INTELLIGENT ELECTRICAL EQUIPMENT FOR WATER AND SEWAGE WORKS

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1. INTRODUCTION

Modern society has turned from the age of construction to the age of demand for comfortable, abundant, and convenient living. This also applies to the water and sewage works field and electrical equipment has also advanced to meet the needs of the age.

In particular, the recent advance of microelectronics and power electronics has been amazing and the development of intelligent electrical equipment has been accelerated by the use of miniature, advanced functions electric parts. We think that this advance will continue in the future and intelligent electrical equipment will contribute to making water and sewage works more advanced (intelligent, high performance).

The intelligent functions for electrical equipment (E) from among the electric (E), instrument (I), and computer (C) which support water and sewage works and the effect of their application are outlined below.

2. LOCAL NETWORK SYSTEM FOR ELECTRICAL EQUIPMENT

2.1 High and low voltage switchgear and power control gear transition

Because high and low voltage switchboards had a bus construction known as the open type until about the 1960s, safety and maintainability were difficult to achieve. Thereafter, the enclosed switchboard and motor control center became the mainstream and safety and maintainability were improved. On the other hand, (1) equipment that cannot be stopped, (2) widely dispersed loads, (3) frequent expansion and replacement, and (4) the indispensability of improvement of maintenance management are special characteristics of water and sewage works.

Numerous advances have been promoted to meet these as electrical equipment. As a result, intelligent high voltage switchgear and the intelligent control center were developed during the latter half of the 1980s. We feel that in the future progress will be made toward making electrical equipment smaller and more intelligent based on these units.

2.2 Outline of FALONET system

The FALONET system (Fuji Aqua LOcal NETwork system), a local network system for electrical equipment, is aimed at the incoming voltage transforming and power facility. Its main components are intelligent high voltage switchgear and an intelligent control center.

Local control stations, which correspond to the conventional auxiliary relay panel, and local control panels, which are dispersed in the field, are connected by serial transmission and the intelligent high voltage switchgear and intelligent control center are connected by FAINS (Fuji Aqua INformation System). This allows the flexible construction of a system for small to large facilities by all-serial transmission from field to center. A system composition example is shown in **Fig. 1**.

2.2.1 Control equipment comprising the system

(1) Intelligent high-voltage switchgear

This is high-voltage switchgear that uses a digital controller called a power unit controller (PUC).

It has three transmission functions (P-link, T-link, and RT transmission) and the same sequence control functions as a medium type programmable controller (PC). The PUC consists of three blocks: basic control section, transforming section, and protective relay section. It can be freely combined and used. The intelligent high-voltage switchgear and PUC are shown in **Fig. 2**, the composition of the intelligent high-voltage switchgear is shown in **Fig. 3**, and the functions of the PUC and CUC are given in **Table 1**.

