

## Analysis of Decommissioning Recommendations of the IAEA and Comparison of Implementation Status Between Korea and the United States

Sunwoo Park, Kwangheon Park\*

*Department of Nuclear Engineering, Kyunghee University, 1732 Deogyong-daero, Giheung-gu, Yongin-si, Gyeonggi-do 17104, Republic of Korea*  
 kpark@khu.ac.kr

### 1. Introduction

Permanent shutdown of nuclear power plants occurs due to the aging of nuclear power plants, changes in energy policy, and accidents. According to the IAEA survey in February 2020, 186 nuclear power plants have been permanently shutdown and about 96 plants are being decommissioned. The progress of nuclear power plant decommissioning by country can be found in Table 1 below. Recently, Kori-1 and Wolsong-1 nuclear power plant have been permanently shut down in Korea. Various preparations are currently underway for the decommissioning of the Kori-1 nuclear power plant. Therefore, this study is intended to help organize the decommissioning data by analyzing the decommissioning recommendations of the IAEA and decommissioning activities in the US.

### 2. Decommissioning phase and activities

The IAEA assists countries with scarce resources in the formulation and implementation of national nuclear power plant decommissioning policies. Since the IAEA is only responsible for reviewing decommissioning programs, all responsibility for decommissioning activities rests entirely with the State. The

decommissioning recommendations of the IAEA are divided into three phases. The first phase is the Initial decommissioning plan phase, which includes the construction phase. The second phase is the on-going (updated initial) plan phase, which includes operation and permanent shutdown. The third phase is the final plan phase, which includes the transition and the end state. The United States follows all of the decommissioning recommendations from the IAEA, and Korea will also follow all of the recommendations from the IAEA in the upcoming decommissioning of Kori-1 Nuclear Power Plant.

However, there are some differences in the details of implementation. In the US, it is possible for a private company to own a nuclear plant, but in Korea, all nuclear power plants are controlled by the state. In addition, various decommissioning strategies are being adopted and progressed due to various differences such as waste management methods, waste disposal methods, geographical features, and environmental conditions.

This paper will classify the decommissioning recommendations of IAEA into construction, permanent shutdown, transition, decommissioning, and end state phases, and also explain the differences of implementations between Korea and the US in each phase.

Table 1: Classification of decommissioning phases of the IAEA (left) and decommissioning phases by country in 2019 (right)

Current Decommissioning Phase	Description	Decommissioning phase	
		1~10	11
1	Drawing up the Final decommissioning plan		
2	Reactor core defuelling		
3	Waste conditioning on-site - only for decommissioning waste		
4	Waste shipment off-site - only for decommissioning waste		
5	Safe enclosure preparation		
6	Partial dismantling		
7	Active safe enclosure period		
8	Passive safe enclosure period		
9	Final dismantling		
10	Final survey		
11	<b>License terminated - legal act at the end of the decommissioning</b>		
		<b>Belgium</b>	1
		<b>Bulgaria</b>	3
		<b>Canada</b>	3
		<b>France</b>	3
		<b>Germany</b>	17
		<b>Italy</b>	4
		<b>Japan</b>	9
		<b>Kazakhstan</b>	1
		<b>Korea</b>	1
		<b>Lithuania</b>	2
		<b>Netherlands</b>	1
		<b>Slovakia</b>	3
		<b>Spain</b>	1
		<b>Sweden</b>	5
		<b>Switzerland</b>	1
		<b>UK</b>	26
		<b>USA</b>	10
		<b>SUM</b>	91
			<b>5</b>
			<b>5</b>

## **2.1. Construction**

The IAEA recommends each member country to establish a decommissioning strategy through the initial decommissioning plan from the construction phase of the nuclear power plant. The decommissioning plan in this phase is suggested to benchmark the decommissioning experiences of other nuclear power plants or prepare with appropriate predictions. The plan should include end states, design regulations, operation records, types and quantities of waste, pre-budget measurements, and basic safety issues. In this phase, the same process takes place in Korea and the United States.

