Modern Electrical Technology for Water Treatment Plants

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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

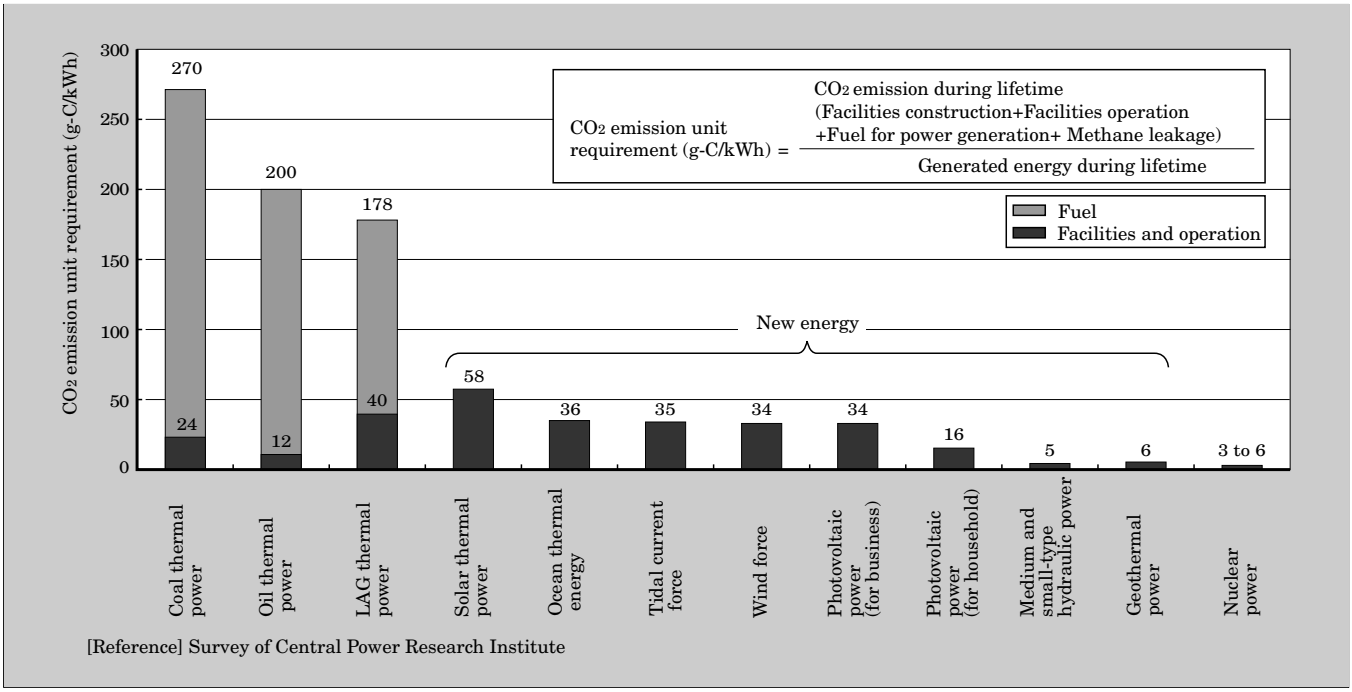
Most of the energy consumption in waterworks and sewerage facilities is electric power consumption. To reduce the power consumption it is effective to accelerate application of dispersed power generation of new energy.

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 CO_2 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 CO_2 emission



[Reference] Survey of Central Power Research Institute

Fig.2 Basic configuration of photovoltaic power generation system

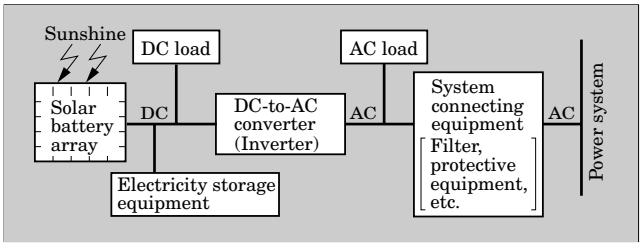


Table 1 Proposed applications of photovoltaic power generation systems to waterworks and sewerage

Features of waterworks and sewerage	Installation location of solar battery	Applied photovoltaic power generation system
Available upper space is wide.	○ Upper space of water filtration basin, filter bed ○ Upper space of first sedimentation, last sedimentation and aeration tank [Cover] ○ Roof of facilities house	○ 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. Detection elements for pressure, flow rate, water quality are scattered.	○ Roof of facilities house ○ Special mounting frame (such as a pole)	○ Small capacity facilities ○ Connected to commercial power system (Storage battery is used in case of power outage)

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.

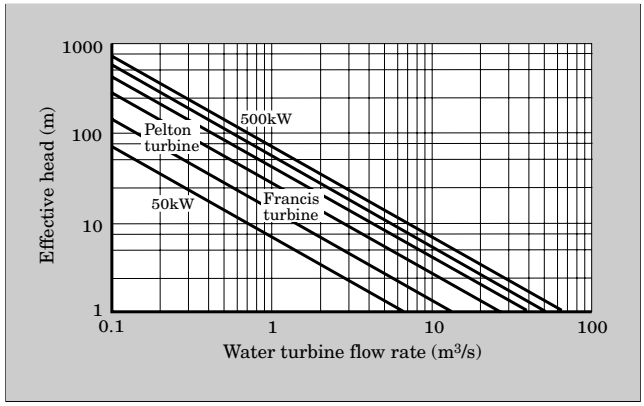
2.1.2 Application to water treatment plants

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 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.

Fig.3 Applicability of water turbine



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 kWs. 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 42m^3/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

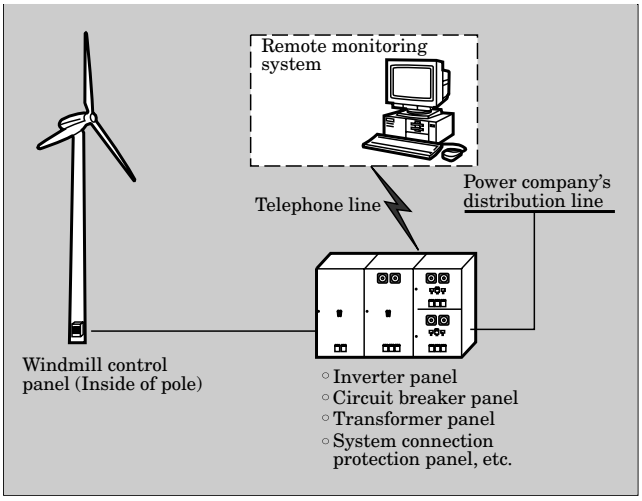
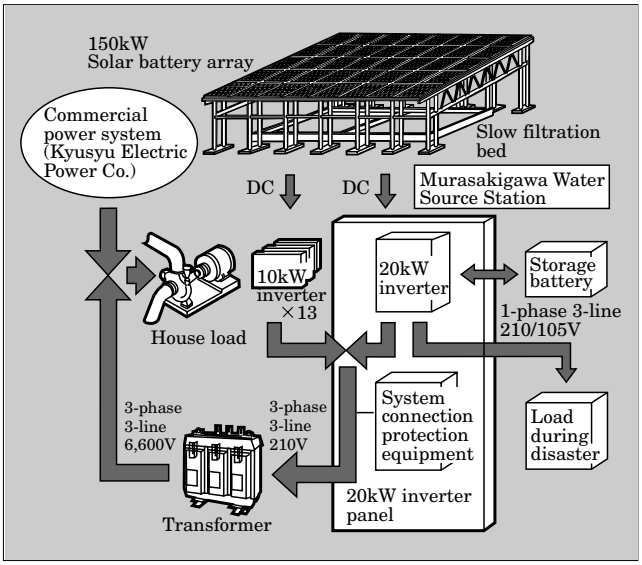


Fig.5 Overview of photovoltaic power generation system in Murasakigawa Water Source Station



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 turbulance 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 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, CO_2: 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

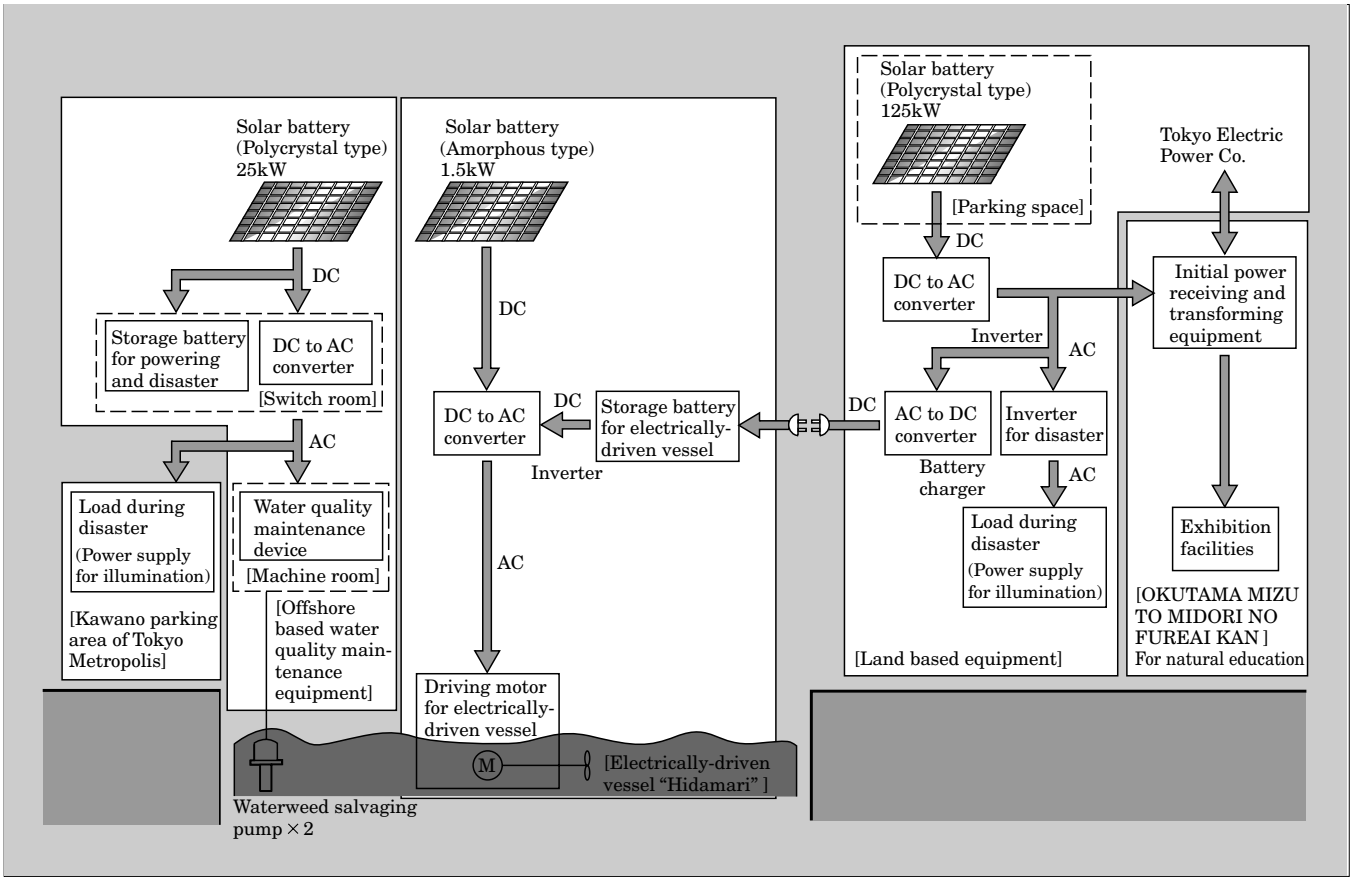


Fig.7 Appearance of vessel for conveying salvaged waterweed

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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

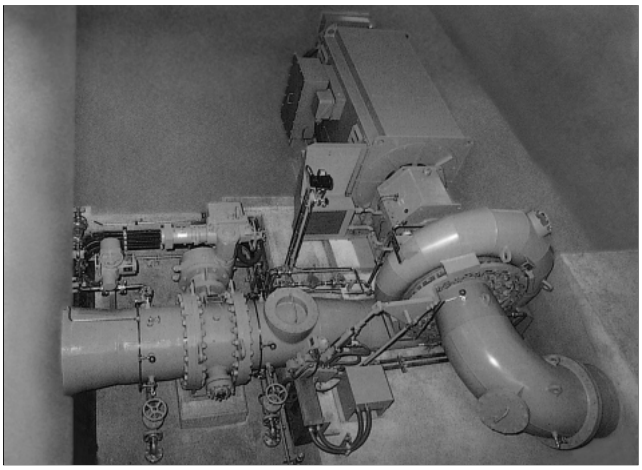
The reservoir covers a vast area of a lake and is suitable for the installation of a large-scale photovoltaic power plant. It is believed that the growth of waterweeds due to water inflows into lakes, marshes and dams may influence the water quality. A system that operates on energy obtained from photovoltaic 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