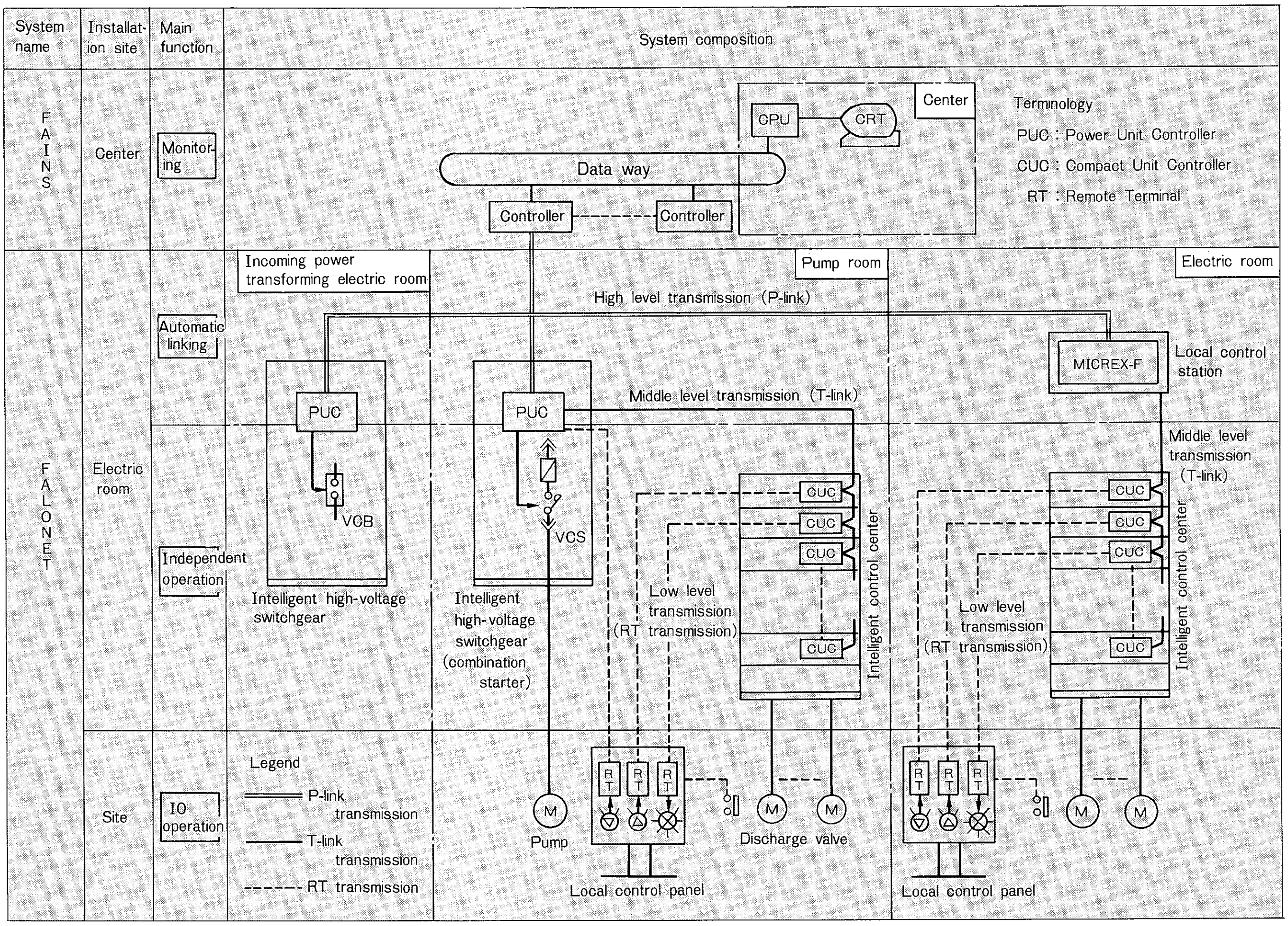
(2) Intelligent motor control center

A control center using a digital controller called a compact unit controller (CUC) is provided at each unit. This center has two transmission functions (T-link, RT transmission) and an independent control function that was formerly performed by auxiliary relays. Line starting, reversible, ⅄-Δ, and other operation modes can be selected and set for the CUC.

(3) Local control station

This unit replaces the conventional auxiliary relay panel. Internally, it uses a general-purpose PC (MICREX-F) as the controller and has two transmission functions (P-link, T-link) and a load group link/independent control function. An advanced automatic control system can be built by

Fig. 1 FALONET system (local network) composition example



adding a fuzzy control function to this controller.

2.3 Expected result and intelligent functions

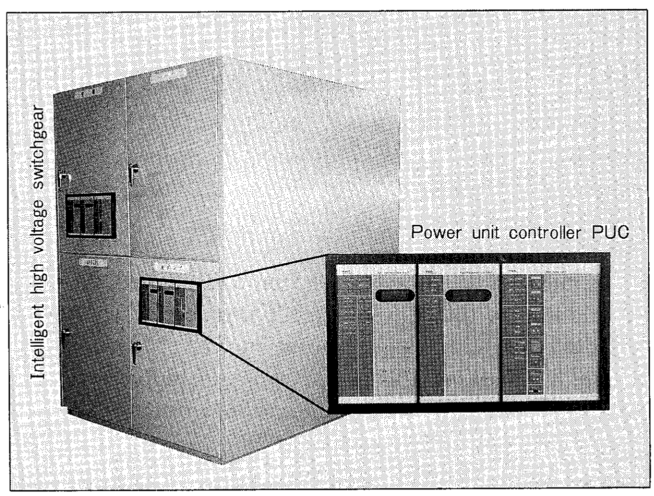
(1) Control functions dispersion

To improve reliability, the system was completely dispersed. An independent control function was provided for each load of the high-voltage switchgear PUC and control center CUC. Low level transmission (RT transmission) also has a 1-to-1 correspondence with the loads. The control functions were clearly divided by incorporating a link/independent control function into the local control station or high voltage combination panel PUC. Complete dispersion allows continuation even if trouble should occur, as well as during facilities expansion, renovation, and maintenance and inspection.

