Introduction of NIMS Signal Analysis Method in NPP

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ABSTRACT

The NIMS, NSSS(nuclear steam supply system) Integrity Monitoring System, is designed to provide an integrated approach that includes areas of monitoring relevant to the integrity of NSSS. The NIMS is an integrated system that monitors the NSSS for loose parts at natural collection zones, coolant steam leakage and pipe crack propagation at potential leak and crack regions, vibration of the reactor core components(core support barrel, fuel assembly, etc.) and reactor coolant pump and motor vibration levels, pump shaft displacement(orbits) and RPM. This paper is intended to introduce the NIMS signal analysis methods using in nuclear power plant.

1. LPMS

The Loose Parts Monitoring System (LPMS) detects the presence of metallic impact(s) due to a loose part within the primary pressure boundary and the steam generators and alerts the operator to the suspected presence of a loose part. And also, it provides diagnostic information related to the location and characteristics of the metallic impact(s), programmed analysis criteria for alarm discrimination to reduce false alarms, simultaneous transient data capture for various LPMS channels, and the function of capturing up to 4 minutes of loose parts data for further evaluation. And it provides logs data and historical analysis, including frequency and time domain analysis, of all captured and logged data.

1.1. Delta-t Analysis

The Delta-t analysis method can be used to perform a more thorough time difference (delta-t) analysis on up to four channels. While many channel combinations are used by the system to automatically calculate source location, this screen can be used for uncommon combinations. The basis of the source location algorithm works as follows: distances between sensors and a grid of potential source locations are calculated based on known plant geometry. The differences in distances between 2 or 3 sensors and a specific source location is then calculated. These distance differences are then converted to time differences (delta-t) based on an assumed constant velocity. Node locations are assigned to pairs of delta-t's that correspond to a triangulation (in the case of a 3 sensor pair) of the source location. The Delta-t Analysis screen can be used to manually produce delta-time combinations to calculate distance and ultimately a source location estimate. Figure 1 shows Delta-t analysis screen.

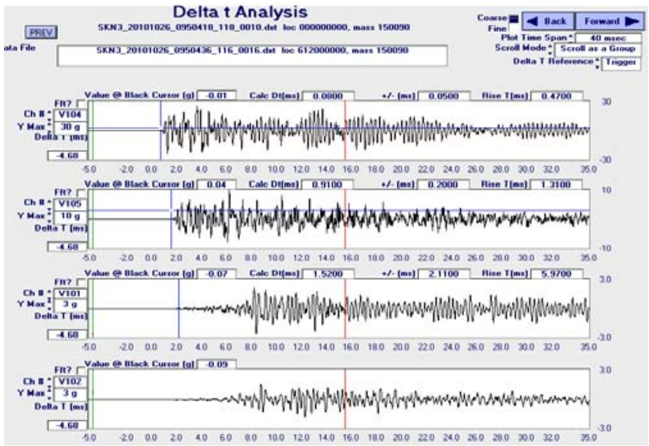

Figure 2. Delta-t analysis screen.

1.2. Frequency Analysis

The Frequency Analysis screen displays the signal waveform and frequency spectrum plot for the two channels selected on the Delta-t Analysis screen. The frequency spectrum displayed is the FFT of the portion of the signal waveform between the red cursors. Several of the features from the Delta-t Analysis screen are also available on the Spectrum Analysis screen including: Event Data File selection, signal filter switch, signal waveform plot scrolling features, signal waveform plot information/selection boxes, and signal waveform plot cursors.

1.3. Impact Analysis

When the "Impact Analysis" button is pressed on the frequency analysis screen, the system will prompt the system operator to select one of the two displayed channels for analysis. The top plot is the raw data for the event. The X scale is time, from 40 msec before the approximate start of the event to 248 msec after the start of the event. The Y scale is magnitude in g. The bottom plot is the Fast Fourier Transform (FFT) of the raw data for the event. The X scale is frequency up to 25 kHz. The Y scale is in relative engineering units. The scales on either plot may be changed (temporarily) to arbitrary scales by means of the touchpad and keyboard. The Start Time and End Time controls act similar in function to the red cursors and can be used to select a specific range over which to do an FFT. The Max Frequency Control is used to easily control the X scale of the Event FFT graph. Figure 2 shows impact analysis screen.

