A Review of Licensing Considerations for Changes of NPP due to NRHES Installation from a Nuclear Safety Perspective

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1. Introduction

Nuclear-Renewable Hybrid Energy System (NRHES) is a conceptual system that integrates the nuclear, fossil, renewables, energy storage and industry customers [1]. Construction of the NRHES facility requires a licensing of the energy-using facility itself as well as a licensing of the design changes of the nuclear power plant (NPP) to supply energy to NRHES. The licensee of NRHES shall determine whether or not the facility is subject to the Nuclear Safety Act [2], depending on whether the energy supplied to the facility contains radioactivity and can harm the public and the environment. And, if applicable, the facilities shall comply with this Act and the related laws and regulations. In the case of extracting and using steam from the NPP as an energy source, the associated design changes of the NPP are required, so it must obtain the permission for the change of operational license of the NPP in accordance with the Nuclear Safety Act.

In this paper, considerations for licensing of the changes of NPP that may be caused by the construction of NRHES are derived with their basis, based on the structure and regulations of the Nuclear Safety Act and the related laws and regulations, etc., from the industry point of view. The NRHES design of the current concept is assume.

2. Coupling of NRHES to NPP

Figure 1 shows the design concept currently under consideration for the steam extraction from NPP for NRHES and the return of condensate.

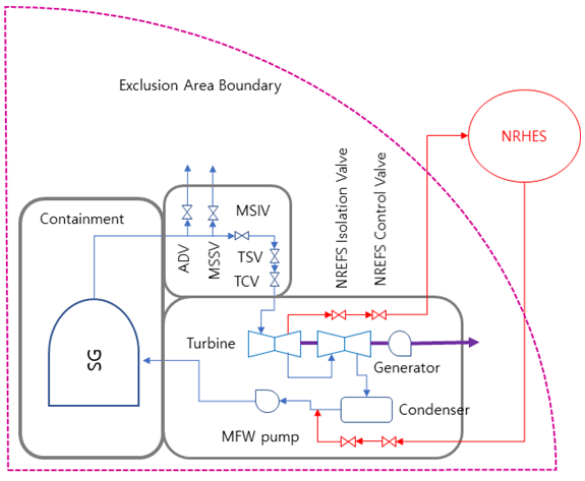

Fig. 1. Design concept NRHES coupled with NPP

We assume the NRHES will be constructed outside the NPP Exclusion Area Boundary (EAB). Steam for NRHES may come from the upstream or downstream of the turbines and the resultant condensate may be returned to the appropriate point of the feedwater system. Currently, NRHES is for the conceptual design stage, and considerations may change as the maturity of the design increases

3. Review Results

Table I shows the legal system applied to the licensing of nuclear facilities in Korea. This shows the structure of the Enforcement Decree, Enforcement Regulations, Notices of Nuclear Safety and Security Commission (NSSC), technical standards, and Safety Review Guides of KINS, starting with the highest Nuclear Safety Act (NSA).

Table I. Safety regulation infrastructure System [3]

	Title	Level
1	Nuclear Safety Act (NSA)	Law
2	Enforcement Decree of NSA	Law
3	Enforcement Regulations of NSA	Ordience
4	Regulations on Technical Standards (RTS) for Nuclear Reactor Facilities, etc of NSA	NSSC Regula-tion
5	Notices of NSSC	NSSC
6	KINS Regulatory Standards/Guideline	KINS rule
7	KINS Safety Review Guides (SRG) & Inspection Technical Guidelines	KINS rule

3.1 Requirements in Regulations

In those laws and rules, the requirements related to the changes in design and operation of NPP that may be affected by the installation of NRHES can be found primarily in RTS [4]. This review examined whether any part that previously complied with regulatory requirements and technical standards can be affected by changes due to NRHES, and whether there is anything additionally required to satisfy the requirements. Major findings from the review on those regulations are as follows:

Generals:

RTS does not have clear regulations on feedwater and condenser systems, turbines and auxiliary systems of

turbine buildings and power conversion systems applicable to the construction of NRHES. This is because NRHES facilities do not constitute "safety-important structures, systems, and components (SSC)" as defined in this RTS, collectively referred to as safety-related SSC that perform essential safety functions and non-safety-related facilities in case of failure. Generally, it can be said that the part without the premise of "SSCs that are important for safety" in the articles of the RTS should be applied.

