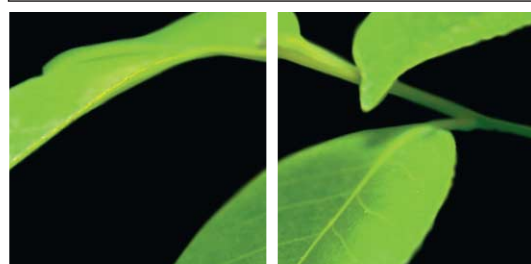


FUJI ELECTRIC REVIEW



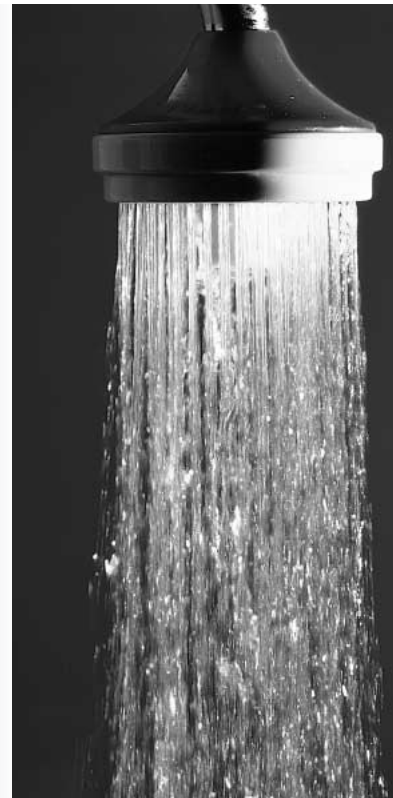
1999 VOL.45

Water Management Technologies



A New Age of Water Quality

Fuji Electric's water quality sensor and control technology is playing an active part from the water source to water taps.



Acute toxicants monitor



Coagulation sensor



High-sensitivity turbidity meter



Trihalomethane analyzer



Service quality monitor

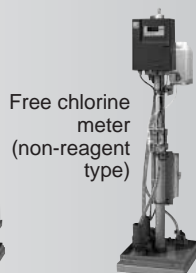
Aiming at reliable supply of safe and nice water, Fuji Electric keeps a sharp watch on water quality from the source to supply taps. Moreover, water quality is controlled by optimum chemical dosing using coagulation sensors and chlorine injection under fuzzy control taking various factors, such as a season, a time zone, and the amount of insolation, into consideration.



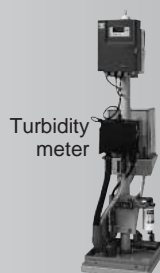
FAINS



Residual chlorine meter



Free chlorine meter (non-reagent type)



Turbidity meter



pH meter



Alkalinity meter



Conductivity meter

FUJI ELECTRIC EQUIPMENT for Water Analysis and Control Systems

FUJI ELECTRIC REVIEW

Water Management Technologies

4

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Cover Photo:

The beautiful Earth that brought up life and gave birth to mankind is now suffering from illness due to the consumption of a large quantity of resources and energy by mankind.

At this very moment, it is an urgent necessity for mankind to concentrate intelligence on the restoration of the beautiful Earth environment.

Fuji Electric as a comprehensive electrical manufacturer with ample experiences and technologies in the field of water treatment has supplied various products for water and sewerage systems to protect the global environment.

The cover photo shows an image of solution technology for water treatment with the material Earth irreplaceable to mankind superposed upon a background showing water, the source of life.

Trends and Future Prospects of Water and Sewage Treatment System Technology

Masakazu Usui
Iwao Matsunaga

1. Introduction

Since developing the first computer control system for waterworks and sewage treatment plants in Japan 30 years ago, Fuji Electric has done much to develop new technologies and put them to practical use to meet the diversified, sophisticated needs of the water treatment market.

Water and sewerage system technologies have faced social problems and subsequent regulation, but these have acted as driving forces for technical development and have resulted in progress in the technologies.

Fuji Electric has developed many systems that were firsts in Japan, for example: water distribution control with demand prediction, development of a numerical formula for the activated sludge process for sewage, practical application of fuzzy control to water quality control, installation of optical fibers in sewers, and use of multimedia communications.

Environments surrounding the water system have greatly changed. The development of new water resources has been difficult and the problem of water quality has been complicated and diversified. A higher level of quality and quantity than before is required for the water system to fulfill its social responsibility.

As for the sewerage system, with the rising level of servicing, such as sewage being regarded as an important component factor in the circulation of water, and with social changes, the role to be played by the sewerage system has become more diversified and sophisticated.

The trends and future prospects of water and sewerage system technology are described below.

2. Trends and Future Prospects of Water and Sewerage System Technology

In water and sewerage systems, facilities scattered over a wide area are connected by water channels and conduits. These facilities influence each other while implementing an overall function.

Therefore, the proper control of water quantity, quality, and pressure is important. In water systems,

there occur changes in source water quality and in service water demand. In sewerage systems, changes in treatment quantity and drainage quality due to rainwater inflow and abnormalities (water shortages, typhoons, conduit damages, and equipment failures) may occur. It is the responsibility of these systems to attain and maintain high-level service while coping with these various changing conditions.

To attain this purpose, a system that can gather the necessary information for management and control facilities in a centralized manner is indispensable.

Water and sewerage system technology must satisfy these requirements and can fulfill its functions by integrating component technologies for electric, instrumentation, computer, and mechanical systems.

2.1 Open monitor and control systems

The rapid spread of personal computers has made data processing technology popular, and created demand for end user computing such that users could freely collect data from monitor and control systems, store that data in their personal computer and utilize that data in various formats.

However, this demand was contradictory because it required that manufacturers guarantee monitor and control systems even if those systems were modified by users.

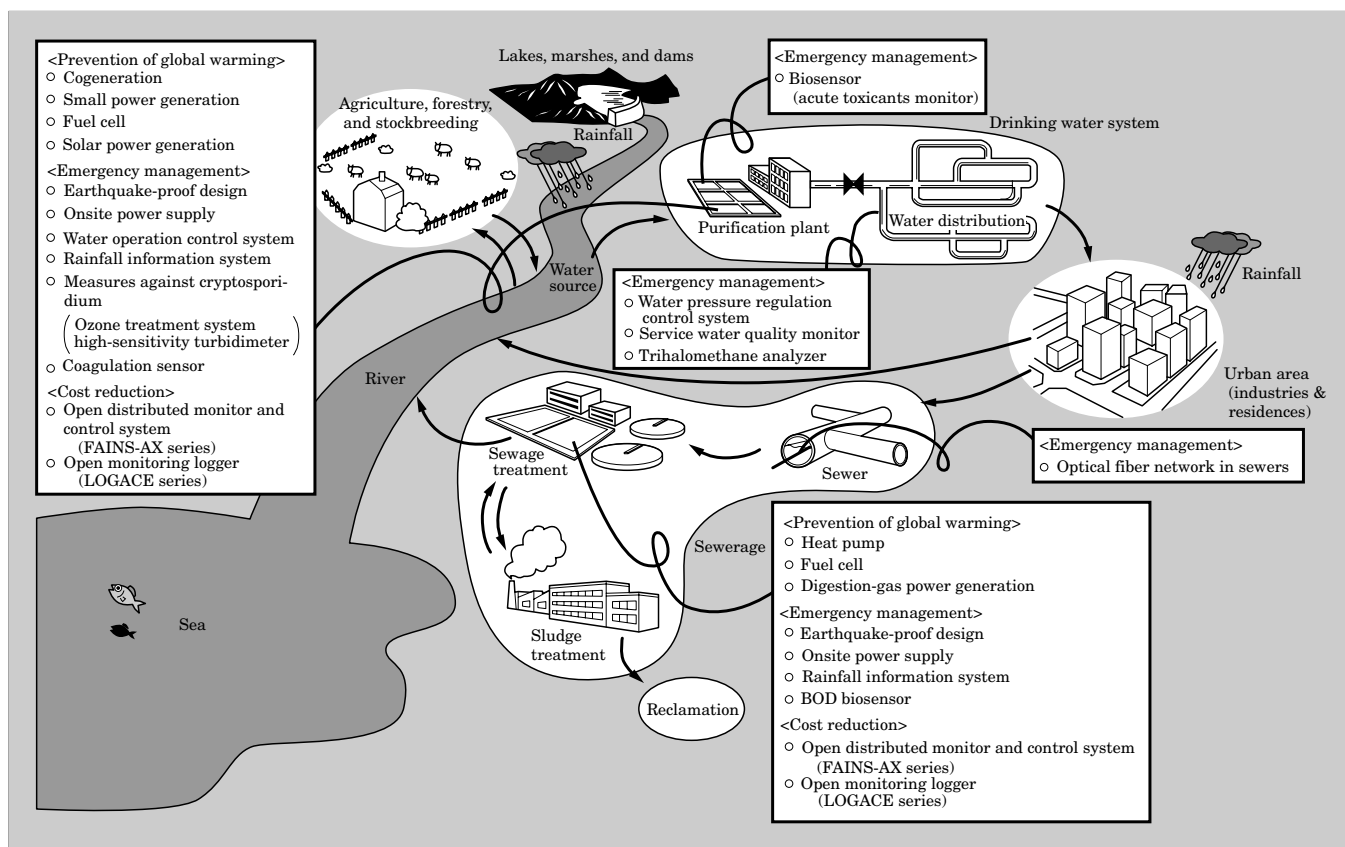
Open systems were created in response to this contradictory demand. Fuji Electric developed the FAINS-AX series of new open distributed monitor and control systems and the LOGACE series of open monitoring loggers.

These series combined Fuji Electric's reliable special-purpose technology with its widely used general-purpose technology, making it possible to offer systems suited to user requirements at a reasonable cost.

2.2 Data transmission, control technology and solutions

To efficiently manage sewerage operations, utilities have recently planned and implemented unmanned pumping plants as well as integrated management systems for entire sewerage systems using optical fiber networks and built in sewer conduits that connect sewerage system facilities with each other.

Fig.1 Solution technologies for water environment



Regarding the plans of optical fiber networks for sewerage systems, based on LAN and optical transmission technologies, Fuji Electric will expand the application range into the remote control of emergency facilities and remote maintenance systems to realize preventive maintenance. Thus, we will offer solution technologies to realize all utility processes from construction to maintenance at a minimum cost.

Figure 1 shows Fuji Electric's solution technologies for water environments. Solution technologies are not limited to the field of communications and control. For example, in the case of installation of an onsite power supply system aiming at global warming prevention and emergency management at an optimized cost, the introduction of a fuel cell system is a solution technology.

The cost optimization of water and sewerage operations can not be attained only by reducing construction expenditures. The cost is closely related to expenses for maintaining facilities and the life of the facilities. That is to say, consideration of the lifecycle cost is very important, and it is necessary to build a system with optimum value using the value engineering (VE) method. Solution technology is attracting attention as it is expected to play an important role.

2.3 Technologies against disasters

Most suspensions of the water supply due to earthquakes or other disasters are the result of "point" damages caused by broken water pipe joints, resulting

in "area" damages downstream.

Divisional water distribution and a water pressure regulation system are effective measures against suspension of the water supply because "areas" are made small and easy to control. These methods have more effect when the exchange of water between divisions is taken into consideration. Fuji Electric, with a good record of accomplishment for supplying these systems, has realized stable water pressure regulation and has improved the efficiency of water supply by the early detection of leakage.

Fuji Electric has introduced to the market many systems for coping with disasters, for example: portable water supply systems utilizing membrane treatments, emergency generators, sensors and communication apparatus with onsite solar cell power supplies, preventive maintenance utilizing artificial intelligence and statistic processing, apparatus diagnosis equipment, and remote maintenance systems using ISDN. As a system vendor, Fuji Electric has tackled many equipment-related problems, including the earthquake-proof design of equipment.

3. Contribution to Prevention of Global Warming

It is no exaggeration to say that the prevention of global warming is technically attributable to the problem of energy. Basically, it is necessary to meet the increasing demand by improving the demand

structure (equalization of loads) without increasing the total generated electric energy. This is one important measure to realize so-called zero emission (reduction of the load due to human work on the global environment to approximately zero).

Fuji Electric established "Fuji Electric's basic policy on environmental preservation" in 1992 and has pioneered technical development for problems of the global environment.

3.1 Activities for zero emission in water systems

Recently, unused energy and wide areas within water facilities have attracted attention.

Tubular and Francis water turbines are used for hydraulic power generation, utilizing the effective head of water flow from reservoirs to purification plants. Fuji Electric has supplied many small hydraulic power plants so far.

Through adoption of a cogeneration system that utilizes exhaust heat, gas-turbine power generation raises total efficiency and is a superior energy-saving system. Fuji Electric, the first company to supply such a system in the field of water and sewerage systems, delivered a gas-turbine power system to the Higashi-Murayama Purification Plant of the Tokyo Waterworks Bureau.

Purification plants and water stations have wide-open spaces and hold promise for solar power generation. Because the energy demand for water systems is greater during the daytime than at night, solar power generation is advantageous. On the other hand, solar power is dependent upon the weather, and therefore, interconnection with utility power supply or the addition of a storage battery is necessary. Fuji Electric is aggressively making efforts to apply solar power generation to water and sewerage systems.

These onsite power systems are closely related not only to energy problems but also to emergency management. They must be considered as a lifeline in case of a disaster such as an earthquake.

3.2 Activities for zero emission in sewerage systems

The temperature of water from sewage treatment fluctuates within a small range between 8 and 13°C. This small range is characteristic of a stable heat source little influenced by climate.

An abundance of low-level energy has been discharged into the water during sewage treatment. However, technology for the efficient utilization of this low-level energy had not been available until recently, and this energy had been referred to as "unused energy." Recently, the appearance of heat pumps with high thermal efficiency has enabled the utilization of low-level energy.

Digestive gas produced in the process of sludge treatment has nearly the same degree of energy as urban gas. Highly efficient operation can be obtained from gas-turbine power generation using digestion gas

as fuel and the heat recovered from a cogeneration system utilizing the gas-turbine exhaust heat. Fuel-cell power generation using digestion gas as fuel is also possible.

Fuel cells have higher power generation efficiency than conventional gas turbines and diesel engines, and fuel-cell power generation combined with the utilization of its exhaust heat can increase the total efficiency to 70 to 80%. Nitrogen oxides in the exhaust gas are as low as several ppm and the fuel cell is an excellent energy source. Fuji Electric has marketed fuel cells, focusing on onsite phosphoric acid fuel cells.

4. Coping with Water Quality Problems

A recent buzzword regarding water systems has been "safety" and people have displayed strong concern for the removal or reduction of pathogenic microbes and harmful substances in raw water and of disinfection byproducts in service water.

Early on, Fuji Electric started development of various water quality analyzers to monitor water system safety and has prepared a line of new water quality analyzers for analysis ranging from raw water to tap water. These analyzers highly integrate chemical, optical, and biological technologies with the physical detection mechanisms used by most of the present sensors, and have a high level of performance equivalent or superior that of the precise analyzers equipped in water quality test rooms.

4.1 Trihalomethane detection and reduction technologies

To solve the problem of carcinogenic trihalomethane currently receiving much attention, it is necessary to continuously monitor the amount generated and increase of trihalomethane in service water and implement measures to reduce the concentration below the permissible limit.

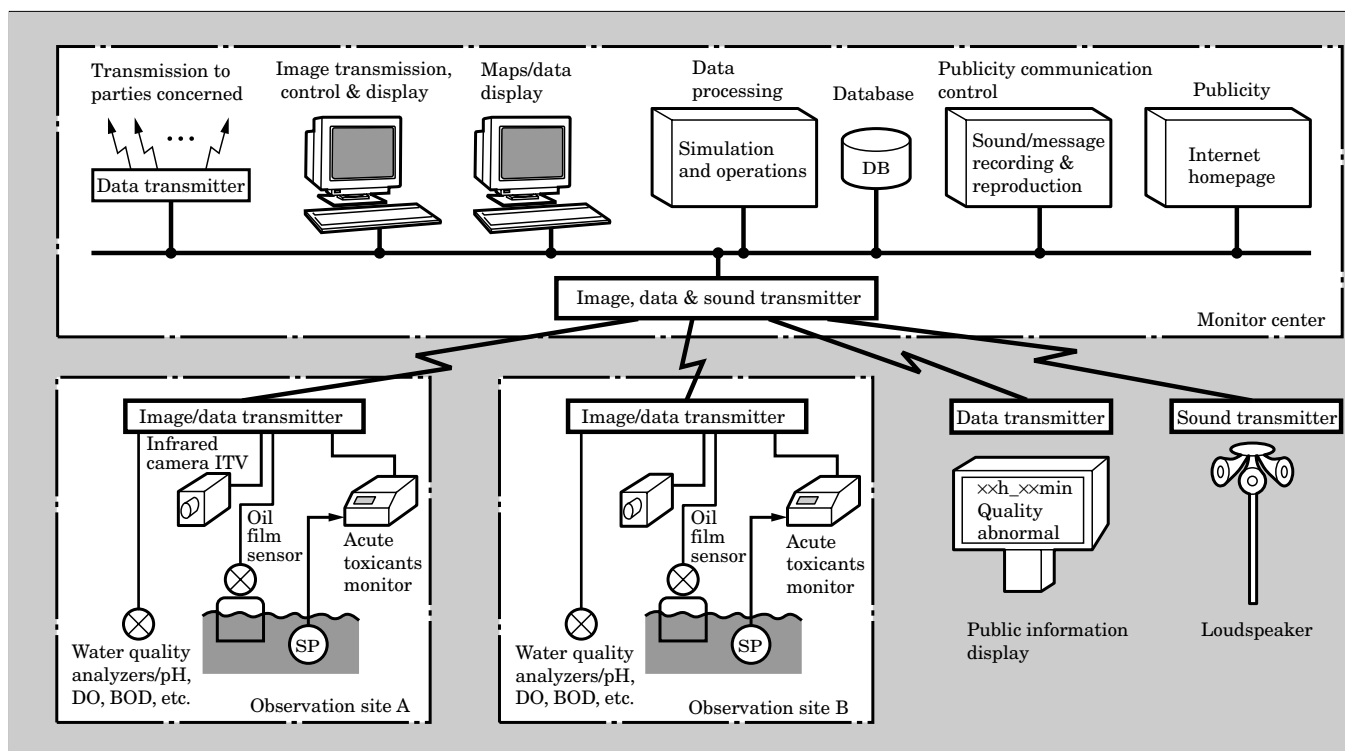
Biodegradation-resistant organic matter such as humic acid and fulvic acid in river water is disinfected by chlorine in the purification or sewage treatment plant. This process forms trihalomethane as a disinfection byproduct.

Fuji Electric developed a trihalomethane analyzer capable of continuous measurement of trihalomethane values in the purification and distribution processes of water systems, a simulation system for predicting increases in trihalomethane formation, and a management system based on both of the above to reduce trihalomethane. These plant solutions can be realized only by integrating sensor, computer, and communications technologies, and Fuji Electric is the only company in the world that possesses this original technology.

4.2 Sensor technology and river water quality management system

When there is a sudden abnormal change in water quality, it is important to detect that abnormality as

Fig.2 Block diagram for a wide-area water quality management system



soon as possible, determine measures to be taken based on the abnormality conditions, and implement those measures promptly. ITV monitoring of the intake and 24-hour observation by the staff of the behavior of fish bred in a water tank have conventionally been performed at water supply utilities as a means of self-protection. However, monitoring by the staff for an abnormality that may or may not occur at an unknown time is unreliable and uneconomical, and in particular, any reduction in night workers is a serious problem for the utilities. Therefore, there is strong demand for automated detection of water quality abnormalities. As abnormality occurrence has spread over a wider area, the necessity for detecting pollution in the total water system and communicating it to parties concerned has increased. In addition, the need to provide decision criteria for the implementation of countermeasures has increased the necessity of river-water quality management systems. Fuji Electric has supplied river-water quality management systems composed of various water quality abnormality detection sensors, data and picture transmission equipment, various displays, database equipment, and public information and communication equipment. Figure 2 shows the system configuration.

4.3 Development of bioassay

Generally, the method of using biological material and evaluating the biological response of an organism to a substance is called a bioassay.

The bioassay is a very effective method for the "evaluation of water toxicity to organisms," "primary

screening of toxic substances" and "evaluation of the effect of water treatment," and has already been applied to drainage regulation and risk assessment in Europe and the USA. We suppose that its importance as a new method of water quality evaluation will increase also in Japan, adding to the conventional methods.

Fuji Electric will construct a database of biosensor sensitivity using microbes for various toxic substances and will also develop a higher sensitivity bioassay that can detect harmful chemical substances with concentrations as low as the chronic toxicity level. With this, we will establish a method for evaluating the influence of chronic toxicity from extremely small amounts of substances contained in drinking water.

5. Conclusion

Water and sewerage operations have a close relation with regional and residential environments, and at the same time, have a social responsibility. In addition, utilities are required to quickly respond to social changes and needs.

Fuji Electric will continue its contribution into the 21st century to the development of water and sewerage systems with the control and system technologies for water treatment plants, developed in anticipation of social needs.

In issuing this special edition, we would like to express our gratitude to the individuals and organization of the water and sewerage industry, and will be grateful for your guidance and support in the future.

Modern Electrical Technology for Water Treatment Plants

Yoshinori Nagakura
Masayoshi Tokuhiro
Kouji Akiyama

1. Introduction

Global environmental problems such as global warming and acid rain originate from carbon dioxide and nitrogen oxide, which are generated mostly from the energy consumption of fossil fuels. To solve these problems there are two methods, one is to restrict the consumption of fossil fuels and change to clean energy, and the other is to reduce energy consumption itself.

This paper will introduce:

- (1) New energy technology and
 - (2) Energy saving technology
- available for the above-mentioned methods in water treatment facilities, and
- (3) Recent initial electric power receiving, transforming and powering equipment and their applications
- that support the above technologies.

2. New Energy in Water Treatment Plants

Most of the energy consumption in waterworks and sewerage facilities is electric power consumption. To reduce the power consumption it is effective to accelerate application of dispersed power generation of new energy.

As alternative energy sources to fossil fuels, there exists solar energy, hydraulic power energy, wind force energy and biogas (sludge digestion gas). A comparison of the CO₂ emission corresponding to each of the power generation systems is shown in Fig. 1.

