Protection and Control System Using Open Network Architecture for Power Systems

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OVERVIEW: Paralleling the rapid penetration of the Internet and corporate intranets, protection and control system for power systems have been quick to exploit these technologies to make the remote control and monitoring of power systems more convenient. By leveraging these networking technologies to achieve a new level of openness, Hitachi, Ltd. has now succeeded in developing a protection and control system that features an IEC (International Electrotechnical Commission)-compliant network protocol: a standardized interface in the area of protection and control systems for power systems. In addition, a compact protection and control unit was developed that incorporates Web server functionality and has the ability to be controlled and monitored over general-purpose browser software, and we are now evaluating the unit for use with various applications. Finally, efforts are also underway to develop a maintenance support navigation system that supports operations and maintenance work using an intelligent (ubiquitous) controller.

INTRODUCTION

THE systems that protect and control power systems demand the high reliability and functionality. At the same time, relentless pressure to hold down costs of protection and control systems has accompanied the deregulation of the power industry, so our efforts have focused on achieving more compact, lower cost systems that provide equivalent or better performance and reliability than previous systems. And finally there is a strong demand to leverage IT and communication technologies in the adoption of open networks, and to adopt remote control capabilities to streamline and raise the efficiency of operations and maintenance.

This article will highlight some of Hitachi's recent initiatives to address these needs. We will describe the features of a protection and control system for power systems intended for domestic and overseas markets, and a maintenance work support system that was developed to boost the efficiency of operations and maintenance work.

TREND TO INCORPORATE IT IN PROTECTION AND CONTROL SYSTEMS

A diverse range of protection and control systems for power systems have been proposed that attempt to leverage and make good use of all the recent advances involving the Internet, corporate intranets, wireless communications, and other ITs (information technologies)[1)].

Looking at the power industry from a global perspective, it has generally been assumed that protection and control systems will be constructed using different manufacturers' equipment, so they have

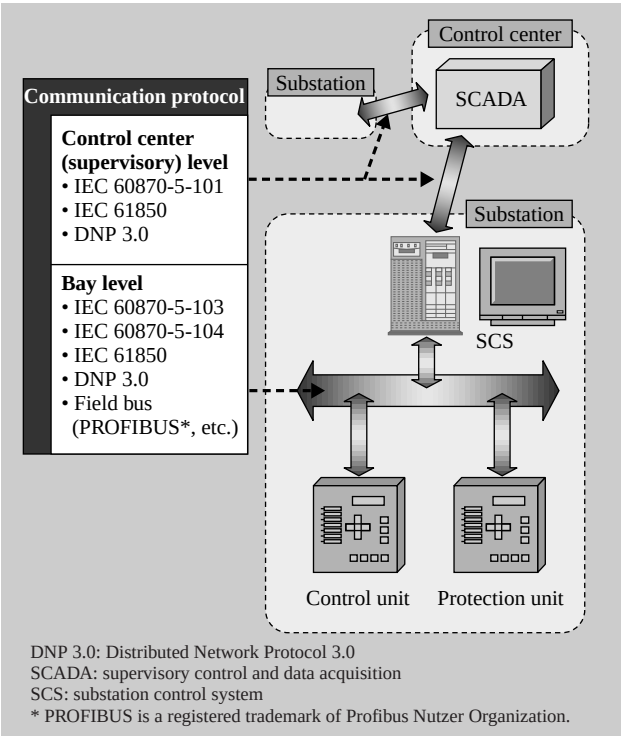

Fig. 1—Main Communication Protocols for Protection and Control Systems.
Protection and control equipment provided by different manufacturers employ an open network protocol to achieve interoperability and interconnect with the control center via an SCS.

employed standardized interfaces such as the IEC 60870-5-101/103 communication protocols based on RS-232C and RS-485 and standardized field buses such as represented by PROFIBUS. Fig. 1 shows the main network protocols that are currently available for protection and control systems.

Against this backdrop, headway has been made in recent years in IEC TC57 toward standardized communication protocols that can be applied from the process and bay levels to the station level, and systems employing high-speed general communications technologies based on Ethernet* are now emerging as the mainstream approach[2)].

PROTECTION AND CONTROL UNIT FOR OPEN NETWORKS

Hardware Configuration

Addressing this new reality, Hitachi developed new series of digital PCUs (protection and control units) that can be flexibly adapted to Ethernet-based open networks (see Fig. 2). The key features of the PCUs are summarized as follows:

(1) Communication with SCS (substation control system) is supported by the industry standard communications protocol IEC 60870-5-104 (which is based on the TCP/IP: Transmission Control Protocol/ Internet Protocol). This ensures full connectivity between different manufacturers' equipment.

