Consolidation of Control Rooms for Achieving Safe, Stable and Efficient Operation by Refinery Operation Modernization Service

- An Application Example at the Sodegaura Refinery of Fuji Oil Company towards an Ideal Refinery -

Hiroshi Isobe *1

The Sodegaura refinery of Fuji Oil Company has long been studying how to create an ideal refinery that can cope with the changing generations of staff due to the mandatory retirement of skilled operators. As a first step, it consolidated its control rooms and updated the control systems in June 2009. Through Refinery Operation Modernization Service, one of its VigilantPlant Services, Yokogawa proposed “an ideal refinery,” “consolidation process of control rooms,” “an image of the consolidated control room,” etc. and worked together to standardize the operation procedures and consolidate the control rooms and control systems. This paper introduces the improvement activities towards an ideal refinery at the Sodegaura refinery and four solutions provided by Yokogawa to solve the customer’s problems: solutions for the consolidated refinery production control system, consolidated control room, operation training system, and safety instrumented system for the refinery.

INTRODUCTION

The consolidation of control rooms was conducted in several refineries in the 1990s and early 2000s as a means of reducing the number of operators and improving the efficiency for enhancing competitiveness. The characteristics of consolidated control rooms vary, reflecting the history of a refinery. Recently, the severe business environment requires the Japanese oil industry to consider a different aspect other than consolidation. Migration of the distributed control system (DCS) gives an opportunity to investigate the control room configuration and operational management system for achieving safer, more stable and more efficient operation.

This paper introduces the refinery modernization activities conducted at the Sodegaura refinery of Fuji Oil Company (FOC) toward an ideal refinery that enables both safe, stable operation and efficient operation. Yokogawa was asked to contribute to a major part of the modernization relating to DCS migration and control room consolidation. Yokogawa offered the Refinery Operation Modernization Service, one of its VigilantPlant Services, which includes four solutions: consolidated refinery production control system, consolidated control room design, operation training system, and safety instrumented system, and completed the work in June 2009.

MAJOR ISSUES FOR MODERNIZATION

As FOC had expanded its upgrading units one by one aiming at high conversion refinery, the operation department had also been expanded to as large as six operation sections responsible for each unit, and the refinery had four distributed control rooms and DCSs acting independently.

- The DCSs were supplied by two vendors and were of several generations, because they had been introduced as process installations.
- The detailed design of the DCS system varied with the operation section.
- Each operation section had its own operation procedures.
- Lack of communication between operation sections was observed since they mainly relied on information through instrumentation signal cables or via the supervisory information system.
- The CPU utilization rate and the number of instruments to be handled by each DCS were approaching the allowable limits due to the repeated expansion and modification of process units.
- The segmented organization resulted in separate
requirements in the education and training of operators, spare parts for the DCS, and maintenance engineers.

To solve these problems and more actively achieve safer and more efficient operation of the refinery and to transfer the knowledge of veteran operators, the refinery decided to consolidate the production organization and control rooms combined with migrating the production control system to the latest one.

**ACTIVITIES TOWARD AN IDEAL REFINERY**

*Figure 1* shows the activities conducted at the Sodegaura refinery of Fuji Oil Company toward an ideal refinery that enables both safe, stable and efficient operation. (1)

The FOC authorized a phased plan toward an ideal refinery to meet the demographic challenges as knowledgeable veterans retire and their places are taken by less experienced personnel starting in 2013. In Phase 1, the consolidation of control rooms and the migration of the production control system were scheduled to be completed in June 2009. After the physical migration, organizational reengineering is planned, as Phase 2, to establish the “Consolidated Operation Center” by 2011.

This project was triggered by a report by the business improvement working group to the top management of FOC in 2004. Until the formal launch of the project in 2007, the control room consolidation working group in the refinery identified the issues involved for safe, stable, and efficient operation, and young operator training for knowledge transfer.

During this preparation phase, Yokogawa proposed a visual concept of an ideal refinery and the human centered configuration of consolidated control room including its migration plan, in collaboration with the customer’s working group. In Phase 1 of the project named the “Control Room Consolidation Project”, Yokogawa undertook the migration work including control room design.

**CONTROL ROOM CONSOLIDATION PROJECT**

The consolidation of control rooms and the migration of the production system in Phase 1 was successfully completed in June 2009. The project is outlined below.

