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FAST FLUX TEST FACILITY NOISE DATA MANAGEMENT

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Abstract - An extensive collection of spectra from an automated data collection system at the Fast Flux Test Facility has features from neutron data extracted and managed by database software. Inquiry techniques, including screening, applied to database results show the influences of control rods on wideband noise and, more generally, abilities to detect diverse types of off-normal noise. Uncovering a temporary 0.1-Hz resonance shift gave additional diagnostic information on a 13-Hz mechanical motion characterized by the interference of two resonances. The latter phenomenon is discussed generically for possible application to other reactor types.

Keywords - Fast reactor; LMFBR neutron noise analysis; reactor surveillance; control rod noise; database software; spectral resonances; Fast Flux Test Facility; interfering resonances.

1. INTRODUCTION

The Oak Ridge National Laboratory (ORNL), in cooperation with the staff of the Fast Flux Test Facility (FFTF), acquires neutron and process noise spectra on the FFTF. An automated data-gathering system (Mullens et al., 1984) is used on this reactor, which is a U.S. government-owned, 400-MW(t) sodium-cooled fast reactor used for test purposes. Objectives of ORNL's noise data collection program include demonstrating automated surveillance.

This system stores spectra and cross spectra on a hard disk. The data accumulation capacity of this system is equivalent to 3840 graphs of spectral functions a day for almost every day of the year. "Eyeballing" by noise specialists is clearly limited to spot-checking. The purpose of the present investigation is to implement a much-needed tool--database management software--to thoroughly examine all data collected. Examples below show some physical insights gained in trial applications of this method, although these do not represent the primary objective of this paper.

2. DATABASE METHODOLOGY

The problem being solved here is how to utilize large masses of data stored on hard disk to give very specific types of information in answer to narrow and precisely formulated questions. In many industries this problem has been solved by the employment of sophisticated database management computer programs. Following these precedents, a commercial software package (Microrim, 1986) was selected for this research. User-friendly commands allow data-moving manipulations as well as arithmetic and logical operations.

It was recognized at the outset that computing efficiencies would be achieved by storing spectral features rather than numerous spectral points in the database. Fig. 1 indicates that more than one such feature can be extracted and stored in a master table. The first feature extraction algorithm used in this application was spectra integrated from 0.47 Hz to 5.17 Hz to obtain rms values; the second was a peak extraction algorithm to obtain resonant frequencies. Appropriate identifying conditions--control rod configuration and type of detector used--are also entered in the database. Managed by the software, disk file to disk file transfers occur throughout the processes of Fig. 1.

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MASTER

Fig. 1. Flowchart of data-handling processes used in the application of database software to FFTF spectral data.

Each master table in the database contains at least two columns with related information. The rows correspond to different features (sequentially acquired) at associated conditions. Specific examples are

- Columns for a rms table: an identification number (ID) such as time or test number, the rms for channel 1, and the rms for channel 2.
- Columns for a resonances table of channel 1: ID, resonant frequency, and spectral value at this resonance.
- Columns for a conditions table: ID, control rod number, rod position, type of detector used for channel 1 in spectral analysis, and type of detector used for channel 2.

The database software allows selectively combining judiciously chosen portions of these tables into master tables having specialized purposes by taking advantage of commands to execute mergings and removals in accordance with logical or arithmetic formulated instructions. For example, one combines rms and conditions tables, then into this new table dc values belonging to the conditions are added; this results in the ability to have a calculated column, $nrms = rms/dc$ value.

Fig. 1 indicates that a master table of data can be subdivided into special smaller tables to which specific inquiries are more efficiently directed. In an example presented in the next section, a specific neutron detector within a specific range of rod configurations is of interest. The reduced table satisfying these conditions would be extracted from the master table by omitting unwanted sensors and rod configurations. Specific inquiries or screenings can be handled using the reduced table.

3. CONTROL ROD EFFECTS

This section presents an example of the application of this database management technique to data from a special test performed by the FFTF staff in January 1957. In this test one particular control rod was inserted to various depths in the core, while the remaining rods were banked together at a more withdrawn position such that reactor power remained constant throughout the test. Then another particular rod was selected for various insertions. With 45 min spent at each of many configurations, there was ample time for spectral analysis. Three 15-min analyses were performed at each configuration using three low-level flux monitors (LLFMs) located in the vessel above the core and three compensated ion chambers (CICs) located outside the vessel. Three days of such data collection yielded important information on how the rms value was influenced by rod configurations.

Obtaining a plot for a particular detector and the position of a particular rod (one of the lines in Fig. 2) is simply a matter of extracting an appropriate reduced table from a suitably constructed master table. The columns of the reduced table were ID, rod number, rod position, detector number, and $nrms$ value. Sections of this table are plotted in Fig. 2.

