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Effects of Switching Faults on Induction Motor Drive System

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Abstract - *Induction motors are mainly preferred in many applications. But these machines are subjected to several internal and external stresses which result in different kinds of faults. But the manufacturers as well as the users of the induction motor drives are concerned about the reliability of the drives when used in an application. Thus it has become extremely important that any faults occurring in these motor should be detected at the earliest. Hence for the detection it is necessary to analyze the impact of these faults on the motor performance. In this paper a 5HP squirrel cage induction motor was simulated in MATLAB and the effect of various kinds of switching faults were analyzed.*

***Key Words*: Induction motor, Switching fault, IGBT fault, DC link capacitor, Diode**

1. INTRODUCTION

Three phase induction motor drive system has become the workhorse in many industries and about 80% of the mechanical output in these industries is provided by induction motors. The reliable operation of these drives ensures maximum financial benefit and energy efficiency in the industry. But these motors are used in many harsh processes and hence they are subjected to many kinds of faults. The faults in an induction motor can be classified into switching fault and machine fault. Machine faults can again be classified into electrical faults, mechanical faults and environment related faults. Switching faults occurs in rectifier diodes, DC link capacitor and IGBT switches of the inverter [1]. Electrical faults consist of unbalanced faults, under voltage and overvoltage. The rotor winding failure, stator winding failure and bearing faults are included in mechanically related faults whereas external moisture, contamination in the ambient temperature which affects the motor performance is termed as environmental faults [3].
As there are much advancement in the field of power electronics it has become inevitable to detect and diagnose any kinds of faults affecting the system. In order to launch an effective fault detection method it is required to analyze the performance of the drive system under normal condition and when subjected to these kinds of faults. This paper focuses on the analysis of the speed and current when these motors are subjected to switching faults. The work is explained in three phases. The first phase explains the causes and effects of various switching faults in an induction motor drive system. The mathematical model and simulation of three phases squirrel cage induction motor drive system is included in the second phase .The analysis of induction motor drive system under various switching faults are explained in the third phase.

2. INFLUENCE OF SWITCHING FAULTS ON INDUCTION MOTOR DRIVE

Power electronics part is considered as the weakest component in drive system and about 38% of the induction motor faults are due to switching faults. In this section the causes and effects of various switching faults on induction motor performance is described. Switching faults may occur due to many reasons which include electrical stress due to stored charge carriers, maximum reverse current, faulty base drive system, manufacturing defects, ageing on capacitor, loose connections, abnormal transients etc. It can result in reduced performance of motor, increase in temperature thereby resulting in an increase in stator current or may even result in shut down of the motor.

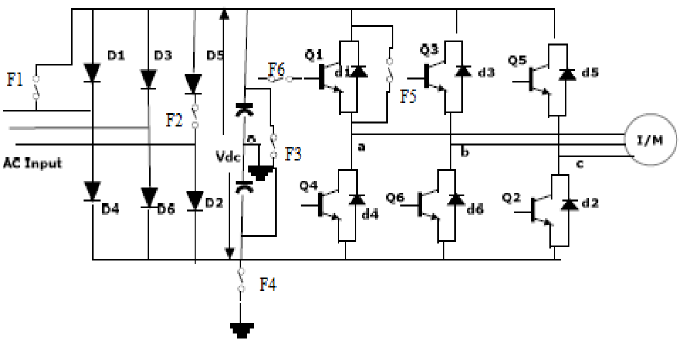

Fig -1: Possible Switching faults in the IM drive

The various switching faults discussed in this work are rectifier diode short circuit fault(F1),rectifier diode open circuit (F2),DC link capacitor short circuit (F3),DC link capacitor earth fault (F4),IGBT short circuit fault(F5),IGBT open circuit fault (F6).All these faults have negative impact on the motor performance.

3. MODELING OF INDUCTION MOTOR

The circuit representation of induction motor is the modeling of induction motor. These are written in d-q rectangular coordinates. Here the three phase induction motor is converted to two phase model by using Clarks and Parks transformation matrix and then the analysis is done. The parameters used for modeling is given in Appendix A. The model is valid under the two assumptions [5-6].

- Each stator phase of the motor has the same number of turns and uniform partial displacement.
- Magnetic saturation is neglected.

