Flexible Operation of Nuclear Power Plant in Republic of Korea: Research and Development Plan

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1. Introduction

Demand on nuclear power flexibility in Korea has been continuously increased due to the worldwide energy transition policy, expanding the portion of renewable energy [1]. In that context, Ministry of Trade, Industry and Energy of Korea announced the 11th basic plan on electricity supply and demand (11th Basic Plan), which could embody the energy mix policy by increasing the generation share of carbon-free and renewable energy up to 70 and 21.7% each by 2038 [2].

Energy storage system (ESS) has played a vital role in energy transition, to secure power grid stability and power quality by balancing power supply and demand [3]. However, there are few challenges, including low energy density; short lifespan; and high installation /maintenance cost [4], which may impede the expansion and growth of renewable energy industry. Flexible operation of nuclear power plant has become one of the most viable option to substitute ESS with superior characteristics (i.e., large power capacity and stability). The flexible operation of NPP can be classified into three different mode (e.g., load following, frequency control, and other forms) based on the magnitude/rate of the power change and response method [5].

Since nuclear power has been utilized as a stable source of baseload, comprehensive study on technical review and safety verification should be conducted before implementation of the flexible operation. This program specified four major research area considering significance and implementation plan as follows: i) program management, ii) core design, iii) nuclear system design/safety analysis, and iv) reactor operation.

2. Research and development overview

Requirement for the flexible operation, including mode of operation, power band, power change rate, number of occurrences per given time, and duty cycle, would be determined by project for program management referring preliminary results and various technical requirements (e.g. European utility requirements).

Technical research and development projects are composed of seven sub-research topics, regarding core design; fuel-cladding integrity; control rod; steam turbine control system; safety analysis/key component integrity; operation support system; and reactor operating procedure.

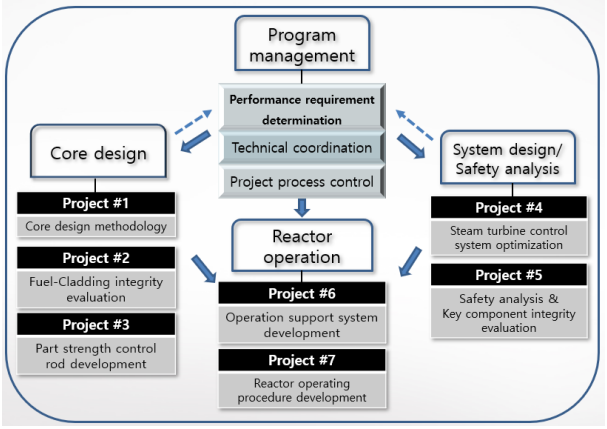

Fig. 1 NPP flexible operation R&D program implementation system

2.1. Core design

Research on core design methodology development, fuel-cladding integrity evaluation, and part-strength control rod development would be conducted in this category and the detailed content of each project is as follows:

i) Core design methodology: reactor core design considering modified control rod material/strategy, data production for core safety analysis, and review/evaluation of performance requirement for the flexible operation.
ii) Fuel-cladding integrity: development of evaluation methodology, fuel damage limit for pellet-cladding interaction (PCI), ramp rate guidance, and real-time PCI monitoring method.
iii) Part-strength control rod: Ag-In-Cd (AIC) alloy control rod design, optimizing manufacturing process/system, and out-of-pile performance evaluation/test.

2.2. System design & Safety analysis

Optimization of steam turbine control system, integrity evaluation on key component, and safety analysis on the system under flexible operation condition would be conducted in this area. Each research topics are focusing on following objectives:

iv) System design: development of monitoring & surveillance system for primary/secondary system

and emergency turbine control algorithm for turbine control system.

v) Safety analysis methodology: methodology review and evaluation on performance & integrity of nuclear steam supply system (NSSS)/secondary system during flexible operation.

2.3.Reactor operation

Research related to operation support system and operating procedure are planned to be carried out in this topic, with the specific details as outlined below:

vi) Reactor operation support system: development of 3-dimensional core power distribution calculation technology and real-time monitoring system for operating limit factors.

vii) Operating procedure: development of periodic test & standard operating procedure and training scenario/program for the verification of revised procedure.

3.Futurework

Subsequent projects for licensing and on-site demonstration for practical implementation of the flexible operation are planned to be commenced after the completion of the preceding R&D projects. Furthermore, continuous investigation on identifying strategies to compensate reduced electricity generation and profits resulting from the application of flexible operation would be performed.

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