2.1 Photovoltaic power generation system

It is said that the amount of solar energy irradiated upon the surface of the earth for only 40 minutes can supply the energy consumed by mankind in one year. However, it is difficult to use this energy steadily

Fig.1 Comparison of power generation systems and CO₂ emission

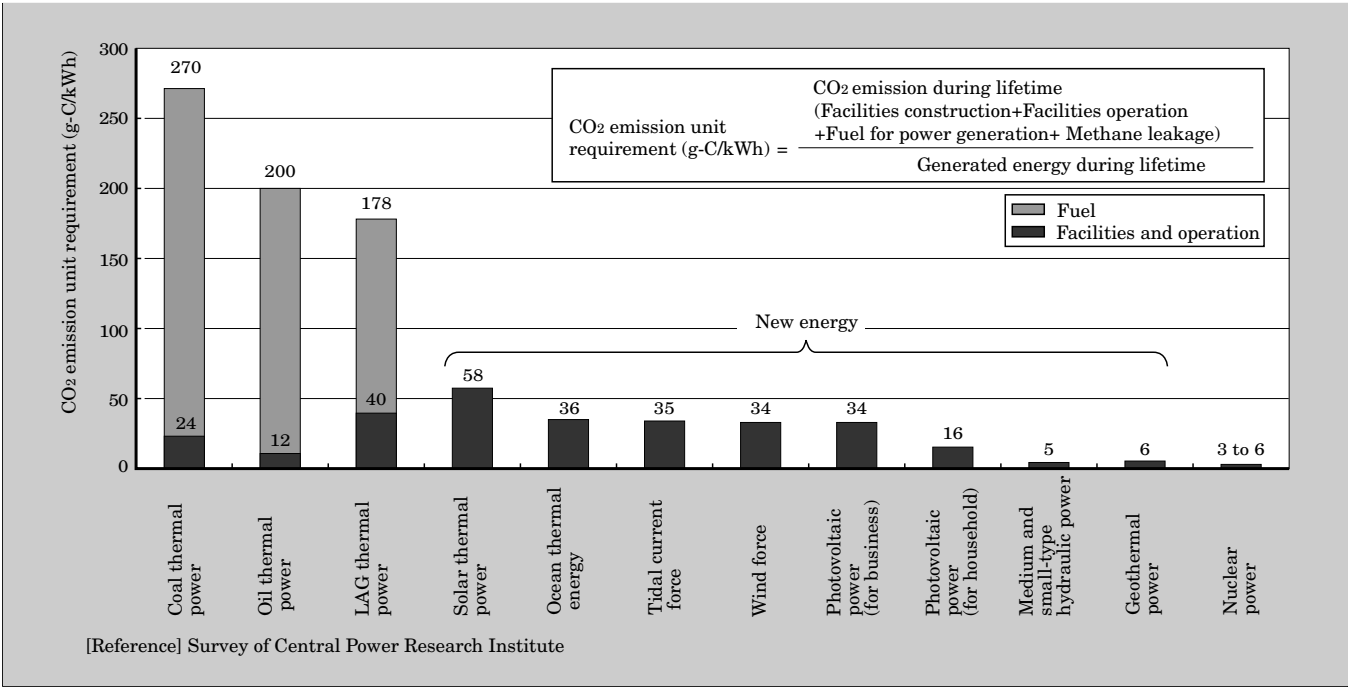


Fig.2 Basic configuration of photovoltaic power generation system

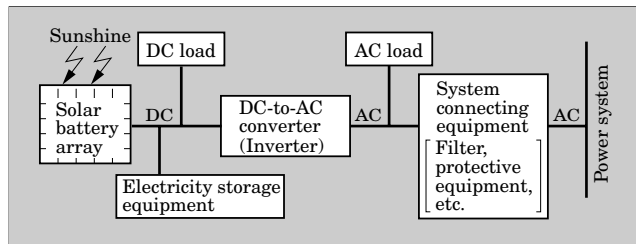


Table 1 Proposed applications of photovoltaic power generation systems to waterworks and sewerage

Features of waterworks and sewerage	Installation location of solar battery	Applied photovoltaic power generation system
Available upper space is wide.	<ul style="list-style-type: none"> ○ Upper space of water filtration basin, filter bed ○ Upper space of first sedimentation, last sedimentation and aeration tank [Cover] ○ Roof of facilities house 	<ul style="list-style-type: none"> ○ Medium and large capacity facilities ○ Connected to commercial power system (usually without storage battery)
Some facilities such as a service reservoir are located among mountains.	<ul style="list-style-type: none"> ○ Roof of facilities house ○ Special mounting frame (such as a pole) 	<ul style="list-style-type: none"> ○ Small capacity facilities ○ Connected to commercial power system (Storage battery is used in case of power outage)
Detection elements for pressure, flow rate, water quality are scattered.		

because its density is low and the quantity of power generation depends on seasonal and meteorological conditions such as sunlight and the weather. On the other hand, solar energy generates no atmospheric pollutants and no noise that can lead to disruption of the earth's environment. Solar energy is a clean and quiet energy source that can be utilized anywhere on the earth. The basic configuration of a photovoltaic power generation system is shown in Fig. 2.

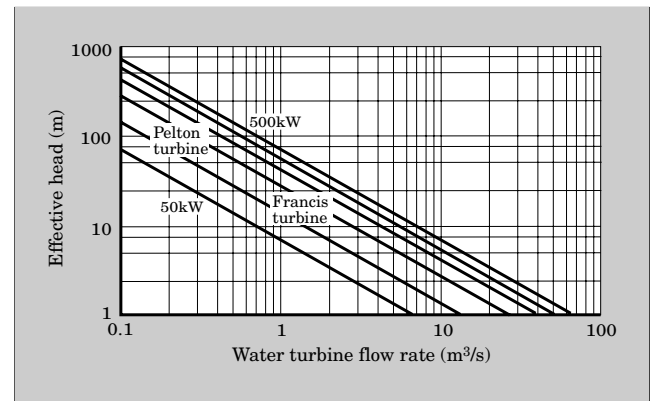
2.1.1 Principle of power generation

A solar battery is configured with pn-junction structure, joining a p-type semiconductor with an n-type semiconductor, and a pair of electrodes for extracting electricity. When light is irradiated upon the junction, electrons (negative charge) and holes (positive charge) are generated by the photoelectric effect, and their movement creates an electromotive force between the electrodes.

2.1.2 Application to water treatment plants

Because there is much available space at the upper part of water treatment facilities, such as at a water service reservoir, and the energy consumption pattern of water treatment is similar to the irradiation pattern

Fig.3 Applicability of water turbine



of solar energy, water treatment plants are highly adaptable to energy applications. The main system applications are listed below.

- (1) A system linked to the electric power system
- (2) A system that independently operates as dispersed power generation using a storage battery
- (3) A system in which wind force power generation, small-type hydraulic power generation, etc. are used in combination.

Proposed applications to a waterworks plant are shown in Table 1.

2.2 Small-type hydraulic power generation system

This system converts the kinetic energy of water into electricity, and the quantity of power generation is determined by the head and flow rate of the water. The advantages are listed below.

- (1) The construction is simple and compact in comparison with other power generation systems.
- (2) Power generation is practical if the water has a head and flow rate.
- (3) Maintenance is unnecessary.
- (4) Among power generation methods, hydraulic power has the lowest emission of carbon dioxide.

2.2.1 Applicability of small-type hydraulic power generation

Fuji Electric provides a series of models widely applicable for power generation with generated outputs ranging from 50kW to several thousand kW. Figure 3 shows a graph of power generation quantity related to the effective head and flow rate. For example, a head of 10m with a flow rate of 42m³/min allows a generated power of 50kW.

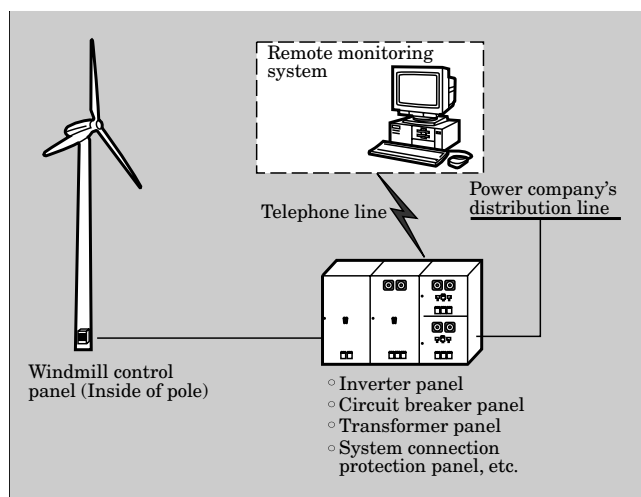
2.2.2 Application to water treatment plants

Hydraulic systems can be employed in water conduction and distribution systems of waterworks and in water discharge systems of sewerage systems. Hydraulic systems are highly adaptable to water treatment plants because the variation in quantity of both the conduction water and the distribution water is similar to that of the electric load in water treatment plants.

Table 2 Supply list of wind power generation facilities

Year delivered	Customer name	End-user name	Specifications			Note
			Capacity	Windmill/generator manufacturer	System connecting equipment mfr.	
1993	Toyo Engineering Co.	Yamagata Prefecture Tachikawa Town	1000kW × 3	US Wind Power	Fuji Electric	
1994	Power Development Co.	Wakamatsu Thermal Power Station	22kW	Isobe Steel Co. (Darius type windmill)	Fuji Electric	
1997	NTT Facilities Co.	NTT Kumejima Radio Relay Station	225kW × 1	Ebara Works	Fuji Electric	
1997	Tohoku Electric Power Co.	Megawa Nuclear Power Station PR Center	Wind: 17.5kW Solar: 3kW	Yamaha Motors Co. Fuji Electric	Fuji Electric	Hybrid system of wind and solar power
1999 (planned)	Shikoku Electric Power Engineering Co.	Tohmen Co. Hokkaido Tomamae Wind Park	1000kW × 20	BONUS	Fuji Electric	

Fig.4 Configuration of wind power generation system



2.3 Wind power generation system

This power generation system utilizes wind energy. The advantages are listed below.

- (1) There is no emission of air pollutants.
- (2) Large-capacity power generation is possible.
- (3) Installation is practical if there is an average wind speed of greater than 6 m/s.

Factors to be considered when determining the installation location are listed below.

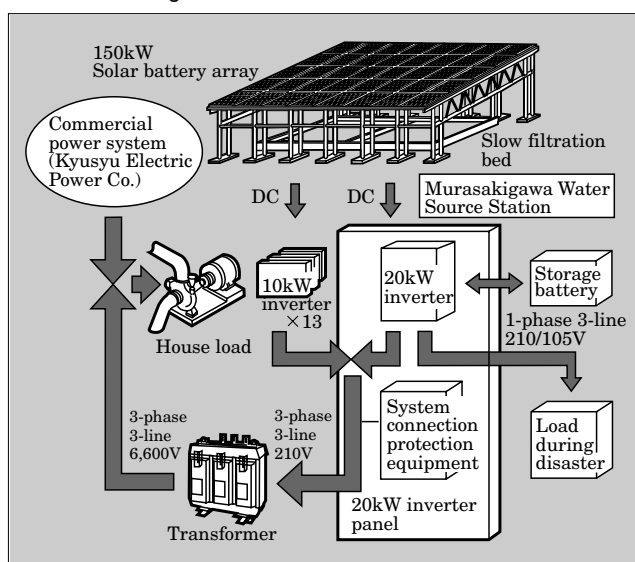
- (1) There are no obstructions in the surrounding neighborhood that would create turbulence in the wind flow. A laminar flow is best if possible.
- (2) There is no radio wave interference such as microwave, radiotelegraphy and televisions signals in the neighborhood.

The system configuration is shown in Fig. 4, and a list of customers to whom systems have been delivered is shown in Table 2.

2.4 Biogas utilizing power generation system

Biogas systems include fuel cell and digestion gas

Fig.5 Overview of photovoltaic power generation system in Murasakigawa Water Source Station



power generation that use biogas (digestion gas generated in the sewerage plant) as the fuel. The fuel cell has the following advantages.

- (1) Efficient high power generation.
- (2) Constituents of the discharged gas are clean (NOx: below 5ppm, CO₂: 60 to 70% of conventional generators).
- (3) The overall efficiency reaches 80% by utilizing the heat generated from the process of its electrochemical reactions.

2.5 Application of new energy systems to water treatment plants

Applications of new energy systems to water treatment plants are introduced below.

2.5.1 Application of photovoltaic power generation system

- (1) Delivery example to the Murasakigawa Water Source Station of the Waterworks Bureau of Kita-Kyusyu City

Fig.6 System configuration of photovoltaic power generation equipment in Ogochi Reservoir

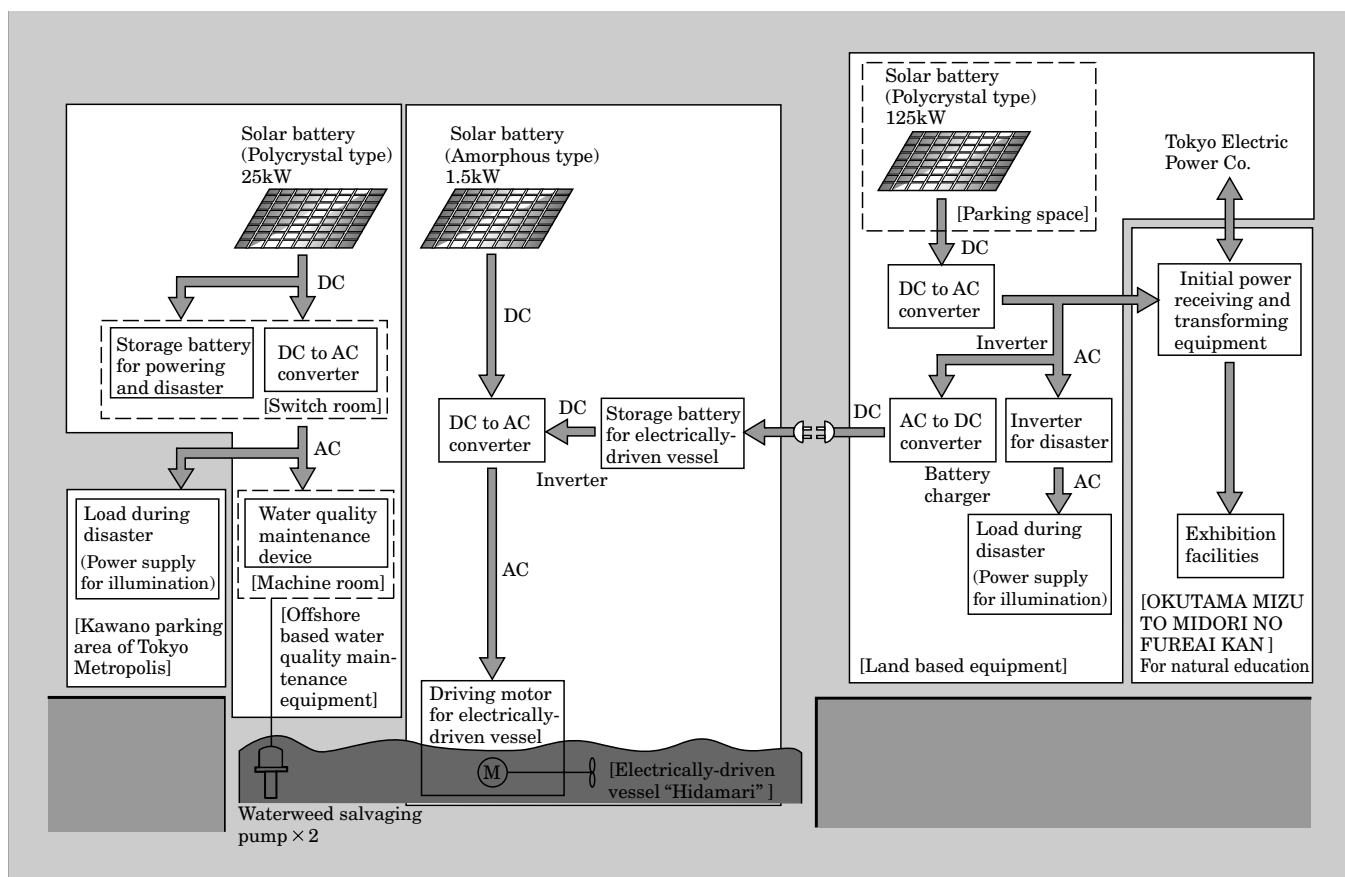


Fig.7 Appearance of vessel for conveying salvaged waterweed



A7530-19-19

In this system, a 150kW solar battery array is installed at the upper side of the slow filtration bed, and DC electric power generated from the solar battery is converted to AC with an inverter and used as a power source after being connected to the initial electric power receiving and transforming equipment. An overview of the power source system is shown in Fig. 5. When a commercial power source is shut down, because of its self-sustaining function with a 20kW

inverter and a storage battery, the system can be used as an emergency power source. Growth of waterweeds in the slow filtration bed is prevented by the covering effect of the solar battery array.

(2) Delivery example to the Ogochi Reservoir of the Tokyo Metropolitan Waterworks Bureau

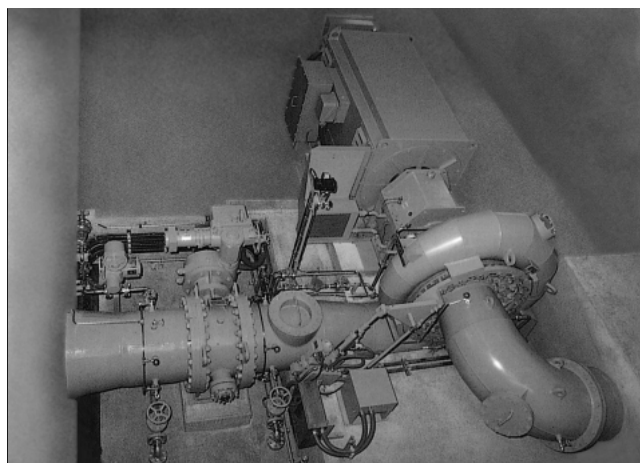
The reservoir covers a vast area of a lake and is suitable for the installation of a large-scale photovoltaic power plant. It is believed that the growth of waterweeds due to water inflows into lakes, marshes and dams may influence the water quality. A system that operates on energy obtained from photovoltaic power generation and maintains the water quality by salvaging the waterweed, has been delivered to the Ogochi Reservoir. The system configuration is shown in Fig. 6 and the appearance is shown in Fig. 7.

The generated outputs are 125kW from the land-based equipment, 25kW from the offshore equipment and 1.5kW from the electrically driven vessel. Each piece of equipment is used jointly with a storage battery to implement a hybrid system for disasters and emergencies.

2.5.2 Application of small-type hydraulic power generation systems

As application examples there are several plants of various capacity from the 20kW micro-hydraulic turbine generator for the Tainai River of Niigata Prefec-

Fig.8 840kW horizontal shaft Francis turbine hydraulic generator for Ken'o 1st Waterworks of Gumma Prefecture



ture to the 840kW horizontal axis Francis turbine hydraulic generator (Fig.8) for the Ken'o 1st Waterworks of Gumma Prefecture.

The historical annually generated energy of the power plant delivered to the Ken'o 1st Waterworks of Gumma Prefecture is 6,303MWh (an average output of 755kW) and the utilization factor is high.

In a small-type hydraulic power plant, now under construction at the Higashi-Murayama Water Purification Plant of the Tokyo Metropolitan Waterworks Bureau, an S-type tubular turbine is to be installed in the existing conduit, and the power plant is to operate while connected to the power system of an electric power company.

The generator will output a rated power of 1,400kW and feed approximately 90% of the usual power demand in the plant by parallel operation of 2 sets of 2,000kW co-generating equipment. It is also planned to use this system as an emergency power source during service outages of the electric power company.

2.5.3 Application of biogas utilizing power generation systems

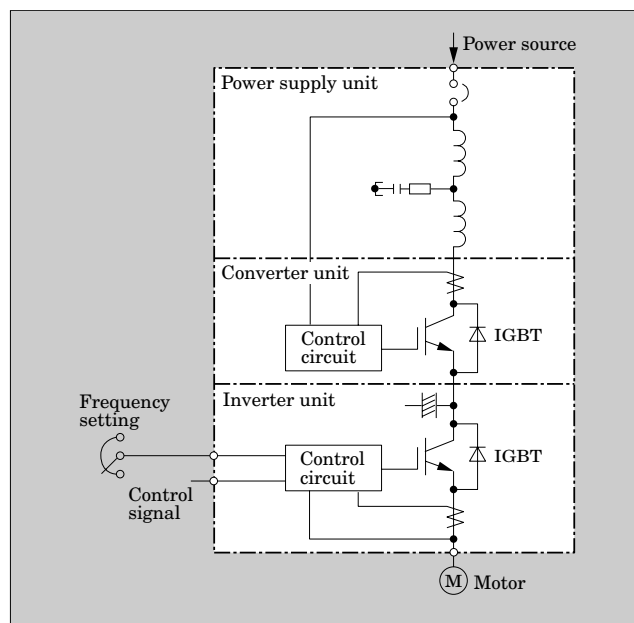
A system among water treatment plants generates electricity by using the digestion gas originated in the sewage treatment plant as fuel. There is also a system that produces sodium hypochlorite by using the DC electric power generated from a fuel cell directly for the electrolysis of salt water.

3. Energy Saving Technology in Water Treatment Plants

3.1 Variable speed control system

Pump or blower motors consume most of the electric power in water treatment plants. Therefore, energy saving by these motors allows the whole plant to effectively conserve energy. Usually the pumps and blowers are manufactured at a rated capacity accord-

Fig.9 Circuit configuration of VVVF with harmonic restrained PWM converter



ing to the rated water (or gas) volume.

However, the pumps and blowers are often driven at less than their rated values. As a result, conventional operation by driving at a fixed speed will restrain the flow rate of discharge valves, etc. and thus some energy will be lost in the discharge unit.

On the contrary, unnecessary energy consumption can be limited if the motor is driven with variable speeds.

The primary frequency control system (VVVF: Variable Voltage Variable Frequency) and the secondary excitation control system (Scherbius), variable speed control systems used for energy saving in many water treatment plants, are introduced in the following.

3.1.1 VVVF with harmonic restrained PWM (pulse width modulation) converter

In this system, the converter unit of a variable speed controller (VVVF) used for driving 3-phase 200V and 3-phase 400V squirrel-cage induction motors is modified to the PWM type (sine wave input type). The advantages of this system are listed below.

Figure 9 shows the circuit configuration.

- (1) Countermeasures against harmonics are unnecessary

Because the current at the power source side is made into a sine waveform by the PWM control, few harmonics are generated.

- (2) Miniaturization is possible

Because the power factor control creates a current flow that is in-phase with the source phase voltage, driving at a power factor of approximately 1 becomes possible, and thus the power transformer and other apparatus can be miniaturized.

Fig.10 Circuit configuration of harmonic restrained PWM Scherbius

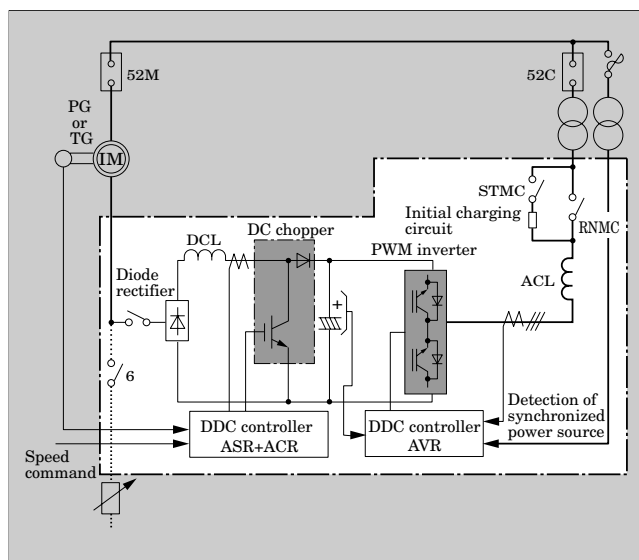
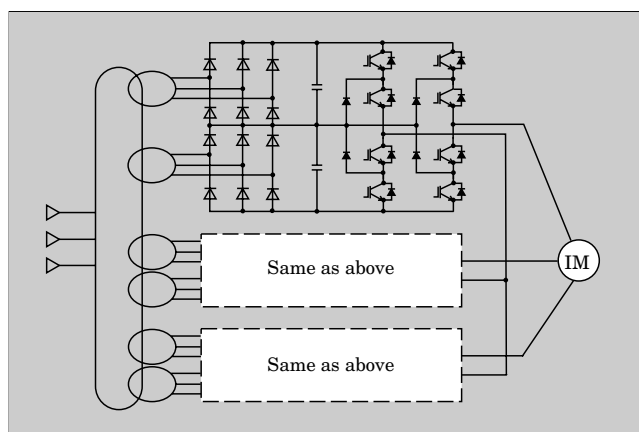


Fig.11 Circuit configuration of high-voltage directly driving VVVF



(3) Maintenance is easy

The intelligent functions allow easy referencing of fault histories, thereby simplifying the maintenance.

