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PRESENT STATUS AND PROSPECTS OF DISTRIBUTION AUTOMATION

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1. FOREWORD

The growth of the information society and the spread of OA (Office Automation), FA (Factory Automation), HA (Home Automation), etc. and other electronic apparatus and equipment to not only the industrial field, but also to the home, is accompanied by actualization of expectations to high quality power supply, including reduction of service interruption, as a social demand.

On the other hand, regarding the distribution system positioned at the end of power currency facilities, large facilities are spreading over broad area and are becoming a complex facility configuration. The trend toward automation of distribution for efficient facility operation, labor-saving and efficient field work, and customer service is rising quickly. Therefore, while planning computer system application development and information network establishment, development of a total automation system of the distribution field is being performed earnestly.

The development of distribution automation technology is shown in *Fig. 1*. The development of Fuji Electric distribution automation system technology is shown in *Table 1*.

Fig. 1 Development of distribution automation technology

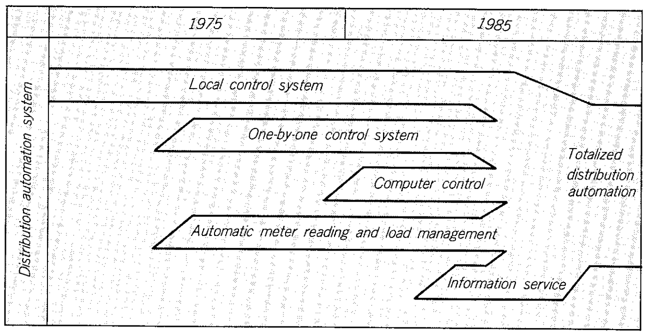


Table 1 Development of distribution automation system technology

Era	Feeder automation system	Automatic meter reading system	Others
1965 ~ 1975		◦ Development of load control system (Shikoku Electric Power Co., Inc.) ◦ Test manufacture of automatic meter reading terminal and field testing at The Tokyo Electric Power Co., Inc. ioji Hachioji section. ◦ Testing of L.V. distribution carrier system at above.	
1975 ~ 1985	◦ Development of distribution automation system and its delivery to The Tokyo Electric Power Co., Inc. Hiratsuka business office.	◦ H.V. distribution carrier system ◦ Test manufacture of L.V. distribution carrier system and field test by Kyushu Electric Power Co., Inc.	◦ Development of electric shock preventing apparatus ◦ Development of sense checker ◦ Analysis of various distribution system phenomena by TNS (system simulation apparatus)
1985 ~	◦ Delivery of distribution automation system to The Tokyo Electric Power Co., Inc. Ohito business office and Joriku Omiya business office. ◦ Delivery of distribution automation system, including RTU (Remote Terminal Unit), to Chubu Electric Power Co., Inc. Nagano business office and Toyohashi business office. ◦ Delivery of feeder automation system, including RTU, to The Kansai Electric Power Co., Inc. NANBA business office and Wakayama business office.	◦ Development and delivery to Kyushu Electric Power Co., Inc. of home terminal unit and automatic metering office. ◦ Development and field testing (The Tokyo Electric Power Co., Inc. and Chubu Electric Power Co., Inc.) of automatic metering terminal. ◦ Research on L.V. distribution transmission characteristics	◦ Research on fault locating system

2. TREND OF DISTRIBUTION AUTOMATION STSTEMS

2.1 Overview

Currently, the following systems are being studied as distribution automation systems: their concepts are shown in *Fig. 2*.

(1) Feeder automation
(2) Feeder operation and management
(3) Load management
(4) Information service

These are finally considered to function as a consistent distribution SCADA system and as a totalized feeder automation system for association with computerization of business processing. However, in this process, the themes will be achieved, in time, while resolving each problem.

Of these, a feeder automation system aimed at

- minimization of troubled area
- shortening of recovery time

has been practicalized at a high pitch and its range of applications has expanded steadily at each utility in recent years.

The feeder automation system is described below.

2.2 Feeder automation system

An automatic recloser, which automatically disconnects fault sections and automatically feeds power to the power source side healthy sections has been used in distribution systems for some time.

The feeder automation system is added to this system, and introduced remote control of switch operation for switching feed to the load side healthy sections and plan work manually or automatically from the business office.

The main functions performed by this system are shown in *Table 2*.

