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Protection of Single Phase Induction Motor from Broken Rotor Bar and Thermal Overload

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Abstract

The advanced machines are generally very reliable and robust but it is need of the time that protection should be given to those motors as they work near to its maximum thermal range. This thermal overload may cause hot spots which then increases the resistance of the machine, increasing the copper and iron losses and also affects the value of current. The thermal overload is also responsible for insulation failure. Along with this broken rotor bar is a common fault which significantly damage induction motor if not detected timely. Timely detection of faults is a necessity for industry to minimize financial losses. Condition monitoring is a usual practice to cue fault development in motor. Available condition monitoring methods required specially designed tools and sensors. This work presents a technique based on current analysis of rotor for broken rotor bars detection and thermal overloading of induction motor. The given method in this work is analyzed on practical setup and obtained results shows that proposed method is reliable and efficient for detecting broken rotor bar. As this method is quite simple to implement, it is used widely.

Keywords: Thermal overload protection, Rotor bar fault, MCSA, FFT, Motor diagnostics.

INTRODUCTION

90% of induction motors are used in industry. Induction motors range from very small fractional horsepower to the thousands of horsepower. They can operate in severe and hazardous conditions so they are expected to perform with high reliability. They are used in applications of pumping, chopping, crushing, machining, centrifuging, and more. Most of bigger companies use three phase induction motor but small scale industries use single phase induction motor. However many manufacturers in industries do not want discontinuity in production output since it results in production loss as well as monitory loss.

Overwhelming use of induction motor in industry has been in the past, present and will be observed in future also. From the survey it has been observed that 41% of faults in induction motor are related to bearings, 37% are stator related, 10% are related to rotor and 12% are other faults. Even if the percentage of rotor fault is less but it is one of the most difficult motor faults to diagnose accurately in the AC induction motor. The studies show that approximately 9-10% of induction motor failures are rotor-related. Broken rotor bars can lead to catastrophic and severe damage to a motor if not repaired early, so accurate diagnosis is a necessity. Taking down a motor for physical inspection is a costly and time-consuming which takes the motor offline for long period of time. Industrialists need a simple, inexpensive and reliable method to determine whether the rotor bars in their motors are ‘healthy’ or ‘faulty’. So this work is an analysis to detect faulty condition of rotor bars. For this condition monitoring is done continuously for solid disclosure of the electrical and mechanical faults at an initial level which will make scheduled and controlled maintenance rather than immediate failure, so that the production losses get reduced and also motor outage time and harm to the motor gets reduced. [4][7].

FFT

One of the foremost causes of failure of enclosed electrical equipment is high temperature. This may be explained in different words because the ambient temperature is the temperature of the air encompassing the motor. This can be called as the threshold point or temperature assumed by the motor when it gets shut off and completely cool. Rise in temperature means the change inside a machine when it is operating at full load. For example; if a machine in a 79°F room operates constantly at full load, then the temperature of winding will increase. The difference between its initial temperature and its final temperature is nothing but the motor's temperature rise. As per mechanical overviews and different studies, around 5 -10% of fault occurs due to broken rotor bars; see Fig. 1 [1].