3.1.2 Harmonic restrained PWM Scherbius

The Scherbius system controls the speed of a high-voltage wound-rotor-type motor by returning its secondary power to the power source through an inverter. Because a PWM inverter is employed instead of the usual thyristor inverter, this system has the following advantages. The circuit configuration is shown in Fig. 10.

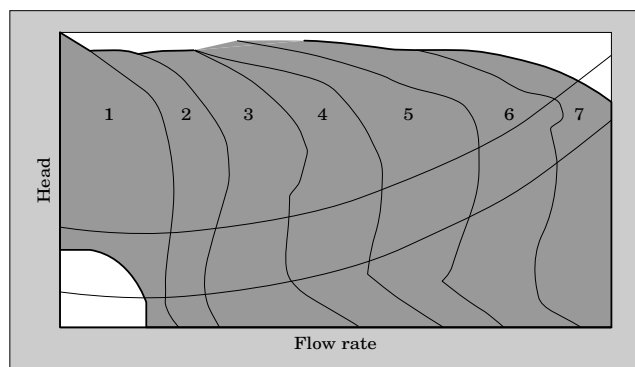
(1) Countermeasures against harmonics are unnecessary

Control at a power factor of approximately 1 is possible, and the percentage of harmonic components can be limited to less than 5%, too.

(2) Operating efficiency is high

Compared with the VVVF, the equipment capacity

Fig.12 Ideal operation region for high-efficiency number of pumps



of the inverter is approximately 2/3, the efficiency of the wound-rotor-type motor is higher than that of the squirrel-cage type, and thus the running efficiency is higher by about 2 to 3%.

3.1.3 High-voltage direct drive VVVF

This system directly controls the speed of a high-voltage induction motor from a high source voltage using high-voltage diodes and high-voltage IGBT elements. The advantages are as follows. The circuit configuration is shown in Fig. 11.

(1) High-voltage motor is directly driven

A 3kV high-voltage motor can be directly driven from a high source voltage. (A 6kV system will be soon introduced to the marketplace.)

(2) Miniaturization is possible

A step-up transformer becomes unnecessary, and miniaturization and improved reliability are achieved.

(3) Countermeasures against harmonics are unnecessary

Adoption of a multiphase diode rectifying system (3 × 12-phase rectification) eliminates the necessity for countermeasures against harmonics.

(4) Extended-life and reduced noise of the motor are realized

Stress to the motor is reduced, because the output current waveform becomes almost a sine wave through employment of PWM control.

(5) Maintenance is easy


Operations and failure diagnosis can be easily carried out by the intelligent functions.

3.2 Energy saving control

The usual energy saving operation of pumps is implemented using a combination of the “number of pumps” control and the “variable speed” control corresponding to increases or decreases of the flow rate and level of water. The resulting energy saving effect is approximately 20%.

As methods to increase the energy saving effect even more, two systems will be introduced here. One is the high-efficiency number of pumps control system, in which a pump head is used as the criteria to

Table 3 Main energy saving apparatus in water treatment plant

Classification	Apparatus name	Summary	Application	Effect	Misc.
Power equipment	Active filter	<ul style="list-style-type: none"> ○ Restricts loss and influence due to harmonics, such as overheat, noise, vibration ○ Compensates reactive power 	<ul style="list-style-type: none"> ○ Harmonics generating apparatus such as variable speed controllers, non-interrupting power supplies, rectifiers 	<ul style="list-style-type: none"> ○ Restricts overcurrent due to harmonics ○ Reduces power charge by improved power factor 	
	Demand controller	<ul style="list-style-type: none"> ○ Supervises control of contract demand 	<ul style="list-style-type: none"> ○ Receiving point power demand 	<ul style="list-style-type: none"> ○ Reduces contract demand ○ Prevents excessive contract demand 	
	Automatic power factor regulator	<ul style="list-style-type: none"> ○ Reduces ohmic loss due to reactive power 	<ul style="list-style-type: none"> ○ Compensation of transformer excitation ○ Induction motor 	<ul style="list-style-type: none"> ○ Reduces power charge ○ Reduces power loss 	<ul style="list-style-type: none"> ○ Reduced voltage drop and increased capacity factor.
	Molded transformer	<ul style="list-style-type: none"> ○ Extensively reduces loss by core material and mold technology 	<ul style="list-style-type: none"> ○ Initial power receiving and transforming equipment, powering equipment, illumination equipment 	<ul style="list-style-type: none"> ○ Compared with usual dry type, no load loss is reduced by approx. 2/3 and load loss by 1/2 to 2/3. 	<ul style="list-style-type: none"> ○ Changeover operation of working number of units ○ Operation at highest efficiency
Pumping equipment	Variable speed controller VVVF	<ul style="list-style-type: none"> ○ Realizes high-efficiency operation by changing frequency and voltage 	<ul style="list-style-type: none"> ○ General-use type squirrel-cage induction motor ranging from 0.2kW to 900kW 	<ul style="list-style-type: none"> ○ Reduces approx. 65% of loss at 70% speed 	
	Thyristor Scherbius	<ul style="list-style-type: none"> ○ Realizes high-efficiency operation by returning secondary slip power to power source 	<ul style="list-style-type: none"> ○ Wound-rotor type induction motor from approx. 100kW to 5,000kW 		
	High-efficiency motor	<ul style="list-style-type: none"> ○ Achieves high-efficiency by using latest design and low-loss material 	<ul style="list-style-type: none"> ○ Induction motor 	<ul style="list-style-type: none"> ○ Maintains high-efficiency at light load (above 50%) 	
Illumination equipment	Power saving device	<ul style="list-style-type: none"> ○ Saves excessive power by restraining excessive voltage to appropriate value 	<ul style="list-style-type: none"> ○ Low voltage powering and illuminating equipment 	<ul style="list-style-type: none"> ○ Reduces working power by 10 to 20% 	<ul style="list-style-type: none"> ○ Apparatus lifetime is expected to increase also
Miscellaneous	Reduced stand-by power	<ul style="list-style-type: none"> ○ Applies Energy Star logo to energy-saving apparatus, according to International Energy Star Program 	<ul style="list-style-type: none"> ○ Computer, display device, printer, facsimile, copy machine 	<ul style="list-style-type: none"> ○ Widely used by most of OA devices 	Logo 

determine whether the number of pumps should be changed. The other is the efficiency-increasing (equalizing) pump driving system, which uses the water supply quantity determined based on predicted demand.

3.2.1 High-efficiency number of pumps control system

Energy saving for the whole plant is attempted by driving the number of pumps that will result in the greatest saving of electric power.

The electric power P_m at the time when m pumps operate to supply water at the flow rate Q and head H is calculated and compared with the electric power at the time when $(m+1)$ and $(m-1)$ pumps run. Then if the value of least power is chosen as the number of driving pumps, operation with the greatest power savings can be achieved.

As shown in Fig. 12, the region corresponding to the number of ideal driving pumps is established in advance, and the number of pumps can be controlled by comparison to this region.

Employment of this system in a water purification plant equipped with approximately 3,000kW of run-

ning pumps, an energy saving effect of 2% or more was achieved in comparison with the conventional system for controlling the number of pumps.

3.2.2 Efficiency-increasing (equalizing) pump driving system by operation program

This system aims to save energy through limiting the energy loss during pump changeover by reducing the unnecessary suspension of pumping operation.

In such a water supply program, the water volume required for a service reservoir is supplied in advance based on predicted demand so that the pumps may be evenly driven, and changeover of the running pumps is controlled.

Employment of this system can expect to yield an energy saving effect of approximately 1% or greater than the conventional pump number changeover method based on the water level of the service reservoir.

3.3 Energy saving apparatus

Summaries of various energy saving electrical apparatus and their effects are shown in Table 3, and their applied system configurations are shown in

Fig.13 System configuration of energy saving apparatus

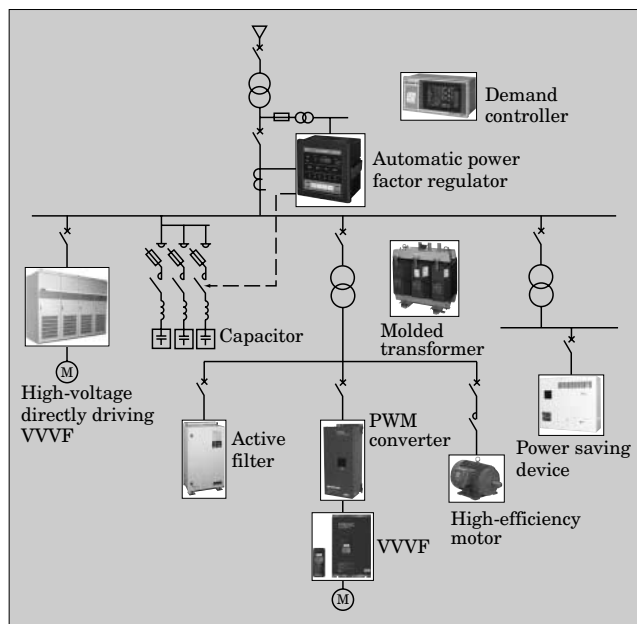


Fig. 13.

4. Recent Initial Power Receiving, Transforming and Powering Equipment in Water Treatment Plants

Equipment recently used for initial power receiving, transforming and powering facilities in many water treatment plants will be described here.

As forms of extra-high-voltage substations, there are steel structure types, housing types and gas insulation types. Recently, the gas insulation type has become frequently used since it allows substantially reduced installation space and high reliability. Fuji Electric has delivered this type to many foreign countries including China and the Southeast Asia area.

4.1 Gas-insulated switchgear (GIS)

This equipment compactly encloses charged parts of circuit-breakers, disconnectors, instrument current and voltage transformers, arresters, buses, etc. in several metal containers that are filled with SF₆ gas (6 fluorine sulfur gas), having excellent insulation characteristics, and are then sealed. Fuji Electric is providing a series of GIS devices ranging from rated voltages of 72kV to 300kV and rated breaking currents of 25kA to 50kA. SF₆ gas insulation has the following advantages in comparison with a conventional air insulation system.

- (1) Substantial reduction of onsite space is possible

The equipment is made compact in size, as various individual power apparatus are unified by SF₆ gas insulation.

- (2) Shortened fieldwork term and highly reliable equipment can be achieved

The unit circuit modules can be completely assembled in the factory and then transported to the site. Therefore, the fieldwork can be finished by connecting only the modules.

- (3) Maintenance can be reduced

Since the components themselves are enclosed in SF₆ gas sealed containers, there is no need to worry about degradation caused by pollution and oxidation. The age deterioration of parts is also much decreased.

- (4) Harmony with environment is obtained

There are no steel supports as in substations with air insulation systems and the appearance is excellent.

- (5) Safety is high

Every container is completely grounded and there is no fear of electric shock.

4.1.1 Front access type GIS (72/84kV)

Under the concepts of “more compactness”, “easier use” and “greater safety”, further miniaturization, front access and completely oil-free equipment are achieved.

- (1) Installation area can be extensively reduced

The skeletal diagram and comparison with a conventional device are shown in Fig. 14. The mounting area is extensively reduced by about 50% in the case of a 2-circuit, 2-bank and 1-VCT system.

- (2) Maintainability is drastically improved

As shown in Fig. 15, all the manipulating and monitoring functions such as manipulators, monitoring instruments and gas components are mounted on the front panel of the equipment. There is no need to turn the equipment to access the side or the back. Thus, daily maintenance can be performed as if this was an ordinary switchboard.

- (3) High safety

Completely oil-free equipment is achieved by making electrically-driven spring-manipulation type circuit breakers.

4.1.2 Super-miniaturization by replacing extra-high-voltage circuit-breaker with vacuum circuit breaker (VCB)

The gas-insulated switchgear is super-miniaturized by replacing the usual 72/84kV gas circuit breaker with a vacuum circuit breaker. This also achieves a cost reduction.

4.2 Digital multi-function relay

The digital multi-function relay is an integrated compact module with functions of protection, manipulation, instrumentation, monitor and transmission for initial power receiving and distribution facilities, and has the following advantages. Table 4 shows the specifications and Fig. 16 shows the appearance of the relay.

- (1) System is readily made intelligent

With its transmission function, the relay can connect to upper level computers through a network. So in addition to the normal operation and supervisory control functions, intelligent functions such as support

Fig.14 Space comparison of front access type GIS

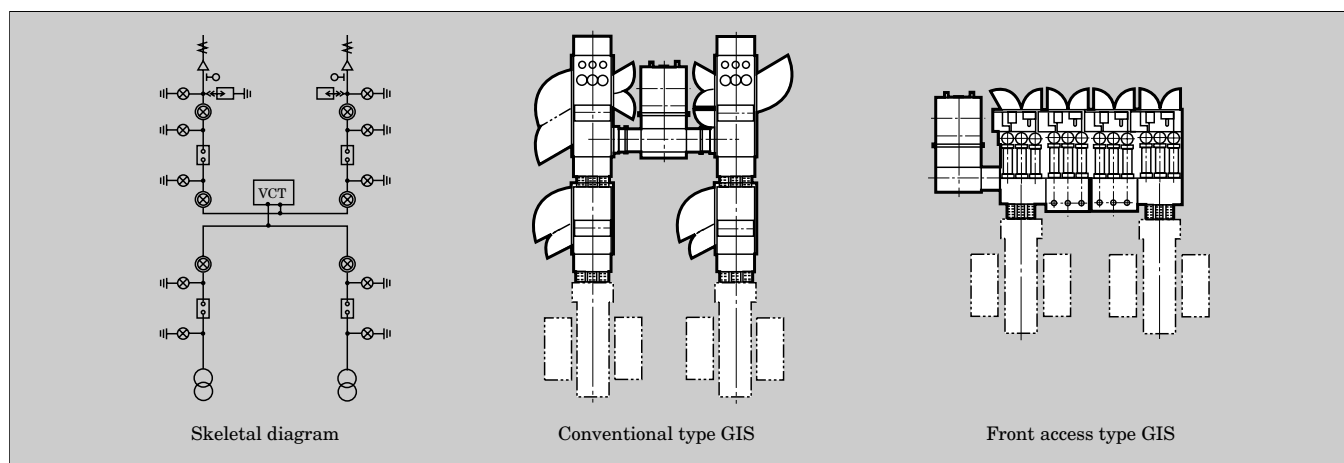


Fig.15 Appearance of front access type GIS



AM180975

Fig.16 Appearance of digital multi-function relay



N99-2332-4

of the operation and maintenance are readily achieved.

(2) Fault analysis is easy

Data at the occurrence of a fault such as currents, voltages, zero sequence currents, zero sequence voltages, etc. are automatically preserved and the instrumentation results can be displayed in the relay itself. Fault analysis is easy, even at a central location, by viewing the transmitted fault data.

(3) Reduced labor for maintenance

In addition to the continuous fault monitoring function of the relay itself, the relay is provided with an automatic checking function which verifies accuracy of the analog input parts and responses of the output relays, and a circuit breaker monitoring function which observes breakage of trip coils and opening/closing times of the circuit breakers. This achieves a reduction in the labor for maintenance.

4.3 Intelligent control center

The intelligent control center is a multistage stacked power board that is a modified conventional control center made highly functional and intelligent

by replacing its control unit with an electronic unit. The intelligent control center has the following advantages and its specifications are listed in Table 5.

(1) Extensively reduced external wiring and shortened construction period

Because the equipment has a transmission function, a total networked system can be built ranging from upper level systems, such as PLCs (programmable logic controllers) and CRT supervisory controllers, to the fields of local operator panels. This enables higher maintenance with detailed data, extensive reduction in the number of external wires and a shorter onsite construction period.

(2) Faults are preventable

The protection performance is dramatically enhanced by new functions such as an overload pre-alarm, ground fault pre-alarm, detection of blocked opening/closing of MCs (magnet contactors) and detection of abnormally configured MC main circuit, together with conventional functions such as overload, open phase, ground fault, instantaneous overcurrent and undercurrent protection. This enhanced protection

Table 4 Function list of digital multi-function relay

○ : With function, — : Without function

Item	Content	Bus unit	Feeder unit (shared combination unit)
Instrumentation functions	Current value indication (A)	—	○
	Voltage value indication (V)	○	—
	Zero sequence current value indication (MA ₀)	—	○
	Zero sequence voltage value indication (MV ₀)	○	—
	Power value indication (W)	—	○
	Reactive power value indication (var) lag power factor	—	○
	Power factor indication (cos ϕ)	—	○
	Frequency indication (Hz)	○	—
	Watt-hour indication (Wh)	—	○
	Fault record (measured value at fault) indication	MA, MA ₀ MV, MV ₀	○ —
Control functions	Open/close manipulation of line switch	—	○
	Remote/direct changeover (control right)	—	○
	Open/close remote control (external contact and transmission)	—	○
Protection functions	Short circuit protection (INST: instantaneous)	—	○
	Overcurrent protection (OC: inverse time-lag)	—	○
	Directional ground protection (DG)	—	○
	Overvoltage protection (OV)	○	—
	Undercurrent protection (UV)	○	—
	Ground overvoltage protection (OVG)	○	—
	Voltage recognition (VR)	○	—
	Remote trip (external trip)	—	○
	Reverse phase and open phase	—	○
Display functions	Relay setting value indication	○	○
	Relay operation indication	○	○
	Line switch status indication	—	○
	Control right status indication (remote/direct)	—	○
Monitoring functions (maintenance support)	CB trip coil breakage monitoring	—	○
	CB opening/closing time monitoring	—	○
Self-diagnostic functions	Constant monitoring function	○	○
	Automatic checking (initiated at fixed cycles every 24 hours)	○	○
	Manual test (initiated anytime)	○	○
	Lamp test	○	○
	Forced operation (each element individually)	○	○
Transmission functions (T-Link)	Reception of line switch open/close signals	Only for types with T-Link	
	Transmission of measured value data to upper system		
	Transmission of protective relay operation signals to upper system		
	Transmission of setting values of protective relays and timers to upper system, and reception of setting values		
	Transmission of line switch status indication signals and control right status indication (remote/direct) signals to upper system		
	Transmission of switchgear side signals (CB draw-out position, etc.) to upper system		
	Transmission of system failures and ID data to upper system		

performance allows the prevention of faults.

(3) Switch room space is saved

The direct connection of control signals with PLCs through transmission lines eliminates the necessity for installation of conventional auxiliary relay panels, and thus space saving of the switch room can be achieved.

5. Conclusion

New energy technology and the energy saving technology have been introduced and applications to water treatment plants have been explained. It will be

Table 5 Function list of intelligent control center

Item	Content		Item	Content	
Applied circuit	Inverter, 1-phase or 3-phase general low-voltage load with inching manipulation		Setting	Item	<ul style="list-style-type: none">○ Protection: CT rating, rated current, overload protection mode, instantaneous operating current of overcurrent, instantaneous operating time of overcurrent, operating current of undercurrent, operating time of undercurrent, ground fault sensitive current, ground fault operating time, ground fault changeover, open phase protection valid/not valid, overload pre-alarm operating current, ground fault pre-alarm operating current, overload protection reset method, starting lock time○ Control: Momentary interruption compensation time, momentary interruption restart time, sequence number, application sorting of fault output contact, processing during CPU error○ Transmission: Transmission address, processing during upper system error○ Operation record: Initial value○ Setting protection: Provided with locking function of setting value
Protection	Overload Open phase Direction ground Instantaneous overcurrent Undercurrent Overload pre-alarm Direction ground pre-alarm MC fault				
	Monitor, display	Monitor display <ul style="list-style-type: none">○ Load current○ Leakage current○ Fault current○ Fault condition○ Setting value○ Operating record			
Manipulation	Operation	<ul style="list-style-type: none">○ Selector switch: REM-DIR-TEST○ Push button switch: ON, OFF, REV			
	Instrumentation, setting	<ul style="list-style-type: none">○ Push button switch: MODE SELECT, SET/FLT, RESET, ^, v, ENTER			
Control	Sequence	<ul style="list-style-type: none">○ Main circuit: Automatic setting (Non-reversible, reversible, power source feed)○ Control circuit: 256-pattern	Test	TEST mode	<ul style="list-style-type: none">○ Protection function: Overload, ground fault○ Control function: Center (via transmission), onsite, MCC
	Restart after momentary power interruption	<ul style="list-style-type: none">○ Compensation time: 0.5 to 5.0 s (in 0.5 s steps)○ Restart: 0 to 60 s (in 1 s steps), Instant restart if interruption is shorter than 0.2 s.			
	Input	<ul style="list-style-type: none">○ Control signal: 4-point (88F, 88R, interlock, external fault)○ Manipulation signal: 4-point (ON, OFF, REV, center)		CPU self-diagnosis	<ul style="list-style-type: none">○ Normally: CPU monitor, Communication monitor○ During operation: ROM monitor, RAM monitor, EE-ROM monitor, Analog input value monitor○ During test: Analog input value monitor
	Output	<ul style="list-style-type: none">○ Operation signal: 3-point (ON, OFF, REV)○ Fault signal: 2-point (Element can be selected)○ Contact capacity: Rated current 1 A, maximum switching capacity 250V AC, 5A			
Memory	Fault current	<ul style="list-style-type: none">○ Overload: 0 to 1000%A○ Ground fault: 0 to 500mA	Transmission	Transmission data	<ul style="list-style-type: none">○ Transmission quantity: Digital 26-items, analog 4-items○ Data contents: Operation signal, fault signal, measured value, setting value, present value of operation record
	Setting value	<ul style="list-style-type: none">○ All setting items			
	Operation record	<ul style="list-style-type: none">○ Operating time○ MC close/open○ Trip○ Overload○ Open phase○ Ground fault○ Instantaneous overcurrent○ Undercurrent○ External fault○ Momentary interruption restart○ MC failure○ Maximum load current○ Minimum load current		Reception data <ul style="list-style-type: none">○ Reception quantity: Digital 22-items○ Data contents: Operation signal, setting value, initial value of operation record	

appreciated if this information is helpful in the implementation of measures to counteract environmental problems, such as reducing fossil fuel consumption by accelerating applications of new energy and energy saving apparatus. Although the new energy

technology still has some subjects that should be improved upon in the future, such as cost reduction and higher efficiency, Fuji Electric will continue to make efforts to provide systems in response to requirements of the age and society.

Instrumentation, Control and Sensor Technology for Waterworks

Kouju Miyairi

1. Introduction

Japan has built up a rich social framework in an environment that has been blessed with the benefits of water. A close relation between the utilization of water resources and social activities has always been maintained. Recently, the water quality of drinking water resources, rivers, lakes and marshes, has degraded year-by-year due to advanced industries, higher living standards and concentrated population. In addition, water shortages due to a lack of rain because of global climactic abnormalities are also making unfavorable circumstances for water volume. On the other hand, waterworks, which form the basis for our standard of living, are becoming more widespread and a stable supply of high quality “safe and good tasting water” is required for the coming 21st century.