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Fig. 2. The nrms value of various neutron detectors versus rod position in three separate tests inserting rod 4, 5, or 9. Regarding rod insertion distances, 36 in. is fully withdrawn.

The insights provided by Fig. 2 on how the control rods influence noise corroborate those of earlier studies (Varnes et al., 1984; Thie et al., 1986):

1. Noise is reduced as a rod is withdrawn toward its full out position (36 in.), since there is less inserted reactivity to be laterally moving within the mechanical guide.
2. In the frequency range selected, 0.47 to 5.17 Hz, the CICs observe this reactivity-induced noise best for the "quiet" rods 4 and 5, because the LLFMs observed additional noise from other sources.
3. The rod at position 9 is by far the noisiest, apparently having more freedom of random lateral motion or having more excitation.

The phenomenon here is well understood (Thie et al., 1986) in terms of the reactivity worth of the inserted rod and the mechanical excitation unique to its position.

The ability of the analysis methodology used here to pick out an anomaly is shown in Fig. 3. Since many nrms values were obtained at a given rod configuration, it was possible to calculate the standard deviations of these values. A high standard deviation for LLFM2 appeared for 0.5 h on January 12, 1987. Its spectrum, shown in Fig. 4, shows the temporary addition of a wideband noise whose origin has yet to be identified. However, no anomalous behavior was observed in its dc value.

4. RESONANCES

One of the master tables constructed contained all of the resonances detected by a peak-seeking algorithm. This algorithm defined a resonance as occurring when there was a reversal in an upward trend of spectral value versus increasing frequency. With spectral statistical accuracy in mind, this reversal needed to be at least a 0.8 factor from the peak attained. Using data obtained from spectra measured during various control rod configurations, 593 rows (stemming from 593 different resonant frequencies) and 6 columns resulted. The columns are ID, resonant frequency, spectral value at resonance, rod number, rod position, and neutron detector used.

Due to statistical uncertainties in measuring a true physical resonant frequency, the resonances fell into ranges clustered about central values. Table 1 shows these central values for the most common resonances. The rich resonant structure of the LLFMs compared to that of the CICs is obvious.

Fig. 3. Standard deviations of sets of nrms values for the rod positions of Fig. 2. For a set of three LLFMs or three CICs, only the largest is plotted; an exception is LLFM2's anomalously large standard deviation being plotted separately from the larger of the other two when rod 9 was at 22 in.

Fig. 4. Wideband additive noise appearing in LLMF2 during a 0.5-h departure from normal behavior on January 12, 1987.

In one investigation the master table was "windowed" to extract small tables defined by a particular rod being inserted and the frequency range restricted to that of a cluster. The results were that no resonance in Table 1 exhibited any statistically detectable frequency changes due to rod position. With rod configurations now ignored, Fig. 5 was constructed; it is essentially a histogram of all of the spectral peaks of a particular detector. Some occasionally occurring resonances in CIC2 are evident. The number of these rarities for CIC2 exceeds the number of rarities for all other detectors put together. This is an unexplained phenomenon associated with CIC2.

It was seen above (in spotting a nrms anomaly) that the large amount of data available enables one to examine statistical measures of quantities. This made possible another investigation: to investigate in a sensitive manner whether individual resonance measurements

Table 1. Central values of peaks in clustered groups of values for the various detectors using data from all PSDs at all rod configurations.*

Peak, Hz	Detectors seeing this peak					
	LLFM1	LLFM2	LLFM3	CIC1	CIC2	CIC3
7.5	x	x	x			
11.	x	x	x			
13.25	x	x	x			
15.35	x	x	x	x	x	x
18.2	x		x			
18.8		x				
19.25	x					
21.6	x	x	x			
23.8	x	x	x			
24.4		x	x			
25.25	x	x	x			
26.8	x	x	x			

*In comparing Fig. 4 with the LLFM2 column, bearing in mind that a $\log_{10} (.8)$ reversal at a peak is required, most of these resonances are obvious. Weak resonances, meeting the reversal criterion only sometimes, are not seen in all spectra.

Fig. 5. Density of the spectral resonances that appear in the power spectral densities of the CICs. Bars of a given type essentially represent a histogram of the occurrences of resonances.

are statistically likely in a cluster. Screenings were performed in which small tables were extracted from the master table using all of the latter's columns but including row-restricting commands such as "project small table from master table using all where ch equals 2 and frequency >13 and frequency <13.5."

