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Proposal for the spent nuclear fuel management plan from the decommissioning of Kori site NPPs

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A B S T R A C T

Kori Unit 1, the oldest commercial nuclear power plant in Korea, was permanently shut down in June 2017, and decommissioning activities will be actively conducted five years later. One of the toughest challenges in decommissioning is the removal of spent fuel from the pool, which is also the first task to be resolved before NPP decommissioning. There are a total of 6 reactors in the Kori site, and the design life of Kori Unit 2, 3, and 4 will expire in 2023, 2024, and 2025, respectively. In addition, up to now, the measures for storing spent fuel in the Kori site have been extended by the use of dense racks or the use of transshipment between nearby nuclear power plants. However, the capacity of the spent fuel pool at the Kori site is expected to be saturated in 2024, and according to the plan for the establishment of the spent fuel interim storage facility, it is expected that the facility will be operational after 2035. Therefore, an effective spent fuel management plan should be established in order to timely carry out the nuclear power plant decommissioning.

The purpose of this study is to propose a management plan of spent nuclear fuels considering not only the Kori Unit 1 but also the whole site including the Kori Unit 2, 3, 4 which will be permanently shut down in the near future. We reviewed the decommissioning cases in the United States and developed a spent fuel management plan applicable to the Kori site for decommissioning. As a possible option for each nuclear power plant, scenarios for constructing a dry storage facility or an independent spent fuel pool island were applied and schedules were established accordingly. Based on this concept, we analyzed the major cost elements required for each option and applied each cost to the scenario, which suggested the most economical scenario. In addition to the economic aspect, we have taken other factors such as the government's high-level waste management policy, site conditions, decommissioning schedule, etc. into a rational fuel management plan for the Kori site. For optimal scenarios, the amount of spent fuel generated at the Kori site was examined and presented for the capacity required for the construction of a dry independent spent fuel storage installation.

1. Introduction

Kori Unit 1, which is the first Korean commercial Nuclear Power Plant (NPP) located at the Kori site, was permanently shut down in June 2017 due to expiration of its extended operational license of 40 years. Following at least 5 years for cooling the Spent Nuclear Fuels (SNFs), the decommissioning of the Kori Unit 1 can start with an approval from the regulatory body. In addition to the Kori Unit 1, the Kori site includes five more NPPs, which are expected to be permanently shut down sequentially during a period between 2023 and 2051 (NSSC, 2017).

Since the removal of SNFs from the spent fuel pool is prerequisite to decommissioning and the amount of the SNFs being stored at the Kori site is reaching about 73% of the storage capacity, a number of the SNFs are expected to be removed as decommissioning of the Kori site takes place gradually. However, because the national repository site for SNFs has not been determined, the removed SNFs should be managed appropriately and efficiently until they can be disposed of at a final repository, by using approaches such as Spent Fuel Pool Island (SFPI) and Independent Spent Fuel Storage Installation (ISFSI) which have been proven to be successful in the U. S. nuclear industry.

The purpose of this study is to investigate the most effective approach for the management of the SFNs to be removed from the spent fuel of the NPPs at the Kori site. For this, several management scenarios employing options such as SFPI and/or ISFSI were

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formulated based on the decommissioning schedules of the NPPs at the Kori site and the estimated amounts of the SNFs to be removed from each NPP. Then, those scenarios were assessed by performing a cost-benefit analysis.

2. Literature review

The SNF management strategies after permanent shutdown will vary depending on the countries and conditions of the plants. Possible SNF management strategies after permanent shutdown can be shown in Fig. 1: (1) if a repository is available, SNFs can be sent directly to the repository for permanent disposal without any interim storage during the decommissioning of NPPs. If a repository is not available yet as in most countries, SNFs should be temporarily stored until they can be sent to the repository by employing options such as (2) SFPI or (3) ISFSI. The SFPI option needs the modification of the existing spent fuel pool while the ISFSI option requires a construction of a dedicated facility. Sometimes, (4) both SFPI and ISFSI options can be employed in sequence.

