FAULT DIAGNOSIS OF INDUCTION MOTOR

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Abstract:

Although, Induction motors are highly reliable, they are susceptible to many types of faults that can became catastrophic and cause production shutdowns, personal injuries, and waste of raw material. Induction motor faults can be detected in an initial stage in order to prevent the complete failure of the system and unexpected production costs.

The purpose of this paper is the analysis of various faults of inverter fed induction machine. The laboratory tests thus conducted have been reported, and it is hoped that the research investigations reported would be very useful to the Power Electronics circuit industry.

Key Words: PWM Inverters, DC Motors, Drive Systems, Open & Short Circuit Test

Introduction

The study of induction motor behaviour during abnormal conditions due to the presence of faults; and the possibility to diagnose these abnormal conditions has been a challenging topic for many electrical machine researchers. Induction motor has been established as the workhorse of industry ever since the 20th century. Speed control of AC motors has been a continuously pressing requirement of industry, so as to ensure better production with a high degree of qualitative consistency. Although recent developments in Power Electronics and Controls have brought forth some very significant drive alternatives like the Switched Reluctance motor, Permanent magnet and Brushless DC Motor; these have not yet become very popular and cost effective for a wide range of applications, especially in the damp-proof, dust-proof and flame-proof environment. Therefore, the widespread use of induction motors is still economically viable as well as popular, and is likely to continue for the next few decades.

Variable speed drives are widely used in all application areas of industry. These include transport systems such as ships, railways, elevators, conveyors; material handling plants and utility companies for mechanical equipment e.g. machine tools, extruders, fans, pumps and compressors. The penetration of variable speed ac drives into these sectors has been further accelerated by the development of new power semiconductor devices and drive concepts, which further allow new functions and performance characteristics to be realized. The application of new Power Electronic components has also initiated a significant change in the market breakups between AC drives and DC drives. The rugged construction of AC drives has opened up a host of new application areas, thereby providing the user and also the manufacturer additional potential to increase their productivity and thus maintain their economic and technical competitive advantages.

Concept Of Drive Systems

While comparing the dynamic performance of a separately excited DC motor with that of an Induction motor, the latter presents a much more complex control plant. This is due to the fact that the main flux and armature current distribution of a DC motor is fixed in space and can be controlled independently; whereas in the case of AC motor, these quantities are strongly interacting. This design constraint makes the induction motor drive structure more complex and non-linear. The drive hardware complexity increases as more and more stringent performance specifications are demanded by the user. The complexity further increases because of the variable frequency power supply, AC signal processing and relatively complex dynamics of the AC machine.

PWM Inverters

One of the best possible methods to control the torque and speed of induction motor is to implement variable voltage and variable frequency inverters. Inverters used for variable speed drive applications should have the capability of varying both the voltage and frequency in accordance with speed and other control requirements. The simplest method to achieve this control is through a six step inverter. But this method suffers from the following limitations:

(i) Presence of low order harmonics, because of which the motor losses are increased at all speeds causing derating of the motor.
(ii) Torque pulsation is present at low speeds, owing to the presence of lower order harmonics.
(iii) The harmonic content increases at low speeds, thus increasing motor losses. Also the increase in V/f ratio at low speed to compensate for the stator resistance drop may cause a higher motor current to flow at light loads due to saturation. These effects may overheat the machine at low speeds.

These limitations of a six step inverter drive are overcome in a pulse width modulated (PWM) inverter. The basic block diagram of a PWM inverter is shown in figure 1.

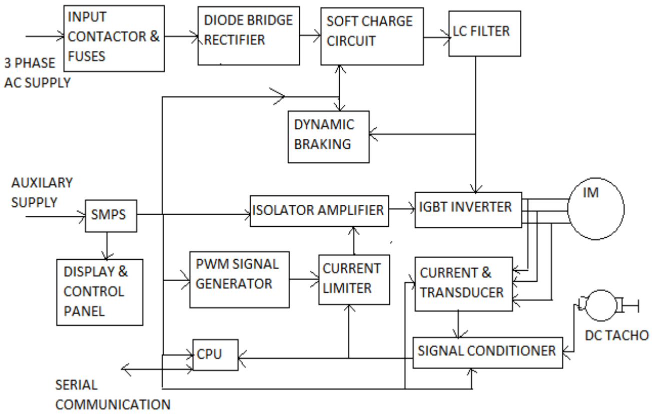

Figure 1. Block Diagram Of Inverter System

Because of a low harmonic content in the output voltage of diode bridge and also due to the presence of harmonics in the input current of a PWM inverter, the requirement of filter size in such systems is small. The drive system consequently delivers smooth low speed operation, free from torque pulsation, thus leading to lower derating of motor and higher overall efficiency. Also because of a constant DC bus voltage, a number of PWM inverters with their associated motors can be supplied from a common diode bridge. However, these advantages are obtained at the expense of a complex control system and higher switching loss due to high frequency operation.

Survey Of Various Faults

A wide range of motors are currently being used for industrial applications. They deliver a wide range of characteristics demanded for specific tasks. Motors for all types of duties and with various characteristics require adequate protection. Hence it is essential that the characteristics of motors be carefully examined and considered before applying protection systems. A three-phase voltage fed inverter can develop various types of faults as shown in figure 2.

