Dynamic Modeling of a Partial Plutonium Recycling Scenario

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1. Introduction

The partial plutonium recycling scenario has been considered as an option for reducing plutonium or transuranic elements (TRU) inventory. In this study, the partial recycle is modeled by mixed oxide (MOX) fuel loading in pressurized water reactor (PWR). The dynamic MOX fuel cycle scenario is set up by the system dynamic DANESS code [1], and applied to the Korean fuel cycle. The DANESS code is used widely in the field of nuclear fuel cycle analysis. The fuel cycle parameters such as material flows, front- and back-end parameters are compared with those of the once-through (OT) fuel cycle.

2. Fuel Cycle Analysis

The number of operating PWRs and Canada deuterium uranium (CANDUs) reactors in Korea in 2000 were 14 and 4, respectively. The total nuclear capacity in 2000 was 13.8 GWe. From the "National Energy Basic Plan"[2], the nuclear capacity in 2017 will increase to 27.3 GWe with 29 total operating reactors. Between 2018 and 2030, it is expected that the annual electricity demand growth rate will be 0.95%/yr, and the nuclear capacity of the year 2030 will become 41.3 GWe which will occupy ~59% of total electricity generation. The nuclear growth rate after 2050 will decrease at the same rate and become 0% in 2100. Eventually, the reactor capacity in 2100 will be ~70 GWe and it will be maintained until 2150. In the calculation, the lifetime of existing reactors will be extended 20 yrs for both the PWR and CANDU reactor. The lifetime of newly constructed reactors will be 60 yrs.

From the analysis results of the once-through fuel cycle, the nuclear power demand is expected to grow to ~70 GWe in the year 2150. As shown in Fig. 1, the total spent fuel inventory will be 186500 t in 2150. The TRU inventory is estimated to be 2100 t in 2150.

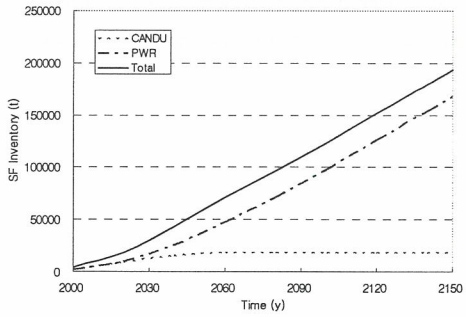

Fig.1. Spent fuel inventory for once-through cycle

In the MOX fuel cycle, it is assumed that the MOX fuel is loaded from 2020 in the 1/3 core of APR-1400. The fraction of APR-1400 with MOX fuel is 12% among the deployed APR-1400. The PWR spent fuel (SF) reprocessing starts from 2018. Ih this fuel cycle, the CANDU SF and MOX SF are not reprocessed. Fig.2 shows the SF inventory. The CANDU SF gives same trend with the OT case. The PWR SF increases very slowly because of the reprocessing from 2018. In 2150 the PWR SF inventory will be ~7200 t which is reduced by ~95%, when compared with that of the OT cycle. The MOX SF accumulates

from 2021 and becomes ~4800 t in 2150. The total SF increases gradually and becomes 30600 t in 2150, which is reduced by ~84%, when compared with that of the OT cycle.

The out-core TRU inventory is shown in Fig. 3. The inventories of plutonium and MA in 2150 are 1652 t and 266 t, respectively. The TRU inventory in 2150 is 1918 t which is reduced by 9%. But the in-core TRU of MOX fuel cycle is ~87 t which is increased by ~50% over the OT cycle, which means the MOX cycle can contain much TRU in the core.

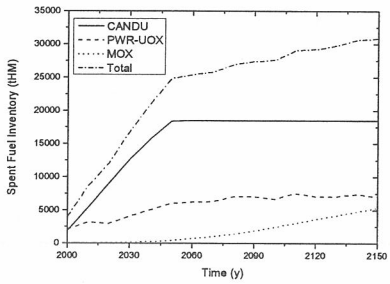

Fig. 2. Spent Fuel Inventory (MOX cycle)

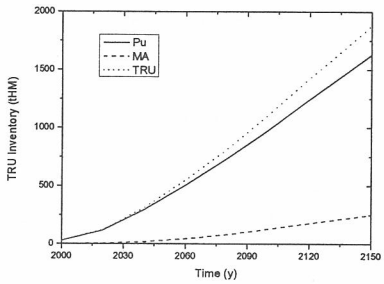

Fig. 3. TRU Inventory (MOX cycle)

3. Summary

From the OT cycle analysis results, the nuclear power demand grows to ~70 GWe in 2150. The SF and TRU out-core inventories in 2150 will be 186500 t and 2100 t, respectively. The MOX fuel cycle gives 84% and 9% lower values for the SF and out-core TRU inventories, respectively.

References

[1] L. V. D. Durpel, A. Yacout, D. Wade, and H. Khalil, "DANESS-Dynamic Analysis of Nuclear Energy System Strategies," Global 2003, New Orleans, November 16-20, (2003).

[2] "National Energy Basic Plan," Korea Ministry of Knowledge and Economy, (2008).