

Maintenance of the System/ Plant Section

4

Inspection

4.3

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1 Preventive Maintenance

Reliable operation of the generator will be ensured only if inspections and overhauls are carried out at regular intervals so that any faults can be detected and corrected before they result in costly failures. Following each inspection, the next inspection should be scheduled.

Provided that commercial tools can be used and that no special skills are required for the dismantling and erection work, the inspections can be supported by skilled power station personnel. The services of trained Siemens service personnel are required for all work which requires special tools as well as specific knowledge of assembly.

Establish a checklist of inspections to be performed and plan tooling and manpower requirements. Siemens offers the appropriate support for the entire process, including the supply of tools and personnel, as well as support for efficient inspection and maintenance planning. For more detailed information, please contact your local Siemens representative or your contact person at Siemens itself.

All findings should be documented for subsequent examinations.

Strategic spare parts already stored for unplanned repairs should be checked at regular intervals. Components packed in plastic sheeting mostly contain a desiccant which must be replaced or reactivated from time to time. Furthermore stock should be checked prior inspection works and refilled if necessary.

Apart from its scope, the timing of an inspection is important. To account for the deterioration and stresses due to different modes of operation, the number of operating hours, the number of starts and the turning times are used as criteria in determining the intervals between the inspections.

Siemens recommendations are a guide to support power plant owners and operators to schedule inspections; however they should also take into account their own experience.

2 Types of Inspection

Depending on the scope, date and duration of the inspections, a differentiation is made between

- Minor Inspection (Mil) (or Short Inspection)
- Medium Inspection (Mel)
(or Intermediate Inspection)
- Major Inspection (Mal) (or Main Inspection)

Type	Features
Mil	Checks and measures required based on observations during operation and checks with minor partial disassembly (opening the manhole cover only) but without rotor removal
Mel	Checks and measures required based on observations during operation and checks with partial disassembly but without rotor removal
Mal	Checks and measures required based on observations during operation and checks with extended disassembly and optionally with rotor removal, but only if really required

Tab. 1: Types of Inspection, Features

The **Minor Inspection (Mil)** can be routinely scheduled or performed when a shutdown occurs. It serves to detect changes at an early stage which have not yet been detected by the monitoring system as well as to verify its results. The generator remains nearly full assembled during a Mil, only the manholes are opened.

The scheduling of **Medium Inspections (Mel)** is generally determined by other power station components. The downtime can be used not only for an extensive inspection but also for small improvements and minor repairs.

During **Major Inspection (Mal)** comprehensive inspections, repairs and renewal of parts, even to a larger extent, are made. The auxiliary plant units have to be integrated. The rotor removal is optionally, but it is required in case of supposed earth fault, vibration deviations or excitation current deviations.

3 Equivalent Operating Hours and Inspection Scheduling

The scheduling of the inspections mainly depends on the number of operating hours, the number of starts and the turning gear operation times.

The total number of equivalent operating hours since the initial commissioning, the last Major Inspection or other incidents important for the inspection schedule corresponds to:

$$T_{\text{equiv}} = T_1 + K_2 \cdot T_2 + n \cdot T_3$$

while:

T_{equiv} - Equivalent operating hours

T_1 - Operating hours since the initial commissioning or the last Major Inspection

K_2 - Weighting factor for turning gear operation

T_2 - Turning gear operation in hours since the initial commissioning or the last Major Inspection

n - Number of starts since the initial commissioning or the last Major Inspection

T_3 - Weight time in hours per start.

In some cases, the turning gear operation time T_2 is not exactly known. In this case, an estimated numerical value may be used which takes into account the mode of operation and corresponds to the minimum of two values.

The following equation is a recommendation for calculating the annual turning gear operation time. A turning gear operation time of 50 hours is assumed for each shutdown procedure, but not more than the difference between 8500 hours per year and the annual operating hours.

$$T_2 = \min \{ n \cdot 50; \quad 8500 \cdot t_{\text{cal}} - T_1 \}$$

while:

t_{cal} - Calendar time in years since the initial commissioning, since the last Major Inspection or since every other incident used to calculate T_{equiv} .

The maximum number of operating hours per year is assumed to be the maximum possible operating hours. A calendar year has 365 days = 8760 hours. However, supposed that every plant has standstills

the average maximum annual operating time is less than the calendar time.

As shown in Figure 1, the evaluation factor for turning gear operation (K_2) depends on the nominal apparent power of the generator (S).

