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Diagnosis of Motor Faults Using Sound Signature Analysis

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Abstract: The objective of this paper is to present recent developments in the field of Induction motor fault signature analysis with particular regard to Sound signature analysis of induction motor of fan. The different types of fan faults that can be identified from the sound signature analysis [1] are, for example, rotor faults, bearing faults, unbalances wings etc. Corresponding to the above-mentioned faults, many types of machine fault signature analysis techniques [2] have been proposed for motor faults detection and diagnosis. These techniques include vibration monitoring, motor current signature analysis (MCSA) [3–6], electromagnetic field monitoring [7], chemical analysis, temperature measurability [8, 9], infrared measurement, acoustic noise analysis [10], and partial discharge measurement [11, 12]. Among these methods, vibration analysis, current analysis and Sound signature analysis are the most popular due to their easy measurability, high accuracy, and reliability.

Keywords: sound signature, motor faults, induction motor, fault detection techniques, wavelet analysis, sensor less monitoring

I. INTRODUCTION

Induction motors are most commonly used electrical machines in industry because of their cheep cost, small size, ruggedness, low maintenance cost, and easy operation with an available power supply. Although these induction motors are very reliable, but they are subjected to different types of faults and failures. These faults may be inherent to the machine itself or due to operating conditions.

The Inherent faults may be are due to the mechanical or electrical forces acting on the machine enclosure. If a fault is not detected or if it is allowed to develop further it may lead to a failure. A variety of machine faults have been studied in the literature [1, 2] such as winding faults, unbalanced stator and rotor faults, broken rotor bars, bearing faults and eccentricity related faults. Several fault identification method have been developed and been effectively applied to detect machine faults at different stages by using different machine variables, such as current, voltage, speed, efficiency, temperature ,vibrations and sound etc.

II. DIFFERENT TYPES FAULTS IN A FAN MOTOR

This section presents a comprehensive description of the most common faults to be found in induction motors. The variety of faults is classified according to their location: stator and rotor which are as shown in Fig. 1.

- Stator winding related faults
- Stator core related faults
- Rotor Winding related Faults
- Broken Rotor Bar Fault
- Bearing and Gearbox Faults
- Other Faults such as misbalancing of fan wings, wings are not tightly attached with motor, problem in power cord, switch etc.

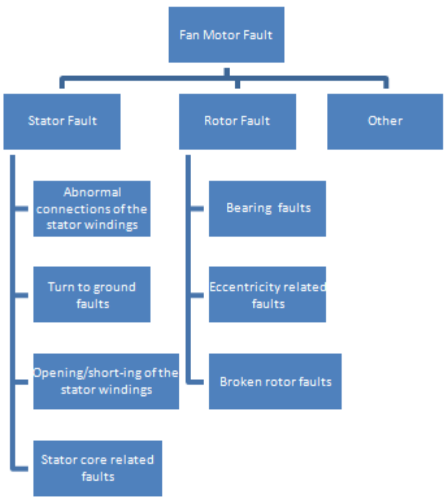

Fig. 1: fan motor related faults

III. VARIOUS TECHNIQUES IN USE FOR CONDITION MONITORING & FAULT DIAGNOSIS

A. Vibration Analysis

Modern condition monitoring techniques encompass many different themes; one of the most important and informative is the vibration analysis of rotating machines. Using vibration analysis, the condition of a machine can be constantly monitored and detailed analysis may be made concerning the health of the machine and the faults which are generated in it. Distress of machinery very often manifests itself in vibration or a change in the pattern of vibration. Therefore Vibration analysis is a powerful tool of diagnosis of faults and troubleshooting in most of the machines. On-load monitoring can be performed in following three ways.

- Periodic field measurements with portable instruments; this method provides information about

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long-term changes in the state of plant. The instruments which are portable are employed with a high load factor and can often be placed under the observation of a single man. Utilization of life curves and the LEO approach assist the decision making.

