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A New Approach to ENFMS by using Variable Moderator Equipment

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1. Introduction

The ENFMS(Ex-core Neutron Flux Monitoring System) is used to calculate the axial power distribution as well as to measure the core power level in PWR(Pressurized Water Reactor). Generally, the EMFMS of OPR1000(Optimized Power Reactor 1000) is composed of 8 channel; four safety channels using fission chambers, two startup channels using BF3 detectors, and two control channels using uncompensated ion-chambers. Recently, the advanced ENFMS, which is used only fission chamber as ex-core detector for all channels, is introduced with advantages of cost and maintenance. However, this ENFMS has the matter that we must consider; since the fission chamber has the unique range (safety and control range) which maintains the linearity [1], positive count rate satisfied with criteria [2] is not guaranteed on startup channel range.

In this study, variable moderator equipment on ENFMs is suggested to remedy this uncertain ENFMS on startup. The sensitivity study of moderator on startup channel range is conducted, and the performance of fission chamber is analyzed by comparision with that of BF_3 detector.

2. Methods and Results

2.1 ENFMS and Moderator of Ex-core Detector

In OPR1000 with ENFMS used only fission chamber, there are four ENFMS with symmetric location as shown in Figure 1. And one ENFMS has a three ex-core detector to monitoring the axial power distribution and calculate the AO(Axial Offeset) or ASI(Axial Shape Index).

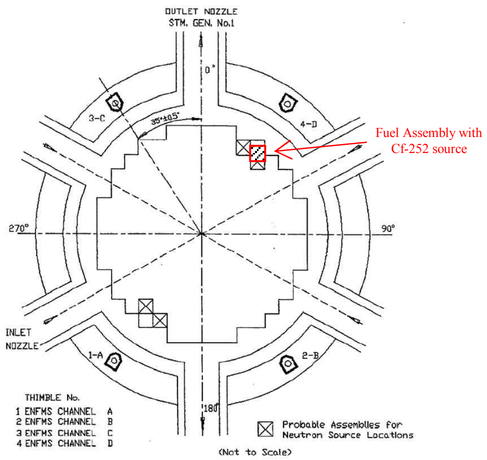

Fig. 1 Radial Locations of ENFMSs

Generally, in order to enhance the sensitivity of ex-core detector, moderator is utilized around the ex-core detector such as Resin or Polyethylene which contains low number of atom. By using the moderator, fast fission neutrons are scattered and slow down to the thermal neutron which is most portion of detection to ex-core detector. It means that moderator has a capability to control the sensitivity of ex-core detector.

2.2 DORT calculation on Startup Range

The DORT code [3], based on the discrete ordinate transport method, was used to calculate fluence inside of ex-core detector. The 47-energy-group DORT calculations were performed with P_5, S_8 approximation [4] in two-dimensional geometries. The cross section data used in this study were from the BUGLE-96 library [5].

In order to simulate the startup range, Cf-252 neutron spectrum is used as a source, because the ex-core detector's signal by Cf-252 source is dominant at startup of initial core. The fuel assembly which contains a Cf-252 source is located as shown in Figure 1; the source strength is set to 4.5×10^7 neutron/sec as typically used in initial core. The fluence is calculated with an R-Θ model about OPR1000 as shown in Figure 1.

To evaluate the effect of moderator, various thicknesses (1, 3, 5, 7, 9, 11, 13, 15cm) of moderator is simulated as sensitivity study. The results of DORT calculation are shown in Figure 2; total and thermal (< 0.1eV) neutron fluence increase from 1cm-thcik moderator to 7cm-thick moderator. Its phenomenon occurred due to the moderator which makes fast neutrons to slow down thermal neutrons and scatter into ex-core detector by the moderator.

As this result, difference of thermal fluence in ex-core detector as thickness of moderator is appeared with maximum 6.65 times between the 1cm-thick moderator and 7cm-thick moderator.