**Background and purposes of the Control Room Consolidation Project**

Sodegaura refinery was operated by six sections, i.e., the onsite plant sections 1 through 4, the power & utilities section, and the offsite section, distributed in four control rooms. The pre-study concluded that the control rooms should be consolidated into one by constructing a new control room and that the DCSs should be migrated, taking the opportunity of a large turnaround scheduled for June 2009. The planned DCS migration was not a simple replacement of each existing DCS system, but introduces a supervisory DCS that can control and monitor the whole plant. It also includes implementation of the consolidated safety instrumented system (SIS) to enhance the safety of the entire plant.

The main purposes of the control room consolidation and the system migration are as follows.

- Enhance the agility and cooperativeness in the refinery, and enhance the integrity of information systems throughout the supply chain, from plant operation to shipping.
- Maintain safe operation by systematic operator training to retain operational expertise.
- Prepare the environment for the above two major purposes by constructing a new consolidated control room and a new system, thus establishing operational integrity.

\[\text{Figure 1 Activities toward an ideal refinery}\]
System Design Policies for the Control Room Consolidation Project

Yokogawa proposed the following basic design policies of the system to achieve these purposes defined by the customer.

- The consolidated refinery production control system
  This includes not only the consolidation of control rooms and the migration of the control system planned in Phase 1, but also further system enhancement for improving plant operation and for operator training scheduled in Phase 2, which will be implemented in 2011.
- Highly efficient operation
- Safety management
- Refinery wide operation
  In the near future, refinery operation will be integrated into one unit, from crude processing to product shipping.
- Operator training for sharing operational expertise
  The same DCS information is available everywhere in the refinery, in meeting rooms, in the field, and in the office. Operation assistance systems are standardized.
- High availability of the systems
  Improve the availability of each device, network, and software by designing the systems considering system operation and maintenance.

YOKOGAWA’S SOLUTIONS FOR THE PROJECT

Yokogawa proposed the Refinery Operation Modernization Service to solve the various issues in the Sodegaura refinery. It consists of four solutions: the consolidated refinery production control system, consolidated control room design, operation training system, and safety instrumented system for the refinery. Yokogawa committed itself to the project, from the preparatory study to completion, in collaboration with the customer.

Figure 2 Overview of the consolidated refinery production control system

Consolidated Refinery Production Control System

The consolidated refinery production control system proposed by Yokogawa utilizes the full functions of CENTUM VP, the latest consolidated production control system as shown in Figure 2. The system can realize highly efficient refinery operation in a consolidated control room by covering a broad range of plant areas and by incorporating many applications such as advanced process control, operation assistance, alarm analysis, and safety instrumented systems.

- HMI for the consolidated control system
  The HMI for the consolidated control system was configured by utilizing the HMI technology of the CENTUM VP. The new HMI can contribute to safe, stable, and highly efficient operation.

- Improved operability by adopting a multi-window function
- Integrated operation of multiple systems, a DCS, SIS, advanced process control system, operation assistance system, alarm analysis system, and supervisory emergency shutdown system, using integrated terminal functions
- Custom-designed furniture for comfortable operation and dual monitoring displays for sufficient information
- Reduced noise by the fan-less housing design
- Dedicated operational HMI console for temporary use
- A space-saving layout by adopting portable HMI consoles which are on-line detachable from the DCS bus

Figure 3 shows the custom-designed desk and dual monitors and also the portable HMI console for temporary use.

Figure 3 HMI consoles

- Refinery-wide DCS bus and supervisory DCS
  The supervisory DCS is installed on top of each unit DCS that collects refinery-wide data such as utility data through the refinery-wide DCS bus and monitors the performance of the refinery. The supervisory DCS also has a refinery-wide control function such as utility balance, and plant manipulations will be carried out through local DCS HMI. In the future, this supervisory DCS will play an important role for total production management of the refinery, from crude processing to product shipping.

- Large channel-capacity and high-speed DCS bus
  The consolidation of multiple large systems such as the total refinery system without losing information was achieved by a high-speed network. Yokogawa provides the Vnet/IP large channel-capacity DCS bus which eases the restrictions on data communication between devices and systems.
DCS everywhere using a ubiquitous LAN
The terminal service function of the CENTUM VP provides an environment for remote viewing of DCS screens. All the information in the DCS is visible in real time from anywhere in the refinery, whether in meeting rooms or at individual desks in offices, through the ubiquitous LAN. This helps transfer operational expertise and develop human resources.

