

User's Manual

AMG Synchronous Generator Marine Application Series

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Chapter 1 Introduction

1.1 General information

This User's Manual contains information on the transport, installation, operation and maintenance of AMG 0180-0500 type of synchronous machines supplied by ABB.

This manual provides information regarding all aspects of installation, operation, maintenance and supervision of the machine and shows how to disassemble/assemble major components, if required. Careful study of the contents of this manual and other machine related documentation before any actions are taken is necessary to ensure proper 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.

ABB constantly strives to improve the quality of the information provided in this User's Manual, and will welcome any improvement suggestions. For contact information, see *Chapter 9.1. After sales*.

NOTE: These instructions must be followed to ensure safe and proper installation, operation and maintenance of the machine. They should be brought to the attention of anyone who installs, operates or maintains this equipment. Ignoring the instruction invalidates the warranty

1.2 European directives

Generators sold to European Union must meet the relevant local directives. The generator is supplied as a component part of generating set, as it has itself no intrinsic function without mechanical power input. Every generator is therefore supplied with an *EC Declaration of Incorporation* according to *Machinery Directive*.

As the standard generator is designed for industrial application, it meets the industrial emissions and immunity standards. If the generator is to be used for residential, commercial or light industrial applications, extra equipment may be required. In this case, please contact generator manufacturer if you have not specified this in advance.

Before the generator is coupled into machinery, it meets the following directives, which are applicable for the component part of machinery-generator:

- Low Voltage Directive 2006/95/EC.
- EMC Directive 2004/108/EC
- Machinery Directive 2006/42/EC

NOTE: Once the generator is coupled into generating set, the generating set manufacturer has to ensure the generating set complies with the relevant EC directives.

All the generators supplied by ABB are CE-marked (see *Figure 1-1. CE-label*) on rating plates. The rating plate can be delivered as loose items in case the generator has to be re-painted before delivered to end user.



Figure 1- 1. CE-label.

1.3 Site conditions

The machinery is to be used on a site with conditions according to Technical Specifications and Conditions laid down by ABB in their contract with the user, and nowhere else.

1.4 Important note

The information in this document may sometimes be of a general nature and applicable to various machines supplied by ABB.

Where a conflict exists between the contents herein and the actual machinery supplied, the user must either make an informed engineering judgment as to a course of action or, if any doubt exists, contact ABB.

The safety precautions shown in this chapter and elsewhere in this User's Manual must be observed at all times.

Safety is dependent on the awareness, concern and prudence of all those who operate and service machines. While it is important that all safety procedures will be observed, care near machinery is essential.

NOTE: To avoid accidents, safety measures and devices required at the installation site must be in accordance with the instructions and regulations stipulated for safety at work. This applies to general safety regulations of the country in question, specific agreements made for each work site and safety instructions included in this manual and separate safety instructions delivered with the machine.

The information in this document is subject to change without notice and should not be construed as a commitment by ABB. ABB assumes no responsibility for any errors that may appear in this document.

This document and parts thereof must not be reproduced or copied without the express written permission of ABB, and the contents thereof must not be imparted to a third party nor be used for any unauthorized purpose.

1.5 Limitation of liability

In no event shall ABB be liable for direct, indirect, special, incidental or consequential damages of any nature or kind arising from the use of this document, nor shall ABB be liable for incidental or consequential damages arising from use of any software or hardware described in this document.

The warranty issued covers manufacturing and material defects. The warranty does not cover any damage caused to the machine, personnel or third party by improper storage, incorrect installation or operating of the machine. The warranty conditions are in more detail defined according to Orgalime S2000 terms and conditions.

NOTE: The warranty issued is not valid, if the operation conditions of the machine are changed or any changes in the construction of the machine,

or repair work to the machine have been made without prior written approval from the ABB factory, which supplied the machine.

NOTE: Local ABB sales offices or third party resellers may hold different warranty details, which are specified in the sales terms, conditions or warranty terms.

For contact information, see the back page of this User's Manual. Please remember to provide the serial number of the machine when discussing machine specific issues.

1.6 General safety

Carrying out certain operations, maintenance procedures and some handling procedures can be dangerous or harmful if the correct safety precautions are not observed.

While it is important that these recommended safety procedures are observed, care near machinery is always necessary. No list can be exhaustive, always be on your guard!

It is important that personnel are aware of the hazards that exist within their working environment. Not only should they be able to identify these hazards, but they should be able to deal quickly and efficiently with the situation by carrying out recognized safety procedures.

They should also be able to recognize warning signs (decals) and visual or audio signals.

The following recommendations are for general guidance:

- Always wear correctly fitted protective clothing, headwear and footwear. Loose or baggy clothing can be lethal when working on or near rotating machinery. Clothing should be laundered regularly. Clothing which becomes impregnated with oil or other substances can constitute a health hazard due to prolonged contact with the skin, even through underclothing.
- As far as it is practicable, work on or close to machinery only when they are stopped. If this is not possible, keep tools, test equipment and all parts of your body well away from the moving parts of the machinery.
- Parts of the synchronous machine and its auxiliary equipment can reach high temperatures. Protective clothing, particularly gloves must be worn at all times.
- Many liquids used in machinery are harmful if swallowed or splashed into the eyes. In the event of accidentally swallowing a potentially dangerous fluid, do NOT encourage vomiting and OBTAIN MEDICAL ASSISTANCE IMMEDIATELY. Wear protective goggles when handling liquids which are harmful to the eyes. If any liquid is splashed into the eyes, wash out immediately and OBTAIN MEDICAL ASSISTANCE IMMEDIATELY.

Safety is dependent on the awareness, concern and prudence of all those who operate and service machines. The machinery may cause severe injury if incorrectly used. Personnel must be aware of the potential hazards that exist when operating or maintaining synchronous machines.

Before attempting to set up, operate or adjust synchronous machines, operators and maintenance people must be technically qualified and must have received the appropriate training.

Personnel must be familiar with the recommended procedures detailed in the User's Manual.

1.6.1 Symbols and decals

Personnel must be familiar with all the warning symbols and decals fitted to the machinery. Failure to recognize a warning and read the associated safety instructions may result in injury or death.

1.6.2 Electrical hazard

The synchronous machine and auxiliary equipment must be disconnected from the electrical power supply during installation, maintenance or setting-up. All voltage parts must also be earthed.

1.6.3 Moving parts

Covers must only be removed by qualified personnel when instructed as part of an installation, maintenance or setting-up procedure. They must be re-fitted as soon as possible. Keep hands and loose clothing clear of all moving parts.

1.6.4 High temperatures

Parts of the machinery and its auxiliary equipment will reach high temperatures. Avoid contact with them. Always wear protective gloves when working in the vicinity.

1.6.5 Electro-Static Devices (ESD)

Precautions must be taken to prevent damage to the electronic control devices of the synchronous machine. Ensure that the operating environment is protected against ESD. Do not touch electronic circuits while unpacking.

1.6.6 Magnetic fields

There is a magnetic field presence in the immediate area surrounding rotating machinery. Ensure that devices that can be influenced or wiped (e.g. magnetic disks, credit cards, watches etc.) by the effects of electro-magnetism are removed from the area.

1.6.7 Noise

Machine rooms can be extremely noisy and damaging to the ears. Ear protection should always be worn where practicable.

1.7 Safety Instructions

1.7.1 General

General safety regulations, specific agreements made for each work site and safety precautions shown in this document must be observed at all times.

1.7.2 Intended use

Electric machines have dangerous live and rotating parts and may have hot surfaces. All operations serving transport, storage, installation, connection, commissioning, operation and maintenance shall be carried out by responsible skilled persons (in conformity with EN 50 110-1/DIN VDE 0105/IEC 60364). Improper handling may cause serious personal injury and damage to property.

These machines are intended for industrial and commercial installations as components as defined in the Machinery Directive (MD) 98/37/EC. Commissioning is prohibited until conformity of the end product with this directive has been established (follow particular local safety and installation rules as e.g. EN 60204).

These machines comply with the harmonized series of standards EN 60034 / DIN VDE 0530. Their use in explosive atmosphere is prohibited unless they are expressly designed for such use (follow additional instructions).

On no account, use degrees of protection \leq IP23 outdoors. Air-cooled models are typically designed for ambient temperatures of $-20\text{ }^{\circ}\text{C}$ up to $+45\text{ }^{\circ}\text{C}$ and altitudes of $\leq 1000\text{ m}$ above sea level. Ambient temperature for air-/water-cooled models should be not less than $+5\text{ }^{\circ}\text{C}$. By all means, take note of deviating information on the rating plate. Field conditions must conform to all rating plate markings.

1.7.3 Transport, storage

Immediately report damage established after delivery to transport company. Stop commissioning, if necessary. Lifting eyes are dimensioned for the weight of the machine, do not apply extra loads. Ensure the use of correct lifting eyes. If necessary, use suitable, adequately dimensioned means of transport (e.g. rope guides). Remove shipping braces (e.g. bearing locks, vibration dampers) before commissioning. Store them for further use.

When storing the machine, make sure that the location is dry, dust and vibration free (danger of bearing damage at rest). Measure the insulation resistance before commissioning. At values of $\leq 1\text{ k}\Omega$ per volt of rated voltage, dry winding. Follow the manufacturer's instructions.

1.7.4 Installation

Make sure of even support, solid foot or flange mounting and exact alignment. Avoid resonances with rotational frequency and double mains frequency as a result of assembly. Turn rotor and listen for abnormal slip noises. Check direction of rotation in uncoupled state.

Make necessary ventilation and cooling system connections. The ventilation must not be obstructed and the exhaust air, also of neighboring sets, should not be taken in directly.

1.7.5 Electrical connection

All operations must be carried out only by skilled persons on the machine at rest. Before starting work, the following safety rules must be strictly applied:

- De-energize.
- Provide safeguard against reclosing.
- Verify safe isolation from supply.
- Connect to earth and short.
- Cover or provide barriers against neighboring live parts.
- De-energize auxiliary circuits (e.g. anti-condensation heating).

Exceeding of limit values of zone A in EN 60034-1/DIN VDE 0530-1 - voltage $\pm 5\%$, frequency $\pm 2\%$, waveform and symmetry - leads to higher temperature rise and affects the electromagnetic compatibility. Note rating plate markings and connection diagram in the terminal box.

The connection must be made in a way that the permanent safe electrical connection is maintained. Use appropriate cable terminals. Establish and maintain safe equipotent bonding.

The clearances between uninsulated live parts and between such parts and earth must not be below the values of appropriate standards and values possibly given in manufacturer's documentation.

No presence of foreign bodies, dirt or moisture is allowed in the terminal box. Close unused cable entrance holes and the box itself in a dust- and watertight manner. For machines with accessories, check satisfactory functioning of these before commissioning.

The proper installation (e.g. segregation of signal and power lines, screened cables etc.) lies within the installer's responsibility.

1.7.6 Operation

Acceptable vibration values have to be determined according to application and corresponding ISO standard. In case of deviations from normal operation - e.g. elevated temperature, noises or vibrations - disconnect the synchronous machine, if in doubt. Establish cause and consult the manufacturer, if necessary.

Do not defeat protective devices, not even in trial run. In case of heavy dirt deposits, clean cooling system at regular intervals.

From time to time, open closed condensation drain holes, if any.

Grease the bearings during commissioning before start-up in case of re-greasable bearings. Re-grease antifriction bearings while the machine is running. Follow instructions on lubrication plate. Use right kind of grease.

Refer to manufacturer's documentation for noise level and information about the use of appropriate noise-reducing measures.

1.7.7 Maintenance and servicing

Follow the manufacturer's operating instructions. For further details, see *Chapter 7. Maintenance* in the User's Manual. Preserve these safety instructions!

1.8 Disposal and recycling instructions

ABB is committed to its environmental policy. We strive continuously to make our products environmentally more sound by applying results obtained in recyclability and life cycle analyses. Products, manufacturing process as well as logistics have been designed taking into account the environmental aspects. Our environmental management system, certified to ISO 14001, is the tool for carrying out our environmental policy.

These instructions are only guide lines and it is the customer's responsibility to ensure that the local legislation is followed.

The material content (average percentage of the mass) which have been used in the manufacturing the electrical machine is shown in *Table 1-1*:

Table 1-1. Material content of the generator.

Steel	70 %
Copper	15 %
Cast iron	10 %
Aluminium	2 %
Insulation materials	2 %
Other	1 %

1.8.1 Recycling of material required for transport

After unpacking of the machine, the package has to be removed. The package is made of wood and can be burned. The plastic material around the machine can be recycled.

After installation of the machine transportation locking have to be removed. The transportation locking is made of steel and can be recycled. Transportation locking can also be stored for possible reuse.

The sea trial package to some countries like Australia has special requirements, and is made of e.g. impregnated wood that must be recycled according to local instructions.

The rust protection material covering the machined surfaces can be removed with petrol based solvent detergents and the cleaning rags are hazardous waste which has to be handled according to the local instructions.

1.8.2 Recycling of the complete machine

Dismantling of the machine

Because of the weight of the components, the person who does the dismantling has to have adequate skills to handle heavy components to prevent dangerous situations.

Frame, bearing housing, covers and fan

These parts are made of structural steel or cast iron, which can be recycled according to local instructions. All the auxiliary equipment, cabling as well as bearings have to be removed before melting the material.

Components with electrical insulation

The stator and the rotor are the main components, which include electrical insulation materials. There are, however, auxiliary components which are constructed of similar materials and which are hence dealt with in the same manner. This includes various insulators used in the terminal box, excitation machine, voltage and current transformers, power cables, instrumentation wires, surge arrestors and capacitors. Some of these components are used only in very limited number of machines.

