Standardization and Systematization of Control Room Operation through the Implementation of an Intelligent Sequence Control System

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Abstract

This paper presents the results through the implementation of IT-based systematization of control room operation.

IT-based systematization, consisting of an Intelligent Sequence Control System (ISCS) for automatic operation and an Advanced Monitoring System (AMS) for automatic monitoring, on the other hand, permits ready achievement of the recommendation target. Moreover, ISCS/AMS are very effective tools by which operators can easily systematize their know-how.

Over 30 ISCS/AMS systems have been implemented at petroleum /petrochemical refineries operated by Idemitsu Kosan in Japan since the year 2000. As a result of the application of ISCS/AMS systems, the following results have already been achieved:

1) Manual operation frequency has been reduced by 93% through the application of ISCS to shutdown operations.
2) Alarm frequency has been reduced by 88% through the application of ISCS to shutdown operations.
3) Operational knowledge has been partially systematized by ISCS/AMS.
4) ISCS/AMS have contributed to know-how sharing and to the standardization of a high level of operational expertise.

Keywords: intelligent sequence control, advanced monitoring, standardization, systematization, know-how, dissemination, operation, refinery, petrochemical

1. Introduction

The background of standardization and systematization of control room operation through the implementation of intelligent sequence control system is shown.

The needs and challenges facing the Japanese petroleum industry are herein discussed. The top three challenges in the petroleum industry are:

1) Dealing with an aging workforce
2) Wrestling with intensified international competition
3) Coping with environmental issues

In the Japanese refining industry, there are three critical needs:

1) Know-how sharing and dissemination
2) More efficient production
3) CO2 reduction and energy savings to cope with environmental issues

Of these, the most urgent is the need to provide the smooth and efficient sharing and dissemination of know-how.

The demographic profile of Japanese refinery operators in 2003 is shown in **Fig.1**. As shown in the chart, three points can be readily observed.

1) The distribution of ages is unequal.
2) A massive retirement will be seen in the coming 5 to 10 years.

3) Operational skill and know-how are predicted to degrade.

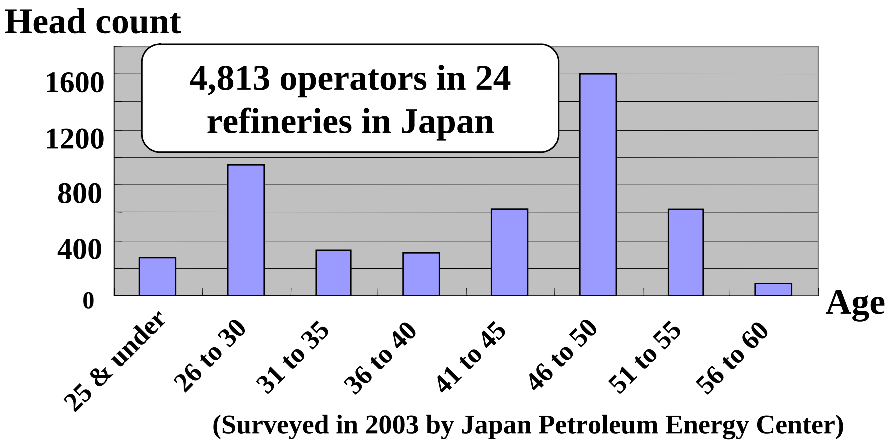


Fig.1 Demographics Profile of Japanese Refinery Operators

As a consequence, secure refinery operation will be difficult to maintain with the same number of operators. Recognizing this trend, we would like to accelerate the dissemination of operational expertise among the fewer remaining workers.

Most refining companies rely on reductions in the Distributed Control System (DCS) alarm frequency and the manual operation frequency to maintain safe and stable operation. Guidelines established by the Engineering, Equipment and Materials User's Association (EEMUA)[1] recommend that 150 alarm events occur per day. However, in practice, this recommendation is extremely difficult to adhere to through the use of DCS and Model Predictive Controls and Alarm Monitoring Systems.

