EXTERNAL REPORT

ON

MAINTENANCE SCHEDULE CHECKLIST

FOR GEPC - RM COMMISSIONING & SERVICES

HYDRO GENERATORS

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1. **INTRODUCTION**

An effective generator maintenance program is a preventive and corrective maintenance schedule that begins with reviewing a generator’s service history. This review may reveal on-going problems that are both integral to the generator itself as well as external conditions (e.g., overloads, unbalances, misapplications) that are adversely affecting the generator’s normal operating condition. Once regular maintenance checks are incorporated into a shop’s work schedule, they soon become transparent yet will secure cost-savings well beyond the investment in time and materials spent in maintaining them.

The maintenance concept is aimed at reducing the probability of failure or damage to the generator under intensive use and under the environmental operating conditions at the site.

The various preventive maintenance actions must therefore be programmed to ensure:
- the operational availability of the generator in accordance with the functional requirements, at optimum cost efficiency,
- the operational safety of the generator, personnel and environment in observance of the applicable regulations,
- the forecast service life of the asynchronous machines.

Failure prevention must therefore be covered by a preventive maintenance task schedule defined in accordance with the various functionalities of the generator components and predefined criteria relative to their state of deterioration.

This section gives general recommendations aimed at maintaining the functional reliability of the generators. The maintenance actions recommended are not all-inclusive as each site will have its own special operating features. By intensifying and continuously developing maintenance and monitoring, enhanced generator reliability will be ensured.

1.1 **SCOPE OF THE DOCUMENT**

This maintenance checklist is intended for the GE Field Service Engineers. It provides all the essential information for safe maintenance, cleaning, inspections, testing and replacement tasks that are necessary to ensure the proper operation of hydro generators and associated equipment. The term generator used in this checklist refers to all kinds of hydro generators listed in the Product Data (See Section-4 in this document).

We, GEPC are committed to supporting all generations of generators installed by us under our various previous names including

As a service to loyal customers to your shop, provide them with a do-it-yourself maintenance checklist. This should include ensuring that the generator is kept free of dirt and debris and examining drive belts for signs
of excess wear. Only qualified technicians or engineers, who understand the principles of operation of the generator and its Control Panels, shall carry out the maintenance.

Personnel intervening on the generator must be completely familiar with information and instructions contained in this manual. In the event of any contradictory information between the various documents covering the generator, the specific contractual documents shall take precedence over the manual, except as concerns the information stipulated in paragraph “1.2. Limit of responsibility and warranty conditions”.

Should any differences be observed on the equipment with respect to this manual, the user shall make the decisions which he may deem necessary, in accordance with the user's engineering skills. Should any incomprehension or doubt remain, the user should contact Power Conversion Services Department.

1.2 LIMIT OF RESPONSIBILITY AND WARRANTY CONDITIONS

Power Conversion shall not be held responsible for any consequences, direct or indirect, resulting from incorrect reading or interpretation of this manual. Failure to observe the instructions given in this manual will cancel the generator warranty. In such a situation, Power Conversion shall not be held liable for any reason whatsoever.

The warranty is limited solely to conformity of the generator with the contractual specifications. The warranty shall only apply provided the generator is used in compliance with the contractual specifications and in strict observance of the information and instructions given in this manual. The warranty obligations shall be cancelled should any generator be modified or repaired without the prior written approval of Power Conversion.

NOTE
The warranty will only be effective provided the instructions given in this manual are thoroughly and strictly observed and provided the installation report has been submitted to GE Power Conversion as required.

1.3 RELATED REFERENCE DOCUMENTS

2. Hydro Generators Operating Manual
3. Spare Parts List
4. Bolt torque Specification
5. Lubrications List
6. GEI Package

In addition, where referenced, check for updates to any vendor maintenance requirements

2. IMPORTANT INFORMATION ABOUT THE CHECKLIST

The manual defines the minimum requirements for maintenance of the Generators for Hydro Applications. These instructions may not cover all variations in equipment, or provide for every possible contingency in connection with performing maintenances. Depending on the operating conditions and environment, extra work may be necessary to maintain the specified condition of the Generator System.

Pictures used in the manual are generic and may not be indicative of your specific configuration.
Certain tasks identified as ‘optional’ or ‘if equipped’ refer to an optional generator test which may or may not be applicable to other ranges of generators. Refer to the specific generator configuration to determine task applicability.

The owner of the Generator is responsible for ensuring all required maintenance is performed and properly documented. If a contracted party is performing maintenance, we advise reviewing your maintenance contract to determine what elements are included.

Maintenance and repair work may only be carried out by trained technical personnel in accordance with all local and national requirements and standards. For safety reasons, you may enter the generators inside only when supported by a second person, so that help can be provided and called for in the case of an emergency.

When handling grease, oil, and other chemical substances, you must observe the applicable regulations and safety data sheets of the manufacturer of these substances with regard to storage, handling, use and disposal. Ensure that the consumables, the process materials and the replacement parts are disposed of safely and in a compliant and environmentally friendly manner!

This includes but is not limited to the following items of concern:

- operation of generators is not functioning as stated within the Operating Manual, or other applicable GE Energy documentation
- liquid (e.g. coolant) leaking from a cooler component
- cable insulation cracking or excessive wear
- loose connections (typically found when troubleshooting)
- operation of generator (e.g. braking sound) is different than the other equipment of the industry

For questions regarding conspicuous items, please contact the local GE Service Provider.

2.1 MAINTENANCE SUPPORT

If there are any questions regarding the requirements of this manual, operation of the generator, safety warnings, or a specific condition of a generator please contact your GE Power Conversion representative.

While performing the maintenance, communicate any discrepancies and abnormalities (i.e. cracks, damage, excessive pitting, missing or broken hardware, etc.) to your local GE Service Provider.

2.2 PREREQUISITES TO PERFORM MAINTENANCE

Never enter, climb or perform work in the Hydro Systems without the appropriate Personal Protective Equipment (PPE). Always adhere to all local and national safety requirements and standards.

Any unsafe conditions including abnormal turbine operation/response must be immediately addressed by properly trained personnel.

During maintenances, the service switch on the control cabinet must be in the "Maintenance" or "Repair" position and returned to the "Automatic" position after maintenance or repair work has been completed.

Environmental limitations exist for certain activities on the Hydro. No work should occur with electrical storms in the area or below the operating range for the Hydro systems, example: -30°C.
HYDRO SYSTEMS REMOTE START POSSIBLE!
The Hydro system remote must be disabled by placing the service switch in the "repair" or "maintenance" position.

All kinds of generator maintenance require pre-maintenance planning and scheduling. This starts with reviewing the generator’s service history usually contained within an equipment maintenance log or, if the log is not available, interviewing the customer, operator or responsible party to determine what type of maintenance is required, preventative or corrective (failure repair). The goal is to determine:

- What kind of maintenance is required?
- What maintenance personnel are needed to perform the maintenance (skill level)
- What parts are needed to complete the maintenance (i.e., bearings, brushes, etc.)
- What kind of scheduling or coordination with other departments is required to perform the maintenance (downtime or off-hours scheduling)
- What kind of safety hazards exist that would interfere with the maintenance.
- If there are problems other than the generator itself that caused the generator breakdown.

Turbine Control System – Safety Chain
The safety chain is designed to immediately bring the turbine offline by opening the grid circuit contactor and immediately applying the hydraulic brake to stop the generator rotor. The safety chain is designed as the last resort to protect the turbine from entering into an unsafe condition. This system must be checked as part of the maintenance procedure and any deficiencies corrected immediately. This includes the proper Hydro system status messages being displayed by the control system and prevention of the Hydro starting up.

If personnel are at risk or for malfunctions of the energy supply of the Turbine Generator System, actuate the 'Emergency Stop' button immediately.

Protective Systems for the WTGS
The Hydro control system relies on the monitoring and protective functions (thermal generator protection, speed monitoring, over current, fault to ground, etc.) in order to protect personnel and equipment. These systems may not be masked or disabled and any deficiencies (malfunctioning components, incorrect settings, etc) must be corrected if found.

Hydro Turbine Electrical Protective Systems (Fuses, Circuit Breakers, ETC)
The turbine electrical system is designed for the proper functioning of the protective devices installed. No alterations without specific direction from GE engineering are allowed. Alterations include rewiring, changing overload settings, and fuse amperage and time response ratings. These could affect the permissible approach distance, leakage/spark distances, and arc flash potential and place personnel and equipment in danger. Cabinets must be properly secured and all associated electrical protection devices functioning properly to ensure they will contain/redirect any potential arc blast.

Access under (or behind for non-ESS turbines) the DTA section is strictly prohibited unless the grid voltage is completely isolated and grounded through an appropriate LOTO. The DTA is designed to direct certain types of arc flash events under (and behind for non-ESS turbines) the DTA to protect personnel in the DTA area.
2.3 MAINTENANCE AND INSPECTION PROOF REQUIREMENTS

The Maintenance and Inspection Proof issued with the manual is a prerequisite for operation of the Generators may be requested as a prerequisite for warranty approval. The proof is included as Appendix “A” and is the minimum required information to record proof of maintenance.

Conspicuous items or other items of concern must be recorded on the Maintenance and Inspection Proof. You are also advised to contact your GE Power Conversion representative. Failure to do so in a timely fashion may impact safety of personnel, generator performance, component reliability and warranty claims.

Examples of conspicuous items include but are not limited to:
- Items which raise a safety or component reliability concern (vibration, noise, weld cracks, excessive wear or corrosion)
- Electrical component arcing /heat damage, cable insulation cracking /excessive wear
- Abnormal condition of drive train components (coupling slippage, gearbox or generator defects)

A maintenance record can be used for the following purposes:
- Verifies that equipment is routinely checked
- Aids troubleshooting and prevention of equipment failure by providing a history of equipment maintenance and problems

Every day records

a) At what time (year, month, day and hour) and in what weather the test is conducted.
b) Voltage, load current, frequency.
c) Ambient temperature (room temperature).
d) Temperature and noise around bearings.
e) Temperatures in stator windings and on frame surface (totally enclosed type).
f) Abnormal vibrations and noise

Records of periodical test and inspection

a) Insulation resistance and the relative humidity
b) Amplitude of vibration
c) The color and contents of grease discharged from bearings.
d) Dirt lodged in and on the generator.
e) Coupling allowance of coupling device; the tension of belts.
f) Fastening bolts for base, foot and other parts.
g) In case of oil lubrication, surface condition and clearness of the oil should be recorded. At the same time, check and make sure there is no leakage.

Some of the values obtained by above-listed tests and inspections are variable; their variable ranges given below:

a) The variation of voltage must be within ±10% of rated voltage. The variation of frequency must be within ±5% of rated value. When rated voltage is applied. When voltage and frequency varies at the same time, the result of absolute values of the two variations must be within ±10%.
b) Temperature rise (maximum ambient temperature of 40°C)
c) Bearing Vibration: In case the vibration measured exceeds the above-specified values, please adopt check and find out the trouble, and corrective measures soonest.
2.4 ALTERATIONS, MODIFICATIONS, AND REPLACEMENT PARTS

Alterations to the generator may adversely affect its operation. Alterations could potentially cause catastrophic failures and include life threatening situations. Only those alterations and modifications specifically authorized by General Electric are permitted. Replacement and maintenance parts must meet all technical requirements specified by GE Power Conversion to ensure proper functioning of the generator and its protective systems. Ordering parts through GE Power Conversion will ensure these specifications are met.

2.5 TRAINING AND SAFETY GUIDELINES

The hydro generator is a specialized equipment that requires equipment specific and other specialized training. Working on/in a hydro plant has unique dangers and significantly reduces the ability of rescue personnel to assist in emergencies. At a minimum there should be two personnel at a time on a turbine trained in the specific hazards and appropriate emergency procedures. This should include emergency isolation points for electrical and hydraulic energy in addition to basic hydro plant controls and operations. Always refer to local and national laws and regulations when determining safety, training, and staffing requirements.

2.6 GE SERVICE AGREEMENTS

From a frame agreement to a full O&M package, GE proposes tailor-made service agreements for the whole fleet, plant or any other type of equipment, meeting all customers’ operational, maintenance and support requirements: flexible in scope of services – from training and technical support to emergency repairs, parts and assessment – equipment covered, as well as contract duration and risk sharing.

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GE Service Agreements
3. **BASIC SAFETY INSTRUCTIONS**

Please observe the Operating Manual and the Safety Manual. Since the generator can be started by the remote control system, it must be shut down and appropriate LOTO applied for maintenance work. The service switch on the control cabinet must also be placed in the “Maintenance” or “Repair” position. The service switch must be placed back in the “Automatic” position after maintenance or repair work has been completed.

Follow the instructions included in these documents as well as all safety signs and marks within the generator. Adhere to all local and national safety requirements and standards.

Never enter or perform work in the Generators without the appropriate Personal Protective Equipment (PPE).

This maintenance manual is not meant to instruct individuals on the proper operation or the safety requirements of the entire range of GE Generators. Included safety warnings highlight only certain hazards and are not all inclusive. Variations in equipment may pose additional hazards to those highlighted. Individuals / companies performing this work are responsible for understanding the scope of work specified within this manual and the associated activities necessary such as working at heights, Environment, Health and Safety, etc. They are responsible for determining and enforcing the training and safety standards for performing this work, complying with Local / National regulations, and the guidelines specified in the Operating Manual.

When handling any chemical substance, you must observe all applicable regulations and the manufacturer’s safety datasheets of these substances with regard to storage, handling, use and disposal. Ensure that all consumables and materials are disposed of in a safe and environmentally friendly manner.

