Analysis of the Induction Motor used in Temperature Controller Machine by Condition Based Monitoring System

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Abstract

Condition monitoring of induction motor have been a challenging task for the engineers and researchers mainly in industries. There are many condition monitoring methods, including visual monitoring, vibration monitoring, thermal monitoring, chemical monitoring, acoustic emission monitoring but all these monitoring methods require expensive sensors or specialized tools whereas current monitoring out of all does not require additional sensors. Current monitoring techniques are usually applied to detect the various types of 3-phase induction motor faults such as Rotor fault, short winding fault, air gap eccentricity fault, bearing fault, load fault etc. If any fault and failures occurs in the induction motor in any time can lead to excessive downtimes and causes a great losses in terms of revenue and maintenance. Therefore, condition monitoring for early fault detection of the motor is needed for the protection of the motor. In the present paper, survey of different types of faults in induction motor generate and their diagnosis techniques.

Keywords: Artificial intelligence techniques for fault diagnosis, Condition monitoring, Fault detection and diagnosis, Induction motor

I. INTRODUCTION

The studies of induction motor behaviour during abnormal conditions due to presence of faults and the possibility to diagnose these abnormal conditions have been challenging topic for many electrical machine researchers. There are many condition monitoring methods including vibration monitoring, thermal monitoring, chemical monitoring, acoustic emission monitoring but all these monitoring methods require expensive sensors or specialized tools whereas current monitoring out of all does not require additional sensors.

Three phase induction motors are commonly used in the industry because of its robustness, simplicity of its construction and high reliability. Although induction motors are reliable we cannot avoid the possibility of failure. These failures may be very harmful to the motor and hence early detection of failure is needed before they affect the whole operational performance.

The percentage of failures in induction motor component is as follows:
- Bearing related faults: 40%.
- Stator winding faults: 38%
- Rotor related faults: 10%
- Other faults: 10%

The major faults of electrical machines can broadly be classified as the following:
- Stator faults resulting in the opening or shorting of one or more of a stator phase winding;
- Abnormal connection of the stator windings;
- Broken rotor bar or cracked rotor end rings;
- Static and/or dynamic air gap irregularities;
- Bent shaft;
- Shorted rotor field winding;
- Bearing and gearbox failures.

Processing techniques are used for condition monitoring and fault detection of induction motors. The signal processing techniques have advantages that these are not computationally expensive, and these are simple to implement. Therefore, fault
detection based on the signal processing techniques is suitable for an automated on-line condition monitoring system. Signal processing techniques usually analyze and compare the magnitude of the fault frequency components, where the magnitude tends to increase as the severity of the fault increase. Therefore, the various signal processing techniques are used for detection of common faults of induction motor. Signal processing techniques have their limitations.

In order to perform accurate and reliable analysis on induction motors, the installation of the motors and measurement of their signal need to be reliable. Therefore, the first aim of this thesis is to design an experimental procedure and an experimental set up that can accurately repeat the measurements of signals and can introduce a particular fault to the motor in isolation of other faults. Stator current contains unique fault frequency components that can be used for detection of various faults of motor. The methods proposed in this research work allow continuous real time tracking of faults in induction motors operating under continuous stationary and non-stationary conditions. Therefore, second aim of this research work is to investigate how the presence of common faults, such as rotor bar fault, short winding fault, air gap eccentricity, bearing fault, load fault, affect on different fault frequencies under different load conditions.

II. VARIOUS TYPES OF FAULTS IN THREE PHASE INDUCTION MOTOR

There are various faults in induction motors. This section describes different faults. The different faults classifications are based on the internal and external type of major faults occurring in the machine. The internal faults are placed under mechanical fault and electrical fault categories. While the external fault placed under electrical, mechanical and environmental fault.

A. Stator Faults

In induction motor the stator faults are occurs mainly due to inter turn winding faults caused by insulation breakdown. They are generally known as phase-to-ground or phase-to-phase faults. Almost 30%-40% faults are stator faults. It is very important to detect them in time because they can lead to the total destruction of the motor. Now a days stator current signal analysis is a popular tool to find out stator winding faults due to the advantage of cheap cost, operation and multifunction. Due to the faults in the induction motor the magnetic field in the air gap of the machine will be non-uniform and results in harmonics in the stator current which can be signatures of several faults.

- Stator faults resulting in the opening, shorting and grounding of one or more stator phase winding.
- Rotor faults caused by the broken rotor bar or cracked rotor end rings.
- Mechanical failure due to bearing failure and air gap eccentricities.
- External faults due to incorrect connection of stator and utility supply.

