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Comparison of the Signal Processing Methodologies for a Leak Detection of the LMR Steam Generator

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1. Introduction

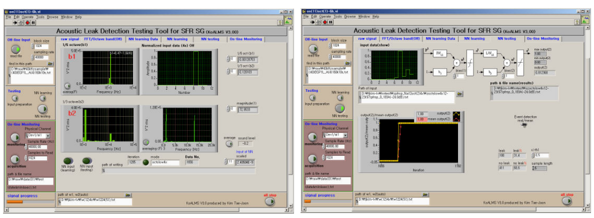
The successful protection of a water/steam into a sodium leak in the LMR SG at an early phase of a leak origin depends on the fast response and sensitivity of a leak detection system. The control time for the protection of the LMR SG is several seconds.

Subject of this study is to introduce the detection performance of the acoustic leak detection system discriminated by a back-propagation neural network according to a preprocessing of the FFT power spectrum analysis and the Octave band analysis, and to introduce the status of the development of the acoustic leak detection at KAERI. It was used for the acoustic signals from the injected Argon gas into water experiments at KAERI, the acoustic signals injected from the water into the sodium obtained in IPPE, and the background noise of the PFR superheater.

2. Experiments

Measurements of the micro-leak noises in a circulating sodium at a sodium temperature of 350~500^{o}C were executed in the IPPE facility, and the experimental works of the Argon gas injection were in a water mock-up facility of KAERI. The Argon gas injection system consists of a micro nozzle, diameter 0.006~ 0.16 mm and a high-pressure outflow system supplied up to 100kg/cm^2. Here we tested the discrimination of an acoustic leak detection by a back-propagation neural network to compare two methodologies of a detection logic according to the adaptation of the signal processing techniques. The test signals are prepared by mixing the signal to amplify and to attenuate the leak signals based on the amplitude of the background noise, the leak signal, and the background noises.

This acoustic leak detection system as shown in Fig. 1, constructed with LabVIEW consists of the unit for preprocessing the signals and the neural network.



(a) (b)

Figure 1. LabVIEW panel of the acoustic leak detection system developed in KAERI; (a) Signal processing panel, (b) Neural network and discrimination panel.

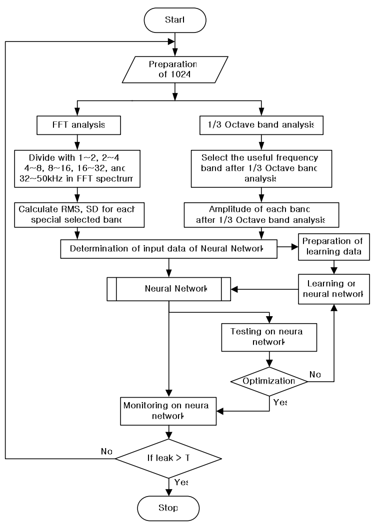
3. Results and Discussion

3.1 Detection methodologies for developing leak detection system of sodium-water reaction system

The signals of the sodium-water reaction at a leak rate increase from 0.005 g/s to 0.183 g/s are introduced, and also in the case of the Argon gas injection into water these frequencies are similar with the calculations in a previous paper [1]. In the Argon gas injection to compare the bubbling frequency regime, the frequency by a bubbling was also around 1~2 kHz followed with the Argon gas flow rates, 0.26~210cm^3/sec, according to the diameter of the micro nozzle under 100kg/cm^2.

As described previously the acoustic leak detection methodologies consist of the neural network and the preprocessing unit of the signals as shown in Fig. 2. The preprocessing unit of (a) in Fig. 2 is used for the frequency band for the FFT power spectrum analysis and the 1/3 Octave band analysis function, and its unit of (b) in Fig. 2 is only used for the 1/6 Octave band analysis where the sampling rate of the input data of a preprocessing is 1024, and the selected frequency band is 0.47~1.6 kHz. After its preprocessing, it is again calculated for the input data of the feature vector for learning about and testing the neural network, and then after an optimizing by a learning of the weight values of the neural network, and we monitor the raw leak signals by using the optimized neural network to detect the leak state or no leak state based on the threshold condition to define the leak.