- Continuous monitoring with permanently installed instruments; it is employed when machine failures are known to occur rapidly and when the results of such failure are totally unacceptable as in the case of turbine generator units.
- Signature analysis: scientifically collecting information, signals and signatures, diagnosing and detecting faults by a thorough analysis of these signatures based on the knowledge acquired in the field, and deciding the severity of faults for decision making, putting them altogether, is called signature analysis.

The technique involves the use of electronic instrumentation especially designed for the purpose of varying capacities, modes of different applications and designing features. Vibration signals are the most significant factor in machine condition monitoring techniques. Periodically checking reveals whether troubles are present or impending. Vibration signature analysis decides which part of the machine is defective and what are the reasons for that. A large number of vibration analysis techniques have been developed for this purpose, but a lot of care is needed to reach a stage of expertise.

B. Motor Current Signature Analysis

Motor current signature analysis (MCSA) is a novel diagnostic process for condition monitoring of electric motor-driven mechanical equipments such as pumps, motor-operated valves, compressors, and processing machinery parts. The MCSA process identifies characterizes overtime instantaneous load variations of mechanical equipment in order to diagnose changes in the condition of the equipments. It checks the instantaneous variations (noise content) occurring in the electric current flowing through the power leads to the electric motor that drives the equipment. Hence the motor acts as a transducer, sensing large and small, long-term and rapid, mechanical load variations, and converting them to variations in the induced current generated in the motor windings. This motor current noise signature is detected, amplified, and further processed as needed to examine its time-domain and frequency-domain (spectral) characteristics. Korde [13] demonstrates that the spectrum analysis of the motors current and voltage signals can hence detect various faults without disturbing its operation using FFT transformation.

C. Temperature Monitoring

Temperature monitoring consists of measuring of the operational temperature and the temperature of surfaces of component. Continuous Monitoring of operational temperature can be considered as a subset of the operational variables for monitoring the performance. The component temperature monitoring has been found to relate to wear occurring in elements of machine, especially in case of journal bearings, where lubrication is found to be either inadequate or invisible. The techniques required for monitoring the temperature of machine components can include the use of optical pyrometers, thermography, and resistance thermometers, thermocouples.

D. Acoustics Emission Analysis

Acoustic emission refers to the propagation of acoustic waves within a material due to sudden release of elastic energy from localized sources under stress. The leading source of these emissions is finely associated with the dislocation accompanying plastic deformation and the initialization or extension of wearied cracks in material under stressful condition. The other sources of acoustic emission are temperature gradients, melting, aging, phase alterations, thermal stress, external mechanical forces, fatigue cracking, and the failure of bonds in mechanically loading of materials. Piezoelectric transducers placed on the surface of the structure which is under test play an important role in measuring the acoustic emissions and loading the structure. Sensors used for determining source location are coupled to the structure by means of a fluid coolant or by adhesive bonds. The amplification of final output of each piezoelectric sensor is done through a low-noise preamplifier, now the output is filtered to remove any noise and further processing is performed by using suitable electronic instruments. Traditionally, as technique acoustic emissions has been prohibited to the monitoring of highly expensive structures due to the expenditure of the monitoring instruments. Since the cost of monitoring instruments continuously fall, in the same way the working range of feasible applications also increasing rapidly. Olsson et al. present a frame work for fault diagnosis of industrial purpose robots using acoustic signals and condition based reasoning. In his frame work he make use of the case-based or condition -based reasoning for identification of faults based on sound or voice recording in fault diagnosis of robots . Wue et al.in his research concluded that he has developed an experimental setup in which faults can be detected online and which also help in the analysis of recent water hydraulic system, and suggested that the incorporation of wavelet transformation into the analysis of acoustic emission opens up the door for further research, which will be very fruitful toward condition monitoring. Choe [8] worked on neural pattern identification of railroad wheel-bearing faults from audible acoustic signals by comparison of Fast Fourier Transform, continuous and discrete wavelets transform (CWT and DWT) features.