The feeder automation system consists of a controller (called "slave" hereinafter), which is combined with a central processing system installed at the office (called "master" hereinafter) and pole switches (called "switch"

Fig. 2 Distribution automation systems

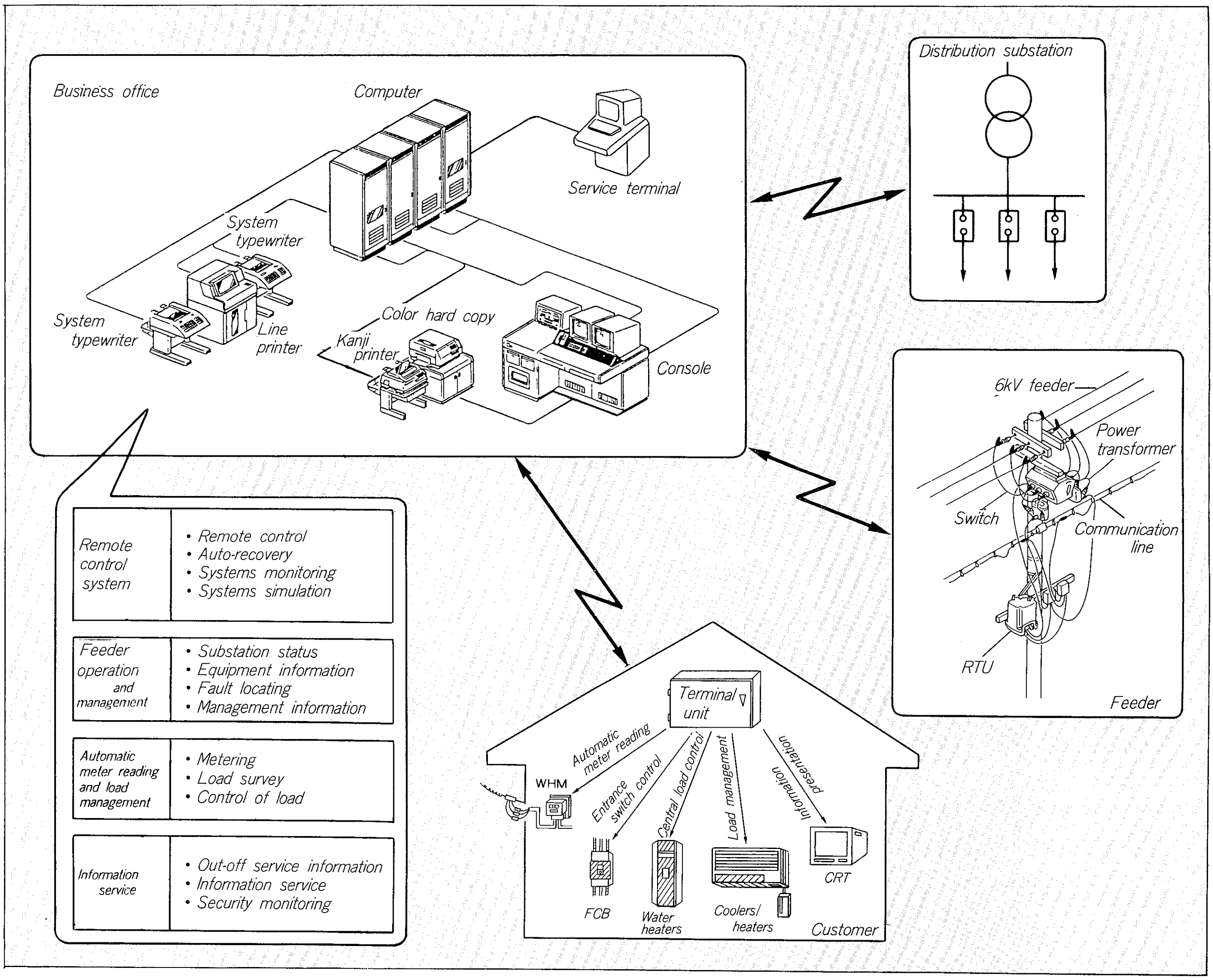
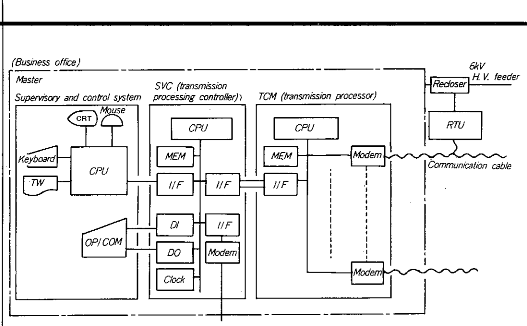
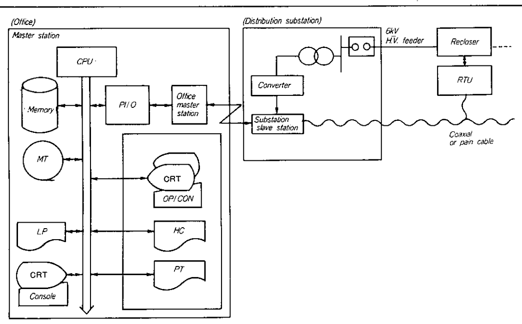
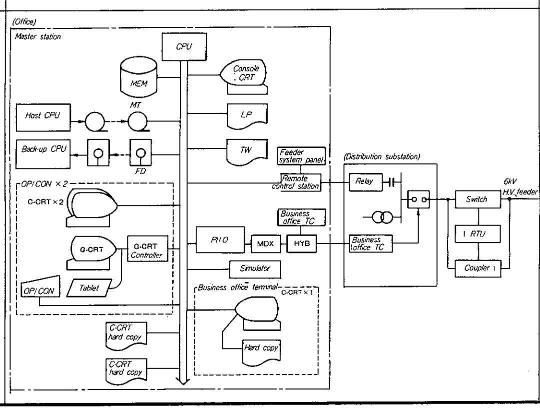


