Transactions of the Korean Nuclear Society Spring Meeting
Jeju, Korea, May 18-19, 2017

Legislation of Accident Management and Related Issues

Ku Young Chung [a*] and Kyun Tae Kim [a]
[a]*Korea Institute of Nuclear Safety, 62 Gwahak-ro, Yuseong-gu, Daejeon, 34142, Republic of Korea*

[*]*Corresponding author: Ku.Chung@kins.re.kr*

1. Introduction

To legislate for the regulatory control of accident management including severe accident management, the Nuclear Safety Act (NSA) was amended in June 2015 [1]. As the effective date of the amendment of the NSA was set to be the 23rd of June 2016, the subsequent rulemaking for the implementation of the amendment of the NSA was completed by June 2016 and the regulatory framework on accident management including the management of severe accident is currently in effect. As required by the amended NSA, the applicant for operating license of a nuclear power plant (NPP) shall submit an accident management program (AMP) and its contents shall meet the pertinent regulatory requirements which were set forth by recently completed rulemaking efforts. This paper provides technical backgrounds for the regulatory requirements for an AMP and discusses the anticipated issues for its implementation.

2. Basic Considerations for Regulatory Framework on Accident Management Program

This section introduces basic concepts utilized for the development of the regulatory framework for the AMP, which mainly addresses how the framework incorporates the defense-in-depth (DiD) principle and recent international efforts for the enhancement of the safety of NPPs after the Fukushima Daiichi accident.

2.1 Reinforcement of Defense-in-Depth

The DiD principle is one of the fundamental design principles since the earliest use of nuclear energy and the means of ensuring safety in the peaceful uses of nuclear energy have progressed from early simple concepts and methods into a methodology resting on a firm foundation of experience [2]. The importance of robust DiD levels in design and operation of NPPs has been emphasized since Fukushima Daiichi accident.

The DiD levels related to the accident condition are explicitly considered in the new regulatory framework for severe accidents as summarized in Table I [3]. The accident conditions are categorized into three DiD levels, which are design basis accident (DBA), prevention of severe accident (SA) and mitigation of SA. In the level of prevention of SA, accidents resulting from multiple failures of safety features and beyond design basis external events are considered.

Table I: Defense-in-Depth Levels for Accident Conditions

Level	Plant State (Accident Condition)	Essential Means
DBA	- Single failure - Design basis external event	- Safety systems including Engineered safety features - EOP
Prevention of SA	- Multiple failure - Beyond design basis external event	- SA prevention features - EOP and/or SA prevention guidelines
Mitigation of SA	- Core melt	- SA mitigation features - SAMG and/or SA mitigation guidelines

2.2 IAEA Vienna Declaration on Nuclear Safety

The IAEA Vienna Declaration on Nuclear Safety (VDNS) [4] provides three safety principles for nuclear power plants (NPPs) and the first principle says that "new NPPs are designed, sited and constructed consistent with the objective of preventing accidents and mitigating possible releases of radionuclides causing long-term off site contamination and avoiding early radioactive releases or radioactive releases large enough to require long-term protective measures and actions". The safety principles are adopted to reflect lessons learned from Fukushima Daiichi accident which resulted in long-term off site contamination of radioactive materials in the vast area near the plant.

The key elements of the safety principles of the VDNS are incorporated into the new regulations which require that the licensee shall establish the objectives of accident management and perform the evaluation to assure that a severe accident is prevented and, should it occur, its consequence is mitigated so as to limit radioactive dose of the public and prevent the large release of radioactive materials that can result in off-site contamination.

2.3 Harmonization of Previous Regulatory Activities

The first stage of regulatory control against severe accidents in Korea started with implementing the TMI action items of the United States Nuclear Regulatory Commission (US NRC) [3]. In 2001 the Nuclear Safety Commission pronounced Severe Accident Policy to establish a systematic regulatory control framework for severe accidents, which addresses [3]:

- Safety goals (quantitative health objectives),
- Probabilistic safety assessment (PSA),
- Severe accident prevention and mitigation capabilities, and
- Severe accident management program.

As required by the Severe Accident Policy and its subsequent administrative orders, the licensee performed PSAs and developed severe accident management guidelines (SAMGs) for all operating NPPs. For the new NPPs, additional design measures for the prevention and mitigation of severe accidents [3]. The new regulations accommodates these previous regulatory actions based on the Severe Accident Policy and pertinent administrative orders with some necessary modifications to reflect IAEA VDNS and other recent international efforts to enhance nuclear safety after Fukushima Daiichi accident.

