THE PROPOSED HUMAN FACTORS ENGINEERING PROGRAM PLAN FOR MAN-MACHINE INTERFACE SYSTEM DESIGN OF THE NEXT GENERATION NPP IN KOREA

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ABSTRACT

Human factors application to nuclear power plant(NPP) design, especially, to man-machine interface system(MMIS) design becomes an important issue among the licensing requirements. Recently, the nuclear regulatory bodies require the evidence of systematic human factors application to the MMIS design. Human Factors Engineering Program Plan(HFEPP), as a basis and central one among the human factors-related documents, has been required to show approaches and activities on human factors application by the MMIS designers.
This paper describes the framework of HFEPP for the MMIS design of next generation NPP(NG-NPP) in Korea. This framework provides an integral plan and some bases of the systematic application of human factors to the MMIS design, and consists of purpose and scope, codes and standards, human factors organization, human factors tasks, engineering control methodology, human factors documentations, and milestones. The proposed HFEPP is a top level document to define and describe human factors tasks, based on each step of MMIS design process, in view point of how, what, when, and by whom to be performed.

1. INTRODUCTION

In the past, there were not much efforts of human factors engineering in the design of nuclear power plant, except in the design of man-machine interface(MMI) of control rooms. TMI-2 accident provided a motivation to nuclear industry to increase interests to human factors, and to enhance regulatory and licensing requirements. United States Nuclear Regulatory Commission (NRC) has published various requirements and guidelines related to human factors engineering design review and operator supporting, system for emergency conditions, such as NUREG-0800, NUREG-0700, NUREG-0801, NUREG-0660, NUREG-0737, etc.

Recently, Electric Power Research Institute(EPRI) in United States developedthe requirements of MMIS, Utility Requirement Document(URD) chapter 10, to meet NRC's regulatory requirements on human factors in new NPP designs, and NRC also revealed their position on how to review and evaluate human factors application to issue design certification approval in evolutionary nuclear power reactors design by Human Factors Engineering Program Review Model(HFERM). This has an evaluation process and methods different from the previous ones addressed mainly in Standard Review Plan(SRP Chapter 18) and NUREG-0700.

There have not been a formal position of the regulatory body in Korea on human factors application to NPP designs to date. However Korea Institute of Nuclear Safety(KINS) requires to submit a human factors engineering programs plan(HFEPP) as a part of the certification of process for design of control rooms, and instrument and control system, from the recent NPP designs.

To meet this regulatory requirement and to comply with increasing importance of systematic application of human factors, HFEPP shall be developed to demonstrate the evident basis and methods of human factors application to the MMIS design of Next Generation NPP development.

The framework of HFEPP for Next Generation MMIS design is established and proposed to manage Human Factors design issues on safety and operation availability sufficiently. This HFEPP addresses how to consider and implement human factors principles in the analysis, design, and evaluation of MMIS.

2. ESTABLISHMENT OF HFEPP FRAMEWORK

HFEPP is to be newly developed for our next generation NPP development. Its purpose is to define the scope and level of depth of the required human factors program. There is not a broadly accepted and formally established plan for NG-NPP in Korea, but only trends to follow international licensing and design certification philosophy, such as keeping with NRC's position and referring to the satisfaction of EPRI URD. The HFEPP should be developed to include all the activities, knowledge, and integrated approach related to human factors, to comply with the current regulatory position.

An efficient plan should be responsive to MMIS development requirements and constraints. It should reflect how safety and availability of the Next Generation NPP can be increased by applying human characteristics to designer's decisions during the development, which will affect human performance in real plant operations. Also it should ensure an integrated application of human factors to MMIS design.

Human performance acts an integral part in the performance of NPP or MMI, wherever human involvement is required. Human Factors Engineering (HFE) concerns the tasks of those engineering and management in a NPP design, especially MMIS, required to provide for effective human performance including operation and maintenance tasks. Accordingly, HFE should be acknowledged equivalently to other design factors of NPP system in aspects of HFE program priorities and development process.

HFE is a part of the mainstream engineering effort throughout the system life cycle. It needs a systematic approach which seeks to optimize the system by integrating the human performance necessary to operate, maintain, support, and control the systems in its intended operational environment. Therefore, the programmatic approach should be presented to assure the integration of HFE into the system development and the achievement of the goals.

