Detection and Diagnosis of Broken Rotor Bars in Induction Motors Using the Fuzzy Min-Max Neural Network

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ABSTRACT

In this paper, a fault detection and diagnosis system for induction motors using motor current signature analysis and the Fuzzy Min-Max (FMM) neural network is described. The finite element method is first employed to generate experimental data for predicting the changes in stator current signatures of an induction motor due to broken rotor bars. Then, a series real laboratory experiments is for broken rotor bars detection and diagnosis. The induction motor with broken rotor bars is operated under different load conditions. In all the experiments, the FMM network is used to learn and distinguish between normal and faulty states of the induction motor based on the input features extracted from the power spectral density. The experimental results positively demonstrate that the FMM network is useful for fault detection and diagnosis of broken rotor bars in induction motors.

Keywords: Condition Monitoring, Fault Diagnosis, Fuzzy Min-Max (FMM) Neural Network, Induction Motor, Pattern Classification

1. INTRODUCTION

A motor is a widely used device for converting electrical energy to mechanical energy. Owing to the use of variable-speed drives in improving motor efficiency, issues related to over-heating and harmonic problems occur; which in turn result in a shorter operational life of motors. In terms of applications, induction motors are widely used in industries, which include manufacturing machines, belt conveyors, cranes, lifts, compressors, trolleys, electric vehicles, pumps, and fans (Montanari et al., 2007).

The Motor Current Signature Analysis (MCSA) technique can be used to examine the supply currents for detecting a particular
motor failure in the drive system. One way to
use MCSA is to sample the harmonics compo-
nents in the stator-current spectrum using the
Fast Fourier Transform (FFT) (Benbouzid &
Kliman, 2003). Current monitoring can then
be implemented by using current transform-
ers on small to large motors. Indeed, a lot of
research work has been conducted to detect
machine faults using MCSA (Thomson et al.,
1999). Methods for detecting mechanical faults
in induction motors using MCSA generally
ignore the load effects (Benbouzid et al., 1999;
Thomson & Fenger, 2001), or assume that the
load is known (Kim et al., 2003).

Comparing different types of soft com-
puting techniques, neural networks have been
shown to be useful for undertaking fault de-
tection and diagnosis tasks (Ho & Lau, 1995;
Tallam et al., 2003). Some of the popular neu-
ral network models include the Radial Basis
Function (RBF) networks (Ghate & Dudul,
2010a) and the Multi-Layer Perceptron (MLP)
networks (Ghate & Dudul, 2010b). One of the
main advantages of these networks is the flex-
ibility to learn from data samples, whereby the
learning procedure does not require an exact
mathematical model of the problem under scru-
tiny. However, the conventional RBF and MLP
networks operate in an offline batch learning
mode, and re-training is necessary if more data
samples are available after the training phase. As
such, in this study, the supervised Fuzzy Min-
Max (FMM) (Simpson, 1992) neural network
is selected mainly because of its capabilities
of online, one-pass learning without the need
for re-training. In other words, FMM has the
capability of learning new data samples and
adapting to new classes incrementally while
refining the existing classes quickly and au-
tonomously (Simpson, 1992).

The organization of this paper is as follows.
In Section 2, the theory and related work of
fault detection and diagnosis of broken rotor
bars are given. The proposed method using the
supervised FMM network is detailed in Section
3. This is followed by an experimental study,
results, and discussion in Section 4. Finally,
concluding remarks are presented in Section 5.

2. BROKEN ROTOR BARS

In this section, the theory of broken rotor bars
is first given. This is followed by a review of
related work pertaining to fault detection and
diagnosis of broken rotor bars.

2.1. Theory

Cast cage and fabricated cage are two different
types of cage rotors in induction motors. Cast
cage rotors are normally used in induction mo-
tors up to 3000-kW rating while fabricated cages
are used in induction motors of higher ratings
and in special application machines (Awadallah
& Morcos, 2003). Cast rotors are difficult to
fix once breakage or cracks develop in them,
although they are more durable and rugged than
fabricated cages. According to Montanari et al.
(2007), broken rotor bars constitute about 10%
of the total induction machine faults. During
broken rotor bars events, the sideband currents
are given by (Awadallah & Morcos, 2003):

\[ f_k = \left(1 \pm 2ks\right)f, \]  \( k = 1, 2, 3. \)  

Where \( k = 1, 2, 3. \) Considering the speed
ripple effects, other frequency spectrums, which
are observed in the stator-current spectrum,
are given by (Awadallah & Morcos, 2003):

\[ f_k = \left[\frac{k}{p}\right](1-s) \pm s f, \]  \( k/p = 1, 2, 3. \)

Where \( p \) is the number of pole pairs, and
\( k/p = 1, 2, 3. \)

2.2. Related Work

Back Propagation (BP) is a commonly used
supervised learning method for feedforward
neural networks (Arabacı & Bilgin, 2010).
In Arabacı and Bilgin (2010), current signals
were transformed to magnitudes using FFT,
and side-band frequency magnitudes were fed
into a feedforward neural network trained with
Condensing Biochemistry into Gene Regulatory Networks
www.igi-global.com/article/condensing-biochemistry-into-gene-regulatory-networks/118155?camid=4v1a

An Immune Algorithm Based Robust Scheduling Methods
www.igi-global.com/chapter/immune-algorithm-based-robust-scheduling/19642?camid=4v1a