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Survey of Condition Monitoring Techniques for Induction Motors

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***Abstract* – Induction motors have been identified as one of the most common and useful type of motors. Thus, these motors are commonly used in domestic applications as well as industrial applications due to their distinctive features. However, it has been determined that these motors tend to fail with the time of operation which can be minimized through proper techniques of monitoring the condition and diagnosing the fault of the induction motor. The following paper will investigate extensively, the faults which could occur in an induction motor as well as the techniques of diagnosing these faults which can provide a better lifetime whilst increasing the reliability in an induction motor subsequently.**

***Keywords* – Condition monitoring, Induction Motor, Motors, Vibration.**

I. INTRODUCTION

The cost of maintenance and the risk of unexpected, catastrophic failures in an induction motor can be determined by condition monitoring techniques. Within the mechanism of condition monitoring the previous records of the motor or statistical estimations of the motor failure is not being considered. Instead, it uses real-time data which is being obtained through experimental procedures in order to determine the fault of the motor. Thereby, this shall be considered as the key parameter for the success of condition based maintenance [1].

Usually induction motors are considered to be less maintenance, high efficient and low cost motors. However, induction motors can be subjected to several faults during operation, though they are considered to be reliable motors compared to other type of motors.

These faults which occur in induction motors can be classified under three main categories [2].

- Electrical faults
- Mechanical faults
- Environmental faults

Throughout the time there have been plentiful researches carried out in determining which parts of the induction motors are widely subjected to failures. According to Krmakar, Chattopadhyay, Mita and Sengupta most common component which is to be failed is bearings. Then comes the stator and rotor respectively [2].

Another similar research was carried out by Sin, Song and Ertugul. As per the research they have carried out it had been determined that 40% of the faults in an induction motor occurs due to bearing failures. 38% of the faults due to stator failure and 10% of the faults due to rotor [1].

Considering the faults which have been obtained by these researches an average chart of faults which could possibly occur in an induction motor shall be illustrated as follows.

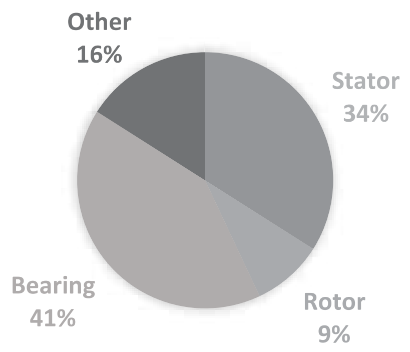

Fig. 1 Common faults in an induction motor

II. FAULTS IN AN INDUCTION MOTOR

A. *Bearing Faults*

The bearing of an induction motor is manufactured to be placed at the rear end and front end of the rotating shaft or the rotor. The main objective of manufacturers to equip bearings in induction motors is to make the rotor rotate smoothly reducing the friction. Considering about the parts of the bearing, these consist of an inner race, which have been attached to the rotor, outer race, which have been attached to the housing of the motor and set of balls which are in between the inner race and outer race of the bearing. Moreover, by applying grease or oil between the races can reduce the friction which is being transmitted to balls subsequently. Fatigue failure, lubrication failure, contamination and misalignment can be depicted as major causes to fail a bearing [2].

B. *Stator Faults*

Almost 35% of faults in an induction motor are caused due to failure of the stator. Thus, it is clear that this component is also a component which fails more often.

The stator can be also considered as a component within the induction motor which shall be subjected to numerous stresses during the time of operation. These stresses which develops while the motor is under operation can be minimized in an effective manner if proper care was taken [2].

Moreover, Sin, Soong and Ertugul highlighted that the stator fault in an induction motor could lead to producing imbalanced magnetic fields depending on the heat which is being generated by the induction motor. Thereby, this fault can lead the motor to create large scale vibrations causing damage to other internal components within the induction motor. If the failure was not identified and fixed it shall further damage the stator windings of the motor [1].

These faults which occur in the stator shall be classified into two categories,

- Faults in the winding of the stator
- Faults in the frame and lamination of the stator.

Out of these faults the most common and crucial fault which could occur in an induction motor due to stator failure is the faults in the winding of the stator.

C. Rotor Faults

Rotor faults are comparatively less significant when it is being compared to bearing failures and stator failures. As per Fig. 1, it illustrates only 9% of rotor faults in an induction motor. Rotor faults can also be categorized further as broken rotor bar fault and Rotor mass unbalance [1, 2].

D. Other Faults

Apart from these major faults which could occur in an induction motor there are less significant faults which still could occur damaging the internal components of the induction motors.

