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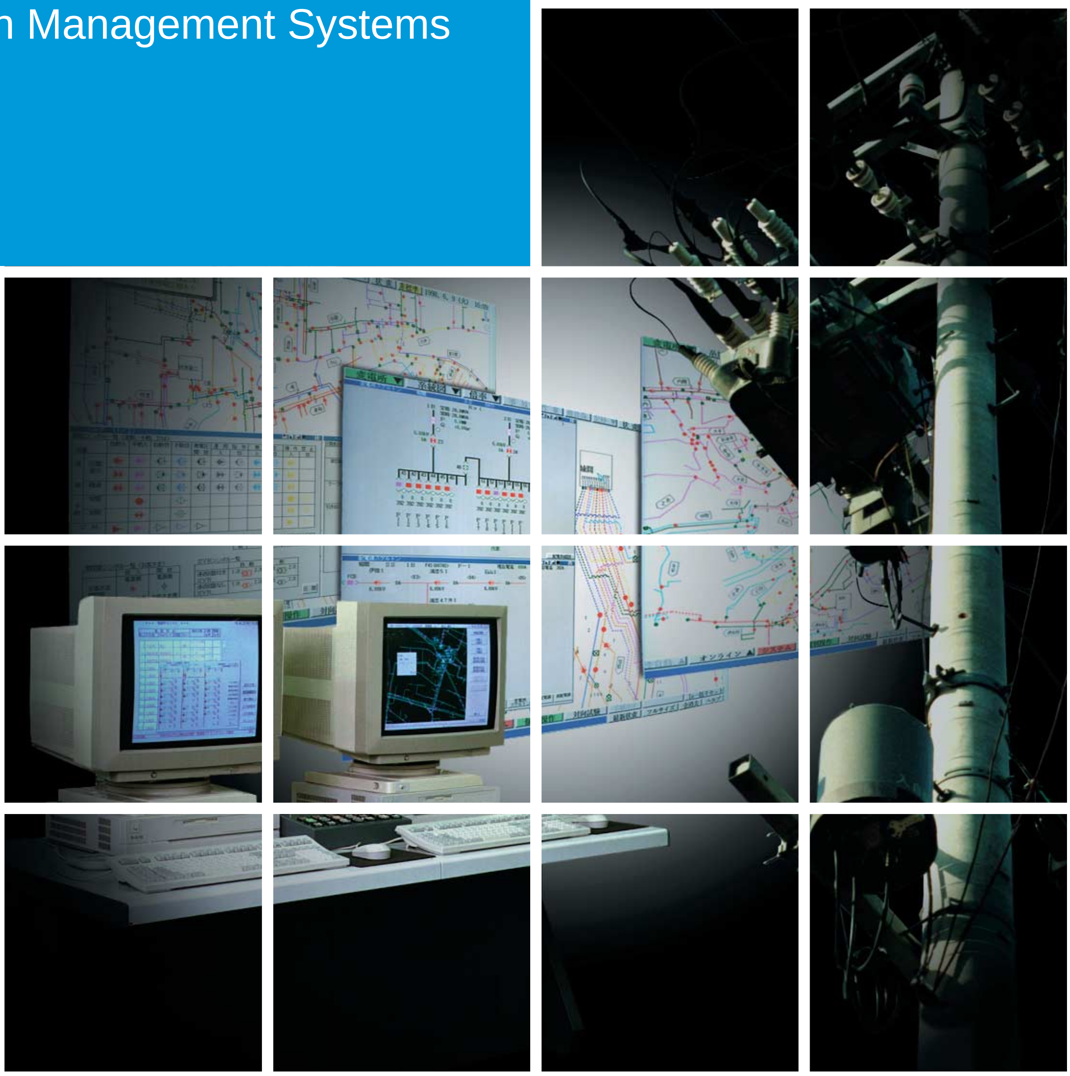
Distribution Management Systems



FUJI ELECTRIC

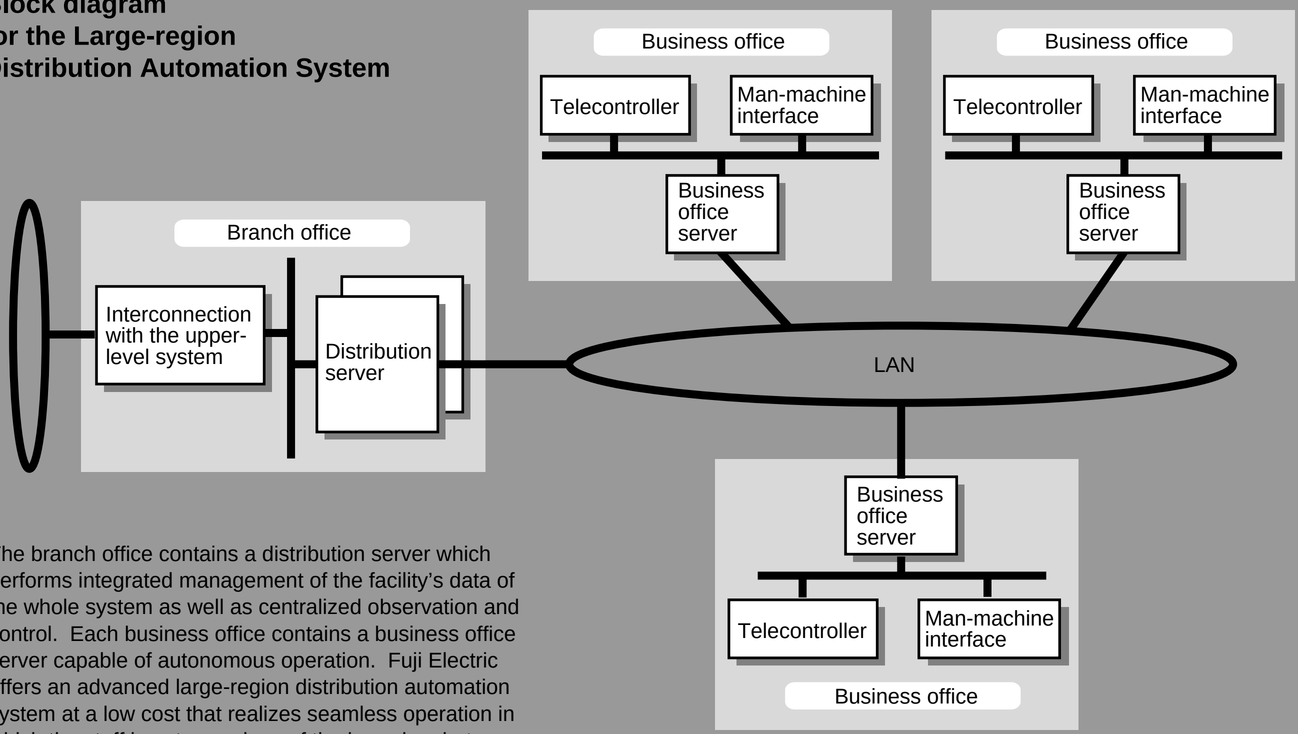
Creating a Better Tomorrow with Trustworthy Technology

FUJI ELECTRIC'S DISTRIBUTION AUTOMATION SYSTEMS

Powerfully Support Operators in the Sophisticated Operating of Distribution Systems

- The Large-region Distribution Automation System utilizing the Open and Distributed Architecture realizes seamless operation.
- A software package for advanced operation support functions based on our abundant field experiences is provided.

Block diagram for the Large-region Distribution Automation System



The branch office contains a distribution server which performs integrated management of the facility's data of the whole system as well as centralized observation and control. Each business office contains a business office server capable of autonomous operation. Fuji Electric offers an advanced large-region distribution automation system at a low cost that realizes seamless operation in which the staff is not conscious of the boundary between business offices.

FUJI ELECTRIC, an Expert in System Control

FUJI ELECTRIC
REVIEW

4

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Distribution Management Systems

CONTENTS

Cover Photo:

Distribution systems at the final stage of the power supply process are directly and extensively connected to customers. There are growing demands for more efficient operation and higher reliability.

Fuji Electric has been involved in the technologies of distribution automation systems and associated equipment and has accumulated plenty of know-how and experiences.

Also Fuji Electric positively tackles the research and development of distribution technologies including customer automation to meet a future information-oriented society.

The cover photo shows an image of the latest distribution automation system.

Fuji Electric Co.,Ltd. Head Office : No.12-1, 1-chome, Yurakucho, Chiyoda-ku, Tokyo, Japan

An Overview of Recent Distribution Management Systems

Kazuhiro Oohashi
Jinpei Kuwayama
Hiroshi Horiguchi

1. Introduction

The advancement of information communications and the sophistication and diversification of city functions have led to larger and more complicated distribution systems. Ten years have passed since the full-scale introduction of computers into these distribution systems. The goals were to improve supply reliability and efficiently operate the equipment.

Recently, accompanying the trend of worldwide deregulation of electrical enterprise lows, the preservation of the global environment, and new information processing systems backed by open system technology in accordance with international standards, distribution automation technology has developed from the viewpoint of different evaluation and framing.

Fuji Electric has been involved in this field from the early stages. Excerpts from the results were published in two special issues of the Fuji Electric Journal which featured distribution automation tech-

Fig.1 Developments of distribution automation systems and changes in required specifications

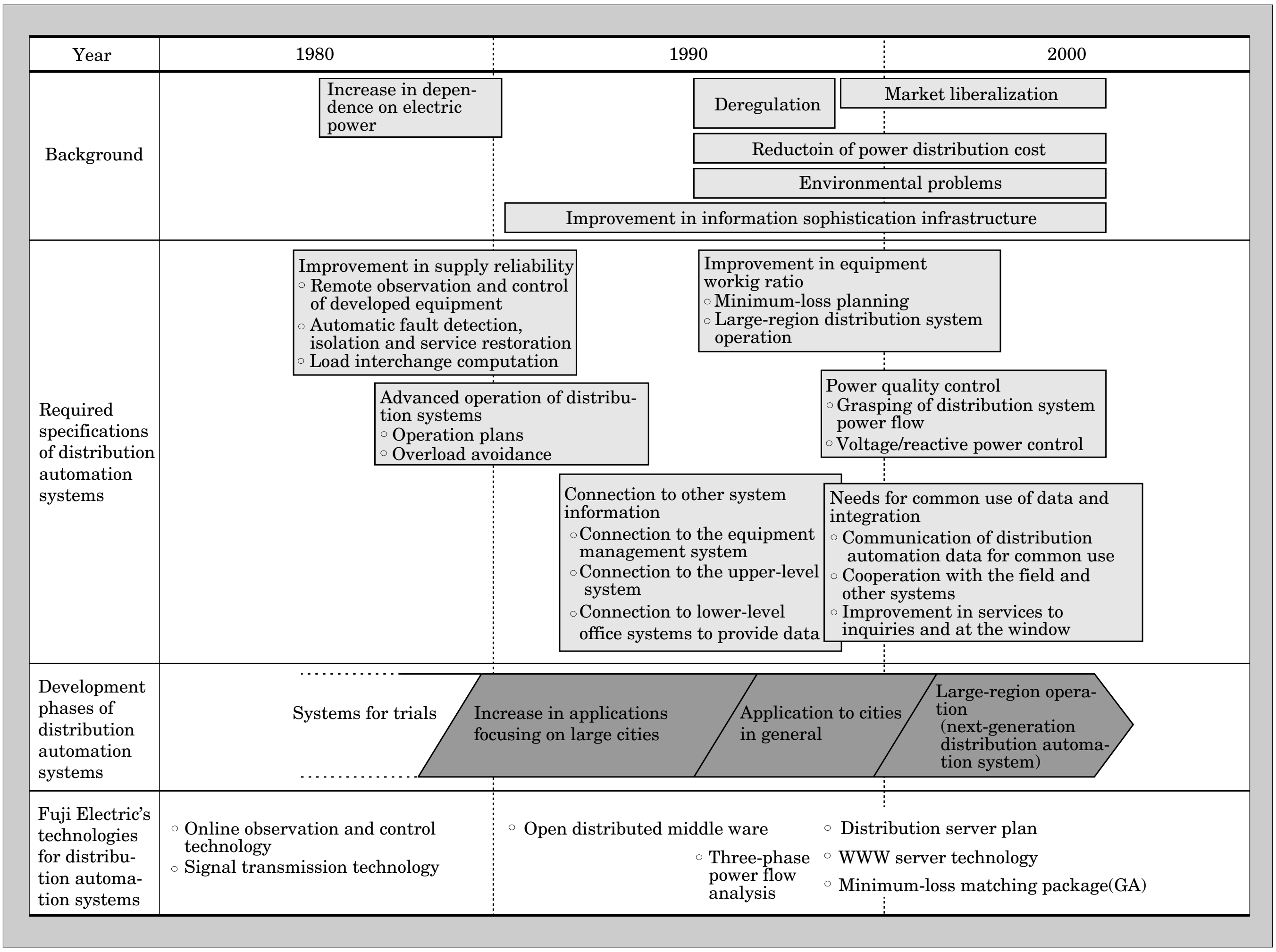
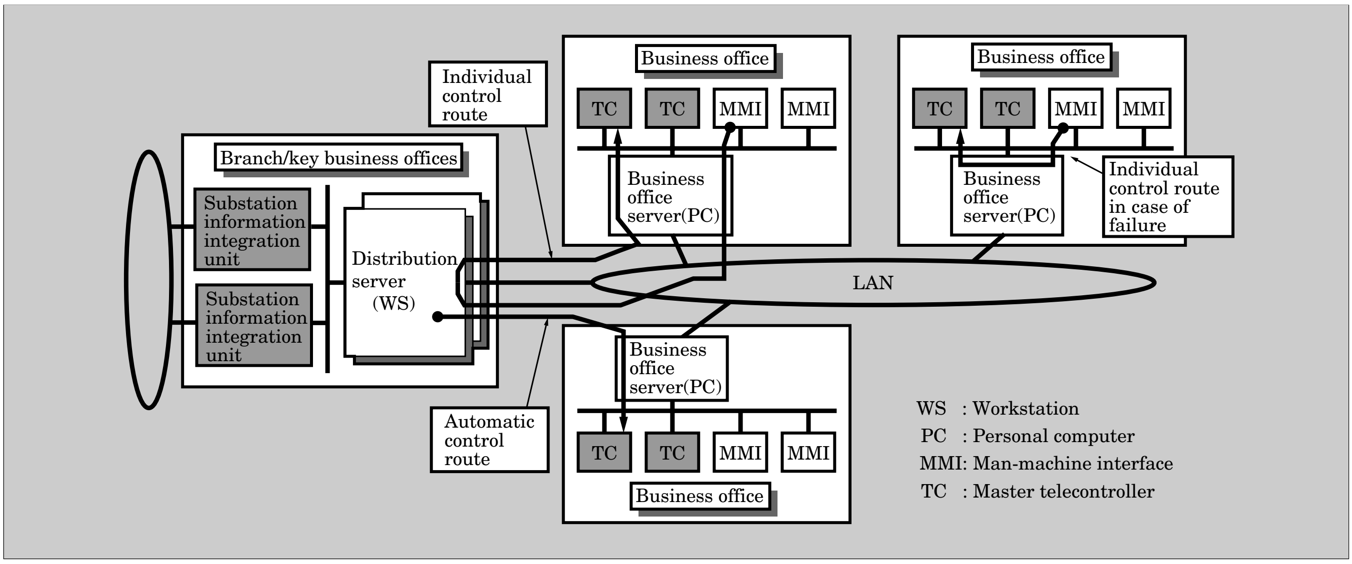


Table 1 New concept of next-generation distribution automation systems

Category	Distribution needs	New concepts		Contents/features
Distribution system operation	Reduction of power distribution cost	Large-region distribution control system plan	○ Large-region distribution system operation with information interconnection between distribution automation systems (interconnection between branch and business offices)	○ Increase in the distribution line working ratio ○ Reduction in night duty
			○ Distributed system configuration with open architecture	○ Facilitated data transmission between systems and function expansion ○ Reduction in initial structuring cost using personal computers
			○ Interconnection with other/upper-level systems	○ Advanced system operation due to data unification ○ Efficient data maintenance
Distribution business	Improvement in equipment working ratio	Distribution system planning support systems		○ Improvement in equipment working ratio by minimum-loss matching computation ○ Designing efficiency enhancement
	Equipment modernization	Compatibility with 22kV/400V direct distribution and 400V low-voltage trunk lines		○ Combination optimized with diversified supply forms
	Improvement in information amenity	System having distribution automation system data for common use		○ Enhanced efficiency in filling in forms and data editing ○ Improvement in services in responding to inquiries and at the window
Power quality control	Power quality observation and compensation to meet diversified power sources and loads	Functions of power quality measurement, analysis, and compensation		○ Power flow computation, imbalance/harmonic analyses, and compensation for systems that include dispersed generation, static var generators and static voltage regulators

Fig.2 Conceptual diagram for a next-generation distribution automation system based on the large-region distribution server concept plan



nologies (Vol. 61, No. 12 of 1998 and Vol. 66, No. 2 of 1993). Although it has been five years since the last issue, this paper will describe recent trends and Fuji Electric's developments and results, focusing on distribution automation and customer automation.