3.1 **EXPLANATION OF THE SYMBOLS**

The basic information for technical documentation for Generator is described in the Safety Manual. The following danger classifications and symbols are used in this Maintenance Manual:

- **NOTE**
  - Notes include user tips and useful information.
  - All notes should be implemented in the interest of a proper use of the generator.

- **ATTENTION**
  - Indicates a procedure, condition, or statement that should be strictly followed to improve these applications.

- **CAUTION**
  - Indicates a potentially Hazardous situation which if not avoided could result in a minor or moderate injury or destruction damage.

- **WARNING**
  - Indicates a potentially Hazardous situation which if not avoided could result in death or serious injury.

- **DANGER**
  - Indicates an imminently Hazardous situation which if not avoided will result in death or serious injury.
<table>
<thead>
<tr>
<th>Hazard</th>
<th>Associated symbol</th>
<th>Hazard</th>
<th>Associated symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hazard caused by accumulator</td>
<td></td>
<td>Floating load</td>
<td></td>
</tr>
<tr>
<td>Electromagnetic field</td>
<td></td>
<td>Poisons</td>
<td></td>
</tr>
<tr>
<td>Magnetic fields</td>
<td></td>
<td>Automatic re-start</td>
<td></td>
</tr>
<tr>
<td>Harmful materials</td>
<td></td>
<td>Chemicals &amp; Corrosives</td>
<td></td>
</tr>
<tr>
<td>Trip hazard</td>
<td></td>
<td>Falling hazard</td>
<td></td>
</tr>
<tr>
<td>High voltage/Electrical shock</td>
<td></td>
<td>Fire-promoting materials</td>
<td></td>
</tr>
<tr>
<td>Explosives</td>
<td></td>
<td>Flammable materials</td>
<td></td>
</tr>
<tr>
<td>Explosive atmosphere</td>
<td></td>
<td>Hot surface</td>
<td></td>
</tr>
<tr>
<td>Gas container</td>
<td></td>
<td>Slippery</td>
<td></td>
</tr>
<tr>
<td>Hand injuries hazard</td>
<td></td>
<td>Heavy load</td>
<td></td>
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**Hazard Signs**

<table>
<thead>
<tr>
<th>Prohibition</th>
<th>Associated symbol</th>
<th>Prohibition</th>
<th>Associated symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>General prohibition</td>
<td></td>
<td>Prohibition for person with cardiac</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>pacemaker</td>
<td></td>
</tr>
<tr>
<td>No fire, open lights and smoking</td>
<td></td>
<td>Prohibition for persons with implants</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td>made of metal</td>
<td></td>
</tr>
<tr>
<td>Do not touch</td>
<td></td>
<td>No standing</td>
<td></td>
</tr>
<tr>
<td>Do not operate</td>
<td></td>
<td>No mobile phones or radios</td>
<td></td>
</tr>
</tbody>
</table>

**Prohibition Signs**
### Mandatory Action Signs

<table>
<thead>
<tr>
<th>Mandatory action</th>
<th>Associated symbol</th>
<th>Mandatory action</th>
<th>Associated symbol</th>
</tr>
</thead>
<tbody>
<tr>
<td>General requirement</td>
<td>![Warning]</td>
<td>Use hard hat</td>
<td>![Helmet]</td>
</tr>
<tr>
<td>Disconnect before open</td>
<td>![Stop]</td>
<td>Use protective clothes</td>
<td>![Safety Vest]</td>
</tr>
<tr>
<td>Safety tagging before work</td>
<td>![Stop]</td>
<td>Use respiratory protection</td>
<td>![Face Mask]</td>
</tr>
<tr>
<td>Use catching belt</td>
<td>![Axe]</td>
<td>Use safety belts</td>
<td>![Goggles]</td>
</tr>
<tr>
<td>Use ear protection</td>
<td>![Ear Defenders]</td>
<td>Use welding shield</td>
<td>![Welding Mask]</td>
</tr>
<tr>
<td>Use eye protection, safety glasses</td>
<td>![Eye Protection]</td>
<td>For pedestrians</td>
<td>![Pedestrian]</td>
</tr>
<tr>
<td>Use foot protection</td>
<td>![Boots]</td>
<td>Lockout prior to work</td>
<td>![Lock]</td>
</tr>
<tr>
<td>Use full face protection</td>
<td>![Goggles]</td>
<td>Use/follow walkway</td>
<td>![Walkway]</td>
</tr>
<tr>
<td>Use hand protection</td>
<td>![Gloves]</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

### 3.2 APPLICABLE REGULATIONS

Reminder about essential data of explosive atmosphere marking (ATEX/IEC/IECEx):

- Manufacturer: GE Power Conversion
- Address: 442, Rue de la Rompure
- 54250 Champigneulles (France)
- Type: xxxxxxxx x / xx
- Manufacturing year: 20xx
- EC marking: xxxx - xx xx xx
- Marking: xx x xx xxxx xx
- Number of EC examination type certificate: xxxxxxx xxxxxxx xxxxxxx

For a reliable use of this machine, particular cautions* have to be taken, including the following complementary conditions:
- The space heater into air has to be switched on when the generator is stopped and cooled down to ambient temperature. The space heater into oil has to be switched on just before generator starting. The space heater must be switched off when the generator is in operation.
- The temperature probes must be connected to a system to monitor the generator and to switch off the generator in case of temperature comes to the trip value.
- All electrical accessories ensuring proper service and safety of the machine shall be of recognized protection mode for the considered use, if they are placed in a hazardous area.

(*) Subject to the installation, maintenance and use in compliance with their destination, the regulation, installation standards in effect (EN/IEC 60079-14) to the manufacturer instructions and good engineering practices.

When the certification standard is EN/IEC (following the standard selected for the certification):

- Installation, maintenance and eventual repairs on the generator have to be executed under appropriated conditions.
- Regarding the risk of electrostatic discharge: when gas group is IIC and the paint thickness on the surface of the material is greater than 0.2 mm, clean with a damp cloth.

User has to take into account external conditions (humidity, salinity, altitude, etc.) and take the appropriate measures to protect the generator. The compliance to these is fully the responsibility of the user.

### 3.3 COMMON HAZARDS

#### DANGEROUS CONSEQUENCES FOR YOUR HEALTH AND THE TURBINE!

Always check all work areas and cabinets before concluding the work. Remove all loose parts, tools and materials from the control cabinets. Tools and materials left in the control cabinets lead to unsafe working conditions for the service technicians when the plant is placed into operation.

**LIFE-THREATENING HAZARD FROM STARTING THE HYDRO PLANT BY THE REMOTE CONTROL SYSTEM!**

Shut down the Hydro plant for maintenance work. Place the service switch on the control cabinet in the "Maintenance" or "Repair" position, and ensure the unit is secured from remote start up.

**LIFE-THREATENING HAZARD FROM ELECTRICAL VOLTAGE!**

First de-energize the electrical equipment to prevent electric shock.

**LIFE-THREATENING HAZARD FROM ELECTRICAL VOLTAGE!**

Electromagnetic fields (EMF) are present within the Hydro generators. EMFs have the potential to adversely affect the operation of a cardiac pacemaker or defibrillator. If you have a cardiac pacemaker or defibrillator implanted inside your body, consult your doctor and/or device manufacturer to determine whether or not you are at risk around Hydro generator components. If EMF measurements are required, then please contact GE for assistance.
3.4 SPECIAL DANGERS – ELECTRIC POWER

Working on / near electrical systems pose significant and unique dangers and all personnel must be properly trained on these hazards. Follow all applicable LOTO rules and ensure that all power supplies (including auxiliary) are disconnected, stored energy (capacitors, batteries, etc.) is discharged or isolated, and where appropriate grounding or short-circuiting of the circuit is performed. Be aware that rotating machinery may generate electrical energy even when offline and lock out where appropriate.

Note the following rules when carrying out any work on the electrical components of the plant, e.g. assembly, connection, opening of a device, and maintenance:

1. disconnection
2. secure against re-connection
3. ascertain safe isolation from supply
4. grounding and short-circuiting
5. cover up adjacent live components or provide them with barriers

In addition, ensure that all drives are at a standstill and all stored energy is removed from the system.

---

**LIFE-THREATENING HAZARD FROM ELECTRICAL VOLTAGE!**

When energized, electrical installations and machinery may contain live exposed conductors or rotating parts. These could cause personal injury or death and material damage if the cover and/or safety devices are removed, or in the event of improper handling, maintenance, or use. Be sure to comply with the applicable safety regulations.

In addition, electrical energy may still be present in devices even after the supply voltage to the device has been switched off. Be sure to secure such devices from re-energization and access until all stored energy has been removed or discharged. Always check for residual voltage before starting work.

Observe the relevant Lockout/Tagout instructions, the Operating Manual, and the Safety Manual.

---

**DANGEROUS CONSEQUENCES FOR YOUR SAFETY AND THE GENERATORS!**

**Electric Shock/Electrocution/Arc Flash Hazards**

Only use fuses with the prescribed amperage! In the case of repairs, care should be taken that design features are not modified in such a way that safety is compromised (e.g. leakage distances and sparking distances in air/approach limits) and that distances are not reduced by insulation materials.

The control system, monitoring and protective functions (generator protection, speed monitoring, fault to ground, etc.) may not be masked or disabled – even for testing.

---

**CONTROL SYSTEM WARNINGS!**

To prevent personal injury or damage to equipment, follow all equipment safety procedures, Lockout Tag out (LOTO), and site safety procedures as indicated by Employee Health and Safety (EHS) guidelines.

This equipment contains a potential hazard of electric shock, burn, or death. Only personnel
who are adequately trained and thoroughly familiar with the equipment and the instructions should install, operate, or maintain this equipment.

Isolation of test equipment from the equipment under test presents potential electrical hazards. If the test equipment cannot be grounded to the equipment under test, personnel must shield the test equipment's case to prevent contact.

To minimize hazard of electrical shock or burn, approved grounding practices and procedures must be strictly followed. To prevent personal injury or equipment damage caused by equipment malfunction, only adequately trained personnel should modify any programmable machine.

Always ensure that applicable standards and regulations are followed and only properly certified equipment is used as a critical component of a safety system. Never assume that the Human-machine Interface (HMI) or the operator will close a safety critical control loop.

### 3.5 GUIDANCE NOTES FOR USERS ON THE SAFETY OF PERSONNEL

During Maintenance, Testing, etc. ensure that only technically competent and authorized persons are permitted to carry out work and that they:
- comply with statutory requirements
- Isolate the apparatus completely, where possible, before opening enclosures and starting work.
- comply with safe working procedures for the safety of themselves and of others, including the use of temporary barriers and warning notices
- are conversant with the information provided, particularly on measures relating to safety
- recognize the hazards which can arise when working on live apparatus and take all the necessary precautions

#### 3.5.1 Equipment under maintenance
- Technical documentation
- Safety instructions
- Right tools

#### 3.5.2 Intervention on electrical equipment
- Equipment isolation
- Power supply off
- Checking before & after intervention

#### 3.5.3 Intervention on mechanical equipment
- Equipment isolation
- Handling conditions
- Checking & Cleaning after intervention

#### 3.5.4 Intervention on hydraulic circuit
- No pressure
- Drain circuit
- Avoid leaks
- Handle solvents with care
- Check before restart
3.5.5 Intervention on compressed air circuit

- Depressurize circuit
- Air compressors data sheet
- Compulsory periodic inspection
- Safety valve rating

Local safety regulations must be observed during erection, commissioning and maintenance of the product. Persons performing this work must be suitably skilled and have been trained to work on this equipment.

**WARNING**

The following general guidelines are provided for your safety and prevent damage to the equipment. Any work on this equipment should only be performed by suitably qualified, competent and medically fit personnel.

Ensure appropriate PPE is used at ALL times.

- All items exposing high voltage must be placed in a suitable enclosure with restricted access.
- This equipment may be connected to more than one live circuit. Disconnect all supplies before working on the equipment. Follow lock out tag out safety procedure.
- Do not touch any terminal part when electric power is ON. This may cause electric shock.
- In case the product is used erroneously, it may cause serious accidents and death.
- Extinction systems. These transformers should be installed in such a way that the heat generated does not represent a fire risk for the materials nearby.

**DANGER**

The site lock out tag out procedure must be followed.

3.6 LOTO

Before any work commences, obtain and review the commissioning site Lock out Tag out (LOTO) procedure. Do not continue until the LOTO procedure has been obtained and deemed satisfactory.

It shall be confirmed that no cabinets could be de-isolated without the knowledge of those working on the cabinets. The permit for any work should have its own isolation carried out or if another isolation is in force for other work, reference to all work protected by a single isolation should be made. At a minimum, the procedures detailed in the Health and Safety Manual should be observed.

3.7 SKILLS REQUIRED FOR SPECIFIC TASKS

Information provided in this manual on the conditions necessary for safety and on any hazards that are reasonably foreseeable during maintenance, together with precautions to be taken to counteract them. However, in certain circumstances, technically competent and authorized personnel may have to gain access
to apparatus, which is not completely electrically isolated. Everyone, under whose authority these persons act, is advised to ensure that appropriate safety procedures are generated and are complied with.

The equipment covered by this manual has been allocated the Apparatus Grade 3. Reference to the Apparatus/Task/Skill Level Schedule, enables the user to select personnel to carry out specified tasks.