(2) Serial transfer by optical fiber cable and expansion to expert system

For more exact monitoring and operation support using an expert system, mode, fault current, and voluminous other data are necessary for each load. A serial transmission method was used to realize this with a small control cable. This allows expansion to an intelligent expert monitoring system for fault point judgment, automatic reset, etc. An optical fiber cable was also used to improve reliability against noise. The use of a special cable simplifies execution and speeds up work.

Fig. 2 Intelligent high-voltage switchgear and PUC



(3) Multiple software

For complete control center unit compatibility, a multiple software method that is used by switching multiple software at the CUC was adopted so that one CUC

Fig. 3 Composition of intelligent high voltage switchgear

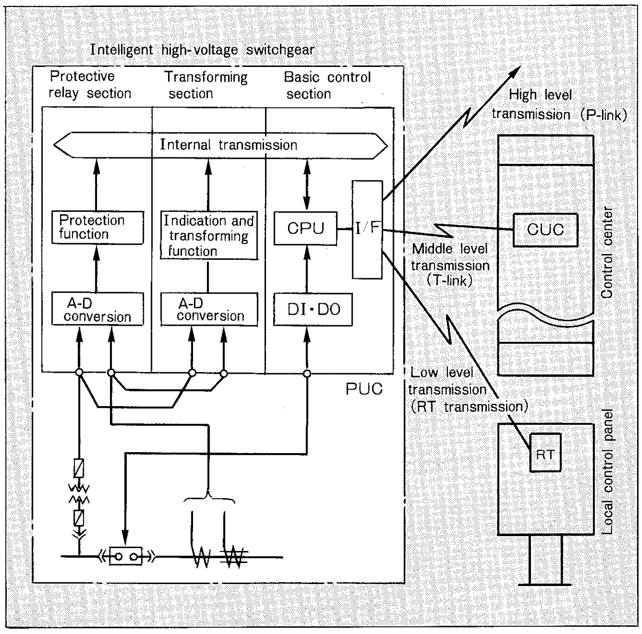
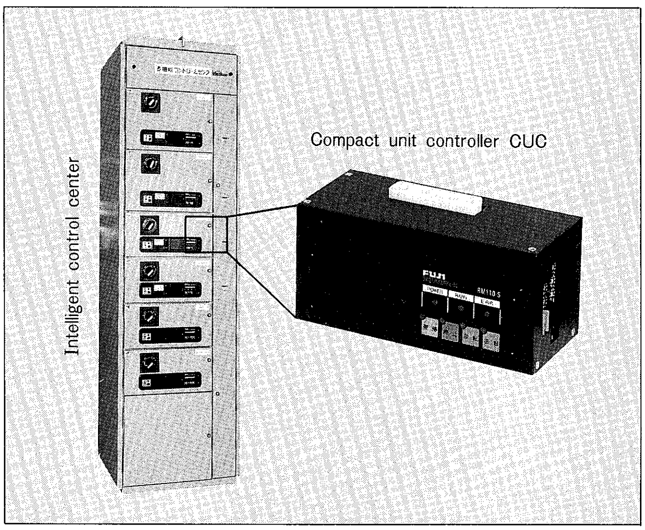


Fig. 4 Intelligent control center and CUC



model can handle all loads. The unit shape was made the same as that of the conventional control center. Therefore, facilities expansion and renovation can be performed quickly. System reliability and maintainability were also improved so that even if trouble should occur, it can be dealt with quickly.

(4) Electronification (relay-less)

The equipment was made intelligent and compact and the sequence control circuit was made electronic to save space. A relay-less system construction was made possible by replacing the control circuit, which is usually made up of auxiliary relays, with PUC, CUC, and PC programs. The transmission cable can also be connected directly to each controller and the need for I/O (input/output device) was eliminated. As a result, the size of the local control station was reduced to 1/3 or less of that of the conventional auxiliary relay panel. Moreover, a special cabinet for each control device is unnecessary and facility planning and design are easier.

