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Innovative Nuclear Power Plant Building Arrangement Considering Decommissioning

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1. Introduction

Nuclear power plants should be decommissioned at the end of its designed lifetime like other power plants. However, unlike others, it requires a unique decommissioning process such as radiation protection, decontamination, spent fuel treatment, and radioactive waste disposal due to potential radioactive contamination. There are mainly two decommissioning strategies for a nuclear power plant: immediate dismantling and deferred dismantling. In the immediate dismantling strategy, decommissioning is started immediately after the permanent shutdown of a nuclear power plant, giving a benefit of recovery and being able to reuse the decommissioned site quickly. The deferred dismantling strategy has 40-60 years safe storage period after permanent shutdown. It reduces radiation and radioactive decommissioning waste generation.

A utility company planning to decommission its nuclear power plant should choose either immediate dismantling strategy for higher utilization of the site or deferred dismantling for lower radiation and less radioactive waste generation.

Innovative nuclear power plant buildings arrangement (INBA) is proposed to solve a dilemma in choosing a decommissioning strategy by bringing out the advantage of immediate dismantling and deferred dismantling together.

2. Concept and operation

In this section, INBA's concept and operating method are described.

2.1 The concept of INBA

The key idea of INBA is the circulative utilization of nuclear power plant site. INBA, as shown in Fig. 1, has an extra space for future construction of the containment structure (CONT), auxiliary building (AUX), and compound building. This allows the construction of new nuclear power plants quickly with safe storage of old nuclear power plants at the same time.

2.2 Operating method of INBA

In phase 1, we construct two units of nuclear power plant with empty extra space (cf. Fig. 1), and operate them during their designed lifetime.

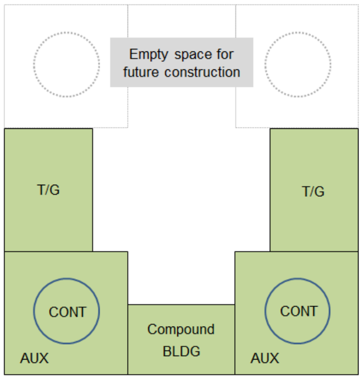

Fig. 1. Site arrangement for circulative nuclear power plant construction method optimized for decommissioning.

In Phase 2, when nuclear power plants' designed lifetime is over, we decommission them immediately except their CONT, AUX, and compound buildings (cf. Fig. 2).

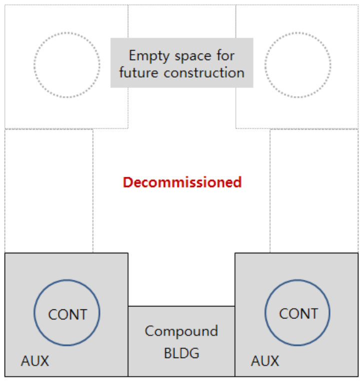

Fig. 2. Immediate dismantling of (1st) nuclear power plants except containment, AUX, and compound buildings.

In phase 3, keeping CONT, AUX, and compound buildings under safe storage condition, we construct new nuclear power plants by using the empty extra space and T/G building decommissioned site, and operate them until the end of their designed lifetime (cf. Fig. 3). During the construction and operation of new nuclear power plants, CONT, AUX, and compound buildings of old nuclear power plants continue safe storage condition.

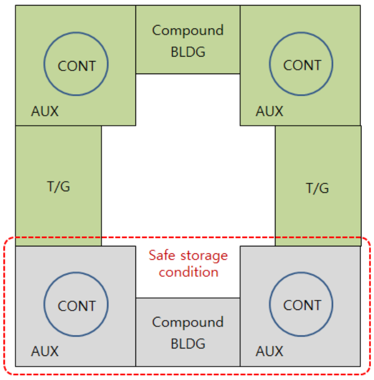

Fig. 3. Construction and operation of new (2nd) nuclear power plants.

