New Technologies for Electric Power Distribution Systems

— to Unify Protection/Control Units so They Can Be Incorporated into Intelligent Substations —

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OVERVIEW: Recently, due to concerns about the liberalization of electricity supply, deregulation, and global impact on the environment, securing a reliable power supply has become an important social need worldwide. To ensure this need is fulfilled, detailed investigations and developments are in progress on power distribution systems and the monitoring of apparatus. These are on (1) "digital technology" based on the application of semiconductor high-speed elements, (2) intelligent substations applying IT (information technology), and (3) system configurations aimed at high-speed communication. Incorporated in these are demands for the future intelligent control of substations, protection, monitoring, and communication systems that have advantages in terms of high performance, functional distribution, information-sharing and integrated power distribution management. Today's conventional apparatus also requires streamlining of functions, improvements in sensor technology, and standardized interfaces. By promoting these developments, the following savings for the whole system can be expected: (1) reduced costs in remote surveillance in the field of apparatus monitoring, operation, and maintenance, (2) reduced maintenance costs based on the integrated management of equipment, and (3) reduced costs due to space saving as a result of miniaturizing equipment.

INTRODUCTION

THE upgrading of our 500-kV trunk transmission system has almost been completed, and the electricity system has been considerably improved. Yet, cost reductions are required to cope with the entry of IPP (independent power producer) and the introduction of power source distributors caused by the deregulation of electric utilities. To achieve this, each electricity supply company is decreasing expenditure by efficiently using equipment, improving operations, and effectively controlling plant-and-equipment investment. The power distribution system also requires reductions in initial investments, such as the unit price of apparatus and miniaturization, and reduced costs for the whole life cycle, including the operation/maintenance costs of the substation system. The construction of a new power distribution system has been considered to meet these requirements. It will adopt "digital technology" and "IT-related technology," which has made rapid advances in recent years.

This system aims at minimizing the total cost, not only reducing of the unit price but also the cost of installation, construction, operation, and maintenance. This article discusses the construction of intelligent substations in the power distribution system, as well as protection/control-unified equipment as examples of the new technology.

INTELLIGENT SUBSTATION

Concept of Intelligent Substations

In conventional substations, substation apparatus, such as switchgear and transformer, control, protection and monitoring equipment is independent of every other device, and connection is based on the signals coming through the cable. On the other hand, an intelligent substation shares all information on apparatus, control, protection, measurement and apparatus monitoring equipment through one bus by applying both "digital technology" and "IT-related technology." Moreover, high efficiency and miniaturization can be achieved because the local cubicle contains unified control/protection and measurement equipment that is one integrated system

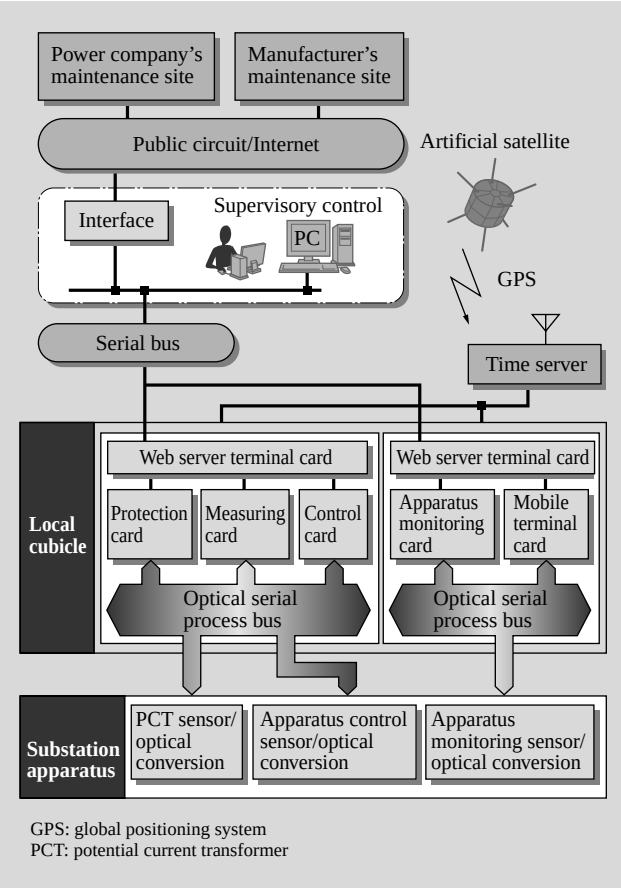


Fig. 1—Intelligent Substation System Configuration (Image). The whole substation system is combined by optical LAN, and apparatus composition is simplified.

