EXTERNAL REPORT

ON

MAINTENANCE SCHEDULE CHECKLIST

FOR GEPC - RM COMMISSIONING & SERVICES

GENERATORS FOR WIND TURBINE APPLICATION
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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 generators and associated equipment. The term generator used in this checklist refers to all kinds of induction generators, DFIG and PM Generators installed for WTGS applications.

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

1. GE Platform Safety Manual
2. GE Platform 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 GE Induction Generators for Wind Turbine 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.

This manual incorporates all range of induction generators, DFIG and PMG equipment. Many sections are mainly applicable to the LV/MV induction generator equipment and many others are applicable to either DFIG or PMGs. Some sections may explain explicitly between the three configurations, but have different requirements for each. These sections are specified in this table:

<table>
<thead>
<tr>
<th>DFIG or Cage Induction Generators</th>
<th>Standard/Medium Speed or Direct Drive PM Generators</th>
<th>Common variance in construction or major accessories</th>
</tr>
</thead>
<tbody>
<tr>
<td>Converter Cabinet (DFIG only)</td>
<td>Converter Cabinet (PMG only) (Threads, MCP)</td>
<td>Power Distribution Panel (PDP)</td>
</tr>
<tr>
<td>Main Control Cabinet (MCC) (DFIG only)</td>
<td>Main Control Cabinet (MCC) (PMG only)</td>
<td></td>
</tr>
<tr>
<td>Low Voltage Distribution Panel (DFIG only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Stator Switch Cabinet (SSC) (DFIG only)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Generator Main Circuit Breaker (GMCB) (PMG only)</td>
<td>Safety Chain</td>
<td>Carbon Brushes</td>
</tr>
<tr>
<td>Cable Twist Switch (PMG only)</td>
<td>Power Cables - Stator</td>
<td></td>
</tr>
<tr>
<td>Power Cable – Rotor (DFIG only)</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

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.
2.1.1 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.

2.1.2 Prerequisites to perform maintenance

Never enter, climb or perform work in the WTGS 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 WTGS. No work should occur with electrical storms in the area or below the operating range for the WTGS, example: -30°C for CWE WTGS. Risks such as falls from the nacelle or hub due to wind speeds, frostbite from wind chill, and other hazards should be considered.

![Turbine Remote Start Possible](image)

The WTGS remote must be disabled by placing the service switch in the "repair" or "maintenance" position.

![Wind Speed Limitations for Work](image)

Unless safety chain is open, the rotor brake will release if wind gusts ≥ 30m/s.

Hub access is only allowed during an average wind speed up to 15 m/s!

Maintenance work on the yaw system may only be carried out up to an average wind speed of 15 m/s! (Individual gusts up to a max. 24 m/s).

For drive train maintenance, the low speed (rotor) shaft lock must be used. This may only be engaged up to the following average wind speed limits:

- 8 m/s for welded mainframe version * (individual gusts up to 14 m/s)
- 12 m/s for 1&2MW-82.5, 1&2MW-100/103 (individual gusts up to a max. 19 m/s).
- 15 m/s for 1&2MW-77 (individual gusts up to a max. 24 m/s).

* The cast and welded frame can be easily distinguished by the lifting lugs. See also the Figures in the section "Machine Head - Bedplate and Generator Frame".

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, pitching blades to the feathered position, and immediately applying the hydraulic brake to stop the rotor. The safety chain is designed as the last resort to protect the turbine from entering into an unsafe condition such as turbine over speed. This system must be checked as part of the maintenance procedure and any deficiencies corrected immediately. This includes the proper WTGS status messages being displayed by the control system and prevention of the WTGS starting up.

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

Protective Systems for the WTGS

The WTGS control system relies on the monitoring and protective functions (thermal motor 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.

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.