2. Trends of Distribution Automation Systems

2.1 Present status and the next-generation concept of distribution automation systems

Figure 1 shows the developments in distribution automation systems and changes in required specifications.

In accordance with other distribution automation systems which have been positively introduced since the 1980s, Fuji Electric has adopted its own "online observation and control technology". This central technology has been widely used in various fields. Thus, we have structured and developed highly reliable systems with advanced functions that include use know-how in operating distribution systems.

In the meantime, we have made ceaseless efforts to

Fig.3 Software configuration for the large-region distribution control system plan

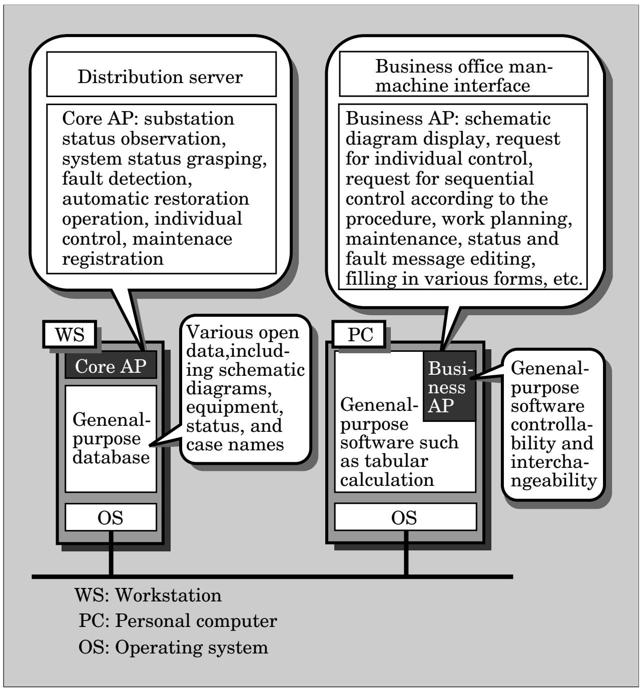


Fig.4 An example of a data system for common use

anticipate users' demands and changes in the environment in order to offer distribution automation systems utilizing the latest technology.

Now, in addition to technical innovations such as information amenity, rapid improvement in CPU performance, and open distributed systems, environments around electrical enterprises have changed greatly. Accordingly, demands for distribution automation systems have changed-from an emphasis on supply reliability to the adding of functions to include advanced operation and information amenity.

Fuji Electric has proposed a new concept shown in Table 1 for the next generation of distribution automation systems that will meet these trends.

2.2 Distribution automation systems based on the large-region distribution server concept

With the increasing use of distribution automation systems, investigations have been made into having the status of system equipment between business offices. This common use will realize automatic fault detection, isolation, and service restoration by any office. In the future, it is hoped that night duty at each business office will be abolished by centralized backup operation performed at night.

Future distribution automation systems will be required to reinforce interconnection with related systems and have functions for sophisticated analysis or decision based on more information. It is also important that each system's base structure has a standard open architecture using de facto or international standards. It should also be an environment where timely information can be obtained from other systems.

Figure 2 shows the conceptual diagram of a distribution automation system based on Fuji Electric's large-region distribution control system plan. Figure 3 shows its software configuration.

This system consists of a distribution server in a branch office (or a key business office) and a local area network (LAN) interconnecting the business offices. Each business office contains a business office server, man-machine interfaces and master telocontrollers. The distribution server performs the integrated management of the facility's data of the distribution systems within its jurisdiction as well as centralized observation and control within the branch office. The business office server stores the entire facility's distribution system data in the distribution server and performs autonomous operation.

The distribution server uses a workstation to maintain reliability through efficient use of existing software. It uses a general-purpose database for free data transmission between systems and ensures sequential expandability for software. The use of personal computers for man-machine interfaces at the business office aims at reduced development cost and improvement in controllability and expandability using diverse general-purpose software.

With this configuration, two or more distribution systems within a business office are integrally managed, and the whole system is open to each business office and seamless operation is realized. In seamless operation, the staff is not conscious of the boundary between business offices due to the methods of automatic fault detection, isolation and service restoration utilizing the whole system.

2.3 Common use of information

Each division of electric power companies has been introducing computer systems that include distribution

Fig.5 Conceptual diagram for a customer automation system

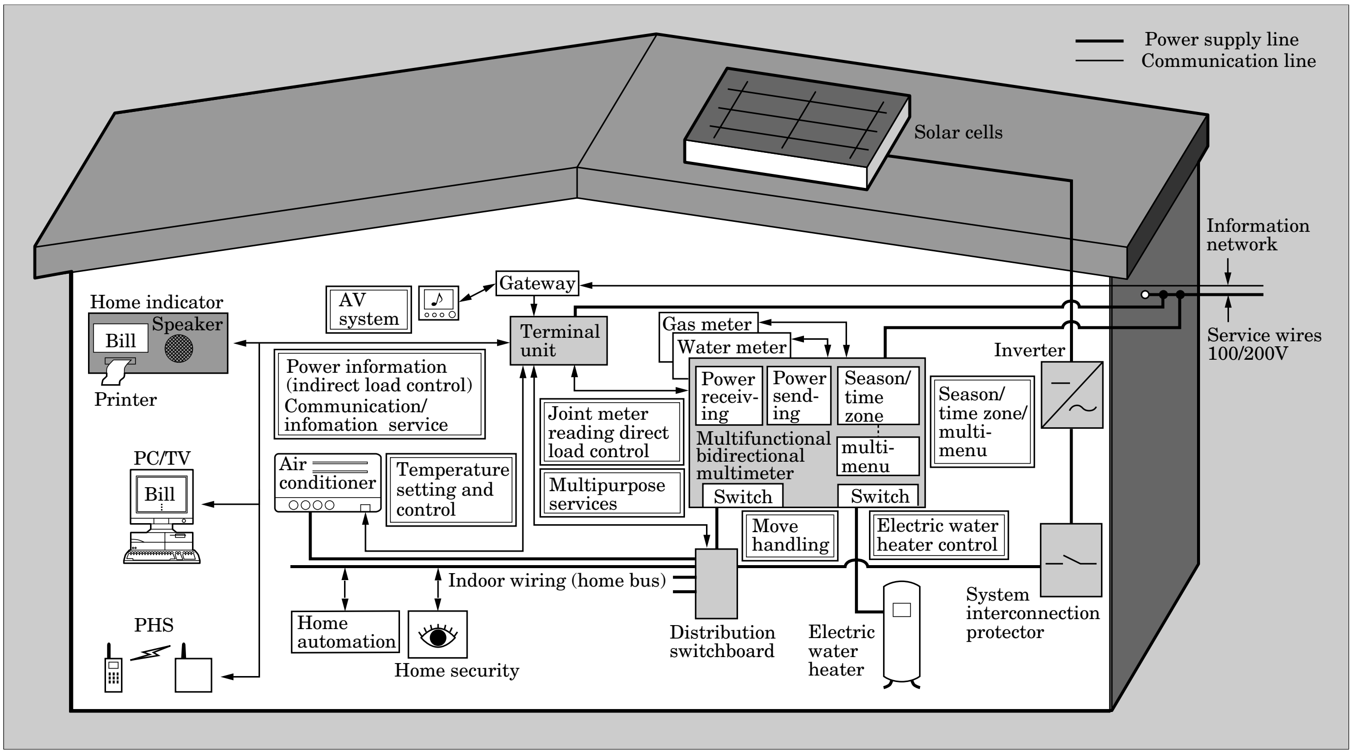
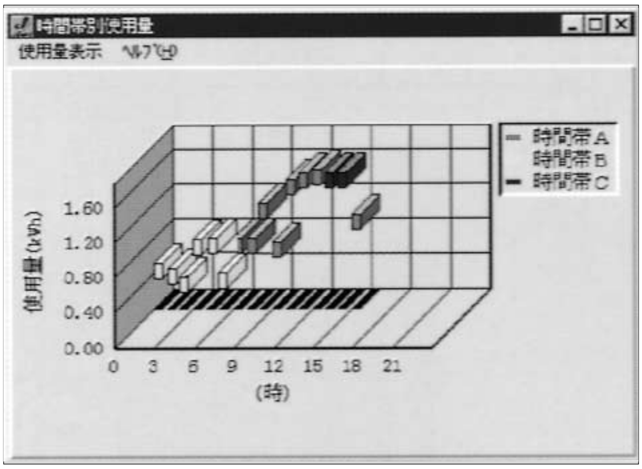


Fig.6 An example of information on power consumption



automation systems.

Improvements in network technology and widely used office automation machines have produced multiple types as well as a large quantity of data. The mechanism of transmitting real-time operation data and analysis data from each system to personal computer terminal units connected to the internal LAN enables the data to be commonly and efficiently used, thus enhancing the efficiency of business management. As a result, this system for the common use of data aims at business interconnection between divisions for maintenance and planning and cooperation support between the field and control room. This system is presently being introduced.

Figure 4 shows a display example of this system using general-purpose software.

2.4 Development toward distribution system planning support

This functions of distribution system planning include developing an optimum power transmission plan to a new supply request and an equipment plan based on the estimated increase in future demand, avoiding supply failures such as overload.

The key is to device a plan that makes the most of existing distribution equipment and suppresses new installations. Solving a combination optimization problem with complicated operating conditions and elements among the vast quantity of distribution system patterns with a computer and showing the operator the most suitable solution was difficult.

Recent technical developments in computer capacity enhancement and man-machine interface enrichments such as graphical user interface (GUI) have led to proposals of various new solutions to the combination optimization problem and easy application of the these techniques to the distribution system planning problem. This has created an environment in which to develop the solution into a support function.

Fuji Electric has applied the genetic algorithm (GA), one of the modern heuristic techniques, to this combination optimization problem. We have realized the distribution system's planning support functions such as generating optimal network configuration and transferring load between substations.

3. Activities for Customer Automation

With regard to customer automation systems, studies and demonstrations in the field focusing on automatic meter reading and load control have been carried out for several years. Some have been put into practical use.

Recently, to improve load factor and reduce CO_2 exhaust, demand side management (DSM) for taking measures for load leveling and energy saving has been studied. Studies into power quality control aiming at multi-menu power service have also begun.

Fuji Electric has participated in this field from the early stages. We have made efforts to expand the product lines of electronic watt-hour meters and customer terminal units and to accumulate know-how in the field and operation/evaluation techniques for various data transmission technologies including a power line carrier system.

New topics for the future include measures for meeting the increase in system interconnections for dispersed generation that reflects relaxed regulation and market liberalization for meeting diversified power supply forms. Further development of non-electric enterprise fields such as information service, heat supply, and home security is also anticipated. Figure 5 shows a conceptual diagram of Fuji Electric's future customer system.

3.1 Trends in automatic meter reading

Backed by data transmission technology development, electronics application to watt-hour meters and diversification of power rate systems, automatic meter reading is being rapidly introduced to bulk customers with complicated meter readings and problematic areas of meter reading, such as apartments with an automatic locking system or mountainous districts. Fuji Electric has marketed a multifunctional electronic watt-hour meter with a load survey function to meet the demand regulation contract of bulk customers and a watt-hour meter and terminal units with the remote function of handling household moves.

3.2 Tackling DSM

The Agency of Natural Resources and Energy, the Ministry of International Trade and Industry has continuously demonstrated centralized load control since 1986 as a measure for load leveling. Fuji Electric has also anticipated.

In the beginning, centralized load control was studied, with a major focus on direct load control to control electric water heaters and air conditioners. However, recent improvements in the information communication infrastructure have reflected growing concern over indirect load control, which guides the power consumption pattern in standard homes and small shops. Customers receive information on rates and demand values from the electric power company.

Fuji Electric, commissioned by the Japan Electric Meters Inspection Corporation (JEMIC) developed and demonstrated a system for indirect load control. Figure 6 shows a display example of this system.

To meet the spread of dispersed generation, we are preparing a series of products and expanding applications for the protection system for dispersed generation interconnection in accordance with the system interconnection guidelines of the Ministry of International Trade and Industry.

4. Conclusion

The advancement of distribution automation systems will continue due to the backup of information communication infrastructure improvement, diversified customer needs, and continuous progress in related technologies.

Fuji Electric will ensure a future course and will contribute to the development of the distribution automation system.

In this special issue, we would like to acknowledge the cooperation of the electric power industry and would appreciate future guidance and support.

Distribution Planning Support System for the Kansai Electric Power Co., Inc.

Susumu Ekawa
Satoru Kusama
Hiroshi Oi

1. Introduction

Recently, electric power utilities in Japan are facing harsh cost reduction in order to realize reduction of electric power price. They must restrain facility investment and achieve more efficient operation.

Reduction in electric power loss (henceforth abbreviated by "loss" in short) of the distribution system leads to a reduction of total power demand and total power generation is reduced, consequently. Considering this background, realization of loss reduction in distribution systems is eagerly awaited in Japan.

Fuji Electric has recently developed a distribution planning support system through a joint project with the Kansai Electric Power Co., Inc. Distribution system expansion planning (generation of future network configuration) has been achieved by human experts and it has been time-consuming. "Distribution planning support system" aims at automation of the planning and addition of an advanced function, namely generation of future network configuration considering loss reduction using only existing switches with forecast demands in the future. "Optimal network configuration guidance package" has been developed in the system. It utilizes genetic algorithm (GA), which is one of the modern heuristic methods. This paper especially summarizes the overview of the package.

2. Outline of the Distribution Planning Support System

2.1 Summary of distribution planning

Distribution planning is based on the actual maximum load results value of the present year. For future demands, a span of 5 years after the next year is estimated. Then, based on this demand analysis and estimation, a facility plan that prevents service interruptions such as overload (a state of excessive power transmission beyond the capacity of the facility) is drafted.

