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# LabVIEW Based Condition Monitoring Of Induction Motor

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**Abstract:**
Early detection of faults in stator winding of induction motor is crucial for reliable and economical operation of induction motor in industries. Whereas major winding faults can be easily identified from supply currents, minor faults involving less than 5 % of turns are not readily discernible. The present work reports experimental results for monitoring of minor short circuit faults in stator winding of induction motor. Motor line current has been analyzed using motor current signature analysis.The current signals that obtained was current of three phase of induction motor in load and no load condition.These are reduced in two equivalent current signals by Park's Transformation and Discrete Wavelet Transform (DWT) in NI LabVIEW 8.5. Feed Forward Artificial Neural (FFANN) based data classification tool is used for fault characterization based on DWT features extracted from Park's Current Vector Pattern.
***Keywords*:** MCSA, FFANN, Discrete wavelet transform, Park's transform, LabVIEW 8.5

## I. INTRODUCTION

Induction motor plays a very important role in industrial as well as commercial purpose due to its low cost, ruggedness, low maintenance and construction. Early detection of faults in induction motor in its initial stage can extends the wear out period. Induction motor faces many problems as shown in Figure 1 among that problem inter turn short circuit is the one of the major fault occurred in the induction motor.

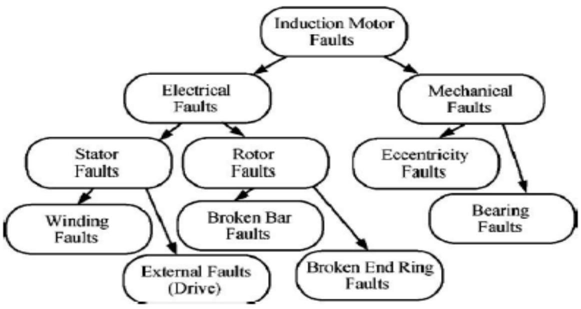


Figure 1 Various Faults in Induction Motor

The various techniques have been proposed for the detection of inter turn short circuit Fault in induction motor. Some of the technique reported [1]-[2] uses mathematical modeling of system. In [1] mathematical modeling of induction motor has been simulated and the result has been reported, the model has been used for all the behavior of motor in load and no load condition. Some of the techniques [3]-[4] uses frequency spectrum for the analysis of inter turn short circuit fault. Fourier transform is not

used for analysis of the signals because these signals are non stationary signals. Induction motor faults diagnosis using stator current envelopes has been used for the detection of broken rotor bar and inter turn short circuit fault [5]. In [6] the fault detection of induction motor is based on negative sequence impedance. The higher order spectra of radial machine vibration for detection inter turn fault is proposed in [7]. A wavelet package for the extraction of useful information for the non stationary signals has been employed in [8]. Inter turn fault detection based on neutral voltage has been proposed in [9], but is being limited to the star connected machine with an accessible neutral. The detection of fault in using park's transform and wavelet has been explained in [10]. In [11] the inter turn fault has been detected by $d_1$ coefficient that is being proceed through ANN for fault classification.

The use of wavelet for the detection of the fault has been use in majority because wavelet deals in both the time and frequency domain. This analysis deals for the stator current during the transient nature of the induction motor. The main advantage of the DWT is that it can be used for the analysis of non-stationary signals. This paper deals with stator current captured from the induction motor in healthy and faulty condition for full load and no-load condition which is non-stationary current signal. The DWT gives the detail and approximate coefficient for those non-stationary signals.

In this paper FFANN *i.e.* feed forward algorithm for the classification of healthy and faulty condition of 3 phase induction motor has been successfully carried out. In FFANN the selection of suitable data for the classification of the fault is the main judgment. The various parameters for the creating the network for fault classification is done on trial and error method. This paper deals with the energy of each detail coefficient has been used for the fault classification.