The arithmetic/logical instruction at the end of this command selects only rows involving the LLFM2 with peaks in the 13. to 13.5-Hz range. One more simple command asking for calculations of basic statistics of this small table's frequency column gives the following results:

Count	= 30
Minimum	= 13.14
Maximum	= 13.33
Average	= 13.28
Standard deviation	= 0.036

(Note that peaks are located with more significant figures than the spectral resolution of the analysis would dictate, as this is the result of an interpolation feature of the algorithm used.) This particular example is shown because, unlike other such tabulations, the resonant frequency departs anomalously from its average: a single spectrum having 13.14 Hz departs 4 standard deviations from the 13.28-Hz average; all other LLFM2 spectra show peaks within 1 or 2 standard deviations of this average. The spectrum where this occurs is the same as that shown in Fig. 4. Figure 6 shows a temporary change in phase behavior, with the slope of phase versus frequency around 13 Hz seen to be a sensitive indicator.

There is some quantitative understanding of phase behavior near 13 Hz, based on a simple model of two mechanical motions at slightly different frequencies (Thie et al., 1986). (The specific structures in motion have yet to be identified.) The model assumes resonant transfer functions H_1 and H_2 , being excited by a common forcing function S :

$$n_1 = (a_{11}H_1 + a_{12}H_2)S + S' \quad (1)$$

$$n_2 = (a_{21}H_1 + a_{22}H_2)S + S' \quad (2)$$

Here the a_{ij} are coupling coefficients for the two motions and the two neutron detector signals n_i . Another forcing function S' , such as reactivity noise, is also provided for. This model successfully computes the type of phase behavior shown in Fig. 6.

Some additional explanation of this double resonance is warranted. Even though seen in a fast reactor, the phenomenon is generic and is quite possible in PWRs. Normal behavior here is LLFM2 "seeing" a frequency 0.1 Hz higher than LLFM1. Such interference causes coherence sinks and rapid rate of changes of phase with frequency due to the close spacing, as well as PSD peaks differing for the two detectors. These three phenomena are clues to the analyst that a double resonant model, such as the one here, is applicable. For the FFTF this double resonance is normal; what is abnormal is a shift of this motion observation by these detectors for about 0.5 h, during which both detectors "saw" the same resonant frequency and hence have little rate of change of phase near 13 Hz.

5. DISCUSSION

In this trial use of database management software for noise analysis assistance, some encouraging features become apparent:

1. Any specified feature of functions commonly used in noise analysis may be examined in all data taken, rather than just spot-checked as would be the case without this proposed tool.
2. With large numbers of answers for specific quantifiers available for averaging, better accuracies are achievable and statistics of answers can be studied to ascertain whether rare events are statistically significant.
3. Screenings of data for the presence or absence of highly specific cases obeying selected--even complex--criteria are quite easy. Programs involving sequences of simple commands are capable of automating the entire process for continued on-line surveillance if desired.
4. This method somewhat stimulates the analyst to formulate logical inquiries into the data; this supplements passive visual searches for the unusual.
5. Data qualification by comparison to any set of rules one might formulate is a straightforward application.
6. Varieties of display (see Figs. 3 and 5) and of intercomparisons are possible and are limited only by the analyst's imagination.
7. Unlike pattern recognition and some other automated data-handling methods, an analyst's interactive approach to the data's features is a natural way to use this tool (i.e., one answer somewhat suggests the next question). Intimate contact seems to be preserved in spite of an intimidating volume of data.

Finally, a few advisory comments should be made regarding further use of the approach proposed here:

1. User-friendly programs with numerous and powerful commands should be used to avoid the distractions of programming intricacies and to minimize obstacles to trying new approaches.
2. The approach of compressing data into specific features is encouraged because of computing time considerations, though this becomes less significant as computers improve. However, one should be alert to the possibility of more information existing in the individual data points and should not always restrict analyses to just a few features.

Fig. 6a. Phases between LLFM1 and LLFM2 during a temporary anomaly on January 12, 1987. The slope in deg/Hz is not excessively large in the 13-Hz region.

Fig. 6b. Phases between LLFM1 and LLFM2 a 0.5 h after the January 12, 1987 anomaly, as representative of normal behavior. With these detectors sensing interfering resonances 0.1 Hz apart, there is an excessively large slope near 13 Hz.

3. Close contact with the data by visual examination of samples should be maintained. Automated manipulations should not be allowed to insulate the analyst from the data.

6. CONCLUSIONS

Using database management software for extracting and handling features from large volumes of noise data functions, such as spectra, has been explored and found useful. Anomalies that might otherwise be buried can be discovered. In application to FFTF data, it was found that some additional insights into previously studied phenomena were gained. The example of an interfering double resonance here can alert analysts to the possible occurrence of similar phenomena in other reactors.

7. ACKNOWLEDGEMENT

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