Fig.1 System configuration

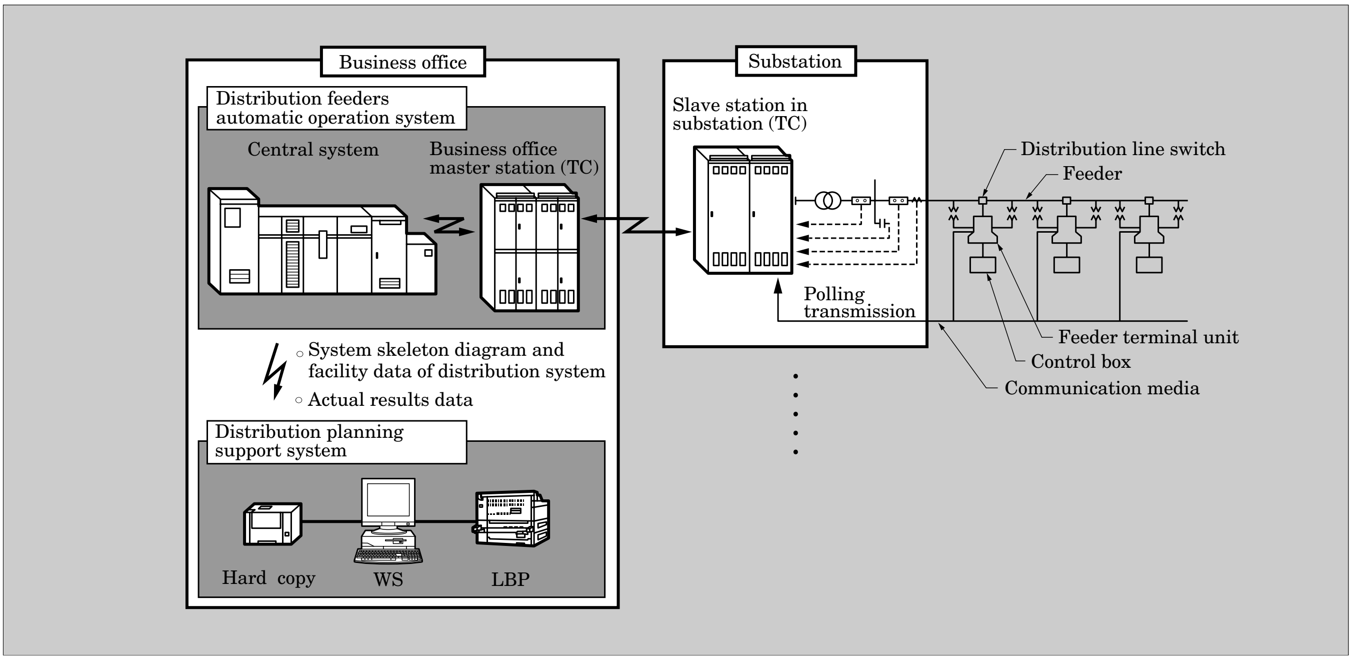


Fig.2 Work flow of distribution planning

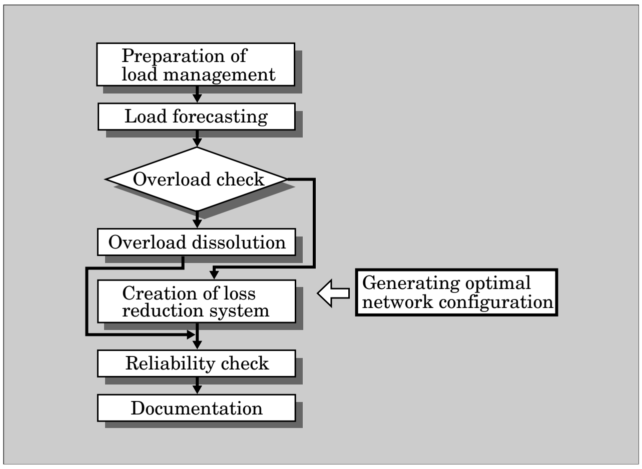


Table 1 Summary of functions

Function	Summary
Load management	Obtain actual maximum and average load value data from the distribution automation system.
Load forecasting	Provide the function to input growth rate, etc. and forecast future load values of each feeder, etc.
Overload check	Check overload of S/S, bank, feeder and generate new network configuration which can cancel overloads.
Inter-substation load transfer	Input transferred load values and generate an optimal network configuration to counterbalance each substation loads.
Simple data maintenance	Potential consumers are reflected to the system, or the system configuration is altered for overload dissolution.
Generating optimal network configuration	Generate a loss reducing system by changing loop opening point between feeders and calculate loss reducing rate.
Automatic contingency analysis	Automatic execution of contingency analysis of one-bank faults and feeder faults.
Principal documents output	Automatically generation of load transferring plan sheets for each feeder and long-term plan sheets, which were manually created previously.

2.2 System configuration

This system is connected online with the existing "Distribution Feeders Automatic Operation System" through a general-purpose workstation via the international standard procedure TCP/IP. This allows data stored in the "Distribution Feeders Automatic Operation System" to be utilized and reduces labor by automatic data input.

The system configuration is shown in Fig. 1.

2.3 Summary of functions

This system has the eight functions shown below. They support enhanced facility planning which is shown in Fig. 2.

(1) Load management
(2) Load forecasting
(3) Overload check
(4) Inter-substation load transfer
(5) Simple data maintenance
(6) Generating optimal network configuration
(7) Automatic contingency analysis
(8) Principal documents output

A summary of the function is shown in Table 1.

2.4 Effects expected by system installation

With installation of this system, greatly improved work efficiency and restraint of new facility investment are expected. The former is achieved through the "Load management," which automatically inputs the actual results data from the distribution feeders automatic operational system for use in the plan, and the "Load forecasting," which predicts future load levels based on collected data. The latter is brought about by the "Overload check," and the "Inter-substation load transfer," which resolves the load exceeding capacity by selecting the existing facility.

Next, a guidance package for the recently developed optimum system will be introduced.

3. Optimal Network Configuration Guidance Package

3.1 Summary of functions

This package offers to operators the optimum system configuration. This is obtained after various problems such as loss reduction and load leveling are examined, aiming for improved system operation. The system configuration considered as optimum stems from an infinite number of system configuration patterns obtained by a combination of on-off positions of the distribution line switches (switches installed in the distribution systems which control electricity flow).

3.2 Features

This package has the following features:

(1) For the first time in Japan, genetic algorithm, one of the modern heuristic methods has been put into practical use for electric power systems.
(2) The package is capable of handling each of three phases with the aim of improving future power quality such as correction of a three-phase imbalance.
(3) The package achieves a processing form that does not depend on database architecture.

3.3 Application to distribution planning support system

By using this package, the following functions are achieved in the distribution planning support system:

(1) Overload check
(2) Inter-substation load transfer
(3) Generating optimal network configuration

The next section will introduce the procedural

Fig.3 Conceptual diagram of searching with genetic algorithm

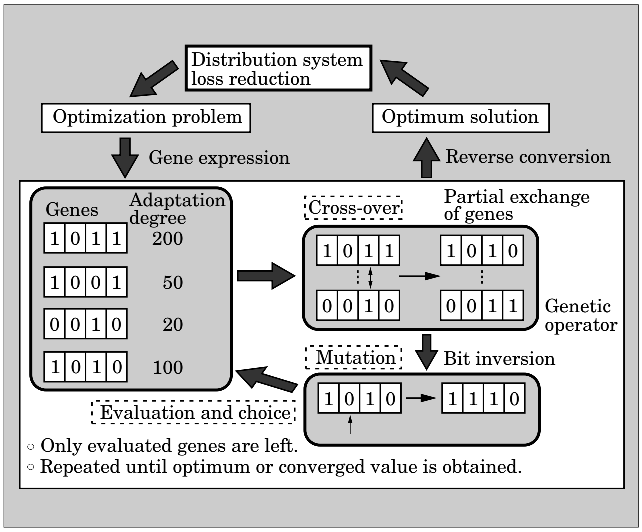
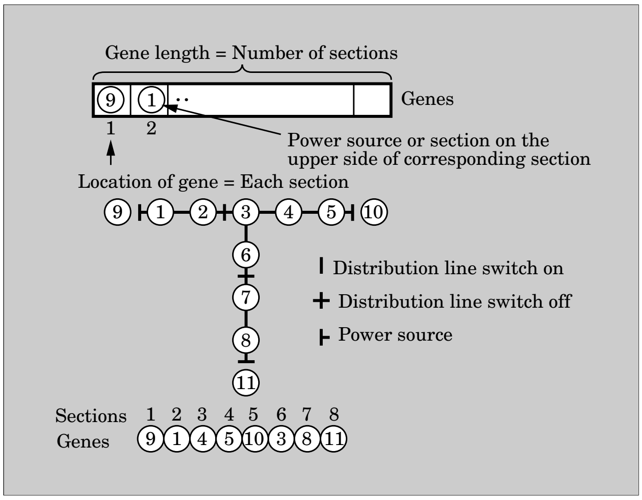


Fig.4 Example of a radial network and corresponding gene string



summary of this package, the achievement of the functions in the system, and the effects. These three topics will be illustrated through the generating optimal network configuration, the most distinguishing characteristic of this system.

4. Generating Optimal Network Configuration

4.1 Basic concept of generating optimal network configuration

Loss reducing systems can be achieved by altering the on-off positions of distribution line switches of existing facilities without requiring installation of new facilities. This problem enables pursuit of a system configuration that can reduce total loss, making every feeder current equal by altering the current flow in the distribution system by changing the on-off positions of the distribution line switches. The problem can be supposed as a combinatorial optimization problem.

Fig.5 Conceptual diagram of a cross-over

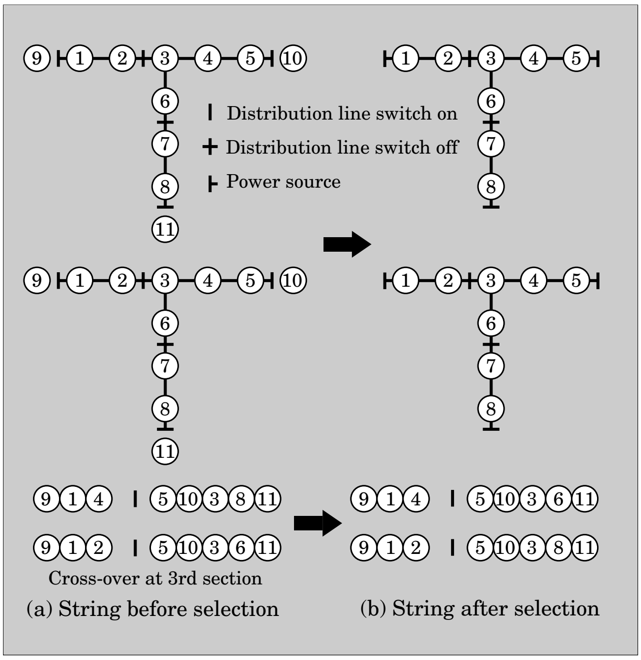
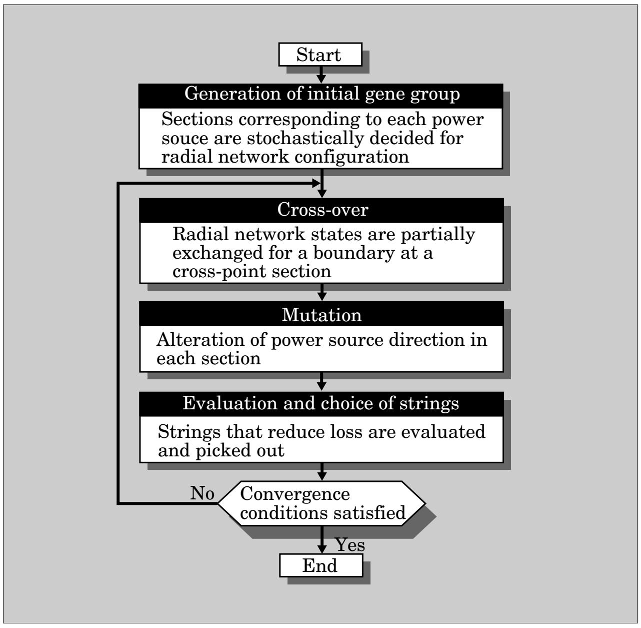


Fig.6 System processing flow



4.2 Summary of function

"Annual average load" data reflects the year's load conditions and is derived from the "Third Wednesday's actual results" data that is stored in the distribution automation system. Based on this data, optimum selection calculation occurs when all loop disconnecting points in one substation move freely (on-off distribution line switches). The system with the least amount of loss at that time is chosen as the optimum system for the year. Every remote controlled distribution line switch in the system is treated as an object for manipulation.

Fig.7 Reference diagram of data processing

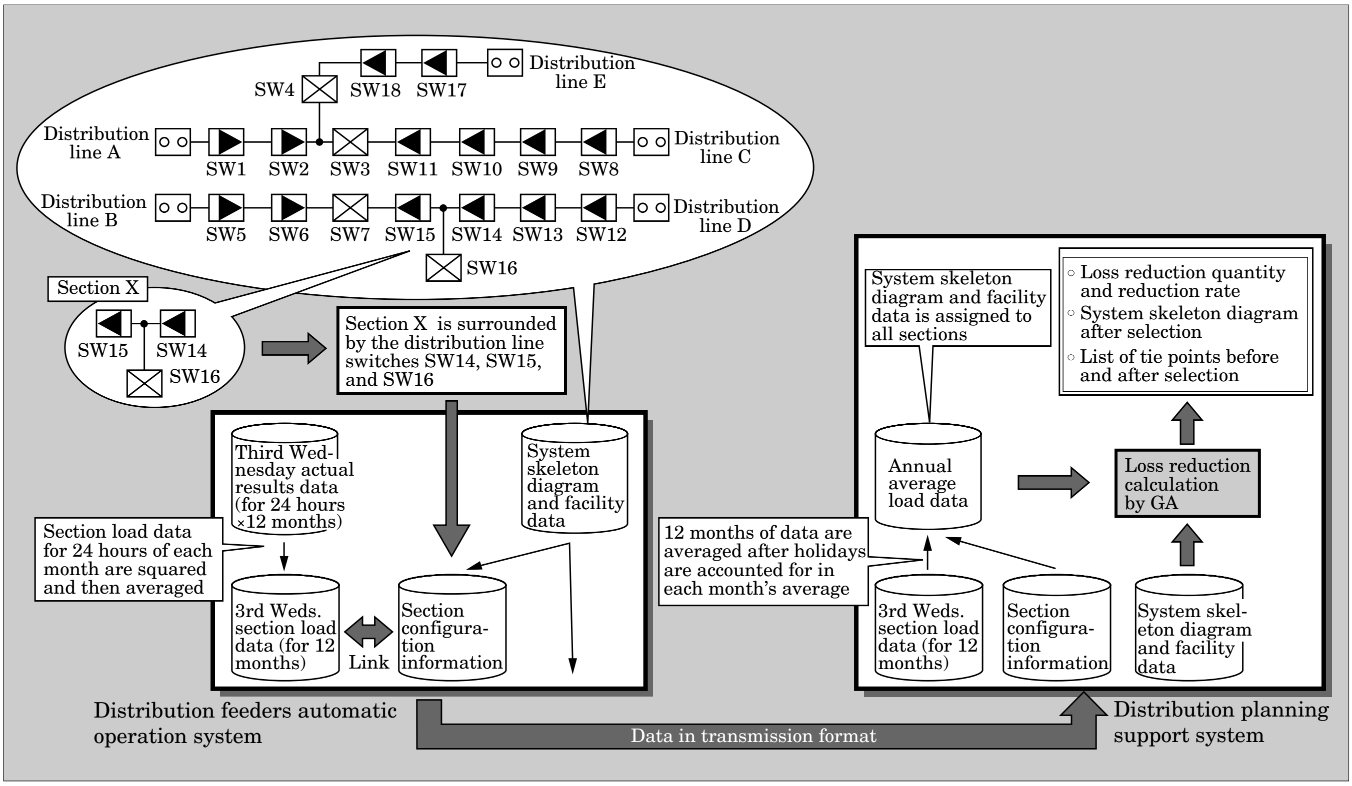


Table 2 Summary of facilities in business office for loss reduction computation

Type	Name of business office	Number of substations	Number of feeders
City	A	16	342
	B	14	211
Country	C	13	132
	D	7	55

Table 3 Effects of loss reduction (per 1 substation)

Type	Name of business office	Annual loss before selection (MWH)	Annual loss after selection (MWH)	Annual loss reduction quantity (MWH)	Loss reduction rate (%)
City	A	767.9	702.8	65.1	9.0
	B	749.3	707.0	42.3	6.5
Country	C	1,389.4	1,284.3	105.1	8.6
	D	630.7	576.1	54.5	7.5

4.3 Loss reduction using genetic algorithm

4.3.1 Genetic algorithm

The process of optimization by the genetic algorithm (GA) is shown in Fig. 3. First, GA expresses the problem through genes using heredity analogy. For example, in Fig. 3 it is expressed with binary numbers and the multiple of such genes are generated. It diversifies the genes by applying genetic operators such as a cross-over (partial exchange between a paired set of genes) and a mutation (alternation of gene information). Ultimately, only genes which adapt themselves to the problem are left for the next generation (evaluation and selection). By repeating the application of genetic operators and generation alternation, suitable genes for the problem are sought. The optimizing process for the combinatorial optimum problem is achieved in this way.