### Table-1: SKILL LEVELS

<table>
<thead>
<tr>
<th>Skill Level</th>
<th>Proposed by Supplier</th>
<th>Customer</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>Operating and maintenance staff with NO electrical knowledge</td>
<td></td>
</tr>
<tr>
<td>B</td>
<td>Maintenance staff with SOME electrical knowledge: not permitted to work on live apparatus</td>
<td></td>
</tr>
<tr>
<td>C</td>
<td>Authorized and competent staff (e.g. Electrician, Commissioning Engineer) with HIGH degree of electrical expertise: trained to work on live apparatus and fully conversant with the apparatus.</td>
<td></td>
</tr>
</tbody>
</table>

### Table-2: APPARATUS/TASK/SKILL LEVEL SCHEDULE FOR ELECTRICAL APPARATUS

<table>
<thead>
<tr>
<th>Grade</th>
<th>Degree of Isolation</th>
<th>Isolation</th>
<th>Setting, Cleaning, Routine Maintenance with POWER OFF</th>
<th>Setting, Routine Testing with POWER ON</th>
<th>Special Testing, Commissioning Fault Finding with POWER OFF</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Simple 100% Isolation. Requires no electrical knowledge to isolate.</td>
<td>A</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>2</td>
<td>Simple 100% Isolation. Requires some electrical knowledge to isolate.</td>
<td>B</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>3</td>
<td>100% Isolation possible. Requires expertise, training etc. and knowledge of the apparatus.</td>
<td>C</td>
<td>B</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>4</td>
<td>100% Isolation not possible because: - Impracticable - Unreasonable - Undesirable</td>
<td>C</td>
<td>C</td>
<td>C</td>
<td>C</td>
</tr>
<tr>
<td>5</td>
<td>Apparatus supplied as loose items chassis etc., for which the customer is responsible for wiring, assembly, etc.</td>
<td>Level of Skill cannot be define by Supplier</td>
<td></td>
<td></td>
<td>C</td>
</tr>
</tbody>
</table>

---

**CLASS II (GE INTERNAL NON-CRITICAL)**

- **Author**: Muthukkumaran, S
- **DocRef**: Maintenance Schedule Checklist for Hydro Generators.docx
- **Revision**: 000
- **Date**: 11/08/2017
- **Page**: 17/65
4. **PRODUCT DATA**

This Maintenance Schedule Checklist covers following ranges of hydro generators installed by GE.

- **Low speed hydro generators** – Bulb turbine
- **Low speed hydro generators** – Kaplan turbine
- **Medium speed hydro generators** – Francis turbine
- **High speed hydro generators** – Pelton turbine
- **Hydro Motor-Generator** – Pump-Turbine
GLOBAL TECHNOLOGY, LOCAL PRESENCE

GE’s broad service portfolio in hydro generator operator’s efforts in making their plants more competitive: meeting all Installed Base challenging requirements, it covers all equipment, from commissioning to end of lifetime: Training, Parts, Diagnosis & Monitoring, Maintenance & Repairs, Service agreements, and Retrofit.

With over 1,000 Field Service Engineers operating in more than 170 countries and a range of Global Excellence Centers, GE supports customers with strong technology and engineering capabilities with quick access to experts.

Portfolio GE

GE product ranges are from First Synchronous generator to High Power Induction machine (Asynchronous)

1887: 1st Synchronous Generator
• 2,800 W, 960 rpm at 32 Hz
• Friedrich A. HASELWANDER

2015: 1st Run of GE VARSPEED (Asynchronous) – LINTHAL
• 250 MVA – 50 Hz
• from 461 rpm to 530 rpm
Motor-generator units are subject to numerous thermal cycles and high centrifugal forces and need to withstand potential fault disturbances such as short circuits. Taking into account these requirements which are particularly important for peak-load units, we incorporate the following features in our design of motor-generators:

- Structural design with oblique elements
- State-of-the-art thrust bearings
- Permanent pre-stressed stator core
- VPI insulation system and slot ripple spring (reliable even under extreme operating conditions)
- Self-ventilated rotor rim (standard or high speed design)
- Bent pole coils (for easier assembly and better surface cooling)
- Active Power up to 500 MW*
- Stator Voltage: up to 21 kV*
- Speed: up to 750 rpm*
- Rotor diameter: up to 10 m*

**Servicing over the Life-Cycle of PSPP**

Based on its comprehensive knowledge of all type of equipment and global fleet experience, component integration and interfacing, GE provides standardized and tailored solutions to maximize PSP availability & reliability, meeting business goals in flexibility and performance improvement.

**Interfaces Systems**

1. Combined bearing
2. Closing pit
3. Coupling shaft turbine and generator rotor
4. Turbine kaplan drive head
5. Oil piping for kaplan drive / air valve for francis turbine
6. Bases in the concrete / lay out / lifting plan of big components (housing, upper bracket, floors, passages and access)
7. Terminals output: phase and neutral / excitation
8. Air/water cooling system
9. Oil cooling system for bearing
10. Auxiliary systems
11. Wiring and instrumentation
12. Firefighting system
13. Ground protection

Ventilation / Cooling System

Combined Bearing System

Combined Bearing Load and Strength

Size / Dimensions of Generator Spider rotor
5. **OVERVIEW OF THE MAINTENANCE WORKS**

Proper schedule of preventive maintenance helps to prevent, detect, and correct conditions that could cause equipment malfunction. This includes inspections for damage and wear, testing, and cleaning of equipment at regular intervals.

---

**Warning**

This equipment contains a potential hazard of electric shock or burn. Only adequately trained persons who are thoroughly familiar with the equipment and the instructions should maintain this equipment.

To prevent electric shock while servicing the equipment, personnel must understand and follow all safety requirements for working around dangerous voltages.

---

Maintenance procedures involve cleaning the equipment and checking for wear and damage through visual inspection and functional testing.

---

**Warning**

To prevent electric shock, make sure all power supplies to the generators are turned off. Ground and discharge equipment before performing any adjustments, servicing, or other acts requiring physical contact with the electrical components or wiring.

Before performing any maintenance procedures, the generator must be de-energized. Do not deviate from the provided de-energizing procedures. If safety requirements cannot be met completely, or if you do not understand them, do not work on the equipment.

Circuit breakers, fuses, and electromechanical devices within the exciter cabinet should not be used as lockout devices. Breakers do not isolate wiring and devices on the line side of the breaker, and electromagnetic devices are not positive isolation since they can be electrically operated.

---

5.1 **MAINTENANCE TYPES**

<table>
<thead>
<tr>
<th>Failure</th>
<th>Planned</th>
<th>Determined Thresholds</th>
<th>Parameters Evolution</th>
</tr>
</thead>
<tbody>
<tr>
<td>Corrective Maintenance</td>
<td>Preventive Maintenance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Palliative Maintenance</td>
<td>Curative Maintenance</td>
<td>Systematic Maintenance</td>
<td>Conditional Maintenance</td>
</tr>
<tr>
<td>Troubleshooting, Repair</td>
<td>Refurbishment</td>
<td></td>
<td>Replacement or Repair</td>
</tr>
</tbody>
</table>

5.1.1 **Corrective Maintenance**

Maintenance is activity executed after a failure detection in order to make the equipment able to fulfil its required function.

Failure Thresholds reached:
- Troubleshooting
- Repair
Palliative Maintenance

Curative Maintenance

5.1.2 Preventive Maintenance
Maintenance is activity executed in order to reduce the probability of failure or damage of an equipment.

Plant Operator benefit:
- Reliability of equipment
- Reduction of unavailability period
- Increase of equipment lifetime

Conditional Maintenance (or 1st level or routine maintenance)

Conditional Maintenance, survey of equipment, subsequent actions
- Without installation shutdown (weekly, monthly, quarterly)
- With installation shutdown (annually)

Systematic Maintenance (or 2nd level or minor & major overhaul)

Systematic Maintenance, no preliminary check, regular interval
- Installation Shutdown
- Equipment Dismantling

Minor Overhaul
- Partial machines inspection
- Operational safety

Major Overhaul
- Minor overhaul inspections
- Casings opened, Rotors taken out
- Finger point [point zero]

Predictive Maintenance

Predictive Maintenance, analyse & evaluation, forecast program
Operating data survey
- Measurement = Instrumentation
- Protection = alarm/trip thresholds
- Record = DCS

5.2 MAINTENANCE INTERVALS

Maintenance tasks plan are broken into four basic periods. Failure to maintain the equipment within the period specified may have an adverse effect on the performance of the Hydro generators or its sub-components and could impact the warranty of certain components.

Machines should not be dismantled more often than necessary; it may be possible under good conditions to reduce the frequency of inside inspection and cleaning to once every five years. It is undesirable for the interval to be longer. The required frequency for each procedure depends on:
- How much the equipment is used
- Operating load conditions
- Ambient environmental conditions

5.2.1 Maintenance Tasks Plan

1. During normal speed operation
2. During transients
3. At standstill
4. During maintenance inspections & repair activity
5.2.2 Maintenance Frequencies (or Intervals)

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Daily</td>
<td>These tasks include cleaning of functional surfaces and checking the nut or the screw or special pin are still at the initial position (paint marking) and not broken.</td>
</tr>
<tr>
<td>Weekly</td>
<td>These tasks include some simple physical tests like the pre-stress checking of the bolting.</td>
</tr>
<tr>
<td>Monthly</td>
<td>These tasks must occur between the period when 360 operational hours have been achieved on the Hydro. These tasks are the routine maintenance tasks include adequate cleaning and inspection as major tasks during this period.</td>
</tr>
<tr>
<td>Semi Annually</td>
<td>These tasks must be completed within 6 months of the anniversary of the 360 operational hour mark of the Hydro and at least once every 7 months thereafter. These tasks should be completed in addition to any other maintenance tasks due during this period.</td>
</tr>
<tr>
<td>Annually</td>
<td>These tasks must be completed by the 12 month anniversary of the 360 operational hour mark of the Hydro and once every 13 months thereafter. These tasks should be completed in addition to any other maintenance tasks due during this period such as the semi-annual maintenance tasks and any special maintenance tasks due such as oil changes.</td>
</tr>
<tr>
<td>Beyond Regular Maintenance</td>
<td>Those tasks that occur at an extended, infrequent or irregular manner such as oil changes, converter coolant exchange, and anchor bolt tensioning, etc. These tasks should be completed at the frequency specified within the pertinent maintenance manual section, as called for within the vendor’s manual or as directed by GE engineering.</td>
</tr>
</tbody>
</table>

Table-3: MAINTENANCE INTERVALS

Unless otherwise specified by contract, a general inspection should be carried out at least two times per year (or after 4000 hours of operation). If the machine is in use daily, GE recommends that inspection of the machine at standstill shall be performed at intervals of approximately EVERY THREE MONTHS without dismantling anything.

The Optional 12 month program is only available for Hydro plant with fully installed and operational auto-lubrication systems. These are necessary for lubricating components to protect against wear and corrosion.

Certain maintenance tasks may be moved to occur at any maintenance cycle to accommodate site needs but must be completed within the specified period.

ATTENTION

12 month optional maintenance interval is only applicable for units with complete auto lubrication systems.

We strongly recommend that Customer shall contact on Power Conversion’s expert services for assistance in isolating the causes of a malfunction and the procedures to be applied when a malfunction is observed. All work performed must be logged in a maintenance record; this work record will be useful to both the customer and the manufacturer.
### 5.3 SCOPE OF MAINTENANCE

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Maintenance Activity</th>
<th>1&lt;sup&gt;st&lt;/sup&gt; Level</th>
<th>2&lt;sup&gt;nd&lt;/sup&gt; Level</th>
<th>3&lt;sup&gt;rd&lt;/sup&gt; Level</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>Monthly (after 360 hrs or every 4,000 hrs)</td>
<td>Annually (every 8,000 hrs of operation)</td>
<td>Beyond Regular Maintenance (every 5 Years i.e., 40,000 hrs of operation)</td>
</tr>
<tr>
<td>1</td>
<td>Regular Maintenance</td>
<td>✓ Standard visual inspection, ✓ Standard cleaning tasks and ✓ Standard functional tests</td>
<td>✓ Complete Visual Inspection ✓ Advanced cleaning (if required) ✓ Additional major tests if required.</td>
<td></td>
</tr>
<tr>
<td>2</td>
<td>Mechanical Disassembly &amp; Overhauling</td>
<td>- ✓ Open inspection of generator subassemblies</td>
<td>✓ Disassemble and Overhauling of major parts such as rotor</td>
<td></td>
</tr>
<tr>
<td>3</td>
<td>Repair / Refurbishment</td>
<td>- -</td>
<td>Component repairs and rotating machine refurbishment After any refurbishment, additional tests shall be performed</td>
<td></td>
</tr>
<tr>
<td>4</td>
<td>Monitoring &amp; Diagnostics</td>
<td>- ✓ Conduct a spectral Analysis to detect various malfunctions</td>
<td>! This calls for specialised know-how, covering all preventive &amp; corrective maintenance actions if required.</td>
<td></td>
</tr>
<tr>
<td>5</td>
<td>Capacity Upgrades / Life cycle expansion projects</td>
<td>- -</td>
<td>✓ Performance improvement ✓ Capacity upgrades ✓ Reliability Centered Maintenance (RCM) tasks</td>
<td></td>
</tr>
<tr>
<td>6</td>
<td>Spares &amp; Parts Replacement</td>
<td>- -</td>
<td>✓ Spare parts availability ✓ Obsolescence management</td>
<td></td>
</tr>
<tr>
<td>7</td>
<td>Responsive Support</td>
<td>- -</td>
<td>✓ Field installation, commissioning and start-up ✓ Maintenance, technical assistance and expert support</td>
<td></td>
</tr>
<tr>
<td>8</td>
<td>Contractual Services</td>
<td>- -</td>
<td>✓ From basic time and material to performance based contracts ✓ Remote monitoring and diagnostics (VISOR) ✓ Fleet management (Marine, Offshore, Navy)</td>
<td></td>
</tr>
<tr>
<td>9</td>
<td>Mobile &amp; Interactive Training</td>
<td>- ✓ As agreed through service orders</td>
<td>- -</td>
<td></td>
</tr>
<tr>
<td>10</td>
<td>Documentation</td>
<td>✓ To be submitted as per the service order agreement</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Table-4: SCOPE OF MAINTENANCE**
### Term

