



Human Factors Review Guide for Korean Next Generation Reactor

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ABSTRACT

Recent applications of advanced electronic technology and automation to the man-machine interface designs of nuclear power plants result in changes of the operators' role and control room design concepts. The differences between advanced control room designs and conventional ones also invoke a new paradigm for human factors regulatory review requirements. In this new paradigm, human factors review should be focused on design process as well as human factors products. In Korea, as a part of the project named "Development of Safety and Regulatory Requirements for Korean Next Generation Reactor," human factors safety regulatory guides are under development at the Korea Institute of Nuclear Safety. The objective of this study is to develop guides for human factors review based on the NUREG-0711 to support the development of Korean human factors safety regulation guides.

This paper describes consideration in the application of NUREG-0711 to the Korean Next Generation Reactor and the development of a computerized system containing comments from the consideration and selected information from references to support the development of human factors safety regulatory guides and possibly the application of these guides.

INTRODUCTION

Human operators play important roles in maintaining the safety of nuclear power plants. Meanwhile, human factors are major factors lessening the safety and productivity of nuclear power plants. This is evident from the fact that human factors were involved in accidents at Three Mile Island (TMI) and Chernobyl nuclear power plants and a considerable portion of nuclear power plant events have occurred due to human error.

After the TMI accident in 1979, which drew concerns on the safe operation of nuclear power plants, U.S. NRC published NUREG-0737 Clarification of TMI Action Plan Requirements [1] and NUREG-0700 Guidelines for Control Room Design Review [2] to require utilities to perform detailed control room design review and install safety parameter display systems and emergency response facilities for operating nuclear power plants.

Recent nuclear power plant designs tend to be more complex due to the advance of technology resulting in the increase of power productivity and the enhancement of safety facilities. The development of communication, computer, and digital technologies in general industries have caused the obsolescence of existing instrument and control (I&C) and control room technology in nuclear power plants. Design efforts to apply the advanced technology to the man-machine interface system (MMIS) of nuclear power plants have been tried in many cases internationally. The efforts diversified

I&C function, increased the level of automation, and utilized advanced human-system interface (HSI) technology. The design of the Korean Next Generation Reactor (KNGR) MMIS, which is currently under development in Korea, utilizes advanced HSI technology. The characteristics of advanced HSI designs comparing to conventional control panels will bring changes in the operator's role, the information presentation scheme, and the operator-system interaction. Hence, nuclear safety regulatory institutes need to enhance human factors engineering (HFE) review requirements and methodologies adaptable to the trend of new designs. NUREGs such as NUREG-0737 and NUREG-0700 that were issued a few years after the TMI accident and applied to conventional control room designs are not enough for new designs. Acknowledging this point, the U. S. NRC published a series of NUREGs in the early 1990s. They are NUREG-0711 Human Factors Engineering Program Review Model [3], NUREG-0700 Revision 1.0 Human-System Interface Design Review Guidelines [4], and revised Standard Review Plan Chapter 18 (draft) [5].

In Korea, Korea Institute of Nuclear Safety (KINS) is developing safety and regulatory requirements for the KNGR through the systematic reform of existing safety regulation requirements and the consideration of issues important for safety improvement [6]. HFE regulatory requirements and guides are under development as part of the KNGR safety and regulatory requirement development. The human factors regulatory documents by the U. S. NRC mentioned above do not fit to the regulatory requirement framework for the KNGR introduced in the next section of this paper. In addition, compared to safety regulation requirements for the KNGR, the requirements by the U. S. NRC are extensive in application to the upgrade of existing control rooms as well as the various reactor designs under development. Since HFE safety and regulatory requirements for the KNGR have different regulatory framework and conditions from the U. S., it is necessary to develop Korean HFE regulatory requirements and guides.

This paper introduces the HFE regulatory requirement framework being developed by KINS and also describes the work performed at Korea Atomic Energy Research Institute (KAERI) to support the development of safety guides by KINS. The work is to make additional comments on NUREG-0711 from the viewpoint of its application to the KNGR and to develop a computerized system with the information on NUREG-0711 translated into Korean, the additional comments, and excerpts of related reference documents.

HFE REGULATORY REQUIREMENT FRAMEWORK

A framework for the safety regulation requirements and guides for the KNGR is shown in Figure 1.