3. Regulatory Requirements and Anticipated Issues on Accident Management Program

This section explains six key elements of the new regulations on AMP and anticipated issues for some key elements are also discussed.

3.1 Accidents Resulting from Multiple Failures

In a design of NPP, DBA conditions assumes postulated initiating event followed by one of the most significant failures of safety systems. This means that accidents involving multiple failures of safety features are not considered as DBAs and historically these accidents are referred to as beyond design basis accidents. But recent IAEA safety standard for the design of NPP [5] requires that the design of new NPP shall consider accidents resulting from multiple failures of safety systems and refers these accidents as design extension conditions (DECs) rather than beyond design basis accidents.

New regulations consider the following nine accidents associated with multiple failures of safety systems [6] as one of the categories of the accident conditions that the AMP shall control, as listed in the Table I.

- Anticipated transient without scram (ATWS),
- Station black-out (SBO),
- Multiple steam generator tube rupture (MSGTR),
- Total loss of feed water (TLOFW),
- Inter-system loss of coolant accident (ISLOCA),
- Loss of shutdown cooling (LOSC),
- Loss of ultimate heat sink (LUHS),
- Small break loss of coolant accident in combination with loss of safety injection or recirculation,
- Loss of spent fuel pool cooling.

New regulation also requires that the licensee shall properly consider additional accidents resulting from multiple failures of safety features based on the result of PSA.

As required by the new regulation, the licensee shall provide the sufficient information that can show the NPP can prevent significant core damage against the considered accidents resulting from multiple failures. The information can be based on the best-estimate analyses.

3.2 Beyond Design Basis External Events

The other one of the accident conditions considered by the AMP to prevent significant core damage is beyond design basis external events. This category is considered based on the lessons learned from Fukushima Daiichi accident, which was caused by an earthquake and tsunami whose magnitude and strength was beyond the design bases.

New regulation requires that the AMP shall consider accident conditions resulting from one of the following beyond design basis external events (BDBEEs).

- Beyond design basis natural events (earthquake, tsunami, etc.),
- Intentional aircraft impact, or
- Combination of consequential damages resulting from a beyond design basis natural event or an intentional aircraft impact.

As required by the new regulation, the licensee shall provide the sufficient information that can show the NPP can restore and maintain essential safety functions including fuel cooling of reactor core and spent fuel pool, and containment function against considered BDBEEs. To restore and maintain the safety functions, the role of mobile equipment is important.

An anticipated issue in the prevention capability against BDBEEs is about the numbers and capacity of mobile features in a site with multiple NPP units. New regulation requires that the prevention capability consider the possibility of simultaneous damage of multiple units in the site so that sufficient number and capacity of mobile features, staffing and appropriate command and control system is provided to respond such an accident condition. Some mobile equipment required by the Fukushima Action Items [7] is considered to be used by multiple units in a site but new regulations have changed the regulatory position not to allow the mobile equipment can be shared by multiple units in a site. The licensee should reassess the response capability with the assumption that multiple units in a site are simultaneously damaged by a BDBEE, and provide sufficient mobile equipment to control the situation.

3.3 Severe Accident Phenomena

Even though the prevention against accidents resulting from multiple failures or BDBEEs are provided, DiD approach in Table I requires another level for the mitigation of severe accidents assuming that severe accidents can happen. The purpose of this level is to maintain containment function to limit the release of radioactive materials to the environment after the core melt. New regulation requires that the containment function of a NPP shall be kept against the following threats arising after significant reactor fuel damage [6].

- Combustion or explosion of combustible gas,
- High pressure/temperature inside the containment,
- Fuel-concrete interaction,
- High pressure melt ejection,
- Direct containment heating,
- Fuel-coolant interaction, and
- Containment bypass including steam generator creep rupture.

The basic acceptance criterion is that the NPP shall eliminate or withstand the considered threats to maintain the containment function of limiting the release of radioactive isotopes to the environment. The specific acceptance criteria can be applied to each of threats. For example, during the progression of severe accidents the hydrogen concentration inside the containment shall be maintained low enough to ensure that the detonation of hydrogen is prevented.

3.4 Consequence Analysis

Before the legislation of accident management, consequence analysis to estimate the expected radiation dose to the public was performed only for DBAs. New regulation expands the scope of consequence analysis to all accident conditions covered by the AMP. This means additional consequence analyses shall be performed for accident conditions resulting from multiple failures, BDBEEs and severe accidents. These analyses can be based on best-estimate methodology for appropriate accident scenarios obtained from PSA insights.

The acceptance criteria for the consequence analyses for accident conditions considered in AMP is 250mSv or less at the plant boundary, which originates US NRC sitting criteria 10 CFR part 100 [8].