2.1.3 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

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

### Records of periodical test and inspection

- Insulation resistance and the relative humidity
- Amplitude of vibration
- The color and contents of grease discharged from bearings.
- Dirt lodged in and on the generator.
- Coupling allowance of coupling device; the tension of belts.
- Fastening bolts for base, foot and other parts.
- 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:

- 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%.
- Temperature rise (maximum ambient temperature of 40°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.

### 2.1.4 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.

### 2.1.5 Training and Safety Guidelines

The wind turbine is specialized equipment that requires equipment specific and other specialized training. Working on/in a wind turbine 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 wind turbine controls and operations. Always refer to local and national laws and regulations when determining safety, training, and staffing requirements.
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:

<table>
<thead>
<tr>
<th>NOTE</th>
<th>ATTENTION</th>
<th>CAUTION</th>
<th>WARNING</th>
<th>DANGER</th>
</tr>
</thead>
<tbody>
<tr>
<td>Notes include user tips and useful information. All notes should be implemented in the interest of a proper use of the generator.</td>
<td>Indicates a procedure, condition, or statement that should be strictly followed to improve these applications.</td>
<td>Indicates a potentially Hazardous situation which if not avoided could result in a minor or moderate injury or destruction damage.</td>
<td>Indicates a potentially Hazardous situation which if not avoided could result in death or serious injury.</td>
<td>Indicates an imminently Hazardous situation which if not avoided will result in death or serious injury.</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: xxxxxxxxx x / xx
Manufacturing year: 20xx
EC marking: xxxx - xx x x
Marking: xx x x xx xxx xx
Number of EC examination type certificate: xxxxxx xxxxxx xxxxx

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 WTGS BY THE REMOTE CONTROL SYSTEM!

Shut down the WTGS 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.
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 authorised 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

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.
CAUTION

Before any work is commenced, the 'Method Statement & Risk Analysis' should have been read and any local site induction courses attended.

The procedures detailed in this document should not be attempted unless they are fully understood and adequate training has been received. Further, the procedures should be followed exactly without any deviation.

No high voltage insulation test is needed in case of damage. This equipment has successfully passed applicable LV/MV/HV insulation test at factory.

Carrying out the protection and safety requests defined in the Low, Medium or High Voltage Regulations that have been established by the regulations from each country, in Force at the time.

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>
<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 1: SKILL LEVELS

<table>
<thead>
<tr>
<th>Apparatus</th>
<th>Minimum Skill Level Required For</th>
</tr>
</thead>
<tbody>
<tr>
<td>Grade</td>
<td>Degree of Isolation</td>
</tr>
<tr>
<td>1</td>
<td>Simple 100% isolation. Requires no electrical knowledge to isolate.</td>
</tr>
<tr>
<td>2</td>
<td>Simple 100% isolation. Requires some electrical knowledge to isolate.</td>
</tr>
<tr>
<td>3</td>
<td>100% Isolation possible. Requires expertise, training etc. and knowledge of the apparatus.</td>
</tr>
<tr>
<td>4</td>
<td>100% Isolation not possible because: - Impracticable - Unreasonable - Undesirable</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>
</tr>
</tbody>
</table>

Table 2: APPARATUS/TASK/SKILL LEVEL SCHEDULE FOR ELECTRICAL APPARATUS
4. **PRODUCT DATA**

This Maintenance Schedule Checklist covers the entire range of induction generators installed by GE. It includes a complete series of the following generators for the wind turbine applications.

**Doubly Fed Induction Generator**
- Power range: up to 3.5 MW
- Voltage: up to 13.8 kV
- Network Frequency: 50 & 60 Hz
- Rated Operating Speed: up to 2200 RPM

**Cage Induction Generator**
- Power range: up to 6 MW
- Voltage: 690V, 3.3 kV
- Network Frequency: 50 & 60 Hz
- Rated Operating Speed: up to 1800 RPM

**Direct Drive - Permanent Magnet Generators**
- Power range: 3 - 7 MW
- Voltage: 690V, 900V, 3.3kV
- Rated operating speed: 10 – 15 RPM

**Medium Speed - Permanent Magnet Generators**
- Power range: 3 - 8 MW
- Voltage: 690V, 3.3kV
- Rated operating speed: 200 – 600 RPM

**Standard Speed - Permanent Magnet Generators**
- Power range: 3 - 6 MW
- Voltage: 690V, 3.3kV
- Rated Operating Speed: 1000 – 1800 RPM
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.

