INSTALLATION, OPERATING & MAINTENANCE INSTRUCTION MANUAL
FOR SYNCHRONOUS GENERATOR

HYUNDAI ELECTRIC

Head Office (Sales & Marketing) 5 Floor, 55, Bundang-ro, Bundang-gu, Seongnam-si, Gyeonggi-do, Korea
Tel : 82-31-8006-6654, 6671 Fax : 82-31-8006-6686

Ulsan(Factory) 1000, Bangeojinsunhwan-doro, Dong-gu, Ulsan, Korea
Tel: 82-52-202-6608 Fax: 82-52-202-6689

Important Notice

The examples and diagrams in this manual are included solely for illustrative purposes. Because of many variables and requirements associated with any particular installation, Hyundai Electric & Energy Systems Co., Ltd cannot assume responsibility or liability for actual use based on the examples and diagrams.

Hyundai Electric & Energy Systems Co., Ltd cannot accept any responsibility for damage incurred as a result of mishandling the equipment regardless of whether particular reference is made in this instructions or not.

The availability and design of all features and options are subject to modification without notice. Should further information be required, contact Hyundai Electric & Energy Systems Co., Ltd.

Manufacturer's Address
Hyundai Electric & Energy Systems Co., Ltd
http://www.hyundai-elec.co.kr

Head Office (Sales & Marketing):
5 Floor, 55, Bundang-ro, Bundang-gu, Seongnam-si, Gyeonggi-do, Korea
Telephone: +82 31 8006 6608
Fax : +82 31 8006 6686

Ulsan (Rotating Machinery Sales Department):
1000, Bangeojinsunhwan-doro, Dong-gu, Ulsan, Korea
Telephone: +82 52 202 6608
Fax : +82 52 202 6995
Service Inquiries: +82 52 202 6671

Contents

Contents

Chapter 1 Introduction

1.1 General information

This User's Manual contains information on the transport, installation, operation and maintenance of synchronous machines supplied by Hyundai Electric & Energy Systems (Hyundai Electric).
This manual provides information regarding all aspects of installation, operation, maintenance and shows how to disassemble/assemble major component, if required. Careful study of the contents of this manual and other machine related documentation before any actions are taken is necessary to ensure functionality and a long lifetime of the machine.

Actions shown in this manual are only to be performed by trained personnel with previous experience in similar tasks, and authorized by the owner of the equipment.

Depending on the application, the machines may also be designed in accordance with the type variant defined in Table 1-1.

Table 1.1 Type definition

Type	Type of construction
HFC	Low voltage cylindrical type rotor machine with open-circuit cooling and air to air
HFJ	Low voltage cylindrical type rotor machine with closed-circuit cooling and air to water cooler
HSR	Medium and high voltage cylindrical type rotor machine with open-circuit cooling and air to air
HSJ	Medium and high voltage cylindrical type rotor machine with closed-circuit cooling and air to water cooler
HAR	Medium and high voltage salient pole type rotor machine with open-circuit cooling and air to air
HAJ	Medium and high voltage salient pole type rotor machine with closed-circuit cooling and air to water cooler

1.2 Site conditions

The machinery is to be used on a site with conditions according to Technical Specifications of customer.

1.3 Safety Precautions

1.3.1 Safety Instructions used in this manual

Read these instructions carefully before operating.
The instructions are used to draw the user's attention different points :

DANGER
This warning is used when an operation, procedure, or use may cause personal injury or loss of life.

WARNING
This Warning is used when an operation, procedure, or use may cause a latently dangerous state of personal injury or loss of life.

CAUTION
This warning is used when an operation, procedure, or use may cause damage to or destruction of equipment and a slight or serious injury.

NOTICE
This warning is used when an operation, procedure, or use may cause damage to or destruction of equipment.

NOTE!
This warning is used when an operation, procedure, or delicate installation requires clarification.

1.3.2 Safety Instructions used in this manual

The instructions are addressed to experienced and qualified technical personnel who are familiar with the procedures and equipment.

1.3.3 General Safety Instruction

• Only use the generator in correct working condition as well as in the manner intended, with due consideration for safety and hazards while following the documentation and the local health and safety regulations.
• Correct any malfunctions without delay that may affect safety or have them rectified by our service organization.
• Always store this documentation with the generator.
• Regularly check that personal work with due consideration for safety and hazards and follow the documentation.
• Use appropriate personal protective equipment at all times
• Follow all information on safety and hazards on the generator and maintain in legible condition.
• On the occurrence of safety-related changes on the generator or in its operating behavior, immediately shut down the generator and correct malfunction without delay.
• Do not make any changes, additions or modifications to the generator. This statement also applies to installation and the settings for safety features.
• Do not circumvent or bypass any safety features. Before opening doors or covers for which the use of a tool is required, the generator must be shut down, electrically isolated and grounded.
• Service parts must comply with the technical requirements defined by the manufacturer. This aspect is only ensured with genuine branded service parts. On the use of other service parts, liability by the manufacturer is excluded.
• Do not make any changes to the program (software) in the programmable control system. Changes to the program must only be made by appropriately trained personnel.
• Comply with stipulated intervals or intervals defined in the documentation for regular inspections and servicing work.
• Use only appropriate tools for undertaking maintenance measures.
• Only allow trainees, apprentices or personnel under instruction or personnel undergoing general training to work on the generator under the constant supervision of an experienced person.
• Only task trained and experienced persons with the attachment of loads and signaling to crane drivers. The person providing the signals must be visible for the operator.
• During installation work above head height, climbing aids and working platforms intended for this purpose with appropriate safety features must be used. Do not use generator components and attachments as climbing aids! During servicing work at heights, wear fall arresting equipment.
• Keep all grips, steps, railing, pedestals, platforms, ladders free of debris and dirt.
• The generator electrical equipment is to be checked regularly; loose connections or burnt, damaged cables must be rectified immediately.
• If work is necessary on electrically live parts, involve a second person who can provide immediate assistance in case of an emergency. Cordon off working area with a red-white safety chain and a warning sign. Only use electrically insulated tools.

1.3.4 General Guidance for Use

Generators have dangerous, live and rotating parts and hot surfaces. All work in relation to transport, storage, installation, connection, commissioning, operation and servicing must be done by authorized, trained specialist staff.

In cases where there is a contradiction between the content of this manual and the machine supplied, contact the manufacturer.

Chapter 2 Packing, Transport and Storage

2.1 Packing

The purpose of packing is to protect goods during transport, transshipment and storage and to minimize the cost of such transport, transshipment and storage. In addition to the economic efficiency of packaging, safety - i.e. retention of the value of the packed goods - is of primary importance. All items will be packed in proper type of packing (box, skid, bundle, drum ,bare, etc.) by the supplier under his responsibility. Packing will be designed according to the type and quality of the item. The packing shall be strong enough to ensure maximum safety during shipping.

2.2 Transport

2.2.1 Protective Measures Prior to Transport

The following protective measures are taken before delivery of the machine from the factory. The same protective measures should be taken, whenever the machine is moved:

• All synchronous machines delivered as a unit are provided with transport locking device protecting the machine against damages during transport. The locking device must be attached whenever the machine is transported.
• Machined metal surfaces, such as the shaft extension, are coated with an anti-corrosive coating before delivery.
• The bearings are greased at the factory or during the tests prior to delivery. This gives sufficient protection against corrosion.
• During shipping the machine should be placed under deck.

2.2.2 Lifting the machine

Before the machine is lifted, ensure that suitable lifting equipment is available and that personnel are familiar with lifting work. The weight of the machine is shown on the rating plate, dimension drawing and packing list.

NOTE!
Use only the lifting lugs or eyes intended for lifting the complete machine. Do not use any small additional lifting lugs or eyes available, as they are there only for service purposes. These additional lifting lugs usually have caution name plates adjacent to them.

NOTE!
The center of gravity of machines with the same frame may vary due to different outputs, mounting arrangements and auxiliary equipment.

NOTE!
Check that eyebolts or the lifting lugs integrated with the machine frame are undamaged before lifting. Damaged lifting lugs must not be used.

NOTE!
Lifting eyebolts must be tightened before lifting. If needed, the position of the eyebolt must be adjusted with suitable washers.

2.2.3 Lifting of unpacked machine

Lifting must be performed with great care and using slings long enough to assure the lifting angle requirements, see *Figure 2-1. Lifting of unpacked machines*. If the requirements are not met, there is a risk of damage.

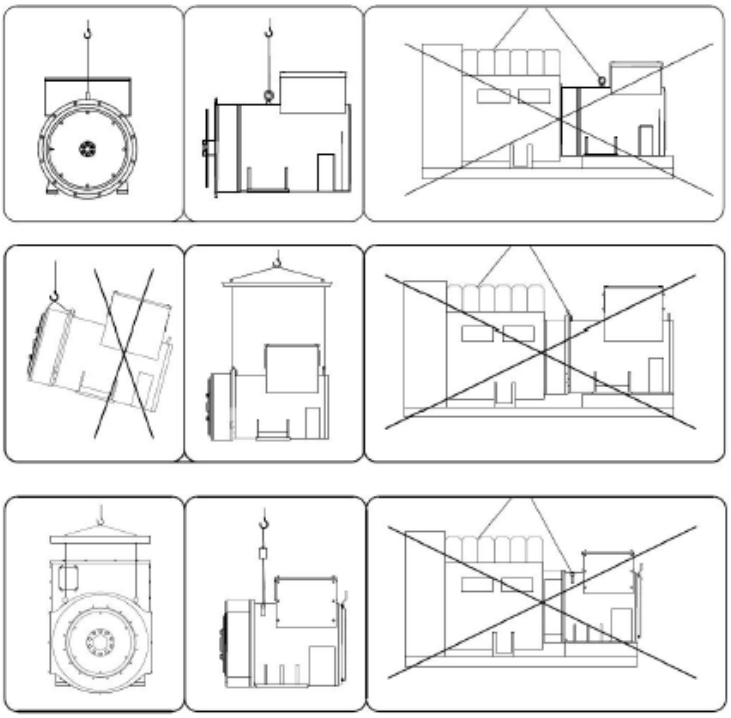


Figure 2-1. Lifting of unpacked machines.

• The machine must be lifted from its frame. Do not attempt to lift the machine from the top cover!
• lift the complete generating set by the generator lifting points.
• When moving the generator always keep it in the horizontal plane, this will reduce the risk of the rotor falling out if 1-bearing design considered.

2.2.4 Checks upon arrival and unpacking

Check upon arrival
Inspect the machine and the package immediately upon arrival. Any transport damage must be photographed and reported immediately, i.e. within less than one (1) week after arrival, if the transport insurance is to be claimed. It is therefore important, that evidence of careless handling is checked and reported immediately to the transport company and the supplier. A machine that is not installed immediately upon arrival must not be left without supervision or without protective precautions. For more details, see Chapter 2.3.Storage.

Unpacking
Place the synchronous machine so that it does not hinder the handling of any other goods and on a flat, vibration-free surface. When the package has been removed, a check should be made to see that the machine is not damaged and that all accessories are included. Tick off the accessories on the packing list which is enclosed. If there is any damage, suspected damage, or if accessories are missing, please report this immediately to the supplier.

Chapter 2 Packing, Transport and Storage

2.3 Storage

2.3.1 Short term storage (less than 2 months)

The machine should be stored in a proper warehouse with a controllable environment. A good warehouse or storage place has:
• A stable temperature, preferably in the range from 10 ºC (50 ºF) to 50 ºC (120 ºF). If the anti-condensation heaters are energized, and the surrounding air is above 50 ºC (120 ºF), make sure that the machine is not overheated.
• Low relative air humidity, preferably below 75 %. The temperature of the machine should be kept above dew point to prevent moisture from condensing inside the machine. If the machine is equipped with anti-condensation heaters, they should be energized. Verify the operation of the anti-condensation heaters periodically. The anti-condensation heaters shall be de-energized when air temperature inside the machine enclosure exceeds +40 ºC. Before connecting power supply to the anti-condensation heater, check the supply voltage and power. If the machine is not equipped with anti-condensation heaters, an alternative method of heating the machine and preventing moisture from condensing in the machine must be used. Machine can be e.g. heated by using power supply in the machine main terminals. Required DC voltage is approx. 5% of the rated voltage and current shall not exceed 30% of the nominal current.
• A stable support free from excessive vibrations and shocks. If vibrations are suspected to be too high, the machine should be isolated by placing suitable rubber blocks under the machine feet.
• Air which is ventilated, clean and free from dust and corrosive gases.
• Protection against harmful insects and vermin.
If the machine needs to be stored outdoors, the machine must never be left ‘as is’ in its transportation package. To store the machine outdoors:
• Take the machine out from its plastic wrap.
• Cover the machine to prevent rain from entering it. The cover should allow ventilation of the machine.
• Place the machine on at least 100 mm (4”) high rigid supports. This prevents moisture from entering the machine from below.
• Provide with good ventilation. If the machine is left in its transportation package, make large enough ventilation holes in the package.
• Use anti-condensation heaters or alternative method of heating for heating the machine and preventing moisture from condensing in the machine
• Protect from harmful insects and vermin.

