Modification of Detector Response Function for Dynamic rod worth measurement

Hwan-Soo Lee [a*], Eun-ki Lee [a]
[a],*KHNP Central Research Institute, 70 1312-gil Yuseong-daero Yuseong-gu, Daejeon, Korea*
[*]*Corresponding author: leehwansoo1@khnp.co.kr*

1. Introduction

The control rod assembly in nuclear power reactor is used for the reactivity control and shutdown the reactor core. During the strartup test for Nuclear power plant, the control rod worth should be measured and met its criteria. There are several kinds of method for control rod worth measurement, most advanced one is DCRM (Dynamic Control rod Reactivity Measurement) method [1], [2].

The dynamic control rod worth is measured and calculated by using the ex-core detector signal and pre-calculated design parameters such as DSCF(Dynamic to Static Conversion Factor), NRCF(Neutron density to Response Conversion Factor). NRCF is calculated using reactor core average neutron flux and DRF (Detector Response Function) [2].

Generally, DRF is generated once at the design level since it is independent for cycle and core design. It is determined by the shape and material of reactor core internal structures and the ex-core detector (U-235 of fission chamber and B-10 of BF3 ion chamber). Recently, nuclear power plants try to change the type of ex-core detector from Ion Chamber to Fission chamber due to the advantages of the maintenance.

In this paper, DRF is modified for the geometrical modeling and others conditions according to its review. And the effect of the DRF change is evaluated by applying the measured DCRM data.

2. Methods and Results

2.1 Detector Response Function Generation

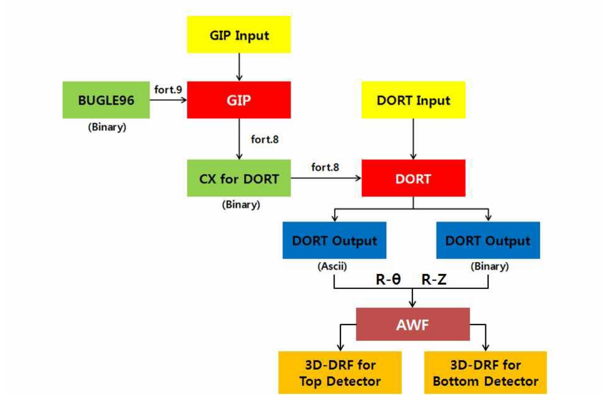


Fig. 1 The framework of DRF Generation

Figure 1 shows the framework for generating DRF. The DORT code [3], based on the discrete ordinate transport method, was used to calculate the radial(R-theta) and axial(R-Z) adjoint flux of the ex-core detector. The cross section data of the BUGLE-96 library [4] and 47-energy-group with P_3, S_8 approximation are used in these calculation [5]. 3D DRF of top and bottom detectors is generated by AWF code for the synthesis of radial and axial results. For the application of DCRM test, all calculation is performed at 0% reactor power and its critical boron concentration condition.

2.2 Review and regeneration of the DRF

Since the type of ex-core detector is changed from the Uncompensated Ion chamber to Fission chamber, DRF should be modified for DCRM and other application. The geometry of the new detector was updated and the source term of adjoint calculation were replaced from B-10(n,a) reaction to U-235(n,f) reaction cross-section as shown in Table 1.

Table 1 Cross sections for Adjoint calculation Source Term

Group	Upper Energy [eV]	Cross Sections of 10B,σ a(E)	Cross Sections of 235U,σ f(E)	Group	Upper Energy [eV]	Cross Sections of 10B,σ a(E)	Cross Sections of 235U,σ f(E)
1	1.7332E+07	4.6017E-01	1.8661E-03	25	2.9721E+05	1.2483E-04	1.1686E-03
2	1.4191E+07	1.9930E-01	1.7354E-03	26	1.8316E+05	9.9395E-05	1.2935E-03
3	1.2214E+07	1.1701E-01	1.5564E-03	27	1.1109E+05	6.5250E-05	1.4419E-03
4	1.0000E+07	8.0472E-02	1.5851E-03	28	6.7379E+04	4.7751E-05	1.6294E-03
5	8.6071E+06	5.2270E-02	1.5718E-03	29	4.0868E+04	3.8705E-05	1.7717E-03
6	7.4082E+06	3.3559E-02	1.2807E-03	30	3.1828E+04	3.2652E-05	1.9076E-03
7	6.0653E+06	2.0534E-02	9.4968E-04	31	2.6058E+04	4.7560E-05	1.9648E-03
8	4.9659E+06	1.1620E-02	9.9954E-04	32	2.4176E+04	8.1865E-05	2.0536E-03
9	3.6788E+06	7.4607E-03	1.0533E-03	33	2.1875E+04	7.1186E-05	2.1544E-03
10	3.0119E+06	5.1166E-03	1.0935E-03	34	1.5034E+04	5.4315E-05	2.5977E-03
11	2.7253E+06	3.1202E-03	1.1186E-03	35	7.1017E+03	5.1733E-05	3.5989E-03
12	2.4660E+06	1.8856E-03	1.1297E-03	36	3.3546E+03	5.0611E-05	4.9638E-03
13	2.3653E+06	1.2690E-03	1.1333E-03	37	1.5846E+03	5.6055E-05	8.2773E-03
14	2.3457E+06	8.6782E-04	1.1374E-03	38	4.5400E+02	6.4960E-05	1.4071E-02
15	2.2313E+06	6.4997E-04	1.1432E-03	39	2.1445E+02	5.8140E-05	1.8532E-02
16	1.9205E+06	5.7614E-04	1.1335E-03	40	1.0130E+02	6.6018E-05	2.8698E-02
17	1.6530E+06	5.5195E-04	1.1089E-03	41	3.7266E+01	5.5672E-05	4.5732E-02
18	1.3534E+06	5.1576E-04	1.0803E-03	42	1.0677E+01	5.3263E-05	5.0701E-02
19	1.0026E+06	4.6334E-04	1.0365E-03	43	5.0435E+00	4.5936E-05	1.4287E-02
20	8.2085E+05	3.8935E-04	9.9990E-04	44	1.8554E+00	4.0490E-05	3.5190E-02
21	7.4274E+05	3.1353E-04	1.0041E-03	45	8.7643E-01	3.5674E-05	6.1676E-02
22	6.0810E+05	2.5383E-04	1.0150E-03	46	4.1399E-01	3.1729E-05	1.6109E-01
23	4.9787E+05	1.8830E-04	1.0617E-03	47	1.0000E-01	2.7876E-05	5.0630E-01
24	3.6883E+05	1.4181E-04	1.1034E-03				

