Detection of Broken Rotor Bar Fault in Induction Motor at Various Load Conditions Using Wavelet Transforms

Sridhar. S
Dept. of Electrical and Electronics Engineering
RNS Institute of Technology
Bangalore, INDIA
prof_sridhar6@rediffmail.com

K. Uma Rao
Dept. of Electrical and Electronics Engineering
R. V. College of Engineering
Bangalore, INDIA
drumarao@yahoo.co.in

Sukrutha Jade
Dept. of Electrical and Electronics Engineering
RNS Institute of Technology
Bangalore, INDIA
sukrutha.jade@gmail.com

Abstract— **Early detection of incipient rotor bar faults are important for efficient operation of large induction motors. This paper presents a methodology to detect rotor bar faults under no-load and loaded conditions, using wavelet transforms. In wavelet analysis, the wavelet coefficients are dependent on the basis function chosen. If these coefficients are used to capture the signature of a fault, then it is desirable to select a wavelet that produces the best results for the signal being analyzed. This paper presents the results obtained from a comparative study done using different discrete wavelet transforms for detection of broken rotor bar fault. Results indicate that the energy content of the wavelet coefficients are sufficient to distinguish between a healthy and faulty machine. The simulation of the proposed methodology is carried out using MATLAB /SIMULINK.**

Keywords— Broken rotor bar fault, Induction motor, Wavelet transforms

I. INTRODUCTION

The asynchronous machines are widely used electrical machines in many industries, mainly because of their reliability, ruggedness and low cost. Induction motors are crucial component of many processes and any faults in the machine or failure of the machine will lead to a sever bottleneck of the process and would also lead to loss of revenue. The major faults of electrical machines can broadly be classified as follows [1]:

1. Stator faults (38%)
2. Rotor faults (10%)
3. Bearing balls faults (40%)
4. Other faults (12%)

Rotor bar fault is an incipient fault. Its effects on the system in the beginning are almost unnoticeable. This motivates the online condition monitoring of induction motor. There are several condition monitoring methods proposed in the literature for monitoring rotor bar fault, which involves measurement of vibrations of the machine, flux in the machine, instantaneous power, instantaneous frequency and stator currents of the machine [2-7]. Motor Current Signature Analysis (MCSA) [8-13] is one among the very popularly used online condition monitoring technique in which stator currents are sampled and processed when the machine is normally running on load. Extensive research is reported to have been focused of extracting the spectral component of the stator current using FFT, Short Time Fourier Transforms (STFT), and wavelet transforms [14-23]. Feature extraction using FFT produces good results when the waveforms examined are stationary or periodic, but is not suitable for non stationary signals. Another problem in computation of fault using FFT is that the frequencies similar to those used for rotor bar breakage detection can be generated due to low frequency oscillating torque loads and voltage imbalance. In such cases, FFT would not produce good results. Therefore, some researchers used STFT method for fault diagnosis. STFT has excellent fault diagnosing capability in the transient region. The main drawback of STFT is it uses constant window size for all frequencies, thereby giving good time resolution but with poor frequency resolution. On the other hand, wavelet transform overcomes these problems, by using variable frequency, variable time window. Because of this ability of time localization and multiresolution analysis, it makes wavelet an attractive technique for fault detection. In this paper an attempt has been made to detect broken rotor bar fault under various load conditions by selecting several wavelet function from the wavelet family. The broken rotor bar fault is simulated in a 4KW, 400V, 50Hz, 4 pole induction motor using MATLAB/ simulink software. The rotor bar is broken at 0.3 sec after the start up in the steady state region.

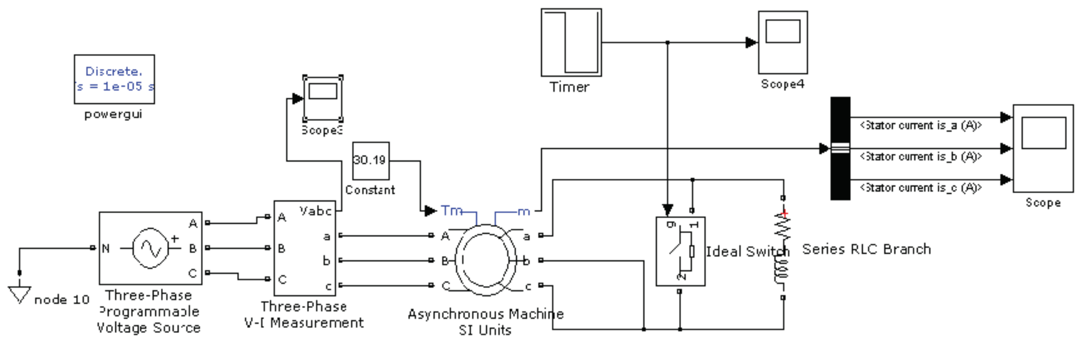

Fig. 1: MATLAB / SIMULINK model of the proposed technique.