## II. DATA REDUCTION USING PARK'S TRANSFORMATION

In three phase induction motor the stator current has been captured which are the current of the three phases *i.e.* $i_a$, $i_b$ & $i_c$. But the analysis of the three phase current is quite difficult task and multi resolution analysis of three signals is difficult in time domain, where as these current signals does not give any fault feature extraction. That is the reason park's transformation is tool used for the conversion of three phase current quantities into two equivalent quantities by using (1) & (2) which is known as park's transformation. The fault feature extracted for full load and no load condition is shown in figure2 and figure3 respectively.

$$Id = \sqrt{\frac{2}{3}}Ia - \frac{1}{\sqrt{6}}Ib - \frac{1}{\sqrt{6}}Ic \qquad (1)$$

$$Iq = \frac{1}{\sqrt{2}}Ib - \frac{1}{\sqrt{2}}Ic \qquad (2)$$

These are the equations that are used for the conversion of a,b,c phase current into direct axis and quadrature axis current. The whole operations for the conversion of three phase current in two phase quantities are performed in NI LabVIEW 8.5.

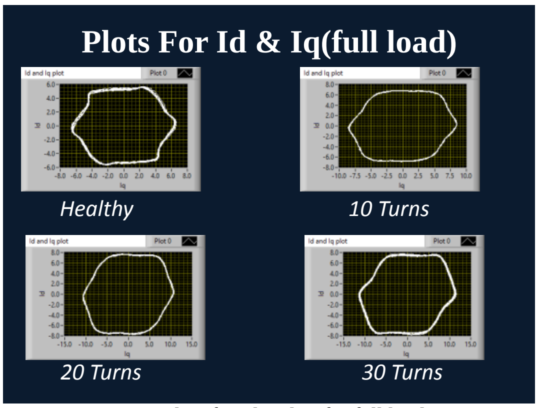


Figure 2 Plots for Id and Iq for full loading

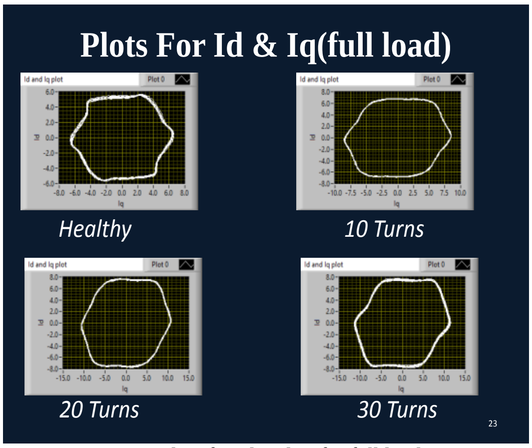


Figure 3 Plots for Id and Iq for full loading

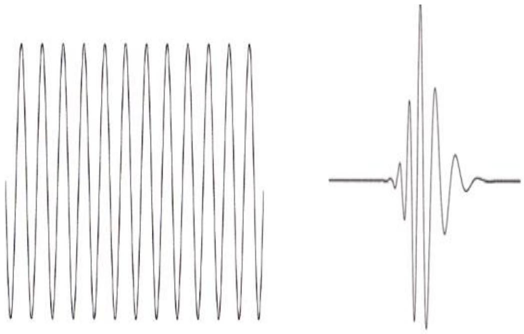

Figure 4. Representation of Wavelet

## III. DISCRETE WAVELET TRANSFORM (DWT)

Wavelets are localized waves. They have their energy concentrated in time or space and are suited to analysis of the transient signal. Wavelets are families of functions generated from one single function, called an analyzing wavelet or mother wavelet, by means of scaling and translating operations. The difference between these wavelets is mainly due to the different lengths of filters that define the wavelet and scaling functions. Wavelets must be oscillatory, must decay quickly to zero (can only be non-zero for a short period), and must integrate to zero. The scaling operation is nothing more than performing "stretching" and "compressing" operations on the mother wavelet, which in turn can be used to obtain the different frequency information of the function to be analyzed. The compressed version is used to satisfy the high frequency needs, and the dilated version is used to meet low frequency requirements. Then, the translated version is used to obtain the time information of the function to be analyzed. In this way, a family of scaled and translated wavelets is created and serves as the base, the building blocks, for representing the function to be analyzed.

Different wavelets such as Haar, Daubechies 4, Symlet and Coiflet are used as mother wavelet.

