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Research Article

DISCRETE WAVELET ANALYSIS FOR STATOR FAULTS DETECTION IN INDUCTION MACHINE

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ABSTRACT

The induction motors are not always operating under complete steady state conditions, therefore prompting the development of non-stationary techniques for fault detection. In this paper an inter-turn short circuit fault is considered in the stator winding. The technique for diagnosis in transient state, especially in startup state is based from using the DWT. The signal used for the fault detection is the stator current. The experimental results show that using DWT can effectively be used to diagnose this type of the fault in the motor.

Keywords: Induction Machine; Fault diagnostic; Stator Inter-Turn Short Circuit; Discrete Wavelet Transform (DWT); Start-up state; Steady state.

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1. INTRODUCTION

The induction motors often working in under undesirable conditions, for example, corrosive and dusty places [1]. These undesirable conditions can cause the induction motor to fail prematurely, if not detected at its early stages of the failure period [2].

The failure of induction motors can bring about a complete loss of the machine itself. Thus, health monitoring techniques to prevent induction motor failures are of extraordinary worry in industry [3-5]. Stator winding faults and eccentricity are among these failures. There are many monitoring techniques are based on motor current signature analysis (MCSA) for example Fourier transform [6-9]. There is absolute confidence how powerful Fourier analysis can be. However, it has a downside in analyzing non stationary signals [10-13].

The wavelet transform method is the better in time varying or non-stationary signals analysis. The wavelet theory is considered of techniques which have been developed for many signal processing applications are performance limited [14-17]. One of its feature is multi-resolution signal analysis with a vigorous function of both time and frequency localization. This method is effective for stationary signal processing as well as non-stationary signal processing [18].

This paper presents the DWT to the diagnosis of stator faults for induction motor. The wavelet technique based diagnosis relies on the band-pass filtering performed by discrete wavelet transform, enabling to extract the harmonic components caused by the fault. The results of the study show that the effectiveness of the proposed technique for stator winding short circuit faults in induction motors.

2. DISCETE WAVELET TRANSFORM (DWT)

The DWT is an efficient and powerful technique that provides time frequency representation of a non stationary signal with good time resolution than a Fourier transforms [19-20]. The DWT is computed with the aid of successive low-pass and high-pass filtering of the discrete time-domain signal together with changes in sampling rates. Fig.1 shows a typical two-level wavelet decomposition tree.

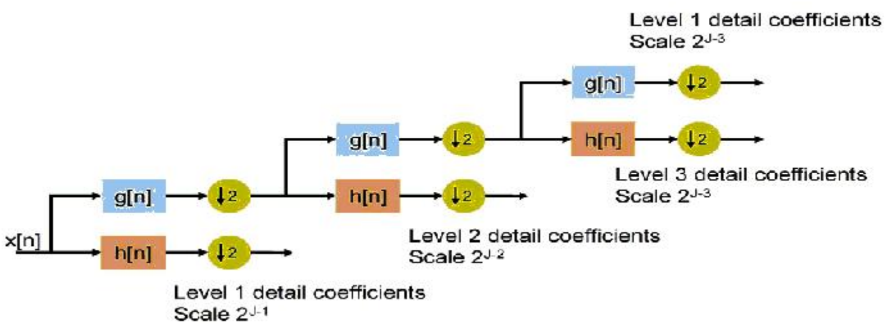


Fig.1. Signal decomposition using DWT.

Each of the wavelet scales corresponds to a frequency band given by [21].

$$f = 2^{(n-m)} \, (f_s / 2^n) \qquad (1)$$

Where f is the higher frequency limit of the frequency band represented by decomposition level m, f_s is the sampling frequency and 2^n is the number of data points in the signal.

For, this number of decomposition level signal, N_f is given by:

$$N_f > \text{int}\left(\frac{log(f_s / f)}{log(2)}\right) + 1 \qquad (2)$$

Considering, f_s= 10000 samples/sec and f = 50 Hz, using equation (2) one obtains $N_f \approx 9$.

The frequency bands associated with each wavelet signal are shown in Table I.