II. SIMULATION RESULT

Fig. 1 shows the MATLAB/SIMULINK schematic for detection of broken rotor bar in squirrel cage induction motor, shortly after breakage. The broken bar model is simulated by connecting an external impedance in series to the rotor end with the help of an ideal switch. The plot of FFT coefficients of the stator current of healthy machine and faulty machine at no load, and full load is shown in the Fig. 2 and Fig. 3 respectively. From the FFT coefficients plot, it is seen that identification of rotor bar fault at light loads is very difficult as compared with its healthy counterpart, because they exhibit the same pattern. Hence the family of wavelets is chosen for the analysis as the basis function for the decomposition. There are many wavelet functions named as mother wavelets. The choice of mother wavelet is very crucial as different types of mother wavelets have different properties. Several popular wavelet functions are Daubechies, Haar, Coiflet, Symlet, BiorSplines, ReverseBior and Dmeyer wavelets. In Table 1, the frequency band levels and frequency divisions of levels are shown for a signal which has 100 kHz sampling rate. The total decomposition level L=11 as calculated according to the following relationship:

$$L \geq \frac{\log\left(\frac{f_s}{f}\right)}{\log 2} + 1 \tag{1}$$

Considering the advantages offered by DWT in signal processing, it is used for stator current condition monitoring of the squirrel cage induction motor. Upon the occurrence of a fault, the variation in the DWT coefficients becomes higher than what they were for a healthy machine. Energy content of the wavelet co-efficients of the stator current is used as a feature for the detection of broken rotor bar fault in induction motor at various loads. The energy content for different wavelets at different loads for both healthy and faulty machine is shown in Table 2. Fig. 4 to Fig. 9 shows the plot of variation of energy for healthy and faulty machine verses different load conditions for different wavelets.

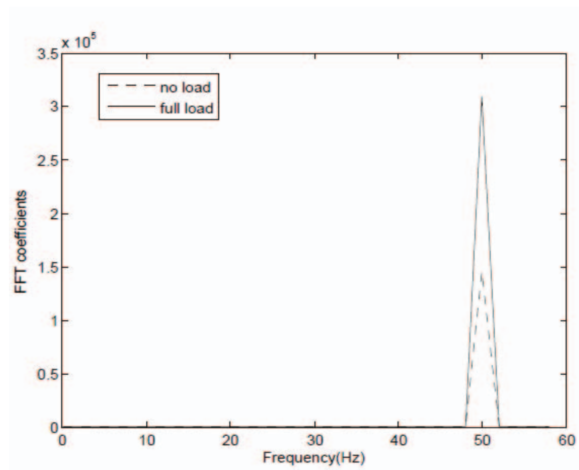

Fig. 2: plot of FFT coefficients for healthy machine at various load conditions.

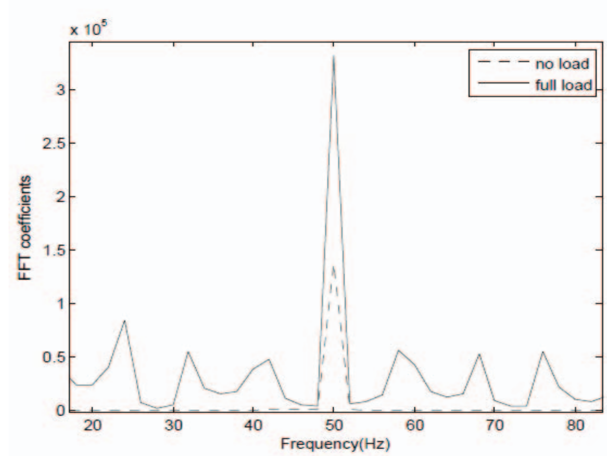

Fig.3: plot of FFT coefficients for faulty machine at various load conditions.

Table 1. Frequency bands for 11 levels of wavelet signals.

