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ANALYSIS OF RELATIONSHIP BETWEEN STABILITY AND FLOW PARAMETERS IN A BWR*

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Results of quantitative analysis of mutual relationship between the BWR stability and channel steam velocity are presented in this paper. The stability parameter, defined by the damping ratio,[1] and the steam velocity are estimated by analysis of neutron noise data from local power range monitor (LPRM) detector signals. These parameters are treated as varying randomly as a function of time.

A theoretical analysis of random fluctuations of BWR stability was studied by Akcasu[2] using a second order stochastic differential equation formulation of the reactivity. He suggested that the variations in the stability margin of a BWR might occur due to random fluctuations in the steam production rate. This will, in turn result in random fluctuations in the steam velocity in a fuel channel. We present a correlation analysis of BWR stability and steam velocity using normal operation data. The stationarity of the data was validated by comparing short data record analysis with long data record analysis. It was suggested by some investigators that averaging large records of data might result in the smoothing of sharp resonance peaks.[3] It is shown here that averaging large data records of a stationary signal will not obscure the neutron spectral characteristics of a BWR during normal operation.

LPRM detector signals in one string of a BWR-4, located near the core axis, were processed using the time series modeling method. The details of model parameter estimation, and optimal model selection are described in Ref. 4. The stability parameter is derived from the univariate modeling of the neutron signal, and the steam velocity is estimated from the bivariate modeling of two LPRM detector signals. The temporal relationship between the various parameters was determined by computing the correlation coefficient, ρ, between pairs of variables.[5] A value of $\rho = \pm 1$ indicates a perfect correlation between the two parameters.

Neutron noise data obtained from an 1100 MWe BWR-4 operating at full power, were processed using short record lengths (ten runs, each 100 s) and a long record length (1000 s). The results of analysis are summarized in Table 1. The following are the calculated correlation coefficients.

Damping ratio with resonance frequency = -0.90

Damping ratio with steam velocity = 0.77

Resonance frequency with steam velocity = -0.77

The neutron spectrum resonance frequency decreases with increasing stability margin (that is, increasing damping ratio), as indicated by the correlation coefficient $\rho_{\xi f_n} = -0.9$. It is seen that the damping ratio and the resonance frequency fluctuate randomly as a function of time, and that averaging does not result in the fading of the resonance peak.

A positive correlation of $\rho_{\xi v} = 0.77$ exists between the damping ratio and the channel steam velocity. This result shows a positive correspondence between the channel steam velocity and the stability margin. Increased void passage rate acts as a stabilizing force for the reactor power generation. This behavior can be explained by studying the closed-loop dynamics of the changes in steam velocity, void fraction and the reactivity. The results presented here agree with the previous studies of BWR stability analysis using the neutronic thermal-hydraulic model.[6] The correspondence between the stability parameter with a parameter such as the steam velocity obtained from a well-established technique, has strengthened the use of neutron noise analysis for BWR stability monitoring. Further implications of this study would be realized with applications to more reliable reactor diagnostics using noise analysis.

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Table 1

Results of BWR-4 Stability Analysis

	10 samples, each with data record length = 100s		One sample with data record length = 1000s
	Mean	Std. Dev.	Mean
Damping Ratio	0.35	0.06	0.35
Peak Frequency (Hz)	0.55	0.05	0.56
Transport, Time (s)	0.167	0.003	0.167
Steam Velocity (m/s)	5.46	0.08	5.46