Responding to such needs of the times, Fuji

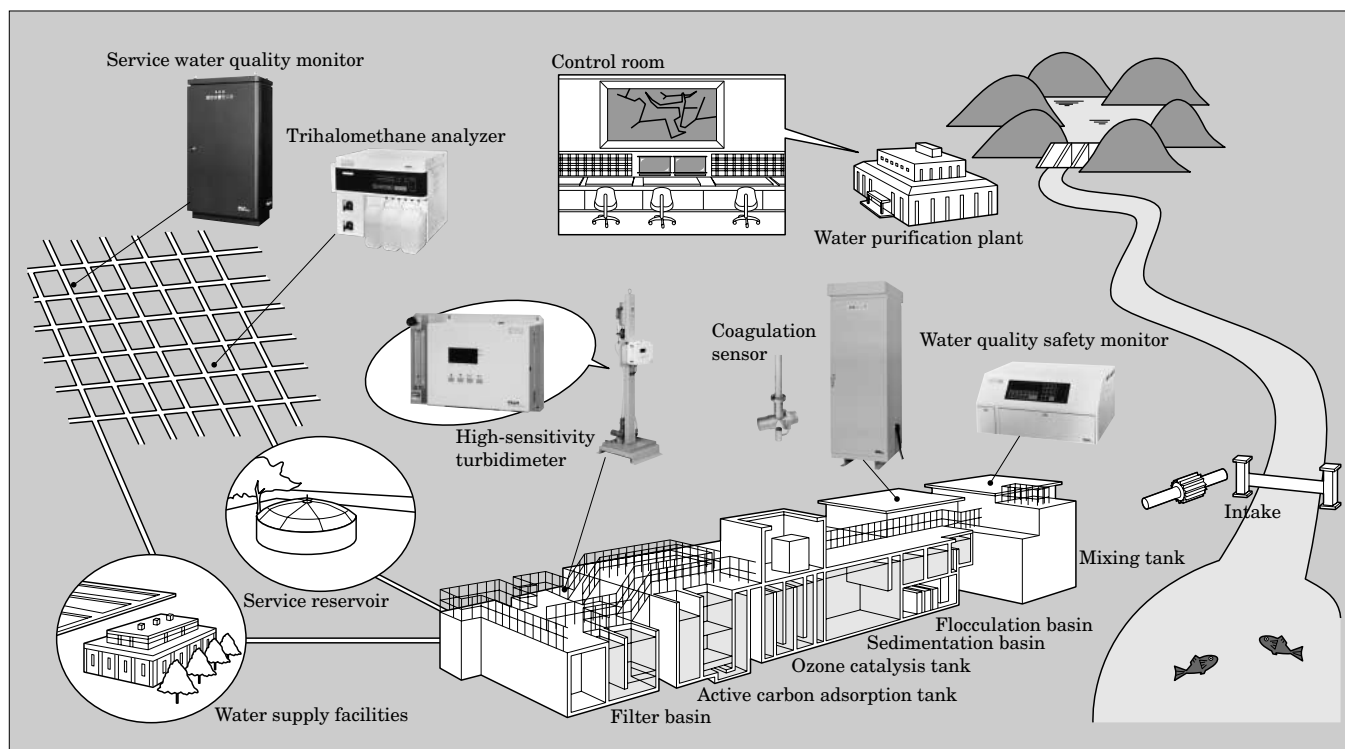
Electric has contributed to problem solving with various system technologies - energy, plant, process and EIC (Electricity, Instrument and Computer) systems - which have been cultivated for many years in the field of waterworks.

This paper will introduce new water quality sensors and original process control and instrumentation systems for waterworks that respond to the latest water environment changes.

2. Sensors

System technology that has responded to water quality changes is represented in the newly developed water quality sensors. Figure 1 shows the relation between the process flow of waterworks and the water quality sensors.

Fig.1 Relation between process flow of waterworks and water quality sensors



2.1 Water quality safety monitor

To verify the safety of a water source, fish are generally kept in raw water and their behavior observed to determine if any abnormality exists in the water. This method has such problems as ambiguity in the observation of fish behavior and the labor required to constantly maintain the many fish in a healthy condition. Thus, another automated method has been required. With a dissolved oxygen electrode, the water quality monitor introduced here directly detects reduced respiration activity of bacteria (nitrifying bacteria) sensitive to acute toxicants in water, and issues an alarm. This monitor is not capable of determining toxicants but automatically samples water for inspection if any toxicant is infected, and this allows the toxicant to be identified later with a precise analyzer.

2.2 Coagulation sensor and controller

In the coagulation-sedimentation process, an important treatment in water purification plants, the coagulant injection rate is largely determined based on raw water quality or the manual analysis of a jar test, however satisfactory results have not been achieved in many cases when the raw water quality suddenly changes. Based on the fluctuation in absorbance of irradiating light, the coagulation sensor and controller measure the mean diameter of flocculated particles in mixing tanks and flocculation basins of the water purification plants. The controller performs optimized coagulant injection control.

2.3 High-sensitivity turbidimeter

Mass infection of the pathogenic organism cryptosporidium occurred in 1996 in the Kanto district of Japan, and the pollution source was believed to be city water. The Japanese Ministry of Health and Welfare issued then tentative guidelines for cryptosporidium that required the turbidity in the effluent from a filter basin to be kept under 0.1 degree. Following these guidelines, Fuji Electric has developed a new type of high-sensitivity turbidimeter. Utilization of the front light scattering particle counter method has allowed this turbidimeter to measure the super-low turbidity of 0.001 degree, impossible for the conventional transmitting light method and the surface light scattering method, and to simultaneously measure particle size distributions (0.5, 1.0, 3.0 and 7.0 μ m or greater). In the field of waterworks, this highly precise hybrid turbidimeter will be a critical device for a new epoch.

2.4 Trihalomethane analyzer

As treated in the new water quality standards, monitoring the concentration of trihalomethane in city water is extremely important because trihalomethane is feared to be a carcinogen. However, gas chromatog-

raphy, an existing analyzing method, requires skill and time because of its complicated pretreatment and is incapable of continuous measurement by batch processing. Thus, a simpler and faster measuring analyzer has been desired. This trihalomethane analyzer is for laboratory use and analyzes quickly and automatically the total trihalomethane in sampled water with a fluorometry method based on the Fujiwara Reaction.

2.5 Service water quality monitor

In Japan, automated daily inspection of the water quality (pH, turbidity, color, residual chlorine, electric conductivity, water temperature and water pressure) as prescribed in the waterworks law is coming into widespread use mostly in large cities, but a color meter which only identifies some colors has been used as a substitute for the color inspection. In coordination with the Japan Water Works Association, Fuji Electric has developed the world's first monitor that is capable of identifying all hues. This monitor can detect color gradations of city water such as red water, white water and black water and has a performance equivalent to that of human eyes. The monitors are placed at multiple points along a water distribution network. Obtaining real-time data by continuous monitoring has enabled the realization of advanced water management such as ensuring the safety of service water quality and preventing expansion of damage due to faults or disasters by centralized monitoring, and monitoring the flow time from the water purification plant by continuous measuring of water pressure, pH and residual chlorine concentration.

3. Process Control Technology

Water management and control represents a technology for handling changes in the water volume. The phrase "water management" often refers to water intake management, water supply management and water distribution management, and here water management and control shall cover these three wide areas.

3.1 Water supply management and control

The principle objective of water supply management and control is to economically and effectively distribute the water volume from a water intake to a service reservoir. Figure 2 shows an overview of water supply management.

(1) Water demand prediction

The prediction of water demand forms the basis of water supply management. Daily demand is predicted for each service district, and based on the results, the water distribution for all the water purification plants and intake stations in a city is determined. Moreover the hourly demand is predicted by calculation from the predicted daily water volume, and then the hourly

Fig.2 Overview of water supply management

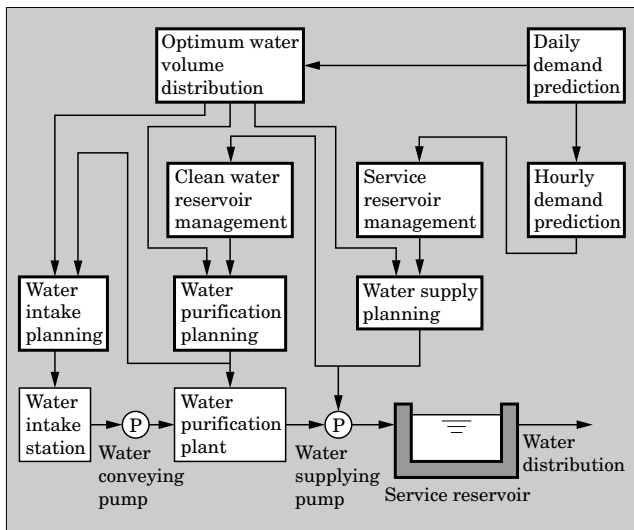
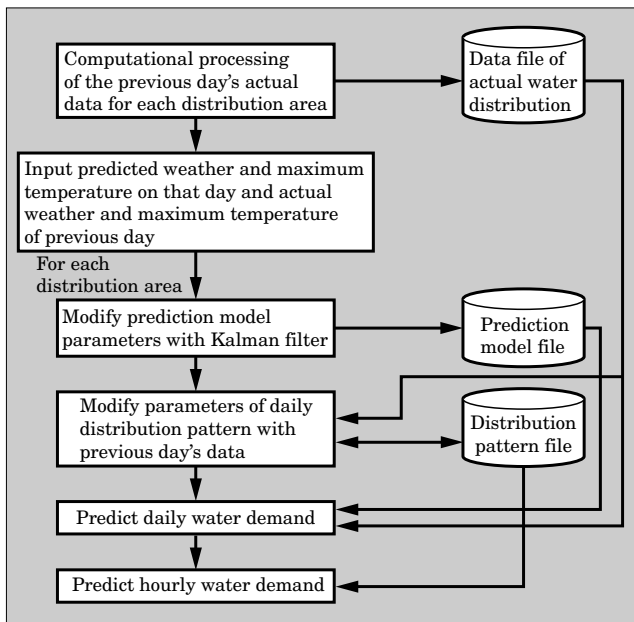


Fig.3 Online processing flow of demand prediction



supply water volume to service reservoirs is planned. An online processing flow of the demand prediction is illustrated in Fig. 3.

(2) Optimum water volume distribution

The supply water volume from each water purification plant is determined when the demand of each service district is planned. The supply water volume plan is prepared such that the management cost is minimized when the water intake capacity, water purification capacity and water supply capacity of each water purification plant are limited. The water volume distribution can be determined to minimize the total limited volume of service water during a water shortage. It is possible to examine the water management plan and to quickly respond to abnormalities such as contamination of the source water by a toxicant.

(3) Service reservoir management

When hourly changes in the water volume from a service reservoir are predicted, it is possible to level off the supply water volume to the service reservoir and to devise a supply water plan for minimizing the number of changes to running supply water pumps. Every approach is combined to optimize each service reservoir. If the service reservoir receives water via the supply water pumps, the number of running pumps is controlled, and if water is received via the inflow valves, water inflow control (stepwise or continuous) is performed.

(4) Water management support simulation

The water management plan for maintaining stable service water volume and pressure is designed under variously assumed conditions in normal and abnormal circumstances, and simulation of the results is performed.

(a) Online simulation

The water level variation of each basin is calculated using the online data (present water level, planned water volume and predicted water demand) at the time of the simulation. Simulation is also performed with modified settings for the change of the planned water volume

(b) Water management planning simulation

Simulation of abnormal circumstances, modified distribution systems or facilities, and for the optimum adjustment of water management plans can be performed under flexible conditions.

3.2 Water distribution control

Water distribution control mainly aims to reduce the quantity of leakage by adjusting water pressure, to evenly serve water during a water shortage, and to maintain the safety of water quality.

(1) Pipe network calculation

The pipe network calculation is a basic analysis method in water distribution control. This method computes the water pressure and flow distribution in a pipe network with given network parameters (pipe networking topology, demand distribution, etc.), and is used to design pipe routing at new installations or during renovation.

(2) Selection of water pressure monitoring point

Based on the result of the pipe network calculation, the pipe network is broken into several blocks and water pressure monitoring points are set up at one or more positions in each of the blocks. If there are multiple positions, the block area is divided to obtain the most effective allocation according to cluster analysis utilizing the similarity of water pressure variations. Then, monitoring points are selected at the positions where there is a large influence and where there is little influence on the water pressure of the pipe network.

(3) Distributed water pressure control (water pressure adjustment)

Water pressure control adjusts the water pressure in each of the blocks with the water pressure adjusting valve for that block. All the logical control is implemented by onsite digital regulators. However, the water pressure setting of each block is determined by a central computer or an operator and transmitted to each onsite regulator.

(4) Water distribution control support simulation

A water distribution control plan is designed under various assumed conditions of normal and abnormal circumstances, and simulation of the results is performed.

(a) Water pressure adjustment simulation

For fair and appropriate service water volume under normal and abnormal circumstances, this simulation obtains the operating information for water pressure adjusting valves and control valves from the mutually given data of service water volume, secondary pressure, end pressure and valve openings.

(b) Pipe network management simulation

Under mostly abnormal conditions, this simulation performs economical management by modifying boundaries of the distribution areas.

(c) Calculation of effect of water pressure adjustment

The effect of reduced service water volume by adjusting water pressure is calculated.

(d) Analysis of residual chlorine concentration

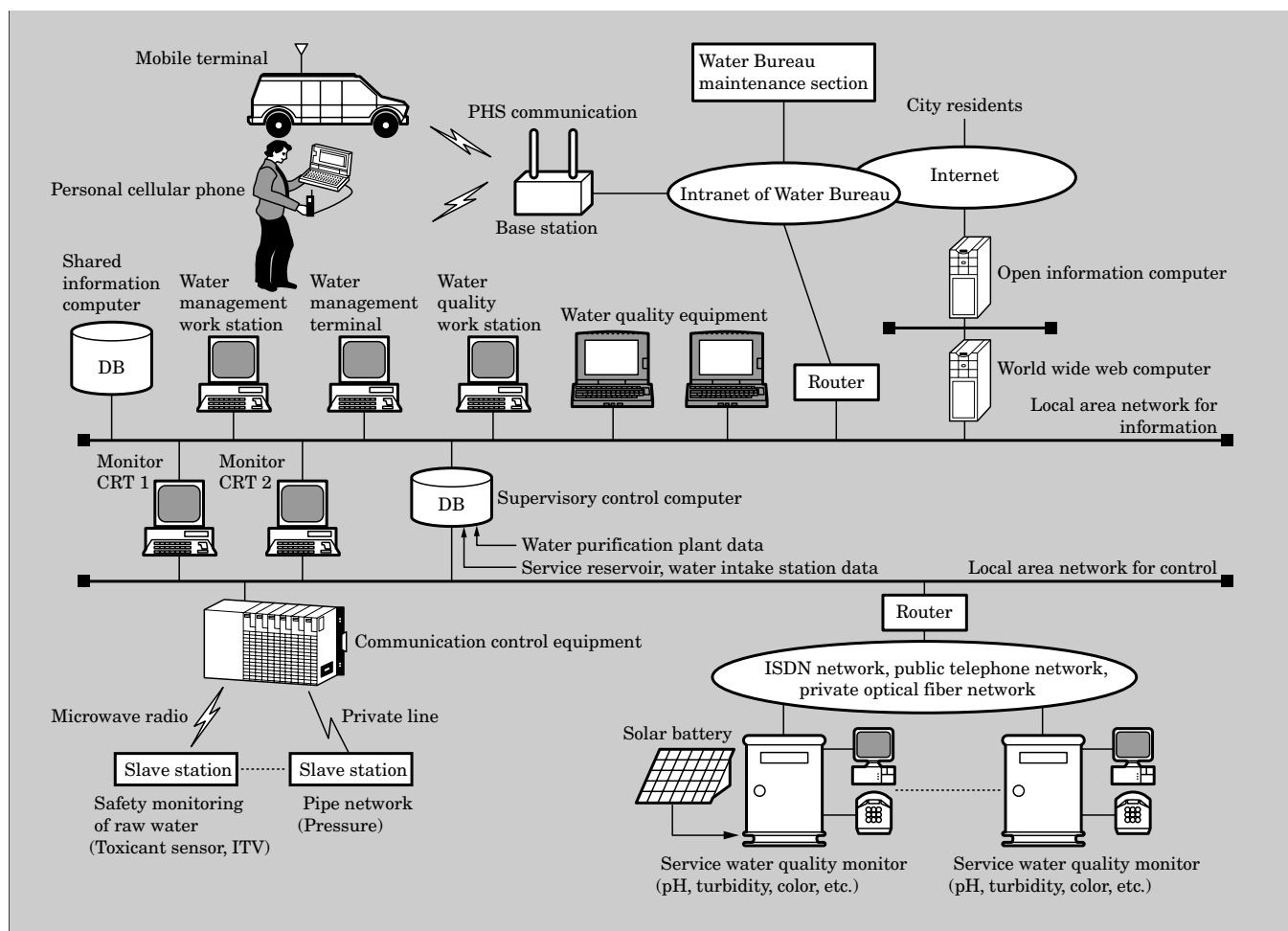
The distribution of residual chlorine concentration at service reservoirs and water faucets is estimated by calculating consumption of the residual chlorine concentration in the pipe network.

3.3 Example of water management system

Water supply management has been mostly introduced into big-city areas such as Tokyo Metropolis, Osaka Prefecture, Kanagawa Prefecture, Yokohama City and Kobe City. In many supervisory control systems for water purification plants, the function of water supply management is included in the supervisory control of external facilities. On the other hand, water distribution management is mainly applied in regional cities such as Matsuyama City, Takamatsu City, Kumamoto City and Matsumoto City. To realize water distribution control, some initial investment such as dividing the pipe network into blocks and providing onsite facilities is still required depending on the scale of the waterworks plant.

In Matsuyama City, time limitations were placed on the feed water during the water shortage of 1994.

Fig.4 The latest waterworks management system



At that time, water distribution control with automatic pressure control valves was implemented in 77% of all the districts and played an important role in the countermeasures against the water shortage.

4. Instrumentation System Technology

Sensor and process control technologies have been introduced as system technologies for waterworks countermeasures against water pollution and water shortages or leaks. Of the instrumentation system technologies that comprehensively manage the aforementioned technologies, this section will describe the technologies most easily affected by disasters, data transmission and power supply technologies.

Figure 4 illustrates an example of an instrumentation system configured with the latest technologies.

4.1 Data transmission

(1) Communication line

Selection of a communication line is important in the configuration of an instrumentation system. The line should actually be selected on the basis of cost-effectiveness after sufficient study of the geographical condition, regional characteristics (whether radio waves can be received, or whether any telephone lines are near) and reliability (especially in disasters), as well as performance (transmission speed, capacity, etc.)

(2) Network technology

Use of the internet or intranet is effective for information exchange (supervisory control data, main-

tenance and management data) between the city residents and related sections of the Waterworks Bureau. In case of an emergency such as an earthquake disaster, the personal handy-phone system (PHS) is necessary for obtaining accurate onsite information. On the other hand, employment of a general purpose LAN and a standard communication protocol allows different companies to be linked with each other through routers and exchange information between the supervisory control system and other related systems.

4.2 Power supply technology

Power supplies are especially important, along with transmission lines, for information communication during disasters. As a countermeasure against power failures, uninterruptible power supplies (UPS) are required for sensors, transmission systems and computer systems. Utilization of solar batteries is also under consideration as emergency power sources for the water quality monitors placed in pipe networks within a city.

5. Conclusion

System technology that responds to changes in the water environment, together with global environmental problems, will become increasingly important in the future. Fuji Electric will continue to provide various system technologies for the effective utilization of limited water resources and supply of safe and good tasting water. We will strive to create a waterworks total management system suitable for the information society of the 21st century.



Instrumentation, Control and Sensor Technology for Sewage Treatment Plants

Jun Umetsu

1. Introduction

Many sewerage facilities are being built recently and their use is becoming more widespread. The technologies used in these facilities, such as sensors, instrumentation systems and control systems, is also improving day-by-day. This paper will describe these latest technologies for sewerage facilities.

2. Sensor

A sensor is equivalent to the human sense of sight and hearing. Various types of sensors are used in sewerage facilities to measure water flow, water pressure, water level and water quality. These sensors are expected to be improved upon in the future, with advanced precision and easier maintenance.

On the other hand, new principles of instrumentation have been put to practical use, and the development of various new sensors is promoted. These new sensors for sewerage facilities will be described below.

2.1 Biosensor

The biosensor is a type of sensor that employs a molecule identification function for biomaterials (enzyme, microbes). The measuring method utilizes the characteristics of biomaterials that catalyze the reaction of a specific chemical substance, and detects with an electrode the change (consumption, generation) in the chemical substance passing through a biomaterial immobilized membrane. The configuration of the enzyme sensor includes the enzyme-immobilized membrane, an electrode transducer and a simple module.

Some biosensors have been already used in the field of medical care to measure blood sugar values and in the field of food. In the field of the sewerage, a water quality meter that uses a nitrifying bacteria biosensor and other water quality biosensors for sensing ammonia, nitrogen and phosphorus is now under development. Biosensors are expected to be used widely in the future.

2.2 Coagulation sensor for sewage dehydration

To efficiently, steadily and continuously process

sludge generated from sewage treatment, determination of the following is necessary: the type of dehydrator, the type of coagulant compatible to properties of the sludge and performance of the dehydrator, and a coagulant injection rate suitable for the concentration of desiccated solids (SS concentration) in the sludge.

Fuji Electric is now developing a coagulant injection control system for sewage dehydration. Corresponding to changes in the condition of the sludge, the system automatically and continuously controls online the injection of coagulant by using a coagulation sensor for sewage dehydration.

The measurement principle of the coagulation sensor utilizes the analysis method of infrared absorbency fluctuation. The coagulation sensor computes and outputs a volume factor by irradiating far-infrared light to an object and then calculating the mean diameter and numeric concentration of flocculated particles in that object from the degree of light absorbance.

3. Instrumentation System

During the treatment process at sewerage facilities, various quantities such as water level, pressure and water quality, including flow rate, are measured and the systems that monitor and control such quantities are configured. These latest systems for the sewerage will be described below.

3.1 Optical instrumentation technology

With the development of low-loss optical fiber in 1970, the application of optics to instrumentation technology suddenly became a leading field of high technology. Optical instrumentation technology is roughly divided into (1) measurement with applied optics and (2) optical measurement using optical fibers. The former category includes point sensors such as the turbidimeter, infrared thermometer, Fourier transformation infrared analyzer, and image sensors for vision-sensing robots and quality inspection or the selection of goods. The latter is an instrumentation system that uses optical fiber cable instead of conventional copper wire. Use of optical fibers has given this technology

broadband characteristics and resistance to lightning, noise and explosions, resolving various problems that had previously held back this technology.

Figure 1 illustrates the optical field bus system in which the FFI system, developed as the world's first optical fiber instrumentation system, is even more open. The sophisticated sensors use microcomputers and their output signals are transmit in digital form.

The advantages, as compared with conventional systems, are as follows: (1) resistance to noise (lightning surge, electromagnetic induction), (2) intrinsically safe explosion-proofing, (3) high accuracy through digitization, (4) realization of self-diagnostic functions and centralized maintenance (remote adjusting from a central location), (5) reduction in the number of cables

by using a star coupler, (6) simplified operation (allowing mixed communication cables with power cables in the same cable root), and (7) an open (internationally standard) multi-vendor network.

