Effectiveness of “Remote Engineering and FAT” on Project Execution and Contribution to Society

Takeshi Ozawa, Naoya Takeda, Hideki Kubota

Yokogawa has a solid track record in integrated control and safety system (ICSS) projects. Recently, the company has been focusing on developing an environment that enables remote engineering and factory acceptance tests (FAT) and has successfully developed applications and conducted tests. This environment is based on the simulation and virtual I/O functions of the CENTUM VP integrated production control system and the ProSafe-RS safety instrumented system, and network technology. With this feature, anyone involved in a project can access this environment at any time and from anywhere. In addition, the feature is attracting attention today with the strong need for social distancing amid the COVID-19 pandemic.

This environment helps achieve the SDGs, specifically fight against communicable diseases (No. 3.3) and reduce energy for alleviating climate change (Nos. 7.3 and 13.3). By providing a means to achieve a new lifestyle in terms of production, it is also expected to improve sustainability (Nos. 9.4 and 12.6).

This paper describes the configuration and achievements of this environment, and discusses how to execute projects more efficiently and the challenges to be solved.

INTRODUCTION

In recent years, an increasing number of companies use public clouds, such as Amazon Web Services (AWS) from Amazon and Azure from Microsoft. The scope of these clouds is expanding beyond web services to include the core systems of companies. Moreover, billions of Internet of Things (IoT) devices have spread to collect information not only in buildings, hospitals, and transportation facilities in cities but also in production facilities such as factories and oil fields. They are used in various ways, from analyzing and using data, to improving operational efficiency. These Internet-enabled services and the style of business regardless of time and place...
are expected to spread.

However, security risks such as viruses and information theft may increase. According to a survey by the Information-technology Promotion Agency, the number of incidents involving targeted mail in Japan doubled from 201 in 2012 to 401 in 2019\(^1\). How to tackle security risks in facilities connected to the Internet is of growing concern.

Yokogawa has already executed many projects on integrated control and safety system (ICSS) engineering independent of time and place. This has been achieved by combining the control station of CENTUM VP, the simulator function of the safety control station of ProSafe-RS, testing procedures, and communication network technology. There is also a need to separate common parts such as virtual machines and TCP/IP communication from those used in a specific company or industry, and then build an environment suitable for ICSS engineering.

This paper explains Cloud Enabled Execution (CEE), which is an engineering environment developed by Yokogawa for secure remote engineering and factory acceptance tests (FAT). We also describe its configuration, challenges, and future plans.

**REQUIREMENTS FOR YOKOGAWA**

Yokogawa’s engineers are working to improve the efficiency of project execution to ensure that customers can complete commissioning and start up plants as planned. As more projects have become global in recent years, there is strong demand for remote engineering environments in which such projects can be carried out from anywhere in the world. By satisfying this requirement, it is possible to develop, test, and review applications and execute projects using a virtual machine, without requiring the people involved to gather at the site and hold face-to-face meetings.

The FAT should involve more customers, especially experts and skilled operators with strong expertise, making it possible to identify and respond to nonconformities at an early stage and to improve quality. However, many of these people are too busy to gather at the site, so a system that enables them to participate in the FAT remotely is needed.

In addition, many companies are expected to contribute to various social activities, particularly the SDGs. The SDGs are a universal pledge involving all countries to achieve a better, sustainable world. Specific goals include reducing energy consumption and fighting against COVID-19 and other infectious diseases.

Yokogawa advocates CEE to respond to the requests of customers. CEE is an engineering environment that uses the latest technologies such as virtual machines and various remote access tools to help execute projects smoothly (Figure 1).

**Figure 1 Example of CEE configuration**

CEE consists of remote engineering, remote FAT, and tools for remote access and video conferencing. Its configuration and achievement are described in the sections “CONFIGURATION OF CEE” and “ACHIEVEMENT OF CEE.”

Although CEE is an established solution, there is also a need to improve the efficiency of safety instrumented system engineering and that of integration testing with subsystems.

With regard to these two improvements, the section “EVOLUTION OF CEE” describes the background, explains an architecture under consideration, and proposes a solution.

**HOW YOKOGAWA’S CEE CONTRIBUTES TO SOCIETY THROUGH THE SDGs**

By using CEE, users can execute global projects and perform remote FAT. Yokogawa provides virtual machines for remote engineering and an IT environment for remote FAT to improve the efficiency of project execution. These technologies are used throughout the phases of a project: from the basic design work in the early stage, to FAT in the final inspection stage just before the system is shipped.

