Hitachi's Project Management Experience On Distributed Control Systems (DCS) In Nuclear Power Plants

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Abstract

Given its commitment to state-of-the-art digital technology developments, Hitachi has experienced many I&C refurbishment projects for Boiling Water Reactors (BWR) as well as new build projects for Advanced BWR (ABWR) applying plant-wide DCS. One of the key points for the successful deployment of a DCS is efficient and effective project management at each project phase. Hitachi has experienced two project management models for new build projects: (1) two separate vendors are responsible for NSP and BOP, and (2) one vendor is responsible for both portions. This paper addresses Hitachi's project management experience and solutions in both cases and their possible application to future new build projects.

1. Introduction

As the scope of digital technology applications to NPP Instrumentation & Control (I&C) Systems increases, the impact to manufacturers and customers of the overall project management scheme (covering everything from the conceptual design phase to the on-site commissioning) will also increase in significance. Based on its extensive experience, Hitachi considers the reasons to be as follows:

- Increased importance and impact of I&C Systems to the safety, economical operation and operational stability of the NPP.
- Increased complexity of the interfaces and data flow between field devices and the control system(s) and between different control systems, in turn making system verification and validation simultaneously more important and more difficult.
- Incorporation of maintainability into the I&C system initial design may impact plant maintainability for the entire plant operating lifespan.

This paper summarizes Hitachi's experiences addressing the challenges faced (especially) from a managerial point of view when applying digital I&C systems to NPPs and reviews their possible applications to future nuclear new build projects.

2. Hitachi Nuclear I&C Systems Experience

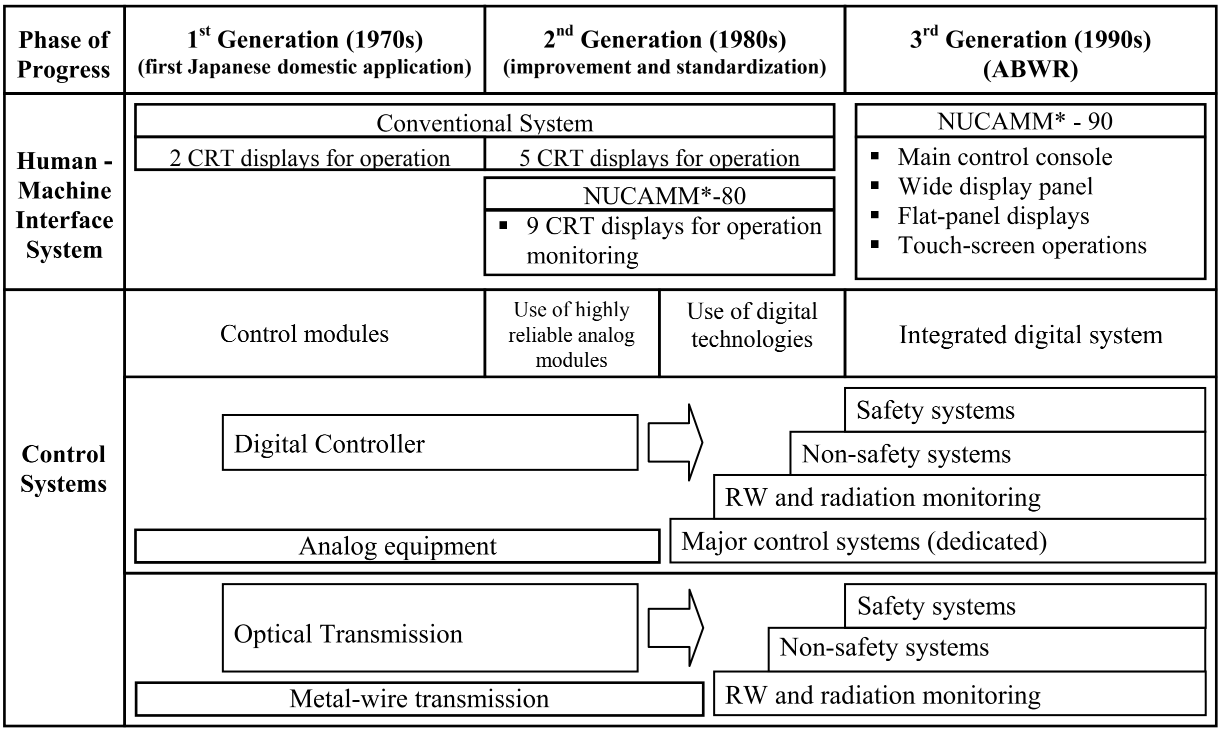
Figure 1 shows the evolution of Hitachi I&C systems.

Hitachi digital technology was first applied to NPP I&C systems in the 1980s. At this stage, the 1st generation, redundancy was developed and applied to the major control systems, dramatically improving their reliability and performance.

In the 2nd generation, 3 improvements were incorporated into the plant: (1) NUCAMM-80, (2) a digital radiation monitoring system, and (3) an optical information transmission system. The optical information transmission system, in particular, had 3 characteristics superior to ordinary electronic transmission systems: (1) superb noise resistance, (2) large transmission capacity and (3) reduction of conventional cabling. A nuclear power plant usually involves tens of thousands of pieces of plant information being transmitted simultaneously to the main control room. Given its high data throughput, optical transmission is expected to be more and more common in future power plants. In keeping with Hitachi's conservative philosophy of step-by-step application of new technologies to NPP control systems, the optical information transmission system and digital processing technology was first applied to every possible part of the radioactive waste processing system. Then, to improve NPP reliability and maintainability, digital technology gradually has been applied to non-safety systems such as the turbine/generator auxiliary systems and to reactor non-safety systems.