2.3.2 Long term storage (2-6 months)

In addition to the measures described in Chapter 2.3.1. Short term storage (less than 2 months), some extra measures need taken depending on whether the machine is stored indoors or outdoors.

NOTE!
Be careful not to damage the seals or the bearings.

Storage indoors
To store the machine indoors:
• If the machine is stored in its transportation package, make big enough holes on the sides of the transportation package so that the D-end and ND-end of the machine are accessible.
• If the protection made by the manufacturer has been removed, protect the unpainted surfaces such as shaft extensions, coupling discs, coupling halves and jacking screws with suitable anti-corrosion agent.
• If the machine has been delivered in fully assembled condition, turn the rotor approximately 10 revolutions once per every 3 months to maintain a protective oil film or grease on the bearing surfaces.

Storage outdoors
• To store the machine outdoors:
• Take all the measures described in Storage indoors above.
• Cover the machine completely with a big enough waterproof cover.
• Remove the side and end covers of the machine.
• Protect the bare shaft surfaces and non-painted parts with anti-corrosive agent.

2.3.3 Very long term storage (over 6 months)

Clean all the protected surfaces listed in Chapter 2.3.1.Short term storage (less than 2 months) and Chapter 2.3.2. Long term storage (2-6 months), and renew the anti-corrosive treatment every 12 months. Otherwise follow the instructions for shorter storage periods.

2.3.4 Rolling bearings apply the following measures:

• Rolling bearings should be well lubricated during storage. For bearings without re-lubrication option this action is neglected.
• Turn the rotor 10 revolutions every three months to keep the bearings in good condition. Remove any possible transport locking device during turning the rotor.
• Machines may be provided with a locking device to protect the bearings against damage during transport and storage. Check the bearing locking device periodically.

2.3.5 Regular checks during storage

The following checks should be made regularly during storage.

Every month:
• Check that the anti-condensation heaters or alternative method of heating the machine is working.
• Check that the ventilation works.

Every 3 months:
• Check the insulation resistance.
• Check that there is no corrosion on the surfaces. If corrosion is observed, remove the corrosion and protect the surfaces.
• Check that the anti-corrosion agents have not cracked.

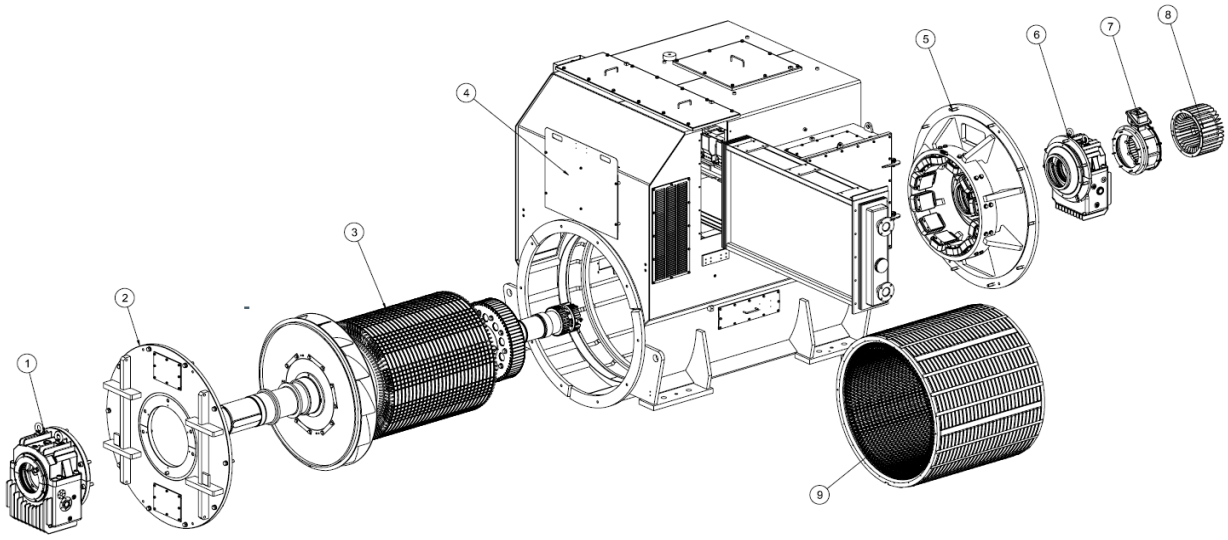
2.3.6 Storage and care after installation

If the machine will not be in operation for a longer period of time after installation, the same measures as in Chapter 2.3.1. Short term storage (less than 2 months) should be applied. Remember to rotate the shaft 10 revolutions at least every 3 months.

Chapter 3 Constructional details of Generator

3.1 General Construction

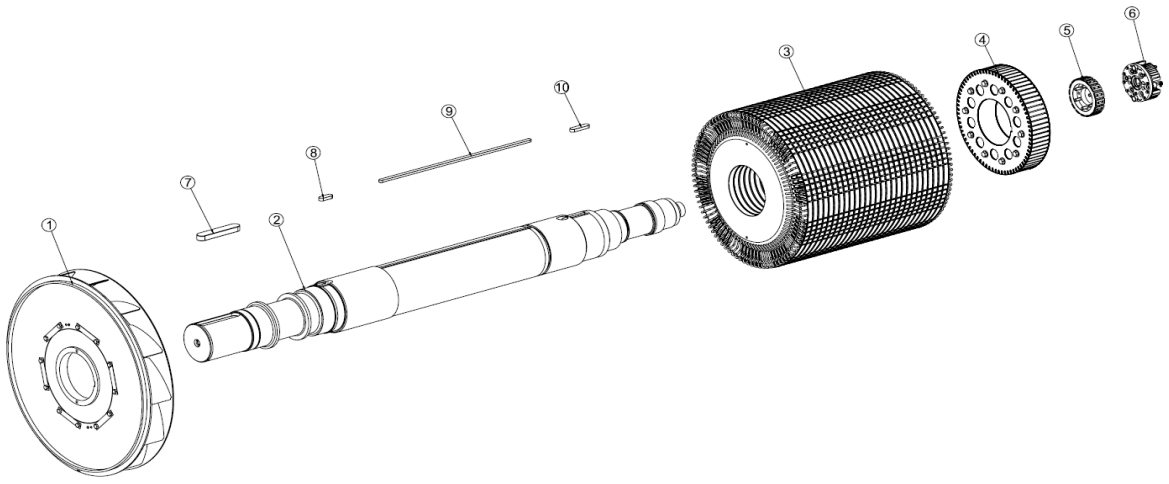
3.1.1 General Construction



1. Bearing (Drive-end side)
2. End shield (Drive-end side)
3. Rotor Assembly
4. Frame Assembly with Stator Winding Assembly
5. End shield with Exciter Poles (Non Drive-end side)
6. Bearing (Non Drive-end side)
7. PMG Stator Assembly
8. Rectifier Assembly
9. Stator Winding

3.2 Construction of Rotor

3.2.1 Rotor Assembly

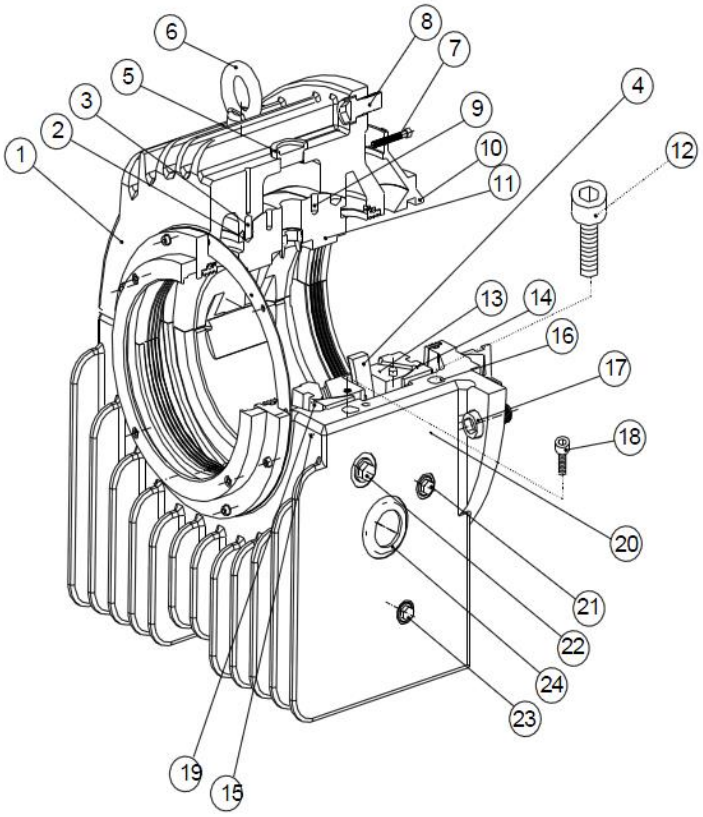


1. Fan
2. Shaft
3. Rotor winding assembly
4. Exciter Rotor Assembly
5. PMG Rotor Assembly
6. Rectifier Assembly
7. Key for DG set coupling
8. Key for Fan
9. Key for Rotor Winding Assembly
10. Key for Exciter rotor

Chapter 3 Constructional details of Generator

3.3 Construction of Bearing

3.3.1 Bearing Assembly



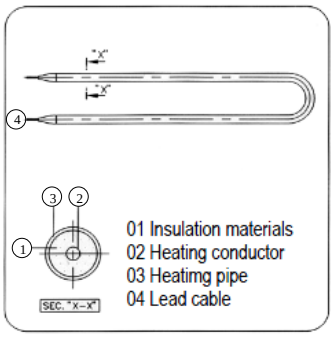
1. Top part of the housing
2. Hole for position pin
3. Positioning pin
4. Oil ring
5. Top sight glass
6. Eye bolt
7. Screw
8. Screw
9. Tapped hole
10. Sealing cover
11. Top part of the shell
12. Screw
13. Bottom part of the shell
14. Spherical seating
15. Engraved number – housing
16. Tapped hole
17. Screw
18. Screw
19. Engraved number – shell
20. Bottom part of the housing
21. Tapped hole for temperature measurement of the journal part
22. Oil inlet connection hole
23. Tapped hole for the oil sump temperature measurement
24. Outlet / bottom sight glass

For the details, check the supplementary manual.
(Please refer to Annex 1 - the supplementary manual for the bearing manual.)

Chapter 3 Constructional details of Generator

3.4 Space heaters

CAUTION
In order to prevent the accumulation of moisture and condensation while the generator is idle, space heaters are provided within the generator frame. The space heaters can be easily removed from outside the enclosure. The heater is comprised of stainless-sheathed Ni-chrome, filled with insulators in the sheath and is U-shaped as shown as below.



3.5 Water cooler

3.5.1 General points

The purpose of the cooler is to remove heat losses of machine.(mechanical, ohmic, etc)
Water cooler is applied if a higher degree of protection is required from IP44 and over. The generators HFJ and HSJ can easily be converted for emergency operation as an open-circuit air-cooled machine if the coolant system or the cooling element fails. The cooler is located on the top of the machine.
The air is circulated by a fan fixed to the synchronous machine shaft.

3.5.2.1 Description of air-water double tube cooler

The double-tube technique keeps the cooling circuit from being affected by possible water leakage.
The double tube provides a high safety level.
In case of leakage, the water goes from the inside of the internal tube to the coaxial space between the two tubes. The water is drained axially to a leakage chamber where it may activate a sensor.

