CHAPTER IV

FAULT DETECTION ALGORITHM

4.1 INTRODUCTION

This Chapter deals with fault detection algorithm developed based on above mentioned technique and experimentation performed on motors. Modern measurement techniques in combination with advanced computerized data processing and acquisition show new ways in the field of Induction Motor monitoring by the use of spectral analysis of operational parameters[40]. Time domain analysis using characteristic values to determine changes by Trend setting, spectrum analysis to determine trends of frequencies, amplitude and phase relation to detect periodical components of spectra are used as evaluation tools.

4.2 FAULTS DETECTION TECHNIQUES

The various stator current monitoring based techniques are presented here

4.2.1 Classical Fast Fourier Transform

The classical Fast Fourier Transform is used. For this method, the stator current monitoring system contains the four following processing sections

4.2.1.1 Sampler

Its purpose is to monitor the three phase stator currents and voltages and sampling the resulting signal. The currents are sensed by Current Transformers and voltage signals by voltage probes. The analog signal is then amplified and conditioned. The conditioning removes the undesirable high frequency components that produce aliasing of the sampled signal while the amplification maximizes the use of the A/D converter input range. The A/D converter samples the filtered signal at a predetermined sampling rate. This is continued over a sampling period that is sufficient to achieve the required FFT resolution.

4.2.1.2 Preprocessor

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 calculated 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 (or windows) of 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

4.2.1.3 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 failure information. The algorithm keeps only those components that are of particular interest because they specify characteristics 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 spectrum where the width is determined by the maximum variation in the motor slip. The detailed Fault Detection Algorithm developed in given the corresponding section.

4.2.1.4 Postprocessor

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

4.2.2 Instantaneous Power FFT

In this case, in place of the stator current, the instantaneous power is used as medium for the motor signature analysis oriented towards mechanical faults detection in a drive system.[41] It was shown that the amount of information carried by the instantaneous power, which is the product of the supply voltage and current, is higher than that deducible from the current alone. In fact, besides the fundamental and the two classical sideband components, the instantaneous power spectrum contains an additional component directly at the modulation frequency. In fact, all the fault harmonics are translated into the frequency band 0-100Hz. This constitutes great advantage because the fault harmonics domain is well bounded. However the power spectra are still noisy, so as instantaneous power FFT, at this stage, does not bring important improvement. Therefore, the stator current should be maintained as the main medium for the motor current signature analysis.

4.2.3 Bi spectrum

Bi spectrum, also called third order spectrum, emerges from higher order statistics. The bi spectrum is defined in terms of the two dimensional Fourier transforms of the third order moment sequence of a process [42]. It is clear from [42] that the spectrum is periodic with the period of 2Π, and preserves both the magnitude and phase information. It is then capable of revealing both the amplitude and phase information of the signals. With these additional provided dimensions, the fault detection and diagnostic process can be enriched [42]. The experimental results indicate that the bi spectrum magnitude of the dominant component, caused by the machine rotation, increased with the fault level increase. These results clearly indicate that stator current bi spectrum is capable of providing adequate and essential spectral information for induction motor condition monitoring and fault detection. This technique should be particularly applied to detect electrical based faults, such as stator voltage unbalance, because those faults do not have a well identified harmonic frequency component.

4.2.4 High Resolution Spectral Analysis

The classical spectral estimation techniques which have been used are among the most robust ones, allowing computationally efficient algorithms like the FFT. However, a main disadvantage of the classical spectral estimation is the impact of the side lobe leakage due to the inherent windowing of finite data sets. Window widening allows us to mitigate the effect of side lobes at the expense of decreasing the spectral resolution which can be no better than the inverse of acquisition time.

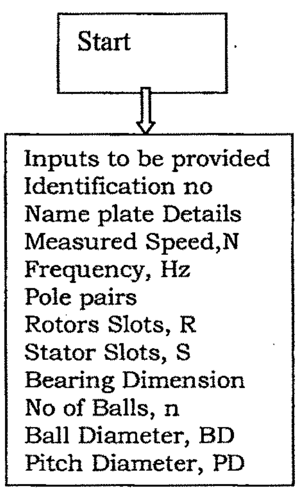
A class of spectral techniques based on an eiganalysis of the autocorrelation matrix has been promoted in the digital signal processing research literature. They may improve or maintain high resolution without sacrificing as much stability, allowing us to keep only the principal spectral components of the the signal and to decrease the noise influence. Two well known eigenanalysis based frequency estimators have been used: multiple signal classification (MUSIC) and ROOT-MUSIC for stator voltage unbalance underscoring[27]. With regard to [27] results, MUSIC and ROOT-MUSIC methods allow us to keep only the main frequencies without other spectral information. Moreover, stator current high resolution spectral analysis, used as medium for induction motors fault detection, will be useful in all faults modifying main spectral components.

4.2.5 Wavelet Analysis

The Fourier analysis is very useful for many applications where the signals are stationary. The Fourier transform is , however not appropriate to analyze signal that has a transitory characteristic such as drifts, abrupt changes, and frequency trends. To overcome this problem, it has been adapted to analyze small sections of the signal at a time. This technique is known as short time Fourier Transform (STFT), or Windowing technique. The adaptation maps a signal into a two dimensional function of time and frequency. The STFT represents a sort of compromise between time and frequency based views of a signal and it provides some information about both. However we can obtain this information with limited precision, and that precision is determined by the size of the window. The fixed size of the window is the main drawback of the STFT[43]. The wavelet transform was then introduced with the idea of overcoming the difficulties mentioned above. A windowing technique with variable size region is then used to perform the signal analysis, which can be the stator current. Wavelet analysis allows the use of long time intervals where we want more precise low frequency information and shorter regions where we want high frequency information. The ability to perform local analysis is one of the most interesting features of the wavelet transform [44].