<table>
<thead>
<tr>
<th>Term</th>
<th>Task Type Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Regular Maintenance Care for the Customer needs</td>
<td>At GE, we understand that the goals of your organization are demanding, and evolving. To help you meet these goals here at GE Power Conversion we provide a service that goes beyond just waiting for your call. We offer a comprehensive range of aftermarket services including replacement units, field services, spares, service agreements, unit upgrades and technical support. Our mission is to satisfy our customers aftermarket needs.</td>
</tr>
<tr>
<td>Disassembly &amp; Overhauling</td>
<td>GE installs the equipment with confidence. Our team of field service engineers are on hand to ensure your assets go into active service functioning efficiently.</td>
</tr>
<tr>
<td>Visual Inspection &amp; Cleaning</td>
<td>Inspection by technicians eyes of the proper condition of installed equipment. This can include cleaning of the WTG to allow proper inspection or use of a tool such as a boroscope to inspect the internals of such components as the gearbox or shaft coupler. Visual inspection of torque markings will fall under this section.</td>
</tr>
<tr>
<td>Function Test</td>
<td>A physical measurement of a generator or check of proper operation of installed equipment. This uses the technician’s hands for simple operation through more sophisticated test equipment such as thermographic imaging equipment.</td>
</tr>
<tr>
<td>Diagnostics and Specialized</td>
<td>Delivering state of the art test and diagnostic services, our specialist field engineers will apply our in house analysis tools to analyse the asset’s performance. We work together with the customer to resolve those issues on installations in the field efficiently and reliably.</td>
</tr>
<tr>
<td>Enhanced Technical Support</td>
<td>We offer enhanced technical support to customers with service agreements. Our enhanced technical support agreements are designed to suit your specific needs including the availability of 24/7 on-call technical assistance, remote support and immediate mobilization to emergencies.</td>
</tr>
<tr>
<td>Lubrication Task</td>
<td>Testing, measuring, adding or exchanging oil, grease or coolant within WTG components. This is typically associated with fluids that are maintained in bulk quantities. It does extend to the replacement of oil filters.</td>
</tr>
<tr>
<td>Torque Requirement</td>
<td>The physical application of torque specifically to fasteners which are particularly critical to the operation and safety of the hydro generator. These tasks are typically not performed on fasteners that have been treated with thread locking compound.</td>
</tr>
<tr>
<td>Repair / Replacement / Refurbishment</td>
<td>Items within the WTG are replaced as an expected wear item such as filters, grease cartridges and bearing seals. Any items that end up being replaced, but not specifically called out as a replacement task, are a result of defects found during other inspection steps and are repairs of defects and not maintenance items themselves.</td>
</tr>
<tr>
<td>Modifications and upgrades</td>
<td>To extend the life of your asset, our engineering design team will provide you with suitable upgrade options aligned to meet your technical specification and requirements to improve</td>
</tr>
<tr>
<td>Spares and Consumables</td>
<td>The GE Parts team is available to advise the appropriate spares and consumable parts for you to hold in stock. For those emergencies the team will provide the parts you need on time and at the quality you expect.</td>
</tr>
<tr>
<td>Training programs</td>
<td>Through our in-depth training modules we provide our customers with the knowledge and skills to operate and maintain equipment in the field.</td>
</tr>
<tr>
<td>Documentation</td>
<td>As part of the service, customers will receive a Final Report documenting the results of the electrical tests and visual inspections performed, as well as both immediate and long term recommendations. Recommendations related to spare parts, future repair needs and additional proposed inspection schedules are also included.</td>
</tr>
</tbody>
</table>
6. REGULAR MAINTENANCE (OR 1ST LEVEL MAINTENANCE)

6.1 STANDARD VISUAL INSPECTION

Prior to start up the Maintenance; discuss with the customer any existing/previous issues with the generator.

<table>
<thead>
<tr>
<th>CAUTION!</th>
</tr>
</thead>
<tbody>
<tr>
<td>Care should be taken that no live parts should be accessed without isolation of AC Breaker as it contains Electrical danger</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>DANGER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Life-threatening hazard from electrical voltage!</td>
</tr>
<tr>
<td>Prior to working on the generator, the unit must be completely de-energized and isolated for safety in accordance with local and national regulations.</td>
</tr>
<tr>
<td>Observe the relevant Lockout/Tagout instructions.</td>
</tr>
<tr>
<td>Wear appropriate PPE for entrance into energized cabinets.</td>
</tr>
<tr>
<td>Due to the design of the generator (permanent magnet excitation) a high voltage is generated at the stator winding when mechanically rotating the machine!</td>
</tr>
<tr>
<td>Never open the terminal box or work on the installation while the machine is rotating!</td>
</tr>
<tr>
<td>The (high-speed if equipped) rotor lock must be applied prior to working on the generator with exception of manual bearing greasing tasks.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>WARNING</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dangerous consequences for your health and the Hydro Plant!</td>
</tr>
<tr>
<td>Only adequately trained persons who are thoroughly familiar with the equipment and the instructions should maintain this equipment.</td>
</tr>
</tbody>
</table>

The schedule should include at least the following items during visual inspection of a generator, wiring and its components before re-applying power.
- Checks that the holding-down bolts are tight.
- Check all visible fixings and bolts, including those holding the cover to the baseplate, the cooler to the cover (if any).
- Inspect the terminal cubicle, bus bar for any insulation failure due to overheating.
- Check for any corrosion of metal parts inside the panels.
- Check for any dust accumulation or any foreign matter.
- Look for leakage of oil from the bearings along the shaft. Clean around the bearing area, and if the machine has cartridge-mounted bearings, clean around the bearing insulation at the cartridge feet.
- Ensure all covers fitted. Additional protection has been installed where necessary.

**NOTE**

Visual Inspections and electrical testing will be performed by qualified GE personnel, and all GE and/or site EHS guidelines will be strictly adhered to.

Historical records of outage test results should be maintained and compared to the new test results. Changes may point to needed repairs and/or rework that may not be evident from the absolute test values themselves.

The GE representative shall have access to a detailed maintenance procedure to be followed for each line of preventative maintenance. Customer support is required to ensure full and safe access is allowed.
6.1.1 Visual Checks (Electrical & Mechanical by off-line)

The following are the standard Visual check requirements:

<table>
<thead>
<tr>
<th>Exterior of the Generator</th>
<th>Mounting &amp; Coupling (Holding down bolts, Hardware)</th>
<th>Contamination</th>
<th>Cleanliness</th>
<th>Loose or displaced parts</th>
<th>Vibration</th>
<th>Mechanical damage</th>
<th>Corrosion</th>
<th>Surface Condition &amp; Wear</th>
<th>Cracks</th>
<th>Overheating, arcing &amp; burning</th>
<th>Corona activity</th>
<th>loose connections</th>
<th>Breaks, tears</th>
<th>Radial misalign</th>
<th>Core tightening</th>
<th>Dusting and greasing</th>
<th>Insulation damage</th>
<th>Ventilation obstructions</th>
<th>Oil/Water leakage</th>
<th>Distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td>All fasteners</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>Electrical systems and cabinets</td>
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<tr>
<td>Pole coil Winding</td>
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<td>Bearings</td>
<td>Bearing &amp; Housing Assembly (Bearings, oil seals, greasing system, Auto-lube system, manual greasing, bearing Insulation)</td>
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<td>Ventilation</td>
<td>Cooling circuit (Cooler, Fan, Filter, pipeline, Instruments)</td>
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<tr>
<td>Exciter</td>
<td>Brushes, DC or Static Exciters</td>
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<td>Carbon brush</td>
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</table>

Table-5: GENERATOR AND ITS COMPONENTS – STANDARD INSPECTION CHECKLIST
6.1.2 Terminal Cubicle Inspection
- Electrical disconnection of main stator & excitation stator
- Disconnect the rotor earth fault (REFM) (if fitted)
- Check Line/Neutral Side Cubicles. Clean out and check tightness of the links (if not taped)
- Check neutral earthing resistor/transformer. Clean out and check tightness of the links (if not taped)
- Functional checks on cubicle heaters (if fitted)

6.1.3 Power Cables – Stator
Inspect the cable connections in the generator terminal box:
- signs of arcing - discoloration of the terminal box/cable
- evidence of over-heating of the cables and cable isolators - discoloration, sintering, cracking
- excess dust/dirt
- verify ground connections are tight, undamaged, and corrosion free
- proper cable spacing
- torque markings of junction box mounting hardware in accordance with the 2x Bolt Torque Specification document
- ensure cable glands are securely tight at generator junction box

Torque Requirement:

Torque check 100 % of bolts to all power cable connections and the unobstructed bolts attaching the junction box to the generator. Refer to the 3MW Series Bolt Torque Specification document for guidance.

6.1.4 Power Cable – Rotor
- Inspect the cable connections in the generator terminal box:
- standard visual inspection for electrical systems
- ensure cable glands are securely tight at generator junction box

Torque Requirement:

Torque check 100 % of bolts within the generator junction boxes including all power cable connections and the unobstructed bolts attaching the junction box to the generator. Refer to the 3MW Series Bolt Torque Specification document for guidance.

6.1.5 Bus bar and Power Cables Inspection
- Shut down turbine and de-energize all relevant components.
- Climb the tower taking care not to disturb any bus bar components that could be loose. Close all hatches below you.
- Start at the top deck and perform inspections moving down-tower.
- Move down tower and visually inspect for the following:
  - Arcing
  - Arcing residue
  - Excessive heat
- Inspect power and control cables checking the following:
  - Attachment joints
  - Compression joints
  - Shrinkable sleeves on compression joints
  - Insulation damage
• Proper cable tray attachment
  - Once entire tower is complete, ensure all work areas are clean. Re-energize relevant components.
  - Restart turbine and ensure there are no fault messages.

6.1.6  Frame and Stator core physical inspection

- Check the paintwork for damage and recommend course of action if required
- Inspect enclosure for contaminants ingress [water, dust...]
- Inspect the entire base frame and generator support frame for Cracking, Weld conditions
- Check mechanical guards - Coupling/shaft protection (if fitted)

In case of the open machine inspection,
- Check inside frame contamination (oil ingress, fallen parts, debris...)
- Bore scope Inspection of other accessible areas [stator and rotor internals]
- Stator windings: Check and clean the stator end windings within reach and winding hardware
- Stator core: Check and clean the stator core within reach
- Record air gap clearances

In case of rotor complete removing, inspect entire stator bore, there should not be any damage caused by copper melting from the rotor or friction between them. The stator laminations should not be loose in the frame. The bore of the stator laminations should be true and concentric with the rabbit [spigot] diameter of the frame.

Signs of rub on bore [would also show on infrared inspection during loop test / core test].
- Bent/spread lamination packs
- Missing fingers at end
- Visual swag of air gap if rotor still installed

6.1.7  Rotor and Field physical inspection

The rotor lamination should be of proper fit on the shaft, sleeve or spider on which the lamination stack is assembled. The outer diameter of the rotor laminations should be true and concentric with the bearing journals. Impact stator and rotor for evidence of stator-rotor contact and visual evidence of post-manufacture machining of the outer diameter of the rotor. Cores should be examined for evidence of shorting or lamination hot spots. Testing may be needed.

6.1.8  Bearing Inspection and Re-lubrication tasks

There are different types of bearings and the required maintenance on them will depend on the type of bearing, operating environment and the generator application. There are lubed-for-life, sealed bearings used in low horsepower generators that do not require lubrication.

Lubrication is only one of three maintenance tasks involved with generator bearings. Cleaning, removal and replacement are the other tasks. In the noise and vibration inspections, the bearings should have been inspected for abnormal noises, vibrations or hot bearings. The “feel” and “sound” tests are simple methods to gauge bearing condition. For the “feel” test, with the generator running, touch the bearing housing. If it is very hot to the touch, the bearing is probably malfunctioning. In the “sound” test, listen for thumping or grinding noises. If they exist, the bearings need a closer look and possible replacement.

For most types, the sources of bearing failures are:

1. Insufficient oil or grease
2. Too much grease causing churning and overheating
3. Worn bearings (i.e., broken balls or rough races, etc.)
4. Hot generator or external environment

If the service history demonstrates repeated bearing failures, check the manufacturer’s specifications to determine if the correct bearing has been installed. If that’s not the case, then an external factor could be the cause. Prior to bearing removal or replacement, clean the housing with solvents or flushing oils. The bearings should be cleaned with a lint free rag. Take a lot of care to keep dirt out of the bearing. When bearings need to be replaced, remove them with the proper tool. Hammers should never be used since they can damage the bearing races. The bearing puller’s claws should be attached to the sidewall of the inner ring or an adjacent part.

