Development of a Spent Nuclear Fuels Arising Projection Program

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1. Introduction

Currently, 20 nuclear power plants (16 PWRs and 4 PHWRs) are being operated in Korea. And 8 PWR type nuclear power plants (4 APR-1000 and 4 APR-1400) will be constructed by 2020 based on the 3rd National Basic Plan for Electric Power Demand and Supply[1]. It is essential to estimate a reasonable amount of spent nuclear fuels (SNF) to propose a sound and in-depth plan. The projection should consider the technology development of a fuel performance and a reactor operation strategy. The amount of spent fuel projection can be changed as a function of the discharge burn-up, cycle length, batch size, and number of reactors. It means that the estimation has to be repeated by corresponding to the changes of a discharge burn-up, cycle length, batch size, and number of reactors. Beside, the life-time expansion of a nuclear power plant (NPP) is a current hot-issue in the world. So the amount of SNF arising projection should be frequently repeated, and it requires a long time.

This program, named as "SFAP", can mitigate this problem. According to changes of a discharge burn-up, cycle length, batch size, and number of reactors, SFAP shows 6 graphic results in a second. SFAP could be applied to most researches related to the SNF management.

2. Calculation models for SNF arising projection[2]

Three models were proposed for the development of a spent fuel arising projection. Eqs. (1), (2), and (3) represent the reactor cycle model, discharge burn-up model, annual average discharge model, respectively. In all the equations, C_f^k, C_c^k, and L_c^k is the amount of spent fuel to be accumulated, the amount of spent fuel accumulated, the total amount of nuclear fuel in the core for unit k, respectively. And the remaining reactor operation time is n.

Model 1 : Reactor cycle model

$$C_f^k = C_c^k + \sum_{i=1}^{n} \frac{L_c^k}{N_b} \int_t^{t+0.99} \delta \left[\sin\left(\frac{\pi}{M_c^k/12}(t - t_b) \right) \right] dt + L_c^k \text{ --- (1)}$$

Where, N_b = number of batchs for unit *k*,
t = calendar year for remaining operation period,
M_c^k = cycle length [month],
t_b = base year.

Model 2: Discharge burnup model

$$C_f^k = C_c^k + 365 \sum_{i=1}^{n} P^k \frac{L^k}{\varepsilon^k} \frac{1}{B^k} + L_c^k \text{ ----------- (2)}$$

Where, P^k = Electric power output[MWe] for unit *k*,
L^k = Capacity factor for unit *k*,
ε^k = Thermal efficiency for unit *k*,
B^k = Discharged burn-up[MWD/MtU].

Model 3 : Annual average discharge Model.

$$C_f^k = C_c^k + \sum_{i=1}^{n} D_{avg}^k + L_c^k$$

Where, D_{avg}^k = Annual average discharge rate[MtU/yr] for unit *k*.

3. Demonstration of the program

Fig 1 shows the program window at the first step of the calculation. Calculation models and NPPs are selected at this stage. All of the models include real amounts of an annual SNF arising by 2003 and estimated projection amounts from 2004 to 2080.

Figure 1. The program window for the selection of NPPs and caculation models at the first step

After the selection of the NPPs and the calculation models, Fig 2 shows the program window at the second step. The NPP's life-time is decided at this step.

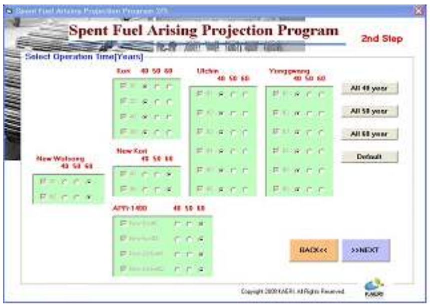

Figure 2. Selection widow for the NPP's life-time at the second step

After the selection of the NPP's life-time, Fig 3 shows the program window at the third step of the calculation. The cycle length and the batch size of the reactors are decided at this step.