An exchanger comprises a fin-tube block containing :

- A steel frame
- A fin-tube block expanded mechanically to the tubes.

The tube bundle is roll-expanded in the end plates.
The water distribution in the tubes is provided by two removable water boxes.
A water box is equipped with collars for fitting the inlet and outlet lines.
Neoprene seals ensure water tightness between the water boxes and the end plates.

3.5.2.2 Description of air-water single tube cooler

The single-tube technique keeps the vertical direction of cooling circuit from being affected by possible water leakage.
In case of leakage, the water goes from the inside of the tube to the frame. The water is drained to a leakage chamber where it may activate a sensor.

3.5.3 Cleaning

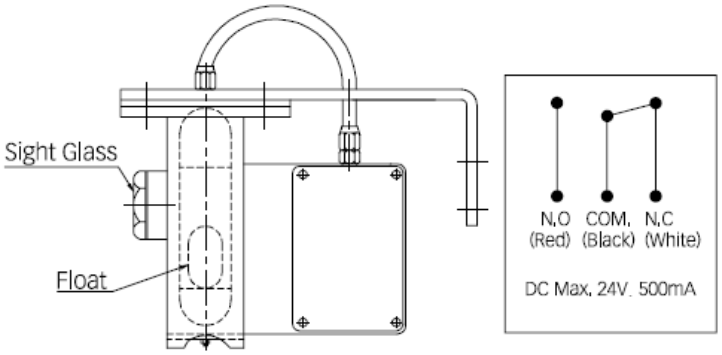
The frequency of cleaning operations depends essentially on the purity of the water used. Annual inspection is recommended at least.

The life of zinc block for anti-corrosion is about a year. Therefore, replace it with a new one every year. Cut off the water supply by isolating the inlet and outlet lines, and drain the water.
Disconnect the leakage sensor, and make sure that there are no leaks.
Remove the water boxes on each side of the machine.
Rinse and brush each water box.

NOTE !
Do not use a hard wire brush as this will remove the protective tar-epoxy layer which has formed on the surfaces of the water boxes. Clean each tube with a metal scraper. Rinse in soft water. Keep the leakage chamber dry(double-tube water cooler only)

3.5.4 Stop the machine

Leak detection for water cooler : If a leak is detected, cut off the power supply of the water inlet / outlet lines and change to emergency operations immediately.
The problem must be ascertained and repaired.
Remove the two water boxes, apply a slight positive pressure in the leakage chamber and between the two tubes(only concerns double tube coolers).
If a tube is damaged, plug it at both ends.
Use a tapered plug.
Preferably the plug should be made of salt-water resistant aluminum bronze or a synthetic material.
3.5.5 Leak detection(Float system)
A magnet float activates a switch located in the float case.



3.5.5 Cooler removal

The cooler unit is slid into its housing.
It is possible to remove the cooler from the housing without removing the water boxes as shown as below.
The cooler is fastened to the housing via a series of screws on the housing.
Remove the water supply and return pipes.
Provide two eye-bolts to hold the cooler when it comes out of its housing.
Remove the cooler using slings that can be attached to the connecting flanges.

3.5.6 Cooler re-assembly

Carry out the operations of the cooler Removal in the reverse order.
Be careful to push the cooler completely into its housing before tightening the fastening screws of the cooler to the casing.

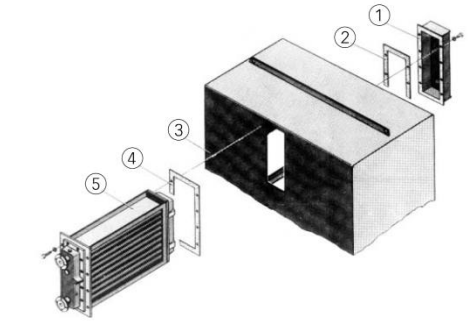
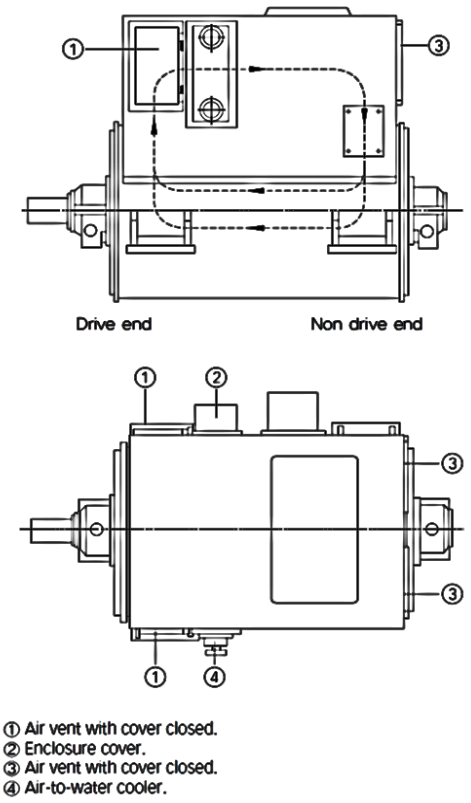


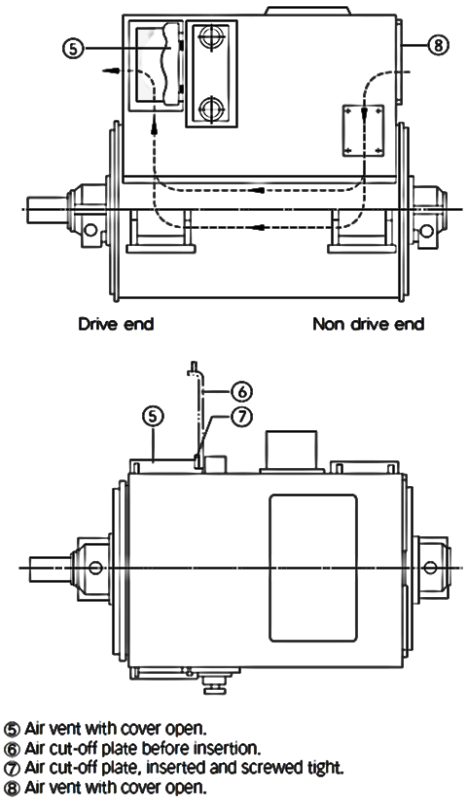
Fig. 3.1 Cooler removal

3.5.7 Cooling water failure emergency operation.

Generators have a facility for emergency operation if the cooling water supply fails.
The following supplements the machine description and the model for the closed-circuit cooling.
Should the cooling water supply fails, the machine can be changed over to an open cooling circuit as follows.



Normal operation with air to water closed-circuit cooling



Emergency operation with open cooling circuit following failure of the cooling water supply

The electrical version of the alternator remains unchanged.
1. Open the air vents at the non drive end for the air inlet and at the drive end for the air outlet(No.3 & 5 of above picture)
2. Remove enclosure or cover NO.2

3. Insert air cut-off plate NO.6 into the slot in the raised section on the housing on the hot air side of the cooler and secure.

3.6 Excitation system

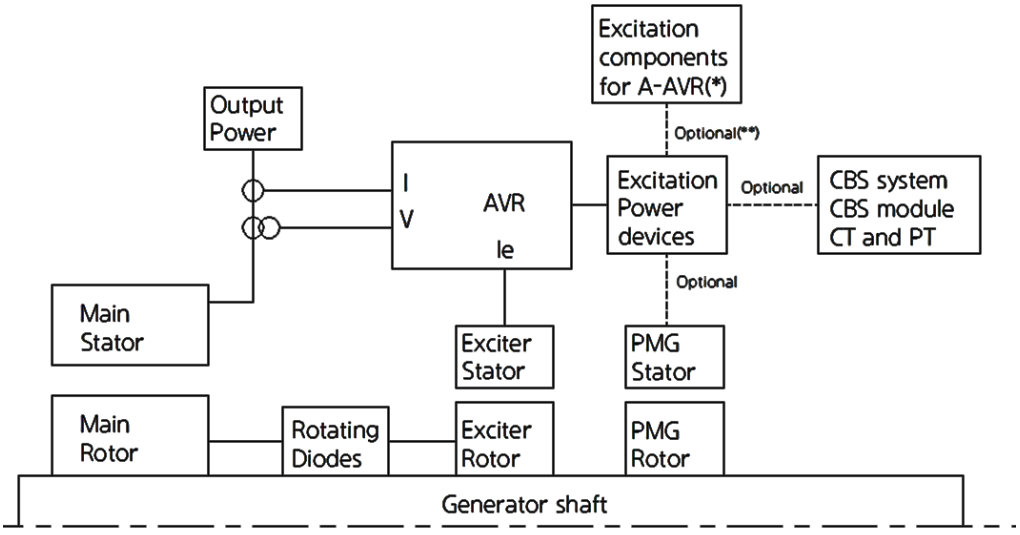
The excitation system consists of AVR and the excitation power supply devices, exciter stator, exciter rotor and rotating diodes.
The AVR (Automatic voltage regulator) is for regulating the generator output voltage by controlling the excitation current. The AVR always monitors the generator output voltage / current and maintain the generator output power as stable condition.

The various excitation system applications have been prepared for different customer demands.

No.	AVR type	Excitation power devices	Remark
1	Digital AVR(*)	PMG	
2	Digital AVR(*)	VT & CBS module with CTs	
3	Analog AVR	Excitation components(**)	

(*) Digital AVR types : HDEC series(HHI standard), DECs series, Unitrol series
(**) Excitation components consists of CT, PT, steady diodes, reactors or other components.

For each AVR system please check the supplementary AVR manuals.
The exciter stator is installed at end shield for the non-drive end side, the excitation current is supplied from AVR and become the stationary field for exciter rotor.
The exciter rotor is installed on the shaft (between main rotor and non-drive end bearing). While the rotor is rotated, the exciter rotor generates AC power by stationary field at exciter stator. This AC power is the source of main rotor field current.
The AC power generated by exciter rotor is rectified by rotating diodes on the generator shaft. The 3 phase full wave rectifier circuit is applied for main rotor magnetization.
For reference, the overall block diagram for excitation system is shown as below.



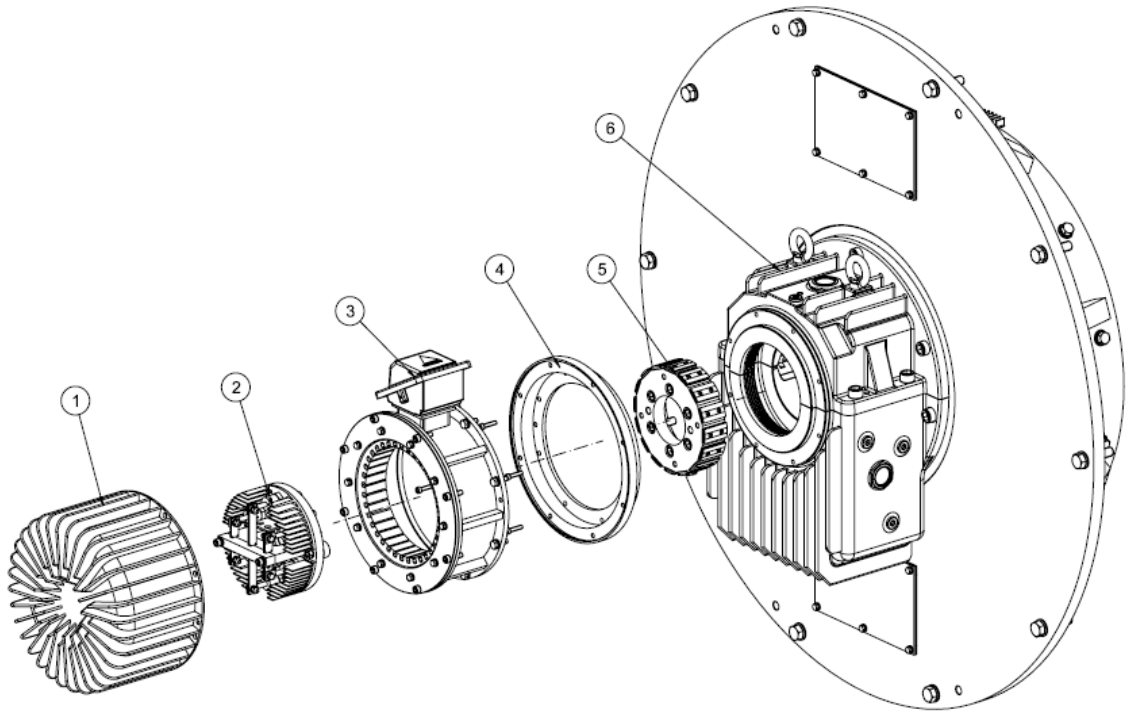
(*) A-AVR : Analog AVR.
(**) Optional : The excitation power devices may be optional depending on the AVR types.