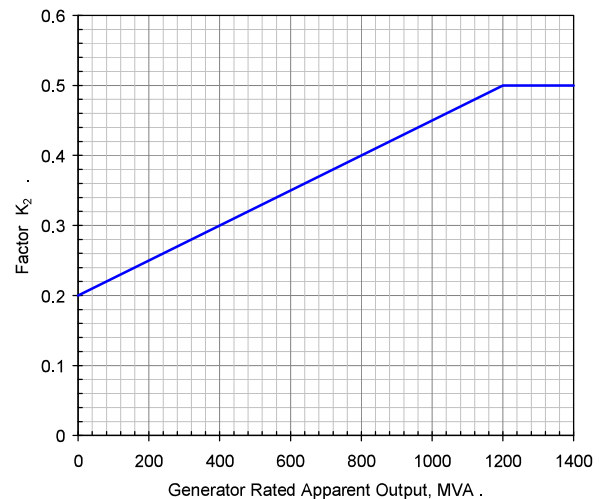


Fig. 1: Weighting factor for turning gear operation K_2

The numerical value of (K_2) for a specific nominal apparent power of the generator (S) in MVA corresponds to:

$$K_2 = S / 4000 + 0.2$$

with a maximum value of $K_2 = 0.5$

As shown in Figure 2, the equivalent evaluation time (T_3) depends on the nominal apparent power of the generator (S).

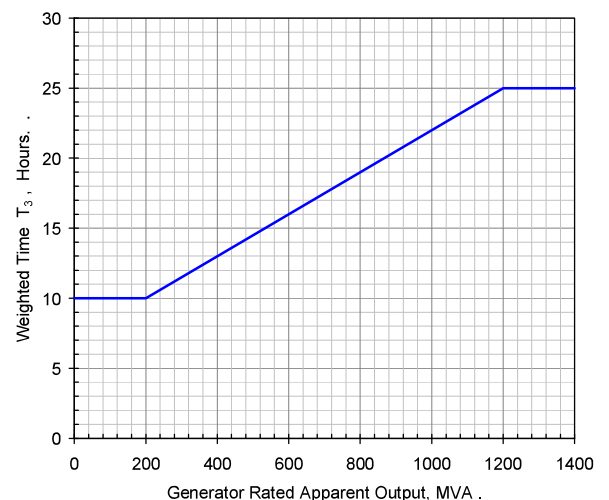


Fig. 2: Weighted time in hours per start T_3

The numerical value of T_3 for a specific nominal apparent power of the generator (S) in MVA corresponds to:

$$T_3 = 0.015h \times S/MVA + 7h$$

with a minimum value of 10 h and a maximum value of 25 h

4 Additional Factors and Recommendations for Scheduling Inspection Intervals

The recommendations given in the following apply to normal operation without major incidents. Abnormal disturbances, such as close-in system faults, faulty synchronizing, asynchronous running and inadmissibly high unbalanced load, may lead to the requirement of shortening the respective inspection interval or perform an immediate check.

When scheduling inspections, also consider the following factors:

- Ambient conditions (moisture, salty air ect.)
- Mode of operation (frequent large and rapid load changes; frequent start-ups and shut-downs)
- Wear and deterioration of components
- Deterioration of running behaviour
- Number of load shedding with overspeed
- Earth faults or interturn faults in generator field circuit
- Water leaks due to cooler or enclosure defect
- Change in coolant flow rates
- Fouling of air filters and/or stator air passages
- Deterioration of shaft insulation
- Cleanliness of the lubricating oil

With proper performance of the generator and provided that the inspection findings obtained by the preceding inspections (s) have been favourable, the intervals between inspections may be lengthened within the limits defined in next paragraph.

5 Recommendation for Inspection Intervals

Major Inspections are recommended to be performed after every equivalent operating time of

$$80000 \text{ h (EOH)} < T_{\text{equiv r}} < 106000 \text{ h (EOH)}$$

It is recommended that one or more Minor and Medium Inspections are performed between Major Inspections.

The resulting generator inspection interval schedule shall be designed to fit into turbine shut downs.

Irrespective of the above-mentioned recommendations, the following total time (operating

time + turning gear operation time + shutdown time) between two inspections on account of adverse long-term influences should not exceed:

	Total time between two inspections
Mil	3 years
Mel	6 years
Mal	12 years

Tab. 2: Maximum Total Time between Inspection Intervals

6 Example Calculations of Equivalent Operating Hours and Intervals between Major Inspections

Exemplary calculations of equivalent operating hours using the above-mentioned methods and equations are given below. These calculations use various nominal outputs for the generator, various turning gear operation times and different numbers of starts. All these parameters are taken into account in the correct selection or calculation of the evaluation factor K2 for turning gear operation and the equivalent evaluation time T3 in hours per start. In this way, the number of equivalent operating hours is calculated adequately for five typical modes of operation, which reflect the various combinations of the regular annual operating time, the turning gear operation time and the number of starts. Selected combinations are shown in Table 3, and they are to a great extent identical with real practical operation.

