The approaches on the determination of frequency-consequence criteria for risk assessment of new reactors

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1. Introduction

The risk is often expressed in terms of surrogate measures such as core damage frequency (CDF) or large early release frequency (LERF), even though the risk in LWR PRAs can be generally expressed as a consequences resulting from exposures. These surrogate measures and the criteria associated with them are LWR-specific and not applicable to all reactor designs. Therefore, a criterion that specifies limiting frequencies for a spectrum of consequences, from none to very severe, needs to be established for new reactors. Based on this concept, NRC proposed the Technology Neutral Framework's frequency-consequence (F-C) curve derived from current regulatory requirements. Each country has also proposed or stipulated various F-C criteria for new or existing reactors. In this paper, F-C criteria for new reactor licensing or existing LWRs in each country are systematically surveyed and analyzed in order reasonably to determine the appropriate F-C criteria.

2. NRC Approach to Technology Neutral Framework of F-C Curve

In the risk-informed and performance-based licensing process being proposed by the NRC, the acceptability of plant risk is represented by a Frequency-Consequence (F-C) curve which depicts acceptable limits in terms of the frequency of potential accidents or abnormal events, and their associated consequences. The F-C curve, shown in Figure 1, has been plotted with current USNRC regulatory requirements specified in 10 CFR Parts 20, 50 and Part 100.

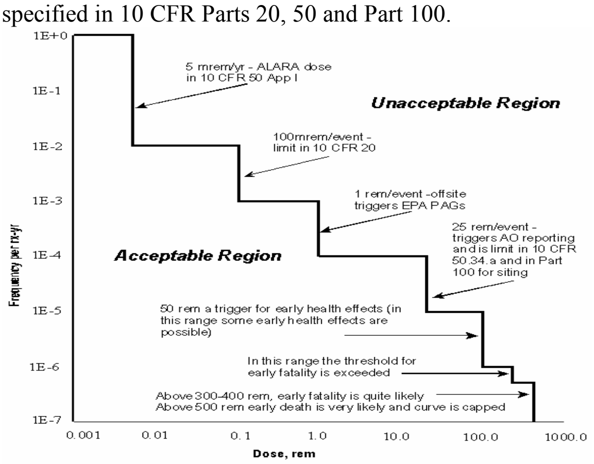

Figure 1: USNRC F-C curve for Tech.-Neutral Framework

This F-C curve has been recently proposed by USNRC as a criterion for selecting licensing basis events (LBEs) that will be used instead of the design basis events (DBEs) or design basis accident (DBA) applied to the LWRs.

3. Comparison of F-C Criteria derived from various guidelines

The principle underlying the F-C curve is that event frequency and dose are inversely related, i.e., the higher the dose consequences, the lower is the allowed event frequency. Various F-C criteria for each country have been compared with NRC's NUREEG-1860. From the standpoint of dose requirements, each F-C curve has plotted and classified into 3 categories according to the conceptual similarity and characteristics as follows:

- *The case #1, Conservative multi-stepped F-C criteria: Canada (C-6) & Switzerland, etc.*
- *The case #2, Limit-to-objective buffed F-C criteria: ICRP 64 & U.K., etc.*
- *The case #3, Significant dose-based F-C criteria: Canada (RD-337), SA & China, etc.*

3.1 Conservative multi-stepped F-C criteria

Figure 2 shows Conservative Multi-stepped F-C criteria derived from CANADA(C-6R1) & Wolsong unit 2 in Korea, Switzerland and ANSI N51.1. As a result, the F-C criteria proposed by NUREG-1860 are more conservative than those of any other guides except for Switzerland's criteria and ICRP 64's target in frequency ranges above 10^{-4} and are less conservative than those any other guides except for ICRP 64's and HSE's limit in frequency ranges below 10^{-4}.

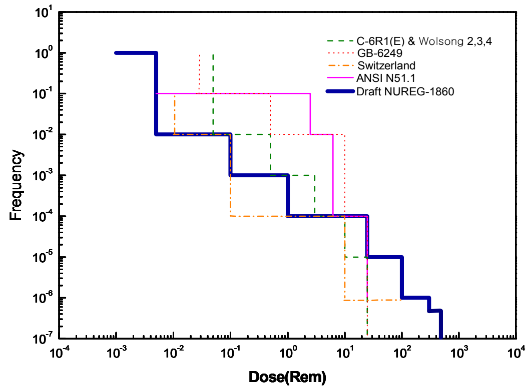

Figure 2: Conservative multi-stepped F-C criteria

3.2 Limit-to-objective buffed F-C criteria

Figure 3 shows Limit-to-objective buffed F-C criteria derived from ICRP 64 and HSE in U.K.