(see Fig. 1). Since an optical bus shares the information between the apparatus and equipment, the amount of cable is sharply reduced. Moreover, as international standards (IEC 61850 and 61375 etc.) are adopted and the system conforms to the telecommunications standard, equipment specifications can be standardized for different vendors.

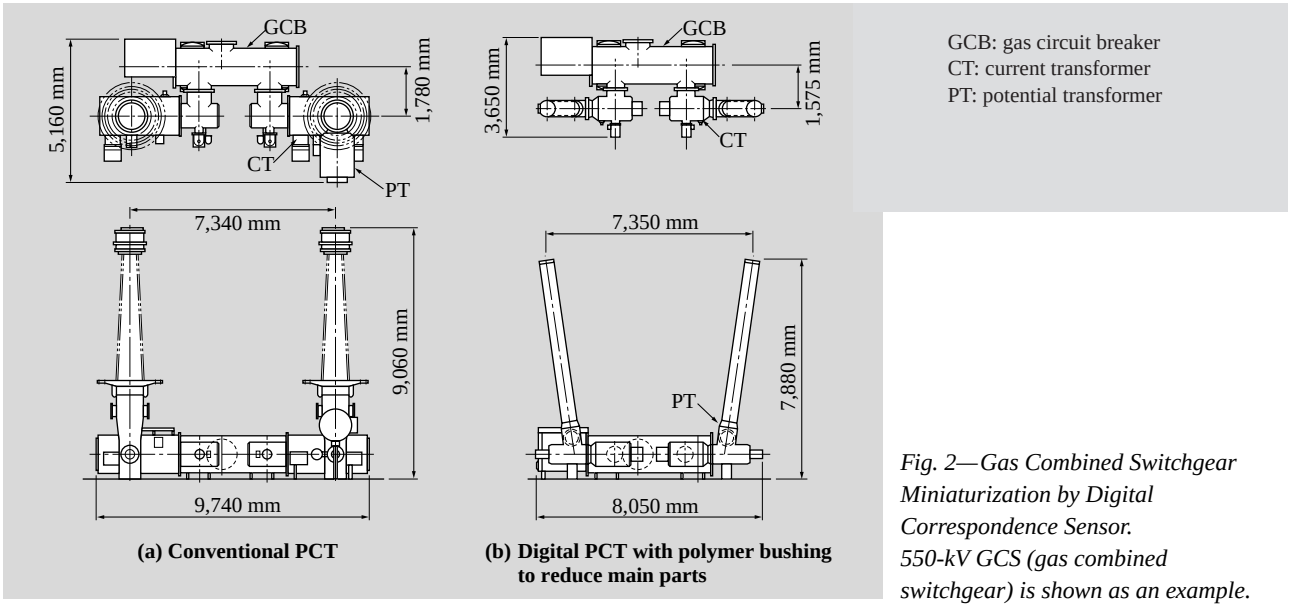
Apparatus Monitoring System

All the data from each monitoring and measuring device is transmitted and used for a higher-level monitoring system via an optical bus. The required data is accessed through the Intranet or the Internet at the maintenance site of an electricity supply company or a manufacturer and the apparatus can be monitored from a remote location. The construction, analysis and diagnosis of the database including trend management and history management also become possible. As a result, signs of abnormalities can be checked out well in advance, and prompt action can be taken in times of emergency. Maintenance plans can also be drafted to ensure reliability, by inspecting revision description and parts management, efficient maintenance planning and reliability maintenance are also realized simultaneously.

DEVICES THAT CAN CONTRIBUTE TO AN INTELLIGENT SUBSTATION

Switchgear and Transformer

The burden can be drastically decreased because the sensor signal from the PCT is digitized at the sensor output edge and the load on the PCT only reaches that of an A-D (analog-to-digital) converter. Rogowski coils are used as the current sensors and capacitive potential dividers are used as the voltage sensors. These sensors drastically reduce the size of the switchgear (see Fig. 2).