Input signal with 100kHz			
Nyquist frequency for 100kHz sampling rate= 50kHz			
Approximations (a_j)	**Frequency bands (Hz)**	**Details (d_j)**	**Frequency bands (Hz)**
a_1	[0-25K]	d_1	[25K-50K]
a_2	[0-12.5K]	d_2	[12.5K-25K]
a_3	[0-6.25K]	d_3	[6.25K-12.5K]
a_4	[0-3.125K]	d_4	[3.125K-6.25K]
a_5	[0-1.562K]	d_5	[1.562K- 3.125K]
a_6	[0-781.25]	d_6	[781.25-1.562K]
a_7	[0-390.625]	d_7	[390.625-781.25]
a_8	[0-195.31]	d_8	[195.31-390.625]
a_9	[0-97.65]	d_9	[97.65-195.31]
a_{10}	[0-48.8]	d_{10}	[48.8-97.65]
a_{11}	[0-24.41]	d_{11}	[24.41-48.8]

Table 2: Total energy content of the wavelet co-efficients at different loads for different wavelets

Type of wavelet	**Machine status**	**No load**	**1/4th load**	**Half load**	**3/4th load**	**Full load**
Daubechies	Healthy	9989.727	9983.69	9975.978	9970.698	9967.706
	Faulty	9989.705	9983.334	9947.353	9946.103	9916.551
Symlet	Healthy	9986.176	9984.445	9979.427	9975.061	9972.246
	Faulty	9986.033	9983.968	9954.395	9936.731	9898.153
Coiflets	Healthy	9994.797	9993.303	9990.511	9988.21	9986.764
	Faulty	9994.611	9992.886	9967.157	9963.472	9938.208
BiorSplines	Healthy	9949.159	9947.121	9941.107	9935.84	9932.483
	Faulty	9949.739	9946.097	9896.393	9881.236	9833.661
ReverseBior	Healthy	9973.184	9971.619	9967.493	9963.994	9961.79
	Faulty	9973.087	9970.295	9926.384	9896.112	9842.588
Dmeyer	Healthy	9998.841	9997.275	9993.828	9990.309	9987.69
	Faulty	9998.846	9997.558	9978.47	9994.888	9983.225