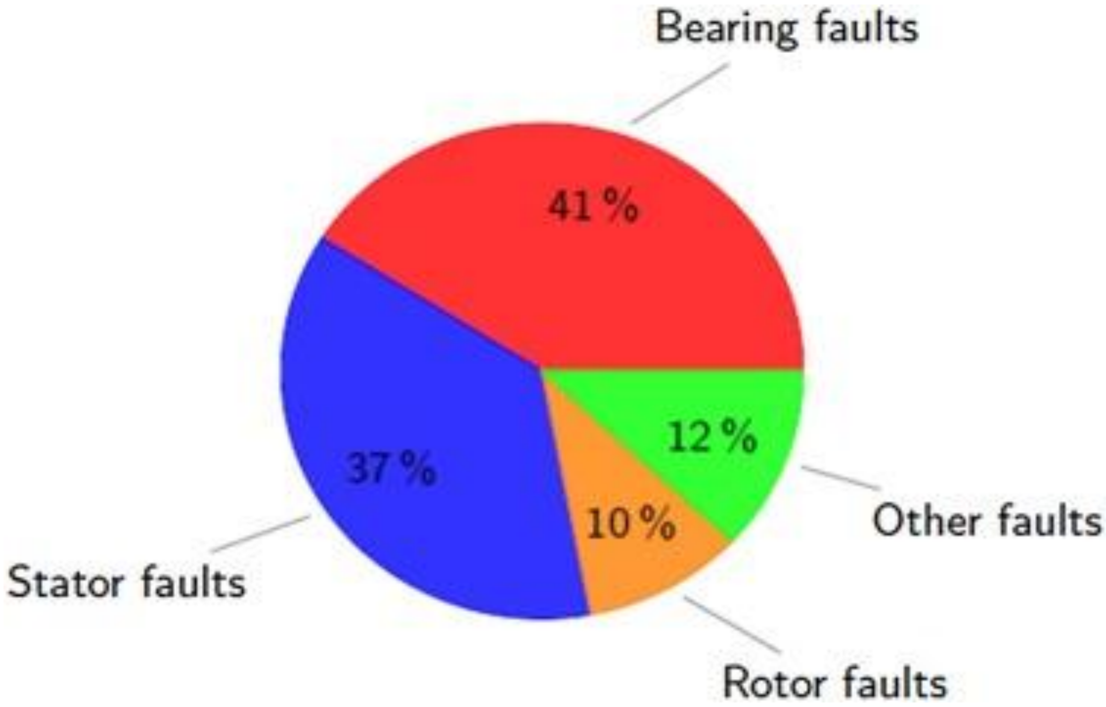

Fig.1 Fault category of Induction machine failure

HOT SPOT

The hot spots are commonly occurring thermal phenomena and refer to areas within electrical enclosures that are not cooled by the forced convection. It is impossible to say where hot spots might occur in an enclosure because the layout, heat load of the electrical equipment, size of the enclosure and ambient conditions are unique to each installation. Hot spots are a result of undercuts or impediments in the path of airflow that prevent air from reaching certain concealed spots within the enclosure. If you assume the enclosure to be a closed space, hot spots are bound to occur close to the top where hot air accumulates; the effect of hot spots is further magnified by extreme ambient conditions. In slightly more uncommon cases, hot spots could be a result of loose and corroded wiring, component failure, and unbalanced loads [13].

BROKEN ROTOR BARS

With improvements in technologies and lessened segment price in recent years, condition monitoring instruments used in condition-based programs has begun to be more steady and practical. Motor is not needed to be taken out of operation as several testing is performed online, and in many cases enough experience is needed for information interpretation and testing. This allows the client to create intelligent choices for coming up with maintenance and repairs, which eventually prompts expanded efficiency [9].

Fig.2 Broken Rotor Bar

In squirrel cage induction motors the rotor windings are fabricated from aluminum alloy or copper alloy or copper. The broken rotor bars (as in Fig. 2) hardly causes immediate failures, particularly in vast multi-pole gradual speed machines. If in any case, there are sufficient broken rotor bar, the motor could not begin because it will most likely be unable to create adequate accelerating torque. Sometimes in any case the present broken rotor bars encourages weakening in different parts that can bring about tedious and costly fixes. The rotor can be corrected at a small amount of the cost of rotor substitution. More typical impacts of broken rotor bars are:

- Broken bars can roots sparking, a genuine worry in dangerous regions.
- If more than one or one rotor bar is broken, the robust bars are enforced to convey extra current prompting rotor core harm from continual raised temperatures in the region of the broken bars and current going through the core from broken to sound bars.
- Non uniform bar expansion may occur due to huge air pockets in die-cast aluminium alloy rotor windings prompting to bending rotor and asymmetry that roots high vibration levels from untimely bearing wear.
- As the speed of rotor is high, broken rotor bars can come up short on the space because of centrifugal force and force across the stator winding leading a

calamitous motor failure.

- The dynamic and static rotor asymmetry could make the rotor rub against the stator winding causing damage to rotor core and even a disastrous fault.

MOTOR CURRENT SIGNATURE ANALYSIS

To ensure safe operation of these machines online, fault diagnostics is very important. Reliability of operation can be increased by timely maintenance. Many tools are present nowadays but still many companies are confronting with surprising failures of system and decreased lifetime of machine. There are many methods of condition monitoring counting thermal monitoring, vibration monitoring, chemical monitoring, but expensive sensors or specialized tools are needed for all these monitoring strategies whereas current monitoring does not need extra sensors. Current monitoring of induction motor is the base of the Motor Current Signature Analysis (MCSA) technique; hence it is not very overpriced. For locating fault frequencies the current spectrum of the machine is used in MCSA. Whenever the fault appears, the frequency spectrum of the current grows into different from healthy motor. The signal processing strategies are utilized for fault detection and condition monitoring of induction machine. Advantages of using the signal processing strategies are that they are economical, and they are easy to implement [12].

