Reactor Deployment Strategy with Introduction of SFR Burners for Spent Fuel Reuse

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1. Introduction

It is generally recognized that the spent fuel discharged from nuclear power plants constitutes the main contribution to nuclear waste. The nuclear waste disposal is an impending challenge in Korea. The neutron balance feature of a fast reactor allows flexibility in the design to achieve a conversion ratio, which can be lower, equal or higher than one, according to specific objectives. This favourable neutron balance feature makes flexible waste management strategies possible by introducing fast reactors having the appropriate conversion ratio.

The previous scenario study showed that a timely deployment of monolithic sodium cooled fast reactors (SFRs) with different conversion ratios: breakeven reactors and burners, and recycling of TRUs by reusing PWR spent fuel in SFRs can lead 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 [1].

In this study, fuel cycle impact with SFR burners having different power capacities in the future nuclear fleet are evaluated to find an efficient reactor deployment strategy with SFR burners only with the same views, supporting the SFR conceptual design study being peformed by KAERI.

2. Deployment Scenarios and Evaluation

2.1 Description of Deployment Scenarios and Assumptions

Dynamic analysis of fuel cycle performance were performed for the period of 2006 - 2100, using the DANESS code [2]. Four deployment scenarios for reactor strategy are considered to evaluate the total amount of cumulative spent fuel and uranium demand only with sodium cooled fast reactor (SFR) burners having different power capacities in the future nuclear fleet. In the dynamic analysis of burner deployment scenarios, the deployment of burners are sought with its power capacity fraction being 30 - 50% in the future nuclear fleet.

SFR burners with a conversion ratio ~0.58 are introduced into the power grid from 2040. The lifetime of existing nuclear power plants is extended to be 60 years same as that of SFRs. Three different power capacities; 600, 1200 and 1800 MWe, are considered for SFRs. Power capacities of PWRs to be deployed are 1000 and 1200 MWe. Especially input data for SFRs are prepared based on the conceptual designs work, where extensive design efforts were made to optimize a transmutation performance for a given power capacity.

SFR fuel is supplied by pyroprocessing of spent fuels, which starts in 2030 with an unlimited amount of fuel cycle facility capacity. The loss rate during pyroprocessing is 0.2%. All TRUs produced from PWRs and SFRs are recycled and transmuted by SFR burners. CANDU (PHWR) reactors will not be deployed any more and will not be included in spent fuel recycling.

2.2 Results and Discussion

In 2007, 16 PWRs (6 OPRs) and 4 PHWRs are in operation. The nuclear electricity generation installed capacity in 2006 was 17.7 GWe, supplying 39.0% of the total electricity. According to the "Third Basic Plan for Long-term Electricity Supply and Demand," the nuclear installed capacity will become 27.3 GWe in 2020 and the nuclear share will be 43.4% of the total electricity generation [3]. Assuming that after 2020 the annual growth rate is 0.9% for next 30 years (2021 - 2050) and is adjusted after 2050 by gradually decreasing its value to reach 0% in 2100, the nuclear electricity generation is projected to increase to 51.1 GWe in 2100, which corresponds to 352 TWh/yr of nuclear electricity generation.

As can be seen in Fig. 1, the cumulative uranium demand is estimated to be less than 740 ktU, 5% of the amount of identified uranium resources 14.8 million tU [4], for all cases with the SFR burner deployment. The uranium saving is estimated to be more than 235 ktU with the burner deployment. Figure 2 shows the number of installed units for different power capacities. Total 48 (59%), 29 (71%), and 18 (66%) units are installed till 2100 for 600, 1200 and 1800 MWe-rated burners, respectively.

Figure 3 shows the accumulation of annual spent fuel arisings for burner deployment cases, comapring with the PWR once-through (PWR-OTC) strategy with no reprocessing. The continuous deployment of 1200 MWe-rated burners is appeared to be most effective in reducing the amount of PWR spent fuel accumulation, thus lightening the burden for PWR spent fuel management. Figure 4 shows the evolution of nuclear reactors till 2100, drawn based on the most efficient SFR burner deployment scenario where the SFR mix ratio in the nuclear fleet in 2100 is 71%. SFR burners are deployed in support of substantial reduction of PWR spent fuel at early stages of deployment.