4.3.2 Loss reduction using GA

(1) Expression of genes

As for loss reduction of the distribution system, radial network configuration, which is a feature of distribution systems, must be first expressed with genes. The gene expression is shown in Fig. 4. When the binary system is used, each on-off condition of the distribution line switches can be expressed with 0 and/or 1.

However, in the case of mutation, a new radial network is generated with this expression by turning off one on-state distribution line switch after configuring a loop system by turning on one off-state distribution line switch. At this time, the process requires prolonged machine time which includes a searching process. This is because selection of distribution line switches for changing the on-off state is required for the system to satisfy a radial network configuration. Therefore, in the developed system, the power source section number of each section expressed with decimal numbers is used as shown in Fig. 4. With this expression, mutation can be simplified because alteration of only one section of the power source direction is carried out. It then handles only the connection section information of the section.

(2) Generation of initial gene population

Initial genes for each section, which supplies electricity from each power source, are decided stochastically for radial network configuration. Multiples of such genes are generated.

(3) Genetic operator

Next, genetic operators (cross-over and mutation) are applied to these genes. Cross-over (partial exchange between paired sets of genes) means a partial exchange of the system configuration because the system configuration is expressed by the genes themselves. Figure 5 shows a simple example of cross-over. The figure illustrates that when cross-over is applied to the genes strings, which express the left two systems, it divides into paired sets at the third section. From the figure, it is understood that the system is partly exchanged.

Mutation (alteration of gene information) means alteration in the power source direction of a certain section. This is because each gene's information denotes the power source direction of the section. As for the upper system after the cross-over shown in Fig. 5, the loads of ②, ③, ⑦ and ⑧ can be altered. As for the load of ②, for example, the present power source direction is ①, but alteration to ③ is possible. In other words, system configuration (on-off state of distribution line switches) can be variously altered by these genetic operators.

(4) Evaluation and selection of genes

Finally, among modified genes, only those which can reduce loss are left for the next generation. By repeating the alteration of system configuration with the genetic operators and repeating the alteration of system configuration with the genetic operators and the generation alternation by leaving only the genes that reduce loss, the solution for reducing loss can be found.

The above-mentioned algorithm is shown in Fig. 6.

4.4 Related matters on processing

The following are matters relating to this function on the start-up of display screens and documents and on data processing.

(1) Matters relating to start-up of display screens and documents

This function is executed for the specified substation on the "Year menu" screen. As a result, loss before selection, loss after selection, loss reduction quantity and loss reduction rate are displayed to every substation on the "Selection result for minimum loss" screen. The sections concerned with selection are also displayed with the mapping method in different colors on the "Distribution line diagram after selection" screen. Furthermore, conditions of the transferred loop disconnection points are printed out as a "List of tie points before and after selection" (document).

(2) Matters relating to data processing

This function handles "3rd Weds. average section load" data as input information. This is drawn from the "System skeleton diagram and facilities" data and "This Wednesday actual results" data stored in the distribution automation system.

Figure 7 shows the related data processing matters of this function.

5. Verification of Loss Reduction Effects

The effects of this function were verified by joint research.

Distribution systems were adopted for verification. Two distribution systems each were selected from business offices in the city and in the country.

An outline of the facilities with verified distribution systems inside business offices is shown in Table 2. The verification results are shown in Table 3.

In Table 3, an annual loss reduction of 69 MWH/year on average for four business offices was achieved for one substation. Loss reduction for two business offices averaged 54.5 MWH/year in the city and 87.4 MWH/year in the country.

6. Conclusion

Practical use of the "Distribution planning support system" introduced in this paper can lead to total cost down, namely realization of efficient planning procedures, avoidance of new equipment installation, and reduction total of generation by loss reduction.

In the future work, a function to generate construction plans for newly installed load will be added based on the practical user needs of actual distribution planning operators in the joint project. It can lead to addition cost down effect by the system.

In addition, practical application of the developed package for realization of advanced operation will be considered such as correction of imbalance of three phases.

Distribution Automation System for Tohoku Electric Power Co., Inc.

Manabu Sekizawa
Yukihiro Okayama
Yasuhisa Kanazawa

1. Introduction

Fuji Electric has been supplying distribution automation systems for large cities to the metropolitan business offices (of cities holding prefectural seats or the equivalent) since 1992, corresponding to the distribution automation systems promoted by Tohoku Electric Power Co., Inc. Fuji Electric has also been delivering smaller and lower priced distribution automation systems for mid-size cities to the business offices of smaller cities. In addition, Fuji Electric has been delivering simplified consoles since 1996 to small-scale business offices adjacent to large- or mid-sized city business offices. The client-server type distribution automation systems for wide areas (hereafter referred to as C/S type distribution automation systems for wide areas) are constructed from simplified consoles as the clients and the existing distribution automation system for large- or mid-sized city business offices as the server.

The C/S type distribution automation system enables backup operation from the system on the server-side by network interconnection between each business office when operators are absent from the business office on the client-side at night or during holidays. In addition, it is possible to restore a wide service interruption fault that extends over multiple business offices.

Functions and features of the C/S type distribution automation system are described below.

2. System Overview

A list of system functions, configuration of the system, appearance of the server system (distribution automation systems for mid-sized cities) and appearance of the client system are shown in Table 1, Fig. 1, Fig. 2, and Fig. 3 respectively.

In this system, each adjacent business office is interconnected via routers using 48 kbit/s optical duplex cables. If independent systems are constructed for each business office, each business office must provide individual main computers and their own telecontrollers that communicate with the feeder ter-

Fig.1 System configuration of C/S type distribution automation system for wide area

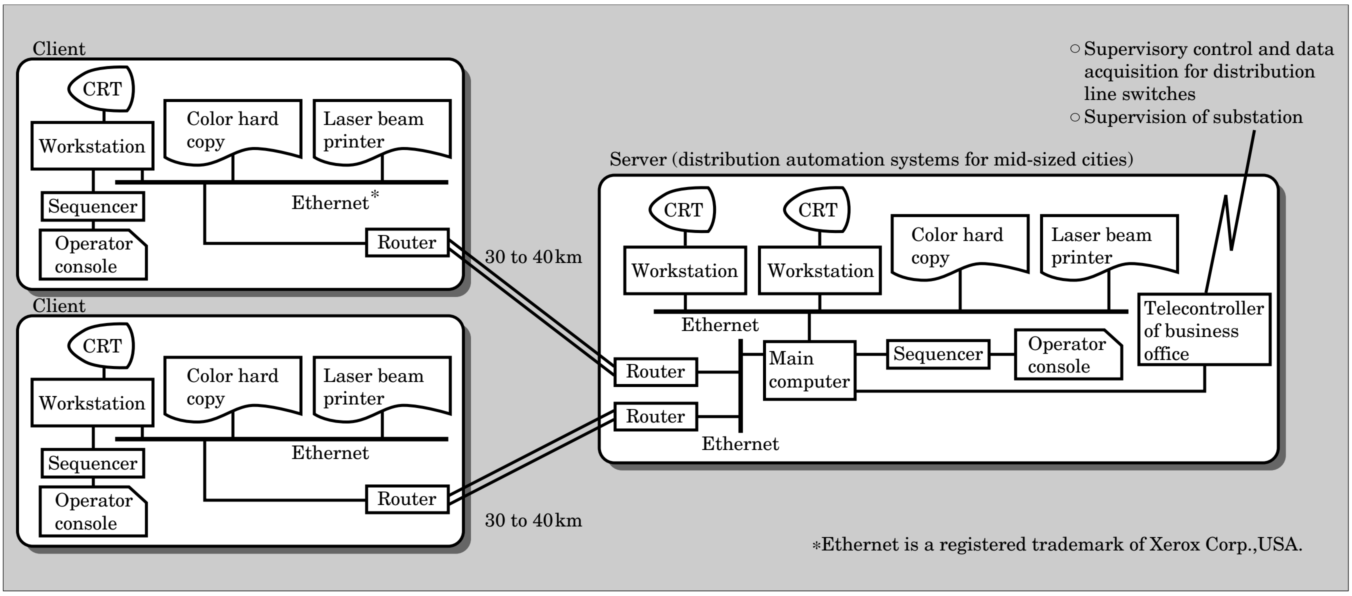


Table 1 List of system functions

Function	Description	Server		Client
		Large city	Mid-sized city	
Remote supervisory control and data acquisition function for feeder (terminal unit, switches, line data)	Supervisory control and data acquisition for terminal units (on/off/lock/ release of lock for switches, etc.)	○	○	○
	Revision of terminal unit functions (TYS, TL, X time delay, etc.)	○	○	○
	Measuring of voltage, current and phase difference of feeder, etc.	○	○	○
Remote supervisory control and data acquisition function for substation (substation data)	Supervising for on/off of secondary CB, 6kV FCB, etc. in bank	○	○	○
	Supervising for information of line-to-ground fault and short circuit (DG, 64B, OC, etc.)	○	○	○
	Manual and automatic control of 43A relays	○	○	○
	Measuring of bank voltage and current, feeder current	○	○	○
System automatic operation function	Detection of fault section of distribution system and load accommodation operation	○	△*1	△*5
	Overload avoidance operation	○	△*1	△*5
	Suspension operation for scheduled outage	○	△*1	△*5
Display function of distribution diagrams, etc.	Display of geographical map and distribution system diagram	○	△*2	△*2
	Display of substation skeleton and SV, TM data	○	○	○
Control documents preparation function	Recording of operation data (incl. high voltage faults original sheet)	○	○	○
	Recording of system operation (incl. switch operation instruction sheet)	○	○	○
	Data for system control (record of feeder daily load, etc.)	○	○	○
	Data for facility control (list of customer data for every feeder, etc.)	○	○	○
Simulation function	Simulation of automatic load accommodation at fault of feeder	○	○	○
	Simulation of training for feeder maintenance	○	○	○
Maintenance function	Maintenance of geographical map and distribution system diagram	○	△*2	△*6
	Maintenance of substation skeleton and facility data	○	△*3	△*6
Information service function	Information of service interruption of feeder (incl. street name and customer data)	○	—*4	—*4
	Information of outage scheduler (incl. street name and customer data)	○	—	—
Automatic maintenance and control function for system	Automatic supervision of TC, terminal units, distribution line switches and transmission path, etc. (retry supervisory function, etc.)	○	○	○
Sound alarm function	Announcement of fault occurrence	○	—	—
	Alarm function by sound (bell, buzzer chime)	○	○	○
Time setting function	Setting function for system control time	○	○	○
Display function on large size screen	Display function of system operating state on large size screen	○	—	—

*1: Automatic accommodation by simplified computation (computation based on existing system and section database)
*2: Distribution system diagram only
*3: Minimum required facility data for load accommodation operation, etc. (number of items, kW, etc. of each section)
*4: Function's interconnected with existing information service system
*5: In accordance with server function
*6: Performed by server-side system

minal units. On the other hand, if a client-server system is constructed, a compact and low cost system can be realized by sharing the main computers and telecontrollers in each business office, and providing only one workstation at the client-side. In addition, since the main computers of the client-server system process tasks on the client-side, tasks on the client-side can be performed with the same functions as the server.

In this system, each workstation forms a distributed system. In order to interconnect each system mutually, the communication between each system and the equalization of databases was formerly processed by application programs for each system. However, this system enables all application software at the server and the client to be processed without having to recognize the allocation of other application programs and databases to specific workstations. This is realized through utilization of Fuji Electric's standard software packages, "Distributed DF-ROSE" (distributed middleware that controls activation of application software in a distributed environment) and

Fig.2 Appearance of server (distribution automation system for mid-size city)

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Fig.3 Appearance of client system

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"Distributed P-FILE" (that equalizes databases in a distributed environment). In this system, with the same development as the addition of only a single console, interconnection between business offices can be realized in which supervisory control and data acquisition of an adjacent business office is possible.

A block diagram of distribution for this system is shown in Fig. 4.

3. Operational Control

This system is applied to operating systems in which backup for the client-side business office is performed by the business office of the server. Facility data of both the server and the client business offices is controlled by the server-side system, and the client-side system controls only the facility data of the client-side business office. Therefore, the distribution systems both of the server and the client business office can be supervised and controlled by the server; only the client-side distribution system can be supervised and controlled by the client.

Control of the feeder terminal units within the business office area of the client-side is performed in accordance with the "control right". When preparing to restore service, if the control right is reserved by the client-side, the restoration procedure is prepared for

Fig.4 Block diagram of distribution

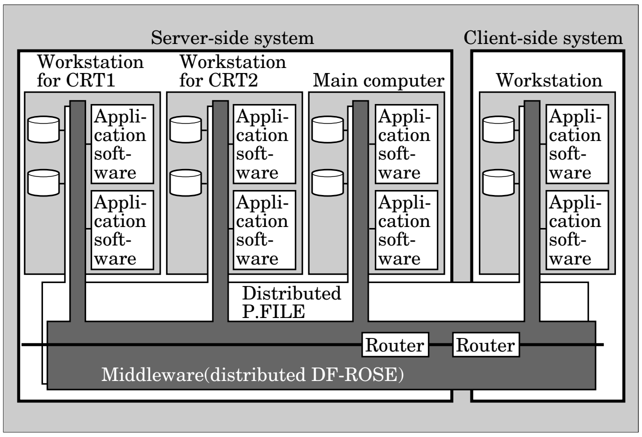


Fig.5 Switch over of operation based on control right

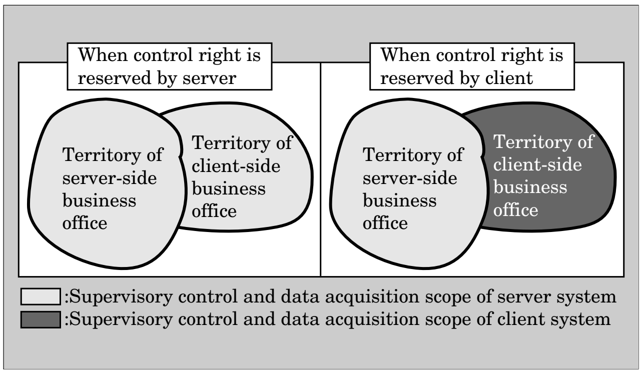
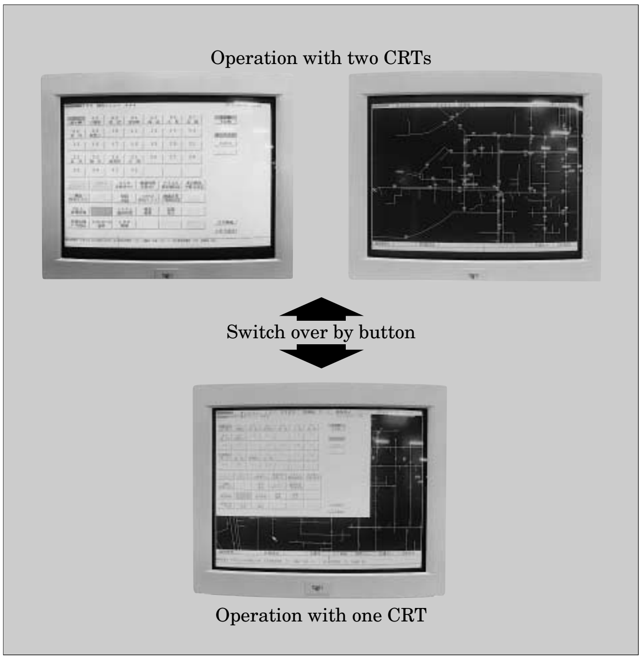


Fig.6 Switch over of CRT display



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each area separately, that is the server-side system prepares for the server-side business office area and the client-side system prepares for the client-side business office area. If the control right is reserved by the server-side, the restoration procedure is prepared for both the server and client areas by the server-side. An image of operation switching based on the control right is shown in Fig. 5.