Based on this the flux linkages are given by equations (1) - (4).

$$\frac{dF_{qs}}{dt} = \omega_b[V_{qs} - \frac{\omega_e}{\omega_b}F_{ds} - \frac{R_s}{x_{ls}}(F_{qs} - F_{mq})] \quad (1)$$

$$\frac{dF_{ds}}{dt} = \omega_b[V_{ds} + \frac{\omega_e}{\omega_b}F_{qs} - \frac{R_s}{x_{ls}}(F_{ds} - F_{md})] \quad (2)$$

$$\frac{dF_{qr}}{dt} = -\omega_b[\frac{(\omega_e - \omega_r)}{\omega_b}F_{dr} + \frac{R_r}{x_{lr}}(F_{qr} - F_{mq})] \quad (3)$$

$$\frac{dF_{dr}}{dt} = -\omega_b[-\frac{(\omega_e - \omega_r)}{\omega_b}F_{qr} + \frac{R_r}{x_{lr}}(F_{dr} - F_{md})] \quad (4)$$

Mutual Flux linkages are given by the equations (5) – (7)

$$F_{mq} = xml^*[\frac{F_{qs}}{x_{ls}} + \frac{F_{qr}}{x_{lr}}] \quad (5)$$

$$F_{md} = xml^*[\frac{F_{ds}}{x_{ls}} + \frac{F_{dr}}{x_{lr}}] \quad (6)$$

The stator equations are given by (7) – (8)

$$i_{qs} = \frac{1}{x_{ls}}(F_{qs} - F_{mq}) \quad (7)$$

$$i_{ds} = \frac{1}{x_{ls}}(F_{ds} - F_{md}) \quad (8)$$

$$i_{qr} = \frac{1}{x_{lr}}(F_{qr} - F_{mq}) \quad (9)$$

$$i_{dr} = \frac{1}{x_{lr}}(F_{dr} - F_{md}) \quad (10)$$

Electromagnetic Torque is developed by equation (11)

$$T_e = \frac{3}{2}\frac{p}{2}\frac{1}{\omega_b}(F_{ds}i_{qs} - F_{qs}i_{ds}) \quad (11)$$

$$T_e - T_L = J(\frac{p}{2})\frac{d\omega_r}{\omega_b} \quad (12)$$

The speed of the machine is given by the equation (13)

$$\omega_r(t) = \frac{P}{2J}\int(T_e - T_L) \quad (13)$$

4. ANALYSIS OF SWITCHING AND ELECTRCAL FAULTS

The three phase sinusoidal PWM voltage source inverter fed squirrel cage induction motor drive system is developed and simulated using MATLAB SIMULINK tool box. The induction motor drive system was made to run at 75% of the rated load and the waveforms in fig 2 and fig 3 were obtained. Fig 2 represents the speed response of the motor when it's made to run under a load of about 75% of rated load. The speed of the motor was analyzed to be 1418RPM.

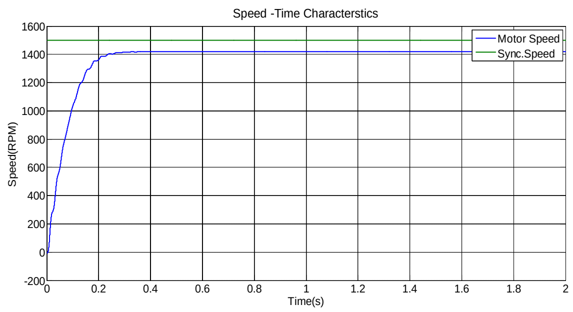

Fig -2: Speed response of induction motor drive under normal condition

In fig 3, the current response of the motor is obtained. The starting current was observed to be 70 A and then the current settled to a value of 10A.

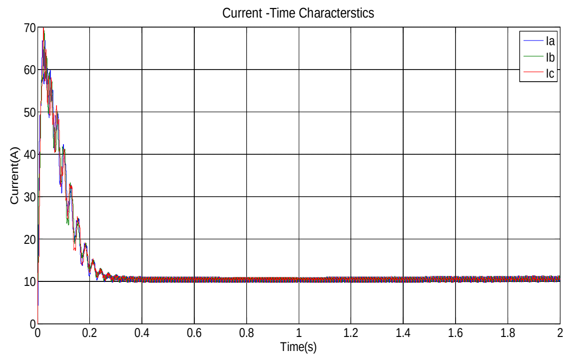

Fig – 3: Current of induction motor drive under normal condition

Simulation of various switching faults was carried out in MATLAB software. A breaker switch was used to either open or short the power electronic devices at an instant of 0.5sec, upto which the machine is running under normal condition with 75% of the rated load. Fig 4 and Fig5 shows the performance of the motor under diode short circuit conditions (F1). In fig 4 there was an increase in the stator currents when the fault is applied at 0.5 sec. A decrease in the speed was also noted in this case [4].