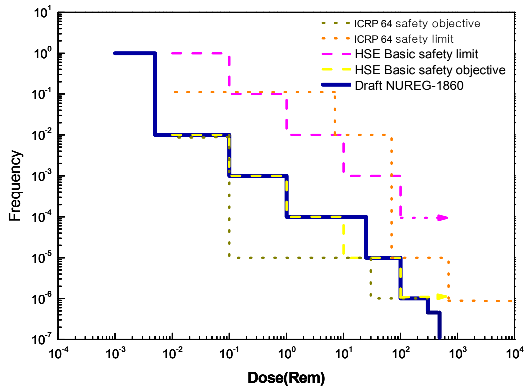

Figure 3: Limit-to-objective buffed F-C criteria

As an evaluation, the HSE's dose target is approximately same to that of NUREG-1860 up to frequency ranges, 10^{-6}.

But, the HSE's dose target is more conservative than that of NUREG-1860 in the frequency range of 10^{-4} ~ 10^{-5}. The HSE's dose limit is less conservative than that of NUREG-1860 in full frequency ranges. The ICRP 64's dose target is same to that of NUREG-1860 in the frequency range above 10^{-3} and more conservative that that of NUREG-1860 in the frequency range below 10^{-3}. The ICRP 64's dose limit is less conservative than that of NUREG-1860 in full frequency ranges.

3.3 Significant dose-based F-C criteria

Figure 4 shows Significant Dose-based F-C criteria derived from South Africa(LG-1037), China(HTR-PM) and Canada (RD-337). As a result, the dose criteria of NUREG-1860 is more conservative than that of any other case in the frequency range above 10^{-4} except for HTR-PM case of China and less conservative than that of any other case in the frequency range below 10^{-4}.

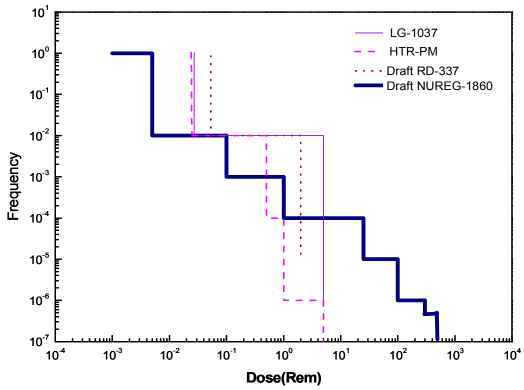

Figure 4: Significant dose-based F-C criteria

The frequency in the F-C curve proposed by NUREG-1860 is based on accident sequence which is resulted from full scope PSA. In the F-C criteria, the frequency of accident sequence applies to other cases such as ICRP 64, etc. But, for South Africa (LG-1037) and CANDA (RD-337), the frequency of the F-C criteria is applied to only the likelihood of initiating events.

The consequence level proposed by NUREG-1860 are more conservative than those of any other guides except for Switzerland's criteria and ICRP 64's target in frequency ranges above 10^{-4}. These dose criteria are firmly based on existing regulations (10 CFR) concerning radiological dose limits. And each dose criterion for those frequency ranges proposed by NUREG-1860 is well supported by the analysis results of pre-application of new reactor such as MHTGR, PBMR. But, the consequence level proposed by NUREG-1860 is less conservative than those any other countries except for ICRP 64's and HSE's limit in frequency ranges below 10^{-4}. Especially, each country has very different consequence level in this frequency region below 10^{-4}. So, the method for determining each consequence of this rare event or accident sequence needs to be properly selected for specific risk assessment.

It is expected that these determinations of consequence level in these frequency ranges greatly depend on the siting and site specific considerations (site boundary, emergency planning, etc.) for new reactors. For a new reactor having minimized offsite emergency preparedness, the dose criteria would lead to be significantly lower in the frequency ranges of rare events in contrast of NUREG-1860, ICRP 64, etc. For example, the consequence level of existing DBA will even be able to apply to the frequency ranges of rare events for the design of a specific new reactor. The assumption can be inferred from Figure 4, the case #3 of F-C Criteria, which LG-1037 and HTR-PM have consequence level similar to or less than that of DBA in the frequency ranges of rare events in contrast of that of NUREG-1860 which is based on technology neutral framework considering various reactors.

4. Conclusion

This paper presents the comparison of F-C curve for the innovative reactor licensing or existing reactors in various countries. It shows that three types of F-C criteria were represented, i.e. multi-stepped conservative F-C criteria, limit-to-objective buffed F-C criteria, practical dose significant F-C criteria. The F-C criteria proposed by NUREG-1860 are more conservative than those of any other guides except for China's case, Switzerland's criteria and ICRP 64's target in frequency ranges above 10^{-4}. And, those are less conservative than those any other guides except for ICRP 64's and HSE's limit in frequency ranges below 10^{-4}. Especially, each country has very different consequence criteria in this frequency region below 10^{-4}. So, the methods for determining each consequence of this rare event or accident sequence needs to be properly selected in specific risk assessment.

In summary, the determination of F-C criteria for new or existing reactors will depend on the selection of frequency ranges (i.e., initiating events or accident sequences), consequence level (existing national regulations concerning radiological dose limits, dose related to early health effect), and especially siting characteristics of new reactors. (i.e., emergency planning, etc) It could be expected that these results derived from this survey would be very usefully utilized in developing specific or technology-neutral regulatory framework.

References

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