In order to realize a future refinery operation, we developed IT-based systematization, consisting of an Intelligent Sequence Control System (ISCS) for automatic operation, and an Advanced Monitoring System (AMS) for automatic monitoring.

2. Future Vision of Refinery Operations

We believe that future refinery operation systems will likely be built with two subsystems for control room operations. The first is the Intelligent Sequence Control System (ISCS), and the second is the Advanced Monitoring System (AMS) [2]. In this section, we describe the necessary functions of these two systems.

2.1 The required functions for future refinery operation systems

1) The functions required in the operation automation support system, i.e. intelligent sequence control system (ISCS), are:
   (a) Prevention of misoperation.
   (b) Enabling of automatic control.
   (c) Provision of safe operation through continuous control.
2) The Advanced Monitoring System (AMS) has two functions:
   (a) Detection of early-stage abnormalities through the monitoring of symptoms.
   (b) Provision of safe operation through continuous monitoring.

Details of the IT-based Systematization for control room operation are shown in **Fig.2**. The system attempts to automate the operational procedures of control room operators. The subject operations are of both steady and unsteady types.

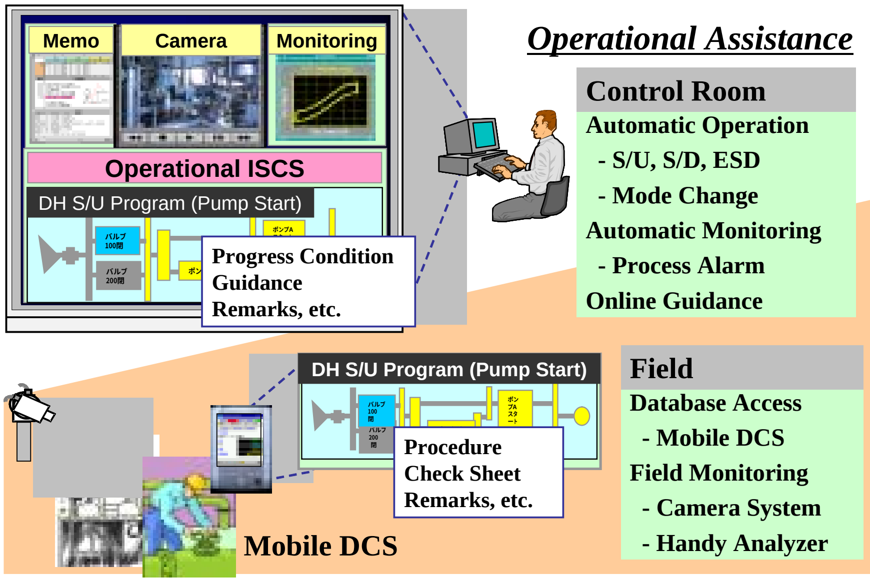


Fig.2 Future Vision of Control Room Operation

Unsteady operation falls in two categories. One category includes startup, shutdown and emergency shutdown operations. The other covers mode change, e.g. crude change and production mode change for kerosene-rich operation in winter.

The intelligent sequence control system is uploaded with the veteran operators' operational know-how. These two subsystems will employ programs simulating the actions of experienced operators to perform know-how dissemination to less-experienced operators. The intelligent sequence control system is capable of displaying operational information or messages in unsteady operation to field personnel.

We believe this function will boost operational efficiency through the combining of control room and field operations.

2.2 The goal of ISCS

The goal of ISCS is standardization and automation of control room operation for both steady and unsteady state. ISCS simulates the control room operator's know-how for control room operation. We can disseminate an experienced operator's know-how by using ISCS, and thus ensure smooth operation.

1) Reduction in operational losses resulting from inadequacies in operator skill.
2) Increased safety and reduced time loss.