Chapter 3 Constructional details of Generator

3.7 Construction of PMG

3.7.1 Construction

The PMG is consisted of stator and rotor part. The detailed components are shown in the below figure. The stator part having the 3 phase windings is bolted on the bearing housing of non-drive-end side. The rotor part having the permanent magnets for magnetic field is bolted on the shaft end.



1. Rectifier Cover
2. Rectifier Assembly
3. PMG Stator Assembly
4. PMG Adaptor Ring
5. PMG Rotor
6. Bearing (Non Drive-end Side)

For the details, check the supplementary manual.

Chapter 4 Installation and alignment

4.1 Installation of generator

NOTICE
Experience has shown that any base mounted assemblies of generator and driven units temporarily aligned at the factory, no matter how rugged or deep in section may twist during shipment. Therefore, alignment must be checked after mounting.

The lubrication measures for normal bearings to be carried out before or during erection of the machines.

Install the machines so that the cooling air has free access and can escape unobstructed. Warm exhaust air must not be drawn in again.

Louver openings must face downwards to maintain the particular degree protection.
Remove the shaft block (where applicable).

Follow the instruction attached to the shaft extension or shown in the terminal box.

The rotors are normally balanced dynamically by mans of a half feather key placed in the shaft extension.
Align the machines carefully and accurately balance the elements to be fitted on the shaft to ensure smooth and vibration-free running.

Place shims under the feet of the machines if necessary to prevent them from being stressed mechanically. Transmissions elements may be fitted and removed only by prevent them from falling out during shipment. A machine must not be commissioned without its transmission element having been fitted.

4.2 Alignment of generator

The correct alignment of machinery is very important for reducing the stress and vibration of the shaft and the wear of the bearing and coupling.
In case a coupling maker gives those instructions, it is recommended that the instructions be followed.

4.2.1 Flexible Coupling

The flexible coupling set forth herein means the one driven through the rubber brush or the leather brush including the gear coupling. In aligning the generator equipped with the sleeve bearing, attention is to be paid to the endplay of the generator bearing and to the position of the coupling. The center of the generator bearing endplay is indicated by the end play indicator.
The bearing endplay can be equally divided by setting the end play indicator to the standard line of the shaft as shown in *Fig. 4.1*

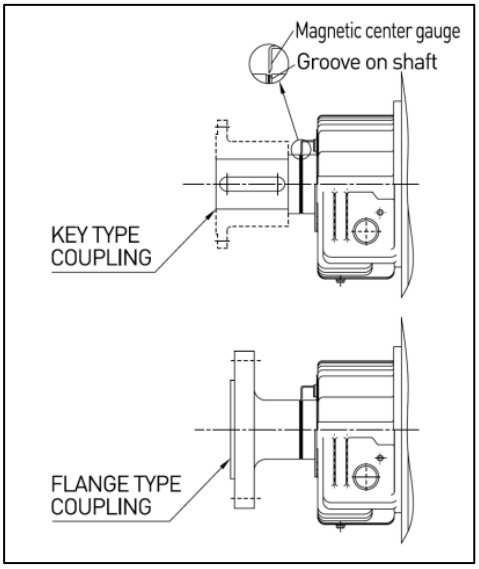


Fig. 4.1 Position of with axial end play

In case of key type coupling, the axial, parallel and angular tolerance are to be acceptable by coupling element property. In case of flange type coupling, coupling works should be carried out in accordance with standard instructions of the engine maker. (HHI alignment standard as shown on *Fig. 4.2*)

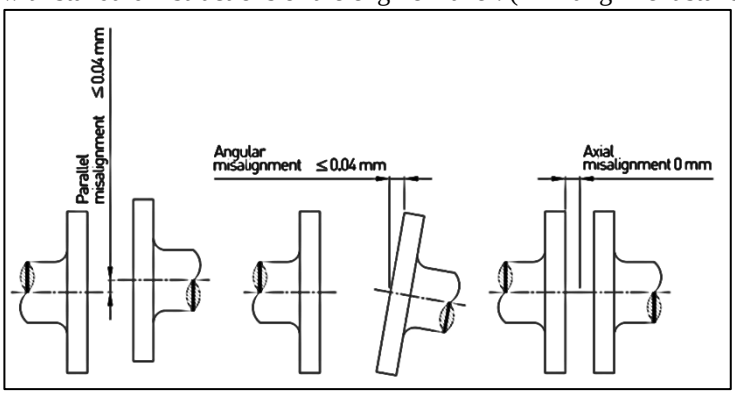


Fig. 4.2 HHI alignment standard

CAUTION
In case the coupling is used, it may be considered that the rotor can be easily moved in the axial direction. In fact, however, it hardly slides in the axial direction at the coupling as the torque grows greater. When by some reason the rotor has undergone some axial movement, and the coupling does not provide enough slip to allow the rotor to return to the magnetic center of the generator, it will continue to operate with the bearing end in contact with the shoulder of the journal.

NOTICE
Experience has shown that any base mounted assemblies of generator and driven units temporarily aligned at the factory, no matter how rugged or deep in section may twist during shipment. Therefore, alignment must be checked after mounting.

4.2.2 Rigid Coupling

In case of the sleeve bearing, when both flanges are connected to each other, the endplay indicator is referred to install the flexible coupling in order to determine the position of the generator.

4.2.3 Alignment

NOTE !
The foot plane is of concern for each unit of rotating equipment. Checked driven equipment if necessary.

Alignment is made to bring the shaft centers of the generator and machine combined with it into the same line; the parallel and eccentricity are measured through the coupling. Generally a thickness gauge or a taper gauge is used in measuring the parallel, and in measuring the eccentricity, a dial gauge is to be fitted to the coupling on one side; the both shafts are to be turned by 0 deg, 90 deg, 180 deg and 270 deg; and the dial gauge reading is to be taken at the four points as shown in *Fig. 4.3* The alignment accuracy is to be generally 0.025 mm or less (both plate and circle).

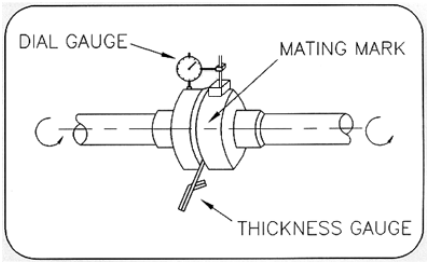
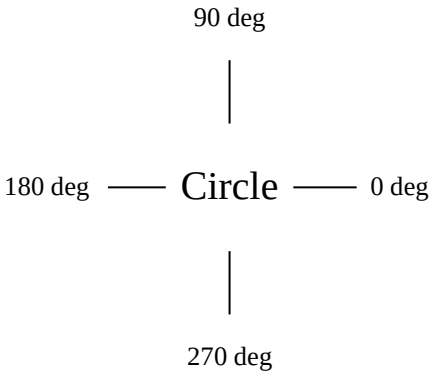


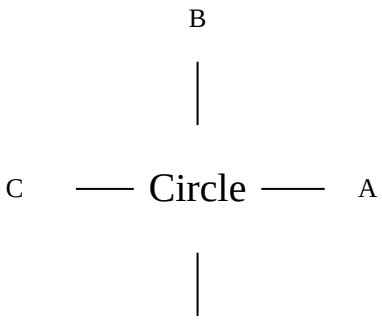
Fig. 4.3 Procedure for Alignment

4.2.4 Measurement of Eccentricity

The both shafts are to be simultaneously turned; the values shall be obtained from the measurement made at four points by means of a dial gauge and are to be recorded; and the corrected value is to be obtained in the following manners.



(Measured Value)



(Measured Value)

Corrected value of left and right = $\frac{A-C}{2}$

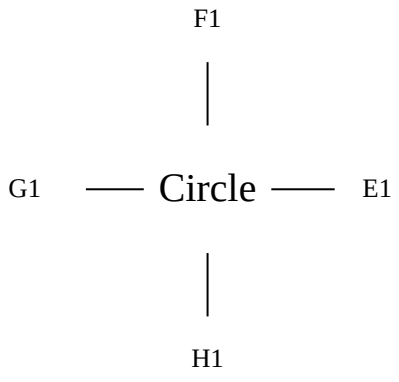
Corrected value of top and bottom = $\frac{B-D}{2}$

(Corrected Value)

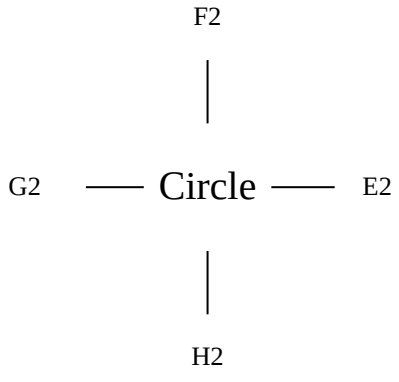
CAUTION
The difference between the total of the measured values at the left and right points (A-C) and the total of the measured values at the top and bottom points (B- D) should not exceed 0.03 mm. The improper fitting of the dial gauge and the erection of the fitting arm, if any, may cause greater difference.

4.2.5 Measurement of parallelism

The values at the four points of E1, F1, G1 and H1 are to be corrected after measurement made by means of a thickness gauge at the position where both shafts were connected to each other at the time of eccentricity measurement; and measurements are to be made again at the points of E2,F2,G2 and H2 after turning both shafts.



(Measured Value)



(Measured Value)

Corrected value of top and bottom = $\frac{(F1+F2)-(H1+H2)}{2}$

Corrected value of left and right = $\frac{(E1+E2)-(G1+G2)}{2}$

(Measured Value)

Chapter 5 Electrical Connections

5.1 General information

Electrical connections are made after the mechanical installation and alignment procedures.
The electrical connections included the connection of main and auxiliary cables, earthing cables and possible external components.

5.2 Connection of main power cables and neutral cable

The main terminal box is typically supplied drilled plate with cable glands if customer send us specification of main & aux cables. If not, cable gland plates will be supplied as blind. The customer or a third party is therefore responsible for this. The stator terminals are marked with the letters U, V and W according to IEC 60034-8. Stripping, splicing and insulating of the cables must be performed in accordance with the instructions delivered by the cable manufacturer. The lugs should not be permanently tightened by bus bars, but only attached (for checking of insulation resistance). The cables must be supported so that no stress is applied to the bus bars in the terminal box. When three-phase cables are used, the prescribed distance must be maintained between the leads at intersections. Bracing and spacers should be used if necessary.

5.3 Earth connection

The ground cable can be connected inside of the main terminal box.
The earth connection of generator frame is located on the foot.

5.4 Insulation distance of main power connections

The connections of the main power cables are designed to withstand demanding operation conditions where the insulators can be subjected to dirt, humidity and surge voltages. In order to ensure lasting and trouble free running, it is therefore important that local requirements or other applicable standards for the insulation distances are met. If no local requirements or other applicable standards are available, it is suggested that the minimum insulation distances mentioned below table. Recommended minimum insulation distances are used. These distances apply both for insulation distances between two different phases, and for insulation distances between one phase and the earth. The air insulation distance is the shortest distance through air between two points with different electrical potential. The surface insulation distance is the shortest distance along surfaces next to each other between two points with different electrical potential.

Nominal Voltage (kV)	HYUNDAI STANDARD	
	Separation distance	Creepage
≤1.1	35	35
3.3 ~ 4.2	55	55
6.0 ~ 7.2	100	100
10 ~ 12	140	140
13.8	165	165

Chapter 5 Electrical Connections

5.5 Connection of auxiliaries and instruments

At the factory, the conductors from supply and monitoring devices are routed inside the machine to a separate terminal box with line-up terminals. The terminal assignment is shown on the auxiliary terminal diagram. Consult the dimension drawing text for details of the maximum conductor cross-sections that can be connected.
The appropriate types of screwed gland for incoming cables are listed in the dimension drawing.
Before closing the terminal box :

1. Consult the terminal diagram before connecting the incoming conductors.
2. Check that the inside of the terminal box is clean and free from odds and ends of wiring material.
3. Ensure that unused cable entries are closed and that the plugs are screwed down tight.