3.2 Network system

The sewerage facilities have equipment both inside and outside of the treatment plants and networks configured for the exchange of information and control among facilities.

3.2.1 Local area network

A local area network is used to transmit information as well as instrumentation and control signals for each piece of equipment inside the plant. Using a local area network, many treatment plants employ a centralized monitoring and distributed control system as shown in Fig. 2.

3.2.2 Regional network

Network systems using telephone lines and optical fiber cables are employed to transmit the instrumentation and control signals of wastewater booster pump stations scattered throughout a wide area and of main line flow rate measuring equipment, and to perform centralized monitoring in the treatment plants.

(1) Small-scale monitoring system

This system monitors and transmits data at fixed time intervals using an ordinary public telephone line as shown in Fig. 3. The cost performance of this system is enhanced through partnered management with neighboring towns and villages.

(2) Remote supervisory control system

This system performs supervisory control with data loggers and CRTs of a remote monitor office by continuously transmitting instrumentation and control data via the private line of a telephone company as shown in Fig. 4. Many such systems are commonly and

Fig.1 Optical field bus system

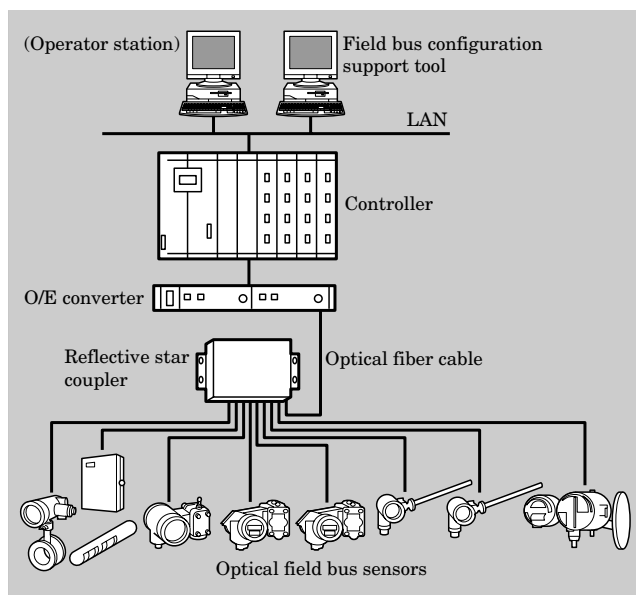


Fig.2 Centralized monitoring and distributed control system

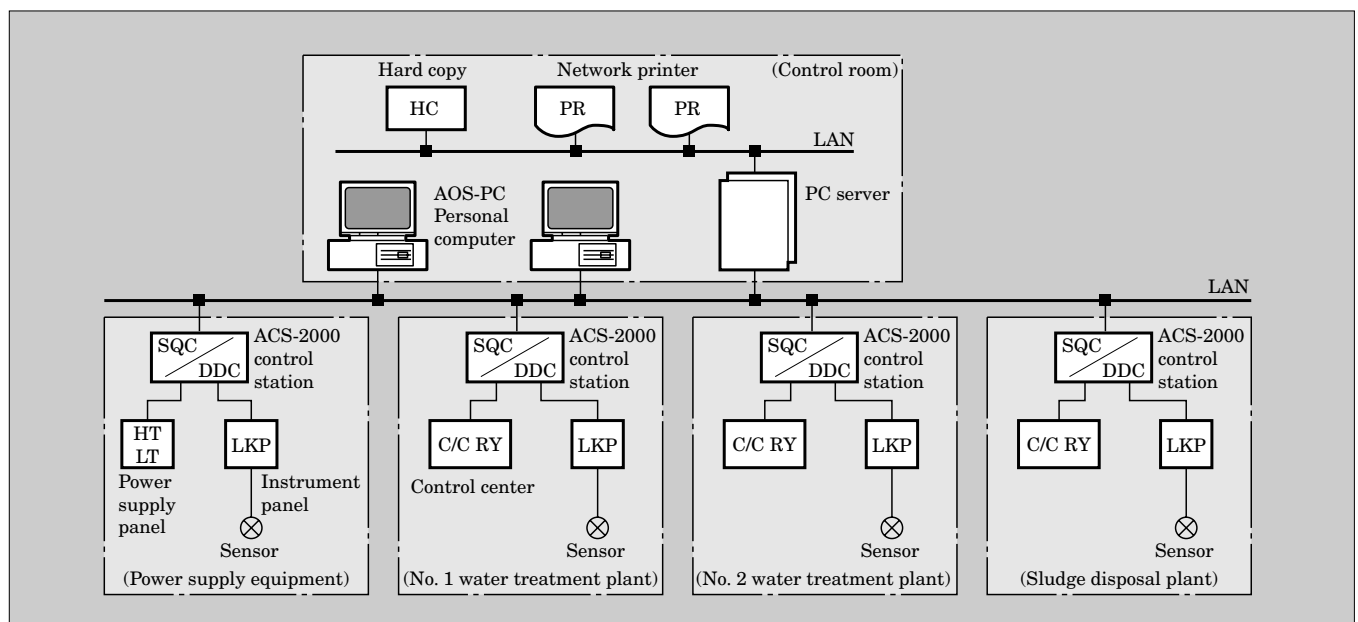


Fig.3 Small-scale monitoring system

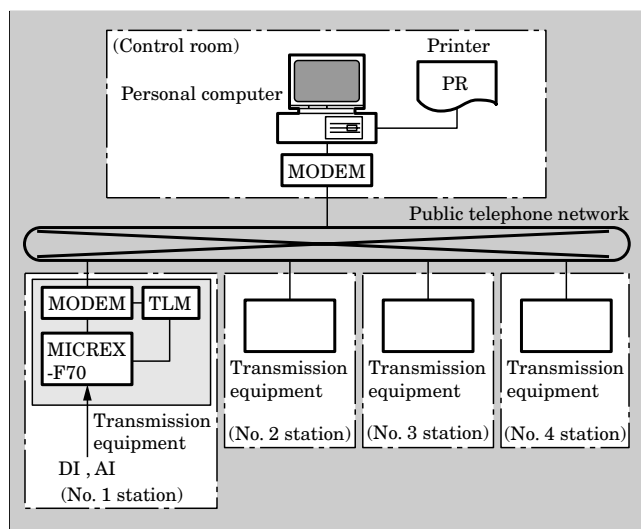
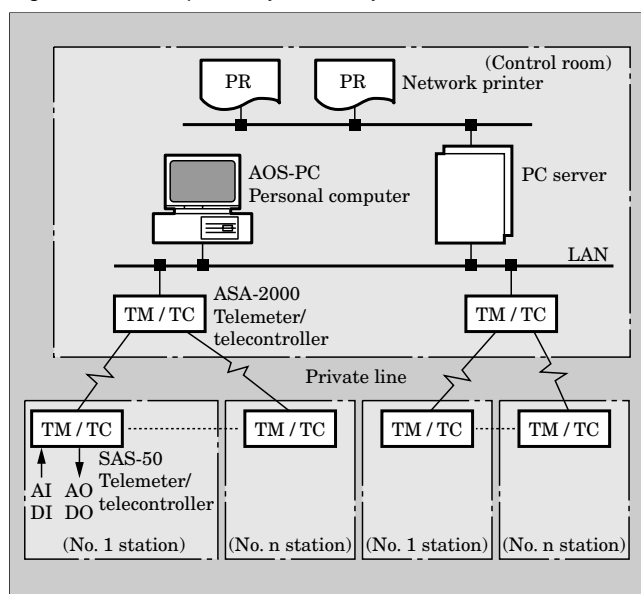


Fig.4 Remote supervisory control system



widely employed at present.

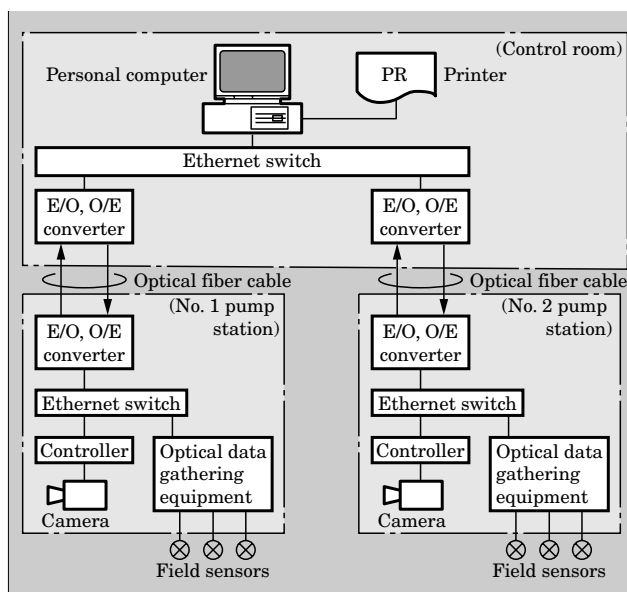
(3) Optical fiber network system

Systems have recently been employed that exchange data through optical fiber cables laid in underground sewerage pipes. This allows construction of a wide area network along with the sewage piping network, and implementation of advanced information exchange. Features of such networks are listed below.

- ① Does not require construction of a special path because vacant space in the sewage pipes can be used.
- ② Resistant to disasters and faults and the reliability is high.
- ③ Can exchange information that is highly dense over a wide area.

These networks are expected to play a big role in the future information society.

Fig.5 Optical fiber network system



The system configuration employs the aforementioned optical field bus system or an Ethernet as shown in Fig. 5.

3.3 System power source

A good-quality power source is necessary to normally run the aforementioned network. A UPS (uninterruptible power supply) is often used as the power source of the network.

4. Process Control

The appropriate control is performed in each treatment process of the sewerage facilities. The recently used new control systems will be described below.

4.1 Advanced control

PID control is extensively used even now for lower-order single loop control. However, there is a limitation on its application to higher-order systems or remarkably non-linear systems such as a time variable system with large dead time, multivariate systems and distributed constant systems. (It can be said that the water treatment process essentially has these characteristics.)

With the utilization of digital controllers, higher-level control systems came to be extensively used. Along with advances in modern control theory and in applications to control technology, the application of such advanced control methods to process control has become possible by utilizing the functions of computers and these controllers. The various control systems that aim at such high-level control are commonly referred to as advanced control systems.

Fuzzy-logic based control is performed in the wastewater pump station of the sewerage facilities.

With fuzzy-logic control, controllers are used to provide proper pump and gate control by: subdividing the process of inflow control into several control rules (previously a task which only skillful operators could perform), judging the circumstances based on rainfall intensity and pump discharge, and understanding the variation rate of the water level.

4.2 Application of AI (artificial intelligence)

Research on AI and its application has centered around the United States since the 1960's. Since the 1980's, applications such as expert systems and machine translation systems have been put to practical use one after another. A system in which problems are solved with using a human rule of thumb (knowledge) is referred to as a knowledge based system.

Various development support systems and tools for knowledge base systems have been already introduced. In the industrial field, centering on expert systems, the

range of applications is rapidly broadening.

In sewerage facilities, neural network systems are actually employed in the inflow prediction system. These systems use personal computers and modify the setting values of various parameters based on the deviation between predicted inflow values and actual measured values. The computers ultimately learn from data to minimize the deviation between predicted and measured values.

5. Conclusion

In addition to the original purpose of sewage treatment, sewerage facilities are deeply concerned with community developments such as advanced information networks. It is believed that these networks will to continue to advance in the future. Therefore, Fuji Electric will not fall behind and will also contribute to social development.



Information Processing System for Water and Sewage Treatment Plants

Yasuhiko Sonomura
Masami Hasegawa
Shinyuu Kamino

1. Introduction

The trend of recent information processing systems in water treatment plants is toward the enhanced requirements of reduced construction, maintenance and managing costs, together with requirements of high functionality, following the rapid progress and improvement of electronics and information processing technologies.

To respond these requirements, Fuji Electric realized an open architecture information processing system, employing the latest technologies as well as technologies and expertise that have been cultivated over many years, based on open architecture. In this paper, we will introduce this latest information processing system.

2. Latest Information Processing System for Water Treatment Plants

2.1 Realization of medium to small-scale systems

2.1.1 SCADA

Fuji Electric has developed FOCUS (Fuji open control universal system) as a SCADA (supervisory control and data acquisition) system. This system can realize a low cost, highly functional control system by applying expertise of the dedicated DCS (distributed control system) system cultivated by Fuji Electric up to the present. The system is configured with an operator station (FOCUS) and controllers. Low cost construction of an open integrated control system is possible using an Ethernet^{*1} as a LAN to connect the two systems.

(1) System specifications

(a) Hardware specifications

PC/AT^{*2} compatible personal computers can be used in all operator stations. Windows NT 4.0^{*3} is used as the OS and InTouch^{*4} is employed as the fundamental part of the HCI (human-computer

interface). An Ethernet is utilized as the LAN for control, but PE/P-LINK (enhanced processor/processor link) made by Fuji Electric can be also used. The following controllers made by Fuji Electric may be connected: ACS (advanced controller) - 2000, ACS-250, MICREX-F and MICREX-SX. Commercially available devices such as network printers for the printing logging panel, color ink-jet printers for the copying panel and magneto-optical disks for data banking can be used as peripheral devices of the FOCUS (personal computer). In this manner, a low priced system can be constructed.

(b) Software specifications

For the FOCUS, a standard panel shown in Table 1

Table 1 Standard panel specifications

Process input	Process value	576 points
	Integrated value	Including the above points
	Digital	10,240 points
Process output	Setup value	128 points
	Operation	512 points
Trend panel		8 pens × 64 pages Storage period: 5 days/1 min collection
Plant panel		Panel sheet: 100 sheets
Logging panel		Sheet: Daily report : 20 sheets Monthly report: 20 sheets Annual report : 20 sheets Storage period: Daily report : 62 days Monthly report: 12 months Annual report : 5 years
Computation expression		Within the limits of Excel
Group loop panel		Displays by grouped instrument modules
Alarm panel		Displays alarms in time series 20 points/panel, 100 panels
Historical message panel		Displays historical messages in time series 20 points/panel, 100 panels
System condition panel		Displays system condition
Remarks	Restriction of signal points: All using Tag= within 44,000 Tags AI per point = using 50 Tags Others per point = using 1 Tag	

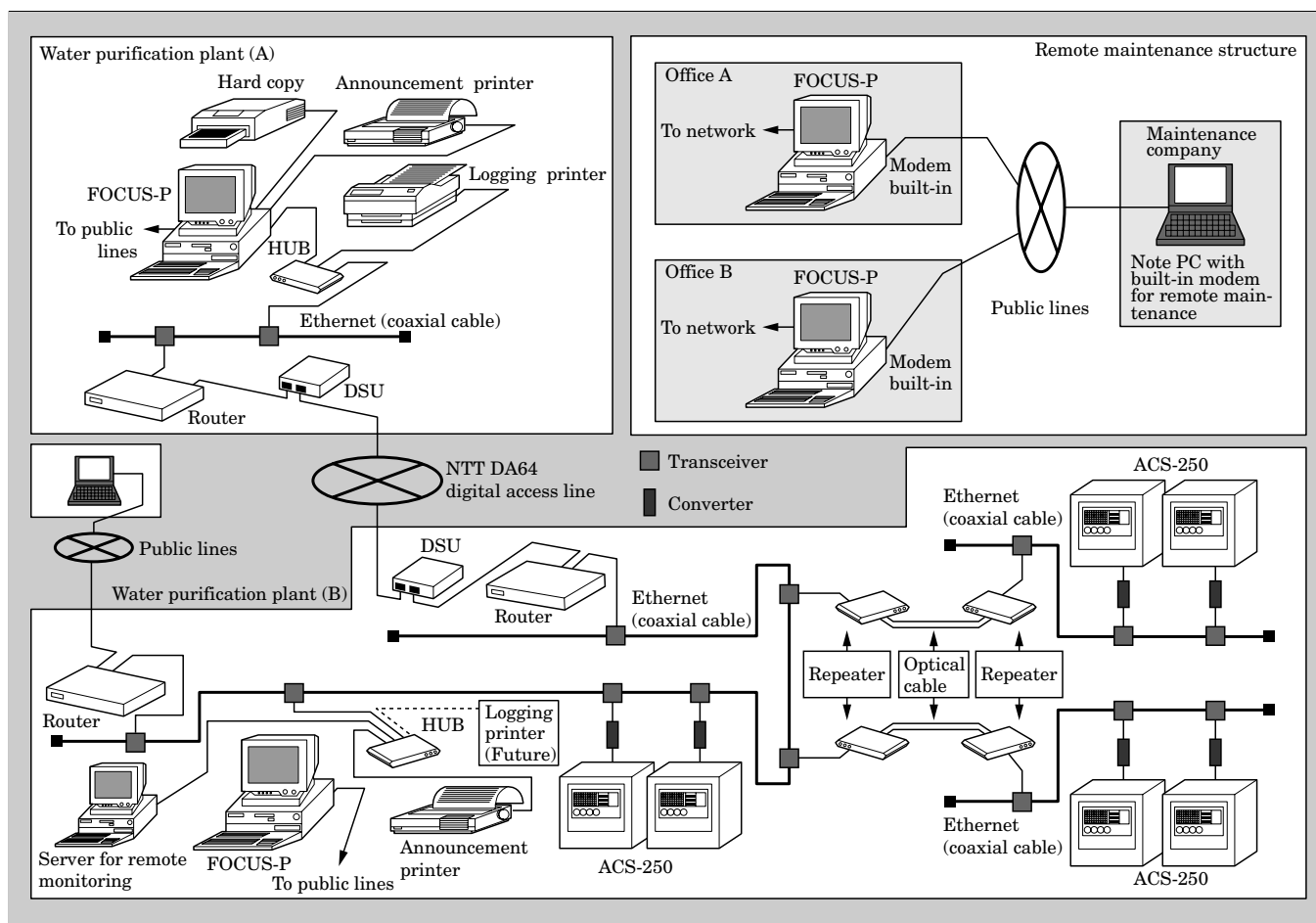
*1 Ethernet : A trademark of Xerox Corporation

*2 PC/AT : A trademark of IBM Corporation

*3 Windows NT 4.0 : A trademark of Microsoft Corporation

*4 InTouch : A trademark of Wonderware

Fig.1 Remote monitoring system



is provided. Each panel is made with InTouch and has an excellent operability due to ample incorporation of Fuji Electric's water treatment technologies.

For engineering support, a plant panel, central to the monitoring operation, can be easily made into visual panel using InTouch. Further, the logging panel format is designed with Excel^{*5}. Therefore, the engineering of the FOCUS is an easy-to-use monitor, able to realize EUC (end user computing).

(2) Examples of FOCUS system applications

Several examples configurations will be indicated below.

(a) Remote monitoring

In addition to stand-alone use, the FOCUS can perform remote monitoring utilizing the merits of an Ethernet. This system configuration is shown in Fig. 1.

Routers are provided for the control LANs of local controllers. These LANs are constructed from an Ethernet. Routers and the FOCUS are connected to the network on the remote side (such as an office). This configuration makes the remote FOCUS able to perform the same operation as the

local FOCUS.

(b) Remote maintenance

The water and sewage treatment plant is an important piece of lifeline equipment. When an obstruction occurs in this monitoring system, immediate measures are necessary. In such a case, if diagnosis, status investigation and software modification of the system are possible from the remote side (such as a manufacturer's office), the restoration time can be shortened. In the FOCUS system, collection of RAS information, straightforward correction or modification of the software and investigation of defects can be performed via a telephone line from a remote station.

(c) Wireless LAN system

When utilizing FOCUS and a wireless LAN, it is possible to use most FOCUS functions with notebook type personal computers from a remote position or freely moving, instead of from fixed CRTs. In this manner, one can visually monitor a plant, into which monitoring CRTs cannot be introduced because of cost or the installation location, by carrying a notebook type personal computer with him. An example system configuration is shown in Fig. 2. The device is configured by simply attaching an antenna to the notebook type

*5 Excel: A trademark of Microsoft Corporation

Fig.2 Wireless LAN system

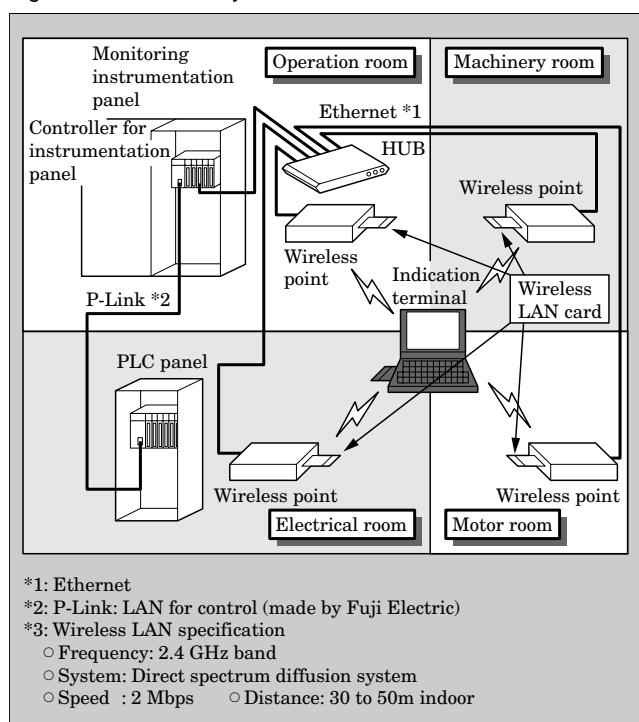
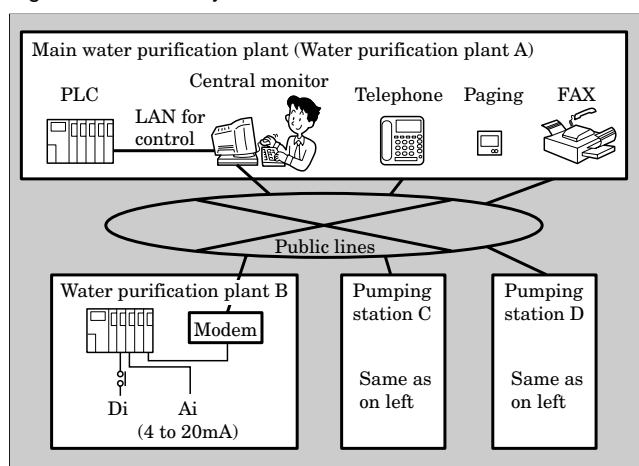


Fig.3 Small-scale system



personal computer and providing onsite access points.

2.1.2 Small-scale wide-area monitoring system

This centralized monitoring system is for a medium to small-scale town to improve the efficiency of maintenance and management (Fig. 3). This system uses a general-purpose personal computer and a public line (including use of a portable telephone) instead of a dedicated line, and has a low price, regarded as important by the management.

A central monitor collects data from each facility at a fixed period or an arbitrary dial-up time. The data is used as panel, trend and logging data.

When an abnormality occurs in any facility, an emergency report is issued to emergency report devices (telephone, paging, etc.) and the central monitor.

2.2 System for large to medium-fields

This system is constructed with a standardized architecture so that it can be applied to all systems from large to small-scale. This system achieves flexibility and low cost in response to the requirements of operation in a plant and yearly systematic construction.

2.2.1 Development concept

As a general trend in information and control system, rapid advances are being made in systematization technology closely related to network systems such as field dispersion, autonomy dispersion and open architecture systems.