1) Single Phasing Fault

The single phasing fault in an induction motor shall be considered to be one of the electrical fault occurs. This type of fault is present only in three phase induction motors. Thus, when one phase of an induction motor is not functioning properly the motor will still keep on functioning from the rest two phases. The common signs of an induction motor are having the single phase can be identified when the motor starts functioning below the speed which has been named on the name late of the motor whilst producing high level vibrations. Blown fuses, incorrect setting of protection devices provided along with the motor and broken relay contacts or damaged relay contacts are main causes of an induction motor to fail due to the single phasing fault [3].

2) Crawling

The fault which is considered to be crawling is an electromechanical fault which occurs only in induction motors which are manufactured with a squirrel cage [2]. First signs of identification of this fault is that the induction motor tends to produce high vibrations as well as noise, while operating at lower speeds than it have been named on the name plate. Moreover, the speed can be considered as low as one seventh of the average synchronous speed of the motor. The reason to a motor to crawl is because there are odd harmonics in the sine wave. In a healthy motor the sine wave which produce is an absolute perfect sine wave [4].

3) Over Voltage and Under Voltage

Over voltage fault and under voltage fault occurs when the voltage level which has been supplied through the supplier keeps on fluctuating. Over voltage fault causes the insulations to be stressed and under voltage fault causes an unexpected rise of temperature through the windings of the stator due to excessive line current [2].

4) Overload

Overload occurs when a greater load has been provided to an induction motor than the load which has been specified in the name plate. The following fault in an induction motor can be easily determined by reduction in torque and comparatively lower torque than it has been mentioned in the name plate. Overloading in an induction motor can cause great damage to other components which are located inside of the motor including bearings, oil seals, rotor, etc.

III. CONDITION MONITORING AND ITS IMPORTANCE

Induction motors are commonly used in industrial applications due to its distinctive features such as low maintenance, low cost, high efficiency, etc. However, these types of motors have limitations as well as the other motors which are available in the market. Henceforth, in an instance where the induction motor exceeds the limitations which have been mentioned in the name plate the motor can damage the internal components. Thus, the condition of the motor should be monitored accordingly to minimize these failures [2].

As per Krmakar, Chattopadhyay, Mita and Sengupta there are three key maintenance strategies in conducting maintenance activities in these types of motors.

A. Breakdown Maintenance

Within this mechanism the motor is being fixed after it breaks down, which could take a longer period of time to fix the issue. It has been identified that this mechanism is a costly mechanism compared to other two strategies of maintenance. Thus, the following strategy of maintenance shall be considered to be an inefficient strategy.

B. Fixed Time Maintenance

In order to perform the following strategy highly skilled technicians will be required. Thereby, this method is considered to be costly as well as the downtime is considerably higher than in the other two strategies.

C. Condition Based Maintenance

This strategy of monitoring the condition of induction motors was considered as the most successful strategy out of all three strategies. The reason behind this is that the condition of the motor has been determined while the motor is under operation. Preventive maintenance strategies will be carried out by the technicians if a fault has been identified.

By practicing the following strategy, the reliability of the motor can be increased whilst reducing the downtime effectively. Furthermore, the maintenance cost can be cut down accordingly.

IV. STRATEGIES OF CONDITION MONITORING

Within the modern context in identifying the faults in an induction motor numerous strategies related to condition monitoring are used such as vibration analysis, acoustic emission, thermal imaging, motor current analysis, surge test etc.

A. Vibration Analysis

Vibration analysis is considered to be one of the oldest strategies still in use, which is considered to be the first type of analysis. An induction motor consists of no faults tends to operate under less vibrations. However, when a fault is gradually developing the vibration starts to increase. Accelerometers and piezo electric sensors are widely used in order to capture these vibrations in the induction motors [1]. Moreover, this strategy is considered as a best strategy to perform predictive maintenance [5].

Performing the condition monitoring strategy of vibration analysis highlights several benefits,

- Life span of the motor can be increased.
- Component damage risk can be reduced.
- Reduction in production downtime.
- Increasing the efficiency of maintenance.
- Prevention of sudden failures.

Software such as MATLAB and LabView been used to analyze the signals further which has been obtained by the transducers. Thus, by analyzing the frequency spectrum it can be determined the faulty component in the induction motor. Thereby, vibration analysis is one of the most useful strategies in condition monitoring.

B. Thermal Imaging

The strategy of thermal imaging is associated with the temperature of the induction motor and the heat it produces. Usually an induction motor produces heat when it is under operation. The phenomena behind this is that the windings of the stator are shorted. Thus, it tends to produce very high current [6]. To capture the heat, IR (Infrared) cameras are used and then converted to videography for further analysis.