In phase 4, after the end of new nuclear power plant designed lifetime, we decommission new nuclear power plants immediately except CONT, AUX, and compound buildings. In this time, we also decommission previous nuclear power plant's CONT, AUX, and compound buildings which have been under safe storage condition (cf. Fig. 4).

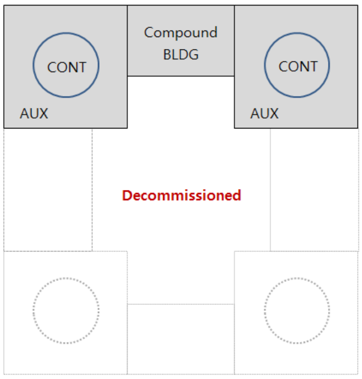

Fig. 4. Immediate dismantling of new (2nd) nuclear power plants except CONT, AUX, and compound buildings.

In phase 5, after decommissioning, we construct and operate new nuclear power plants on decommissioned site (cf. Fig. 5).

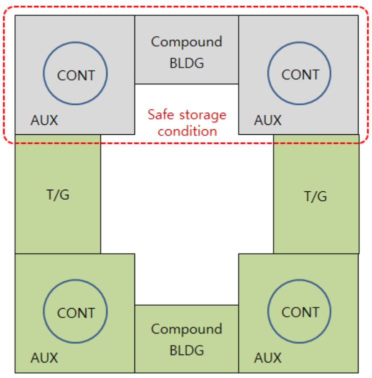

Fig. 5. Construction and operation of new (3rd) nuclear power plants.

3. Expected benefits

By adopting INBA, we can gain the benefits of immediate dismantling strategy to recover and reuse decommissioned site early, and deferred dismantling strategy to reduce radiation and radioactive decommissioning waste generation together.

3.1 Early site recovery

Current nuclear power plant life cycle is composed of five phases: construction (5years), operation (60years), spent fuel residual heat removal (5years), and decommissioning (7 years). In INBA, seven year's decommissioning period in this life cycle is reduced by two years. It is enabled by dismantling only uncontaminated area immediately, and contaminated area dismantling is delayed until 2nd nuclear power plant decommissioning (cf. Table. I). This benefit shortens the cycle of a nuclear power plant, and gives additional power generation time.

Table. I. INBA life cycle

Period	Activity	Time
1	1st NPP construction	5yrs
2	1st NPP operation	60yrs
3	Spent fuel residual heat removal	5yrs
4	1st NPP decommissioning (Uncontaminated area only)	2yrs
5	2nd NPP construction	5yrs
6	2nd NPP operation	60yrs
7	Spent fuel residual heat removal	5yrs
8	2nd NPP decommissioning (Uncontaminated area)	2yrs
	1st NPP decommissioning (Contaminated area) *overlap with period 7	5yrs

3.2 Radioactive decommissioning waste reduction

Applying deferred dismantling strategy to contaminated area such as CONT and AUX buildings reduces radioactive decommissioning waste generation. NRC reports that 50 year's safe storage decreases more than 90% of radioactive decommissioning waste (cf. Fig. 6).

This is a great advantage for countries where radioactive waste disposal cost occupies a large portion of total decommissioning cost. In South Korea, it is estimated to cost around 40% of total decommissioning cost.

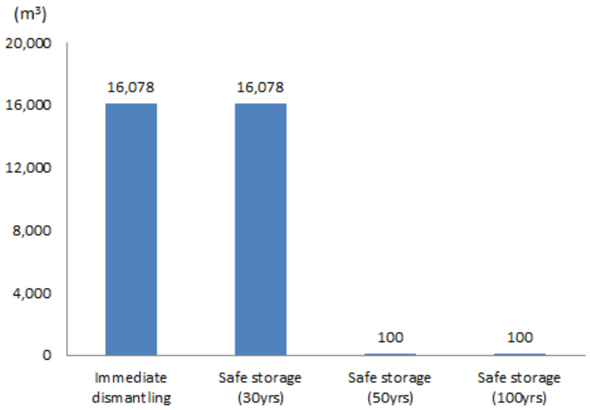

Fig. 6.Comtaminated materials from pressurized water reactor decommissioning.

