CONDITION MONITORING BASED CONTROL USING PIEZO SENSOR FOR ROTATING ELECTRICAL MOTORS

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Abstract: *A protection system for rotating electrical motors through condition monitoring to identify the problem the problematic source in the motor and to protect due to excessive vibration without human observation. Maintenance of electrical motors is important the condition monitoring of motor is gaining importance in industry to reduce the downtime time costs and increase motor reliability. In the work a simulation model has been developed using piezoelectric sensor for condition monitoring to detect the problem .If any problem is occurred in any location in the motor then vibration of the whole system increases. It extracts the maximum value of vibration signals coming from different bearing positions of the motor. If the magnitude of vibration is in "unacceptable" range. If the value of vibration is in "unsatisfactory" range then an alert on the computer screen .The "unsatisfactory" and "unacceptable" condition it displays of defective part. This system not only protects the unscheduled shut down of motors but also increases the lifetime of motor components in the present paper, MATLAB/SIMULINK software is used to diagnosis the different fault of induction motor. Fast Fourier Transform (FFT) is used for diagnosis of the different fault in induction motors. The results and observations obtained are discussed and then final conclusions are made.*

Keywords: Condition Monitoring, Vibration Analysis, motor current signature analysis, Fast Fourier Transform, MATLAB/SIMULINK.

I. INTRODUCTION

Induction motors finds application in almost every kind of industries all around the world. Although, Induction motors are extremely consistent, they are vulnerable to many types of faults. There are many methods available for detection of faults in Induction Motor but most of the methods require expensive sensor or specialized tools whereas current monitoring out of all does not require additional sensors. The Motor Current Signature Analysis uses the current spectrum of motor for locating characteristic fault frequencies.

There are countless faults in a simple motor, but these faults are difficult to detect so that any person has to go to the motor when the motor is spoiled and find that fault. In this project we have explored the types of motor and the motor fault and the causes of fault and the technique to improve it. In this project we have studied about motor and the faults in motor. We know that there are a lot of fault inside the motor. And when the motor is running then it is very difficult to detect these faults.

And until we detect the fault, the motor has gone dead. Therefore, it is very difficult to detect the fault in the motor at the running time. We have only used this project to study. So inside this project we have used two types of work. Fast Fourier Transform, MCSA (motor current signature analysis), Condition Monitoring, Vibration Analysis, MATLAB/SIMULINK.

In this project paper we will see how we have studied a motor. And at the same time, using some techniques, we can increase the efficiency of the motor and its capacity and its life. Through this project, we want to show how we can check a motor during the running condition. We will see How Can We Monitor on The Real Time Basis to the Motor. And without stopping the motor, we can know its condition. During each second we will be able to find every single condition of the motor. Under what conditions the motor is now working and what kind of improvement it can be made. All this we can check by a simulation model. Through this simulation, we will study different waveform. By these waveform, we can study the motor accurately And detect changes in the motor. And through this, we can save prematurely accidents in the motor. Motor can be saved from premature deterioration and its life can be increased.

II. VIBRATION DIAGNOSIS

Vibration control and vibration diagnostics are Different practical problems. In vibration diagnostics, the oscillation force that is applied to the defective zone defines the fault and the force is linearly related with the oscillation acceleration. For diagnostics, often both the vibration-acceleration and the vibration-velocity are measured in restricted low frequency ranges.

Most vibration measurements usually use sensors of vibration-acceleration that work based on the piezoelectric effect. For this type of sensors the output electric charge is proportional to the force applied to the sensor. The vibration signal is converted in electric signals. It is necessary to analyses this signal without losing the diagnostic information. There are very strict requirements for the analyzing instruments. The operations that the vibration analyzing instruments must perform are the following:

- Measurement of overall vibration level in a standard frequency range and using the units required by these standards.
- Spectral analysis of the vibration, by using FFT.
- Analysis of the oscillation power of separate vibration components extracted preliminary from the vibration signal. The analysis of the spectrum of random high frequency vibration signal is usually used.[9].

Fast Fourier Transform

Many different techniques can be found for the fault diagnostics of an induction motor. All of them have their own benefits and drawbacks. In this case, fast Fourier transform was chosen to be a sufficient diagnostic method for induction motor fault detection.

Due to the advancement of digital signal processing techniques the role of frequency in the signal become very important part of the detection of the fault in the induction machine. The fast Fourier transform is the advance version of the discrete Fourier transform, the data computing time is less in the FFT than discrete Fourier transforms [3]. The FFT algorithm is widely used for the detection of rotor broken bar fault, motor fault etc. It is possible to find out power spectral density of the motor stator current [4]. The stator current shows the side bands around the fundamental frequency. The fundamental frequency of the motor is 50Hz. If any fault is occurred then amplitude of the side lobes are increased that is clear indication of fault.

