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Motor Current Signature Analysis to Detect the Fault in Induction Motor

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Abstract
In this work induction motor faults detection using electrical signature analysis techniques are introduced, and the advantage of these techniques are explained. By monitoring the current of the electrical machines we can significantly reduce the costs of maintenance by allowing the early detection of faults, which could be expensive to repair. The induction machines used for home appliances as well as industrial purpose. With the industrial growth, it has become necessary to monitor the condition of the machine. There are many condition monitoring methods including vibration monitoring, thermal monitoring, chemical monitoring, but all these monitoring method require expensive sensors or specialized tools where as current monitoring out of all does not require additional sensors. This paper presents the review of identify the different types of faults in the induction motor by monitoring the current. The signal processing techniques are used for condition monitoring and fault detection of induction motor. The signal processing techniques have advantages that this are not computationally expensive, and these are simple to implement.
Keywords: Fault diagnosis techniques, Induction motor, Motor current signature analysis, Signal processing techniques.

I. INTRODUCTION

Induction motors are a critical component of many industrial processes due to its robustness and reliability. Online fault diagnostics of these machines are very important to ensure safe operation, timely maintenance, increased operation reliability. There are many published techniques and commercially available tools to monitor induction motors to insure a high degree of reliability. In spite of these tools, many companies are still faced with unexpected system failures and reduced motor lifetime. There are many condition monitoring methods including vibration monitoring, thermal monitoring, chemical monitoring, but all these monitoring method require expensive sensors or specialized tools where as current monitoring out of all does not require additional sensors.[1]

It is observed that the technique called 'Motor Current Signature Analysis' (MCSA) is based on current monitoring of induction motor, therefore it is not very expensive. The MCSA uses the current spectrum of the machine for locating fault frequencies. When fault present, the frequency spectrum of the current becomes different from healthy motor. The signal processing techniques are used for condition monitoring and fault detection of induction motor . The signal processing techniques have advantages that this are not computationally expensive, and these are simple to implement.

II. ELECTRICAL SIGNATURE ANALYSIS

Electrical Signature Analysis is the procedure of capturing a motor's current & voltage signals and analyzing them to detect various faults. Current park's vector, current monitoring, and current signature analysis, fall under the category of electrical analysis. This method are used stator current to detect various kind of machine faults.

Currents signals can be selected to be analyzed to detect faults inside the motor. The selected signal is called a diagnosis media, and the output of the analysis applied to the selected diagnosis media is called a signature. Each healthy motor gives a certain signature and this signature is affected when faults exist inside the motor. By comparing signatures during motor operation with its original healthy signature, faults can be identified at early stage. Hence decisions can be taken whether to continue or to stop the motor operation.

2.1 Why Current signature analysis ?

- Electrical signals are easier, simpler, and cheaper to be measured and stored.
- Direct access to motor itself is not required and signals can be measured from control panels.
- Online fault monitoring can be achieved without the need to shutdown the motor.[2]
- Faults can be identified at an early stage before becoming severe. Hence, sudden motor shut down are avoided, and maintenance cost is reduced.

2.2 Motor Current Signature Analysis

Motor Current Signature Analysis (MCSA) is a technique used to determine the operating condition of AC induction motors without interrupting production. Motor current signature analysis is that it is sensing an electrical signal that contains current components. MCSA detect the faults at an early stage and avoid the damage and complete failure of the motor. By using MCSA , accurate analysis of fault is possible. An idealized current spectrum is shown in Fig.1. Usually a decibel (dB) versus frequency spectrum is used in order to give a wide dynamic range and to detect the exclusive current signature patterns that are characteristic of different faults.[3]

Motor Current Signature Analysis (MCSA) is based on current monitoring of induction motor therefore it is not very expensive. The MCSA uses the current spectrum of the machine for locating the fault frequencies. When a fault is present, the frequency spectrum of the line current becomes changed from healthy motor. Motor Current Signature Analysis (MCSA) based methods are used to diagnose the common faults of induction motor such as broken bar fault, short winding fault, bearing fault, and load fault.

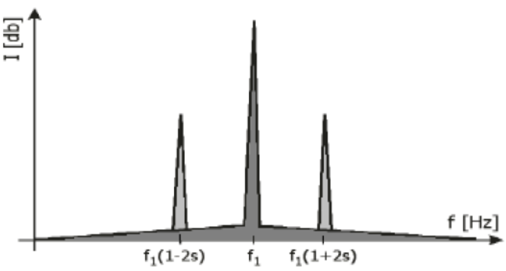

Fig.1. An idealized current spectrum.

III. CURRENT MONITORING TECHNIQUES

The current monitoring techniques consist of following stages. The fig 2. shows the block diagram of current monitoring techniques.