Chapter 6 Commissioning

6.1 General

Commissioning work (The generator start-up) should be performed according to this chapter. The commissioning report is very important for the maintenance, trouble shooting and future support from us. The commissioning checklist is prepared as below.

6.2 Checking list of mechanical construction

The generator should be checked mechanically before commissioning.

Seq. No.	Checkpoint	Check
1	Confirm the installation and alignment work is finished according to Chapter 4. The alignment report should be made and attached at the commissioning report.	
2	Confirm the fixing the generator on the foundation. - The foundation bolt / nut should be checked one by one. - Any crack or foundation condition should be reported.	
3	If rotor turning gear at prime mover is available and the lubrication condition is prepared, the rotor should be turned with low speed. - confirm that no abnormal sound is occurred.	
4	Check the terminal boxes and confirm any loosen parts and cabling condition on terminal blocks.	

6.3 Checking list of electrical connections

The generator should be checked electrically before commissioning.

Seq. No.	Checkpoint	Check
1	Before main power cable (at main terminal box) connection, the insulation resistance value for each parts should be confirmed. - main stator winding (busbar) - main rotor winding and exciter rotor - exciter field - space heater	Insulation resistance measurement method is referred 6.4 Insulation resistance measurement.
2	The main power cable should be connected on the busbar tightly. - confirm the insulation resistance value after connection.	
3	Confirm the condition of cable gland and main terminal box assembly	
4	The auxiliary terminal box and its blocks should be checked according to the connection drawing.	
5	Confirm the condition of cable gland and auxiliary terminal box assembly	

6.4 Insulation resistance measurements.

The insulation resistance is a spot insulation test which uses an applied DC voltage to measure insulation resistance in MΩ. The measured insulation resistance intended to indicate the condition of insulation. Portable insulation tester is generally used for this test.

6.4.1. Test voltage and minimum value for Insulation resistance test

The test voltage is different from the machine rated voltage. The *Table 6.4.1* describes the test voltage and minimum value for the test.

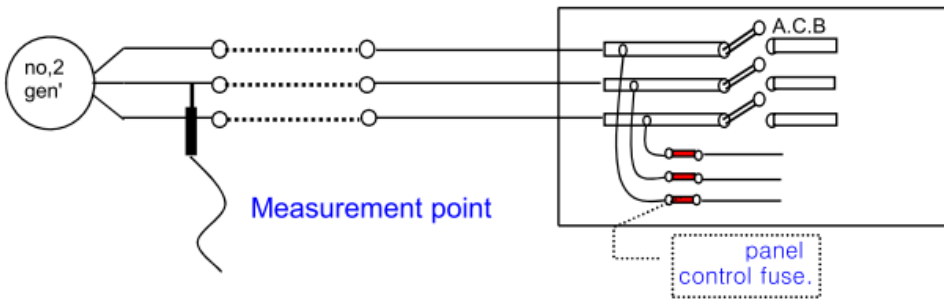
Table 6.4.1

Rated voltage(Vr) For stator winding	Test voltage in DC	Minimum value for stator winding	Check
Vr < 2500V	500Vdc	5 MΩ	
2500V<Vr<5000V	1000Vdc	10 MΩ	
5000V<Vr<12000V	2500Vdc	10 MΩ	
Vr>12000V	5000Vdc	10 MΩ	
For rotor winding and space heater	500Vdc	5 MΩ	

6.4.2. Measurement points

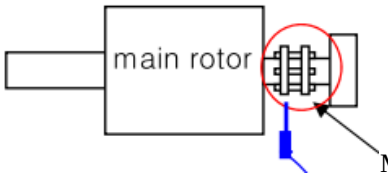
6.4.2.1 Measure point of stator

Generator main terminal bus bar side is the measuring point. If power cable is already installed, the panel control fuse should be removed. Please check the main switch board back side for fuse removal.



6.4.2.2 Measure point of rotor

Generator main terminal bus bar side is the measuring point. If power cable is already installed, the panel control fuse should be removed. Please check the main switch board back side for fuse removal.



Measure insulation resistance between connector ring and ground

Measurement point

6.5 AVR connection check

The AVR connection shall be checked according to AVR connection drawing very carefully. Simple connection error may lead to abnormal phenomenon.
Please note that the AVR has been set during shop test period so the final setting should be checked once again before running the generator.

Below 4 connection points shall be confirmed very carefully.
1. Sensing voltage connection (2phase or 3phase)
   If this cable is not connected, the generator voltage may be increased too high. (loss of sensing)
2. Sensing current connection (1 phase)

If this cable is not connected, the parallel running of generator will not be possible.

3. AVR field output
   If this cable is not connected, the generator voltage will not be build-up. Only residual voltage (below 10% rated voltage will be applied at the generator bus bar.
4. AVR Excitation input
   If this cable is not connected, the generator voltage will not be build-up. Only residual voltage (below 10% rated voltage will be applied at the generator bus bar.

6.6 First run of the set of prime mover and generator

Only 6.2~6.5 items are checked carefully, the generator set may be operated with the procedure below

Seq. No.	Checkpoint	check
1	Confirm if the space heater is switched off. (If the space heater is switched on/off by generator breaker, this sequence may be neglected)	
2	Confirm if the excitation current is switched off	
3	Confirm if Lubrication system for the bearing is prepared properly.(*)	
4	Start prime mover (engine, turbine or motor) and check if the prime mover speed is reached to rated speed.	
5	At the rated speed, confirm if any abnormal noise or vibration is not occurred.	
6	Excitation on and check the no load voltage build up	
7	At the rated voltage, confirm if any abnormal voltage control is not occurred. (ex. voltage hunting)	
8	If load is available, switch on the generator circuit breaker and check the voltage control	
9	Reduce the generator load to zero and open the breaker	
10	Confirm if excitation current is switched off	
11	Confirm if space heater is switched on.	

(*) Regarding lubrication system preparation, please refer to the chapter 3.3 construction of bearing

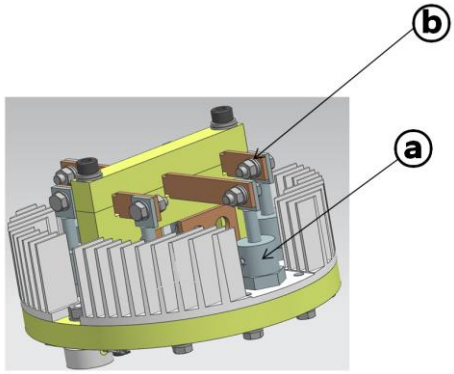
6.7 General Construction

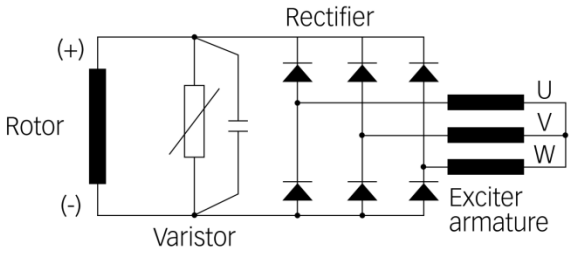
6.7.1 Recommended torque values for bolts and screws

Recommended torque values for metric 8.8 class bolts and screws specified in ISO.

Bolt Diameter	M6	M8	M10	M12	M14	
Pitch	1.0	1.3	1.5	1.8	2.0	
Torque [kgf·cm]	110	210	430	750	1,210	
Bolt Diameter	M16	M20	M22	M24	M30	M36
Pitch	2.0	2.5	2.5	3.0	3.5	4.0
Torque [kgf·cm]	1,800	3,500	4,900	6,000	12,400	21,500

For the rectifier assembly, the torque values in the table below are recommended.





Part	ⓐ	ⓑ
Torque	300 [kgf•cm]	210 [kgf•cm]

Chapter 7 Operation

7.1 General

To ensure trouble-free operation, the generator must be carefully looked after and supervised. In case any deviations from normal operating condition, e.g. temperature rise, vibration, noise or etc., generator must be stopped and cause must be found to be correct.

Always before starting the generator, ensure the following;
There must be no work in progress

- All of associated with the generator must be ready to start up the generator.
- All protection function for prime-mover must to be ready for activation.

NOTICE
Temperature of generator surface could be increased based on amount of loads and operation time and it could be personal injury or damage to generator. Especially, overload operation could be critical damage to generator. If necessary, consult the manufacturer for special instruction.

7.2 Normal operating conditions

In the HHI's approval drawing, operation conditions such as maximum ambient temperature, applied rule is described. Also the IEC standard and HHI's own standard are applied to the generator design.
Operating environment shall be free from dust, salt and corrosive gases in the air and external vibration in the foundation.

7.3 Start-up procedure

The sequential procedure for generator starting is referred to Chapter 6.6 starting.

Always before starting up generator, ensure that following;

- There must be no work in progress
- All of associated with the generator must be ready to start up the generator.
- All protection function for prime-mover must to be ready for activation.

To start the generator;
1. Turn off the space heater, if interlock system is not furnished at switchgear panel.
2. Check whether a Lo unit or Jack up unit is installed on the generator.
If a Lo unit or Jack up unit is installed, please operate each unit refer to the project document for "Bearings Lubrication Operation principles" before operating the generator.
3. Operate the generator by starting of prime mover.
4. Check the rated speed and voltage. Speed will be controlled by governor of prime-mover and voltage will be controlled by AVR (excitation system) of generator.
5. Synchronize with other generator or grid (if necessary).
6. Close the generator circuit breaker and check the load operation (if necessary).

7.4 Continuous supervision

The periodic supervision is to allow operating person to be familiar with the generator in normal

operating conditions. This activity is best way to detect and fix abnormal occurrences in future. Also operating person shall log the various parameter of generator during operation periodically. From above operator's feeling and collected data could be used for reference for maintenance work, trouble shooting and repairs.
Recommended data to be logged are as follows;

- Generator load
- Power factor
- Speed
- Voltage
- Current

For the regular supervision, the relative facilities such as counting device of start and duty timer is recommended to be included in the system.
If DCS or SCADA system is storing the data of generator as well as Prime-mover's operation, the trend data will be of help to investigate the phenomenon of unexpected failure.

7.5 Shut down procedure

Always before stopping the generator, ensure that following;

- There must be no work in progress
- All of associated with the generator must be ready to stop the generator.
- All protection function for prime-mover must to be ready for activation.

The shut-down of the machine depends on the application, but main guidelines are:
1. De-load the generator's output to about zero.
2. Open the generator breaker.
3. Switch the machine excitation off (if applicable).
4. Stop the prime-mover.
5. Turn on the space heater, if interlock system is not furnished at switchgear panel.

Chapter 8 Maintenance

8.1 Preventive maintenance

A synchronous machine often forms an important part of a larger installation and if it is supervised and maintained properly, it will be reliable in operation and guarantee a normal life time.

The purpose of maintenance is therefore to :

- Secure that the machine will function reliably without any unforeseen actions or interventions.
- Estimate and plan service actions in order to minimize down time.

This chapter presents recommendations regarding maintenance program, and work instructions how to conduct common maintenance tasks. These instructions and recommendations should be read carefully. Note that the maintenance recommendations presented in this chapter represent a minimum level of maintenance. By intensifying maintenance and supervision activities, the reliability of the machine and the long-term availability will increase.

The data obtained during supervision and maintenance is useful for estimating and planning additional service. In case some of this data indicates something out of the ordinary, trouble shooting will aid in locating the reason for the trouble. HHI recommends the use of experts in the creating maintenance programs, as well as in performing the actual maintenance and possible trouble shooting.

8.2 Safety precautions

Before working on any electrical equipment, general electrical safety precautions are to be taken into account, and local regulations are to be respected in order to prevent personnel injury. This should be made according to instructions of security personnel.

Personnel performing maintenance on electrical equipment and installation must be highly qualified. The personnel must be trained in, and familiar with, the specific maintenance procedure and tests required for rotating electrical machines.