All these components are in an inert stage once the manufacturing of the machine has been completed. Some components, in particular the stator and the rotor, contain a considerable amount of copper which can be separated in a proper heat treatment process where the organic binder materials of the electrical insulation are gasified. To ensure a proper burning of the fumes the oven shall include a suitable after burning unit.

The following conditions are recommended for the heat treatment and for the after burning to minimize the emissions from the process:

- Heat treatment:
 - Temperature: 380-420 °C (716-788 °F).
 - Duration: After receiving 90 % of the target temperature the object shall stay a minimum of five hours at this temperature.
- After burning of the binder fumes.
 - Temperature: 850-920 °C (1562-1688 °F).
 - Flow rate: The binder fumes shall stay a minimum of three seconds in the burning chamber.

NOTE: The emission consists mainly of O₂-, CO-, CO₂-, NO_x-, C_xH_y-gases and microscopic particles. It is on the user's responsibility to ensure that the process complies with the local legislation.

NOTE: The heat treatment process and the maintenance of the heat treatment equipment require special care in order to avoid any risk for fire hazards or explosions. Due to various installations used for the purpose it is not possible for ABB to give detailed instructions of the heat treatment process or the maintenance of the heat treatment equipment. These aspects must be taken care by the customer.

Hazardous waste

The oil and grease from the lubrication system is a hazardous waste and has to be handled according to local instructions

Landfill waste

All insulation material can be handled as a land fill waste.

Chapter 2 Transport and storage

2.1 Transport and unpacking

2.1.1 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.

2.1.2 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.

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.

2.1.3 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.

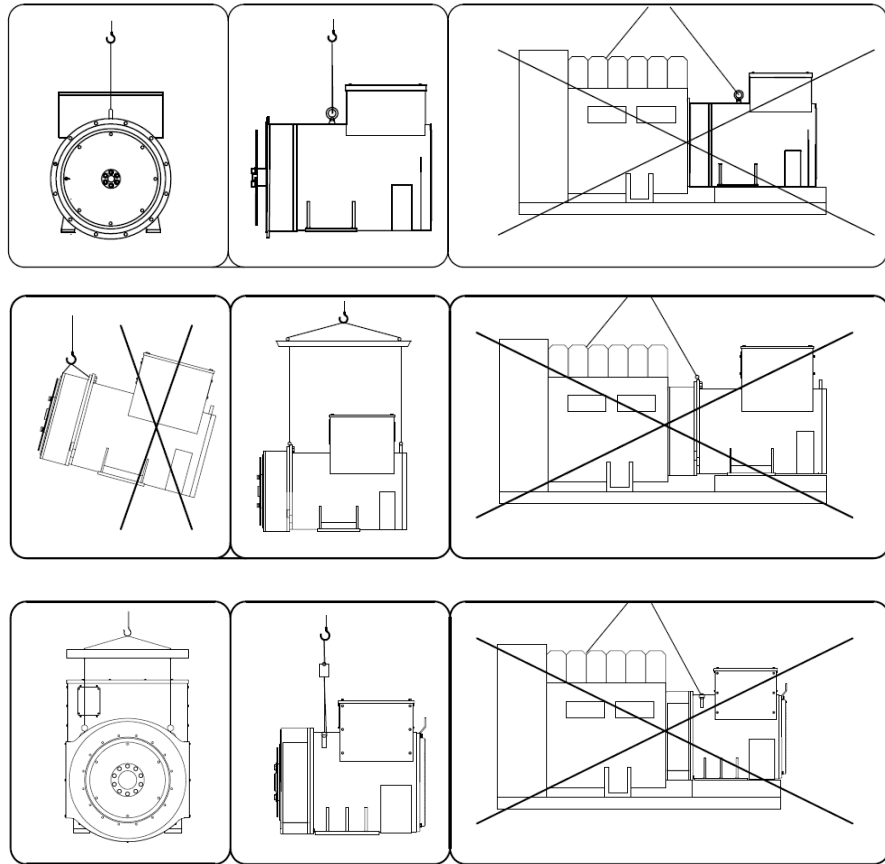


Figure 2-1. Lifting of unpacked machines.

NOTE:

- The machine must be lifted from its frame. Do not attempt to lift the machine from the top cover!
- Do not 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.

2.1.4 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. Use checklists in *Annex 5. Commissioning Report*.

A machine that is not installed immediately upon arrival must not be left without supervision or without protective precautions. For more details, see *Chapter 2.2. 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.

Recycle packing material acc. to *Chapter 1.7.1. Recycling of material required for transport.*

2.1.5 Bearing plate

If re-lubrication is needed, a stainless steel bearing plate is attached to the machine frame. The bearing plate indicates the type of the bearings and lubrication to be used, see *Figure 2-2. Bearing plate for grease lubricated rolling bearings* as an example.

Drive end (DE) bearing	6324/C3	1
Non-drive end (NDE) bearing	6317/C3	2
Lubrication interval at 70°C (158°F) bearing temperature	4400 Hours	3
Quantity of grease	72	4
Applicable greases	ESSO UNIREX N2	5

Note! Every 15°C (27°F) increase above 70°C (158°F) in the bearing temperature halves the rated lubrication interval.
Additional information: see the maintenance manual.

Figure 2-2. Bearing plate for grease lubricated rolling bearings

Notation used in *Figure 2-2.*:

1. Bearing type of D-end.
2. Bearing type of ND-end.
3. Lubrication interval.
4. Quantity of grease for D-and ND-end bearings.
5. Type of grease delivered from factory.

NOTE: The information given on the bearing plate must imperatively be followed. Failure to do so will void the warranty for the bearings.

If bearing re-lubrication is not needed for the bearing types used in generator, no bearing plate is attached, neither.

2.2 Storage

2.2.1 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 °C (50 °F) to 50 °C (120 °F). If the anti-condensation heaters are energized, and the surrounding air is above 50 °C (120 °F), 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-energised when air temperature inside the machine enclosure exceeds +40 °C. Before connecting power supply to the anti-condensation heater, check the supply voltage and power in the *Annex 8. Technical Specification* or *Annex 4. Connection Instructions*. 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.

2.2.2 Long term storage (2-6 months)

In addition to the measures described in *Chapter 2.2.1. 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.

2.2.3 Very long term storage (over 6 months)

Clean all the protected surfaces listed in *Chapter 2.2.1. Short term storage (less than 2 months)* and *Chapter 2.2.2. Long term storage (2-6 months)*, and renew the anti-corrosive treatment every 12 months. Otherwise follow the instructions for shorter storage periods.

2.2.4 Rolling bearings

Apply the following measures:

- Rolling bearings should be well lubricated during storage. Acceptable grease types are presented in *Chapter 2.1.5. Bearing plate*. 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. Tighten the transport locking device according to the axially locating bearing type, see *Table 2-1. Tightening torque for horizontal machines (lubricated screw)*.

NOTE: A too high tightening torque on the transport locking device will damage the bearing.

NOTE: The type of bearings used are found on the bearing plate, see *Chapter 2.1.5. Bearing plate* and *Annex 8. Technical Specification*.

Table 2-1. Tightening torque for horizontal machines (lubricated screw).

Axially locating bearing type	Tightening torque/[Nm]	Tightening torque/[lb ft]
6317	50	37
6319	60	44
6322	120	90
6324	140	100
6326	160	120

2.2.5 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, see *Chapter 7.6.4. Insulation resistance test*.
- 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.

2.2.6 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 2.2.1. Short term storage (less than 2 months)* should be applied. Remember to rotate the shaft 10 revolutions at least every 3 months.

Chapter 3 Installation and alignment

3.1 Preparations for installation

3.1.1 General

Good planning and preparation results in correct installation, assures safe running conditions and maximum accessibility. During installation, general as well as local safety instructions must be followed.

NOTE: Install anti-condensation heaters to keep the machine interior dry when there is a risk of condensation.

NOTE: Protect the machine against dust and rain.

Tools and materials

Suitable material for set-up and shimming as well as other auxiliary tools for installation are normally not included in the ABB delivery. Auxiliary tools for installation are to be supplied by the customer.

The following should be available on site if required:

- Attachments for gauges, extension brackets and other alignment tools.
- A lever for turning the rotor.
- Other auxiliary tools and materials for the installation, like hydraulic jacks and bracket plates with adjusting screws.

General tightening torques

General tightening torques for screws is given in *Chapter 7.4.4. The tightness of fastenings*. Use these values if no specific tightening torques are given in this manual or in the mechanical and electrical drawings.

NOTE: The values in *Table 7-10. General tightening torques* are general, and do not apply to various items, such as diodes, support insulators, bearings, cable terminals or pole fastenings, surge arrester, capacitors, current transformers, rectifier and thyristor bridges, or if some other value is given elsewhere in this manual or in the mechanical and electrical drawings, see *Mechanical Drawings* and *Electrical Drawings*.

3.1.2 Removal from storage

When bringing machine from the outside, at a temperature of below 0 °C, do not do any work on the machine until its temperature has risen sufficiently (5 to 10 °C).

The transfer from a cold temperature to ambient temperature can cause condensation inside machines and may be dangerous for the winding. It is therefore important to check the winding insulation resistance before the start up (see *Chapter 5. Commissioning*).

3.1.3 Check of foundation

The structural design of the foundation is not included in the ABB scope, and the customer or a third party is therefore responsible for this.

The installation of the machine should be planned as early as possible.

Before lifting the machine onto the foundation:

- Check that the position of the fixing holes and the height of the foundation are in agreement with corresponding measurements on outline and foundation drawings in *Annex 1. Main Dimension Drawing*.
- Check that the foundation is flat. If any inclination has been agreed upon, the permissible inclination must be stated on the installation drawing.
- Sweep or vacuum-clean the foundation.

Additional instructions for single bearing generator

- Check that the dimensions of the flange, coupling discs and offset are in accordance with corresponding measurements on dimension drawings.
- Check that the offset (AH) is in accordance with corresponding measurement on dimension drawing (see *Figure 3-1*. below).

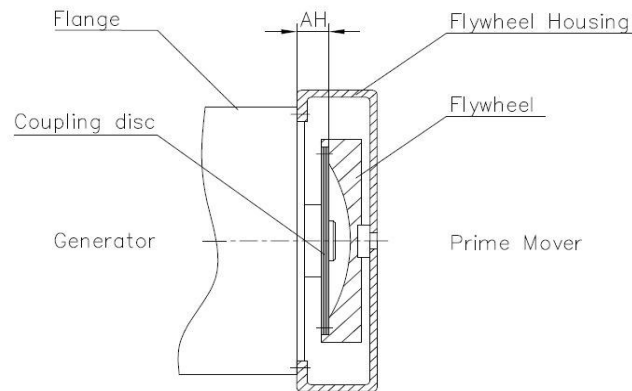


Figure 3-1. Connection with the engine.

NOTE: To measure the AH, it is better if choose four different positions on the circle: top, bottom, right, left, i.e. 90°, and select the average value of them.

3.1.4 Disassembly of the transport locking device

All machines with sleeve or roller bearings have transport locking devices installed. For machines with sleeve or cylindrical roller bearings, the transport locking device is made of a steel bar attached to both the bearing shield on the D-end and to the end of the shaft extension.

The transport locking device has to be removed prior to installation. The shaft extension has to be cleaned of its anti-corrosive coating. The locking device should be stored for future use.

NOTE: In order to avoid bearing damages, the transport locking device must be fitted to the machine whenever the machine is moved, transported to another location or stored, see *Chapter 2.1.1. Protective measures prior to transport*.

3.1.5 Coupling type

Machines with rolling bearings must be connected to the driven machine with flexible couplings, e.g. pin couplings, or gear couplings.

NOTE: The machine is not suitable for belt, chain or gear connection unless it is specifically designed for such use. The same applies for high axial thrust applications.

3.1.6 Assembly of the coupling half

This chapter concerns mainly DAE designed generators, only. For DBE design different coupling solutions e.g. belt drive or coupling other than coupling discs is not allowed.

Assembly

The following instructions must be taken into account when assembling the coupling half:

- Follow the general instructions of the coupling supplier
- The weight of the coupling half can be considerable. A suitable lifting gear may be needed.
- Clean the shaft extension of its anti-corrosive coating, and check the measurements of the extension and the coupling against the provided drawings. Ensure also that the keyways in the coupling and the shaft extension are clean and free from burrs.
- Coat the shaft extension and hub bore with a thin layer of oil as to facilitate the mounting of the coupling half. Never coat mating surfaces with molybdenum disulphide (Molykote) or similar products.
- The coupling must be covered with a touch guard.

NOTE: In order not to damage the bearings, no additional forces should be applied to the bearings when assembling the coupling half.

Balancing of coupling

The rotor is dynamically balanced with half key as standard. The way of balancing is stamped to the shaft end:

- H=half-key.
- F=full key.

The coupling half must be balanced respectively.

3.1.7 Belt drive

Machines designed for belt drives are always equipped with cylindrical roller bearing in the D-end.

If a belt drive is used, make sure that the driving and the driven pulleys are correctly aligned.

NOTE: Suitability of the shaft end and the bearings for the belt drive must be always checked before use. Do not exceed the radial force specified in the order definitions.

3.2 Installation and alignment

The machine is normally transported and lifted as one ready assembled unit onto the foundation, see *Annex 1. Main Dimension Drawing*.

NOTE: The customer is responsible for machine installation (unless mentioned otherwise in the contract). ABB cannot be hold responsible for damage

which may occur to the machine or to surrounding equipment subsequent to:

- Excessive transmitted vibrations.
- Poor design of foundations and/or structures.
- Poor installation.
- An alignment fault.
- Poor storage conditions.
- Non-respect of check instructions before start up.
- An incorrect electrical connection.

In order to ensure a long and satisfactory lifetime of both the driving and driven machine, the machines have to be properly aligned to each other. This means that the radial, as well as the angular deviation between the two shafts of the machine has to be minimized. The alignment must be performed with great caution because alignment errors might lead to bearing and shaft damages.

To install and align the machine:

- Mount the machine on the base frame.
- Align the machine in axial and horizontal directions.

NOTE: Alignment must be performed with great caution. Failure to do so can result in serious vibrations and damage to both generator and prime mover.

- If one bearing design is considered, align and couple the coupling discs with the flywheel and couple the flange with the flywheel housing.

NOTE: Alignment must be performed with great caution. Failure to do so can result in serious vibrations and damage to both generator and prime mover.

3.2.1 Run-out of the coupling halves

The alignment procedure is started by measuring the run-out of the coupling halves. This measurement will show any inaccuracy of the shaft and/ or coupling halves. The run-out of the coupling half in respect to the bearing housing of the machine is measured.

Place the gauges according to *Figure 3-2. Measuring the run-out at the coupling half*. Similarly check the run-out of the coupling half of the driven machine in respect to its bearing housing. A simple lever arm is needed to turn a rotor of a sleeve-bearing machine. The admissible run-out error is less than 0.02 mm (0.8 mil).

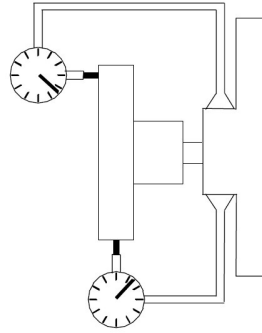


Figure 3-2. Measuring the run-out at the coupling half.

3.2.2 Alignment of machines

In order to ensure a long and satisfactory lifetime of both the driving and driven machine, the machines have to be properly aligned to each other. This means that the radial, as well as the angular deviation between the two shafts of the machine has to be minimized. The alignment must be performed with great caution because alignment errors will lead to bearing and shaft damages.

Before alignment remove the transport locking device. After the machine has been roughly positioned, the final alignment can start.

NOTE: Alignment must be performed with great caution. Failure to do so can result in serious vibrations and damage to both driving and driven machine.

Alignment of the generator with coupling discs

In accordance with common practice, parallel and angular misalignment should not exceed 0.05-0.10 mm and axial misalignment should not exceed 0.10 mm, (see Figure 3-3. Checking of misalignment of coupling discs below).

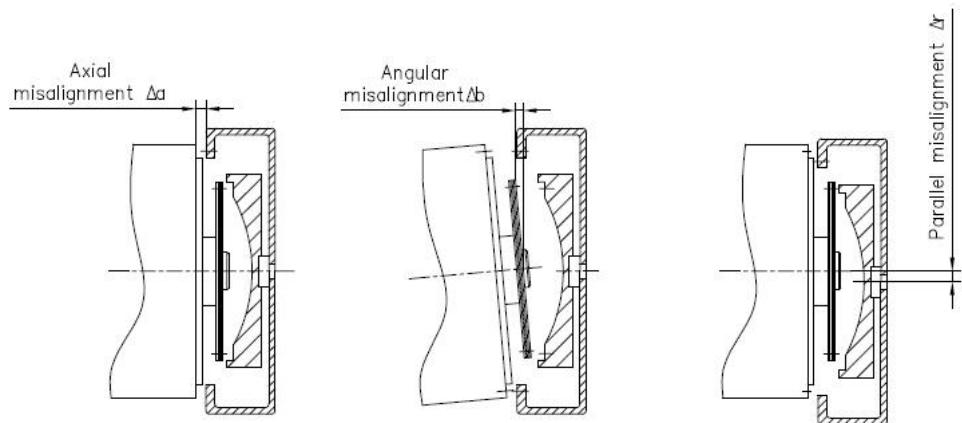


Figure 3-3. Checking of misalignment of coupling discs.

NOTE: Definite alignment tolerances are impossible to state as many factors influence the tolerances. Too large tolerances will cause vibration and may possibly lead to bearing or other damages. It is, therefore, recommended to aim at as narrow tolerances as possible. Misalignments above are maximum permissible misalignment.

In general, during the alignment tighten the screws to the recommended torque, see Chapter 7.4.4. The tightness of fastening and check that there is lateral play on the crankshaft. (0.1-0.6 mm)

NOTE: After aligning of the machine, tighten the screws coupling the flange and the flywheel housing first. Then tighten the screws for the coupling discs and the flywheel across.

Alignment of the generator without coupling discs

The alignment is done in accordance with the recommendations given by the coupling manufacturer. Parallel, angular and axial alignment of the machine is required. Some standard publications give recommendations for coupling alignment, see for example *BS 3170:1972 Flexible couplings for power transmission*.

In accordance with common practice, parallel and angular misalignment should not exceed 0.05-0.10 mm and axial misalignment should not exceed 0.10 mm, see *Figure 3-4. Definition of misalignment*. The corresponding run-out is 0.10-0.20 mm for parallel and angular misalignment, and 0.20 for axial misalignment.

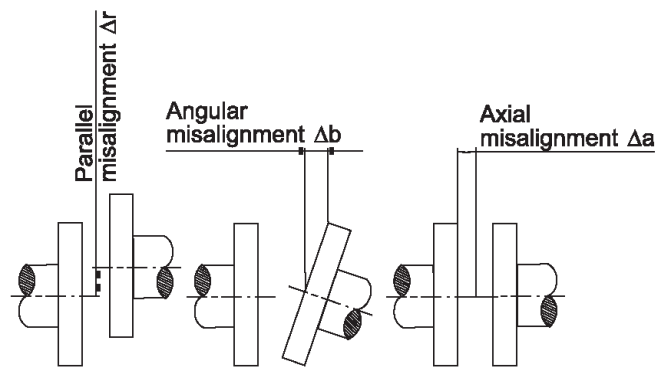


Figure 3-4. Definition of misalignment.

Notation used in *Figure 3-2. Definition of misalignment*:

- Parallel misalignment Δr .
- Angular misalignment Δb .
- Axial misalignment Δa .

Final alignment

To avoid the force created by misalignment for the machine, correct alignments as below:

1. Mount the alignment equipment. If gauges are used, it is practical to adjust the dial gauge in such a way that approximately half of the scale is available in either direction. Check the rigidity of the gauge brackets in order to eliminate the possibility of sag, see *Figure 3-5. Alignment check with gauges*.

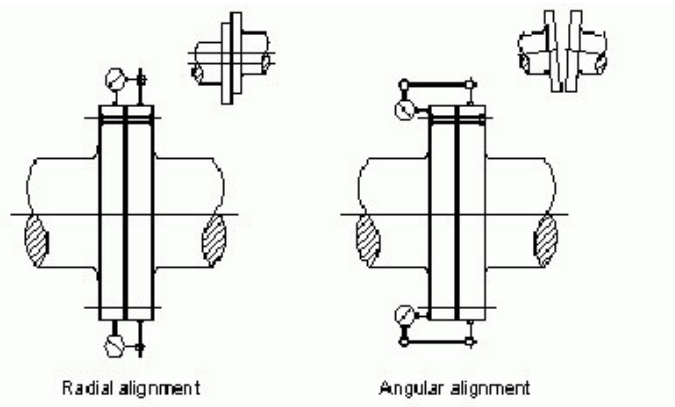


Figure 3-5. Alignment check with gauges

2. Measure and note readings for parallel, angular and axial misalignment in four different positions: top, bottom, right and left, i.e. every 90°, while both shafts are turned simultaneously. Record the readings in the *Annex 5. Commissioning Report*.

3. Align the machine vertically by shimming plates.

- Tighten the screws of the frame feet.
- Slacken the rear bottom screws of the prime mover.
- Tighten the front bottom screws/nuts of the prime mover.
- Measure the distance between the bottom of the machine feet and the bed plate and make corresponding solid blocks or wedges or reserve a necessary of shims.
- Fit the solid blocks or shims under the generator feet. Tighten the fixing bolts.
- Tighten the rear bottom screws of the prime mover, fit solid blocks if necessary.
- Tighten the screws to the recommended torque, see *Chapter 7.4.4. The tightness of fastenings* and check that there is lateral play on the crankshaft (0.1-0.6mm).

NOTE: During this performance, use torsional spanner for tightening the screws which connect the flange of the generator and the flywheel housing of the engine, and the coupling discs and flywheel. For recommended torques see *Chapter 7.4.4. The tightness of fastenings*.

More detailed instructions for installation may be given in instructions supplied by driven/driving machine manufacturer.

4. Check the alignment again. Make corrections if necessary.

5. Re-tighten the screws. During this performance, use torsional spanner for tightening the screws. The recommended torques are shown in *Table 7-10. General tightening torques*.

NOTE: The tolerances given by the coupling manufacturers indicate tolerances for the coupling, not for the driving-driven machine alignment. The tolerances given by the coupling manufacturer should be used as a guideline for the alignment only if they are narrower than the maximum permissible misalignments shown above.

Correction for thermal expansion

Thermal expansion should be taken into account when aligning the machine. The temperature of the machine is lower during installation than it will be during operating conditions. For this reason the shaft centre is going to lie higher when the machine is in operation. Depending on the type of coupling, the distance between the machine and the driven equipment may have to be compensated because of thermal expansion. The upward thermal expansion of the electrical machine can be estimated using the following formula:

$$\Delta H = a \times \Delta T \times H \text{ [mm]}$$

Where:

$$a = 10 \times 10^{-6} \text{ K}^{-1}$$

$$\Delta T = 40 \text{ K}$$

$$H = \text{shaft height [mm]}$$

Due to the thermal expansion of the electrical machine, the vertical movement of the shaft is approximately 0.04-0.05 mm for each 10 °C difference in temperatures as illustrated in *Figure 3-6. The correlation between thermal expansion and machine temperature rise.*

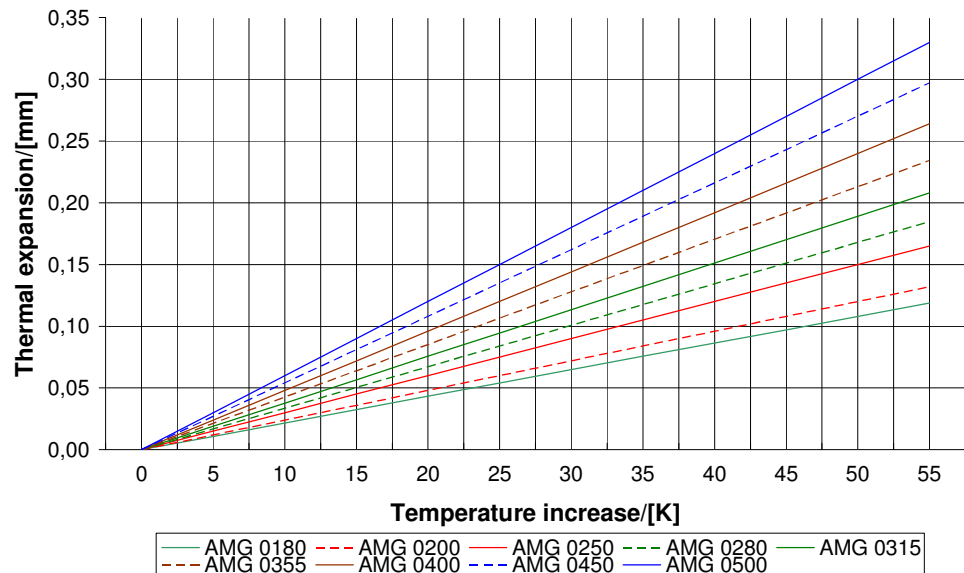


Figure 3-6. The Correlation between thermal expansion and machine temperature rise.

Permissible misalignment

Definite alignment tolerances are impossible to state as too many factors have an influence. Too large tolerances will cause vibration and may possibly lead to bearing or other damages.

Therefore, it is recommended to aim at as narrow tolerances as possible. Maximum permissible misalignments are shown in *Table 3-1. Recommended permissible misalignments.* For definitions of misalignment, see *Figures 3-3. Checking of misalignment of coupling discs* and *3-4. Definition of misalignment.*

NOTE: Tolerances given by the coupling manufacturers indicate tolerances for the coupling, not for the driving-driven machine alignment. The tolerances given by the coupling manufacturer should be used as a guideline for the alignment only if they are narrower than the maximum

permissible misalignments shown in *Table 3-1. Recommended permissible misalignments*

Table 3-1. Recommended permissible misalignments.

Coupling information		Permissible misalignment		
Coupling diameter	Coupling type	Δr	Δb	Δa
100-250 mm (4-10")	Rigid flange	0,02 mm (0,8 mil)	0,01 mm (0,4 mil)	0,02 mm (0,8 mil)
	Gear	0,05 mm (2,0 mil)	0,03 mm (1,0 mil)	0,05 mm (2,0 mil)
	Flexible	0,10 mm (4,0 mil)	0,05 mm (2,0 mil)	0,10 mm (4,0 mil)
250-500 mm (10-20")	Rigid flange	0,02 mm (0,8 mil)	0,01 mm (0,4 mil)	0,02 mm (0,8 mil)
	Gear	0,05 mm (2,0 mil)	0,03 mm (1,0 mil)	0,05 mm (2,0 mil)
	Flexible	0,10 mm (4,0 mil)	0,05 mm (2,0 mil)	0,10 mm (4,0 mil)

3.3 Final inspection of installation

3.3.1 Covers and enclosures

After the machine has been erected and aligned, check carefully that no tools or foreign objects have been left inside the enclosures. Clean also any dust or debris.