2.3 The goal of AMS

The goal of the AMS is to detect abnormalities which cannot be caught by the DCS alarm function. The AMS simulates the control room operator's know-how for the monitoring of operating conditions. Continuous monitoring provides that operating conditions remain within acceptable parameters, thus improving system functioning.

1) The system is characterized by wide surveillance with a small number of fieldworkers engaged in simultaneous, parallel tasks.
2) It is also characterized by reduction of the control room operator's load through the automation of process-surveillance.

3. Structure of ISCS

3.1 ISCS Standard Module

ISCS consists of two types of functions. One is Connect Icons and the other is User-Defined Modules. Connect Icons connect User-Defined Modules. User-Defined Modules are procedures for control and monitoring. We can make User-Defined Modules using Unit Icons. We can customize control and monitoring procedures by simply selecting the appropriate User-Defined Module and inputting the desired parameters, as shown in **Fig.3**.

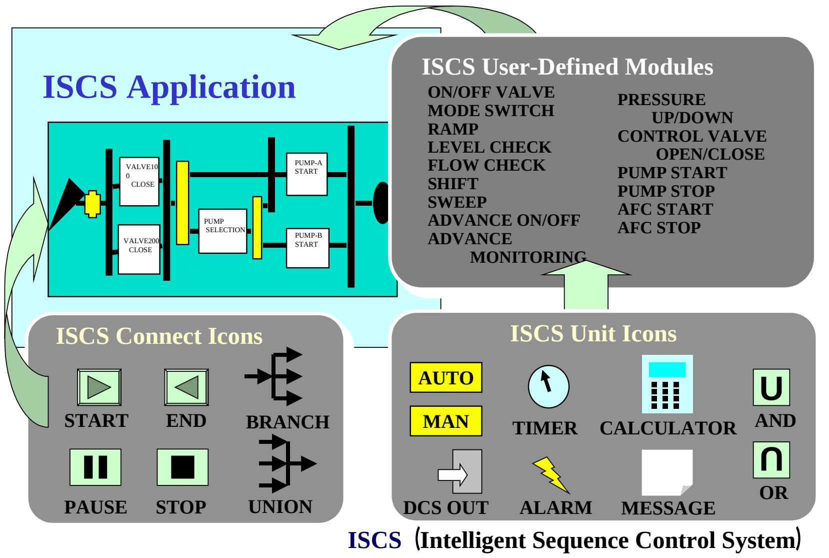


Fig.3 ISCS Standard Module

ISCS application includes the basic control mechanism (or operational procedure) as well as an experienced operator’s know-how in dealing with normal/abnormal conditions. With Connect Icons and User-Defined Modules, we have the ability to develop our own standardized application.

3.2 ISCS Control Mechanism

Once we install ISCS application, ISCS system engine employs an expert system to change the order of the User-Defined Modules according to the process condition and communicates with DCS, as shown in **Fig.4**. ISCS automatically determines the order of execution by its expert engine [3]. Control systems based on FORTRAN or C languages, on the other hand, require the involvement of programmers to alter the execution order.

