Dynamic Analysis of Fast Reactor Scenario by Using DANESS Code

Chang Joon Jeong, and Won. Il. Ko
Korea Atomic Energy Research Institute, 1045 Daedeok-daero, Yuseong-gu, Daejeon, 305-353, Korea
Corresponding author: cjjeong@kaeri.re.kr

1. Introduction

For a sustainable nuclear power generation, a spent fuel (SF) or transuranic (TRU) element reduction has become an important issue, which is also a main goal of the Generation-IV (Gen-IV) reactor system. As one of the Gen-IV reactor, the Korea advanced liquid metal reactor (KALIMER) has been studied [1]. Recently, KALIMER with a low and high conversion ratio (CR) has been studied for a break-even core or burning TRU [1].

A dynamic analysis method has been widely used for the fuel cycle analysis [2-4]. In this study, the system dynamic DANESS (Dynamic Analysis of Nuclear Energy System Strategies) code was used for the fast reactor (FR) scenario analysis. It was developed for the fuel cycle study by Argonne National Laboratory (ANL) [5]. In this study, the KALIMER scenarios were analyzed with different conversion ratios (CR) for investigating the impact of the CR on SF or out-pile TRU inventory. Also, the long-term heat (LTH) load of the SF to the repository was analyzed.

2. Once-through Fuel Cycle Modeling

The once-through (OT) fuel cycle was modeled based on the current operating reactor. In 2000 there were 4 CANDU reactors and 12 PWRs, and the total reactor capacity was 13.8 GWe. From the "National Energy Basic Plan"[6], the nuclear capacity in 2018 will increase to 27.3 GWe with 29 operating reactors. After 2018, it is assumed that the nuclear capacity increases continuously and becomes ~70 GWe in 2100. This capacity maintains until 2150. The life time of an existing reactor is extended for 20 yrs for both the PWR and CANDU reactors. The life time of a newly constructed reactor is 60 yrs.

Fig. 1 shows the variation of the nuclear power demand and deployed capacity with time. In 2150, both the demand and deployed capacity are expected to be ~70 GWe. According to the deployed capacity, the PWR SF inventory increases continuously with time and becomes ~168000 t in 2150, while the CANDU SF remains at a constant value at ~18500 t after 2050. Consequently, the total SF will be ~186500 t in 2150. Fig. 2 shows the out-pile TRU inventory. According to the SF inventory, the out-pile inventories of Pu, MA and TUR are 1940 t, 160 t and 2100 t, respectively in 2150. The fission product (FP) inventory in SF is ~8600 t in 2150.

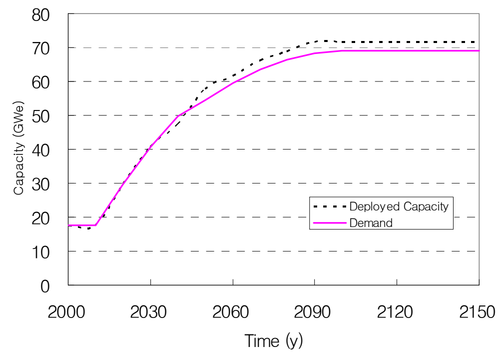

Fig. 1. Nuclear Demand and Produced Power

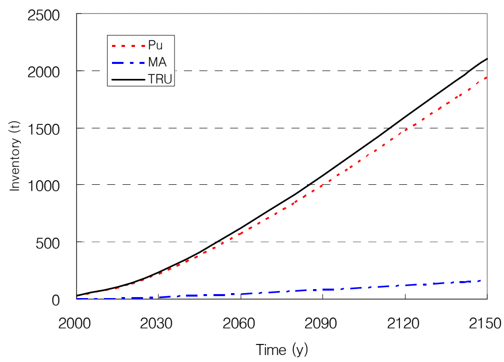

Fig. 2. Out-pile TRU Inventory of Once-through Cycle

3. Fast Reactor Cycle Results

In the KALIMER scenario, the sensitivity calculations were performed for three different conversion ratios of 0.3, 0.61 and 1.0. In the fast reactor (FR) cycle analysis, it was assumed that the new FR is constructed from 2025 and operated from 2030. In order to feed the FR, it was also assumed that the PWR SF is reprocessed from 2025 and the FR SF reprocessing begins in 2030. In this study, the CANDU reactor SF is not reprocessed.