The advantages of using wavelet techniques for fault monitoring and diagnosis of induction motors is increasing because these techniques allow us to perform stator current signal analysis during transients. The wavelet technique can be used for localized analysis in the time-frequency or time-scale domain. It is then powerful tool for condition monitoring and fault diagnosis especially during transients.

4.3 FAULT DETECTION ALGORITHM



-Acquire the 3 voltages, 3 currents with minimum sampling frequency of 10kHz.
- Calculate RMS value of current in each phase
- Calculate RMS value of voltage in each phase
- Calculate Power input Power factor,
- Current Unbalance, %
- Voltage Unbalance, %
- Calculate Fundamental Frequency of voltage and current
- Process the captured signal of Voltage and Current into its Frequency Spectrum through FFT.
- Calculate THD in Voltage and Current
- Calculate the slip S from Current Signature by jotting down the peaks near to the fundamental frequency and finding the frequency components fb1 and fb2

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Rotor Faults

1. Calculate $f_{b1} = (1-2s)f$, $f_{b2} = (1+2s)f$,here f, is the measured fundamental frequency obtained from FFT. S is slip calculated above.

2. Check whether at fb1 & fb2, there is a peak or not in FFT spectrum. If peak exist at these components then follow step 4

3. If peak does not exists at fb1 & fb2, then peak must have shifted due measurement and signal processing , then search for peak in vicinity of fb1 & fb2 (Shift may be of order of 0.2 –0.5Hz) and take that as fb1 & fb2

4. Find the magnitude of fb1, fb2 from the FFT spectrum, in db

5 Find the magnitude of Fundamental frequency from FFT spectrum in db

6. Following is the fault identification
   No Rotor fault – If difference between fb1 & f is more than 45 db
   Fault developing- If difference between fb1 & f is between 45 to 30 db
   Fault exist- If difference between fb1 & f is less than 30db

7. Approximate no of faulty bars can be calculated as

$$n = \frac{2Rs}{\left(10^{\frac{N}{20}} + p\right)}$$

, N = Av db difference of fb1, fb2 with f

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Diagnosis of Air gap Eccentricity

1) Calculate fec with nd =1 and nw= 1,3,5,7 , these are termed as fec-d
2) Calculate the fec with nd= 0 and nw=1,3,5,7, these are termed as fec-s
3) Calculate the fec1= f1+fr and fec2= f1-fr
4) Check whether the peaks are there at these calculated frequencies or they are shifted due to signal processing or FFT (shift may be of order of 0.2 –0.5 Hz)
5) Find the magnitude of these frequency components and for first measurement, this will be the reference value. Store the value of 's' also.
6) For second or after measurement, these magnitudes will be compared with the magnitudes stored.
7) For diagnosis, after the peak has been ascertained, magnitude of fec-d for particular of nw should be almost equal.
8) Calculate the db difference (for same of nw) between fec-d & fec-s, if difference is less than 15 db than it is a fault
9) If recent measurement values are more than reference then calculate the db difference and if difference is more than 10 db than it is a fault.

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Diagnosis of Bearing faults

1) Calculate the fb, fo, fi based on the inputs
2) Calculate the fbng for different m
3) Check whether the peaks are there at these calculated frequencies or they are shifted due to signal processing or FFT (shift may be of order of 0.2 –0.5 Hz)
4) Find the magnitude of these frequency components and for first measurement, this will be the reference value.
5) For second or after measurement , these magnitudes will be compared with the magnitudes stored.
6) If recent measurement values are more than reference then calculate the db difference and if difference is more than 10 db than it is a fault.

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Diagnosis of Stator inter turn faults

$$fsc = f_1\left[n\left(\frac{1-s}{p}\right) \pm k\right]$$

$$fsc = f_1\left[(jrtR)\left(\frac{1-s}{p}\right) \pm 2jsa \pm ist\right]$$

where f1= supply frequency
n=1,2,3,...
k=1,3,5..
s= slip
p= pair of poles

1) Calculate fsc for different values of n & k
2) Do not consider those frequency components which are same as that in eccentricity faults
3) Check whether the peaks are there at these calculated frequencies or they are shifted due to signal processing or FFT (shift may be of order of 0.2 –0.5 Hz)
4) Find magnitude of these remaining components and store them if it is first measurement
5) For second measurement, compare the magnitude of these components with first measurement.
6) If db difference is more than 15 db than it is a fault.

4.3 CONCLUSION

The fault detection algorithm is developed based on the techniques and experimentation performed on the motors. The various outcomes from the experimentation have been used in formulating the algorithm to detect the different faults within the motors. The algorithm for detect of Rotor bar failures, eccentricity faults, Bearing faults and Stator inter turn faults has been developed. This algorithm is capable of handling various configuration and types of induction motors, irrespective of its This algorithm will be helpful in formulating the desired hardware and software scheme to detect the fault online. It is hoped that this account will be of help to those who are interested in understanding the powerful capability of MCSA.