As of 31 December 2015, 33 reactors have been permanently shut down in the United States, of which 12 are in decommissioning process and 17 were decommissioned (IAEA, 2016). Among them, some PWRs, which are the same reactor type as Kori Unit 1, employed both SFPI and ISFSI options for interim storage as shown in Table 1. In order to setup the SFPI, they modified the existing spent fuel pool by installing independent components for cooling, cleanup, monitoring, controls, and electrical power. After the modification, the removed SNFs were stored in the SFPI. Once the ISFSI was constructed, the SNFs were transferred to the ISFSI from the SFPI, which continued to be in operation until the SNFs' transfer to the ISFSI was completed. Following this, the decommissioning of SFPI was initiated. The SFPI option enabled the decommissioning activities to be carried out in a timely manner by isolating the systems related to cooling of SNFs from the other parts of the NPP.

The SFPI is typically designed to be much smaller due to a lower heat load expected after permanent shutdown, because most systems are not in service any longer and a lower heat-producing rate occurs due to decay of radioactive nuclides in the SNFs. Generally, the potential benefits of SFPI can be summarized as follows (IAEA, 2004):

- Reduced occupational exposure (the SFPI may be located in areas of low radiation dose).
- Lower cost of operation (spent fuel decay heat will decrease after shutdown, thereby allowing the installation of smaller, more efficient, pumps and heat exchangers).
- Cooling efficiency (the SFPI heat exchanger may utilize water to air, thereby reducing the need for a service water or sea water support system).
- Improvements in maintenance and system performance (obtained through a design that implements or incorporates independence, diversity and redundancy of electrical, mechanical and instrumentation systems).
- Practical safety applications (the SFPI services and systems can be color coded and labelled to distinguish them from other plant systems and components, to provide some assurance that decommissioning activities will not be performed on the SFPI).
- Physical protection (more easily applied because of the SFPI's smaller physical size).

It would be desirable to construct an ISFSI to transfer nuclear fuel from the NPP in an early stage of the decommissioning not relying on the SFPI. However, considerable time is needed for acquisition of the regulatory permits for the ISFSI facility

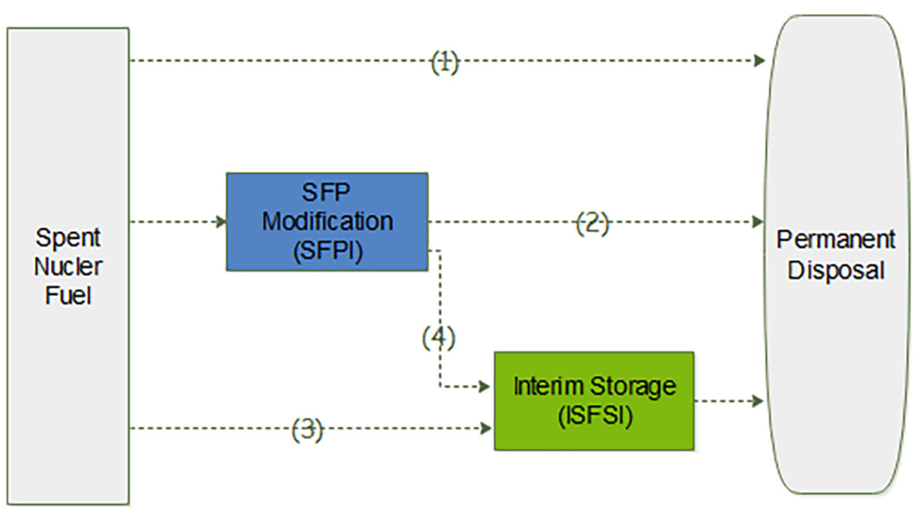

Fig. 1. SNF management strageties after NPP permanent shutdown.

Table 1
Examples of decommissioning NPPs in the U. S. (IAEA, 2016).

NPP	Commercial operation	Permanent Shut down	Implementation of SFPI	Transfer to ISFSI
Connecticut Yankee	1968-Jan.	1996-Dec.	1998	2004–2005
Maine Yankee	1972-Dec.	1997-Aug.	1998	2002–2004
Rancho Seco	1975-Apr.	1989-Jun.	1999	2001–2002
San Onofre 2&3	1983-Aug. 1984-Apr.	2013-Jun.	2015	2015–2019
Trojan	1976-May	1992-Nov.	1989	2002–2003