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Smart wireless sensor networks for online faults diagnosis in induction machine ☆

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ABSTRACT

Online induction machine faults diagnosis is a concern to guarantee the overall production process efficiency. Nowadays, the industry demands the integration of smart wireless sensors networks (WSN) to improve the fault detection in order to reduce cost, maintenance and power consumption. Induction motors can develop one or more faults at the same time that can produce sever damages. The origin of most recurrent faults in rotary machines is in the components: stator, rotor, bearing and others. This work presents a novel methodology for the online faults diagnosis in induction motors. This technique uses the smart WSN to obtain the machine condition based on the motor stator current analysis. The implementation of the proposed smart sensor methodology allows the system to perform online fault detection in a fully automated way. Simulation results presented show the efficiency of the proposed method to detect simple and multiple faults in induction machine. It provides detailed analysis to address challenges in designing and deploying WSNs in industrial environments, and its reliability.

1. Introduction

The fast advancement in WSNs is due to not only the innovations in the communications and computer-engineering fields, but also the development of new transducers, since as data-capture devices they play a key role in online monitoring systems. Taking into account the features of WSN motes (e.g., consumption, price, and size), special attention should be paid to the research and the achievement of new generation transducers, provided that they are compatible with these features and can therefore be included within the nodes of a WSN [1,2]. The development of wireless sensor networks is the result of the deployment of large number of these smart sensors. The collaborative operation of WSN brings significant advantages including flexibility, high fidelity, self-organization, aggregated intelligence via parallel processing, low cost, low consumption and rapid deployment. These features make WSN a promising platform for online and remote implementation of fault diagnosis system. Instead of proposing a new fault detection method for a specific motor failure, the main focus of this work is to perform a system overview for a global automated current motor analysis especially where the nonintrusive nature of electrical signal based machine. This enables us to implement the online induction machine fault detection in a smart WSN architecture. In the proposed smart WSN scheme, every smart sensor attached to the induction motor determines the

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condition of the motor if it is healthy or faulty and sends the fault nature if it exists. The smart sensor takes this decision based on the electrical data measured from the induction motor, and then the fault detection scheme is applied at the same smart sensor. Only the detected fault nature is sent to the local supervisory center via WSN and to the remote user via IP networks. In this approach the data communication burden is reduced because the WSN transmits only the motor condition to monitor efficiency and health condition in an online and nonintrusive manner. In other alternative approach, the electrical data are collected and transmitted through WSN and processed in the diagnosis center using alternative algorithms for fault detection. This method needs high bandwidth especially for great number of sensors and high capacity (for the diagnosis center) to process all gathered data. In case that, in some applications, other sensors data such as temperature and vibration are readily unavailable, it presents also many complexities for real time applications. Due to the limitation of WSN technology such as long latency, relaxed data throughput, limited reliability, and the system scalability are the objectives of applying the smart WSN scheme to perform online faults diagnosis for industrial machine [3,4].

Induction motors are key elements in every industrial process; their robustness, low cost, easy maintenance and versatility make them popular in many applications from home appliance to sophisticated industrial equipments. In industry, the most popular induction motor is the squirrel-cage motor that they can keep working under certain fault conditions without giving any sign of failure until it is too late when production costs have excessively risen or the machine have suffered irreversible damage. Thus, when induction motor start developing incipient faults it is important to detect the fault early because it is easier to repair and benefiting the industry in cost and maintenance time. Online continuous monitoring of rotary machine can diagnose electrical and mechanical faults opportunely avoiding expensive reparations and unscheduled shutting downs of production line preventing incoming losses. The approach presented in this paper minimizes the time interval between the fault occurrence and its diagnosis, and to provide a system overview where the non-invasive enables its application in a WSN architecture. To attain this short detection time, the proposed fault detection method should be implemented at the smart sensor level. The paper discusses the development of sensors for identifying mechanical faults in induction motors is organized as; Section 2 describes the wireless sensor networks implemented in this architecture. Section 3 presents the fault diagnosis method based on WSN. Section 4 describes the architecture design of the proposed online fault detection method and Section 5 presents the experimental validation of this architecture. Finally the work is concluded in Section 6.

2. Related works

Induction motors are nowadays extensively used in industrial, commercial, aerospace, and military applications due to their simple construction and the reliability. In this way, early fault detection and identification permit preventative and condition-based maintenance to be arranged for the electrical machines during scheduled downtimes [5].

Various methods for induction motor fault detection have been reported in the literature. In [6], authors have suggested an online induction motor diagnosis system using motor current signature analysis with advanced signal-and-data-processing algorithms. The proposed system diagnoses induction motors have four types of faults such as breakage of rotor bars and end-rings, short-circuit of stator windings, bearing cracks, and air–gap eccentricity. Advanced signal-and-data-processing algorithms are composed of an optimal-slip-estimation algorithm, a proper-sample-selection algorithm, and a frequency auto search algorithm for achieving MCSA efficiently. In [7], authors have investigated the detection of rolling-element bearing faults in induction motors by stator current monitoring. A fault model has been suggested, which takes in consideration fault related air–gap length variations and changes in the load torque. The frequency contents of the stator current are obtained for the three major fault types. The spectral analysis shows that characteristic vibration frequencies are discernible in the torque spectrum. The torque oscillations lead to changes in the stator current spectrum. In [8], a formulation of a mixed eccentricity index has been developed considering the interaction between static- and dynamic-eccentricity flux density waves. In [9], authors have taken the initial step to investigate the efficiency of current monitoring for diagnostic purposes. The effects of stator current spectrum are described and the related frequencies determined. The frequency signatures of some asymmetrical motor faults are well identified using advanced signal processing techniques such as high-resolution spectral analysis. In [10], authors have presented the use of the induction motor current to identify and quantify common faults based on bi-spectrum analysis. A modified bi-spectrum based on the amplitude modulation feature of the current signal is then adopted to combine both lower sidebands and higher sidebands simultaneously.

The signal processing tools used in induction motor fault diagnosis are much diversified. In [11], author presents an original fault signature based on an improved combination of Hilbert and Park transforms. The fault signature is analyzed using the classical fast Fourier transform (FFT), the effects of mechanical faults are described, and the related frequencies are determined. In [12], author proposes the use of the Wigner–Ville distribution for the time–frequency decomposition of the startup current signals, since this is a tool showing a good trade-off between time and frequency resolution both for low and high frequency regions. In [13], authors have presented a diagnosis method of induction motor faults based on time–frequency classification of the current waveforms. This method is composed of two sequential processes: a feature extraction and a rule decision. In the process of feature extraction, the time–frequency representation has been designed for maximizing the separability between classes representing different faults. The disadvantages of time–frequency tools are: first the compilation of their algorithms is time consuming compared to that of FFT. Second, the extraction of information necessary for diagnosis is difficult.