

High-performance Digital Protection and Control Unit for Distribution Substations

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OVERVIEW: As regards protection relay systems that shoulder the burden of protecting and controlling electric power systems and equipment, as a result of the rapid popularization of Internet and intranet systems in recent years, information-communication technologies and digital technologies are being applied in order to improve equipment performance and save labor costs incurred in on-site operation and maintenance by means of remote supervision. Likewise, as regards a protection and control system for a distribution substation, digital protection relays have generally been used, and space has been saved by combining relay elements, and “maintenance-free” operation has been achieved by means of self-diagnosis tools. Aiming to contribute to further improvement in reliability, reduced total costs by integrating functions, and streamlining of operation and maintenance, Hitachi is developing a protection and control unit for distribution substations. The protection and control functions are combined in one unit, however, they are independent from each other. In addition, a web server is also incorporated into the unit, thereby allowing the unit to be operated remotely from distant locations. Moreover, to simplify complex system fault analysis, it provides a fault-recording function that uses a general-purpose analysis tools utilizing data based on the COMTRADE (common format for transient data exchange) format.

INTRODUCTION

IN recent times, information-communication technologies focused on the Internet and digital technologies accompanying performance improvements in microcomputers have made striking advances. Accordingly, as regards electric power system protection and control equipment, on top of improvements to the functions of the systems themselves, functionality is continually being improved by combining other functions such as remote supervision, measurement, and fault recording.

Moreover, as regards a protection and control system for a distribution substation, from the electromagnetic-relay era through to the static-relay era, digital protection and control units have been applied. From now onwards, the retrofit of conventional systems is continuing to increase.

In the rest of this paper, a high-performance digital protection and control unit—which further improves functionality and reliability while improving cost performance by streamlining and combining operation and maintenance—is overviewed (see Fig. 1).

DEVELOPMENT CONCEPT

Concerning the concept on which the digital protection and control unit is based, the following three main points were set as development targets (see Fig. 2).

(1) Next-generation compatibility

Applying digital and information-communication technologies, the system must meet the needs of diversified systems for next-generation protection and control system and for remote maintenance and operation as well as reducing costs through function combination.

(2) Retrofit compatibility

The system must be able to take over protection relays technologies and knowhow inherited from the analog era, and it must be able to retrofit conventional units via compatible unit dimensions.

(3) High reliability

As for protection relays for use in distribution substations, since the number of substations is high, with regard to economic efficiency, it is clear that system reliability must be further improved.