3. VARIABLE SPEED CONTROLLER AND HARMONIC COUNTERMEASURES DEVICE

3.1 Variable speed controller and harmonc countermeasures device transition

Beginning from the 1960s, thyristor serbius, centered about pumping stations, was used as the variable speed controller in the water and sewage works field and led to the introduction of a high efficiency variable speed controller. Thereafter, variable speed drive was widely adopted with the increased capacity and functions of the transistor inverter. On the other hand, countermeasures against the harmonic current generated by a variable speed controller are shifting from the LC resonant filter, which tunes and absorbs the high frequencies, to an active filter, which cancels the harmonic current by generating a harmonic current of its own. A variable speed controller system that reduced the generation of harmonic current has also been realized. In the future, we think that development of an easy-to-maintain variable speed controller for squirrel cage motor and increasing of the capacity and advancement of the functions of the harmonic countermeasures device will proceed.

3.2 High capacity and intelligent VVVF controller

Variable drive inverters have been serialized by power semiconductor element making up the main circuit and commutation method, modulation method, and other technological conditions, and by the obfictive application. The voltage type PWM control transistor inverter extensively used in the water and sewage works field is introduced here.

In the past, transistor inverter parallel operation was difficult and could not be used with large loads. However, the development of current balance control has made parallel connection of inverter units possible. At the present time, capacities up to 450 kW at 400 V can be handled and it is has become easy to convert most water and sewage works loads to variable speed drive.

Intelligence and precision are realized by making the control circuit all-digital. A serial interface for connection to a higher level system is also provided. The features of these are:

(1) Strengthening of tripless construction

The states which trip an inverter the easiest are overcurrent at starting acceleration, momentary stopping by a momentary power failure, overcurrent at restarting, etc. Therefore, reliability versus variable speed controllers dropped, but stable, continuous operation without tripping

3.3 Harmonic countermeasures device

A variable speed controller that uses a power semiconductor element generates a harmonic current. The

Table 1 PUC and CUC functions

Composition		Function
PUC	Basic section	(1) Switching, control functions (COS, CS) (2) Status, alarm display function (3) Circuit breaker, combination starter independent/linked control function (4) Transforming section and protective relay section transmission interface (5) High level (center monitoring room, etc.) and low level (control center, local control panel) transmission interfaces
	Trans-forming section	(1) Following power transforming functions: 3 units x voltage, 1 unit x zero phase voltage, 3 units x current, 1 unit x frequency, 1 unit x power factor, 1 unit x power, 1 unit x reactive power (2) Following indicator functions (digital display) 3 phases x voltage, 3 phases x current, zero phase voltage, frequency, power factor, power, electric energy, reactive power (3) Transmission of measured values (1) and (2) above via the basic section
	Protective relay section	(1) Following protective relay functions: 2 units x overcurrent, 1 unit x overcurrent ground, 1 unit x directional ground, 1 unit x overvoltage ground, 1 unit x low voltage, 1 unit x overvoltage (2) Protective relays of (1) above malfunction display (3) Transmission of set value of (1) above via the basic section
CUC		(1) Status and alarm display function (2) Independent control function (3) High level (intelligent high voltage switchgear, local control station) and low level (local control panel) transmission function (4) Starting method selection function (5) Control function (selected by DIP switch)

higher capacity of equipment and the increase in the number of installations has been accompanied by an increase in the flow of this harmonic current to the power system. Therefore, harmonic obstruction generation preventive measures have become indispensable.

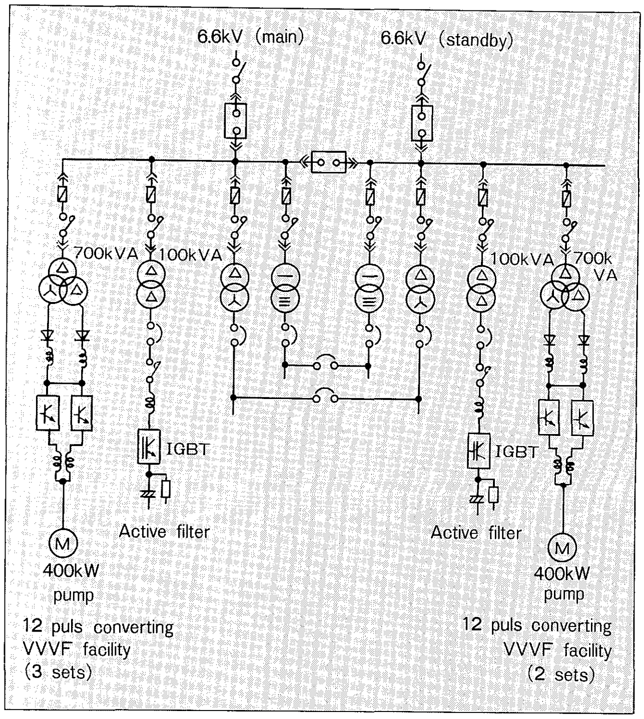
3.3.1 Power supply harmonic lowpass type VVVF inverter