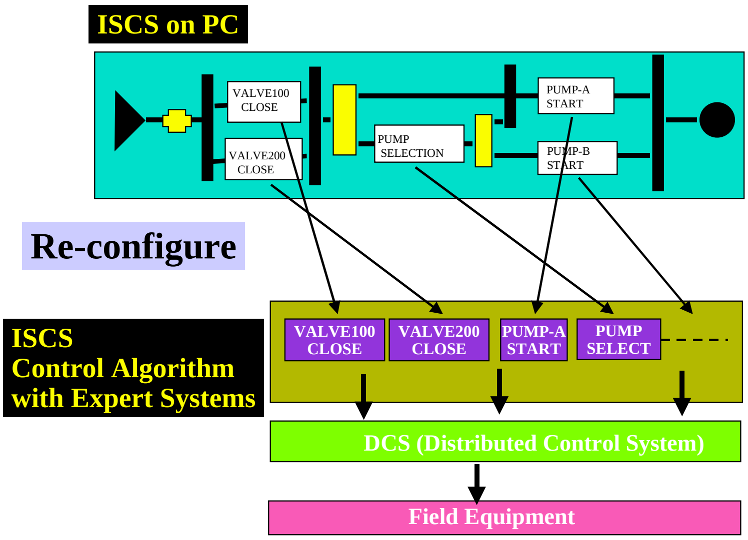


Fig.4 ISCS Control Mechanism

4. Applications of ISCS/AMS and Their Effects

Control room operators usually spend a lot of time on operation and monitoring. We have applied many ISCS/AMS applications to our petroleum/petrochemical refineries to improve control room operations. In this section, we describe the effects of ISCS/AMS applications.

4.1 Applications of ISCS

4.1.1 Standardization of Optimal Operational Procedures

In order to apply ISCS, we have standardized the operational procedures of control room operation. These operational procedures vary somewhat from person to person. We selected the best pattern of procedures to create the Standardization of Operational Procedures. This standardization thus represents a composite of the optimal procedures of individual operators (**Fig.5**).

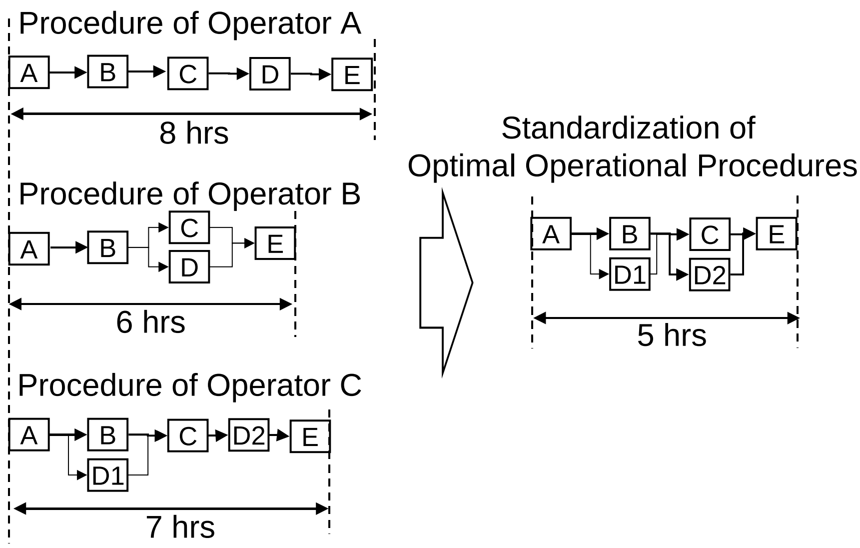


Fig.5 Standardization of Optimal Operational Procedures

4.1.2 Reduction of Operators' Workload

ISCS is applied to automate the shutdown operation in distillation column. The reasons for this automatization are:

1) The details of the shutdown/start-up operational procedure depend on skillful operators, and those details are not generally explicitly defined in a manual. Thus, we need to standardize the operational procedure for shutdown/start-up.
2) The shutdown/start-up operation takes a long time. Thus, reduction of the control room operator's workload by automation is needed.

The result of ISCS in shutdown operation at a distillation column is shown in **Fig.6**. The number of manual operations has been reduced by 93%, and the frequency of alarm occurrences has been reduced by 88% through applying ISCS.