Table 1. Frequency levels of wavelet coefficients

Level	Frequency band
d6	156.25 312.5 Hz
d7	78.12 56.25 Hz
d8	39.06 78.12 Hz
d9	19.53 39.06 Hz
a9	0 19.53 Hz

3. EXPERIMENTAL RESULTS

The characteristic of the machine were: 1.1 kW, 220/380V, 50 Hz, 4 pole, Squirrel-cage induction motor (Fig. 2).

Fig.2. Experimental test bench

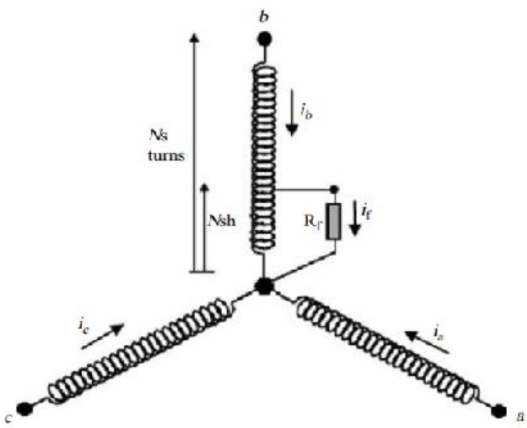


Fig.3. Stator inter turn fault in phase *b*

In experimental analysis, it is extremely important if we expect good results that we adjust the acquisition parameters correctly in order not to miss important information. The motor current data was sampled at 10 kHz, i.e, 100000 samples was obtained at measured time of 10 s.

The proposed stator fault diagnosis method is tested on a Y-connected (Fig.3). Tests are achieved by connecting an external shorting variable resistor R_f between terminals pairs to introduce the short circuit fault. The resistor allows the fault current to be controlled to avoid damaging the stator windings when the inter turn short circuit appears. In this paper, the short circuit turns are almost 58 of the total turns in the b-phase.

Figure 4 shows the experimental stator current in steady state and startup state for a loaded machine. The oscillations shown in Fig. 4.a, justify the presence of the stator inter turn fault in phase *b*.