1) Sampler

Its main purpose is to monitor a current of single-phase stator. The single-phase current is sensed by using Hall Effect Sensor and generates the signal proportional to it. The analog signal given to analog-to-digital (A/D) converter. The filtered current is sampled by A/D converter at predetermined sampling rate. This is continued for a sampling period which is sufficient to achieve required FFT.

2) Pre-Processor

It converts the sampled signal to the frequency domain using an FFT algorithm. The generated spectrum includes only the magnitude information about each frequency component. Signal noise that is present in the spectrum is reduced by averaging a predetermined number of generated spectra. This can be accomplished by using either spectra calculated from multiple sample sets or spectra computed from multiple predetermined sections of a single large sample set. Because of the frequency range of interest and the desired frequency resolution, several thousand frequency components are generated by the processing section.

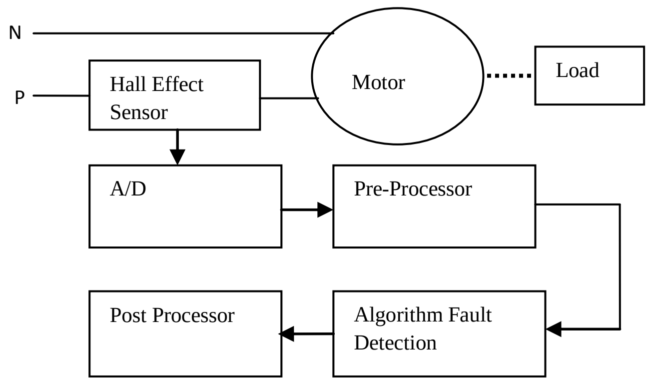

Fig 2. current monitoring scheme

3) Fault Detection Algorithm

In order to reduce the large amount of spectral information to a usable level, an algorithm, in fact a frequency filter, eliminates those components that provide no useful information. The algorithm keeps only those components that are of particular interest because they specify characteristic frequencies in the current spectrum that are known to be coupled to particular motor faults. Since the slip is not constant during normal operation, some of these components are bands in the spectrum where the width is determined by the maximum variation in the motor slip.[4]

4) Postprocessor

Since a fault is not a specious event but continues to degrade the motor, the postprocessor diagnoses the frequency components and then classifies them (for each specified fault).

IV. SIGNAL PROCESSING TECHNIQUE TO DETECT THE FAULT

There are several processing technique to detect the faults

1) Fast Fourier Transform

A Fast Fourier Transform (FFT) is an algorithm to compute the discrete Fourier transform (DFT) and its inverse.. A Fourier transform converts time (or space) to frequency and vice versa; an FFT rapidly computes such transformations. As a result, fast Fourier transforms are widely used for many applications in engineering, science, and mathematics. A FFT analyser is required for converting the signals from the time domain to the frequency domain. FFT reduce the amount of calculation required. Fourier transforms are great to analyse standing signals. It means non transitory. FFT not provide simultaneous time and frequency localization. It is not efficient for representing discontinuities.

2) Shot Time Fourier Transform

The short-time Fourier transform (STFT), is a Fourier-related transform used to determine the sinusoidal frequency and phase content of local sections of a signal as it changes over time. The main advantage of time frequency analysis is to discover the patterns of frequency changes, which usually represent the nature of the signal. As long as this pattern is identified the machine fault associated with this pattern can be identified. Another important use of the time frequency analysis is the ability to filter out a particular frequency component using a time varying filter.[6]

3) Wavelet Transform

It is different from other signal processing method. It is localized in both time and frequency domain because wavelets have limited time duration and frequency bandwidth. It represent a signal with a few coefficient. It overcome the drawback of FFT and STFT . It provides the variable window size.

The wavelet transform (WT) has gained widespread acceptance in signal processing and image compression. Because of their inherent multi-resolution nature. Wavelet transform decomposes a signal into a set of basis functions These basis functions are called wavelets. Wavelets are obtained from a single prototype wavelet y(t) called mother wavelet by dilations and shifting.

$$\psi_{s,\tau}(t) = \frac{1}{\sqrt{s}}\psi\left(\frac{t-\tau}{s}\right)$$

where s is the scaling parameter and t is the shifting parameter. The wavelet transform is computed separately for different segments of the time-domain signal at different frequencies. Wavelet coefficients, at a first level of decomposition, are obtained from a signal under analysis by applying a mother wavelet. The process can be repeated if the mother wavelet is scaled and translated. The mother wavelet function (denoted by ψ (t)) and its scaling function (given as ϕ(t)).

4.1 Application Of Wavelets In Induction Machine Fault Diagnosis.

Wavelet decomposition results in useful data contained in 'details' and 'approximate' parts as shown in the simplified block diagram of Figure3. The 'approximation' signal can be further decomposed into a new set of 'approximation' and 'details' signals and continue until n decomposition levels are obtained.

