

TAIYO
THYRISTOR
INVERTER
TYPE

S

SUMMARY

SHAFT SERIES
GENERATING
SYSTEM

System Output
200 KW thru.
4000 KW



TAIYO S SERIES SHAFT GENERATING SYSTEM

*assures you great energy-saving,
labour-saving and dependability*

TAIYO "S" series shaft generating system has been developed by fully utilizing the supreme techniques and knowhow accumulated over many years by TAIYO for producing ships' electrical machinery and apparatus. This system has high performances and high quality and can always supply constant frequency and voltage even though the speed of the main engine greatly fluctuates, thereby assuring the saving of energy and labor.

(Combination shop test view of 3.5MW 6.6KV system by using temporarily shaft & bearing)

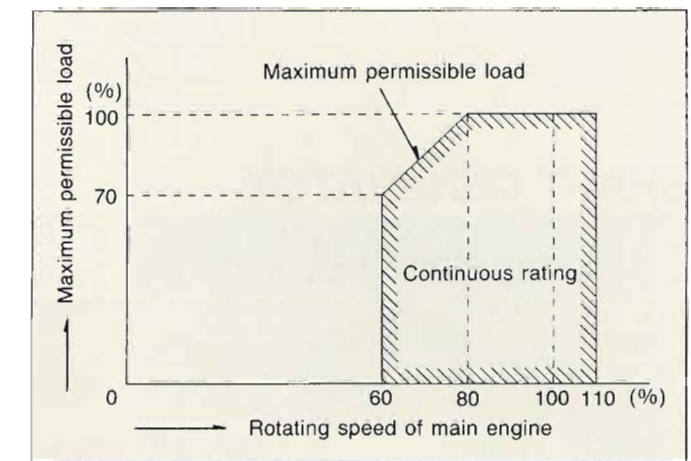


STANDARD SPECIFICATIONS

Output: 200-4000Kw
Voltage: 450V, 6.6kv, 3.3kv
Frequency: 60 Hz or 50 Hz
Number of phase: 3 phase 3 wire
Power factor: $\cos\phi = 0.8$
Rating: Continuous
Ambient temperature: 45°C or 50°C
Insulation: F class
Enclosure: Enclosed drip-proof type (IP-22 or IP-23) or Totally-enclosed type (IP-44)

Revolution speed (100% revolution speed)
Model SIG, SPG, SHG: 110, 92, 79, 69, 62, 55 min⁻¹
Model SFEK: 1200 min⁻¹

A special request is acceptable for other r.p.m. by the consultation.



APPLICABLE STANDARDS & RULES

TAIYO "S" SERIES SHAFT GENERATING SYSTEM complies with the specification of the following Classification Societies and Standards.

• Classification Societies:

JG Ministry of Transportation, Japan
NK Nippon Kaiji Kyokai
LR Lloyd's Register of Shipping
ABS American Bureau of Shipping
DNV Det Norske Veritas
BV Bureau Veritas
GL Germanischer Lloyd
CCS Cina Classification Society
KR Korean Register of Shipping
CR China Corporation Register of Shipping
RINA Registro Italiano Navale

• Standards:

ISO International Organization for Standardization
IEC International Electrotechnical Commission
JIS Japanese Industrial Standards
JEC Japanese Electrical Committee
JEM The standard of Japan Electrical Manufacturers' Association

Other Classification Societies and Standards not listed above may also be complied by the consultation.

SYSTEM CONFIGURATION & PRINCIPLE

Basic Principle

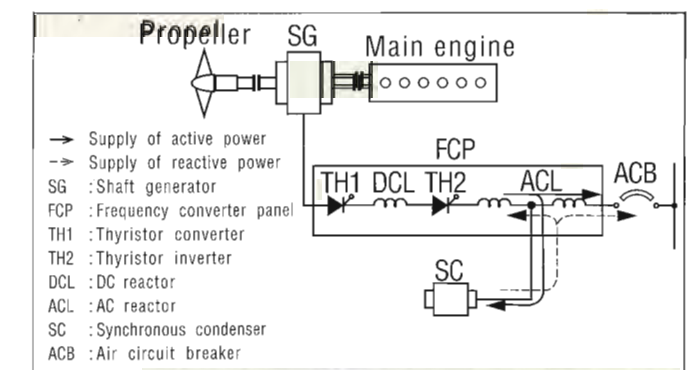
AC power from a shaft generator with a fluctuating frequency due to revolution fluctuation of main engine is converted into DC power with no relation to frequency by means of thyristor converter (TH1).