- Input supply single line to ground fault F_1.
- Rectifier diode short circuit fault F_2.
- Earth fault on DC bus F_3.
- DC link capacitor short circuit fault F_4.
- Transistor base drive open fault F_5.
- Transistor short circuit fault F_6.
- Line to line short circuit at machine terminals F_7.
- Single line to ground fault at machine terminals F_8.
- Single phasing at machine terminals F_9.

A three phase voltage fed inverter can develop any of the above stated faults, out of which the open base drive and shoot through are the most common.

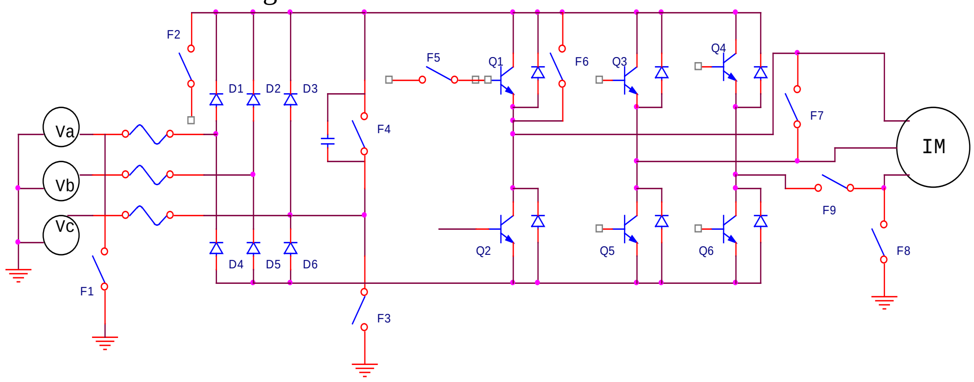

Figure 2. Failure Mode Of PWM Inverter

Analysis Of Various Faults

Different fault mode conditions on the machine side are applied and tested practically on the induction motor at a fixed load of 5Nm and fixed reference speed of 314.16 rad/sec (1500 RPM) with a current limit of 10A.

One-Phase Shorted To Ground

One of the motor terminals is shorted to ground when the motor is running under steady-state set speed conditions. The oscilloscope waveforms of speed-time, current-time and torque-time characteristics are shown in figure 3. From the waveforms, it is observed that although the torque pulsations are high, the motor can be run with reduced load depending on the application requirement. Also, the fault mode current is higher than the starting current. Hence, this aspect has to be taken into consideration in designing the drive system.

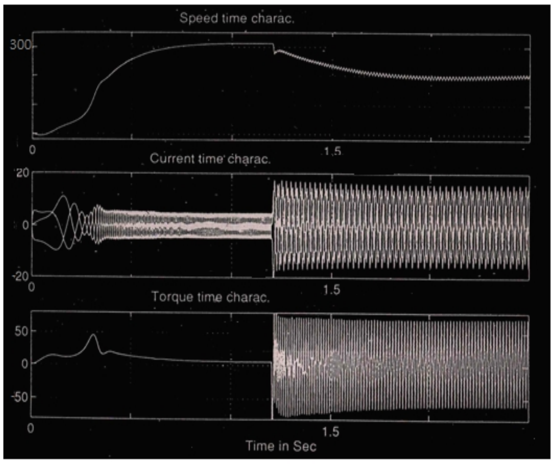

Figure 3. Single Phase Short Circuit to Ground

One-Phase Open Circuited

When the motor is running under steady-state conditions, it is possible that one phase may become open-circuit. The waveforms of figure 4 depict that fault is applied at time t = 1.2 sec. It is evident that although the torque pulsations are high, one can run the motor with reduced load. The torque pulsations in this case are relatively less as compared to the previous case where one of the phase has been short circuited to ground. Also, the fault mode current is almost equivalent to the starting current.

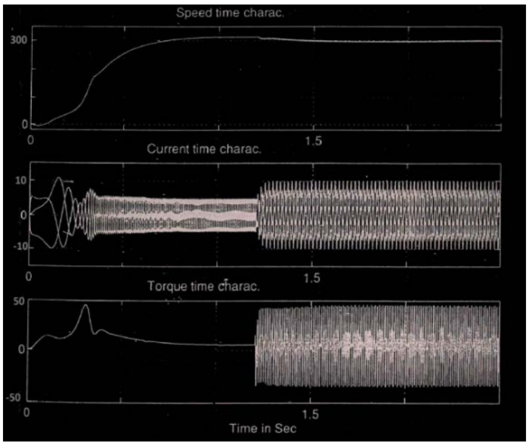

Figure 4. Single Phase Open Circuit

Two Lines Short Circuited

In this case, one of the motor terminal gets connected to the other, when the motor is running under set reference speed and set values of torque as well as current limit. From figure 5, it is observed that after the fault is applied at t = 1.2 sec, both current and torque slowly damp to zero. Thus the motor cannot continue to operate in this condition.