By using virtual machines, users can delay the purchase of machines for the target system’s engineering and those for the human machine interface station (HIS). This also reduces maintenance work and makes it possible to introduce the latest machines as deliverables. Furthermore, the existing plant assets can be effectively used and shared, which helps save energy and alleviate climate change (SDGs 7.3 and 13.3).

Remote engineering and FAT eliminates the need for staff to visit the site, thus reducing travel expenses. Furthermore, it contributes to avoiding infectious diseases associated with human movement (SDG 3.3) and reducing energy consumption for transportation, thus alleviating climate change (SDGs 7.3 and 13.3). This new productive lifestyle also helps strike a balance between job satisfaction and economic growth (SDG 8) and improve sustainability (SDGs 9.4 and 12.6).

**CONFIGURATION OF CEE**

CEE provides a virtual machine for remote engineering and an IT environment for remote FAT. The requirements for remote execution are different from the general IT environment: both engineering-specific requirements and security must be considered. This section outlines the security requirements and plant networks and describes the details of remote engineering and FAT.
Security Requirements

Internet-enabled services must satisfy stricter security requirements than a stand-alone network. This section explains the basic requirements for selecting devices and applications to be used in CEE. Figure 2 shows the security requirements regarding CEE.

The top priority is to prevent leakage of customer information and damage caused by viruses. Therefore, unrestricted connections and inbound communications to the CEE environment should be prohibited. For remote execution, however, customers need to access the system via the Internet from the outside and operate and check the HIS.

To solve this issue, we adopted a particular communication method with a remote access tool on the Internet. In this method, the CEE environment periodically sends out signals to the remote access tool. When the tool recognizes an authorized person who wants to gain access, it sends a response signal. Upon receiving the response, the CEE environment establishes a session for sharing the HIS screen. All other inbound communications from the outside are blocked, preventing unauthorized access from the outside.

In addition, this method meets the following security requirements.
- A session-connected type
- At least 256-bit advanced encryption standard (AES) encryption
- Authentication for each session
- Protected by a one-time password
- Multi-factor authentication is possible, or the source IP addresses can be limited.
- Multiple major security certifications, such as ISO27017 and service organization control (SOC), have been obtained.
- Must not have caused any security incidents such as information leakage.
- The network is separated from Yokogawa’s office network and other projects to reduce the risk of virus infection and unauthorized access.

Overview of Plant Network

A plant network consists of three layers: field network, control network, and control information network. The field network connects field devices and measuring instruments to a controller, and various standards are set by industries and manufacturers. The Vnet/IP control network is a redundant, high-speed network, conforming to international standards. The status of the communication path is continuously monitored. If any error occurs in one path, the communication is automatically and quickly switched to the other path to continue control communication. The control information network is similar to general TCP/IP networks used for the Internet and intranets.

CEE uses the functions of the control station simulated on a virtual machine or those of the HIS. This feature makes an engineering environment available early in the project. Since the virtual machine simulates the behavior of networks, there is no need to set up real control and field networks; engineering can be performed only with a TCP/IP network (Figure 3).

Remote Engineering

To achieve remote engineering with CEE, the following requirements should be satisfied.
- The HIS screen is clearly visible even when accessed remotely and is thus suitable for plant operation.
- The virtual machine environment (including OS, Microsoft Office, etc.) is suitable for engineering. CEE is offered as a cloud service, which can be used on premises or as a public cloud. The environment in the latter case is usually designed for servers. Therefore, it is necessary to check its compatibility with CENTUM VP, ProSafe-RS, development tools, and a ledger output function.
- The security requirements described in the section “Security Requirements” are satisfied.

To meet them, CEE provides the engineering environment shown in Figure 4.
Effectiveness of “Remote Engineering and FAT” on Project Execution and Contribution to Society

Figure 4 Overview of the CEE engineering environment

- A firewall is installed to restrict communication with external networks (including Yokogawa’s office).
- A server is set up as a gateway to transmit only the desktop screen data. The firewall blocks communication on ports that are not used for CEE. It is almost impossible for viruses to infect the screen data. This setting is more secure than a virtual private network (VPN), which allows all communications.
- File transfer such as exporting the application database might spread viruses, and so should be performed via a securely designed file server.
- The risk of information leakage is minimized by separating the network and controlling access for each customer project.

These requirements ensure that an engineering environment can be accessed at any time and used in real projects. To increase the number of virtual machines while maintaining the flexibility of configuration, a hybrid environment consisting of a public cloud and on-premises setting can be arranged (Figure 5). It comes with the high scalability of the public cloud (no limit on the number of virtual machines) and the high flexibility of the on-premises setting (the number of virtual machines is limited but no restriction on the kind of OS, and its configuration can be changed at Yokogawa’s discretion).

