Dynamic Analysis of the Dry Process Fuel Sodium−Cooled Fast Reactor Cycle

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1. INTRODUCTION

Development of a Generation−IV (Gen−IV) reactor system was initiated with a different fuel and coolant from the conventional nuclear reactors, aiming at extensively increasing the safety and economic efficiency and drastically minimizing the radioactive wastes. Among the proposed Gen−IV concepts, the liquid metal reactor such as the lead−cooled fast reactor (LFR) and the sodium−cooled fast reactor (SFR) is being widely studied due to the advantages of its ability of a full fissile plutonium and transuranics recycle which extends the natural resource use and curtails the waste production. Also, the dry process fuel cycle is recommended because it has proliferation−resistant characteristics since the sensitive materials are not separated during the process.

In this study, a symbiotic fuel cycle between the once−through power plant and the SFR utilizing the dry process fuel has been analyzed. Important fuel cycle parameters such as the amount of spent fuel (SF) and the corresponding plutonium, minor actinides (MA) and fission products (FP) inventories are investigated and compared with those of the once−through fuel cycle. Parametric calculations were performed by the DYMOND code, which has been used for the analysis of the Gen−IV roadmap studies.

2. CALCULATION PROCEDURE

The fuel cycle calculations were performed under the assumption that the nuclear energy demand grows from 13.7 GWe in 2000 to 63.6 GWe in 2100 for all the cases. In 2000, there were 12 pressurized water reactors (PWR) and 4 pressurized heavy water reactors (PHWR) in Korea, but there will be no more constructions of PHWR after 2000. The reactor life time was assumed to be 40 yr for both the PWR and PHWR.

The SFR considered in this study is a modified BN−600 type reactor. The BN−600 is a pool−type sodium−cooled prototype reactor developed by Russia. It generates 600 MWe (1470 MWth) and uses UO2−PUO2 fuel, which is recycled via a dry process. For the SFR fuel cycle, it was assumed that the dry processing begins in 2010 and the SFR is deployed in 2015. The reactor life time was assumed to be 60 yr. The scenario of the SFR deployment along with the LWR is shown in Table I.

Table I Deployment capacity (%) for the LWR and SFR

Year	LWR	SFR
2000 2014	100	0
2015 2039	95	5
2040 2049	90	10
2050 2100	85	15

3. RESULTS AND DISCUSSION

Based on the once-through fuel cycle, the number of PWRs in 2100 is expected to be 47 with the reactor power of 1.4 GWe. The number of PHWR becomes 0 after 2040. For the SF inventory, itincreases with time and the total SF will be 102.23 kt in 2100. Beyond 2049, the PHWR SF remains constant at 17.2 kt. The total amount of U and Pu in SF will be 95.59 kt and 1.23 kt, respectively. The total amount of MA and FP in SF will be 0.13 kt and 5.28 kt, respectively.

Figure 1 shows the deployed reactor capacity of the SFR scenario. The demand power is almost the same as that of the once-through fuel cycle. Beyond 2020, the PWR sharing of the electricity generation deceases and ultimately it goes down to ~80% in 2100. On the other hand, the remaining SFR capacity increases to ~20% in 2100. The corresponding numbersof PWR and SFR are 40 and 18, respectively, in 2100.

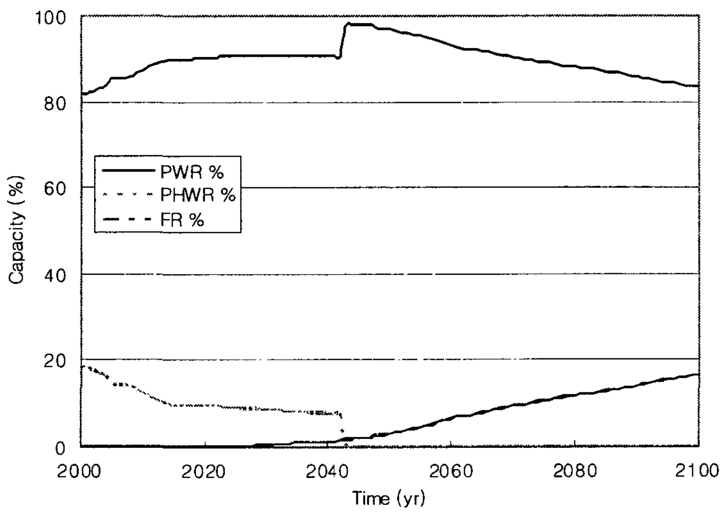

Fig. 1 Reactor capacity variation for the SFR scenario

According to the number of deployed reactors, the PWR SF decreases with time and becomes ~0 kt after 2065. The PHWR SF inventory is ~17 kt, which dominates the total SF inventory after 2065. The total amount of U, Pu, MA and FP are 88.49 kt, 0.70 kt, 0.12 kt and 5.16 kt, respectively.

The results for the SFR scenario are given in Table II and compared with those of the once-through scenario. The PWR SF decreases with time and becomes ~0 kt, while the PHWR SF dominates after 2040 and remains constant at ~17 kt, which results in a total SF of ~17 kt in 2100.

The total amount of U and Pu in SF will be 15.95 kt and 0.92 kt, respectively. In the case of the SFR scenario, there is recovered uranium of ~72 kt. The total amount of MA and FP in the SF will be 0.12 kt and 5.14 kt, respectively.

From the above results, it was found that the SFR scenario does not contribute to the reduction of the amount of MA and FP, which is an important factor that should be considered when designing a repository. For the further destruction of MA, an actinide burner can be considered in the fuel cycle.

Table II Comparison of the amount of SF (kt) and heavy element (kt)

	Once-through	SFR
PWR SF	85.03	0
PHWR SF	17.20	17.20
FR SF	0	0
Total SF	102.23	17.20
Pu	1.23	0.92
MA	0.13	0.12
FP	5.28	5.14
U	95.59	15.95
Recovered U	-	72.59