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Evaluation for Effect of Dynamic Control rod Reactivity Measurement Position for Fuel Transition Reactor Core Design

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1. Introduction

Recently, new type of fuel assembly, HIPER (High Performance with Efficiency and Reliability) [1] have gotten the license approval to use at OPR1000 in South Korea from Nuclear Safety and Security Commission. KHNP starts to load the HIPER to the reactor, prepare the reactor core design for fuel transition. In case of fuel transition, there are some consideration for reactor core design and operational design due to change of the active fuel position. And current nodal based neutronics design code such as ANC and ASTRA, is not available to simulate all the regional differences of each fuel positions detailly.

For operational concern of fuel transition, DCRM (Dynamic Control rod Reactivity Measurement Methodology) [2] is necessary to evaluate the impact of fuel transition, because the CEA (Control rod Element Assembly) and fuel position is very connected with measurement of the precise control rod worth.

In this paper, the control rod worth by DCRM method is evaluated for fuel transition reactor core design, and sensitivity study for the active fuel position versus reactivity within and out of test range is performed.

2. Methods and Results

2.1 Nuclear Design for Transition Reactor core

Most of APR1400 and OPR1000 loaded PLUS7™ [3]

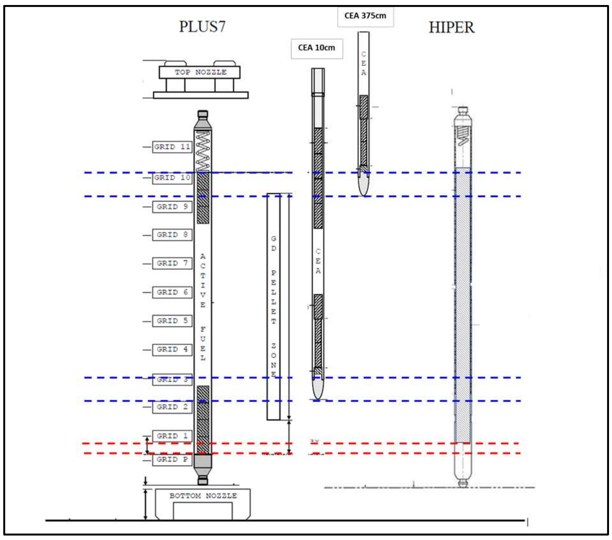

Fig. 1 Configuration of each Fuels and CEA position

fuel assembly only. Once HIPER is started to load, there are two types of fuel assembly in reactor core at least for three (3) cycles. The first cycle of fuel transition reactor core typically loads one thirds new types of assemblies, about 67 FAs for 3 batches of OPR1000.

The active core position of HIPER and PULS7™ fuel are different as shown in Figure 1. The active core of HIPER is higher than PLUS7 ™ about 2.8cm, the difference is caused by the bottom end cap size difference.

As mentioned above, current neutronics reactor core design code is not able to reflect each different active fuel zones. Normally, reactor core designer utilizes the weighted active core position by weighting the number of each fuel assembly types.

2.2 Dynamic Control rod Reactivity Measurement

The DCRM is the method to measure the control rod worth during the reload startup physics test for PWRs. According to DCRM test, the control rod worth is measured by just inserting and withdrawing the test control rod continuously, and calculates control rod worth using ex-core detector signal and prepared DCRM constants. It is obvious that reactor active core position and CEA position affect to the measured rod worth. In DCRM method, the test range of CEA is set to 10 cm to 375cm. The reason why is to prevent the stuck control rod at the top and bottom during the test.

As shown in Figure 1, CEA position in reactor is not fixed and active fuel zone is different with PLUS7 ™ and HIPER. Therefore, it is needed to evaluate the DCRM control rod worth effect for transition core. And test position is also necessary to check its adequacy.

2.3 Evaluation for Fuel Transition Reactor core

RAST-K, KHNP in-house nodal diffusion code, is used to simulate the transition reactor core and calculate the control rod worth. The active core position is modified as weighted their active core position by using the number of each fuel assemblies. The reactor core design used for this study is nominal OPR1000 equilibrium core design.

Thirteen (13) control rod worth are calculated and table 1 shows control rod worth among the PLUS7™ 100% and 1st cycle (PLUS7™ 70% HIPER 30%) and HIPER 100% reactor core conditions. The rod worth is calculated within test range of CEA (10 - 375 cm), because DCRM test measured just within the range.

All of rod worth shows negligible changes and slightly reduced rod worth. Since HIPER' active fuel zone is little bit higher, the overlapped portion of the B4C of CEA is little bit reduced.

Base on these results of calculation, it is found out that here is no need for any changes to the current test range.