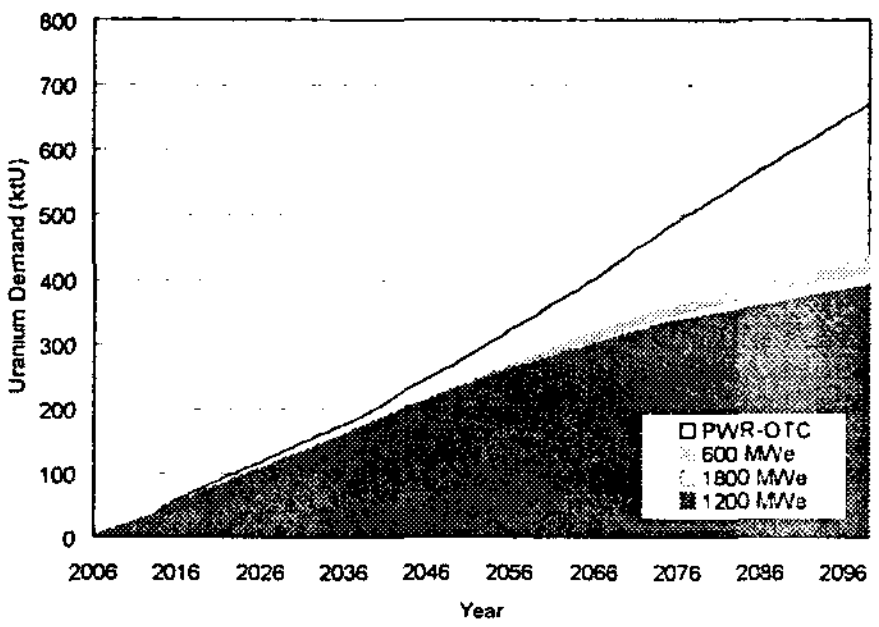

Fig. 1. Cumulative uranium demand

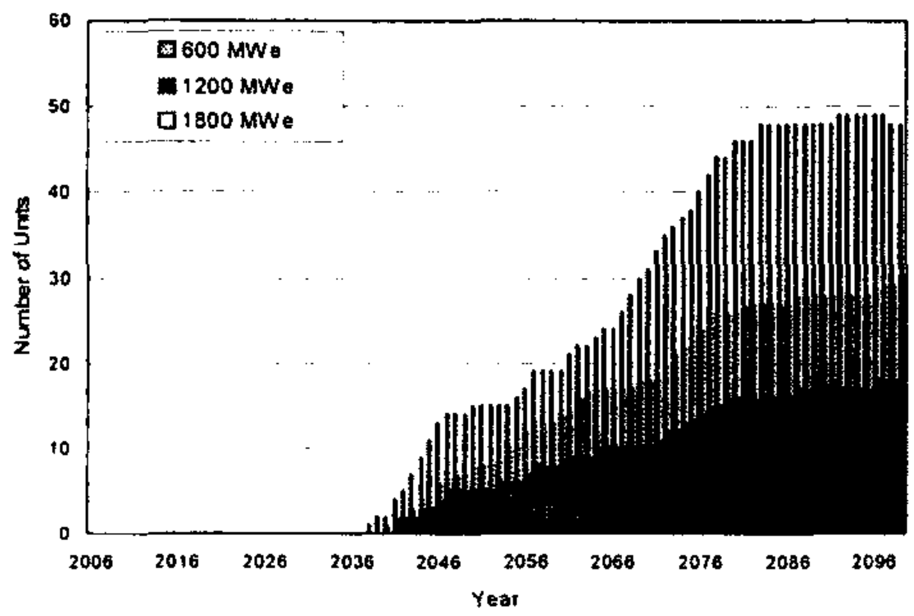

Fig. 2. Number of installed units

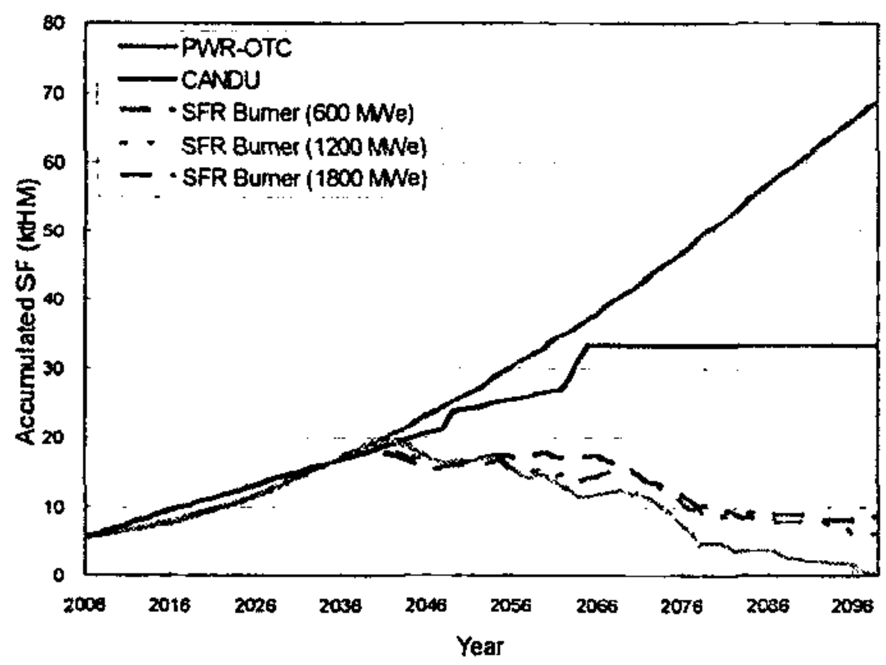

Fig. 3. Cumulative PWR spent fuel

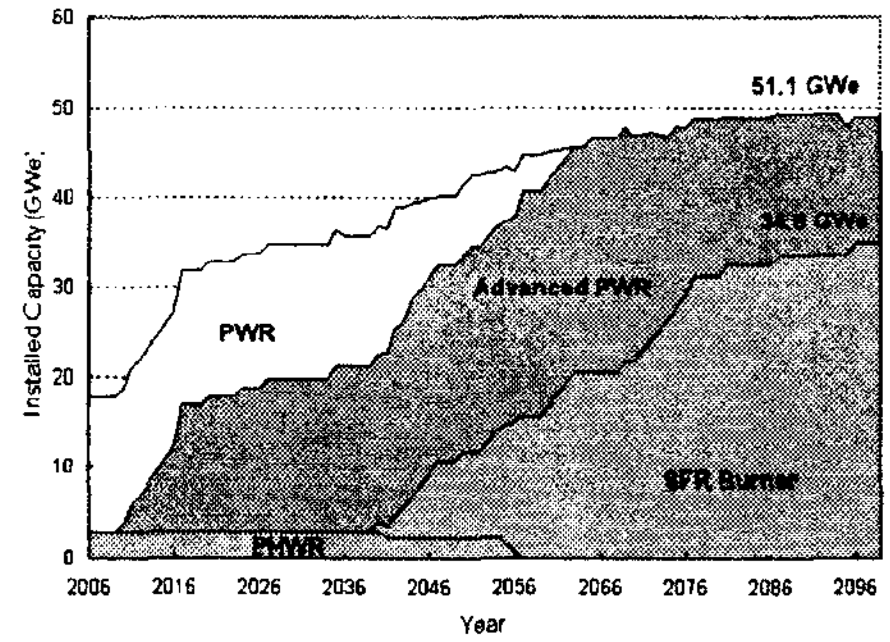

Fig. 4. Reactor deployment scenario with SFR Burners (1200 MWe)

3. Conclusion

Efficient reactor deployment strategies with the introduction of SFR burners only starting in 2040 are drawn, based on different power capacities. The mix ratio of SFR burners having different power capacities in the nuclear fleet in 2100 is estimated to be 60 - 70%. The use of SFR burners 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. These effects do not largely depend on burner's power capacity. A smaller capacity unit is more timely deployable in the nuclear fleet.

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