B. Rotor faults

From the survey it has been showed that 10% faults of total induction motor failures are caused by rotor winding. Induction motor rotor faults are mainly broken rotor bars because of pulsating load and direct on line starting. It results into fluctuation of speed, torque pulsation, vibration, overheating, arcing in the rotor and damaged rotor laminations.

The reasons for rotor bar and end ring breakage are as following:
1) Thermal stresses :-Thermal stresses due to thermal overloaded and unbalance, hot spot or excessive losses rotor sparking (mainly fabricated rotor).
2) Magnetic stresses :-Magnetic stresses caused by electromagnetic field, unbalance magnetic pull, electromagnetic noise and vibration
3) Residual stresses :-Residual stresses due to manufacturing problems
4) Dynamic stresses :- Dynamic stresses arise from shaft torque, centrifugal forces and cyclic stresses
5) Environmental stresses:- Environmental stresses caused by contamination and abrasion.
6) Mechanical stresses: Mechanical stresses due to loose lamination, fatigued parts, bearing failure etc.

C. Bearing faults

The majority of electrical machines use ball or rolling element bearings and these are one of the most common causes of failure. These bearings consist of an inner and outer ring with a set of balls or rolling elements placed in raceways rotating inside these rings. Faults in the inner raceway, outer raceway or rolling elements produce unique frequency components in the measured machine vibration and other sensor signals. These bearing fault frequencies are function of the bearing geometry and the running speed. Bearing faults can also cause rotor eccentricity. A common cause for rolling element bearing failure is flaking, which occurs due to localized fatigue and results in the contamination of the lubricant oil with metal fragments. Other internal causes for bearing faults are vibration, inherent eccentricity and bearing current due to solid state drives. External causes are contamination and corrosion, improper lubricant and improper installation. About 40% of faults are bearing related.

This fault contains over 40% of all machine failures. Bearings are common elements of any electrical machines. The rotary motion of shaft is permitted by the bearings. As seen above the bearings are single largest cause of machine failures. Basically bearings consists of two rings which are known as the inner and the outer rings. A set of balls or rolling elements placed in raceways rotate inside these rings. A continuous stress on the bearing results into the fatigue failures. These failures are at inner or outer races of the bearings. This kind of failures results in rough running of bearings which results in detectable vibrations and increased noise levels. Contamination, corrosion, improper lubrication, improper installation and brine ling are the external factors which are also responsible for the bearing fault. Now when flux disturbance like rotor eccentricities occurs, it results in unbalanced shaft voltages and currents which are also the reason for bearing failures.

D. Eccentricity related faults

Unequal air gap that exist between stator and rotor is known as machine eccentricity. When the eccentricity becomes larger, the resulting unbalanced radial forces can cause stator and rotor rubs, and this can result in stator and rotor core damage. The eccentricity is divided into two parts:
1) Static eccentricity
2) Dynamic eccentricity.

In the case of static eccentricity the position of the minimal radial air gap length is fixed in space. Incorrect positioning of the stator or rotor core at the commissioning stage results into static eccentricity. In the case of dynamic eccentricity, the centre of the rotor is not at the centre of the rotation and the position of minimum air gap rotates with the rotor. This misalignment caused due to the several factors such as bent rotor shaft, bearing wear or misalignment etc. An air gap eccentricity is permissible up to 10%. An inherent level of static eccentricity exists even in newly manufactured machines due to manufacturing and assembly methods.

III. CONDITION MONITORING AND NEED OF CONDITION MONITORING

CM has great significance in the business environment due to the following reasons
- Increased machine availability and reliability
- Improved operating efficiency
- Improved risk management (less downtime)
- Reduced maintenance costs (better planning)
- Reduced spare parts inventories
- Improved safety
- Improved knowledge of the machine condition (safe short-term overloading of machine possible
- Extended operational life of the machine
- Improved customer relations (less planned/unplanned downtime)
- Elimination of chronic failures (root cause analysis and redesign)
- Reduction of post overhaul failures due to improperly performed maintenance or reassembly.
- It uses certain signal processing techniques to detect the faults related to different parameters which provides us a detail analysis of problem.
- The CM is a non invasive technique of measurement, i.e. the measurement is made outside the induction motor (the internal body measurement is not required).
- The Condition Monitoring (CM) is useful for the areas such as offshore oil industry, petrochemical industry, gas terminal and oil refineries where the induction motor is frequently installed in large no.

