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Experimental investigations on induction machine condition monitoring and fault diagnosis using digital signal processing techniques

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Abstract

Condition monitoring is used for increasing machinery availability and machinery performance, reducing consequential damage, increasing machine life, reducing spare parts inventories, and reducing breakdown maintenance. An efficient condition monitoring scheme is capable of providing warning and predicting the faults at early stages. The monitoring system obtains information about the machine in the form of primary data and through the use of modern signal processing techniques; it is possible to give vital information to equipment operator before it catastrophically fails. The suitability of a signal processing technique to be used depends upon the nature of the signal and the required accuracy of the obtained information. Therefore, in this paper, signals obtained from the monitoring system are treated with different processing techniques with suitably modified algorithms to extract detailed information for machine health diagnosis. In this study, on-line analysis of the acquired signals has been performed using C++, while MATLAB has been used to perform the off-line analysis.

Keywords: Induction machine; Fault; Condition monitoring; Diagnostic; Digital signal processing; Fourier transform

1. Introduction

Predictive maintenance by vibration monitoring of electrical machine is a scientific approach that becomes the new route to the maintenance management [1–4]. Electrical machines, even new ones, generate some level of vibration [5–17]. Small levels of ambient vibrations are acceptable. However, higher levels and increasing trends are symptoms of abnormal machine performance. Machine vibration analysis becomes one of the important tools for machine faults identification. There are two types of analysis, time domain and frequency domain. The frequency domain analysis is more attractive one because it can give more detailed information about the status of the machine whereas; the time domain analysis can give qualitative information about the machine condition. Generally, machine vibration signal is composed of three parts, stationary vibration, random vibration, and noise. Traditionally, Fourier transform (FT) was used to perform such analysis. If the level of random vibrations and the noise are high, inaccurate information about the machine condition is obtained. Noise and random vibrations may be suppressed from the vibration signal using signal processing techniques such as filtering, averaging, correlation, convolution, etc. Sometimes random vibrations are also important because they are related to some types of machine faults hence; there is a need to observe these vibrations also.

Signals obtained from the transducers are in the form of continuous voltage or current signals. It is necessary to define their values at certain instants of time to be suitable for digital signal processing (DSP) applications. The obtained digital signal is an adequate substitute for the underlying continuous signal if the interval between the successive samples is sufficiently small. The sampling frequency must be twice the highest frequency compo-

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nents of the signal (according to Shannon's theorem) to avoid aliasing of high frequencies components in the low frequency region of the spectrum. In the present work, the sampling frequency has been selected to be four times the highest frequency component of the signal to prevent any possibility of aliasing and to ensure the complete reconstruction of the signal.

In this paper, signals obtained from monitoring system as shown in Fig. 1, are treated with different processing techniques with suitably modified algorithms to extract detailed information for induction machine diagnosis. All the techniques used here for signal analysis and processing have been implemented in C++ and MATLAB software. On-line analysis of the acquired signals is performed using C++, while MATLAB is used to perform the off-line analysis.

2. Nature of electrical machine faults

The induction motor is considered as a robust and fault tolerant machine and is a popular choice in industrial drives. It is important that the measures are taken to diagnose the state of the machine as and when it enters into the fault mode. It is further necessary to do so on-line by continuously monitoring the machine variables. The reasons behind failures in rotating electrical machines have their origin in design, manufacturing tolerance, assembly, installation, working environment, nature of load and schedule of maintenance. Induction motor like other rotating electrical machine is subjected to both electromagnetic and mechanical forces. The design of motor is such that the interaction between these forces under normal condition leads to a stable operation with minimum noise and vibrations. When the fault takes place, the equilibrium between these forces is lost leading to further enhancement of the fault.

The motor faults can be categorised into two types: mechanical and electrical. The sources of motor faults may be internal, external or due to environmental, as presented in Fig. 2. Internal faults can be classified with reference to their origin i.e. electrical and mechanical or to their location i.e. stator and rotor. Usually, other types of fault i.e. bearing and cooling faults refer to the rotor faults because they belong to the moving parts. Fig. 3 presents the fault tree of induction machine where the faults are classified according their location: rotor and stator.

3. Simulation of induction machine under healthy and fault conditions

Modelling and simulation of electrical machine dynamics has attracted many researchers since the early days of electrical machine invention [18]. The fast advances in computing facilities and the improvement in numerical techniques have lead to improvement in accuracy and simulation efficiency. Mathematical models have been developed to include the effect of core loss, saturation effect, winding distribution, and inherent machine faults [18–24].

3.1. Dynamic analysis of induction motor

For simulation of dynamic state, the choice of model is made on the basis of operating conditions as follows:

- Machine operating from balanced sinusoidal supply under nominal voltages, and under/over voltages (phase variable model).
- Machine operating from balanced non-sinusoidal supply obtained from inverter (stationary reference frame model).
- Machine operating from unbalanced sinusoidal supply (instantaneous symmetrical component model).

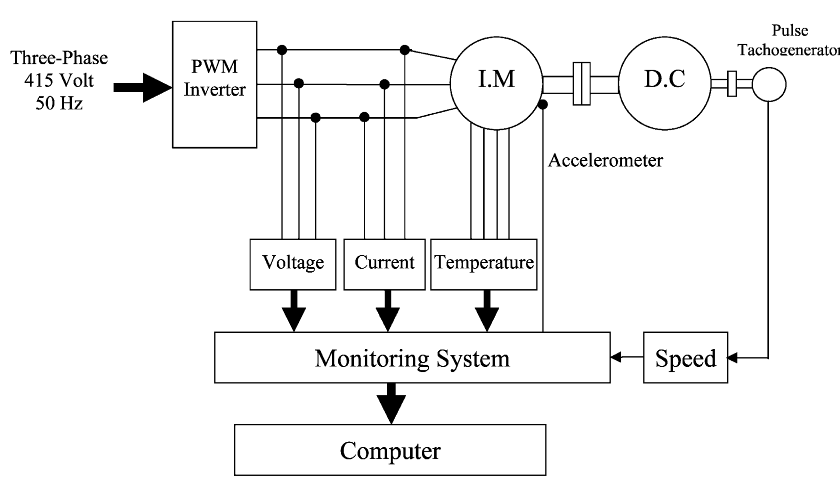

Fig. 1. Schematic diagram of the monitoring system.