Review of hierarchy of the safety goals for the nuclear power plants

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1. Introduction

Many Countries have developed the safety goals for nuclear power plants for basic safety principles to protect from radiation exposure. The safety goals cover the safety requirements for workers, public, and environment including deterministic and probabilistic objectives. In establishing the safety goals, it is international opinion that a hierarchical structure of safety goals best meets the needs of regulating the safety of nuclear power plants in a systematic way, rather than simple enumeration of safety goals. While regulating safety of nuclear power plants is the responsibility of each country, international cooperation is also needed across nations. For this reason, there were several international cooperative researches for establishing a hierarchical framework of the safety goals. This paper reviews these hierarchies of the safety goals from international cooperative researches. It is also investigated how the safety goals in various countries are set up in different ways.

2. International Cooperative Research

It was confirmed that the hierarchy of safety goals for the nuclear power plants in various countries. In this paper, the background of this hierarchy is investigated and international cooperative researches is reviewed. IAEA provided the fundamental safety objectives and safety principle in 2006[1], which have contributed to several international cooperative researches for safety goals. In 2006, Western European Nuclear Regulators' Association (WENRA) set up the Reactor Harmonization Working Group (RHWG) and provided safety reference levels for existing reactors [2]. WENRA RHWG also proposed safety goals for new reactors in 2009. They provided qualitative safety goals such as protection of the public, the environment, and future generations. Also, they proposed seven safety objectives from the IAEA Safety Fundamentals and recommended to use quantitative safety targets in conjunction with the proposed qualitative safety objectives rather than just acceptance criteria [3]. The proposed safety objectives are given in Table 1.

In 2011, Multinational Design Evaluation Programme (MDEP) proposed a hierarchy of safety goals as shown in Figure 1. It covers deterministic and probabilistic safety goals and targets. At this time, goals mean qualitative objectives and targets mean quantitative objectives. This approach is useful for technology-neutral, which can apply to non-water-cooled-reactors [4].

Table 1. Proposed safety objectives

O1. Normal operation, abnormal events and prevention of accidents
O2. Accidents without core melt
O3. Accidents with core melt
O4. Independence between all levels of defence-in-depth
O5. Safety and security interfaces
O6. Radiation protection and waste management
O7. Leadership and management for safety

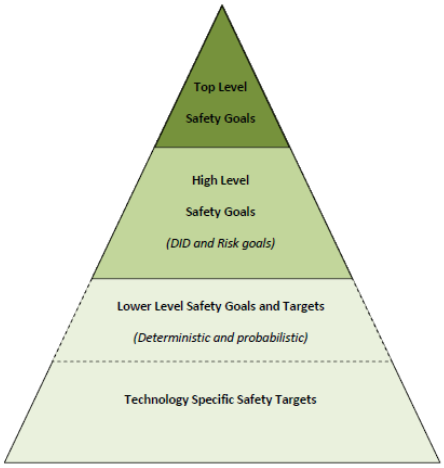

Fig. 1 Hierarchy of safety goals proposed by MDEP

As a part of IAEA project, efforts are given to enhance the existing framework of safety goals. Figure 2 shows the hierarchy of safety goals proposed in the draft-Technical Document (TECDOC). In a hierarchy, it is important that the higher level should be coherent and consistent with the lower level. Also it is possible that the lower level is derived from the higher level [5]. Based on the IAEA's hierarchy of safety goals, the CANDU Owners Group (COG) proposed preliminary concept level hierarchical framework of Canadian safety goals for nuclear power plants. The preliminary framework is proposed for site-level safety goals, which consists of Top level, Upper level, Intermediate level and Low level safety goals. Qualitative Top and Upper levels are defined as the protection of the public from the consequences of accidents at nuclear power plant sites and the elimination of the potential for extensive societal disruption due to a nuclear incident. For quantitative lower levels Large Off-Site Release Safety Goal (LORSG) and Site Severe Core Damage Frequency (Site SCDF) are proposed. Also, it is suggested that the Site SCDF can be considered as a surrogate for the LORSG, but not in all cases [6].