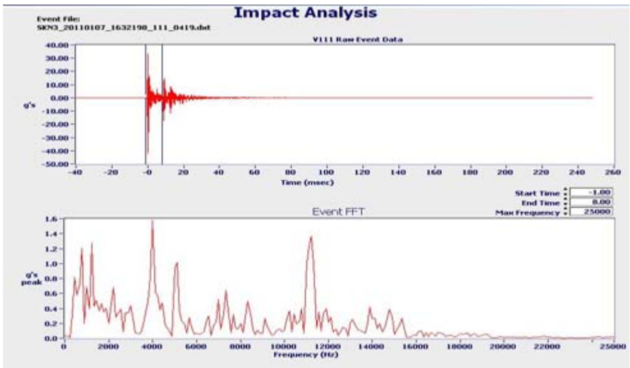

Figure 2. Impact analysis screen

1.4. Mass Analysis

Figure 3 shows the mass analysis method for the event. The mass analysis screen has four displays. The top display is the raw data from the first 10 msec (approximately) of the event.

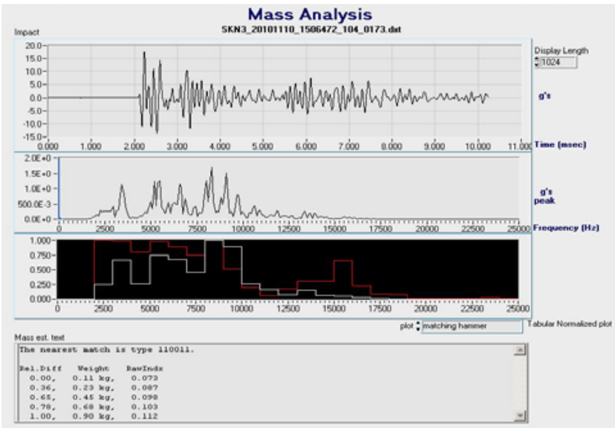

Figure 3. Mass analysis screen

The second display is the spectrum analysis of this raw data. The spectrum shown in the second display is split into 1 kHz bands and the sum of each band is shown in white on the third display. Similar plots for each of the baseline hammers for this channel are available on this display. Any one or all of the baseline hammer plots may be selected for display using the control below the display on the right. The LPMS system will display the plot of the baseline hammer that most closely matches the unknown plot within pre-defined criteria. If none of the baseline plots meet the criteria, the system considers the mass as unknown. The text box at the bottom of the display ranks the mass of the unknown object against the mass of all of the baseline hammers for that channel. Only the initiator channel is used for mass analysis.

2. ALMS

The NIMS Acoustic Leak Monitoring System (ALMS) is designed to detect the presence of leaks and pipe cracks at specific locations and within specific components of the primary system and alerting these conditions to the operator. The ALMS is an acoustic leak detection system that monitors for leaks continuously. Each of its channels consists of a sensor placed at a selected location and a preamplifier with a filter. These channels are connected to a computer which performs data acquisition, processing, display and recording functions..

2.1. Sensing Equipment

1. Acoustic Sensors : The ALMS system has been prepared to use high temperature Acoustic Emission sensors. These sensors are made for rugged, high temperature, high nuclear radiation environments. The sensor is terminated in a BNC connector. these sensors are installed to monitor for leaking and cracking in the RCS.
2. Preamplifier : The preamplifier processes signals in the following way: First, the charge received from the sensor is converted into a voltage for further preamplifier processing. Then the amplifiers and filters this converted sensor signal to eliminate noise and increase the “Signal to Noise” ratio. sensor mounting rigidness.
3. Alarm unit : The ALMS AU performs AE signal measurements and stores, displays and analyzes the resulting data. An internal control computer provides for data storage and operator analysis and display. As part of the AU design, the Alarm Relay Panel is used as an interface for the alarm relay contact outputs.
4. Alarm processing : Leak monitoring channels have alarm setpoints to alert the plant staff to changes in monitored signals. Each channel has an ASL (Average Signal Level) setpoint, a warning time window and an alarm time window. ASL is a log scale version of average RMS signal level. When the ASL voltage rises above its channel high alarm setpoint the AU alerts the operator with a warning indicator (High warning with yellow background). When the ASL measurement

exceeds the ASL high alarm setpoint for the duration of the entire warning time window a warning alarm will occur (High Alarm on amber background). Finally, when the ASL measurements exceed the ASL high alarm setpoint for the duration of the entire high alarm time window, a leak alarm will occur (Leak Alarm on amber background).