The number of equivalent operating hours is calculated for a calendar year ($t_{\text{cal}} = 1 \text{ year}$). It is assumed that the actual, exact value for the turning gear operation time is unknown. Therefore an estimated equivalent is calculated using the method described above and the number of starts n (Table 3).

Operating Mode	Load Ranges	Annual Operation Time in h	Annual No. of Starts	Annual turning gear operation time in h
A	Base load	7000	10	500
B	Lower medium load	5000	50	2500
C	Upper medium load	3000	150	5500
D	Peak load	2000	250	6500
E	Operation in industrial power station	7000	10	500

Tab. 3: Typical Operating Modes

The five modes of operation in Table 3 are used in Table 4 for different generator nominal outputs.

Generator rated power $S = 600$ MVA				
Operating type	$T_2 \cdot K_2$ in h	$n \cdot T_3$ in h	T_{equiv} per year in h	Intervals for Major Inspections in years
A + E	175	160	7335	11
B	875	800	6675	12
C	1925	2400	7325	11
D	2275	4000	8275	10

Generator rated powers $S = 300$ MVA				
Operating type	$T_2 \cdot K_2$ in h	$n \cdot T_3$ in h	T_{equiv} per year in h	Intervals for Major Inspections in years
A + E	175	160	7335	11
B	688	575	6262	12*
C	1513	1725	6237	12*
D	1788	2875	6662	12

Generator rated powers $S = 100$ MVA				
Operating type	$T_2 \cdot K_2$ in h	$n \cdot T_3$ in h	T_{equiv} per year in h	Intervals for Major Inspections in years
A + E	113	100	7213	11
B	563	500	6063	12*
C	1238	1500	5738	12*
D	1463	2500	5963	12*

Tab. 4: Example calculations of equivalent operating hours T_{equiv} of the generators for one year and intervals between Major Inspections.

* The calendar time which has passed since the last Major Inspection / the first commissioning must not exceed 12 years.

The currently recommended scope of the inspections is described on the following pages. Please contact Siemens for up to date and complete engineering service recommendations.

Work required	Minor inspection	Medium inspection	Major inspection
Vibration measurement at various load stages on the entire shafting	x	x	x
Record operating data of the generator and the auxiliary systems	x	x	x
Shaft voltage measurement to assess the bearing insulation	x	x	x

Work required	Minor inspection	Medium inspection	Major inspection
Electrical measurements			
Measure insulation resistances of stator winding	x	x	x
Measure insulation resistances of temperature sensor	x	x	x
Measure winding resistances			x
Measure resistances of temperature sensors			x
Perform high pot (high-voltage) test ¹⁾			x
Perform tan δ and partial discharge measurement ²⁾			x
Perform stator core interlamination verification test (such as EI-CID measurement)			x
Visual inspections			
Inspection of the end winding spacers	x	x	x
Inspection of the circuit ring and circuit ring supports	x	x	x
Inspection of the pressure plates and their locking elements	x	x	x
Inspection of the stator core bore for pressure marks in the core tooth area			x
Inspection of the end winding support and its bracing	x	x	x
Inspection of the end winding insulation	x	x	x
Inspection of the outer corona protection (OCP) insulation in the step iron region	x	x	x
Inspection of the winding surface sealing	x	x	x
Inspection of the winding end leads	x	x	x
Inspection of the RTD connections	x	x	x
Check stator vent slots			x
Inspection of the sealing between laminated core and air guide walls, between air guide walls and housing, between bushing support and housing and between laminated core and housing and renew if necessary		x	x
Check tightness of foundation bolting		x	x

¹⁾ Test to be conducted depending on available measurement equipment whether as AC test (preferred) or as DC test.

²⁾ Tests to be performed if AC equipment is available on site. Test results only comparable if the same equipment is used with identical boundary conditions using the same procedure.

1 General Information



⚠ WARNING

Starting machine parts. People could be severely injured.



Before starting any work on the generator or its auxiliary equipment:

- ***Disconnect them from the electricity supply***
- ***Secure against accidental switching on again***

Do not launch the turbine-generator set if persons are working on the generator or its vicinity!

2 Insulation Resistance Measurement

After each shutdown, prior to carrying out the inspection, the insulation resistances should be measured according to documents [1] and [2] (see end of document).

3 Stator Winding

Depending on the scope of the inspection, the windings in the slot section of the core and in the end winding areas should be inspected for proper seating. Means to check if winding does not move and all distances are kept as specified. After opening the generator, the interior should always be inspected for contamination of any kind. If contamination is detected, its cause should be determined and corrected in order to preclude any new contamination. The generator interior should be cleaned thoroughly.

The exposed OCP of the end windings should be visually inspected for signs of erosion. The areas of inspection are located at the exit edge of both ends of the core, in the step iron regions. A boroscope should be used for this inspection. Any findings should be reported to Siemens Engineering for evaluation and further recommendation.

4 Terminal Bushings and Phase Connectors

The terminal bushings should be inspected to establish their condition. It should be checked that the flexible links are still in good condition and are properly attached. Checking of proper attachment of the flexible links covers both the connections to the terminal bushings and the connections to the phase connectors. The terminal bushings should also be checked for proper connection to the bus bars arranged external to the generator.

5 Replacement of Flexible Links

Flexible links that are no longer in good condition must be replaced without delay. The following requirements must be observed during replacement of flexible links:

- Grounding of the phase connector ends and the generator terminal bushings must be performed before work is started.
- Cleanliness (absence of foreign matter) of the end-winding region must be assured at all times. The precautionary measures given in the next section must be strictly observed.
- The new flexible links must be of the same type and length as the flexible links to be replaced. Fitting of flexible links of differing types or lengths should only take place when expressly instructed by Siemens generator engineering.
- Replacement flexible links are to be checked first for proper condition (surface finish, absence of deformation).
- Flexible links are to be installed in accordance with the assembly procedures documented in the installation manual.
- Vibration behavior of replacement flexible links is to be checked with the aid of a stroboscope at 50 or 60 Hz and 100 or 120 Hz after restart. Any significant differences in vibration behavior relative to unreplaced flexible links should be reported to the Siemens AG.

6 Flanged Joints and Metering Connections

All stator flanges should be checked for proper attachment. The stator should be checked for tight anchoring to the foundation. All metering connections should be checked for proper mounting and condition so far as practicable. Prior to restart, the insulation resistance of the stator winding should be measured. If necessary, appropriate measures should then be taken to increase insulation values.



NOTICE

Even minimal-size metallic particles left inside after work on the generator can lead to large-scale damage during generator operation.

In order to prevent such damage to the generator and the stator winding, the following precautionary measures must be taken.

1. Only persons assigned to such work may enter the interior of the generator.
2. Persons assigned to such work must be in the possession of clear work and safety procedures and have been informed of special features of the work scope involved and of the associated potential dangers.
3. All persons entering the interior of the generator must wear clean overshoes.
4. Before entering the generator interior, all persons must empty their pockets and remove all metallic objects worn (such as watches, chains, earrings etc.).
5. Tools required for work inside the generator may only be transported within boxes, and must be returned to these boxes after use.
6. After completion of work inside the generator, the completeness of tool kits should be verified

against tool lists and the results of this check logged.

7. All winding areas on which work is to be performed must be covered carefully before work is started.
8. All parts to be installed or removed should be listed, with details of where to find them after work is finished.
9. Should a part be dropped despite all the above precautionary measures, it is imperative that it be located and removed. Site management should be informed in the case of any problems in this context.
10. Generator openings should be closed off with the original covers for the duration of any work breaks.
11. The use of the attached check list (4.5-2001) for works at the generator is strictly required.

Also refer to the following information (if included):

- [1] 4.5-2300 Insulation Resistance Measurements on Stator Winding
- [2] 4.5-2310 or 2311 Drying the Windings

Work required	Minor inspection	Medium inspection	Major inspection
Electrical measurements			
Measure insulation resistance	x	x	x
Measure winding resistance		x	x
Visual inspections			
Inspection of the slot wedges			x
Inspection of the retaining rings		x	x
Inspection of the bearing journals	x	x	x
Inspection of the sealing surfaces (rotor bushing area)	x	x	x
Inspection of the coupling face for pressure marks			x ¹⁾
Inspection of the fans	x	x	x
Removal, cleaning and non-destructively testing of all the fan blades, checking the threads			x
Inspection of the balancing weights	x	x	x
Inspection of the end windings via borescopic inspection	x		
Borescopic inspection of end windings, including, in particular, the contacts between axial direct-current supply line and A coil		x	x
Inspection of the air gap accessible to inspection between rotor and stator windings		x	x
Borescopic inspection of accessible corner brazes and the corner brazed joint at the pole transition conductor at the transition from pole 1 to pole 2		x	x
Inspection of the radial cooling air vent paths			x

1) Only if rotor removal is required due to operation incidents such as high vibration levels, rotor earth fault indication

1 General Information



WARNING

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- **Disconnect them from the electricity supply**
- **Secure against accidental switching on again**

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2 Rotor Wedges and Retaining Rings

The rotor should be subjected to a simple visual examination. The wedges and retaining rings should be inspected for proper condition as far as accessible.

3 Shaft Journals

The shaft journals should be checked for any damages, e.g. grooves, arching or heat discoloration. In the event of any irregularities being detected, the reconditioning should be carried out according to the instructions given by our erection engineers.

4 Cleaning the Rotor

As far as accessible the rotor should be cleaned thoroughly, even if the visual inspection did not reveal any contamination. Cleaning the rotor should be done very carefully so as not to impair any of the numerous insulated parts. Therefore it is recommended to order skilled trained Siemens personnel regarding qualification. Regarding tooling Siemens can support with special vacuum cleaners as well as with recommendations for solvents and chemical cleaners not affecting any of the different rotor materials.

5 Fan blades



WARNING

Risk of injury from the effects of arcs and flying debris.

Fan blades must be handled with great care! Damaged or incorrectly mounted fan blades can work loose and cause a short circuit in the stator end winding. Flying debris could break through the enclosure.

- ***The fan blades may only be removed and refitted by trained assembly personnel. This must be done very carefully.***
- ***If the vibration values increase, the vibration protection monitor must bring down the system to standstill immediately.***

The fan blades must be removed and tested non-destructively. The fan has to be turned to do this. Check that the threads are in faultless condition.

Siemens Service must be informed promptly if the tests find defects. They will initiate the necessary actions.

6 Coupling

The coupling flange at the rotor should be checked both at the guide flange and the fitting bolt holes. The coupling bolts should be checked for proper condition.

7 Insulation Resistance Measurements

Prior to recommissioning, the insulation resistance of the rotor winding should be measured (see below, document [1]) and, if necessary, improved by drying the windings (see document [2]).



NOTICE

Disconnect telemetry system (if present) before measuring insulation resistance.

Also refer to the following information:

- [1] 4.5-3300 or 3301 Insulation Resistance Measurements on Rotor (and Exciter) Windings (Chapter *Operation*, Section "Standstill")
- [2] 4.5-2310 or 2311 Drying the Windings (Chapter *Operation*, Section "Standstill")

Work required	Minor inspection	Medium inspection	Major inspection
Check the cooling water inlets and outlets	x	x	x
Check the vent and drain tubes	x	x	x
Check the temperature measuring device	x	x	x
Remove cooler element, clean on the water and air sides, renew seals			x
Leakage test		x	x
Inspect via borescope the returning chambers of the coolers; check the coating condition	x	x	x
Replace gaskets of the returning chambers of the disassembled cooler elements			x

1 General

Depending on the extent of the inspection, the air cooler sections should be cleaned thoroughly both on the air and water sides. During a less extensive inspection, the tubes should be cleaned on the water-side only. For this purpose, no withdrawal of the cooler sections will be necessary.

The cooler cleaning interval depends on the cooling water condition and is indicated when a substantial reduction of the heat removal capacity is observed at the cooler sections. A repetition of the tube cleaning every two months may be necessary when the cooling water is heavily contaminated. It may be possible, however, that the interval between one cleaning and the next may amount to several years. It is recommended to perform the first cleaning operation two months after initial commissioning. The date at which the next cleaning will be required can be determined at that time. The intervals for cleaning can, however, be definitely fixed only after several years of operation.

The coolers should be withdrawn from their wells when more extensive inspection work is required. After withdrawal, the coolers should be thoroughly inspected on the air side. On detection of any contamination, the air side should be cleaned by means of dry and clean compressed air. The coolers should then be installed in the generator housing, using new gaskets for reassembly.

Depending on machine size and total cooling air flow the leakage air flow can amount to 0.5 m³/s. Control the leakage air filter sequentially.

2 Mechanical Cleaning on Water Side

For this purpose, no withdrawal of the cooler sections will be necessary.

Close water inlet valves at the individual cooler sections and then open vent and drain valves.

Detach return water channels after all water has been drained from the cooler sections.

The tubes are cleaned by special brushes, which are moved up and down in the individual tubes of the tube bundle. After all tubes are brushed, a new flat gasket should be fitted and the return water channel bolted tightly to the tube sheet of the cooler section. This should be followed by reopening the inlet and outlet valves, whereby the tube bundle is flushed with cooling water.

3 Chemical Cleaning

Brushing of the tubes normally suffices for cleaning. Any scale deposits which cannot be removed by brushing should be dissolved with a chemical solution.

The following globally available cleaning agents are recommended:

Water Side:

Cleaning agent	Manufacturer
P3-288	Henkel KGaA, Düsseldorf
SAF-ACID	Drew Ameroid GmbH, Hamburg
Vecom BA-S	Vecom GmbH, Hamburg

Air Side:

Cleaning agent	Manufacturer
P3 Grato 90	Henkel KGaA, Düsseldorf
Ameroid ACC9	Drew Ameroid GmbH, Hamburg
Vecom B-85	Vecom GmbH, Hamburg

Equipment Required:

Pump
Vessel
Piping
Shutoff fittings
Cleaning agents

Close water inlet valves and then open vent and drain valves. Drain water from cooler sections. Close drain valves and water outlet valves. Connect circulating pump to cleaning circuit via water inlet and outlet pipes. Fill system. Close vent valves and circulate cleaning agent through the circuit. After cleaning, thoroughly flush circuit with water.

Remove cleaning equipment. Place water circuit in service again. It is advisable, in the event of sufficient experience not being available, to have such chemical cleaning work performed by specialist firms.



WARNING

Toxic materials.

When performing chemical cleaning work be sure to observe the applicable instructions for the handling of chemicals.

4 Hydraulic Cleaning

Close water inlet valves at the individual cooler sections and then open vent and drain valves. Detach return water channel after the water has been completely drained from the cooler. Keep health and safety guidelines for hydraulic cleaning with high pressure steam.

High-Pressure Water Spray Cleaning

Connect high-pressure water spray cleaning unit and push spray nozzle into each individual tube.

Steam Cleaning

Connect steam lance to a steam generator or operating steam supply. Insert steam lance into each individual tube.

After cleaning, remove cleaning equipment. Refit return water channels, using only new gaskets and place water circuit in service again.

Cleaning Cooler on Air Side

To do this, the cooler sections must be removed according to the respective instruction and set down on a support.

To remove minor contaminations, clean the fins and tubes with dry compressed air.

In case of more severe fouling, high-pressure water spray cleaning may be used. Recommended pressure: 120 bar with 3 mm dia. spray nozzle. Distance between spray nozzle and tube bundle should be approximately 2 meters.

Work Required	Minor inspection	Medium inspection	Major inspection
Perform bearing pedestal insulation measurement	x	x	x
Check bearing surfaces and babbitt bonding by ultrasonic and dye penetration testing			x
Check bearing clearances	x	x	x
Check seat of bearing shell in bearing shell support	x	x	x
Check and renew rigid labyrinth seals if necessary	x	x	x
Check bearing thermometer	x	x	x
Check hydraulic shaft jacking (if existing)	x	x	x
Replace the HP hoses for shaft jacking device (if existing)		x	x

1 General information



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The insulation resistance of insulated bearings should be measured prior to each inspection. If the insulation resistance is found to be bad, a particularly thorough inspection must be made to see whether any form of electrical corrosion (electrochemical erosion) can be found.

The bearings should then be dismantled and cleaned thoroughly. Bearing sleeves and shaft journals should

be checked for proper condition. All parts of the bearings must be examined for signs of wear.

The inspection procedure described above should be performed at all sleeve bearings of the turbine generator.



NOTE:

You will find more detailed information about inspection work on bearings in the supplier's documentation in chapter Components and Purchased Parts.

2 Check the state of wear of all parts of the bearings.

The state of wear of all parts of the bearings must be determined by a visual inspection. Especially the assessment of the bearing surfaces of the bearing shells requires a great deal of experience. In case of doubt, always insert new bearing parts.

The insulating coatings on the spherical surfaces in the upper and lower parts of the housing must be inspected. Contact Siemens without delay if they are found to be damaged.

Work required	Minor inspection	Medium inspection	Major inspection
Electrical measurements			
Check insulation resistance of the windings	x	x	x
Check blocking characteristics of the diodes		x	x
Check RC circuit blocks/overvoltage protection		x	x
Check winding resistance of rotor and stator windings	x	x	x
Visual inspections			
Check condition and function of rotary rectifier wheels, check stator and rotor winding	x	x	x



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Work required	Minor inspection	Medium inspection	Major inspection
Check condition and performance of temperature gauges and alarms	x	x	x
Check condition and performance of grounding brushes	x	x	x
Visually inspect earthing cables (baseframe-enclosure, enclosure-cooler)	x	x	x
Check leakage water supervisory equipment	x	x	x
Check performance of anticondensation heater*	x	x	x

* If existing

Work required	Minor inspection	Medium inspection	Major inspection
Control of shaft lifting (hydrostatic) of bearing before start-up	x	x	x
Control of oil lubrication flow of bearing before start-up	x	x	x
Visual inspection of bearings for any oil leakages	x	x	x
Vibration measurement at various load stages on the entire shafting	x	x	x
Shaft voltage measurement	x	x	x

1 General

During operation of a generator, voltages are set up along the rotor due to magnetic unbalances. This shaft voltage would cause a destructive current to flow through the bearings and other components if the rotor were not insulated from ground at least at the exciter end. For reasons of interchangeability; all stator components coming into contact with the generator rotor are insulated.

2 Checking the Bearing Insulation During Installation

2.1 Bearings

Prior to inserting the rotor and supporting it on the bearings, the insulation resistance of the assembled bearings should be measured separately by means of a 100 V megger applied between the bearing and the base plate. The values measured should be recorded.

The bearing shells are insulated inside the bearing housings. The shaft seals are insulated mounted. The bearing shell potentials are lead out of the bearing housings by wires.

With satisfactory insulation, a value in excess of 0.5 megohms is to be expected. If an insulation resistance value below 0.5 megohms is measured, the insulating parts should be checked for moisture, contamination or metallic contacts. The measurement should be repeated immediately after the rotor has been supported on the bearings.



NOTICE

During this measurement both rotor bearings must be insulated, and the generator rotor must not come into contact with the turbine shaft through measuring devices or similar parts, to prevent the generator rotor from being grounded.

Since, with the rotor inserted, all individual resistances measured previously are now in parallel in the measuring circuit, the total resistance will be slightly lower than the lowest individual resistance value measured before.

2.2 Final Checking

After the generator rotor has been insulated from the bearings, a final insulation check should be performed. The total insulation resistance must not be

less than 0.5 megohms. Due to contact with the shaft, the measuring circuit covers in parallel:

TE/EE bearings with pipework

3 Checking the Bearing Insulation of the Assembled Unit

Checking the bearing insulation during operation may be done by way of the shaft voltage prevailing with the generator running in an excited condition. For this purpose, the potential of the insulated bearings is accessible external to the generator. With the generator running, the components coming into contact with the shaft are separated from the shaft by an oil film, which has insulating properties. Consequently, a non-defined resistance value is set up at the potential measuring points of the bearings which is dictated by the magnitude of the resistances of the oil film and insulating parts. The following method permits the insulation to be checked without disassembly of components being required.

Useful results are, however, to be accepted only if the turbine end of the generator rotor and the turbine shaft are grounded properly during the measurements. Grounding must be maintained to discharge to ground any static charges occurring continuously during operation due to steam and oil film friction.

3.1 Checking the Insulation with the Generator in an Excited Condition

Due to the rotor grounding arrangement at the turbine end, the shaft voltage should be measured at the exciter end. Since the result depends, however, on the function of the rotor grounding system (carbon brush sliding on shaft), the shaft voltage should first be measured according to fig. 1 with the generator running and excited. Normally, this will be an ac voltage of a few volts on which a small dc component is superimposed. Measurement should be performed by means of a voltmeter in the ac range. The voltage should be picked off the shaft for example through a sliding contact with an insulated handle, which is connected to the meter by a cable (all not scope of supply!).

The shaft voltage measured in this way should then be compared with the voltage measured according to fig. 2. If the two readings are not identical, the rotor grounding system should be rectified first before taking any further readings to check the insulation for shaft currents.

If the shaft voltage can be accurately measured according to fig. 2, the measuring brush on the shaft

should first be connected to the potential measuring terminal on the insulated bearing at the exciter end and by means of a cable. The oil film is thus bridged, and the component assumes the shaft potential. With satisfactory insulation, the instrument will continue to indicate a shaft voltage of the original magnitude. Insufficient insulation resistance will result in a current flow through the insulation that can be read on the ammeter. The bridging of the oil film results in a reduction of the original shaft voltage or in its complete collapse.

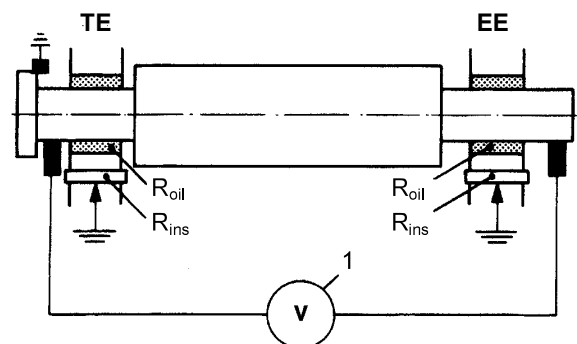
The resulting current can be measured for a brief moment by means of an ammeter connected into the circuit between the measuring brush and the potential measuring terminal (fig. 3).

3.2 Checking the Insulation With the Generator in Non-Excited Condition

A bridge instrument must be used to locate insulation defects with the generator running and in non-excited condition. To measure the resistance of the insulated component with respect to the shaft and ground, the bridge instrument should be connected between this component and ground. The resistances (R_{oil} and R_{ins} in series) of the parts in contact with the shaft are then connected in parallel with the measuring voltage.

