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COMPUTER AIDS FOR PLANT OPERATION

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Abstract:
Plant operation involves a high degree of interdependence between process equipment, control systems and human operators. Nowadays, flexible production in the process industry is greatly owing to the operator's control skills and intelligence. In this situation, computer aids in various forms are key factors in solving operational problems. This paper considers a framework of plant operation for safe and efficient production in a plant.

INTRODUCTION

A comprehensive control and instrumentation system with distributed CPU, called DCS (distributed control system), has been used in the process industry in Japan since 1975 [1]. The DCS is a customized computer for system control. Transfer from panel operation based on analog controllers to console operation or CRT (cathode-ray tube) operation based on DCSs is going on even now.

CRT operation brought accurate and stable conditions to plants, using sophisticated computer control technology. It realized higher quality products, energy conservation, yield increase, and so on. It also saved space and labor in the control room. The resulting situation, however, generated new problems in plant operation. This paper considers some aspects of plant operation for solving these problems.

PLANT OPERATION ENVIRONMENT

A plant is composed of equipment and computer systems for control and management. All computer systems should be functionally integrated into a plant-wide manufacturing information system. Figure 1 shows a common model having a hierarchical structure.

The basic control system determines control actions and actuates the equipment. At present the DCS is widely used in almost all continuous plants and many batch plants; it provides both feedback and sequential control functions, the former for basic regulatory control and the latter for automatic sequence execution.

Recently the greater part of automatic control aimed at more flexible production is realized by sequential control, the event-driven system for automatic startup and shutdown of equipment items and automatic suspension of plant operation. However, the process control aspect of sequential control has not been studied enough in comparison with feedback control, because of the different dynamic representations. When investigating plant operation, it is necessary to examine plant-wide conditions under feedback control and sequential control. Figure 2 illustrates the interdependence of the controlled object, the sequential control equipment, and the operator [2].

In addition to basic control system, various advanced control systems are implemented for optimization and adaptation, to accommodate large variations in the production system environment. These functions are usually created in process computers connected to the DCS. More efficient connection between basic and advanced control systems should be considered.

Various computer systems for management are also connected to the DCS, to acquire actual operating data. These computers are usually called business computers. Intelligent integration of control systems and management systems is a target for computer integrated manufacturing (CIM) in the process industry. A recent survey on process CIM in Japan states that the process industry expects innovation of plant control and operation using information technology [3].