DWT is any wavelet transform in which the wavelet is discretely sampled. It transforms the distorted signal into different time frequency scales detecting the disturbances present in the power signal.
The DWT of f (t) is defined as:
DWT f (a,b) = $\sum f(t)\, \psi_{a,b}(t)$ (3)

Where, $\psi_{a,b}(t)$ is mother wavelet a, b are scale and translation factor.

Multi resolution analysis is the first main characteristic of Wavelet transform. Multi resolution analysis technique is analysis of the signal at different frequencies with different resolution. Multi resolution analysis technique decomposes the given signal into several other signals with different levels of resolution which provide valuable information in time and frequency domain. It uses the wavelet function (ψ) and scaling function (φ) to decompose the signal into high frequency component and low frequency component by processing the signal into high pass filter and low pass filter. The wavelet function ψ generates high frequency component (detailed coefficient) and φ will generate low frequency component (approximate coefficient). This work deals with the five level decomposition. The schematic diagram of decomposition is shown in figure5 and the frequency distribution of the five levels is shown in table I.

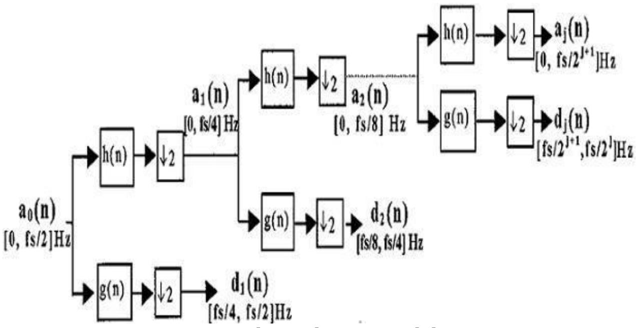

Figure 5. Multi resolution signal decomposition

Table I.
Frequency levels of wavelet coefficient

| Decomposition Level | Frequency component (Hz) |
|---|---|
| d1 | 5000-2500 |
| d2 | 2500-1250 |
| d3 | 1250-625 |
| d4 | 625-312.5 |
| d5 | 312.5-156.25 |
| a5 | 0-156.25 |

## IV. EXPERIMENTAL SET-UP

In order to achieve the fault diagnosis of induction motor, a modern lab test bench is setup as shown in figure4 .The set up consist of an 2 h.p.,3 phase 415 V,4 pole, 50 Hz. squirrel cage induction motor.


Figure 6. Experimental set up

In 3 phase induction motor on which the experimentation is carried out has three phases and each phase consist of 300 turns. For the creating the faults manually the tapping are provided at the outer side of induction motor. Each set of tapping has the 10turns short circuit capacity in this set up motor has 70- 80 turns capacity of inter turn short circuit fault. The spring and belt arrangement is made for the mechanical loading of motor.

In order to acquire the data, the Tektronix DSO, TPS 2014 B, with 100 MHz bandwidth and adjustable sampling rate of 1GHz is used to capture the current and voltage signal. The Tektronix current probes of rating 100 mV/A, input range of 0 to 70 Amps AC RMS, 100A peak and frequency range DC to 100KHz are used to acquire the stator current signals and the voltage probes of Tektronix make are used for acquiring the stator voltage signals. Approximately, 500 sets of signals are captured on different load conditions and at different mains supply conditions.

Stator current and phase voltage of the motor for different number of short circuited turns is captured in order to compare with healthy condition of motor shorted number of turns. Different experiments were conducted with 10turns, 20turns and 30 turns short circuited to access the performance of; and effect on the motor. Three currents Ia, Ib and Ic and voltage Va were captured with sampling frequency of 10 kHz .This data is then processed and analyzed using MATLAB.

## V. FAULT EXTRACTION USING DWT

In the condition monitoring of induction motor using LabVIEW the three phase stator current has been captured using data acquisition system. The three phase current has been converted in two equivalent current quantities. The faults have been characterized by using park's transform approach. An important step is the selection of the mother wavelet for the fault extraction. There are different families of the wavelet *viz.* Gaussian, Mexican, Hat, Morlet, Meyer, Daubechies, Coiflet, Biorthogonal etc. In this method deubechies-4 (DB-4) wavelet has been selected as a mother wavelet.