(2) Protection and control functions have been combined in one unit, so the overall size of Hitachi's new digital PCUs has been substantially reduced (compared to previous Hitachi's models).

(3) Hitachi's new series of digital PCUs are extensible and can be flexibly adapted to various protection and control applications (functions can be readily added via the system bus).

(4) Clock can be precisely synchronized (1 ms resolution) using a GPS (global positioning system).

(5) Hitachi's new digital PCUs are user-friendly and have user configurable I/Os.

Network Technologies

The PCU was designed and built for interconnection over a network based on TCP/IP. More specifically, the unit supports the IEC 60870-5-101 protocol that is widely used in legacy power plant protection and control systems for communication between SCSs, and the IEC 60870-5-104 that is based on TCP/IP (Ethernet). Fig. 3 shows a typical architecture of the open network protection and control system. In addition, a Web server function in the PCUs is made possible by the general-purpose high-speed Ethernet connectivity, and a remote analysis of disturbance record and monitoring functions are achieved by delivering saved data as a file transfer from the PCUs to an SCS.

APPLICATION OF IT TO A MAINTENANCE LAN

Implementation of New Digital Relay Unit as Series

One objective in applying IT to digital protection and control systems is to enable remote control and

* Ethernet is a trademark of Xerox Corp. in the U.S.

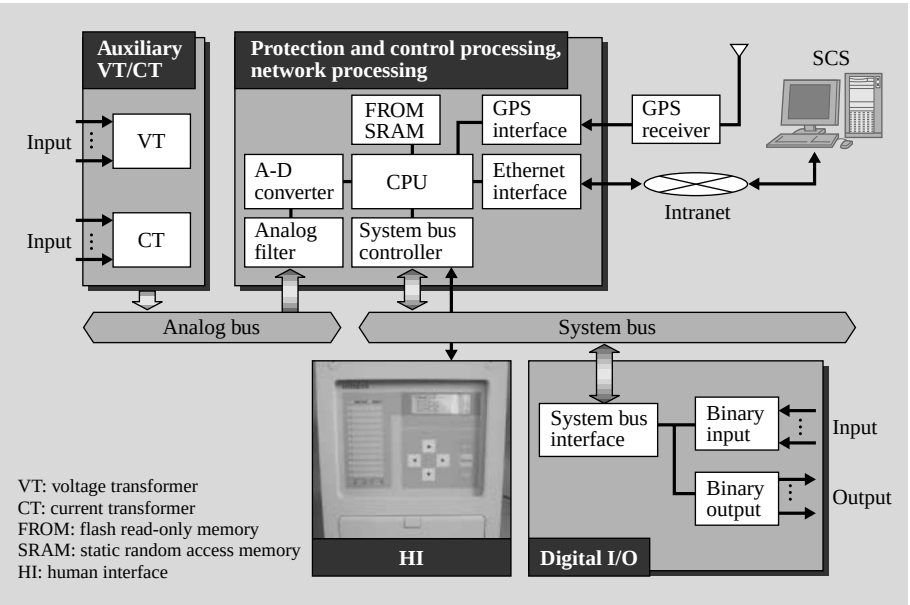

Fig. 2—Hardware Configuration of Open Network-enabled Protection and Control Unit. Communications with SCS are supported by implementing an open network protocol based on an Ethernet interface. A system bus interface supporting easy extension of I/O (input and output) is also provided.