**Lubrication List**

<table>
<thead>
<tr>
<th>Component</th>
<th>Manufacturer</th>
<th>Lubricants</th>
<th>Quantity</th>
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<tbody>
<tr>
<td>Generator Bearings</td>
<td>Manual greasing:</td>
<td>Grease type: Klüberplex BEM 41-132</td>
<td>Approx 800 g [PMMG]</td>
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<td>Automatic lubrication system</td>
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<td>system</td>
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<tr>
<td>Converter Cooling Circuit</td>
<td>60 Hz market:</td>
<td>Top up with premixed coolant per GE 108W1957P001</td>
<td>Single loop:</td>
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<tr>
<td></td>
<td>50 Hz market:</td>
<td>Top up with premixed coolant per GE 109W0166P001, 109W0067P001 (distilled</td>
<td>Dual loop – inside:</td>
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<td></td>
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<td>water) Glysantin G55/Zerek G55</td>
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<td>Radiator Cooling Circuit –</td>
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<td>DFTG: Approx 73 liters</td>
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<td>Dual Loop Cooling System</td>
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<td>(PMM only)</td>
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<td>SSC K1 pin contactors</td>
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<td>Mersen</td>
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6.1.9 Bearing Sealing Inspection

All joints between the various components of a machine are sealed to prevent dust and water getting in, and the internal air from getting out. There are also seals inside the machine to ensure that the cooling air is confined to its proper path and is not allowed to take other paths which would result in less efficient cooling. It is important that all these seals are properly made when the machine is first installed, that they are properly maintained, and that when maintenance is done, and a seal is broken, it is correctly re-made when the machine is re-assembled.

The material used for seals is either expanded silicone rubber strip for non-machined joints, or thin neoprene-bonded cork for machined joints or those where the components are totally flat. Both materials are stuck to one of the surfaces using a silicone rubber adhesive such as Hylosil®.
When maintenance is carried out, the gasket material should be inspected when the joints are taken apart, and new material, together with a supply of adhesive, should be ordered as required, ready for re-assembly. If the machine is duct-ventilated, the duct work seals between sections should be part of the machine maintenance program.

### 6.1.10 Stator winding inspection

Initial cleaning should be done with a soft brush and low-pressure compressed air. Greasy deposits should be removed by rubbing with a lint-free cloth dampened with white spirit.

**WARNING**

SOLVENTS SHOULD ONLY BE USED IN WELL-VENTILATED PLACES AND CARE SHOULD BE TAKEN WITH REGARD TO NAKED FLAMES.

**CAUTION**

Do not allow solvents to soak into the windings as this causes porosity of the insulation and allows the penetration of semi-conducting dirt detrimental to insulation resistance.

**NOTE**

Hardened dirt may be removed by using a fairly stiff brush. Do not use wire brushes or scrape with a knife on windings or leads.

The stator winding supports and lashings should be inspected for rigidity. After cleaning, the insulation resistance should be tested with a Megger or similar tester. A record should be kept of insulation-resistance readings of the windings, as a trend towards lower readings can be a warning of impending failure. Ensure that comparable conditions exist at each inspection. If abnormally low readings are obtained the cause should be investigated. The windings may need to be wet-cleaned and dried out.

### 6.1.11 Cooling Circuit and Heat Exchanger Inspection

For generators running continuously day and night, a cooling circuit examination is necessary.

- Check generator air inlet filters (if fitted)
- Check generator air inlet pressure switch (if fitted and accessible)
- Check general status and operation of cooling air fan generators (if fitted and accessible)
- Visual inspection of heat exchangers (no disassembly included)

**CACA (IC6A1A6)**

- Check for excessive vibration.
- Check the bearing temperatures and oil levels. If the bearings are supplied with oil from the prime mover system, check the oil flow.
- Check the winding temperatures.
- Check the cooling air temperatures in and out.
- Check that the cooler fans are running.
- Check for oil leaks from bearings, seals, sight-glasses and pipework.

The cause of any appreciable change from previous operating levels should be investigated, in case there is a change of circumstances, which requires attention and correction.
If any protection or measuring devices cease to work, report the failure so that steps can be taken for their repair or replacement. Temperature detector elements in the stator winding are not repairable, but spare elements are usually provided and should be wired in as required.

**CACW (IC8A1W7)**

- Check for excessive vibration.
- Check the bearing temperatures and oil levels. If the bearings are supplied with oil from the prime mover system, check the oil flow.
- Check the winding temperatures
- Check the cooling air temperatures in and out.
- Check the water flow to the cooler
- Check for oil leaks from bearings, seals, sight-glasses and pipework.

The cause of any appreciable change from previous operating levels should be investigated, in case there is a change of circumstances which requires attention and correction.

If any protection or measuring devices cease to work, report the failure so that steps can be taken for their repair or replacement. Temperature detector elements in the stator winding are not repairable, but spare elements are usually provided and should be wired in as required.

**6.1.12 Generator Cooling Fan (if equipped)**

- Inspect the fan housing and flanges for cracks at manufactured/assembled bends.
- Perform a function test of the generator fan, checking for abnormal operation noise or excessive vibration.

**6.1.13 Generator Air Outlet Ducts**

The air outlet from the generator is transferred outside the nacelle by one flexible duct. Doubly-fed induction generators have an additional flexible duct that transfers air from the slip ring cabinet to the outside of the nacelle.

- check for tears or any other damage in duct
- check that the duct is not stretched tight as the nacelle will move +/-25 mm (+/-1 inch) in the wind, but the duct should also not be too loose
- check that the clamps on both sides of the duct are tight

**6.2 STANDARD CLEANING (OR DUST REMOVAL) TASK**

Buildup of dust on electrical components and wiring can damage components and cause mis-operation.

Buildup of dust on components can increase operating temperature, reducing their normal life. On stand-off insulators, dust can collect enough moisture to produce a current path to chassis ground. Dust (especially metallic dust) on wire surfaces can cause tracking between connector pins. Tracking is usually capacitive in nature and involves a buildup of electrical charge along the wire surface. This can cause intermittent problems that are hard to find.

To remove dust from the components
1. Clean stand-off insulators with a clean, dry cloth. Do not use any solvents.

2. Using a fine-filtered vacuum cleaner with a non-metallic nozzle, remove dust and dirt from wiring and electrical components.

3. Inspect cabinet air filters, if equipped. Shake or vacuum filters clean, or replace, as required.

Note: Dust is best removed by vacuuming with a grounded vacuum nozzle/brush. A less desirable method is blowing with a low-pressure air source that is filtered and has a water/oil separator.

4. After cleaning, examine the parts for pitting or other signs of metal deposits on insulation or insulated parts. If parts are pitted, do not reuse.

6.2.1 Clean the exterior of the generator

- If the generator is equipped with air filters, they should be replaced (disposable type) or cleaned and reconditioned (permanent type) at a frequency that is dictated by conditions. It is better to replace or recondition filters too often than not often enough.
- On open ventilated generators, screens and louvers over the inlet air openings should not be allowed to accumulate any build-up of dirt, lint, etc. that could restrict free air movement.
- Totally enclosed air to air cooled and totally enclosed fan cooled generators require special cleaning considerations. The external fan must be cleaned thoroughly since any dirt build-up not removed can lead to unbalance and vibration. All of the tubes of the air-to-air heat exchanger should be cleaned using a suitable tube brush having synthetic fiber bristles (not wire of any type).

6.3 STANDARD FUNCTION TESTS

6.3.1 Brief Test Descriptions

Insulation Resistance & Polarization Index - a basic characteristic of all insulating materials and has been recognized for many years as one measure of a system's reliability. Factors affecting insulation resistance are contamination, moisture, dust, dirt, oxidation and material degradation due to mechanical and/or electrical factors.

Winding Resistance - recorded to provide current winding resistance, which can be compared to prior tests for trending purposes.

RTD Resistance - performed to ensure the Resistance Temperature Detectors (RTD's) are functioning properly in all slots.
PDA Test (Off Line) - utilizes existing PDA Couplers to record current partial discharge results of the winding. Results can be compared to prior test results for trending purposes.

Dissipation Factor / Power Factor (Doble) Test (Off Line) - results can be compared to prior tests to indicate insulation condition changes. These changes can be caused by factors such as contamination or insulation degradation.

Stator Core Loop Test - to determine and identify stator core iron issues when simulating rated flux density.

Stator Core EL CID Test - a low power alternative to the Stator Core Loop Test. It avoids the testing problems of set-up and safety usually associated with the high excitation of the Stator Core Loop Test, yet provides an accurate indication of lamination damage.

AC or DC Hipot Testing - typically performed at "Suitability for Service" levels (or unit voltage × 1.25 = kVAC test voltage) to ensure the integrity of the insulation system. Test levels and plan will be reviewed with customer prior to performing actual test.

DC Leakage / Absorption Test - performed to ensure the integrity of the stator insulation system. A series of high voltage insulation resistance measurements taken at increasing steps of test voltage on a scheduled time basis. Test data is very useful for trending purposes to highlight potential insulation degradation.

Rotor AC Drop Voltage Test - to identify shorted turns in rotor poles. Performed by applying an AC voltage across the entire field pole circuit and measuring the voltage drop on individual poles.

Wedge Tightness - the purpose of the stator wedge is to retain the coil/bar into the slot with the proper tightness, while also preventing movement in the slot. Inspection will confirm if there are hollow or loose wedges, and may result in the need to perform a complete or partial rewedge of the stator.

Borescope Inspection of Vent Slots - to detect contamination, blockage, as well as corona armor damage. Extra attention is focused on the high voltage portion of the winding.

Borescope Inspection of Rotor Poles - to detect loose or broken connections, coil damage, ground and turn insulation movement and/or cracking.

Stator Roundness / Air Gap Checks - to identify conditions that may be outside acceptance criteria for normal operating conditions.

6.3.2 Tests before and after maintenance

1. Slip ring sparks and patina  
2. Slip ring sparks and patina  
3. Airflow  
4. Shaft current  
5. Vibration  
6. Breaking operation  
7. Noise  
8. Leakage oil / water

6.3.3 Tests at standstill

1. Insulation resistance  
2. Corrosion  
3. Partial discharge  
4. Cracks  
5. Corona signs  
6. Tightness  
7. Dust moisture  
8. Runout / Circularity / verticality
6.3.4 Generator Running Tests (Online)

Wires and cables with damaged insulation are dangerous when carrying electricity. They can also intermittently short, causing equipment and functional failure.

To check wires and cables
1. Check all wires and cables for fraying, chipping, nicks, wear, or rodent damage.
2. Check all wires and cables for signs of overheating or carbonization.
3. Repair minor low-voltage insulation damage with a good grade of electrical tape. If a damaged cable carries high voltages, replace the cable.
4. Replace any cables or wires that have excessive damage.

GE performs on-line monitoring of power circuits to determine the health of a generator. Our generator circuit-testing instrument is low voltage, battery operated, highly portable and capable of full remote monitoring from the Generator Control Centre. Data is collected, stored, trended and recalled to provide you with comprehensive reports.

Stator electrical test: 10 min Insulation Resistance, Polarization Index, Winding Copper Resistance test, Winding RTD and IR test, Air RTD and IR test, Bearing RTDs test, Stator per phase, Stator phase balance test, Main heater check.

Field electrical test: 10 min Insulation Resistance, Polarization Index, Winding Copper Resistance test, RTD resistance check and Insulation resistance test.

Other electrical tests: Phase rotation, shaft voltage test, shaft discharge resistor, voltage balance or phase balance test.

6.3.5 Generator Static Test (Off-line)

Off-Line generator circuit testing provides you with consistent testing in a safe, simple and cost-effective manner. It also is in a single box with a temperature recorder, DLRO, Megger, DC Hi-pot set and surge tester. Additional pieces of equipment to perform this type of testing are no longer required.

1. Visual checks (mechanical & Electrical) 2. Winding Insulation
3. Voltage Drop Test 4. Final IR and HV
5. Bearing Insulation 6. Cold resistances
7. End float and Magnetic centre

6.4 GENERATOR MONITORING & DIAGNOSIS

1 Day Outage Assessment

Evaluate components with high risks of failure to anticipate forced outage

Power plant performance depends on very complex interactions between all components and systems. Backed by an in-depth knowledge, GE’s advanced monitoring and diagnosis methods provide evaluation and analysis with accurate data to better operate, maintain equipment and identify action plans.

a. Temperature Measurement (Air, Machine, Winding and Bearing)
b. Vibration (generator frame, bearing housing)
c. Noise level
d. Step voltage
e. Waveform analysis and O.C. Oscillogram at rated voltage
7. GE ADVANCED MAINTENANCE BEYOND REGULAR MAINTENANCE

7.1 ADVANCED CLEANING

Cleaning of windings and the Interior of the generator

Cleaning Windings with Solvents
Washing Windings with Detergent Water
Cleaning of the Brush Gear and Slip-Rings

7.2 ADVANCED TESTING, MONITORING & DIAGNOSIS

In addition to those standard checks, GE Field Service Engineer shall conduct the following additional function tests for those machines installed at least a year ago during maintenance, if required.

- Reliability Centered Maintenance (RCM)
- ViSoR Remote Monitoring System

7.2.1 Reliability Centered Maintenance (RCM)

RCM is a specific process used to identify the policies which must be implemented to manage the failure modes which could cause the functional failure of any physical asset in a given operating context.

- Comprehensive database
- Maintenance cost effectiveness
- Longer useful life
- Improved operating performance

In the wider view, PAS 55 defines Asset Management as:

“Systematic & coordinated activities and practices through which an organization optimally manages its physical assets and their associated performance, risks and expenditures over their lifecycles for the purpose of achieving its organizational strategic plan.”

- Ensure realization of inherent safety and reliability of the equipment system.
- Restore equipment to inherent (functional) levels when deterioration occurs.
- Obtain information needed for design improvements where reliability proves inadequate.
- Accomplish these goals at a minimum total life-cycle cost.

RCM Process
7.2.2 ViSoR Remote Monitoring System

Virtual System Room (ViSoR) provides secured remote access on Pilot server, Data historian and other applications (ex HMI).

ViSoR PC host “ViSoR gateway” software provides remote access capability.

ViSoR PC host Data Historian PC.

Provides isolation and security of the control system.

