The Development of Regulation Guideline Manual Regarding Beyond Design Basis Accident and Severe Accident

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Abstract: After Fukushima accident, many countries have analyzed Fukushima accident and established action plans for evaluation and development of emergency response facilities and emergency response organization for further improvements to nuclear safety and emergency protection. In Korea, the stress test for 2 units of operating nuclear power plant(NPP) was fulfilled as Fukushima follow-up measures. Reflecting the lessons learnt from Fukushima accident and the experiences of stress tests in Korea, the issues of human and organizational factors under beyond design basis accident (BDBA) and severe accident (SA) conditions should be addressed systematically during the design process of a new NPP under construction. According to the Nuclear Safety Act (NSA) revised and promulgated on June 22, 2015, operating licensees or applicants are required to submit an accident management plan (AMP) which describes the organizational responsibilities, equipment, and procedures or guidelines for implementing the accident management strategy. According to new Nuclear Safety and Security Commission (NSSC) rules, the AMP should be developed to cover accident including BDBA and SA. And human factors aspects also should be considered in AMP. In this matter, Korea Institute of Nuclear Safety (KINS), which is a technical support organization, developed the regulatory guideline supplement the existing regulatory guidelines related to human factors engineering program. It presents additional requirements to address HOF(Human and Organizational Factors) issues related to BDBA and SA conditions during the design process of a new NPP under construction. And for helping practical and comprehensive application of regulatory guideline for new NPP, the handbook has been developed. In this paper, the method and consideration for each human factors element of regulatory guideline are researched based on emergency response facilities and organization in BDBA and SA

Keyword: Fukushima accident, Human factor, Beyond design basis accident, Severe accident

1 Introduction

A NPP includes various human, technical, organizational factors, and complicated socio-technical system susceptible to occur unpredictable conditions by the interaction of these factors and external environment. Consequently, administrator and regulatory authority should recognize that abnormal and accident condition not considered in the design process, and prepare for emergencies. As the lessons learnt from Fukushima accident, it is necessary to enhance the capabilities to prevent or mitigate against unexpected and rare events such as beyond design basis events and severe accident[1].

After Fukushima accident, many countries recognize important issue to have enough capability for accident management to assure the safety of NPPs under the conditions of beyond design basis events and severe accident[2] [3] [4].

Accordingly, In Korea, Nuclear Safety Act (NSA) revised and promulgated on June 22, 2015, operating licensees or operating license(OL) applicants are required to submit an accident management plan(AMP) which describes the organizational responsibilities, equipment, and procedures or guidelines for implementing the accident management strategy. According to new Nuclear Safety and Security Commission(NSSC) rules, the AMP should be developed to cover the following accident conditions: design basis accidents(DBAs), accident caused by multiple failures, beyond design basis external events(BDBEEs), and severe accident(SA). In this regulatory guideline, BDBAs refer to the accident caused by multiple failures or BDBEEs. Moreover, the rule of ‘Regulations on Technical Standards for Nuclear Reactor Facilities, etc.’, prescribes that human factors shall be taken into account to develop accident management strategy and implementation methods. Therefore, accident

management measures should be developed by reflecting the human factors principles to accommodate the capabilities and limitations of accident management staffs.

Consequently, KINS(Korea Institute of Nuclear Safety), Korea nuclear regulatory authority, developed guideline for additional requirements to address human and organizational factors issues related to BDBA and SA conditions during the design process of NPP[5].

However, the guideline suggest the requirements related BDBA and SA condition issue, so it is need for applicants to a detailed material which describe practical guidance and application measure of newly developed guideline. For this reason, KINS has been researched the manual for applicants to apply the newly developed guideline for considering BDBA and SA to NPP.

The manual is developed focused on human factors which applicants have to consider to human factors program review model(HFEPRM) in NUREG-0711 according to the accident management plan implementation[6]. Therefore, the manual present established human factors activities, revised Nuclear Safety Act, human factors activities considered BDBA and SA to help understanding for applicants which should apply and implement the guideline. And, in the process of manual development, the important factors which need further consideration for accident management plan is selected.

2 Method

2.1 Development approach

This research considered important principle in the manual development process as follows.

First, the manual identifies considerations for each human factors in HFEPRM based on accident management facility. In this study, the mobile generator, mobile seawater pumper, firefighting pumper, Emergency Containment Spray Backup System(ECSBS), Containment Filtered Venting System(CFVS) were considered as accident management facilities.

Second, the manual describes the analysis method for each human factors based on stress test experience to promote applicants understand and apply the newly developed guideline. In the manual, it is referred to the stress test result of Kori 1 Unit conducted in 2014[7].

2.2 Development process

The manual was developed through (1) review of literature, stress test experience issue, expertise suggest in the guideline development process and (2) collect comments of advisory group consist of applicant, designer, researcher.