This system, based on the above-mentioned trend, is developed to incorporate general-purpose technologies such as the personal computer and the Ethernet, aiming to improve maintainability and to achieve high functionality, high performance and high reliability corresponding to the open architecture.

This system enables configuration of systems that conform to the present state and in which the combination of old and new systems is becoming commonplace. This system is planned as a successor to the resources (hardware and software) constructed for the MICREX-IX integrated control system released in 1992.

The introduction of new technologies, compliance with an open architecture environment, enrichment of the service environment, and flexible response to user requirements, and guarantee of reliability are also planned for this system.

2.2.2 System requisites

When constructing an advanced open process automation system, it is necessary to maintain the past high reliability and real-time performance and further, to employ an open architecture, an important concept for information control. Requisites for the advanced open process automation system will be described below.

(1) Open architecture of data

The process data, operation and history data and trend data stored in the information processing system should be able to be freely exported to a personal computer connected to the network, and be used for such applications as the creation of statistic materials, evaluation of maintenance and management, development of operation plans, etc.

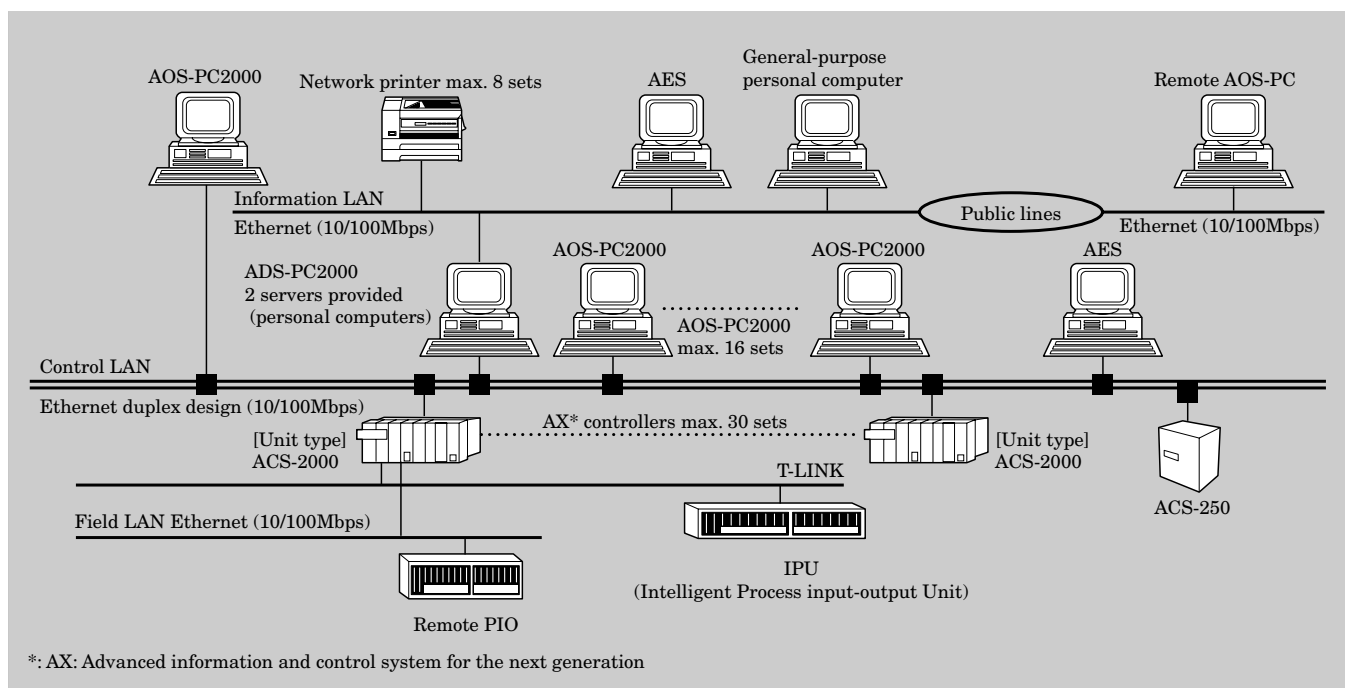
(2) Realization of end user computing

Through offering a support system that utilizes an easy to understand, personal-computer-like graphical user interface and ISV (independent software vender) software, the system should be able to be improved or modified by the user himself.

(3) Freedom and cost reduction

In the past manufacturer's standard, DCS (distributed control system), the user's freedom of selection was restricted to some extent to realize high reliability and comfortable operability.

Fig.4 System for large to medium field



Coupled with the adoption of an open architecture, utilization of de facto standards eliminates dependence upon manufacturer standards and results in demand for systems with a high degree of freedom, and downsizing results in cost reductions.

(4) Fusing of control and information

Due to the open architecture of the database, the user should be able to effectively utilize stored data, which could not be sufficiently utilized in the past. Further, the data should be able to be used in a high-level information and control package, and in the systems of business management, work management, utilization and opening of information, equipment maintenance, etc.

(5) Realization of general-purpose hardware

The system should be constructed using the latest devices on the market as components.

2.2.3 System configuration and features

The system configuration is shown in Fig. 4.

This system realizes an information system consisting of: operator stations, open database stations, high-speed control LANs, high-speed control stations and intelligent field centers. Furthermore, the configuration of this system integrates functionality through a high-speed LAN with operation control systems, work support service systems, multi-media communication systems and computer network systems, providing solutions to the aforementioned requisites.

(1) Open architecture

With the integration of monitoring and control, it is inevitable that demand increases for system integration with a production control system. However, since there is a large difference between plant control and production control from the viewpoint of processing

speed and function, coexistence of the plant control with the production control is a big problem.

In response to this problem, an operation environment is realized in which there is a link function between the process data and management data by employing an Ethernet, an open network, as the LAN for control in this system.

In addition, an SQL server is mounted on the database to provide open data so that the user can utilize the plant data freely and easily. The stored data can be edited and modified by using a commercially available spreadsheet program or database software.

Moreover, the user can utilize the same functions as in a HCI device through a general-purpose LAN from an AOS (advanced operator station) -PC (personal computer) for HCI use located at an arbitrary site.

This system is an open information processing system, is a successor to the high reliability and high performance of DCS, and will comply with future networks.

(2) Excellent reliability and maintainability

This system realizes high reliability and maintainability with an advanced self-diagnostic function and RAS information based on the technologies cultivated in the IX series for custom devices.

To achieve the required reliability of the operation system, duplex design for an Ethernet that uses any information, control or onsite LANs is made possible in addition to the conventional duplex system for the devices.

To achieve the required maintainability of the support system, it is possible to read the various types of RAS information and write programs from an AES

(advanced engineering station) that is remotely located and connected to information and control LANs. Coexistence of AES and AOS functions in the same personal computer provide the benefit that a manager in office or a maintenance person in a maintenance room can obtain RAS information in addition to monitoring the operation state.

2.2.4 Overview of the system

(1) Control LAN function

This system utilizes an Ethernet, a practical de facto standard in the OA field, and at this time, newly employs an FL-Net compatible protocol, recognized by JEMA as JPCN-2, allowing easy connections with products made by other manufacturers, while maintaining the real-time characteristic of data. In the past, this characteristic was considered difficult to maintain.

With this protocol, cyclic transmission, the transmission of information within a definite time, and message transmission, the transmission of management information and schedule information, are realized.

The FL-Net compatible protocol uses UDP/IP, a standard Internet protocol, as a basic part, and employs a token function, to avoid the collision of information and guarantee the reliability and real-time characteristic.

(2) HCI function

This innovative system can display panels identical to those of the HCI of the plant via public lines (ISDN, frame relay, etc.) from the remote-side general-purpose PC and the combination of an AOS-PC2000 (personal computer), an HCI using open architecture software. Further, a remote control monitoring system visible through a browser can be realized.

Moreover, in the operator station, the system can monitor camera images of a local patrol terminal. Onsite images can be monitored and controlled using remote connections, mobile computing and wireless technology.

The visibility of HCI itself is improved by increasing the number of colors and enabling color expression for the targeted plant. Operability is also improved by the Windows-like panel configuration, panel development, three-dimensional appearance of operation switch buttons, etc.

Either "mouse" or "touch" can be selected as the pointing device. Figure 5 shows examples of the panel.

(3) Data base function

Connection with general-purpose database

In business reporting by the user, instances of report generation based on operation data and control data are increasing.

Therefore, it is desired that the user himself can easily extract the operation data and control data, and then edit the data with general-purpose software.

In the ADS, connection with a general-purpose

Fig.5 Examples of panels

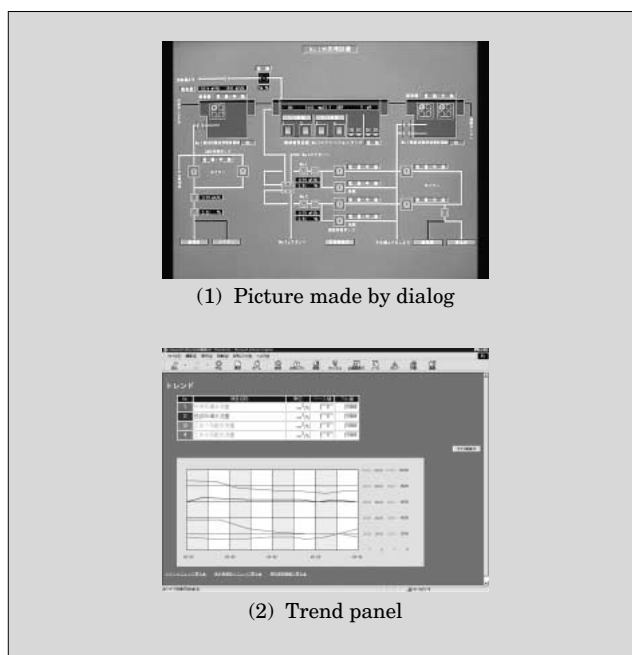
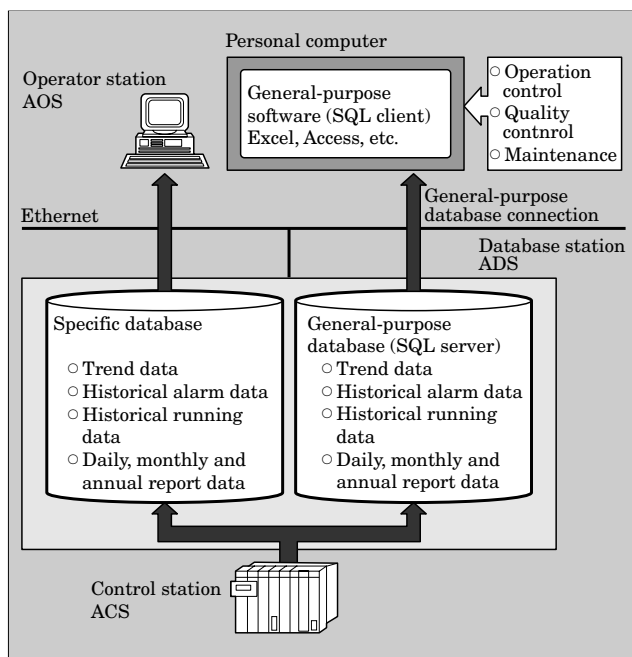


Fig.6 Database connection



database is possible (Fig.6). The general-purpose database is equipped with a Windows SQL^{*6} Server of the Microsoft Corporation. The trend, logging, alarm and operation history data managed by the ADS (advanced database station) has been stored in the general-purpose database. The user is offered an environment where he can freely manipulate this data using general-purpose software such as Excel and Access^{*7} through an Ethernet line on the persona

*6 Windows SQL : A trademark of Microsoft Corporation

*7 Access : A trademark of Microsoft Corporation

computer of a client.

(4) Controller function

For process control devices, open architecture and information-orientation are promoted by upgrading conventional technologies. New devices such as an intelligent field center and local handy terminals are provided.

Durable PC boards (PCU), which employ static type RAM disks having no moving parts can be mounted on the ACS-2000 controller. In this manner, advanced control (analysis and forecast calculation), conventionally required of workstations, can be computed on devices in the local field. This functionality

can be realized on distributed controllers in the local field by improving the calculation speed and real-time characteristics. Further, the product series is strengthened with regards to telemeter and telecontrol functions.

(a) Intelligent field center (IFC)

The intelligent field center (Fig. 7) realizes onsite LAN (Profibus^{*8}) transmission of all signals by integrating the conventional functions of control centers and auxiliary relay panels into a dedicated electronic control unit.

The control unit is equipped with a protection function, and memory functions of fault electrical current and operation history. Facilitating the collection of RAS information makes it possible to shorten the MTTR (mean time to repair).

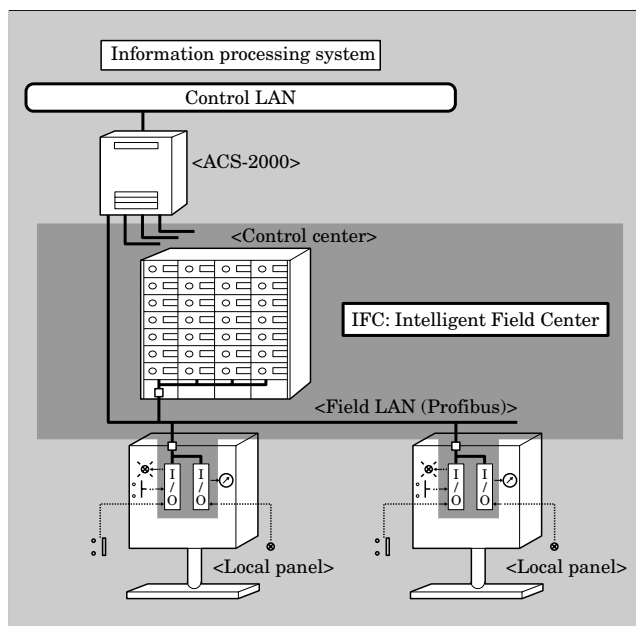
The employment of an onsite LAN (Profibus) facilitates cable cost reduction, wiring work rationalization and the addition of devices, as well as making possible the integration of management and control information, reduction of maintenance cost, promotion of sensor intelligence and construction of an inter-operable multi-vender system.

(b) Coagulation control system (advanced control)

It was confirmed by various experiments that the coagulation and sedimentation processes in a water purification plant depend on the size of particles in coagulation flocs. An advanced coagulant feed system (Fig. 8) combining a device to measure the coagulation flocs in real-time (coagulation sensor) with a model forecasting control device (coagulation controller) has been developed.

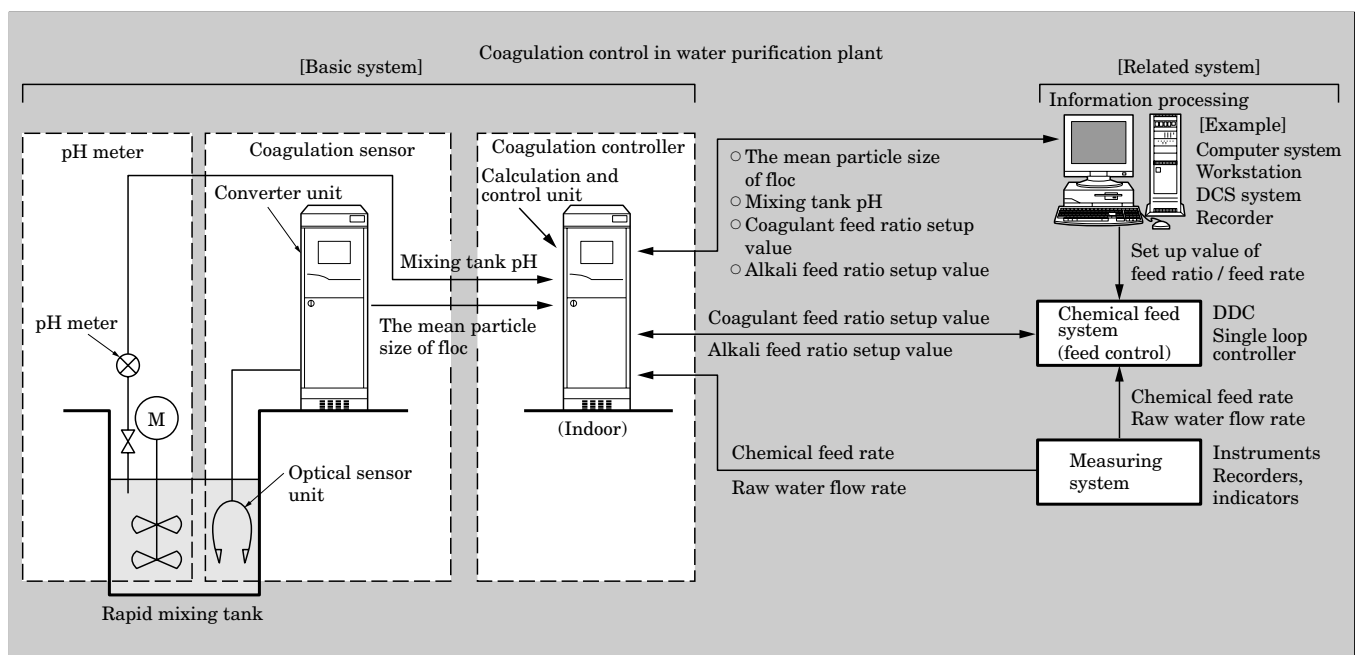
Conventionally, due to chemical feed ratio control

Fig.7 Configuration of intelligent field center system



*8 Profibus: A trademark of Siemens A.G.

Fig.8 Advanced control system



based on raw water turbidity (feedforward control) or chemical feed control based on operator's experience, too much coagulant has often been injected. However, due to feedback control based on the floc particle sizes, the coagulant came to be adequately injected.

In this control, since parameters must be adjusted depending on the characteristics of each mixing tank and water, it is necessary to gather data for a fixed period after introduction. However, this data analysis and parameter setting can be easily performed with support tools and engineering support.

(c) Telemeter and telecontrol

ASA (advanced supervisory and data acquisition)-2000 is a TM/TC (telemetry and control equipment) device that can be connected through a dedicated line on the voice call band to multiple large-capacity slave stations.

Connection between a master station and other controllers or HCI devices is possible with a company specific LAN (DPCS (distributed process communication system) -F and P/PE-LINK) and an Ethernet (compatible with FL-Net), making flexible configurations possible.

The master station can be connected with slave stations of various scales and functions such as the SAS (supervisory and data acquisition system) -50 in addition to the ASA-2000.

The slave stations can be constructed as multi-function devices by attaching not only a transmission function but also various sequence functions.

The transmission system can perform high-speed (maximum 9,600 bps) and highly reliable transmission by employing the HDLC (high-level data link control procedure) transmission method in addition to the CDT (cyclic digital telemeter) transmission method (cyclic transmission method).

The SAS-15 is a 1:1 type, compact-size and highly expandable TM/TC device that transmits over a dedicated line on the voice call band. Since the capacity and layout are fixed, such software as a layout table is unnecessary.

Since the master station can be connected via a T-Link (terminal link) to sequencers of the company and other controllers, flexible configurations are possible.

(5) Process I/O functions

In addition to the conventional IPU (intelligent process input-output unit), an open architecture PIO (process input-output control unit) is employed in the system.

The open architecture PIO^{*9}, a remote process input-output device developed under the basic principle of "small and high-reliable open architecture PIO", is connected to a 10 Mbps or 100 Mbps Ethernet.

Features of the open architecture PIO are listed below.

- (a) Remote process input-output device connected with an open architecture IO bus

The I/O bus that connects process input-output devices is an Ethernet that is an open architecture LAN. The interface technology is open so that controllers from other companies in addition to those from Fuji Electric may be connected.

- (b) Process input-output device equipped with features for the PAS (process automation system) market

This process input-output device is equipped with features for the PAS market such as a RAS function, redundancy function and resistance to the environment.

- (c) Process input-output device conforming to international standards

This process input-output device conforms to international standards such as safety standards, CE marking specifications and intrinsic safety standards, adapting to the worldwide market.

3. Conclusion

In this paper, we have introduced the latest information processing system for water and sewage treatment plants.

In the future, we will offer products and services for system lifecycle management, from daily maintenance through renovation, for the safe operation of this system.

*9 Incollaboration with Yokogawa Electric Corporation and Fuji Electric



Advanced Water Treatment Technology for Waterworks and Sewerage Systems

Kazutaka Takahashi
Norimasa Nonaka
Ryutaro Takahashi
Nobuyuki Motoyama
Kousei Sasaki

1. Introduction

One hundred years have elapsed since modern waterworks made their debut in Japan. Over this period, the saturation level of waterworks has exceeded 93% and Japan has literally entered an “era of high saturation.” However, due to the progress of industrial activities and concentration of the population in cities, various types of effluent flowing into the public water area has increased, and the offensive taste and odor of the tap water has become problematic. Further, it has become evident that various micro-organic pollutants and chlorinated materials exist in rivers, and the existence of trihalomethanes (THMs) in tap water has also become evident. Therefore, measures must be implemented in waterworks from a new viewpoint.

The recent deterioration of the water environment is becoming increasingly serious and the water environment is undergoing many various changes, regardless of artificial or spontaneous reasons such as micro-pollutants, such as pesticides and neutral detergents, eutrophication and the generation of pathogenic organisms.

In the future, the introduction of treatment and monitoring systems for pathogenic organisms, pesticides and micro-organic substances will be necessary, and especially, the regulation of disinfection byproducts is anticipated to become stricter.

It is expected that these treatment systems and measuring and monitoring system for micro-chemical substances will be developed in the future.

As for the trend of sewerage systems, the saturation level has exceeded 50% and their role is diversifying, as these systems are becoming an important infrastructure for daily life.

In the past, the role of sewerage systems was to collect and treat the wastewater discharged from the city and to remove the wastewater from our living area. Recently, however, treated sewage effluent has become an important water resource in the city.

Reflecting that status, disinfection of the treated sewage effluent requires a severity of methods. For example, when the treated sewage effluent is discharged into a clear stream where sweetfish are

swimming and many sorts of aquatic life are living, chlorination is not suitable because of its residual property and influence upon the ecology. Disinfection using ozone or ultraviolet radiation is required because its non-residual property. Therefore, at the Hirose-river purification center in Sendai-city, ozone disinfection was employed. Further, when reusing treated water, the necessary disinfection level differs depending on the use, and disinfection technologies shall be investigated in consideration of water quality items that provide a person with comfort such as transparency.

In the past, the purification process utilized conventional treatments to guarantee tap water in conformance with tap water quality standards. Now, however, due to the state of water pollution in water resources, it is becoming necessary to maintain the water quality of raw water itself for tap water.

In this paper, the latest advanced water treatment technology for waterworks and sewerage will be introduced.

2. Advanced Water Treatment Technology for Waterworks and Sewerage

2.1 Current practices of advanced water treatment

2.1.1 Advanced water purification in waterworks

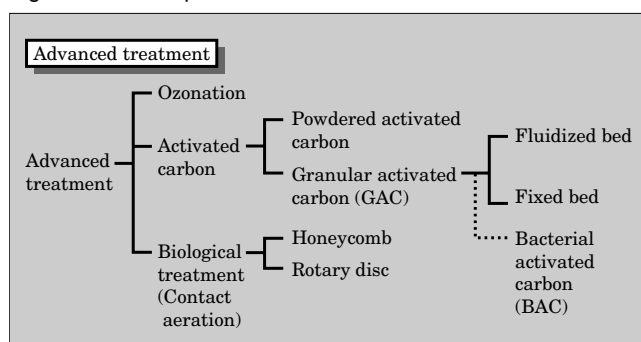
This treatment technology is used to treat odorous substances, trihalomethane forming precursors (THM-FP), trihalomethanes, color, ammonium nitrogen, anionic detergents, etc. which cannot be removed by conventional potable water treatments (coagulation-settling, slow filtration, rapid filtration and chlorination). This treatment technology is being applied in addition to the conventional treatment.

