Feasibility Study of Technology-neutral Regulatory Framework for Fusion Power

Jae Young Choi*, Juhyung Lee, Tae Il Kim, Soon Heung Chang
Dept. of Nuclear and Quantum Eng., Korea Advanced Institute of Science and Technology,
335 Gwahak-ro Yuseong-gu, Daejeon, 305-701, Republic of Korea
**Corresponding author: cjy89magic@kaist.ac.kr*

1. Introduction

After Fukushima Daiichi nuclear accident, safety of nuclear power and public acceptance as well become the most crucial issue. Not only how to make the system safe but also how to establish society acceptance is big problem. Actually, this kind of problem is closely linked to how to regulate nuclear power plant.

In the not too distant future, innovative nuclear reactors including sodium-cooled fast reactor (SFR), high temperature gas-cooled reactor (HTGR) and fusion reactor will be realized, which have more safety features than water-cooled fissile reactors. Even they have inherent safety features; however, buildup of such as innovative power plant is impossible without providing persuasive regulations based on reasonable regulatory framework. As we have seen from lessons of Fukushima accident, failure of reasonable regulation and occurrence of terrible accident could spoil realization of plan.

For the case of fusion power plant, Korea has domestic plan to begin construction of fusion DEMO (DEMOnstration) plant at 2022. Although the needs of regulation for fusion power are clearly expected from licensing of fusion DEMO plant, there are no study on regulation concepts of fusion DEMO plant since technology and design of fusion power plant is being developed even now. Expedite study on development of regulatory framework for fusion power is positively necessary to prepare for meeting regulatory demands at a proper time.

In the present study, first, domestic plan to realize innovative reactor plant including fusion power plant are organized. In addition to this, previous study on development of regulatory framework for innovate reactors are reviewed. Technology-neutral safety approach for establishment of regulatory frame has been come into spotlight and has being developed to utilize the methodology for deriving safety requirement regardless of reactor design. Technology-neutral safety approach for new reactor designs is also reviewed. Then, inherent safety features of fusion power to be expected are suggested based on the report of 'Safety and Environmental Assessments of Fusion Power; SEAFP', which is resulted from European fusion development agreement (EFDA). Finally, feasibility of technology-neutral safety approach for fusion power is explored.

2. Current State of Future Innovative Reactors Regulation

2.1 Domestic Plan of Future Innovative Reactors

As continuous technology research has been conducted for innovative reactors, such as Sodium Fast Reactor (SFR) and Very High Temperature gas-cooled Reactor (VHTR), demonstration of unproved technology and the licensing of the proven reactor construction come up an important issue. Korean government established "Future long-term nuclear system development plan" in order to support the schedule of proven reactor construction by regulatory background [3].

In the same manner, National Fusion Research Institute (NFRI) suggested a long-term plan for fusion DEMO (DEMOnstration) plant development. For the early stage of this research, DEMO plant regulatory concept study is in progress in order to give a guideline of plant design concept study. Furthermore, the development of regulatory concept in early period is expected to prevent confusion from licensing process. Detailed research plan of fusion DEMO plant is shown compared to other innovative reactors in Fig. 1.

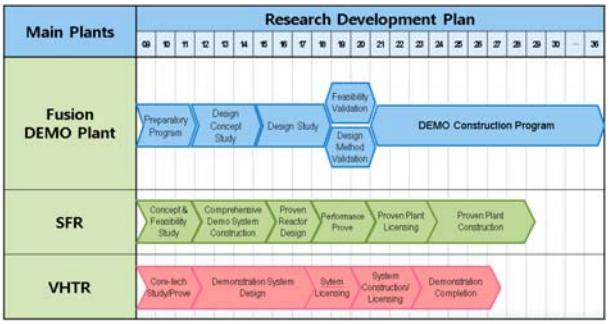

Fig. 1. Domestic development time table of future innovative reactors

Current state of regulatory study which was conducted by Korea Institute of Nuclear Safety (KINS) for innovative GEN IV reactors is being focused on technology-neutral regulatory system in order to widen regulatory range from LWR to innovative reactors [4]. Also, US.NRC started to utilize risk information and to adopt technology-neutral regulatory instead of current regulation. Therefore, Domestic plan for DEMO plant will be also focused on technology-neutral regulation to apply new inherent concept of innovative reactors.