In the 3rd generation, digital technology was applied to the control and instrumentation facilities of the entire plant, including the neutron monitoring system, the safety protection system, the reactor recirculation internal pump control system, and the control rod control system. Hitachi expanded the use of digital technology throughout the plant and completed the "NUCAMM-90" total-digital system, integrating instrumentation, control, protection and HMI.

Using the know-how gained with NPP digital I&C systems as well as new electronics and general-purpose technologies, Hitachi continues to develop supervisory and control systems excelling in operability and maintainability and complying with international standards [1].



*NUCAMM: Nuclear Power Plant Control Complex with Advanced Human-Machine Interfaces

Figure 1 The Evolution of Hitachi Nuclear I&C Systems

To summarize, Hitachi has acquired the following valuable strong points from continuous involvement in NPP construction over 30 years:

- Establishment of an NPP total digitization scheme that includes safety critical systems.
- Continuous improvement through application of accumulated lessons-learned from past project experiences.

3. Hitachi I&C Project Management Scheme

3.1 Project implementation breakdown

Common project implementation elements consist of planning, design, manufacturing, tests (at factory) and commissioning (at site). Even though I&C components have changed from conventional relays and analog devices to digital devices, project management basis basically has not changed; however, the expansion of the digitization scope and of the numbers and complexity of interfaces among components (as shown in section 1) will require project managers to have an increasingly strategic view of the overall I&C system. Important points identified from Hitachi's experience are as follows:

- Appropriate management planned and properly traced to recognize deviations between the plan and the implementation at each phase.
- Concept, design and test phases are crucial. Especially, the development of test procedures should be considered from the early stages of the project (design phase at the latest).
- A well-considered and detailed commissioning test plan is essential to avoid schedule slippage and unexpected work.

3.2 Hitachi project implementation

The following descriptions summarize examples of the management schemes adopted in each project phase in the latest ABWRs by Hitachi.
The descriptions given below are general; the detailed strategies taken in the latest ABWR are shown in section 4.

3.2.1 Integrated System Configuration Applying Unified DCS Products (Conceptual Phase)

In every BWR/ABWR project in which it has been involved, Hitachi has adopted a unified series of DCS product for its scope of supply. By doing so, the following advantages can be expected:

- Design, manufacturing and test procedures can be unified, which results in a higher quality and more economical system.
- Interfaces between controllers can be simplified. For example, gateways for converting transmission protocols interfacing different series of products can be eliminated.
- Plant-wide consistent maintainability and reduced variety of DCS spare parts can reduce utilities costs.

3.2.2 Design Automation (Design Phase)

People make mistakes; in general, one may therefore assert that simple, repetitive and/or iterative work should be automated in order to reduce the number of mistakes. Hitachi has developed schemes for the automatic generation of elementary diagrams and software logic diagrams for standardized parts by utilizing pre-developed information such as I/O point data.

3.2.3 Strategic Tests (Test Phase)

Efficient as well as effective test in factory and on site is essential for success. Especially, commissioning test planning plays an essential role for integrated digitized systems compared to conventional systems. Hitachi has been making efforts to rationalize test where it is justified to do so. The following items are general measures taken in the latest projects:

- Maximizing human resources
- Incorporating lessons-learned from past projects into the test plan
- Utilizing the latest information technology

4. Actual Application Example for ABWR I&C Implementation

In this chapter, actual application examples for schemes shown in section 3.2 are described.

4.1 Integrated System Configuration Applying Unified DCS Products

Hitachi has experienced two types of DCS application. One is taking an entire plant I&C system; the other is taking either NSP or BOP.

4.1.1 Case 1: Entire Plant I&C System

General configuration of the first case is shown in Figure 2. In Figure 2, all the systems ranging from safety systems to non-safety systems such as NSS and BOP are configured as integrated systems by the same DCS product series. The limited variety of DCS components permits the unification of design, manufacturing and test procedures.