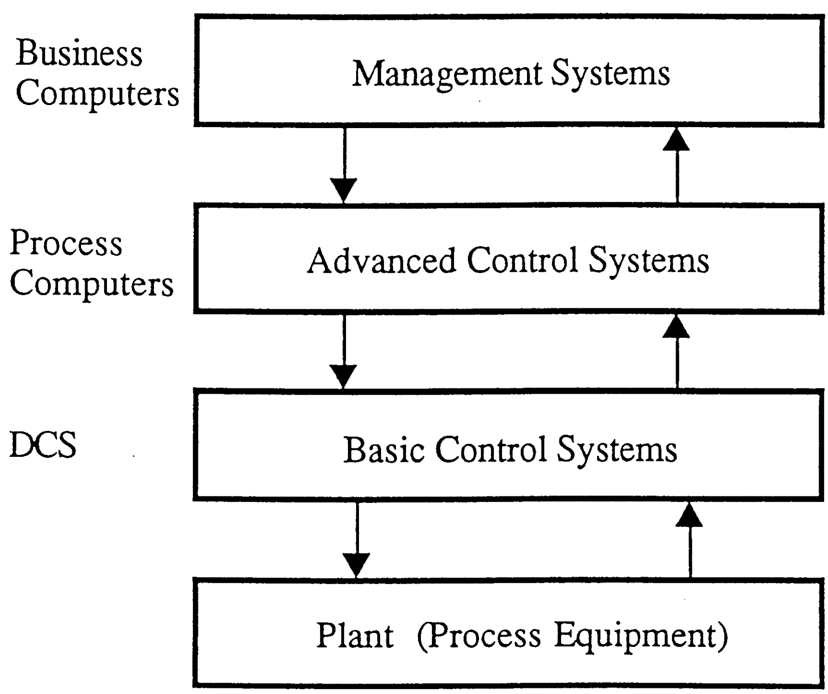

Fig.1 Configuration of various computer systems

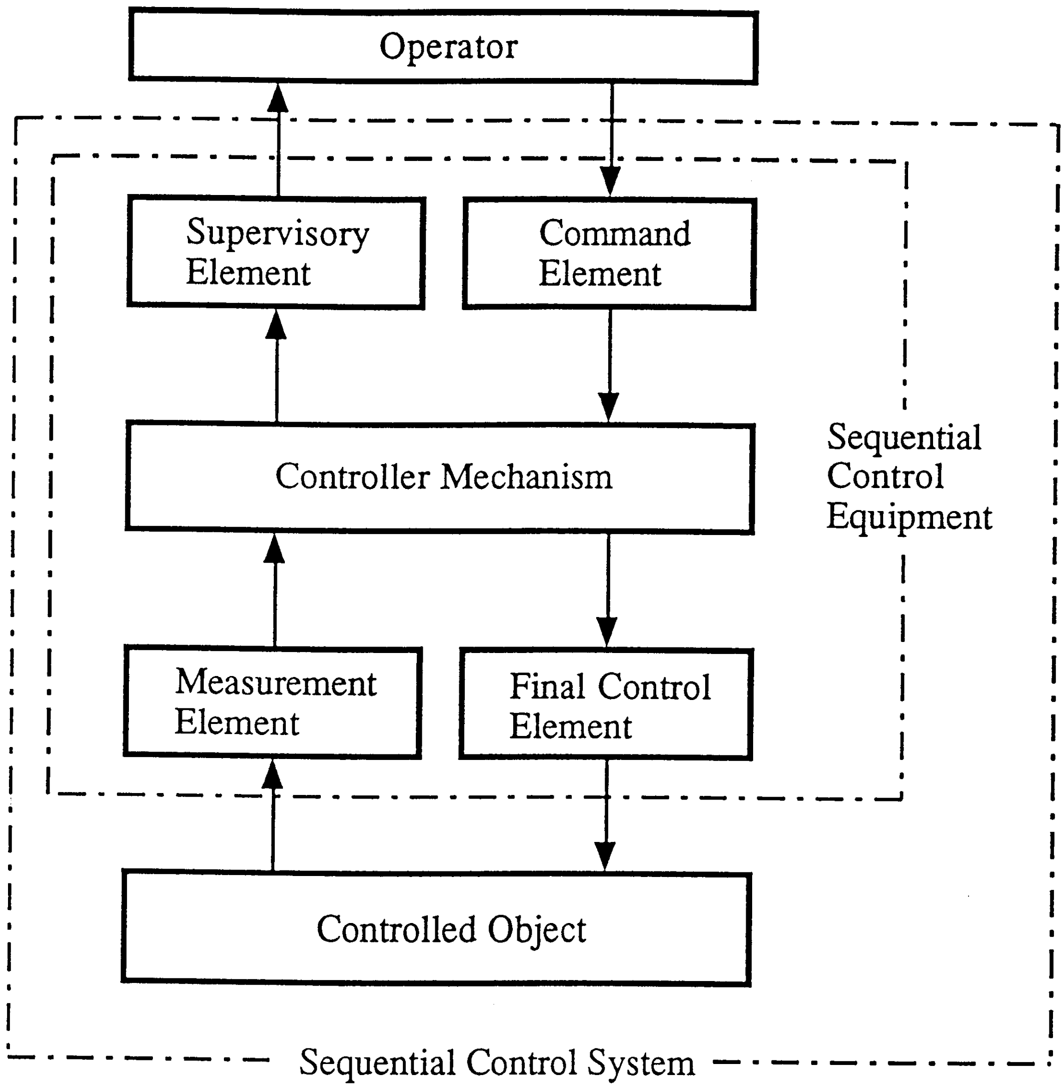

Fig.2 Configuration of sequential control system

PLANT OPERATION ISSUES

Plant operation is complex composite of equipment items, control systems, and human operators. Recently, several surveys on plant operation have been published in Japan [4-6]; This implies that plant operation is a crucial issue for the Japanese process industry.

A recent survey on CRT operation in Japan states the future of plant operation as follows [4]: Broader duties must be carried out by fewer operators, using more sophisticated control and related technology. Under the predicted situation, each component of plant operation, i.e. control systems, operators and processing equipment has respective obstacles to overcome. The following is a summary of those obstacles:

Control Systems;

Simplification of supervision and manipulation on CRT
Upgrading of supervision, control and management functions
Upgrading of reliability and safety of hardware and software
Development of plant simulator for practical use
Development of efficient and intelligent sensing devices
On-line device fault diagnosis
Integration with other information systems such as OA systems
Development of a common data-base for all computer systems
Sustainable system architecture
Open network architecture of DCS

Operators;

Clarification of duties and roles
Measurement of level of knowledge and skills
Method of training
Achieving operator satisfaction

Processing Equipment;

Upgrading of processing equipment reliability and safety
Achieving flexible operation by processing equipment retrofit
Automating equipment
Simplification of maintenance

PLANT OPERATOR

The operator has many tasks, such as to keep the process running as nearly as possible to a given condition, to preserve optimality, to detect failures, and to maintain safety [7]. In most plants, the operator must have not only control skills but also comprehensive knowledge and techniques, such as process maintenance and production control. Does a human operator always have to master highly developed techniques for automation? In Japan opinion is divided on this question.

Automation often creates black box processes with more sophisticated computer control systems. But some tasks will not be automated for various reasons, such as cost performance and safety. As a result, there will be many isolated islands of automation. This situation will impose a severe burden on the operator.

There are two approaches to the above situation. One is to clarify the work of the operator under specified circumstances and provide appropriate training; the other is to develop an operator-friendly, computer-aided operation support system for commercial operation. These two approaches are examined in the following sections.

TRAINING SIMULATOR

Simulators are used successfully in such industries as aerospace, air transport and nuclear power. In these industries, simulation training is credited as a significant factor in diminishing accidents. In process industries, training simulators were first introduced to large continuous plants, such as refineries and town gas production plants.

In CRT operation the operator can get information only via CRT. The first objective of the training simulator is to acclimatize operators to the computer environment of operation. First, the operator must master screen manipulation on the CRT at the operator station. Second, the operator must learn special procedures for unusual operation, such as startup and shutdown of equipment items, and for emergency operation.

It is important that the operator can use a logical approach to understanding the state at the time. He should consciously reason out the meaning of things, analyze the situation, and make a rational decision [7]. This approach enables the operator not only to take over conventional control skills but also new skills via computer aid for more flexible operation of the production system. The operator cannot easily visualize what is happening in the processes. Computer aids for visualization of the process state, steady-state process simulation and qualitative process simulation can be used to support the operator's understanding.

In the training simulator, on-line simulation is used to experience operating problems and to take timely corrective action. Therefore, the system should be capable of accurately representing startup, shutdown and emergency conditions at an operator station. This requires dynamic, interactive, process-specific models over broad operating ranges. Especially, combined discrete and continuous process modeling is necessary for a high fidelity training simulation. However, at present, simplified models are used for the training simulator.

A recent survey on operator training reviewed 20 training simulators in the refining, petrochemical and chemical industries in Japan [6]. It summarizes objectives, hardware, software, training contents and so on. Generally, simulation is reportedly very useful for operator training. General configuration of operator training simulators is shown in Fig. 3.

The training simulator can also be used to improve the man-machine interface of the operator station.

For this purpose, the behavior of trainees at the operator station should be observed carefully and analyzed. New information technology such as multi-media and virtual reality techniques, is essential for cooperative human computer interaction. These techniques will enhance operator control skills; the resulting improvement in man-machine interface will help lessen human error.

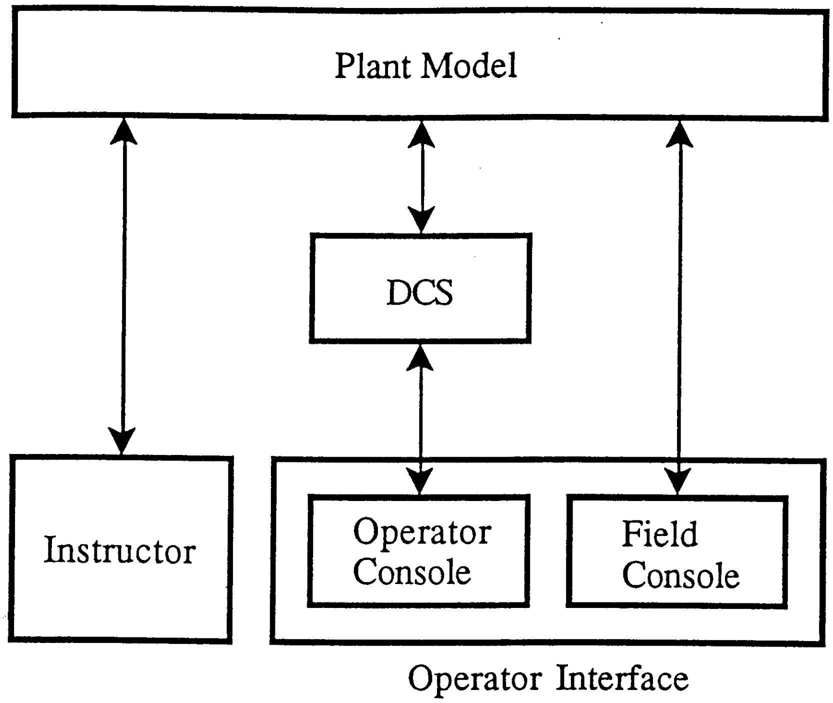

Fig.3 Configuration of training simulator

OPERATION SUPPORT SYSTEM

A combined batch/continuous plant generates difficult operational problems because both discrete and continuous dynamics must be considered in decision making. To resolve these problems, dynamic simulations that predict plant-wide states can be run. A Japanese chemical company developed an operation support system with operational guidance derived from the model predictive control concept [8]. Figures 4 & 5 show process flow of the objective plant and operational problems in the plant. The proposed operation support system was implemented in an actual plant, yielding considerable productivity increase and continuous unit stability.

To develop an intelligent operation support system for advanced plant operation, cooperative work is essential between operators who have extensive experience with real time data and engineers skillful at modeling and simulation. This is an example of integration of design and operation. A comprehensive database should also be provided for this integration [9]. Up-to-date data should be kept in constant readiness for reference in the data-base.