(a)



(b)

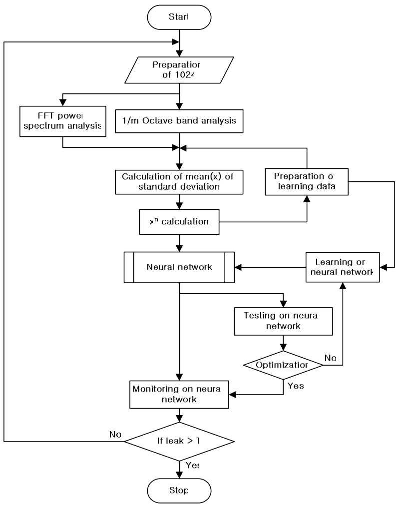


Figure 2. Detection methodologies for developing leak detection system of sodium-water reaction system

3.2 Performance of the acoustic leak detection system using test signals

The performance of the developed acoustic leak detection methodologies of Fig. 2 by using the sodium-water reaction noises controlled with the attenuation of the leak signal against the background noise of the PFR superheater was shown to detect a leak up to ~ -27dB according to the learning conditions of the neural network.

Fig. 3 resulted by (a) in Fig. 2 is shown to compare the results in the cases of the use of the mixed signals with -19.9 dB ~ - 25dB using the PFR background noise and the sodium-water reaction noises for a learning and the signals without a mixing of the signals for another learning. In the case of the test without the mixed signals the limit of the detection performance was about -22dB. After the learning of the neural network used of the mixed signals, the limit of the detection performance was about -27dB.

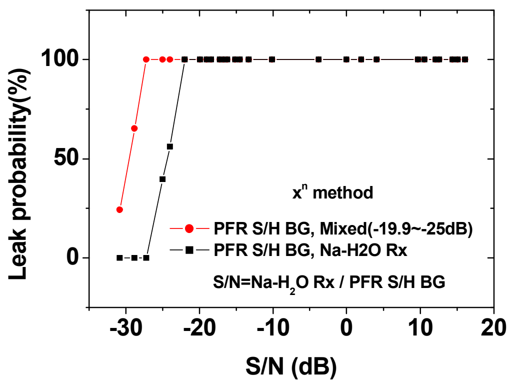


Figure 3. Leak probability tested by the developed acoustic leak detection system used with or without the signal mixing of the background noise and the sodium-water reaction signal.

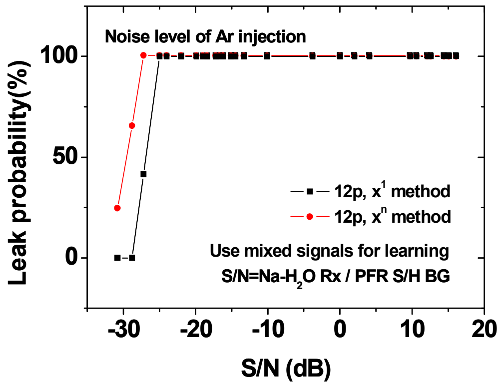


Figure 4. Leak probability tested by the developed acoustic leak detection system to be amplified the input data of the neural network before input to the neural network.

The Fig. 4 resulted by (b) in Fig. 2 is shown to compare the results of the mixing signals for learning of neural network and the technique used to amplify with the input data of the neural network four times before the learning. The performance of this result is to show the effect with the amplifying of input data of the neural network, and without the amplifying of the input data of the neural network. This methodology is able to achieve the effect to be regenerated the significant signal with the poor signal.

4. Conclusion

To protect the LMR SG from a damage of a tube bundle owing to the origin of secondary leaks it is necessary to detect a leak before developing the leak status. When we compared the leak detection methodologies, it was benefit to detect it by using the 1/6 Octave band analysis. And the comparison according with the learning conditions of the neural network after the mixing of the background noise and the sodium-water reaction signal provide good results by the developed acoustic leak detection methodology it was possible to detect a leak up to -27dB according to the learning conditions. At present the system has no errors for detecting a leak, but in the future it must be absolutely assured without an error for detecting a leak.

ACNOWLEDGEMENT

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[1] Kim Tae-Joon, Simulation of Water/Steam into Sodium Leak Behavior for an Acoustic Noise Generation Mechanism Study, Journal of the Korean Nuclear Society, Vol. 33, No. 2, pp. 145-155, 2001.