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Parameter identification and slip estimation of induction machine

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ABSTRACT

This paper presents a newly developed algorithm for induction machine rotor speed estimation and parameter detection. The proposed algorithm is based on spectrum analysis of the stator current. The main idea is to find the best fit of motor parameters and rotor slip with the group of characteristic frequencies which are always present in the current spectrum. Rotor speed and parameters such as pole pairs or number of rotor slots are the results of the presented algorithm. Numerical calculations show that the method yields very accurate results and can be an important part of machine monitoring systems.

1. Introduction

Asynchronous motors are the most popular types of electric machines in use [1,2]. The diagnosing of the health of induction motor is crucial and still receiving more and more attention. Undetected faults may lead to excessive vibrations, poor starting performance, torque fluctuation or higher thermal stresses which can lead to catastrophic failures. For these reasons, a variety of faults which can occur in induction machines, have been extensively studied [3,4] and many monitoring methods have been proposed to detect problems [5–9]. However, due to the different effects produced by various types of fault, a diagnostic technique which is proven to be effective for the detection of a particular fault, may not work at all when used to diagnose a different problem [8].

Some recent works [1,8] are focused on the development of diagnostic techniques which are able to detect any fault in the motor with a minimum knowledge about its parameters and construction. A desired technique also should require only those signals, measurement of which is necessary for proper motor control. The motor current signal is usually available and can be acquired. Following these goals, the authors have developed a new non-invasive diagnostic technique based on current measurement.

2. Concept of motor fault detection method

In diagnostic engineering, the fast Fourier transform (FFT) is commonly used. However, to properly utilize the FFT result, the physical properties of a system and the operation conditions should be known. For example, in order to estimate the frequencies related to a rotor fault, knowledge of motor parameters and rotor speed is necessary. Inaccurate parameter estimation may result in a faulty machine being mistaken for a healthy one and vice versa. The main concept of the presented method assumes that the only available data is motor current. Detection of motor faults on the basis of current spectrum analysis is difficult and requires additional knowledge about spectrum behavior.

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Nomenclature

f	power supply frequency
f_{brb}	broken rotor bars frequency
f_{eh}	high frequency eccentricity
f_h	higher harmonics of power supply
f_{el}	low frequency eccentricity
f_{PSH}	principal slot harmonics
f_r	rotor speed frequency
$\tilde{f}_r$	a set of candidates for rotor speed
f_{synch}	synchronous mechanical frequency
k	rotor slotting effect order number
n_d	eccentricity order
p	fundamental number of pole pair
$\tilde{p}$	estimated number of pole pair
p_{max}	maximum number of pole pairs
p_{min}	minimum number of pole pairs
R	number of rotor bars
$\tilde{R}$	estimated number of rotor bars
R_{max}	maximum number of rotor bars
R_{min}	minimum number of rotor bars
s	slip per unit
σ	interval depends on number of number of pole pairs
v	order of stator time harmonic

The power spectrum of motor current is dominated by a peak at the power supply frequency which in motors that are not connected to variable frequency drives, is equal to 50 Hz in Europe. However, there are also plenty of other non-dominant frequencies in the current spectrum which are always distinguishable from noise. It is possible to select motor parameters which are fitted best to the measured frequencies and then use them for fault detection. The block diagram of such a diagnostic system is shown in Fig. 1.

The estimation of the dominant power supply frequency is used as the basis for further calculations. Once identified, it is possible to select a set of frequencies related to rotor eccentricities. However, this set depends on motor parameters. The main idea is to find motor parameters which match frequencies related the rotor eccentricities.

3. Overview of frequencies in motor current spectrum

In many diagnostic methods [10–12], estimation of rotor speed is the basis for the identification of further frequencies. Rotor slot harmonics (also called the principal slot harmonic or PSH) are some of the most important frequencies in many sensorless speed estimation schemes [2,5]. Those frequencies are given in compact form in [6]:

$$f_{eh}=\left[(kR\pm n_d)\frac{1-s}{p}\pm v\right]f \tag{1}$$

where k=1,2,3,..., is the rotor slotting effect order number; R is the number of rotor bars; n_d is eccentricity order (n_d=0 means existence of only static eccentricity); s is the slip per unit; p is the fundamental number of pole pairs; v=1,3,5,…, is the order of stator time harmonic; f is the power supply frequency. For k=1, v=1, and n_d=0, Eq. (1) describes the principal slot harmonics f_{PSH}. The determining of f_{PSH} allows an estimation of slip s to be made. Knowing the slip enables calculation of rotor rotating frequency f_r by rearranging of the equation:

$$s=\frac{f_{synch}-f_r}{f_{synch}} \tag{2}$$

where $f_{synch}=f/p$ is a synchronous mechanical frequency. However, the estimation of f_r on the basis of f_{PSH} involves knowledge of parameter values which are used in Eq. (1). The concept of the presented paper assumes that those parameters are not known.

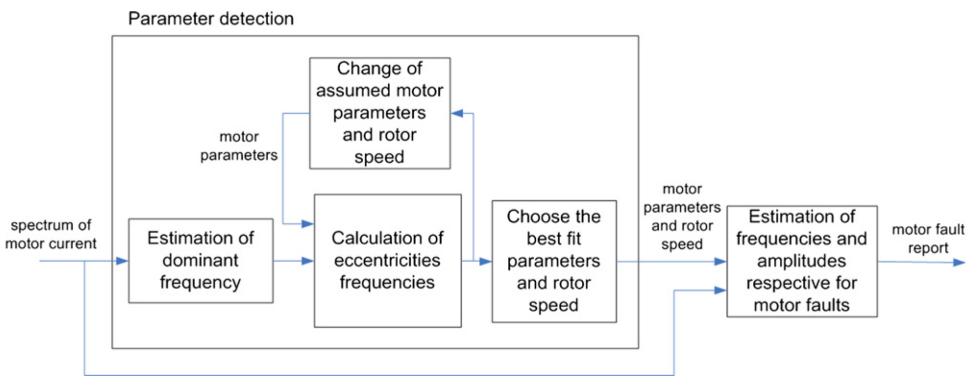

Fig. 1. Motor parameters and rotor speed detection scheme.