When installing the covers, check that all sealing strips are intact before mounting them.

Store alignment and assembly accessories and transport locking devices for future use.

Chapter 4 Electrical connections

4.1 General

Electrical connections are made after the mechanical installation and alignment procedures. The electrical connections include the connection of main and auxiliary cables, earthing cables and possible external components. In order to determine proper actions, see *Annex 3. Main Connection Drawing*, *Annex 4. Connection Instructions*, *Annex 10. Option Connection Drawing* and *Annex 11. Layout of connection*. For optional PMG-unit, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.

NOTE: When making holes or threads through the terminal box, check always that no components will be damaged. Metal particles can be hazardous for the electrical components.

4.2 Automatic Voltage Regulator

4.2.1 General

AVR (Automatic Voltage Regulator) is a device that continuously monitors the voltage at the voltage regulating point of the system and automatically initiates corrective actions to maintain the terminal voltage of the generator. AVR also controls that the synchronous generator operates within pre-set limits.

An auxiliary winding supplies the excitation power to the field winding of the shaft driven by a three phase exciter under the control of the AVR. A voltage feedback is supplied by the voltage transformer and a current feedback is provided by the current transformer. The transformers are installed in the generator.

Operational limits, such as over and under excitation, machine voltage and Volts/Hz, are implemented in the AVR. Static reactive power compensation in parallel operation and several other software functions are also available. The AVR is equipped with the PC software for the AVR.

More detailed information about the AVR used in the specific generator can be found in the AVR manual, see *Annex 6. Automatic Voltage Regulator User's Manual* and in *Annex 8. Technical Specification*.

4.2.2 Configuration

The voltage regulator with actual value reading and set point formation is active in the automatic mode. The limiter functions which protect the machine against excessive loads are also active in the automatic mode. In addition to the actual voltage regulator function, reactive power or power factor regulators are also available. Reactive power and power factor regulators can be switched on and off.

NOTE: Reactive power and power factor regulators are not available in island systems.

In the manual mode the actual value is formed from the measurement of the excitation current and passed with the set-point value to the excitation current regulator. The output from the regulator is passed to a switch which is used to select the corresponding mode. This mode is only used for test purposes and as an

emergency regulator in the event of failure of the voltage regulator. The limiter functions are not active in this mode.

4.2.3 Mechanical installation

If the AVR is delivered as a separate item, the unit should only be installed in indoor areas which are dry and dust-free and do not contain any gases, acid fumes or similar.

4.2.4 Earthing and wiring

The emission limits in accordance with standard EN 50081-2 (1993) will only be complied with if the connections for the power electronics supply and the field output are made using shielded cables earthed at each end. We also recommend that shielded cables are used for the analog and digital connections.

4.3 Electrical connections

4.3.1 General information

The safety information in *Chapter 1.5. General Safety* and *Chapter 1.6. Safety Instructions* must be observed at all times. Study the connection diagrams delivered with the machine before starting the installation, see *Annex 3. Main Connection Drawing*, *Annex 4. Connection Instructions*, *Annex 10. Option Connection Drawing*, *Annex* and *11. Layout of connection*. For optional PMG-unit, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.

Before you start the installation:

- Verify that voltages and the frequencies indicated on the rating plate of the machine and in *Annex 8. Technical Specification* are correct.
- Make sure that the sizes of input cables are adequate for the maximum load current and in accordance with local standards.
- Make sure that cable terminations are of appropriate type and of correct size.
- Check the connections of all devices, such as temperature probes.

NOTE: Prior to installation it is important to check that the incoming cables are not connected to the supply network. The cables should be grounded.

4.3.2 Connection of main power cables and neutral cable

The main terminal box is typically supplied undrilled as the size and number of the customer's cables is unknown. 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.

Check the phase sequence, see *Figure 4-1. Phase sequence (IEC)*.

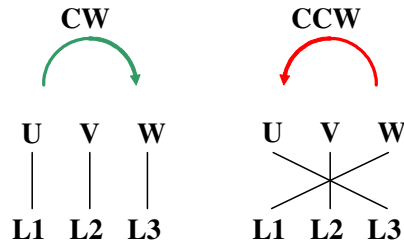


Figure 4-1. Phase sequence (IEC).

In Figure 4-1.:

- CW=clockwise.
- CCW=counter clockwise (facing generator drive end).

The neutral terminal is marked with the letter *N*.

4.3.3 Earth connection

The ground cable can be connected inside of the main terminal box.

4.3.4 Insulation distances 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 in *Table 4-1. 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.

Table 4-1. Recommended minimum insulation distances.

Recommended minimum insulation distances: $U \leq 690$ V	
Air insulation distance/[mm]:	6
Surface insulation distance for even surface/[mm]:	10
Surface insulation distance for finned surface/[mm]:	8

4.3.5 Connection of auxiliaries and instruments

Connect the instruments and auxiliary equipment according to the connection diagram in *Annex 3. Main Connection Drawing* and *Annex 10. Option Connection Drawing*.

Chapter 5 Commissioning

5.1 General

Commissioning is not considered finalized before a commissioning report has been made and distributed to all concerned parties (customer and supplier). A commissioning report is a vital tool for future service, maintenance and trouble shooting.

NOTE: The commissioning report has to be sent to ABB in order to obtain future warranty claims.

A recommended commissioning report can be found in *Annex 5. Commissioning Report*. General safety precautions must be followed during commissioning and all work has to be performed by qualified personnel.

5.2 Check of mechanical installation

Before commissioning:

1. Check that the installation and alignment is made acc. to *Chapter 3. Installation and alignment*.

NOTE: The alignment protocol should always be included in the commissioning report.

2. Check that the machine is properly fixed to the foundation.
3. Check for cracks in the foundation and the general condition of the foundation.
4. Check the tightness of the fixing bolts.
5. Open the machine, and check that the air-gap is free.
6. If possible, turn the rotor by hand and make sure that the rotor turns freely and that there are no abnormal sounds.
7. Check the assembly of the main terminal box.
8. Check that all transport locking devices are removed.

5.3 Check of electrical installation

The power cables can be permanently connected to the terminals in the main terminal box after the stator insulation resistance has been measured, see *Chapter 7.7.4. Insulation resistance measurements for auxiliaries*.

Before commissioning, check the connection of power cables:

1. Check that the fixing bolts are tightened with the correct torque.
2. Check that the power cables are suitably routed and do not cause any additional strain to the terminal bars.
3. Check that the power cables are correctly stress-relieved.
4. Check the connections of the auxiliary equipment.
5. Check the tightness of the cable glands and enclosure sealing.

5.4 Insulation resistance measurements

Measure the insulation resistances of windings and all auxiliary equipment before making any electrical connections and applying voltage to the machine.

Measure the insulation of at least the following parts:

- Stator and rotor winding.
- Exciter winding.
- Anti-condensation heaters (optional).

The measured values indicate the condition of the insulation between the winding (or other circuit to be tested) and the frame of the machine. For detailed information on how to conduct these measurements see *Chapter 7.6.4. Insulation resistance test*.

If the insulation resistance is under the specified value, it must be corrected before starting the machine, see *Chapter 7.6.8. Drying*.

Measure the insulation resistance well before the planned first start so you will have time for any necessary corrective actions.

The winding must be dry during the test. Therefore the anti-condensation heaters should be active during storage and installation.

5.5 Automatic Voltage Regulator (AVR)

Pre-settings and testing by ABB

The AVR has been tested with the specific generator and all the basic settings have been modified and saved so that the AVR will also work at site. The correct AVR and the correct generator can be identified by checking the serial numbers on the test report, see *Test Reports*.

Settings used in testing can be found in *Test Reports*.

Checking at site before first run

All the settings has to be checked once more at the site of the generator. If there is need to change the settings it must be done by a qualified person such as an ABB or AVR representative.

NOTE: Settings for the network must also be checked and verified.

NOTE: For detailed information about the settings and commissioning see *Annex 5. Commissioning Report*, *Annex 6. Automatic Voltage Regulator User's Manual* and *Annex 7. Test Reports*.

5.6 Starting

Start-up of the machine

The starting of the machine depends on the application, but main guidelines are:

1. Switch the anti-condensation heaters off if not operated by switchgear.
2. Start to rotate the machine.
3. Maintain rated speed.
4. Switch the machine excitation on (unless self excited automatically).
5. Maintain rated voltage.
6. Check synchronizing parameters (if necessary).
7. Synchronize the machine to the grid (if necessary).

Recommended values for synchronizing are:

- $\Delta U=2\%$.
- $\Delta f=0.7\%$.
- phase angle $<15^\circ$.

Maximum values $\Delta U=4.5\%$ and $\Delta f=4.0\%$ should not be exceeded.

NOTE: Operation of the machine at reduced speed under 75 % of rated speed should be avoided.

5.7 Running the machine the first time

5.7.1 Bearings with re-lubrication option

In case of a newly installed machine, or a machine which has been out of service for more than 2 months, inject new grease into the bearings immediately after start-up. New grease must be injected when the machine is running, and is injected until old grease or excess new grease is discharged through the lubrication channel in the bottom of the bearing housing, see *Figure 5-1. Example of lubrication channel through bearing arrangement of horizontal machine.*

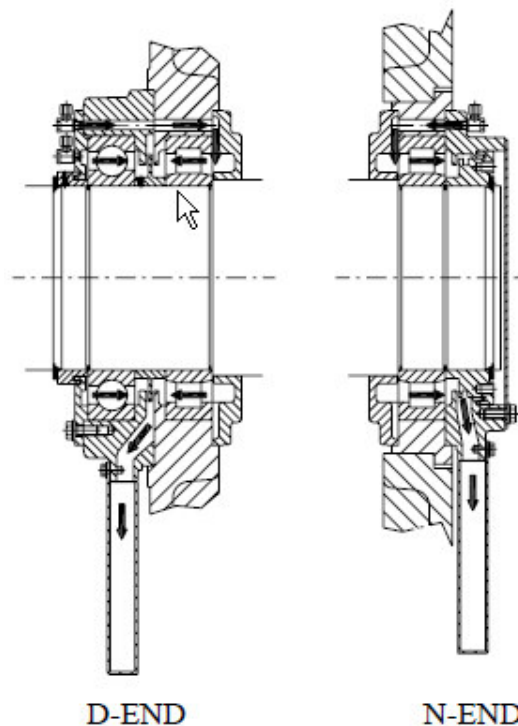


Figure 5-1. Example of lubrication channel through bearing arrangement of horizontal machine.

NOTE: The re-lubrication interval will never be longer than 12 months.

The type of original grease used is found on the bearing plate on the machine. Acceptable types of grease can be found in *Chapter 7.5.5. Bearing grease.*

The temperature of the bearings will initially increase because of the excess grease. After few hours, the excess grease will be discharged through the lubrication valve and the temperature of the bearing will return to normal running temperature.

If available, and after the machine has been running for several hours, measure the vibrations or SPM-values from the SPM-nipples, and record the values for future reference use.

5.8 Shut down

The shut-down of the machine depends on the application, but main guidelines are:

1. Reduce the output of the machine to zero.
2. Open the main breaker.
3. Switch the machine excitation off (when applicable).
4. Stop the engine.
5. Switch the anti-condensation heaters on if not automatically done by switchgear.

Chapter 6 Operation

6.1 General

To ensure trouble-free running, a machine must be looked after and carefully supervised.

Always before starting up the machine ensure that:

- No maintenance is ongoing.
- Personnel and equipment associated with the machine are ready to start up the machine.

For the start-up procedure see *Chapter 5.6. Starting*.

In case any deviations from expected normal operation are noticed, e.g. elevated temperatures, noise or vibration, shut down the machine and find the reason for the deviations. If necessary, consult the manufacturer of the machine.

NOTE: The machine may have hot surfaces when running with load.

NOTE: Overloading the machine may cause winding damages.

6.2 Normal operating conditions

The machines supplied by ABB are individually designed to operate in normal operating conditions according to the IEC standard, technical specifications and internal ABB standards.

The operation conditions, such as maximum ambient temperature and maximum operating height, are specified in the performance data sheet. The foundation should be free from external vibration, and the surrounding air free of dust, salt and corrosive gases or substances.

6.3 Protection of synchronous generators

Protection of synchronous generators depends e.g. on the generator type and application. Recommended protections in general are:

- Thermal overload in stator winding; $I >$
- Network short-circuit, $I \gg$
- Stator interwinding short-circuit, differential protection relay.
- Stator earth-fault, earth-fault relay.
- Over voltage, over voltage relay.
- Unbalanced load or shorted turns in the same phase, $I2/I_n$.
- Under excitation and loss of synchronism, under-reactance relay.
- Under voltage and intermittent loss of voltage, under voltage relay.
- Temperature supervision of temperature detectors, PT-100 monitoring.
- Inlet cooling air temperature high.

Additional protection:

- Frequency disturbance.
- Reverse power.
- Diode fault.
- Vibration level.

NOTE: Depending on the scope of the supplied generator, only some of the protections may be applicable in practice. Necessary level of generator protection shall be defined by the customer and necessary items shall be included in the generator scope on request.

6.4 Start-up procedure

Always before starting up the synchronous machine check that:

- No shutdown procedures are in operation.
- Personnel and equipment associated to the machine are ready to start up the machine.

For start-up procedure, see *Chapter 5.6. Starting*.

6.5 Continuous supervision

A counter for the number of starts and a duty time meter should be included in the system. The operating personnel should inspect the synchronous machine at regular intervals. This means that they should listen to, touch and smell the synchronous machine and its associated equipment in order to obtain a feeling for normal operating conditions.