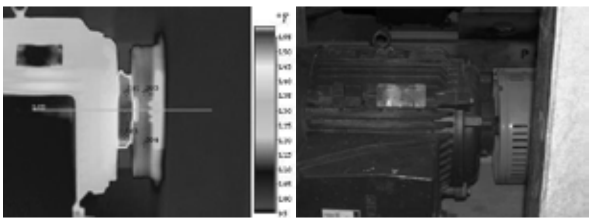

Fig. 2 - An induction motor with faulty bearing [7]

As it has been illustrated in Fig. 2 the following motor is having a faulty bearing. This can be easily determined due to infrared image obtained. However, through naked eye it is not possible to obtain an IR image. Thus, thermal imaging is considered to be one of the most used strategies when monitoring the condition of machinery.

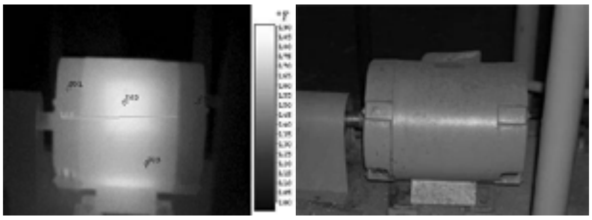

Fig. 3 - A motor which is been heated [7]

Another similar example is illustrated upon figure 3 of a motor which has been heated up during the time of operation through an infrared camera and through naked eyes.

C. Acoustic Emission Testing

Strategy of acoustic emission is another commonly used strategy in order to determine the faults in an induction motor. Usually when performing this type of condition monitoring technique the sensors are placed on the surface of the motor. When the motor starts operating if there is any defect the motor tends to activate the fault. Thereby the faulty spectrum shall be obtained through the sensors which are mounted on the surface of the motor. This strategy does not cause any physical damage to the motor and also it provides real-time process information. However, there are several limitations within this mechanism such as, these sensors are susceptible to attenuations and background noises which are really high [8, 9].

D. Noise Monitoring

Faults in an induction motor can also be determined by monitoring the noise it produces. Using the specially designed equipment the spectrum of the noise can be obtained. However, this strategy is not an accurate strategy of monitoring the condition of the induction motors .The phenomena behind this is background noise cannot be eliminated while obtaining the readings of the induction motor. Thus, this technique is not commonly used within the industry [6].

E. Motor Current Signature Analysis

This technique is widely used within the industry to detect the bearing damages and broken rotor bars in an induction motor. Within the following mechanism the stator current shall be used to obtain the power spectrum. However, if the rotor bars are broken the current is not supplied through those bars making the rotor bas asymmetric. This phenomena can cause reduction in harmonics related to stator winding currents [6, 10].

F. Air Gap Torque Monitoring

When an induction motor is under operation between the flux and current linkages the air gap torque is produced. However, the harmonics contain zero conditions when an induction motor is operating under its normal conditions. If there is an unbalanced power supply to the motor these harmonics can deviate from zero condition to non-zero condition. Thus, rotor faults and unbalanced stator windings can be determined by the following technique [6, 8].

G. Surge Test

The faults in the windings of the stator can be effectively determined by the following mechanism. Moreover, if a motor is about to fail electrically the failure in the stator winding can be considered to be one of the first signs. Reduction of windings in the stator of the motor is the reason it fails in following manner [11]. Identical high voltage pulses and high frequencies shall be provided to two phases of the motor while the other remaining phase is being grounded. Therefore, through the pulses which are reflected, the winding and insulation faults can be detected [8].

H. Instantaneous Angular Speed

Determining the issues related to non – symmetric stator cores can be identified using the following technique. This technique is defined as “variation of the angular speed within one revolution of the motor shaft”. As well as to determine the faults in stator core this technique is also used in order to determine faults in the rotor. However, when determining the faults in the rotor of the induction motor the speed of the rotor is considered to be uniform which illustrates the difficulties in determining the faults in the rotor [1].

V. CONCLUSIONS

Reliability can be improved, and maintenance cost can be reduced effectively through accurate means of monitoring the condition of the induction motors. The techniques of condition monitoring are based on sampling the signals which were obtained through the specially designed transducers and processing the signals through various software such as Matlab and LabView to analyze the fault. Hence, deciding which component is faulty and repairing or replacing would be convenient. The following paper provides in detail survey related to condition monitoring and fault diagnosis of induction motors.

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