4. Operation

The screen display of this system is performed by a multi-window method in which multiple screens are superimposed and displayed on one CRT, enabling the simultaneous observation of multiple screens and improved visibility. Since operation buttons on the console are displayed on the screen, with the exception of the minimum required buttons such as a control execution button which remain on the console, most operations can be performed by only a click of the mouse. A mapping display is used to display the distribution system diagram. Displayed in a true reduced scale and corresponding to the geographical map, the distribution system diagram enables supervision of the system charging and service interrupting states and control of the distribution line switches by clicking on switch symbols in the distribution system diagram.

By pressing a single button, display of the distribution system diagram, procedure manual and substation skeleton diagram of the server-side system can be switched to either a mode in which the displays are superposed on one CRT screen or to a mode in which each display is shown on separate CRTs. With this system, in the normal state, the distribution system diagram, procedure manual and substation skeleton diagram are displayed on separate CRTs and operation is performed by a single operator; during a fault state, the distribution system diagram, procedure manual and substation skeleton diagram are displayed on a single CRT and separate operations are performed by two operators. A superimposed display on one CRT is provided at the client-side to save space. The display is shown in Fig. 6.

5. Simulation Functions

This system is capable of performing the following simulations for an actual distribution system.

(1) Fault simulation in which a simulated fault occurs
(2) Maintenance simulation in which simulated maintenance for the facility is performed
(3) Outage scheduling simulation in which simulated outage scheduling is performed

The operators can simulate various cases by combining these simulation functions. For example they can maintain a system in which installation of more facilities is scheduled, simulate the occurrence of a fault in the system, and prepare the scheduled outage procedure and maintain the outage schedule during the addition of distribution line switches as if in an actual system revision. The data used for the simulations such as the distribution line current, load and bank voltages can be selected by the operators as described below. Operator training and the verification of operation results in consideration of load fluctuations according to the seasons or time changes such as day and night are possible.

(1) Copy data in an actual system, and use.
(2) Multiply data in an actual system by a ratio instructed by the operators, and use.
(3) Use the individual data set by the operators.

6. Conclusion

The wide area C/S type distribution automation system for Tohoku Electric Power Co., Inc. described here is a system that interconnects up to two clients per server. Striving for functional advancement of wide area interconnections and interconnected systems that enable mutual backup by application of this system, Fuji Electric will continue to develop technology to improve electric power supply reliability, improve operational efficiency and conserve energy.

The authors extend their heartfelt thanks to the related individuals from whom we received much guidance and cooperation in the development of this system.

Distribution Load Monitoring and Control System for Tohoku Electric Power Co., Inc.

Yoshiaki Hashiura
Yoshikuni Kobayashi
Yasuji Shimizu

1. Introduction

Electric power companies have recently been increasing their operating efficiency by automating meter reading and voltage or current measuring, lowering total costs by controlling equipment investment through the introduction of demand side management and controlling the transformer load, and maintaining the power quality in response to an increase of distributed power sources and harmonics generating devices.

Under these conditions, Tohoku Electric Power Co., Inc. and Fuji Electric have collaborated with 3 other manufactures to develop and field test a load monitoring and control system for a distribution system which automatically and remotely controls metering, supervisory control, data acquisition, and the measurement of individual customer load conditions (watt-hour, power quality and equipment condition).

This paper will present a summary of the developed system.

Fig.1 Configuration of load monitoring and control for a distribution system

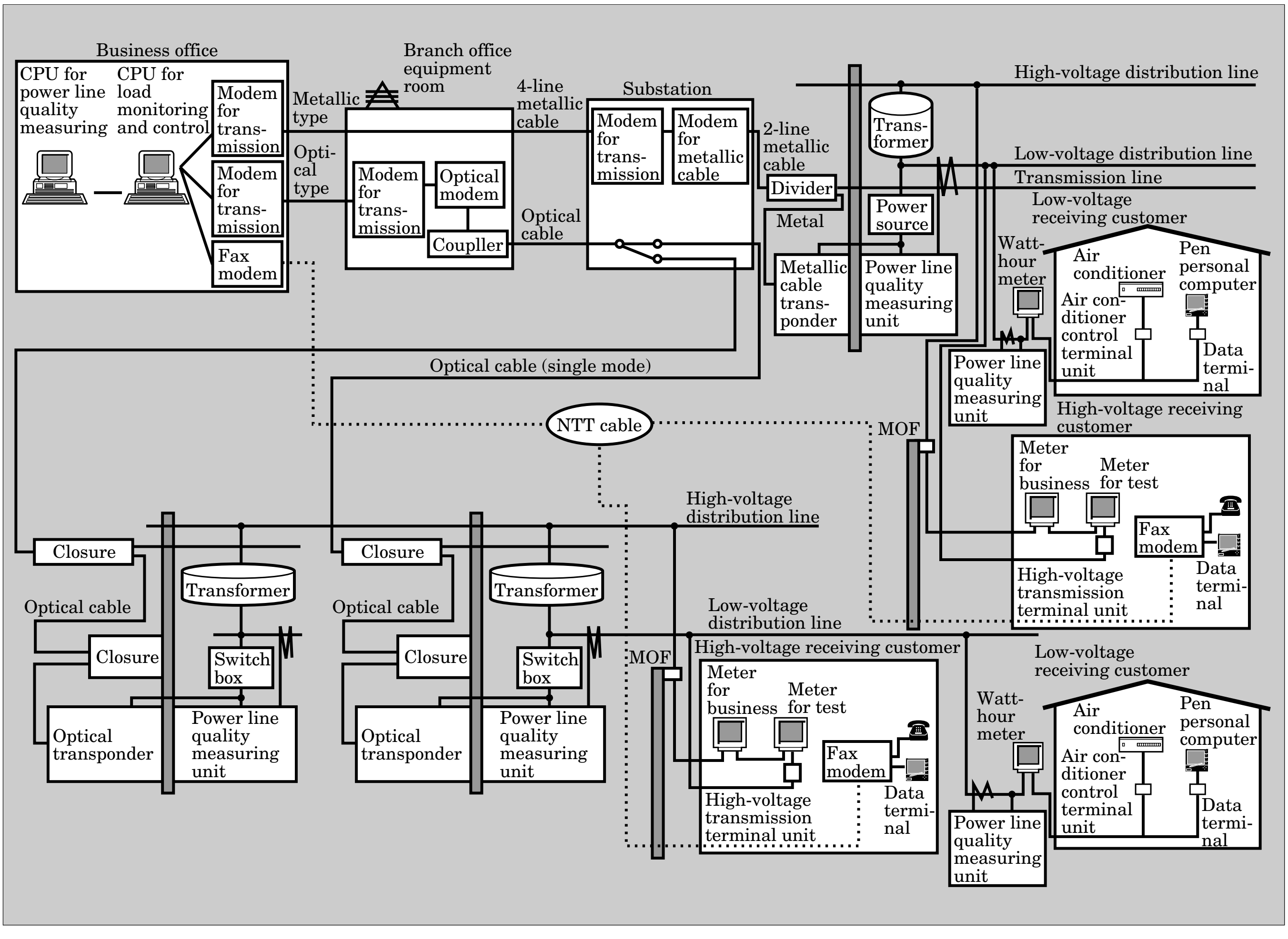


Table 1 Transmission specifications

Type / Parameter	Optical transmission	Metallic transmission
Cable	Single mode optical fiber cable	2-line metallic cable
Standard	—	Conforms to ITU-T V.23
Transmission speed	9,600 bit/sec	1,200 bit/sec
Frequency	—	1,700Hz±400Hz
Modulation method	Base band	FSK
Transmission level	– 6 to – 2dBm	0dBm±2dB
Receiving level	– 14 to – 40dBm	0 to – 30dBm
Input impedance	—	10kΩ or more
Output impedance	—	600Ω±20%
Transmission code	JIS 7 unit code	JIS 7 unit code
Error inspection	Horizontal and vertical parity	Horizontal and vertical parity
Transmission procedure	Polling method	Polling method

Table 2 System functions

Parameter	Function
Customer information	○ Display, registration and deletion of information for low-voltage customer ○ Display, registration and deletion of information for high-voltage customer
Time correcting	○ Time scheduling of head office ○ Time correction to every device
Meter reading by request	○ Reading present value of meter (low-voltage, high-voltage) ○ Reading a predetermined value of meter (high-voltage)
Monthly metering	○ Maintenance for monthly metering (low-voltage) ○ Setting and maintenance of determing date (high-voltage) ○ Automatic monthly metering ○ Metering result display
Load survey	○ Collection of road survey data ○ Data accumulation and graph display
Collection of power quality data	○ Collection of status data (service interruptions, voltage failures, etc.) ○ Collection of measuring data (line voltage, usage rate, harmonics, etc.)
Transmission to information terminal unit	○ Notification of monthly kWh ○ Notification from Tohoku Electric Power Company ○ E-mail exchange (transmission, reception)
Load control	○ Air conditioner
Inspection of transmission reliability	○ Collection of receiving rate

2. Summary of the Load Monitoring and Control System for a Distribution System

2.1 Configuration of the load monitoring and control for a distribution system

Figure 1 shows the system configuration.

A master data exchanger and modem are installed

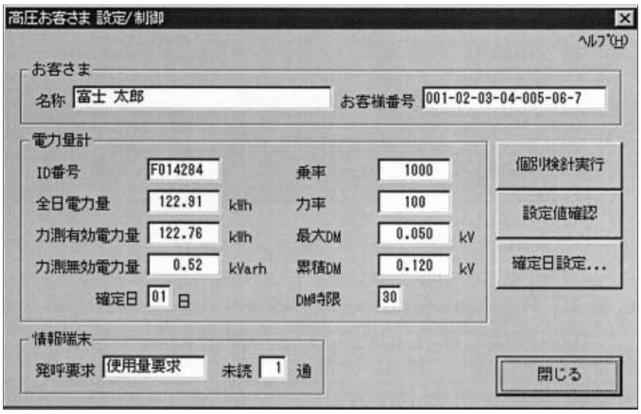


Fig.2 Example of CPU display for load management and control

in the business office, and individual devices are supervised and controlled from the office. Devices for conversion of signal transmission media, address management of terminal units, a transponder for collecting the local data of each unit, and power line quality measuring units for measuring the line voltage and utilizing rate of transformer are mounted on an electric pole. A low-voltage watt-hour meter that is built into a low-voltage power line carrier, a high-voltage watt-hour meter, a high-voltage transmission terminal unit, and a power line quality measuring unit for detecting leakage current are installed on the outside wall of a customer's office. A low- and high-voltage information terminal unit that displays power supply information and exchanges mail, and a control unit for turning an air conditioner on or off are installed inside of the customer's office.

2.2 Transmission line

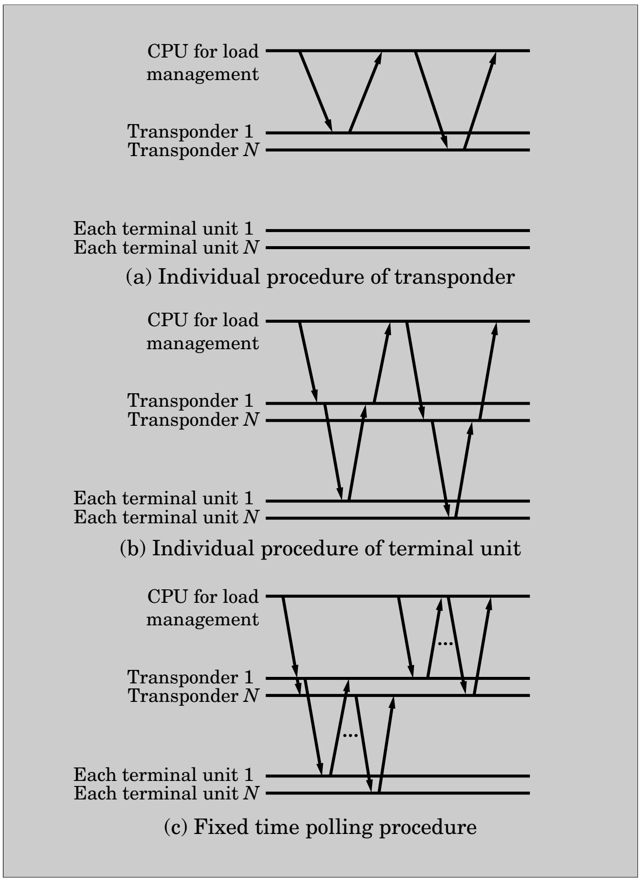
As transmission media, metallic pair cables (personal communication line) or optical cables are used to connect the business office to an electric pole, and a low-voltage power line carrier is used to connect each unit to the electric pole. In the metallic cable method, 4-lines of metallic pair cables are connected from the business office through a transmission modem to a substation; and an unoccupied cable (1 pair of the 5-pairs of metallic cables for the automated distribution system) is used to connect the substation to the transponder. In the optical cable method, an unoccupied optical cable (2 cores) for PHS (personal handy-phone system) is used, and a telecommunication line is utilized to provide information to high-voltage customers.

Specifications of each transmission line are shown in Table 1.

3. System Functions

The system configured with a personal computer, registers and maintains a customer's database and transfers data (data acquisition, setting, control and

Fig.3 Transmission procedure



information exchange).

Table 2 and Fig. 2 show the system functions and a display example, respectively. Automatic meter reading of the low- and high-voltage watt-hour meter has two functions, manual acquisition of each present value of the watt-hour meter, and automatic acquisition of monthly metering according to the metering schedule. The system also has a load survey function that acquires information of the consumed power every 30 minutes with the metering function of the high-voltage watt-hour meter. Other telecommunication functions with the power line quality measuring unit include the acquisition of status data such as service interruption information and measurement data such as line voltages.

Notice of consumed power, information from the power company, e-mail communication and information from the master can be indicated on the customer's display.

4. Transmission Specifications

4.1 Telegram

Telegrams are composed of a control section and an information section. The control section is an instruction code indicating the telegram item, and the address of the desired transponder. The information section is of variable length. In the case of an upward-telegram, an instruction is appended to the address of the desired terminal for transmission. In the case of a downward-telegram, a reply is appended. The address for both the transponder and each terminal unit is a unique 12-digit number, consisting of the manufacturer, manufacturing date, number and model. All asterisk marks ("*") indicate simultaneous addresses.

Fig.4 Transponder for metallic cable

4.2 Transmission procedures

Communication with each unit was performed with the following three transmission procedures.

(1) Individual procedure corresponding to transponder

Individual data for each transponder is transmitted through a metallic pair or an optical cable. The telegram utilized in this procedure is a registered telegram of the controlled terminal address for the transponder.

(2) Individual procedure corresponding to terminal unit

Individual data is transmitted through metallic pair or optical cables and a low-voltage power line carrier. The telegram utilized in this procedure includes a request to read the watt-hour meter.

(3) Monthly polling procedure

This procedure transmits an all-at-once instruction to each transponder. After collecting local data from the low-voltage power line carrier to the transponder, data is collected from the telecontrol master. The transponder selects and extracts the desired address of devices from the stored terminal addresses of the procedure used for monthly metering of the watt-hour meter.

These transmission procedures are shown in Fig. 3.

5. Field Test

5.1 Mounted units

Developed units have been mounted on-site and tested. The optical cable route of the main line consists of 2 routes and 2 transponders. The metallic pair cable route of the main line consists of 2 routes and 3 transponders. Mounted below each transponder are 26 terminal units, and in another route, 2 high-voltage information terminal units are connected directly by a telephone cable. As an example of a field device, Fig. 4 shows a mounted transponder for metallic pair cable.

5.2 Results

Using the monthly polling procedure, reliability was confirmed each hour by transmission. The total reliability was also collected for each terminal network control unit. An hourly and monthly receiving rate of approximately 100% has been maintained over a testing period of approximately one-year. With consideration of error control operations such as retry, it has been confirmed that there will be no problem with the implementation of data transmission. It has also been confirmed that there are no problems preventing the practical application of functions such as metering, supervision, control and measuring for each unit.

6. Conclusion

As the result of this research, operation of each unit has been confirmed, and data transmission technology that combines a low-voltage power line carrier and an optical or metallic pair cable has been verified. In the future, we will attempt to make the system more complete for practical application by extending main load monitoring and control system functions (such as data transmission via a "linked transmission system" that is connected with a metallic pair cable and a high-voltage power line carrier) for distribution systems.

