Broken Rotor Bar Fault Detection using Wavlet

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Abstract - Motor current signature analysis has been successfully used for fault diagnosis in induction motors. However, this method does not always achieve good results when the speed or the load torque is not constant, because this cause variation on the motor slip and fast Fourier transform problems appear due to non-stationary signal. This paper experimentally describes the effects of rotor broken bar fault in the stator current of induction motor operating under non-constant load conditions. To achieve this, broken rotor bar fault is replicated in a laboratory and its effect on the motor current has been studied. To diagnose the broken rotor bar fault, a new approach based on wavelet transform is applied . The diagnosis procedure was performed by using the virtual instruments. The theoretical basis of proposed method is proved by laboratory tests.

Keywords – Fault diagnosis, broken rotor bar fault, Wavelet Transform, Multi-resolution analysis

I. INTRODUCTION

A wavelet was used to decompose the residual stator current after filtering the noise using a notch filter. Just as the Fourier transform decomposes a signal into a family of complex sinusoids, the wavelet transform decomposes a signal into a family of wavelets. Unlike sinusoids, which are symmetric, smooth, and regular, wavelets can be symmetric or asymmetric, sharp or smooth, regular or irregular. The family of wavelets contains the dilated and translated versions of a prototype function. Traditionally, the prototype function is Called a mother wavelet. The scale and shift of wavelets determine how the mother wavelet dilates and translates along the time or space axis. For different types of signals, different types of wavelets can be selected that best match the features of the signal we want to analyze.The wavelet indicator for detecting the broken rotor bars by calculating the absolute values of the summed coefficients in the third pattern which were normalized against the summation of the wavelet coefficient, the number of scales, and the number of samples used was presented

A. Methedology-

The Language of Technical Computing MATLAB® is a high-level language and interactive environment for numerical computation, visualization, and programming. Using MATLAB, you can analyze data, develop algorithms, and create models and applications. The language, tools, and built-in math functions enable you to explore multiple approaches and reach a solution faster than with spreadsheets or traditional programming languages, such as C/C++ or Java™. You can use MATLAB for a range of applications, including signal processing and communications, image and video processing, control systems, test and computational finance, and computational biology. More than a million engineers and scientists in industry and academia use MATLAB, the language of technical computing

II. FAULT DETECTION USING WAVLET

A. MACHINE FAULT DIAGNOSIS USING WAVLET-

There are two levels of fault diagnosis:
1. Traditional control
2. Knowledge based fault diagnosis

Fault diagnosis techniques contain the feature extraction module (wavelet), feature cluster module and the fault decision module (1). Indicators of faults include the negative sequence current, impedance and the park's vector. Motor current signature analysis (MCSA) is used to diagnose the stator short circuit fault.

Multi resolution analysis and good time localization are particularly useful characteristics of wavelets in the context of fault diagnosis. Signal processing techniques like the FFT are based on the assumptions of constant stator fundamental frequency, load, motor speed and the assumption that the load is sufficient.

The use of wavelets for induction machine fault detection is documented in various journals. They have been shown to yield satisfactory results for detecting electrical and mechanical faults [3]. Wavelet decomposition results in useful data contained in '*details*' and '*approximate*' parts as shown in the simplified block diagram of Figure 1. The '*approximation*' signal can be further decomposed into a new set of '*approximation*' and '*details*' signals and continue until *n* decomposition levels are obtained.

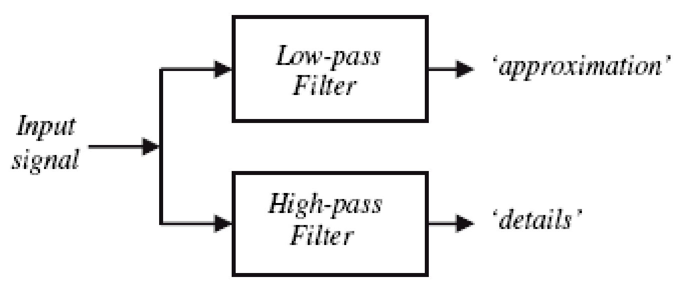


Figure .1 First level decomposition.