During this modification of DRF modeling, we reviewed the whole input data, such as the detail geometry and other condition in DORT and AWF calculation. We found that the cavity size in DORT modeling differs from its drawing. Cavity and concrete wall modeling are modified as shown in Figure 2.

For improvement of the accuracy, the smaller mesh size of the ex-core detector and thermal expansion were applied in this calculation. As known in the previous work [1], fuel assembly type and its burnup is not affected to DRF result, those are not changed in this work.

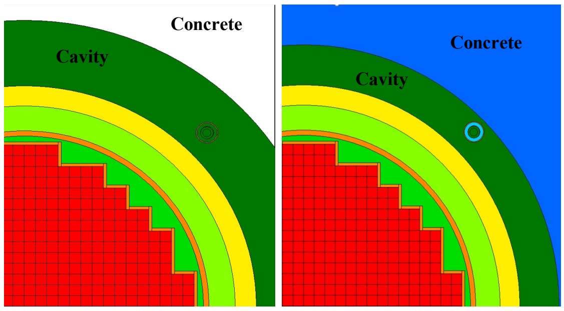
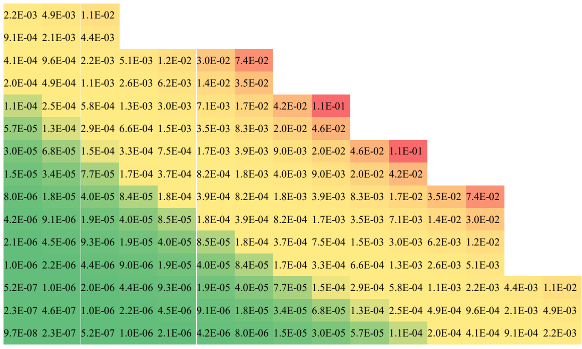


Fig. 2 DRF R-theta Modeling (Left: Old, Right: New)

2.3 Results of new modeling

Figure 3 shows the radial distribution for the old and new of 3D DRF. As results of the calculation, the peaking value near the ex-core detector is reduced and other sides' values are increased as compared to the old one. That result is caused by the modified concrete wall modeling which makes the more scattered neutrons affect in further peripheral fuel assembly and broaden the distribution of the DRF. It was checked that the changed source term and other conditions are not affected to the result through the sensitivity simulation.



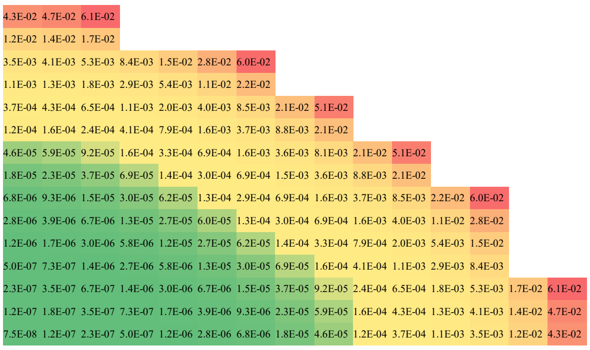


Fig. 3 Radial Distribution of DRF(Upper: Old, Lower : New)

2.4 Evaluation of DRF by using DCRM results

In order to evaluate the DRF, new DRF was applied to two cases of DCRM measurements data. As shown in Table 3, the applications of new DRF shows much better results compared to the old DRF application, maximum error of CASE#1 +12.6% reduced to -0.6% and that of CASE #2 14.5% was reduced to -0.3%. The application of broaden DRF was affected to reduced errors sharply and increase the overall accuracy of DCRM measurement. Through the sensitivity study, it was checked that most of this improvement is caused by correcting the cavity remodeling.

Table 3 Results of Modification of DRF Modeling

Control Rod	CASE #1		
	Prediction	Measurement Error(%)	
		Old (%)	New (%)
1	331	-4.4	-7.7
2	964	**+11.8**	**-3.8**
3	856	**-9.0**	**+1.3**
4	1041	**+12.6**	**-0.6**
5	1210	1.0	+2.7
6	891	-2.9	+2.5
Total	5,293	+2.63	0.0

Control l Rod	CASE #2		
	Prediction	Measurement Error(%)	
		Old (%)	New (%)
1	360	+3.3	0.1
2	980	**+10.9**	**-3.8**
3	845	**-14.5**	**-6.3**
4	1,034	**14.5**	**-0.3**
5	1,243	-3.5	-1.4
6	931	-6.3	-2.4
Total	5,393	+0.8	-2.5

3. Conclusions

In this study, DRF was modified for modeling of the new ex-core detector of NPP, and evaluate the application of DCRM test results. The change of the adjoint source term and correcting the cavity and concrete wall modeling make the DRF broaden and the peaking position also changed. The main reason for this broadening is that scattered adjoint sources from concrete wall move to the peripheral assembly. As a result of applying the DCRM measurement data, all maximum and total error are drastically reduced. The new DRF is going to be applied to NPPs.

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