IV. CONDITION MONITORING OF INDUCTION MOTOR

It is required to detect, identify and then classify different kinds of failure modes that can occur within a machine system. Often several different kinds of sensors are employed at different positions to acquire vital signals from machine. These signals are 37
V. CONDITION MONITORING TECHNIQUES

Most commonly used techniques are described below

A. Visual Monitoring:
This method ranges from a simple visual inspection by the unaided eye, through to the use of bore scopes for better access, microscopes to increase magnification, and closed circuit television cameras.

B. Thermal Monitoring:
Thermal monitoring can, in general, be used as an indirect method to detect some stator faults (turn-to-turn faults) and bearing faults. In a turn-to-turn fault, the temperature rises in the region of the fault, but this might be too slow to detect the incipient fault before it progresses into a more severe phase-to-phase or phase-to-neutral fault. In the case of detecting bearing faults, the increased bearing wear increases the friction and the temperature in that region of the machine. This increase in temperature of motor can be a detected by thermal monitoring. The thermal monitoring of electrical machines can be completed by measuring local temperature of the motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a electric surface of a solid or even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter. Due to the shorted turns in the stator winding the value of electric discharge, which is even higher than a motor or by the estimation of the parameter.

C. Vibration Monitoring:
The vibrations are produced mainly due to the inter turn winding faults, single phasing and supply voltage unbalance. It is also a parameter which is very useful for monitoring the health of induction motor. Vibrations in electric machines are caused by forces which are of magnetic, mechanical and aerodynamic origin. Vibration monitoring technique is widely used to detect mechanical faults such as bearing failures or mechanical imbalance. A piezo-electric transducer providing a voltage signal proportional to acceleration is often used.

D. Air Gap Torque Monitoring:
The air gap torque is produced by the flux linkage and the currents of a rotating machine. It is very sensitive to any unbalance created due to defects as well as by the unbalanced voltages. If the harmonic contains zero frequency that means the motor is operating in normal condition. The forward stator rotating field produces a constant while the backward stator field produces a harmonic torque. If we consider the speed of forward and backward rotating field as +ωs, -ωs, the speed of rotor as ωr(1-s), and speed of rotor magnetic field as sωs, then the value of the frequency will be -2ωs. Hence it indicates the gap in the stator winding and voltage.

E. Noise Monitoring:
By measuring and analyzing the noise spectrum we are able to do noise monitoring. Due to the air gap eccentricity the noise is produced. This noise is used for fault detection in induction motor. However it is not the accurate way to detect the fault by noise monitoring because of the noisy background from the other machines. Ventilation noise is associated with air turbulence, which is produced by periodic disturbances in the air pressure due to rotating parts. The noise is due to the Maxwell’s stresses that act on the iron surfaces. These forces are responsible for producing the noise in the stator structure.

F. Motor Current Signature Analysis:
MCSA is a non-invasive, online monitoring technique for the diagnosis of problem in induction motor. A full mathematical analysis (with experimental verification) of a three phase induction motor operating with broken rotor bars was published by Williamson and Smith (1982)- this gives an excellent in-depth analysis. It is well known that a three phase symmetrical stator winding fed from a symmetrical supply will produce a resultant forward rotating magnetic field at synchronous speed, and, if exact symmetry exists, there will be no resultant backward rotating field. In most applications stator current is monitored for diagnosis of different faults of induction motor.

G. Partial Discharge:
Partial discharge can be described as an electrical pulse or discharge in a gas filled void or on a dielectric surface of a solid or liquid insulation system. This theory involves an analysis of materials, electric fields, arcing characteristics, pulse wave propagation and attenuation, sensor spatial sensitivity, noise and data interpretation. This is a small electric discharge, which occurs due to insulation imperfection. One of the main factor of partial discharge is poor manufacturing which results into voids or air pockets, which get discharged. A deteriorated winding has a PD activity approximately 30 times or even higher than a
winding in good condition. So this is a very useful technique to monitor the effectiveness of the winding and also the health of the motor.

**II. Wavelet Analysis:**

Wavelets are functions that can be used to decompose signals, similar to how to use complex sinusoids in Fourier Transform to decompose signals. The wavelet transforms computes the inner products of the analyzed signal and family of wavelet. In general terms, mathematical transformations are applied to signals to obtain further information from that signal that is not readily available in the unprocessed signal. Most of the signals in practice are time domain signals. That is, whatever that signal is measuring, is a function of time. The frequency spectrum of a signal is basically the frequency components of that signal. It indicates what frequencies exist in the signal.