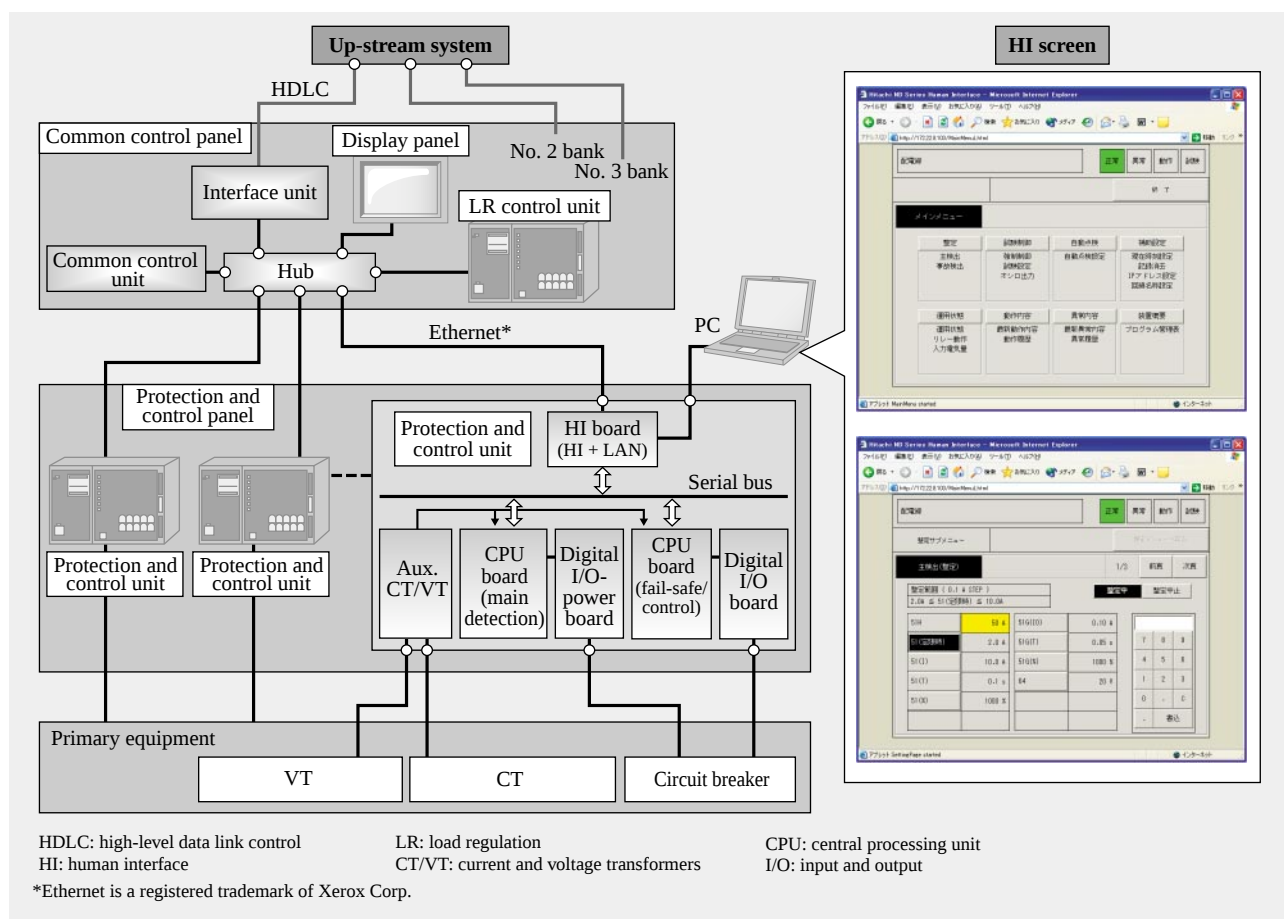


Fig. 1—Example Configuration of Digital Protection and Control Unit.

The protection and control units are installed according to either distribution lines or circuit lines of banks. The interface unit and the common-control unit incorporated on the common-control panel are connected by a general-purpose Ethernet technology, i.e. TCP/IP (transmission control protocol/Internet Protocol). By combining the protection and control functions, total cost is reduced, space is saved, and Ethernet communication reduces the amount of wiring.

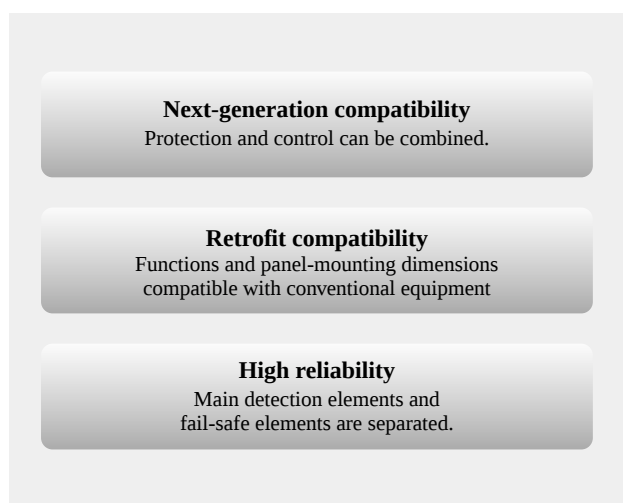


Fig. 2—Basic Concept of Digital Protection and Control Unit. The digital protection and control unit is configured to ensure reliability of the protection function that eliminates system failure and also to meet diversified system needs.

OVERVIEW OF DIGITAL PROTECTION AND CONTROL UNIT

Features

The unit-type digital protection and control system comes with the following five main features:

(1) Compactness

With the panel-mounting dimensions left the same as in a conventional device, only the depth dimension of the unit is scaled down. And housing the control and protection functions as an integrated unit enables the units either to be distributed on local control cubicles or to be centralized in a control room.

(2) Low power consumption

Decreasing the number of parts and adopting low-voltage reduces power consumption.

