

Spectrum Analysis of Sidebands in Industrial Drives

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ABSTRACT

This paper deals with the diagnosis of induction motors (IM) with the so-called motor current signature analysis (MCSA). The MCSA is one of the most efficient techniques for the detection and the localization of electrical and mechanical failures, in which faults become apparent by harmonic components around the supply frequency. This paper presents a summary of the most frequent faults and its consequences on the stator current spectrum of an IM. A three-phase IM model was used for simulation taking into account in one hand the normal healthy operation and in the other hand the broken rotor bars, the shorted turns in the stator windings, the voltage unbalance between phases of supply and the abnormal behavior of load. The MCSA is used by many authors in literature for faults detection of IM. The major contribution of this work is to prove the efficiency of this diagnosis methodology to detect different faults simultaneously, in normal and abnormal functional conditions. The results illustrate good agreement between both simulated and experimental results.

Keyword Fault Diagnosis, Induction Motor, Motor Current Signature Analysis, Multiple Faults

1. INTRODUCTION

The Induction motors play an important role in industry for the rotating machine practice because of their hardiness low costs and quasi-absence of maintenance. Nevertheless, it arrives that this machine presents an electric or mechanical defect. The faults of these machines are varied. However, the most frequent are (Benbouzid (2000), Razik (2002) and Trajin et al. (2008): opening or shorting of one or more of a stator phase winding, broken rotor bar or cracked rotor end rings, static or dynamic air-gap irregularities, and bearing failures. In order to avoid such problems, these faults have to be detected to prevent a major failure from occurring. It is well known that a motor failure may yield an unexpected interruption at the industrial plant, with consequences in costs, product quality, and safety. During the past twenty years, there has been a substantial amount of fundamental research into the creation of condition monitoring and diagnostic tech-

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niques for IM drives. Different detection approaches proposed in the literature, those based on the Extended Park's Vector Approach (EPVA), which allows the detection of inter-turn short circuits in the stator winding (Acosta et al., 2004). The EPVA is appropriate for the stator windings monitoring. Çalis and Çakir (2007) used the $2.s.f_s$ spectral component in the stator current zero crossing times (ZCT) spectrum as an index of rotor bar faults. However, the major deficiency for this fault indicator, for low slip IM Operating at no load condition it may then be difficult to read its value. In Casimir et al. (2006), the authors studied the diagnosis of IM by pattern recognition method. This method consists in extracting features from the combination of the stator currents and voltages. Some of these features could be irrelevant or redundant. Therefore, the Sequential Backward Selection (SBS) algorithm is applied to the complete set of features to select the most relevant. Then they used the k-Nearest Neighbours (kNN) rules to monitor the IM functioning states. This rule is applied with reject options in order to avoid automatic classifications and diagnosis errors. Didier et al. (2007) employed the Fourier Transform of the stator current and they analyzed its phase. It is shown that the basically calculated phase gives good results when the motor operates near its nominal load. For weak load, the results obtained are not robust enough for the detection of an incipient rotor fault. In Li and Mechefske (2004), the authors used the vibration monitoring methodology to detect incipient failures in IM. Vibration monitoring system requires storing of a large amount of data. Vibration is often measured with multiple sensors mounted on different parts of the machine. The examination of data can be tedious and sensitive to errors. Also, fault related machine vibration is usually corrupted with structural machine vibration and noise from interfering machinery. To overcome these problems Poyhonen et al. (2003) used the Independent Component Analysis (ICA) to compress measurements from several channels into a smaller amount of channel combinations and to provide a robust and reliable fault diagnostics routine for a cage IM. This paper is focused on the Motor Current Signature Analysis (MCSA) approach. This technique utilizes results of spectral analysis of the stator current (precisely, the supply current) of an IM to spot an existing or incipient failure of the motor or the drive system. It is claimed that MCSA monitoring is the most reliable method of assessing the overall health of a rotor system (Thomson, 2001). Unlike the greater part of techniques, MCSA can provide the same indications without requiring access to the motor.

2. DIFFERENT TYPES OF FAULTS

2.1. Broken Rotor Bars

It is well known that, under normal conditions of working, a 3-phase IM with symmetrical stator winding fed from a symmetrical supply voltage with frequency f_s , will produce a resultant forward rotating magnetic field at synchronous speed and if exact symmetry exists there will be no resultant backward rotating field. When rotor defect appears, it creates in addition of the direct rotor field an inverse field that turns to the speed $(-s.\omega_s)$. It is due to the fact that the rotor currents are now direct and inverse following the unbalance of resistances. It is the interaction of this field with the one descended of stator windings that induces an e.m.f. and current in the stator winding at $(1-2.s).f_s$. This cyclic current variation causes a speed oscillation at twice the slip frequency $(2.s.f_s)$ and finally, this speed oscillation induces, in the stator current spectrum, an upper component at $(1+2.s).f_s$, and so on (Çalis and Çakir (2007) and Mehala and Dahiya (2009)). Therefore, broken rotor bars induce harmonic components in the stator current at frequencies given by Thomson (2009) and Jung et al. (2006):

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