(a) Conventional PCT

(b) Digital PCT with polymer bushing to reduce main parts

Fig. 2—Gas Combined Switchgear Miniaturization by Digital Correspondence Sensor. 550-kV GCS (gas combined switchgear) is shown as an example.

Present studies on miniaturizing conventional equipment have so far been aimed at standardizing series. Advanced miniaturization will be attempted by digitizing this system, corresponding to its need.

Protection and Control

Intelligent substations require protection and control equipment to be installed outdoors and this needs to be compact so that the local cubicle is able to contain them. Outdoor installation requires improvements in insulation against heat and airtightness besides parts reliability. Compact protection and control equipment will generate demand for unified fabrication of protection/control and high-density components. The current protection/control system that uses compact equipment is described below.

LATEST PROTECTION AND CONTROL SYSTEM

Trends in Protection and Control Systems

Due to the rapid progress in today's information field, applying digital technology and adding IT function to the protection/control system are possible, to support stable power supply, and improve maintenance. In Japanese protection/control systems, digitization has made advances since the last half of the 1980s. Digital technology has unique advantages, namely minimizing maintenance and improving reliability, and it has speeded up the conversion from individual analog-type to digital-type relays.

Now, however, digitization is not only required for independent single-function equipment, but for the "systematic operation and employment" of the whole substation. Such systems have greatly improved efficiency in employment and maintenance using IT. The key phrases to fulfill these needs are as follows:

(1) Slimming of total system as a protection control equipment

→ Unification of equipment

(2) High efficiency of employment/maintenance support using IT technology

→ Extended employment/maintenance by remote control

(3) System directly linked to the equipment for protection/control

→ Distributed installation near the apparatus

Thus, there has been a need for constructing a high efficiency system through system-wide miniaturization and integration of IT.

Unified Protection and Control Unit

The protection and control units of the substation are designed and allocated with respect to individual

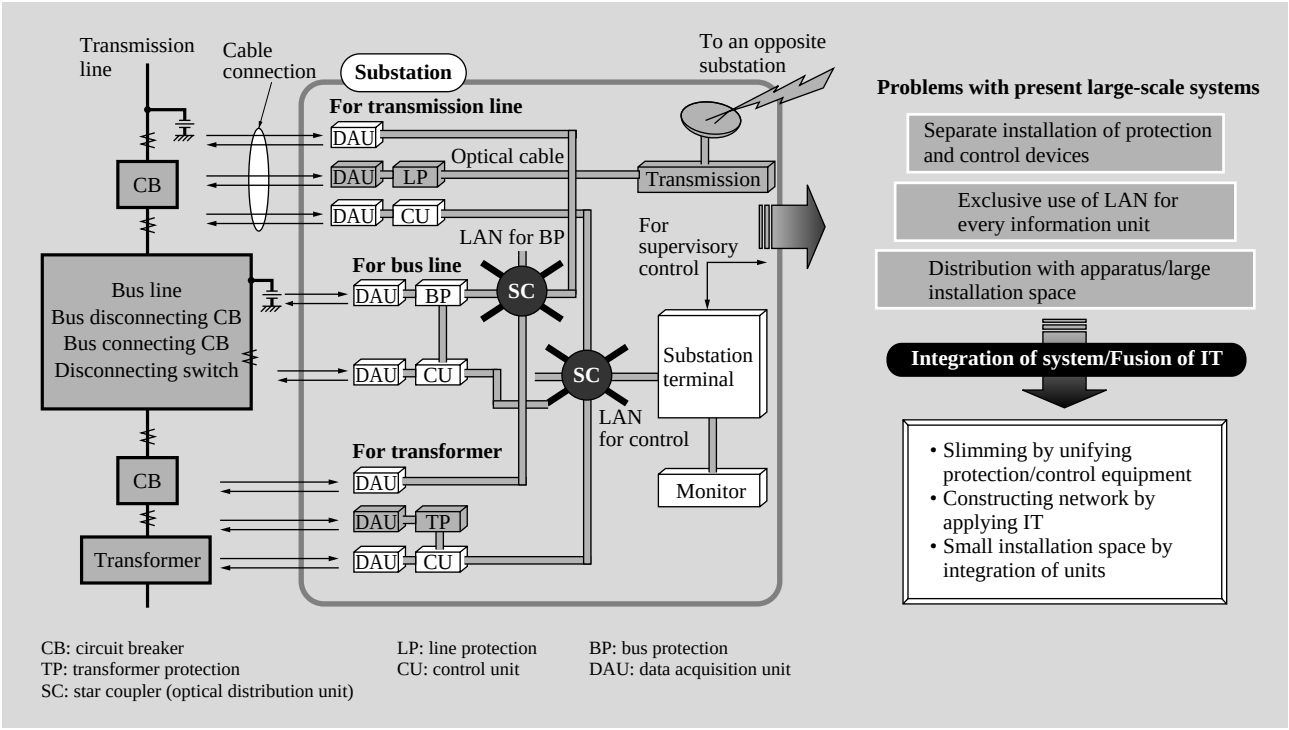


Fig. 3—Example of Combination of Optical LAN Application and Protection/Control Equipment, and Problems of Large-scale System.

The present substation system consists of exclusive use of LAN (local-area network) for every information unit.

functions and uses. Units are made according to their respective protection and control object. A cable or an exclusive-use LAN transfers the information between the protection/control equipment (see Fig. 3).

In detail, the information from the protective unit is transmitted to DAU (data acquisition unit) by optical transmission, and is then forwarded to the control room terminal, which has superior control. Such method is generally and commonly used.

This system's digital equipment, protection, control, and information object equipment have a common basis. Therefore, combining the control/protection equipment of every circuit unit can slim the total system. This equipment is compact, and configures the protection and the control units in one cubicle. Thus, hardware is reduced and there are considerable savings in power consumption.

The functions of the operation unit, which is the central component of the equipment, can be improved and shared, reducing the number of sections. As the dimensions of the whole unit are reduced by 50%, both the protection and control units can be configured into a single unit. The characteristics of this single unit are discussed below:

(1) Operation unit

The protection and control units need to be separated in the operation unit, which is equivalent to the center of the unit.

Therefore, the CPU (central processing unit) was separate and the use of a high-performance 32-bit RISC (reduced instruction set computer) processor enabled us to reduce the total number of boards to 70%.

(2) Input transducer

The input transducer, providing input current and voltage to the system, was until now, individually mounted away from the operation unit. However, adopting a toroidal coil reduced the space by half, but doubled the number of mountings. The input section was improved to the extent that it is only a card mounted in the operation unit.

(3) Power unit

The power unit supplies power to the operation unit. As the number of CPU boards applied to the operation unit has been reduced and the application circuit for the protection/control unit has been standardized, the power supply capacity is halved as is the mounting space. Consequently, the power unit has become so compact that it can be mounted in the operation unit.

(4) Interface

By mounting the Ethernet* LAN port in the operation unit, it can now respond to a flexible network configuration. Ethernet LAN is based on the TCP (transmission control protocol)/IP (Internet protocol), which is a general-purpose standard network interface. This is a high performance all-in-one operation unit. We slimmed down the system by mounting the protection and control equipment, which until now had been independent, into a single 350-mm width panel (see Fig. 4). The advantages of this equipment are as follows:

(a) Perfect isolation between protection and control unit from input to output

(b) Large reduction in installation space (Half the conventional space)

