Introduction to Feasibility Evaluation for Supercritical Water-Cooled Reactor Development in Korea

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1. Introduction

The supercritical water-cooled reactor (SCWR) is selected by Generation IV International Forum (GIF) as one of the six Gen IV reactor types. However, the level of Korean participation is still limited to several key areas and the decision-making on whether going into full-scale research is yet to be made. In these circumstances it has been decided to launch a feasibility study in 2007 to identify the required research areas and assess the domestic capability and resources as well as economics for development of an SCWR.

This paper introduces a preliminary status of feasibility evaluation for an SCWR development in Korea. Specially, evaluation item derivation and criteria selection, technology tree development, and optimal capacity review are described. These subjects are a portion of "Feasibility study for an SCWR" but they will be key factors to identify the most optimum way of an SCWR R&D strategy in future.

2. Feasibility Evaluation for an SCWR

Existing pressurized water reactor can be applicable to an SCWR development, but it is true that there are weak points and an insufficient experience to this technology development. Therefore, a unique evaluation method for an SCWR is required to include selection of evaluation items and criteria, technology tree development, and optimal capacity review.

2.1 Selection of Evaluation Items and Criteria

In this section the feasibility evaluation areas and main items for SCWR development are described. The evaluation areas are policy and development environment, technology and safety, and economic feasibility. The object and evaluation items for each category are provided below.

The purpose of the policy and development environment evaluation is to make it clear the developmental necessity including the industrial need in aspect of national policy and environment necessary to develop, and to provide the frame for SCWR development.

The main items and contents for this evaluation are (i) to review an energy demand and supply outlook and an electric power development plan, (ii) nuclear power reactor development strategy, (iii) decision of rational nuclear reactor capacity, (iv) SCWR technology development roadmap, (v) resource availability and utilization, (vi) concerning of SCWR development, (vii) sustainability, and (viii) proliferation resistance, etc.

The technology and safety evaluation presents to analyze and evaluate the relative level of all SCWR development technologies including specially core and fuel design, and system arrangement compared to conventional pressurized water cooled reactor. It also includes the required SCWR technology development, verification, and layout of procuring safety necessary to develop.

The main items and contents for this evaluation are (i) to look out our current level and future status of the required technologies, (ii) to evaluate the established PWR technology application, technology improvement, and technical shortage, (iii) to compare all SCWR technologies with PWR's, (iv) to apply computer code systems and analysis methodologies, (v) to plan technology development and to presume the development cost, (vi) to license SCWR technologies, etc.

The economic feasibility evaluation covers economic feasibility for the purpose of reactor development by using qualitative and macroscopic data of nuclear power plant concept including a reactor.

The main items and contents for this evaluation are (i) to set up the economic evaluation methodology, (ii) to analyze the economic influenced factors and systems, (iii) to get the materials on economic factors, and (iv) to evaluate the plant construction and maintenance costs, etc.

All evaluation items and criteria are summarized in Table I.

Table I: Summary of evaluation items and criteria

Evaluation item	Evaluation criteria
1. Policy and development environment	
Necessity of electric power demand	Necessity or not
Necessity of reactor development strategy	Necessity or not
Resource availability	Availability review and environmental response
2. Technology and safety evaluation	
Analysis of domestic and abroad technology development status	Technology level difference
Technology tree for SCWR development	Technology difference comparing with PWR
Evaluation of technology development layout	Derived technology, development difficulty, duration, cost

(Table I continued)

Evaluation of optimal capacity and moderator	Economical efficiency comparing with PWR, fuel cycle
Evaluation of domestic development possibility	Development possibility comparing with PWR and other Gen-IVs
Establishment of optimal development plan	Development strategy, technology tree
Technology difference comparing with PWR	Technology difference
Relative safety evaluation comparing with PWR	Qualitative and quantitative evaluation
Licensing	License possibility
3. Economic feasibility	
Establishment of economic evaluation methodology	Evaluation methodology reflecting the SCWR characteristics
Analysis of economic influenced factors and materials	Construction cost, Electricity generation cost
Economic evaluation	Economic evaluation comparing with PWR

2.2 Technology Tree Development for SCWR

The technology tree development is a very important subject to derive the specific and critical technologies for SCWR and to establish the direction of domestic SCWR technology development hereafter.

The preliminary version of technology tree is developed so far and this technology tree is divided into seven (7) top-tier technologies which are core design, fluid system design, mechanical system design, instrument and control system design, safety analysis, materials, and supercritical water chemistry. Each top-tier technology is also categorized in five (5) levels.

Through preparation of technology evaluation sheet, the qualitative evaluation is performed to develop the SCWR technology tree. This technology evaluation sheet includes that (i) a definition of technology, (ii) an applicable domestic technology, (iii) a lack of domestic technology, (iv) an outlook of future technology development, (v) a technology procurement plan by international cooperation or by a concentrative effort internally, (vi) an experimental facility and analysis tool, and (vii) a development budget and period, etc.

During next two years, this technology evaluation sheet will be developed continuously to describe each key technology in detail and will provide a basis of SCWR technology tree development.

2.3 Review of Optimal Capacity for SCWR

An SCWR is a reactor generating electric power by using water coolant among six Gen IV reactor types. In a safety aspect similar event conditions and assumptions for PWRs are applicable to the present SCWR concept because UO_2 fuel and water coolant are used for the reactor.

A loss of coolant event will be one of the most limiting cases to look into because a large amount of energy accumulated in a fuel rod will affect whether fuel failure will be occurred or not. Then the maximum value of the accumulated energy, defined as a linear heat density, is limited during normal operating condition for PWRs and this parameter is the most critical factor to determine a total power of core.

Thus, a physical size of SCWR's core is very similar to PWR's and then determining a capacity of SCWR is inferred from APR1400's. In other words, an SCWR's power will be 1800 MWe in electric power which is calculated from a power of 4000 MWth with 45% efficiency for APR1400. This value of electric power, 1800 MWe, comes from considering only an aspect of safety, and it will be reviewed for both technical and economical aspects in further to select an optimal capacity of SCWR.

3. Conclusions

The feasibility evaluation for an SCWR development is introduced. The feasibility evaluation items and criteria in three areas are described. A preliminary technology tree is developed and a generating power of core is reviewed for an SCWR. The feasibility evaluation will be performed continuously for each item by using these criteria. The technology tree development and optimal capacity selection for SCWR will be progressed further. In addition, a detailed economical evaluation will be performed by using a new analysis methodology and several schemes of moderating core will be also reviewed.

Through a feasibility study for SCWR based on these various evaluations, the viability of SCWR development will be assessed by 2009 and the results of the assessment will become a basis for the government level decision-making for SCWR development policy and roadmap in Korea.

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