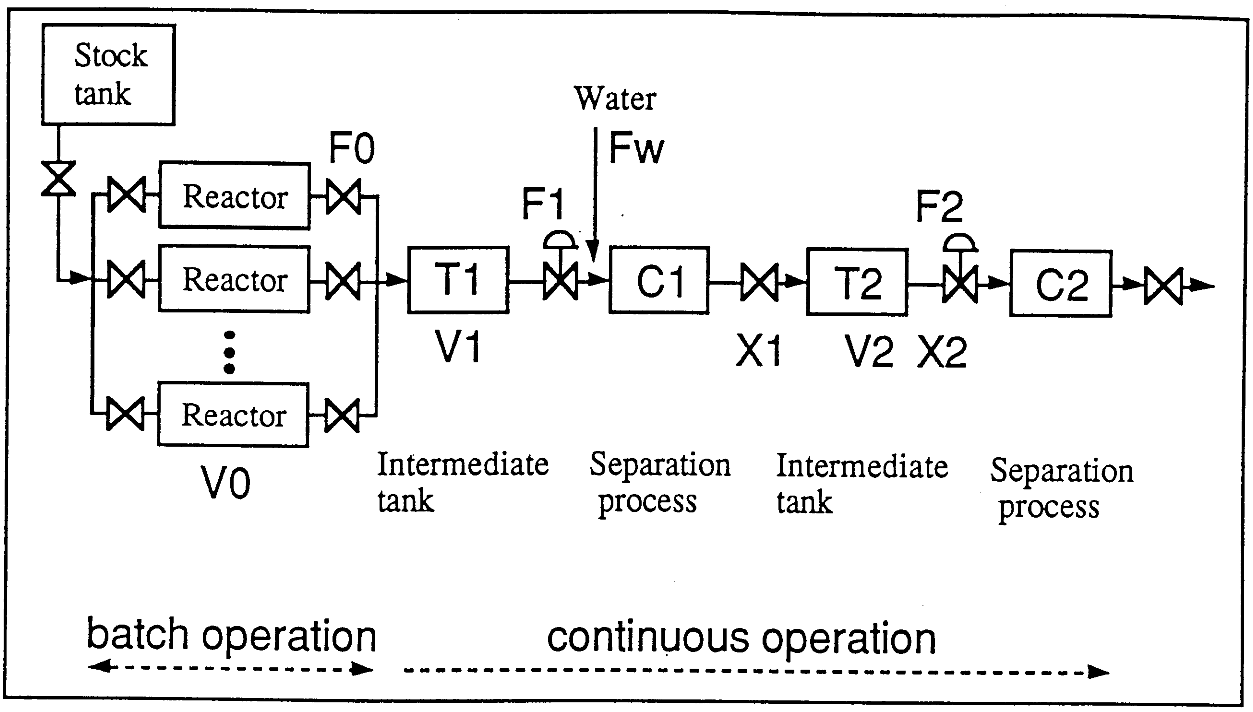

Fig.4 Process flow of combined batch/continuous process plant

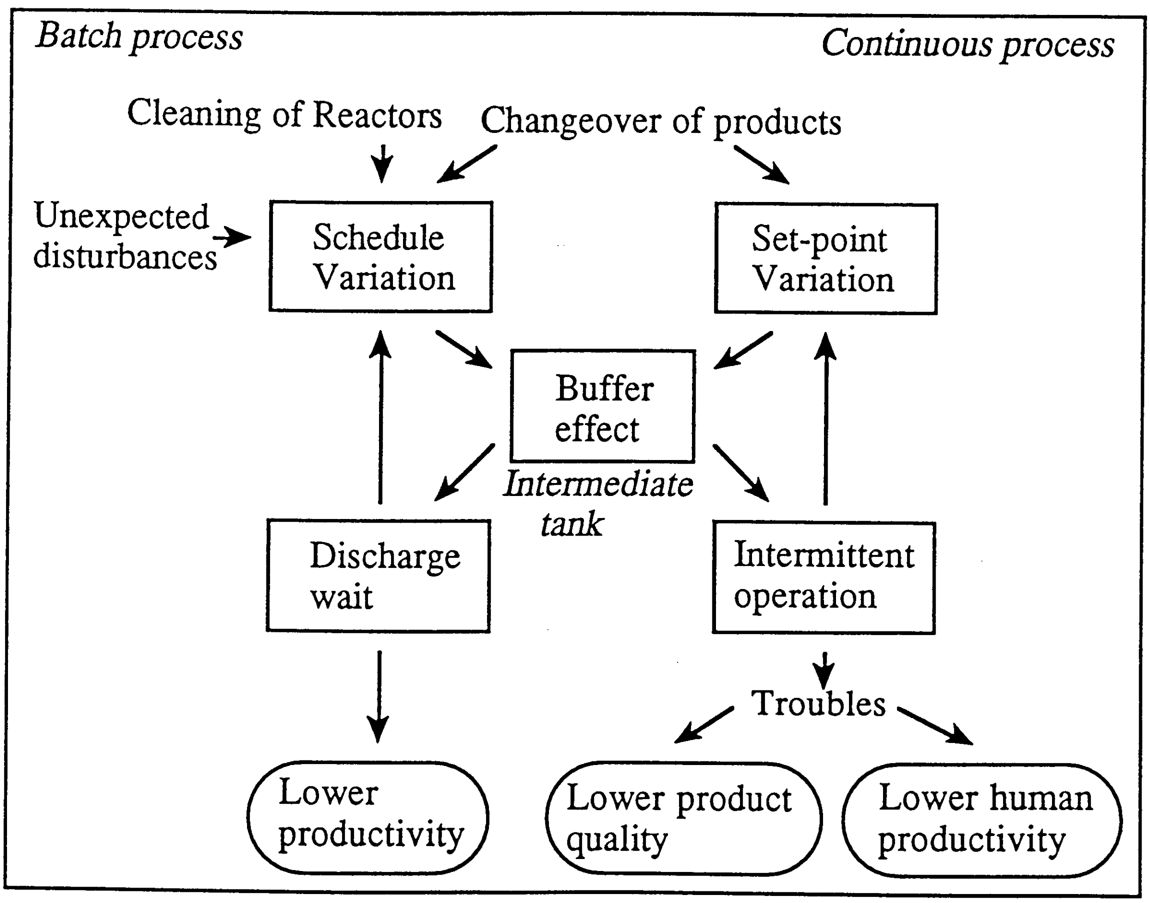

Fig.5 Operational problems in combined process plant

ENGINEERING ENVIRONMENT

Popularization of object-oriented programming and graphical user interface for workstations has been changing the modeling and simulation environment. Research on modeling tools began in the 1980's in chemical engineering; the objective was to support the rapid modeling and easy maintenance of models. These researches were stimulated by the progress of software engineering in computer science.

For example, experience using "G2," a commercial tool for simulation and real time expert systems with over 2000 installations worldwide, reportedly yields a productivity factor increase of about 20 times. The graphic construction of the application domain and structured natural language for expression of knowledge, models and other information allows the engineer to directly build and manage the simulation without conventional programming. Figure 6 is an example of evolutional design of a utility plant control system using simulation [10].