Since the transistor type VVVF inverter uses a diode rectifier at the power source side, low harmonic (5th, 7th, 11th, 13th) currents are generated at the power supply side. To suppress the generation of harmonic current at the power supply side, the conventional power supply side rectifier has been replaced by a sine wave.PWM transistor converter and a method which flows a sine wave current synchronized with the power supply voltage has been adopted. As a result, the generation of low harmonic currents has reduced to 1/10 of that in the past and installation of a harmonic filter and other countermeasures have become unnecessary. The load power factor has also become 1.0 and improvement of the power factor is also beneficial.

3.3.2 Active filter

The active filter performs PWM control by using the

Fig. 5 Active filter application skeleton example



high speed switching function of an IGBT (insulated gate bipolar transistor) and other self arc quenching elements.

A harmonic current with a phase opposite that of the harmonic current of the load is generated and the harmonic current is canceled and the flow of harmonic current to the was made possible by using the following two methods:

(a) Method that maintains the maximum troque by high speed operation torque limiting control and performs acceleration by controlling the frequency.

(b) Method that prevents overcurrent tripping by instantaneous current value limiting circuit.

(2) Completion of man-machine interface and data transmission function

A data display is provided at the inverter monitor, and frequency, voltage, rotating speed, and other operation display and overcurrent at acceleration and other trouble details display are performed. A trouble diagnosis system which can retrieve the trouble generation cause and operation status when trouble occurs is also used. For organic and more detailed control of the related load, data transmission is performed with the PC and personal computer and other high level controllers and various parameters can be monitored and their setting can be modified.

power system is suppressed. Compared to the conventional LC resonant filter, this method features (1) good harmonic compensation performance, (2) batch compensation of an unspecified number of high frequencies is possible, (3) the system side impedance has virtually no affect, (4) there is no danger of burning, (5) it is small, etc. It also has power factor improvement and voltage fluctuation control functions by reactive power control and is intelligent. An example in which the need for an LC resonant filter and

Fig. 6 6.6 kV 100 kVA active filter

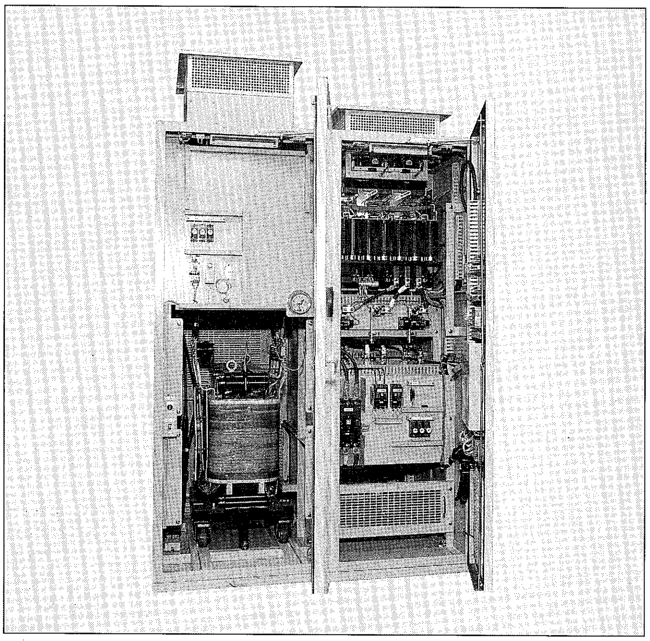
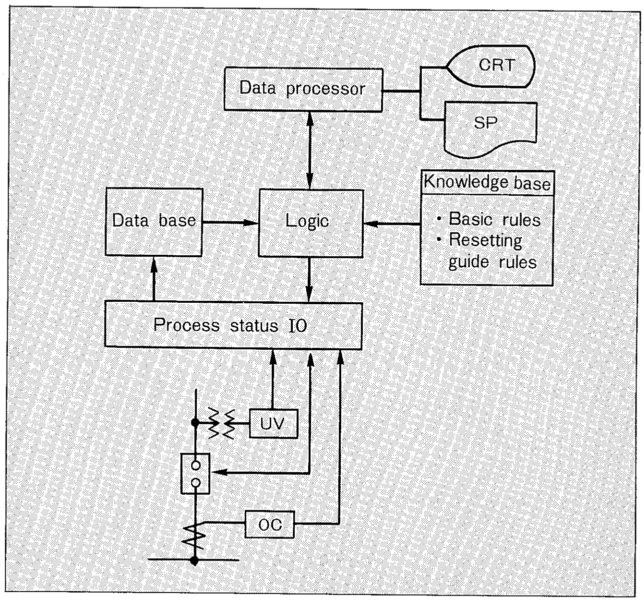