Table 2 Functions of feeder automation system

Item	Contents
Information management	Distribution system current status (switch on/off, section charged/not charged, etc.) monitoring and status change (at a fault) judgment and display
Troubleshooting/recovery	Preparation and execution of system switching procedure at feeder fault and substation fault Preparation and execution of procedure for return to original system after recovery
Work out-off service processing	Preparation and execution of interchange operating procedure by work contents input (including date and time and place)
Emergency operation	Preparation and execution of system switching procedure for specific section out-off service in an emergency
Overload survey	Preparation and execution of overload detection and overload removal operating procedure by constant monitoring of feeder current
Load interchange computation	Preparation of load curves, optimization of system switching procedure based on section load computation, voltage drop calculation, etc.
Remote control	FCB on/off operation
Manual setting	Manual setting of manual switch status and setting of automatic switch mode, operation prohibit, etc.
Logging	Preparation and printing of status record, operation record, trouble report, etc.
Maintenance	Facilities date (switch, line, etc.) and screen data maintenance
Display	Display of street map correspondence feeder system chart and display of substation skeleton diagram
Simulation	Generation of simulated faults, preparation of recovery procedure, simulated execution of switch operation

Table 3 Classification of feeder automation system

System scale	System configuration example	System features	Main functions		Features			
			Display of electric system	Fault recovery, work out-off service processing	Economy	Operability	Maintainability	Expandability
Small		(1) Consists of master station, slave stations, and signal transmission line, etc. (2) Data route: Feeder direct transmission (3) Collecting of switch data (may also fetch some high-level data) (4) Personal computer (microcomputer)	· Facilities table (character CRT) · Table	· No procedure preparation · Manual execution	◎		◎	
Medium		(1) Consists of master station, substation slave station, slave station, and signal transmission line, etc. (2) Data route: Via substation (May also be via central system or centralized transmission line) (3) Collecting of switch and substation data (4) Minicomputer	· Skeleton diagram (character CRT)	· Manual and automatic preparation · Automatic execution				◎ (Collecting of AI, feeder data, etc.)
Large		(1) Consists of master station, substation remote control, slave station, and signal transmission line, etc. (2) Data route: Via substation (May also be via central system or central transmission line) (3) Collecting of switch data and substation data (4) Super minicomputer	· Displaying on the area map (character CRT)	· Manual and automatic preparation · Automatic execution		◎		◎ (same as the above)

hereinafter) and transmission equipment, etc. However, the data transmission route and computer differ with the functions demanded by the system. The scale of the system also differs with this.

The system scales and performances viewed from the main functions are compared in *Table 3*.

(1) Small scale system

This system has the minimum functions and facilities for on/off control of switches. It is operated while judgments are made by the operator based on the switch data.

The master consists of a supervisory and control part made up of a personal computer, character CRT, printer, and operator console for final execution of the remote control operation and a transmission processing part, which exchanges signals between master and RTU's, etc. It is a system which emphasizes economy more than functions.

The feeder status data is displayed in table form on a CRT and the switching operation is controlled remotely by direct selection of the facility data by the operator.

Since the only maintenance is correction of the facility data, it is easy, but since connection of the entire system cannot be confirmed, its dependence on the operator is high.