8.3 Recommended maintenance program

Abbreviation used in maintenance program

- V = Visual checking
- C = Cleaning
- D = disassembling and assembling
- R = reconditioning or replacement
- T = testing and measurement

NOTE !
Not all options are applicable for all machines.

Table 8.3.1 Maintenance intervals

Maintenance interval					
	In equivalent operating hours ir time period, whichever comes first				
Maintenance object	T1	T2	T3	T4	Check/test
	4000	8000	24000	80000	
	0.5 year	Annual	3-5 years	Overhaul	

Table 8.3.2 Maintenance objects for general construction.

Maintenance object	T1	T2	T3	T4	Check / Test
Machine operation	V/T	V/T	V/T	V/T	Starting, Shut down, Vibration measurement
Exterior	V	V	V	V	Rust, Leakage
Fastenings	V	V	V	V	Tightness of all fastenings

Table 8.3.3 Maintenance objects for cable connection

Maintenance object	T1	T2	T3	T4	Check / Test
Cabling	V	V	V/T	V/T	Wear, Fastening
Connections	V	V	V/T	V/T	Oxidation, Fastening
Terminal box	V	V	V	V	General condition
Cable transits	V	V	V	V	Condition of cables entering the machine and inside the machine

Table 8.3.4 Maintenance objects for main stator and rotor

Maintenance object	T1	T2	T3	T4	Check / Test
Stator core	V	V	V	V/C	Fixing, Cracks, Welds
Stator winding insulation	V/T	V/T	V/T	V/T/C	Wear, Cleanliness, insulation resistance
Stator coil overhangs	V	V	V	V	Insulation damages
Stator coil supports	V	V	V	V	Insulation damages, tightness
Stator terminal bars	V	V	V	V	Fixing, insulation
Stator cable terminal fastening	V	V/T	V/T	V/T	Tightness, condition
Rotor winding insulation	V	V/T	V/T	V/T/C	Wear, Cleanliness, insulation resistance
Rotor coil supports	V	V	V	V	Movement, bending
Rotor balancing weights	V	V	V	V	Movement, fixing
Connections in rotor	V	V	V/T	V/T	Fixing, general condition

Table 8.3.5 Maintenance objects for excitation system

Maintenance object	T1	T2	T3	T4	Check / Test
Exciter diode bridge	V	V	V	V	Cleanliness, operation
Exciter semiconductors	V	V	V	V	Operation, fixing, damage
Exciter winding insulation	V	V/T	V/T	V/T	Wear, cleanliness, insulation resistance
Current transformer for parallel operation	V	V	V	V	Operation, cleanliness, damage
Temperature detectors	V	V/T	V/T	V/T	Operation, resistance
Anti-condensation heaters	V	V/T	V/T	V/T	Operation, insulation resistance
Auxiliary terminals (if applied)	V	V	V	V	Wiring condition

Table 8.3.6 Maintenance objects for bearings

Maintenance object	T1	T2	T3	T4	Check / Test
Bearing assembly	V	V	V	V	General condition, damage

8.4 Maintenance of general construction

To ensure a long life span for the general construction of the machine, the machine exterior should be kept clean and should periodically be inspected for rust, leaks and other defects. Dirt on the machine exterior exposes the frame to corrosion and can affect the cooling of the machines.

8.4.1 Checking during running of machine

During the first days of running it is important to keep the machine under close surveillance in case any changes occur in the vibration or temperature levels or there are abnormal sounds.
During running, pay special attention to temperature and vibration levels.

8.4.2 Vibration

Reciprocating engines used as prime mover impress vibrations on the alternator because of the pulsating torque output.

1) Permissible vibration stress measured at the bearing is :

Rotation Speed	Item	Permissible level
< 10 Hz	Vibration amplitude, S	< 0.40 [mm-peak]
10-100 Hz	Vibration velocity, Veff	< 18 [mm/s·rms]
>100 Hz	Acceleration, b	< 1.6 g

Please inquire if a higher vibration stress level is expected.

2) Permissible vibration stress measured at turbine generator bearing housing is :
(less than following value)

1500/1800 rpm	Amplitude (mm:peak-peak)	Velocity (mm/sec)	Acceleration (m/s^2)
Vertical	37	2.3	3.6
Horizontal	37	2.3	3.6
Axial	37	2.3	3.6

Reference : IEC 60034-14, ISO10816-13, JIS B0906

8.4.3 Temperature levels

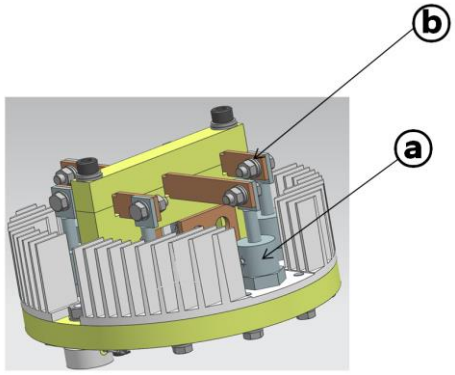
The temperature of bearings, stator windings and cooling air should be checked when the synchronous machine is running.
The bearing might not reach a stable temperature until after several (1~3) hours, when running at full speed.
The stator winding temperature depends on the load of machine. If full load cannot be reached during or soon after commissioning, present load and temperature should be noted and included in the commissioning report.

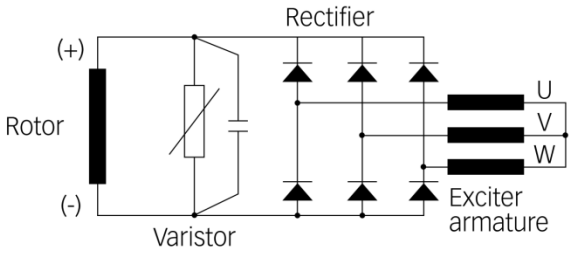
8.4.4 The tightness of fastenings

Recommended torque values for metric 8.8 class bolts and screws specified in ISO

Bolt Diameter	M6	M8	M10	M12	M14	
Pitch	1.0	1.3	1.5	1.8	2.0	
Torque [kgf·cm]	110	210	430	750	1,210	
Bolt Diameter	M16	M20	M22	M24	M30	M36
Pitch	2.0	2.5	2.5	3.0	3.5	4.0
Torque [kgf·cm]	1,800	3,500	4,900	6,000	12,400	21,500

For the rectifier assembly, the torque values in the table below are recommended.





Part	ⓐ	ⓑ

Torque	300 [kgf•cm]	210 [kgf•cm]

8.5. Maintenance of bearing

8.5.1 Operating description

NOTICE
Before starting, check if the bearing is filled with oil or not to the necessary oil level.

CAUTION
Prolonged operation at extremely slow rotation speeds (several rpm) without lubrication could seriously damage for the service life of the bearing.

CAUTION
If the bearing temperature exceeds the normal operating value by 15 K, stop the machine immediately. Inspect the bearing and determine the causes. Setting values of a safety device - Alarm: 95℃ - Trip: 100℃

8.5.2 Oil change

8.5.2.1 Ring lubrication system

Check the bearing temperature regularly.
The governing factor is not the temperature rise itself, but the temperature variations over a period of time. If abrupt variations without apparent cause are noticed, shut down the machine and renew the oil.

The lubrication oil indicated on the data plate is used for starting up the machines at an ambient temperature of above +5℃.

At lower temperatures (to about -20℃), it is necessary to preheat the oil.
If the ambient temperature is below -20℃ another type of oil according to the special conditions is used.
Do not mix oils of different grades.
Recommended oil changing intervals are about 3000 and 6000 operating hours in the case of intermittent and continuous duty.
When cleaning, first flush the bearings with kerosene and then with oil.

NOTE !
If the lubrication oil contains unusual residues or its color looks changed, bearings shall be inspected.

Pour in the kerosene and oil through the top sight-glass hole.
Leave the drain open until all the kerosene has been removed and clean oil runs out. Now, plug the drain and fill the bearing with oil up to the center of the lateral inspection glass.
When the machine has run up to speed, check the oil ring through the top inspection glass to see that it rotates correctly, and check the bearing temperature.
Should the bearing temperature not drop to the normal value after the oil change, it is recommended that the surfaces of the bearing shells be inspected.

If the bearings are fitted with thermometers for checking the bearing temperature, fill the thermometer well in the upper bearing shell for thermo feeler with oil to improve heat transfer and top up with oil every time the lubricating oil is changed.

8.5.2.2 Forced lubrication system

Check the bearing temperature regularly.
The governing factor is not the temperature rise itself, but the temperature variations over a period of time. If abrupt variations without apparent cause are noticed, shut down the machine and renew the oil.

Recommended oil changing intervals are about 20,000 operating hours.

After the machine has come to a stand-still, the old oil is drained out of the bearings and oil tank and operate the oil pump with kerosene for a short time and then with oil to clean the bearings.

For the oil pump, the oil tank, the cooler and the pipe lines: Pour in the kerosene and then the oil through the filling opening of the oil tank. Leave the drains open from time to time until all the kerosene has been removed and clean oil runs out of the bearings and oil tank. Then plug the drains and fill the tank with oil. Should the bearing temperature not drop to the normal value after the oil change, it is recommended that the surfaces of the bearing shells be inspected.

8.5.3 Dismantling, assembling

Supplementary Sleeve Bearing User's Manual.

8.6. Maintenance of stator and rotor winding

The windings of rotating electrical machines are subjected to electrical, mechanical and thermal stress. The windings and insulation gradually age and deteriorate due to these stresses. Therefore, the service life of the machine often depends on the insulation durability.

Many processes leading to damages can be prevented or at least slowed down with appropriate maintenance and regular testing. This character offers a general description on how to perform basic cleaning, maintenance and test.

Before conducting any maintenance work on the electrical windings, general electrical safety precautions are to be taken and local regulations are to be respected in order to prevent personnel accidents.

Independent test and maintenance instructions can also be found in the following international standards:
• IEEE Std 43-2000, IEEE Recommended Practice for Testing insulation Resistance of Rotating Machines

8.6.1 Cleaning of stator and rotor winding

Insulated windings should be kept reasonably clean of dirt, oil, metal particles and other contaminants. A film of dirty oil tends to accumulate particles that may interfere with satisfactory ventilation of the machine.

Access the rotor and stator assemblies and then clean windings using one or all of the following methods.

Chapter 8 Maintenance

WARNING
Use cleaning solution in an open or well-ventilated area; avoid breathing fumes. Keep away from open flames. Do not use a wire brush or a steel blade scraper to clean parts. Do not use gasoline, fuel oil or kerosene for cleaning.

8.6.1.1 Cleaning method

1. Vacuum Cleaning
To remove dust, dirt and particles the use of suction is preferable to blowing out with compressed air, since there is less possibility of damage to insulation and less chance of blowing conducting or harmful particles into areas that may later result in damage during operation.

2. Compressed Air Cleaning
Compressed air to blow out loose dust and particles from inaccessible areas such as air ducts and between stator end turns.

3. Solvent Cleaning
Solvent Cleaning: A method for removing all visible oil, grease, soil, drawing and cutting compounds, and other soluble contaminants from steel surfaces. It is intended that solvent cleaning be used prior to the application of paint and in conjunction with surface preparation methods specified for the removal of rust, mill scale, or paint.
3.1 System Procedure Before Solvent Cleaning
Prior to solvent cleaning, remove foreign matter (other than grease and oil) by one or a combination of the following: brush with stiff fiber or wire brushes, abrade, scrape, or clean with solutions of appropriate cleaners, provided such cleaners are followed by a fresh water rinse.
3.2 Methods of Solvent Cleaning
Remove heavy oil or grease first by scraper. Then remove the remaining oil or grease by either of the following methods:
1) Wipe or scrub the surface with rags or brushes wetted with solvent. Use clean solvent and clean rags or brushes for the final wiping. Acceptable solvents are lacquer thinner and denatured alcohol.
2) Steam clean, using detergents or cleaners and follow by steam or fresh water wash to remove detrimental residues.
3) Solvent cleaned surfaces should be primed or prepared as specified before any detrimental corrosion or recontamination occurs.