E. Noise analysis

Noise signals are utilized for condition monitoring because noise signals measured at regions in proximity to the external surface of machines can contain vital information about the processes which are occurring in internal parts, and can provide valuable information about a machine's present working condition. When machines are in a good working condition, their spectrum of noise frequency has varieties of unique shapes. As soon as development of faults comes into notice, the spectrum of frequency also varies. Each and every portion of frequency spectrum can

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be related to a specific source within the motor. This is the most common process for measuring noise and analysis in condition based maintenance. Many times the signal under monitoring is submerged within some other signal and it cannot be detected by a straightforward time history or analysis of spectrum. In this case, specialized or finely used signal processing techniques need to be implemented.

F. Wear debris analysis

It is not possible to examine the working parts of a complex motor on load, and also not easy to strip down the motor. Circulation of oil through machine signifies the condition of parts that has been noticed. Testing of the oil signifies that any particle if it has carried with it, allows continuous observation of the motor on load or at shutdown condition. Various kinds of techniques are applied; some are very easy while others involving difficult painstaking examination tests and expensive instruments. Currently available lubricant sampling or monitoring techniques like rotary particles depositor (RPD), spectrophotometer oil analysis programme (SOAP), Ferro graphic oil analysis and recent software used techniques are available to distinguish between damaged debris and normal wear debris. Every motor or machine designed undergoes a phenomena of wear and tear during operation conditions ,however modern Condition monitoring techniques are available to monitor this process of wear and tear and initiate maintenance preventive routines which depend on recognising any problem before it develop to the state of final breakdown. recently, engineers have expand their knowledge of condition monitoring within operating equipments by studying and analysing the particles of metallic debris found in lubricating oil of motor engines, gearboxes of machines, final drive units and transmissions, or in hydraulic fluid, and recording the number, size, and type of fragments of debris.

G. Vibration Signature Analysis

The word signature has been coined to designate signal patterns which characterize the state or condition of a system from which they have taken. Signature analysis is widely used as a tool for diagnosis of system having electrical and mechanical faults. In most of the cases, verities of signal processing techniques are undertaken on those signals in order to enhance or extract specific features of such signatures. It is quite essential to keep in mind the verities and range of transducers used as pickup for capturing vibration or sound signal. Diagnosis of faults based on signature analysis makes a great use of signal processing techniques involving one or more methods to deal with the problem of improvement in the signal to noise ratio. Vibration-based monitoring techniques have been widely used for detection and diagnosis of bearing defects for many years. These techniques have been applied separately in time domain as well as in frequency domains. A time-domain analysis mainly focuses on statistical characteristics of vibration signal such as peak level of signal, standard deviation as well as skewness, crest factor and kurtosis of signal. A frequency domain method uses Fourier methods to transform the time-domain signal to the frequency domain, where further analysis is carried out, and conventionally using vibration amplitude and power spectra. It is kept in mind that use of any of the two domains implicitly excludes the direct use of information present in the other.

H. Sound signature analysis

Sound signature is useful for finding mechanical faults such as rotor faults, bearing faults, unbalanced fault in wings etc .In our project, we record the sound of real time signal of healthy and faulty fan. We will analyse these signals in MATLAB using wavelet analysis. In wavelet we used db3 decomposition at level 5. The block diagram used for the fan fault diagnosis system is shown in fig. 2 the system consists of following steps: system, Acquisition, pre-process, wavelet analysis and others the following steps have been followed:

- Acquisition of data: Sound signal, current and rpm are recorded with the help of mice, ammeter, and tachometer.
- Pre-processing of data: Recorded sound signal is weak and noisy. So amplification and filtration of signal is done.
- Analysis of data using MATLAB: Preprocessed signal is analyzed in MATLAB with the help of wavelet.
- Identification of fault: Artificial neural network is used to identify faults