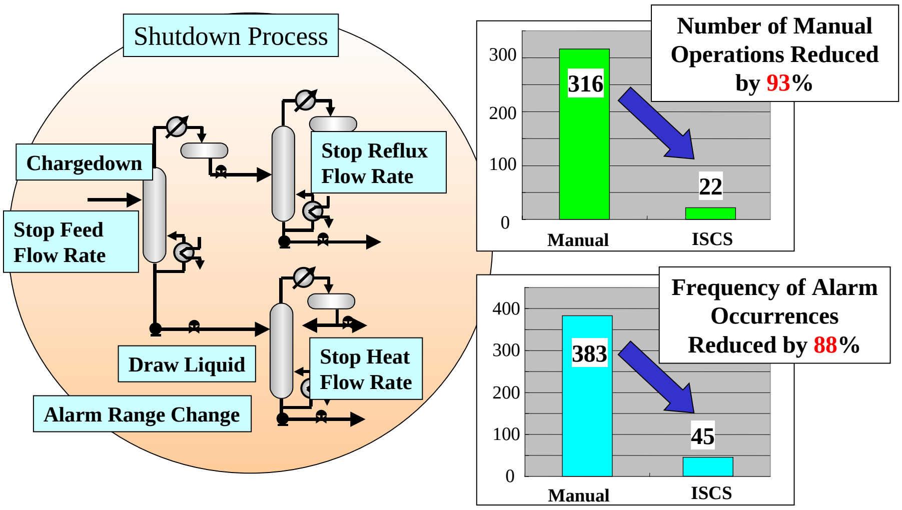


Fig.6 Application for Distillation Column Shutdown Operation

4.1.3 Sharing Skilled Operator's know-how

A skilled operator can operate the plant through his expertise. However, this know-how (tacit knowledge) has not to date been quantified and documented in manuals. Because many skillful operators will retire by 2010, their know-how must be systematically integrated into ISCS in order to be disseminated.

The flow chart of ISCS shows the skilled operator's operational procedure (middle of **Fig.7**). The text information of ISCS shows the experience and causes, i.e., know-how and "know-why", that must be disseminated (the upper right of **Fig.7**). The trend chart of ISCS shows how the process status will be changed. (the bottom right of **Fig.7**).

This information is integrated in ISCS and provides assistance to junior control room operators.

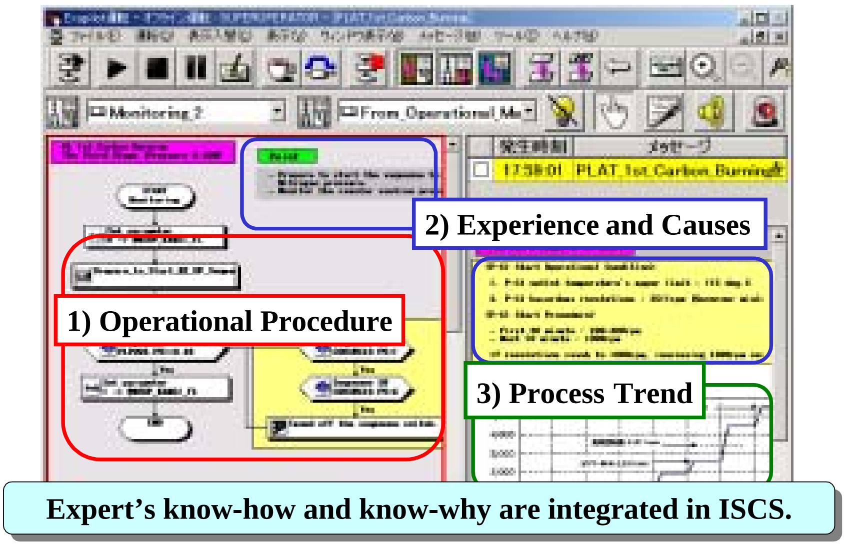


Fig.7 Application for Reactor Carbon Burning Operation

4.1.4 Safe and Smooth Operation

An example of the advantages of ISCS in the decomposition furnace decoking process is shown in **Fig.8**. This pink line represents the charge flow rate. The green line represents the tube temperature by manual operation, and the blue line represents the tube temperature by ISCS.

Comparing these two lines, it can be readily seen that the distribution of tube temperature with ISCS is much smaller.