In the past, NRC staff has reviewed detailed plant design prior to making a safety determination. However, because of the development of new digital technology and the application of advanced MMI components, the most parts of MMI design will not be completed prior to the issuance of design certification for the evolutionary or revolutionary reactor under review. NRC has found that the detailed MMI design information was not available for staff reviews in initial design, hence, the NRC has the position that the evaluation for design certification shall be performed based on a design process plan addressing HFE program elements, required to develop an acceptable detailed design specification.

MMIS requirement of EPRI-URD volume II chapter 10 has presented a new design approach to meet licensing requirements more enhanced in human factors aspects. It contains any requirements to enhance performance of operator and system. However, there is no precedent cases of design

and evaluation in accordance with MMIS concept. It is meaningful to present milestones of how and what to do for thee volutionary MMIS design.

The framework of HFEPP for the MMIS design of Next Generation NPP in Korea is developed based on the systematic approach philosophy, the MMIS requirement of EPRI-URD volume II chapter 10, NRC's intention in the HFE review model, Korean standard requirements documents(K-SRED),and the current Korea human factors practices.

3. SCOPE OF HUMAN FACTORS ENGINEERING

The system development process can be partitioned into several phases. Generally, the process can have the phases of partitioned conceptual design, preliminary design, detailed design, production, and operation. The results from the phases also can be variable with licensing requirements.

Human factors activities should be identified as early as possible in the conceptual design phase, and should be performed in accordance with the design process suitable for the development of systems to assure that the functions of whole system are allocated to accomplish system design goals. There are many cases that are not necessary to perform every activity in detailed and accurate manner. Human factors engineering acts more important roles during the specific analysis, design and evaluation phases. Furthermore, the level of human factors engineering involvement depends on the level of automation(or human involvement), technical risk, cost, schedules, etc. In our MMIS design, the human engineering analysis should be complete as far as possible to ensure that the concept is compatible with the human's characteristics, capabilities, and limitations, and also with the licensing requirements.

The appreciation of HFE can be described in terms of the products of its application and the process of applying it. HFE contributes to the well integration of human with other system elements. The way to achieve this integration leads to the design of interface between human and other system elements. There are a number of different types of human-system interface; managerial interface, functional interface, informational interface, environmental interface, organizational interface, operational interface, physical interface, mental interface, etc. Integrating HFE into MMIS design can be implemented through the application of systematic design process. Fig.1 illustrates a design process for the MMIS design of NG-NPP. HFE related activities in this design process are as follows;

- HFE Program Planning
- Function Analysis
- Function Allocation
- Preliminary Design
- Task Analysis
- MMI Design Guideline Development
- Detailed Design
- Manning/Training requirement Development
- Test and Evaluation Planning

HFEPP for the MMIS design covers all the above mentioned activities and human system interface.