DC power is smoothed by DC reactor (DCL) and then inverted to AC power with a constant frequency by means of thyristor inverter (TH2).

Waveform of AC inverted by the thyristor inverter (TH2) is improved by AC reactor (ACL) and then fed to buses through an air circuit breaker (ACB). In order to make the frequency and voltage at buses constant, the phase control by means of thyristor converter (TH1) and thyristor inverter (TH2) as well as voltage control using the shaft generator (SG) and synchronous condenser (SC) are performed.

A compensator for the low speed rotation of shaft generator, a frequency drooping characteristic apparatus during parallel operation and various kinds of protection circuit are provided.

Reactive power required for the thyristor inverter (TH2) and load as well as a sustained short-circuit current required for selective tripping during a short-circuit at buses are supplied from the synchronous condenser



Application System

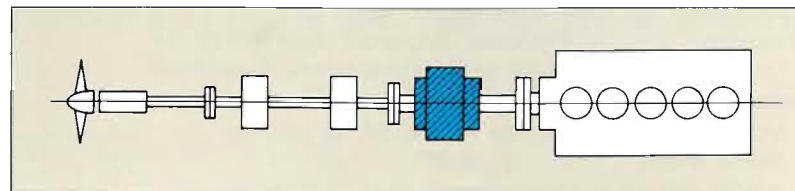
When both a shaft generator and waste gas turbo-generator are installed in the system also equipped with a control circuit comprising thyristor inverter TH1 and thyristor converter TH2, a shaft motor at the time of this system can be operated as excessive waste gas thereby recovering the energy of waste gas for the purpose of propulsion of propeller.

MAJOR MODELS

* Symbols for types: IEC60034

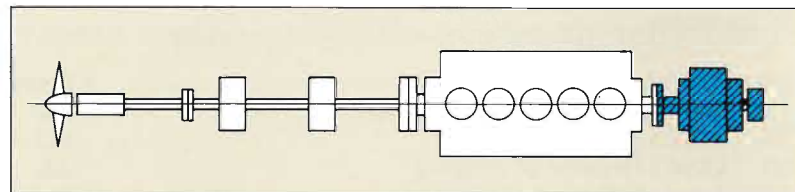
SHAFT GENERATOR

Model SIG



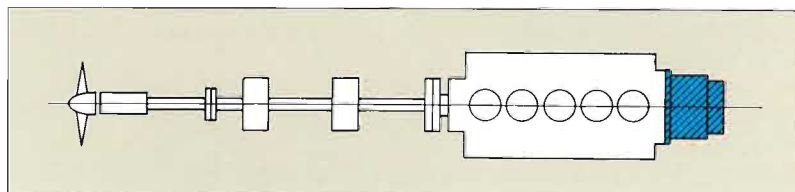
To be built in intermediate shaft. (IM5510)
Shaft and bearing shall be supplied by shipbuilders.
Protection: IP 22 (Upper) IP 44 (Lower)
(IP 23 or IP 44 is also applicable by options)
Salient pole type, self-excitation with brushes.
Forced ventilation by top mounted fan.
System output: 200KW–4000KW
R.P.M.: 110, 92, 79, 69, 62, 55 min⁻¹

Model SPG



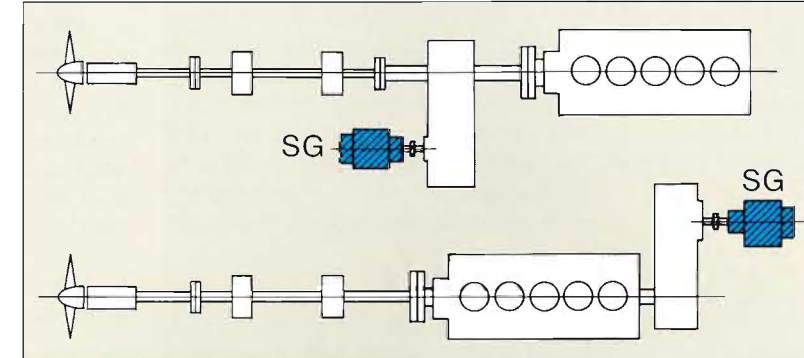
To be coupled with the fore end of main engine. (IM7105)
Shaft and single bearing shall be supplied by us.
Protection: IP 22 (Upper) IP 44 (Lower)
(IP 23 or IP 44 is also applicable by options)
Salient pole type, self-excitation with brushes.
Forced ventilation by top mounted fan.
System output: 200KW–2000 KW
R.P.M.: 110, 92, 79, 69, 62, 55 min⁻¹