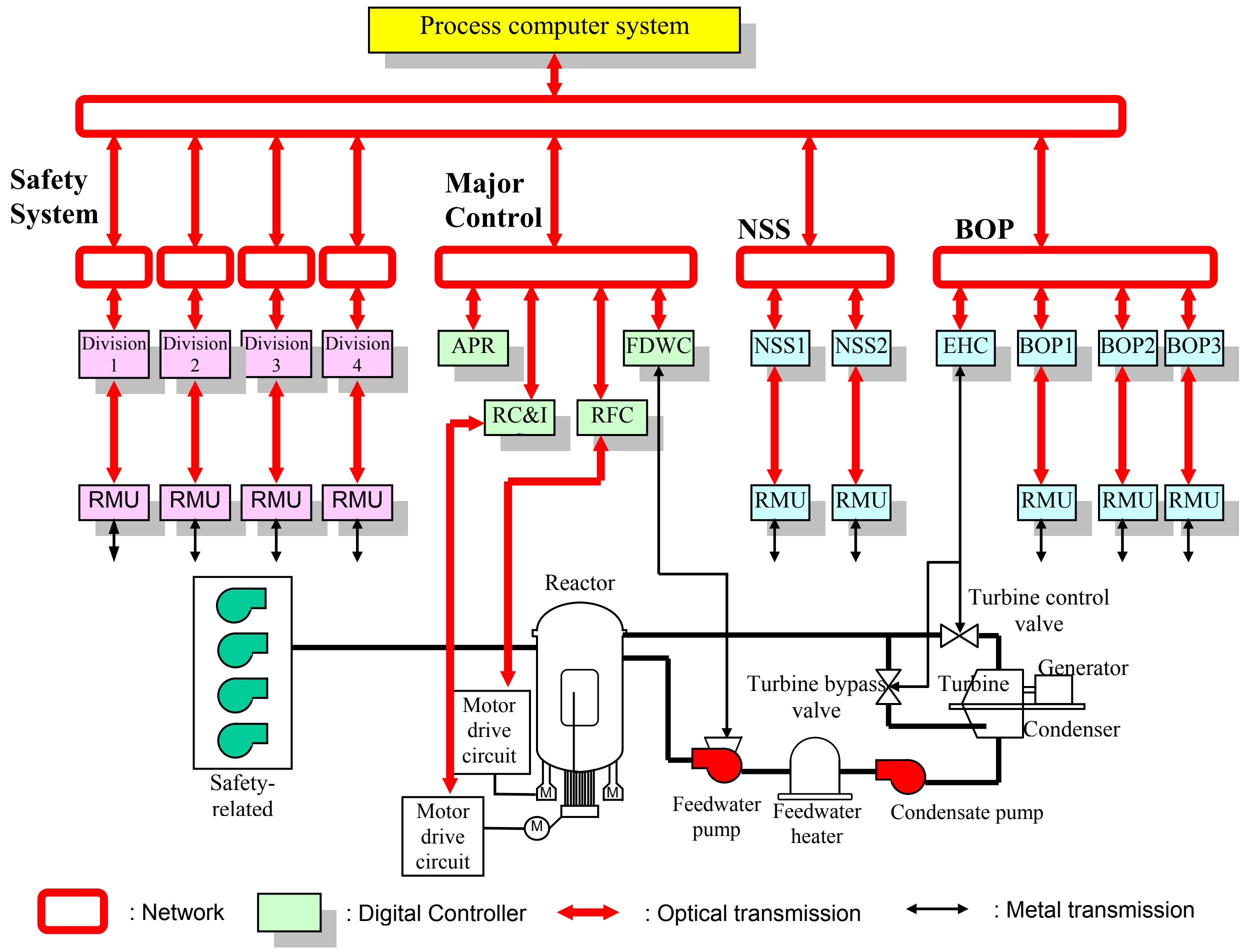


Figure 2 General system configuration of Hitachi DCS in ABWR

For example, the following benefits can be obtained:

- Standardized basic circuits for power distribution, cabinet structure, etc., which results in rationalized design and manufacturing.
- Unified data and control network transmission interface test procedures can be applied, which contributes to reducing work loads for transmission confirmations on the tens of thousands of interfacing points of an entire ABWR.
- Simplified interface between controllers. For example, gateways for converting different and incompatible DCS transmission protocols can be eliminated. The existence of gateway may increase negative factors such as complexity of the system configuration, failure modes and workload.
- Consistent maintainability for the I&C system, which can be realized by supporting a plant-wide consistent DCS product series. Furthermore, a reduced variety of DCS spare parts provides economic benefits.

To summarize, the integrated system configuration applying unified DCS products is profitable both to manufacturers and users from the view point of quality and economy.

4.1.2 Case 2: Scope-Limited (NSP or BOP)

General configuration of the second case is shown in Figure 3. In this case, one of the differences from the previous case is the existence of gateways between NSP and BOP to convert transmission protocols; in addition to transmission interfaces, some NSP and BOP logics are connected also by hardwired circuits.

Caution should be exercised when designing and testing interfaces involving more than one vendor. In Hitachi's latest ABWR for this case, the following principles were established to reduce design risks:

- Project-wide management standards were agreed to by the both parties for key engineering documents, IBD (Interlock Block Diagram) and ECWD (Elementary Control Wiring Diagram) before commencing the project.
- Common engineering documents such as interface signal lists (see Figure 4) were prepared by the party handling the signal source and confirmed by both parties at the early design stage.

To summarize, splitting I&C system scope of supply into 2 or more vendors may increase project risks such as adding more interfacing points and hardware components compared to the previous case (one vendor/supplier); however, Hitachi has experienced managing this case from its early design to final commissioning stage.

