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The Operation Methods of the Electric Power System for Kori Units 3&4 after Permanent Shutdown

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1. Introduction

According to The 8th basic plan for long-term electricity supply and demand issued by the Ministry of Trade, Industry and Energy, 11 of 25 operating nuclear power plants in South Korea will be permanently shutdown by 2031[1]. And the design life of Kori Units 3 and 4 is expected to expire in 2024 and 2025 respectively.

When switching from normal operation to the decommissioning phase, no more electricity is produced, only consumption. Therefore, the new power system operation methods with reliability and cost competitiveness in power supply are required.

In this study, the new power system operation methods are proposed and its validity is verified.

2. Methods and Results

2.1. Design basis accident(DBA) Analysis

2.1.1 DBA

Once the nuclear fuel in the reactor is permanently withdrawn, the radiation risk decreases dramatically. In addition, no function is necessary to maintain the integrity of the pressure boundary of the reactor coolant and maintain safe shutdown condition of the reactor.

Therefore, new DBA concept such as spent fuel pool(SFP) accident is considered as follow.[4]

1) Loss of SFP cooling function
2) Loss of SFP coolant

According to the results of the DBA analysis of Kori Unit 1[4], it was proved that alternative cooling can be performed by using onsite and offsite water sources without operating the power system even if a SFP accident occurs.

2.1.2 Safety-related function

The definitions of safety-related functions specified in US 10CFR50.2 [9] is shown in Table 1. According to the DBA analysis result, the function of the power system does not correspond to any safety function.

Table 1: Definition of safety-related function

Safety-related structures, systems and components means those structures, systems and components that are relied upon to remain functional during and following design basis events to assure: ① The integrity of the reactor coolant pressure boundary, ② The capability to shut down the reactor and maintain it in a safe shutdown condition, or ③ The capability to prevent or mitigate the consequences of accidents which could result in potential offsite exposures comparable to those referred to in § 50.34(a)(1), § 50.67(b)(2), or § 100.11 of this chapter, as applicable.

2.1.3 Regulatory issues

Kori Unit 1 has been permanently shutdown for the first time in South Korea in 2017. When applying for license to change operation, licensee requested that safety function of the power system should be exempted based on the DBA analysis result.

However, that request was conflict with the notice of the Nuclear Safety and Security Commission(NSSC). This is because the notice(regulations regarding the safety classification of nuclear reactor facilities and standards for each grade) defines the function to maintain SF cooling in wet storage or to power to equipment of safety class 1,2 or 3 as safety class 3.

Consequently, Kori Unit 1 was licensed to maintain the safety function of the power system.

2.2. Safety function exemption

2.2.1 Kori Unit 3&4 Criteria

Kori Units 3 and 4, the initial models of South Korea's nuclear power plant(NPP), were supplied by Westinghouse Corporation of the United States. And adopted ANSI N18.2, the latest industrial standard at the time, in the safety classification of plant structures, systems, and components (SSCs).

Subsequently, the revised industrial standard ANSI/ANS-51.1 was applied to the Korea Standard NPP which has been built since the late 1980s.

The difference between the two standards is the safety classification method for Class-1E electrical equipment. In ANSI N18.2[7], C-1E equipment was not classified the safety class, but in ANSI/ANS 51.1[8], it was classified safety class 3.

Table 2: Comparison of safety classification criteria

Category	Kori Units 3&4	Korea Standard NPP
Criteria	ANSI N18.2(1973)	ANSI/ANS 51.1(1983)
C-1E Equipment Safety Class	Not Applicable	SC-3
Related NSSC Notice	Notice 83-5	Notice 94-10

2.2.2 Nuclear safety regulation system

The legal framework for Nuclear Safety in South Korea, as shown in Figure 1 below, consists of four stages: Act(the Nuclear Safety Act), Presidential Decree(the Enforcement Decree of the same Act), Prime Minister's Regulation(the Enforcement Regulations of the same Act), the NSSC Regulation (the Enforcement Regulations Concerning the Technical Standards of Nuclear Reactor Facilities, etc., the Enforcement Regulations Concerning the Technical Standards of Radiological Safety Management, etc., and NSSC Notice).

In particular, regulation regarding the safety classification of nuclear reactor facilities follow the notice of the NSSC. [6]

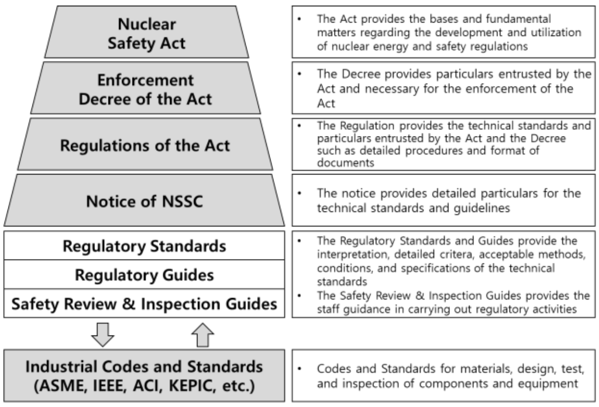

Fig. 1. Legal framework for nuclear safety regulation

2.2.3 Revision history of related regulations

The first regulation on the safety classification in South Korea nuclear reactor facilities was established in October 1983 by applying ANSI N18.2. [10]

Subsequently, Kori Unit 3 acquired an operating permit in June 1985, meeting the relevant regulatory requirements, and Kori Unit 4 also acquired an operation permit in August 1986, and began commercial operation.