When DWT is applied to extract the scaling and wavelet coefficients from a transient signal, a large amount of information in terms of these coefficients is obtained. Although the information is useful, it is difficult for ANN to train/validate that large information. Another alternative is to input the energy contents in the detailed coefficients according to Parseval's Theorem.

$$\int f(t)^2 = \sum_k Cj(k)^2 + \sum_{x=1}^{j} dx(k)^2 \qquad (3)$$

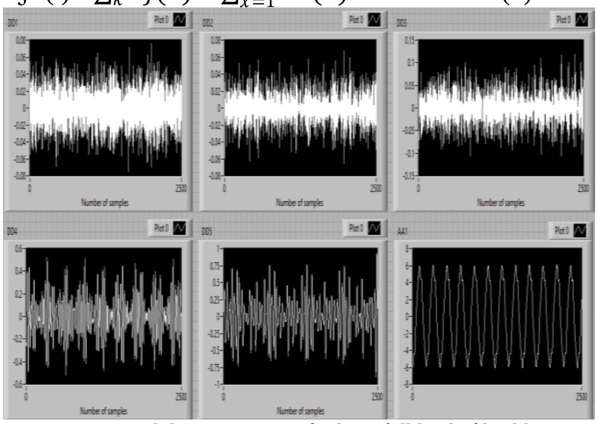

Figure 7. 5 Level decomposition of Id For full load of healthy condition

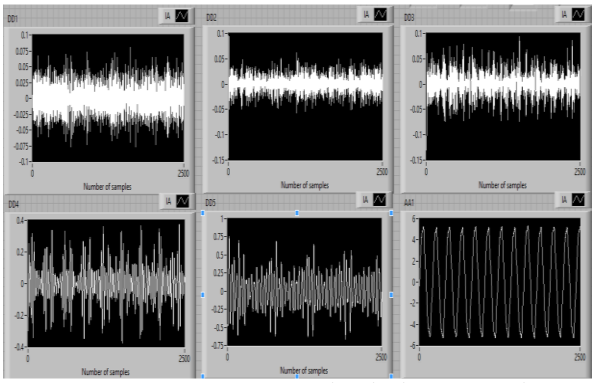

Figure 8. 5 Level decomposition of Iq for full loading of healthy condition

## VI. ALGORITHM FOR THE PROPOSED STRATEGY

The following algorithm shows the total work done in NI LabVIEW8.5.

1. Capture the current of three phases *i.e.* $I_a$, $I_b$ and $I_c$ using data acquisition system.
2. Apply park's transform to compute $I_d$ and $I_q$ to obtain park's vector pattern.
3. Compute the DWT of $I_d$ and $I_q$.

Where f (t); Signal to be decomposed, $C_j$ is approximate coefficient of decomposed signal, d is detail coefficient to be decomposed.

The meaning of parseval's theorem is that the energy contained in the signal is equal to summation of the energy contained in detail and approximate coefficient at any $j^{th}$ level. As only non stationary waves are concerned only second part of 3 is concerned. In proposed strategy the park's current pattern ($I_d$ & $I_q$) is plotted for the line current fed from stator side which is shown in figure2.1 and figure2.2. These signals are decomposed up to $5^{th}$ level using DWT ($DB_4$) which is shown in Figure7 and figure8 shows the 5 level decomposition of $I_d$ and $I_q$ for full loading of Induction motor.

4. Obtain the energies of the level decomposed in d1-d5 using Parseval's theorem by using 3

The energies calculated for the detail coefficient (d1-d5) using Parseval's theorem are used as an input for classification of faulty and healthy condition of the motor.

## VII. RESULT AND DISCUSSION

In this paper ANN 3 layer connected with connected fully FFANN is used for the training and supervised leaning algorithm called as back propagation algorithm. Input layer consist of 10 neurons get from the energy of the d1-d5 for $I_d$ and $I_q$ on the other hand the output layer consist of the 2 neuron which are the two output condition of motor *i.e.* Healthy and faulty. With respect to hidden layer it is customary that number of neurons in hidden layer is done by trial and error. Same approach is used in this paper for the classification the fault.