Figure 5 Hybrid environment

From Remote Engineering to Remote FAT

To perform software FAT and hardware FAT remotely, an environment is needed that enables Yokogawa and its customers to access the remote engineering environment and the target system (Figure 6). Its requirements are as follows.
- Enables customers to operate and test the HIS through the Internet. Just like the engineering environment, the FAT environment must be able to share the screen, and this sharing must not interfere with the plant operation.
- Enables the entire project team to share punch items (changes and non-conformities that occur while executing FAT).
- Provides adequate communication means among remote sites.
- Meets the security requirements described in the section “Security Requirements.”

To prevent spoofing and unauthorized access, remote connection tools have the functions described in the section “Security Requirements”: user authentication, user
 authorization for each project, and multi-factor authentication. Fixed cameras and head-mounted cameras are used in projects. We have confirmed that both can smoothly distribute video footage of cabinets and other hardware via the Internet in real time.

For communication and information sharing, Cisco Webex or Microsoft Teams is used; both are popular video conferencing tools. The Online Punchlist Management System (PLMS), which is Yokogawa’s proprietary web-based punch item management system, is used to manage punch items. PLMS enables users to share the content of punch items online with those involved in the project. These multiple applications are used to implement remote FAT safely and effectively.

**ACHIEVEMENT OF CEE**

CEE improves the efficiency of project execution by actively using virtual machines and remote FAT. Using multiple virtual machines increases the average utilization rate of plant assets, allowing resources to be used more efficiently. Remote FAT also reduces the need for people to travel and promotes online communication. With these benefits, CEE is becoming increasingly popular: in the first half of fiscal 2020, CEE was used in more than 100 projects, three times that in the previous half year.

CEE is expected to be introduced more widely due in part to the spread of COVID-19.

**EVOLUTION OF CEE**

As mentioned in the section “REQUIREMENTS FOR YOKOGAWA,” CEE has two points to be improved.

- **Improvement 1:** Streamlining the engineering of the safety instrumented system
- **Improvement 2:** Improving the efficiency of integration tests with subsystems

Improvement 1 is to connect a CEE virtual machine to a real safety control station for developing applications and performing tests, which has not been achieved yet. This improvement is needed in the engineering of the ProSafe-RS safety instrumented system, which ensures safe plant operation for protecting humans and the environment.

The simulator function of the safety control station is not used to test the safety instrumented system. Instead, the input/output of actual signals from the I/O module of a real machine should be checked. Such a test setting (Figure 7) allows CEE to test the validity of the safety function logic more flexibly at an early stage.

Since the virtual machine and the control station communicate via Vnet/IP, a dedicated network card that supports a special protocol, not TCP/IP, is needed. A Vnet/IP-enabled virtual network card has already been developed, and we are now verifying its compatibility with a virtual machine. Vnet/IP requires high reliability; there is no problem when the engineering environment and the real machine are installed in the same location, but if not, care must be taken. Especially when they are far apart, a delay depending on the distance is inevitable. To solve this problem, we are studying the use of public clouds that have data centers all over the world. It is possible to select any data center geographically close to the real machine.

Improvement 2 is to connect the control station or the safety control station of the real machine with third-party subsystems through the Internet. In recent years, controllers from other companies are often integrated into the system, and the timing of the integration test has been an issue. Currently, integration tests are conducted by bringing in the real machine or using a substitute machine on site. If connection via the Internet is allowed, tests can be conducted with subsystems installed in the field, which will eliminate the need for transporting the real machine of the safety instrumented system and thus accelerate the FAT process (Figure 8).

**CONCLUSION**

To perform engineering and FAT remotely, it is necessary to meet the requirements for ICSS engineering and implement
security measures for communications via the Internet. As a solution, this paper presented Yokogawa’s cloud engineering environment, CEE, which has already been introduced in many projects where it has greatly enhanced project execution and contributed to the SDGs, particularly the fight against communicable diseases.

In addition to the two improvements presented in this paper, Yokogawa will continue to develop CEE to enhance the efficiency of project execution and contribute to our customers, the SDGs, and other social goals.

REFERENCES


* CENTUM VP, Vnet/IP, and ProSafe-RS are registered trademarks of Yokogawa Electric Corporation.
* All other company names, organization names, product names, and logos that appear in this paper are registered trademarks or trademarks of their respective holders.