III OUTLINE OF THESIS REPORT

The studies of induction motor behavior during abnormal condition due to presence of faults and possibility of diagnose this abnormal condition have been a challenging topic for the many electrical machine researchers. There are many conditions monitoring method including vibration monitoring, thermal monitoring, chemical monitoring acoustic emission, but all these monitoring method required expensive sensor [2] or specialized tools whereas current monitoring out of all does not required additional sensors. The first methods utilized to detect motor failures, such as chromatographic analysis, noise analysis, temperature analysis, and vibration analysis have been slowly changing to new on-line monitoring techniques for electrical equipment. The various advanced signal processing techniques such as Fast Fourier Transform, Short Time Fourier Transform, Gabor Transform, and Wavelet Transform are used to diagnose the faults of induction motor [5]. A suitability of the signal for different type of faults is also discussed in detail. FFT is easy to implement but the drawback of this technique is that it is not suitable for analyzing transient signals. Although Short-Time Fourier Transform (STFT) can be used for analyzing transient signals using a time-frequency representation, but it can only analyze the signal with a fixed sized window for all frequencies, which leads to poor frequency resolution.

It is important to detect the fault in induction motors in an early stage itself due to the cut-throat competition and stringent reliability standards. As far as the stationary signals are concerned, conventional signal processing techniques such as FFT analysis, cosine transform etc. were used earlier to analysis the fault condition and are proved to be working perfectly. Among the total induction motor faults, around 30-40 % are related to the stator winding insulation and core. Among the possible causes, thermal stresses are the main reason for the degradation of the stator winding insulation. Generally, stator winding solution thermal stresses are categorized into two types: aging and overloading. Electrical stresses, mainly related to the machine terminal voltages, also cause insulation degradation.

Vibration problems can occur at any time in the installation or operation of a motor. When they occur it is normally critical that one reacts quickly to solve the problem. If not solved quickly, one could either expect long term damage to the motor or immediate failure, which would result in immediate loss of production. The loss of production is oftentimes the most critical concern. To solve a vibration problem one must differentiate between cause and effect. For this to happen, one must first understand the root cause of the vibration. In other words: where does the force come from? Is the vibratory force the cause of the high levels of vibration or is there a resonance that amplifies the vibratory response. Perhaps the support structure is just not stiff enough to minimize the displacement. In this paper the various sources of electrical and mechanical forces will be explained. Additionally, how the motor reacts or transmits this force and how this force can be amplified or minimized will be explained as well.

IV. BACKGROUND OF PROJECT

Induction motor have been widely use in high-performance electrical drive and industries. There are many differences Induction Motor in the market and all with it good and bad attributes. Such bad attribute is the lag of efficiency. In order to overcome this problem fault detection is introduce to the system. There are also many types of fault detector used in the industry. The productivity of the industrial systems based on these drives is very critical. Thus reliability of this operation is of paramount importance. The reliability of this operation is frequently impacted by faults which affect this operation. Thus the study of performance of these machines under fault conditions gives better idea of their reliable operation perhaps even indicating better choices while designing them. Thus the primary focus of this work is to investigate by modeling, simulating and related case studies.

V. OBJECTIVE

The objectives of this project are:

i. To fulfill the requirement for the Engineering Project.

ii. To explorer and apply the knowledge gain in lectures in to practical applications.

iii. To fault diagnosis the fault of Induction motor with motor current signature analysis and comparing with Fast Fourier Transform (FFT) using MATLAB simulation software.

iv. To analyze the behavior of the induction motor under faulty conditions.

v. To design the motor current signature analysis and Fast Fourier Transform (FFT) and tune it using simulation.

vi. To compare and analyze the result between motor current signature analysis and Fast Fourier Transform (FFT) simulation result using Induction motor in MATLAB.

vii. 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, effect on different fault frequencies under different load conditions .

viii. In this research work, condition monitoring and fault detection of induction motors is based on the signal processing techniques. 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 third aim of this thesis is to utilize the various signal processing techniques for detection of common faults of induction motor.

Signal processing techniques have their limitations. For example, some faults could be not diagnosed using Fast Fourier Transform, if the loading condition is too low or the fault is not too severe [6]. Therefore, the final aim of this thesis is to investigate new features using different techniques such as Fast Fourier Transform (FFT), to find better features for detecting common faults under different loading conditions.

