Application of Temporary Neutron Monitoring System for Subcriticality Monitoring during Initial Fuel Loading of OPR1000

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1. Introduction

The subcriticality of reactor core has to be monitored and confirmed before any core alterations will occur during fuel loading. As of now, Nuclear Instrumentation Module (NIM) type device widely used for monitoring the subcriticality. NIM device manually operated is susceptible to noise because BF3 detector is far from preamplifier. A Temporary Neuron Monitoring System (TNMS) has been developed to monitor the subcriticality during initial fuel loading of OPR1000, which have remote manipulation and the minimum distance between the detector and preamplifier in the cylinder. Manipulation of TNMS is easer and the reliability of the signal is improved.

2. Temporary Neutron Monitoring System

2.1 TNMS Configuration

TNMS consists of two parts; one is circuit board, another is dunker. Circuit board converts pulse signal into neutron counts via pre-amplifier, amplifier, counter & timer (Fig.1), subsequently. High voltage supplier provides optimal operating voltage with electric field in BF3 detector.

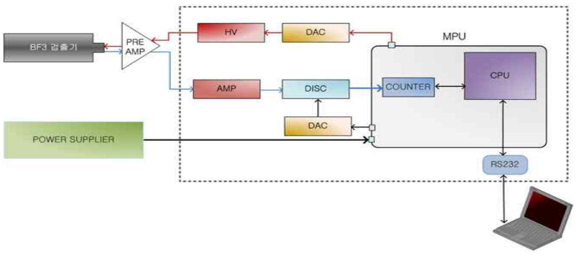

Fig. 1 TNMS Schematic Configuration

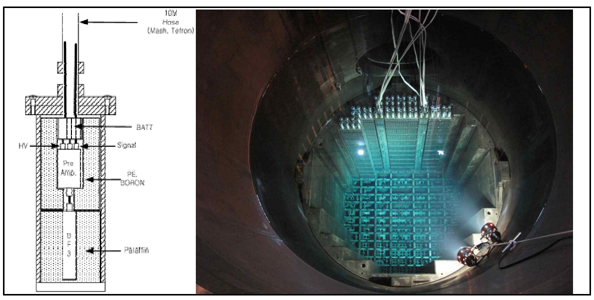

Fig. 2 TNMS installed OPR1000 Reactor Core

BF3 detector and pre-amplifier have been located in two cylinders, and then installed into the dunkers of reactor core as shown in right hand side of Fig.2, that like a fuel assemblies. Neutron detectors in two dunkers were monitoring subcriticality during fuel assemblies had been loaded in reactor core.

2.2 Neutron Detection

The pulsed operation of the gas-filled detector illustrates the principles of basic radiation detection. Typical gases used in detectors are argon and helium, although boron-triflouride (BF3) is utilized when the detector is to be used to measure neutrons. Fig. 3 shows a schematic diagram of procedure for optimizing gain (G), applied high voltage (HV), discriminator voltages (ULD, LLD).

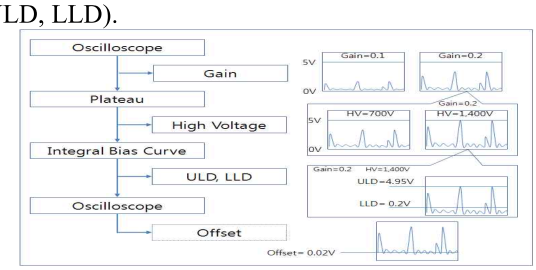

Fig. 3 Schematic Diagram of Neutron Detection

The pulse height have dependency with gain(G), which is tentatively determined by that of peak pulse should be located within oscilloscope window. The relationship between the applied voltage and pulse height in a detector is very complex. Pulse height and the number of ion pairs collected are directly related.

Fig. 4 shows neutron count rate according to the applied voltage. Operating voltage is determined by at near a half of plateau. High Voltage(HV) play a role of maintaining the electric escape efficiency even though pulse signal give rise to decrease operating voltage due to pulse generation period.

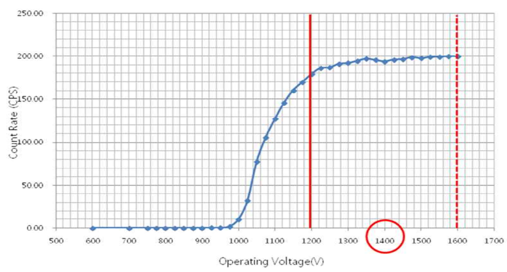

Fig. 4 Plateau Curve Analysis

There Gas-filled detector have alpha and background noise signal within pulse signal. Decreasing discriminator voltage, neutron count rate are measured as shown in Fig.5. To discriminate those noises, project the very steep slope at the beginning of the integral bias curve down two decades. Discriminating at this point is projected to reduce the unwanted counting component to a value less than 1%. If there is a reasonable amount of counts above the discriminator level to provide good counting statistics, the discriminator level settings are acceptable.

