A Study on Fault Diagnosis of Induction Motor using Neural-Wavelet

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Abstract: - The induction motors effort to widely industrial fields. On the contrary, faults of the induction motors cause another faults of the whole system, because the faults of the induction motors often progress through long time. It is very important that diagnosis for diagnosis fault and extracted fault feature from the acquired signal using wavelet transform. Extracted features use the fault diagnosis with neural network.

Key-Words: - Induction Motor, Wavelet, Neural Network, Fault Diagnosis

1 Introduction
An induction motor, which is convertible to mechanical energy from electrical energy, widely uses various industry fields. Also, it is important that the induction motor should be managed each part, because the induction motor has contributed a major field in the industrial system.

The faults of induction motor have mainly occurred in bearing, rotor, stator. In order to detect these faults, vibration method has mainly used. However, it is necessary that the induction motor attach vibration sensor, which is a big volume for vibration signal. Besides the vibration sensor is expensive, so it is not reasonable for small size induction motor. Also, the fault of induction motors often progress a long time. It causes confusion of the whole system. Therefore it is important that the induction motor detects early diagnosis.

The majority of the motor failures are caused by combination of various stresses. The Thermal stresses due to thermal overload and unbalance, hot spots or excessive losses, sparking. The magnetic stresses caused by electromagnetic forces, unbalanced magnetic pull, electromagnetic noise and vibration. Residual stresses due to manufacturing problems, dynamic stresses arising from shaft torque, centrifugal forces and cyclic stresses, environmental stresses caused for example by contamination and abrasion of rotor material due to chemicals or moisture. The Mechanical stresses due to loose laminations, fatigued parts, bearing failure, etc[1].

In this paper, we diagnose fault of the induction motor via spectral analysis based on wavelet transform. Typically, electrical faults of induction motor occurred to high vibration amplitude at double source frequency of signal spectral analysis. And mechanical faults of induction motor is excellent in operating frequency[2]. After extracted feature via wavelet spectral analysis, we implemented fault diagnosis of the induction motor using neural network for the best suited classification.

2 Main Subject

2.1 Wavelet Transform
Wavelet transform was first suggested by Morlet who are geologist in France. The wavelet transform is recently remarkable various field. The wavelet transform was developed as an alternative approach to the short-time Fourier transform to overcome the resolution problem. The wavelet analysis is done in a similar way to the short-time Fourier transform analysis, in the sense that the signal is multiple with a function similar to the window function in the short-time Fourier transform, and the transform is computed separately for deferent segments of the time-domain signal.

The wavelet transform is called as time-scale transform. The scale, as a mathematical operation, either dilates or compress a signal. Larger scales correspond to dilated signals and small scales correspond to compressed signals. In terms of mathematical functions, if f(t) is a given function f(st) corresponds to a contrasted version of f(t), if s>1 and to an expanded version if f(t), if s<1. However, in the definition of the wavelet transform, the scaling term is used in the denominator, and therefore the opposite of the above statements holds, i.e., scales s>1 dilates the signals whereas scales s<1, compresses the signal. The mother wavelet is chosen to serve as a prototype for all windows in the process. All the windows that are used are the dilated(or compressed) and shifted versions of the mother wavelet. There are a number
of functions that are used for this purpose. The Morlet wavelet and the Mexican hat function are two candidates. Once the mother wavelet is chosen the computation starts with \( s=1 \) and the continuous wavelet transform is computed for all values of \( s \), smaller and larger than “1”. However, depending on the signal, a complete transform is usually not necessary. For all practical purposes, the signals are bandlimited, and therefore, computation of the transform for a limited interval of scales is usually adequate. For convenience, the procedure will be started from scale \( s=1 \) and will continue for the increasing values of \( s \), i.e., the analysis will start from high frequencies. This first value of \( s \) will correspond to the most compressed wavelet. As the value of \( s \) is increased, the wavelet will dilate.

The Fourier transform defined by Fourier use basis functions to analysis and reconstruct a function. Every vector in a vector space can be written as a linear combination of the basis vectors in that vector space, i.e., by multiplying the vectors by some constant numbers, and then by taking the summation of the products. The analysis of the signal involves the estimation of these constant numbers(transform coefficients, or Fourier coefficients, wavelet coefficients, etc). The synthesis, or the reconstruction, corresponds to computing the linear combination equation.

A basis of a vector space \( V \) is a set of linearly independent vectors, such that any vector \( v \) in \( V \) can be written as a linear combination of these basis vectors. There may be more than one basis for a vector space. However, all of them have the same number of vectors, and this number is known as the dimension of the vector space. For example in two-dimensional space, the basis will have two vectors.

\[
v = \sum_k v_k b_k
\]

Equation (1) shows how any vector \( v \) can be written as a linear combination of the basis vectors \( b_k \) and the corresponding coefficient \( \mu_k \).

This concept, given in terms of vectors \( v \) can easily be generalized to functions, by replacing the basis vectors \( b_k \) with basis functions \( \psi_k(t) \), and the vector \( v \) with a function \( f(t) \). Equation (2) then becomes

\[
f(t) = \sum_k \mu_k \psi_k(t)
\]

The complex exponential(sines and cosines) functions are the basis functions for the Fourier transform. Furthermore, they are orthogonal functions, which provide some desirable properties for reconstruction.