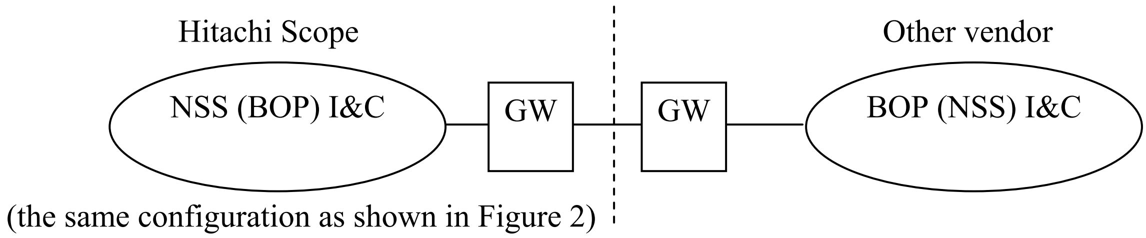


Figure 3 Conceptual System Configuration of Hitachi DCS in ABWR (Hitachi responsible for either NSS or BOP)

No.	Signal Name	Signal Type (A/D)	Cable No.	Signal Sender							
				Interlock Block Diagram			Elementary Diagram				Panel No.
				SH-No.	Rev.	Responsibility	SH-No.	Rev.	Responsibility	Spec.	
EG-H001	Generator Output A	A	BR261Z01				EG013	0			H11-P679

Signal Receiver										Remarks
Interlock Block Diagram				Elementary Diagram					Panel No.	
SH-No.	Rev.	Confirmed Date	Responsibility	SH-No.	Rev.	Confirmed Date	Responsibility	Specification		
				BR261	0				H11-P710-1	

Figure 4 Example of Interface Signal List Used for Inter-Vendor Connections (in 2 parts)

4.2 Design automation

The entire NPP I&C documents library is comprised of more than 10,000 drawings, and making document creation efficient will contribute to efficient overall plant implementation.

As digitization scope expands, elementary diagrams for digitization parts can be limited to several basic types. For example, drawing formats are basically the same for (1) identical I/O modules models, (2) identical switchgear circuits and (3) cabinets with identical structures.

By utilizing the above features, Hitachi generated many of digitized-related elementary diagrams automatically according to the following scheme as an example.
First, I/O point tables for all the DCS equipment are prepared. As a general design routine, the tables are created for a set of design activities such as I/O point allocation to each I/O module. Note that the I/O table generation are conventionally done as a necessary design step, not an added activity just for automatic elementary diagram creation. The I/O point tables include attributes such as I/O module type, switchgear circuit types and chassis/slot/channel to be allocated.
Then, each I/O point identified in the I/O point tables is copied to formats prepared for each designated types in advance.

Furthermore, the I/O point names are automatically copied to desired part in software logic diagram so that unnecessary manual duplications, which can be causes of careless mistakes, can be avoided. Refer to Figure 5 for an example of design automation.

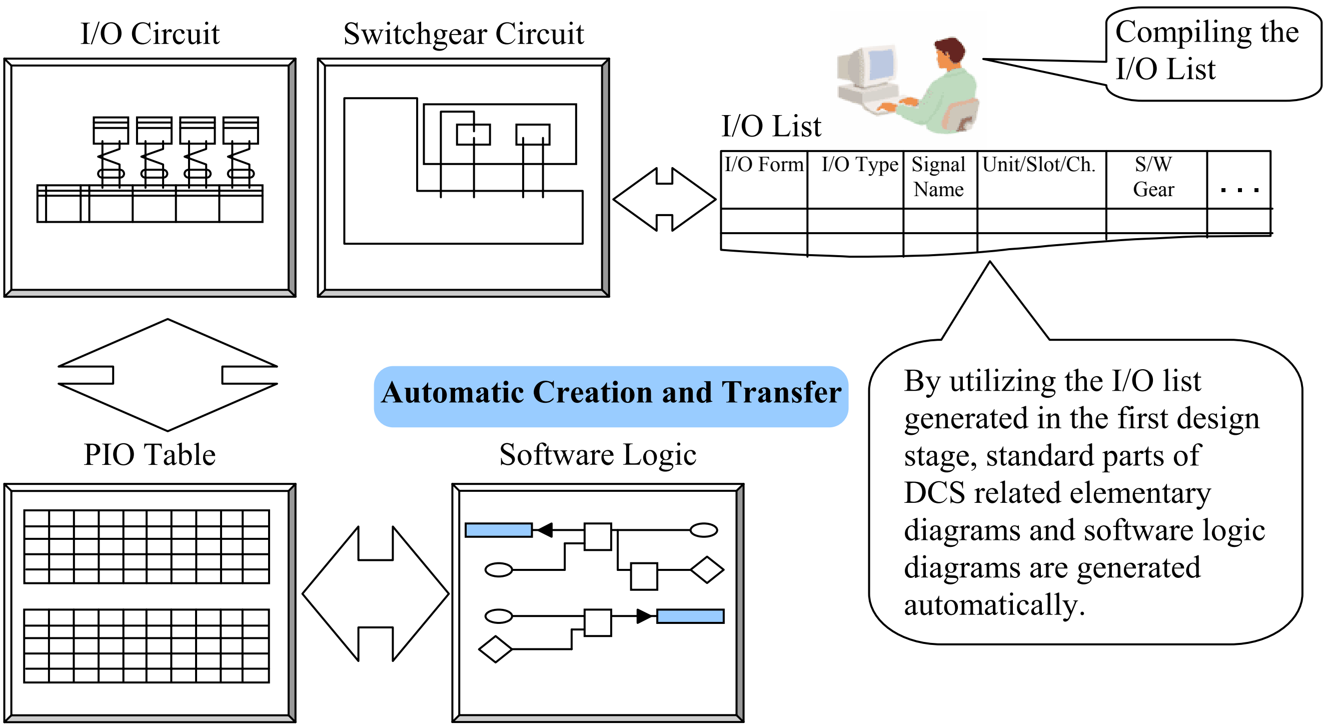


Figure 5 Example of Design Automation

4.3 Strategic Tests

4.3.1 Maximizing Human Resources

1) Constituting an Appropriate Organization Structure
Generally the site organization structure was made considering the following two points:

- Grouping horizontal organizations for Electrical Group, Control Group and Instrumentation Group
- Grouping vertical organizations for every main function

An example of a site organization structure is shown in Figure 6. Thus, test groups are made in the light of technical fields and functions.