The deployed capacity of the KALIMER for each CR is shown in Fig. 3. It can be seen that the FR capacity increases with an increasing conversion ratio. The KALIMER fractions in 2150 are 9 GWe, 16.2 GWe, and 64.2 GWe for CR of 0.3, 0.61, and 1.0, respectively. These deployed capacity variations are mainly dependent on the availability TRU from the PWR SF.

The SF inventories generally decrease with an increasing CR compared to that of the OT case. For the CR of 0.3, 0.61, and 1.0, the SF decreased by 10%, 17%, and 38%, respectively compared to that of the OT. As shown in Fig. 4, The out-pile TRU inventories of each CR in 2150 are 1380 t, 1190 t, and 1045 t, respectively, which are reduced by 34%, 44%, and 50%, respectively, compared to that of the OT. From the results, it is known that the deployment of a FR of low CR does not reduce the out-pile TRU inventory much, which is due to the limitations in deploying such low CR reactors because of the TRU availability constraints.

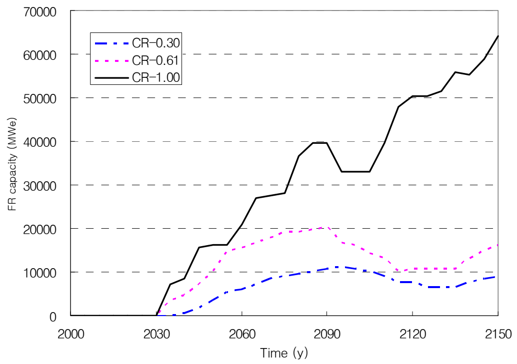

Fig. 3. Deployed Fast Reactor Capacity

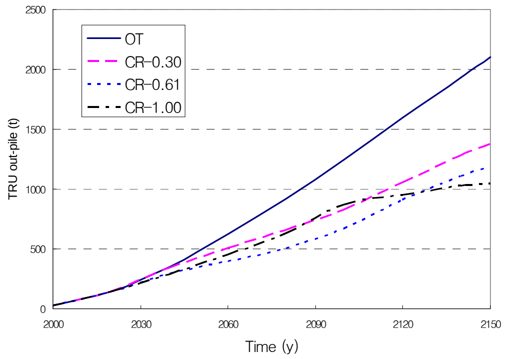

Fig. 4. Comparison of the TRU Inventory

The short-term decay heat at the shutdown of a repository with an active cooling and the integrated long-term decay heat determine the amount of waste that can be emplaced in a repository [7]. In this study, only the long-term heat load is discussed.

The LTH of the Pu-241 isotope is very low because Pu-241 decays out very fast. The LTH corresponding to Am-241 and Am-242m in the out-pile inventories are mainly responsible for the total LTH. The LTH of Am-241 and Am-242m decreases with an increasing CR. The LTH of Am-241 isotope is decrease with an increasing CR. The LTH of Am-241 for CR of 0.3, 0.61 and 1.0 at 300 yrs are reduced by 57%, 68%, and 74%, respectively compared with that of the OT case. The total LTH, shown in Fig. 5, decrease with increasing the CR. The integrated LTH over the period when the ventilation stops at 300 yrs to 1500 years later, the LTH of the OT case is 1.32×10^{10} W-y. The corresponding LTH at CR of 0.3, 0.61, and 1.0 are 8.2×10^{9}, 6.6×10^{9}, and 5.8×10^{9} W-yr, respectively, which are reduced by ~38%, ~50%, and ~57% compared with that of the OT case.

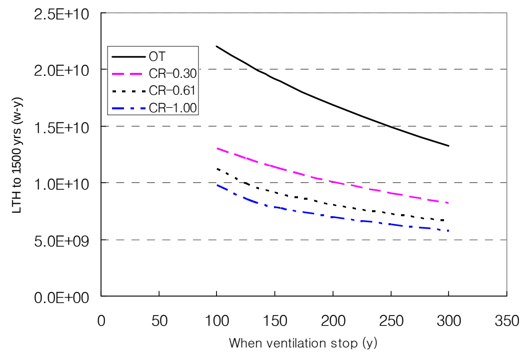

Fig. 5. Comparison of the Long-term Heat Load

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