(c) Direct coupling between protection and control unit by an isolated interface

Remote Control Functions by Web Correspondence

The amount of operation and maintenance needs

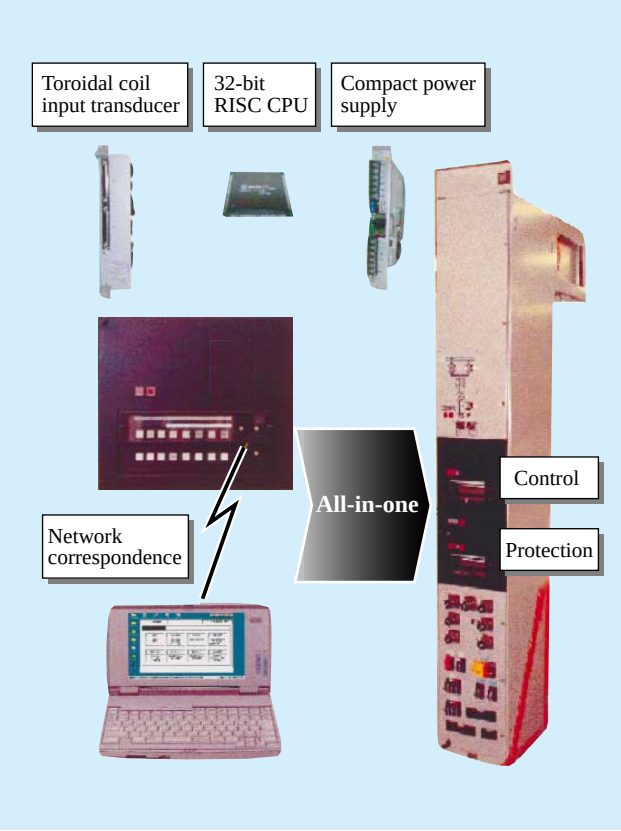


Fig. 4—Compact Type Operation Unit and Single Protection/Control Equipment.
The protection and control part are separated by independent structure, and CPU, input transducer and power supply unit are mounted in equipment. A protection unit is shown in the right of this figure.

*: Ethernet is a trademark of Xerox Corporation, U.S.A.

to be reduced and detailed information in real time is required on the digital protection and control unit, during disturbances, or when the operations manager is notified of changes in the status of local equipment to ensure system stability. Also, there have been demands for remote operation, and manned-control-station operation to remote unmanned substations. A conventional digital panel saves and analyzes system information (the current/voltage data) when faults occur, and the CPU has highly automated observation functions.

However, our system collects the voltage and current data that is saved inside the panel, in the remote maintenance section, and the results of automatic observation are analyzed and applied immediately.

The system has an interface, which directly acquires the data via the network from the protection and control units in the substation. It is normally situated in the processing unit and the various kinds of information and operations supplied from the remote end, enable us to view progress in the network (see Fig. 5).

The interface characteristics are as follows:

(1) The TCP/IP which is widely used as the standard network interface has been adopted, improving operability enabling easy access to exclusively used networks. By using an ordinary browser, most personal computers can access the network easily.

(2) The server is in the panel, and individual and detailed information is disclosed to the operator as web-site information. Also, the information is accessible by many clients at the same time via an exclusive-use network, and the data is the same even when faults occur.

(3) By using an ordinary browser, connection using a general public circuit is possible without limiting the communication medium or use of the exclusive network.

The cost of the communication and network equipment is reduced, and as the system is highly efficient, it further reduces costs.

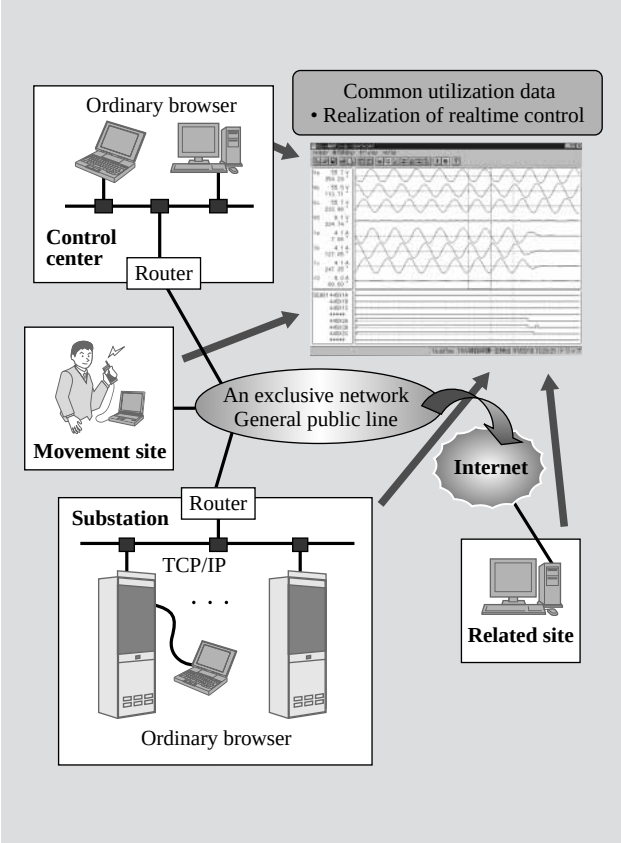


Fig. 5— The Example of Construction of a Network and Simultaneous Employment of Data.
By mounting general-purpose network interfaces as standard, it is possible to carry out operation and check the data simultaneously with the equipment of the other site by the ordinary browser. From now on, the system configuration increasing operation efficiency is also expected.