3.3 Economic analysis

To assess the economic impact of INBA, economics of current nuclear power plant design with immediate dismantling (scenario I) and INBA (scenario II) is compared. Scenario II has shorter period than scenario I: scenario I has 77 years and scenario II has 72 years. We assume that we construct a new nuclear power plant and operate it during five years' spare time in case of scenario II. Also, following assumptions are used for calculation.

Table. II. Assumptions for economic analysis

Item	Assumption	
Comparison object	APR1400 * 2units	
Standard life cycle	Construction	5 years
	Operation	60 years
	Spent fuel residual heat removal	5 years
	Decommissioning	7 years
	Total	77 years
LCOE	48.8 KRW/KWh (2014)	
Electric charges	54.89 KRW/KWh (2014)	
Discount rate	5%	
Inflation	0%	
Rad. Waste reduction	50%	

In scenario II, decommissioning period is reduced by two years by applying INBA. It enables to have 4.2 years' additional power generation period in one cycle of APR1400, which increases 6.9% of power generation.

Safe storage for CONT, AUX, and compound buildings reduces radioactive decommissioning waste. In this conservative analysis, 50% radioactive waste reduction is assumed by 70 years safe storage and it decreases the levelized cost of electricity (LCOE) from 43.78 KRW/KWh to 43.13 KRW/KWh.

In conclusion, shown in fig. 7, scenario II increases 6.9% of power generation and 6.6% of profit compared to scenario I (net present value at 2014). Regarding 6.6% of profit increase, 5.8% is from the reduction of radioactive decommissioning waste and 0.8% is from the increased power generation period.

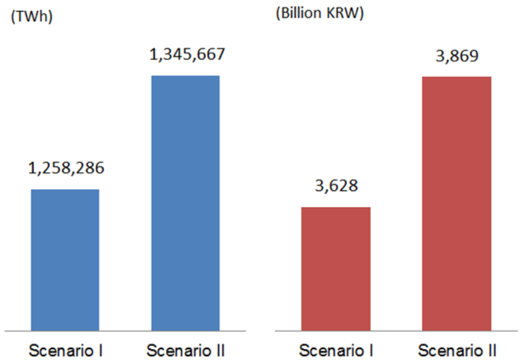

Fig. 7.Comparison of power generation (Left) and profit (Right) between scenario I and II

The land cost of extra space for future construction is not considered in this analysis because specific land cost information was not available.

3.4 Additional benefits

There are some anticipated benefits of INBA. Firstly, we may reduce O&M cost for safe storage of CONT, AUX, and compound buildings, because we can share resources for safe storage O&M with new nuclear power plants constructed on decommissioned site. Secondly, some structures such as turbine-generator buildings foundation and sea water inlet/outlet structure might be reused. Thirdly, we may exempt the construction of an interim storage facility for spent fuel. Many decommissioning projects in the United States have chosen the construction of an interim storage facility instead of an isolated spent fuel pool for spent fuel storage during safe storage period based on economic analysis. However, storing spent fuel in an isolated spent fuel pool might be more economical if we operate new nuclear power plants adjacent to the AUX building in which there is a spent fuel pool, and it supplies resources to maintain a spent fuel pool with marginal cost. Those potential benefits need additional investigation to prove their practicality, but if they are realized, it will improve economics of INBA significantly.

3. Conclusions

Recent studies about decommissioning cost show it to continually rise, and it is one of main causes to deteriorate economics of nuclear power. To recover it, we need a solution to improve the economics of a nuclear power plant over its entire life time including decommissioning.

If INBA is applied for future nuclear power plant construction and operation, it will contribute to improve economics of nuclear power and recover its competitiveness against other energy such natural gas and renewables by increasing power generation period of the site and reducing radioactive decommissioning waste generation at the same time.

ACKNOWLEDGEMENTS

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