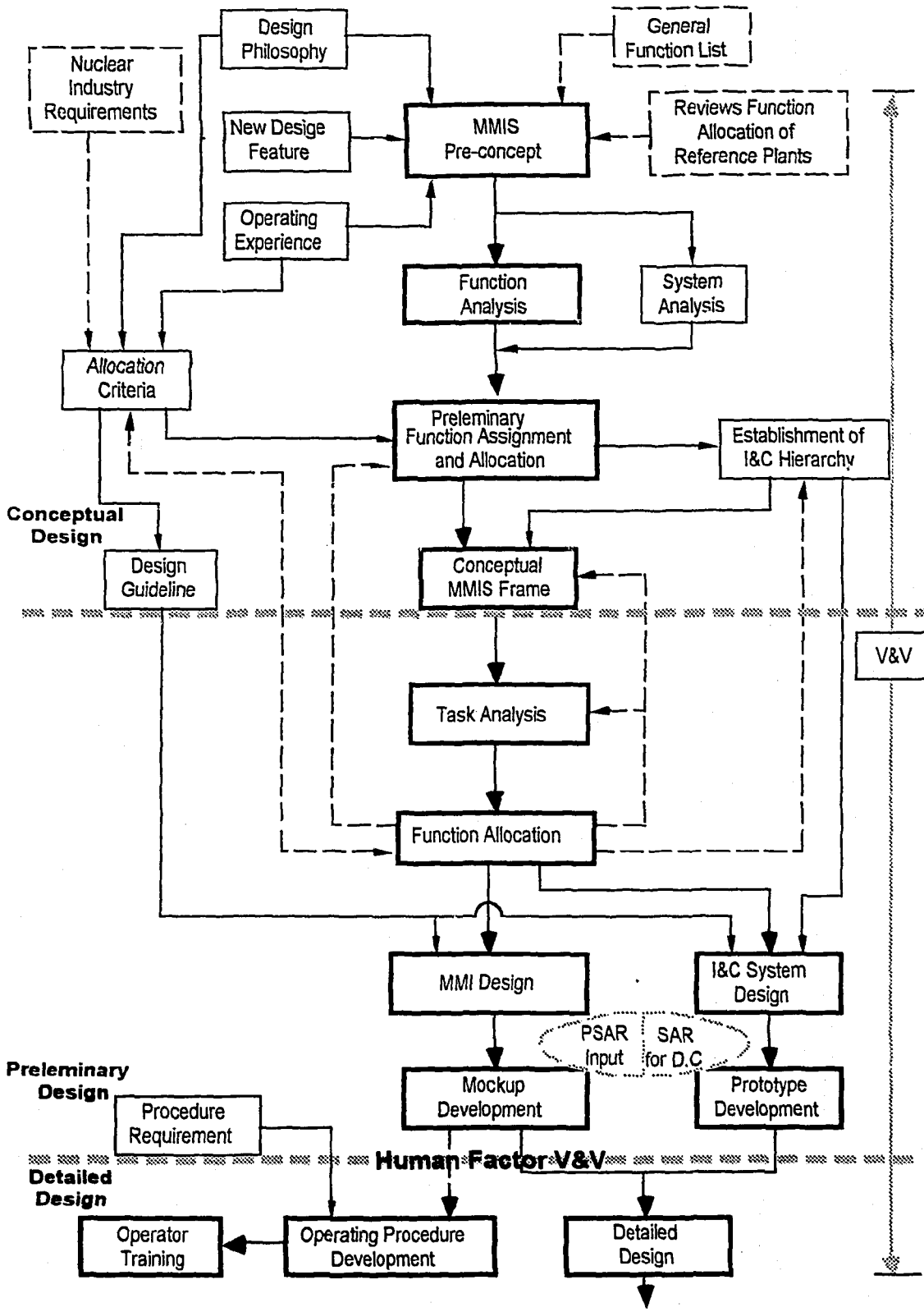

Fig.1 Design Process for MMIS

4. FRAMEWORK OF HFEPP

HFEPP needs to ensure that HFE will be systematically applied to the MMIS design. This section introduces the framework of HFEPP details of which will be developed further as a formal HFEPP for the MMIS design. The contents of proposed HFEPP consists of the followings;

1. Introduction
2. Codes and Standards
3. Human Factors Organization
4. Human Factors Tasks
5. Design Control Methodology
6. Human Factors Documentations and Milestones.

4.1 Introduction

This is a general statement on the purpose and scope of HFE tasks in the MMIS design process. This identifies that the usage of HFEPP, the coverage of HFE, the position of HFEPP relative to other various HF related documents.

4.2 Codes and Standards

This section mentions the regulatory documents, other documents and standards applicable to performing human factors engineering tasks including analysis methods (for functional analysis, task analysis, link analysis, etc.), design guidelines, and design criteria.

4.3 Human Factors Organization

This section identifies the composition of members responsible for HF engineering, their responsibilities and technical knowledge required, the position and functional relationship of HF team in the overall organization for NG-NPP development, expecting that human factors engineering maintains a position to make appropriate effects on the entire MMIS development.

4.4 Human Factors Tasks

A design approach for the MMIS development is mentioned here. Through this design approach, the description of human factors tasks should provide their validity for execution by presenting technical bases according to the MMIS design process shown in Fig. 1. For effective execution of human factors tasks, the methods and goals of tasks at each step of design process shall be identified and also list reference documents. These tasks include the followings:

- Operating Experience Review(OER) :

Utilization of operator interviews, questionnaires, reviews of event reports in Korea, and the results from detailed control room design review(DCRDR) performed on Korean NPPs. Human factors specialists, I&C specialists, and operators participate in this task.

- Design Concept Definition :

A preliminary design concept including a conceptual control room layout and information presentation strategy is established in this task by the application of staffing concepts, OER, HF guidelines, and design philosophy.