Table 1 Control rod Worth Comparison for Fuel Transit Reactor Core Design

CEA No.	Control Rod Worth [pcm]			Difference (A)-(C)
	P-100% core(A)	P-70%/H-30% core	H-100% core(C)	
CR#1	381.1	380.5	379.3	**0.48%**
CR#2	399.6	399.8	399.0	0.15%
CR#3	265.1	265.3	264.8	0.12%
CR#4	526.0	526.0	526.1	**-0.01%**
CR#5	458.3	459.1	456.3	0.43%
CR#6	804.7	806.1	801.5	0.40%
CR#7	1005.7	1006.9	1003.2	0.25%
CR#8	805.2	806.6	801.9	0.40%
CR#9	714.3	714.6	713.8	0.07%
CR#10	794.3	795.2	792.4	0.24%
CR#11	716.2	716.5	715.7	0.08%
CR#12	792.3	793.1	790.4	0.24%
CR#13	190.9	191.1	190.5	0.20%

The CR#4 is peculiar case which increase the rod worth 0.1 pcm, but it is meaningless because rod worth depends on the flux distribution which is available to be changed against active core position.

2.4 Sensitivity Study

The sensitivity study is performed to figure out the effects by movement of active core zone and effect of non-test worth of CEA.

Figure 2 shows that the result of active core position changes versus control rod worth for CR#5. As the active core move to above, control rod worth decrease gradually, because the active fuel overlapped CEA is decreased.

The full-length rod worth is bigger than test length rod worth about 5pcm to 11pcm. Its difference is about 2% of each rod worth. It is reasonable error quantity to adapt as an operational uncertainty. It is way better getting about 8 pcm disadvantage for the acceptance criteria than the less safe test and more risky operation.

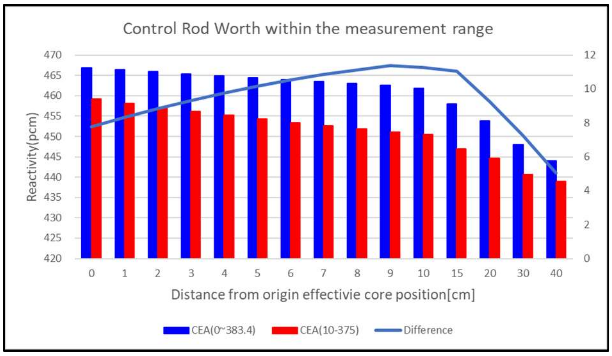

Fig. 2 Control rod worth of full-length and test range

The out of the test parts(0-10cm, 375-383.4cm) also are evaluated to analyze the effect of non-tested rod worth related with the fuel transition reactor core design.

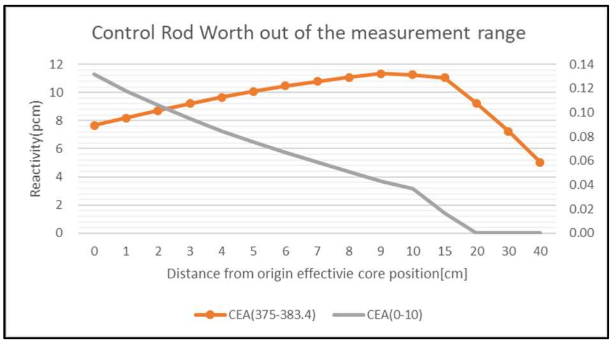

Fig. 3 Control rod worth out of test range

Figure 3 shows that the worth for low part of CEA (0-10cm) are very negligible, around 0.1 pcm. Since the bottom of CEA consists of CEA tip and reduced B4C, and those does not have much neutron absorbing cross section.

The top part of CEA (375-383.4cm) worth which is not tested, is about 5 pcm to 11 pcm. As active core moves higher, non-tested top worth increase. And it reaches at 15cm higher position, then the worth is decreased. That means active core moves over the 15cm, the active core covers all CEA length and no changes. As mentioned above, it is acceptable amount of non-tested reactivity as an additional uncertainty to perform better and safer test environment.

3. Conclusions

In this study, the control worth by DCRM and its test position are evaluated for the fuel transition reactor core design, especially, the case of PLUS7^{TM} and HIPER fuel assemblies. The nominal OPR1000 reactor core loading pattern and RAST-K code are used for this study. The results show that there are no significant changes of control rod worth for fuel transition reactor core design. It means that it is not necessary to change the current DCRM's CEA test position. And, the sensitivity study of non-test region worth for fuel transition. The non-tested top worth shows around 8pcm, it is also confirmed it is acceptable amount of value to have as the operational uncertainty for better test environment.

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