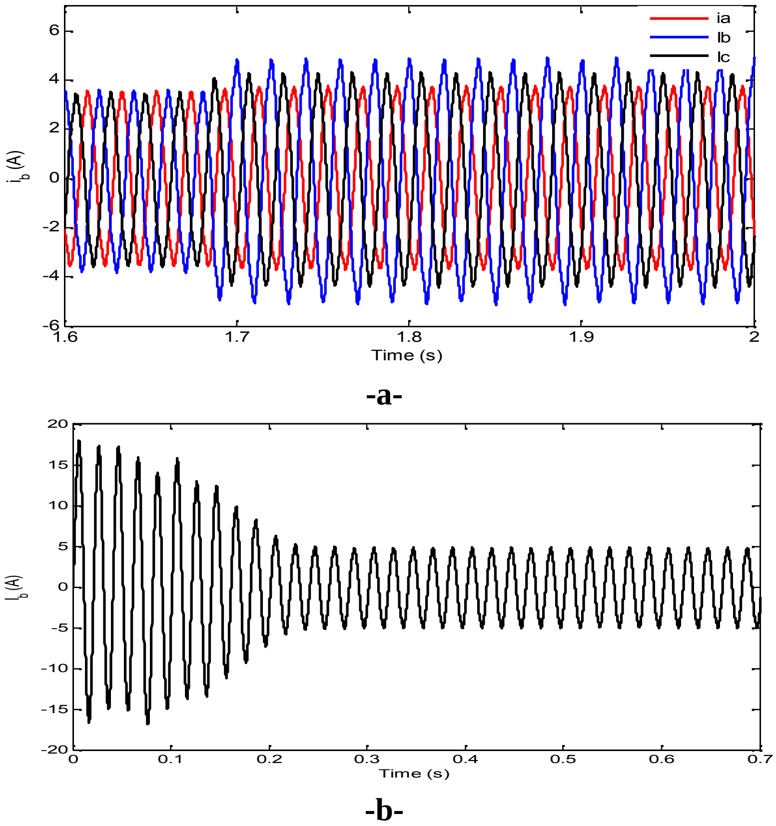
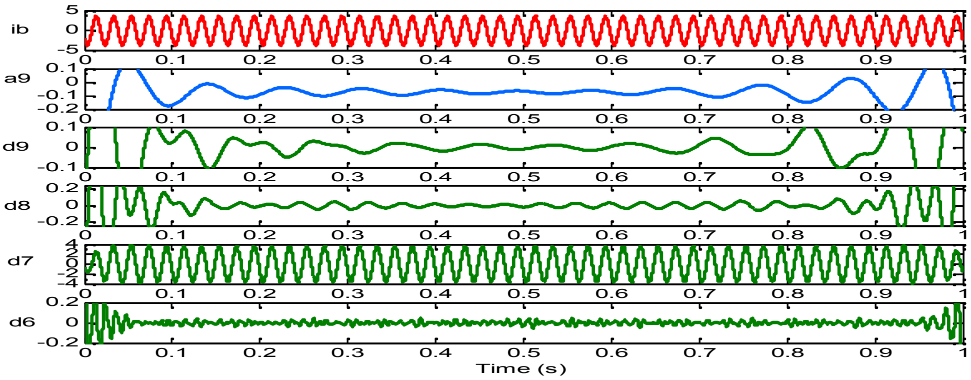
