Dynamic Analysis of the Accelerator Driven System Scenario

Chang Joon Jeong and Tae Yung Song
Korea Atomic Energy Research Institute, P.O.Box105, Yuseong, Daejeon, Korea 305-600
cjjeong@kaeri.re.kr

1. Introduction

The spent fuel minimization and reduction of the radioactive source term in high level wastes considered to be important to the development and operation of final waste repositories. The full utilization of uranium resources will contribute simultaneously to waste minimization because burning of transuranic (TRU) elements and minor actinides (MA) can substantially reduce the long term radiotoxicity source term of the waste while at the same time producing energy. In addition, the transmutation of long-lived fission products is, in principal, feasible in symbiotic fuel cycle system when enough excess neutrons are made available in critical or subcritical systems.

In Korea, the Hybrid Power Extraction Reactor (HYPER) [1,2] has been developed since 1997. The HYPER system is designed to transmute TRU and some fission products such as I-129 and Tc-99. The basic HYPER system has a 1000 MWt reactor power and its effective multiplication factor is a 0.98. The inventory of TRU is 6510 kg at BOC and 282 kg of TRU is transmuted per year. In case of the fission products, I-129 and Tc-99 are transmuted with the rates of 7 and 27 kg/yr.

In this study, a symbiotic fuel cycle between once-through power plant and HYPER 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 [3] 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 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 construction of the PHWR after 2000. Table I compares the material inventory change between charge and discharge. In the FR fuel cycle analysis, it was assumed that the new HYPER is constructed from 2035. In order to feed the FR, it was also assumed that the SF of the PWR and PHWR is reprocessed from 2030 and the HYPER SF reprocessing begins in 2035. The electricity generation (or capacities) by the deployed HYPER is 10%, 15% and 20% for the time periods of 2035-2059 and 2060-2084, and 2085- 2100, respectively.

Table I Comparison of the Material Inventory (%)

Material	HYPER	
	BOC	EOC
U	16.53	18.96
Pu	68.50	53.85
MA	14.60	11.94
FP	0.37	18.96

3. Results and discussion

During the current century, nuclear power was assumed to grow from 13.716 GWe in 1999 to 25.2 GWe in 2015 based on a nuclear power plant construction plan. [4] From the year 2016 to 2100, the growth rate of nuclear power was assumed to be 1%. For the reactor information of the once-through fuel cycle, currently operating reactors were considered, which are 12 PWRs and 4 PHWRs. The reactor life time was assumed to be 40 yrs for both the PWR and PHWR. In this scenario, all the PHWRs were assumed to be shutdown after their life time and there will be no more PHWR construction.

In 2100, the demand is expected to be 58.8 GWe. If all the PHWRs are shutdown, the electricity generation is dominated by the PWR after 2040. The number of operating PWRs increases with time and becomes ~42 in 2100 for the reactor power of 1.4 GWe, while the number of PHWRs becomes zero after 2040. The SF inventory increases with time, and the total SF will be 94.0 kt in the year 2100. After 2049, the PHWR SF remains constant at ~17 kt. The total amount of U and Pu in SF will be 87.9 kt and 1.1 kt, respectively. The amount of MA and FP will be 0.12 kt and 4.9 kt, respectively.

Figure 1 shows the deployed reactor capacity of the HYPER scenario. The demand power is almost the same as that of the once-through fuel cycle. Beyond 2040, the PWR sharing of the electricity generation deceases, ultimately it goes down to ~80% in 2100. On the other hand, the remaining HYPER capacity increases to ~20% in 2100.

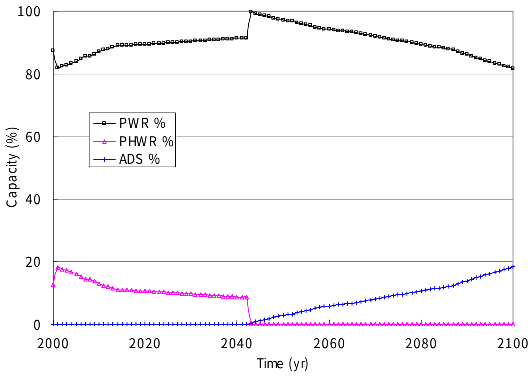

Fig.1 Reactor capacity variation for HYPER scenario

The number of PWR and HYPER increases and reaches 34 and 30, respectively, in 2100. According to the number of deployed reactors, the total SF increases until ~2040, but it starts to decrease after 2040. This is because the reprocessing is started from ~2030. As shown in Table II, the total amount of U will be 82.85 kt, in which the recovered uranium is included. The amount of Pu, MA and FP are 0.23 kt, 0.03 kt and 4.89 kt, respectively.

From the above results, it was found that the HYPER scenario contribute to a reduction in the amount of Pu and MA, which is important when designing a repository. However, it is needed to consider a system for reduction of fission products in future.

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

	Once-through	HYPER
PWR SF	76.92	19.30
PHWR SF	17.10	0.0
HYPER SF	0	0.0
Total SF	94.02	19.30
Pu	1.13	0.23
MA	0.12	0.03
FP	4.86	4.89
U	87.90	18.05
Recovered U	-	64.80

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