(2) Medium scale system

This system collects the switch data and substation data, and performs automatic recovery and return at a distribution system fault and prepares and executes the normal work procedure.

The CPU is a minicomputer, and the man-machine system consists of an operator console, made up of two character CRTs and an operator console, and a kanji printer and hard copy unit.

A substation RTU is installed at the substation to collect the substation data.

The distribution system is displayed on the CRT screen by a skeleton diagram represented by the electrical connections only; feeder direction, line bends, distance, and other geographical elements are all removed.

Since a skeleton diagram can be drawn automatically from the facilities data by using this, maintenance is easy and operability is improved.

(3) Large scale system

This system has almost the same functions and composition as the medium scale system. However, a graphic CRT is used at the operator console and the distribution system display is a street mapping system with map superimposed on a feeder system diagram.

By means of this, the operating status of the distribution system can be grasped easily and sending of instruction to the site at fault occurrence and at work and information service to the customer, etc. can be performed quickly and positively. It can also be used as a distribution facilities installation drawing.

2.3 Communication media

Considering remote supervision and control, metering, and other multi-purpose use, coaxial cable, optical cable, and power line as use of existing facilities have been available for some time as communication media that can be used in distribution automation.

These must be selected by considering the functions, data amount, geographical characteristics, economy, and future mode, etc. of the distribution automation system based on the features shown in *Table 4*.

2.4 RTU (Remote Terminal Unit)

The RTU demands integration of the conventional automatic recloser function and SCADA function, remote setting of the automatic recloser type and time, metering function, fault detection function, etc. A micro-processor is used to make it small and light weight.

Recently, sensors which are attached to the RTU and detect voltage, current, etc. are being developed for feeder operation and management. There are many of these. The noncontact type centered about the optical sensor is becoming the mainstream from the standpoint of securing reliability.

Since the installation environment is the most severe of even the outdoor independent installation considered the normal environment, lightning surge resistance, weather resistance, and maintenance-free operation by strengthening of insulation harmonized design against the entry of lightning, radiowaves, and other external surges, suppression of the internal temperature rise, etc. is planned.

2.5 Future development topics

Future feeder automation system development topics are:

(1) Development of advanced fault recovery techniques using artificial intelligence (AI).
(2) Development of new sensors for degradation forecasting and preventive maintenance.
(3) Building of an optimum network that uses various communication media to efficiently transmit a large amount of data.

Table 4 Comparison of communication media

Item / Media	Features								
	Speed	Capacity	Multi-purpose	Flexibility	Reliability	Security	Constructivity	Maintenance	Economics
Optical fiber cable	◎	○	◎	×	◎	◎	○	◎	×
Coaxial cable	◎	◎	◎	○	○	○	○	○	○
Communication cable	○	×	○	○	○	○	◎	◎	◎
Powerline carrier	○	×	×	○	○	○	◎	◎	◎

3. DEVELOPMENT TO A TOTALIZED FEEDER AUTOMATION SYSTEM

Besides the feeder automation system described in the preceding section, research and development is being carried out on automatic metering, central load control, information service to customers, etc.

3.1 Automatic meter system

Research has been conducted on an automatic meter system for watt-hour-meter since 1965 for the purpose of making metering work less labor intensive and more efficient against skyrocketing labor costs and increased demand.

The transmission line of the automatic metering system, in which metering terminals are expanding over broad area with use optical cable, communication cable, power lines, telephone circuits, etc. according to the application area. Big merits of the powerline carrier system that used this kind of feeder are that pair cable is unnecessary and cost. Establishment of this technology is a topic. The popularity of electrical appliances in the home is noticeable and there are also many thyristor-applied apparatus. The noise included in the commercial power frequency has also been eliminated, and to establish a powerline carrier system, the characteristics of the feeder as a communication line must be grasped.

Fuji Electric, in cooperation with utilities, is studying the actual state of low voltage feeders. The noise near 4V in the 1 to 2KHz band is observed as shown by the feeder noise waveform example shown in *Fig. 3*. Viewed from the signal level, it is a value that cannot be ignored. Research on the optimum feeder powerline carrier system is advancing with this basic study as the background.

The problem of cost is also a big problem in practicalization. Terminal cost reduction by measuring part electronics, integration with the transmission part, and establishment of mass production technology, etc. should be undertaken.