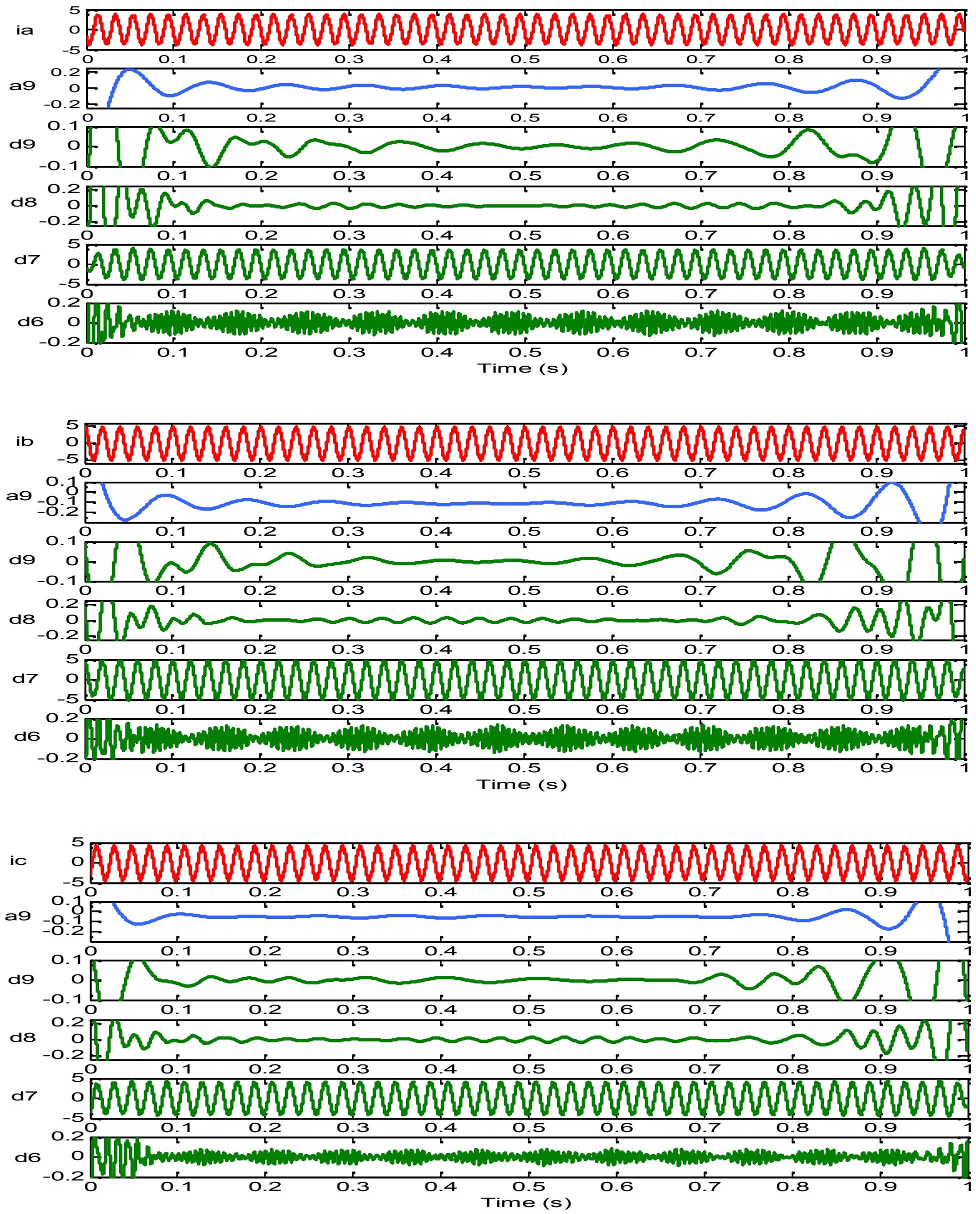