Advanced treatments are roughly classified into the following three treatments (Fig.1), and when necessary, are applied in combination in addition to independent application. In particular, ozonation is effectively applied together with activated carbon in many cases.

(1) Effects of ozonation

Ozonation is a treatment that uses the much stronger oxidation of ozone instead of that of chlorine.

Fig.1 Advanced potable water treatment



The function and main usage effects of ozonation are as follows:

- Odor destruction : Odor and taste removal
 - Removal of trihalomethanes and trihalomethane forming precursors
 - Removal of color
 - Conversion into smaller organic molecules :
Improving adsorption of activated carbon
 - Generation of biodegradable organic matter :
Improving treatment of biological activated carbon (BAC)
 - Removal of pesticides etc.
 - Oxidation of iron and manganese
 - Inactivation of virus
- (2) Effects of biological treatment

Biological treatment is used to obtain the effect of treatment from a biochemical reaction created by organisms existing on a biofilm. There are two types of biological treatments, anaerobic and aerobic, but the aerobic treatment is normally used in the waterworks.

Biological treatment is effective on ammonium nitrogen, algae, moldy odors, anionic detergents, manganese, etc., and removes turbidity. Biological treatment reduces the color, KMnO_4 consumption, etc., but the potential for forming halogenated organic matter is hardly removed if the precursor is soluble.

(3) Effects of activated carbon

There are three advanced treatments: ozonation, activated carbon and biological treatment. However, if ozonation and activated carbon are used together, odors are almost perfectly removed, and the life of the activated carbon is prolonged because the burden has been shared between ozonation and activated carbon.

Among the activated carbon treatments, there is a so-called biological activated carbon (BAC) treatment. This treatment is a system in which microorganisms are attached on the surface of granular activated carbon, and both physical adsorption of the activated carbon and biological treatment by microorganisms are simultaneously performed. As mentioned above, in this case, the life of the activated carbon increases by three times or more compared to the normal case.

Ozonation at the previous stage of the biological activated carbon treatment is effective in improving biological treatments. Ozonation and biological acti-

Table 1 Principal sewage advanced treatments and functions for the purpose of water reuse

Water quality item	Sand filtration	Activated carbon filtration	Ozone	Biofiltration
SS	◎	—	—	◎
Turbidity	◎	△	△	○
Color	—	○	◎	△
Odor	—	◎	◎	△
BOD	○	△	△	○
COD	△	○	△	△
Detergent	—	○	○	△
T-P	—	—	—	—
T-N	—	—	—	—
$\text{NH}_3\text{-N}$	—	—	—	○
E.-coli	△	—	◎	○
Dissolved inorganic substances	—	—	—	—

◎: Better ○: Effective △: Less —: None

vated carbon treatment are generally applied in combination. The effects of combined ozonation and biological activated carbon treatment is as follows:

- The burden of the treatment can be shared.
- The combination has a wide-ranging treatment effect.
- By combining the biological activated carbon treatment at the next stage of the ozonation, byproducts formed by ozonation are removed.

Bio-refractory organic substances are decomposed into biodegradable substances in ozonation, and these are biologically removed in the biological activated carbon treatment tank.

2.1.2 Advanced water purification in sewerage

Advanced water purification is a general term for higher-level treatment technologies whose aim is reuse, environment protection, or the removal of substances that cannot be removed by conventional secondary treatments. The treatments are classified mainly into the removal of organic substances and removal of nutrients.

The following technology exists for advanced treatments in sewerage:

(1) Removal of organic substances

Coagulation and sedimentation, sand filtration, activated carbon filtration, ozonation, biological fixed bed, ultra-filtration and reverse osmosis

(2) Removal of nutrients

Coagulation and sedimentation, crystallization dephosphatation, break point chlorination, ion-exchange, activated sludge with coagulant, phospho-stripping, anaerobic-aerobic activated sludge, biological denitrification, oxidation ditch, batch-type activated sludge and reverse osmosis

From amongst these technologies, ozonation is especially excellent in removing colors and odors, disinfecting reused water, and in eradicating the ozone

by self-decomposition so as not to influence the environment, differing from the residual of chlorination (Table 1).

2.2 Innovative advanced water treatment

2.2.1 Disinfection technology for *Cryptosporidium parvum* oocysts by ozone

In recent years, water-born group infection by *Cryptosporidium parvum* oocysts has become a severe social problem.

Cryptosporidium parvum is a parasitic protozoa, and only approximately $3\log_{10}$ of the infectious type of oocysts could be removed with conventional rapid filtration. Further, chlorination as a disinfectant in the waterworks hardly has any disinfecting effect. Moreover, the infective doses for human are so small that a 50% infective dose is 132 oocysts and a 1% infective dose is 2.4 oocysts. Therefore, this has become a very serious problem to guarantee water quality for sanitary tap water. To inactivate the *Cryptosporidium parvum* oocysts, treatment with ozone seems promising and the CT values of $2\log_{10}$ inactivation are 3.5 to 17mg·min/L estimated with the animal infection method and 12 to 16mg·min/L estimated with excystation. However, because of different experiment conditions and estimation methods, the CT values are greatly discrepant. Therefore, it is necessary to gather even more knowledge for defining the level of ozonation in water treatment.

Recent research on the ozonation disinfection of *Cryptosporidium parvum* oocysts conducted by the authors will be reported below.

(1) Influence of residual ozone

When testing under the conditions of pH 7, water temperature of 20°C and residual ozone of 0.05 to 0.5mg/L using excystation and the DAPI/PI staining test, the results showed that the influence of residual ozone was small and that the inactivation effect could be expressed with simple CT values. The inactivation CT values of 1 and $2\log_{10}$ were 6.3 to 7.6 and 10 to 12mg·min/L with excystation and 7.5 to 12 and 16 to 24mg·min/L with the DAPI/PI staining test. Further, the inactivation curve by ozone could be expressed with a series event model, and could be approximated with a two-hit model for estimation by excystation and with a one-hit model for estimation by the DAPI/PI staining test.

Using the mouse infection method, tests were conducted under the conditions of pH 7, water temperature of 20°C and residual ozone of 0.3 and 0.5mg/L. To estimate the infection, a *Cryptosporidium parvum* oocysts suspension after ozonation was centrifuged and washed 3 times, diluted step-by-step with 5 successive dilution series, and given to 5 scid mice (6 weeks of age) by oral-injection at every dilution step. After 4 weeks from the oral-injection, the oocysts in feces were examined, and an MPN (maximum probable number) was calculated. Defining ID (infective dose) as 1 MPN,

and IF (infective factor) as the reciprocal of ID (infective dose), the relativity of the infective factor was estimated with IF/IF_0 (ID_0/ID). As the result, the $2\log_{10}$ inactivated CT values are approximately 3 and 6mg·min/L at residual ozone levels of 0.3 and 0.5mg/L respectively, and the lower the residual ozone is, the smaller the CT value. The $2\log_{10}$ inactivated CT values reported by Finch, et al. were 1.7 and 2.6mg·min/L at residual ozone levels of 0.25 and 0.5mg/L respectively, showing a similar tendency. From these results, inactivation by estimation of infection could possibility be dependent upon the residual ozone. The cause of the difference between our research and Finch's research must be investigated, but, judging both results comprehensively, the $2\log_{10}$ inactivated CT value by estimation of infection is considered to be 6mg·min/L at the maximum.

(2) Influence of pH

In the excystation test, an experiment was conducted under the conditions of water temperature of 20°C, residual ozone levels of 0.1, 0.3 and 0.5mg/L and pH 6, 7, 8 and 9. The $1\log_{10}$ inactivated CT values were scattered about 5.5 to 9.0mg·min/L at the residual ozone level of 0.5mg/L, but were 6.3 to 7.6mg·min/L at the residual ozone level of 0.1mg/L and 6.7 to 6.9mg·min/L at the residual ozone level of 0.3mg/L, and no large difference existed. From these results, it is considered that the influence of pH does not exist under the condition of constant residual ozone.

(3) Others

Methodology has been investigated to estimate the inactivation level of animal infection with alternative methods such as excystation, DAPI/PI staining, etc., but these methods have not yet been sufficiently established. With the exception of specific organizations, there are many difficulties in introducing an estimation method by animal infection. From the viewpoint of the actual circumstances of the waterworks and sewerage fields in Japan, progress in research into the relation between both animal infection and alternative methods is desired.

2.2.2 Control of bromate ion formation

Bromate contamination, based on the guideline value of 25 µg/L in the WHO drinking water quality guideline (1993), has been determined to be a carcinogen, and in addition, the maximum contaminant level (MCL) of 10 µg/L was indicated by USEPA last year. These values are open to further discussion, but when raw water includes a high concentration of bromide ion due to the influence of sea water flowing against the stream, there exists a possibility that bromate ion exceeding these values is formed by ozonation.

To control this bromate ion, various research has been implemented. As an example, if the main goal of ozonation is to control trihalomethane formation, it has become clear that bromate ion formation can be controlled with the following method.

Fig.2 THMFP removal and bromate ion formation by ozonation

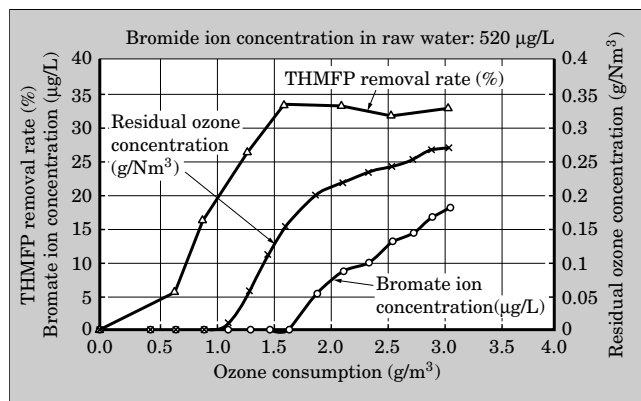
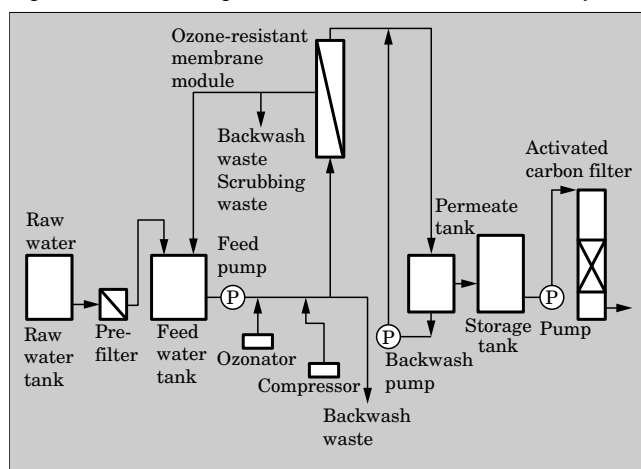


Fig.3 Schematic diagram of advanced water treatment system



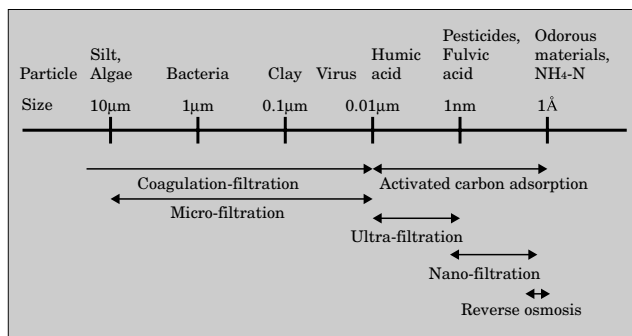
Bromate forming characteristics from the batch test shown in Fig. 2 indicate that ozone first reacts with the THM forming precursor followed by an increase of residual ozone in the treated water, and then the bromate ion is formed. From these characteristics, if residual ozone control is used for ozone dosage control and the residual ozone is controlled to approximately 0.1 to 0.2mg/L at the point where the residual ozone is a maximum, it is understood that the bromate ion formation will be restricted and sufficient removal of the THM formation ability will be obtained.

2.2.3 Advanced water treatment with ozone resistant MF membrane

Application has begun of micro-filtration (MF) membranes and ultra-filtration (UF) membranes to water purification, and these have been introduced into and are operating in more than one hundred small plants. In Europe and America, membrane filtration facilities have been already operating in purification plants of the several ten-thousands tons/day scale. In Japan, as a response to problems such as Cryptosporidium, it is considered that in the future, purification facilities using micro-filtration membranes and ultra-filtration membranes will be introduced into larger-scale purification plants.

On the other hand, due to the contamination of

Fig.4 Particle size and separation method



water resources, many purification plants are considering the introduction of advanced treatment facilities using ozone and biological activated carbon. In the advanced treatment MAC 21 project, a hybrid treatment of membranes and advanced treatment was also considered. However, when using organic membranes, deterioration of the membrane material became problematic, and therefore, the combination methods were limited. As a solution, a micro-filtration membrane using PVDF resistant to dissolved ozone as membrane material has been developed, enabling a more effective combination of membranes and advanced treatment (Fig. 3).

(1) Ozone resistant membrane module characteristic

Type of membrane : Outer skin hollow fiber

Membrane material : PVDF

(polyvinylidene fluoride)

Nominal pore size : 0.1 μm

Membrane area : 50 m²

(2) Membrane treatment and effects with ozone resistant membrane

Presently, the membrane filtration equipment approved for water supply is the equipment that uses micro-filtration membranes and ultra-filtration membranes, and treats turbidity and disease-causing germs such as bacteria, Giardia and Cryptosporidium. Conventional coagulation/sedimentation/filtration and membrane filtration basically treat the same substances. However, conventional technology treats water quality in mg/L orders, but in principle, membrane filtration perfectly removes particles larger than the pore size of the membrane. Since Cryptosporidium has the possibility to cause disease even when there are several oocysts in 1 m³ of water, conventional treatments may be difficult for operation and control. On the other hand, conventional treatments may surpass membrane filtration in such water quality criteria as color components.

Membrane filtration has the feature of perfect removal of impurities larger than the pore size as shown in Fig. 4, and in addition, the use of coagulant is zero or very small and the area for the facility can be reduced. However, membrane filtration must be combined with advanced treatments such as activated carbon adsorption for substances such as odorous

substances and pesticides that are difficult to remove with micro- or ultra-membrane filtration. Of the various combination methods, use of ozone resistant membranes is considered as a method that limits clogging and fouling of the membrane while utilizing the feature of membrane filtration. Use of ozone as a pre-treatment of membrane filtration promotes the insolubility of metallic salts, coagulation of impurities in raw water, decomposition of sticky organic matters, and limits clogging and fouling of the membrane. Further, by keeping the dissolved ozone concentration on the surface of the membrane, the multiplication of organisms on the surface is prevented and organic substances adsorbed on the surface or inside of the membrane are decomposed. As a result, a high flux can be maintained. Currently, a high flux of 5m/day per unit of transmembrane pressure, 4 to 5 times greater than the conventional membrane filtration for waterworks, is obtained in water with ozone dosing of 2mg/L. Moreover, the frequency of cleaning the membrane with chemicals is remarkably reduced,

facilitating operation and maintenance control. As for the water quality, good water treated with advanced treatment is obtained by combining ozonation and activated carbon.

3. Advanced Water Treatment for Sewerage

3.1 Nitrogen and phosphate removal

Advanced water treatment for sewerage and the technology of Fuji Electric is shown in Table 2. Regarding nitrogen and phosphate removal, representative of advanced treatment technologies, Fuji Electric has accumulated many good results for process control systems of the anaerobic-anoxic-aerobic method (A2O) and Modified Ludzack-Ettinger (MLE) process with coagulant.

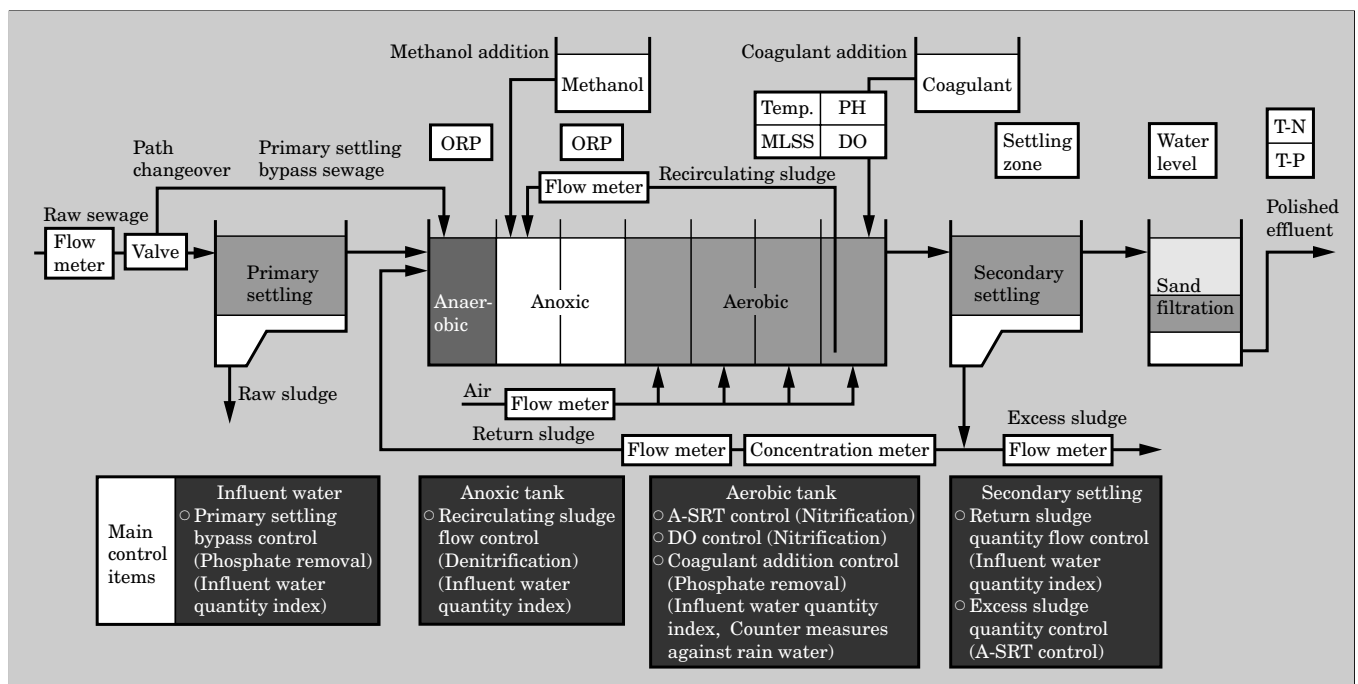
Figure 5 shows an overview of the process control systems of the anaerobic-anoxic-aerobic method. Nitrogen removal consists of 2 stages of nitrification and denitrification, and performs A-SRT control that controls the removal of excess sludge to stabilize the nitrification and the restoration of sludge to efficiently denitrify, etc. Phosphate removal can perform primary sedimentation bypass control to maintain a high-level of phosphate removals corresponding to variations in the inflow water quality, coagulant adding control, etc. Highly reliable control is a feature of Fuji Electric's technology.

In addition to the above-mentioned controls, computer based technology is developing to simulate the behavior of organisms in each reaction tank related to nitrogen or phosphate removal, and to predict the treated water quality. It is believed that the introduction of this simulation technology will lead to the

Table 2 Sewage advanced treatment and Fuji Electric's technology

Advanced treatment	Fuji Electric's technology
Nitrogen and phosphate removal	<ul style="list-style-type: none"> ○ A2O process control system ○ MLE nitrification-denitrification process with coagulant control system ○ Dual tank type intermittent aeration ○ Dual tank type intermittent aeration with membrane separation
Disinfection of treating water	○ Ozone disinfection
Reuse of treated water	<ul style="list-style-type: none"> ○ Ozonation ○ Advanced oxidation process (AOP)

Fig.5 Anaerobic-anoxic-aerobic process control system



realization of greater stability in the operation of advanced treatment processes.

Fuji Electric has independently developed a dual tank type intermittent aeration process and dual tank type intermittent aeration process with membrane separation as advanced treatment processes for small-

Fig.6 Flow diagram of dual tank type intermittent aeration process with membrane separation

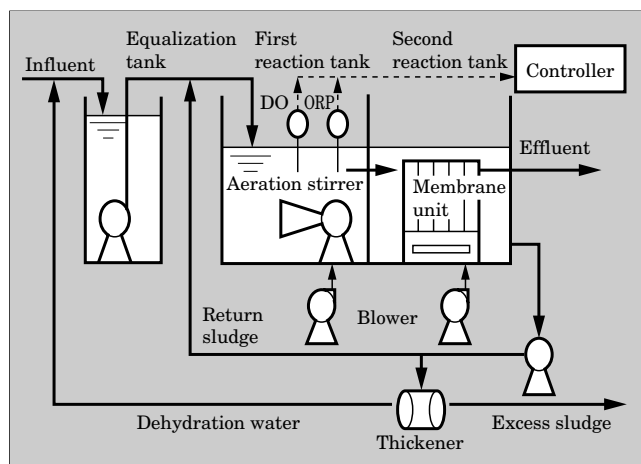


Table 3 Pilot plant treatment results for dual tank type intermittent aeration with membrane separation

Item	Influent water	Treated water	Removal ratio
BOD (mg/L)	181	<1	99% or more
COD (mg/L)	93	5.9	94%
SS (mg/L)	120	<1	99% or more
T-N (mg/L)	42	5.0	88%
T-P (mg/L)	4.5	0.1	97%

Table 4 Pilot plant test results

	Item		Treatment with additional ozone	Conventional treatment without ozone
Experimental conditions	Quantity of water treated (m³/day)		10	10
	Retention time in whole aeration tank (h)		24	24
	Aerobic tank (h)		12	12
	Anaerobic tank (h)		12	12
	MLSS concentration (mg/L)		3,000 to 4,500	2,500 to 4,500
	Sludge return ratio (%)		36	36
	Water recirculation ratio (%)		16	16
	Ozone treatment sludge (m³/day)		0.36	—
Ozone dosage				
for treating sludge (kgO₃/kg VSS)		0.05	—	
for treating water (mg/L)		16	—	
Water quality		Raw water	Treated water	Treated water
	T-BOD (mg/L)	191	11.6	10.8
	S-BOD (mg/L)	32.6	1.7	1.0
	T-COD (mg/L)	122	20.0	13.6
	S-COD (mg/L)	28.3	14.2	7.5
	SS (mg/L)	240	19.6	10.3
	T-N (mg/L)	34.4	7.1	5.6
	NH₄-N (mg/L)	18.1	0.1	0.1
	NOx-N (mg/L)	0.0	3.4	2.2
	T-P (mg/L)	4.2	2.3	1.8
	PO₄-N (mg/L)	1.3	1.6	1.2
Sludge	Excess sludge quantity (kg/day)		0	ca. 0.7

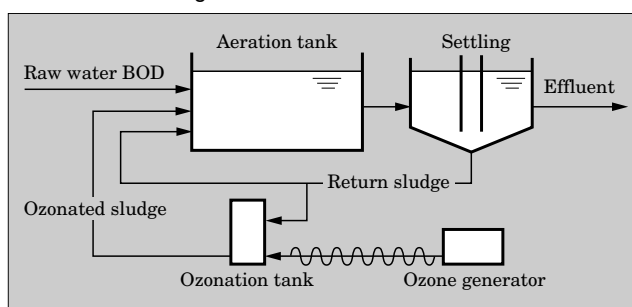
scale treatments. A flow diagram of the dual tank type intermittent aeration process with membrane separation, the most advanced treatment process, is shown in Fig. 6. This process repeats aeration and stirring and creates anaerobic-anoxic-aerobic conditions in a time series using the oxidation reduction potential (ORP) as a control index to remove nitrogen and phosphate simultaneously in each reaction tank. Table 3 shows the results of domestic sewage. The treated water quality is very good as BOD and SS (suspended solids) are less than 1mg/L, T-N is 5mg/L and T-P is 0.1mg/L. In the future, these advanced treatments will be widely introduced.