(3) High reliability

The hardware (excluding the auxiliary CT/VT) of the main detection elements and fail-safe elements are

separated, thus preventing unwanted operation due to single failures of the unit. Moreover, self-diagnosis functions are improved, thus preventing unwanted relay lock. Environmental performance is also improved, thus reducing effects from such as noise.

(4) High functionality

Harnessing various network interfaces like Ethernet and HDLC, the system enables economical wiring. Furthermore, it can handle both portable HIs via web-server functions and panel-operation HIs operated in front of the unit.

(5) User friendliness

On top of supporting fault recording during system fault and easy protection-relay performance analysis by general-purpose PC, the unit has an LCD (liquid crystal display) mounted on the front of the unit combined with ample key switches. As a result, confirmation of data and manipulation is simple and easy. And the panel-mounting dimensions were designed with their retrofit in mind.

Functions Overview

An external view of digital protection and control unit for a distribution substation is shown in Fig. 3, and its main specifications are listed in Table 1.

(1) System configuration

The main functions of the protection and control unit—divided between the auxiliary CT/VT, a CPU board including an input-signal-processor, a digital I/O board, an HI board including a communication-interface function, and auxiliary power-supply unit—are all mounted in one unit. And as for the system bus that connects the CPU board and the HI board, a CAN (controller area network) of serial buses is adopted, thereby improving reliability and simplifying unit internal connections by loose coupling as well as making expandability easier.

(2) CPU board

By housing analog input circuits, calculation circuits, and I/O interface circuits in one board, the board can be used for any of the main detection element, fail-safe element or control. Utilizing an analog input circuitry with high-speed sampling at a 7.5-degree electrical angle, as well as improving the digital filter processing and simplifying the hardware, makes possible A/D (analog-to-digital) conversion suitable for 14-bit precision. As for the calculation circuitry, applying a function-consolidated-type microcomputer fitted with a flash memory enables high-speed calculation possible at high reliability as well as miniaturization and reduction of power consumption.



Fig. 3—External View of Digital Protection and Control Unit. Remote operation by general-purpose PC (portable HI) is possible.

TABLE 1. Main Specifications of Digital Protection and Control Unit

All functions are housed in the unit, and “maintenance-free” operation is attained through self-diagnosis capability.

Item	Specification
Processor	• 32-bit RISC (floating-point calculation)
Analog I/O	• 2,400/2,880-Hz sampling • Analog input channel: 9 channels • A/D converter: 16 bit (14-bit precision)
HI	• Alphanumeric/katakana-script display LCD (20 characters by 4 lines) • 24 keys, LED × 16 • Portable type HI (RJ-45)
Digital I/O	• Digital input: 110-V-DC photo-coupler (max. 24 points) • Digital output: contacts (max. 24 points)
Communication network	• Ethernet interface (10BASE-T) • HDLC, RS422
Auxiliary power supply	• DC 110 V

RISC: reduced-instruction-set computer

LED: light emitting diode

A/D: analog-to-digital

(3) HI

The unit supports HIs that can be operated by PC connection (i.e. a portable HI) or by operating key switches on the front of the unit. The PC can be either connected via a network or by direct connection into the front panel. As for the panel-operated HI, an LCD display and ample switches are provided, so stable relay operation and detailed display of operation and abnormality information are made easy. As for the communication interface, a standard Ethernet interface (10BASE-T) is implemented, making it possible to

utilize the unit on a network.

(4) Auxiliary power supply

It is possible to choose between a double power-supply scheme, which can split the power supply between the protection and control functions, or a single scheme, which is packaged as standard.

CREATING HIGHLY FUNCTIONAL PROTECTION AND CONTROL UNIT

Next-generation Digital Protection and Control Unit for Distribution Substation

A digital protection and control system for a next-generation distribution substation—which achieves improved total economical efficiency, labor cost saving during on-site operation and maintenance, further integration, and improved equipment functionality—is described in this section:

(1) System configuration

The protection and control units are installed for each circuit of distribution feeders and transformer banks. That is to say, the units mounted on a common control panel (such as a common-control unit for controlling primary equipment and interface units connecting upstream systems) are connected to the protection and control unit by means of the Ethernet TCP/IP. Due to this configuration, maintenance can be done on individual circuits, and since circuit extension is done in units, maintainability is excellent.

