Development of Strategic Technology Roadmap for Establishing Safety Infrastructure of Fusion Energy

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1. Introduction

The Korean Government established an "Act for the Promotion of Fusion Energy Development (APFED)" and formulated a "Strategy Promotion Plan for Fusion Energy Development." KINS has carried out a safety review of KSTAR (Korea Superconducting Tokamak Advanced Research), for which an application for use was received in 2002 and the license was issued in August 2007. With respect to the APFED, "Atomic Energy Acts (AEAs)" shall apply in the fusion safety regulation. However the AEAs are not applicable because they aim for dealing with nuclear energy. In this regard, this study was planned to establish safety infrastructure for fusion energy and to develop technologies necessary for verifying the safety.

The purpose of this study is to develop a "Strategic Technology Roadmap (STR) for establishing safety infrastructure of the fusion energy", which displays the content and development schedule and strategy for developing 1) the laws, safety goals and principles, and safety standards applicable for fusion safety regulation, and 2) core technology required for safety regulation of fusion facilities.

2. Overview on the STR

The laws for the safety regulation should be sound and complete in content and structure to achieve its purpose for the safety confirmation. Also, the safety goal, principles, standards, and guides, i.e., the "Safety Documents System," which applies to the design and operation, should guarantee the achievement of safety confirmation. In addition, the organization entrusted to confirm and secure the safety regulation of fusion facilities should have sufficient expertise.

In this regard, the scope and content of this project are set to identify required laws, safety documents system, and technologies for safety regulation and to establish schedule and strategy for developing them.

2.1 Scope

a. For applying to the fusion facilities, we will revise and amend the existing nuclear laws,
b. establish a safety goal to be a final one ultimately achieved for the fusion safety,
c. propose safety principles to be scales for setting up the safety requirements for achieving the goal,
d. develop safety standards and guides observed for satisfying the goal and the principles,
e. and finally develop technologies necessary for the safety regulation of fusion facilities.

2.2 Vision, Goal, and Strategies

a. The vision is to secure the safety of fusion energy,
b. the goal is to establish the safety system of fusion energy and the regulatory capacity,
c. and the strategies are 1) to enact the laws, 2) establish the safety goal and principles, 3) build the safety standards and guides, and 4) develop the regulatory technologies and capacity.

2.3 Scenario

To the end of 2007, we developed a draft for the amendment of AEA and Presidential Decrees, and according to a status of the safety technologies we will formulate them from 2015 when the technical standards are embodied. To 2020, we will revise and amend the safety standards and the safety review plan including the detailed technical contents through reflecting the design of a fusion DEMO reactor and the R&D results.

By utilizing experiences of KSTAR and ITER and developing the related technologies, we can secure the safety regulation system, which will be utilized for the safety review to 2020's when a unique design for the Korean DEMO reactor is completed. Figure 1 shows the scenario, which can be summarized below:

a. Step 1('06～'08): Establish a foundation of the safety regulation for fusion experimental devices
b. Step 2('09～'20): Develop the regulatory system and capacity for a fusion DEMO reactor
c. Step 3('21～'35): Develop the regulatory system and capacity for fusion commercial reactors

3. Development of the STR

3.1 Quantitative Goals for Fusion Safety

The fusion plant is preferable to a nuclear one in a viewpoint of non-proliferation and intrinsic safety. However, the safety issues, i.e., hyper degree of a vacuum, cryogenic problems, high magnetic field, high voltage, etc., are revealed to be more complicated and diverse. The realization of a fusion plant seems to be very time consuming and an expectation for quality of life becomes higher. Considering the acceptability in a future society, the safety goal is at least equal to that of the nuclear one, or should be more strengthened.

For the STR, we established the contents and schedules for developing the laws of safety regulation, the safety documents, and the related technologies. As we mentioned, the STR aims for securing the safety in

the process of design, construction, and operation, equal to or more than that of the nuclear plant.

3.2 Considerations for Safety Regulation

The fusion system has an intrinsic safety, i.e., it terminates voluntarily unless it attains the specific condition. Nevertheless, it should be noted that tritium, i.e., a radioactive isotope is utilized as the fuel, and high energy neutrons are emitted due to the fusion reactions. Since the neutrons activate structures to be radioactive wastes, an occupational exposure can be a technical issue. In particular, when accidents related to the tritium occur, they can leak to the environment and the general public can be influenced.

