Prboceedings of the Korean Nuclear Society Autumn Meeting
Seoul, Korea, October 1995

The Strategy for Intelligent Integrated Instrumentation and Control System Development

Kee-Choon Kwon, Chang-Shik Ham
Korea Atomic Energy Research Institute

Abstract

All of the nuclear power plants in Korea are operating with analog instrumentation and control (I&C) equipment which are increasingly faced with frequent troubles, obsolescence and high maintenance expenses. Electrical and computer technology has improved rapidly in recent years and has been applied to other industries. So it is strongly recommended we adopt modern digital and computer technology to improve plant safety and availability. The advanced I&C system, namely, Integrated Intelligent Instrumentation and Control System (I^3CS) will be developed for beyond the next generation nuclear power plant. I^3CS consists of three major parts, the advanced compact workstaion, distributed digital control and protection system including Automatic Start-up/Shutdown Intelligent Control System (ASICS) and the computer-based alarm procesing and operator support system, namely, Diagnosis, Response, and operator Aid Management System (DREAMS).

1. Introduction

Nuclear power plants operating in Korea have analog instrumentation and control (I&C) equipment which are increasingly faced with frequent troubles, obsolescence and high maintenance expenses. The digital technology provides advantages such as processing of numerous data, improvement of system reliability, flexibility of adding new functions, automation of periodic tests, self-diagnostics, and improved operation and maintenance using standardized components. So it is strongly recommended that our nuclear industries adopt the modern digital and computer technology to improve nuclear power plant (NPP) safety, availability and operating functions.

After TMI-II accident, many analyses pointed out that deficient information and human error caused the accident. The operator should take sufficient information to identify the plant

status in the transient situation. For the sake of getting the sufficient information, the I&C system should adopt an advanced digital technology. To reduce human error and support the operator's tasks, the new concept focused on the operator tasks should be applied to the advanced I&C system. The Electric Power Research Institute (EPRI) suggested that the advanced I&C system, especially related with the operator tasks including control room, will be strongly focused on human factors engineering and advanced digital technology. <Fig. 1> illustrates the strategy of technology approach of advanced I&C system. Westinghouse AP600 I&C system, ABB-CE Nuplex 80+, CANDU 3 I&C system, and EdF N4 I&C system were designed to adopt these new concepts. We established these new concepts for the design of beyond the next generation NPPs.

2. Target of I^3CS

We proposed the advanced I&C system, namely, Integrated Intelligent Instrumentation and Control System (I^3CS) on the application of the new concepts focused on the advanced digital technology and human factors engineering for beyond the next generation NPPs. The comparison of I^3CS and the other major I&C system is shown in <Fig. 2>. I^3CS reflects a concept of EPRI Utility Requirement Document (URD) such as top-down approach based on the functional task analysis, modern digital technology, standardization and simplification, availability and reliability, and protection of investment. The major targets of I^3CS are as follows :

- Reduced Human Errors
  First of all, the design methodology for reduction of human error should be developed. It is feasible that the design for reducing human error is to be achieved by top-down approach to reconstruct the I&C architecture including control room based on a task allocation by the functional-based task analysis. Second, a cause for human error should be eliminated. Because the auto start-up and cooldown system reduces the operator intervention in operation of start-up and cooldown mode, operator errors will be significantly reduced. Intelligent operation support system aids to identify the plant status in the transient condition, make a decision of the operator tasks, and guide operator actions.

- Improved Availability and Reliability
  The reactor protection system and safety related system will be designed by digital technology with automatic test function and self-diagnosis features. These technologies will significantly help to reduce the inadvertent reactor trips. The use of digital technology in NPPs takes advantages such as processing of numerous data, flexibility of adding a new function, and reduction of Operation and Maintenance (O&M) expense. However, an application of digital technology may bring about a new problem to assure safety and reliability as concerns common mode failure and software verification and validation (V&V). Especially the safety and reliability of software are critical issues in introducing the digital I&C systems in NPPs.

- Standardization and Simplification
  I^3CS uses the industrial open architecture and off-the-shelf equipment manufactured in the domestic industry. Because the off-the-shelf equipment is developed with the design of

adapting the industry standard, modularizing and simplifying. Repair of I&C equipment will be completed by simple modular replacement in the field. O&M cost may be reduced.

- Assure License
  To apply digital technology, especially digital safety system, we should consider common mode failure, software verification and validation(V&V), establishment of quality assurance program and resolution of elecromagmetic interference. A number of method and tool to solve these problems are being studied and developed, but not completely solved till now. These problems are directly connected with licensing issues. For the sake of protection of utility's investment, license should be assured by solving these problems.

3. Development of I^{3}CS

I^{3}CS concept has been developed on the basis of the technical review and functional-based task analysis for next generation NPPs performed by top-down approach. I^{3}CS integrates an advanced I&C technology as follows :

- Robust and fault-tolerant control method
- Intelligent supervisory control technique
- Intelligent operator support technology
- Human factor engineering concept
- Integrity of sensor loop using a smart sensor
- Fully distributed communication network using field bus

3.1 Advanced Compact Workstation

The advanced compact workstation will adapt a compact workstation concept on the application to next generation NPPs. This compact workstation will be upgraded by adding the new design features on the basis of functional-based task allocation. The added design features are as follows :

- Extension of supervisory functions
- Extension of coordinated function between operators
- Consolidation of operator support function
- Intelligent soft control technique
- Electronic display of normal and emergency procedures
- Extension of overview display
  - two detailed system overview mimic
  - selected movable overview display

3.2 Fully Distributed Digital Control and Protection System

The control and protection concepts applied to next generation NPPs will also be adopted in I^3CS by adding the following design features :

- Fully distributed communication network
- Supervisory control coordinating primary and secondary system
- Automatic Start-up and shutdown Intelligent Control System (ASICS) with supervisory coordinator
- Robust and fault-tolerant control
- Addition of Macro control functions
- Certainly resolution for common-mode failure, software V&V and ElectroMagnetic Interference (EMI)

3.3 DREAMS (Diagnosis, REsponse and operator Aid Managemnet System)

At present, one of the most important issues in human factors engineering field is to reduce human errors. To reduce human errors, there are two ways that eliminate the essential cause of human errors to intervene operator and inform the operator what to precisely identify plant status in emergency condition and direct the operator actions. DREAMS provides the operator with information that supports the operator to diagnose abnormalities of plant, to manage the operator response on the application of the following technologies.