VI. NEED FOR CONDITION MONITORING

Rotating electrical machines are the essential components in industry. The unscheduled shut down caused by a failure of machines can cause enormous costs. The most common types of faults in rotating electrical machines have been categorized according to the different components of machines [11,12] -(i) Stator fault (37%), (ii) Rotor fault(10%), (iii) Bearing faults (41%), (iii) Other fault (12%).

Condition monitoring is defined as the continuous evaluation of the health of the plant and equipment throughout its service life. It is important to be able to detect faults while they are still developing. This is called incipient failure detection [7]. The incipient detection of motor failures also provides a safe operating environment. It is becoming increasingly important to use comprehensive condition monitoring schemes for continuous assessment of the electrical condition of electrical machines. By using the condition monitoring, it is possible to provide adequate warning of imminent failure. In addition, it is also possible to schedule future preventive maintenance and repair work. This can result in minimum down time and optimum maintenance schedules [8]. Condition monitoring and fault diagnosis scheme allows the machine operator to have the necessary spare parts before the machine is stripped down, thereby reducing outage times. Therefore, effective condition monitoring of electric machines is critical in improving the reliability, safety, and productivity.

EXISTING CONDITION MONITORING TECHNIQUES

This research is focused on the condition monitoring and fault diagnosis of electric machines. Fault diagnosis is a determination of a specific fault that has occurred in system. Condition monitoring has great significance in the business environment due to following reasons:

- To reduce the cost of maintenance
- To predict the equipment failure
- To improve equipment and component reliability
- To optimize the equipment performance
- To improve the accuracy in failure prediction

The condition monitoring of electrical and mechanical devices has been in practice for quite some time now. Several methods have evolved over time but the most prominent techniques are thermal monitoring, vibration monitoring, and electrical monitoring, noise monitoring, torque monitoring and flux monitoring [5].

The most commonly used condition monitoring system is the vibration-based condition monitoring. The vibration monitoring technique is based on the principle that in running condition all systems produce vibration. When a machine operates properly, vibration range is small; however, when a fault develops and some of the dynamic processes in the machine change, the vibration also changes. Vibration based condition monitoring is the most reliable method to assess the overall health of a rotating motor drive system. Vibration based condition monitoring system requires storing of a large amount of data. Multiple sensors are mounted often to measure the vibration on different parts of the machine. In abnormal condition the machine vibration will be very high.

VII. SIGNAL PROCESSING TECHNIQUES FOR FAULT DETECTION IN INDUCTION MOTOR

The first step for condition monitoring and fault diagnosis is to develop an analysis technique that can be used to diagnose the observed current signal to get useful information. There are several signal processing techniques which are very useful for fault diagnosis purpose. These are classified below [5, 14, and 15]:

1. Frequency domain: Fast Fourier Transform (FFT)
2. Time-Frequency techniques:
    a. Short Time Fourier Transform (STFT)
    b. Gabor Transform (GT)
3. Wavelet Transform (WT)
4. Time series methods
5. Fuzzy logic
6. Artificial Intelligent
7. PI controller

VIII. FAULT DETECTION FOR THE MOTOR CURRENT SIGNATURE ANALYSIS (MCSA) AND FAST FOURIER TRANSFORM (FFT):

The techniques of fault diagnosis consist of using fast Fourier transform (FFT) or MCSA or extraction component, feature cluster component, and the fault decision component. In order to diagnose the fault in stator short circuit, Motor Current Signature Analysis or (MCSA) is utilized. Techniques of signal processing such as the FFT are formed on the basis of load, fundamental frequency of constant stator, assumption on sufficient load and the speed of motor.

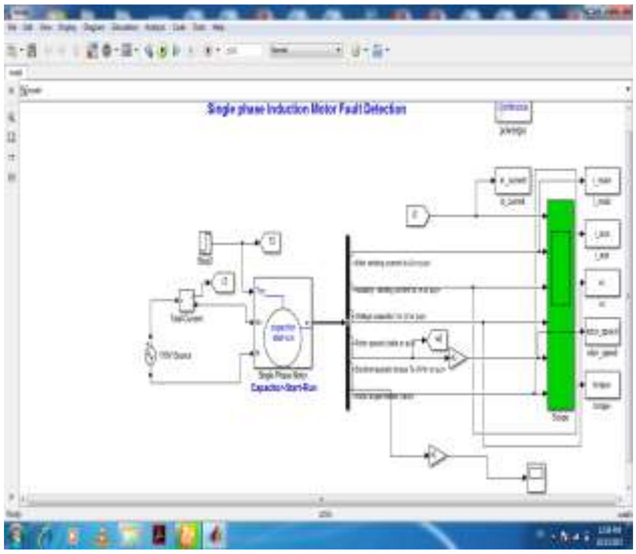

Figure 1. Simulink model of an induction motor

In this simulation model, we have analyzed the motor. First, the normal condition of the motor has been kept. In which initial value of different parts of the motor has been entered. After this the Normal condition of the motor was prepared. After considering the normal condition of the motor, separate value of the motor is different from the initial value of the motor has been entered. In the simulation model, comparison of different parts of the motor in normal and abnormal condition is considered. After analyzing, the fault in the motor is detected.