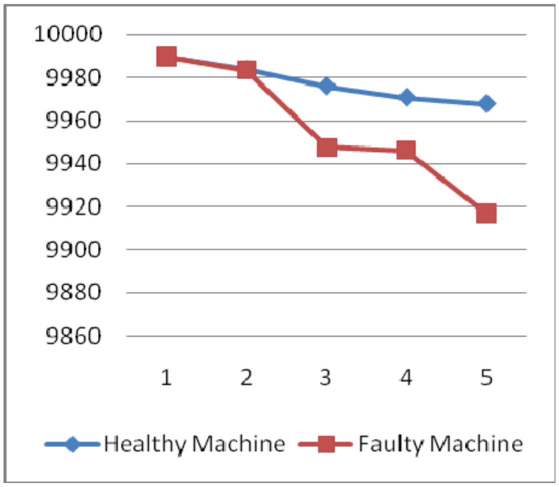

Fig.4:Plot of wave energy for Daubechies wavelet

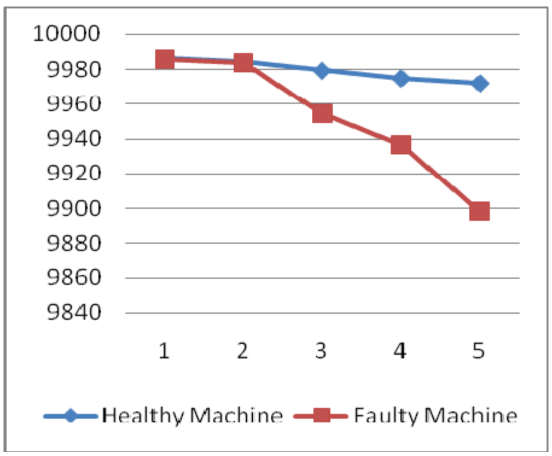

Fig.5: Plot of wave energy for symlets

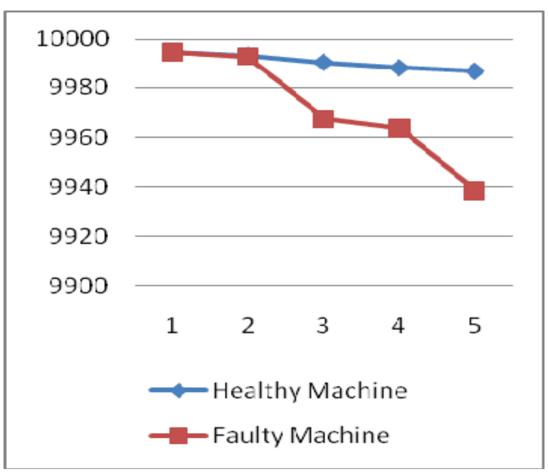

Fig.6:Plot of wave energy for coiflets

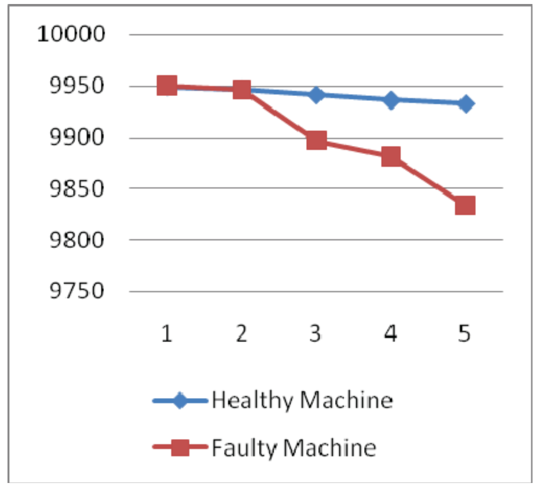

Fig.7:Plot of wave energy for Bior wavelet

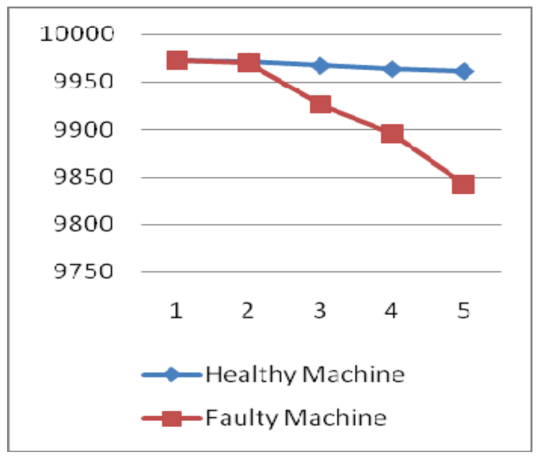

Fig.8:Plot of wave energy for Rbio wavelet

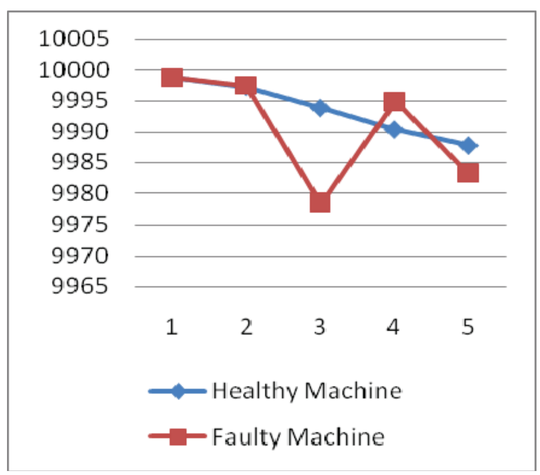

Fig.9:Plot of wave energy for Dmey wavelet

III. CONCLUSION

Fault detection in incipient stages is important for control and protection of squirrel cage induction motor. This paper aims to develop a diagnosis system of rotor bar failure immediately after its breakage. By using MATLAB, a model is simulated for fast fault detection using DWT of the stator current. The percentage of energy corresponding to the approximation and detailed coefficients is found to give clear information to distinguish between the healthy machine and faulty machine at different load conditions. It is found that the energy values are nearly equal at no load and $1/4^{th}$ load for different types of wavelets, and are different for higher loads for healthy and faulty machine. Since induction motors in real world applications are never run on no load, it would be more appropriate to have a minimum of 30% loading to do the analysis on load. It is further noted that apart from Dmeyer, the remaining wavelets used can substantially distinguish between healthy and faulty machine. Though Daubechies wavelet is extensively used in literature for the analysis of broken rotor bar fault, in the present work it is seen that symlets and ReverseBior give satisfactory results as compared to Daubechies wavelets. Though higher order of Daubechies wavelet (greater than 40) gives better results, greater the order, greater is the computational burden and a wise choice is a tradeoff between the accuracy and the complexity

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