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 characteristics of the resulting data. This implies that lower levels of decomposition provide detail data that contains the highest frequency components. For the induction machine signature analysis, the higher frequency wavelet components represent system noise or harmonics due to the input power inverter. Therefore decomposition levels higher than one are of interest in the technique presented in this paper.

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 [8]. In this study a statistical analysis of the wavelet '*detail*s' coefficients is used as the basis for fault detection. From the mean or standard deviation of the wavelet coefficients it could be inferred that the average magnitude of frequency components are present in the signal under analysis. Each level of the signal detail coefficients provides frequency resolution that allows unique signature characteristics to be deduced. That is if the *n*-level detail coefficients are analyzed then each level represents the spatial information for a small range of frequencies. This allows the analysis of the frequency differences and their time location in the signal under analysis. In this paper, the standard deviation of the wavelets coefficients is used to identify frequency anomalies in a given time range in the input data set.

B. Discrete wavelet transform fault detection-

Wavelet techniques are new in the field of fault diagnosis. They are useful due to their ability to extract all the information in both time and frequency domain. They provide a sensitive means to diagnose the faults in comparison to other signal processing methods like the fourier transform, the drawbacks of which include the need to use a single window function in all frequency components and the acquisition of linear resolution in the whole frequency domain. This is an important reason for the interest in wavelets in time–frequency analysis as can be seen in presented a review of the diagnosis of machines using the condition-based maintenance approach.
Wavelet transformation is of many kinds but the most important among them:

1. Discrete wavelet transformation
2. Continuous wavelet transformation
3. Wavelet packet decomposition transformation

The wavelet is divided into two main groups. One is the discrete wavelet transform represented in the following eq.:

$$DWT(n,k) = \frac{1}{\sqrt{a}} \sum x(n)\, h\left(\frac{k - m b_0 a_0^n}{a_0^n}\right) \quad (1)$$

Where $h(m)$is the mother wavelet $x(n)$ is the input signal and the scaling and translation parameters " a "and " b " are functions of the integer parameter m .the second wavelet type is the continuous wavelet transform (cwt) which can be represented as follows:

$$w(m,n) = \int_{-\infty}^{\infty} f(t)\psi^*_{n,m}(t)\mathrm{d}t \quad (2)$$

Denotes the complex conjugate, where f (t) is the waveform signal and ψ (t) is a wavelet.

Where m and n are the wavelet dilation and translation used to transform the original signal to a new one with smaller scales according to the high frequency components
This relation is valid for the orthogonal basis of wavelet transform (a =2 and b =1).

Two properties of the wavelet are noteworthy:

When a wavelet satisfies an admissibility condition, a signal with finite energy can be reconstructed without needing all values of its decomposition. The admissibility condition is represented by the following equation:

$$\int \frac{|\psi(w)|^2}{|w|} dw < +\infty \quad (3)$$

Where ψ (w) is the fourier transform of the wavelet function ψ (t) used to investigate the signals and then to reconstruct them without losing any information. According to the admissibility condition, the fourier transform goes to zero as is shown in the following equation

$$\psi|(w)|^2 = 0 \quad (4)$$

Another important property of the wavelet is:

$$\int \psi(w) = 0 \quad (5)$$

To remedy the squared relationship between the time bandwidth product of the wavelet transform and the input signal, certain regularity conditions are imposed so as to ensure the smoothness and concentration of the wavelet function in both time and frequency domains. The decomposition can be implemented using filtering and down-sampling, and can be Iterated, with successive approximation as in .The total decomposition levels can be calculated according to the following relationship:

$$M \geq \frac{\log\left(\frac{f_s}{f}\right)}{\log(2)} + 1 \quad (6)$$

where M=Total no of levels

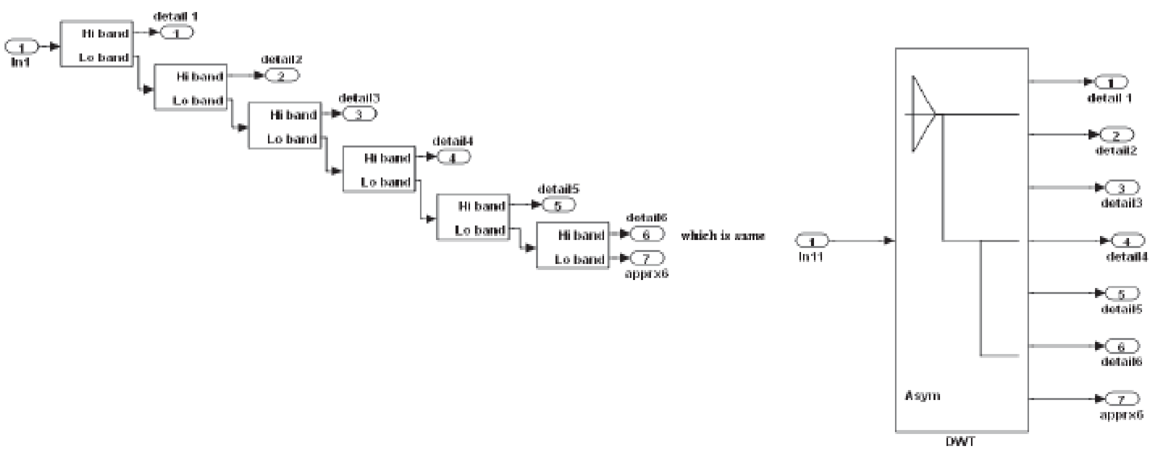


Figure 2 wavlet decomposition

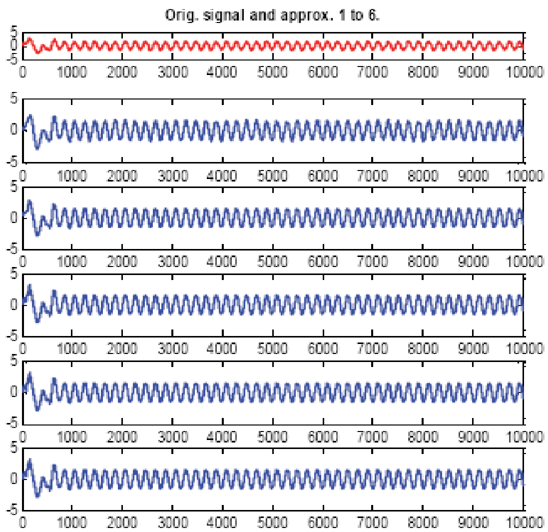
C. Fault in induction motor-

There are different types of fault in induction motor such as broken rotor bar fault, eccentricity fault etc but in this paper broken rotor bar fault is studied. Electric drives are used in safety-critical applications or industrial processes where the immense costs of unplanned stops are unacceptable. Fault detection depends on the availability of information from the system. In this work, the fault detection is done using wavelet for analysis of stator current as can be shown in fig.11 for the healthy case, fig.12for broken rotor bar case and fig.13 for the stator short winding case respectively.

D. Broken rotor bar

Key reasons for a broken rotor bar are :
1. Direct on line starting which leads to excessive heating and mechanical problems.
2. Variable mechanical load.
3. Unsatisfactory rotor cage manufacturing.

E. Simulation study-



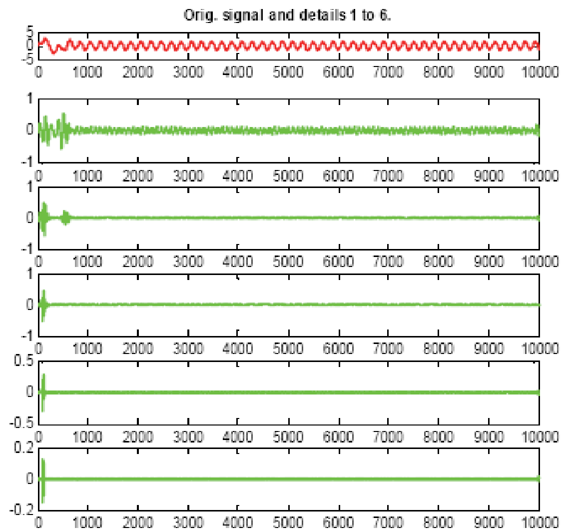
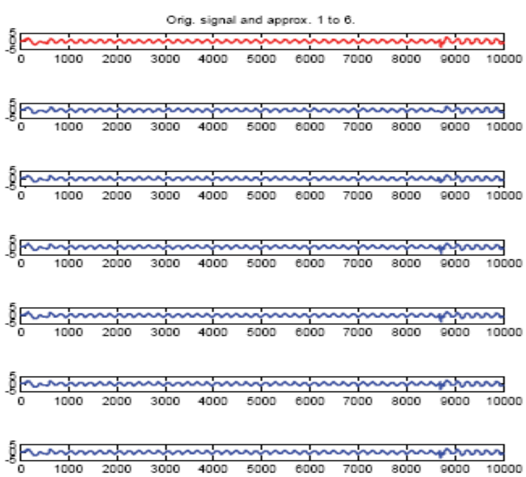