4. Steam Cleaning
To provide general guidelines for steam cleaning electrical winding, stator and rotor that have been processed through a complete resin impregnation and cure process.
(Do not steam clean green windings.)
4.1 Scope
1) Cleaning and removal of foreign materials that have accumulated near or on the windings of stators, rotors, exciters, armatures.
2) Cleaning of the outside of these units; provided the defined bake times required to dry the unit after cleaning is adhered to.
4.2 Definitions (optional)
1) Green winding – any winding that does not have a fully cured application of resin or varnish on it.
4.3 Special Tools Required
1) Vacuum Cleaner – preferably with a clean filter so any collected materials can be bagged and saved for evaluation.
2) Preheated oven large enough to accommodate the part.
3) Water containment system to assure water is diverted to a location it can be recovered from and properly disposed of.
4) Calibrated temperature measuring device.

8.6.1.2 Cleaning instructions

Chapter 8 Maintenance

1. Electrical Windings

• Remove any baffles, shrouds, or other feature that may be removed that could block access to the areas that require cleaning.

• Vacuum the loose debris from the unit. (DO NOT use an air hose at this operation.)

If practical, use a vacuum with a bag and send the bag with materials collected to QC when task is complete (this is most important for warranty repair work).

• Initiate pre-heat of oven at 50 – 65 ^{0}C before starting the steam cleaning process.

The oven must be preheated before placing the just cleaned part into it. Oven must have calibrated controls and have a temperature recording chart in use.

• Do not begin steam cleaning frame until the steam cleaner spray is clearly a mixture of steam and water. (Do not use soap or detergent.)

• Make sure the waste water is diverted to a location where it can be contained.

• Make sure no unauthorized personnel are in the work area for safety reasons.

• To avoid the risk of damage from the steam cleaning process:

1) The nozzle should typically be held 305 to 610 mm from any coil. The practical minimum Distance from nozzle to coils is 105 mm.
2) Avoid a direct spray onto any temperature sensing device or its leads.
3) Only turn the stream of steam on when the wand or nozzle is moving and turn it off before it stops moving.
4) The motion of the wand should create a sweeping type action.
5) Do not apply a continuous stream to any point on the windings.

• Start cleaning at the top surfaces and gradually work down. Repeat the process several times as needed. Estimated time to clean parts effectively is a minimum of 15minutes plus 3 minutes for every 450 kg of mass. The actual time will vary based on the condition of the unit, but everyeffort should be made to completely clean the unit so a second cleaning can be avoided.

• Place the unit into a preheated 50 – 65 ^{0}C oven as soon as possible, but not to exceed 90 minutes from the time the cleaning operation is complete.

• Have inspection visually verify the unit is clean and free of damage.

1) Look for any damage to coils or leads. Highest risk is damage caused by high pressure fluids hitting coil wedges, temperature sensors, space heaters, and coils.
2) Look for evidence of residual debris or dirt that may not have been removed by the steam cleaning process. If a possible problem area exists, sample the area by applying a strip of masking tape to the area, removing and attaching the masking tape to clear plastic film.
Identify the location the sample was collected from and forward samples with this work instruction.

2. Stator and Rotor cores

• Remove any baffles, shrouds, or other feature, that may be removed, that could block access to the areas that require cleaning.

• Vacuum the loose debris from the unit. (DO NOT use an air hose at this operation.)

• Remove any oil, grease or similar materials from the unit with a combination of scrapers, cloths, solvents, or high pressure fluid stream at room temperature or cooler.

• Preheat the part in an oven at 105 – 120 ^{0}C before starting the steam cleaning process. The oven must be preheated before placing the part into it. Oven must have calibrated controls and have a temperature recording chart in use.

• Do not begin steam cleaning frame until the steam cleaner spray is clearly a mixture of steam and water. (Do not use soap or detergent.) Check temperature of fitting as it enters the flow control handle. I should be greater than 65 ^{0}C.

• Make sure the waste water is diverted to a location where it can be contained.

- Make sure no unauthorized personnel are in the work area for safety reasons.
- Start cleaning at the top surfaces and gradually work down. Repeat the process several times as needed. Estimated time to clean parts effectively is a minimum of 15minutes plus 3 minutes for every 450 kg of mass. The actual time will vary based on the condition of the unit, but every effort should be made to completely clean the unit so a second cleaning can be avoided. Orient the part so it will freely drain and not puddle in hidden recesses.
- Cleaning must include in this order:
  1) The slots in the stator or rotor.
  2) The vents in the core.
  3) The Outer diameter of the stator and around the stator studs if applicable
  4) Any accessible area on the Inside of the frame
  5) The entire outside of the frame.
- Place the unit into a preheated 105 – 120 ^{0}C oven as soon as possible, but not to exceed 90 minutes from the time the cleaning operation is complete. The oven must be preheated before placing the just cleaned part into it. Oven must have calibrated controls and have a temperature recording chart in use.
- Have inspection visually verify the unit is clean and free of damage

8.6.2 The correct operating temperature

The correct temperature of the windings is ensured by keeping the exterior surfaces of the machine Clean, by seeing to the correct operation of the cooling system by monitoring the temperature sensors.

For air cooled machines it is important to the cleanliness of air inlets and outlets of air filter.

If the machine is equipped with the temperature detectors, stator operating temperature must be monitored. Significant temperature differences among the detectors or high temperature could be a sign of damage in the windings.

8.6.3 Insulation resistance test

During general maintenance work and before the machine is started up for the first time or after long standstill period, the insulation resistance of stator and rotor windings must be measured.

The insulation resistance measurement provides information about the humidity and dirtiness of the insulation. Based upon this information, correct cleaning and drying actions can be determined.

For new machines with dry winding, the insulation resistance is very high. The resistance can, however, be extremely low if the machine has been subjected to incorrect transportation and storage conditions and humidity, or if the machine is operated incorrectly.

NOTE !
Windings should be earthed briefly immediately after measurement in order to avoid risk of electric shock.

Conversion of measured insulation value

In order to be able to compare measured insulation resistance value, the values are stated at 40℃. The actual measured value is therefore converted to a corresponding 40℃ value with the help of the following figure. The use of this figure should be limited to temperature near to the standard value of 40℃, since large deviations from it could result in errors.

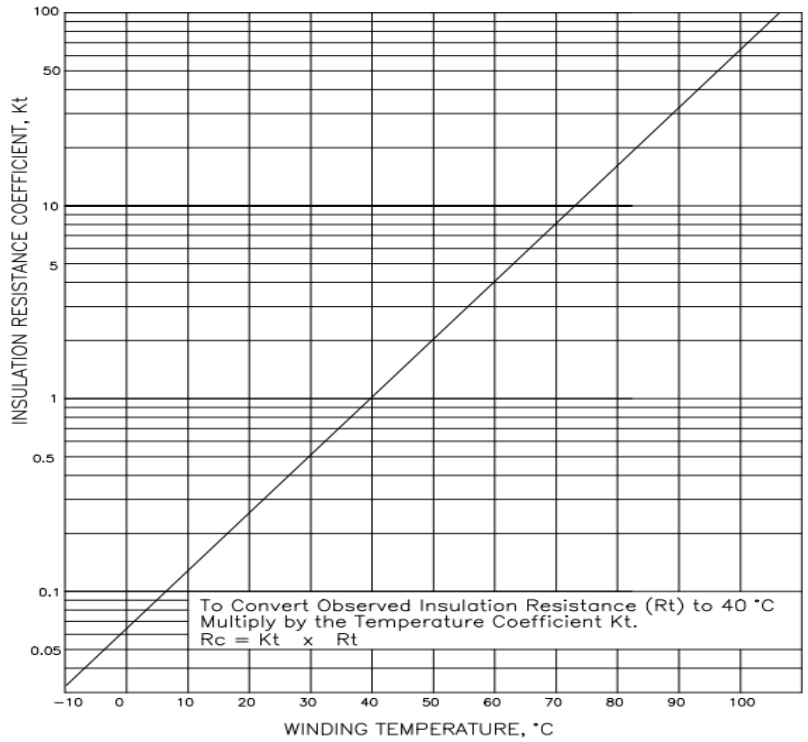


Fig. 8.6.3 Correlation between the insulation resistance and the temperature

- Rc : Insulation resistance value corrected to 40℃
- Rt : Measured insulation resistance at temperature t℃
- Kt : Insulation resistance temperature coefficient at temperature t℃

Example :

Rt = 30 MΩ measured at 20℃

Kt = 0.5

R40 = 0.5 x 30 = 15 MΩ

General consideration

The following consideration should be noted, before deciding any actions based upon the insulation resistance tests :

- If the measured value is considered too low, the winding must be cleaned and /or dried, see Chapter 8.6.7 Drying for details.
- Machines, that are suspected to have a moisture problem, should be dried carefully independent of the measured insulation resistance value.
- The insulation resistance value will decrease when the winding temperature rises.
- The resistance is halved for every 10-15℃ temperature rise.

Minimum values for insulation resistance

The limit values for minimum insulation resistance and critical insulation resistance(for measurement at a winding temperature of 25℃) and for measuring voltage can be derived from the following table depending on the rated voltage for the machine.

	Limit values at rated voltage	
	Rated voltage < 2kV	Rated voltage ≥ 2kV
Measuring voltage	500V DC (Min. 100V DC)	500V DC (Max. 1000V DC)
Minimum insulation resistance with new machine. Cleaned of repaired windings	10 MΩ	100 MΩ
Critical specific insulation Resistance after long period operation	0.5 MΩ / kV	5 MΩ / kV

Stator winding insulation resistance measurement
The insulation resistance is measured using an insulation resistance meter. The test voltage is 500V or 1000 VDC. The test time is 1 minute, after which the insulation resistance value is recorded. Before the insulation resistance test is conducted, check that :

CAUTION
If any CT or PT of generator is earthed, it should be removed before megger test.

- Opening the side cover of cable gland (or main terminal) box on generator top side.
- You can see the generator main bus bars.
- Connect the each terminal of Megger Tester between Main Bus Bar (One Phase) and frame earthling.
- If the measurement value is greater than 100 MOHM, the condition of generator stator winding is O.K. If not so good, please sufficiently dry the generator windings using the space heater installed into generator body. And then retry the megger test.
- After megger test, please connect the jumper line between main bus bar and frame earthling in order to remove the voltage charged into the generator stator windings.

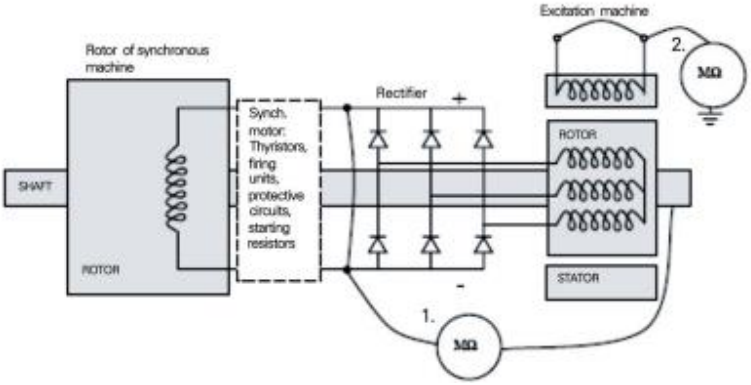
(Please note that this action is for the safety.)

Insulation resistance measurement of the rotor field winding and excitation machine
The test voltage for the rotor winding and excitation machine is 100V or 500VDC. When testing the windings of the rotors:

- Short circuit the rectifier before measuring
- Measure the rotor winding temperature if possible or estimate otherwise measurement temperature of the rotor winding.
- Opening the air intake side (or inspection cover) of frame body.
- You can see the rotating rectifier's rings on the generator rotor part
- Connect the each terminal of 500V Megger Tester between Rectifier Ring (for Rotating Diode) and Frame Eathing.
- If the measurement value is greater than 10 MOHM, the condition of generator rotor winding is O.K. If not so good, please sufficiently dry the generator windings using the space heater installed into generator body. And then retry the megger test.
- After megger test, please connect the jumper line between rectifier ring and frame earthing in order to remove the voltage charged into the generator rotor windings.

(Please note that this action is for the satiety.) When testing the stator winding of the excitation machine:

- Disconnect the power supply cables from the voltage source.
- Connect the insulation resistance meter between the stator winding and the frame of machine as shown in below figure.



- Measurement of winding of the rotors.
- Measurement of the stator winding of the excitation machine. MΩ represents the insulation resistance meter.