2.2 Technology-neutral Regulatory Framework

Technology-neutral regulation utilizes risk information for the purpose of efficient, stable and predictable licensing process. For the risk-informed regulation requirement, US.NRC suggested Frequency-Consequence Curve which restricts allowable dose compared to event (or accident) frequency [5]. This curve diagram becomes a guideline to satisfy top-tier safety requirement and to identify licensing basis events which includes design based accidents. This regulatory system expected to replace 10CFR50.

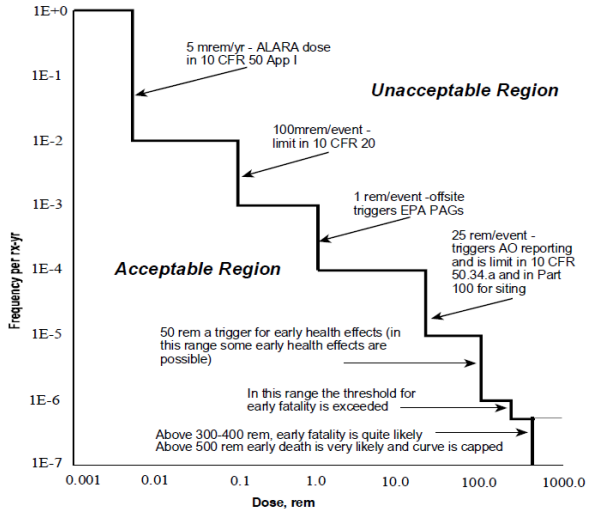

Fig. 2. Frequency-Consequence Curve for future reactor regulation

Newly suggested regulation system based on technology-neutral regulation concept for future innovative reactors can be summarized as following;

1) Technology-neutral requirement
   - Defense in Depth (Deterministic approach)
   - Allowable risk criteria (Probabilistic approach)
   - Performance criteria
2) Inherent technology requirement
   - Inherent feature of innovative reactors

3. Technology-neutral regulatory approach for fusion power

3.1 Inherent safety features of Fusion power plants

In Europe, program of fusion power development has proceeded by EFDA after 1990s. EFDA also conducted conceptual study on safety feature of fusion plant and the effect on environment of the plant [1]. They analyzed for 1200MWe of fusion power plant with various reactor design which was suggested for realizable options. Based on safety analysis, they arranged inherent safety features of fusion power to be expected as follows;

- Fusion reactivity is automatically ended at off-normal condition
- To continue reaction, fuel (D and T) should be provided in succession; the amount of fuel to react for 1 minute is enough in the blanket
- After shut down, decay heat is very limited not to threat integrity of blanket.
- Internal energy of fusion power plant is also limited to threat integrity of confinement.

These characteristics are closely linked to Fundamental Safety Functions of IAEA, i.e. Control of Reactivity, Removal of the heat from the core, Confinement of radioactive material [2]. If the safety characteristics are achieved in fusion power plant, inherent safety features of fusion power automatically perform safety function of nuclear power. In this sense, there are possibilities that regulatory item will be extremely reduced in nuclear fusion.

REFERENCES

[1] European Fusion Development Agreement, Safety and Environmental Impact of Fusion, EFDA-S-RE-1, 2001.
[2] International Atomic Energy Agency, Fundamental safety principles, safety fundamentals, No.SF-1, 2006.
[3] 미래 원자력시스템 개발 장기 추진계획, 제 255 차 원자력위원회 의결, 2008. 12.22
[4] Development of Technology-neutral Regulatory Framework for Future Innovative Reactors, KINS, 2010.02
[5] NUREG-1860, Feasibility study for a risk-informed and performance-based regulatory structure for future plant licensing, 2007.12