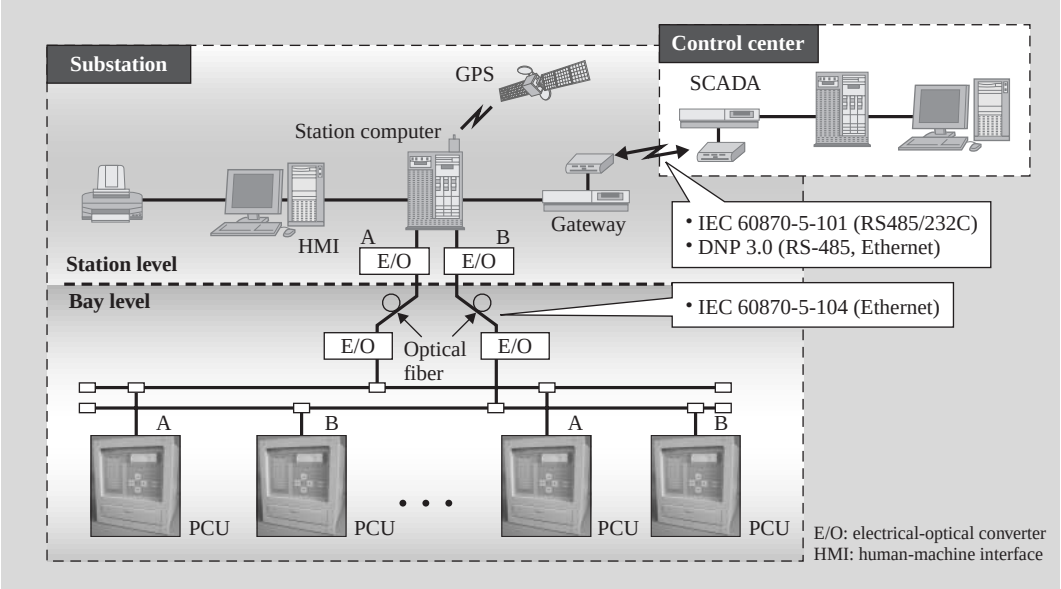

Fig. 3—Overview of Open Network-based Protection and Control System. Remote control and monitoring can be easily implemented by deploying an Ethernet-based IEC communication protocol between bay level in substation and SCADA system in control center.

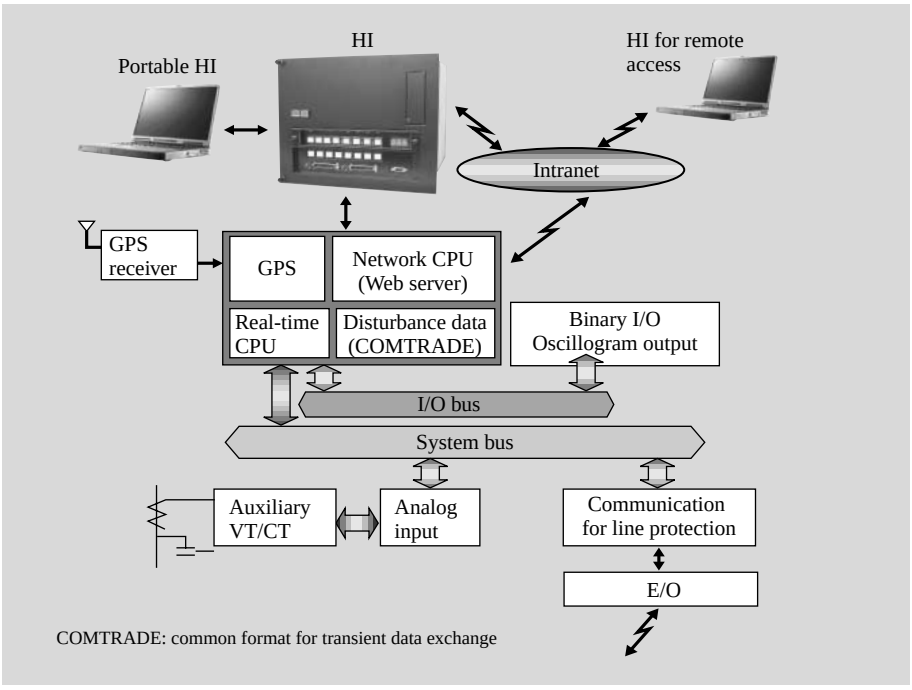

Fig. 4—System Configuration of New Digital Relay Unit. Dual processors for real-time protection/control processing and networking are implemented on a single printed circuit board. This ensures real-time processing performance and flexible accommodation of remote monitoring, control, and analysis over network applications.

monitoring capabilities by employing an operations/maintenance LAN (local area network). By implementing remote control and monitoring using ordinary PC browser software over a network connection, data can be accessed anytime, from anywhere, and over the same user interface. This approach should also support simple operability while maintaining high-speed responsiveness.

To meet these needs, we have developed a new network-ready digital relay unit. Building on Hitachi's previous model, the concept behind the new relay unit was to develop a system that maintained compatibility with a previous model yet was implemented much more compactly and supported interconnection over general networks. Fig. 4 shows the system configuration.

The key features of the network-ready digital relay unit are summarized as follows:

(1) Standard module

By standardizing hardware and software and configuring them in a standard-module library, these resources can be commonly used for various applica-

tions. It is also compatible with the current module that has an excellent performance record.