Fig. 7 Incoming voltage transforming automatic power failure resetting system



power factor improvement capacitor has been eliminated by providing both harmonic compensation and power factor improvement functions at one active filter is shown in **Fig. 5**. The efficacy of the active filter as a countermeasure that realizes the overall harmonic amount restriction policy set forth by the Electric Association Cooperative Study Group is high.

Figure 6 shows a 6.6 kV 100 kVA active filter.

4. INTELLIGENT INCOMING VOLTAGE TRANSFORMING AND POWER SUPPLY FACILITY

4.1 Incoming voltage transforming and power supply facility transition

Of the electric equipment for water and sewage works, the reliability of the incoming voltage transforming and power supply facility is the most important from the standpoint of securing the reliability of the entire plant.

The special high voltage substation has evolved from the the initial structure type to the gas insulated switchgear (GIS) and cubicle type GIS (C-GIS) and reliability and safety have been secured and advancements have been made toward miniaturization. Private power generating equipment have advanced from the no turbocharging diesel engine to high turbocharging and the uninterruptible power supply (UPS) has evolved from the thyristor type to the IGBT type and advancements have been made in higher efficiency and reduced size.

In recent years, it has been developed into systemized intelligent equipment to obtain still greater reliability and advanced maintenance management. In the future, we think that it will be connected to the FALONET previously described and will advance toward a total intelligent system.

4.2 Intelligent incoming voltage transforming facility

Stopping of the incoming voltage transforming facility at a water and sewage works is connected to stopping of the plant and has a large affect on social living. Therefore, construction of a supervisory and control system capable of natural prevention of and rapid recovery from trouble and planned repair and inspection was planned. The main systems are introduced below.

4.2.1 GIS monitoring system

This system acquires partial discharge, LA leakage current, circuit breaker operating time, trouble zone detection, and other data by means of sensors installed to the GIS and quickly forecasts insulation deterioration, local overheating, and other abnormality indications based on a diagnosis algorithm. This performs trouble natural prevention and forecasting and improves the efficiency of maintenance work.

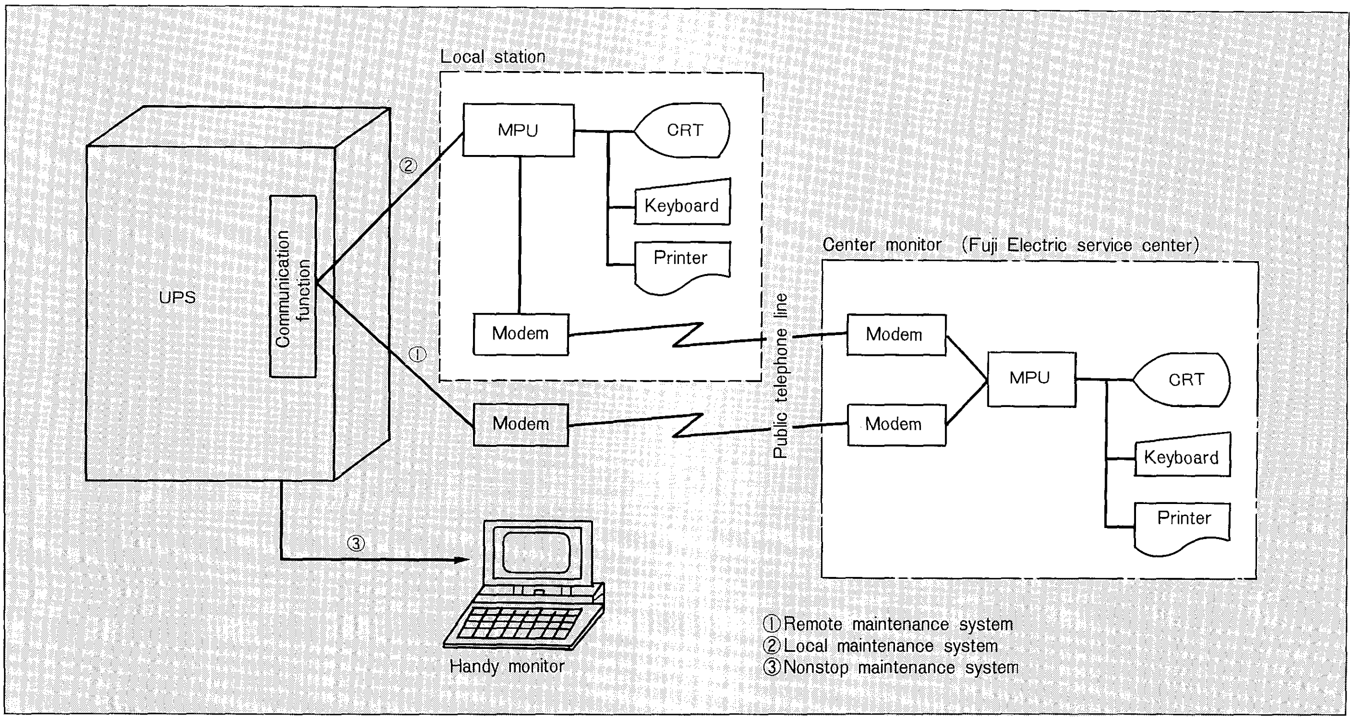
4.2.2 Oil filled transformer diagnosis expert system