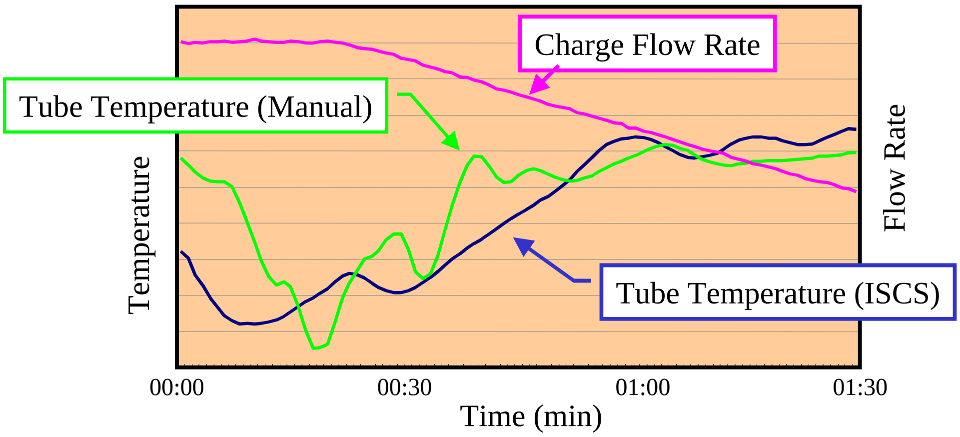
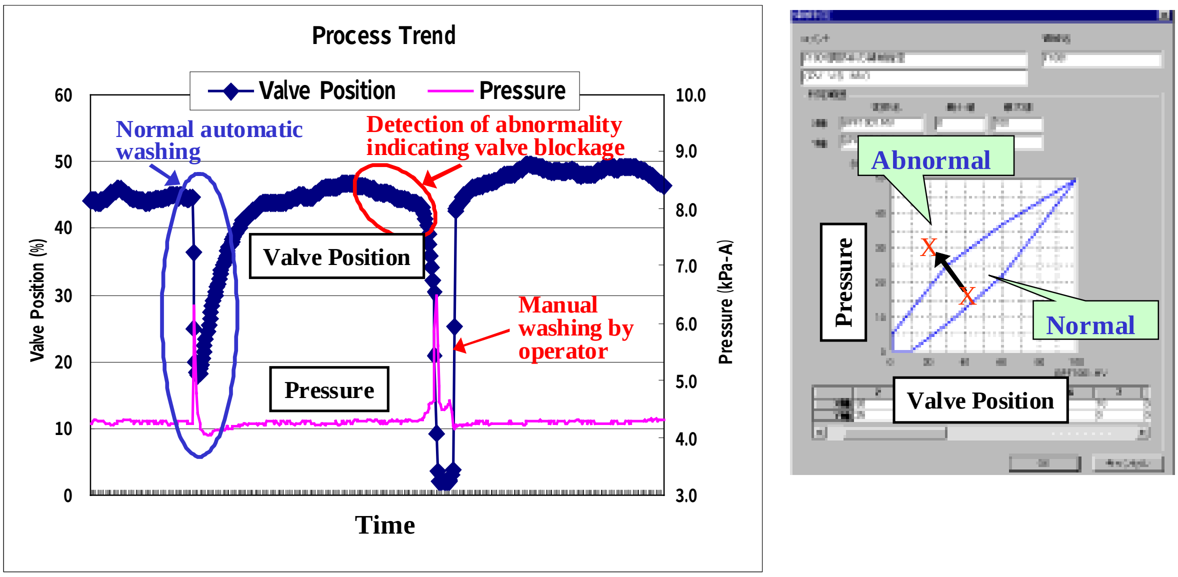


Fig.8 Application for Decomposition Furnace Decoking Operation

4.2 Applications of AMS

4.2.1 The application of AMS in Valve Block-Tendency Detection

A control valve position graph (open %) is shown in **Fig.9(a)**. This valve is washed according to a specified schedule (blue oval in **Fig.9(a)**). However, the control valve can sometime become stuck because of dirt and contaminants.