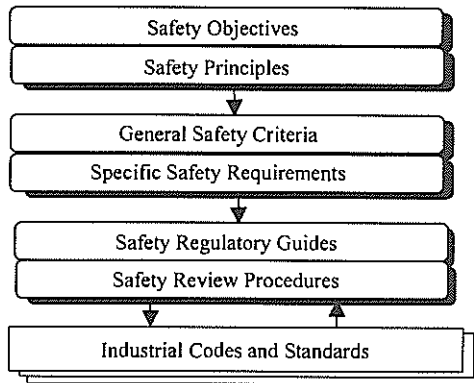


Figure 1. Framework of Safety Regulation Requirements and Guides

Elements in this framework are defined as follows [7];

- Safety Objectives: Ultimate aims which have to be achieved in nuclear safety
- Safety Principles: The most essential elements which have to be observed for accomplishing Safety Objectives
- General Safety Criteria: General standards for measuring compliance with Safety Principles
- Specific Safety Requirements: Detailed rules which have to be applied in obeying Safety Principles and General Safety Criteria
- Safety Regulatory Guides: Acceptable methods or specifications for implementing mandatory requirements
- Safety Review Procedures: Internal guidance of KINS' staff on safety review

The major items and development status of HFE regulatory requirements and guides under the framework of overall safety regulation requirements and guides are shown in Figure 2 [6, 7]. This development is also performed by KINS.

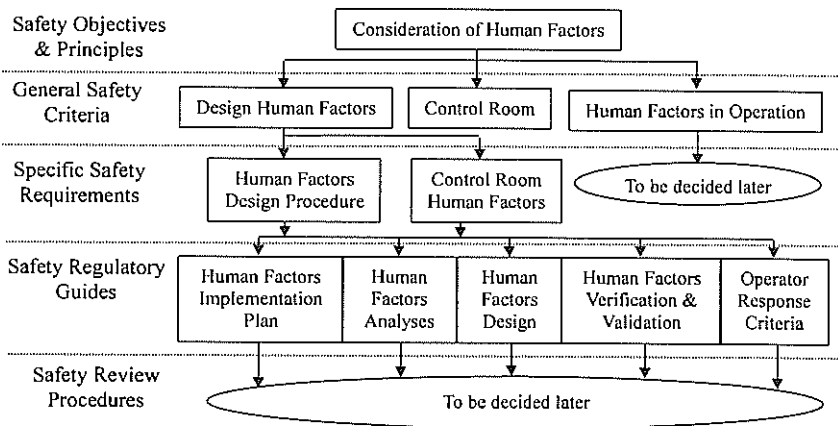


Figure 2. Elements of HFE Safety Regulation Requirements and Guides

In the safety principles, the consideration of human factors from the early stage of design is mentioned. The general safety criteria regarding HFE consist of three elements, 'Design Human Factors,' 'Control Room,' and 'Human Factors in Operation'. Among these, 'Design Human Factors' and 'Control Room' are related to design aspects, and 'Human Factors in Operation' to operation aspects. The specific safety requirements developed so far contain HFE requirements for the design process itself and control rooms as a product of the design process. Specific safety requirements for 'Human Factors in Operation' of the general safety criteria will be decided later. A total of five elements are under development for the safety regulatory guides. The elements are 'Human Factors Implementation Plan,' 'Human Factors Analyses,' 'Human Factors Design,' 'Human Factors Verification & Validation,' and 'Operator Response Criteria.' The first four elements will be developed based on NUREG-0700 Rev. 1 and NUREG-0711. 'Operator Response Criteria' will be developed based on the Draft Reg. Guide DG-1040 and referred to ANSI/ANS-52.2 and 58.4.

COMMENTS ON HFE REVIEW

This study was performed to support KINS staff for their development of four elements of safety regulatory guides which are 'Human Factors Implementation Plan,' 'Human Factors Analyses,' 'Human Factors Design,' and 'Human Factors Verification & Validation.' Since these elements are to be developed based on NUREG-0711 and NUREG-0700 Rev. 1, comments on the application of NUREG documents to the KNGR are discussed.

NUREG-0711 describes background, objective, applicant submittals, and review criteria for the following 10 HFE elements;

- 1) HFE Program Management,
- 2) Operating Experience Review,
- 3) Functional Requirements Analysis (FRA) and Function Allocation (FA),
- 4) Task Analysis,
- 5) Staffing,
- 6) Human Reliability Analysis (HRA),
- 7) Human-System Interface (HSI) Design,
- 8) Procedure Development,
- 9) Training Program Development, and
- 10) Human Factors Verification and Validation (V&V).

Meanwhile, NUREG-0700 Rev. 1 is for the review of HSI design and consists of Part 1 and Part 2. Part 1 of NUREG-0700 Rev. 1 has contents similar to the review criteria of corresponding elements of NUREG-0711 except the elements of 'Staffing,' 'Human Reliability Analysis,' 'Procedure Development,' and 'Training Program Development.' Part 2 contains detailed design review guidelines and is not considered in this study. Therefore, in this study, additional comments on NUREG-0711 were made from the following viewpoints;

- Importance for the achievement of HFE review objective,
- Details and supplemental points when applied to the review of KNGR design,
- Review methods and assessment measure for implementation results,
- Relationships among HFE elements, and
- Details of submittal contents

In this section, the resulting comments are described with respect to the HFE elements of the NUREG-0711.