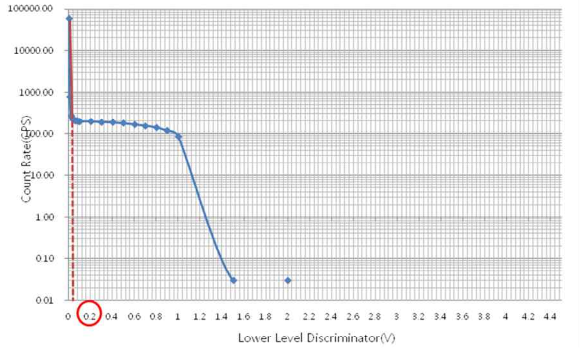

Fig. 5 Integral Bias Curve Analysis

3. Subciriticality Monitoring

Requirement for fuel loading is that the loading will be monitored by two temporary fuel loading channels to ensure adequate monitoring of the subcritical multiplication status of the core. Initial fuel loading in OPR1000 has been performed by two TNMS monitoring the subcriticality during all loading steps. As loading sequence of initial core, TNMS measured the neutron count rate in Fig. 6 as bellows. Two TNMS channels are revealed as core alteration due to loading fuel assembly, neutron source and TNMS movements.

As shown in Fig. 6, most count rate of TNMS Set A higher measured values than Set B because Set A is closer to neutron source than Set B. It is also shown that at the beginning of loading the alteration of core due to fuel assembly loaded in core inferred from measured data.

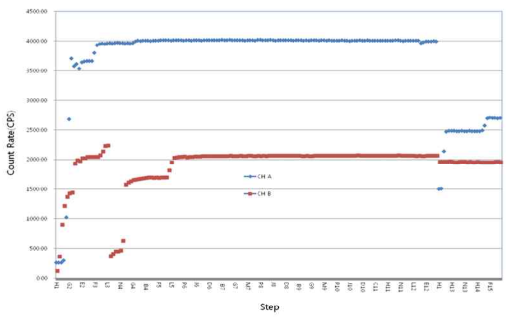

Fig. 6 Pulse Count Rate according to Fuel Loading Sequence

Subcritical multiplication factor is defined as bellows:

$$M = \frac{C_i}{C_0} \qquad (1)$$

Then, inverse count rate ratio is

$$\frac{C_0}{C_i} = \frac{1}{M} = 1 - K_{eff} \qquad (2)$$

Where C_0 is initial count rate (CPS), C_i is count rate at i-th loading step.

Fig. 7 shows ICRR plotting as a fuel loading sequence of OPR1000.

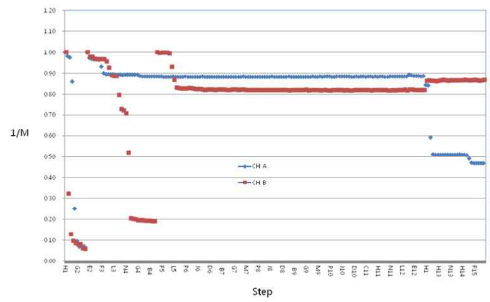

Fig. 7 Inverse Count Rate Ratio (1/M) according to Fuel Loading Sequence

4. Conclusion

TNMS have been developed for subcriticality monitoring of initial fuel loading, especially for OPR1000. By plateau and integral bias curve analysis, optimal system parameters are determined for TNMS to operate at the optimal operating conditions.

Initial fuel loading of OPR1000 was completed by TNMS with more reliable signal than the previous NIM device. It is sure that TNMS have a capability of monitoring alteration of reactor core as fuel loading, source and TNMS movements with ease to handle and improved reliable signal.

Reference

[1] "DOE Fundamentals Handbook Instrumentation and Control," DOE-HDBK-1013/2-92, Vol. 2, 1992.

[2] Y.S. Choi and H.S. Lee, "Technical Support for Temporary Neutron Monitoring System pre-test," 2012-50003339-Jeon-0081TC, Feb. 2012.

[3] KHNP SWN, "Initial Fuel Loading," 9S-L-422-01, Test Procedure. 2012.