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Process Based Decommissioning Scenario Design for PWR and CANDU 6 NPPs

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1. Introduction

Domestic nuclear reactors are mostly PWRs and there are four CANDU 6 nuclear reactors. Starting with Kori unit 1 (PWR type, 587MWe), Wolsung unit 1 (CANDU 6 type, 700MWe) and other old Nuclear Power Plants (NPPs) are expected to be decommissioned after permanent shutdown. Standardization of decommissioning scenarios and processes will serve as a baseline for dismantling experience and reuse of knowledge. This study suggests an approach to derive decommissioning scenarios and processes at the level that may comprehensively be applied to decommission NPPs.

2. Decommissioning Steps

Decommissioning tasks are planned and managed in steps. These decommissioning steps will be equally applicable to decommissioning of other NPPs as well as Kori unit 1. The domestic decommissioning steps are classified into operation, permanent shutdown management and decommissioning preparation, decommissioning start and execution, release of management zone and site restoration.

3. PWR and CANDU NPPs Decommissioning

Domestic NPPs are largely divided into PWR and CANDU 6 types. In PWR type, decommissioning plan (DP) should be prepared to reflect the plant characteristics due to design characteristics, operation history, and layout, etc. Since CANDU 6 differs from PWR in terms of radiation source, system and facility capacity, layout and configuration, this difference is reflected in DP. However, decommissioning scenarios and processes may be defined identically for all NPPs from a comprehensive viewpoint.

3.1. SSCs classification for PWR and CANDU

Structures, Systems and Components (SSCs) of PWR and SSCs of CANDU 6 differ in capacity and size. There are SSCs of CANDU 6 that are not in PWR NPPs, and PWR SSCs that are not in CANDU 6 NPPs. Table 1 compares the main facilities and equipment of OPR1000 (Korean standard PWR, 1000MWe) and CANDU 6 (700MWe) NPPs. Because CANDU 6 NPPs uses heavy water, there are moderator systems, heavy water upgrading facilities and tritium treatment facilities not available in PWR NPPs. PWR NPPs are lined with Carbon Steel (CS) inside reactor building, which is superior to CANDU 6 NPPs for structural integrity against high pressure.

Table 1. NPPs Decommissioning Scope (PWR/CANDU 6)

No.	PWR (OPR1000)	No.	CANDU6
1	Containment Building	1	Reactor Building
2	Primary Auxiliary Building	2	Service Building
3	Secondary Auxiliary Building		
4	Main Steam Structure	3	Main Steam Structure
5	Fuel Building	4	Spent Fuel Storage Facility
6	Radioactive Waste Building		
7	Auxiliary Boiler Building	5	Auxiliary Steam Facilities
8	CCW Heat Exchanger Building	6	Cooling Water Facilities
9	Turbine Building	7	Turbine Building
10	Emergency Diesel Generator Building	8	Standby Diesel Generator Facility
11	FP&W/W Treat Building	9	Water Purification Building
		10	Water Treatment & Storage Facility
12	Circulation Water Intake Structure	11	Circulation Water Intake Structure
13	ESW Intake Structure	12	ESW Intake Structure
14	Chlorination Facility	13	Chlorination Facility
15	Yard Transformer Area	14	Yard Transformer Area
16	Switch Yard	15	Switch Yard
17	Yard Facility	16	D2O upgrading facility
		17	Tritium treatment facility
18	Administration/Shop/Warehouse	18	Administration/Shop/Warehouse
19	Access Control Building	19	Access Control Building
20	Under Ground Utilities	20	Under Ground Utilities
21	N2&H2 Gas Storage Area	21	Gas Storage Area
22	Shared Systems	22	Shared Systems
23	Guard House	23	Guard House

3.2. Decommissioning Tasks

Tasks for decommissioning NPPs may be defined differently depending on the viewpoint and depth of view. Here, we group the tasks into 15 items as shown in Table 2. These 15 task groups do not conflict with ASME Decommissioning Handbook (2004) and OECD/NEA International Structure for Decommissioning Costing (ISDC, 2012). The subtasks in each task group are defined in detail for the objects to be dismantled.

Table 2. Decommissioning Task Group

No.	Task	No.	Task
1	Project Management, Planning and Engineering	9	Dismantle HVAC items
2	Site Preparation	10	Dismantle Mechanical Equipment
3	Characterization	11	Dismantle Piping
4	Drain and Flush	12	Dismantle Structural Steel
5	Dismantle building / architectural structure	13	Demolition
6	Dismantle Electrical items	14	Disposition
7	Dismantle Electrical Bulk Material	15	Procure Equipment and Services
8	Dismantle I&C items		

Most dismantling tasks are related to safety, and ALARA measures are needed to ensure that there are no radiation safety problems, especially in the radiation management area. Dismantling tasks may be decomposed into subtasks as shown in Table 3, and there may be differences depending on dismantling business. Table 3 provides an illustration of radiation and general industrial safety relevance of dismantling mechanical equipment. Subtasks related to radiation safety are subject to radiation evaluation and monitoring and may cause exposure to the general public as well as dismantling workers.