Remote Access Functionality

**VISOR PC:**
- Historical Data
- System Health

**HPMs, GENERIC PCs:**
- Monitoring of operator display
- Alarms, events etc
- Access to PC Web Pages/Error logs

**CONTROL NETWORK**

**DP, AUTOMATION, DRIVE CONTROLLERS:**
- Controller Application Monitoring
- Trip Histories, Continuous Data etc
- Access to Controller Web Pages/Error logs

**PROGNOSTIC APPLICATIONS:**
- Rotating Machines
- MV7000/SD7000 Drives
- HPCI/PECe Controllers

Visor Architecture
Visor Differentiators:
- System approach to monitoring
- Interface to GE PC engineering tools
- Follows security best practice
- Low cost (<$5K for Visor DMZ)
- "Virtual" RM&D Centre

Visor Benefits:
- Maximizes operational availability
- Supports commissioning activities
- Lowers warranty costs
- Potential for Service Agreements
- Operational data leads to product improvement

7.3 MAINTENANCE OF BEARINGS

Hydro Systems Shaft line bearing arrangements have either (1) Two bearings, (2) Three bearings, (3) Four bearings or (4) Five bearings

Shaft Line with TWO Bearings

Shaft Line with THREE Bearings
7.3.1 Maintenance of Sleeve Bearings

**Daily inspections**

1. Ensure the volume and quality of lubrication oil is in compliance with specifications.
2. Ensure there is motion of the oil ring and it is not clamped.
3. The indicator of the shaft endplay should be restricted within the specified range of the red groove of the shaft or the ±3mm (.118 in.) range of the drive-end shaft shoulder, or the bearing may be damaged.

**Regular examination**

1. Periodical change of oil: The oil reservoirs of self (not flood) lubricated bearings should be drained and refilled about every six- (6) months. More frequent changes may be needed on high-speed (3600-rpm) generators or if severe oil discoloration or contamination occurs. In conditions where contamination does occur, it may be advisable to flush the reservoir with kerosene to remove any sediment before new oil is added. Proper care must be taken to thoroughly drain the reservoir of the flushing material before refilling with the new oil.

2. Refill the reservoir to the center of oil sight glass with a turbine grade of oil that is rust and oxidation inhibited. Refer to the outline and lubrication nameplate for the correct viscosity.
3. Quantity of lubrication oil: Please refer to the lubrication nameplate for oil quantity.
4. Oil viscosity

**ATTENTION**

Prior to disassembling, ensure the power supplies are disconnected and there are no moving parts.
7.4 BOLTED CONNECTIONS TIGHTENING SOLUTION

Vibration during equipment operation can loosen mechanical and electrical connections and cause intermittent equipment failure. Additionally, dust and moisture in loose connections can cause loss of low-level signals at terminal boards and also thermal runaway at bus connections.

To prevent component damage caused by static electricity, treat all boards and devices with static-sensitive handling techniques. Wear a wrist grounding strap when handling boards or components, but only after boards or components have been removed from potentially energized equipment and are at a normally grounded workstation.

To prevent equipment damage, do not remove, insert, or adjust board connections while power is applied to the equipment.

To check connections
1. Check all hardware and electrical connections by attempting to move the device/wire, and tighten them if needed.
2. Tighten or replace any loosened crimp-style lugs.
3. Tighten or replace all loose or missing hardware.
4. Inspect boards for correct seating, and check that any plugs, wiring, and but connectors are tight.

The indications given by the coupling manufacturers concern the misalignment tolerated for proper functioning of their own supply. Whereas the bearings and rolling element bearings of the machines cannot accept such misalignments as these will result in an abnormal work rate on the rolling element bearings and bushes, or even the shaft.

Precise instruments are required to measure the misalignment (dial gauges, laser) and the instruments must be correctly mounted (free of any deformation of supports, etc.).

The measurement resources used should make it possible to cancel the effects of run-out.
7.4.2 Pinning the Generator

Pin the generator. This will be useful for reinstallation of the machine at a future date.

Generator Positioning: When handling, transporting and positioning the generator next to the driven machine, the rotor locking system must be in place.

The rotor locking system must be removed:

- for a horizontal generator, prior to the shaft line adjustment,
- for a vertical generator, prior to placing it opposite the shaft end of the driven machine.

NOTE
Following final installation and alignment of the generator, the generator should be pinned to determine the correct position of the generator should it be moved at a future date.

For the pinning, two holes must be drilled diagonally opposite each other on a diameter of sufficient size in the baseplate or chassis. This operation is performed after final tightening of the generator.

7.4.3 Connections to cooling circuit

Air/air cooling by duct

The external airlines must be cleaned before making any connections to avoid clogging the cooling system and the resulting loss of heat exchanger efficiency.

Generators designed for cooling by air must be connected to the airlines using appropriate seals to prevent leaks.

At the duct air inlets, grills should be installed to prevent penetration of any solid foreign matter; this can include filters for dust. The load losses in these ducts including grills and possible filters must be indicated to us at the moment of design of the generator.

Air/water cooling

NEVER USE THE COOLING SYSTEM PIPING AS A STEPPING SURFACE.

For generators equipped with a hydro-cooling system, the external lines must be systematically cleaned to prevent any risk of fouling and clogging of the air/water exchanger.

Before connecting, you must check that the water used is compliant with the contractual specifications communicated to the generator builder.

The following is required:

- Complete cleaning of water inlet and return pipes (flushing).
- Check for absence of foreign matter suspended in cooling water.
- Appropriate analysis confirming contractual characteristics of water supplied to generator builder.

It is also necessary to ensure that the cooling fluid is protected against freezing.

The inlet and/or outlet pipe must be equipped with an isolating valve and a system for adjusting the water pressure and flow as required by the hydro-cooler utilisation conditions defined on the nameplate.
The hydro-cooler must be connected using appropriate connection fittings and seals to prevent any risk of leakage and must be compatible with the operating pressure. The circuit must be equipped with a safety valve calibrated to the maximum test pressure of the cooler.

After filling the heat exchanger with water, the tightness of the circuit, its pressure and flow rate must be carefully checked.

For any extended period of non-use, the cooling circuit must be drained.

### 7.5 MAINTENANCE OF SLIP-RINGS

#### Adjustment of carbon brush

1. **Brush pressure for normal operation:**
   
   Electro-graphite brush... 0.2~0.25 kg/cm²
   
   When frequent vibrations are evident or the brush is small (area below 0.5 cm²), the pressure should be greater than as shown.

   **WARNING**
   
   Ensure generator is disconnected from power supplies and there are no accessible moving parts before maintenance operation.

2. **Adjustment of brush pressure:**
   
   The brush pressure should be adjusted to keep normal operation as it wears. The brush pressure may be reduced after use, so it is necessary to re-adjust. For adjustment, please turn adjusting screw, pressure adjusting pin or pressure adjusting plate as shown in Fig. 14 to obtain the correct tension (=0.23 x brush cross sectional area in cm²) ±10% kg.

3. **Brush pressure need not be adjusted if constant force spring is used as shown in Fig. 15 and Fig. 16.**

### Brush replacement

The carbon brush is a part of the equipment which is easily worn away, replace it after it is worn to V ~ 3/4 of original size.

a) **Brush material**
The brush material is important to the performance of the generator. Only the most appropriate materials are chosen by TWMC, and are listed on the nameplate of the generator. It is important to know this when you replace the brush, so a recommended type is used.

b) Dimensions

**ATTENTION**

The gap between a brush and its holder is important for good performance and safety of the motor.

c) Adjustment of new brushes

1. Polish the new brush with a file until it assumes the appropriate contour of the slip ring that it touches.
2. Place sandpaper (JIS R6252 No. 40... 50) on the slip ring with the abrasive face of the paper against the brush to induce a closer contact by rubbing against each other.
3. Repeat item 2 with fine sandpaper (JIS R6252 No. 100 to 200) until the contact surface between brush and slip ring exceeds 80%.
4. Finally, clean the contaminated slip ring and brush with clean cloth or compressed air.

8. MAINTENANCE AND REPAIR SERVICES FOR HYDRO GENERATORS

GE has been providing quality AC electric generator service and repair for more than 50 years through our global network of service centres. We service equipment from many manufacturers and from a wide range of industries, including generators used in special applications.

You can trust trained GE experts to ensure that the correct materials and procedures are applied to provide the reliability, quality, and performance you require.

Our generator services include:
- Test and inspection
- Failure analysis and diagnostics
- Rebuilds and repairs
- Stator rewinds
- Coil manufacturing
- Insulation system upgrades
- Vacuum pressure impregnation (VPI)
- Replacement parts (exchange program)
- New generators
- Equipment management programs
- Engineering support with on-site field engineering available as needed
- Full on-site service capabilities
- Emergency response, 24x7

**UPGRADE KIT FOR PLANNED MAINTENANCE**

GE offers an extensive set of upgrade solutions with fast lead-time implementation: improvements matching major planned maintenance period, requiring no additional downtime, thus allowing operators to faster adapt their units to the changing market.
RETROFIT

Tailor-made solutions adapted to each plant specific needs, GE either replaces or reconditions major components in order to restore original performance levels, respond to new operating patterns, extend plant life and optimize plant layout, or to increase performances. GE customized solutions cover either single component or entire systems/plants (integrated, turnkey solutions) whatever the origin of their equipment.

Up to 30% additional turbine output improvement thanks to upgrades
Up to 5% increase in runner efficiency (with same discharge) by using the latest design.

REPAIR & REFURBISHMENT

- Corona
- Wedging Core Lamination
- Loose bolts
- Bearing pads
- Slip ring
- Pole connections
- Damper winding

We offer a complete range of services for generators in our network of service facilities or on-site at your location. This chapter helps the user with parts replacement, as well as to identify and order replacement parts.

Replacement parts may contain static-sensitive components. Therefore, GE ships replacement parts in anti-static bags. When handling electronics, make sure to store them in anti-static bags or boxes and use a grounding strap (per the following Caution criteria).

Troubleshooting should be done at the system component level. The failed system component (least replaceable part) should be removed, returned to GE, and replaced with a known good spare. Do not attempt to repair system components.

Prior to ordering a replacement part for a GE product, the following items should be understood:
  - How to accurately identify the part
  - If the part is under warranty
  - How to place the order

REPLACE

Bolt washers
Seals
Wedges
Joints
Oil additives
Bar coils
Pole connections
Brushes
9. **FAULT FINDING**

9.1 **FAILURE TO START OR ACCELERATE**

1. Check all connections against the circuit diagram see that there are no open circuits and that all terminals and contacts are clean and right.
2. Check supply voltage at all the generator terminals to see if any reduction is taking place due to line drop. If on autotransformer start is being used, select a higher tapping.
3. Ensure that the machine is not overloaded – try to start the generator uncoupled from load.
4. Check that any thermal, over current or over-voltage protection devices have not been tripped, and that they have been set correctly.
5. Check that stator line currents and phase resistance is balanced and that the insulation resistance is correct.
6. Inspect the rotor bars and end rings.
7. In case of SR Generators, check the rotor resistance-circuit and control.
8. If generator crawls at low speed, the generator and load torque speed curves are probably mismatched. (This is only likely to be of concern when starting STAR/DELTA).
9. Load inertia may be too high, thus resulting in a prolonged start-up time – consult GEPC.

9.2 **VIBRATION**

1. Run the machine unexcited. If excessive vibration occurs, then it may be of mechanical origin. Check the alignment. If work has been done on the machine, check for correct re-assembly, tightness of holding down bolts and presence of dowels.
2. If vibration is not present unexcited, excite the machine to rated voltage on open circuit. If vibration appears, check that the machine air-gaps are all within 10% of one another.
3. If the vibration is not present on no-load, add load until it appears. Assuming that the load is balanced, such load-dependent vibration could arise from conditions in the field windings, and GE Energy Power Conversion, Rotating Machines should be consulted.
4. If vibration occurs after a system fault or accidental mal-synchronization, then movement could have occurred or damage could have been done. Consult GE Energy Power Conversion, Rotating Machines.
5. Check the rotor bars, end rings and other rotating parts for damage.

9.3 **MECHANICAL NOISE**

Mechanical noise may occur after work has been carried out on the machine. If this happens, shut down at once and check that no tools, nuts and bolts or debris have been left inside, and that the components have been assembled correctly.

If the noise occurs and no work has been done or if work has been carried out and the above check made, check that:

1. Nothing is rubbing on the shaft (e.g. fan baffles or bearing seals) or coupling.
2. The alignment is correct.
3. The bearing oil supply is working.
4. The air gaps are equal.
5. There is no foreign matter in the air gaps. If there is, establish where it came from.

9.4 **MAGNETIC NOISE**

1. Check that the load currents are balanced and that the three phase resistances are equal.
2. Check all connections. Ensure that there are no bad contacts, and that all connections are clean and tight.
3. Measure the air gap for eccentricity.
4. Check the value of the supply voltage at the generator terminals.
5. Check that the stator line currents and phase resistance are balanced and that the insulation resistance is correct.
6. Inspect the rotor bars and endings.

9.5 WINDING OVERHEATING

Check the following points:
1. Is the load normal, with balanced line currents and the expected power factor?
2. Is the cooling system working properly?
   Are both fans running?
   External air flow normal and not blocked by tarpaulins, polythene sheets or rubbish?

9.6 BEARING OVERHEATING

5. Self-contained bearings
   a. Is the oil level correct and is the ring rotating?
   b. Is the ambient temperature around the bearing higher than usual?
   c. Are the cooling fins on the bearing housing insulated with dust and dirt?
6. Bearings with an external oil supply
   a. Are the oil flow and temperature normal?

If the rise in bearing temperature follows after work has been done on the machine, check that the bearing has been correctly assembled and that the thrust or location faces are not permanently in contact.

