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Consideration of spent fuel pool island as an interim management option of spent nuclear fuel for Kori unit 3 & 4 during decommissioning of Kori site

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A B S T R A C T

An effective decommissioning plan is a key to the safe management of spent nuclear fuel (SNF) and cost optimization during the decommissioning process. The multi-reactor Kori site in the Republic of Korea currently has 5 operating reactors and the oldest of these reactors, Kori 1, has been shut down and is scheduled to be decommissioned in the near future. This paper evaluates the feasibility of a spent fuel pool island (SFPI) for the Kori site as a part of spent fuel management strategy for decommissioning. The current decommissioning strategy for Kori 1 was reviewed and an overall decommissioning plan for Kori site was developed as a basis for this analysis.

A cost assessment was performed to evaluate the cost effectiveness of an SFPI as an interim storage measure as compared to concrete cask, metal cask, and dual purpose transportation and storage cask (DPC) systems. Based on the decommissioning plan assumptions and economic parameters, the net present value (NPV) for these options was calculated and used as the basis for cost effectiveness comparisons. The total estimated cost of an SFPI is approximately $120 Million (M), which is significantly lower than that of a concrete cask system ($203 M), a metal cask system ($659 M) and DPC system ($874 M).

1. Introduction

The Republic of Korea is one of the leading nations in a nuclear energy technology. Currently, 24 reactors are in operation producing about 23,116 MW electricity with 5 units operating at the Kori site [1]. The first commercial nuclear power plant (NPP), Kori unit 1, was permanently shut-down in June 2017. Korea Hydro and Nuclear Power (KHNP) plans to submit a decommissioning plan for Kori unit 1 in 2018. Decommissioning is expected to begin in 2022 after 5 years of spent nuclear fuel cooling [2].

During the decommissioning of an NPP a primary concern is how to safely manage the spent nuclear fuel which releases large quantities of radiation and decay heat. The SNF from power reactors is stored in a water-filled pool adjacent to the reactor to allow its heat and radiation levels to decrease [3]. Safe management of SNF during decommissioning focuses on protecting the workers, public and environment from radiation exposures [4].

The removal of SNF from the SFP is a critical step for the NPP decommissioning process [4]. Most decommissioning activities will be delayed if SNF removal and storage is not first completed in a timely fashion [5]. In order to facilitate the NPP decommissioning process, several options exist for removing and managing the SNF. These include transshipment of SNF to neighboring NPP storage pools, using onsite dry storage systems, and modifying and isolating the current SFP to create a spent fuel pool island (SFPI).

1.1. Spent fuel pool island concept

A SFPI is a method to manage and isolate the spent fuel pool and its supporting systems from the existing plant to facilitate decommissioning activities without removing the spent fuel from the storage pool [5,6]. During the plant operation the SNF stored in the SFP generates thermal energy, which is discharged through the plant cooling system. After plant shutdown, the spent fuel thermal output decreases, therefore, the full cooling capacity designed for plant operations is no longer necessary [5]. After plant shutdown, the SFP can be isolated into a stand-alone system with a separate and smaller cooling system, water purification system, and make-up water system. The spent fuel pool essentially becomes an “island”, that is it is no longer connected to, or dependent on, the original plant systems [6,7]. The new spent fuel pool island electrical, water, and cooling systems are clearly identified (color coded) to prevent inadvertent disruption during the plant dismantling.

The SFPI concept has been implemented during the decommissioning process at several NPPs in the United States (U.S.) including

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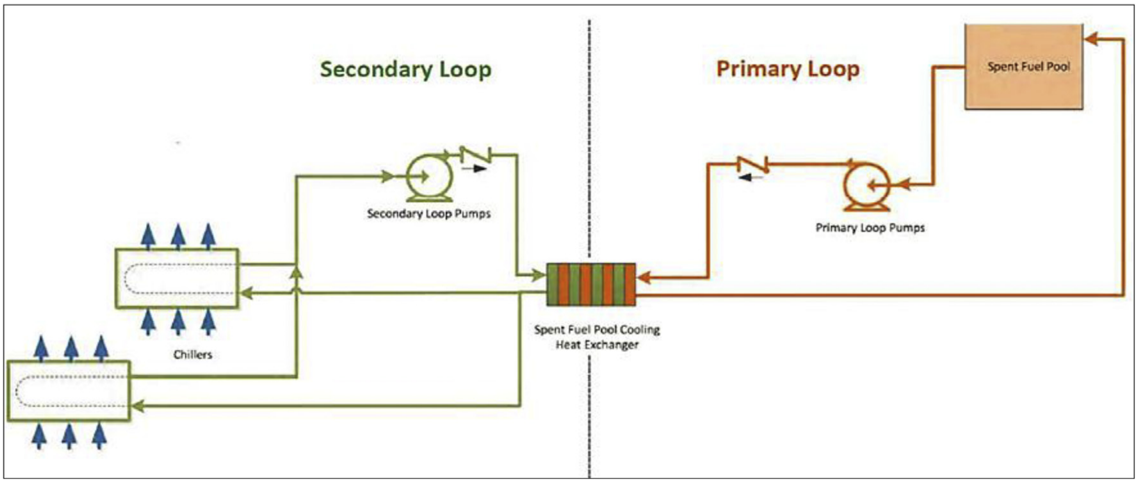

Fig. 1. SONGS unit 2 & 3 SFPI cooling system [19].