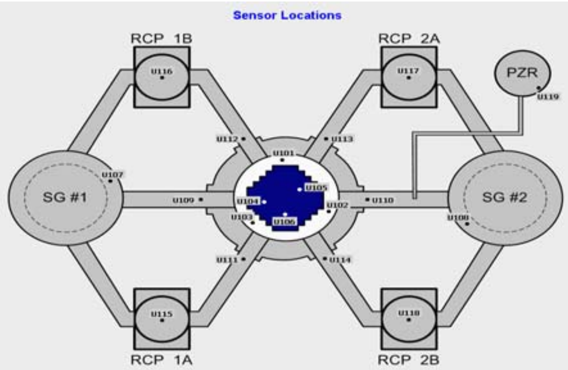

Figure 4. ALMS sensor location

2.2. ALMS crack detection method and AE hit driven features

The ALMS is also designed to have the capability of monitoring for bursts of acoustic energy. This energy is produced during periods of crack growth. Normal plant operation provides too much background noise for crack monitoring to be reliable. During relatively quiet periods, during hydrotesting for example, a crack monitoring session permits the trending of crack burst activity. While a crack detection session is in progress, any AE event or “HIT” that satisfies the crack event criteria, such as the threshold, threshold type, HIT Definition Time (HDT), HIT Lockout Time (HLT), and Peak Definition Time (PDT) are logged in the Crack Event Log. The HDT, HLT, and PDT define the expected HIT envelope for the ALMS. This prevents the multiple peaks in a single AE event from being counted as more than one HIT. The HDT is set to allow detection during the expected duration of the waveform. The PDT is set to allow the peak of the waveform to be detected during the HDT. The HLT is set to insure that the remaining peaks of that AE are not sensed as a new HIT until the waveform is over. Referring to the Hit based features, this section tries to provide a better definition as to what exactly each feature means to the AE user. Figure 5 shows a fictitious Acoustic Emission waveform with some of the AE features superimposed on the waveform. during the expected duration of the waveform. The PDT is set to allow the peak of the waveform to be detected during the HDT. The HLT is set to insure that the remaining peaks of that AE are not sensed as a new HIT until the waveform is over.

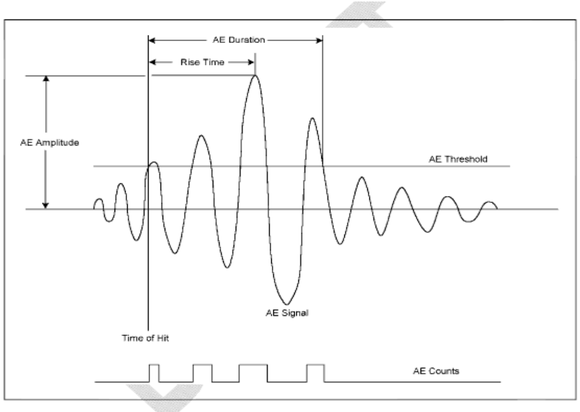

Figure 5. AE hit feature extraction diagram

3. RCPVMS

The Reactor Coolant Pump Vibration Monitoring System (RCPVMS) is one of the monitoring systems of NIMS. The Primary Function of the RCPVMS is to monitor the shaft displacement of the Reactor Coolant Pump (RCP) and to monitor RCP motor and pump vibration. The RCPVMS causes alarms locally and at the Information Processing System (IPS) if excessive vibration or shaft displacement is detected. Shaft displacement employs proximity probes which measure rotational displacement of the pump shaft. A proximity probe is also used as a key-phasor signal to get a reference indication for shaft orbit plots and also as a tachometer signal to determine pump shaft rotational speed. The motor vibration sensors are located at the elevation of the upper motor bearing and pump thrust bearings. The RCPVMS is a continuous monitoring system which provides diagnostics tools (software) to assist in the evaluation of the performance of the RCP and in the evaluation of alarm conditions. Figure 6 shows the RCPVMS monitor screen layout.

