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DWT and Hilbert Transform for Broken Rotor Bar Fault Diagnosis in Induction Machine at Low Load

B. Bessam[a,b], A. Menacer[a], M. Boumehraz[b], H. Cherif[*]

[a]LGEB Laboratory, Department of Electrical Engineering, University of Biskra, BP 145, 07000, Biskra, Algeria
[b]LMSE Laboratory, Department of Electrical Engineering, University of Biskra, BP 145, 07000, Biskra, Algeria
[*]LGEB Laboratory, Department of Electrical Engineering, institute of sciences and technology, University El-Oued, Algeria,

Abstract

In this paper a new technique for broken rotor bars diagnosis in induction machine at low load and non stationary state is proposed. The technique is used in order to remedy the problem from using the classical signal-processing technique FFT by analysis of stator current envelope. The proposed method is based from using discrete wavelet transform (DWT) and Hilbert transform. The Hilbert transform is used to extract the stator current envelope. Then this signal is processed via DWT. The efficiency of the proposed method is verified by simulation tests.

Keywords: Induction Motor, Diagnosis, Hilbert transform, discrete wavelet transform;

1. Introduction

Three-phase induction motors are the "workhorses" of industry. They are the most widely used electrical machines, for their reliability and simplicity of construction. In an industrialized nation, they can typically consume between 40% and 50% of all the generated capacity of that country [1]. But, they are subject to failures, which may be inherent in the machine itself, or due to operating conditions. Failure surveys [2], have reported that percentage failure by components in induction motors is typically:

- stator related (38%);
- rotor related (10%);
- bearing related (40%);
- and others (12%).

But, in recent years, due to the need to support the severe voltage stresses of solid-state inverters, and to operate in highly corrosive and dusty environments, the design and build quality of stator windings have achieved marked

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improvements, while cage rotor design has undergone little change [3]. So, nowadays, rotor failures account for a larger percentage of total induction motor failures, with broken rotor bars being one of the most common causes [4].

Traditionally, the monitoring and diagnostic of broken rotor bars based on motor current signature analysis (MCSA) [5] used as non invasive method to detect sidebands harmonics around the fundamental supply frequency expressed by:

$$f_{rbb} = (1 \pm 2s)f \tag{1}$$

Where f_{rbb} is the related broken bar frequency, f is the power supply frequency and s is the slip.

However, at low load these components $(1\pm2s)f$ are relatively close to the fundamental component, which makes their detection much more difficult. To avoid this problem, the amplitude modulation (AM) of stator current induced by rotor asymmetry is exploited in aid of diagnostic. In fact, the rotor fault effect can be localized in the stator current envelope spectrum at frequency expressed by [6]:

$$f_0 = 2ksf \tag{2}$$

This last information has the ideal frequency location for a discrete wavelet transform (DWT) which has been already applied directly to stator current for diagnosis of broken rotor bar faults in induction machine [7]. In this case, the DWT is used as an efficient time-domain algorithm which gives optimal accuracy at low frequency and non-stationary state.

Wavelet transform is an analysis method for time varying or non-stationary signals and uses a description of spectral decomposition via the scaling concept. Wavelet theory provides a unified framework for a number of techniques which have been developed for various signal processing applications [8]. One of its features 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.

The main objective of this paper is proposing a method for the rotor fault diagnosis based on wavelet and Hilbert transform. The proposed method consists in applying the DWT of stator current envelope, to compute the energy associated to the rotor fault in the frequency bandwidth where the total rotor fault effect is localized. Then, this energy computation is used to detect a rotor fault and to evaluate its severity at low load and non stationary state.

2. Hilbert transform of a phase stator current (HT)

The HT is a well-known signal analysis method, used in different scientific fields such as fault diagnosis [9], geophysical data processing, detection of mechanical load faults in induction motors [10], diagnosis of rotor cage faults in induction motors [11], and others.

The HT of a real signal $x(t)$, such as the phase current, is used to emphasize its local properties. Mathematically, it is defined as a convolution with the function $1/t$, as follows [2]:

$$HT(x(t)) = y(t) = \frac{1}{\pi t} \times x(t) = \frac{1}{\pi} \int_{-\infty}^{+\infty} \frac{x(\tau)}{t-\tau} d\tau \tag{3}$$

The divergence at $t = \tau$ is allowed for by taking the Cauchy principal value of the integral. By coupling the $x(t)$ and its HT, the so-called analytic signal (AS) $\vec{x}(t)$ is created:

$$\vec{x}(t) = x(t) + jy(t) = a(t)\, e^{j\theta(t)} \tag{4}$$

where

$$\begin{cases} a(t) = \left[x^2(t) + y^2(t)\right]^{1/2} \\ \theta(t) = arctan(x(t)/y(t)) \end{cases} \tag{5}$$

Where $a(t)$ is the instantaneous amplitude of $\vec{x}(t)$, which can reflect how the energy of $x(t)$ varies with time and $\theta(t)$ is the instantaneous phase of $\vec{x}(t)$.