- Computer-based dynamic alarm processing techniques (DYNAS:DYNamic Alarm processing System)
  - alarm suppression on operating mode
  - alarm suppression on direct precursor and cause-consequence relationship
  - dynamic prioritization dependent on plant state.
- Model-based fault detection and diagnosis functions
- Integrated operation support and management system with computer-based normal and emergency procedures display, and technical specification monitoring

4. Conclusions

There are vigorous studies to solve the obsolescence problem of conventional I&C systems and to apply the advanced I&C systems domestically and in foreign countries. It is inevitable that develop the advanced I&C and apply to next NPPs will be constructed in our country. To develop the advanced I&C system, like I^3CS domestically, it is necessary to co-operate with utility, research institute, industrial company and university. And one organization should coordinate overall systems.

References

[1] NP-7343, EPRI, Integrated Instrumentation and Control Upgrade Plan, Feb. 1992

[2] F. Ridolfo, et al., "The Nuplex80+ Advanced Control Complex from ABB Combustion Engineering," Nuclear Safety, pp.64-75, Vol.34, No.1, 1993.

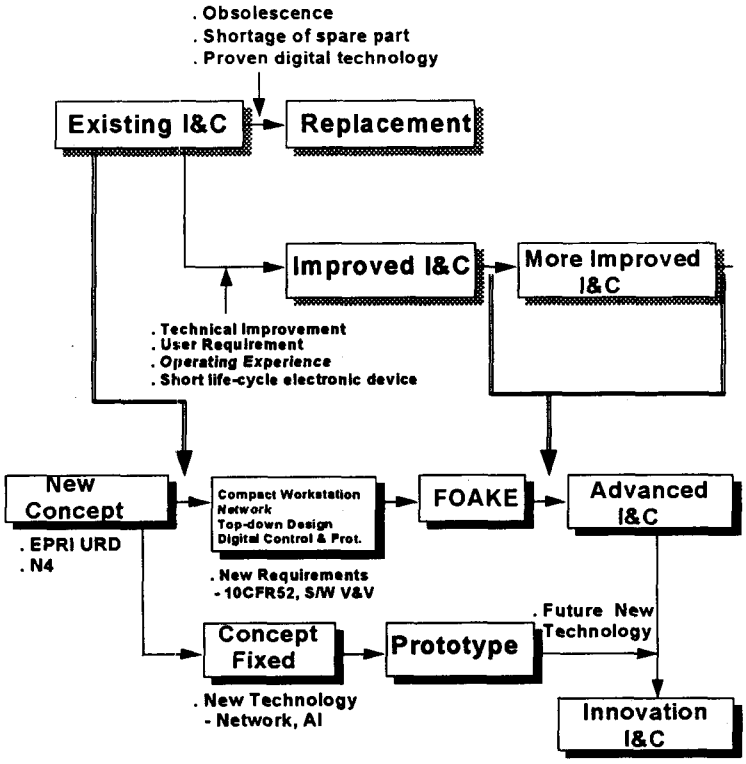
[3] AP600 Design Workshop Information Package Instrumentation and Control/Man-Machine Interface, Nov. 1990.

[4] EPRI, Advanced Light Water Reactor Requirements Document, June 1990.

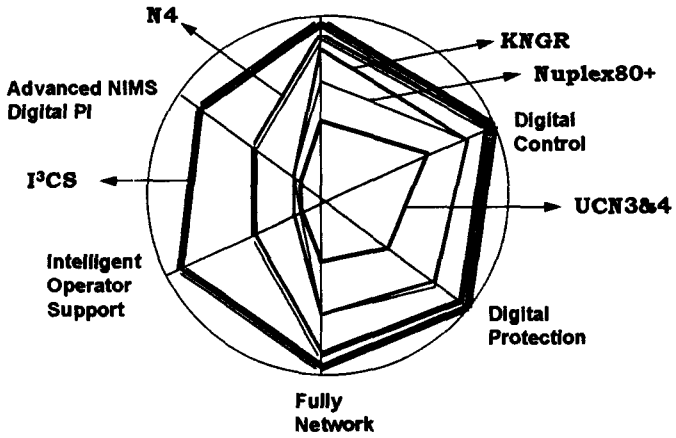
[5] J. D. White, et al., European Instrumentation and Control, NTIS of U.S., Dec. 1991.

[6] IEEE/ANS 7-4.3.2-1993, "Standard Criteria for Digital Computers in Safety Systems of Nuclear Power Generating Station", 1993.

[7]K. C. Kwon, et al., "Proposed Plan for the development of Advanced Instrumentation and Control Technology in Korea," IAEA Technical Committee Meeting on "Advanced Control and Instrumentation Systems in Nuclear Power Plants:Design, Verification and validation", Helsinki, Finland, June 20-23, 1994.



<Fig. 1> The Strategy of Technology Approach



<Fig. 2> Comparison of Major I&C Systems