Rancho Seco [8,9], Yankee Rowe [10–12], Trojan [13–15], Main Yankee [16,17], and most recently, SONGS Unit 2 and 3 [18–20].

1.2. SFPI subsystems

The SFPI is comprised of several subsystems. The SFPI cooling subsystem eliminates the decay heat from the SNF stored in the fuel pool by circulating borated water via a heat exchanger to a secondary loop where fan coils disperse the heat to the atmosphere. This maintains the temperature of the SFP within the allowable limits [17]. Fig. 1 shows the SONGS unit 2&3 SFPI cooling system.

The SFPI purification subsystem maintains the water chemistry of the SFP. The SFPI makeup water subsystem provides make-up water to the primary and secondary SFPI systems [17]. The SFPI ventilation subsystem maintains the temperature and relative humidity of the fuel building atmosphere, providing adequate fresh air for the occupants. The separate SPFI electrical distribution subsystem provides electrical power to support operation of the SFPI equipment. It also has the capacity to support other long-term plant loads which may be required during decommissioning activities [17].

2. Methodology

2.1. Current SNF management status at Kori Site

Currently, SNF from operating pressurized water reactors (PWRs) in the Republic of Korea is stored in on-site spent fuel pools. Fig. 2 shows the Kori site cumulative storage volumes of SNF in pools as of September, 2017 [21]. It is projected that Kori site SNF storage pools will be saturated by 2024. Kori unit 3&4 pools are currently holding a large amount of SNF for Kori site due to their high capacity.

To effectively manage SNF storage and to facilitate the decommissioning of Kori 1 in June 2022 and subsequent NPPs, KHNP plans to implement onsite dry storage in phases. Currently, KHNP has decided to construct a dry storage facility for the Kori unit 1 fuel assemblies. An SFPI could be considered as an interim SNF management option for Kori 3&4 depending on its cost effectiveness, the immediate need for a storage facility, and regulatory acceptance.

2.2. Decommissioning plan for the Kori Site

The expected plant shut-down schedule for Kori site is shown in Table 1. The permanent shut-down of Kori unit 1 was effective in June 2017. The permanent shutdown dates for Kori unit 2, 3, and 4 are 2023, 2024, and 2025 respectively.

KHNP operates Kori plants on a twin-unit basis. The units are located closely and share some common systems. Fig. 3 shows the geographical close proximity of the Kori units.

Fig. 4 shows decommissioning phases in the Republic of Korea applicable to the decommissioning of Kori site. The first two years are for pre-planning phase. In this phase the NPP licensee should decide on the decommissioning strategy, how to safely store SNF, acquire an operation license (OL) alteration approval, prepare the decommissioning organization, and commence preparation for the decommissioning plan (DP) and the decommissioning engineering plan. The second phase is a transition phase that takes a minimum of five years. The 2nd phase is characterized by the removal SNF from the reactors and its placement in the SFP for cooling. The application for the approval of the

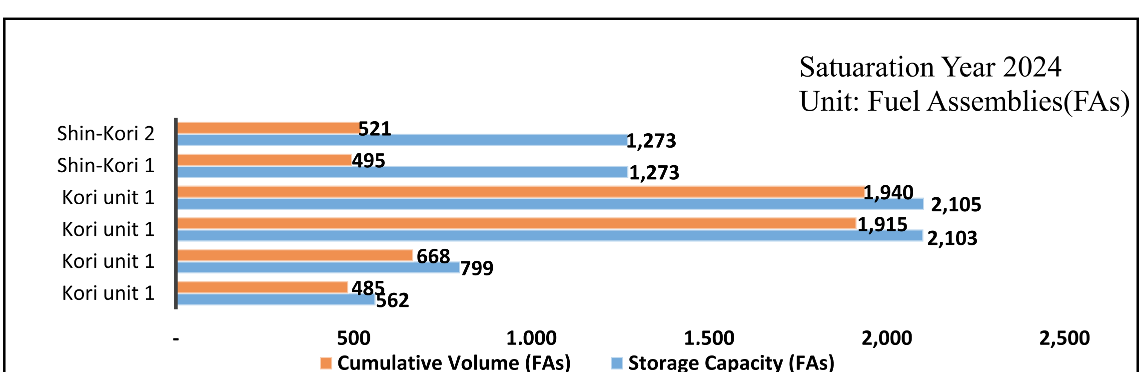

Fig. 2. Kori site spent fuel storing status (as of sep, 2017) [21].