Standardizing operation methods
In the course of the system consolidation, existing different system specifications must be consolidated into one standard set of specifications. These include specifications for applications and HMI. By standardizing the system interface, operation procedures were also reviewed for standardization, thus providing an environment for transferring expertise.

System design considering ease of maintenance
Large-scale complex systems require vigilant design to improve integrity and availability. High-reliability design policies including redundancy, duplication, and quick system recovery are adopted. In addition, remote maintenance enables problems to be detected and solved at an early stage, leading to stable operation.

Human Centered Design for Consolidated Control Room
As a total system vendor, Yokogawa also offers the Control Room Design service utilizing its design expertise developed through years of experience, pursuing the ideal consolidated control room. For the new consolidated control room, Yokogawa designed the layout, lighting and acoustic systems considering ergonomic factors such as operability, workability, visibility, and comfort. The control room layout also takes such factors as communication between sections and future expandability into consideration. As a result, the new control room is human centered in terms of both comfort and vigilance. Figure 4 shows the completed consolidated control room.

Figure 4 Consolidated control room
Yokogawa shared the concept of the consolidated control room with the customer from the design phase of layout, HMI, lighting and acoustic systems using high-precision image illustrations as shown in Figure 5 and demonstrations with actual products.

The design philosophy of Yokogawa’s Control Room Design service is “Human Centered” and the philosophy is achieved using unique design practices that simultaneously satisfy safety, efficiency, and comfort. Our designs are appreciated by many users from various industries.

Operation Training System
In 2008, FOC introduced a new type of Fluid Catalytic Cracker (FCC), RxCat, as its second unit. The new one is very different from the existing FCC in operation that FOC decided to introduce the Operator Training System (OTS) to ensure a quick start-up. OTS was configured by combining the OmegaLand dynamic simulator (2) with the DCS side by side.

Furthermore, since the existing DCS was migrated to the latest version of CENTUM VP accompanied by the consolidation of control rooms, OTS was also used for operator training of the new operation screens for the consolidated refinery production control system. This reduced the risk due to changing a DCS vendor and enabled quick start-up of the new DCS.

OTS was set up in the newly constructed training room and a new system for the Crude Distillation Unit (CDU) was also developed to transfer the expertise of veteran operators. Figure 6 shows a picture of training using OTS.

Figure 6 Operator training using OTS
Safety Instrumented System for the refinery
Taking the opportunity of DCS migration, the consolidated safety instrumented system (SIS) was installed to enhance the safety of the entire refinery. The existing emergency shutdown (ESD) system using the conventional relay system was replaced with the SIL3-certified ProSafe-RS safety instrumented system (3). ProSafe-RS meets all the requirements covered by IEC 61508/JIS C 0508 and also

Figure 5 Realistic illustration
proves to stakeholders that the company is committed to safety.

The safety instrumented system is core infrastructure of the consolidated refinery production control system for safe and highly efficient operation. Figure 7 shows an overview of safety instrumentation for the refinery based on ProSafe-RS.

**Figure 7 Safety instrumentation for the refinery based on ProSafe-RS**

ProSafe-RS, the digital SIS, can be integrated with DCS and ESD triggers and events can be seen on the same HMI display of the unit DCS. Emergency responses can be carried out on the HMI of unit DCS and using the new ESD console shown in Figure 8.

The reliability of the ESD system has been improved by the following features of ProSafe-RS.

- Diagnosis of the entire path from a system I/O card to emergency shutdown valves without obstacles such as hard relays
- Diagnosis of wiring from ESD contact signals including pressure switches
- Partial stroke test of emergency shutdown valves

**Figure 8 New ESD console with the minimum number of switches and independent alarms**

ProSafe-RS is not a simple replacement of relay based SIS distributed throughout the refinery, but a refinery-wide safety instrumented system. This delivers the following safety enhancements.

