Exploratory Study on Safety Objectives of the Fusion DEMO Plant

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1. Introduction

For realization of fusion power plant, various technical subjects should be overcome in the future. Among them, fusion-specific safety standards and licensing regulations should be developed at a proper time in order to avoid additional delay in construction of the plant. Although these needs are clearly expected from licensing of fusion DEMO (DEMOnstration) 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. It is a big dilemma to initiate this research in such situation to prepare for meeting regulatory demands expected in 2030s.

For the early stage of this research, safety objectives, which are the ultimate goals for safety and the foundation of safety infrastructure, should be considered. Since these are very inclusive and implicative to be top tier of safety document system, it can be generally discussed and expected for fusion power regardless of phase of fusion technology development.

In the present study, first, existing safety objectives for fissile nuclear power are reviewed. Then examples of safety goal for fusion facilities including ITER licensing are summarized to read the trend of safety goals for the fusion facilities. Finally, based on these reviews and reasonable considerations, safety objectives for fusion power plant in the future are proposed.

2. Reviews of Existing Safety Goals

2.1 Safety Objectives for fissile power plants

In spite of distinguishing features of fusion power plant compared with those of fissile power plant, big picture of safety goals will not be changed much due to their own generalness. Therefore, review on safety goals, which has been established and generally accepted is necessary before considering of how to set up safety goals for nuclear fusion plant.

After Three Mile Island (TMI) and Chernobyl accidents, safety regulatory experts in national and international organization including International Nuclear Safety Advisory Group (INSAG) have actively discussed on safety target to establish world-wide consensus for nuclear safety. Products from these efforts are found in crucial safety documents and policy statements including INSAG-12: Basic Safety Principles for Nuclear Safety (Rev.1) [1], International Atomic Energy Agency (IAEA) Safety Fundamentals [2] and US Nuclear Regulatory Commission (US NRC) policy statement [3] as summarized Table 1. In addition, general safety gorals reflect in Korea nuclear legislation [4] through article 1(purpose), 12 and 22 (permit criteria); protection of public health and environment from radioactive materials

Table I: Major references of Safety Objectives for fission power plant

Document	Qualitative	Quantitative
INSAG-12	General Nuclear Safety Radiation Protection Technical Safety	Core Damage frequency(CDF) $\leq 10^{-5}$/RY Large off-site release frequency $\leq 10^{-6}$/RY (for future plants)
IAEA Safety Fundamentals	General Nuclear Safety Radiation Protection Technical Safety	none
US NRC policy Statement	General Nuclear Safety	Additional risk $\leq 0.1\%$
Korea nuclear Legislation	General Nuclear Safety	none

Safety Goals has been set for fissile nuclear power plant in qualitative and/or quantitative ways.

US NRC proclaimed qualitative safety goals focusing on additional risk to public from nuclear power plant operation in 1986. Public protection to make no significant additional risk compared to other ways of electricity generation was stipulated as qualitative safety goals [3] and has been accepted in most nations as basic safety philosophy. INSAG declared more systematic qualitative safety objectives which consist of four parts: General Nuclear Safety, Radiation Protection and Technical Safety. Also, most of these were reflected in Safety Fundamentals published by IAEA. The followings are stated contents in each part:

General - public and environment protection from radiological hazard are generally described
Radiation protection - radiation exposure are concerned, ALARA (as low as reasonably achievable) principle is generally accepted

Technical – accidents prevention with high confidence, accidents mitigation

Quantitative targets could supports to determine the achievement of qualitative safety goals. US NRC suggested specific value of additional risk from nuclear operation to achieve their safety goals. In INSAG-12, quantitative objects are described within technical safety objective part. Core damage frequency and large off-site release of radioactive materials are recommended for methodologies to indicate quantitative safety targets, which have been world-widely accepted and used. For future nuclear power plant, more rigorous standards are required to improve safety of nuclear power.

2.2 Safety Objectives for fusion facilities

Up to date, study on fusion-specific regulation was mainly focused on fusion experiment facilities for licensing and regulating them. US Department of Energy (DOE) played a leading role in development of fusion-specific regulating structure. As a result of these pioneering endeavor, DOE standards [5][6] for magnetic fusion facilities was published in 1996. Goals for safety of fusion facilities are written in fusion safety policy [6] which can be summarized as follows:

- Public protection: No significant additional risk
- Fusion facility workers protection: No greater risk compared to other industrial facility
- ALARA principle selected
- The need for an off-site evacuation plan shall be avoided.
- Wastes, especially high-level radioactive wastes, shall be minimized.

The safety objectives of International Thermonuclear Experimental Reactor (ITER) are described in ITER technical basis [7] published in 2002. General safety objective, no evacuation and radioactive waste reduction are also adopted. Instead of being described in safety objectives, ALARA is mentioned in safety principle.

The most interesting feature from these examples compared to original safety goals for fissile power is the exclusion of off-site evacuation plant. No need of evacuation was considered to demonstrate the favorable safety characteristics of fusion. [7] Because of the potential to be safe enough to eliminate off-site evacuation due to inherent safety of fusion power, it is very interesting to watch whether no off-site evacuation will be also included in safety target of fusion power plant or not.

2.3 Establishment of Safety Objectives for Fusion DEMO plants

With previous reviews on existing safety goals for fissile power plant and fusion facilities, the following points are considered to establish and propose safety objectives for fusion DEMO plant. :

- Introduce the original structure of INSAG safety objectives which has been generally accepted and keep general points which can be applied to fusion power plant as well.
- Clarify non-radioactive hazards, which may newly arise in fusion power plant, such as high electromagnetic fields and hydrogen explosion due to dust in vacuum vessel
- Modify quantitative safety goal which can be compatible to those for future plant. (CDF cannot be just applied since there are no core and no considering decay heat in the fusion plant)
- Consider potential to include needless of off-site evacuation in quantitative safety objectives (If it is achievable and reflect in fusion power plant design, it will be the most favorable feature of fusion plant)

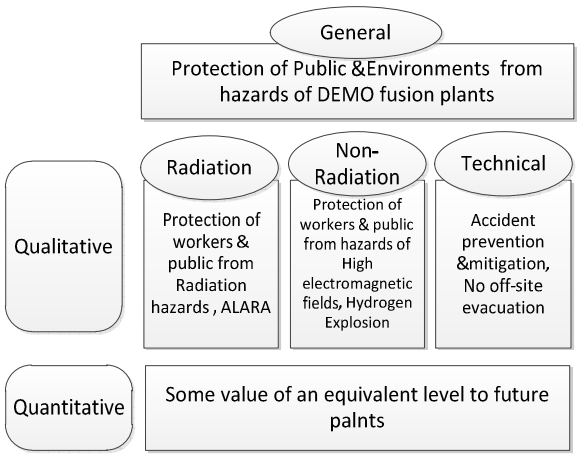

Fig. 1. General structure of proposed safety objectives for Fusion power plant

3. Conclusions

In this study, existing safety objectives of fissile nuclear plant and fusion experimental facilities are reviewed. A blueprint of safety objectives for fusion power is proposed.

REFERENCES

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