IX. RESULT DISCUSSION AND CONCLUSION

The below figure shows the voltage and current waveform for the Simulink model of figure 1 where the output will be normal till the fault occurs. At the time the fault occurs, the input trips off and the motor stops its operation.

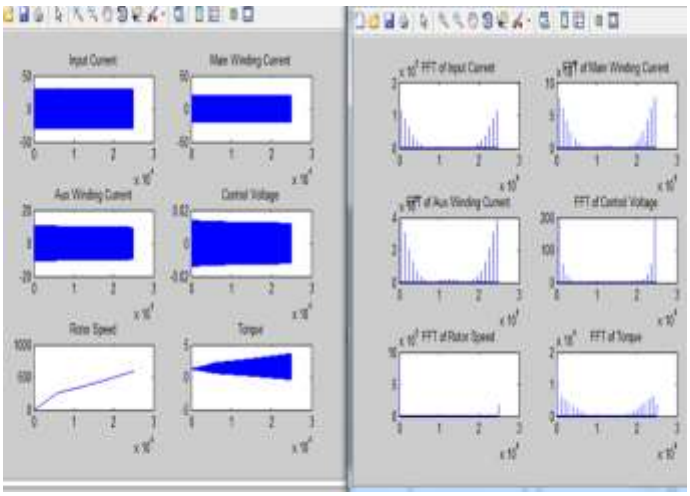

Figure 2. Simulation output of IM during normal operation

The above figure 1 shows Simulink model of an Induction Motor. The induction motor was simulated during starting from rest with rated voltage applied and no mechanical load. health of induction motor, Stator input voltage, speed and torque, symmetrical components of stator current, symmetrical components of stator induced voltage, symmetrical components of stator input voltage are shown. The above simulation runs for 2.0 seconds. The motor is started from rest with rated voltage and no load. From the output of the FFT it is seen the health of the motor remains good after the transient time. Figure 2 shows the output of IM and FFT output.

The above figure 2 shows the output waveform for IM which shows the normal flow of motor current till the fault occurs, when the fault occurs the motor operation stops.

The above figure shows the voltage and current waveform for the Simulink model of figure 2 where the output will be normal till the fault occurs. At the time the fault occurs, the input trips off and the motor stops its operation.

A broken bar causes several effects in induction motors. A well know effect of a broken bar is the appearance of the so-called sideband components. These sidebands are found in the power spectrum of the stator current on the left and right sides of the fundamental frequency component.

Other electric effects of broken bars are used for motor fault classification purposes including speed oscillations, torque ripples, instantaneous stator power oscillations, and stator current envelopes. Here the fault monitoring method is based on torque ripples for broken bar detection, while the fault diagnostic method is based on the three-phase stator current envelope for classification of broken rotor bars and inter-turn short circuits.

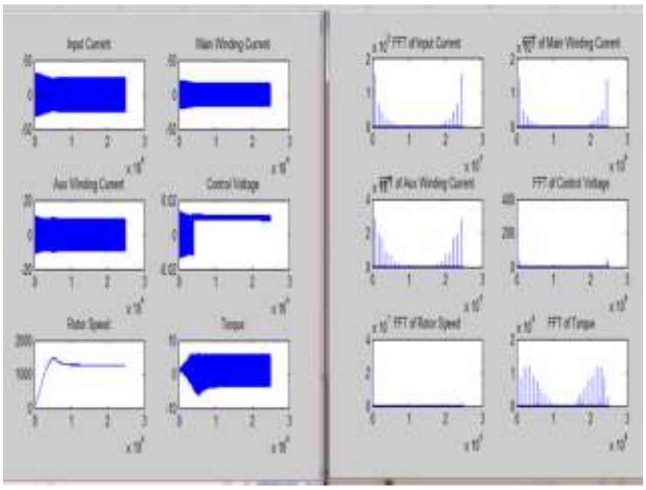

Figure 3. Simulation output of IM during faulty condition.

The above figure shows the speed and torque waveform which is abnormal condition after few oscillations and when a fault occurs.