## **2.2. Operation and Permanent shutdown**

Operation and permanent shutdown phases are affected by the Operating License. The IAEA recommends each country to submit an on-going decommissioning plan in the operation phase and update the decommissioning plan at least every five years. The decommissioning plan of this phase must reflect any unusual events or changes that occur during operation. The Korea Nuclear Safety Act requires that the decommissioning plan be updated every ten years in this phase.

Permanent shutdown can be categorized into three cases: planned shutdown, which proceeds according to the operation plan, early shutdown due to economic, technical and political problems, and shutdown after extended operation. All three permanent shutdown scenarios are based on appropriate national judgments.

There is a difference in administrative procedures of permanent shutdown certification between Korea and the United States. Permanent shutdown certification of the US takes place within 30 days after the execution of permanent shutdown, and permanent shutdown certification of Korea proceeds through a review of operational change applications.

## **2.3. Transition**

Decommissioning activities begin in the transition period. The IAEA sets the transition phase as the beginning of final decommissioning planning.

It could be performed in this period to prepare decommissioning activities such as spent fuel removal, draining circuits, conditioning of all operational waste, decontamination of the facility, cleaning of systems, management of operational waste, licensing process, initial dismantling and safe enclosure preparation. If deferred dismantling is planned, additional preparation for Safe Storage (SAFSTOR) activities should be considered. SAFSTOR is a procedure for the safe storage of radioactive material until the start of decontamination and dismantling procedures.

In the transition phase, the preparation for decommissioning begins with the preparation of the decommissioning plan. Decommissioning Licensing proceeds for three to five years based on the decommissioning plan. Each country is granted a license to execute the decommissioning through the Decommissioning Licensing process. Decommissioning strategy and schedule of nuclear power plants and related facilities, measures to prevent disasters from radiation, decontamination methods appropriate for the type and quantity of radioactive material, decommissioning costs, environmental impact assessments, and results of local public hearings should be included in the decommissioning plan.

The decommissioning plan submitted during the transition phase is called as Post Shutdown Decommissioning Activities Report (PSDAR) in the United States and the final decommissioning plan in Korea. The decommissioning plans of Korea and the United States mostly have similar systems, except for the small differences in some aspects of their implementation. Examples of detailed differences in the decommissioning plan of the US and Korea are given below. The United States should consider managing GTCC waste, but not Korea. In the United States, a decommissioning plan is required to be submitted within two years after a permanent shutdown, but in Korea, it is required to be submitted within five years. In the United States, approval of the decommissioning plan is not mandatory, but in Korea, it must be approved.

## **2.4. Decommissioning**

Full-scale decommissioning begins after the transition phase. The decommissioning strategy is discussed in the transition phase. When selecting a decommissioning strategy, regulation, ethical factors related to the decommissioning cost, radiological factors considering the type and quantity of used materials, knowledge management, stakeholder engagement, financial resources, material management, end state, and socio-economic factor should be considered. Decommissioning strategies such as immediate dismantling, deferred dismantling, and entombment are selected by considering the above items.

The IAEA also recommends that several supplementary documents be prepared along with the decommissioning plan. It is included in this supplement to report on physical and radiological characterization of the facility, waste management plan, safety assessment report, environmental impact assessment, and emergency plan.

The IAEA recommends including 15 items in the decommissioning plan. The contents of the 15 items are as follows; 1. General information about decommissioning; 2. Facility descriptions, such as site, building, system, radiological conditions and

operational records of the facility; 3. Decommissioning strategy considering alternatives; 4. Project management; 5. Decommissioning activities such as demolition, decontamination, restoration; 6. Surveillance and maintenance; 7. Waste management; 8. cost estimate and funding mechanism; 9. Safety assessment; 10. Environmental assessment; 11. Health and Safety; 12. Quality assurance of equipment, programs, strategies, records, etc.; 13. Emergency planning; 14. Physical security and safeguard; 15. Final radiation survey. The above items should be implemented under conditions satisfying modularity, minimization, and avoiding overdesign, which are desirable characteristics of the dismantling proposed by the IAEA.