Because the fusion facilities have these risks, they are subject to the safety regulation. Although technical standards for the safety regulation do not exist in foreign countries as well as Korea, we will prepare them through utilizing experiences for the nuclear ones and considering unique characteristics of the fusion system. The safety regulation of fusion facilities should consider below.

a. Radiation aspect: tritium, activation products and radioactive wastes, shielding high energy neutrons, influences of non-ionized radiations
b. Industrial aspect: cryogenic damage and lack of oxygen due to the massive helium leakage, handling toxic materials, hydrogen explosion and fire, influences of electromagnetic wave
c. Others: classification, inspections, and acceptance criteria for the fusion facilities and components

3.3 Suggestions for Safety Regulation System

Because the AEA is based on the existing nuclear system and not adequate for the fusion one, it is necessary to develop laws, technical standards, safety regulatory requirements, and detailed regulatory guides, etc., for separately handling the fusion one.

The fusion technologies are incomplete ones requiring the comprehensive R&D, and a concept of the Korean DEMO reactor is not yet determined. In this regard, for the adequate regulation of a fusion system under the research, the regulatory R&D has to progress with the promotional one. It is necessary to perform the regulatory R&D for tritium breeding, maintenance of a vacuum, superconducting magnets, ultra high heat-resisting and low activated materials, high efficient power conversion system, activated dust in the tokamak, loss of vacuum, analysis of LOCA, etc.

4. Summary and Conclusion

In conclusion, the vision for fusion safety regulation is to "secure the safety of fusion facilities to a level the public accepts and feels relieved." This was derived from and based on the regulatory goal generally agreed for nuclear plants. In addition, the goal is to "establish the safety infrastructure and secure the technical expertise for the regulation of fusion facilities."

Securing the safety is a precondition for developing and using fusion energy. The government is responsible for establishing infrastructure and building up expertise for fusion safety regulation; the STR developed in this study could be a useful guide in this regard. KINS, to which nuclear safety regulation is entrusted, should improve the relevant laws and regulations and develop necessary technologies in accordance with the STR.

In addition, the developed roadmap needs to be updated periodically to keep in track with the advances and progress in technology.

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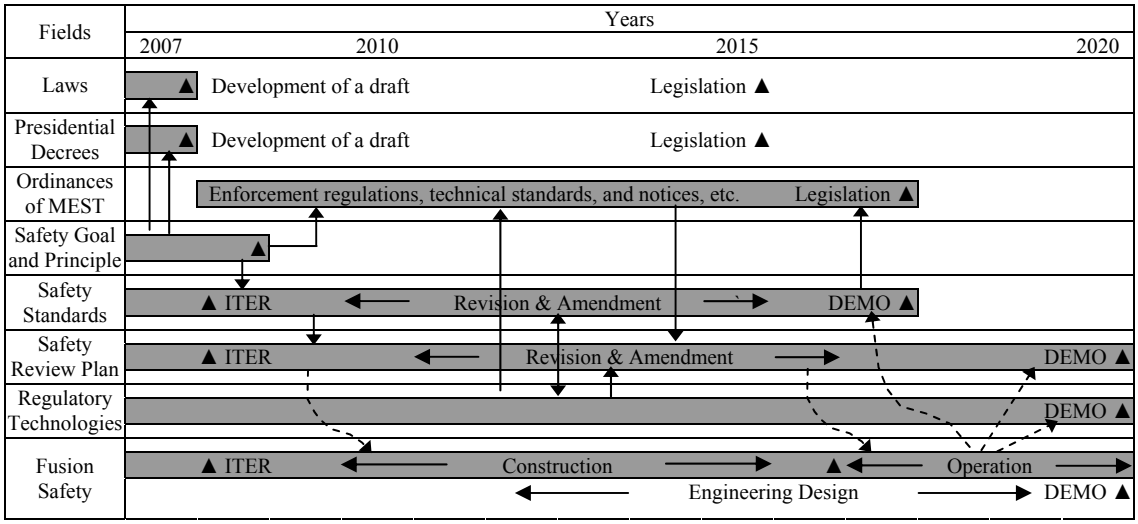

Figure 1. Scenario for developing the laws of fusion regulation and the related technologies