The object of the supervision inspection is to thoroughly familiarize personnel with the equipment. This is essential in order to detect and fix abnormal occurrences in time.

Data from the supervision inspection should be kept for future reference and can be of help in maintenance work, trouble shooting and repairs. It is also recommended that the operational data (generator load, power factor, speed, voltage and current as a minimum) shall be recorded and stored for future reference.

The difference between supervision and maintenance is rather vague. Normal supervision of operation includes logging of operating data such as load, temperatures etc., and the comments are used as a basis for maintenance and service.

- During the first period of operation (<200 h) supervision should be intensive. Bearing and winding temperatures, load, current, cooling, lubrication, and vibration should be checked frequently. The bearing temperatures and lubrication should be monitored closely, see *Chapter 5.7.1. Bearings with re-lubrication option*
- During the following duty period (200-1000 h) a check-up once a day is sufficient. A record of supervision inspection should be used and filed. If operation is continuous and stable, the time between inspections may be further extended.

6.6 Shut down procedures

To stop the synchronous machine:

1. Switch the main breaker open.
2. Switch excitation off (if applicable).

When the synchronous machine is not in operation, anti-condensation heaters must be switched on to avoid condensation inside the machine.

For detailed shut down instructions, see *Chapter 5.8. Shut down*.

Chapter 7 Maintenance

7.1 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.

The difference between supervision and maintenance is rather vague. Normal supervision of operation and maintenance includes logging of operating data such as load, temperatures, vibrations, as well as measurement of the insulation resistances.

After commissioning or maintenance, the supervision should be intensive.

This chapter presents recommendations regarding maintenance program, and work instructions how to conduct common maintenance tasks. These instructions and recommendations should be read carefully and be used as a basis when planning the maintenance program. 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, the trouble shooting guides in *Chapter 8. Troubleshooting*, will aid in locating the reason for the trouble. ABB recommends the use of experts in the creating maintenance programs, as well as in performing the actual maintenance and possible trouble shooting.

The ABB After Sales organization is happy to assist in these issues. The ABB After Sales contact information can be found in *Chapter 9.1.5. After sales contact information*.

An essential part of the preventative maintenance is to have a selection of suitable spare parts available. The best way to have access to critical spare parts is to keep them on stock. Ready-made spare part packages can be obtained from the ABB After Sales, see *Chapter 9.2. Spare parts*.

7.2 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 the security personnel.

Personnel performing maintenance on electrical equipment and installations must be highly qualified. The personnel must be trained in, and familiar with, the

specific maintenance procedures and tests required for rotating electrical machines.

For general safety instructions, see *Chapter 1.5. General Safety* and *Chapter 1.6. Safety Instructions*.

7.3 Maintenance program

This chapter presents a recommended maintenance program for ABB machines. This maintenance program is of a general nature, and should be considered as a minimum level of maintenance. Maintenance should be intensified when local conditions are demanding or very high reliability is required. It should also be noted that even when following this maintenance program, normal supervision and observation of the machine's condition is required.

NOTE: Different types of the generators contain different items to be maintained. Maintenance program described in this chapter contains references to the accessories that are not available on all machines. Operator shall create suitable maintenance program based on basis of this information.

The maintenance program is based on four levels of maintenance, which rotate according to operating hours. The amount of work and down time vary, so that level 1 includes mainly quick visual inspections and level 4 more demanding measurements and replacements. More information about the spare part packages suitable for this type of maintenance can be found in *Chapter 9.2. Spare parts*. The recommended maintenance interval can be seen in *Table 7-1. Recommended maintenance program*. The operation hour recommendation T in this chapter is given as equivalent operating hours, $T(Eq. h)$. That can be counted by the following formula:

$$T(Eq. h) = \text{actual operating hours} + \text{number of starts} \times 20.$$

Table 7-1. Recommended maintenance program.

Interval/[T]:	L1	L2	L3	L4
4 000	X			
8 000		X		
12 000	X			
16 000		X		
20 000	X			
24 000			X	
28 000	X			
32 000		X		
36 000	X			
40 000		X		
44 000	X			
48 000			X	
52 000	X			
56 000		X		
60 000	X			
64 000		X		
68 000	X			
72 000		X		
76 000	X			
80 000				X

Level 1 (L1)

Level 1 or L1 maintenance consists of visual inspections and light maintenance. The purpose of this maintenance is to do a quick check whether problems are

beginning to develop before they cause failures and unscheduled maintenance breaks. It gives also suggestions what maintenance issues must be performed in the next larger overhaul.

The maintenance can be estimated to last approximately 4-8 hours, depending on the type and installation of the machine and the depth of the inspections. Tools for this maintenance include normal servicing tools i.e. wrenches and screw drives. The preparations consist of opening the inspection covers. It is recommended that at least the operational spare parts package is available when commencing this maintenance.

The first Level 1 maintenance should be performed after 4 000 equivalent operating hours or six months after commissioning. Subsequently the L1 maintenance should be performed yearly halfway between Level 2 maintenance, see *Table 7-1. Recommended maintenance program*.

Level 2 (L2)

Level 2 or L2 maintenance consists mainly of inspections and tests and small maintenance tasks. The purpose of this maintenance is to find out whether there are problems in the operation of the machine and to do small repairs to ensure uninterrupted operation.

The maintenance can be estimated to last approximately 8-16 hours, depending on the type and installation of the machine and the amount of servicing to be done. Tools for this maintenance include normal servicing tools, multimeter, torque wrench and insulation resistance tester (Megger). The preparations consist of opening the inspection covers. Spare parts suitable for this level of maintenance are included in the recommended spare parts package.

The first Level 2 maintenance should be performed after 8 000 equivalent operating hours or one year after commissioning. Subsequently the L2 maintenance should be performed yearly or after every 8 000 equivalent operating hours, see *Table 7-1. Recommended maintenance program*.

Level 3 (L3)

Level 3 or L3 maintenance consists of performing extensive inspections, tests and larger maintenance tasks that have come up during L1 and L2 maintenance. The purpose of this maintenance is to repair encountered problems and replace parts subjected to wear.

The maintenance can be estimated to last approximately 16 - 40 hours, depending on the type and installation of the machine and the amount of repairs and replacements to be done. Tools for this maintenance include the same tools as for L2 and in addition an endoscope and an oscilloscope.

The preparations consist of opening the inspection covers. Spare parts suitable for this level of maintenance are included in the recommended spare parts package.

The Level 3 maintenance should be performed after every 24 000 equivalent operating hours or at a three to five year interval. When L3 maintenance is conducted it replaces the L1 or L2 maintenance otherwise scheduled, and it leaves their rotation unaffected, see *Table 7-1. Recommended maintenance program*.

Level 4 (L4)

Level 4 or L4 maintenance consists of performing extensive inspections and maintenance tasks. The purpose of this maintenance is to restore the machine into a reliable operating condition.

The maintenance can be estimated to last approximately 40-80 hours, depending mostly on the condition of the machine and the needed reconditioning actions.

Tools for this maintenance include the same tools as for L3, and in addition, the rotor removal equipment. The preparations consist of opening the inspection covers, and the removal of rotor and exciter, if applicable.

The amount of spare parts required for this level of maintenance is difficult to determine. At least the recommended spare parts package is recommended, but spare parts included in the capital spare part package would ensure a fast and successful execution of this maintenance.

The Level 4 maintenance should be performed after every 80 000 equivalent operating hour. When a L4 maintenance is conducted it replaces the L1, L2 or L3 maintenance otherwise scheduled, and it leaves their rotation unaffected, see *Table 7-1. Recommended maintenance program.*

7.3.1 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 7-2. Maintenance intervals.

Maintenance interval					
In equivalent operating hours or time period, which ever comes first					
Maintenance object	L1	L2	L3	L4	Check/test
	4000	8000	24000	80000	
	0,5 year	Annual	3–5 years	Overhaul	

Table 7-3. Maintenance objects for general construction.

Maintenance object	L1	L2	L3	L4	Check / Test
Machine operation	V/T	V/T	V/T	V/T	Starting, shut down, vibration measurement, no-load point
Mounting and foundation	V	V/T	V/T	V/T/D	Cracks, rust, alignment
Exterior	V	V	V	V	Rust, leakage, condition
Fastenings	V	V/T	V/T	V/T	Tightness of all fastenings

Table 7-4. Maintenance objects for cable connection.

Maintenance object	L1	L2	L3	L4	Check / Test
Cabling	V	V/T	V/T	V/T/D	Wear, fastening
Connections	V	V/T	V/T	V/T/D	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 7-5. Maintenance objects for stator and rotor.

Maintenance object	L1	L2	L3	L4	Check / Test
Stator core	V	V	V	V/C	Fixing, cracks, welds
Stator winding insulation	V	V/T	V/T/C	V/T/C	Wear, cleanliness, insulation resistance, (high voltage test)
Stator coil overhangs	V	V	V	V	Insulation damages
Stator coil supports	V	V	V	V	Insulation damages, tightness
Stator slot wedges	V	V	V	V	Movement, tightness
Stator terminal bars	V	V	V	V	Fixing, insulation
Stator cable terminal fastenings and crimps	V	V/T	V/T	V/T	Tightness, condition
Instrumentation	V	V	V	V	Condition of cables and cable ties
Rotor winding insulation	V	V/T	V/T/C	V/T/C	Wear, cleanliness, insulation resistance, voltage drop test
Rotor coil supports	V	V	V	V	Movement, bending
Rotor balancing weights	V	V	V	V	Movement, fixing
Damper bars	V	V/T	V/T	V/T	Cracks, corrosion, ultra sound and knocking test
Shaft	V	V	V	V	Cracks, corrosion
Air gap	V	V	V	V	Cleanliness, equality
Connections in rotor	V	V	V/T	V/T	Fixing, general condition

Table 7-6. Maintenance objects for excitation system.

Maintenance object	L1	L2	L3	L4	Check / Test
Exciter diode bridge	V	V/T/C	V/T/C	V/T/C	Cleanliness, operation
Exciter semiconductors	V	V/T/C	V/T/C	V/T/C	Operation, fixing
Exciter connections	V	V/T/C	V/T/C	V/T/C	Fixing, general condition
Exciter winding insulation	V	V/T	V/T	V/T	Wear, cleanliness, insulation resistance
Exciter air gap	V	V/T	V/T/D	V/T/D	Cleanliness, equality
Automatic Voltage Regulator (AVR)	V	V/T	V/T	V/T	Operation, settings, stability test
Current transformer for parallel operation	V	V	V/T	V/T	Operation, cleanliness
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	V	V/T	V/T	V/T	General condition, terminals, wiring condition
Exciter stator fixing	V	V	V	V	General condition, cracks

Table 7-7. Maintenance objects for bearings.

Maintenance object	L1	L2	L3	L4	Check / Test
Bearing assembly	V	V/T	V/T	V/T	General condition
Re-lubricated bearing	R	R	R	R	Re-greasing
Closed bearing (no re-lubrication)	V	V	V/R	R	Condition, change bearing

Table 7-8. Maintenance objects for cooling system.

Maintenance object	L1	L2	L3	L4	Check / Test
Fan	V	V	V	V	Operation, general condition, cracks
Air intake	V	V/C	V/C	V/C	Cleanliness, operation
Air outlet	V	V/C	V/C	V/C	Cleanliness, operation

7.4 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 machine.

7.4.1 Checks during running of the 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, see *Chapter 7.4.2. Vibration and noise* and *Chapter 7.4.3. Temperature levels*.

7.4.2 Vibration and noise

High or increasing vibration levels indicate changes in the machine's condition. Normal levels vary greatly depending on the application, type and foundation of the machine. The vibration measurements and levels are discussed in detail in *Chapter 5. Commissioning*. Some typical reasons that might cause high noise or vibration levels are:

- Alignment, see *Chapter 3. Installation and alignment*.
- Air gap, see *Chapter 3. Installation and alignment*.
- Bearing wear or damage.
- Vibration from connected machinery, see *Chapter 5. Commissioning*.
- Loose fastenings, see *Chapter 3. Installation and alignment*.
- Rotor imbalance.
- Coupling.

Normal vibration levels

The following instructions are part of the following two ISO standards:

1. ISO 10816-3:1998 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts: Part 3: Industrial machines with nominal power above 15 kW and nominal speeds between 120 r/min and 15 000 r/min
2. ISO 8528-9:1995 Reciprocating internal combustion engine driven alternating current generating sets: Part 9: Measurement and evaluation of mechanical vibrations.

Measurement procedures and operational conditions

General procedures described in ISO 10816-1 are used, subject to the recommendations listed below.

Measurements are usually made when the rotor and the main bearings have reached their normal steady-state operating temperatures and the machine running under specified conditions, e.g. at rated speed, voltage, flow, pressure and load.

If the measured vibration exceeds the acceptance criteria and excessive background vibration is suspected, measurements should be made with the machine shut down to determine the degree of external influence. If the vibration with the machine stationary exceeds 25 % of the value measured when the machine is running, corrective actions may be necessary to reduce the effect of background vibration.

Measurement equipment

The measurement equipment must be capable of measuring broad-band r.m.s vibration with flat response over a frequency range of at least 10 Hz to 1000 Hz, in accordance with ISO 2954. Depending on the vibration criteria, this may require measurements of displacement or velocity or combinations of these (see ISO 10816-1).

Measurement location

Use a measurement location that is exposed and accessible during normal operation. Make sure that there are no local resonances or amplification so that the final measurements will reasonably represent the vibration of the bearing housing. The locations and directions of vibration measurements should provide adequate sensitivity to the machines dynamic forces. Typically, this will require two orthogonal radial measurement locations on bearing cap or frame. Place the

transducers at any angular position on the bearing cap or frame. Vertical and horizontal directions are usually preferred for horizontally mounted machines. In some cases it may be recommended to measure the vibration also in the axial direction. When recording the results of the measurements, record the specific locations and directions with the actual values.

Evaluation of RIC engine generating sets

The main excitation frequencies of the RIC engine (Reciprocating Internal Combustion) are in the range of 2 Hz to 300 Hz. However, when considering the overall generating set structure and components, a range of 2 Hz to 1000 Hz is required to evaluate the vibration.

Experience has shown that with a standard design of generating set structure and components, damage would not be expected if vibration levels remain below value 1 (See *Table 7-9. Vibration velocities* below):

Table 7-9. Vibration velocities.

Engine speed/[rpm]:	Limit 1/[mm/s]:	Limit 2/[mm/s]:
≥1300 but <2000	20	28
>720 but <1300	18	22

If the vibration levels fall between values 1 and 2, assessment of the generating set structure and components may be required along with an agreement between the generating set manufacturer and the component supplier in order to ensure reliable operation.

In some cases vibration levels can be above value 2 but only if individual special designs of generating set structure and components are applied.

In all cases the generating set manufacturer remains responsible for the compatibility of the generating set components (see ISO 8528-5:1993, 15.10).

Additional information

For more details about vibration measuring, see the following International Standards where applicable:

- ISO 2954 Mechanical vibration of rotating and reciprocating machinery - Requirements for instruments for measuring vibration severity.
- ISO 5348 Mechanical vibration and shock - Mechanical mounting of accelerometers.
- ISO 7919 Mechanical vibration of non-reciprocating machines - Measurements on rotating shafts and evaluation criteria.
- ISO 8528 Reciprocating internal combustion engine driven alternating current generating sets.
- ISO 10816 Mechanical vibration - Evaluation of machine vibration by measurements on non-rotating parts.

7.4.3 Temperature levels

The temperatures of the bearings, stator windings and cooling air should be checked when the synchronous machine is running.

The bearings might not reach a stable temperature until after several (2-6) hours, when running at full speed.

The stator winding temperature depends on the load of the machine. If full load cannot be reached during or soon after commissioning, the present load and temperature should be noted and included in the commissioning report.

7.4.4 The tightness of fastenings

The tightness of all fastenings should be verified regularly. Special focus should be given to fixing and the rotor parts, which must remain correctly tightened at all times. Loose fastening in these parts can lead to sudden and severe damage to the entire machine.

General values for tightening torques are presented in *Table 7-10. General tightening torques*.

Table 7-10. General tightening torques.

Screw torque			
Property class			
	4.8	8.8	10.9
Screw	Tightening torque [Nm]		
M8	10-12	22-30	30-35
M10	20-25	45-60	65-80
M12	36-45	80-105	110-130
M14	55-70	125-165	180-210
M16	90-110	195-265	280-330
M18	120-150	265-355	380-450
M20	170-210	375-500	540-650
M22	230-290	515-680	740-880
M24	300-375	655-870	940-1120
M27	450-530	955-1270	1400-1650

NOTE: The values in *Table 7-10. General tightening torques* are general, and do not apply to various items, such as diodes, support insulators, bearings, cable terminals or pole fastenings, surge arrester, capacitors, current transformers, rectifier and thyristor bridges, or if some other value is given elsewhere in this manual or in the mechanical and electrical drawings, see *Mechanical drawings* and *Electrical drawings*.

7.4.5 Rotor construction control

Particular attention should be paid to rotor construction, because even small damages in the rotor can lead to severe damages in the stator. In addition, mechanical problems in the moving parts such as the rotor have a tendency to develop faster than in the stationary parts of the machine.

Therefore, rotor construction should be checked yearly, preferably using an endoscope and ultrasonic equipment. The condition and tightness of the fastenings should be checked carefully.

7.5 Maintenance of bearings

Bearings are either re-lubricated or closed antifriction bearings without re-lubricating possibility. Calculated bearing lifetime is mentioned in the technical specification. Actual lifetime of the bearing depends however heavily on the operating conditions and calculated value shall be only used as a guideline.

The lifetime of the DE- and NDE-bearings without re-lubricating option is sometimes likely to be shorter than the lifetime of the electrical machine. Therefore, the bearings could be changed sometimes. The maintenance of rolling bearings requires special care, tools and arrangements as to ensure a long lifetime of newly fitted bearings. During bearing maintenance, ensure that:

- No dirt or foreign debris is allowed to enter the bearings at any time during the maintenance.

- The bearings are washed, dried and pre-greased with suitable and high quality rolling bearing grease before assembly.
- The disassembly and mounting of the bearings does not damage the bearings. The bearings must be removed by using pullers and fitted by heating, or using special tools for the purpose.

NOTE: If there is a need to change bearings, please contact ABB After Sales, see After Sales contact information in *Chapter 9.1.5. After Sales contact information*.

NOTE: WHEN DISMANTLING THE MACHINE, ALWAYS CHANGE THESE CLOSED BEARINGS.

NOTE: Remember to tighten the screws correctly. When tightening screws, following procedure shall be followed:

- Clean the thread of the screw
- Use appropriate screw locking agent
- Tighten the bolts in crossing order in two phases with the torque wrench (the tightness of fastening refer to *Table 7-10. General tightening torques*)

For more information see *Chapter 7.4.4. The tightness of fastenings*.

7.5.1 Bearing construction

Closed anti-friction bearings

Closed bearings cannot be re-greased and only maintenance operation is to regularly check cleanliness of the bearing, keep bearing clean, protect surface of the bearing from corrosion and visually check the condition of the bearing.

Re-greasable anti-friction bearings

In order to operate reliably, bearings must be satisfactorily lubricated to prevent direct metallic contact between rolling elements, bearing and cage races, to prevent wear and to protect surfaces from corrosion. To ensure reliable operation, the bearings should be regularly re-greased with high-quality rolling bearing grease.

The choice of grease, greasing and cleaning intervals must therefore be scrupulously respected. All this information is given on the lubrication plate.

The best operating temperatures are obtained when the bearing receives the minimum necessary quantity of lubricant to ensure reliable lubrication. It is therefore important that the machine manufacturer's instructions are respected. Excess lubricant quickly increases the operating temperature, particularly at high rotation speeds.

When it is necessary to change from one type of grease to another, for any reason whatever, the mixability of lubricants must be taken into consideration. If incompatible greases are mixed, the consistency may become very different and the maximum usage temperature of the mixture may become low enough to cause a bearing failure.

New grease must always be added to bearings while they are still lubricated satisfactorily, and always with the machine in operation. Grease shall be added in accordance with information given on the greasing plate.

Like all essential parts of the machine, bearings must periodically be cleaned and checked. The frequency of the operation and the procedure to be used depend more than anything on operating conditions.

For cleaning, preferably use white spirit, good quality paraffin, petrol or benzol. After this operation, parts shall be immediately coated with oil or grease to protect against corrosion.

7.5.2 Re-greasing intervals

The re-greasing of non-closed bearings can be performed either manually or by means of an automatic system. In either case, it has to be verified that a suitable amount of the correct grease is entering the bearing at suitable intervals. The re-greasing interval is found on the bearing plate.

NOTE: Grease can cause skin irritation and eye inflammation. Follow all safety precautions specified by the grease manufacturer.

NOTE: Regardless of the re-greasing interval, the bearings need to be re-greased at least once per year.

The re-greasing intervals are calculated for an operating temperature of 70 °C (160 °F). If the operating temperature is lower or higher than the assumed, the re-grease interval has to be altered accordingly. Higher operating temperature decreases the re-greasing interval.

NOTE: An increase in the ambient temperature raises the temperature of the bearings correspondingly. The values for the re-greasing interval should be halved for every 15 °C (30 °F) increase in bearing temperature and may be once doubled for a 15 °C (30 °F) decrease in bearing temperature.

Re-greasing intervals for frequency converter drives

Higher speed operation, e.g. in frequency converter applications, or lower speed with heavy load will require shorter lubrication intervals or a special lubricant. Consult manufacturing ABB factory After Sales department in such cases.

NOTE: The constructional maximum speed of the machine must not be exceeded. The suitability of the bearings for high-speed operation must be checked.

7.5.3 Re-greasing for re-lubricated bearings

Some of rolling bearings of rotating electrical machines in D-end need to be re-greased, see *Chapter 7.5.2. Re-greasing intervals*. The re-greasing can be performed either manually or by means of an automatic system. In either case, it has to be verified that a suitable amount of the correct grease is entering the bearing at suitable intervals.

NOTE: Grease can cause skin irritation and eye inflammation. Follow all safety precautions specified by the grease manufacturer.

Manual re-greasing of the bearings

Machines suited for manual re-greasing are equipped with grease nipples. In order to prevent debris from entering the bearings, the grease nipples, as well as the surrounding area has to be cleaned thoroughly before re-greasing.

Manual re-greasing while the machine is running

- Re-greasing while the machine is running:
- Verify that the grease to be used is suitable.
- Clean the grease nipples and the area around them.

- Verify that the lubrication channel is open, if equipped with a handle, open it.
- Press the specified amount and type of grease into the bearing.
- Let the machine run 1-2 hours in order to ensure that all excess grease is forced out of the bearing. The bearing temperature may temporarily increase during this time.
- If equipped with a handle, close it.

NOTE: Beware of all rotating parts during the re-greasing.

Manual re-greasing while the machine is at a standstill

Preferably, re-grease the machine while it is running. If this is not possible, or considered dangerous, the re-greasing has to be carried out while the machine is at a standstill. In this case:

- Verify that the grease to be used is suitable.
- Stop the machine.
- Clean the grease nipples and the area around them.
- Verify that the lubrication channel is open, if equipped with a handle, open it.
- Press only half the amount of the specified type of grease into the bearing.
- Run the machine for a few minutes at full speed.
- Stop the machine.
- After the machine has stopped, press the specified amount of the correct grease into the bearing.
- Let the machine run 1-2 hours in order to ensure that all excess grease is forced out of the bearing. The bearing temperature may temporarily increase during this time.
- If equipped with a handle, close it.

Automatic re-greasing

A variety of automatic re-lubrication systems is available on the market. However, ABB recommends only the use of electromechanical re-lubrication systems. The quality of the grease entering the bearing has to be checked at least once per year: the grease has to look and feel like new grease. Any separation of the base oil from the soap is not acceptable.

NOTE: If an automatic re-greasing system is used, double the amount of grease indicated on the bearing plate.

7.5.4 Bearing plate

All machines with re-lubrication option are supplied with bearing plates attached to the machine frame. The bearing plates provide bearing information, such as:

- Bearing type.
- Lubricant used.
- Re-greasing interval.
- Re-greasing amount.

For more details regarding the bearing plate, see *Chapter 2.1.5. Bearing plate*.

NOTE: It is essential that the information provided on the bearing plate is taken into account when using and maintaining the machine.

7.5.5 Bearing grease

It is essential to use grease of good quality and with the correct base soap. This will ensure a long and trouble free lifetime of the bearings. Grease used for re-greasing should have the following properties:

- Be special rolling bearing grease.
- Be of good quality with a lithium complex soap, and with mineral-, or PAO-oil.
- Have a base oil viscosity of 100 to 160 cSt at 40 °C (105 °F).
- Have a consistency NLGI grade of 2 (as a recommendation).
- Have a continuous temperature range between -30 °C (-20 °F) and at least +120 °C (250 °F).

Grease with the correct properties is available from all major lubricant manufacturers. If the make of grease is changed and compatibility is uncertain, consult the manufacturing ABB factory, see *Chapter 9.1.5. After Sales contact information*.

NOTE: Grease additives are recommended. However, a written guarantee should be obtained from the lubricant manufacturer stating that the additives do not damage the bearings or the properties of the grease in the field of the operating temperature. This is especially important for EP additives.

NOTE: Lubricants containing EP admixtures are not recommended.

NOTE: Different makes of grease must not be mixed, unless the compatibility has been verified.

Recommended rolling bearing grease

ABB recommends any of the following high performance greases to be used:

- Esso Unirex N2 (lithium complex base).
- Klüber Klüberplex BEM 41-132.

Re-greasing intervals for greases fulfilling the required properties other than the ones mentioned above should be halved.

Rolling bearing grease for extreme temperatures

If the bearing operating temperature is above 100 °C (210 °F), please consult the manufacturing ABB factory for suitable greases.

7.5.6 Fitting and replacing the closed DE-bearing

Bearing removal

1. Support the shaft.
2. Remove the 8 screws of the NDE shield on the stator.
3. Tap off the DE shield.
4. Remove bearing retainers.
5. Extract the ball bearing with a puller (see *Figure 7-1. The bearing puller*).

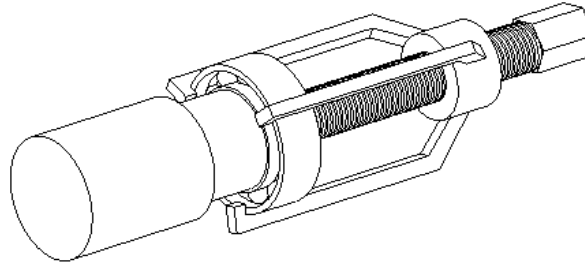


Figure 7-1. The bearing puller.

6. Check the O-ring seal and the preloading wavy washer and replace them (if necessary)

Re-fitting the new bearing

1. Clean the shaft end.
2. Fit a new bearing, after heating it by induction system to 80 °C maximum.
NOTE: Do not hit or press to the outer ring during assembly, as this will damage the balls.
3. Install bearing retainers, if needed.
4. Attach the DE shield to the stator with 8 screws.

7.5.7 Fitting and replacing the closed NDE bearing

Remark, that if the generator is delivered with optional PMG-unit (*permanent magnet*), the bearing removal procedure is slightly different compared to design without this optional PMG.

Bearing removal

1. Support the shaft.
2. Remove the grille of NDE shield.
3. Remove PMG stator,
4. Remove PMG rotor attached with one bolt and a pin. For more detailed information about this optional PMG-unit, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.
5. Remove the NDE shield
6. Extract the ball bearing with a puller (see *Figure 7-1. The bearing puller*).
7. Check the O-ring seal and the preloading wavy washer and replace them (if necessary)

Refitting the new bearing

1. Clean the shaft end.
2. Fit a new bearing, after heating it by induction system to 80 °C maximum.
NOTE: Do not hit or press to the outer ring during assembly, as this will damage the balls.
3. Check the preloading wavy washer and replace it (if necessary).
4. Attach the NDE shield.
5. Attach the PMG stator and PMG rotor, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.
6. Attach the air intake grille to the NDE shield.

7.6 Maintenance of stator and rotor winding

The windings of rotating electrical machines are subjected to electrical, mechanical and thermal stresses. 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 chapter offers a general description on how to perform basic maintenance and tests.

In many countries, ABB Service also offers complete service maintenance packages, which include comprehensive testing.

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, see *Chapter 7.2. Safety precautions* for more information.

Independent test and maintenance instructions can also be found in the following international standards:

1. IEEE Std. 43-2000, IEEE Recommended Practice for Testing Insulation Resistance of Rotating Machines
2. IEEE Std. 432-1992, IEEE Guide for Insulation Maintenance for Rotating Electrical Machinery (5 hp to Less Than 10 000 hp).

7.6.1 Particular safety instructions for winding maintenance

Some of the hazardous works of the winding maintenance include:

- Handling of hazardous solvents, varnishes, and resins. Hazardous substances are required for cleaning and re-varnishing windings. These substances can be dangerous if inhaled, swallowed or in any contact with skin or other organs. Seek proper medical care if an accident occurs.
- Dealing with flammable solvents and varnishes. Handling and use of these substances should always be by authorized personnel and proper safety procedures must be followed.
- Testing at high voltage (HV). High-voltage tests should only be conducted by authorized personnel and proper safety procedures must be followed.

Dangerous substances used in winding maintenance are:

- White spirit: solvent.
- Trichloroethane: solvent.
- Finishing varnish: solvent and resin.
- Adhesive resin: epoxy resin.

NOTE: There are special instructions for handling dangerous substances during maintenance work. Important handling instructions can also be found on warning labels of the packing.

Some general safety measures during winding maintenance are as follows:

- Avoid breathing air fumes; ensure proper air circulation at the work site or use respiration masks.

- Wear safety gear such as glasses, shoes, hard hat and gloves and suitable protective clothing to protect the skin. Protective creams should always be used.
- Spray-varnish equipment, the frame of the machine, and the windings should be earthed during spray-varnishing.
- Take necessary precautions when working in pits and cramped places.
- Only personnel trained to do high voltage work can carry out a voltage test.
- Do not smoke, eat, or drink at the work site.

7.6.2 Timing of the maintenance

There are three main principles for timing the winding maintenance:

- Maintenance of the windings should be arranged according to other machine maintenance.
- Maintenance should be performed only when necessary.
- Important machines should be serviced more often than the less important ones. This also applies to windings that become contaminated rapidly and to heavy drives.

NOTE: As a rule of thumb, an insulation resistance test should be done once a year. This should suffice for most machines in most operating conditions. Other tests should only be conducted if problems arise.

A maintenance program for the complete machine, including windings, is presented in *Chapter 7.3. Maintenance program*. This maintenance program however, should be adapted to the customer's particular circumstances, i.e. servicing of other machines and operating conditions as long as recommended servicing intervals are not exceeded.

7.6.3 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 and by monitoring the temperature of the cooling air.

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

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

7.6.4 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 windings, 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 resistance values

In order to be able to compare measured insulation resistance values, the values are stated at 40 °C. The actual measured value is therefore converted to a corresponding 40 °C value with the help of the following diagram (see *Figure 7-2. Correlation between the insulation resistance and the temperature*). The use of this diagram should be limited to temperatures fairly near to the standard value of 40 °C, since large deviations from it could result in errors.

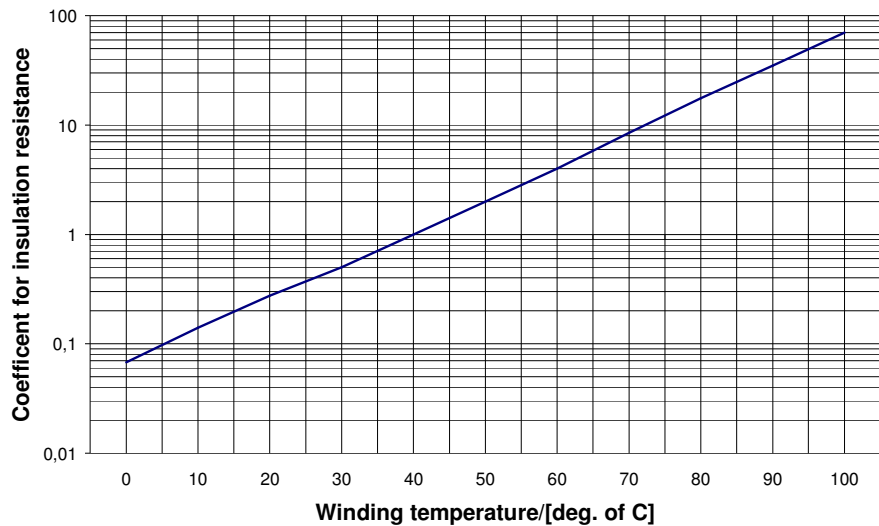


Figure 7-2. Correlation between the insulation resistance and the temperature.

- R =Insulation resistance value at a specific temperature.
- R_{40} =Equivalent insulation resistance at 40°C.
- $R_{40}=k \times R$.

Example:

$R=30 \text{ M}\Omega$ measured at 20 °C.

$k=0.25$.

$R_{40}=0.25 \times 30=7.5 \text{ M}\Omega$.

Table 7-10. Temperature values in degrees Celsius [°C] and degrees Fahrenheit [°F]

°C	0	10	20	30	40	50	60	70	80	90	100	110
°F	32	50	68	86	104	122	140	158	176	194	212	230

General considerations

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 7.6.8. Drying* for details. If these measures are not sufficient, expert help should be acquired.
- 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 °C temperature rise.

NOTE: The insulation resistance indicated in the test report is normally considerably higher than the values measured on site.

Minimum values for insulation resistance

The following criteria apply to windings in a normal condition.

Generally, the insulation resistance values for dry windings should exceed the minimum values significantly. Definite values are impossible to give, because resistance varies depending on the machine type and local conditions. In addition, the insulation resistance is affected by the age and usage of the machine. Therefore, the following values can only be considered as guidelines.

The insulation resistance limits, which are given below, are valid at 40°C, and when the test voltage has been applied for 1 minute or longer.

Rotor:

- For rotors: R (1-10 min at 40 °C) > 1.5 MΩ.
- Carbon dust on naked copper surfaces lower the insulation resistance values of the rotor.

Stator:

- For new stators: R (1-10 min at 40 °C) > 1000 MΩ.
- For used stators: R (1-10 min at 40°C) > 100 MΩ.

If the values indicated here are not reached, the reason for the low insulation resistance should be determined. A low insulation resistance value is often caused by excess humidity or dirt, the actual insulation being intact.

Stator winding insulation resistance measurement

The insulation resistance is measured using an insulation resistance meter. The test voltage is 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:

- The secondary connections of the current transformers (CT's), including spare cores are not open, see *Figure 7-3. Connection of the stator windings for insulation resistance measurements, part a.*
- All power supply cables are disconnected.
- The frame of the machine and the stator windings not being tested are earthed.
- All resistance temperature detectors are earthed.
- Possible earthing of voltage transformers (not common) must be removed.

The insulation resistance measuring should be carried out in the terminal box. The test is usually performed to the whole winding as a group, in which case the meter is connected between the frame of the machine and the winding, see *part a* and *part b* of *Figure 7-3. Connection of the stator windings for insulation resistance measurements.* The frame is earthed and the three phases of the stator winding remain connected at the neutral point, see *part A* of *Figure 7-3. Connection of the stator windings for insulation resistance measurements.* In the figure MΩ represents the insulation resistance tester.

If the measured insulation resistance of the whole winding is lower than specified, and the phase windings can easily be disconnected from each other, each phase can also be measured separately. This is not possible in all the machines. In this measurement, the tester is connected between the frame of the machine and one of

the windings. The frame and the two phases not measured are earthed, see *part c* of *Figure 7-3. Connection of the stator windings for insulation resistance measurements*. In the figure MΩ represents the insulation resistance tester.

NOTE: When phases are measured separately, all star-points of the winding system must be removed. If the star-point of the component cannot be removed, as in a typical 3-phase voltage transformer, the whole component must be removed.

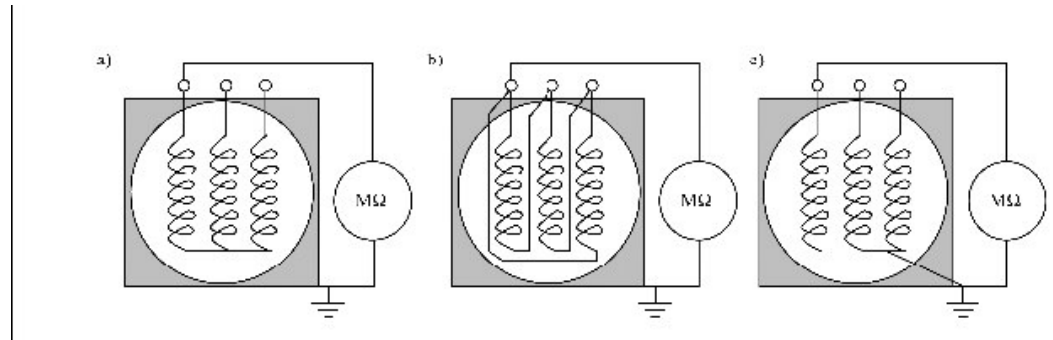


Figure 7-3. Connection of the stator windings for insulation resistance measurements.

In *Figure 7-3*:

- a) Insulation resistance measurement for star connected winding.
- b) Insulation resistance measurement for delta connected winding.
- c) Insulation resistance measurement for one phase of the winding. MΩ represents insulation resistance meter.

NOTE: After the insulation resistance measurement the winding phases must be earthed to discharge them.

Insulation resistance measurements of the rotor field winding and excitation machine

The test voltage for the rotor windings and excitation machine is 500 VDC. 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..
- Connect the insulation resistance meter between the rotor windings and the shaft of the rotors as shown in *Figure 7-4. Connections for insulation resistance measurements*. The measurement current must not go through the bearings.
- After the insulation resistance measurement, discharge the windings by earthing them.

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 the machine as shown in *Figure 7-4. Connections for insulation resistance measurements*.

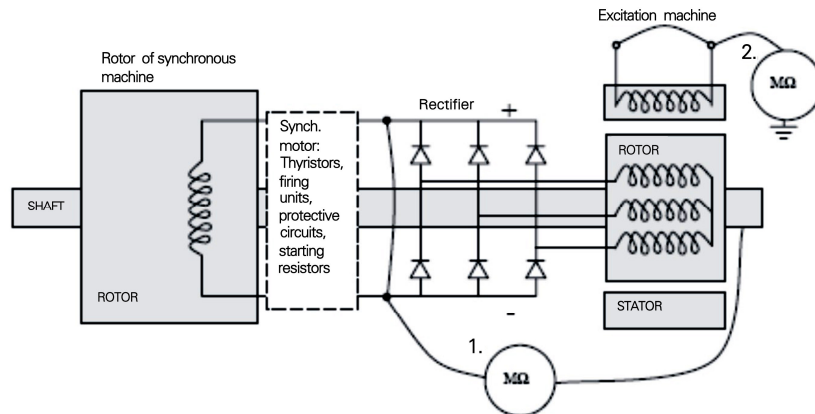


Figure 7-4. Connections for insulation resistance measurements.

- 1) Measurement of windings of the rotors.
- 2) Measurement of the stator winding of the excitation machine. MΩ represents the insulation resistance meter.

7.6.5 Polarization index

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 than the insulation resistance. When the winding temperature is below 50 °C (122 °F), 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 temperatures above 50 °C (122 °F).

Dirt and humidity accumulating in the winding normally reduces the insulation resistance, and the polarization index, as well as their dependence on temperature. Thus, the line in *Figure 7-2. Correlation between the insulation resistance and the temperature* becomes less steep. Windings with open creepage distances are very sensitive to the effects of dirt and humidity.

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. Values 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:

$$PI = \frac{R_{1\min}}{R_{15s}} \quad \text{or:}$$

$$\frac{R_{10\min}}{R_{1\min}}$$

NOTE: If the insulation resistance of the winding is in the range of several thousands of MΩ, the polarization index is not a meaningful criterion of the condition of the insulation, and it can be disregarded.

7.6.6 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.

AC voltage is used for the high voltage test and the test voltage is 1500 V.

7.6.7 Visual winding inspection

Winding inspections 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 creepage 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, tyings, and around slot ends. Loose supports and slot wedges are signs of further deterioration. Check for abrasion marks and powder near the supports, tyings, and at the slot ends. Complete loosening of the slot wedges and bent coils are serious problems that must be rectified immediately.

Hair cracks and fractures in metal parts such as supporting bolts and squirrel cage windings are also signs of deterioration, but they take longer to develop into a failure.

Humidity in the winding often causes e.g. rust on iron, drop marks, dripping, and wetting marks on dirt layers. Bush-shaped patterns, often charred and left behind by the tracking currents, warn 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.

Over temperatures that last only for a short period of time can leave marks all over the machine.

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 °C or 662 °F)
- There are color differences in the fastening bolts of synchronous machines.
- Insulation may shrink or split (usually over 200 °C or 392 °F), tyings may crack (over 220 °C or 428 °F), and polyester film or fibers may melt (over 250 °C or 482 °F).
- Swelling of the slot insulation is also possible.

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

7.6.8 Drying

The windings must be dried:

- After washing (especially a 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 (9 °F) per hour, and the final temperature should not exceed 105 °C or 220 °F). A sudden temperature rise or a too high final temperature can cause steam to be formed in the cavities of the windings, 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 windings 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 °C (or 194 °F) for 12 to 16 hours and then 105 °C (220 °F), for six to eight hours. These times can vary, and the correct time should be monitored with an insulation resistance test.

Effective drying is achieved with the right balance of heat and ventilation. The air circulation inside the machine should be as effective as possible.

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. Adequate fresh-air circulation is essential, whatever heating method is 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 continues, however, the insulation resistance increases until it reaches a stable value.

7.6.9 Other maintenance operations

Usually, ABB made winding are trouble free and in addition to periodical monitoring they require only occasional cleaning and drying as described above. If extraordinary circumstances occur and other maintenance is required, it is best to acquire professional help. The ABB After Sales organization is happy to assist in question regarding maintenance of electrical machine windings, for contact information see *Chapter 9. After sales and spare parts*.

7.7 Maintenance related to electrical performance, excitation, control and protection

The electrical performance of a synchronous machine is mostly defined by the condition of the rotor and stator windings and the operation of the excitation system. The main machine winding maintenance is described in *Chapter 7.6. Maintenance of stator and rotor winding*. In this chapter the focus is on the maintenance of the excitation system and the control and protection systems. For optional PMG-unit, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.

7.7.1 Exciter insulation resistance measurement

The insulation resistance in the exciter can be tested with the winding insulation resistance test. The procedure is described in detail in *Chapter 7.6. Maintenance of stator and rotor winding*. The test voltage for the exciter stator should be 500 VDC and the test should be performed in the terminal box after the cables have been disconnected.

The resistance of the exciter rotor is usually measured jointly with the rotor of the main machine, see *Chapter 7.6.4. Insulation resistance test*. The resistance of the exciter rotor can also be measured separately, but this requires special arrangements.

7.7.2 Protection trips

The synchronous machine needs to be protected with alarms and 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.

7.7.3 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. These include for example performance deviations and loss of excitation. For detailed information about AVR connection and settings see *Annex 3. Main Connection Drawing* and *Annex 6. Automatic Voltage Regulator User's Manual*.

7.7.4 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. Contact After Sales for more information.

7.7.5 Diode fault

If a diode in the rotating rectifier fails, the generator must be tripped. To determine and locate a faulty diode:

Open the covers at the non-drive end of the machine and measure the insulation resistance 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.

NOTE: Do not open the service covers or end shields unless it is certain that the machine is isolated from its driving source.

To replace faulty diodes:

- Open the service doors at N-end shield of the machine.
- Disconnect the wires connected to the diodes and exciter winding connection cables.
- Check the condition of the diodes by measuring the resistance over a diode in both directions.
- Replace the damaged diode(s).
- Clean the contact surfaces, 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 results as a significant increase in excitation current.

7.8 Maintenance related to thermal performance and cooling system

An increase in the machine's temperature is usually caused by:

- A decline in the effect of the cooling system.
- Excessive amounts of heat produced by the machine.

If the machine temperature exceeds normal values, determine which of these two causes is responsible for the increase in the temperature. Excessive heat production might be caused e.g. by a winding problem or by network unbalance and in these cases corrective actions on the cooling system would be ineffective or harmful.

7.8.1 Cooling System

The machine is cooled with a shaft mounted fan. The cooling air is taken in from the surroundings air at the non-drive end and it is blown out from the top and the sides of the machine at the drive end (IC 0A1). The cooling air should be as clean as possible because dirt that drifts into the machine causes contamination and reduces the efficiency of the cooling.

If winding or cooling air temperature detectors show an abnormal temperature, the cooling system has to be checked. Either of the following two reasons could be causing the problem in the cooling system:

- Problems with air filters (if applicable):
 - ⇒ Check the condition of the air filters.
- Problems in air circulation inside the machine:
 - ⇒ Ensure good air circulation inside the machine. The machine interior should be cleaned and checked during overhauls or if problems arise..

Other possible causes for poor cooling system performance include elevated ambient temperature or high intake air temperature. In addition, bearing malfunction might lead to high bearing temperature.

When abnormal temperature rise has been detected, it should be also checked that temperature measurement system is operating correctly.

Chapter 8 Troubleshooting

This chapter is intended as a help in the event of an operational failure with an ABB 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 ABB should be contacted for more information or technical assistance regarding troubleshooting and maintenance.

For optional PMG-unit, see *Annex 9. Permanent Magnet Regulator (PMG) User's Manual*.

8.1 Mechanical performance

Table 8-1. Trouble shooting for mechanical performance.

Troubleshooting Mechanical performance

Experienced malfunction				
Vibration	Noise	Possible cause		Corrective action
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)	Check and repair cooling 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 ABB 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
x	x	Airgap not uniform		Measure and adjust airgap

8.2 Lubrication system and rolling bearings

Table 8-2. Trouble shooting for lubrication and rolling bearings.

Experienced malfunction					
High bearing temperature	Lubricant leaks	Bearing noise or vibration	Possible cause		Corrective action
●		●	Insufficient lubrication	Insufficient amount of grease	Check bearing condition, add grease
●	●	●	Unsuitable grease quality or viscosity		Check ABB grease recommendations, change grease
●			Excessive axial forces	Faulty coupling or mounting	Check coupling, mounting and alignment
●		●	Reduced grease quality	Incorrect regreasing period	Check ABB recommendations, regrease
●		●		Faulty operating conditions	Check ABB operating and grease recommendations
●	●		Excessive lubrication		Clean bearing and add correct amount of lubricant
●		●	Damaged bearing parts	Impurities in grease	Change grease, check bearing condition
●		●		Bearing currents	Check bearing and insulation condition
●		●		Complete bearing failure	Replace bearing
●		●		Normal wearing	Replace worn bearing parts
●			Faulty instrumentation	Faulty temperature detector	Check bearing temperature measurement system
	●	●	Faulty bearing seals		Check bearing seals and lubricant quality
●			Incorrectly assembled bearing		Replace bearing, ensure correct assembly
●		●	Outer ring is rotating due to unbalanced load		Rebalance machine, repair bearing bore and replace bearing
		●	Bearing noise due to deformed roller element		Replace bearing
		●	Foreign matter inside the bearing		Clean bearing assembly, check seal conditions and replace bearing

8.3 Thermal performance, open air cooling system

Table 8-3. Troubleshooting for thermal performance.

Troubleshooting

Thermal performance, open air cooling system

Experienced malfunction				
High winding temperature	High cooling air temperature	Possible cause		Corrective action
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	Clean machine parts and air gaps
x	x		Faulty cooling arrangement	Inspect cooling arrangement condition and correct assembly
x	x		Air intakes are blocked	Clear air intakes of debris
x	x		Air filter is clogged	Clean or replace air filters
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 ABB 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

8.4 Electrical performance and excitation system of generators

Table 8-3. Trouble shooting for electrical performance.

Troubleshooting

Electrical performance and excitation system of generators with transformer excitation

Experienced malfunction							Possible Cause	Corrective action
Lost excitation	Increase in excitation current	Malfunction during start-up	Performance deviation	Operation not adjustable	Faulty parallel operation			
	x		x			Abnormal speed	Faulty speed control	Check speed control of operating machine
		x	x			Network phase unbalance		Check that network balance fulfils requirements
			x			Speed variation of operating machine		Check speed control of operating machine
x		x				Field application failure	Faulty settings	Check excitation panel relay and voltage regulator setting
x		x					Faulty wiring	Check excitation panel control cubicle and generator
x		x					Demagnetised excitation magnet	See main connection diagram to restore permanent magnet excitation
x	x		x	x		Defective voltage transformer		Check transformer winding insulation resistance and connections
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 main machine 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		Excitation equipment fault	Excitation panel equipment	Check and replace excitation panel equipment
x	x	x	x	x	x	Faulty AVR settings		Check and adjust voltage regulator settings
			x			Bad AVR tuning parameters	Voltage oscillation, poor response	Check AVR tuning (PID parameters)
x	x	x	x	x	x	Defective AVR		Check and replace voltage regulator
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

Chapter 9 After sales and spare parts

9.1 After sales

The after sales support for rotating electrical machines manufactured by ABB.

9.1.1 Site services

The Service department provides:

- Installation and commissioning
- Maintenance and inspections
- Trouble shooting and service
- Upgrading and modifications.

9.1.2 Spare parts

Co-ordinates spare parts packages delivered with the machine

Sells genuine spare parts after the machines has been delivered.

9.1.3 Warranties

The Service department handles warranty issues regarding the machines.

9.1.4 Support for service centers

The Service center support provides help for Service centers in questions concerning the mechanical construction as well as in electromagnetic and insulation technology issues.

9.1.5 After sales contact information

Contact the Service department by:

Phone 8:30 am - 5:30 pm +86 791 835 0869

(GMT: +8)

Fax +86 791 835 0814

e-mail: aftersales.generator@cn.abb.com

9.2 Spare parts

9.2.1 General spare part considerations

The machines manufactured by ABB are designed and manufactured to provide reliable and trouble free operation for decades. This requires, however, that the machines are properly maintained and operated. This maintenance includes changing of parts subjected to normal wear.

There is always an inevitable amount of uncertainty related to wearing. The wear rates of these parts vary greatly according to application, environment and particular conditions. Therefore, the condition of these parts should be checked regularly and a sufficient amount of spare parts should be kept in stock. These

spares help to minimize down time if the need appears. The extent of the stock should be decided based upon the importance of the application, the availability of the particular spare part and the expertise of the local maintenance personnel.

9.2.2 Periodic part replacement

There is always mechanical wearing when two moving surfaces are in contact with each other. In electrical machines most of the mechanical wearing occurs between the rotating shaft and stationary parts. The bearing parts will eventually wear out and need to be replaced, even if correct greasing is maintained. Other wearing parts are the seals that are in constant contact with the rotating shaft.

The parts mentioned above make an extensive, but not a complete, list of the mechanically wearing parts. These parts have an estimated life span, but as mentioned earlier, their actual durability can vary significantly. For this reason, at least these parts should be kept in stock. It should also be noted that the replacement of these parts, due to normal wearing, is not covered by the warranty.

9.2.3 Need of spare parts

Other types of wear occur due to elevated temperatures, electrical disturbances and chemical reactions. The wear of the diodes in the rectifier bridge is usually related to abnormal electrical operating conditions. It is usually a slow process, but it is strongly dependent on the operation conditions of the machines and system disturbances.

The electrical windings of the ABB machines have good protection against wear, but only if correct maintenance and operating conditions are followed. The correct operating temperature must not be exceeded and the windings must be cleaned from dirt regularly. The winding can also be subjected to accelerated wear due to a number of electrical disturbances.

9.2.4 Selection of the most suitable spare part package

ABB provides three levels of ready made spare part packages. The personnel best informed of the machine's operational conditions should select the most suitable package based on criticality of the application and on the financial risk related to the duration of downtime and loss of production.

Operational spare parts for commissioning and to ensure usability

These are the most essential spare parts that you should have always available.

Recommended maintenance parts for trouble shooting and scheduled maintenance

These parts enable should be available while doing medium term maintenance.

These parts also enable fast recovery in case of failure in the most of the accessories.

Capital spare parts to reduce repair time in case of serious damage

These spare parts are recommended when the machine is a part of essential processes.

These spare parts enable fast recovery even in case of a serious damage.

9.2.5 Typical recommended spare parts in different sets

Below is presented a general recommendation of the typical spare parts for different packages. To receive a quotation for specific parts for a specific machine, please contact the ABB After sales organization.

Please note that even though ABB has customized the spare part sets to match the machine, they might contain references to accessories not found on all machines.

9.2.5.1 Operational spare parts package

Spare part:	Amount:
Automatic voltage regulator (AVR)	1 pc
Rectifier	1 set
Varistor	1 pc
Bearing for D-end (if have)	1 pc
Bearing for NE-end	1 pc
Connection copper bar	1 set

9.2.5.2 Recommended spare parts package

Spare part:	Amount:
Anti-condensation heater	1 set
Safety package	1 set

9.2.5.3 Capital spare parts package

Spare part:	Amount:
Exciter rotor	1 pc
Exciter stator	1 pc
Rectifier bridge	1 set
Rotor (complete)	1 pc
Stator with frame	1 pc

9.2.6 Order information

To ensure fast and correct spare part order and delivery, our After sales personnel should be provided with the serial number of the machine in question. The serial number can be found either on the rating plate fixed to the machine frame, or stamped on the machine frame, and is also given in this manual.

In addition, provide specific and detailed information about the parts ordered. The contact information of ABB's After sales organization can be found in *Chapter 9. After sales and spare parts.*