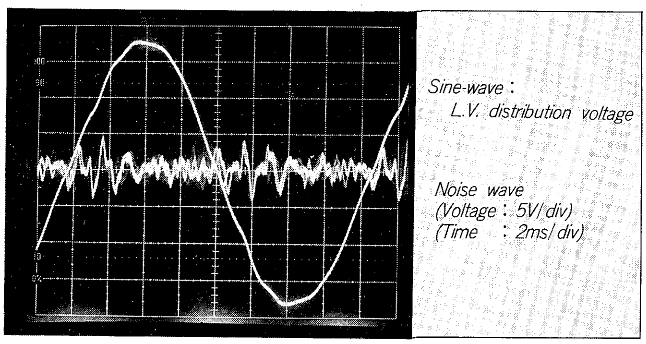
3.2 Load control system

The daty and night load difference is becoming very large, and to continue to send quality electricity, greater equipping and reinforcement than power supply facilities is necessary, but the pursuit of economy is retrogressing. To counter this, development of a load control system aimed at bottomming-up at light load and peak-up of high peak loads is necessary.

In the United State and Europe, the implementation of load control is old and water heaters, heat storage heaters, and other late night loads are turned on and off by a ripple control system. The control systems are mainly the powerline carrier system and VHF radio·one-way control system.

In Japan, some water heaters are controlled by the ripple control system. Since the load control system collects the water heater data at the center and calculates the

Fig. 3 Feeder noise waveform example



load distribution and controls the heaters, a two-way communication system is necessary. If automation becomes popular in the home and central control of indoor apparatus is realized, more detailed load control is possible by connection to a home controller.

3.3 Information service to customers

At utilities, such business with each customer as:

(1) home moving (new construction, demolition, move, etc.)
(2) Service interruption (off) and resumption (on)
(3) Contracted capacity change and other work and its notification
(4) Out-off service (fault, work)
(5) Charges and electric power amount notification

is performed by hand. The establishment of a two-way communication system with the customer and the necessary control and notification of this business by transmitting pictures and voice and fire alarm, gas leakage alarm, burglar alarm, and other home security business attempt to provide more detailed service. Since the data amount is large, establishment of a high speed and large capacity information network will become a research topic from this.

4. FUTURE TECHNOLOGICAL DEVELOPMENT AND DIRECTION OF CORRESPONDENCE

Fuji Electric undertook distribution automation research at an early stage and has manufactured large scale, medium scale, and low scale feeder automation systems up to here with the guidance of utilities. Besides, we have also undertaken technological development in the automatic metering and other distribution fields. To meet the severe demands for improvement of power supply reliability and for more efficient and labor saving facilities operation, development must be advanced by emphasizing:

(1) development of high reliability equipment and systems,
(2) improvement of maintainability and operability,
(3) improvement of the man-machine interface apparatus and functions.

One end of the basic approach of technological development is described below.

(1) Development of high reliability equipment and systems

In the increase of the importance of the distribution automation system in the duties of supplying power, our mission is to provide higher reliability systems. Especially, current technological advance, centered about electronics technology, is very fast and instead of following these advances, new technology based should be undertaken, based on past technological experience, and development of high reliability products matched to needs should be advanced.

Many people participate in distribution field automation work, and procedures become routine and an operating system is established. Therefore, even though we speak of development of automation, even construction of a new system that ignores past operating procedures is not necessarily a good system. We feel that system development must be performed with the close cooperation from the system study state.

(2) Improvement of maintainability and operability

Because there is a tremendous number of distribution systems, these system are studded over a wide area, and system modifications are a daily occurrence, a system architecture that not only minimizes maintenance and inspection work, but can also cope easily with system modifications even from the standpoint of operation is indispensable. Especially, a software system aimed at simplicity and easy handling and operation which allow even general maintenance personnel to deal with data input and changes, CRT changes, etc. which accompany facility changes.

(3) Man-machine interface equipment

To operate a feeder automation system smoothly and to use its function, the functions, composition, and share of work of the man-machine interface equipment with the operation and maintenance personnel and system which monitor and operate the system are very important. Recently, the advance of various display parts has been noticeable and high performance of the CRT display is advancing. From the standpoint of software, there is introduction of a street mapping system, etc. As a result, the functions share, composition, etc. of the man-machine interface equipment related to supervision and control is being studied from the standpoints of operability, economy, or miniaturization, etc.

5. CONCLUSION

The current state and trends of the distribution automation field was described above. However, automation of the distribution field has only started, and there are still many topics which should be developed. In meeting the high precision information age, the distribution automation system is indispensable and is incorporated in it.

Fuji Electric is receiving the guidance of all users and is meeting the needs of such an age and is cooperating in the development of a better system.