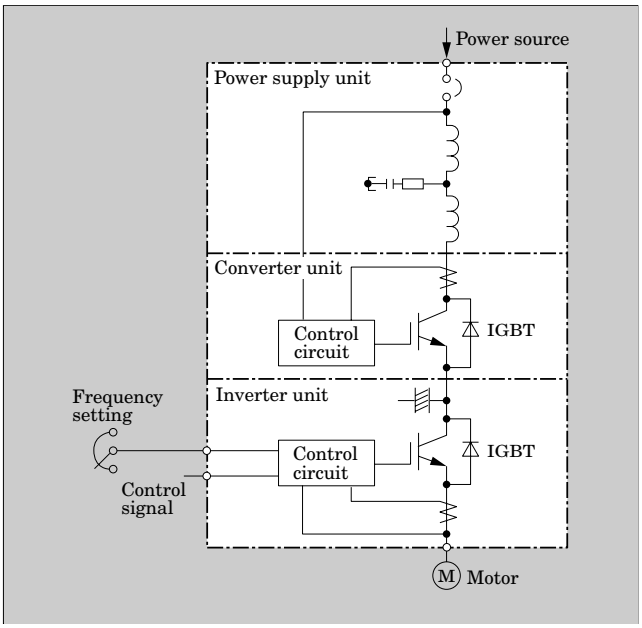
Pump or blower motors consume most of the electric power in water treatment plants. Therefore, energy saving by these motors allows the whole plant to effectively conserve energy. Usually the pumps and blowers are manufactured at a rated capacity according to the rated water (or gas) volume.

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.

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



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

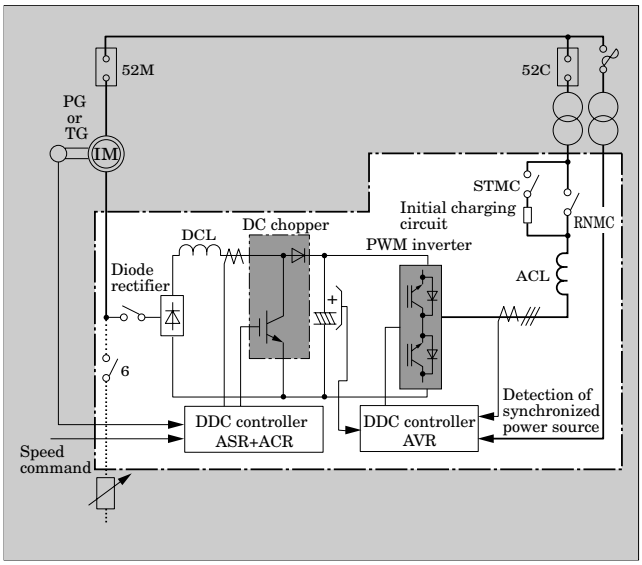
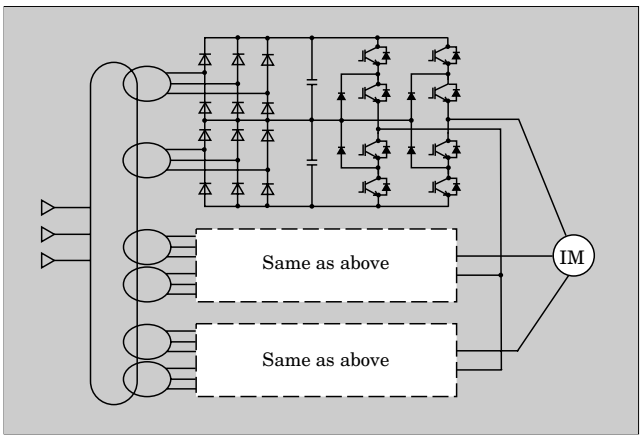


Fig.11 Circuit configuration of high-voltage directly driving VVVF



(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 thyrister inverter, this system has the following advantages. The circuit configuration is shown in Fig. 10.

