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Objective Provision Tree for K-DEMO

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1. Introduction

Korean Fusion DEMO Plant (K-DEMO) is planned as the first fusion power plant constructed in South Korea. However, several key technologies such as plasma, materials, and cooling still have large uncertainties. So, studies related with safety were also limited. In current nuclear field based on technology-neutral approach [1], safety principles and design have been considered for Generation IV (Gen-IV) nuclear power plants in parallel. This strategy can save resource, time, and manpower while keeping achievable safety. For this reason, the studies related with safety affecting significant design parameters for planned construction or fusion plants was needed and required even though K-DEMO is staying in pre-conceptual design phase.

Objective Provision Tree (OPT) is one of the tools of Integrated Safety Assessment Methodology (ISAM) developed by Risk and Safety Working Group (RSWG) for design and assessment of Gen-IV [2]. This is suitable tool to recognize and investigate safety issues from previous engineering experience. The purpose of this paper is to suggest multiple barriers/critical safety function and to describe the current status of the OPT for the conceptual design of K-DEMO.

2. Objective Provision Tree for K-DEMO

The OPT is a practical tool which should be applied on line to design and/or to assess the structure of the safety architecture coherently with the Defense-in-Depth (DiD) [2][3]. This tool ensure safe design through application of DiD philosophy from beginning of the design phase.

The logical framework of the OPT method is graphically depicted in terms of a tree such as that shown in Fig.1. The hierarchy structure of OPT is consist of 6 levels from the top to the bottom.

- Level of DiD: level 1 to 5
- Objectives and Barriers: to be achieved and to be protective
- Safety Function: to be maintained (to be performed successfully)
- Challenge: to cope with
- Mechanism: to be prevented or controlled
- Provision: to be implemented to prevent and/or control mechanisms

To perform the OPT, we selected 5 panel who have expertise for fusion area (plasma and magnet, blanket and thermo-hydraulic, tritium control). The level of DiD defined in this paper is level 2 (Control of abnormal operation and Detection of failure) and level 3 (Control of accident within the design basis)

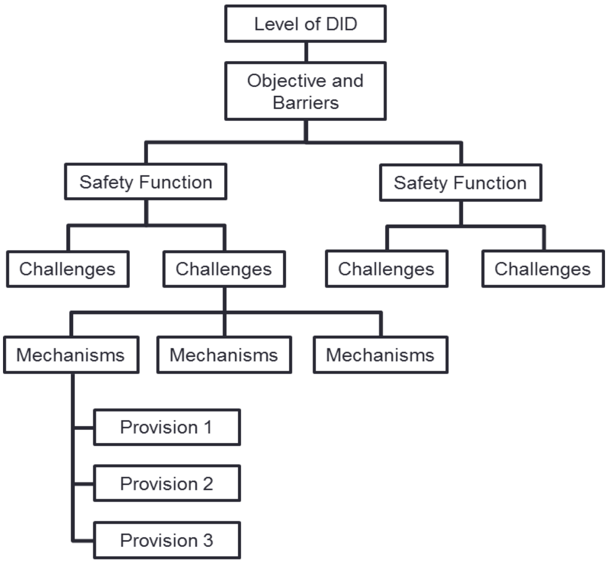

Fig.1 Hierarchy structure of OPT [4]

2.1 Define Barriers and Critical Safety Function

The safety of fission power plant has been addressed through DiD, multiple barriers, and Critical Safety Functions (SF). Fusion power plant also should need the multiple barriers and critical safety functions for securing nuclear safety. For this reason, we defined the multiple barriers and critical safety functions shown in Fig. 2.