Table 3. Safety related subtasks of dismantling mechanical equipment

No.	Subtask for dismantling mechanical equipment	Safey Related	
		Radiological	General Industry
1	General	○	○
2	Other Equipment		○
3	Equipment Insulation	○	○
4	Condenser & Aux		○
5	Install temporary containments for rad work	○	
6	Coolant pump removal	○	○
7	Pressurizer removal	○	○
8	Steam generator removal	○	○
9	Reactor Internals Removal	○	○
10	Reactor Vessel Removal	○	○
11	Remove contaminated equipment	○	○
12	Remove large equipment (> 10,000 lbs)		○
13	Remove tank resins	○	○
14	Remove tanks	○	○
15	Main Mechanical Equipment Removal		○
16	Surface Decontamination	○	○
17	Aux Mechanical Equipment Removal		○
18	Remove crane	○	○
19	Remove Diesel generator		○

3.3. Tasks Application to SSCs

Since dismantling targets are composed of SSCs, dismantling should be planned based on SSCs. The subtasks for dismantling SSCs are selected to reflect on dismantling scenarios and processes and may be derived when necessary. Reactors for PWR and CANDU NPPs are commonly composed of Vessel and Internals. RPV & Internals of PWR, and CALANDRIA Shell, Fuel Channel (FC) and Ion Chamber (IC) of CANDU 6 should be applied differently in dismantling process and method.

Radioactive structures include PWR bio-shield concrete and CANDU 6 concrete CALANDRIA VAULT. Because CANDU 6 replaces the fuel bundle daily and the nuclear fuel is not enriched to use U-238, Radiological activation of the structures nearby CALANDRIA will be very low compared to PWR. This means that the segmenting and demolishing methods of activated structures may be different from PWR cases because the depth of radiologically activated structures is smaller than that of PWR. Bioshield Concrete and Concrete CALANDRIA Vault may be demolished through scabbling and block cutting, but there will be a difference in working conditions and speed.

4. Decommissioning Scenario

Decommissioning scenario may be specified differently depending on decommissioning strategy. The United States has proven scenarios with many nuclear dismantling experiences. Although there is no experience of decommissioning NPPs in Korea, the US case will be referred to. However, there are limitations in applying the US cases not only because there is a lack of technology development and industrial infrastructure required for dismantling projects, but also because Korean regulations, laws and technical requirements differ from those of the US. Process based decommissioning scenarios that reflect various domestic dismantling requirements will be an alternative to this.

4.1. Decommissioning Strategy & Scenario

Decommissioning strategy is classified into SAFSTOR, ENTOMB and DECON. Kori unit 1 will be dismantled according to DECON strategy. Decommissioning scenario should be derived to fit the strategy and be defined and managed by a combination and interrelationship of decommissioning processes. The scenario reflects input and output of resources and information between the processes, so resources and information for dismantling tasks affect the performance of processes and scenario. For example, if we plan a scenario to remove steam generator after reactor vessel dismantling is finished, process is controlled not to start steam generator removal process until reactor vessel dismantling process is finished

4.2. Process Based Decommissioning Scenario

Decommissioning process may be set for each task in Table 2 and Table 3. Figure 1 shows the process of removing Reactor Vessel and Internals and packaging them according to waste stream. It is applicable to PWR (Kori unit 1) and CANDU 6 (Wolsung unit 1). Other equipment in reactor building (Pressurizer, Steam Generator, RCP, Tank, etc.) may also be dismantled by the process of Figure 1.

The dismantling of major equipment within reactor building is completed after the dismantling of each equipment is finished, as shown in Figure 2. According to the dismantling process, it may be implemented to dismantle RCP, PZR, SG, and other tanks. Even though start and end times of each process may differ, the dismantling scenario is completed when all processes are finished.

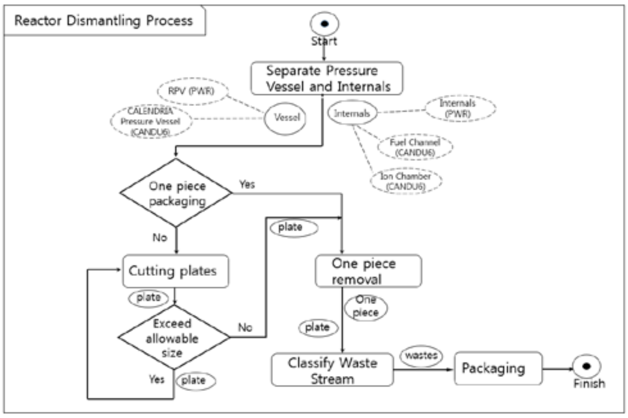

Fig. 1. Reactor Dismantling Process (PWR, CANDU 6)

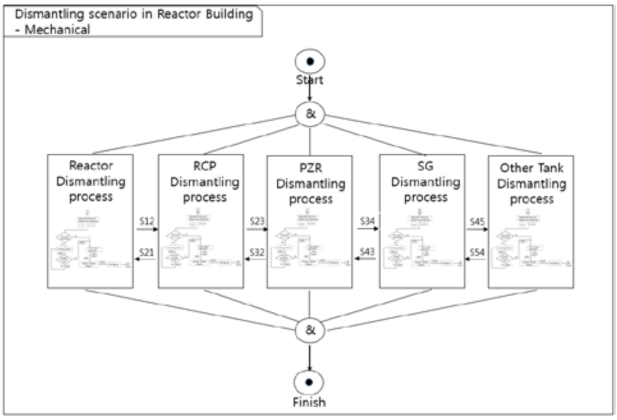

Fig. 2. Dismantling scenario in Reactor Building (Mechanical)

5. CONCLUSIONS

We propose a method to design process based decommissioning scenario of NPPs. By extending this method, it is possible to connect all decommissioning steps and tasks for PWR and CANDU 6 NPPs on process basis. If process based decommissioning scenario is comprehensively constructed, it may be reused in various decommissioning projects.

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