(2) Reduced size and weight

By consolidating the functions needed by the protection relay, the hardware has been substantially reduced in size and weight, and the power consumption has also been reduced (the protection and control, HI, and communication functions are all embedded in one board).

(3) All in one

The digital relay unit is an all-in-one implementation with the DC/DC converter, auxiliary VT/CT, CPU and binary I/O unit.

(4) Networking

Functionality of the unit is flexibly adapted to IT and is based on remote operation technologies. A network processor with Web server functionality is implemented right on the CPU board that also employs another processor for protection and control. These two processors are very closely coupled. This design not only minimizes data transfer bottleneck, but also eliminates unnecessary protocol conversions, and this speeds up communication processing, resulting in improving operational responsiveness.

(5) Time synchronization

The digital relay unit features an interface for GPS-time synchronization.

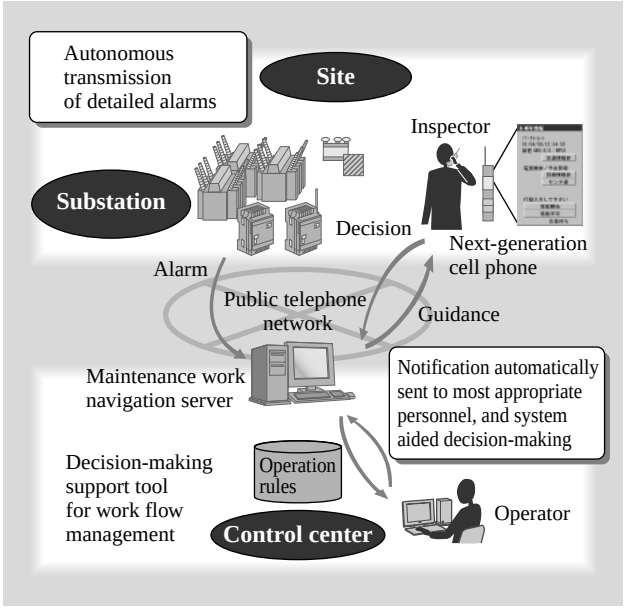

Fig. 5—Overview of the Maintenance Support Navigation System.

When an alarm is received from an intelligent controller, the maintenance work support navigation server supports decision-making by automatically sending all information pertaining to the problem to the appropriate personnel.

(6) Supports international standard format for disturbance data

The digital relay unit supports data format in compliance with IEC standards, thus permitting to analyze disturbance recording data by any manufacturers' analysis software.

(7) High reliability

The number of component parts has been reduced by combining and consolidating functions, resulting in reducing the failure rate. In addition, human programming errors in the manufacturing stage have been eliminated by adopting a software CAD (computer-aided design) system that automatically generates programs from logic diagrams.

Maintenance Support Navigation System

Overview of the maintenance work support system

This system consists of three constituent elements: control center, substation, and maintenance inspectors. By coordinating these various sources of data, the state of protection/control equipment and inspector's findings can be brought into accord, and maintenance work can be done online in real time. Fig. 5 shows the configuration of the maintenance support navigation system. For software, we provided an environment for executing a data collection agent using an intelligent controller, which is a small-size unit for ubiquitous computing. This agent collects data and performs other actions, which can be triggered at a pre-defined time or by changes in the state of pre-selected data. One advantage of this approach is that the format of collected data and other data collection attributes can be modified as needed to meet various data collection conditions determined and distributed by the power center. The collected data is sent autonomously from the intelligent controller to the control center.

Maintenance work navigation server

The maintenance work navigation server is installed in the control center where maintenance work is controlled. Built into the maintenance work navigation server is a decision-making support system, and the on-going work flow is managed by the WFM (work-flow management system)[3]. The navigation server receives data from the intelligent controller that is passed on to the operators and inspectors to assist them in their decision-making. In addition, tasks that are coordinated with other posts can be multiplex processed.

CONCLUSIONS

This article gave an overview of a protection and control system with open network capability for power systems, and a maintenance work support system. It is a challenge to meet all of the requirements that current protection and control systems for power systems must satisfy: besides meeting the highest standards of reliability and advanced functionality, every aspect must be designed to hold down costs, they must be network-ready, and they must be made more intelligent to accommodate diverse system needs. In the coming years we will see an increasing shift toward open distributed systems with more advanced networking capabilities.

Hitachi will continue to meet these needs by developing cost-cutting methods and increasing the availalbility of equipment and systems.

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