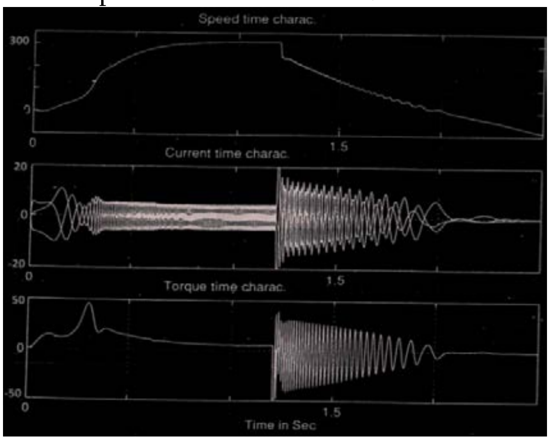

Figure 5. Line To Line Short Circuit

Two Lines Open Circuited

Two lines of the motor input terminals are open-circuited while the motor is running at a set value of torque, current limit and speed conditions. The oscillogram waveforms of figure 6 depict that after the fault is applied at t = 1.2 sec, both current and torque slowly damp to zero. The time taken by the current and torque characteristics to damp to zero is more as compared to the previous case where two lines were short circuited. These results indicate that the motor cannot continue to operate in this condition.

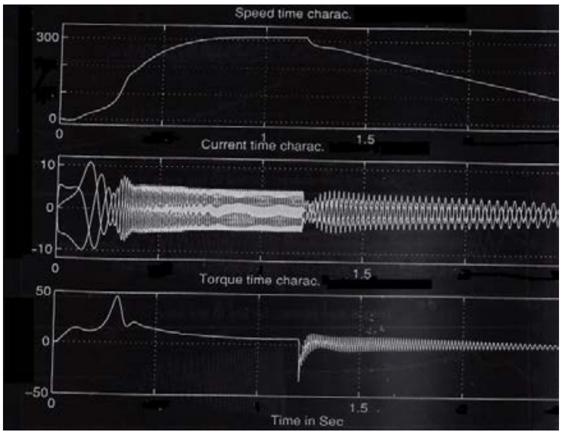

Figure 6. Two Lines Open Circuit

Three Phase Open Circuit

All the three lines of the motor terminals may get open circuited while the motor is running in steady state condition. As observed from figure 7, both current and torque immediately reach zero as soon as the fault occurs. Hence, it is not possible to continue running the motor under this condition.

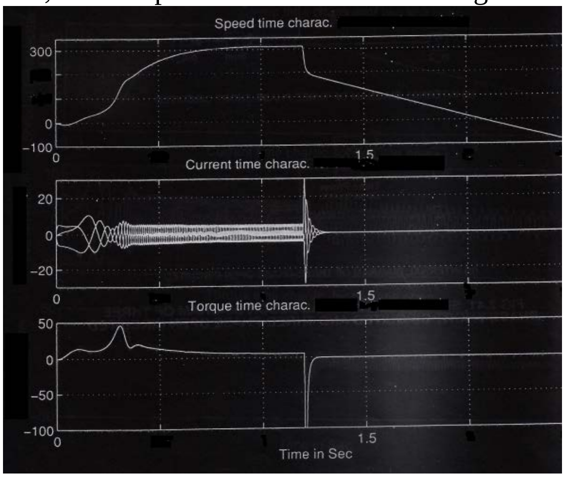

Figure 7. Three Phase Open Circuit

Three Phase Short Circuited

When the motor is running under set values of torque, current limit and speed conditions, it may happen that all the three lines of the motor terminals get short circuited. As shown in the waveforms of figure 8, as soon as the fault occurs, both current and torque immediately reach zero. This condition takes a little extra time as compared to the case of figure 7. As a result, the motor cannot continue to run in this condition.

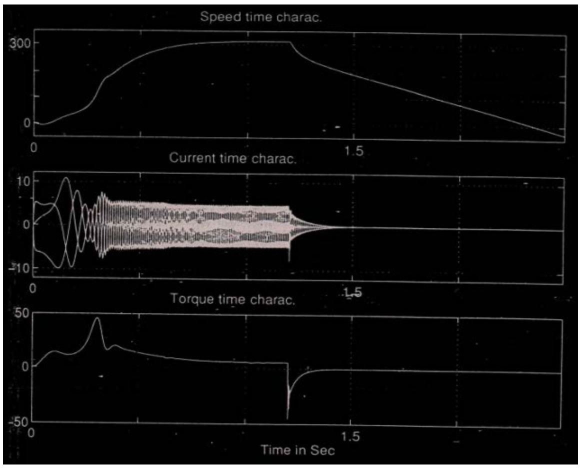

Figure 8. Three Phase Short Circuit

Conclusion

The comprehensive study carried out on the six cases of machine side faults revealed that the motor can run only under single line open or short circuit cases. The duration of time that the operator can allow the motor to operate under these two fault conditions is based upon the motor over-load carrying capacity and insulation capacity. The experimental investigation results should be kept in mind while designing a drive system since the power semiconductor devices are very sensitive to the fault conditions. It is hoped that the research investigations reported would be very useful to the industry in improving the Power Electronics circuit reliability.

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