**I. By using Thermographs Instrument:**

Modern thermal imaging cameras contain computers to directly indicate the temperature of the surfaces, as well as to provide the ability to compare past images with the present image, enabling changes in the thermal image to be easily detected.

**J. Expert Systems:**

It is a computer program for performing a suitable data acquisition and a FFT is to be activated for stating the stationary condition of the machine. By using this technique the harmonic contents are eliminated and perform the reduction of the large amount of spectral information to a suitable level. The system can detect the health of the motor by using signature extraction and fault identification from the various harmonic components and from the condition of the motor.

**K. Fuzzy Logic System:**

For induction motor fault detection, the machine condition is described by linguistic variables. Basic tools of fuzzy logic are linguistic variables. Their values are words or sentences in a natural or artificial language, providing a means of systematic manipulation of vague and imprecise concepts. Fuzzy subsets and the corresponding membership function is constructed for any one parameter for example stator current amplitude. A knowledge base consisting of rule and databases is formed to support the fuzzy inference. Fuzzy rules and membership functions are constructed by observing the data set. Once the form of the initial membership functions has been determined, then fuzzy if-then rules can be derived.

**L. Artificial Neural Network:**

The architecture of the neural network indicates the arrangement of the neural connection as well as type of units characterized by an activation function. The processing algorithm specifies how the neuron calculates the output vector for any input vector and for a given set of weights. The adjustment of weights is basically known as the training of the neural network. The fault severity evaluation can be done by the supervised neural network, which can synthesize the relationship between the different variables. The neural network can acquire knowledge through the training algorithm and store the knowledge in synaptic weights.

The objective of training the network is to adjust the weights so that application of a set of inputs produces the desired set of outputs.

**M. Neural Fuzzy System:**

By combining ANN techniques and fuzzy logic, a neural-fuzzy system is created. The neural-fuzzy is an ANN structured upon fuzzy logic principles, which enables this system to provide qualitative description about the machine condition and the fault detection process. Fuzzy parameters of membership functions and fuzzy rules provide the knowledge.

**VI. Signal Processing Techniques**

There are several signal processing techniques which are very useful for fault diagnosis purpose. These are classified below:

1) Frequency domain Fast Fourier Transform (FFT)
2) Time-Frequency techniques Short Time Fourier Transform (STFT)
3) Wavelet Transform (WT)

**VII. Artificial Intelligence Techniques**

Artificial neural networks (ANNs), fuzzy, or neuro-fuzzy systems are now used extensively for speed, torque estimation, and solid-state drive control of both dc and ac machines. They are particularly suited for ac machines’ applications where the relationships between motor current and speed are nonlinear. These AI techniques are now being extended as a decision making tool to MCSA results for condition monitoring and fault detection of machines. Speed is estimated from measured terminal
voltage and current. Induction machines of different power ratings can be accommodated using minimal tuning of the neural network. Detection effectiveness of 93% or more is achieved.

VIII. LEAKAGE CURRENT ANALYSIS - THROUGH BEARING

Causes of bearing damage, for the most part, can be broadly classified within three categories:
- Lubrication
- Mechanical
- Electric Discharge Machining (EDM) or Bearing Currents

It is important to seek to identify the specific cause of failure in order to not repeat the failure, often within a short period of time. Bearing current failures, for example can occur in as short a time as one week after installation. Others, such as insufficient grease, can take several years to develop into a problem.

IX. LITERATURE STUDY

A. S.K. Sethiya[1]

Condition based Maintenance or predictive maintenance, uses primarily nondestructive testing techniques, visual inspection, and performance data to assess machinery condition. It replaces arbitrarily timed maintenance tasks with appropriate maintenance task at only when warranted by equipment condition. Condition-monitoring maintenance task intervals must be properly understood and task intervals should be determined based on the expected P-F interval. The P-F interval governs the frequency with which the predictive task must be done. Technological advances are accepted and applied to CBM systems, which includes improved knowledge of failure mechanisms, advancements in failure forecasting techniques, advancements in monitoring and sensor devices, advancements in diagnostic and prognostic software, acceptance of communication protocols, developments in maintenance software applications and computer networking technologies.

B. Ravi C. Bhavsar[2]

Condition Monitoring of electrical machines are increasing due to its potential to reduce operating costs, enhance the reliability of operation and improve service to customers. Condition Monitoring of induction motors is a fast emerging technology for online detection of incipient faults. This paper includes a comprehensive review of different types of faults occur in induction motor and also point out the latest trends in condition monitoring technology. Most frequent electric faults in case of induction motor has been described over here along with their detection techniques. It also contains the different monitoring methods of three phase induction motor which are used previously and also important for now a days like AI based detection techniques.