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.

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 INTERVALS**

Maintenance tasks 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 WTGS 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

<table>
<thead>
<tr>
<th>Term</th>
<th>Definition</th>
</tr>
</thead>
<tbody>
<tr>
<td>Break-in Maintenance (BIM)</td>
<td>These tasks must occur between the period when 360 operational hours have been achieved on the WTGS and the 5 month anniversary of the date when they were achieved. These tasks are specific to the break in of certain components on the WTGS and are necessary only once in the lifetime of the system.</td>
</tr>
<tr>
<td>Semi Annual (SA)</td>
<td>These tasks must be completed within 6 months of the anniversary of the 360 operational hour mark of the WTGS 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>Annual (A)</td>
<td>These tasks must be completed by the 12 month anniversary of the 360 operational hour mark of the WTGS 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>
</tbody>
</table>
Beyond Regular Maintenance (BRM) those tasks that occur at an extended, infrequent or irregular manner such as oil changes, converter coolant exchange, 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.

Table-3: MAINTENANCE INTERVALS

<table>
<thead>
<tr>
<th>Table</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>360 Hours</td>
<td>BIM</td>
</tr>
<tr>
<td>6 months max</td>
<td>SA</td>
</tr>
<tr>
<td>12 months maximum</td>
<td>SA</td>
</tr>
</tbody>
</table>

Semi-Annual tasks should be performed every 6 months (7 max)
Annual tasks should be performed every 12 months (13 months maximum)

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 WTGS 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. Examples are the High Wind and Low Wind checklists.

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.
5.2 SCOPE OF MAINTENANCE

<table>
<thead>
<tr>
<th>S.No.</th>
<th>Maintenance Activity</th>
<th>Break-in Maintenance</th>
<th>Annually</th>
<th>Beyond Regular Maintenance</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Regular Maintenance tasks</td>
<td>✓ Standard visual inspection, ✓ Standard cleaning tasks and ✓ Standard functional tests</td>
<td>(after 360 hrs or every 4,000 hrs)</td>
<td>(every 8,000 hrs of operation)</td>
</tr>
<tr>
<td>2</td>
<td>Mechanical Disassembly &amp; Overhauling</td>
<td>✓ Open inspection of generator subassemblies</td>
<td></td>
<td>✓ Disassemble and Overhauling of major parts such as rotor</td>
</tr>
<tr>
<td>3</td>
<td>Optional Tests</td>
<td>-</td>
<td>-</td>
<td>! Optional Tests</td>
</tr>
<tr>
<td>4</td>
<td>Repair / Refurbishment</td>
<td>-</td>
<td>-</td>
<td>After any refurbishment, additional tests shall be performed.</td>
</tr>
<tr>
<td>5</td>
<td>Monitoring &amp; Diagnostics</td>
<td>✓ Conduct a spectral Analysis to detect various malfunctions</td>
<td></td>
<td>! This calls for specialised know-how, covering all preventive &amp; corrective maintenance actions if required.</td>
</tr>
<tr>
<td>6</td>
<td>GE Specialized Maintenance</td>
<td>-</td>
<td>-</td>
<td>! DDMS, Generator Performance monitoring and reliability tests</td>
</tr>
<tr>
<td>7</td>
<td>Modify/Upgrade</td>
<td>-</td>
<td>-</td>
<td>! On-request only</td>
</tr>
<tr>
<td>8</td>
<td>Spares List</td>
<td>-</td>
<td>-</td>
<td>✓ As recommended</td>
</tr>
<tr>
<td>9</td>
<td>Training</td>
<td>✓</td>
<td>-</td>
<td>As agreed through service orders</td>
</tr>
<tr>
<td>10</td>
<td>Documentation</td>
<td>✓</td>
<td>-</td>
<td>To be submitted as per the service order agreement.</td>
</tr>
</tbody>
</table>