In this paper the FFANN with following assumption has been used for classification of the healthy and faulty condition of the motor for the purpose of training the network *viz.* Learning rate L.R.=0.8, Momentum=0.7, Transfer function of TanhAxon is used ,data used for training purpose TR=75%, , Testing is =25 %.With these assumption the variation of the MSE and percentage accuracy of classification for the healthy and faulty condition of the stator current with respect to number of processing elements in hidden layer has been obtained.

Table II shows the variation of the average MSE's with the variation of the number of processing elements in the hidden layer. The variation of the % accuracy with the variation of the number of the processing element is shown in Figure7.

TABLE II.
MSE AND % ACCURACY FOR THE CLASSIFICATION FAULT

| Number of processing element | MSE | Percentage accuracy of classification | |
|---|---|---|---|
| | | Healthy | Faulty |
| 1 | 1.91E-11 | 66.3 | 89.7 |
| 2 | 2.24E-11 | 55.6 | 92.6 |
| 3 | 2.91E-11 | 88.9 | 96.3 |
| 4 | 4.37E-11 | 66.7 | 88.9 |
| 5 | 4.82E-11 | 100 | 100 |

## VIII. CONCLUSION

This paper deals with the problems related to the inter turn short circuit of 3 phase induction motor. The line current are captured from the data acquisition and are passed through some signal processing tools and data reduction tool *i.e.* Park's transform. The processed data has undergone the DWT for the extraction of the fault feature of the motor compared to the healthy condition of the motor. FFANN with 5 processing element are useful for the classification of the faults that has been extracted from the feature of the DWT. Proposed methodology is being useful in detecting the fault even though there is three percent turns of the stator are short circuit. This method can be useful for the preventive measure for the restriction of the inter turn short circuit fault in 3 phase induction motor.

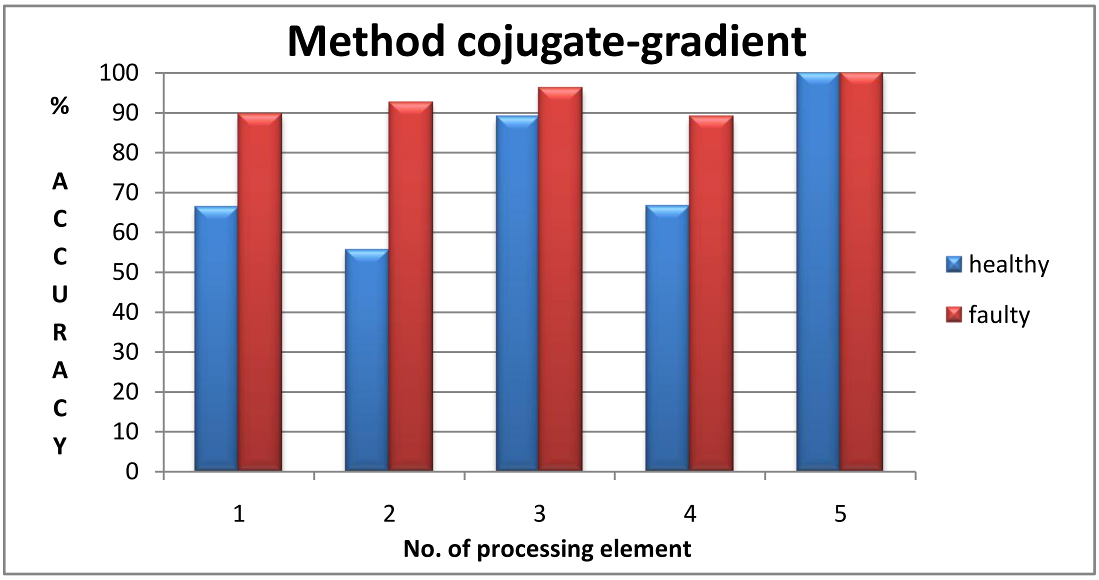


Figure 9. Variation of the % accuracy with number of processing elements in hidden layer

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