An anticipated issue in the consequence analyses for accident conditions resulting from multiple failures, BDBEEs and severe accidents is about the analysis assumptions and methodologies. The regulatory guide for consequence analysis [9] allows the use best-estimate methodology and realistic assumptions, which means that widely used best-estimate computer codes for source term evaluation of severe accidents like MELCOR [10] or MAAP [11] can be used for the consequence analysis. More detailed regulatory positions for consequence analysis are to be provided as a safety review guideline of KINS by the end of 2017.

3.5 Probabilistic Safety Assessment

PSAs for NPPs are performed on the basis of the implementation of the Severe Accident Policy in 2000s. New regulation stipulates quantitative health objectives as one of the objectives of the AMP and require the licensee to perform PSAs to confirm the health objectives are met. New regulation also adds additional objective related to the off-site long-term contamination, which is to limit the possibility of the large release of Cs-131. The specific objectives to maintain the acceptable low risk of a NPP are as follows [6].

- Early and cancer fatality risk shall be less than 0.1% of the total risk, or equivalent performance goal shall be met,
- The total frequency of the accidents with the release of more than 100TBq of radionuclide Cs-137 should be less than 1.0×10^{-6}/year

An anticipated issue in the PSA is about how to evaluate the frequency of the accidents with the release of more than 100TBq of radionuclide Cs-137, which is new to the PSA experts in Korea. Another issue is about how to reflect recent safety enhancements like mobile equipment after Fukushima Daiichi accident into the PSA modelling. KINS will review international approaches on the mentioned issues and set regulatory positions in a safety review guideline by the end of 2017.

3.6 Accident Management Strategy and Implementation

New regulations require that an AMP shall provide specific information on accident management strategy as an integrated strategy to cover all types of accident conditions in Table I, which explains how the NPP can stop the progression of an accident, mitigate its consequence and restore the plant into a safe condition. The strategy consists of the identification of key safety function, diagnosis of plant damage and overall actions to restore safety functions, and the structure and interface control of accident management procedures and guidelines, including emergency operating procedures (EOP), procedures and guidelines for BDBEE, and SAMG [12].

The implementation framework of AMP consists of staffing, command and control, integration of functions to implement accident management strategy, and testing, surveillance, inspection and maintenance program for equipment used for accident management [12].

4. Conclusions

Major contents of recently completed legislation of accident management are introduced and their technical backgrounds are discussed. The new regulations for the AMP requires various evaluations and assessments to assure that the severe accident is appropriately prevented and, should it occurs, its consequence is appropriately mitigated enough to protect people and the environment. For development of an AMP, a few anticipated issues are introduced, which are mainly related to the absence of specific safety review guidelines. These guidelines are to be developed by the end of 2017 and that can enhance the consistency of the regulation of AMPs.

REFERENCES

[1] "Nuclear Safety Act", Law no. 13389, 2015.
[2] IAEA INSAG-10, "Defence in Depth in Nuclear Safety", 1996.
[3] K. Chung, S. Lee, "Enhancement of Nuclear Safety in Korea: A Regulatory Perspective", International Conference on Effective Nuclear Regulatory Systems: Sustaining Improvements Globally, Vienna, Austria, 11-15 April 2016.
[4] IAEA CNS/DC/2015/2/Rev.1, Vienna Declaration on Nuclear Safety, Vienna, Austria, 9 February 2015.
[5] IAEA Safety Standards SSR 2/1, "Safety of Nuclear Power Plants: Design (Rev. 1)", Vienna, 2016
[6] Nuclear Safety and Security Commission Notice No. 2016-02, "Regulation on specific standards for the scope of accident management and the evaluation of accident management capabilities", Seoul, 2016.
[7] Seon H. Song, "Regulatory Actions and Follow up Measures against Fukushima Accident in Korea", Int'l conference on Effective Nuclear Regulatory Systems, April 9, 2013, Canada.
[8] 10 CFR part 100, "Reactor Site Criteria", US NRC.
[9] KINS regulatory guide No. 16.4, "Consequence analysis of accident", 2016.
[10] L.L. Humphries et al. "MELCOR Computer Code Manuals, Vol. 1: Primer and Users' Guide, Version 2.1.6840," SAND 2015-6691 R, Sandia National Laboratories, August 2015.
[11] EPRI Technical Report, "Modular Accident Analysis Program 5 (MAAP5) Application Guidance", 2015.
[12] Nuclear Safety and Security Commission Notice No. 2016-03, "Regulation on the preparation of accident management program", Seoul, 2016.