(a) Process Trend **(b)** Normal-Status Domain

Fig.9 Surveillance in a Blocked-Control-Valve Scenario

The red oval in **Fig.9(a)** shows an imminent control valve blockage. This control valve blockage can be detected by comparing pressure vs. valve position through the application of AMS. The inner domain of the blue line in **Fig.9(b)**, where the Y-axis is pressure and the X-axis is valve position, occurs in normal control valve functioning. Thus, an imminent control blockage can be identified as a transgressing of the blue parameter lines.

Before the application of AMS, this would seriously affect the operating process, because operational action could only be taken after the valve was completely occluded. However, through the application of AMS, the disturbance to the process is minimized, as early operational action can be taken when even a slight valve blockage occurs. It is difficult to detect such a slight blockage in advance by the HI/LOW alarm of a DCS standard-function.

5. Evaluation of the application of ISCS/AMS systems

In our evaluation of the results of the application of ISCS and AMS, we came to the following conclusions:

1) Can the automated systems be used in unsteady operational situations?

Automation of the grade change, the charge change, and S/U and S/D processes has been achieved. The number of manual operations and alarms were reduced by over half after applying ISCS/AMS systems.

2) Can ISCS be applied when a manual operation is required as a part of a process?

Yes. When the manual field operation is necessary, ISCS sequence stopped, and the control room operator restarts the program after the field operator’s work has been accomplished.

3) Has operational safety been improved?

Automation allows a reduction in manual adjustment frequency, and ensures the prevention of misoperations. Operations free of procedural omissions and mistakes are made possible by programming the end-check of the field work into ISCS.

4) Did cooperation between control room operators and field operators become more efficient?

Although oversights are reduced, efficiency is not apparently improved.

A portable terminal through which field operators can be informed of the status of ISCS is being developed as one of the functions of FSS (Fieldwork Support System). DCS information can also be confirmed in the field. Once these improvements have been made, field operators can initiate ISCS directly from the field.

Thereafter, it will be determined whether control room operator and field operator functions can be combined.

5) How much has development efficiency been improved and maintenance costs reduced?

Development lead time is reduced to from 1/5 to 1/10; the operator can develop the program on his own. In addition, the operator himself carries out maintenance, and special maintenance stuff is unnecessary.

6) Can the developed program be easily adapted to a different plant?

If the plant is the same kind of plant, yes. However, conversion to different kinds of plant is generally difficult because every plant has different facility conditions.

For example, check logic of the control loop varies among the plants.

7) Can operational know-how be disseminated?

Know-how that can be standardized can be disseminated.

Systematization of expert know-how obviously promotes standardization.

Uneven operations among experienced operators can be to be improved to a single optimal operation. The less-skilled operator is thus able to easily learn the optimal operation.

8) Can operational know-how about abnormalities be disseminated?

No, not in ISCS and AMS, because operational know-how about abnormalities cannot be standardized. It is necessary to train for operations in abnormal situations by training simulators and OJT (On the Job Training). Idemitsu has constructed a DCS sequence and a hard sequence for the emergency shutdown procedure in all plants.

6. Conclusions

This paper presented the applications of ISCS/AMS and their effects for control room operations. Successful standardization and systematization of control room operation can be realized. ISCS and AMS achieved the desired effects:

1) Standardizing optimal control room operation and monitoring, enabling every operator to perform the best-in-class operation.
2) Accumulation and dissemination of skilled operators' know-how
3) Safe and smooth operation under unsteady operational conditions
4) Reduction in operators' workloads

With respect to future research, we are currently developing a portable terminal system through which field operators can be informed of the status of ISCS. We believe it will lead to more efficient cooperation between control room operators and field operators.

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