The authors would like to express their appreciation for all the cooperation and guidance received in the development of this system.

Distribution Automation System for The Okinawa Electric Power Co., Inc.

Hideaki Kawamitsu
Masaru Yoshida
Susumu Sato

1. Introduction

The Okinawa Electric Power Co., Inc. and Fuji Electric have been promoting the review of specifications and functions of distribution automation systems, to rapidly restore faults and further improve efficiency of distribution management. In this case, partial operation was started of a remote control system whose main function was remote control of distribution line switches.

This system uses two UNIX*1 workstations and has an open distributed configuration that connects the peripheral devices with a standard LAN. This configuration is highly expansible and reliable.

A summary of the system is introduced in this paper.

2. System configuration

The overall configuration and information flow of the distribution automation system in The Okinawa Electric Power Co., Inc. are shown in Fig.1 and the distribution automation system installed in the branch office is shown in Fig. 2.

*1 UNIX : A registered trade mark in the USA and other countries and is licensed by X/Open Company Ltd.

Fig.1 Configuration of the distribution automation system

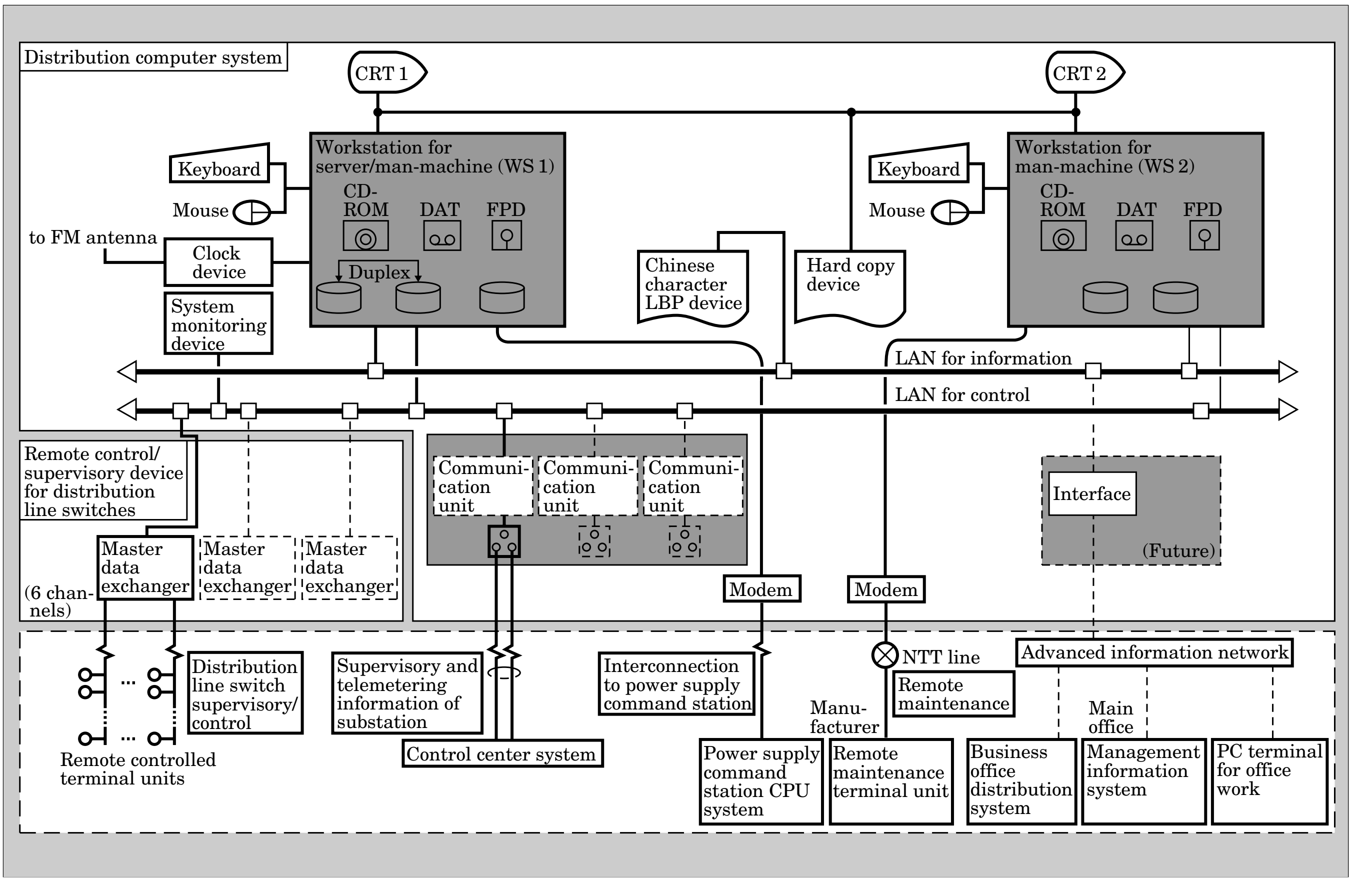


Fig.2 Appearance of the distribution automation system

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Table 1 List of system functions

Function	Remote control	Automatic control
System management function	○	○
CRT display function	○	○
SV information monitoring function	○	○
Numerical information monitoring function	○	○
Manual setting function	○	
Line switch remote operation function	○	
Outage scheduler function		○
FDIR (fault detection, isolation, and restoration) function		○
Simplified remote procedure operation function		○
Overload releasing operation function		○
Load management calculation function		○
Grounding point mark/display function		○
Measuring load data storing function		○
Monitoring result recording and report generation function	○	
Facility data report generation function		○
Measuring load report generation function		○
Facility data maintenance function	○	
Simulation function		○
Power supply system interconnection function		○
Remote maintenance function	○	
Master data exchanger function	○	
Control center IF device function		○

<Note> For functions having ○ in both the remote and automatic control columns, a part of the function is mounted on the remote control system.

2.1 Computer system configuration

This system is configured from the core devices of workstation 1 (WS 1) which performs server processing and man-machine processing (CRT 1) during normal operation, and workstation 2 (WS 2) which performs man-machine processing (CRT 2) during normal operation and back-up operation when WS 1 is stopped. The system also contains the following devices, connected via a LAN: master data exchanger DX devices 1 to 3 that communicate with feeder terminal units, communication interface devices 1 to 3 that receive supervisory and telemetering information through the control center from the substations, a laser beam printer, etc.

The LAN is divided into a LAN for information and a LAN for control. The LAN employs the widely utilized Ethernet[*2]. Therefore, it has become possible to interconnect with other systems and participate in an advanced information network easily and at low cost.

2.2 System development method

The system has been developed as divided into a remote control system whose main task is to remotely operate distribution line switches, and an automatic control system that largely manages tasks such as the service restoration function and outage scheduler function. In this case, partial operation with the remote system was started. Table 1 lists the system functions of remote and automatic control systems.

3. Special system functions

A summary of the special system functions is described below.

3.1 System management

(1) Simultaneous parallel operation

Two desks (1 CRT/desk) are used in the system. These desks are simultaneously operated in parallel to fully utilize the merits of a distributed system, and to enable effective and efficient usage when feeder faults occur frequently due to a storm or other cause, or when jobs are piled up by many maintenance cases. Examples of simultaneous parallel operation are listed below.

(a) When feeder faults occur frequently due to a storm or other cause:
By displaying separate fault case names in the right and left desks, the faults can be independently processed.

(b) When jobs are piled up:
By releasing the restriction of limiting the on-line function only to one desk, two operators can independently process separate jobs on the right and left desks.

Table 2 shows the modes of the system.

(2) Back-up operation

In conventional centralized systems, it was common to configure a dual or duplex system or to separately provide a back-up system not used in normal operation as countermeasures to prevent stop-

*2 Ethernet : A registered trade mark of Xerox Corp., USA.

Table 2 Modes of the system

CRT 2 / CRT 1	On-line	Mainte-nance	Outage sched-uler	Opera-tion train-ing	Tempo-rary opera-tion	Stop
On-line	○	○	○	○	○	○
Maintenance	○	○*1	○	○	○	○
Outage scheduler	○	○	○*2	○	○	○
Operation training	○	○	○	○	○	○
Temporary operation	○	○	○	○	○	○
Stop	□	○*3	○*3	○*3	○*3	○

○: Changeover possible, □: Back-up operation

*1: For the same case names, the maintenance function is restricted to make simultaneous operation impossible. When an overlapping part with separate case names is changed, an error will be detected during data verification.

*2: For the same case names, the outage scheduler function is restricted to make simultaneous operation impossible.

*3: When changing between normal and back-up operations, the contents during operation are destroyed, and the mode becomes on-line operation. It is possible to set the operation mode again.

page of the mini-computer during maintenance or due to a fault. However, in this system, a back-up supervisory control and data acquisition function for man-machine processing is mounted on the WS2, which is normally used only as CRT2. Therefore, the system is able to continuously operate by automatic changeover when the server stops.

With this configuration, operation of the distribution system can be continued in the normal manner if the server function should stop. As shown in Table 2, even during a back-up operation, tasks other than on-line operation can be performed in the same manner as during normal operation.

3.2 Man-machine

(1) Display of distribution system skeleton

The distribution system display is usually a mapping system that displays on a geographical map, or a skeleton system that indicates the connection status. Taking into account the geographical understanding and visualization of the connection, a simplified mapping system has been adopted. This simplified mapping system displays the distribution system skeleton (a 1-page layout drawing describing all distribution lines covered by a branch office) on the screen in the same format as that currently used at The Okinawa Electric Power Co., Inc. An example of the display by the simplified mapping system is shown in Fig. 3. Its main features are listed below.

(a) The display ranges can be changed over 3 stages: total, medium and detailed ranges.

(b) The connection status and service range of the system can be viewed at a glance by color display (total 12 colors) at every distribution line. Further, when stopped due to a fault, the display flashes in black to notify the operator.

(c) Smooth scrolling over the total range by mouse operation is possible when displaying the medium or detailed ranges. Therefore, conventional operations such as "display capture" are unnecessary.

(d) A "jump-to" display function can instantaneously display the desired screen by specifying a place such as a substation.

(2) Multi-window display

In recent computer systems, screen display functions such as multi-window display have rapidly improved compared with conventional mini-computer systems. In this system, the multi-window function is applied to improve operability and visualization. Because of the specific uses of supervisory control and data acquisition, the display specification specifies restrictions to eliminate screen overlapping. This facilitates screen operation (position and size of the

Fig.3 Example of the display by the simplified mapping system

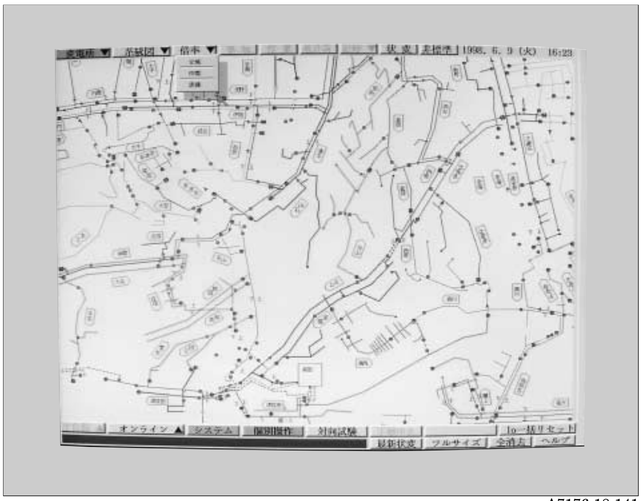

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Fig.4 Example of the multi-window display

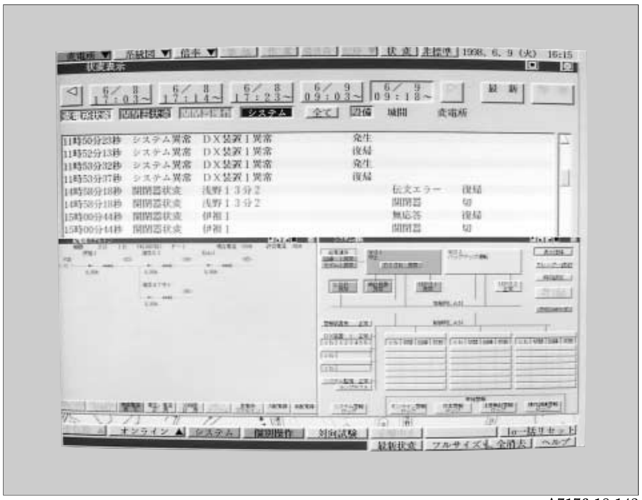

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Fig.5 Example of the distribution line skeleton display

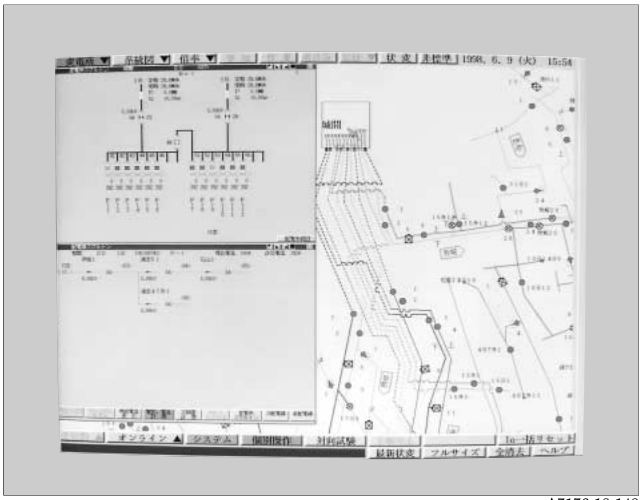

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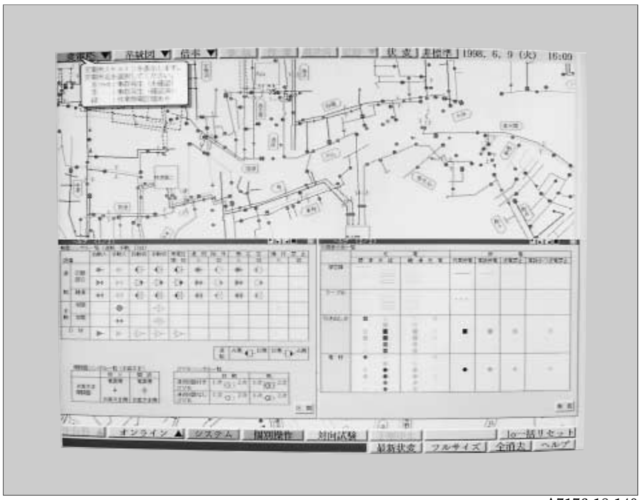
Fig.6 The operation guide and help windows



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screen are changed just by selecting buttons on the screen with the mouse). Figure 4 shows an example of multi-window display. Main features of the multi-window listed below.

(a) The most frequently used distribution skeleton is displayed always in full-size.

(b) Up to three general displays can be shown in 1/4 size, eliminating overlapping.

(c) A 1/4 size display can be changed into a full-size display.

(3) Distribution line skeleton display

The distribution line skeleton can also be displayed to estimate a line-to-ground point from the horizontal row display of the ground current at a feeder high impedance fault, and to verify the distribution line operation status from the horizontal row display of voltages, currents and X time delay values. The skeleton, automatically constructed from the distribution system data and on-line status, displays the charged range that exceeds the linked switches. An example of the distribution system skeleton is shown in Fig. 5.