Model SHG



To be coupled with the fore end of main engine as over hanged. (IM5205)
Flanged shaft and stator shall be mounted on the crank shaft and casing of main engine respectively. (without bearing).
Protection: IP 22 (Upper) IP 44 (Lower)
(IP 23 or IP 44 is also applicable by options)
Salient pole type, self-excitation with brushes.
Forced ventilation by top mounted fan.
System output: 200KW–2000KW
R.P.M.: 110, 92, 79, 69, 62, 55 min⁻¹
(Available max. output may be effected by main engine model)
(due to mechanical strength of the engine frame and bearing)

Model SFEK



To be coupled with the step up gear box.
Flange or free shaft end, for rigid or flexible coupling. (IM1105)
Protection: IP 22 (IP 23 or IP 44 is also applicable by options)
Cylindrical pole type, brushless excitation self-ventilation, double bearing in the end brackets, sleeve bearing forced lubrication supplied from gear box.
System output: 200KW–4000KW
R.P.M.: 1200 min⁻¹

SYNCHRONOUS CONDENSER

Model CFB



Protection: IP 22 (IP 23 or IP 44 is also applicable by options)
Cylindrical pole type, brushless excitation, self-ventilation, double bearing in the end brackets, starting induction motor is over-hanged type without bearing.
Model CFB: *Ball bearing grease lubrication type
For system output 200KW–700KW.
*Ball bearing+Roller bearing oil bath lubrication type
For system output 800KW–2000KW.
Model CFEK: *Sleeve bearing forced lubrication type
For system output 2000KW–4000KW.

FREQUENCY CONVERTER PANEL

Model THP



Protection: IP 22 (IP 23 is also applicable by options) Self-standing, dead front type, forced air cooling by fan mounted inside the panel (with air filter)
Contained components: 3 phase pure bridge thyristor converter, 3 phase pure bridge thyristor inverter, excitation rectifier device, A.V. R. for shaft generator, control unit, D.C. reactor, A. C. reactor, check meter, alarm indication panel, various protection devices.

FEATURES

SAVING ENERGY AND LABOUR

Energy can be saved since the main engine with a low running cost is used for driving during voyage. Moreover, since the operating time of an auxiliary diesel engine is greatly reduced, the replacement for consumable parts can be reduced so that maintenance and inspection costs can be reduced.

A WIDE WORKING REVOLUTION RANGE

Even if the rotating speed of propeller fluctuates in a wide range of 60% to 110%, power can be fed continuously and efficiently. When the functions of automatic synchronizing, preferential tripping and automatic start of an auxiliary generator are added, a continuous power source corresponding to the maneuvering situations of a ship can be secured, and thus this system can be applied to low-cost fixed-pitch propeller-driven ships.

FUNCTIONS

Maintenance of constant voltage and constant frequency

- Constant voltage: Constant voltage is maintained by A.V.R. built in synchronous condenser.
- Constant frequency: A constant frequency is maintained by controlling the active power by means of A.V.R. of shaft generator, phase control of converter and inverter.

Parallel operation with other diesel or turbine generator

- Synchronizing: This is performed by adjusting the output frequency (rpm of synchronous condenser) of the shaft generator and by aligning speed.
- Allocation of active power: This can be done by providing a droop for the output frequency of shaft generator.
- Allotment of reactive power: This can be done by a cross current compensator of the synchronous condenser.

Measures against short-circuit accidents

- Supply of sustained short-circuit current required for selective tripping: This is supplied by the release of energy of rotation of synchronous condenser and the action of compound exciter.
- Protection of frequency converter panel: If a short-circuit accident occurs at the load side, gate shift of the converter are immediately performed and the current through the DC circuits in the frequency converter panel is set to zero in order to prevent the melting of fuses of thyristor.
- Re-feeding after opening short-circuited point: When the short-circuited point is opened, the converter begins to control and operate the inverter for immediately starting re-feeding.