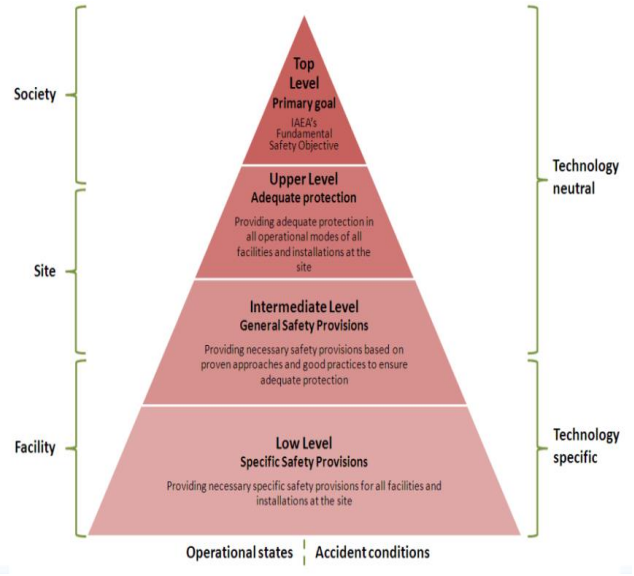

Fig. 2. Hierarchy of the safety goals proposed by IAEA

3. Safety Goals in various countries

In the United States, two quantitative safety goals and two health objectives were presented for the policy statement in 1986 [7]. In addition, the Large Early Release Frequency (LERF) and Core Damage Frequency(CDF) were defined as supporting criteria for health objectives. In Korea, it is also presented that a qualitative safety goals of protecting the health and property of the public in the Radiation Emergency Management Act, and the quantitative health objectives in the following level are presented in the Nuclear Safety and Security Commission (NSSC) Notification in 2016 [8]. In both countries, the health objectives are set to a relative concept that the prompt risk and cancer risk from the nuclear power plants should be less than 0.1% of total risks or risk due to other causes. However, there is another quantitative goal in Korea. This is a criterion that the accident involving the release of more than 100 TBq of Cs-137 should be less than 1E-6 per reactor-year. This standard has been set as a safety goal for Large Release Frequency (LRF) in Canada with Small Release Frequency (SRF) and Core Damage Frequency (CDF)[9]. On the other hand, Finland requires LRF to be extremely small [10]. There are also qualitative safety goals, quantitative health objectives, subsidiary criteria in Japan. However, unlike the US and Korea, the quantitative health objectives are expressed in absolute values. The criteria for the prompt fatality and cancer fatality from nuclear power plants should be less than 1E-6 per reactor-year. Also, the CDF and Containment Failure Frequency (CFF) are used as subsidiary criteria [11].

Table 2: Quantitative safety goals in various countries

Country	Quantitative goals	Subsidiary goals
Korea	Prompt/Cancer, 0.1% Cs137 100 TBq	CDF, LERF
United States	Prompt/Cancer, 0.1%	CDF, LERF
Canada	LRF, SRF, CDF	
Japan	Prompt/Cancer, 1E-6/ry	CDF, CFF
Finland	Annual Dose, Cs 137	CDF, LRF

3. Conclusions

It is found that many countries have proposed hierarchical structure of safety goals based on the reviewing of international cooperative researches. Although safety regulation is the responsibility of each countries, it is helpful for those countries to cooperate in these researches on the framework of the safety goals. This is because the impact of a nuclear power plant accident may cross the borders of countries. Also, it can enhance the safety of nuclear power plants by sharing each other's experience. Establishing the framework of safety goals helps the public easily understand that nuclear power plants are operated in a safe manner and they do not impose undue risk to the public. The lower levels can be derived from higher levels. It is possible that technology-neutral safety goals can be developed and be applied to non-water-cooled-reactor. For this reason, in the hierarchy, the upper level should be consistent with the lower levels. From the review of the hierarchy of the safety goals, it could be found that many countries set up their safety goals in a hierarchical structure.

REFERENCES

[1] IAEA, Fundamental Safety Principles, IAEA Safety Standards for protecting people and the environment, Safety Fundamentals No. SF-1, 2006.
[2] RHWG, Harmonization of Reactor Safety in WENRA Countries, WENRA Reactor Harmonization Working Group, 2006.
[3] RHWG, Safety Objectives for New Power Reactors, WENRA Reactor Harmonization Working Group, 2009.
[4] MDEP, The structure and Application of High Level Safety Goals, OECD NEA Multinational Design Evaluation Programme, 2011.
[5] NPSAG, Support to the IAEA in development of a safety goals framework for nuclear installations (35-001), Nordic PSA Group, 2014.
[6] J. Vecchiarelli, K. Dinnie and J. Luxat, Development of a whole-site PSA methodology, COG-13-9034 R0, CANDU Owners Group, 2014.
[7] USNRC, Policy Statement for Safety Goals for the Operations of Nuclear Power Plants, Federal Register 30028, 1986.

[8] NSSC, Rules related to Specific Criteria for Accident Management Scope and Accident Management Capability, NSSC Notification 2016-2, Nuclear Safety and Security Commission, Seoul, Korea, 2016.
[9] CNSC, Design of Reactor Facilities: Nuclear Power Plant, Regulatory Document REGDOC-2.5.2, Canadian Nuclear Safety Commission, 2014
[10] Ministry of Employment and the Economy, Government Decree on the Safety of Nuclear Power Plants, 733/2008, 2008
[11] OECD/NEA, Probabilistic Risk Criteria and Safety Goals, NEA/CSNI/R(2009)16, Organisation for Economic Co-operation and Development/Nuclear Energy Agency(OECD/NEA), Paris, France, 2009.