PWR Spent Fuel Management for Its Reuse with SFR Deployment Scenarios

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1. Introduction

The neutron balance feature of a fast reactor allows flexibility in the design to achieve a conversion ratio according to specific objectives. This favorable 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 sodium cooled fast reactors (SFRs) with different conversion ratios: burners (BNs) and breakeven reactors (BKs), and recycling of transuranics (TRUs) by reusing PWR spent fuel in SFRs can lead to the substantial reduction of the amount of PWR spent fuel and a significant improvement on the natural uranium resources utilization [1].

In this study, fuel cycle impact with different deployment times of SFR burners and breakeven reactors in the future nuclear fleet are evaluated to investigate an efficient reactor deployment strategy with the same views.

2. Deployment Scenarios and Evaluation

2.1 Description of Deployment Scenarios and Assumption

Dynamic analyses of a fuel cycle performance are performed for the period of 2006 - 2100, using the DANESS code [2]. Deployment scenarios for SFR BNs (conversion ratio 0.61) and BKs (conversion ratio 1.0) are simulated to evaluate the total amount of cumulative spent fuel and uranium demand with deployment times being 2040 - 2070.

600 MWe-rated SFRs are introduced into the power grid from 2040 - 2070. The lifetime of existing nuclear power plants is extended to be 60 years same as that of SFRs. Power capacities of PWRs to be deployed are 1000 and 1400 MWe. Especially input data for SFRs are prepared based on the conceptual designs work [3,4].

SFR fuel is supplied by pyroprocessing of spent fuels, which starts 10 years before the SFR deployment 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 SFRs. CANDU (PHWR) reactors will not be deployed any more and will not be included in spent fuel recycling.

2.2 Results and Discussion

The installed nuclear electricity generation 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 [5]. Assuming that after 2020 the annual growth rate is 0.9% for the 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 a nuclear electricity generation.

SFR units are installed more timely in the nuclear fleet with an earlier SFR deployment. This aspect is more effective for the SFR breakeven reactor deployment.

Figures 1 and 2 show the accumulation of annual spent fuel arisings for the SFR deployment cases, comparing with the PWR once-through (PWR-OTC) strategy with no reprocessing. In Fig. 1, an earlier deployment of SFR burners reduces the amount of PWR spent fuel accumulation more efficiently, thus facilitating PWR spent fuel management more easily. As can be seen in Fig. 2, this aspect is the same at early stages of SFR breakeven reactor deployment. However, the continuous deployment of breakeven reactors eventually increases the amount of PWR spent fuel accumulation, which might burden the PWR spent fuel management.

In Figs. 3 and 4, the uranium savings are estimated to be more than 118 ktU with the BN deployment and 92 ktU with the BK deployment, respectively. A larger uranium saving is achieved with an earlier deployment of SFRs, which leads to an improvement on the natural uranium resources utilization. The uranium saving is obtained more efficiently with the BK deployment, comparing with the BN deployment.

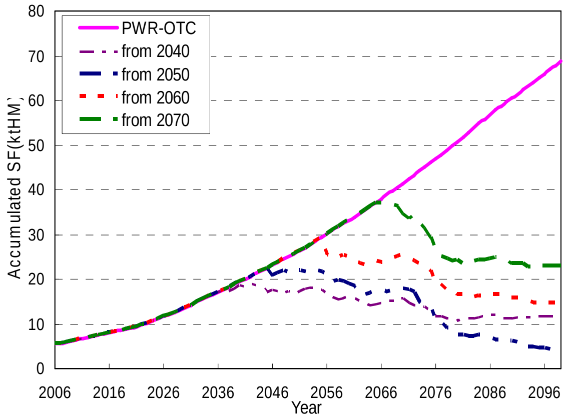

Fig. 1. Cumulative PWR spent fuel (BN only case).

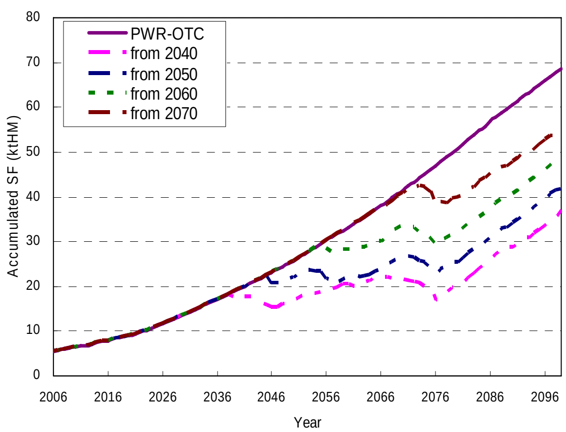

Fig. 2. Cumulative PWR spent fuel (BK only case).

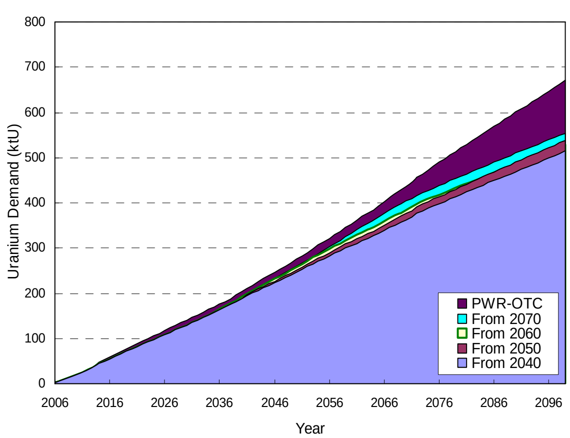

Fig. 3. Cumulative uranium demand (BN only case).

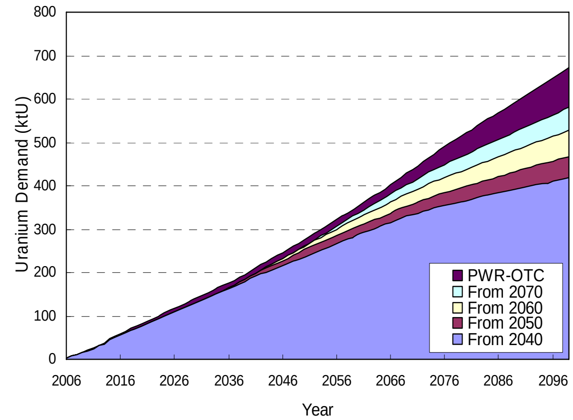

Fig. 4. Cumulative uranium demand (BK only case).

3. Conclusions

An earlier deployment of sodium cooled fast reactors (SFRs) with different conversion ratios: burners (BNs) and breakeven reactors (BKs), and recycling of transuranics (TRUs) by reusing PWR spent fuel in SFRs can lead to an improvement on the reduction of the amount of PWR spent fuel and the natural uranium resources utilization. SFR units are installed more timely in the nuclear fleet with an earlier SFR deployment.

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