Inverter control

- To increase the active power and reduce control reactive power, phase-control angle is made as large as possible and then the control with a constant margin angle of commutation is performed. Also, if the revolutions of the shaft generator decrease and DC voltage of converter drops, then the supply of active power is maintained by reducing the phase-

EXCELLENT CONSTANT-FREQUENCY AND CONSTANT-VOLTAGE CHARACTERISTICS

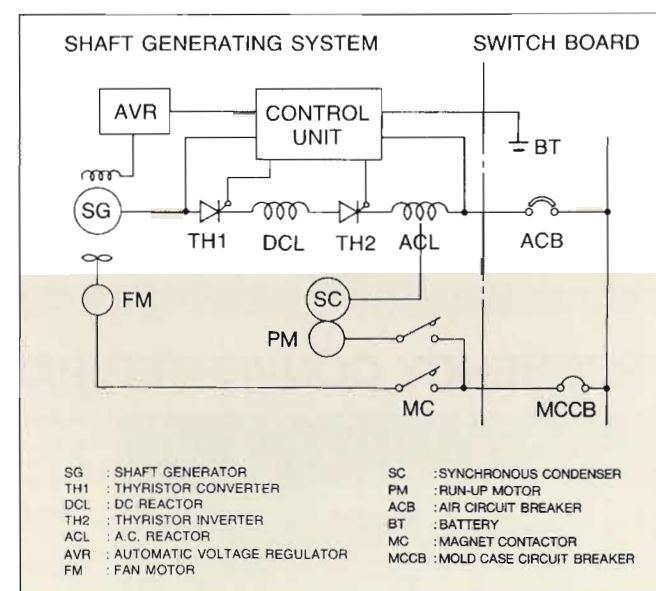
Even though the revolution of the main engine suddenly fluctuates, frequency and voltage hardly fluctuate. Also, frequency and voltage characteristics at the time of a sudden change in load are almost the same as those of the auxiliary diesel generator, and thus the system can be always operated in parallel with other generators.

control angle of the inverter and then lowering the DC voltage of inverter to a value corresponding to the DC voltage of converter.

Protection

- To cope with overload, the main circuit (thyristor fuse) is protected by a current limiter. If DC short-circuit or the like occurs at inverter side, then a protector is operated, the converter is stopped, A.C.B. is tripped and then the power generation at the shaft generator is halted thereby preventing the equipment from being damaged.

Main circuit diagram



CONSTRUCTION

SHAFT GENERATOR

Stator

The stator frame is constructed of welded mild steel plates, being so designed as to have sufficient mechanical strength and to withstand electric shock.

The stator core is built in such a manner that silicon steel plate which is good in magnetic characteristics and coated with an insulating varnish for prevention of eddy current is punched, and the punched plate elements are piled along the inner circumference of the stator frame from one side and equipped with air duct at each of regular pile intervals. The core thus formed is forced in and fastened by stator clampers made of mild steel plate.

The stator winding is formed of electric enameled wire of insulation class "F", and slots of the stator core are protected with an insulating material of class "F".

The winding thus placed is fastened to the stator core by special wedges, while the coil ends outside the laminated stator cores have taping rendered, and then class "F" alkyd varnish are impregnated and dried to ensure characteristics such as heat resistance, moisture-proof, salt-proof and oil-proof.

TAIYO "S" SERIES SHAFT GENERATORS are therefore usable in excellent condition over a long period of time under particular marine environment.



Rotor

Model: SIG, SPG, SHG

The rotor is in use of a salient pole rotating field type. The filed core is of mild steel massive or steel amination structure. The field coil is formed of slab shaped electric wire of insulation class "F" and fitted to the field core, and then class "F" alkyd varnish are thoroughly impregnated and dried. Each core with coil is firmly bolted to the shaft.