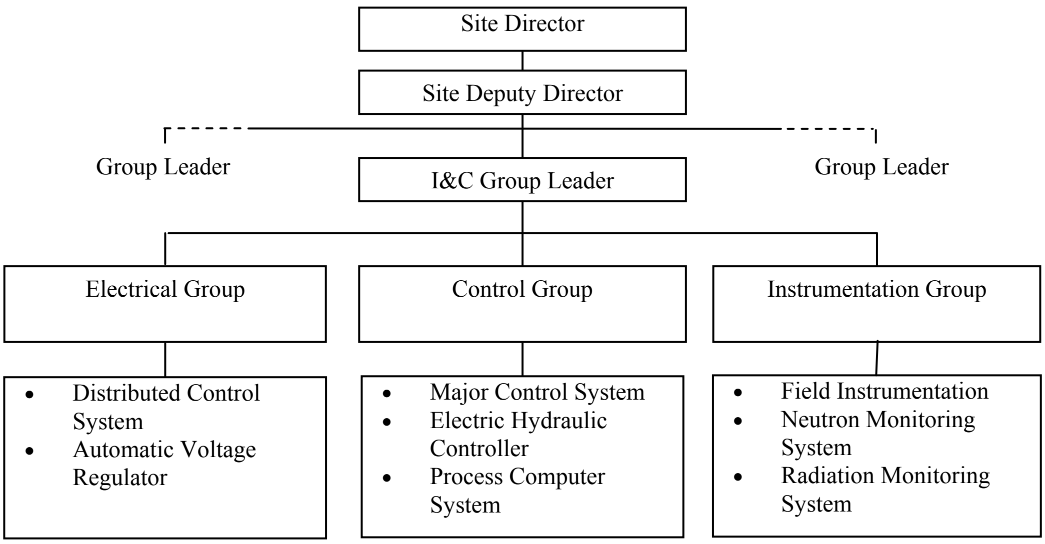


Figure 6 Example of Site Organization Structure

2) Effective Use of Experienced Engineers for Site Management
By taking advantage of its highly-experienced human resources pool, Hitachi dispatched experienced senior persons to the site temporarily to ensure smooth test implementations especially regarding analysis of plant behaviour during important tests such as LOCA/LOPA simulation tests. (LOCA: Loss Of Coolant Accident, LOPA: Loss Of Power Accident)

3) Persistent Activities for Seamless Communication
Because hundreds of personnel work simultaneously in different groups and on different kinds of activities during NPP construction, effective communication is crucial for smooth and safe implementation on-site. The following measures were taken to ensure seamless communication:

- Brief group meeting every evening for common understanding among the various groups (group meetings are held in the mornings).
- Meeting with construction group once a week to adjust the test schedule to the cabling schedule.
- Advanced special coordination meetings among key personnel of related groups before critical tests in order to anticipate and prevent trouble.

4.3.2 Incorporating Lessons-Learned from Past Projects into the Test Plan

Hitachi has its own database on lessons-learned from past incidents, and its internal regulations stipulate the incorporation of lessons-learned into internal procedures, design, test plans, etc.
For example, based on past troubles experienced on neutron sensors for fuel loading, Hitachi has since conducted neutron monitor tests in advance of fuel loading thus changing the existing standard test schedule as shown in Figure 7. Specifically, in addition to the tests before delivering the products to the site, the following 2 tests were implemented from a risk mitigation point of view.

- Measurement of SRNM (Start-up Range Neutron Monitor) was confirmed by neutron source for fuel loading chamber before fuel loading
- Noise immunity was confirmed by several tests.