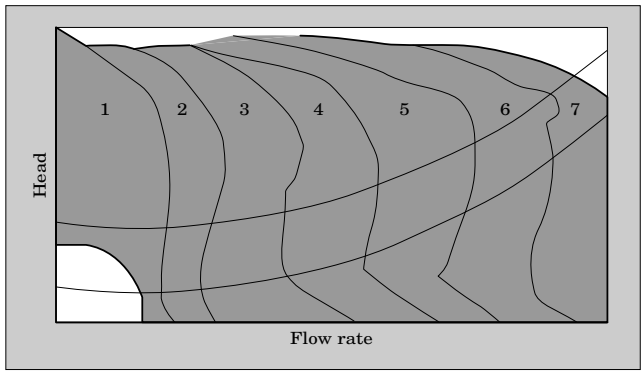
(1) Countermeasures against harmonics are unnecessary

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	○ Restricts loss and influence due to harmonics, such as overheat, noise, vibration ○ Compensates reactive power	○ Harmonics generating apparatus such as variable speed controllers, non-interrupting power supplies, rectifiers	○ Restricts overcurrent due to harmonics ○ Reduces power charge by improved power factor	
	Demand controller	○ Supervises control of contract demand	○ Receiving point power demand	○ Reduces contract demand ○ Prevents excessive contract demand	
	Automatic power factor regulator	○ Reduces ohmic loss due to reactive power	○ Compensation of transformer excitation ○ Induction motor	○ Reduces power charge ○ Reduces power loss	○ Reduced voltage drop and increased capacity factor.
	Molded transformer	○ Extensively reduces loss by core material and mold technology	○ Initial power receiving and transforming equipment, powering equipment, illumination equipment	○ Compared with usual dry type, no load loss is reduced by approx. 2/3 and load loss by 1/2 to 2/3.	○ Changeover operation of working number of units ○ Operation at highest efficiency
Pumping equipment	Variable speed controller VVVF	○ Realizes high-efficiency operation by changing frequency and voltage	○ General-use type squirrel-cage induction motor ranging from 0.2kW to 900kW	○ Reduces approx. 65% of loss at 70% speed	
	Thyrister Scherbius	○ Realizes high-efficiency operation by returning secondary slip power to power source	○ Wound-rotor type induction motor from approx. 100kW to 5,000kW		
	High-efficiency motor	○ Achieves high-efficiency by using latest design and low-loss material	○ Induction motor	○ Maintains high-efficiency at light load (above 50%)	
Illumination equipment	Power saving device	○ Saves excessive power by restraining excessive voltage to appropriate value	○ Low voltage powering and illuminating equipment	○ Reduces working power by 10 to 20%	○ Apparatus lifetime is expected to increase also
Miscellaneous	Reduced stand-by power	○ Applies Energy Star logo to energy-saving apparatus, according to International Energy Star Program	○ Computer, display device, printer, facsimile, copy machine	○ 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 Pm 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 running 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

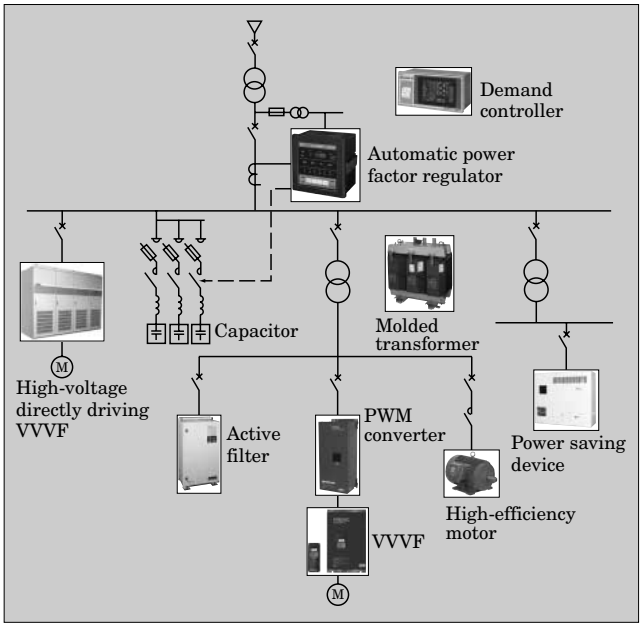


Fig. 13.