In October 1994, that regulation was revised and the cited standard was changed to ANSI/ANS 51.1. In addition, transition provisions deemed appropriate were applied for reactor facilities with safety classification in accordance with ANSI N18.2 (1973) prior to the effective date. [11]

The criteria of Kori Units 3 and 4, which do not apply safety class to C-1E electrical equipment, and the current notice of NSSC, are superficially in conflict. But it is confirmed that the safety classification method based on the existing licensing basis was suitable as a result of checking the revision history of notice of NSSC.

2.3. Power system operation methods

2.3.1 Design requirements

Design requirements applied to the power system of Kori Units 3 and 4 are US 10CFR50 Appendix A. General Design Criteria (GDC), US NRC Regulatory Guide, and the IEEE Industrial Standards. GDC 17 and 18 regulate general requirements related to power system design, and Regulatory Guides and Industrial Standards deal with the details of design.

Figure 2 is a schematic diagram of the design requirements for the power system, and shows the correlation between each requirement.

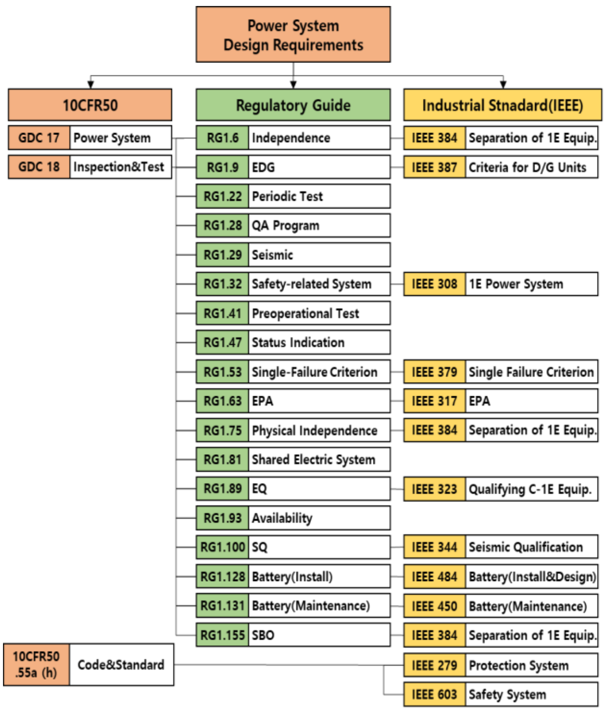

Fig. 2. Design requirements for the power system

After permanent shutdown, the power system no longer performs safety function, so all safety-related design requirements that applied to the existing power system do not apply.

2.3.2 Power system reconfiguration

Based on the analysis results of whether the power system performs safety functions and the design requirements are valid, the power system operation methods are summarized in Table 3 below.

Table 3: Comparison of safety classification criteria

Power System	Equipment	Normal Operation (Qty.)	Permanent Shutdown
Offsite Power	345kV SWYD	1	Maintained
	PPS	2	Maintained
Onsite Power	Generator	1	Abandoned
	MTR	1	Abandoned
	UAT	2	Abandoned
	SUT	2	Maintained (1 Operation)
	1E Bus Tie BKR	None	New
	N-1E Bus Tie BKR	1	Maintained
	13.8kV SWGR	4	Abandoned
	4.16kV SWGR	4	Maintained
	480V LC	33	Partial Maintained
	480V MCC	73	Partial Maintained
Emergency Power	EDG	2 (Auto start)	1, (Manual start)
	AAC DG	1	Abandoned
	Mobile Gen.	1	Abandoned

Figures 3 below is a single line diagram of an existing power system during normal operation, and figures 4-5 are S showing how to power each onsite load for SF cooling and decommissioning in each situation based on a new power system.

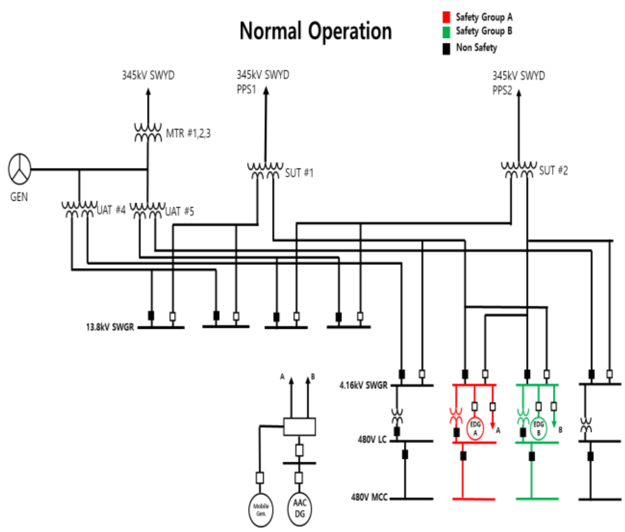

Fig. 3. Power System (Normal Operation)

Figure 4 below shows the power system after permanent shutdown phase. Generator, MTR, UAT are unnecessary because power plants no longer produce electricity.