Table 4: SCOPE OF MAINTENANCE

We recently rolled out a new methodology for performing maintenance which we called a Balance Scope maintenance. Instead of having a Semi-Annual and Annual maintenance we developed a High Wind Maintenance and a Low Wind Maintenance. The Low Wind and High Wind maintenance are meant to be interchangeable with the Semi-Annual and Annual maintenance.

This naming convention has been the source of many questions and misunderstandings so we have decided to change the naming convention used to BMA, BMB, and BMC. BM=Balanced Maintenance and A,B,C= the various components of the maintenance Cycle. Part A will be the replacement for the High Wind, Part B will be the replacement for the Low Wind Maintenance, and Part C will be a down tower maintenance which will be performed with the pad mount transformer de-energized.
<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 WTGS. 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.

---

**CAUTION!**
Care should be taken that no live parts should be accessed without isolation of AC Breaker as it contains Electrical danger.

**DANGER**
Life-threatening hazard from electrical voltage!

Prior to working on the generator, the unit must be completely de-energized and isolated for safety in accordance with local and national regulations.

Observe the relevant Lockout/Tagout instructions.

Wear appropriate PPE for entrance into energized cabinets.

Due to the design of the generator (permanent magnet excitation) a high voltage is generated at the stator winding when mechanically rotating the machine!

Never open the terminal box or work on the installation while the machine is rotating!

The (high-speed if equipped) rotor lock must be applied prior to working on the generator with exception of manual bearing greasing tasks.

**WARNING**
Dangerous consequences for your health and the WTGS!

Only adequately trained persons who are thoroughly familiar with the equipment and the instructions should maintain this equipment.

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>Component</th>
<th>Contamination</th>
<th>Cleanliness</th>
<th>Loose or Displaced Parts</th>
<th>Vibration</th>
<th>Mechanical Damage</th>
<th>Deterioration</th>
<th>Surface Condition &amp; Wear</th>
<th>Cracks</th>
<th>Worn parts</th>
<th>Overheating, Accidental &amp; Burning</th>
<th>Corona, Arcing, &amp; Sparking</th>
<th>Core Migration</th>
<th>Core Traverse</th>
<th>Core Insulation</th>
<th>Core Degradation</th>
<th>Core Overheating</th>
<th>Core Distortion</th>
<th>Core Water Leaks</th>
<th>Distortion</th>
</tr>
</thead>
<tbody>
<tr>
<td>Exterior of the Generator</td>
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<tr>
<td></td>
<td>Mounting &amp; Coupling (Holding down bolts, Hardware)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>All fasteners</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<tr>
<td>Electrical systems and cabinets</td>
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<td></td>
<td>Electrical cables, bus bars, cabinets</td>
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<tr>
<td></td>
<td>(Cable glands, Lugs/Connectors, Insulation, protective devices like rubber mats, busbars cages, armor cost, cable bundle rings)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td>Generator Frame</td>
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<td></td>
<td>Stator Frame</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>(Key bars, Core studs)</td>
<td>X</td>
<td>X</td>
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<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>Core Assembly</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>(Lamination, Finger plates)</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>Slot Section</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>(Slot Fillers, Wedges, Ripple Springs)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>End winding Support System</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></td>
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</tr>
<tr>
<td></td>
<td>(Bracing, Ties, Coil/Bar Insulation)</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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<tr>
<td></td>
<td>Circuit Rings and Main &amp; Neutral Leads</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
<td>X</td>
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</tr>
<tr>
<td></td>
<td>Coolers</td>
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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 Converter Cabinets (PMG only) (Threads, PDP, MCP)

Cabinet/Housing:
Perform standard visual inspections for cabinets.
Note: Cabinets may have grills in in-accessible locations on upper levels of the PPM. There are no filter elements in these requiring inspection and cleaning.
Perform standard function tests for cabinets.