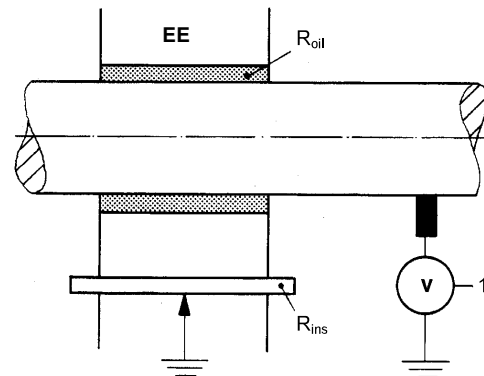
This measurement is not practicable with the generator at standstill, since a stable oil film providing for full insulation can only be formed above a speed of approximately 3.33 to 6.66 s^{-1} .

In case of a low insulation resistance, it must be assumed that the insulation is defective, requiring detailed checking of the insulating parts. Such an insulation test requires great experience in the interpretation of the results and should be performed only by a Siemens specialist.



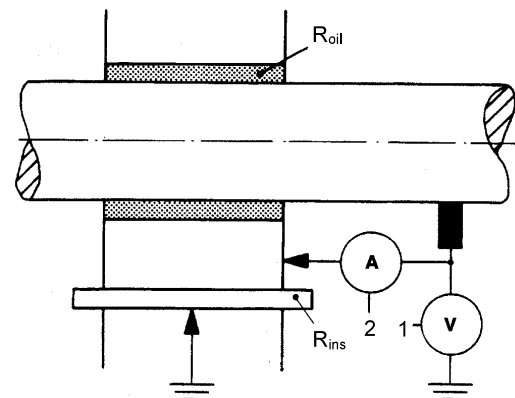
1 Voltmeter (ac range)

Fig. 1 Measurement of shaft voltage with the generator in excited condition



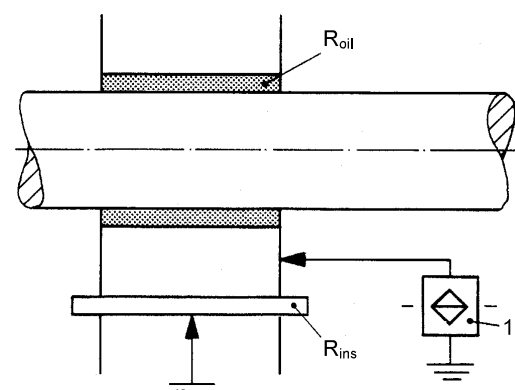
1 Voltmeter (ac range)

Fig. 2 Measurement of shaft voltage at exciter end with the generator in excited condition



1 Voltmeter (ac range)
2 Ammeter

Fig. 3 Measurement of shaft current with the generator in excited condition



1 Bridge instrument

Fig. 4 Measurement of insulation resistance with the generator in non-excited condition

During an inspection, the individual components of the generator are exposed to the ambient conditions which may result in hazards to these components. It is therefore strongly recommended to take suitable measures for preventing any exposure to moisture, especially rain, snow, liquids of any kind and condensation. Covering the components will not afford sufficient protection.

To avoid the above-mentioned hazards, the assembly work during an inspection should be accomplished under protection from weather conditions. The generator should only be opened if an uninterrupted execution of the work will be ensured and provided that the necessary protective measures can be taken. After opening of the unit and withdrawal of the rotor, the stator openings should be promptly reclosed. The stator should be dried by means of a portable air dryer or fan-forced heater and kept above ambient temperature level. The air dryer or fan-forced heater should be arranged so that the air will circulate

through the stator interior in a closed circuit for ventilation of the entire internal space.

The rotor should be protected in such a manner that especially the retaining ring area can be kept dry and above ambient temperature level. The air dryer or fan-forced heater should be arranged so that the air will circulate in a closed circuit.

The cooling water should be drained from the coolers. The coolers should be cleaned, dried and maintained in dry condition by suitable measures.

Normally, a condensation hazard can be recognized with the help of a dewpoint measuring device. In case of doubt, however, it is recommended to dry the components on a continuous basis in order to achieve a markedly low dew-point temperature on these components, i.e. to maintain their temperature above ambient temperature level.

For further information see chapter *Standstill*.

	Description of works to be carried out	To be checked by	Date	Name/Signature
1	Issuing of work permit for works on generator			
2	Area around generator to be barred off (work passes to be issued to individual workers) and supervisor to be nominated for the period the generator is open. Closing during breaks and process interruptions to be assured.			
3	Cleanness check of area around generator			
4	Instruction of workers regarding working inside and around the generator			
5	Listing of all tools used for repairwork inside of generator. Tools to be marked			
6	Checking of inside of generator immediately after manholes are opened (first man inside generator)			
7	All opening of generator, pipework and bearings to be temporarily covered			
8	Listing of all material removed from the generator parts to be collected in separate boxes			
9	Checking of complete generator inside prior to closing of manholes (last man inside generator)			
10	Check of whereabouts of tools used inside of generator			
11	Checking the material removed from generator			
12	Release of generator for start-up			
13	Return of work permit			