A Sustainable Reactor Deployment Scenario with Introduction of SFRs

Young-In Kim, Byung Chool Won, Dong Uk Lee and Dohee Hahn

Korea Atomic Energy Research Institute 1045 Daedeok-daero, Yuseong-gu, Daejeon 305-353, Korea, yikim2@kaeri.re.kr

1. Introduction

One of essential conditions for the large expansion of nuclear energy is sustainability with the minimization of waste and radiotoxicity, and the preservation of natural uranium resources. The sustainability requirement can be fulfilled by fast reactors with a closed fuel cycle. Large transuranics (TRU) stockpiles already accumulated in the spent fuel of thermal reactors, dictates the use of fast reactors with uranium-TRU(plutonium and minor actinides) fuel cycle for the large-scale deployment of nuclear power in the current century and beyond.

A disposal of PWR spent fuel mainly contributing to nuclear waste is an impending challenge in Korea. The previous scenario study showed that a timely deployment of sodium cooled fast reactors (SFRs) with 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 impacts with SFR burners in the future nuclear fleet are evaluated to investigate an efficient reactor deployment strategy with SFR burners only with the same views, supporting the sustainability of nuclear energy specific to Korea.

2. Deployment Scenarios and Evaluation

2.1 Description of Deployment Scenarios and Assumptions

Dynamic analyses of a fuel cycle performance are performed for the period of 2006 - 2150, using the DANESS code [2]. A sustainable deployment scenario for SFR burners (BNs) with its conversion ratio being 0.61 into the future nuclear fleet is simulated to evaluate the total amount of cumulative spent fuel and uranium demand with deployment times being 2040 - 2150 from the viewpoint of fuel mass balance for sustaining a closed fuel recycling in the long-term perspective.

600 MWe-rated SFR burners with a conversion ratio 0.61 are introduced into the power grid from 2040. The lifetime of existing nuclear power plants (NPPs) 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 SFR burners are prepared based on the KALIMER-600 burner core design specifications [3].

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

The nuclear electricity generation installed capacity in 2008 was 17.7 GWe, supplying 34.0% of the total electricity. According to the "First Basic Plan of National Energy [4]" and the "Fourth Basic Plan for Long-term Electricity Supply and Demand [5]," the nuclear installed capacity will be 32.9 GWe in 2022 and the nuclear share will be 59.0% of the total electricity generation in 2030. After 2022 the total electricity generation is projected to grow annually by 1.0% for the next 28 years (2023-2050); adjusted after 2050 to decrease gradually to 0% by 2100 and after 2100 to be constant until 2150. The nuclear share of 59.0% planned as of 2030 is maintained until 2150. The total installed nuclear capacity is projected to increase to 73.9 GWe in 2100, which corresponds to electricity generation rate of 550 TWh/yr as estimated by an average capacity factor of 85%.

Figure 1 shows the accumulation of annual spent fuel arisings for the SFR burner deployment, compared with the PWR once-through (PWR-OTC) strategy with no reprocessing. The continuous deployment of burners effectively reduces the ongoing accumulation of PWR spent fuel to below 20 ktHM about 30 years after the introduction of commerical SFRs and even could exhaust all of the PWR spent fuel accumulation in a shorter period of time before 2100, thus lightening the burden of PWR spent fuel management.

As can be seen in Fig. 2, the cumulative uranium demand for PWRs up to 2150 is estimated to be 1,161 ktU, 7.8% of the amount of identified uranium resources 14.8 million tU [6] with the SFR burner deployment, which represents a uranium saving of 465 ktU. Figure 3 illustrates reactor mix ratios in the nuclear fleet until 2150, where the SFR mix ratio of 42% as of 2100 is held constant until 2150. This value is given by the availability of the TRU amount or plutonium to supply as start-up fuel and compensation of burnt-up fuel of a TRU component, which strongly depends on the amount of PWR spent fuel accumulated from the achivement of PWR NPPs operation. Figure 4 shows the evolution of nuclear reactors until 2150, drawn based on the efficient SFR burner deployment scenario.

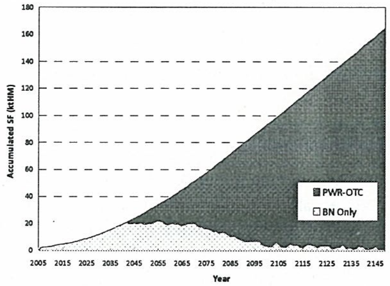

Fig. 1. Cumulative PWR spent fuel

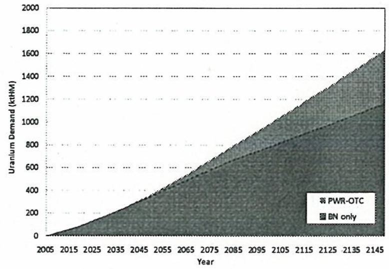

Fig. 2. Cumulative uranium demand

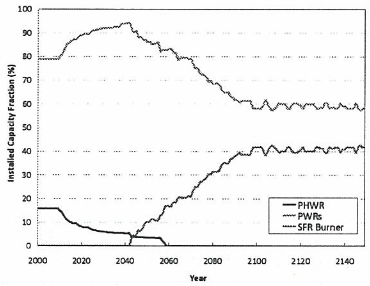

Fig. 3. Reactor mix ratios

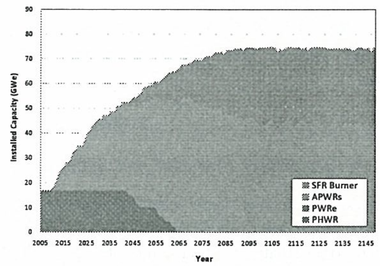

Fig. 4. Reactor deployment scenario with SFR burners

3. Conclusion

An efficient reactor deployment strategy with the introduction of SFR burners starting in 2040 are evaluated from the viewpoint of sustaining a closed fuel recycling in the long-term perspective. the SFR mix ratio of 42% in the nuclear fleet as of 2100 is held constant untill 2150. 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 an improvement on the natural uranium resources utilization, thus contributing to the sustainability of nuclear energy in Korea.

Acknowledgement

This work has been performed under the National Mid- and Long-term Nuclear Research and Development Program of the Ministry of Education, Science and Technology, R.O.K.

REFERENCES

[1] Y. I. Kim, S. G. Hong and D. Hahn, "SFR Deployment Strategy for the Re-Use of Spent Fuel in Korea," Nuclear Engineering and Technology, Vol. 40, No. 6, p. 517-526, Oct. 2008.
[2] L. Van Den Durpel, A. Yacout, D. Wade, H. Khalil, "DANESS Dynamic Analysis of Nuclear System Strategies," GLOBAL 2003, New Orleans, USA, Nov. 16-20, 2003.
[3] S. G. Hong, S. J. Kim and D. Hahn, "Establishment of Gen IV Sodium Cooled Transmutation Nuclear Reactor Concept," KAERI/RR-2679/2006, Korea Atomic Energy Research Institute (Aug. 2006).
[4] "The First Basic Plan of National Energy (2008-2030)," Ministry of Knowledge Economy (MKE), Aug. 27, 2008.
[5] "The Fourth Basic Plan of Long Term Electricity Supply and Demand (2006-2022 year)," Ministry of Education, Science and Technology (MEST) announcement 2008-372, Dec. 29, 2008.
[6] OECD/NEA-IAEA, Uranium 2005: Resources, Production and Demand (2006).