NOTE
All dirt and debris must be vacuumed from the cabinet

Dangerous consequences for your health and the WTGS!
Doors that are not securely latched may come open in the event of an arc flash. Verify that all door latches are completely engaged and tightened during maintenance inspections.

Cable Terminals/Cables:
- Perform standard visual inspections for electrical systems.
- Perform standard visual inspections for fluid systems.

Cooling System

Potential Exposure to chemical irritants!
Potential exposure to chemicals when working with converter coolant. Proper PPE is required.

NOTE
Gen 0 and Gen 1 system designs differ. The same tasks are performed, but a different method may be used to accomplish each.
- Verify appropriate mixture of 50/50 coolant: distilled water or appropriate pre-mix coolant mixture with refract-o-meter. A concentration ratio is between 47 %–53 % glycol to distilled water is acceptable. If necessary adjust the system to reach the appropriate ratio. Expect the refract-o-meter to indicate between -30 °C to -40 °C. Refer to the Lubricant List document for guidance.
- Drain and replace the entire volume of coolant in the converter every 5 years or as required. Refer to appropriate GEI for correct work steps.
- Standard function tests for the coolant pump mechanical systems
- Nominal operating pressure is close to 40 psi / 2.7 bar

**NOTE**
For all pump types and system configurations, pressure near this value is indicative of proper operation. Values significantly different could be indicative of system alignment issues, system blockage, degradation of equipment or improper installation.

- Carry out a visual inspection of the stainless steel filter element directly upstream of the pump per standard visual inspections of filtration. If after cleaning the filter is determined to be damaged or unserviceable, replace the filter.
- Visually inspect the Bypass filter element as per standard visual inspections of filtration. If after cleaning the filter is determined to be damaged or unserviceable, replace the filter.

**Converter Cooling Circuit – Dual Loop Cooling Circuit (GEN 1)**

**ATTENTION**
Dangerous consequences for the WTGS!
Converter cooling circuit and external radiator cooling circuit in the dual loop cooling system operate with different coolants!

- standard visual inspections for fluid systems; check for Ice damage to external system; fasteners secure on external equipment (if accessible); damage or corrosion of expansion vessel
- check the liquid cooling circuit at all four outside pipe units for air in the system, each pipe unit has three valves to check. If necessary, vent the system. Refer to the appropriate GEI for correct work steps.
- verify system low pressure alarm does not actuate when pump off (measure accumulator charge pressure indirectly).
- Check the concentration of the internal and external loop cooling liquid. These loops have different coolant requirements. Verify appropriate mixture of 50/50 coolant: distilled water or appropriate premix coolant mixture with a refract-o-meter. A concentration ratio between 47%-53% glycol to distilled water is acceptable. If necessary adjust the system to reach the appropriate ratio. Expect the refract-o-meter to indicate between -30 °C to -40 °C. Refer to the Lubricant List document for guidance.
- Drain and replace the entire volume of coolant in both converter cooling loops every 5 years or as required. Refer to appropriate GEI for correct work steps.

**Internal Coolant Pump:**
- no signs of coolant leakage internal to the converter threads
- standard function tests for mechanical systems
- nominal operating pressure is close to 40 psi / 2.7 bar

**Stainless Steel Filter Element:**
Carry out a visual inspection of the stainless steel filter element directly upstream of the pump per standard visual inspection of filtration. If after cleaning the filter is determined to be damaged or unserviceable, replace the filter.

**Bypass Filter Element (if equipped)**
Perform standard visual inspections of filtration. If after cleaning the filter is determined to be damaged or unserviceable, replace the filter.