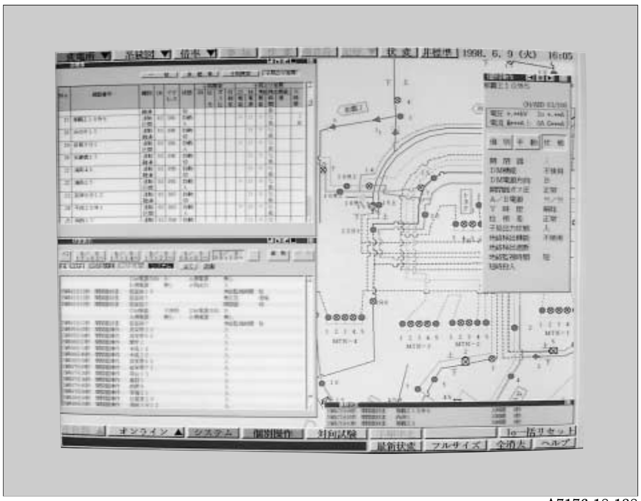
(4) Enhanced operation guide

The operation guide and help screens can be displayed to assist operation. The operation guide shows the function of the screen buttons with an exploded view as shown in Fig. 6, and is displayed by selecting a button on the screen with the right button of the mouse. A tool to edit the contents of the guide is installed to make the guide more suitable for the practical operation. The help screen shows the meanings of symbol shapes and colors for each switch, and has a section to assist in verification of the distribution system status.

(5) Display of status change

Status change information (include fault information and operation result) is stored internal to the system and is displayed on the screen. When necessary, this information can be edited, displayed and output to an LBP (laser beam printer) in a business form. Special status change information, fault information, and operation result recording printer has been eliminated.

Fig.7 The status change window and most recent status change pop-up display



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Further, the most recent three lines of the list can be displayed in a small pop-up display to assist in status verification. The status change information can be stored up to a maximum of 10,500 lines (21 pages) and is destroyed one page a time from the oldest page. Therefore, when feeder faults frequently occur due to a storm or other cause, a series of fault information cannot be destroyed before verification. Fig. 7 shows an example of the status change display and the most recent status change pop-up display.

3.3 Remote operation

(1) Verification at distribution line switch operation

In conventional systems, when remotely operating the distribution line switch, it was common to perform

Fig.8 Input window of the telecommunication information from substation

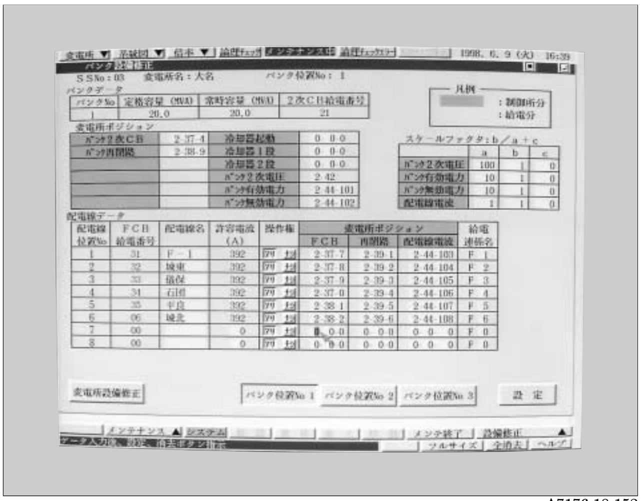

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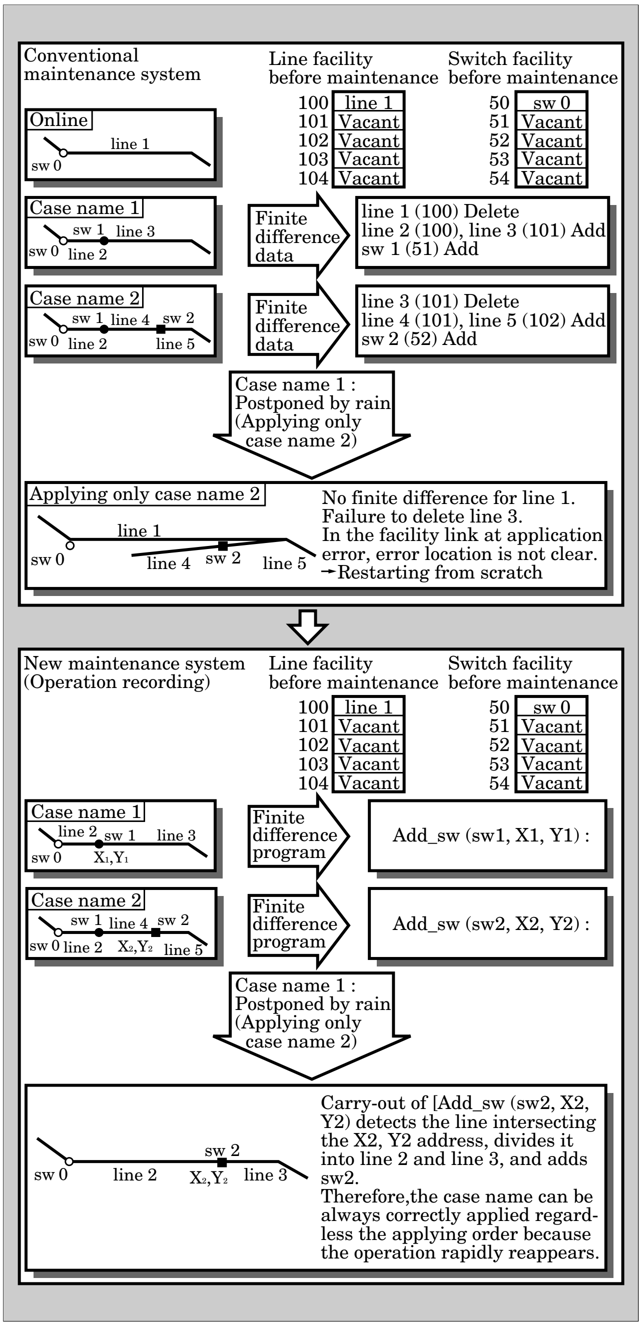
Fig.9 Outline method of the operation recording maintenance



the two actions of depressing the "execute" button or operating the control key on the console after selecting the device and operation content.

In this system, improved operability and facility of the operator console were planned with an equivalent or more reliable interlock to the previous system, and messages and an easy to read pop-up display for verification by the operator during remote operation.

(2) Summation of current flow through the distribution line switches

All of the controlled feeder terminal units have a function for measuring current flow. Utilizing this function, the system collects the measured current values of all controlled feeder terminal units over a period of 15 minutes and calculates the section loads with high accuracy.

(3) Simplified remote procedure operation

When changing the load during an emergency such as a fire, most conventional systems function such that the changeover operation can be carried out only through the steps of "case name registration → procedure establishment → procedure evaluation (temporary operation) → procedure implementation". However, in this system which gives priority to emergencies, a simplified remote procedure operation function has been utilized where the procedure can be established and implemented as extensions of individual operations. The operation method of the simplified remote procedure operation is simple; the procedure is established by selecting the distribution line switch on the power supply side of the load desired to changeover, and then directing the changeover from the pop-up display for individual operation. Because the system urges the operator to direct the implementation of each procedure, if determined to be unsuitable, the operator can stop the procedure. Changing back to the original network by switch operation is performed in the same manner as the changeover.

3.4 Facility data maintenance

(1) Maintenance of telecommunication information from a substation

In conventional systems, telecommunication information from a substation is maintained by the manufacturer. Even if the information is standardized, it is maintained by the manufacturer for non-standard substations. Therefore, the information is lacking in flexibility since the maintenance work is entrusted to the manufacturer whenever a substation is expanded or converted.

Since the substation information handled by this system is collected and reedited in the control center and then transmitted to the distribution side, all of the information of each substation is allocated to different channels and words. Therefore, information is introduced as facility data and can be maintained by the operator. With this measure, it becomes possible to flexibly correspond to expansion and conversion of the substations and to reduce commission costs to the manufacturer. Maintenance by the manufacturer is restricted only to cases of expanding hardware such as the master data exchanger. Figure 8 shows the input screen of telecommunication from a substation.

(2) Operation recording maintenance method

In conventional systems, there are finite differences in facilities for each case name. When applied to the maintenance system, future facilities may be planned based on piled up case names in a time series. However, if a case is postponed because of the weather or other cause, application of the next case name will be attempted. However, application of that case will fail because the expected line does not exist. Some cases were restarted from scratch because it was difficult to determine the location of the cause of the error.

In this system, a method has been established in which the data maintenance records the operation itself, converts it with a finite difference program and stores it. Therefore, a case name can be applied regardless of its order since operation of the case name rapidly reappears. Even if an application error occurs during a reappearing operation, it is simple to correct the error since the device or operation that caused the error is known. By adopting this system, it is possible to solve the problems of facility maintenance in system interconnections between business offices. In the past, these problems have been considered difficult to solve.

An outline of this method is shown in Fig. 9.

4. Future Plans

A remote control system was installed in the Urasoe branch office of The Okinawa Electric Power Co., Inc. in June 1998 and is currently in operation. An automatic control system is currently under development, aiming for completion by the beginning of 1999.

5. Conclusion

This paper has summarized the distribution automation system of The Okinawa Electric Power Co., Inc. Fuji Electric will attempt to develop and expand the system, aiming for further improvements in reliability, efficiency of operation and man-power savings in distribution automation systems.

The authors would like to express appreciation to the associated engineers for their guidance and cooperation.

Automatic Meter Reading Systems for Bulk Customers

Hideichi Kikuchi
Kazuhisa Murata
Fumio Takahashi

1. Introduction

Power supply contracts with bulk customers (those customers having a contracted power demand of greater than 500kW) are so complicated that metering is usually performed exclusively by employees of the electric power utility company. In addition, the improvement of metering efficiency has become a serious problem for electric utility companies because of the concentration of most metering operations on the last day of each month or on the first day of the next month. Furthermore, determining the precise load conditions of the bulk customers become more important as the difference between day and night power demands has increased. All these circumstances have increased the need for practical application of an automatic metering system for bulk customers as early as possible.

Fig.1 Basic configuration of the automatic meter reading system for bulk customers

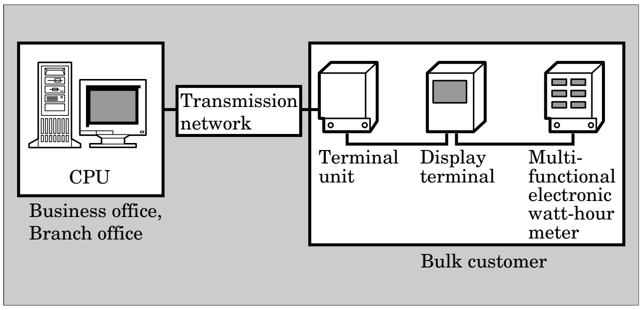


Table 1 Components of the automatic meter reading system for bulk customers

Component	Function
Central processing unit	○ Acquires and displays the indicated values measured by multifunctional meters via the transmission network and terminal units.
Terminal unit	○ Reads and sends back indicated values of the multifunctional meter according to commands from the CPU.
Display terminal	○ Processes the indicated data values measured by the multifunctional meter for each time zone and displays them. ○ Communicates with multifunctional meter and sends back measured values via the terminal unit according to commands from the higher level. ○ Stores 30 min. interval meter readings of power consumption for 44 days.
Multifunctional watt-hour meter	○ Measures the power consumption and sends back the measurement via the terminal unit according to commands from the CPU. ○ Stores 30 min. interval meter readings of power consumption for 10 days.

Therefore, in collaboration with The Tokyo Electric Power Co., Inc. and Kyushu Electric Power Co. Inc., Fuji Electric has developed and is now supplying the central network control units, terminal units, power supply display terminals (hereafter referred to as display terminals) and multifunctional electronic watt-hour meters with automatic meter reading ports (hereafter referred to as multifunctional meters) of an automatic meter reading (AMR) system.

A summary of the AMR system for bulk customers is presented below.

2. Summary of the Automatic Meter Reading Systems for Bulk Customers

2.1 Basic Configuration of the System

The basic system configuration is shown in Fig. 1 and a summary of component functions is listed in

Fig.2 External view of the multifunctional electric watt-hour meter with automatic meter reading port

A6202-16-225

Fig.3 External view of the power supply display terminal

A6202-16-226

Table 2 Overview of functions of the automatic meter reading system for bulk customers

Classification	Setting/checking item	Function
Setting/ checking command telegram to multi-functional watt-hour meter	Meter reading of predetermined value	Calls predetermined value data
	Present value meter reading	Calls present value data
	Set value check	Calls set value data
	Time/decided date change	Sets time and decided date
	Max. demand reset	Resets demand value
	30 min. interval meter reading	Calls 30 min. interval meter value
	Meter reading for 30 min. interval for 10 days	Calls 30 min. interval meter value for 10 days
Setting/ checking command telegram to display terminal	Setting/check of demand calendar	Sets/calls demand calendar
	Setting/check of time band selection pattern	Sets/calls time band selection pattern
	Meter reading for 30 min. interval for 44 days	Calls 30 min. interval meter value for 44 days

Table 3 Summary of the delivered systems

Item \ Customer	The Tokyo Electric Power Co., Inc.	Kyushu Electric Power Co., Inc.
Start of application	Since 1995	Since 1996
No. of consumers	Approx. 14,000	Approx. 2,800
Transmission line	NTT line Optical cable	Metallic pair cable Optical cable Security communication line NTT line

Fig.4 Configuration of the automatic meter reading system for bulk customers for The Tokyo Electric Power Co., Inc.

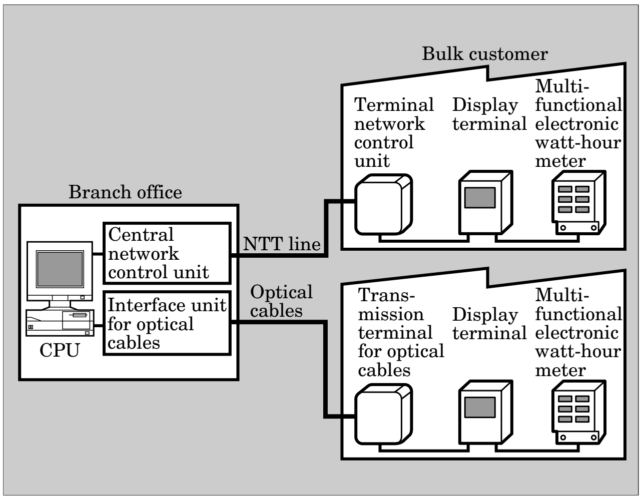


Table 4 Data transmission specifications of NTT lines

Transmission method	Half duplex
Transmission speed	1,200 bits/sec.
Synchronous method	Start-stop synchronization
Modulation method	FSK
Transmission code	JIS unit 7 code
Error detection	Horizontal/vertical parity check
Error control	Retry
Response method	Conversational with no response
Control codes	STX: Start of the text ETX: End of the text
Bit sending order	Lower order bit preceding

Table 1.

Meters are read such that computers in the business offices and branch office read the measurement values of multifunctional electronic watt-hour meters via various transmission lines as well as corresponding terminal units. A two-wire current loop bi-directional communication system, requiring fewer wire connections and physically smaller installation spaces, is utilized to interface the multifunctional electronic watt-hour meters and display terminals to the higher level system. A display terminal is installed for consumers that require measurements for each time zone. The display terminal indicates measurements for each time zone based on measurement by the multifunctional electronic watt-hour meter. An external view of the multifunctional electronic watt-hour meter is shown in Fig. 2 and an external view of the display terminal is shown in Fig. 3.

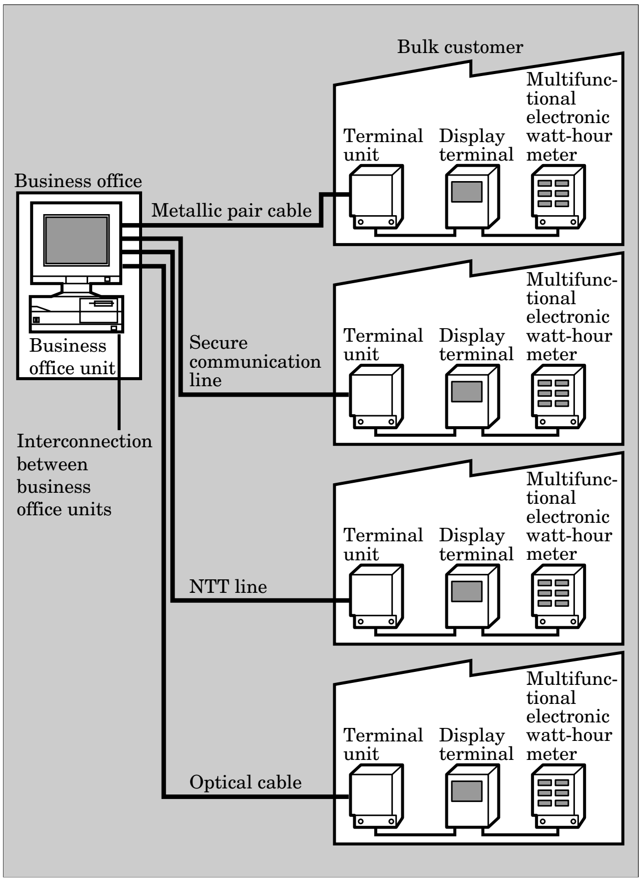
2.2 System functions

As shown in the summary of system functions (telegrams) in Table 2, in addition to functions that read predetermined meter values on a predetermined meter reading day, a 30 minute meter reading function is provided to enable the acquisition of the power consumption every 30 minutes.