If new grease is supplied and deteriorated grease discharged properly, the generator will run smoothly. When generators cannot run well because of trouble of bearings, tips for diagnosis are (1) Noise from bearings, and (2) Temperature rise of bearings. When the temperature rise exceeds the specified limit, please check and see whether there is anything wrong.

   a) When temperature rise varies during running, consider the following:
   b) The viscosity resistance of newly supplied or discharged grease.
   c) Insufficient grease or deteriorated grease.
   d) Grease in bearing caps or on retainers falls into the bearing and viscosity resistance there in increases abruptly.
   e) The variation of load will cause the temperature of generator to go up.

9.7 LEAKAGE OF OIL

7. Self-contained bearings
   a. Is the bearing overfilled with oil?
8. Bearings with external oil supply
   a. Is the oil exit pipe flowing freely?
   b. Is the specified oil flow rate being exceeded?
9. Both kinds of bearing
10. GENERATOR FAILURE MODES

Main Problems Affecting Generator Performance are –

Thermal
- Insulation Breakdown
- Bearing burning
- Brushes wear
- Core melting
- Deformations
- Property change
- Life reduction

Electrical
- Tri-phase Short Circuit
- Bi-phase Short Circuit
- Synchronization Error
- Half poles Short Circuit
- Corona partial discharge
- Electrical field in the roebel bar
- Bar vibration
- Shaft current

Ambient
- Oxidation / Corrosion / Erosion
- Golden mussel
- Insects
- Noise
- Burn
- Dust
- Moisture
- Oil/Water leakage

Mechanical

Electrical vibration
- Magnetic unbalance
- Non concentric generator rotor
- Winding problem

Mechanical vibration
- Mechanical Unbalance
- Misalignment
• Bearing wear and Geometry
• Shear pin failure
• Coupling defects
• Shaft bow
• Rubs

**Hydraulic vibration**
• Vortex interaction
• Hydraulic unbalance
• Cavitation
• Hydraulically induced axial vibration
• Runner blade vibration

Cracks

Deformation / buckling

**Altogether**
• Wear
• Deformation
• Contamination
• Corrosion
• Change property
• Safety
• Life reduction
• Availability
• Reliability
• Costs
11. RECOMMENDED MAINTENANCE TOOLS

The following check lists should be on hand for the procedures in this document.

11.1 SAFETY EQUIPMENT
- Site-specific/confined space manual
- Personal safety gear (such as safety boots, safety glasses, hard hat, high-voltage gloves, face shield, safety jacket)
- High-voltage ac/dc detector (with an insulated pole of appropriate length)
- Locks and tags, ganger and caution tape
- Protective grounding cables and grounding stick
- Static-charge wrist straps

11.2 TYPICAL MAINTENANCE TOOLS

<table>
<thead>
<tr>
<th>Maintenance Job</th>
<th>Required Tools</th>
</tr>
</thead>
<tbody>
<tr>
<td>General</td>
<td>Camera, Laptop computer, Handheld</td>
</tr>
<tr>
<td>Door/outer area</td>
<td>Hand brush, standard screw driver set, ratchet set &amp; torque wrench</td>
</tr>
<tr>
<td>Foundation</td>
<td>Tape meter &amp; go no go gauges</td>
</tr>
<tr>
<td>Anchor bolts</td>
<td>Tensioning cylinder, hydraulic power unit or hydraulic manual pump</td>
</tr>
<tr>
<td>Electrical cabinets</td>
<td>Torque wrench, vacuum, electrician screwdriver set, Torx key set, Allen key set, multi-meter, pliers, paint brush &amp; laptop computer</td>
</tr>
<tr>
<td>Converter cooling system</td>
<td>socket set, refractometer, refill pump, pressure gauge coolant container /bucket, Allen key set open-end wrench, cherry picker, portable ladder, pressure gauge &amp; PPE</td>
</tr>
<tr>
<td>Bedplate</td>
<td>Hydraulic/electronic torque tool, power unit</td>
</tr>
<tr>
<td>Generator frame</td>
<td>Hydraulic/electronic torque tool, power unit</td>
</tr>
<tr>
<td>High speed coupler</td>
<td>Torque wrench</td>
</tr>
<tr>
<td>Generator bearings</td>
<td>Grease gun &amp; scraper (spatula)</td>
</tr>
<tr>
<td>Generator alignment</td>
<td>Alignment set/toolbox, alignment tools</td>
</tr>
<tr>
<td>Generator to bedplate attachment</td>
<td>Torque wrench</td>
</tr>
<tr>
<td>Generator elastomeric mounts</td>
<td>Torque wrench</td>
</tr>
<tr>
<td>Generator slip ring compartment)</td>
<td>Vacuum, caliper gauge, paint brush, pipe clean brush, multi-meter &amp; tic-tracer</td>
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</tbody>
</table>
12. **MAINTENANCE SCHEDULE**

<table>
<thead>
<tr>
<th>S. No</th>
<th>TASK DESCRIPTION</th>
<th>1st Level</th>
<th>2nd Level</th>
<th>3rd Level</th>
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<tbody>
<tr>
<td></td>
<td><strong>REGULAR MAINTENANCE (OR 1ST LEVEL MAINTENANCE TASKS)</strong></td>
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<td>1</td>
<td>Pre-requisites to perform maintenance</td>
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<td>2</td>
<td>LOTO</td>
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<td>Terminal Cubicle Inspection</td>
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<td>Bearing Inspection &amp; Re-lubrication</td>
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<td>15</td>
<td>Generator Cooling Fan (if equipped)</td>
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<td>16</td>
<td>Generator Air Outlet Ducts</td>
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<td><strong>STANDARD CLEANING</strong></td>
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<td>17</td>
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<td></td>
<td><strong>STANDARD FUNCTION TESTS</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>18</td>
<td>Tests Before and After Maintenance</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>19</td>
<td>Tests at Standstill</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>20</td>
<td>Stator Insulation Resistance (IR) Tests</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>21</td>
<td>Rotor Insulation Resistance (IR) Tests</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>22</td>
<td>Polarization Index (PI)</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>23</td>
<td>High Voltage (HV) Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>24</td>
<td>Winding Resistance Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>25</td>
<td>Phase Rotation Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>26</td>
<td>Shaft Voltage Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>27</td>
<td>Voltage Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>28</td>
<td>Voltage Balance Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>29</td>
<td>Winding Insulation Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>30</td>
<td>Bearing Insulation Test</td>
<td>✓</td>
<td>✓</td>
<td>✓</td>
<td>GE</td>
</tr>
<tr>
<td>No.</td>
<td>Task Description</td>
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<td>-------------------------------------------------------</td>
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<tr>
<td>32</td>
<td>Cold Resistance Test</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>33</td>
<td>Voltage Drop Test</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>34</td>
<td>Final IR &amp; HV Test</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>35</td>
<td>Temperature measurement</td>
<td>✓</td>
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<tr>
<td>36</td>
<td>Vibration (generator frame, bearing housing)</td>
<td>✓</td>
<td></td>
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</tr>
<tr>
<td>37</td>
<td>Noise Level</td>
<td>✓</td>
<td></td>
<td></td>
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<tr>
<td>38</td>
<td>Step Voltage Test</td>
<td>✓</td>
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</tr>
<tr>
<td>39</td>
<td>Waveform Analysis</td>
<td>✓</td>
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<tr>
<td>40</td>
<td><strong>ADVANCED CLEANING</strong></td>
<td></td>
<td></td>
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</tr>
<tr>
<td>41</td>
<td>Cleaning of windings and Interior of the generator</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>42</td>
<td>Cleaning of windings with Solvents</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>43</td>
<td>Cleaning of windings with Detergent Water</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>44</td>
<td>Cleaning of Brush Gear and Slip-rings</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
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<tr>
<td>45</td>
<td><strong>ADVANCED TESTING, MONITORING &amp; DIAGNOSIS</strong></td>
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<td></td>
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<tr>
<td>46</td>
<td>Reliability Centered Maintenance (RCM)</td>
<td>✓</td>
<td></td>
<td></td>
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</tr>
<tr>
<td>47</td>
<td>ViSoR Remote Monitoring System</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>48</td>
<td>Maintenance of Bearings</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>49</td>
<td>Bolted Connections Tightening Solution</td>
<td>✓</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>50</td>
<td>Maintenance of Slip rings</td>
<td>✓</td>
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</table>

Table 8: Preventive Maintenance Schedule for Generators
## GLOSSARY OF TERMS

<table>
<thead>
<tr>
<th>Abbreviation</th>
<th>Description</th>
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</thead>
<tbody>
<tr>
<td>AC</td>
<td>Alternating Current</td>
</tr>
<tr>
<td>CACA</td>
<td>Closed Air Circuit, Air cooled</td>
</tr>
<tr>
<td>CACW</td>
<td>Closed Air Circuit, Water cooled</td>
</tr>
<tr>
<td>CMS</td>
<td>Condition Monitoring System</td>
</tr>
<tr>
<td>CT</td>
<td>Current Transformer</td>
</tr>
<tr>
<td>DC</td>
<td>Direct Current</td>
</tr>
<tr>
<td>DE</td>
<td>Drive End</td>
</tr>
<tr>
<td>EHS</td>
<td>Environment, Health and Safety</td>
</tr>
<tr>
<td>ETD</td>
<td>Embedded Temperature Detector</td>
</tr>
<tr>
<td>GA</td>
<td>General Arrangement</td>
</tr>
<tr>
<td>GE</td>
<td>General Electric</td>
</tr>
<tr>
<td>GEI</td>
<td>Technical document that provides instruction on a specific piece of equipment</td>
</tr>
<tr>
<td>GFCI</td>
<td>Ground Fault Circuit Interrupter</td>
</tr>
<tr>
<td>IC</td>
<td>International Cooling Code</td>
</tr>
<tr>
<td>IP</td>
<td>International Protection Code</td>
</tr>
<tr>
<td>IR</td>
<td>Insulation Resistance</td>
</tr>
<tr>
<td>LOTO</td>
<td>Lock Out Tag Out</td>
</tr>
<tr>
<td>LVMD</td>
<td>Low Voltage Mains Distribution</td>
</tr>
<tr>
<td>MCC</td>
<td>Main Control Cabinet</td>
</tr>
<tr>
<td>NDE</td>
<td>Non Drive End</td>
</tr>
<tr>
<td>PDC</td>
<td>Power Distribution Cabinet</td>
</tr>
<tr>
<td>PI</td>
<td>Polarisation Index</td>
</tr>
<tr>
<td>PLC</td>
<td>Programmable Logic Control</td>
</tr>
<tr>
<td>PMG</td>
<td>Permanent Magnet Generator</td>
</tr>
<tr>
<td>PPE</td>
<td>Personal Protective Equipment</td>
</tr>
<tr>
<td>R1</td>
<td>Resistance after 1 minute</td>
</tr>
<tr>
<td>R10</td>
<td>Resistance after 10 minutes</td>
</tr>
<tr>
<td>RPM</td>
<td>Revolutions Per Minute</td>
</tr>
<tr>
<td>RTD</td>
<td>Resistance Temperature Detector</td>
</tr>
<tr>
<td>RTE</td>
<td>Rotor Telemetry Equipment</td>
</tr>
<tr>
<td>UPS</td>
<td>Uninterruptible Power Supply</td>
</tr>
<tr>
<td>VT</td>
<td>Voltage Transformer</td>
</tr>
</tbody>
</table>
### 14. APPENDIX A

**14.1 MAINTENANCE REPORT**

1. Customer name : ________________________________________________
2. Job name : ___________________________________________________
3. Order number : ________________________________________________
4. Maintenance carried by : _________________________________________
5. Department : __________________________________________________
6. Maintenance start date : _________________________________________
7. Maintenance End date : _________________________________________
8. Site in-charge / Reporter : _______________________________________

<table>
<thead>
<tr>
<th>S.No</th>
<th>TASK DESCRIPTION</th>
<th>COMMENTS (Include actions completed, observations and any follow-on recommendations)</th>
<th>INITIALS</th>
<th>DATE DD/MM/YY</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Pre-requisites to perform maintenance</td>
<td>Prior to service start-up, discuss with customer any existing/previous issues with the generator. The goal is to determine: What kind of maintenance is required? What maintenance personnel and skill level are needed? What sub-assemblies or parts are needed to complete the maintenance? What kind of scheduling or coordination with other departments is needed? What kind of safety hazards exists with the maintenance? What caused other than the generator breakdown?</td>
<td></td>
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<tr>
<td></td>
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<td>---</td>
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<td>---</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
| 2 | **LOTO**  
Before any work commences, obtain and review the commissioning site  
Lock out Tag out (LOTO) procedure. Do not continue until the LOTO  
procedure has been obtained and deemed satisfactory |   |
| 3 | **STANDARD VISUAL INSPECTION**  
Prior to start up the Maintenance; discuss with the customer any  
existing/previous issues with the generator.  
Perform Mechanical disassembly of the following:  
Electrical disconnection of main stator & excitation stator  
Disconnection of bearing instrumentation & pipe work  
Removal of bearing covers, shells & seals  
Disconnect the rotor earth fault (REFM) (if fitted) |   |
| 4 | **Visual Checks (Mechanical)**  
Inspection should look for:  
Evidence of damage caused by dirt, loose parts, or foreign objects.  
Verification that air inlets are not blocked  
Evidence of moisture and/or dirt build-up  
Unusual noises, leaking oil seals, or high vibration  
Oil level gages (if present) should be checked  
Evidence of degradation of foundation, bed plates, anchor bolts  
Evidence of oil rings turning (if applicable)  
Evidence of leaking oil and water piping and connections |   |
| 5 | **Visual Checks (Electrical)**  
Insulation damage, soft or degraded insulation  
Short circuit damage over the coil or windings exposed  
Partial discharge activity |   |
| 6 | **Terminal Cubicle Inspection**  
Check Line/Neutral Side Cubicles. Clean out and check tightness of the  
links (if not taped)  
Check neutral earthing resistor/transformer.  
Clean out and check tightness of the links (if not taped)  
Functional checks on cubicle heaters (if fitted) |   |
| 7 | **Power Cables – Stator** |   |