**External Coolant Pump**

Perform standard function tests of mechanical systems.

### 6.1.4 Converter Cabinets (DFIG only)

#### Distortion Filter and Pump Cabinet:

Perform standard visual inspections for cabinets, electrical systems and fluid systems, discoloration of zinc plating on bolted connections, fuses (proper amperage, integrity of ceramic bodies, installation, corrosion, spark marks)

Verify operation is free of abnormal noise or excessive vibrations.

#### Heat Exchanger Cabinet

**Potential Exposure to chemical irritants!**

Potential exposure to chemicals when working with converter coolant. Proper PPE is required.

Perform standard visual inspections for cabinets, electrical systems and fluid systems, secure attachment of bolted cover – vital for cooling airflow, relief valve attached to drain assembly

**Cooling System:** Check the concentration of the internal and external loop cooling liquid; verify appropriate mixture of 50/50 coolant: distilled water or appropriate pre-mix coolant mixture with a refractometer. A concentration ratio is between 47 % -57 % glycol to distilled water is acceptable. If necessary adjust the system to reach the appropriate ratio. Expect the refractometer to indicate between -30 °C to -40 °C, refer to the Lubricant List document for guidance, and check the pre-pressure in the system

**NOTE**

Pressure will vary according to the temperature of the fluid. Initial information on pre-charge pressures will be included with the unit.

<table>
<thead>
<tr>
<th>Fluid Temperature</th>
<th>System Pressure</th>
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<td>C</td>
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<tr>
<td>-30</td>
<td>1.3</td>
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<td>-20</td>
<td>2.2</td>
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<tr>
<td>-10</td>
<td>3.1</td>
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<tr>
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<td>60</td>
<td>13.6</td>
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<td>70</td>
<td>16.1</td>
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</table>
Lubrication Requirement: Drain and replace the entire volume of coolant loop every 5 years or as required. Refer to appropriate GEI for correct work steps.

Coolant Pump: no signs of coolant leakage internal to the converter; standard function tests for mechanical systems

AC Entry Cabinet/Generator Rotor Cable Enclosure (DFIG only)
- standard visual inspection for cabinets and electrical systems
- proper clamping of cable strain reliefs
- discoloration of zinc plating on bolted connections
- fuses (proper amperage, installation, corrosion, and spark marks)
- circuit breakers (tight connections, corrosion, spark marks)

Inductor Cabinet (DFIG only)
- standard visual inspections for cabinets and electrical systems
- secure attachment of bolted cover
- verify integrity of ceramic bodied fuses
- verify rotor inductor 1 and 2 are from same manufacturer
- discoloration of zinc plating on bolted connections

Bridge Cabinet (DFIG only)
- standard visual inspections for cabinets and electrical systems
- discoloration of zinc plating on bolted connections
- tight and seated pin connections
- secure attachment of bolted cover
- IGBTs – ensure the area is free of dirt and dust that could lead to an arcing event
- verify all IGBTs in a phase (for rotor bridge 1 and 2) are from the same manufacturer
- capacitors for dielectric leakage and/or deformation
- heat sinks (clean if required)

Converter Control Cabinet (CCC) (DFIG only)
- standard visual inspections for cabinets and electrical systems
- tight and seated pin connections
- capacitors for dielectric leakage and/or deformation
- confirm the air-to-air heat exchanger is free of flow restrictions
- proper operation of heating elements
- actuation of E-stop

Internal fan impellers operating properly without abnormal noise or excessive vibration (clean if required)

Main Control Cabinet (MCC) – (PMG only)