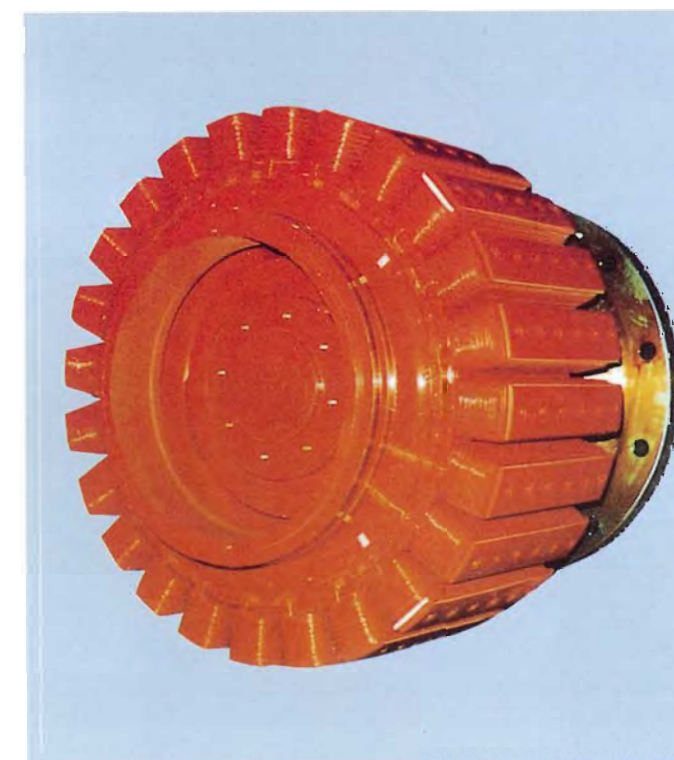
Model: SFEK

Cylindrical rotor is used. The field core is made up of laminations of silicon steel plate.

The laminated core is fitted into the shaft or the spider and clamped at both end by rotor clampers, and serves also protect the winding.

The field winding is formed of electric wire of insulation class "F" and placed in the slots furnished with a class "F" insulation material, and fixed firmly to the field core by special wedges. The coil ends are bound by special tape so as not to move out by centrifugal force.

The detail dimensions of the shaft for each model used high quality forged steel are carefully designed and manufactured after thorough discussion with prime mover maker about torsional vibration analysis.

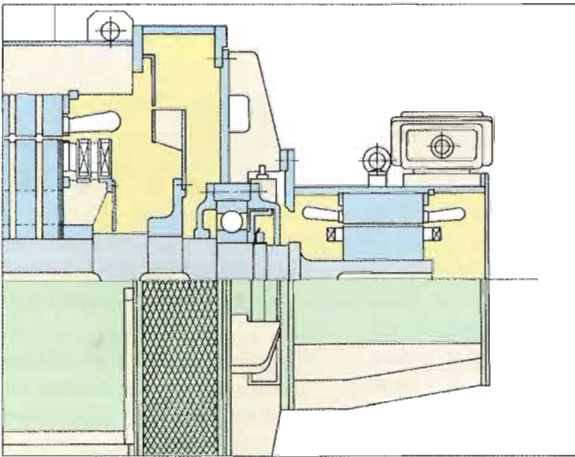


SYNCHRONOUS CONDENSER

It has similar structure and electrical specifications with normal generator, but has starting induction motor coupled to the end of the shaft.

In the case of the operation of shaft generating system, starting is performed by the induction motor and after synchrony has been achieved, this synchronous condenser is operated as synchronous motor and maintain commutation power source for the thyristor necessary for the operation of the system.

And it is capable of supplying reactive power requires for frequency converter panel and load, and also generating a short circuit current of sufficient magnitude and duration for selective tripping.



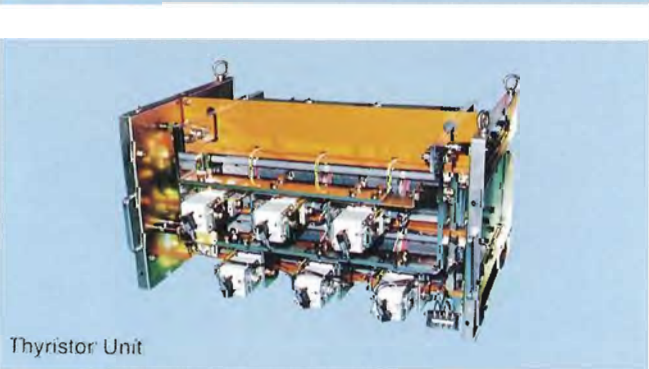
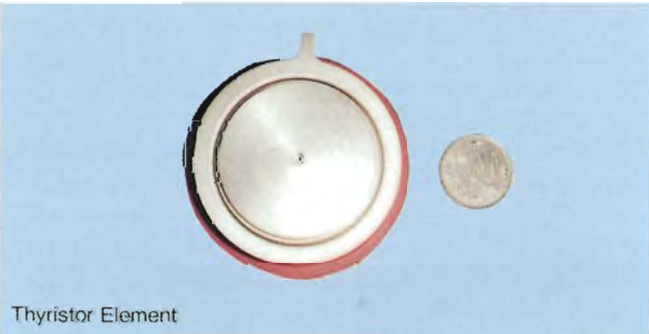
FREQUENCY CONVERTER PANEL

Main Circuit

It is composed of inverter and converter of each three-phase thyristor bridge. Output control of the system is performed by phase control of inverter and converter, and therefore quick response and stable control is obtained against frequency and load fluctuation of the shaft generator caused by speed change of the main engine.

