Sequential detection of spectral changes for the SFR heat exchanger monitoring

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In a sodium-cooled fast reactor (SFR), the heat exchanger (HE) should be permanently monitored in order to quickly detect water or nitrogen leaking into a sodium circuit, which can affect the reactor performance or safety. The monitoring system uses accelerometers installed on the HE. The goal is to detect the vibration produced by a small HE leak in the presence of high normal operating noise coming from process (boiling, turbulence) and equipments (pump, turbine, etc.). The solution developed in the paper is based on the combination of the fast Fourier transform (FFT)-based spectral analysis of accelerometer's signals with the Finite Moving Average (FMA) test for the reliable detection of abrupt changes in the spectral density of measured signals. This presentation addresses the sequential detection of suddenly arriving small spectral changes. The detection should be done with a short detection delay. If the detection delay is greater than a prescribed value it is considered as missed. The optimality criterion minimizes the worst-case probability of missed detection provided that the worst-case probability of false alarm during a certain period is upper bounded. This kind of criterion is typical for safety-critical applications such as cyber-physical systems security (see for example [1]) or nuclear reactors security. The proposed solution is based on the spectral analysis of the accelerometer's signals. The suboptimal CUSUM-type transient change detection algorithm [2], applied to the FFT is studied. The spectral analysis of the records coming from the SFR Phénix permits to establish the descriptions of the null hypothesis (normal operating noise coming from the HE and other equipment like pumps, turbine, etc.) and alternative hypothesis (an additive sum of normal operating noise and the useful signal corresponding to a leak of the HE). It is assumed that some information on the abnormal vibrations produced by a small HE leak is available to design the model of signal to be detected. The worst-case probability of missed detection and the worst-case probability of false alarm are calculated and analyzed as functions of the spectral densities of normal and abnormal operating modes of the SFR HE. References 1. V. L. Do, L. Fillatre, I. Nikiforov, and P. Willett Security of SCADA Systems Against Cyber–Physical Attacks. IEEE Aerospace & Electronics Systems Magazine, v. 32, n.5, pp. 28 - 45. 2. B. K. Guépié, L. Fillatre, and Igor Nikiforov Detecting a Suddenly Arriving Dynamic Profile of Finite Duration. IEEE Transactions on Information Theory, v. 63, n. 5, pp. 3039 - 3052