FAST FOURIER TRANSFORM METHOD

For the detection of rotor fault the Fast Fourier Transform (FFT) technique is used successfully in the induction motor. It depends on the steady state analysis of the machine. This strategy is effectively utilized with Motor Current Signature Analysis (MCSA) system from few decades [13]. For many applications in mathematics, engineering, science Fast Fourier transforms are used widely. Let u0... uN−1 be complex numbers. The DFT is defined by the formula [4],

$$U_k = \sum_{n=0}^{N-1} \left(u_n e^{-i2\pi kn/N} \right)$$

Where k = 0...N-1

DESIGN METHODOLOGY

As shown in fig.3 the work consists of microcontroller along with other peripherals. We will be using microcontroller Arduino Uno. Other peripherals include Induction motor, signal conditioning circuit, current transformer, serial communication circuit, USB to serial converter, PC and power supply. We will be monitoring broken rotors and for the broken rotor detection, we will have to measure current. The current of motor will be monitored through current transformer. Current should be effectively monitored to achieve improved condition monitoring and protection system for induction motor.

Signal conditioning circuit will be used to measure current at microcontroller end. Signal conditioning is needed to make the current signal compatible to microcontroller to read. Current will be measured through internal ADC of microcontroller. The current data in the form of digital signal will be transmitted to PC end through serial communication circuit and USB to serial converter. At the PC end, current data will be processed through various blocks. Also, temperature of the motor will be measured using temperature sensor LM35. Output of this sensor is analog.