8.6.4 Polarization index for Medium voltage machine

For the polarization index test the insulation resistance is measured after the voltage has been applied for 15 seconds and 1 minute (or 1 minute and 10 minutes). The polarization index test is less dependent on the temperature is below 50℃, it may be considered independent of temperature. High temperatures can cause unpredictable changes in the polarization index. Therefore the test should not be used in temperature above 50℃.

Dirt and humidity accumulating in the winding normally reduces the insulation resistance, and the polarization index, as well as their dependence on temperature.

There are several rules for determining the lowest acceptable value with which the machine can be safely started. For the polarization index (PI), the values usually range between 1 and 4. Value close to 1 indicate that the windings are humid and dirty.

The minimum *PI* value for class *H* stator winding is more than 2, where

$$\text{PI} = \frac{R1min}{R1.5s} \text{ or } \text{PI} = \frac{R10min}{R1min}$$

Note !
If the 1 minute insulation resistance is above 5000 MΩ, it can be disregarded.

8.6.5 High voltage test

A voltage test is used to check for electrically weak spots in the windings that may lead to insulation failure during servicing. It is carried out during major inspections, troubleshooting and repairs.

8.6.6 Visual winding inspection

Winding inspection give information on:

- The rate of contamination ; presence of dirt and humidity
- Stability of bracings, vibration marks, and cracking

- Marks of overheating
- Marks of movement
- Tightness of the slot wedges
- Winding overhangs and their supports

When examining the contamination, particular attention should be paid to the open creep age surfaces, as the insulation resistance is easily affected by the dirt accumulating there.

Accumulating dirt blocks the coil gaps and air ducts, and thus diminishes the cooling capacity of the machine. As a result, the winding temperature rises, and aging may speed up considerably.

Mechanical strain, vibration, and shocks may cause cracks on the edges of the supports, bindings, and around slot ends. Loose supports and slot wedges are signs of further deterioration. Check for abrasion marks and powder near the supports, bindings, and at the slot ends. Complete loosening of the slot wedges and bent coils are serious problem that must be rectified immediately.

Humidity in the winding often causes e.g. rust on iron, drop marks, dripping, and wetting marks on dirt layers. Brush-shaped patterns, often charred and left behind by the tracking currents, warm of an approaching failure. In rare cases, the conductors are corroded.

Marks of the electrical effects (apart from tracking current marks), are usually hidden inside the slot and conductor insulations.

The following are marks of overheating:
Copper in the damper windings grows darker (darkening may also be due to the gases in the environment), and it oxidizes.

- Core laminations of the rotor become blue (over 350℃)
- There are color differences in the fastening bolts of synchronous machines.
- Insulation may shrink or split (usually over 200℃), bindings may crack (over 200℃), and polyester film or fibers may melt (over 250℃).

Prolonged periods over temperatures cause premature aging. The insulating materials become brittle and darken in the early, stages. As a result, the windings split, disintegrate, and fracture.

8.6.7 Drying

The winding must be dried:

- After washing (especially water wash and rinse)
- If they have become humid in use or during a standstill.

Drying should always be started with an external blower or warm air. Other means should be attempted, only if blower and warm air do not suffice.

During drying, the rate of temperature rise of the winding should not exceed 5 K per hour, and the final temperature should not exceed 105℃. A sudden temperature rise or a too high final temperature can cause steam to be formed in the cavities of the winding, which in turn can destroy the windings. During the drying process, the temperature should be monitored periodically, and the insulation resistance should be measured at regular intervals.
A very wet machine should be dismantled and the winding dried in an oven. Every part should be checked. If the machine is not very wet, the winding can be dried by passing a current through it.

If the winding is dried by passing a current through it, the source of electricity can be e.g. a welding machine or a similar device.

Note !
Direct current or alternate current can be used. The current must not exceed 25% of the nominal current, which is indicated on the rating plate on the machine. The winding temperature should also be continuously monitored.

When drying in an oven, the temperature rise and the maximum temperature should be monitored carefully. The oven temperature should be around 90℃ for 12 to 16 hours and then 105℃, for 6 to 8 hours. These times can vary, and the correct time should be monitored with and insulation resistance test.

Drying in an oven with good ventilation is the most effective technique. Unfortunately this is not usually possible at the machine's operating site. Therefore, either hot-air-blow or heating the windings with current should be used.

An insulation resistance test should be performed after drying the windings. When drying is started, the insulation resistance decreases due to the temperature rise. As the drying continuous, however, the insulation resistance increases until it reaches a stable value.

8.6.8 Maintenance related to electrical performance, excitation, control and Protection

8.6.8.1 Protection trips

The synchronous machine needs to be protected with alarms or alarms/trips in case of abnormal running conditions, both electrical and mechanical. Some of these protections can be reset and the machine restarted directly as the fault is located.

8.6.8.2 Automatic voltage regulator (AVR)

The automatic voltage regulator (AVR) is important in controlling and protecting the machine, and problems in connections or settings of the AVR might lead to different types of operational faults. For detailed information about AVR see Annex 2 - AVR manual.

8.6.8.3 Insulation resistance measurement for auxiliaries

To ensure correct operation of the machines protections and other auxiliaries, their condition can also be determined by an insulation resistance test, however this is not recommended.

8.6.8.4 Diode fault

If a diode in the rotating rectifier fails, the generator must be tripped. To determine and locate a faulty diode:
Open the rectifier covers at the non-drive end of the machine and measure the voltage with an ohm-meter over one of the diodes.

If diode failure is detected, disconnect all diodes and test them separately to locate the faulty diode.

To replace faulty diodes:

- Open the rectifier cover at Non-Drive end of the machine.
- Disconnect the wires connected to the diodes and exciter winding connection cables.
- Check the condition of the diodes by measuring the voltage over a diode in both directions
- Replace the damaged diode(s).
- Clean the contact surface and apply electric joint compound.

- Fasten the diode(s). Bind the connection leads of the diodes as on original assembly.
- Check fastening and locking of all rectifier bridge components.
- Make sure that no tools etc. are inside the machine and close the service covers.

After replacing the diodes, the condition of the diodes can be checked by comparing no-load excitation current to commissioning values. A diode failure result as a significant increase or decrease in excitation current.

Chapter 9 Troubleshooting

9.1 General

This chapter is intended as a help in the event of an operational failure with an HHI delivered machine. The troubleshooting charts given below can aid in locating and repairing mechanical, electrical and thermal problems and problems associated with the lubrication system. The checks and corrective actions mentioned should always be conducted by qualified personnel. If in any doubt, the After Sales of HHI should be contacted for more information or technical assistance regarding troubleshooting and maintenance.

For optional PMG-unit, see *Annex 3. Permanent Magnet Regulator (PMG) User's Manual.*

9.2 Mechanical performance

The kind of experience		Possible cause		Corrective action
Vibration	Noise			
x	x	Lubrication malfunction		Check lubricant quality and quantity and lubrication system function
x	x	Bearing malfunction	Damaged bearing parts	Check bearing condition and replace bearing parts
x	x		Faulty bearing assembly	Check alignment
x	x	Faulty cooling fan(s)	Imbalanced or damaged fan(s)	
	x	Malfunctioning cooling system		Inspect and repair cooling system
	x	Malfunctioning excitation system		Inspect and repair excitation system
x	x	Machine misalignment		Check machine alignment
x	x	Rotor or shaft imbalance		Rebalance rotor
x	x	Loose parts in rotor		Check rotor wedges, poles etcx, repair and rebalance rotor
x	x	Vibration coming from connected machinery		Check the balance of connected machinery and coupling type
x	x	Axial load coming from connected machinery		Check alignment and coupling function and type
x	x	Faulty or incorrectly assembled coupling		Check coupling function
x		Insufficient foundation strength Reinforce foundation as per		Reinforce foundation as per HHI instructions
	x	Main machine or excitation machine winding fault		Check main machine and excitation machine windings
x	x	Excessive network unbalance		Check that network balance fulfils requirements
x	x	Bearing misalignment		Check bearing pedestal alignment
	x	Foreign material, moisture or dirt inside the machine		Check and clean machine interior, dry windings

9.3 Lubrication system and rolling bearings

The kind of experience			Possible cause		Corrective action
High Bearing Temperature	Lubricant leaks	Bearing noise or vibration			
x		x	Insufficient lubrication	Insufficient amount of grease	Check bearing condition, add grease
x	x	x	Unsuitable grease quality or viscosity		Check HHI grease recommendation, change grease
x			Excessive axial forces	Faulty coupling or mounting	Check coupling, mounting and alignment

x		x	Reduced grease quality	Incorrect regreasing period	Check HHI recommendation, regrease
x		x		Faulty operating conditions	Check HHI operating and grease recommendations
x	x		Excessive lubrication		Clean bearing and add correct amount of lubricant
x		x	Damaged bearing parts	Impurities in grease	Change grease, check bearing condition
x		x		Bearing currents	Check bearing and insulation condition
x		x		Complete bearing failure	Replace bearing
x		x		Normal wearing	Replace wom bearing parts
x		x	Faulty instrumentation	Faulty temperature detector	Check bearing seals and lubricant quality
	x	x	Faulty bearing seals		Check bearing seals and lubricant quality
x			Incorrectly assembled bearing		Replace bearing, ensure correct assembly
x		x	Outer ring is rotating due to unbalanced load		Rebalance machine, repair bearing bore and replace bearing
		x	Bearing noise due to deformed roller element		Replace bearing
		x	Foreign matter inside the bearing		Clean bearing assembly, check seal conditions and replace bearing.

9.4 Thermal performance, open air cooling system

The kind of experience		Possible cause		Corrective action
High winding temperature	High cooling air temperature			
x	x	High intake air temperature	Ambient temperature too high	Add ventilation to decrease ambient temperature
x	x		Exiting air is pulled back in	Ensure sufficient clear distances surrounding the machine
x	x		Heat source nearby	Place heat sources further away, check ventilation
x	x	Faulty air flow	Dirty machine interior	Inspect and repair cooling system
x	x		Faulty cooling arrangement	Inspect and repair excitation system
x	X		Air intakes are blocked	Check machine alignment
x	x		Air filter is clogged	Rebalance rotor
x	x	Damaged cooling fan(s)		Replace fan(s)
x	x	Cooling fan rotating in the wrong direction		Replace fan(s) or change rotating direction of external fan
x		Overload	Control system setting	Check machine controls, eliminate overload
x	x	Overspeed		Check actual speed and HHI speed recommendations
x		Network unbalance		Check that network balance fulfils requirements
x	x	Faulty instrumentation or measurement system		Check measurements, sensors and wiring
x		Main machine or excitation machine winding fault		Check main machine and excitation machine windings

9.5 Electrical performance and excitation system of generators

The kind of experience						Possible cause		Corrective action
Lost excitation	Increase in excitation current	Malfunction during start-up	Performance deviation	Operation not adjustable	Faulty parallel operation			
			x			Speed variation of operating machine		Check speed control device of prime mover
x		x				Field application failure	Incorrect setting or defect of auxiliary relay	Check auxiliary relay of excitation panel and AVR setting parameter
x		x					Incorrect wiring	Check wiring of inside excitation panel and interface cable.
x		x					Demagnetized excitation magnet	Carry out the field flushing.
x	x		x	x	x	Defective parallel operation transformer		Check transformer winding insulation resistance and connections
x			x			Defective current transformer		Check transformer winding insulation resistance and connections
x	x					Short circuit excitation system failure		Check operation of short circuit excitation system
			x			Main generator winding fault		Check generator winding and insulation resistances
x			x			Excitation system winding fault		Check exciter winding and insulation resistances
x	x	x	x	x		Faulty rotating rectifier		Check connection and condition of rectifier components
x		x	x	x		Faulty wiring in excitation system		Check electrical connections in excitation system
x	x	x	x	x	x	Faulty AVR settings		Check and adjust AVR setting parameters.
			x			Incorrect AVR tuning parameters	Voltage oscillation, poor response	Check AVR tuning (PID parameters)
x	x	x	x	x	x	Defective AVR		Check and replace AVR.
x	x	x	x	x	x	Faulty AVR wiring or incorrect connections		Check AVR wiring and connections
			x			Power factor variation over permitted values		Check AVR condition
			x	x	x	Faulty external voltage reference system		Check connections and condition of voltage reference
x		x				No actual value information for AVR		Check actual value measurement system and electrical connections