Fig.5 External view of the central network control unit (TPC-NCU)

Fig.6 External view of the terminal network control unit (TP-NCU)

Fig.7 Configuration of the automatic meter reading system for bulk customers for Kyushu Electric Power Co., Inc.



3. Delivered Systems

3.1 Summary of the delivered systems

A summary of the automatic meter reading systems for bulk customers delivered to The Tokyo Electric Power Co., Inc. and to Kyushu Power Co., Inc. is shown in Table 3.

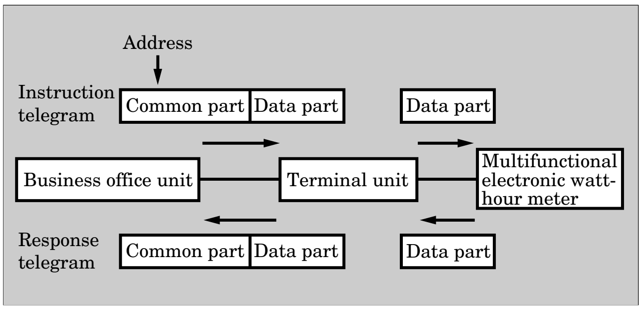
3.2 Automatic meter reading system for bulk customers delivered to The Tokyo Electric Power Co., Inc.

3.2.1 System configuration

Configuration of this system is shown in Fig. 4. The Tokyo Electric Power Co., Inc. utilizes NTT's (Nippon Telegraph and Telephone Corporation's) line and optical cables as its transmission line for the automatic meter reading system for bulk customers. A no-ringing communication service contract (refer to section 3.2.2) is selected for the NTT lines, making system configuration possible without requiring new transmission lines to be laid.

Among systems that utilize NTT lines, Fuji Electric has supplied central network control units (TPC-NCU) for installation in branch offices of The Tokyo Electric Power Co., Inc. terminal network control units (TP-NCU) for installation in the customers, multifunctional electronic watt-hour meters, and display terminals.

Fig.8 Data flow



3.2.2 No-ringing communication service contract

This system uses a normal NTT line as its transmission line but utilizes a no-ringing communication service contract for the automatic meter reading, making it possible to utilize the user's telephone as the transmission terminal for automatic meter reading without ringing the bell. To enable no-ringing communication, the line is first connected to the no-ringing trunk of the telephone company, and then the user's number is called. If the user's terminal is utilized while performing data transmission, the data transmission is interrupted automatically, giving priority to telephone calls.

Data transmission specifications are shown in

Fig.9 External view of the terminal unit for metallic pair cables

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Fig.10 External view of the terminal unit for optical cables

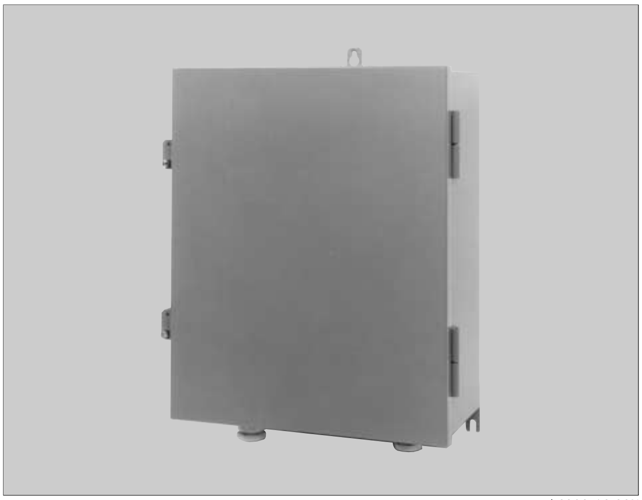

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Table 5 Data transmission specifications of transmission terminals for metallic pair cables in business office units

Transmission method	Half duplex
Line structure	Multi-drop
Transmission speed	1,200 bits/sec.
Synchronous method	Start-stop synchronization
Code type	NRZ equal length code
Transmission code	JIS unit 7 code
Control codes	STX: Start of the text ETX: End of the text
Error detection	Horizontal/vertical parity check
Bit sending order	Lower order bit preceding

Table 6 Data transmission specifications of transmission terminals for optical cables in business office units

Transmission method	Half duplex
Line structure	Multi-drop
Transmission speed	4,800 bits/sec.
Synchronous method	Flag synchronization
Code type	Manchester code
Transmission code	JIS unit 7 code
Error detection	CRC-CCITT
Bit sending order	Lower order bit preceding

Table 4.

3.2.3 Central network control unit (TPC-NCU)

The external view is shown in Fig. 5. This unit is activated by the CPU and connects lines in accordance with the no-ringing communication service interface. By sending signals, it automatically checks responses of the no-ringing line and terminal network control unit and if errors have occurred, transfers the error information to the CPU.

3.2.4 Terminal network control unit (TP-NCU)

The external view is shown in Fig. 6. This unit, together with the multifunctional electronic watt-hour meter, is installed by the bulk customer and communicates with the central network control unit and multifunctional electronic watt-hour meter.

3.3 Automatic meter reading system for Kyushu Electric Power Co., Inc.

3.3.1 System configuration

Configuration of this system is shown in Fig. 7. Kyushu Electric Power Co., Inc. uses the following as transmission lines for the automatic meter reading system for bulk customers: metallic pair cables that utilize spare lines for automatic control of the distribution line, optical cables, secure lines that utilize spare lines of the telephone line for secure communication and are installed for bulk customers, and NTT lines that utilize the customer's network. Fuji Electric has mainly developed units for the customer and has been delivering terminal units for metallic pair cables, terminal units for optical cables, display terminals and multifunctional electronic watt-hour meters.

3.3.2 Terminal unit

Details of the terminal units for metallic pair cables and terminal units for optical cables used for data transmission between the business office and multifunctional electronic watt-hour meters shall be introduced here.

These units have been developed to lower total costs by utilizing a spare line of the distribution feeder automation system as the higher level transmission line. This terminal performs such necessary minimum functions as communication with higher and lower level lines, telegram distinction, address setting, status display, etc. As shown in Fig. 8, the contents of data are not checked for data transmission. A summary of each terminal unit is introduced below.

(1) Terminal unit for metallic pair cables

As shown in the external view of Fig. 9, this terminal uses the same housing as the multifunctional electronic watt-hour meter. Therefore mounting of the transmission terminal and connection of the cable is the same as for the multifunctional meter, resulting in a simpler mounting procedure.

Data transmission specifications are shown in Table 5. A multi-drop configuration is utilized for the connection, allowing branching from anywhere.

(2) Terminal unit for optical cables

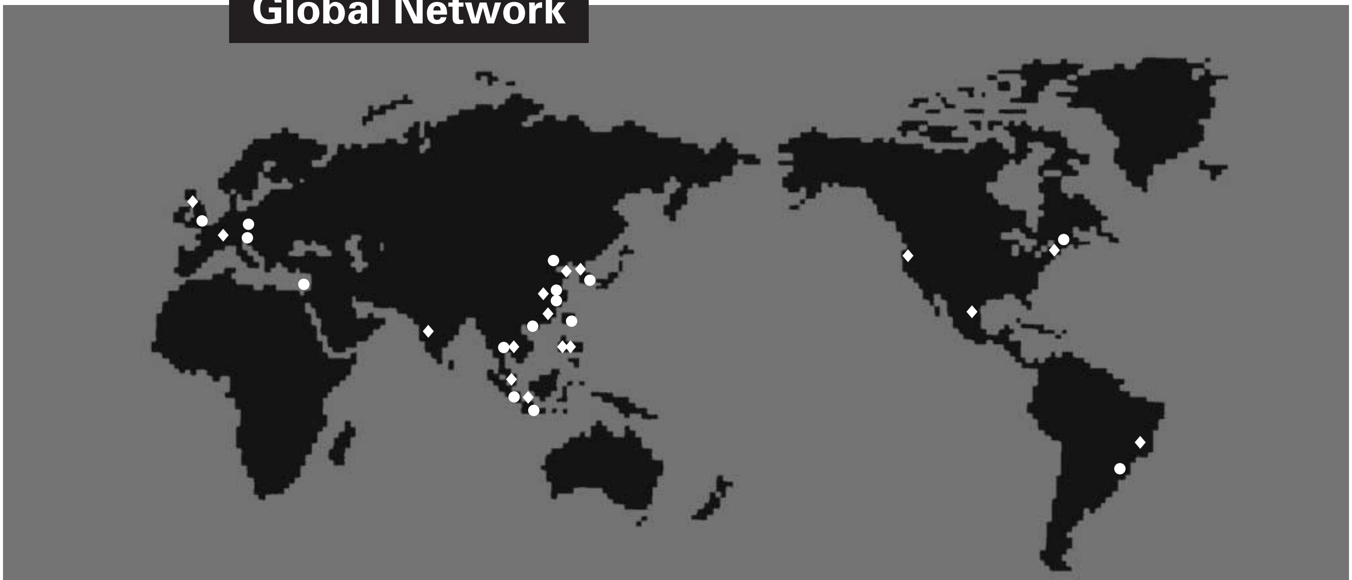
Figure 10 shows the external view and Table 6 lists the transmission specifications. The method of transmission is synchronous transmission by means of HDLC. Easy to handle PCS cable is used as the connecting optical cable.

4. Conclusion

A summary of the automatic meter reading system for bulk customers has been presented above. Fuji Electric plans to continue to reduce unit costs and contribute to the practical application of automatic meter reading systems.

The authors would like to express their deep gratitude to the guidance and collaboration received all those affiliated with this project.

Global Network



● : Overseas Representative Offices ◆ : Overseas Manufacturing Bases

AMERICA

■**FUJI ELECTRIC CORP. OF AMERICA**
●Head Office
Park 80 West Plaza Ⅱ, Saddle Brook, NJ07663, U.S.A.
TEL : (201) 712-0555 FAX : (201) 368-8258

■**FUJI ELECTRIC DO BRASIL INDUSTRIA E COMERCIO LTDA.**
Rua Guajajaras, 1707, Barro Preto,
CEP 30180-101 Belo Horizonte, M. G., BRASIL
TEL : (031) 291-5161 FAX : (031) 291-8185

EU

■**FUJI ELECTRIC CO., LTD.**
Erlangen Representative Office, Sieboldstr. 3, D-91052
Erlangen, F.R. GERMANY
TEL : (09131) 729613, 729630 FAX : (09131) 28831

■**FUJI ELECTRIC GmbH**
Lyoner Str. 26,
D-60528 Frankfurt am Main, F.R. GERMANY
TEL : (069) 6690290 FAX : (069) 6661020

■**FUJI ELECTRIC CO., LTD.**
London Representative Office, Commonwealth House, 2 Chalkhill
Road, Hammersmith, London W6 8DW, U.K.
TEL : (0181) 233-1166 FAX : (0181) 233-1160

■**FUJI ELECTRIC (U.K.) LTD.**
London Representative Office, Commonwealth House, 2 Chalkhill
Road, Hammersmith, London W6 8DW, U.K.
TEL : (0181) 233-1130 FAX : (0181) 233-1140

ASIA

■**FUJI ELECTRIC CO., LTD.**
Beijing Representative Office, Suite 3603, China World Tower,
China World Trade Center No. 1, Jian Guo Men Wai Avenue,
Beijing 100004, THE PEOPLE'S REPUBLIC OF CHINA
TEL : (010) 6505-1263, 1264 FAX : (010) 6505-1851

■**FUJI ELECTRIC CO., LTD.**
Hangzhou Representative Office, #402 Heng He Bldg.,
23-2 Huan Cheng Dong Lu Hangzhou City, Zhejiang Province,
THE PEOPLE'S REPUBLIC OF CHINA
TEL : (0571) 704-5454 FAX : (0571) 704-3089

■**SUZHOU LANLIAN-FUJI INSTRUMENTS CO., LTD.**
Songlin Economic & Technical Development
Zone, Wujiang City, Jiangsu Province 215200,
THE PEOPLE'S REPUBLIC OF CHINA
TEL : (05223) 41-1594 FAX : (05223) 41-1654

■**FUJI ELECTRIC TECHNOLOGY AND SERVICE (SHENZHEN) CO., LTD.**
No. 44 Dongjiao Street., Zhongxing Rd., Shenzhen City,
Guangdong Province 518014,
THE PEOPLE'S REPUBLIC OF CHINA
TEL : (0755) 220-2745 FAX : (0755) 220-2745

■**FUJI ELECTRIC CO., LTD.**
Taipei Representative Office, 5th Fl.,
Taiwan Fertilizer Bldg., No. 90, Nanking E Rd.,
Sec.2 Taipei, TAIWAN
TEL : (02) 561-1255, 1256 FAX : (02) 561-0528

■**FUJI/GE (TAIWAN) CO., LTD.**
12F, No.70, Cheng Teh N. Rd., Sec.1, Taipei, TAIWAN
TEL : (02) 556-0716, 9061 FAX : (02) 556-0717

■**FUJI ELECTRIC (ASIA) CO., LTD.**
10th Fl., West Wing Tsimshatsui Centre, 66 Mody Rd.,
Tsimshatsui East Kowloon, HONG KONG
TEL : 2311-8282 FAX : 2312-0566

■**FUJI ELECTRIC KOREA CO., LTD.**
16th Fl. Shinsong Bldg. 25-4 Youido-Dong,
Youngdungpo-Gu, Seoul, 150-010, KOREA
TEL : (02)780-5011 FAX : (02)783-1707

■**FUJI ELECTRIC CO., LTD.**
Bangkok Representative Office, Room No.1202, 12th Fl.
Two Pacific Place
142 Sukhumvit Rd. Bangkok 10110, THAILAND
TEL : (02) 653-2020, 2021 FAX : (02) 653-2022

■**P. T. BUKAKA FUJI ELECTRIC**
Plaza Bapindo, Menara Ⅰ, 24th Fl. Jl. Jendral Sudirman Kav,
54-55 Jakarta 12190, INDONESIA
TEL : (021) 5266716～7 FAX : (021) 5266718

■**FUJI ELECTRIC CO., LTD.**
Singapore Representative Office, 401 Commonwealth Drive,
#04-05 Hawpar Technocentre, Singapore 149598, SINGAPORE
TEL : 479-5531 FAX : 479-5210

■**FUJI ELECTRIC SINGAPORE PRIVATE LTD.**
401 Commonwealth Drive, #04-05 Hawpar Technocentre,
Singapore 149598, SINGAPORE
TEL : 479-5531 FAX : 479-5210

■**FUJI/GE PRIVATE LTD.**
171, Chin Swee Rd., #12-01/04 San Center,
Singapore 169877, SINGAPORE
TEL : 533-0010 FAX : 533-0021

■**HOEI ELECTRONICS (S) PRIVATE LTD.**
No.5 Pereira Road, #02-04, Asiawide Industrial Building,
Singapore 368025, SINGAPORE
TEL : 285-3238 FAX : 285-7317

■**GE/FUJI ELECTRIC CO., LTD.**
Nicolaou Pentadromos Centre, Office 908,
Block A, P. O. Box 123, Limassol 205, CYPRUS
TEL : 5-362580 FAX : 5-365174

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