Fig.4. Stator current for faulty induction motor: -a- steady state, -b- startup state

The experimental tests of the induction machine operating at steady-state with speed 1437rpm. The stator fault situation in stator phase '*b*': 12.5 % of the windings short circuited. Fig. 4.a shows the three phase currents.

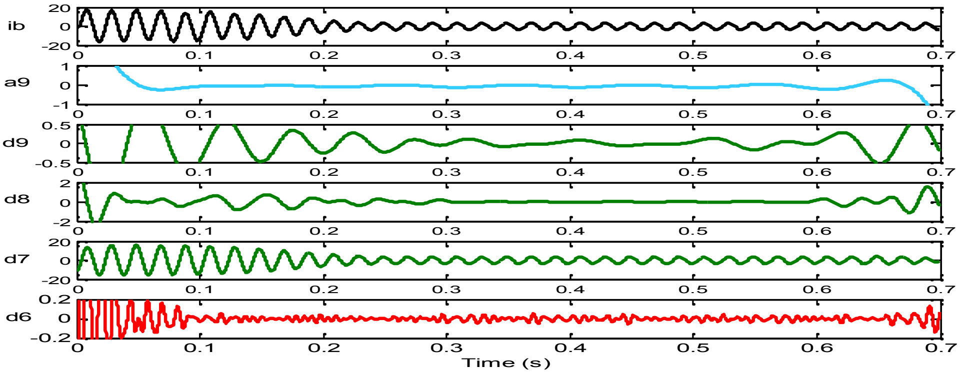


-a-

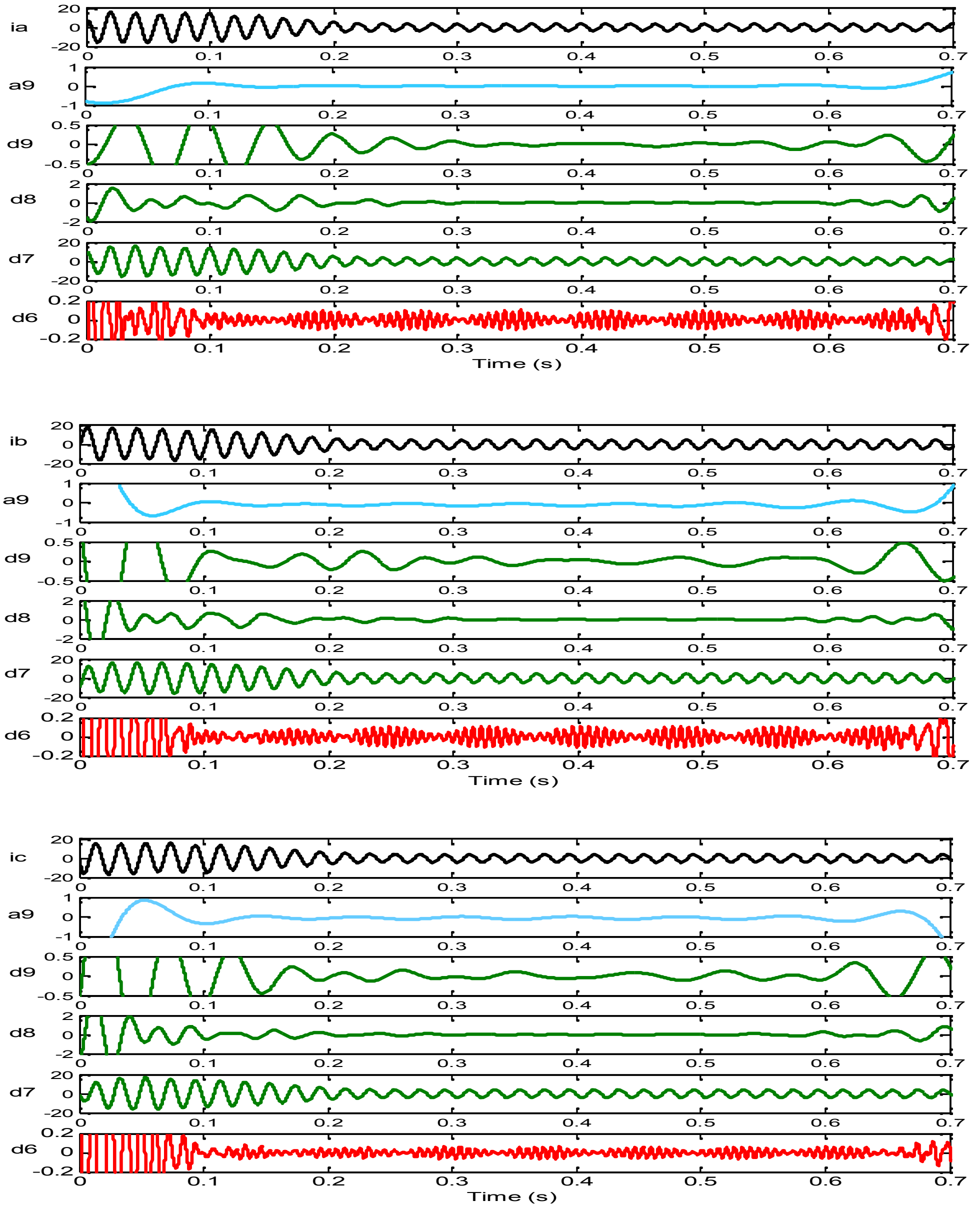


-b-

Fig.5. DWT analysis of the stator current in steady-state: -a- Healthy machine, -b- Inter-turn short circuit in phase b



-a-



-b-

Fig. 6. DWT analysis of the startup stator current: -a- Healthy stator, -b- stator inter-turn short circuit in phase b

After this, discussion about the results of the experiments is presented in Fig.5 for healthy motor and motor under stator inter-turn short circuit fault conditions. In Fig 5 shows the approximation and detail signals of the steady-state acquired from the wavelet analysis of the stator currents in healthy mode (Fig.5.a) and faulty conditions of the stator winding (Fig.5.b) respectively. From the detail level 'd6', show significant oscillations as compared to the healthy case. This is due to the unsymmetrical of the stator currents when stator winding short circuits fault of the phase '*b*'.

Figure 6 shows the spectral analysis the stator current in start-up state for the machine. The Fig. 6.b clearly shows that the stator faults can be detected of the perturbations that appear in the high-level signal of the decomposition 'd6'.

4. CONCLUSION

In this paper, The DWT is applied to the stator current signals at the start-up transient state and at steady state of the machine. The experimental results confirm that the DWT is reliable tool to extract stator winding short circuit faults, particularly in the presence of inter-turn short circuit at start-up state.

There are many other common faults which require investigation in future work whether the use of DWT is feasible for example rotor broken bar and eccentricity faults.

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