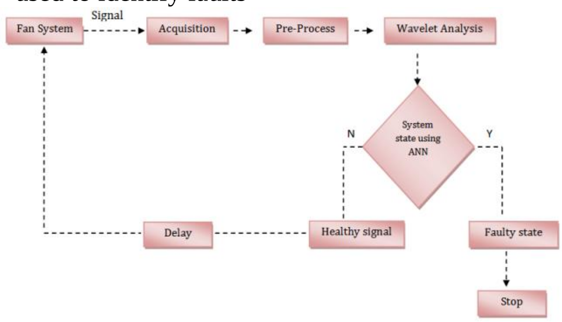

Fig. 2 Block diagram of fan fault diagnosis system

- Signal Observation

The signal observation is sound signal, current signal, temperature etc. Here real time sound signal is to be used to diagnose the mechanical faults like bearing fault etc. The sound signal of healthy and faulty fan system can be acquired by using sound recorder.

- Acquisition

The signal is observed with the help of microphone. Microphone converts the sound signal into electrical signal. Acquired Electrical signal is analog in nature and can't be read by computer, an analog to digital converter is used to convert analog signal into digital signal. This digital signal is transmitted to the computer for decomposition. Where it can be easily processed and analyzed. The below figure shows the acquisition process.

Fig. 3 Acquisition System

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- Pre-Process

These processes can be applied to the real time signal. If the observed signal is noisy we have to use filters for removing the noise present in the signal. The observed signal if in any case is weak we have to use amplifiers for amplifying the weak signal.

- Wavelet Analysis

The processed signal is now analysed with the help of wavelet 3-step decomposition of the signal at 5 levels. We need the five-levels of approximation and five levels of details in MATLAB 7.0.1. Wavelet analysis decomposes the real time signal into one approximation and some detailed signal depending upon the level of decomposition as shown in below figure 4

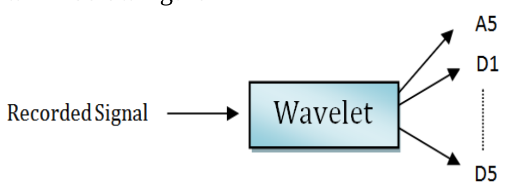

Fig. 4 Wavelet transform to decompose recorded signal.

- System State

All decomposed components of faulty signals are compared with healthy signal. If there found an error in the system, it will display the faulty state of fan system and will stop. If this is healthy then the loop will continuously check the fan system after a periodic delay as shown in below fig 5.

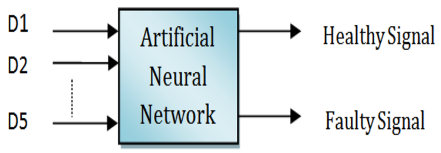

Fig.5 ANN system for fault diagnosis.

IV. CONCLUSION

In this paper, authors have been presented a brief review of art of machinery fault detection; different conventional and recent techniques were discussed for machine fault signature analysis with particular regard to rolling contact bearing fault diagnosis through analysis of vibration or sound. After reviewing the literature on motor fault signature analysis, we come to the following conclusion.

- Prevention of potential failure is required for reliable and safe operations of machineries and the prevention of catastrophic failure can be done by proper maintenance and monitoring. Maintenance based on condition is the most suitable technique to avoid unwanted futuristic failures through condition monitoring or signature analysis for rotating machines. Vibration signature analysis is the best possible technique available for fault identification.

- Among all machine components rolling contact bearing is needed more attention towards signature analysis. A lot of workspace is present in bearing fault signature analysis through vibration data for multiple points or generalized faults.
- Vibration analog signal can be converted in discrete data for further investigation and various time domain and frequency-domain features can be used for further observations. In motor fault signature analysis, wavelets transform as well as Hilbert transform have tremendous scope.
- Expert system based on ANN and fuzzy logic can be developed for robust fault categorization with the use of extracted features from vibration signal.

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