- Simultaneous ESD of the entire refinery in the case of a large-scale earthquake
- Automation of the prioritized emergency pressure reduction sequence in the case of an earthquake

In the case of an earthquake, all the high-pressure units at the refinery must be depressurized sequentially according to the preset priority while keeping the flow for flaring (Note 1) under the allowable limit. Figure 9 shows the block diagram of the sequence control of the automated emergency pressure reduction.

**Figure 9 Block diagram of sequence control of emergency pressure reduction**

### OUTLINE OF CONSTRUCTION FOR CONSOLIDATION OF CONTROL ROOMS AND MIGRATION OF PRODUCTION SYSTEM

The migration of the DCs throughout the refinery and the migration of the existing ESD circuit to ProSafe-RS had to be completed during the short period of the scheduled turnaround in 2009. Table 1 shows the outline of the migration. Though it was a big project, it was completed in just 14 days.

System migration in such a short time and without any trouble was achieved thanks to meticulous preparation, detailed scheduling including resource allocation, an outstanding start-up team supported by a backup team in Yokogawa, specialists and subsystem engineers capable of quick troubleshooting, and a hot line to the quality assurance department.

<table>
<thead>
<tr>
<th>Item</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Control room</td>
<td>Consolidating four control rooms into one control room.</td>
</tr>
<tr>
<td>Yokogawa’s start-up</td>
<td>Up to 60</td>
</tr>
<tr>
<td>Total loop test and</td>
<td>Switched signal: Approx. 15,000 points, Completed in 14 days</td>
</tr>
<tr>
<td>interlock test</td>
<td></td>
</tr>
<tr>
<td>System migration</td>
<td>Simultaneous migration of 144 field devices</td>
</tr>
<tr>
<td>Breakdown</td>
<td>HMI: 44</td>
</tr>
<tr>
<td>Server: 16</td>
<td></td>
</tr>
<tr>
<td>Control station: 68</td>
<td></td>
</tr>
<tr>
<td>Safety controller: 14</td>
<td></td>
</tr>
</tbody>
</table>

Note 1) A system to discharge and incinerate excessive gas out of the plant.
EFFECTS OF CONSOLIDATION OF CONTROL ROOMS

Among the many positive effects of consolidation of control rooms, the greatest one is a sense of unity and face-to-face communication between people. People can broaden their outlook by working together. Figure 10 shows a picture of people working together in cooperation.

The renovated control room makes people feel relaxed and secure, and as a result, they can concentrate on plant operation. Improvements in data integrity and data availability accelerate communication between units to optimize the operation among units. Standardization of operation procedures, a secondary effect of the system consolidation, has promoted the transfer of operational expertise. Introduction of the safety instrumented system has enhanced safety. Another intangible but valuable effect of the renovation is the motivation of young operators. They are stimulated by the new control room, new system and new way of plant operation, as are all the people in the refinery.

Continuous improvement activities toward establishing the production center are expected to create a variety of effects in future.

FUTURE PLAN

The consolidation of control rooms and migration of the production system prepared the infrastructure for further improvements at the Sodegaura refinery. The next steps toward organizational and operation procedural renovations have started.

Increased productivity of operators as a result of consolidation will be used for further improvement of plant operation as well as human resource development. The consolidated control room is now the center of operation and it will be an enabler of two-way optimization of refinery operation, both refinery-wide and organizational-wide. The refinery can be operated refinery-wide as one unit, while organizational integration can realize flexible production to accommodate a changing environment.

The seeds of consolidation have just been planted, and the benefits will continue to be harvested. Yokogawa will continue to support the improvement activities of customers to materialize the VigilantPlant as a “collaborating partner” aiming at a safe and efficient leading-edge plant.

CONCLUSION

Japanese refiners are facing tough challenges from overseas competitors. In refinery operations, safety is always the top priority, but continuous improvements are the only way to cope with the challenges. A recent focus is integration. Integration of planning and production functions and integration of operation between on-site units and between on-site and off-site will lead to a world-class refinery operated by the minimum number of people.

This example of the consolidation of control rooms at the Sodegaura refinery of Fuji Oil Company will have a great impact on the oil industry as an exemplary approach which other refineries are sure to follow.

To help customers achieve the ideal refinery, Yokogawa will offer solutions for realizing VigilantPlant, and share the targets together with customers through the VigilantPlant Services.

REFERENCES


* VigilantPlant and VigilantPlant Services are registered trademarks of Yokogawa Electric Corporation.