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Review

A review of stochastic resonance in rotating machine fault detection

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ABSTRACT

Condition-based monitoring and machine fault detection play important roles in industry as they can ensure safety and reduce breakdown loss. Weak signal detection is an essential stage in many signal processing-based machine fault detection methods because the acquired machine signals are always corrupted by heavy background noise. Stochastic resonance (SR) is a nonlinear phenomenon in which the weak signal can be enhanced with the assistance of proper noise. Due to this distinct merit, SR has been extensively investigated in rotating machine fault detection. Given this, the present study is committed to providing a comprehensive review of SR from history to state-of-the-art methods and finally to research prospects, along with the applications in rotating machine fault detection. First, the classical SR theory including the history, merits and limitations is introduced and discussed, and the basic research progress of SR is reviewed. Second, the modified SR methods designed for processing the rotating machine signals are reviewed and summarized. Third, applications of SR for analyzing different kinds of rotating machine fault signals are introduced. Finally, the open problems, challenges and research prospects of SR in rotating machine fault detection are discussed.

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1. Introduction

Rotating machine condition monitoring and fault detection are essential to guarantee machine's safe operation, to reduce unscheduled maintenance, and to avoid catastrophic malfunction [1–5]. Generally, signal processing-based machine fault detection can be realized by three successive steps: signal acquisition, feature extraction, and fault identification. In the first step, vibration signal [6–11], sound signal [12,13], acoustic emission signal [14–16], and motor current signal [17,18] are acquired from sensors that are attached to or placed near to the running machines. Then, the features that can reflect machine condition are extracted using time-domain analysis [19], frequency-domain analysis [20], or time-frequency analysis [21,22] techniques. Finally, the extracted features are evaluated, compared, and fused to generate a comprehensive conclusion for fault detection.

In practice, the signal acquired from a running machine is always subjected to noise interference that comes from environment, acquisition circuit and signal transmission channel, which significantly decreases signal-to-noise ratio (SNR), affects the quality of features and further decreases the accuracy of fault detection. Thus, weak signal detection (WSD) technique is always applied on the raw acquired signal to filter out unrelated noise and to enhance the weak useful signal.

Plenty of WSD techniques have been investigated and applied in rotating machine fault detection, and some of them are briefly reviewed as follows. The first kind is the digital filters through which the out-band noise components are suppressed or eliminated while the in-band useful frequency components are retained. The typical filters include the finite impulse response (FIR) filter in which the output is the linear weighted summation of several inputs, and the infinite impulse response (IIR) filter in which the output is the linear weighted summation of several previous outputs and several inputs. Many methods have been proposed to design the optimal filters to wipe out the noise and retain the fault information in the machine signal, such as the spectral kurtosis [23] and the infogram [24].