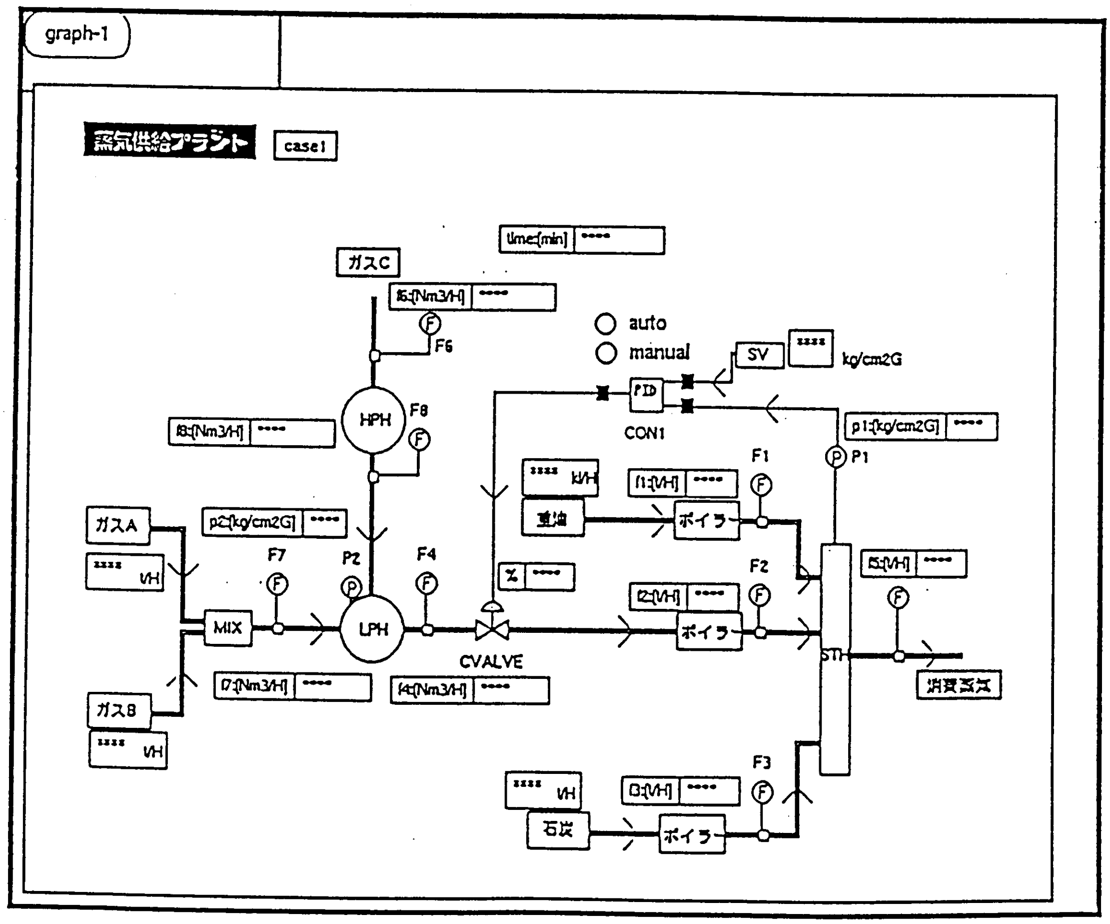

Fig.6 Flow diagram of utility plant

Object-oriented simulation is an indispensable technique for rapid development of application systems. Commercial modeling tools such as "Visual Modeler," developed by a Japanese chemical company, can be used to build own simulators for various existing plants. The combination of this kind of simulator and actual DCS offers a powerful research environment for plant operation.

The fact that simulation is widely accepted for operator training is very significant. Plant models used in the simulator can be common topics for operators and engineers. Conversation between them will afford total understanding of the processing system at the operating phase. Then, problems should be investigated by engineers deeply, for a better solution. To this end, the engineer must be familiar with the data analysis and be able to easily adjust the models in the simulator. Therefore, computer environment for rapid modeling is inevitable for the engineer.

Dynamic simulation has been studied vigorously in chemical engineering and control engineering. In these areas, off-line simulation is used to analyze system performance and design an optimal system. We should make the best use of simulation experience to developing a training simulator. Simulation is a useful technique not only for plant operation but also for system design. It is one of the most powerful computer aids for testing and verifying the performance of proposed design of such systems as:

Model predictive control
Fuzzy or linguistic control
Plant-wide control system
Process retrofit design
Integration of management and control systems

CONCLUSION AND FUTURE DEVELOPMENT

Plant operation is a complex activity involving processing equipment, control systems and human operators. Regarding each component, there are obstacles to ensuring safe and efficient operation for flexible production in the plant. In particular, coordinative human computer interaction is a crucial issue, given the growing complexity of the process and control technology. Simulation training shows promise as a method of solving the problem. Also, many computer aids must be provided to support the operator's decision.

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REFERENCES

[1] S. Yamamoto and I. Hashimoto: Present status and future needs- the view from Japanese industry, In "Chemical Process Control- CPC IV (Edited by Y. Arkun & W.H. Ray)," pp. 1-28, CACHE, Austin (1991).

[2] D. Hiranaka and H. Nishitani: Sequential control issues in the plant-wide control system, Proc. of ADCHEM'94 (May 25-27), Kyoto (1994).

[3] Management Systems Committee: Report on Present Status and Future Needs in CIM in Japanese Process Industry (In Japanese), Japan Society of Chemical Engineers, October (1993).

[4] Plant Operation Technology Committee: Survey on CRT Operation (In Japanese), Japan Society of Chemical Engineers, July (1992).

[5] JEMIMA (Japan Electric Measuring Instrument Manufacturer's Association): Survey on Reliability and Safety of Control Systems for Safe Plant Operation (In Japanese), March (1993).

[6] Toyo Engineering Corporation: Survey on Operator Training in Japanese Petroleum and Chemical Industries (In Japanese), March (1993).

[7] E.R.F.W. Crossman: Automation and skill, In "The Human Operator in Process Control (Edited by E. Edwards and F.P. Lee)," pp.1-24, Taylor & Francis Ltd., London (1974).

[8] H. Deguchi, Y. Yamasaki, and H. Nishitani: Operation support system using dynamic simulation for a combined batch/continuous plant, Proc. of ADCHEM'94 (May 25-27), Kyoto (1994).

[9] T. Kaneko, G. Suzuki, T. Honda, M. Tsuchiya, Y. Nishi, and N. Mizutani: Process plant CIM considering plant life cycle model- integration of design and operation phases using comprehensive database, Paper No.144a, AIChE Meeting (Nov.7-12), St. Louis MI (1993).

[10] H. Nishitani: Simulation environment for instrumentation, Chemical Engineering (In Japanese), pp.48-54 (1992).