Thyristor stack consisting Inverter and Converter

It has compact construction with having protection fuses, snubber circuit, gate filter etc. in it's single unit of three-phase thyristor bridge. Draw-out system is employed for installation and removal so that whole stack can be drawn out for easy maintenance.



Digital Control Unit

The control unit controls digitally the pulse generator that controls thyristor stacks; the PID controller designed to control outputs from equipment and devices; the command signal generator that supplies control command signals; and the AVR's that are used for controlling the output voltage of the shaft generator.



Graphic Panel (Color Liquid Crystal Display)

The touch panel type color LCD is installed. This LCD Provides an itemized indication of failures; shaft generator's voltages, currents and frequencies shown in the forms of a trend graph; and the maintenance contents and trouble-shooting function for the system.

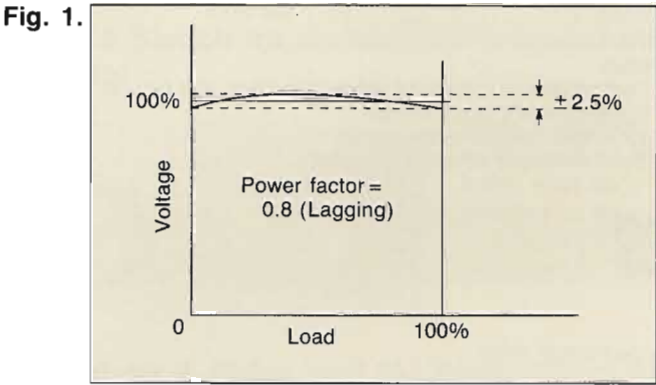


CHARACTERISTICS

Steady-state Voltage Regulation

Operating with its automatic voltage regulator, the generator gives its output voltage according to the regulation curve shown in Fig. 1.

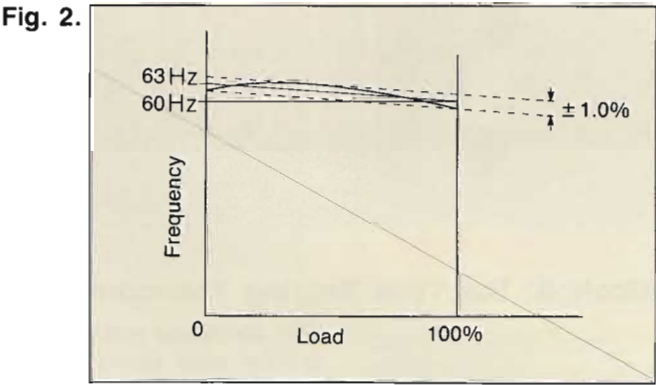
When the load on a generator is varied gradually from no load to full load or vice versa at the rated power factor, while the speed of the prime mover is fluctuated between 60 and 110% of the rated speed, the variation of the steady-state voltage shall be within $\pm 2.5\%$ of the rated voltage.



Steady-state Frequency Regulation

When the load on a generator is varied gradually from no load to full load or vice versa, frequency fluctuation shall be maintained within $\pm 1.0\%$ of the set droop characteristic.

Droop characteristic is shown in Fig. 2.



Instantaneous Frequency Regulation

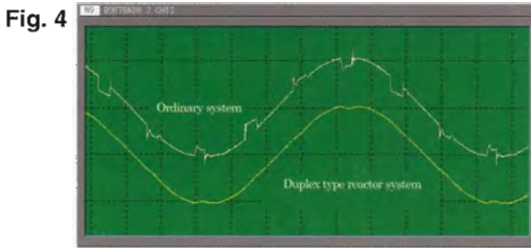
When a load corresponding to 80% of the rated current is suddenly given to and taken from a generator which is operating under no load, the frequency fluctuation shall be maintained within 8.0% of the rated frequency.