Siting

Regarding the technical standards for siting, the feedwater and condenser systems, turbine and auxiliary systems to be modified by the NRHES are nuclear facilities, thus, Article 4 (Geological Features and Earthquakes), Article 5 (Limitations on Location), Article 6 (Meteorological Conditions), and Article 9 (Feasibility of Emergency Plans) should be considered. However, since most SSCs in the power conversion system of NPP are already constructed and operated to meet those requirements, it is expected that the connection to be added due to NRHES will also meet those requirements without any problems.

Nearby Facilities

Article 8 (Impact of Human Induced Events) may vary depending on what NRHES facilities are. In other words, as required by this regulation, it should be evaluated whether it can be affected by accidents from the nearby industrial facilities and transportations that produce or handle dangerous materials.

Reactor Core

The protection of the reactor required by Articles 18 (Inherent Protection of Reactor) and 19 (Suppression of Reactor Power and Power Distribution Oscillations) may be satisfied by limiting the operating range of the NRHES so as not to exceed the protectable range of the reactor.

General Design

Articles 15 (Environmental Effects Design Bases, etc.), 37 (Overpressure Protection), 38 (Alarm device, etc.), 42 (Design Basis Accident), 46 (Optimization of Radiation Protection), 48 (Establishment, Adjustment, etc. of Limiting Conditions for Operation), 56 (Operating Procedures), 57 (Management of Human Factor), 59 (Fire Protection Program), and 62 (Radiation Protection Program) may generally be applicable to NRHES and it is necessary to evaluate whether or not to apply them according to the detailed design of NRHES.

Other regulations of RTS can be regarded as involving no direct relationship with design changes due to NRHES.

3.2 Requirements in NSSC Notices

Among the 34 NSSC Notices, it can be identified that an evaluation of the influence of NRHES is needed for (1) Technical Standards for Siting (2017-15) [5], (2) Evaluation of Radiation Environmental Impact (2020-07), (3) Safety Valve (2016-12), (4) Pre-operational Inspection (2018-07), (5) Fire Protection Program (2017-28), (6) Periodic Inspection (2017-28), etc. The application and compliance with those Notices can be evaluated once the design of NRHES is determined to some extent.

For example, the existing NPP have already complied with the Notice 2017-15 and the impact of addition of NRHES to NPP is not significant, so there is no change in the Safety Analysis Report, but issues such as distance to population centers may need to be evaluated based on construction time.

Regarding the Notice 2017-28, since turbine and generator systems are specified as the items for periodic inspection, valves and controls for turbine and generator systems as part of the NRHES facility may be subject to periodic inspection, so they should be considered.

3.3 Requirements in Safety Review Guides

Basically, Safety Review Guides [6] are not necessarily required to be used for safety review to ensure the safety of nuclear power plant design and operation, but compliance with the guidelines eliminates the need for further review. The guides were developed on the basis of the USNRC Standard Review Plan (NUREG-0800) [7] and has been revised periodically in case of changes in technical contents.

Among the SRGs for the systems of nuclear power plants, Sections 10.2 (Turbine and Generator Systems) and 10.4.7 (Feedwater and Condenser Systems) may be affected by the design and operation of NRHES. In addition, the technical standards required by Section 2.2 (Potential Hazards around the Site) should be applied to the location of the facility.