2.1.1 Review of issues and contents identified in the guideline development process

The guideline was developed base on literature review, stress test experience, academic professional opinion to identify guideline requirement, and improved reliability through in-depth review of working group consist of various experts. In this process, literature related to BDBA and SA research could be review, and various issue and resolution approach considering BDBA and SA condition could be discussed. Through this process, it was identified issue and considerations which were not reviewed in the guideline development process, and analysis of human factors in HFEPRM in the BDBA and SA condition.

2.1.2 In-depth review of multidisciplinary experts

The manual was review by multidisciplinary 6 experts including applicants, designer, researcher, and professor. Applicants comments about current state of accident management facility preparations and design for construction NPP and operation NPP. Designers review various limitations of human factors in BDBA and SA condition, and suggested task analysis approach based on accident scenario. Researchers and Professor reviewed the validity of analysis approach for each human factors, and relevant research and legal requirement. Through this process, the issues and limitation for each human factors, and resolution approach were considered from various standpoint.

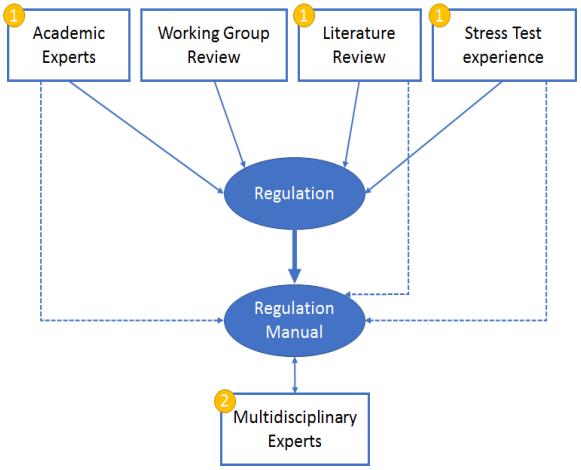

Fig.1 Manual development process frame

3 Result

The manual reflected human factors considerations and related to BDBA and SA condition refer to stress test experience of Kori Unit 1, and suggest analysis method of accident management facility for each HFEPRM factors. This research described the analysis case of task analysis and human factors verification and validation which provide important effect and result to other factors in HFEPRM.

3.1 Task Analysis

Task analysis is conducted to analyze operation tasks which operators should perform to prevent and mitigate accident for power plant safety from high level task to detailed level task step by step, and identify the task characteristics and task requirements such as alarm, response, teamwork, and workplace factor, etc. The task analysis such as hierarchical task analysis(HTA) and task decomposition were conducted through select representative procedure, and identify task requirements for each task step in design basis accident(DBA) condition. However, these analysis can be carried out because the procedure such as emergency procedure is not yet developed in BDBA and SA condition. In addition, under the BDBA and SA conditions, the tasks for accident management could be varied depending on plant conditions. Therefore, it is necessary to conduct task analysis based on the accident scenarios.

The manual described the case study of task analysis based on the scenario which carry out comprehensive evaluation of earthquake, tsunami, and other natural disaster, loss of safety function, severe accident, disaster prevention and emergency response capability was selected among the stress test scenarios of Kori 1 Unit. And the task analysis was fulfilled focused on (1) important operation task, (2) staffing composition, (3) suitability of available time and required time for each task.

In this research, the scenario which station black out including Alternative Alternating Current Diesel Generator(AAC DG) accompanied by loss of ultimate heat sink with 0.3g earthquake was selected for case study of task analysis in BDBA and SA condition. In this condition, operators decide the optimum path of operation procedure such as figure 2, and response to the accident.

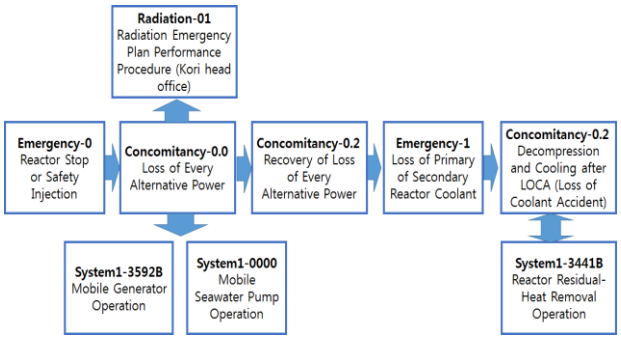

Fig. 2 The optimum path of operation procedure

After determine the optimum procedure path for accident scenario, the scenario assumption such as task, performance goal, success and failure criteria for each procedure in scenario. Table 1 describes the scenario assumption result of mobile diesel generator operation procedure(system 1-3592B) in accident scenario in figure 2.

