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System Requirements Analysis for a Computer-based Procedure in a Research Reactor Facility

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1. Introduction

A system presenting operating procedures using computers has been explored since the 1980s and several power plant applications were by the late 1990s. However, applications of such systems on operating plants have not been accepted due to some problems such as the cost-benefits of control room upgrade and associated regulatory uncertainty. However, with the advent of fully computerized control rooms, the implementation of a computer-based procedure system (hereafter, CBP) will be increasingly widespread in new plant construction. It is generally accepted that computers are well-suited to such tasks as monitoring, display, and logical evaluation of real-time data. This can address many of the routine problems related to human error in the use of conventional, hard-copy operating procedures.

An operating supporting system is also required in a research reactor. A well-made CBP can address the staffing issues of a research reactor and reduce the human errors by minimizing the operator's routine tasks. A CBP for a research reactor has not been proposed yet. Also, CBPs developed for nuclear power plants have powerful and various technical functions to cover complicated plant operation situations. However, many of the functions may not be required for a research reactor. Thus, it is not reasonable to apply the CBP to a research reactor directly. Also, customizing of the CBP is not cost-effective. Therefore, a compact CBP should be developed for a research reactor. This paper introduces high level requirements derived by the system requirements analysis activity as the first stage of system implementation.

2. System Requirement Analysis

2.1 Digitalization and Staffing

A fully digitalized main control room has been chosen in most new construction plants. Digitalization of the main control room has brought convenience in monitoring and control works to operators. The computer-based plant systems have sufficient capability to provide various operation supporting functions. Thus, additional equipment is not required for implementing the supporting functions such as CBP.

Addition of the CBP function into the operator workstation provides an integrated monitoring and operation including the procedure for the current situation, real-time data, and related process display with operators. Thus, it can address control room staffing and human factors engineering (HFE) issues. For the economic reasons, the number of staff members required in a research reactor operation should be optimized. The CBP can perform large amounts of routine tasks of operators, improve the overall operator performance, and reduce the potential for human error.

2.2 Basic Principles

In spite of these benefits, there are some concerns about the impact of computers on the role and performance of human operators, and about the allocation of decision-making authority to computers. The conservative approach introduced in IEEE Std. 1786[1] is applied to these concerns. The basic principles of this approach are as follows:

- Procedures are written and developed directions for human operators.
- The role of CBP is to facilitate the human operator's elective use of procedures.
- Operator roles and responsibility should not vary with the procedure media.
- Although CBP is used, paper-based procedures should be provided.
- The CBP should be implemented within the framework of a formal human factors program.

2.3 Conceptual Framework

The CBP can be implemented as various levels of functional capability and IEEE Std. 1786[1] classifies the CBPs as three types. Type 1 CBPs represent the procedure as a text document style for operational use on a computer display. Type 2 CBPs use dynamic process data for an embedded display to evaluate plant conditions. Type 2 CBPs cannot issue control commands, but they may provide access to soft control capabilities that exist outside of the CBPs. Type 3 CBPs include embedded soft controls that may be used to issue control commands to plant equipment. Type 3 CBPs may include automatic sequences of steps that are determined (i.e., a deterministic result when evaluated for any given set of inputs).

2.4 System requirements

Recently, a document (IEEE Std. 1786[1]) was issued as a consensus-based standard by the IEEE Standards Association in 2011. The document describes the CBP philosophy, framework, and detailed guidance. CBP requirements for a research reactor should be developed based on the principles of human factors, cognitive science, and automation in the standard

Also, nuclear plant practices (SKN 3&4, US-APWR, etc.) have been reviewed. Such systems provide powerful and various functions, such as real-time data, soft-control, crew synchronization, multi-execution, browsing mode supporting, and so on. The system has been a main procedure and paper-based procedures have been the backup materials against failure of the system.

Several requirements have been issued on the table by considering the codes and standards, the practices, and the operating situation of a research reactor. Through discussion, review and engineering judgments, high-level requirements can be summarized as follows;

- A light-weight system: Generally, the number of operating and maintenance staff members of research reactors is small. Thus, many various known collaboration and supporting functions may not be included in the requirements.
- Selection strategy of application procedures: As experience in the NPPs, it is proper that the emergency operating procedure becomes the first application of the CBP. The reason is that many operators' tasks and high human error probability exist in emergency situations. Finally, all procedures will be computerized.
- Level of computerized: Currently, a type 2 CBP is applicable. Real-time information (process parameters and equipment status) provision may be important, and the provision of deterministic and automatic calculation results may also be useful. However, the embedded controls and the procedure automations are less important in a research reactor.
- CBP and CBP builder: CBP will be applied to many research reactors around the world. Thus, a builder generating CBPs suited to various research reactors should also be considered.
- Allocation of display functions: Display screen for the CBP should be close to other related screens for alarm and process display.
- System classification: The electrical class may be non-1E and the seismic category may be non-seismic. The level of QA (Quality assurance) and V&V (Verification and Validation) comply with SIL (Software Integrity Level) 2 guided in IEEE 1012 [2].
- Human factors engineering: The CBP should meet the HFE requirements of NUREG-0711 [3] and NUREG-0700 [4].
- Backup procedure: The backup paper-based procedure should be provided for failure of the CBP.
- Procedure consistency: Procedures on the CBP should be presented in a manner that is compatible with a presentation of paper-based procedures.
- Complicated functions: Various operation modes (read, write, monitoring, etc.) of the CBP, cooperation support between operators and supervisor, full concurrency support, embedded control functions, and automatic executions are considered as optional requirements.
- Training: Operator training on the use of the CBP should emphasize the importance of employing a questioning attitude, and should reinforce the need to monitor the processing performed by the CBP and to override the CBP if required. Training should provide the operators with a thorough understanding of the CBP, the goals of each procedure, what information is processed and how, what actions it will take, and when it will terminate. Transition to a paper-based procedure should be addressed in the training.

The high level requirements have not been completed as the final requirements yet. More reviews will be conducted and additional requirements can be issued before the system implementation.

3. Conclusions

Operation support tools are under consideration for application to research reactors. In particular, as a full digitalization of the main control room, application of a computer-based procedure system has been required as a part of man-machine interface system because it makes an impact on the operating staffing and human errors of a research reactor. To establish computer-based system requirements for a research reactor, this paper addressed international standards and previous practices on nuclear plants. Combining the analysis results with the operating philosophy of research reactors, this paper introduced several high-level development requirements for a light-weight computer-based procedure system. In next phase, a system prototype will be developed and application test to a research reactor will be conducted in the final phase.

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