Reactor Deployment Strategy with SFR Introduction for Spent Fuel Reuse

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1. Introduction

With the continuous expansion of nuclear power capacity, overall PWR spent fuel storage capacity is foreseen to be saturated by 2016, even if considering the expansion of spent fuel storage pools at each nuclear power site. In addition, it is difficult to decide the waste disposal site from the viewpoint of public acceptance. The radioactive waste disposal is an impending challenge in Korea.

The sodium cooled fast reactor (SFR)/PWR coupling scenario study have already shown that SFRs can substantiate the domestic waste management claims in Korea by reducing the amount of spent fuel and the environmental burden by decreasing radiotoxicity of high level waste through transmutation [1]. SFRs are designed to recycle transuranics (TRU) by the reuse of PWR spent fuel, which is of benefit to efficiently use natural uranium, thus contributing to a sustainable development.

In this study, efficient reactor deployment scenarios with SFR introduction are sought to optimize the SFR deployment strategy for replacing existing nuclear fleet, with the view of the efficient uranium utilization and the spent fuel reduction through its reuse.

2. Scenarios and Evaluation

2.1 Description of Scenarios and Assumptions

Seven deployment scenarios for reactor strategy are considered to evaluate the total amount of uranium demand and spent fuel accumulated with different SFR missions and mixing ratios in the future nuclear fleet:

Case 1: PWR once-through cycle (OTC), direct disposal of spent fuel without treatment;
Case 2: Breeder (BR) only with all of decommissioned PWRs being replaced with breeders;
Case 3: Burner (BN) only with mixing ratio of SFRs in 2100 being 30~40%;
Case 4: Breakeven (BK) reactor only with mixing ratio of SFRs in 2100 being 30~40%;
Case 5: (BK + BN) with mixing ratio of SFRs in 2100 being 30~40%;
Case 6: (BN + BK) with mixing ratio of SFRs in 2100 being 30~40%;
Case 7: (BN + BK) with mixing ratio of SFRs in 2100 being ~50%.

This scenario study aims to find an efficient reactor deployment scenario which can meet the requirements: (1) the amount of uranium demand accumulated shall be below 5.0% of identified uranium resources and (2) the amount of spent fuel arising accumulated shall be kept below 20 ktHM.

The lifetime of existing nuclear power plants is extended up to 60 years same as that of SFRs. SFRs are introduced into the power grid from 2040. Three types of SFRs; breeder (BR)(breeding ratio 1.22), breakeven (BK) reactor (breeding ratio 1.0) and burner (BN) (conversion ratio 0.61) are considered for SFR deployment. Power capacities of PWRs and SFRs are 1000 MWe and 600 MWe, respectively. Especially input data for SFRs are prepared based on the KALIMER-600 designs.

Existing SFR fuel is supplied by pyroprocessing of spent fuels. All TRUs produced from PWRs and SFRs are recycled and transmutated by SFRs. CANDU (PHWR) spent fuel recycling is not considered. It is assumed that reasonable amount of PWR spent fuel should be maintained for supplying SFR fuel without interruption even after 2100.

2.2 Results

According to the "Basic Plan for Long-term Electricity Supply and Demand," the nuclear electricity generating capacity in 2005 was 17.7 GWe and will become 27.3 GWe in 2020 [2]. The nuclear share will be 43.4% of the total electricity generation in 2020. Assuming that annual growth rate after 2020 is 2.0%, the nuclear electricity generation is projected to increase to 54.8 GWe in 2100, which corresponds to 480.3 TWh/yr of nuclear electricity generation.

As can be seen in Fig. 1, the accumulated uranium demand is estimated less than 740 ktU, 5% of the amount of identified uranium resources 14.8 million tU [3], for all cases with SFR deployment. The uranium saving is estimated more than 158 ktU with the SFR deployment. Figure 2 shows the accumulation of annual spent fuel arisings for several SFR deployment cases. The introduction of burners effectively reduces the spent fuel accumulation below 20ktHM in 40 years after SFR introduction.

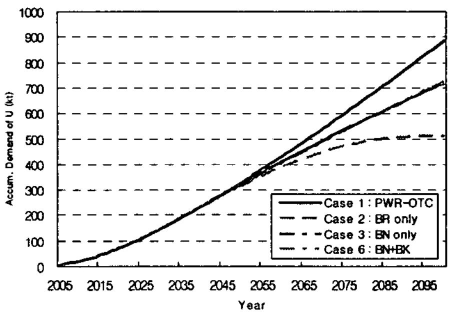

Fig. 1. Accumulated uranium demand

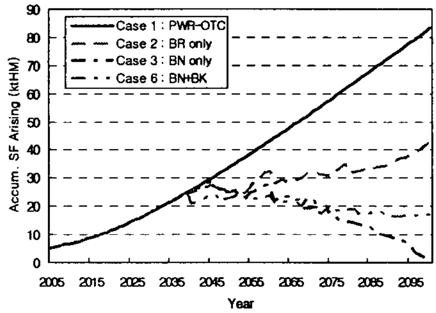

Fig. 2. Accumulated spent fuel arisings

From the synthetic comparison of results, Case 6, where burners (BNs) are deployed prior to breakeven reactors (BKs), is selected as the most appropriate SFR deployment scenario. Figure 3 illustrates reactorwise generation capacities within the total nuclear power demand in Case 6, where the SFR mixing ratio in the nuclear fleet in 2100 is 35.0%. Figure 4 shows the evolution of nuclear reactors till 2100, drawn based on the SFR deployment scenario. SFRs are to be deployed in support of substantial reduction of PWR spent fuel at the first stage of deployment.

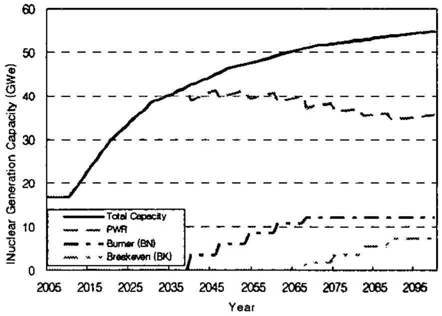

Fig. 3. Reactorwise nuclear capacities (Case 6)

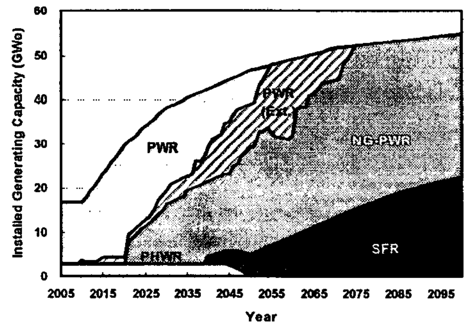

Fig. 4. Reactor deployment scenario

3. Conclusion

An efficient reactor deployment strategy with SFR introduction starting in 2040 is drawn, based on the most appropriate SFR deployment scenario where burners are deployed prior to breakeven reactors in order to substantially reduce PWR spent fuel at early deployment stage. The SFR mixing ratio in the nuclear fleet in 2100 is about 35%. PWRs remain a main reactor type till 2100 and SFRs will be in support of waste minimization and fuel utilization.

The use of SFRs and recycling of TRUs by reusing PWR spent fuel leads to the substantial reduction of the amount of PWR spent fuel and environmental burden by decreasing radiotoxicity of high level waste, and a significant improvement on the natural uranium resources utilization.

REFERENCES

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[3] OECD/NEA-IAEA, Uranium 2005: Resources, Production and Demand(2006).