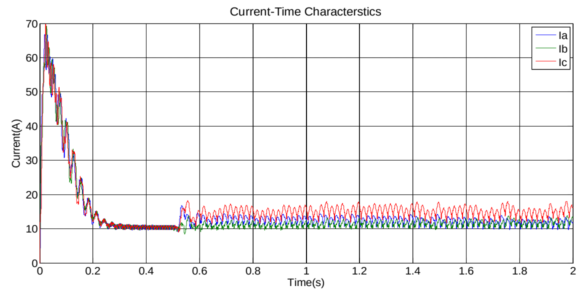

Fig. -4: Current response during fault F1

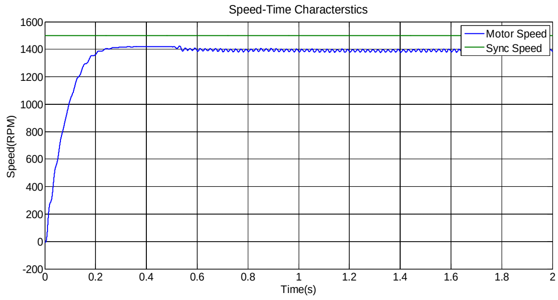

Fig -5: Speed response during fault F1

One of the diodes was opened and the effect of diode open circuit fault (F2) on motor performance is shown in fig 6 and fig 7. In this case there will be reduced voltage across the dc link as the opening of any one of the diodes makes the motor to work in single phase condition. Due to this fault the motor continues to work with reduced performance [8].

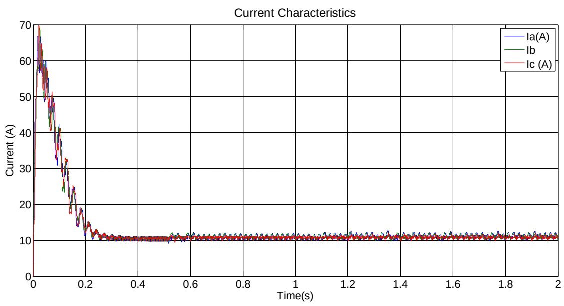

Fig -6: Current response during fault F2

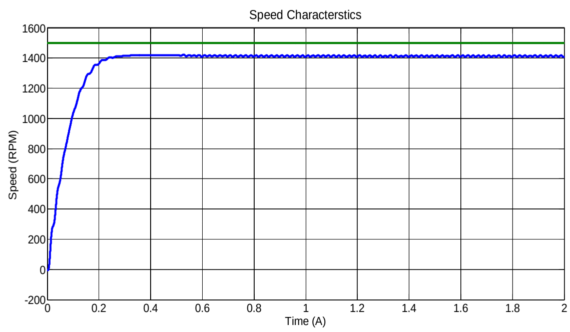

Fig -7: Speed response during fault F2

Capacitor if short circuited (F3) also has adverse effect on the system. When short circuited there is a high short circuit current flowing through the machine at the instant of fault. This fault will then result in a decrease in stator current as well as in speed. The fault developed causes the motor to stop working. Fig.8 and Fig.9 shows the motor performance under this condition.

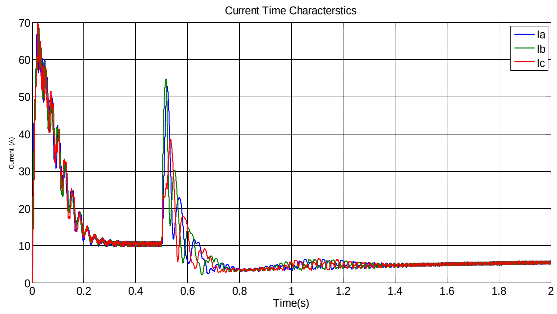

Fig -8: Current response during fault F3

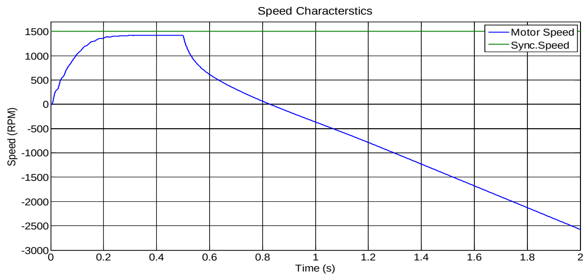

Fig-9: Speed response during fault F3

Fig.10 and Fig.11 shows the variations of stator current and motor speed of three phase induction motor drive system under capacitor earth fault (F4) .This fault causes an increase in the stator current to 11 A and a decrease in the speed of induction motor drive system to 1250 RPM.