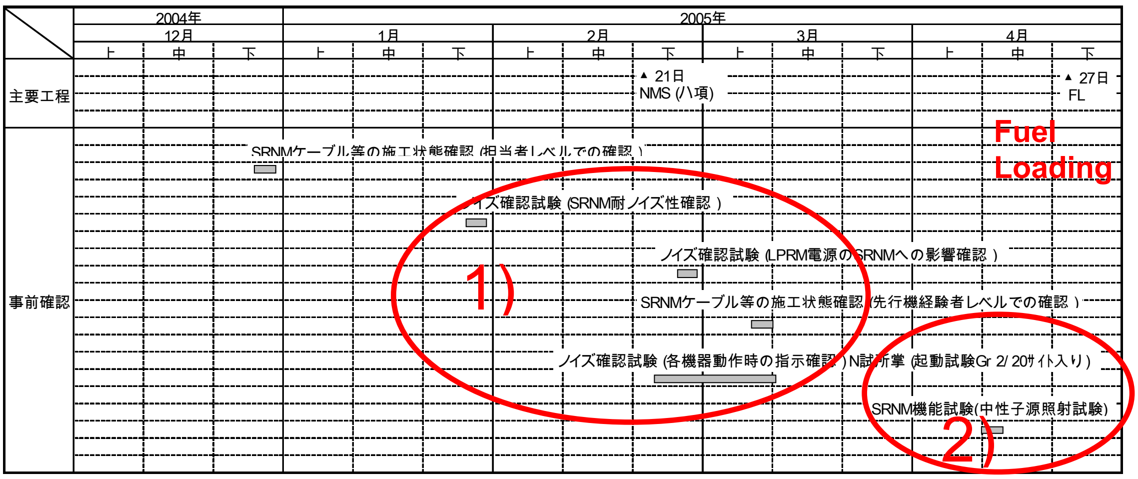


Figure 7 Neutron Monitor Test before Start-up Test

4.3.3 Utilizing Information Technology

By utilizing remote monitoring and information exchange technology, Hitachi conducted site commissioning tests effectively with reduced costs. One of the biggest benefits was the reduction of travel costs for test and commissioning personnel.
The methods taken at the latest ABWR were as follows:

- Temporary read-only monitoring of plant status from the factory by applying one-way gateway technology (see Figure 8)
- Communication between site and factory through video-conference meeting systems and intra-net systems

However, merely technological measures are insufficient when direct face-to-face human contact is required and/or when complicated information must be exchanged or difficult problems resolved. Hitachi has had many experiences of visiting NPP sites for only a one hour meetings for trouble shooting, requesting schedule changes, etc., which helped the situation proceed smoothly. In such situations, Hitachi's experience demonstrates that email exchanges, phone conversations and video conferences are not enough for addressing the issue.

To summarize, effective management and use of the available means of communication requires careful judgment and experience.

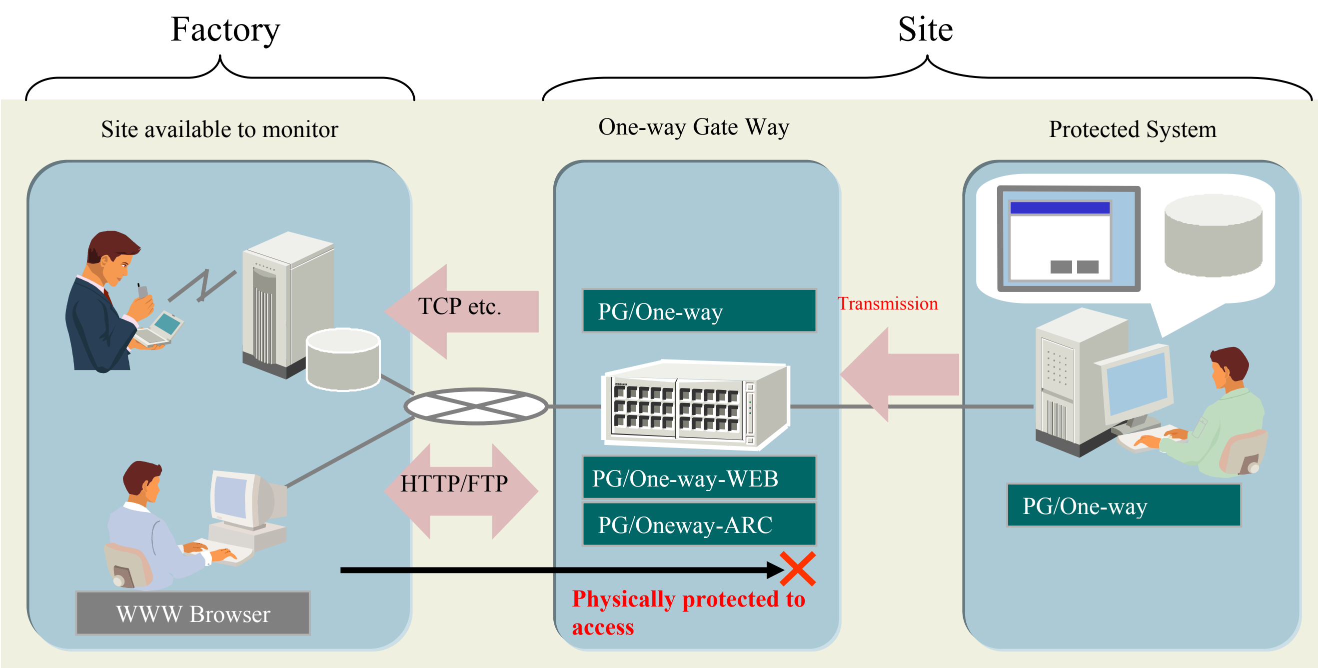


Figure 8 Example of one way gate way technology

5. Possible Application of I&C Systems in the Next New Build Projects

In this section, possible applications of Hitachi I&C systems to future new build projects are shown based on the contents of the previous sections.

5.1 Further Improvement of the Design / Test Process

5.1.1 Design Process

As shown in reference [1], Hitachi is now developing its new DCS platform for use in the non-Japanese NPP I&C market. By the new DCS platform, a programming tool with the following enhanced features easily handled by a third-party is being considered:

- Intuitive Operation & Easy Modifications
  - User interface with standard Windows® functionality
  - Online program changes with the process running

® Windows ® is a registered trademark of Microsoft Corp. in the USA and other countries.