The available time and required time should be verified during task analysis for reliability and availability of important human action analysis in BDBA and SA condition. Thus, it is necessary to analyze the action and role of accident management staff. In the manual, it is describes the framework which propose the analysis of operator assignment, operator performance, evaluation criteria including performance error and time, etc. (Table 2)

Table 1 Scenario assumption and basis (mobile generator)

Procedure (performance step)	System 1-3592B (mobile generator operation)
Task	Mobile Generator(MG)
Performance goal	Connect operation of MG to class line XSW-2A or XSW-2B
Success criteria	After MG operation request, connect MG to one of class line and initiate power supply in 2 hours
Failure criteria	Fail to connect and initiate power supply to one of class line because of communication, lack of operator, work environment,

Table 2 Framework example of task analysis in BDBA and SA (mobile generator)

Step-9.6.1	Local Performance
Assignment	EO, AO1
Operator performance	Input incoming line breaker(52/M-AAC A or 52/M-AAC B) to channel by control of breaker input button of AAC DG remote control board in MCR or high voltage distribution board in local.
Evaluation criteria	1. Assignment of local operator and redundancy of emergency operation performance. 2. Barrier factor such as light of moving route, entrance, etc. 3. Adequacy of communication facility 4. The required time to open/input breaker 5. Breaker input method in the loss of DC power
Evaluation	Omission, Performance error, Completion time

3.2 Human Factors Verification and Validation

In BDBA and SA condition, it is necessary to verify and valid that operators have capability to response accident and conduct safe operation according to scenario assumption, and identify limitations and problems such as facility, operator level, moving path, environment, etc. from various perspective. The manual describes the scenario result of Kori 1 Unit stress test to enhance effective understanding. Table 3 describes the result of mobile generator operation of team 1.

According to scenario performance result, most of task steps were fulfilled to success criteria appropriately. However, some of task steps were not satisfy the success criteria because of limitation of facility, power plant operation status, evaluation time, etc. The mobile generator operation was also faced with validation limitation by power plant operation status.

The manual reviewed considerations to evaluate operator's capability for response to BDBA and SA condition in terms of validation process, evaluation subject, participants, scenario, equipment, etc. by comparing to DBA condition.

Table 3 The performance result of accident scenario validation (mobile generator)

Procedure (performance step)	System 1-3592B (mobile generator operation)
Success criteria	After MG operation request, connect MG to one of class line and initiate power supply in 2 hours
Performance result	After SBO(station black out), Initiate power supply to class line A in 1 hour 51 minutes 40 seconds
Success/Failure	Although mobilization of mobile generator, the evaluation of cable connection and breaker control was fulfilled virtually because the NPP was in operation.

4 Discussion and Conclusion

The purpose of manual development is for applicants to apply guideline which reflected human factors consideration related to BDBA and SA condition for each HFEPRM factors practically to NPP. In the process of manual development, important consideration for manual application was suggested from multidisciplinary experts' depth-review process as follows:

First, under the BDBA and SA conditions, the tasks for accident management could be varied depending on plant conditions. For that reason, task analysis of BDBA and SA condition may be performed based on accident scenario rather than procedure. And the tasks for accident management should be identified by treatment of important human action. Accordingly, treatment of important human action will be preferential factors which should be performed first in the HFEPRM. Thus, it should be regarded as important activity that identify basis of accident scenario selection in the process of task analysis considering BDBA and SA condition.

Second, for human verification and validation considered severe accident such as stress test,

various limitations should be resolved beforehand as follows:

- severe accident management guideline and procedure development completion
- enough operator to respond to BDBA and SA including main control room operator, local operator, emergency facility operator
- assurance of local availability
- organization based on training program
- assurance of simulator fidelity considered BDBA and SA model

Third, it is need to develop the analysis strategy of HFEPRM factors for each operation NPP and construction NPP. The operation and construction NPP has difference of preparation of accident management facility. Operation NPP in Korea, has preparation strategy of mobile generator, mobile pump, and integrate place for heavy equipment, with the exception of mobile seawater pump and firefighting pumper. Construction NPP, on the other hand, may not demand mobile generator and mobile seawater pump by additional installation and design improvement of AAC DG. Therefore, when it apply the guideline and manual, applicants and regulatory authority should recognize that operation NPP and construction NPP could have different strategy in terms of functional requirement analysis and functional allocation, task analysis, staffing and qualification, and human performance verification and validation, etc.

The establishment of regulation related to BDBA and SA still need much research and discussion. The limitation described above also one of subjects should be resolved by discussion between applicants, regulatory authority, designers, researcher. KINS will be conduct stress test gradually targeting operation NPP in Korea, and it is expected that some of these limitation would be resolved or considered. And the manual would provide for applicants to apply newly demanded requirement in accident management plan practical to NPP through valuable guidance of analysis and consideration in BDBA and SA condition for each HFERRM factors. And this manual will be utilized to not only construction NPP, but also operation NPP by reference material for stress test evaluation.

5 References

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