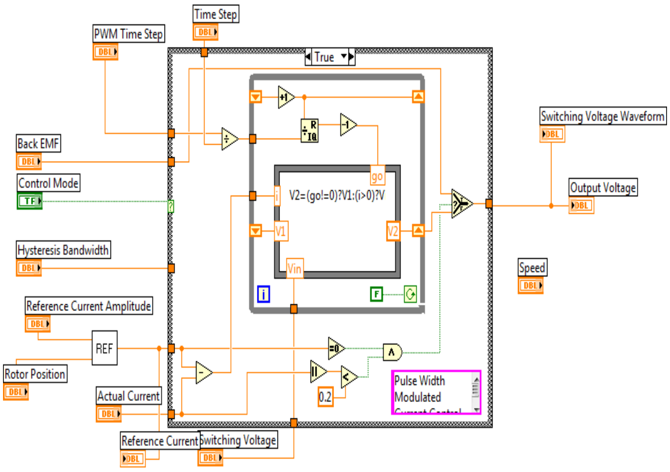

Figure 2: Simulation of Controller in Phase A motor in Block Diagram window LabVIEW

The outputs of the "motor" sub-VI include the line currents, the phase voltages, the torque and the rotor position. Similar to the practical motor drive system, the" control" sub-VI is implemented as the current controller of the motor. From the control point of view, PM motors can accommodate the identical current controller. The only difference is that they need either sinusoidal or rectangular current reference signals respectively. Therefore, the first function of the "control" sub-VI is to generate the three-phase current reference signals. The reference current waveforms can be either as ideal sine waves or as piecewise rectangular waveforms, which can be expressed per phase as shown below.

$$i_1 = I_m \sin(\theta_e) \qquad -(11)$$

$$i_2 = I_m \sin\left(\theta_e - \frac{2\pi}{3}\right) - (12)$$

$$i_3 = I_m \sin\left(\theta_e - \frac{4\pi}{3}\right) - (13)$$

Here I_m is the amplitude of the stator current command. As stated previously, because of the three phase symmetry, only one phase of the current reference signal is shown in figure.3.

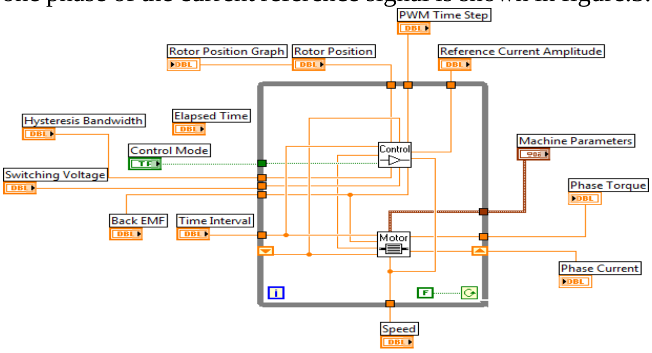

Figure 3: Simulation of Motor phase A in Block diagram window

Case 1: Normal Condition

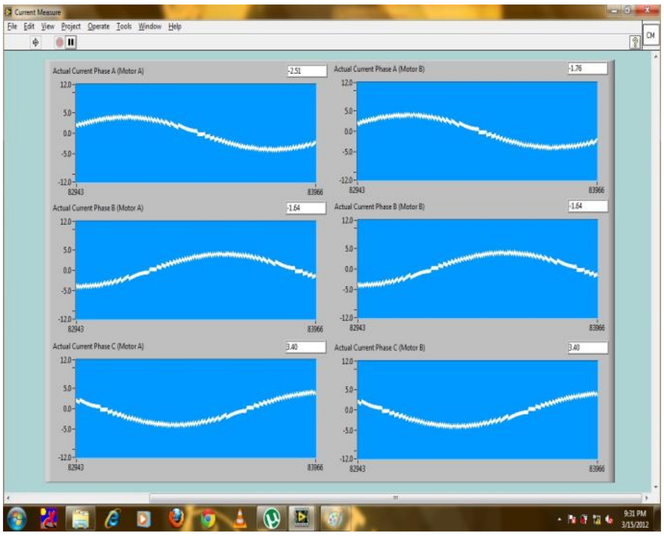

Figure 4: Simulation of Output Current Waveforms in Normal Condition of induction motor

Figure.4 shows the Normal condition is a condition where all the phases (A, B, C) work with a 120º phase shift between each phases (0º , -120, -240º).

Case 2 : Short circuit condition

Short Circuit is the first fault condition that is been simulated using LabVIEW, and its corresponding simulation waveforms of motor A and motor B are given below.

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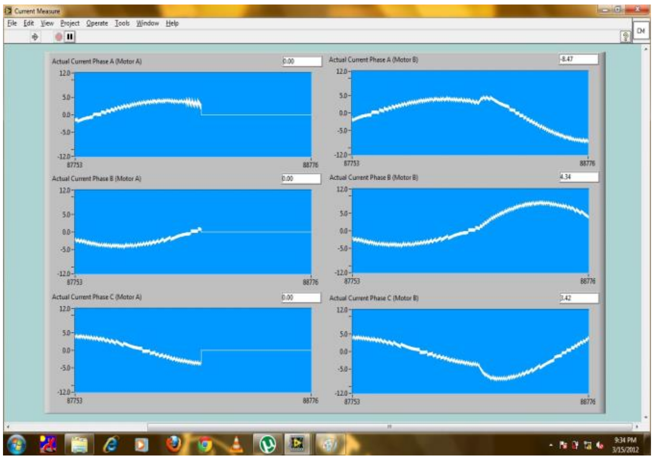

Figure 5: simulation of output current waveforms in short circuit condition of induction motor

Figure 5. shows the short circuit is the first fault condition that is been simulated using labview, and its corresponding simulation waveforms of motor.

V. CONCLUSION

This paper describes about the fault condition in three phase induction motor using laboratory virtual instrumentation engineering workbench software through Graphical Programming Language software. It also provides the various output waveforms of current in both the conditions short condition and normal condition. It is being variedly used as the application in various industries like textile and production where the manufacturing load is shifted to a standby motor B in case a fault is detected in any of the phases of motor A, which inturn reduces the wastage of time, money and resources.

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