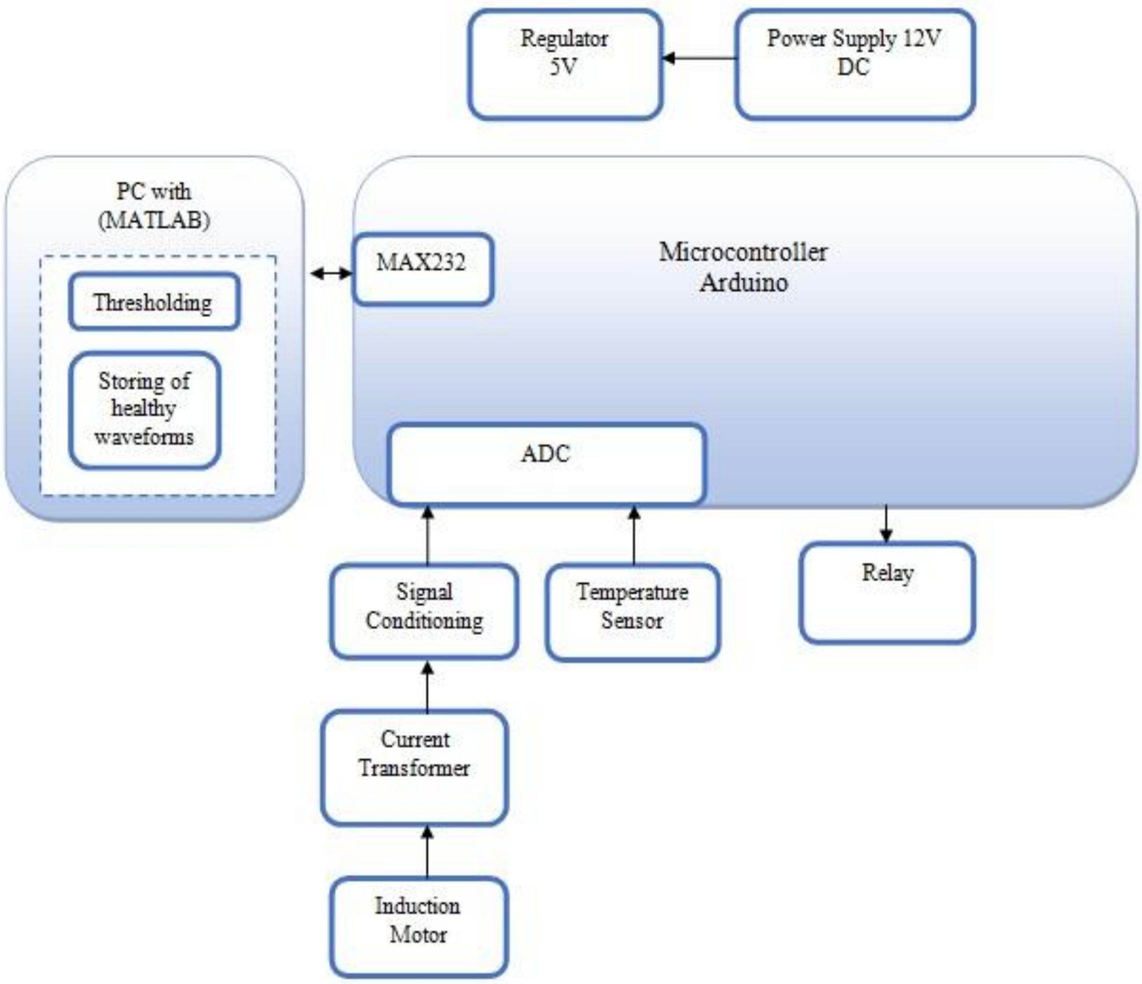

Fig.3 Block diagram of proposed system

We have to use another ADC channel to acquire the signal of temperature sensor. Similar to first fault, signal of vibration sensor is also sent to Matlab and get processed. FFT of the signals will be calculated and compared with the previously stored healthy waveform. Relay will be used to switch on/off the motor. The complete setup of work is shown in the Fig.4.

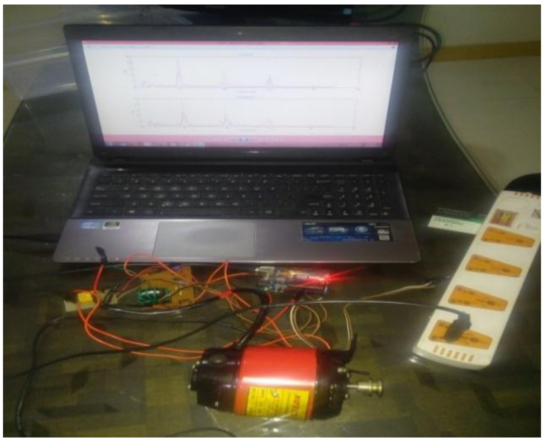

Fig.4 Test Setup

RESULTS

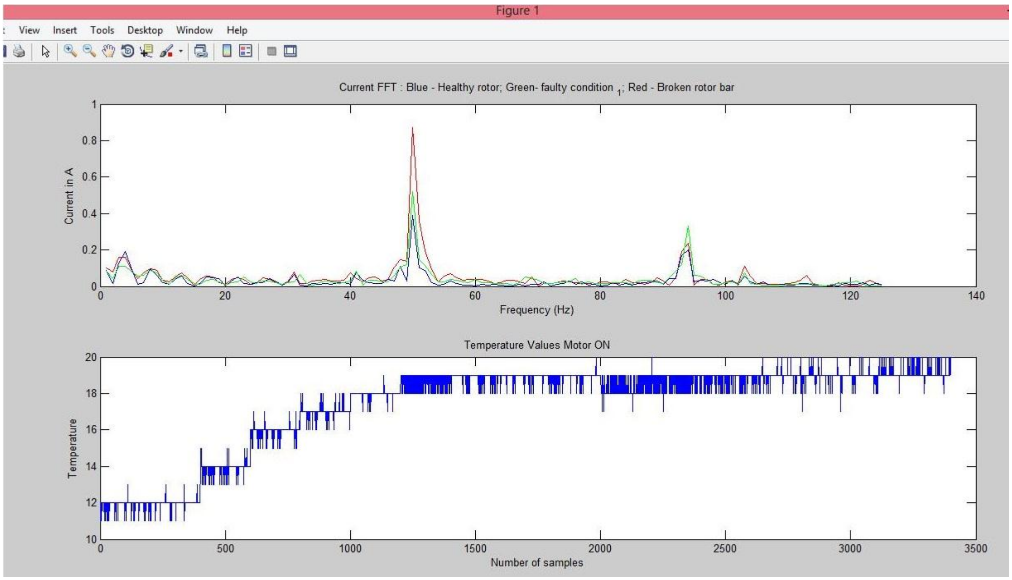

Fig. 5 Fault Current and Temperature Rise Test Results

In the upper graph of Fig. 5 blue line shows healthy current, green line shows the graph when three bars are broken and red line is showing condition when 6 bars are broken. The lower graph shows the rise in temperature. As soon as motor exceeds the set temperature limit it will be tripped automatically due to the relay action.

CONCLUSION

Any failure of IM can reduce production and may produce huge losses in terms of lost profits and maintenance; the broken rotor bar is one of them. If it is not detected early may cause permanent damage. Hence up to date detection of incipient motor faults is very important. There are some industries which cannot afford the costly tools to give protection to the machines hence the FFT is considered as the cost effective method used for protection. Thus any industry can utilize this method to give protection against broken rotor bars. Also, it is possible to monitor fault online without doing the shutdown of the motor. The stated technique can be conveniently applied to detect faults at an early stage before becoming major. It is imperative contribution tool for condition monitoring of induction machines.

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