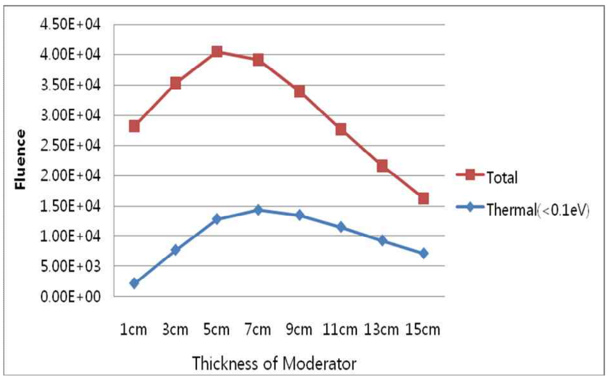

Fig. 2 Fluence in Ex-core Detector on Startup

2.3 Analysis of Fission chamber with BF_3 detector

To analyze the performance of fission chamber on startup range, it is need to compare with BF_3 detector as generally used on startup channel in OPR1000.

The neutron fluence weighted by neutron response function ($^{235}U(n,f)$ for fission chamber and B(n,a)Li for BF_3 detector) are calculated by using the DORT calculation results (Case of 7cm-thick moderator). The real neutron signal can be predicted by weighting the neutron response function. Because the detecting signals from fission chamber are caused by fission reaction with ^{235}U and neutron and BF_3 detector also makes the signal from B(n,a)Li reaction.

As shown in Table 1, expected signal for BF_3 is about 6.67 times larger than that of fission chamber. This result is gotten by assuming that BF_3 and fission chamber have same geometry and same self-sensitivity. This result shows large difference between fission chamber and BF_3 detector. And fission chamber has limited range for keep linearity about detection signal to power. If detectable range of fission chamber is lowered to get a more signals, the linearity is broken on high power range due to the much signal. Therefore, it is necessary to think about operating both low power range such as startup channel range and high power range as safety channel range.

Table 1 Comparison of Weighted Fluence between BF3 and Fission Chamber Detector

	BF_3 Detector		Fission Chamber	
	Thermal	Total	Thermal	Total
Startup Channel	5.37E+07	5.59E+07	8.05E+06	8.38E+06
BF_3/F.C	Thermal		Total	
	6.67		6.68	

2.4 New approach to ENFMS using Variable Moderator Equipment

For ENFMS using only fission chamber for all power range, new ENFMS design is suggested as shown in Figure 3. Variable moderator instead of fixed moderator is utilized to control the sensitivity of fission chamber.

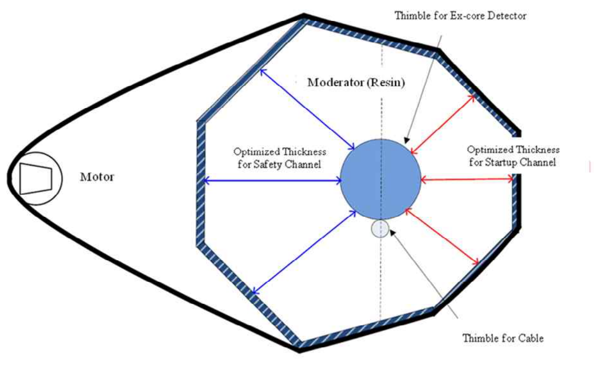

Fig. 3 ENMFS using Variable Moderator Equipment

As the DORT calculation result, it is possible to control the sensitivity of detector by thickness of moderator. In new ENFMS design, two kinds of moderator type, startup range and power range, is applied on the variable moderator equipment. Firstly, the capable range of fission chamber on startup is set by raising the sensitivity with optimized thickness of moderator, and then, the direction is faced to the reactor core during startup. At the power range, the moderator which reduced the sensitivity by changing the optimized thickness of moderator for power ranges. Then, linearity of fission chamber during the operation can be maintained with stable count rate due to controlling of sensitivity by changing optimized moderator thickness for each case.

3. Conclusions

The ENFMS using only fission chamber for all power range is recently introduced for advantage of price, maintenance, and spatial problem, especially small & middle sized reactor such as SMART. To make up for this ENFMS, variable moderator equipment is suggested. This equipment makes fission chamber stable performance both startup and power range by adjusting the sensitivity of fission chamber.

This design of ENFMS is needed to more research for utilization at nuclear power reactor. The relation of startup signal and power range signal during changing the moderator should be studied. And, it should be studied about lots of other important safety criteria about changing the ENFMS.

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