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Application of Dempster–Shafer theory in fault diagnosis of induction motors using vibration and current signals

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Abstract

This paper presents an approach for the fault diagnosis in induction motors by using Dempster–Shafer theory. Features are extracted from motor stator current and vibration signals and with reducing data transfers. The technique makes it possible for on-line application. Neural network is trained and tested by the selected features of the measured data. The fusion of classification results from vibration and current classifiers increases the diagnostic accuracy. The efficiency of the proposed system is demonstrated by detecting motor electrical and mechanical faults originated from the induction motors. The results of the test confirm that the proposed system has potential for real-time applications.

Keywords: Dempster–Shafer theory; Data fusion; Neural network; Fault diagnosis; Induction motor; Condition monitoring; Vibration signal; Stator current signal

1. Introduction

Induction motors are widely used as industrial prime movers to drive pumps, compressors and fans, for their reliability and simplicity in construction. Although induction motors are reliable, they are subjected to some mode of unexpected faults. These faults may be inherent to the machine itself or due to operating conditions [1]. The origins of inherent faults are due to the

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mechanical or electrical forces acting on the machine. In general, condition-monitoring schemes have been widely used to sense specific failure modes in one of three main induction motor components: the stator, the rotor, and the bearings [2]. Even though vibration and thermal monitoring have been used for decades, most of the recent research has been directed toward electrical properties monitoring of the motor with emphasis on monitoring the stator current of the machine [3]. Many researches have been directed toward using the stator current or vibration spectrum to sense the faults such as broken rotor bars, mechanical imbalance and bearing faults. All of the presently available techniques require the user to have some degree of expertise in order to distinguish a normal operating condition from a potential failure mode. This is because the monitored data are influenced by many factors, including electric supply, static and dynamic load conditions, noise, motor geometry and fault conditions; and can be caused by a number of sources, including those related to abnormal operating conditions [4].

The trend in recent years has been to automate the analysis of the measured signals by incorporating expert systems or neural networks (NNs) into the on-line monitoring schemes [5–7] to detect only single fault conditions. NN has gained popularity over other techniques, as it is efficient in discovering similarities among large bodies of data. NN is the functional imitation of a human brain, which simulates the human decision-making and draws conclusions even when presented with complex, noisy, irrelevant information. NNs can represent any non-linear model without knowledge of its actual structure and can give results in a short time during the recall phase. Denoeux [8] proposed a new adaptive pattern classifier based on the Dempster–Shafer theory of evidence and demonstrated the excellent performance of this classification scheme compared to the existing statistical and neural network techniques.

Sensors are used extensively in condition monitoring and diagnosis system to tackle the problem of perception by providing information of the machine. A particular sensor is considered appropriate for a sensing task when a relationship or mapping between the measured quantity and the condition of machinery exists. The exactitude with which this relationship is known depends on how well understood the measurement is. In this regard, physical descriptions of sensors are essential. Unfortunately, such descriptions or physical models are only approximations owing to our lack of complete understanding of the principles governing the transducer operation and consequently the resulting measurement. This is often exacerbated by incomplete knowledge and understanding of the environment and its interaction with the sensor. In addition, sensor measurements inherently have varying degrees of uncertainty which are usually, spurious and incorrect. This coupled with the practical reality of occasional sensor failure greatly compromises the reliability and reduces the confidence in sensor measurements. Also, the spatial and physical limitations of sensor often mean that only partial information can be obtained with a single sensor. As a result of these shortcomings, a single sensor has limited capabilities for resolving ambiguities and ability to provide consistent descriptions of the measurement. Despite advances in sensor technologies and computational methods and algorithms which are aimed at extracting as much information as possible from a given sensor, the irrefutable fact remains that no single sensor is capable of obtaining all the required information reliably, at all times under different dynamic environment [9].

Three methods for combining this uncertain information commonly used in artificial intelligence are those presented by Bayes, Dempster–Shafer and Endorsement theories [10]. Bayes and Dempster–Shafer are the most widely known and used. Bayes' theorem provides a numerical method for updating the probability of a hypothesis given an observation of evidence.