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 SF_6 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. SF_6 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 SF_6 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 SF_6 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

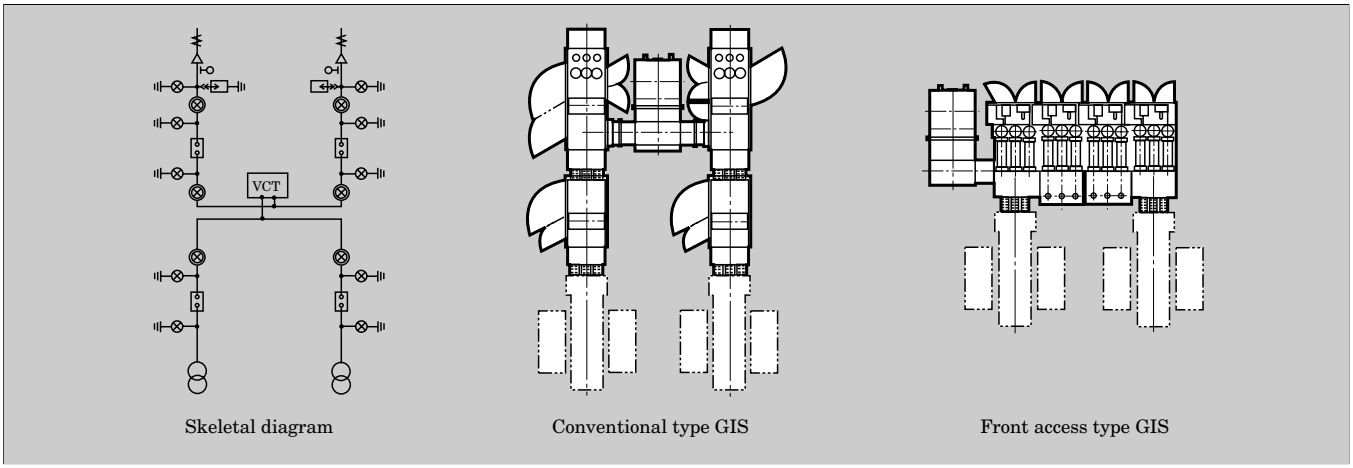


Fig.15 Appearance of front access type GIS

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Fig.16 Appearance of digital multi-function relay

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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 ($\cos \phi$)		—	○
	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	○ 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 Overloard pre-alarm Direction ground pre-alarm MC fault		Test	TEST mode	○ Protection function: Overload, ground fault ○ Control function: Center (via transmission), onsite, MCC
Monitor, display	Monitor display	○ Load current ○ Leakage current ○ Fault current ○ Fault condition ○ Setting value ○ Operating record		CPU self-diagnosis	○ Normally: CPU monitor, Communication monitor ○ During operation: ROM monitor, RAM monitor, EE-ROM monitor, Analog input value monitor ○ During test: Analog input value monitor
Manipulation	Operation	○ Selector switch: REM-DIR-TEST ○ Push button switch: ON, OFF, REV	Transmission	System	○ F-NET: Normally provided with T-Link ○ Transmission rate: 500kbs ○ Transmission distance: 1km ○ Transmission line: 2-wire twisted pair cable ○ Number of terminals that can be connected: 32/1-link to 128/4-link
	Instrumentation, setting	○ Push button switch: MODE SELECT, SET/FLT, RESET, ∧, ∨, ENTER		Transmission data	○ Transmission quantity: Digital 26-items, analog 4-items ○ Data contents: Operation signal, fault signal, measured value, setting value, present value of operation record
Control	Sequence	○ Main circuit: Automatic setting (Non-reversible, reversible, power source feed) ○ Control circuit: 256-pattern		Reception data	○ Reception quantity: Digital 22-items ○ Data contents: Operation signal, setting value, initial value of operation record
	Restart after momentary power interruption	○ 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	○ Control signal: 4-point (88F, 88R, interlock, external fault) ○ Manipulation signal: 4-point (ON, OFF, REV, center)			
	Output	○ 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	○ Overload: 0 to 1000%A ○ Ground fault: 0 to 500mA			
	Setting value	○ All setting items			
	Operation record	○ 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			

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.