Connection between Protection/Control Equipment and Apparatus

In this system, the substation and the maintenance site are connected with the exclusive-use network in random time. The system can be constructed with shared and same-time data. Furthermore, the control and protection units are dispersed on the outside of the cubicle, with the units and the equipment communicating directly to one another. As a result, a large-scale substation system can be constructed at low cost (see Fig. 6).

The system has the following advantages because the protection and control units are placed near the equipment:

(1) Reduced mounting space for the protection and control units

(2) Reduced construction costs by shortening the cable route from the equipment to the units, and the construction period

(3) Higher reliability of information because the information from the equipment is directly transmitted to the network.

Increased reliability is expected, as a higher class network is multiplexed with one for waiting and the other for regular use. Here, the regular diagnosis for each unit is possible, by establishing an exclusive-use server in both the maintenance site and the substation. Utilizing the system for future diagnoses is possible.

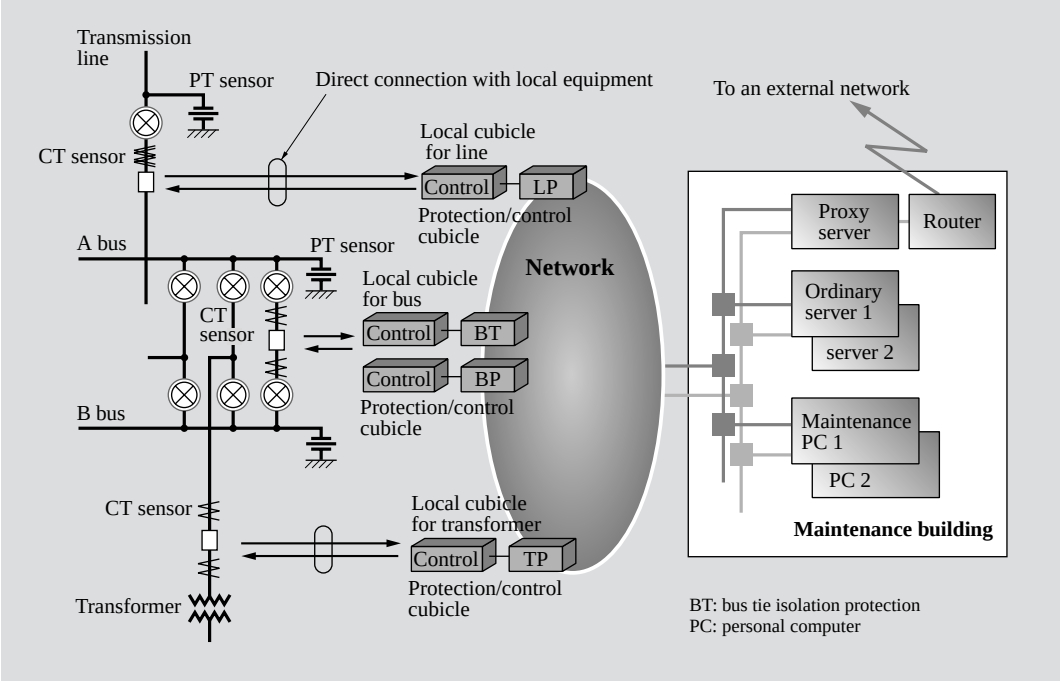


Fig. 6—Direct Combination of Apparatus, and an Example of Network Application. Intensive management of equipment and protection/control information is attained by arranging cubicle type protection/ control equipment near the apparatus, and carrying out network combination of this equipment.

CONCLUSIONS

We described the emerging new technology in the electricity supply system. With the progress in communication technology and expansion of IT-related technology, research and development have also been progressing based on the concept of an intelligent system, not only on units or equipment, but also the constitution of the system itself. It is entirely conceivable that the needs of future clients will become even more diversified in this field. We will have to speed up the development and release of products that have compatibility and are low in cost, in accordance with the demands of these future clients.

REFERENCE

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