HFE Program Management

- Applicants should submit the HFE Program Plan (HFEPP) for the review of regulatory institutes. Since parts of the plan can already be implemented at the time of the review, it is possible that modification to satisfy the reviewer's comments may be difficult or too late. HFEPP for the KNGR is better to be reviewed and approved before the significant portion of the design proceeds. HFE tasks, organization, and relationships between HFE tasks should be reviewed seriously.
- HFE issue tracking is an important task in the HFE program. Issue selection criteria, issue management and handling procedures, and issue analysis methods should be described in detail.

Operating Experience Review

- Issues in the operation of previous plants or from the previous applications of technologies should be collected and analyzed, and the results should be reflected in the current design. Hence, operating experience review is an important HFE element.
- Near miss cases can provide information as important as that of plant events, and the number of cases is greater than the events. Hence, it is desirable to include the analysis of near miss cases into the operating experience review.

- The review of HEDs issued for previous plants should be included in the operating experience review.
- For new technologies to be applied to HSI design, operating experience review would be better performed for the experience from not only nuclear power plants but also other industries such as chemical plants, aviation industries, militaries, and medical industries. New technologies to be applied to the design should be proven as stated in '2 Use of Proven Technology' of the safety principles in the design of the safety and regulatory requirements and guides for the KNGR [6].

Functional Requirements Analysis (FRA) and Function Allocation (FA)

- Although functions important to safety should be identified, other general functions are better to be included in the analysis in order to reflect the results of FRA to the design.
- FRA should be done to the level of monitoring and control functions with which FA is reasonably performed. The suitability of FA should be described to justify FA results.

Task Analysis

- Task analysis identifies task requirements for plant personnel to achieve the functions allocated to them. Documentation should show the relationship between task analysis and the results from FRA and FA.
- Since the KNGR HSI design will be a lot different from that of previous plants, substantial derivation of task requirements is an important HFE task for HSI to be designed coincidentally with the task requirements.
- Due to the difference of HSI devices between the KNGR and previous plants and also the utilization of computer systems in the KNGR, not only control room operation but also maintenance, test, inspection, and surveillance tasks will be changed from those of previous plants. Tasks expected to face changes should be treated seriously during task analysis.

Staffing

- Due to the changes of HSI design and resulting plant personnel tasks, staffing analysis should be performed carefully.

Human Reliability Analysis (HRA)

- A probabilistic risk analysis (PRA) team in general performs HRA. In this HFE element, a clear definition of data input-output between the HFE design team and the PRA team should be described. Design data from PRA required by the HFE design team should be identified and interactions between the two teams should be described.

Human-System Interface (HSI) Design

- Review criteria in the NUREG-0711 are stated in categories such as task-related HSI requirements, HSI characteristics, general HSI design feature selection, guidelines for detailed HSI design, analysis for detailed HSI design, the HSI evaluation. The categories should be detailed including, for example, functional requirements of interfaces and tradeoff analyses of different designs [8].
- It should be assured that the results of task analysis are reflected in HSI designs.
- HSI evaluation should be performed independently of the HFE V&V activities. Although HSI evaluation, in general, includes processes similar to the verification during HFE V&V, applicants must not substitute this evaluation with the verification in HFE V&V activities. HSI evaluation should be defined as an activity for the assessment of HSI designs throughout the HSI design phase.

Procedure Development

- Using a computerized procedure system in the KNGR has been considered. Not only the procedure

itself displayed as a part of HSI, but also interface with other information displays and controls should be efficient to enhance operator performance and not to induce human errors.

- In the case of using computerized procedures, guidelines for modification, management, and validation of the procedures should exist.
- In KNGR design computerized procedures are used mainly, but paper procedures can also be used during control room operation in the case that computerized procedures are not available. When operators change the procedure use from computerized procedures to paper procedures, there may be differences in operator performance due to the transition of procedure use. If performance degradation is to be observed or expected during the transition, there should be countermeasures against the degradation, i.e. limitation of operation.

Training Program Development

- Since KNGR HSI will be a lot different from those of previous plants, training requirements should be identified clearly during the design phase for actual training at the site to be effective.

Human Factors Verification and Validation

- NUREG/CR-6393 Integrated System Validation: Methodology and Review Criteria [9] is useful for this activity.

COMPUTERIZED SYSTEM FOR HFE REGULATION

A computerized system to support the HFE safety regulatory guide development by KINS was developed. Items for the computerization include the following: NUREG-0711 translated into Korean, our comments on NUREG-0711 when applied to the KNGR, reference materials of NUREG-0711 and documents related to the comments, and the original review criteria of NUREG-0711. Review criteria of NUREG-0711 were included for the KINS staff to use the translated version in comparison to the original. The following requirements for effective use of the system were derived [10];

- 1) Enable quick approach to the interesting sections of the translated NUREG-0711,
- 2) Display reference materials while users see the translated NUREG-0711,
- 3) Display the comments corresponding to the paragraphs of the translated NUREG-0711,
- 4) Display reference materials related to the comments,
- 5) Display the original review criteria while users see the translated NUREG-0711, and
- 6) Make it possible to use parts of computerized system files for other documentation of KINS.