Both Korea and the United States follow the recommendations of the IAEA. However, there are some differences in the implementation of decommissioning activities and administrative procedures. In the United States, licensees should submit a License Termination Plan (LTP) two years before decommissioning of nuclear power plants are completed and LTP must be approved by the NRC. The LTP contains all the recommendations of the IAEA. Since the submission of the LTP is before the completion of the decommissioning work, it should include information on residual dismantling activities and the completion of the site restoration. In addition, the decommissioning process is completed by submitting a Final Status Survey Report (FSSR) including the results of the final site radiation survey.

In Korea, the decommissioning completion report and FSSR are required to be submitted at the completion of the decommissioning activity. Decommissioning activities in Korea are terminated through the assessment of the final site status of the regulator.

### **2.5. End State**

After the end of the decommissioning activity, the final status of the site shall be consistent with the content of the decommissioning plan and meet the regulatory requirements. Regulatory authorities in each country should review and decide whether to terminate the license. Based on these procedures, the decommissioning of the site is completed.

The IAEA proposes annual dose criteria as 0.01mSv to 0.3mSv at sites where decommissioning activities have been completed, and additional consideration of ALARA under this condition is recommended. The use of the site after decommissioning activities may be divided into limited permits such as recycling to other nuclear power plants or radioactive material handling facilities, and non-limiting permits such as green fields, non-nuclear power generating plants, industrial facilities, and non-industrial facilities.

The United States proposes 25mrem/yr (0.25mSv) as the deregulated dose criteria. In the US, shipping ports, Haddam Neck, Maine Yankee, and Big Rock Point nuclear power plants are being used as green fields, and Fort St. Vrain nuclear power plants are being recycled (partially recycled) to gas-fired power plants.

Korea proposes 0.1mSv/yr as the deregulated dose criteria. KHNP is currently preparing to dismantle Kori-1 nuclear power plant, and a detailed site reuse plan will be presented later.

### **3. Conclusion**

The IAEA is responsible for providing guidelines for the decommissioning activities of nuclear power plants. The IAEA also strives to avoid confusion in decommissioning activities by presenting the elements that need to be implemented at various phases, including the operation of the plant, preparations for decommissioning, decommissioning activities, and completion of decommissioning.

The US has completed decommissioning of approximately 16 nuclear power plants, and decommissioning of 15 nuclear power plants is underway. Korea has completed decommissioning legislation reflecting the recommendations of the IAEA and is planning and implementing decommissioning of Kori-1 nuclear power plant.

The decommissioning systems of Korea and the United States are mostly similar. However, while US nuclear power plants can be privately owned, all Korean nuclear power plants are national projects. In addition, there are differences in the resources available in the treatment of waste. Because of these differences, the details of the decommissioning process between Korea and the United States are different.

Korea is in the beginning stages of the decommissioning of nuclear power plants. Korea has built a solid infrastructure by preparing the decommissioning-related nuclear act and decommissioning projects. It is expected that Korea will be able to produce positive results in the global decommissioning market by carrying out the decommissioning business on the basis of the above infrastructure.

### **REFERENCES**

- [1] Elearning.iaea.org. (2020). OPEN-LMS: E-learning on Spent Fuel and Radioactive Waste Management, Decommissioning and Environmental Remediation. at: <https://elearning.iaea.org/m2/course/index.php?categoryid=60> [Accessed 23 Feb. 2020].
- [2] Prs.iaea.org. (2020). PRIS - Reactor status reports - Permanent Shutdown - By Country. [online] Available at: <https://pris.iaea.org/PRIS/WorldStatistics/ShutdownReactorsByCountry.aspx> [Accessed 23 Feb. 2020].

[3] NUCLEAR POWER REACTORS IN THE WORLD: nuclear power. S.I: INTL ATOMIC ENERGY AGENCY, 2019.

[4] Korean Sixth National Report under the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. (2017). Nuclear Safety and Security Commission, pp.106-109.

[5] United States of America Sixth National Report for the Joint Convention on the Safety of Spent Fuel Management and on the Safety of Radioactive Waste Management. (2017). U.S. Department of Energy, pp.96-110.