Turbine and Generator Systems

For Section 10.2, since the operation of NRHES may affect turbine operation, analysis considering the NRHES operation should show that the turbine can be prevented from over-speeding under any conditions and tested during operation including NRHES. One of the important requirements in Sec. 10.2, the extraction check valve installed in the turbine extraction line must be closed within an appropriate time to maintain a stable turbine speed when a turbine generator stop signal is generated. For this item, it should be shown that stable turbine speed can be maintained for the stop signal through analysis and test considering the NRHES operation.

Feedwater and Condenser Systems

Section 10.4.7 requires appropriate protection from dynamic effects caused by flow instability (e.g., water hammer) that may occur during abnormal or accident conditions as well as normal operation in accordance with Article 15 of the RTS (Environmental Effects Design Bases, etc.). The feedwater system itself is not an

SSC important to safety, but this requirement is applied because the water hammer phenomenon of the feedwater system could affect other safety SSCs and shall be considered in the design and operation of return pipes of condensate from NRHES.

Nearby Facilities

Regarding Sec. 2.2, design basis events in or around reactor facilities are defined as accidents with a occurrence probability of 10^{-7}/year or higher, and are determined as accidents with sufficient potential to significantly affect the safety of reactor facilities, exceeding the guidelines specified in the NSSC Notice 2017-15. Reactor facilities should be properly protected for accidents that may occur due to industrial, military, or transportation facilities in or around the site, or activities occurring here, ensuring that they can be operated while maintaining an acceptable level of safety. NRHES corresponds to such facilities.

Accident Analysis

Regarding the chapter 15 (accidents analysis), it was confirmed that the sections in Table II below could be affected by NRHES. For these accidents, it is necessary to ensure that the operation or failure of the NRHES is properly considered in the analysis. In particular, the effect on turbine speed should be evaluated for all the NRHES related transients and accidents.

Table II. Sections of accident analysis related to NRHES

Sec	Title
15.0.2	Review of Transient and Accident Analysis Method
15.1.1 - 15.1.4	Decrease in Feedwater Temperature, Increase in Feedwater Flow, Increase in Steam Flow, and Inadvertent Opening of a Steam Generator Relief or Safety Valve
15.1.5	Steam System Piping Failures Inside and Outside of Containment (PWR)
15.2.1 - 15.2.5	Loss of External Load; Turbine Trip; Loss of Condenser Vacuum; Closure of Main Steam Isolation Valve (BWR); and Steam Pressure Regulator Failure (Closed)
15.2.6	Loss of Nonemergency AC Power to the Station Auxiliaries
15.2.7	Loss of Normal Feedwater Flow
15.2.8	Feedwater System Pipe Breaks Inside and Outside Containment (PWR)
15.3.1 - 15.3.2	Loss of Forced Reactor Coolant Flow Including Trip of Pump Motor and Flow Controller Malfunctions
15.3.3 - 15.3.4	Reactor Coolant Pump Rotor Seizure and Reactor Coolant Pump Shaft Break

4. USNRC Perspectives

The US Nuclear Regulatory Commission (NRC) presented its regulatory principles on industrial facilities using heat produced by nuclear power, such as NRHES, as SECY-11-0112 [8]. In this document, NRC indicated that the enactment of current rules or policy changes should not be required, except for the costs and insurance considerations related to the decommissioning of facilities. Therefore, other related issues such as power plant sites will be reviewed on a case-by-case basis in accordance with existing guides and requirements.

5. Concluding Remarks

Considerations for licensing changes to nuclear power plants that may be caused by the construction of NRHES were derived. Assuming the NRHES design of the current concept, regulatory documents ranging from the Nuclear Safety Act to the Safety Review Guides of KINS were applied. Such an application of the existing requirements is in the same context as the perspective of the regulatory principles proposed by the USNRC for industrial facilities using the nuclear heat.

From the preliminary review, some items including the siting issues including the population center distance, turbine protection, accident analyses related to secondary system failure such as steam line break were identified. These problems must be fully considered as NRHES design progresses and are expected to be possible to solve.

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