Current Safety Goal and Design Practice in View of New Trends after Fukushima Accident

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1. Introduction

Recent accident in Fukushima Daiichi plant in Japan has turned down the ambitious stream of nuclear renaissance world-wide and nuclear industry is trying hard to enhance safety of the nuclear plants. Many countries are cutting down their nuclear projects planned or proclaiming to close all nuclear plants. But until we could find other sources of energy in future, nuclear power should still play a major role. Thus, demands for safety being extremely high, we might need a paradigm shift in safety concept. We need to propose higher safety goal in a more systematic way to public. Internationally IAEA [1] proposes a framework from which to develop new safety rules and requirements. This TECDOC recommends that quantitative safety goals stated in probabilistic terms be implemented and proposes new "Safety Approach (Fig.1)" for new NPPs like:(1) quantitative safety goals, (2) fundamental safety functions, and (3) defence in depth. IAEA-TECDOC-1366[2] concludes that tying the levels of defence in depth (DID) concept to safety goals could assure that a NPP design is safe, sound and has a balanced DID.

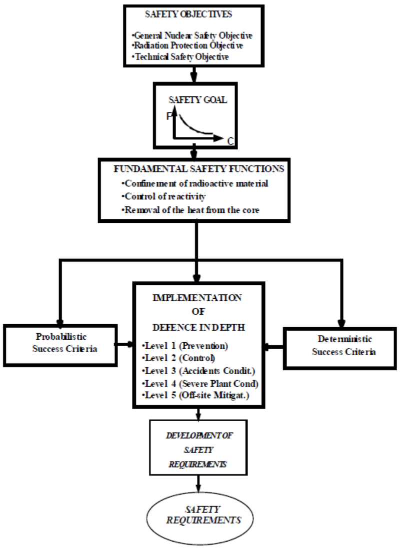

Fig. 1. IAEA Safety philosophy incorporating new safety approach

As part of our efforts to establish regulatory framework for safety of High Temperature Gas-cooled Reactor (HTGR), we have recapitulated in this paper the current safety goal and design practice in view of this new trends for safety reflecting lesseons from Fukushima.

2. Current Safety Goal and Design Approach

This section recapitulates the current design practice in terms of safety goal, General Design Criteria (GDC) and design basis accident to evaluate whether they are tied together in a systematic way.

2.1 Safety Goal

The Korean government issued a policy statement on severe accident of nuclear power plant on August, 2001. In this policy statement a safety goal was proposed in a form of quantitative health objective (QHO) such that an additive risk of early fatality and cancer fatality caused by accident or operation of nuclear power plant should not exceed 0.1% of early fatality and cancer fatality resulting from other base accidents and cancer mortality, respectively. This quantitative health objective (QHO) of additional 0.1% risk was adopted from the US NRC safety goal. The QHO is rather widely accepted one also in other countries and generally PSA is needed to assess whether a specific plant satisfies this safety goal or not. But in reviewing the QHO for operating plants, we had some conceptual difficulties. One conceptual difficulty comes from applying the concept of risk to show public that the nuclear power plant satisfies the QHO.

In nuclear business, risk is defined as Risk = Frequency $\times$ Consequence. According to this definition, we could show that the risk is not significant in case the frequency is extremely low even though the consequences from a severe accident are huge. Nuclear power plant was shown to satisfy the safety goal using this logic for most cases. But the frequency does not have any meaning for the people living near a nuclear power plant at the time of accident. For that situation, the risk accepted by the public must be considered as Risk = Hazard + Outrageous which is developed for risk communication with the public.

The difference between the definitions of risk is depicted conceptually in Fig.2 below. If we suppose fatality from base accident is 20 in a city with 2000 people, the average risk becomes 0.01(=20/2000) per year. Now suppose that a nuclear power plant operates normally for 49 years but a severe accident occurs at 50^{th} year and mortality rises up to 1000. In this case we, the nuclear community, calculate the risk to be 0.01 (=1000/2000/50) per year, but the risk recognized by the public living near the plant at the time of accident is just 0.5 (=1000/2000), 50 times higher than our estimation. So the acceptance of the current QHO developed on the premise of the above logic needs to be critically evaluated. This is clearly proven in the recent Fukushima accident occurred at May, 2011. Until the accident Fukushima BWR plant was claimed one of the most safe plant because the core damage frequency was very low.

