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GROUP REF. : SC B3
PREF. SUBJECT :PS3
QUESTION N° : 2

Question 3.2：
What examples and return of experience can be provided on digital substations and digital twins? Which emerging digital technologies will improve substations for the grid of the future?

A Study For Digital Twins for Substation Control Circuits

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1. Summary

Currently, while the renewal of equipment installed during the period of high economic growth continues, future manpower reductions are inevitable due to the decrease in the number of workers caused by the declining birthrate and aging population. While there is a demand for more efficient work, the control cable switching work for electrical work to replace substation equipment has become a burden for checking disconnection/connection points and revising connection tables to confirm the state of cable connections. In addition, since a huge amount of information is written by hand, it is easy to make mistakes, which may lead to human error. Therefore, in order to carry out improving level of maintenance work with a limited number of personnel, this research used DX technology to create a tool that enables visualization of cable connections between devices and semi-automatic creation of forms to be used in construction work, and verified the tool's ability to do so.

2. Overview and system design of digital twins of control circuits

1） Overview of digital twins of control circuit

In general, a digital twin is one that aggregates information on objects that exist in the real substation and reproduces and manages these objects in digital space. As shown in Figure 1, the digital twin in this study refers to a system that improves the efficiency of control cable management operations at substations by capturing the connection information of various equipment and control cables installed in substations, which are managed using a vast amount of paper drawings, and utilizing this data.

2） System design

Substations have a large number of drawings, but the management of drawings and construction supervision of control cable switching work requires a great deal of human intervention. Therefore, in designing the digital twin system, we identified issues in the control cable switching work, and studied how to improve accuracy and work efficiency by systemization. The following is a summary of the key points of the system design that are expected to be highly effective.

The first issue is that it takes time to examine cable connections between devices. For example, in order to figure out that a power board and a transformer are connected by a single control cable, it is necessary to check using two control cable connection tables, as shown in the image in Figure 1, which is inefficient and prone to reading errors.

Here, if the systemization can visually reproduce the connection status regarding the devices and their control cables as shown in Figure 2, it will be possible to quickly and accurately confirm the connections between devices. In addition, real-time system management of the connection information of these control cables allows the latest control cable connection status to be known even while construction is in progress, which is useful when multiple construction projects overlap.

The second issue is that it takes time to prepare forms. When we perform control cable switching work, from the viewpoint of preventing connection errors, we prepare a control cable disconnection and connection procedure and check list (hereinafter referred to as a check form), which describes the connection procedure of control cables, and use it for checking work during installation. The creation of these forms is all done by manual input, which requires a great deal of manpower.

As shown in Figure 3, systemization allows information such as the connection status of devices registered in the system and the types of control cables connected to the devices to be automatically transcribed into the check form. Hence, semi-automation of check forms makes it possible to create check forms in a short time and prevents errors in the entries.

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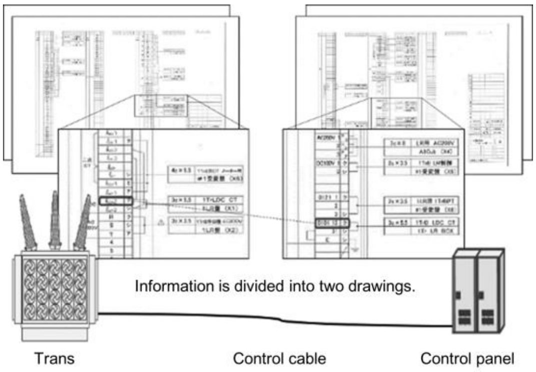

Fig.1 Information management image of control cables connection status by paper documents

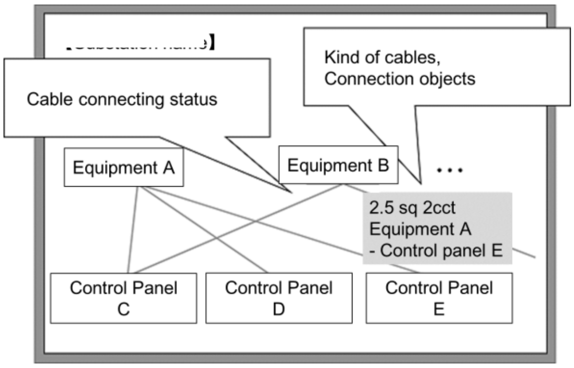

Fig.2 Information management image after systemization

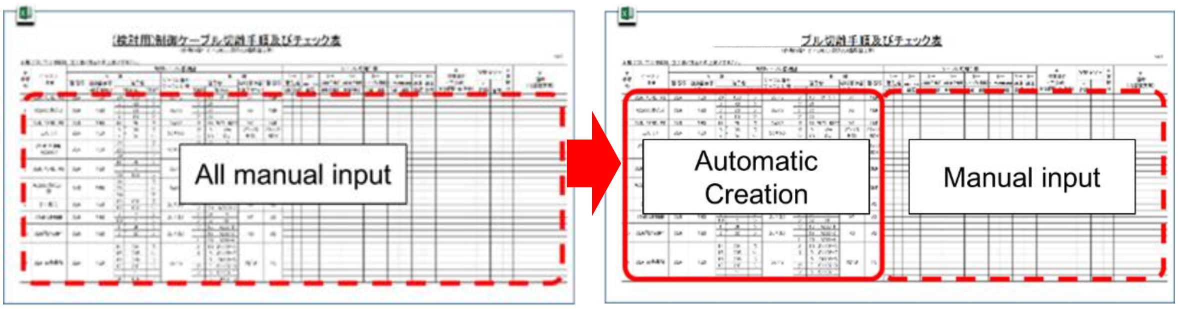

Fig.3 Image of creating check form

3. Verification of prototype tools

In a distribution transformer replacement project, a database of control cables in substations was developed, and semi-automatic creation of check forms was actually performed using a prototype tool. At the database development stage, we confirmed that the database of cable connection tables could be created without any problems, and the semi-automated creation of check forms was almost problem-free. However, the system was unable to distinguish between terminal blocks with the same name and number within a single power board. As a result of the verification, issues such as the need for operational countermeasures for special cases that cannot be distinguished in the system were identified.

The verification results showed that the introduction of the system was expected to reduce the workload by approximately 40.5 % (assuming the replacement of transformers at power distribution substations).

4. Conclusion

We studied a system that contributes to operational efficiency in control cable switching operations using a digital twin. We designed a system that enables visualization of cable connections between devices and semi-automatic creation of forms, and confirmed through on-site verification of the prototype tool that there are no problems with the installed functions. In the future, it will be necessary to study operational countermeasures identified in the verification.