Voltage Wave Form

Improved Voltage waveforms of the shaft generator, with a distortion factor of 8% or lower, are our standard by the use of a duplex reactor (see the attached Fig.3).

Systems with a 5% or even lower distortion factor are optionally available.

Given below are examples of improved waveforms obtained through using the duplex reactor, compared with ordinary waveforms without using such reactor. (see the attached Fig.4)

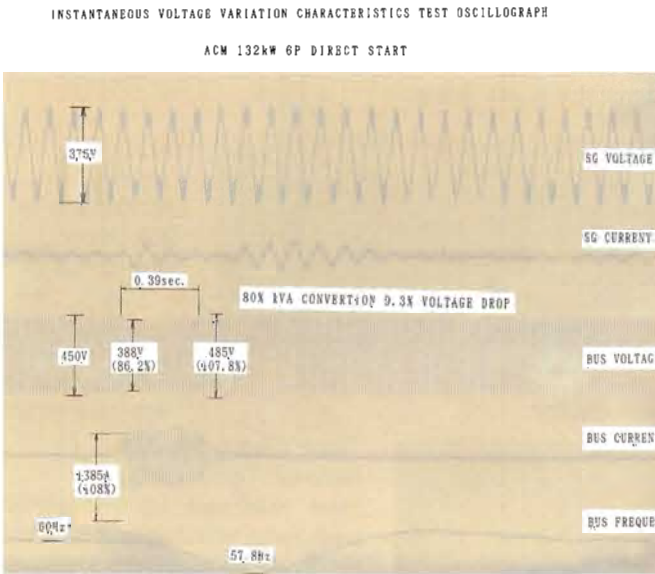


Instantaneous Voltage Regulation

When a load (125% impedance) corresponding to 80% (power factor below 0.4) of the rated current is suddenly given to a generator which is operating under no load at the rated frequency, the instantaneous voltage regulation shall be within 15%.

The oscillograph data of instantaneous voltage regulation test when 132 kW induction motor was started in the 600 kva shaft generating system by direct-in-line starting system is shown in Fig. 5.

Fig. 5



Temperature Rise Limits

The temperature rise in the generator windings of class F insulation generator, as measured by the resistance method, is generally limited to the values indicated in Table 1 as standard, however the details of each part shall be in accordance with the requirement of applied classification societies.

Table 1. Limits of temperature rise (by the resistance method)

Windings	Coolant	32°C Sea water	36°C Fresh water	45°C Air	50°C Air
Stator winding		108°C	104°C	95°C	90°C
Field winding	Multilayer coil	108°C	104°C	95°C	90°C
	Cylindrical	118°C	114°C	105°C	100°C

Insulation Strength

The strength of the insulation is checked by conducting the voltage withstand test, described in Table 2. The indicated test voltage (of commercial line frequency) is applied for one minute.

Table 2. Voltage withstand test

Component		Test voltage
Rotating Machinery	Stator winding	2E + 1,000 volts (1,500 volts minimum)
	Field winding	10Ex (1,500 volts minimum)
Frequency converter panel	Bus circuit	2,000 volts
	Control circuit	500 volts

Notes:
Test voltage is impressed between winding and ground
E = generator's rated voltage
Ex = rated voltage of the exciter
Semi-conductor circuit is excluded.

STANDARD ACCESSORIES

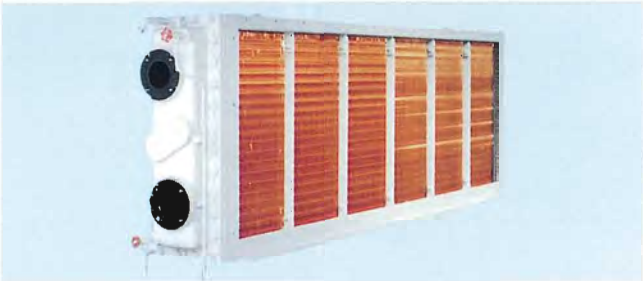
Water-Cooled Air Cooler (For water-cooled air cooling type generator only)

The totally enclosed IP-44 type generator requires water cooled air cooler (cooling-air to cooling-water) mounted on top of the generator and uses sea water or fresh water for cooling.

Cooling tube is double tube construction having the leak-detecting groove. This tube has the excellent resistance against the corrosion and erosion-corrosion, which leads to its long life. Extra tubes equivalent to 5% of the total number are provided as spare with blind plug in the cooler.