- Functional Analysis :

This task is performed using the functional breakdown results obtained previously for a Korean standard nuclear power plant. The functions of MMIS are determined for control rooms and local control areas with MMI and I&C through this functional analysis. Preliminary function allocation, function assignment in the control rooms, and a hierarchical configuration of I&C system will be done using the results of this task.

- Function Allocation :

Function allocation is a process iterative throughout the conceptual and detailed design phases. Therefore, iterative reviews of human machine function allocation take place. In the detail design phase, trade off analyses will be performed to determine the optimized allocation of MMIS functions, for examples, between hardware, software, and operators, in view of reliability, safety, and cost. In this task, the involvement of human factors specialists and I&C specialists is more required than in any other tasks.

- Task Analysis :

This task is performed to determine the operator task performance requirements in consideration of the established MMIS configuration. Control and information requirements for operator tasks are defined, and detail functions are reallocated, by using of reference operating procedures. Afterwards, the results from this task will provide the bases for procedure development, personnel qualification and training requirements.

- Man Machine Interface Design :

Through the application of HF guidelines and criteria, the detailed design is performed including information display formats, man-computer interaction dialogue, command modes, inter-frame relationship, data coding, etc.

- Link Analysis :

This is performed to examine the organization of operator tasks in terms of logical grouping and sequencing of activities, at the levels of both overall workplace and control interface by using of mockups.

- Environmental Design :

In this task, human factors guidelines and requirements are applied to the design of environment such as HVAC and lighting system together with the consideration on noise and vibration limit for operations and maintenance habitability and safety.

- Operating Procedure Development:

Based on the task analysis, the modification of operating procedures is performed in this task.

- Human Factors Verification and Validation :

Test and evaluation plan is also incorporated in HFEPP. Human engineering evaluation at each stage of analysis and design actually tests the adequacy of human factors engineering efforts.

Human factors evaluation is performed by using prototypes, dynamic mockups, and a site-specific training simulator with the application of HFE analytical techniques, experimental methods, walk-through and talk-through techniques, according to various design phases.

4.5 Engineering Control Methodology

This section describes the methods on how HFE activities are integrated with the engineering control methods in the MMIS development. The engineering control methods in this section include the followings;

- work methods to support the process of developing, design requirements, design guidelines and guidance for V&V at each design stage,
- methods for the HFE issues tracking system to manage and feedback HF issues in aspects of NG-NPP development management, and
- methods for the configuration control to effectively control the communications between design teams for the modification and adjustment of the plan and tasks in NG-NPP development.

4.6 Human Factors Milestones and Documentation

This section describes the schedule for HF engineering activities in relation with the schedule of whole NG-NPP development. This section also mentions about what types of documents to be made and how to make.

5. DISCUSSION

Although the HFEPP proposed in this paper is under development, it presents the importance of HFE in the MMIS design, and identifies systematic ways of the application of HFE to the MMIS design in relation with the whole NG-NPP development, considering current and future trend of nuclear regulatory requirements.

REFERENCES

1. U.S. NRC, "Standard Review Plan", NUREG-0800, Rev. 1, 1984

2. U.S. NRC, "Guidelines for Control Room Design Reviews", NUREG-0700, 1981

3. EPRI, Human Factors Guide for NPP Control Room Development, EPRI/NP-3659, 1984

4. EPRI, Advanced Light Water Reactor Utility Requirement Document Vol. II, Rev. 5, Chapter 10. MMIS. 1992

5. IEEE Guide for the Application of Human Factors Engineering to Systems, Equipment, and Facilities of Nuclear Power Generating Stations, IEEE Std 1023-1988, 1988.

6. U.S. NRC, "HFE Program Review Model and Acceptance Criteria for Evolutionary Reactor" (Draft), 1992.

7. W. E. Woodson, Human Factors Design Handbook, 1981.

8. G. Salvendy, Handbook of Human factors, 1987.

9. T. Lupton, Human factors, IFS.UK, 1986.

10. U.S. DoE. Human Engineering requirements for Military system, Equipment and Facilities(MIL-H-46855B), 1979.

11. J.D. Beattie, J.S. Malcolm, "Development of a Human Factors Engineering program for The Canadian Nuclear Industry, 35th HSI Conference, 1991.