FFT-ApEn Analysis for the Vibration Signal of a Rotating Motor

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This paper presents the FFT-ApEn analysis method for the fault detection of an electric motor under different rotating speeds. Motor vibration signals are analyzed using the Fast Fourier Transform (FFT) and Approximate Entropy (ApEn) to obtain the fault factor of a motor under different rotating speeds. The effectiveness of the proposed FFT and FFT-ApEn analyses for predicting the fault is verified through the experimental data. It is found that the FFT-ApEn analysis for the vibration signal can more precisely identify the fault as compared to the conventional FFT analysis method. In addition, the magnitudes of the frequency components are extracted for the recognition of the fault modes. The frequency spectrum analysis is used for distinguishing four operating statuses, i.e., normal, carbon brush failure, abnormal noise and bearing failure. Moreover, the FFT-ApEn method can successfully discriminate four different operating statuses of a motor without removing any motor parts. Hence, the FFT-ApEn analysis method is of great significance for a motor to have a real-time monitoring ability.

1. INTRODUCTION

A motor is an indispensable component in the modern industry. The temperature, noise, voltage, current and vibration signals are the most common parameters for detecting whether the status of a motor is normal or faulty. Among all state-monitoring techniques, the vibration signal analysis is the most classical technique to evaluate the status of a rotating machine. The analysis of a vibration signal is very critical to effectively monitor and control if a rotating motor possessed high productivity and reliability. Generally, for a fault diagnosis technique, the characteristic features of vibration signals were analyzed in frequency domain or chaotic phase space. For examples, Arslan et al. disclosed the relationship between statistical vibration parameters, tool wear, and surface roughness of a work piece during high speed turning operation. Javed et al. presented a method for feature extraction or selection, and the proposition was applied to time-frequency analysis of non-stationary signals using discrete wavelet transform. Zhang et al. used variational mode decomposition to detect the defect signals of different locations in a multistage centrifugal pump. They studied the failure mechanism of bearing rollers, and established the defect signal models of different locations, and simulated the fault signals of outer race defect, inner race defect, as well as the rolling element defect. Also, empirical mode decomposition (EMD) has been widely used for analyzing non-stationary signals due to its ability to self-adaptive decomposition of non-stationary signals. The EMD method can accurately identify and diagnose the running state and bearing fault type at early stages of their development. Generally speaking, for a motion system, the complexity and chaos degree can be described by the Approximate Entropy (ApEn). The higher the complexity and chaos degree of a motion system are, the bigger the ApEn value of the system becomes. The ApEn analysis method has a strong ability of resisting noise interference in random signals, deterministic signals or these two mixed signals. Since this method was proposed, it has been successfully applied to the analyses of heart rate variability and endocrine hormone release pulsatility. Sparacino et al. studied a distorted portrait of the secretion rate at the gland level by ApEn analysis. They reported whether and how this distortion can influence the regularity of hormone pulsatility. On the other hand, in conventional condition monitoring, the commonly used method is the vibration analysis in frequency domain through Fast Fourier Transform (FFT). FFT is an algorithm to realize discrete Fourier transform and able to convert the vibration signal from its time-domain representation to its equivalent frequency-domain representation. Gao et al. presented an algorithm, FFT-AFD (Adaptive Fourier Decomposition), reducing the computational complexity of the AFD. AFD is originated with the purpose of positive frequency decomposition of signals. They have proven the effectiveness, accuracy, and reliability of the FFT-AFD algorithm, as well as laid a foundation for its practical applications. Nevertheless, frequency analysis is only one aspect of interpreting the information contained in a vibration signal. In view of this, this paper presents a FFT-ApEn method for the fault detection of a motor on the basis of both the chaotic space and frequency-domain analysis of vibration signals at different ro-