A proper sacrificial anode material (zinc for sea water, mild steel for fresh water) is provided as protection metal against electrolytic corrosion, which can be easily replaced from outside without removing water chamber. In the event of a failure of the cooler, generator can be converted to drip-proof machine by simple operation of the blind plate and can be operated continuously by 100% capability.

Inner tube: Aluminum brass for sea water, copper for fresh water
Outer tube: Finned copper
Water chamber: Cast iron with Neoprene coating
Tube plate: Naval brass
Leakage detector: Float type



Anti-condensation Heater

Sheathed wire type element is installed in the stator frame, and the circuit shall be interlocked with the aux. terminal of A.C.B. so that it will be activated automatically while the generator is not in use.



AC100, 110 or 200, 220 V single phase

Air Filter



Type: Viledon PS/400N
Material: Tetron Cordelan
Heat resistance: Up to 100°C (with flame retarding and self-fire-extinguishing properties.) Regeneration is possible by washing with water.

Current Transformer for Cross-Current Compensation



To be provided only when parallel operation is intended, and shall be installed in the switchboard.

OPTIONAL ACCESSORIES

Some of the optional accessories may be provided as standard by the requirement of applied classification society.

Embedded Temperature Detector for Stator Winding



PT 100 ohm sensor 6 pcs for each generator (3 for working, 3 for spare)

Thermostat for Outlet Air Temperature of Air Cooler



Thermostat is provided to protect generator by sending alarm signal in case cooling water is not supplied rightly. (Normal closed contact)

Auto. De-excitation Device

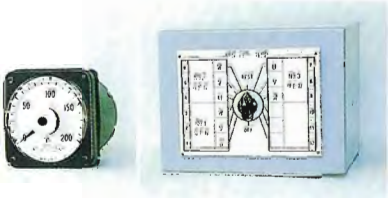


Following parts are provided to protect Static Condenser against short-circuit accident from stator winding up to FCP out put terminal

- 1 set of solid-state percentage differential relay (to be installed in the FCP)
- 6 sets of Current transformer (3 sets at the neutral to be mounted on the generator and other

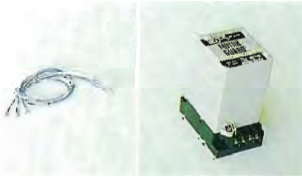
- 3 sets to be installed in the FCP)
- 1 set of relay for exciter field short circuiting (to be installed in the FCP)

Meter & Switch for Embedded Temperature Detector



Meter & selector switch for 3 — 18 points shall be installed on the surface of the switchboard

Thermister & Relay Unit for Stator Winding



- PTC thermistor sensor 6 pcs for each generator (3 for working, 3 for spare)
- Electronic type relay unit one pc. for each generator

Embedded Temperature Detector for Bearings



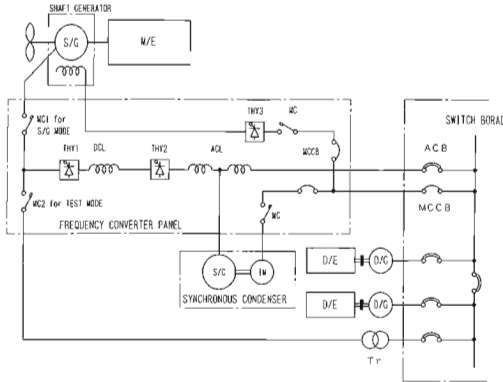
PT 100 ohm sensor one set for each bearing

Simulation (the TEST MODE)

The power supply from the shaft generator is removed and the test drive of the frequency converter panel is done in the power supply from a main switchboard.

The state of the drive (revolution and voltage, etc.) and the state of the control signal in the control circuits is displayed on the screen, and then you can confirm whether the control circuit operates normally.

Connection diagram of TEST MODE is shown below.



STANDARD SPARE PARTS

- Bearing One set for each kind of every 4 working sets or less
- Resistor One set for each kind of every 10 working sets or less
- Air filter Working quantity
- Carbon brush Working quantity
- Brush holder One set for each kind of every 4 working sets or less
- Thyristor One set for each kind of every 10 working sets or less
- Thyristor fuse One set for each kind of every 4 working sets or less
- Control fuse Working quantity
- Printed circuit board One set for each kind
- Other. required by applied classification society are also provided as standard.