- Complying with International Programming Language Standards
  - IEC 61131-3 languages: FBD, ST and SFC (future)
  - Selectable language which best suited to the application
- Improvement of Development Efficiency
  - Multi-user program development functionality
  - Accommodating import and export of third-party databases (an example is shown below)
- User Authentication
  - Security features such as password-protection and access controls

The following is an example of accommodating import and export of a third-party database.
By the features shown in Figure 9, hardware configuration data can automatically be created in the programming tool by imported data, and the hardware configuration data in the programming tool can be exported to electronic files to be reused by the third party database. The advantage of this feature is that it allows automatic hardware configuration work to be a part of the standardized work flow of both Hitachi and any other third party applying Hitachi DCS.

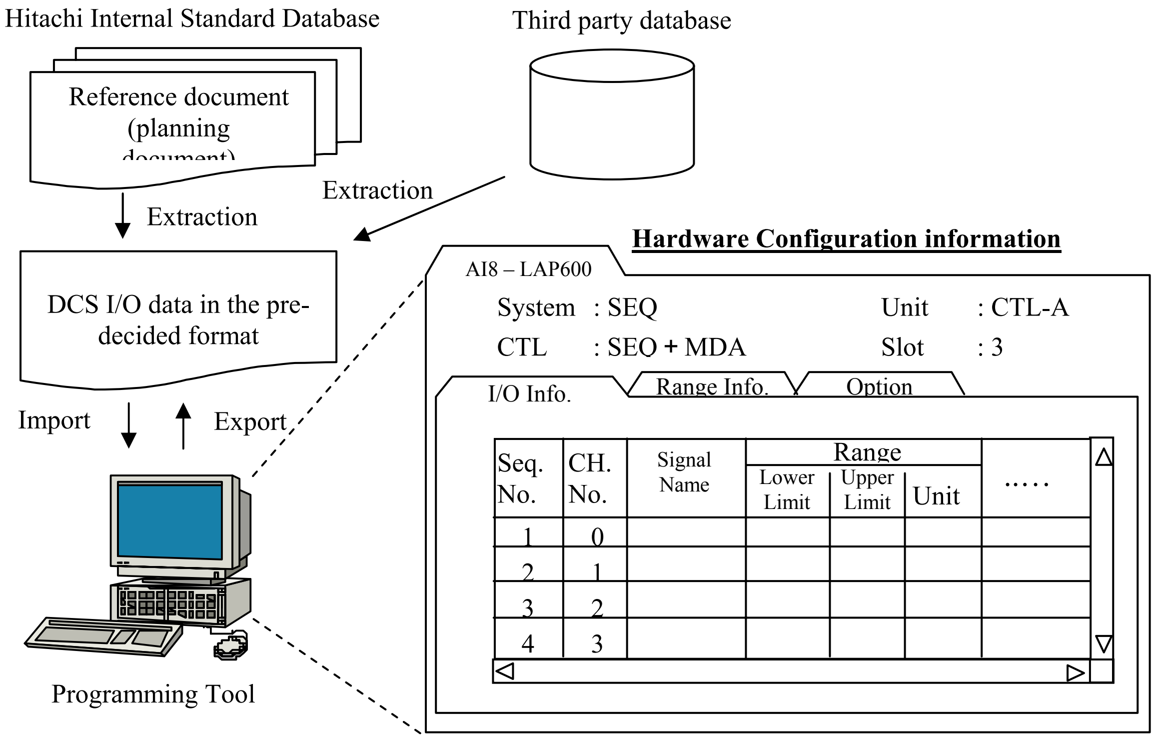


Figure 9 Automatic Hardware Configuration Generation

5.1.2 Test Process

Hitachi is planning to improve its DCS test process as follows:

1) Applying PC-based Emulation Technology
As adopted by most DCS vendors, Hitachi is planning to apply PC-based emulation technology to its programming maintenance tool to enable verification of program control logic behaviour before downloading to DCS controller.

2) Applying Virtual I/O Simulator
Hitachi is planning to adopt a virtual I/O simulator which simulates the I/O for multiple DCS controllers. By providing simulated I/O to the controller, program debugging of DCS controllers without any I/O modules is possible.

There are four types of modelling objects in an I/O simulation:

- Non-Control data for simple data (e.g., switches)
- Schedule data for scheduled serial data (e.g., actual test data)
- Feedback data for simple process models (e.g., first order filters)
- Logical data for complex process models (e.g., plant model)

Refer to Figure 10 for the conceptual description of virtual I/O simulator.

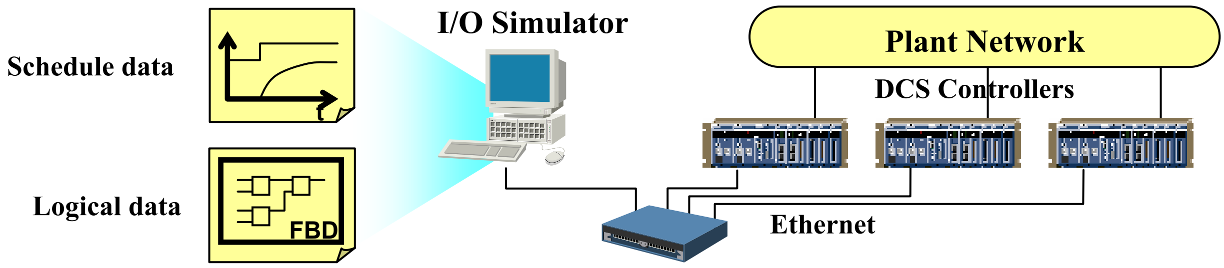


Figure 10 Conceptual Description of Virtual I/O Simulator

3) Full Scope Plant Simulator
Hitachi is planning to deploy a full scope simulator to the Japanese ABWR currently being constructed. The full scope simulator consists mainly of the following components:

- Programming tool to create DCS program
- PC-based DCS emulator which acts as DCS controllers to interface with such elements as field devices and main control room panels which are realized by plant simulator
- Plant simulator

By the configuration, the Hitachi full scope simulator provides:

- Plant process computer training and testing
- A variety of computer-based training methods
    - Overall plant and individual system operation and control
    - Team training to study interactions, individual system and plant maintenance
    - Process responses for realistic operator training
    - Initiation of malfunctions and transient situations by Instructors
- Software compatibility with that in the actual plant

Thereby, the following 3 features, that is, (1) plant procedure development and optimization, (2) reduced commissioning time and (3) optimization of operations including startup and shutdown can be realized.
Refer to Figure 11 for a general description of the Hitachi full scope simulator.

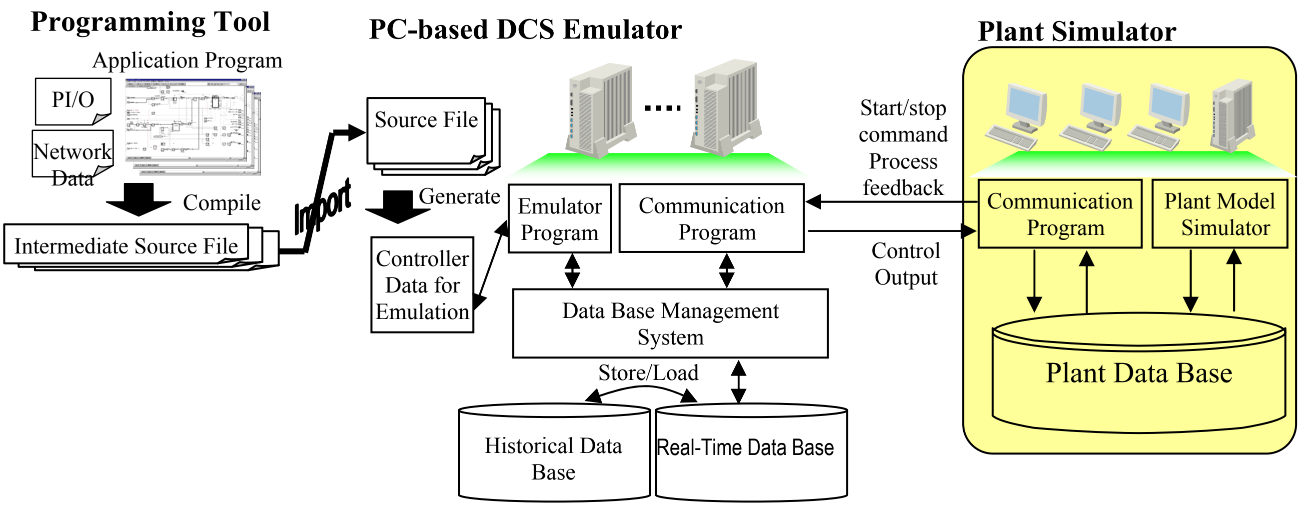


Figure 11 General Description of Hitachi Full Scope Simulator

5.2 Utilization of ABWR Human Factor Engineering Experience

Human factor engineering is one of the most important factors for plant safety, operability and maintainability. Human factor engineering must be appropriately initiated at the conceptual design phase, and numerous investigations spanning from human machine factors to plant operating policies are necessary to develop the main control room design. Hitachi, together with utility companies and the other manufacturers, was involved in the ABWR main control room development considering mainly the following items:

- Overall HMI system design policy including DCS and display system architecture covering all the major plant scope such as safety system, NSP and BOP.
- Total plant automation policy to reduce operator work load.
- Design target for achieving plant safety, operability and maintainability. (e.g., criteria for each device design such as location and hardware/software in main control room panels)

The above points are not peculiar to ABWR; therefore, Hitachi's accumulated know-how based on its ample experience can be applied to main control room design works in the new build projects of other reactor types.

5.3 Involvement in Test Planning from the Early Stages

As shown in the previous sections, it is important for both manufactures and utilities to start test planning in the early stages. Hitachi can contribute to the next new build projects in terms of test planning by utilizing its experience of different project management styles.

6. Conclusion

- Hitachi has established and successfully implemented 2 types of management styles for NPP total digitized system including safety critical system.
- Hitachi has accumulated lessons-learned from its past experiences and utilized them in subsequent projects.
- Hitachi's experiences over past ABWR projects can be applied to the coming new-build projects.

7. References

[1] K. Ishii, M. Kobayashi, M. Shiraishi, S. Masunaga, H. Harada, G. Raiskums and S. Tikku, "**Distributed Control System Application to CANDU Plants Recent Activities for Adaptation of DCS Platform to IEC Standards", 27th Annual Conference of the Canadian Nuclear Society (2006)**