This system inputs gas in oil analysis, ground bus current, ultrasonic emission, oil level, oil temperature, load current, and other data into an expert system and quickly diagnoses and forecasts transformer internal insulation deterioration, local overheating, and other abnormality indications.

4.2.3 Incoming voltage transforming expert system

The automatic power failure reset system and trouble recovery guidance system are typical examples of incoming voltage transforming expert systems at water and sewage works. Quick and positive operation in an emergency has been made possible by using these systems. An incoming voltage transforming automatic power failure resetting system is shown in **Fig. 7**.

Fig. 8 UPS remote maintenance system



4.3 Intelligent power supply facility

As facilities have becomes more efficient, more advanced, and more informationalized, more electronics applied devices have come into use. The supply of stable power to these devices is an important element from the standpoints of facility operation and management. Therefore, greater improvement of power supply facility reliability and maintenance support are indispensable. An example is introduced below.

4.3.1 Power generating facility maintenance expert system

An emergency private power generating facility is an important facility that supplies power when a power failure occurs. To maintain the engine related equipment, special technology and a grasp of the equipment inherent characteristics are necessary. The power generating facility maintenance expert system constantly maintains the power generating facility in the optimum state by means of data obtained during routine test operation for trouble prediction diagnosis and quick response to abnormalities.

4.3.2 IGBT type UPS and maintenance system

The use of data communication equipment in the electrical equipment of water and sewage works has increased. Therefore, the demand for a reliable UPS, which supplies power to these equipment, is increasing steadily.

The IGBT type UPS suitable for computer and other electronics applied equipment is outlined below.

(1) IGBT type UPS

An all IGBT type UPS, which uses an IGBT element at both the rectifier and inverter sides has been practicalized. As a result, (1) 50% to 80% smaller size and higher capacity than in the past, (2) 100% correspondence to computers and other rectifier loads, (3) improvement of the transient voltage fluctuation (±5% or less), (4) reduction of the input harmonic current (5% or less), (5) high input power factor (0.95 or greater), and (6) low noise (65dB A) were realized and a high performance product matched to the environment was obtained.

(2) UPS maintenance system

This system allows the collection of the measured waveform, operation and trouble status, and other data of each part during operation to improve reliability and make daily maintenance work more efficient and advanced, and to speed up recovery from trouble.

The maintenance systems are (1) remote maintenance system that uses a telephone line to monitor (at the Fuji Electric service center) the equipment remotely, (2) local maintenance system that monitors the equipment at a central monitoring room, etc., and (3) nonstop maintenance system that monitors the equipment with a handy monitor. The composition is shown in **Fig. 8**.

5. CONCLUSION

Intelligent electrical equipment for water and sewage works was outlined above. Many of these new systems have already been delivered and are operating. In the future, we will make development efforts toward improving reliability and productivity so that we can offer a total system that is simpler and easier to use.