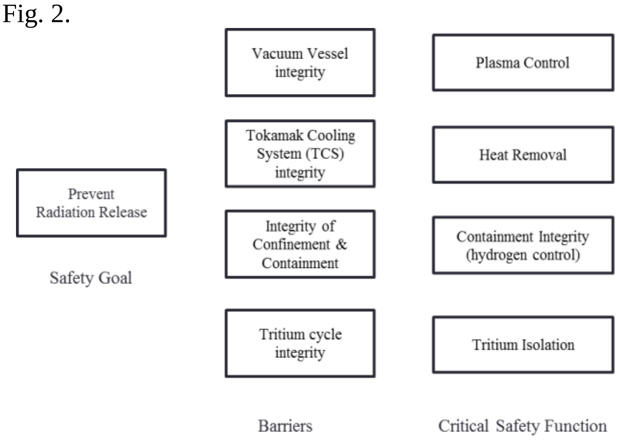

Fig.2 Multiple barriers and critical safety functions for fusion power plant

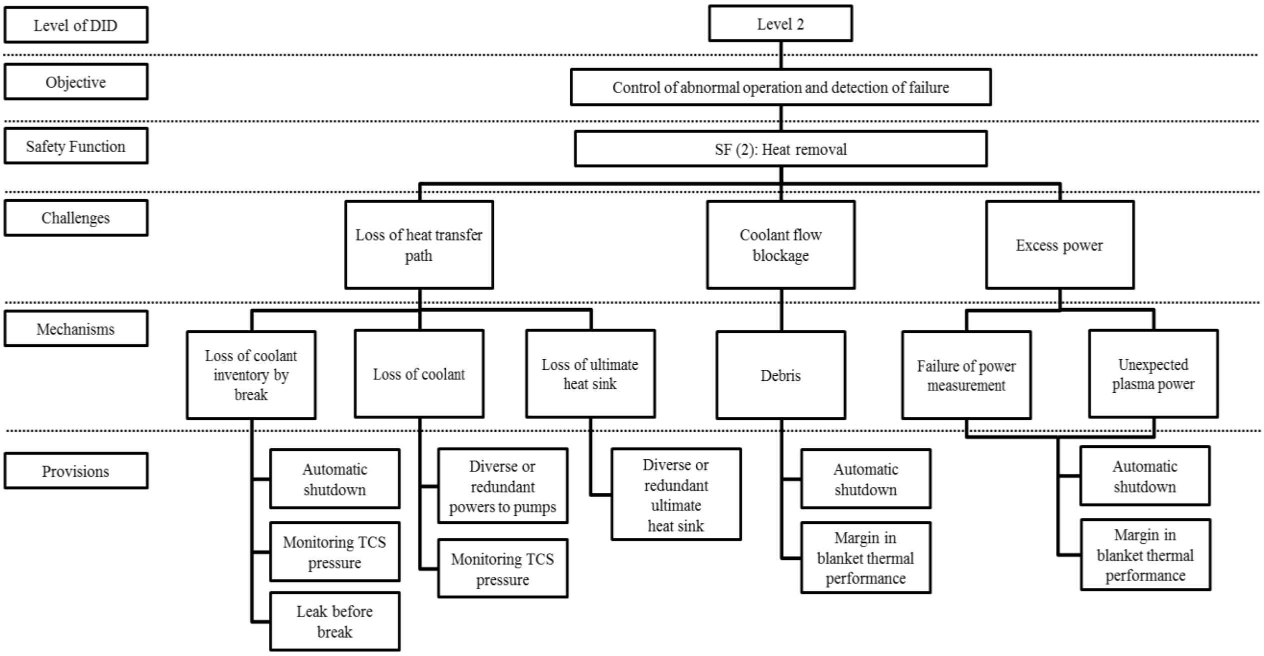

Fig.3 OPT result – DiD level 2, SF 2

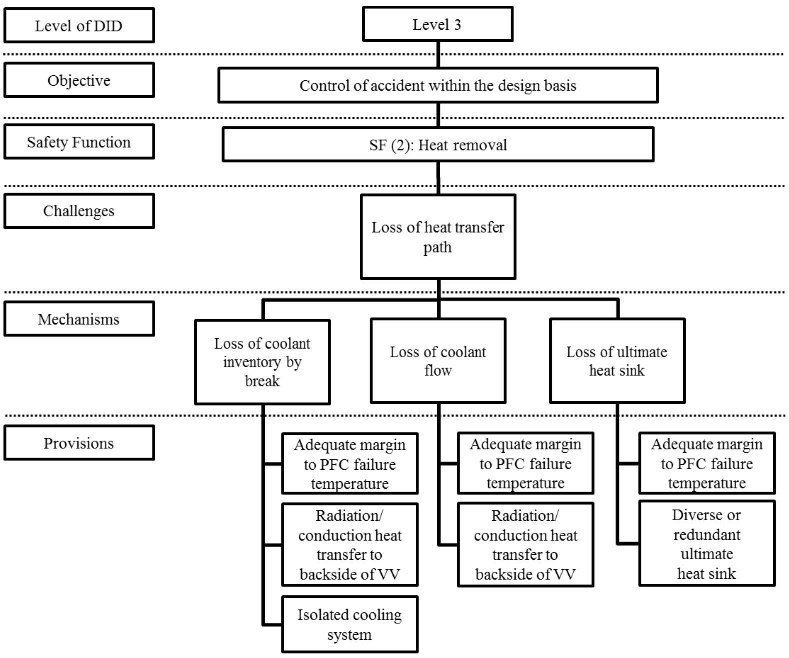

Fig.4 OPT result – DiD level 3, SF 2

2.2 OPT process

In this paper, we performed OPT for all SF (plasma control, heat removal, containment integrity, tritium isolation) of DiD level 2 and 3. The criteria of OPT process is followed:

● Level 2 OPT

- Objective: Control of abnormal operation and detection of failure
- Challenges and mechanisms: phenomena that is occurring abnormal condition and accident during operation if action for prevention is not carried out.
- Provisions: monitoring and diverse/redundant systems to prevent mechanisms

● Level 3 OPT

- Objective: control of accident within the design basis
- Challenges and mechanisms: phenomena that is threatening safety functions during accident and occurring severe accident if action for mitigation is not carried out.

- Provisions: safety margin and systems (active and passive) to mitigate mechanisms

Fig. 3 and 4 show the OPT results for SF 2. Highly important phenomenon is loss of heat transfer path that involve loss of coolant inventory, forced convection and ultimate heat sink. Fusion power plant will be operated in high pressure and temperature condition because of use of water as coolant. If the heat generated in fusion reactor and other component is not removed adequately, structures and systems such as vacuum vessel that involve tritium and activated materials can be damaged. So, provisions were comprised of passive/active safety system and diverse/redundant system. Using the same strategy, provisions for other SFs was considered.

3. Conclusions

In this paper, critical safety functions were defined and OPT for K-DEMO was described and performed. We have carried out researches related to safety for fusion power plant in collaboration with the academies funded by NFRI during the past 4 years. As part of this research, Integrated Safety Assessment Methodology (ISAM), which was used to develop GEN-IV nuclear systems, was used to determine the technical safety issues and regulatory requirements for K-DEMO. OPT is one of ISAM tools. It can help designers to identify weakness and provisions needed to design plants. The results through this tool are expected to contribute on detailed design for K-DEMO as guidance for safety systems in the future.

ACKNOWLEDGEMENT

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