Figure. 3.a

Figure 3 b



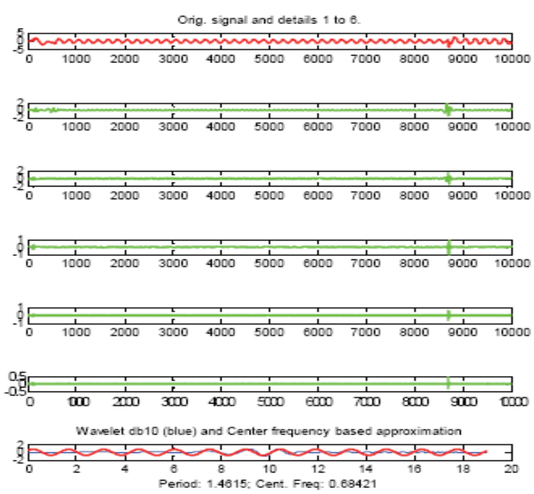


Figure.4 a

Figure. 4 b

The simulation results under the condition that the motor Operates with rated load and no. 1 and 2 rotor bar breaks Successively are provided in fig. 1, indicating that there would once Broken rotor bar fault occurred, moreover, the amplitudes of These components increase gradually along with the fault Progression. Obviously, for an ideal motor, the fault indicators rather distinctive, as makes it easy to achieve the sensitive And reliable detection of broken rotor bar fault. Pay attention that the stator current spectrum refers to the Self-adaptive filtered spectrum,

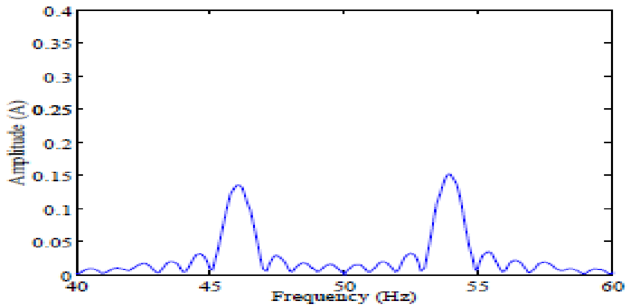


Figure 5.a Stator a-phase current spectrum

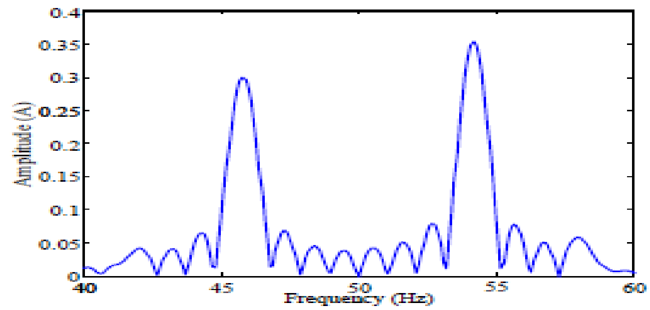


Figure5 .b Simulation results of broken rotor bar fault

Fig.5 demonstrates clearly that the stator current spectrum Comprises quite a few peaks besides those associated with the For Instance, the motor air-gap eccentricity likewise leads to the Occurrence of superimposed components in the stator current