Based on these requirements, a framework for the use of the system was drawn in Figure 3.

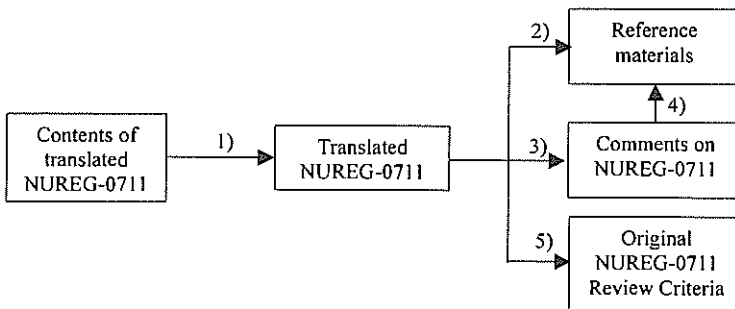


Figure 3. Framework of Items in Computerized System

In Figure 3, the numbers near arrows show the corresponding user requirements. Files of computerized system items were transformed to HTML files, and then button type links and hypertext links were added to the HTML files by using Netscape Composer™ [10]. The results can be seen by using a web browser. Figure 4 shows a sample display of the computerized system.

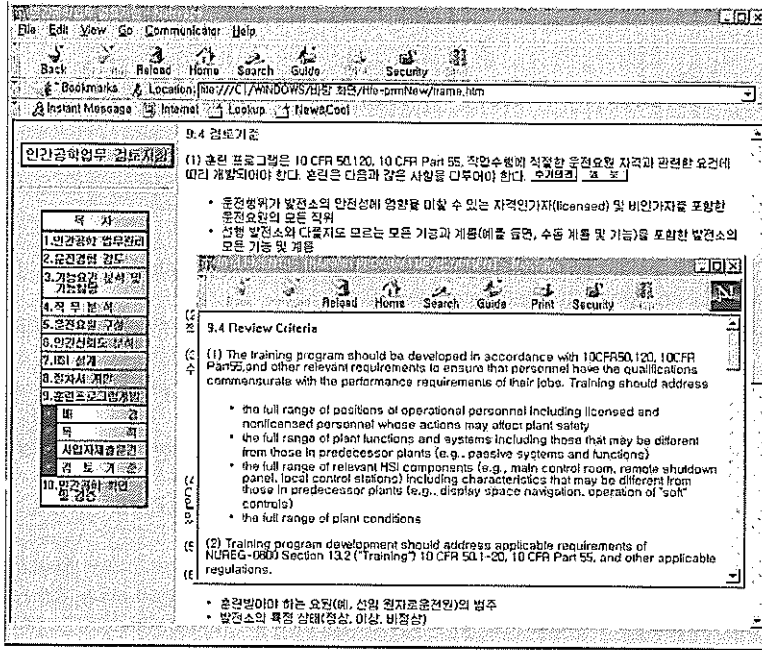


Figure 4. A Sample Display of the Computerized System

The background window of Figure 4 shows menus for the 10 HFE element titles of the translated NUREG-0711 and subsection titles of a selected HFE element in the left area, and the selected subsection of the translated NUREG-0711 in the right area. If users click on one of the 10 element title menus, then four subsection titles, which are background, objective, applicant submittal, and review criteria, appear right below the selected element title. By clicking on one of the subsection titles, the user can see the contents of the corresponding translated NUREG-0711. Hypertext links and buttons in the content display area can be used to see the comments and related reference materials. In this case, a new window is created to display these as shown as a small-sized active window in Figure 4.

CONCLUSION

Within the framework of Safety and Regulatory Requirements for the KNGR, various HFE requirements and guides are developed or to be developed. The KNGR, compared to previous Korean nuclear power plants does not have many changes in the process system but rather the HSI design. KNGR HSI design considers the use of a large display panel, information display based on visual

display units, advanced alarm systems, a computerized procedure system, and computerized controls, all of which are a lot different from the previous control room design features. Hence, the review of KNGR HFE activities and HSI design becomes more important. In order to support HFE safety regulatory guides, comments on NUREG-0711 were made in consideration of its application to the KNGR, and a computerized system was developed for easy access to the comments, NUREG-0711, and other related materials. Results from this study will help the development of HFE safety regulatory guides and further the regulatory review of KNGR HFE activities and HSI design in the future.

ACKNOWLEDGEMENT

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