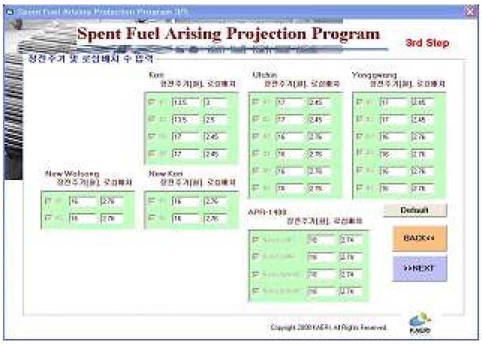

Figure 3. The third step window for input of the cycle length and the batch size of NPPs

After the cycle length and batch size of the reactors are decided, Fig 4 shows the program window at the fourth step of the calculation. The discharge burn-up, and the capacity factor of the reactors are decided at this step.

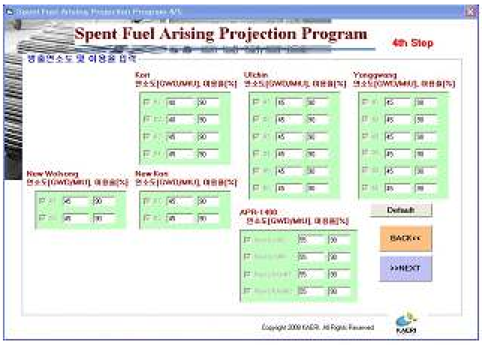

Figure 4. The fourth step window for input of the discharge burn-up and the capacity factor of NPPs

After the discharge burn-up and the capacity factor of the NPPs are decided, the result window appears. The result consists of 6 graphic forms. The annual SNF generation amount and the annual SNF accumulation for each NPP, NPP sites and for the total selected NPPs are presented at this step. Fig 5 shows the graph for the annual accumulation amount of SNF at each NPP site. And Fig 6 shows the graph for the annual amount of the SNF generation with the 3 calculation models.

The Table 1 is a comparison between the real accumulation amount and the result of the program. Table 1 shows that the results of the program are very similar to the real value.

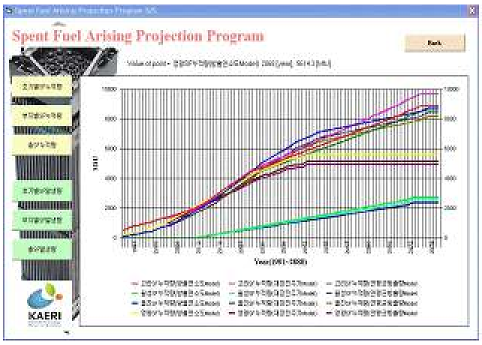

Figure 5. The graph of annual SNF accumulation amount with 3 calculation models

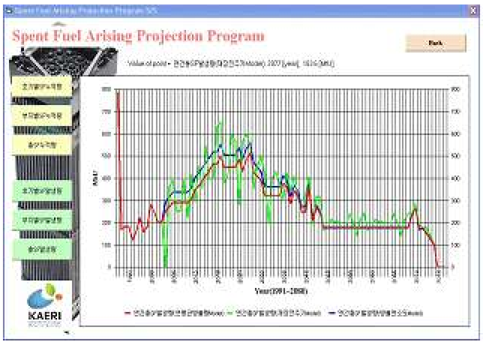

Figure 6. The graph of annual SNF generation amount with 3 calculation models

Table 1. Comparison between real accumulation amount and the result of the program. Unit : [MtU]

NPP Site	Real Value	Results of the program		
	Accumulation amount in 2006	Annual Ave.	Reactor cycle	Discharg Burn-up
Kori	1,563	1,553	1,532	1,573
YG	1,357	1,321	1,312	1,382
UC	1,053	1,044	1,010	1,095
WS	4,698	4,647	-	-
Total	**8,671**	**8,564**	**8,501**	**8,697**

4. Conclusions

This program can handle changes of each NPP's life-time, discharge burn-up, cycle length, batch size and capacity factor, and it also generates 6 results in a second. And the result is very similar to real value. This program could be applied to most researches related to a SNF management.

REFERENCES

[1] Ministry of Knowledge Economy, "National 3rd Basic Plan for Electric Power Demand and Supply(2006~2020)", 2006-349(2006).

[2] D. K. Cho, "Projection of Spent Fuel Arising Using Three Estimation Models", Transactions of the Korean Nuclear Society Spring Meeting, Gyeongju, May 29-30, 2008.