Let \( f(t) \) and \( g(t) \) be two functions in \( L^2[a,b] \). The inner product of two functions is defined by equation (3).

\[
< f(t), g(t) > = \int_a^b f(t) \cdot g^*(t) dt
\]

\[
CWT_s^\phi (\tau, s) = \Psi_s^\phi (\tau, x) = \int x(t) \cdot \psi^*_s (t, \tau) dt
\]

According to the above definition of the inner product, the CWT can be thought of as the inner product of the test signal with the basis functions where,

This definition of the CWT shows that the wavelet analysis is a measure of similarity between the basis and the signal itself. Here the similarity is in the sense of similar frequency content. The calculated CWT coefficients refer to the closeness of the signal to the wavelet at the current scale[3].

2.2 Neural Network

Back propagation learning algorithm is consists of forward process and backward process. It is important for learning to update the weight. The back propagation algorithm executes to update weight at backward process. Forward process presents a input pattern in neural network, and computes output about each node using the input function and activation function. At this moment, input signal is forwarded only output layer direction. Output value at output layer will be not equal to desired value and then occur an amount of error. Backward process have to compute, gets the error. It is used to update the weight by backward process. After weight value is adjusted, the error decrease then first. This procedure executes several times over till the system becomes stabilized or total error comes to the desired value[4].

Fig 1. shows a flow chart how the neural network use the whole system.
2.3 Fault of the induction motor

A fault of induction motor can be divided mechanical fault and electrical fault, and its cause mainly condenses the fault of bearing, rotor and stator. Fault frequency of the bearing faults is decided the mechanical construction and the rotated velocity of the induction motor.

A specific frequency is generated by fault of the bearing as follow[5].

\[
f_o = f_s \pm (0.6n f_s) \\
f_i = f_s \pm (0.4n f_s)
\]  

(5)

\[f_s : frequency \ of \ source; k : positive \ number; n : number \ of \ bearing \ ball; f_s : rotated \ velocity\]

Fault of inner-turn coil may cause a fault of stator. This is accompany with a disproportion of the stator with a harmonic gap flux and current-time harmonic change. This fault have to detect via relative change of source current[6].

Fault of the rotor have a problem which is combination between bar and end-ring. This is increased in damage of many breakdown. Fault of the rotor causes a change of toque wave, velocity, vibration, frequency element in source current.

A specific frequency is generated by rotor bar broken as follow[7][8].

\[f_{brb} = f_s \left[ k \left( \frac{1-s}{p/s} \right) \pm s \right] \]  

(6)

\[f_s : source \ current; \frac{2k}{p} = 1,5,7,13, ...\]

2.4 The method of fault diagnosis

In order to diagnose the induction motor, sensor acquires current at stator and then current signal is inputted by USB bus via data acquisition board. This signal is converted by wavelet transform and then computed wavelet coefficient. The wavelet coefficient are used neural network input.

3 Experiments and Results

In order to diagnose the induction motor, fault measurement system is constructed fault trial induction motor, drive inverter, coupling. Table 1 shows resources of induction motor for implementation in this paper.

<table>
<thead>
<tr>
<th>Section</th>
<th>Item</th>
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<tr>
<td>Facility</td>
<td>Rated power [kW]</td>
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<tr>
<td></td>
<td>Rated voltage [V]</td>
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<tr>
<td></td>
<td>Rated velocity [rpm]</td>
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<td>Rated toque [Nm]</td>
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<td>Slot number</td>
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<tr>
<td></td>
<td>Pole number</td>
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<td>External diameter [mm]</td>
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</tr>
<tr>
<td></td>
<td>Rotor bar</td>
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</table>

In order to construct fault diagnosis system of induction motor, sensor acquires current at stator and then current signal is inputted by USB bus via data acquisition board. This signal is converted by wavelet transform and then computed wavelet coefficient. The wavelet coefficient are used neural network input.
In order to detect a fault parts of induction motor and auto-recognition, computes wavelet coefficients of input signal every one second, and then 20 test patterns which consist of 10 wavelet coefficients are used neural network input. The neural network is consists of the 10 input neuron and 2 hidden neuron, 3 output neuron. Learning rate fixed 0.5. Limit error fixed 0.01.

Fig. 3 shows a construction of neural network.

![Neural Network Model](image)

Fig. 3. Neural Network Model

In order to implement fault diagnosis of the induction motor, acquires signal input using National Instrument DAQ board and DAQ assistant of LabVIEW. Inputted signals are used feature calculation and programmed diagnosis.

Fig. 4 shows a result of the fault diagnosis program.

![Fault Diagnosis of the induction motor](image)

Fig. 4. Fault Diagnosis of the induction motor

4 Conclusion

In this paper, to acquire a current signal of the stator, we use a data acquisition board. After acquired signal, computed wavelet coefficient and then classified normal mode or fault pattern. In order to detect automatic diagnosis, wavelet coefficients are used the input of the neural network.

We proposed that a fault of the induction motor was diagnosed by wavelet coefficient and neural network. This system may contribute the fault diagnosis of small and medium induction motor, because the system can use a simple device and confirm a result of the fault diagnosis.

If the system apply the diversity sensor like a vibration sensor, thermistor, noise sensor, etc., we expect to develop a confidential system for the fault diagnosis of the induction motor.

References:


