Core Component Vibration Monitoring in BWRs Using Neutron Noise

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Neutron noise from in-core fission detectors in a BWR was investigated to determine its effectiveness as a monitor of mechanical vibrations of core components. In this study the general properties of BWR neutron noise were characterized, and a signal enhancement method was implemented to improve the measurement sensitivity.

Neutron noise is presently being used to monitor the movement of the core barrel in PWRs.[1-3] However, neutron noise has not been used in BWRs because some noise analysts have prediced that the neutron noise caused by boiling voids would likely mask reactivity noise in BWRs introduced by mechanical vibration and thereby limit the usefulness of neutron noise for monitoring such vibrations.

Neutron noise in BWRs is believed to be separable into "global" and "local" components.[4] The global noise is caused by total core reactivity changes and dominates in the frequency range 0 to ~ 1 Hz, whereas the local noise is caused by voids in the vicinity of the detector and is significant in the noise spectrum from 1 to ~ 10 Hz. (These frequency ranges are, of course, approximate and will vary slightly depending upon the reactor). The local noise is generally much lower in amplitude than the global noise and therefore we postulated that it might be possible to detect mechanical vibrations through induced neutron noise in BWRs at frequencies greater than 1 Hz.

We also postulated, that the masking effect of local boiling noise might be further reduced by crosscorrelating the signals from two in-core detectors at different radial core positions. Wach and Kosály have shown that if two detectors are placed one

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downstream of the other in a flow channel, then voids will be detected as they pass each detector and the local noise will be coherent with a fixed time delay between detectors.[4] Conversely, we believe that if the two detectors are in different flow channels, then the local noise should be uncorrelated and therefore should be eliminated by cross correlation. A vibration-induced reactivity fluctuation, however, will be correlated and therefore enhanced by cross correlation.

To test these postulates, neutron noise signals from 43 radially spaced in-core fission ionization chambers in the Browns Ferry Unit 2 BWR were analyzed at power levels of 5, 25, 40, 50 and 100% of the full rated power of ~ 1100 Mwe. The power spectral density (PSD) of each detector and the cross power spectral density (CPSD) between selected pairs of detectors was computed. Figure 1 shows a typical PSD and CPSD from Browns Ferry at 100% power and the PSD of a typical PWR in-core detector.

As postulated, the BWR noise is larger than in a PWR. Even above 1 Hz, BWR noise is one to two orders of magnitude greater than the PWR PSD which decreases the sensitivity for vibration detection. The global noise (0 - ~ 2 Hz) being caused by total core reactivity fluctuations, is coherent (correlated) and therefore is not eliminated by 2-detector cross correlation methods. However, the CPSD analysis eliminates the uncorrelated local boiling noise at frequencies greater than ~ 1-2 Hz (Fig. 1).

We therefore conclude that neutron noise will in the future prove to be as useful in BWRs as it has been in PWRs for monitoring vibration of in-core components, However, because of the global noise, it will probably only prove useful at vibration frequencies greater than 1-2 Hz.

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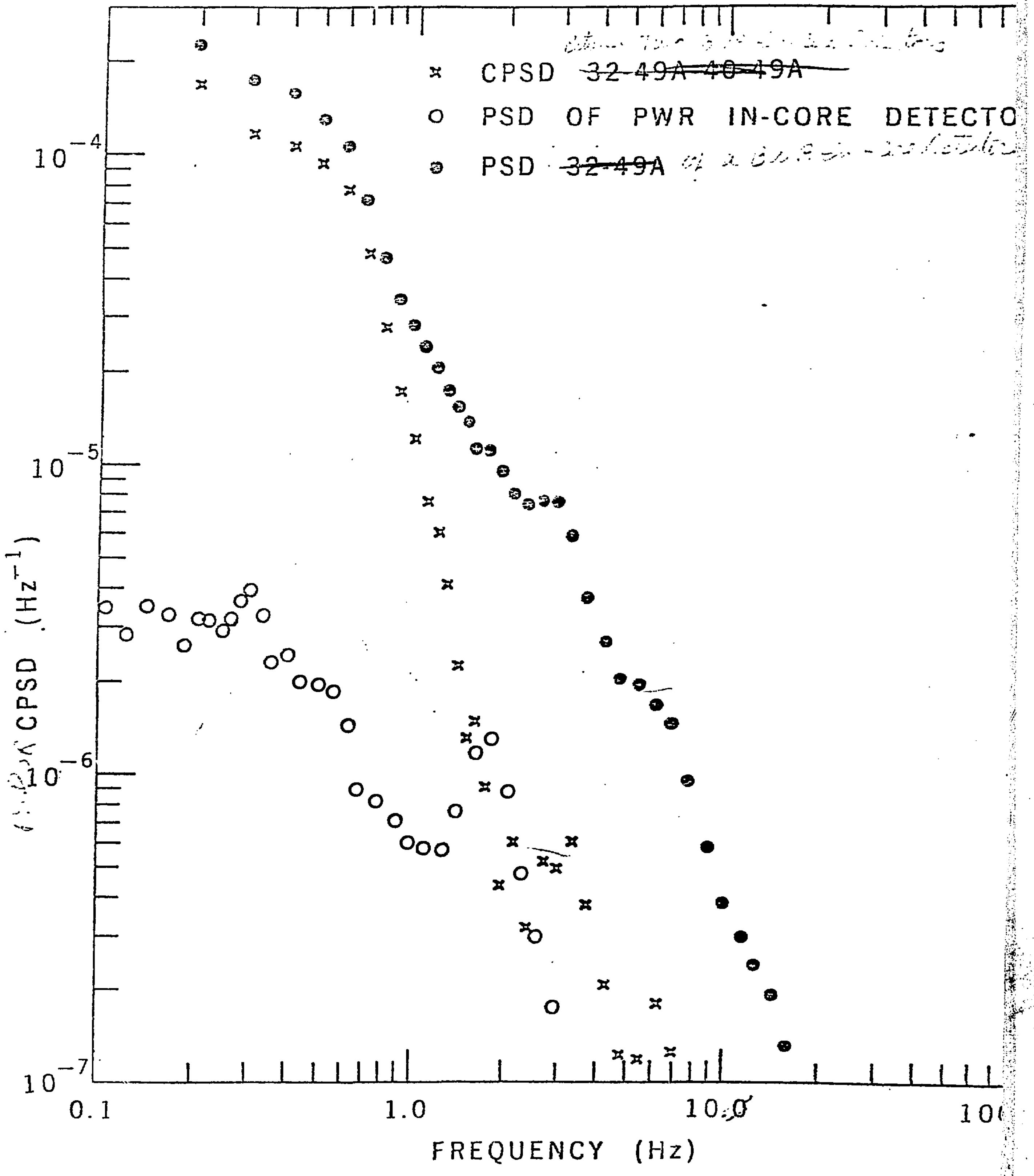

CPSD ~~32-49A 40-49A~~
PSD OF PWR IN-CORE DETECTO
PSD ~~32-49A~~
10^{-4}
10^{-5}
10^{-6}
10^{-7}
CPSD (Hz^{-1})
0.1
1.0
10.0
100
FREQUENCY (Hz)

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