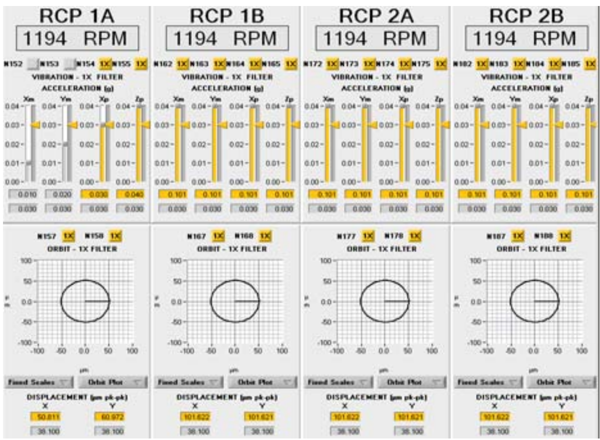

Figure 6. RCPVMS monitor screen layout

4. IVMS

The Internals Vibration Monitoring System (IVMS) is one of the NIMS's monitoring systems. The IVMS is designed to monitor the motion/vibration of the core support barrel and the core fuel assemblies. The changes in a vibration signature indicate mechanical changes of the core barrel/fuel assemblies which should be brought to attention of nuclear plant operators. The IVMS has been designed to provide a broad range of analyses to allow the user to determine the dynamic behavior of the core. Characterizing internals motion requires knowledge of the structural characteristics of the reactor internals and a certain amount of experience in recognizing certain motion related characteristics and patterns. Some qualitative judgments are also required in characterizing internals motion. The results obtained from the analysis of random data will be determined by the statistical methods used to analyze this data. It is not necessary to understand the statistical methods involved but it is necessary to understand the significance of the values obtained. Figure 7 shows ex-core neutron detectors and vibration modes of reactor internals.

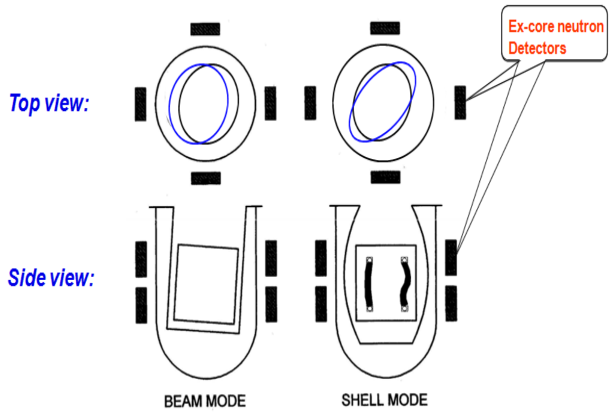

Figure 7 Ex-core neutron detectors and vibration modes of reactor internals

5. CONCLUSION

The features and benefits of NIMS operating in nuclear power plant are as follows:

• An integrated networked, monitoring environment where subsystems provide independent
surveillance, alarming, logging and analysis capabilities

• System monitoring and control, managed simultaneously from multiple locations

• Ease of use, flexible and reliable performance

• Cost effectiveness when compared to multiple stand-alone systems

• Continuous real-time monitoring of individual systems while supporting on-demand analysis functional

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BIOGRAPHIES

Sang-Guk Lee received B.S., M.S. and Ph.D. degrees in mechanical engineering at Pukyong National University. He worked as a principal research scientist at Korea Electric Power Co. KEPRI for 16 years and as an instructor at Korea Institute of Maritime and Fisheries Technology for 8 years, respectively. Dr. Lee was the convener of condition monitoring & diagnostic machines ISO TC108 SC5. He is currently a vice-president of the Korean Society for Power System Engineering and principal research engineer at Korea Hydro & Nuclear Power Co. Central Research Institute. His research interests are in the area of the acoustic emission, ultrasonic and vibration condition monitoring & diagnostic technology for power plant equipments.