The above figure 3 shows the voltage and current waveform for the Simulink model of IM where the output of motor is abnormal. Figure 3 shows the faulty condition of the motor At the time the fault occurs, the input trips off and the motor stops its operation.

In the hardware model, using the Piezo sensor, with the help of vibration, sensor has detected changes in the motor. The fault has been detected by placing the sensor on the body of the motor. After comparing vibration of motor, the normal and abnormal condition is detected.

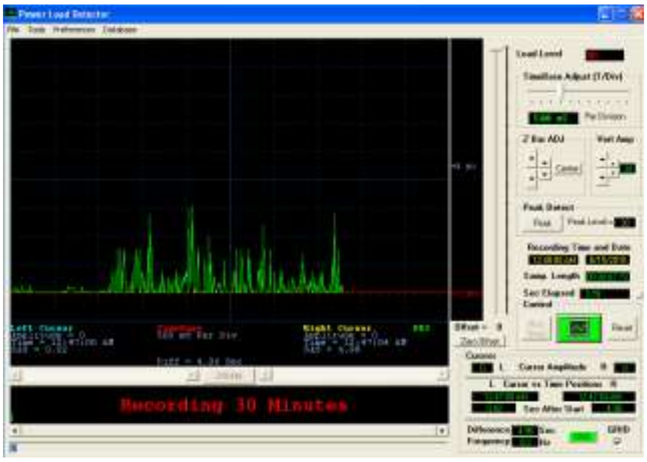

Figure 4. 50 rpm geared motor in normal condition

figure 4 shows the output signal of 50 RPM geared motor in normal condition. After detecting the vibration signal from motor with the help of piezo sensor, output of the motor vibration is as shown in the figure 4. This output signal shows the normal operation of motor. When the motor works on the normal condition, then the vibration inside the motor is much less. In the normal operation of motor vibration spikes is low as shown in the figure 4.

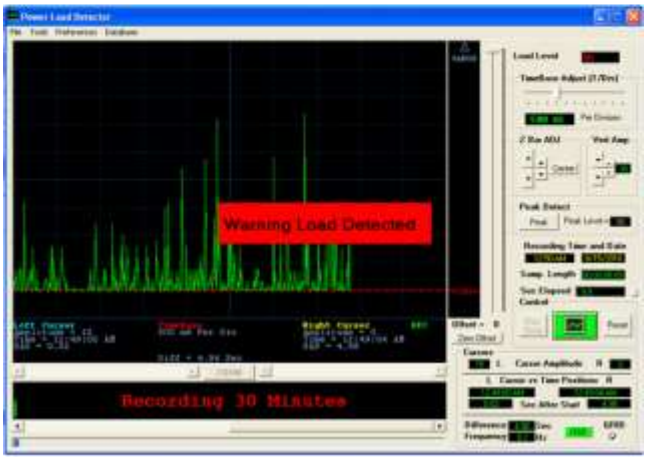

Figure 5. 50 rpm geared motor in damage condition

Figure 5 shows the output signal of 50 RPM geared motor under faulty condition. After detecting the vibration signal from motor with the help of piezo sensor, output of the motor vibration is as shown in the figure 5. This output signal shows the faulty condition of motor. In the faulty condition of motor vibration spikes is high as compare to normal condition as shown in the figure 5. It shows warning alert message on the screen when piezo sensor detects the fault. When the motor works on the abnormal condition compared to the normal condition, then vibration increases inside the motor. If the fault is not corrected, then gradually this vibration in the motor increases and the motor will be damaged.

X. CONCLUTION

The condition monitoring of induction motors have been a challenging task for the engineers and researchers mainly in industries. In the simulation model, comparison of different parts of the motor in normal and abnormal condition is considered. In the hardware model, using the Piezo sensor, with the help of vibration, sensor has detected changes in the motor. In the above output we have tested on different type geared motor which generates different output through which we can analysis the amount of vibration generated by the motors.

In this work, the basic concepts about induction motors and ac drives, as well as the various types of induction motor faults has been presented. Moreover, the physical phenomenon associated with each of these faults was described, and the features of the induction motor performance resulting from these faults was presented using the Simulink model for each these faults.

The aim of this work is to advance the field of condition monitoring and fault diagnosis in induction motor operating in variety of operating conditions. With the help of condition monitoring we can easily avoid the critical emergency shutdown as well as reduce the maintenance costs of motor other faults. Electrical Fault such as unbalanced voltage supply, single phasing. Condition monitoring, signal processing and data analysis are the key parts of the Motor fault detection scheme.

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