Pre-filtering and Location Estimation of a Loose Part

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Abstract

In this paper, two pre-filtering techniques are presented for accurately estimating the impact location of a loose part. The reason why a pre-filtering technique is necessary in a Loose Part Monitoring System is that the effects of background noise on the signal to noise ratio (SNR) can be reduced considerably resulting in improved estimation accuracy. The first method is to take a moving average operation in the time domain. The second one is to adopt band-pass filters designed in the frequency domain such as a Butterworth filter, Chebyshev filter I & II and an Elliptic Filter. To show the effectiveness, the impact test data (signals) from the YGN3 power plant are first preprocessed and then used to estimate the loose part impact position. Resultantly, we observed that SNR is much improved and the average estimation error is below 7.5%.

I. Introduction

An LPMS (Loose Part Monitoring System) is a diagnostic system that monitors the integrity of the Nuclear Steam Supply System (NSSS) and analyzes the impact event caused by moving or loose parts. This system provides the necessary information for the operator's proper decision to maintain a reliable and safe nuclear power plant. The loose parts, metal pieces, are produced by being parted from the structure of the reactor coolant system (RCS) due to corrosion, fatigue, and friction between the components in the RCS and also by coming into the RCS from outside during the period of reactor test operation, refueling, and maintenance during overhaul. These loose parts are mixed with reactor coolant fluid, move with high velocity along RCS circuits, and generate collisions with RCS components. When a loose part strikes against a component within the pressure boundary, an acoustic impact wave is produced and propagates along the pressure boundary. In order to detect the impact signal, a conventional LPMS uses an accelerometer sensor installed on the outer surface of the pressure boundary of the RCS components and announces an alarm when the detected impact signal exceeds a certain level which is pre-set by the operator. The sensors are usually installed on the probable places where loose parts may collect or exist such as the upper head of the reactor pressure vessel, the hot chamber of the Steam Generator. Fig.1 shows typical sensor locations, where the sensor locations are marked with small block rectangle.

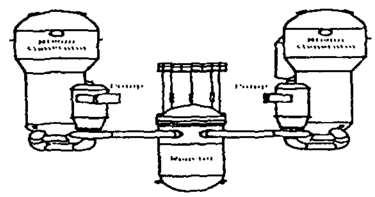

Fig.1. The typical sensor locations at LPMS

In most LPMS, some type of signal filtering exists as a part of signal conditioning for the impact detection. Usually, band-pass filters are used to restrict the accelerometer signal to frequency bands so as to get an improved SNR (signal-to-noise ratio) for impact signals. This frequency band is typically in the range from 1,000 to 20,000 Hz as indicated by the theoretical and experimental result [1]. High-pass filters may typically be set for 500 to 1,000 Hz as a means to reduce the level of induced ac power line frequency signals, low-frequency flow and vibrations noise, and acoustics tones associated with reactor coolant pump. Band-Pass filters are typically set between 10,000 and 20,000 Hz. These bands include passing all of the acoustic signal while filtering high-frequency electrical noise, removing higher frequency acoustic or sensor resonance, or setting the filter to provide the best SNR for impact calibration signal. Since the lighter mass of a loose part produces higher frequency impact signals, band-pass filters limit the minimum loose part that can be detected.