III. EXPERIMENT AND RESULT

A. PROPOSED CIRCUIT FOR SIMULATION-

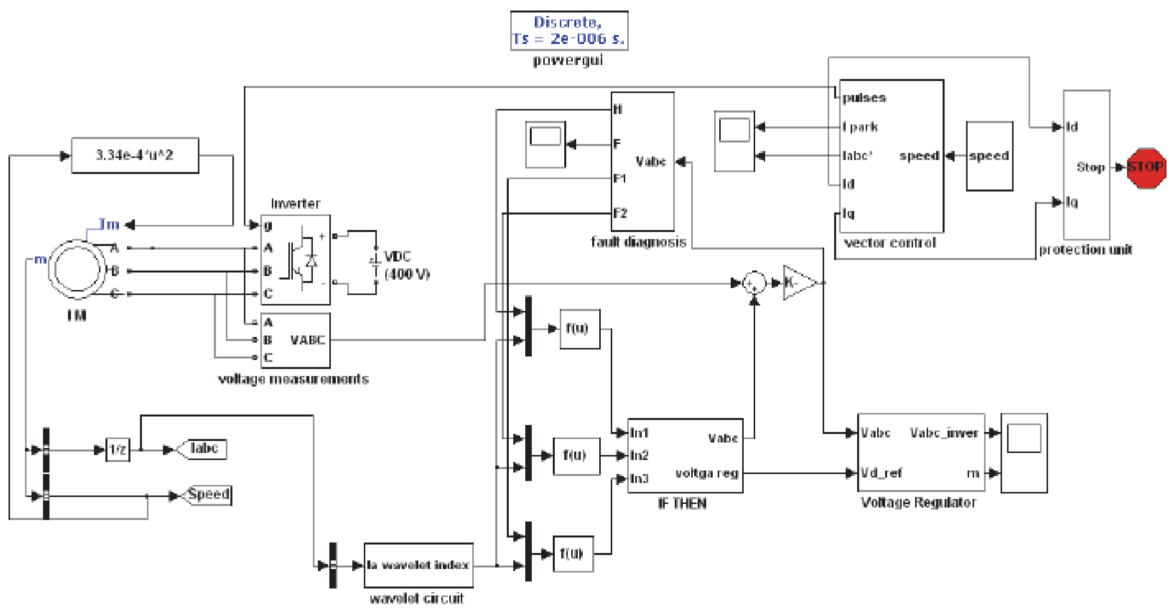


Figure. 6 simulation circuit

B.RESULT

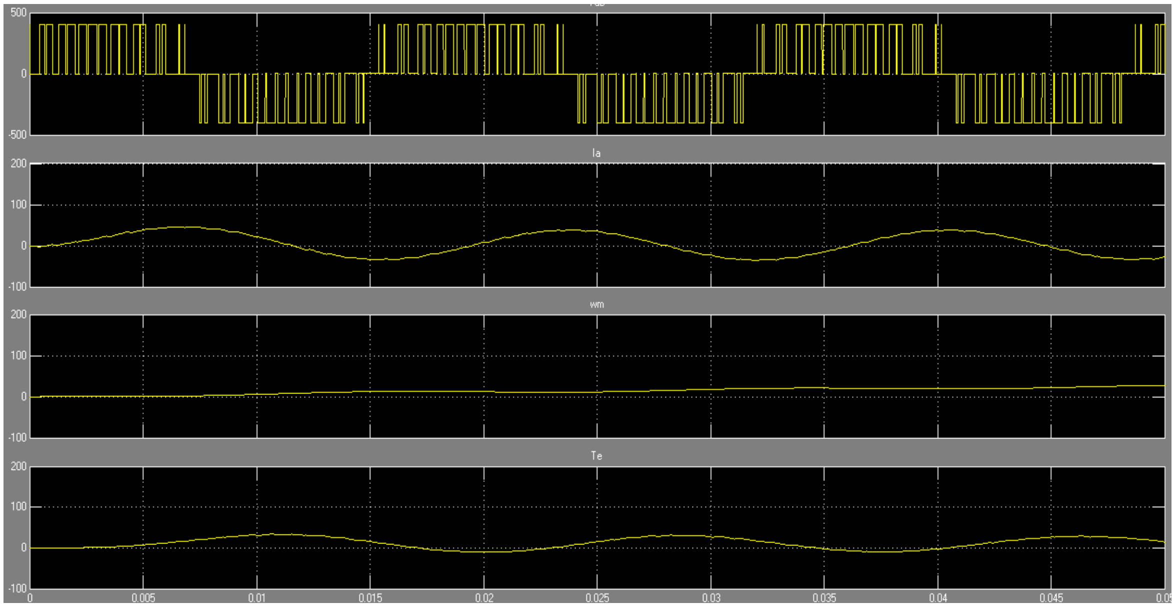


Figure 7 a Output of a healthy induction motor

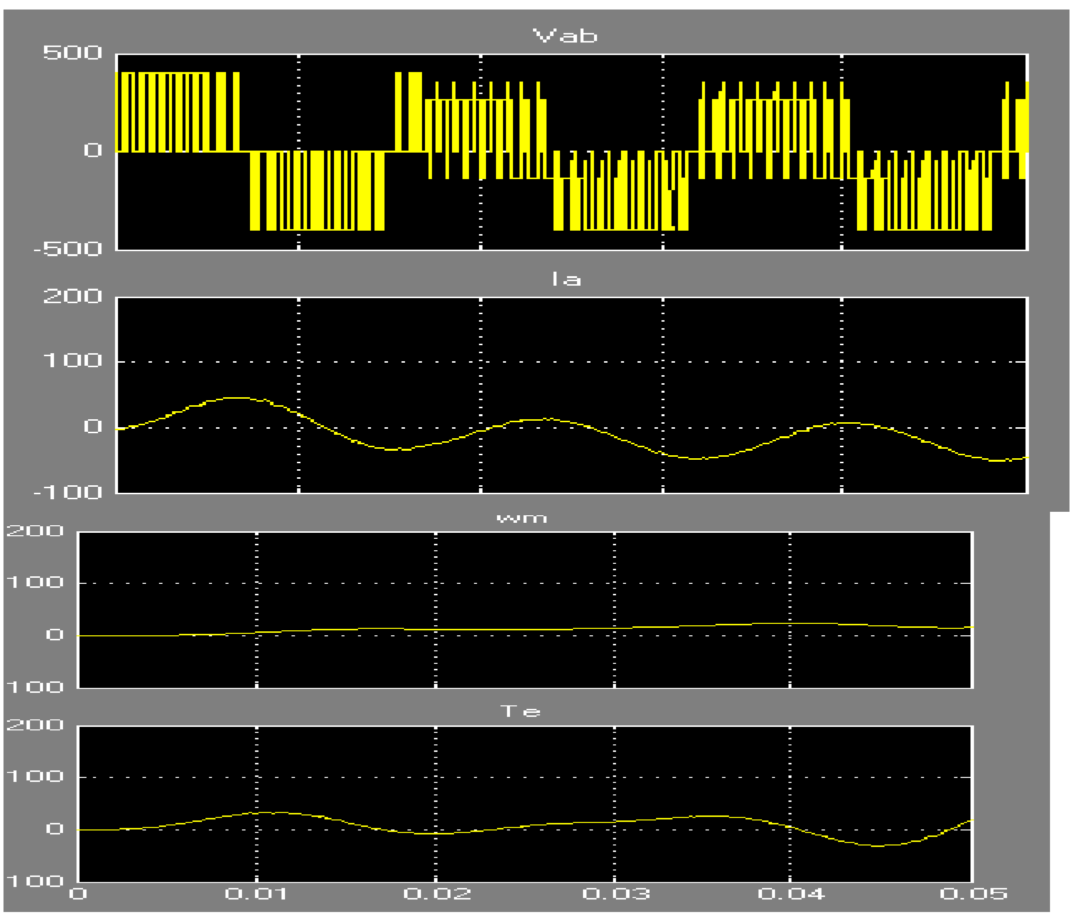


Figure. 7 b Output of a faulty induction motor

IV.CONCLUSION

The wavelet is considered as powerful tools in the fault detection and diagnosis of induction motors. Many wavelet classes can be generated by different kinds of mother wavelets and can be constructed by filters banks. The improvement of fault detection and diagnosis can be exploiting the wavelet properties to get high detection and diagnostics effectiveness. Theories of wavelet need to be pushed forward to insure best choosing of mother wavelet. The wavelet index can distinguish correctly between the faults and healthy induction motor.Matlab/simulink excellent package for both simulations and practice experiments in the diagnostic of induction machines with wavelet.

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