Integrated Training System for Operation and Maintenance Using VR Plant

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Operation training for plant operators and maintenance training for maintenance technicians are currently executed individually by using separate training systems and scenarios in the case of off-the-job training. However, because the systems are not available online, on-the-job training requires trainees to go to the plant with expert operators and maintenance technicians, or to use another field support system. Yokogawa has developed a training system that can be used for both operation and maintenance training by integrating the existing dynamic process simulation technology with the latest 3D visualization technology. It has also developed a consulting service to build single or cooperative training scenarios for operation and maintenance.

INTRODUCTION

Recently, the problem of declining field skills is becoming increasingly serious due to aging plant facilities and retiring expert operators. Expectations are rising that the latest digital technologies, such as AI, the industrial internet of things (IIoT), big data analysis, and digital twins, will be the solutions to achieve safe and secure operation of plants. The key is how these digital technologies are used.

Yokogawa has been focusing on the 3D virtual plant model using virtual reality (VR) and 3D visualization technologies. By integrating a 3D virtual plant model with a dynamic simulator that faithfully reproduces the actual plant processes, it is possible to perform in a virtual space training and investigations that cannot easily be performed in actual plants. With this technology integration, Yokogawa aims to provide young employees with the opportunity of experience-based training, help improve field skills in plant operations, and reduce human errors arising from insufficient skills and operation time in the field.

This paper describes the problems in facility management, a specific solution to the problems using this technology, and the values of the solution. Then, examples of introducing this solution and its future prospects are described.

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OUTLINE OF YOKOGAWA'S SOLUTION

Problems

Declining field skills resulting from retiring skilled operators is a major problem for customers' facility management, both in Japan and abroad[(1)]. According to a survey by the Japan Institute of Plant Management[(2)], the recruitment and development of human resources is a serious issue, along with measures for aging facilities, that must be solved to ensure stable operation of existing plants (Figure 1). Also, the shortage of instructors and maintenance technicians for newly constructed plants is a severe management issue to be solved for customers to ensure sustainable growth.

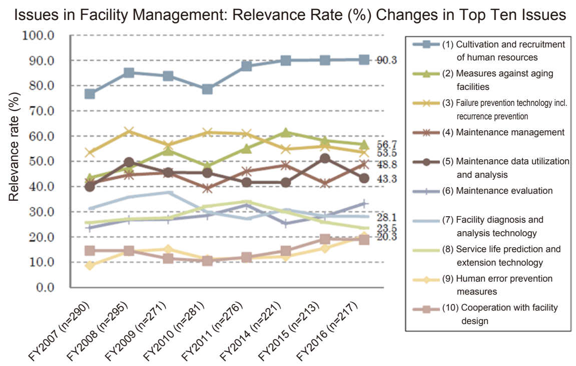

Figure 1 Fact-finding survey on maintenance(1)(2)

Operator training must appeal to the preferences of the younger generation in their twenties and thirties, who have high IT literacy. With the progress in IT technologies, more operations are expected to be conducted remotely and operators will have fewer opportunities to visit the field. Therefore, the key point for solving the problems in cultivating human resources is how young operators can learn the expertise and knowledge of skilled operators and the method of operational collaboration with maintenance technicians in the field.

Solution to the Problem

Yokogawa's solution offers an environment in which training and investigations that are not easily conducted in reality can be conducted in a virtual space using a 3D virtual plant and a dynamic simulator. Figure 2 shows a comparison of training methods in real and virtual spaces.

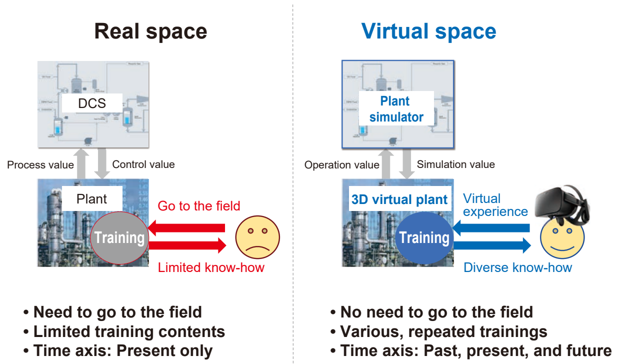

Figure 2 Comparison of training methods in real and virtual spaces

In the real space, the frequency and opportunity of training for enhancing the skills of young operators are limited by the physical restrictions on location, time, and manpower. Also, instructors cannot design the training contents as they would like, because different types of training (routine work, irregular work, emergency, and other types) have different levels of difficulty. Especially for emergency situations such as fatal fires, it is difficult for the training environment to simulate exactly the real situation. In contrast, our solution using a virtual plant enables instructors to train young operators repeatedly according to a plan, unrestricted by the above physical limitations. In addition, experience-based training using VR technology will promote intuitive understanding of operations and improve the effectiveness of training. As a result, it is possible to make the training highly efficient, which is not easy for training in the real space. Also, the solution can be used to upgrade operator training to more realistic training, whereas conventional operator training with an operator training simulator (OTS) has been conducted mainly on 2D screens. Moreover, 3D contents using mechanical 3D CAD data enable simultaneous, high-quality training of plant operators and maintenance technicians, in which operators and technicians cooperate as they follow the same scenario.