Power is supplied only through the SUT, and during normal condition, only one transformer is operated to supply power to onsite load. If it is not available, power can be supplied through the other standby SUT.

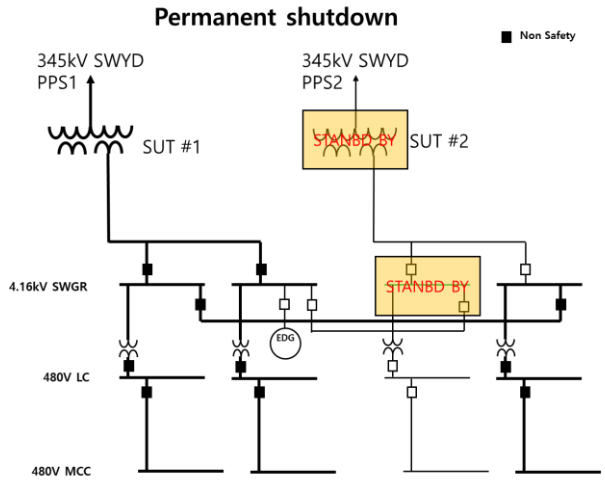

Fig. 4. Power System (Permanent Shutdown)

Figure 5 below shows the power system when two SUTs are not available. When a DBA occurs, the function of the power system is no longer required.

But only one emergency diesel generator is used as backup power to maintain the reliability of power. It is also operated from automatic start to manual start.

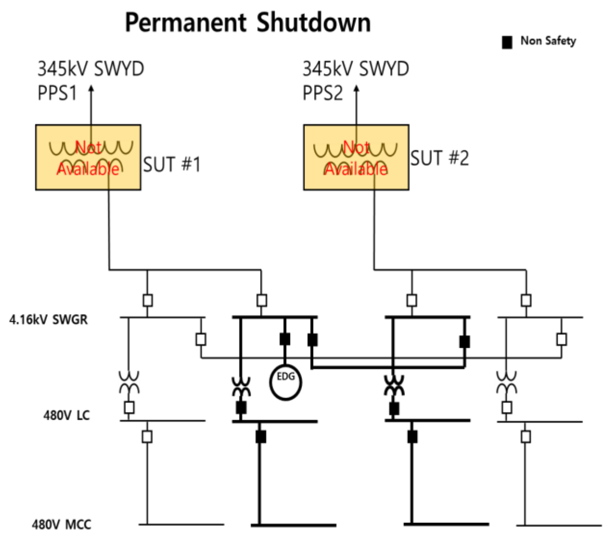

Fig. 5. Power System (SUTs not available)

2.3.3 Operating cost

Table 4 below shows the expected operating cost savings by operating the new power system during the 15-year scrapping period. The operating cost savings were calculated to total 4 billion won in Kori Units 3 and 4.

When operating only one SUT, electricity costs of 1.2 billion won were saved per power plant due to a reduction in transformer power loss of 9,882,639kWh.

In addition, maintenance costs of 0.8 billion won were saved per power plant due to the reduction in managed electrical equipment and the extension of the maintenance cycle, per power plant.

Table 4: Operation saving cost

Category	K3(won)	K4(won)	Sum(won)
Electricity bill	1.2 billion	1.2 billion	2.4 billion
Maintenance cost	0.8 billion	0.8 billion	1.6 billion
Sum(won)	2.0 billion	2.0 billion	4.0 billion

2.4. Design validation

2.4.1 Transformer capacity

When supplying power to all onsite loads with one SUT, the loads should not exceed the rated capacity of the transformer. As shown in Table 5 below, it was calculated as having 17.7% margin compared to the transformer rating.

Table 5: Transformer capacity calculation

Category	Calculation
Transformer Capacity	28.13MVA
Maximum load capacity	23.14MVA
Margin	17.7%

2.4.2 Short circuit capacity

The maximum fault current that can occur in a new power system should not exceed the breaker rated capacity of the breaker. As shown in Table 6 below, it was calculated as having least 7.1% margin compared to the breaker rating.

Table 6: Short circuit capacity calculation

Category	Interrupting Capability	Closing and latching capability
BKR Rating	46,773A	130,000A
Maximum Short Current	43,471A	77,319A
Margin	7.1%	40.5%

3. Conclusions

In this study, the new electric power system operation methods were suggested for Kori Units 3 and 4 after permanent shutdown phase.

According to DBA analysis result and 10CFR50.2, electric power system no longer performs the safety function. Therefore, it is unnecessary to apply safety-related design requirements that have been applied to existing power system.

When applying the new power system operation methods, the cost of electricity bills and maintenance would be reduced by about 4 billion won during the 15-year decommissioning period of Kori Units 3 and 4.

In addition, as a result of design verification of the new power system, the transformer capacity has a margin of 17% and the short circuit capacity of breaker has a margin of 7%. Therefore, the reliability of the power system was verified.

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