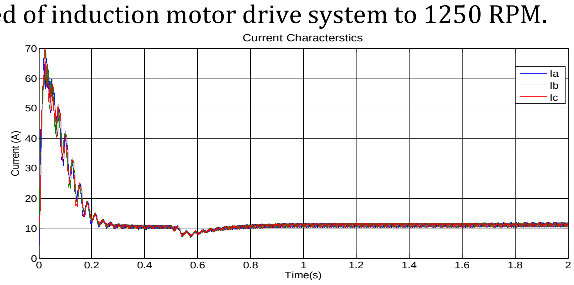

Fig -10: Current response during fault F4

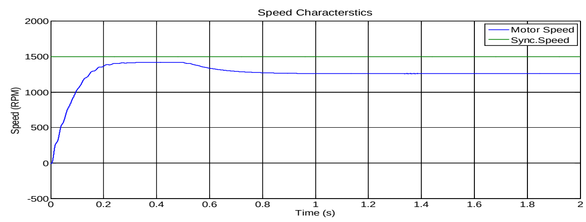

Fig. 11 .Speed response during fault F4

IGBT faults are considered as the major fault compared to other switching faults. If an IGBT short circuit fault (F5) occurs on the system which is already working the dv/dt resulting from rapid desaturation of the IGBT will trigger the gate voltage of the IGBT and causes flow of high magnitude of stator current as shown in Fig.12.Then the operation of the motor stops by decreasing the speed to zero which is shown in Fig.13

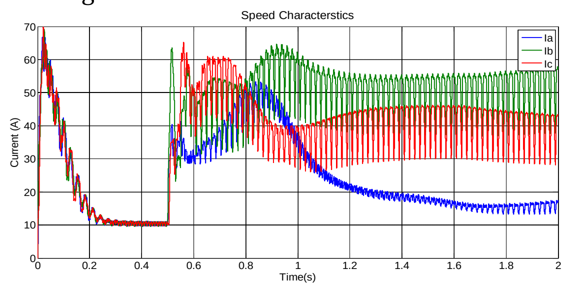

Fig. 12 .Current response during fault F5

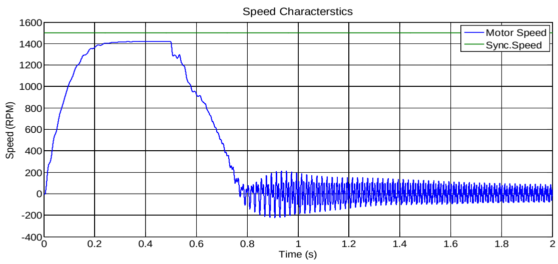

Fig.13 .Speed response during fault F5

Fig.14 and Fig.15 shows the performance of the motor under IGBT open circuit fault (F6) conditions. IGBT open circuit fault will not result in shutdown of the drive system But there is decrease in speed and an increase in the current due to this kind of fault. When fault occurs at 0.5sec the motor continues to work but with reduced performance because the antiparallel diode connected in parallel with the faulty IGBT serves the purpose of the IGBT[3] and maintains the current flow. The current goes to a value of 18A whereas speed moves to 1380 RPM.

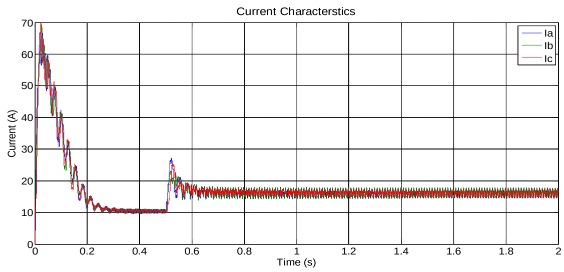

Fig. 14. Current response during fault F6

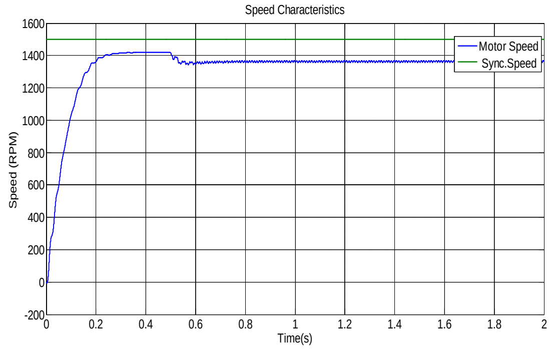

Fig. 15. Speed response during fault F6

5. CONCLUSION

The squirrel cage induction motor drive system proposed for this work was modeled and simulated using MATLAB Simulink. The switching faults such as rectifier diode faults, DC link capacitor fault and inverter IGBT fault were simulated using a breaker switch and it was made to turn on and turn off at 0.5 sec. The stator currents and the motor speed were used to analyze the severity of the fault. It can be observed that all these faults can affect the performance of the motor and the most severe fault among these is the fault on the IGBT switches.

APPENDIX A: MOTOR PARAMETERS

Rated voltage = 220V
Horse power = 5 hp
Rated speed = 1430rpm
No. of poles = 4
Stator winding resistance, Rs = 0.813Ω
Rotor resistance, Rr = 1.515 Ω
Stator leakage inductance, Lls = 1.78e-3 H
Rotor leakage inductance, Llr = 0.45e-3 H
Moment of inertia, J = 0.070 Kg m2

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BIOGRAPHIES

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