C. Sudhanshu Goel[3]

This work is aimed to act as a guide for an industrial or academic user to choose the right technique for condition based maintenance of their equipment and to present a comprehensive review of prevalent condition monitoring technologies, i.e. Vibration signal analysis, Acoustic emission testing, Ultrasound condition monitoring, Infrared thermography and lubrication oil analysis. A detailed review of condition monitoring techniques which can be used to detect a particular type of fault is presented with an aim to identify the most suitable technique for fault diagnosis. It is concluded that the most suitable condition monitoring technique for a particular operation can only be decided by taking in consideration the factors like equipment under test, its loading, defect type and ambient conditions, etc.
D. Praveen Kumar Shukla [4]

CM (Condition Monitoring) is a process of monitoring the operating parameters of machine to know the monitored characteristics and to predict machine health. In industries protection of devices such as motor has become challenging work. Further in this paper, various condition monitoring techniques are given with the specific advantages and disadvantages. For the condition monitoring of alternating motor, the economical and latest method is analyzing the stator current through LabVIEW. An intelligent diagnostic condition monitoring system has been proposed. This system will provide continuous real time tracking of different faults occurring in the system and for automatic decision making estimates the severity of faults, the variety of condition monitoring techniques are available but acoustic emission and stator current analysis have proven to be most accurate and suitable techniques. Current analysis technique is however most economical. Also, an intelligent diagnostic CM system for AC motors has been proposed. This technique provides continuous real time tracking of different faults and estimates severity of faults for automatic decision making. It is expected that motor protection system as proposed in this research will be faster, more efficient and user friendly than the other techniques.

E. Neelam Mehta [5]

Small single phase Induction machine are used for home appliances hence the machine monitoring plays an important role for industrial as well as domestic appliances growth. Various fault detection method has been used in past two decades. Special attention is given to non-invasive methods which are capable to detect fault using major data without disassembly the machine. The Motor Current Signature Analysis (MCSA) is considered the most popular fault detection method now a day because it can easily detect the common machine fault such as turn to turn short ckt, cracked /broken rotor bars, bearing deterioration etc. The present paper discusses the fundamentals of Motor Current Signature Analysis (MCSA) plus condition monitoring of the induction motor using MCSA. This technique can be fairly simple, or complicated, depending on the system available for data collection and evaluation. MCSA technology can be used in conjunction with other technologies, such as motor circuit analysis, in order to provide a complete view of the motor circuit. The result of using MCSA as part of motor diagnostics program is a complete view of motor system health.

X. LITERATURE REVIEW

A brief review of most frequent electric faults in case of induction motor has been described over here along with their detection techniques. This paper also contains the different monitoring methods of three phase induction motor which are widely used like AI based detection techniques. By applying the data collected through different Condition Monitoring Techniques preferably Vibration and Temperature Monitoring to the different Fault Detection Techniques such as MCSA & AI, we can find out the Faults of the Induction Motor before it will be existed in the Motor. Once we find out the Faults before it will be existed in the Motor, we can rectify or can take precautions. so we can reduces the Motor failure and also increases the availability, reliability, performance of the Motor. In different Fault Detection Techniques we observe that in the AI Techniques using the fuzzy logic fuzzy logic allows combining information from different signals together to make a more accurate judgment regarding the health of the motor.

XI. EXPERIMENTS AND RESULT:

Predictive maintenance management program utilizes a combination of the most cost-effective tools, i.e. thermal imaging, vibration monitoring, tribology, and other non-destructive testing methods, to obtain the actual operating condition of critical plant systems and based on this factual data all maintenance activities on an as-needed basis are scheduled.

XII. CONCLUSION

By applying the data collected through different Condition Monitoring Techniques preferably Vibration and Temperature Monitoring to the different Fault Detection Techniques such as MCSA & AI, we can find out the Faults of the slip ring Induction Motor before it will be existed in the Motor. We can reduce the Motor failure and also increases the availability, reliability, performance of the Motor.

- Reduction in maintenance costs: 25% to 30%
Elimination of breakdowns: 70% to 75%
- Reduction in equipment or process downtime: 35% to 45%
- Increase in production: 20% to 25%
- Increased component operational life/availability.
- Better product quality.
- Improved worker and environmental safety.

REFERENCES