**CLASS II (GE INTERNAL NON-CRITICAL)**

**Revision** : 000  
**Date** : 11/08/2017  
**Page** : 56/65
8. **Power Cable – Rotor**

9. **Bus bar and Power Cables Inspection**

10. **Frame and Stator core physical inspection**
    - Check the paintwork for damage and recommend course of action
    - Inspect enclosure for contaminants ingress (water, dust...)
    - Check mechanical guards - Coupling/shaft protection (if fitted)
    - Inside frame contamination (oil ingress, fallen parts, debris...)
    - Borescope Inspection of other accessible areas (stator and rotor internals)
    - For any coil movement, plugged vent holes, coil bracing adequate and intact, lamination damage, tightness of wedges, etc.
    - Stator core: Check and clean the stator core within reach

11. **Rotor and Field physical inspection**
    - Check and clean all reachable rotor components
    - Check all rotor components out of hands reach
    - Check and clean rotating excitation equipment (all components fitted)
    - Check the rotor mounted suppression resistors
    - Check rotor shaft grounding brush & brush older
    - Rotor earth fault (REFM) components check (if fitted)
    - Visually inspect rotor mounted fans
    - Balance weights properly secured
    - Signs of bar movement
    - Signs of rotor/stator rub or lamination damage
    - Cooling ducts clear
    - Rubbing marks on shaft
    - Keyway distortion
<table>
<thead>
<tr>
<th>Bearing Inspection &amp; Re-lubrication</th>
</tr>
</thead>
<tbody>
<tr>
<td>Note the bearing oil flow, vibration and temperature levels (if generator is found running and sensors are operative)</td>
</tr>
<tr>
<td>Visual inspection of bearing housing, pipework and related hardware</td>
</tr>
<tr>
<td>Check bearing oil inspection glass</td>
</tr>
<tr>
<td>Check tightness of oil flange bolts</td>
</tr>
<tr>
<td>Bearing RTD resistance check and insulation resistance test</td>
</tr>
<tr>
<td>Inspect oil filters and check operation of filter blockage sensor (if fitted)</td>
</tr>
<tr>
<td>Check jacking oil lift and record data. (if fitted)</td>
</tr>
<tr>
<td>Check bearings insulation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Bearing Sealing Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Visual inspection of bearings journal and seals</td>
</tr>
<tr>
<td>Check bearing seal clearances</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Stator Winding Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>The following electrical tests shall be conducted in the stator as well as in the exciter windings.</td>
</tr>
<tr>
<td>10-minute insulation resistance with polarization index</td>
</tr>
<tr>
<td>Winding copper resistance</td>
</tr>
<tr>
<td>Winding RTD resistance check and insulation resistance test</td>
</tr>
<tr>
<td>Air RTD resistance check and insulation resistance test</td>
</tr>
<tr>
<td>Stator space heater function checks</td>
</tr>
<tr>
<td>Check whole rectifier plate for continuity and break insulation</td>
</tr>
<tr>
<td>Individual checks on diodes (not included, except when a problem has been detected)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Cooling Circuit &amp; Heat Exchanger Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td>Check generator air inlet filters (if fitted)</td>
</tr>
<tr>
<td>Check generator air inlet pressure switch (if fitted and accessible)</td>
</tr>
<tr>
<td>Check general status and operation of cooling air fan generators</td>
</tr>
<tr>
<td>Visual inspection of heat exchangers</td>
</tr>
<tr>
<td>Check for excessive vibration.</td>
</tr>
<tr>
<td>Check the bearing temperatures and oil levels. If the bearings are supplied with oil from the prime mover system, check the oil flow.</td>
</tr>
<tr>
<td>Check the winding temperatures</td>
</tr>
<tr>
<td>Check for oil leaks from bearings, seals, sight-glasses and pipework.</td>
</tr>
<tr>
<td>16</td>
</tr>
<tr>
<td>17</td>
</tr>
</tbody>
</table>
| 18 | STANDARD CLEANING  
All parts should be cleaned and baked dry to remove all dirt and contamination.  
To remove dust from components, clean the stand-off insulators with a clean, dry cloth. Do not use any solvents. Using a fine-filtered vacuum cleaner with a non-metallic nozzle, remove dust and dirt from wiring and electrical components. Inspect cabinet air filters, if equipped. Shake or vacuum filters clean, or replace, as required.  
After cleaning, examine the parts for pitting or other signs of metal deposits on insulation or insulated parts. If parts are pitted, do not reuse. |
| 19 | Cleaning the exterior of the generator  
Wear gloves and eye protection when using cleaning fluids and use them only in a well-ventilated area.  
Normal household cleaners may leave a salt residue behind and must not be used |
| 20 | STANDARD FUNCTION TESTS |
| 21 | Tests Before and After Maintenance |
| 22 | Tests at Standstill |
| 23 | Insulation Resistance (IR) Tests on Stator  
Perform IR check between generator leads and ground. This determines condition of the ground insulation. Record, temperature correct and trend |  
<p>| Generator voltage | Test voltage (VDC) | Acceptable reading |
| &lt; 1000 | 500 | &gt; 5 megohm |
| 1000 – 2500 | 1000 | &gt; 100 megohm |
| 2501 – 5000 | 2500 | &gt; 100 megohm |</p>
<table>
<thead>
<tr>
<th></th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>24</td>
<td><strong>Insulation Resistance (IR) Tests on Rotor</strong></td>
</tr>
<tr>
<td></td>
<td>A 500V tester to be used, and the tester earth lead fixed to the rotor body. Make sure that all</td>
</tr>
<tr>
<td></td>
<td>diodes are temporarily short circuited to avoid damaging them, and make sure that the short</td>
</tr>
<tr>
<td></td>
<td>circuits are removed when testing is complete.</td>
</tr>
<tr>
<td>25</td>
<td><strong>Polarization Index (PI)</strong></td>
</tr>
<tr>
<td></td>
<td>Ratio of the 10 minute IR to the 1 minute IR. (10 min IR / 1 min IR)</td>
</tr>
<tr>
<td></td>
<td>Determines condition of ground insulation Test voltages similar to the IR test voltages.</td>
</tr>
<tr>
<td></td>
<td>Acceptance criteria ratio &gt; 2</td>
</tr>
<tr>
<td>26</td>
<td><strong>High Voltage (HV) Test</strong></td>
</tr>
<tr>
<td></td>
<td>Megger readings must be taken before High Potential Tests. The test voltage must be of</td>
</tr>
<tr>
<td></td>
<td>approximately sine wave form and during the application of the test the peak value as determined</td>
</tr>
<tr>
<td></td>
<td>by a Peak reading voltmeter shall be not more than 1.45 times the R.M.S. Value.</td>
</tr>
<tr>
<td>27</td>
<td><strong>Winding Resistance Test</strong></td>
</tr>
<tr>
<td></td>
<td>A comparison of the line to line resistances of the generator’s winding. This test should be</td>
</tr>
<tr>
<td></td>
<td>done at the generator terminals using a meter capable of measuring low resistance (milliohms).</td>
</tr>
<tr>
<td></td>
<td>A typical ohm meter does not have adequate accuracy. Record, temperate correct and trend. Each</td>
</tr>
<tr>
<td></td>
<td>phase should be within +/- (3% - 5%) of the average of all three phases.</td>
</tr>
<tr>
<td>28</td>
<td><strong>Phase Rotation Test</strong></td>
</tr>
<tr>
<td></td>
<td>The correct rotation of the machine must first be checked in accordance with the outline drawing</td>
</tr>
<tr>
<td>29</td>
<td><strong>Shaft Voltage Test</strong></td>
</tr>
<tr>
<td></td>
<td>The volts are to be measured by Avometer and recorded.</td>
</tr>
<tr>
<td>30</td>
<td><strong>Voltage Balance Test</strong></td>
</tr>
<tr>
<td></td>
<td>A clamp-on ammeter to be used to take readings in each phase of a generator in actual operation</td>
</tr>
<tr>
<td></td>
<td>under normal load. A Tachometer to be used to check the speed of a generator.</td>
</tr>
<tr>
<td>31</td>
<td><strong>Winding Insulation Test</strong></td>
</tr>
<tr>
<td></td>
<td>The minimum insulation resistance to ground is 1 megohm per kv of rating plus 1 megohm at 40</td>
</tr>
<tr>
<td></td>
<td>degrees Celsius ambient.</td>
</tr>
<tr>
<td>Number</td>
<td>Test Description</td>
</tr>
<tr>
<td>--------</td>
<td>------------------</td>
</tr>
<tr>
<td>32</td>
<td>Bearing Insulation Test</td>
</tr>
<tr>
<td>33</td>
<td>Cold Resistance Test</td>
</tr>
<tr>
<td>34</td>
<td>Voltage Drop Test</td>
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<tr>
<td>35</td>
<td>Final IR &amp; HV Test</td>
</tr>
<tr>
<td>36</td>
<td>Temperature Measurement</td>
</tr>
<tr>
<td>37</td>
<td>Vibration (generator frame, bearing housing)</td>
</tr>
<tr>
<td>38</td>
<td>Noise Level</td>
</tr>
<tr>
<td>39</td>
<td>Step Voltage Test</td>
</tr>
<tr>
<td>40</td>
<td>Waveform Analysis and OC Oscillogram at rated voltage test</td>
</tr>
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</table>

**GE ADVANCED MAINTENANCE Beyond REGULAR MAINTENANCE**
<table>
<thead>
<tr>
<th></th>
<th>ADVANCED CLEANING</th>
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<tbody>
<tr>
<td>41</td>
<td>Cleaning of windings and Interior of the generator</td>
</tr>
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<td>42</td>
<td>Cleaning of windings with Solvents</td>
</tr>
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</tr>
</tbody>
</table>

ADVANCED TESTING, MONITORING & DIAGNOSIS

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<tr>
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</tr>
</thead>
<tbody>
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<td>ViSoR Remote Monitoring System</td>
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<td>48</td>
<td>Bolted Connections Tightening Solution</td>
</tr>
<tr>
<td>49</td>
<td>Maintenance of Slip rings</td>
</tr>
</tbody>
</table>
Site Engineer Report

Guidance – Ensure all Maintenance Schedules completed are recorded; if any schedules could not be completed record the reasons for future record.
Capture any observations and recommendations for follow-up actions and priority of that action. Include any Client/Customer Comments i.e. immediate or next routine visit.

_________________________________________________________ _________________________________________________________
_________________________________________________________ _________________________________________________________
_________________________________________________________ _________________________________________________________
_________________________________________________________ _________________________________________________________
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Site Engineer Name  Signature  Date

Client/Customer Name  Signature  Date

CLASS II (GE INTERNAL NON-CRITICAL)
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15. **GE POWER CONVERSION CONTACT DETAILS**

GE has been setting the standard in manufacturing rotating machines for over 125 years. We continue to deliver innovative mechanical power solutions to the world. Generators are designed and manufactured to operate efficiently and reliably in challenging applications and severe environments where reliability and ease of maintenance is critical.

The Power Conversion Service department has been operational since the electrical rotating machines first began to be manufactured in 1904. Power Conversion Service excels in performance and innovation. Our experienced specialist teams travel throughout the world ensuring minimum intervention time, providing our customers with the technical and research resources of a major manufacturer. Our Service department comprises sections for: replacement parts and generators, maintenance and repair, expertise and diagnostics, installation & commissioning.

If any machine failure or problem occurred during normal operation or maintenance work please contact any one of the below GE operated offices

<table>
<thead>
<tr>
<th>Service Location</th>
<th>Local number</th>
<th>Dialling costs</th>
<th>Language</th>
</tr>
</thead>
<tbody>
<tr>
<td>ANZ</td>
<td>+61 1300 193 189</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
<tr>
<td>China</td>
<td>+86 400 021 5605</td>
<td>Local costs / International</td>
<td>Chinese</td>
</tr>
<tr>
<td>France</td>
<td>+33 17731 23 23</td>
<td>Local costs / International</td>
<td>French / English</td>
</tr>
<tr>
<td>Germany</td>
<td>+49 69 6612 5588</td>
<td>Local costs / International</td>
<td>German / English</td>
</tr>
<tr>
<td>India</td>
<td>+91 44 496 80008</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
<tr>
<td>MENAT (UAE)</td>
<td>+971 2699 4931</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
<tr>
<td>(excluding Iran)</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>UK</td>
<td>+44 1788 56 3800</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
<tr>
<td>NAM</td>
<td>+1 844 437 4474</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
<tr>
<td>Iran</td>
<td>+33 619365696</td>
<td>Local costs / International</td>
<td>English</td>
</tr>
</tbody>
</table>

* Note that you may be charged different rates when calling from a mobile. Toll free numbers are toll free only in certain countries. Please check with your local provider.

Contact via E-Mail:
Please open the >contact us file.
Please fill in all mandatory fields as accurate as possible (if applicable). Save the file as a .pdf then email to: escc.geem@ge.com.
If you are located in Iran, please email to: service.iran@ge.com
16. MODIFICATION RECORD

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Author</th>
<th>Approver</th>
<th>Details</th>
</tr>
</thead>
<tbody>
<tr>
<td>000</td>
<td>2017-08-11</td>
<td>S. Muthukkumaran</td>
<td>Adrian, Wingham</td>
<td>Initial Issue</td>
</tr>
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