CONF-801053--8

Advances in Noise Analysis for Nuclear Plant Surveillance and Diagnostics*

D. N. Fry N. E. Clapp, Jr. W. H. Sides, Jr.
J. T. Mihalczo, W. T. King

Oak Ridge National Laboratory
Oak Ridge, Tennessee

INTRODUCTION

We are currently demonstrating an automated surveillance system at Sequoyah-1. The need for such a system was discussed at last year's Water Reactor Safety Research Information Meeting,[1] where we reported our application of noise analysis to a variety of safety-related problems in nuclear plants, including loose-parts monitoring, stability monitoring, bulk coolant boiling detection and postaccident monitoring and diagnosis. It was evident to the Nuclear Regulatory Commission (NRC) from these as well as previous diagnostic tasks[2,3,4] that "baseline" data are invaluable in assessing the significance of safety-related events in nuclear plants. Therefore, the NRC has asked us to install and demonstrate an automated surveillance and baseline noise signature acquisition system at the Tennessee Valley Authority's Sequoyah-1 pressurized-water reactor plant.

We are also developing a non-perturbing method that can be used to monitor subcritical reactivity during initial core loading in LWRs, in fuel storage and processing facilities, and potentially during postaccident recovery operations such as TMI-2.

AUTOMATED SURVEILLANCE SYSTEM

ORNL noise analysts, under Department of Energy (DOE) funding, previously developed a surveillance system to monitor nuclear plant signals for changes in their statistical properties that may be indicative of anomalous conditions or an approaching component failure.[5] The system employs pattern recognition techniques in conjunction with consistency checks (to maintain a low false alarm rate) and is designed to operate on-line and continuously, with only infrequent need for human attention.

*Research sponsored by the Office of Nuclear Regulatory Research, U. S. Nuclear Regulatory Commission under Interagency Agreement DOE 40-544-75 with the U. S. Department of Energy and contract W-7405-eng-26 with the Union Carbide Corporation.

The system begins operation in a "learning" mode, during which a sufficient number of power spectral densities (PSDs) of each signal are measured to determine the baseline PSD and its statistical variations. The length of the learning period, selected by the noise analyst, is usually 10-24 hours.

After the learning period, the system begins the surveillance mode, in which recently acquired PSDs are statistically compared with previously learned (baseline) PSDs to determine whether the current values are within expected statistical variations. If they are not, the PSDs are stored for later study by a noise analyst. Current PSDs are also compared with a "trend" PSD, which is the average of all acceptable PSDs accumulated since the baseline was established. This trend comparison permits slow variations in the PSD to be accepted by the system as normal.

SEQUOYAH DEMONSTRATION

The automated surveillance and baseline signature acquisition installed at Sequoyah-1 has access to power-range neutron flux, pressure, flow, temperature, vibration, and pressurizer level signals (a total of 23) by means of a patch panel. The system can monitor simultaneously any 16 of these signals, as selected by the analyst. At present only four channels are capable of performing noise analysis - - the other 12 signals are used to provide a plant status label for each noise signature that is stored on the magnetic disk. An expanded system, to be installed next year, will have the capability to perform noise monitoring on all 16 channels. One of these systems will be operational at Sequoyah for $\sim$ 18 months or until the first refueling.

Hopefully, this demonstration will show that a means is now available to obtain - - on-line and without a need for human attention - - the long-term characteristics of plant sensor noise signals, properly documented in a concise, easily retrieved form.

SUBCRITICAL REACTIVITY MONITORING

We are also developing a method to determine the reactivity of a far-subcritical system from neutron noise spectral density measurements performed with a special ^{252}Cf source/detector.[6,7] The advantage of this method of reactivity determination over alternative methods is that it determines the reactivity at the subcritical state of interest without requiring a calibration at the delayed critical condition. Thus it is well suited for applications such as initial core loading, fuel storage facility monitoring, and postaccident core condition measurements.

We have performed calculations to estimate the detector efficiency and the length of time required for performing Cf-driven measurements during fuel loading operations in a boiling-water reactor. Our next step is to investigate the influence of spatial harmonics on the interpretability of such measurements by performing time-dependent, two-dimensional diffusion theory calculations of a large LWR core.

OTHER ADVANCES IN NOISE ANALYSIS

In addition to the studies outlined above, we have made advances in assessment of other surveillance and diagnostic methods as reported in references 8-22.

References

1. D. N. Fry, "Application of Noise Analysis to Safety-Related Diagnostics and Assessments," Seventh Water Reactor Safety Research Information Meeting at the National Bureau of Standards, Washington, D.C., November 5-9, 1979.

2. D. N. Fry, R. C. Kryter, and J. C. Robinson, "Analysis of Neutron-Density Oscillations Resulting from Core Barrel Motion in a PWR Nuclear Power Plant," Annals of Nucl. Energy, 2, 341-351 (1975).

3. D. N. Fry, et al., "Use of Neutron Noise to Detect BWR-4 In-Core Instrument Tube Vibrations and Impacting," Nucl. Technol, 43, 42-54 (April 1979).

4. R. C. Kryter, et al., "TMI-2 On-Site Monitoring and Diagnostic Measurements Using Noise Analysis," unpublished summary report prepared for the President's Commission on the Accident at Three Mile Island (August 1979).

5. W. H. Sides, Jr. and K. R. Piety, "Automated Pattern Recognition System for Noise Analysis," Trans. Am. Nucl. Soc., 34, 720-722 (June 1980).

6. J. T. Mihalczo, V. K. Paré, G. L. Ragan, M. V. Mathis and G. C. Tillet, "Determination of Reactivity from Power Spectral Density Measurements with Californium-252", Nucl. Sci. Eng. 66 29-59 (1977).

7. W. T. King, "Feasibility of ^{252}Cf Source Driven Neutron Noise Measurements in Water Moderated Reactors," Ph.D. dissertation, The University of Tennessee (1980).

8. F. J. Sweeney, "Modeling the Local Component of In-Core Neutron Detector Noise in a BWR," Trans. Amer. Nucl. Soc. 33, 854 (November 1979).

9. F. J. Sweeney, "Sensitivity of Detecting BWR Control Rod Vibrations Using Neutron Noise," Trans. Amer. Nucl. Soc. 33, 793 (November 1979)

10. B. R. Upadhyaya and M. Kitamura, "Monitoring BWR Stability Using Time Series Analysis of Neutron Noise," Trans. Amer. Nucl. Soc. 33, 342 (November 1979).

11. M. Kitamura, "Detection of Sensor Failures in Nuclear Plants Using Analytic Redundancy," Trans. Amer. Nucl. Soc. (June 1980).

12. F. J. Sweeney and J. C. Robinson, "Relative Importance of Attenuation and Reactivity Effects in Explaining Local and Global BWR Neutron Noise," Trans. Amer. Nucl. Soc. (June 1980).

13. J. E. Stoneking and R. C. Kryter, "Screening Procedures for Vibrational Qualification of Nuclear Plant Piping," Proc. Fourth National Congress on Pressure Vessel and Piping Technology, San Francisco, August 1980.

14. F. Sweeney, "A Theoretical Model of Boiling Water Reactor Neutron Noise," Ph.D. dissertation, The University of Tennessee (1980).

15. B. R. Upadhyaya and M. Kitamura, "Stability Monitoring of Boiling Water Reactors Using Time Series Analysis of Neutron Noise," submitted for publication in Nuclear Science and Engineering.

16. R. C. Kryter et al., "Application of Noise Analysis to Safety-Related Assessment and Reactor Diagnostics," Proc. International Meeting on Thermal Reactor Safety, Conf-800403, Knoxville, April 1980.

17. F. Shahrokhi, "Metallic Loose-Parts Detection and Characterization," Ph.D. dissertation, The University of Tennessee (1980).

18. M. Kitamura and B. R. Upadhyaya, "An Improved Time Series Modeling Approach for Diagnosis and Surveillance of Reactors," Proc. International Meeting on Thermal Reactor Safety, Conf-800403, Knoxville, April 1980.

19. J. C. Robinson and D. N. Fry, "Diagnostics at TMI Using Noise Analysis," Proc. International Meeting on Thermal Reactor Safety, Conf-800403, April 1980.

20. F. J. Sweeney et al., "Stochastic Modeling of BWR Neutron Noise," 13th Informal meeting on Reactor Noise, Cadarach, France, May (1980).

21. W. H. Sides, Jr., "An Automated Noise Analysis System for Improving Plant Performance," NRC-IEEE Conference on Advanced Electrotechnology Applications to Nuclear Power Plants, Washington, DC, January 1980.

22. R. C. Gonzalez, "Application of Pattern Recognition Technique to Nuclear Reactor Surveillance," Proc. IEEE Conf. Decision and Control, Vol. 2, p 1069-1071, December, 1979.