Fuji Electric has been actively dealing with the ozonation of sewage and has accumulated much experience with ozone disinfection that is harmless to the ecology in the discharge area and suitable for the reuse of treated water.

3.2 Activated sludge process without excess sludge

Activated sludge process is widely used for wastewater that includes organic substances. This is an

Fig.7 Flow diagram of activated sludge process without excess sludge



excellent process that utilizes organism functions, but the multiplied organisms must be removed from the system as excess sludge and disposed of. In recent years, because of the increase of sludge quantity and the shortage of sludge disposal areas due to higher sewerage saturation levels, it is strongly desired to reduce the excess sludge quantity. As a countermeasure to this problem, a new activated sludge process has been developed.

Figure 7 shows the basic flow diagram of the process. A constant quantity of activated sludge is pulled out through a return sludge line and returned to an aeration tank after treatment with ozone. The principle of this process is that the activated sludge is converted to organic matter able to biologically decompose due to the strong oxidation reaction of ozone in an ozone reaction tank. This organic matter becomes food

for the activated sludge in the aeration tank and decomposes into water and carbon dioxide, without creating sludge.

Table 4 shows experiment results in a pilot plant for 5 months where identical raw water has been treated both without and with additional ozone for comparison.

4. Conclusion

We introduced some of the concepts and Fuji Electric's technologies for advanced water treatment in waterworks and sewerage system. At Fuji Electric, we will continue to employ new technology and to develop more efficient and more highly advanced treatment systems in the future.



Engineering and Construction Techniques for Waterworks and Sewerage Systems

Yusuke Yamaguchi
Mamoru Sato

1. Introduction

Engineering can be defined as means and procedures for promoting system configuration and constructing a plant through the whole process of planning of the plant to its maintenance and management after the completion and depends largely on human intellectual work. Along with the greater sophistication and larger scale of plants, engineering work is rapidly increasing in complexity and scale. Special emphasis has been placed on engineering work because its quality greatly affects the quality and cost of the entire system.

On behalf of the company, a “site superintendent” is given authority and made responsible for onsite construction to complete a job to a purchaser’s satisfaction by the delivery date. It is important to establish construction techniques for this purpose.

In recent years, there have been urgent demands for public works in Japan to reduce cost and guarantee quality in response to the trends toward an improved bidding and contracting system and business globaliza-

tion. Furthermore, relaxation of various restrictions and computerization in the public sector are strongly demanded as part of administrative reform. Increased efficiency and labor savings are also required for public works.

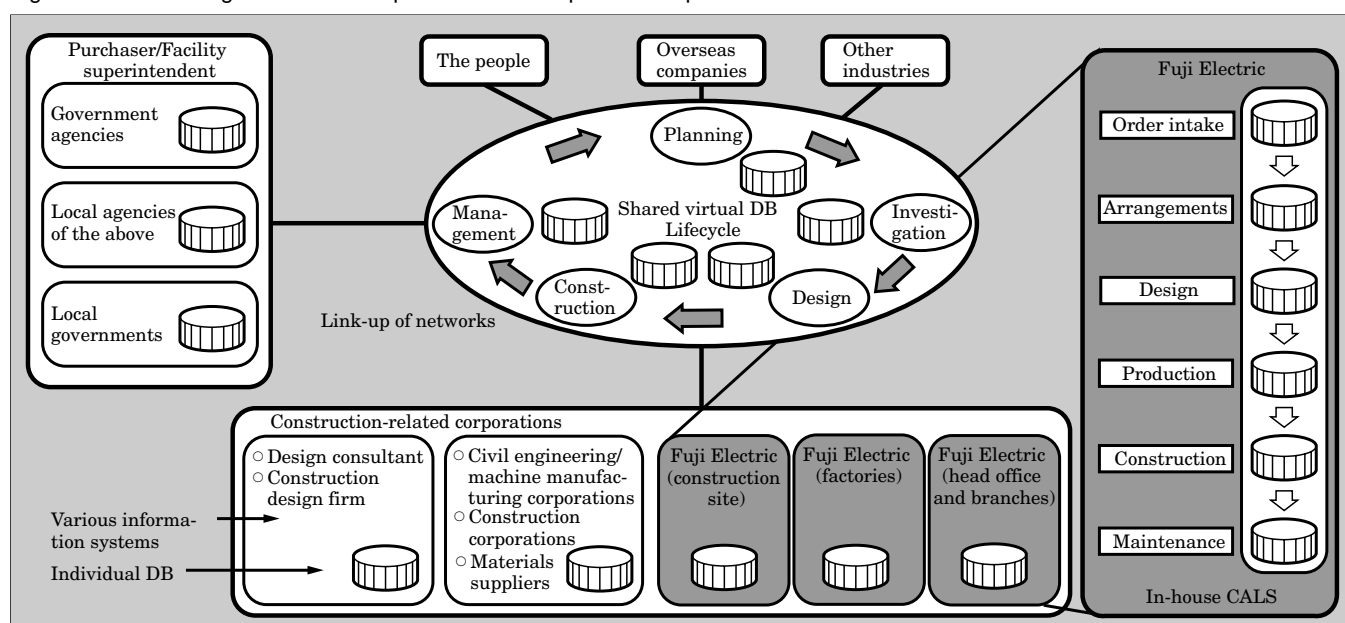
This paper introduces Fuji Electric’s handling of CALS (commerce at light speed), which is of increasing importance to engineering and construction techniques.

2. CALS

CALS was initiated by the Department of Defense (DOD) of the United States and is now performed worldwide led by private sectors.

Within private industry in Japan, CALS is actively performed under the guidance of the Ministry of International Trade and Industry (MITI). Within public works, “basic concepts for upgrading CALS/EC for construction works” have been drafted by the “Study Group for an Integrated Information System to Supporting Public Works” as promoted by the Ministry

Fig.1 Schematic diagram of CALS in public works and private companies



of Construction.

In the CALS/EC for construction works, all stages such as planning, design, cost estimate, bidding, contract, construction and maintenance are performed based on CALS for the purpose of lower total cost, greater efficiency and improved quality. An “action program” was prepared in 1997 and specific field tests are being implemented.

Figure 1 shows a schematic diagram of CALS implementation within public works and within a private company.

3. Fuji Electric's Handling of CALS

Fuji Electric has been participating in committees of the Inter-company Electronic Commerce Promoting

Fig.2 Key system for arrangements of plant components: ACTION

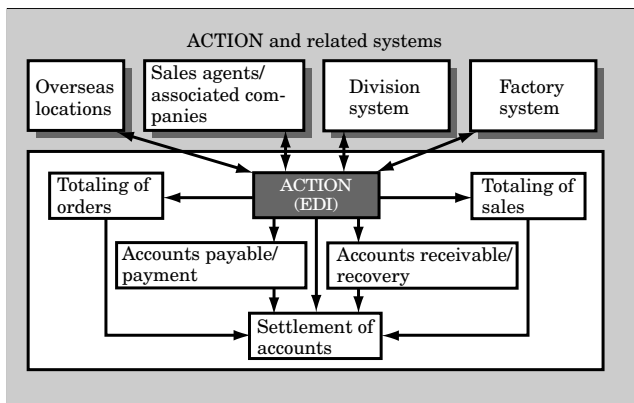
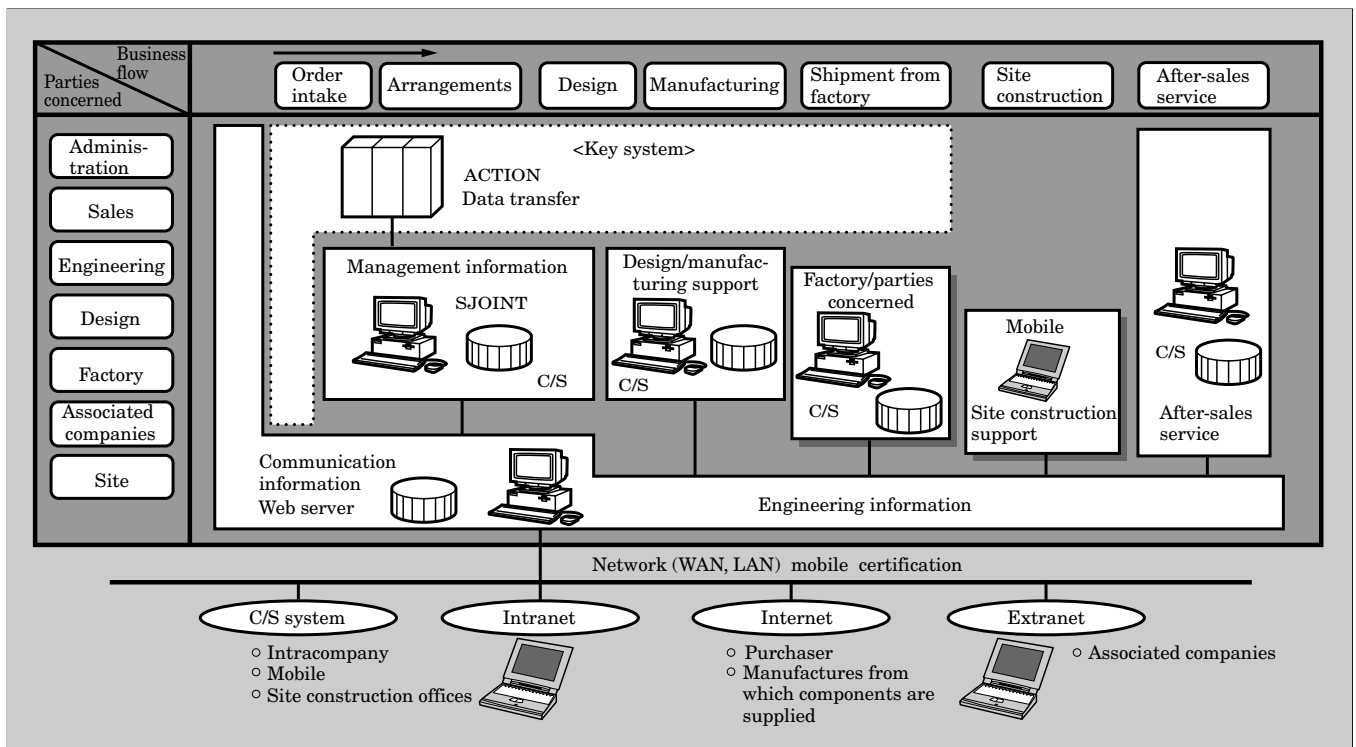


Fig.3 Integrated information system in public systems division



Organization and CALS Promoting Organization, promoted by MITI for the investigation, research, popularization, and education about CALS.

While implementing CALS, Fuji Electric and its associated companies are promoting business renovation of the whole Fuji Group by encouraging an upgrade of the information infrastructure, such as expanding networks and restructuring all key systems, aiming at data digitization, information sharing and paperless business.

3.1 Key system for plant-component arrangements

In corporate management, to restructure all business processes of a group of companies into a whole, cooperation is becoming increasingly important between departments concerned with sales, design, manufacturing, physical distribution and onsite construction.

In the restructuring of key system for plant-component arrangements, the primary objective is to share information within the group and build an integrated system to support order receipt, arrangements, sales and schedule control for the purpose of improving the function (F), quality (Q), cost (C), delivery (D), safety (S), and efficiency in overhead departments. Information sharing can be achieved by linking key system with systems of various departments in the company and its associated companies. (refer to Fig. 2)

3.2 Integrated information system in public systems division

In public systems division, purchasers are the

Fig.4 Example of intranet homepage



ministries, their agencies and local governments throughout Japan. Since many sales locations and sites are scattered throughout the country, business liaison through networks is very important.

Due to company-wide computerization, internal and external company telecommunication infrastructures such as intra-company networks and ISDN were dramatically improved, and information processing technologies such as the internet and mobile communication have made great advancement. This allows the integration of conventional business support systems and the construction of an integrated information system (Fig.3) that covers all relevant departments, site construction offices and associated companies, contributing to improved engineering work.

In public systems division, an intranet and an extranet were constructed as corporate CALS systems and put into operation. The former handles information ranging from order intake and site construction to maintenance throughout product lifecycles (information about communication, management and engineering). The latter handles information transfers and business liaisons with associated companies.

The sharing of information through the intranet is described below.

(1) Sharing of communication information

Communication among participant members is very important for unifying members' desires in the same direction and attaining an objective. A networked system and digitization eliminates location and time restrictions.

E-mail, a bulletin board system, an electronic conference room and schedule management are configured on the intranet as part of the shared communication information.

(2) Sharing of management information

Within the public systems division, an information system (SJOINT) was formed in 1993 that has been utilized for the division's business. It is consistent

information, from order intake through site construction for individual projects, in order to increase the efficiency of paperwork and share the information with other concerned parties.

ACTION system is only used to enter the data of arrangements information, avoiding duplicate entries. Not only the division's data but data from factories are automatically transferred from ACTION to SJOINT, where updated data is always available.

(3) Sharing of engineering information

In the manufacture, construction and maintenance of a plant system, not only is communication and management information necessary, but engineering information such as communication notes, specifications and drawings is also essential.

The aforementioned information is processed and altered, new information is created over the course of plant processes from order intake through site construction, and an enormous amount of data is transferred from upstream to downstream divisions. Great care must be taken so that no errors occur during processing and alteration.

For these reasons, the company constructed a system using CASE (computer aided system & software engineering) and has been improving the productivity and quality of delivered systems.

The above activities are, however, information sharing between limited sections, and still much effort must be expended to exchange engineering information between organizational groups.

Information used while conducting a plant's business includes a variety of documents, drawings, photographs, videos, spreadsheets and databases. There are many technical challenges to the distribution of digitized information of the above, and to the digitization, distribution and exchange of past information assets, for which high expectations are placed upon the realization of EDI (electric data interchange) to standardize information exchange.

Figure 4 shows the top page of an intranet.

3.3 Project homepage

In this intranet system, all the members concerned with the project share information from order intake to shipment and maintenance. Information is managed for each project to increase the information transfer speed, to attain instantaneous information and to promote each project smoothly.

Shared information about each project can be entered in the form of a homepage (Fig. 5) and all the information about that project can be obtained on the homepage.

Communication information and information created by the support and management systems to be described later can be shared by making the information public as FQCDS information.

However, specifications and working drawings, which are the result of engineering, have not yet been

Regarding the distribution of drawings, since CAD tools are not standardized there are many challenges to be overcome for the exchange of such information, including data exchange.

In addition, management and database information entered through a C/S (client/server) system is available and can be viewed with a Web browser by connecting a Web server and database. This contributes to improved management of various divisions based upon correct and wide-ranging information.

There are many types of content and information media to be shared in engineering tasks. It is required to develop CALS constituent technologies such technology to digitize content and information, workflow techniques (seal of approval, confirmation), technology to control altered information and security technologies.

Design, manufacturing and testing have been mechanized and automated.

Fuji Electric constructed and has been utilizing an engineering environment which can provide integrated support not only to a monitoring and control system for water treatment FAINS but also to control systems for

The diagram illustrates a proposed design methodology. At the top, a workflow is shown: a **Purchaser** provides **Control specifications** to a **Documenter**, who generates documents. These documents are then processed by an **Editor**, who sends them to a **Monitor**. The **Monitor** generates a **Program** which is sent to a **Controller**. Below this, a **Conventional process** is shown with a large 'X' over it, indicating it is being replaced. The conventional process includes icons for **Design**, **Synthesis**, **OR**, **Simulation**, and **Verification**, along with a table of numbers. To the right of the conventional process, a list of three benefits is provided: 1. Productivity improvement, 2. Quality improvement, and 3. Match between documents and specifications.

Design	3
Synthesis	4
OR	5
Simulation	6
Verification	7
	8

1. Productivity improvement
2. Quality improvement
3. Match between documents and specifications

The support system aims at improving quality and productivity of engineering tasks by automatically generating downstream information from upstream information. Basic concepts for system design, software design and test scheduling to achieve this goal are listed below.

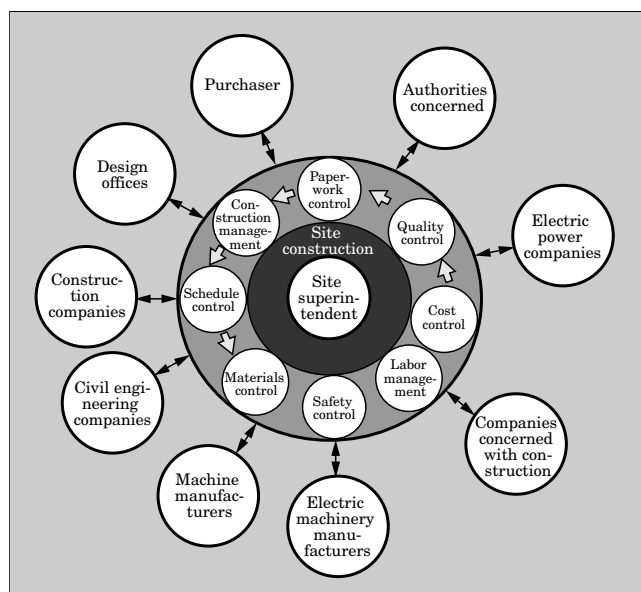
- These concepts create an environment for a common platform that can be used uniformly with various packages. Generated information is publicly displayed on a project homepage, conveyed to other divisions, and utilized for copying and processing by downstream divisions.

Figure 7 shows management tasks for site construction. A site superintendent must fully understand the objective and contents of the construction and manage it (schedule, materials, quality, labor costs, safety, paper work, costs, etc.) in accordance with drawings, specifications, related laws and regulations and contract conditions.

In the past, however, sites have been treated as if they were solitary islands with regard to information. Site construction is managed as if in a virtual factory, but in reality, there are many challenges in terms of production rationalization systems and job support through networks, compared with those in a factory.

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Fig.7 Management tasks for site construction

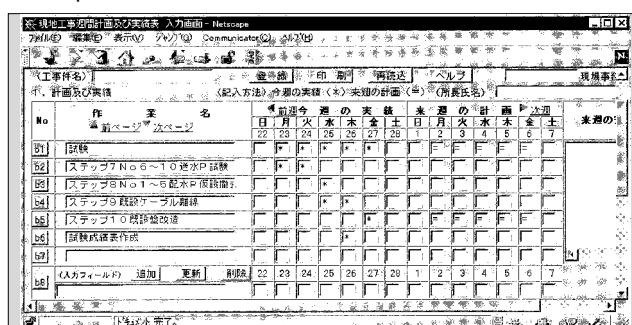


construction of a mobile network environment, Fuji Electric has constructed and started operation of an environment where company divisions and remote sites can exchange information interactively. Site support systems are intended to improve quality and reduce costs of construction management, allowing site superintendents to perform efficient jobs and all parties concerned to convey information at higher speed.

Collection of site construction information for each project on the project homepage allows company divisions and remote sites to share information, and makes it easy to post and to reuse various drawings and materials onsite.

In addition, laws and regulations related to site construction, internal regulations for safety and sanitation, and job manuals are posted on the homepage so that they may be thoroughly understood by site superintendents scattered across the country. The support system reduces jobs in administrative departments that handle the distribution of documents and notification of their alterations. The time required for information conveyance can be considerably reduced by

Fig.8 Example of homepage for weekly schedule and performance



the system compared with mail or home delivery in the form of paper.

Figure 8 shows an example homepage for a weekly schedule and performance.

4. Conclusion

This paper has presented Fuji Electric's approach to engineering and construction techniques for waterworks and sewerage systems, focussing mainly on Fuji's support system from the viewpoint of information sharing.

Browsing, processing, conversion and generation of digitized information are performed throughout the lifecycles of products and facilities according to the CALS concept, "data is only once created and used as many times as possible." Introduced as an example in this paper is the CALS implementation from order intake to delivery and maintenance of waterworks and sewerage systems products in a group of companies.

Application of ISO9000S (quality ISO) and ISO14000 (environment ISO) to public works are under study. Fuji Electric is pushing hard to obtain more ISO certifications. CALS is an efficient means of handling the thorough documentation (procedures, evidences) required for obtaining ISO certification.

Fuji Electric's CALS has just begun. Fuji Electric will continue to promote and spread CALS applications within companies, capitalizing on experiences and techniques accumulated in CALS activities.

Global Network

■ : Representative Office ● : Sales Bases ◆ : Manufacturing Bases

AMERICA

- **FUJI ELECTRIC CORP. OF AMERICA**
USA
Tel : (201) 712-0555 Fax : (201) 368-8258
- ◆ **U.S. FUJI ELECTRIC INC.**
USA
Tel : (908) 560-9410 Fax : (908) 457-0042
- ◆ **GE FUJI DRIVES AMERICA S.A. DE C.V.**
MEXICO
Tel : (08) 154-7000 Fax : (08) 154-7007
- **GE FUJI DRIVES USA, INC.**
USA
Tel : (054) 387-5925 Fax : (054) 387-8580

EU

- **FUJI ELECTRIC CO., LTD.**
Erlangen Representative Office
F.R. GERMANY
Tel : (09131) 729613, 729630 Fax : (09131) 28831
- **FUJI ELECTRIC GmbH**
F.R. GERMANY
Tel : (069) 6690290 Fax : (069) 6661020
- ◆ **FUJI ELECTRIC (SCOTLAND) LTD.**
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FRANCE
Tel : (04) 73-98-26-98 Fax : 04-73-98-26-99

ASIA

East Asia

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Beijing Representative Office
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Taipei Representative Office
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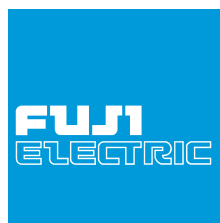
Southeast Asia

- **FUJI ELECTRIC CO., LTD.**
Bangkok Representative Office
THAILAND
Tel : (02) 653-2020, 2021 Fax : (02) 653-2022
- ◆ **FUJI ELECTRIC (MALAYSIA) SDN. BHD.**
MALAYSIA
Tel : (04)403-1111 Fax : (04)403-1496
- ◆ **FUJI ELECTRIC PHILIPPINES, INC.**
PHILIPPINES
Tel : (02)844-6183 Fax : (02)844-6196
- **P. T. BUKAKA FUJI ELECTRIC**
INDONESIA
Tel : (021) 5266716~7 Fax : (021) 5266718
- ◆ **P. T. FUJI DHARMA ELECTRIC**
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Tel : 479-5531 Fax : 479-5210
- ◆ **FUJI/GE PRIVATE LTD.**
SINGAPORE
Tel : 533-0010 Fax : 533-0021

South Asia

- **THERMAX FUJI ELECTRIC LTD.**
INDIA
Tel : 0212-770436 Fax : 0212-77-5686

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