The method to construct a 3D virtual plant is described below, and follows the order of: preparing a 3D CAD model, constructing a virtual environment, and system integration.

Preparing a 3D CAD model

A 3D virtual plant model is constructed using the 3D CAD model created during the construction of a plant (Figure 3). When a 3D CAD model is not available, a 3D plant model is prepared based on the point cloud data produced by 3D laser scanner measurements or the results of photogrammetric survey.

Figure 3 Original 3D CAD model

Constructing a virtual environment

Then, a virtual environment is constructed by modifying the 3D CAD model, to produce a virtual reality experience.

First, the colors and textures of the 3D CAD model are made closer to those of the real plant, by using rendering technology. This rendering is performed semi-automatically when capturing the CAD data using the device information data table included in the CAD data (Figure 4). The state after rendering is called a 3D virtual plant model in this paper.

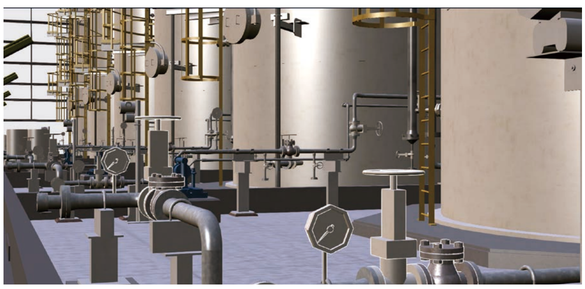

Figure 4 After semi-automatic rendering

To reproduce a graphic image that is close to the real image, a 3D virtual plant model is constructed by using advanced rendering technology, taking into consideration the surface color and texture of the object, conditions of the light source and shadows, their effects on the object, and reflections.

Then, operation input points and output operations are defined to enable devices (valves, pumps, etc.) to be operated in the 3D virtual plant model. Various simulation scenarios can be defined and displayed as graphics.

Figure 5 shows a completed 3D virtual plant model.

Figure 5 3D virtual plant model after constructing the virtual environment

System integration

The 3D virtual plant model prepared above is integrated with various systems to leverage the advantage of being a virtual space that is an environment closer to the reality.

To obtain meter readings based on the real plant processes, the 3D virtual plant model is integrated with a dynamic simulator, such as OmegaLand by Omega Simulation Co., Ltd., using the open platform communications (OPC) interface which is prevalent in the instrumentation industry. Simulation results are displayed on indicators. When valves are operated, the indicated values are recalculated according to the amount of operation. Therefore, operators can feel a sense of immersion as the environment changes realistically in response to the inputs.

Next, a data server, in which mechanical 3D CAD data and document data of devices and piping and instrumentation diagrams (P&ID) of the plant are stored, is placed in the network, and mapped to the 3D virtual plant model. Figure 6 shows an example of accessing 3D CAD data.

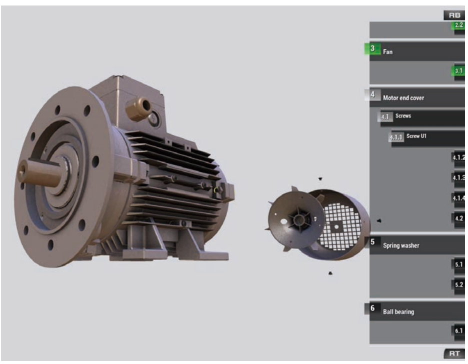

Figure 6 Example of accessing device 3D CAD data

By integrating animation scenarios in accordance with disassembly procedures, maintenance procedures can be learned while checking inside those devices that are hard to disassemble. Figure 7 shows an example of accessing document data. This function enables young operators to learn various related knowledge on the object device simultaneously.

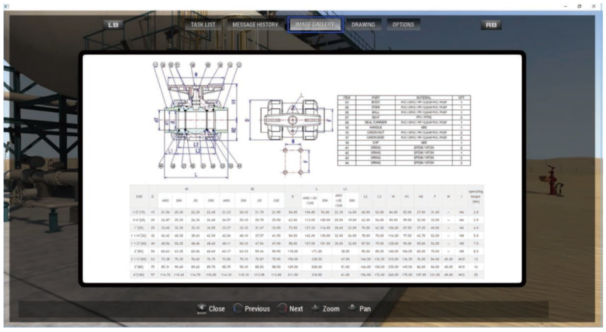

Figure 7 Example of accessing device document data

The constructed 3D virtual plant model is accessed via the network. Therefore, training can be conducted at any time, anywhere.

Values

This solution offers the following specific values.