(2) Protection and control unit

Connected to substation equipment, this unit supports functions for maintaining power lines and bank units, controlling switches, and monitoring. To improve cost efficiency, the protection and control functions are integrated. And to ensure reliability, the internal parts are configured in consideration of prevention of tripping or stoppages of both the protection and control functions due to a single failure.

The CPU board, the digital I/O board, and the auxiliary power-supply unit are separated for the protection and control. The protection function is composed of the main detection-relay and the fail-safe relay. Although the hardware for the main detection relay and the fail-safe relay is separated, the fail-safe relay is fitted in the control hardware for reasons of cost efficiency. As a result, in the event of a stoppage of the control function, the fault-detection-relay output is bypassed, and a temporary single-trip method by the main detection relay is applied.

Remote Maintenance Network

As regards the remote maintenance and control

using an operation and maintenance network, if browser software on a general-purpose PC is utilized and the PC is connected to the network on the same user interface anytime from anywhere, and convenient operability will be required.

To satisfy this requirement, a web-server function is incorporated on the HI board that is separated from the CPU board that executes real-time calculations for protection and control. This set-up ensures high performance for these calculations, also assures good operation responsiveness.

Fault-recording Feature

In the case of a substation without a fault-recording feature, analysis on the aspects of complex system faults is difficult; accordingly, the developed unit is fitted with a function for recording such faults. In the event of a fault occurring, trip-command output and relay operation points are triggered, and analog input waveform and digital input data are stored in a flash memory. The saved data complies with the COMTRADE (common format for transient data

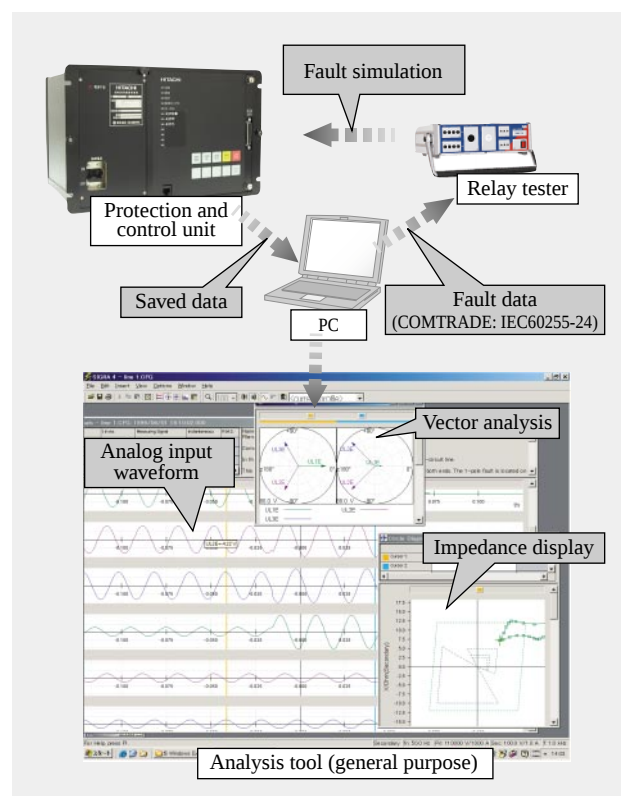


Fig. 4—Overview of Fault Recording Function. Analog input waveform and relay operation status before and after trigger points can be displayed as time charts, and vector-analysis charts and impedance displays can also be shown graphically.

exchange) format, so faults can be displayed and analyzed by using a general-purpose fault-analysis tool. As regards this tool, analog waveforms before and after a trip occurs and relay-operation status—along with vector and impedance charts—can be displayed in the form of time charts. The fault data can be downloaded in the format without stopping protection and control functions. Thus, the data can be managed easily. What is more, fault-detection data can be reprocessed by means of a relay tester compatible with COMTRADE, thereby allowing various simulation tests to be carried out (see Fig. 4).

CONCLUSIONS

A high-performance protection and control unit for application in distribution substations was developed. From now onwards, aiming to eliminate power-system

faults, or prevent the spreading, and to assure stable power distribution, Hitachi will provide high-reliability protection and control systems that maintain protection and control functions at all times and allow simple operation and maintenance, by means of merging diversified system needs and cutting-edge technologies. In doing so, we will continue to provide power-system protection and control units that meet the needs of our customers.

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