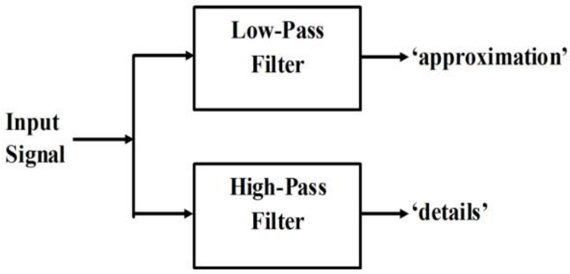

Fig.3. First level decomposition.

The 'details' signal contains high frequency information whereas the approximate part contains signal data with the low frequency components. Computing this decomposition to n levels results in those higher detail parts being removed, thereby reducing the overall frequency of the resulting data. This implies that lower levels of decomposition provide detail data that contains the highest frequency components. Fault patterns are obtained from the information yielded by the n-level wavelet decomposition through a variety of strategies, including filter banks and classification algorithms. The wavelet 'details' coefficients is used as the basis for fault detection. Each level of the signal detail coefficients provides frequency resolution that allows exclusive signature characteristics to be deduced. This allows the analysis of the frequency differences and their time location in the signal under analysis. The standard deviation of the wavelets coefficients is used to identify frequency anomalies in a given time range in the input data set.[7]

V. ALGORITHM FOR FAULT DETECTION

The standard deviation of wavelet coefficients is used to detect loose connection and stator resistance unbalancing fault in induction motors. Greater concentration of mid and low range frequency deviation is caused by these faults. The diagnostic method proposed does not depend on operating frequency of motor. The basic values for decision process are known as Standard Deviation of Wavelet Coefficients (SDWC) and denoted by 'β'. The set values are calculated by 'n' level decomposition of phase, and standard deviation of coefficient is obtained. To determine optimal threshold value of β for different faults is done by experimentation. These ratios will be denoted by βHigh, βMid, and βLow for different three signature types found. i.e. βHigh is the range of SDWC for no fault, βMid range is for fault of winding resistance and βLow range is for open winding. The decision steps are as shown in figure 4. [7]

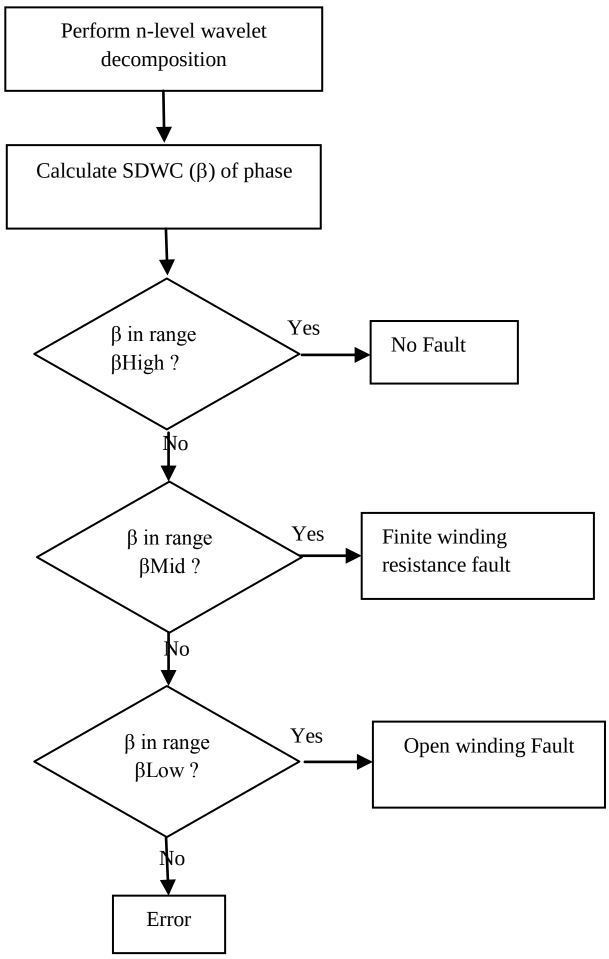

Fig.4. Flow chart of the algorithm.

VI. Conclusion

This paper described about the motor current signature analysis in induction motor. This method is a highly versatile and proven technology for condition monitoring and fault analysis of motors. . The advantage of using the Motor current Signature Analysis method can detect these problems at an early stage and thus avoid secondary damage and complete failure of the motor. Another advantage of this method is that it can be also applied online. The major benefits includes the prevention of lost downtime, avoidance of major motor repair, or replacement costs. The use of induction motor fundamentals and signal processing concepts in MCSA ensures the reliable data, appreciating the operational condition of the motor and correct interpretation of the data.

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