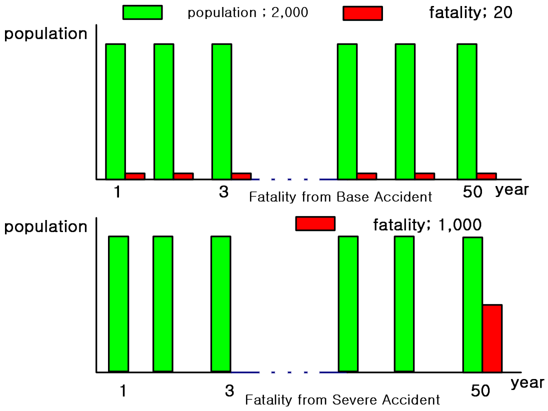

Fig. 2. Concept of Fatality

Actually all the evaluation performed for operating plants in Korea using the concept of risk satisfy this goal. But our previous deterministic analyses [3] showed that the containment pressure should be maintained below P_{DBA} to satisfy the QHO for some accident scenario. So we must keep in mind that nuclear plants are designed to satisfy various code and standards first, and then satisfying the safety goal is shown generally later, for other purposes, in probabilistic terms. The safety goal is not a binding goal to be reflected in the current deterministic design process.

2.2 General Design Criteria

Domestic Technical Standards correspond to GDC of Appendix A to 10CFR Part 50 and is a top level safety requirement just next to the safety goal in regulatory framework of both countries. Art.28 or GDC 25 is titled "reactivity control system redundancy and capability" and it requires two independent reactivity control systems of different design principles shall be provided. It also requires that " one of the system shall use control rods, ~ . The second reactivity control system shall be capable of reliably controlling the rate of reactivity changes resulting from planned, normal power changes (including xenon burnout) ~". This is the reason why the current PWR has two reactivity control systems, one with control rods and the other with boron. This GDC ,expressed in deterministic way and coming from the application of DID, surely contributed to the safety of the current. But it does not show how having the two independent reactivity control system is in connection with the safety goal. Also remember that this GDC was established at early 70's and it has no direct connection with safety goal which was established at 80's.

2.3 Acceptance Criteria for DBA Design

Safety objectives are implemented through dose acceptance criteria for design basis accidents. The dose criteria are prescribed in 10 CFR 50.67[4] as follows ;

a) An individual located at any point on the boundary of the exclusion area boundary (EAB) for any 2-hour period following the onset of the postulated fission product release, would not receive a radiation dose in excess of 250 mSv total effective dose equivalent(TEDE)

b) Adequate radiation protection is provided to permit access to and occupancy of the control room under accident conditions without personnel receiving radiation exposures in excess of 5 mSv TEDE for the duration of the accident.

But we must keep in mind that the use of 250 mSv TEDE is not intended to imply that this value constitutes an acceptable limit for emergency doses to the public under accident conditions. Rather, this 250 mSv TEDE value has been stated as a reference value, which can be used in the evaluation of proposed design basis changes with respect to potential reactor accidents of exceedingly low probability of occurrence and low risk of public exposure to radiation. Thus, still these acceptance criteria are not closely tied with the current QHO.

4. Conclusion

In this paper, we have recapitulated the current design practice regarding the safety goal, GDC, and the acceptance criteria for DBA design. And it was shown that the safety goal is established and used to show that the current operating plants satisfy the goal in probabilistic terms. The safety goal is not a criterion incorporated in design process. But the Fukushima accident requires a paradigm shift in safety and we believe the only way to cope with the expectation of public is to provide an ultimate safety of nuclear plant in more systematic way starting with the safety goal the public accepts. Efforts in this approach should be pursued , at least for future reactors like HTGR.

REFERENCES

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[3] Namduk SUH , Changwook HUH, Deterministic Evaluation of Quantitative Health Objective and Target of Severe Accident Management, OECD/NEA Workshop ISAMM-2009, Swiss, 2009

[4] USNRC, CFR Part 50, Domestic Licensing of Production and Utilization Facilities, Sec 50.67 Accident Source Term, 10CFR50.67