- This solution provides an integrated virtual training environment for plant operators and maintenance technicians, and improves the operational collaboration between operation and maintenance.
- One problem in responding to emergency situations that are high risk but have a low probability of occurrence is that the operation takes a long time due to the insufficient skills of field operators. To solve this problem, the inspection route and work procedures in case of emergencies can be trained repeatedly in the virtual plant. Thus, human errors can be eliminated and the operation hours reduced.
- This solution enables intuitive learning of operation procedures like in a video game, based on the experiences in the virtual space using the latest technologies including VR. Therefore, young people who have high IT literacy are likely to positively accept this type of training.
- This solution enables simulated on-the-job training (OJT) by sharing a 3D screen remotely, and reduces the costs for preparing OJT and the travel costs for inviting young operators from distant locations for each OJT.

There is also a problem that preliminary tests cannot be conducted sufficiently at the stage of designing a new project or before periodic maintenance of existing plants. A 3D simulator enables trial implementation of assumed procedures and optimization of the field work procedures in advance.

EXAMPLE OF INTRODUCTION

An example of introducing this solution to a petrochemical plant is described.

Background of Introduction

The customer was looking for a solution partner to help them introduce the latest digital technologies (3D, VR/AR, and digital twin) to their actual plant and achieve safe and secure operation. Yokogawa proposed a stepwise approach as shown in Table 1 for introducing the solution to the actual plant, which was accepted by the customer. It was decided that Phase 1 of the project would be executed jointly by the customer and Yokogawa.

Table 1 Proposed approach for introducing digital twin

Phase	Proposal
1	Construction of 3D virtual plant model and dynamic simulator, and preparing scenarios
2	Aligning the 3D VR plant with the plant information management system and facility management system
3	Introducing digital twin (online dynamic simulator) to the actual plant

Procedure

Table 2 shows the project execution procedure of phase 1. As quick delivery (within two months) had been requested, an upper limit was placed on the number of devices to be modeled in the client's refinery, as shown in Table 3. The dynamic simulator was constructed under similar conditions and integrated with the 3D virtual plant model.

Table 2 Project execution procedure

Step	Contents
Kick-off meeting	Ensuring that the project organization and scope are shared
Receiving and analyzing plant information	3D CAD data, PFD, P&ID, materials and heat balances, standard work procedures
Model development and testing	Constructing a 3D virtual plant model and dynamic simulator
Review meeting	Biweekly progress check of model development with the client
Scenario preparation	Facility failure prediction and disassembly/ assembly, isolation and maintenance of control valves, and throughput maximization
System delivery	–

Table 3 Scope of modeling

Object device	Upper limit
Automatic control valves (SDVs, PCVs, LCVs, and FCVs)	90
Manual valves (globe valves and ball valves)	60
Field indicators and transmitters	60
Others (control panels, buttons, etc.)	90

The field works and maintenance scenarios for training field operators, along with the scenarios for predicting facility failures and maximizing throughput for phases 2 and 3, were prepared together with the client.

Results

Yokogawa successfully met the client's request to deliver the system with the constructed 3D VR plant to the headquarters of the client in just under two months, as a model case of digital technology. The client greatly appreciated Yokogawa for working on the project together, sharing the future vision and achieving the goal in a short period. Based on this successful project in which many staff of the client, from management to field operators, experienced Yokogawa's solution, they are considering introducing Yokogawa's solution to the plant that was used in this project and to other facilities such as gas plants.

Yokogawa received the following comments from the client regarding their expectations and requests on this solution.

- They want to visualize the details of the plant, which are difficult to see in the actual plant, in the 3D virtual plant. Simulation and visualization of the inside of distillation towers and pipelines would develop an intuitive, deeper understanding of devices and processes.
- They want to have the plant behaviors in past events of actual plants reproduced in the 3D VR plant. When the actual plant is shut down in an emergency for some reason, reproduction in the 3D VR plant of the conditions of the actual plant before it is suddenly stopped would help investigate the root causes and plan preventive measures.

CONCLUSION

This paper described a solution for improving field skills by experience-based training using a 3D VR plant and an example of introduction to a client. Yokogawa plans to use this solution for OJT and supporting daily operations, by connecting the training scenario to the working control system and by using augmented reality (AR).

This solution is applicable to a wide range of industries besides petrochemicals. By combining it with the systems in customers' plants and with various solutions of Yokogawa, this solution will deliver further value. Yokogawa will focus on customer surveys, work in line with customers' viewpoints, and continue to propose valuable solutions.

REFERENCES

(1) Yasuki Sakurai and Yosuke Ishii, "Efficient Field Communication with Augmented Reality," Yokogawa Technical Report English Edition, Vol. 60, No. 1, 2017, pp. 21-24

(2) Japan Institute of Plant Maintenance, Report on Fiscal 2016 Fact-finding Maintenance Survey, 2017 (in Japanese)