DANGER

Life-threatening hazard from electrical voltage!
All tests requiring entry for work in cabinets shall be performed with power completely de-energized and isolated for safety in accordance with local and national regulations. Observe the relevant Lockout/Tagout instructions. Wear appropriate PPE for entrance into energized cabinets.
- signs of animal activity
- standard visual inspections for cabinets
- condition of fiber optic cables
- cleanliness of MIF II (digital feeder protection) circuitry
- verify proper motor protection settings per drawings
- Verify that doors open, close and latch properly. This includes the main door and the keyboard door
- verify that the ventilation is expelling hot air out of the cabinet
- verify that the heaters are functioning and blowing by modifying and returning thermostat settings
- verify tight connection of the components and cable clamps
- Verify that the Transformer LV Winding Relay (GE MIF II) is reading current from all 3 phase CT's (verify real-time values are non-zero on faceplate)
- with the WTGS energized and in stop mode, press the “Emergency Stop” button located on the front of the cabinet door and verify the fault condition on the turbine status

**WARNING**

Dangerous consequences for your health and the WTGS!

Doors that are not securely latched may come open in the event of an arc flash. Verify that all door latches are completely engaged and tightened during maintenance inspections.

**Filter Element**

- Carry out a visual inspection of the general condition of inputs and outputs of the master computer ventilation.
- Perform standard visual inspections for filtration.

**NOTE**

In dusty environments, it may be necessary to inspect and clean filters more frequently than the stated maintenance interval to ensure proper thermal performance of the WTG.

- If after cleaning the filter is determined to be damaged or unserviceable, replace the filter.

**Filter Fan and Thermostat**

- Inspect for damage to the fan assembly.
- adjust thermostat to verify that the fan is functioning correctly
- monitor fan operation for abnormal noise or excessive vibration
- verify the thermostat is returned to 25 °C

**Turbine PC (if installed) and Turbine Control System**

- Ensure devices show no deformations.
- Remove dust and dirt on device surfaces and verify nothing is located at the top of the IPC.

**NOTE**

All dirt & debris must be cleaned from the cabinet

- Check the free storage space of the Turbine Controls PC. If free storage space is lower than 10 % delete unused and/or temporary files

**UPS**

This test is to verify the proper operation/functionality of the UPS. The turbine must be energized and placed in stop mode prior to testing.
6.1.6 Main Control Cabinet (MCC) (DFIG only)
- Perform standard visual inspections for cabinets and electrical systems.

Ventilation:
- check that the fan thermostat is properly set per the schematic and that the fan is functioning correctly
- monitor fan operation for abnormal noise or excessive vibration
- adjust the heater thermostat and verify heaters are functioning and blowing warm air
- Verify heater and fan thermostats are restored to proper setting per schematic.

E-stop Switch:
This test is to verify the proper operation/functionality of the emergency stop switch. The following steps are required prior to testing:
- with the WTGS energized and in stop mode, press the “Emergency Stop” button located on the front of the cabinet door and verify the fault condition on the turbine status

UPS
- De-energize the UPS by unplugging the power input to the unit. Verify that the PLC & PC remain operating for at least 5 minutes after the power has been removed.

6.1.7 Low Voltage Main Switch Cabinet (if equipped)
Note: This cabinet contains a circuit breaker or fuses that connect the MVSG to the LVMD.
In addition to the standard visual inspection checks, inspect the following:
- Spark marks, overheating, corrosion or moisture
- Torque mark on connections
Fuses and fused isolation switches (proper installation, fork blade connection integrity)

Circuit Breaker (if equipped)
In addition to standard visual inspection checks inspect the following:
- General condition of the arc chutes
- Cracks in the housing of the chambers
- Verify that the main breaker settings are consistent with current site-specific settings
Check the cycle count of the main circuit breaker. If value exceeds 9,000 cycles, the circuit breaker must be serviced. Refer to manufacturer’s recommendations.
Lubricate the interlock shafts of the main circuit breaker. Refer to the Lubricant List document for guidance.
6.1.8 Low Voltage Distribution Panel (DFIG only)

**DANGER**

Life-threatening hazard from electrical voltage!

All tests requiring entry for work in cabinets shall be performed with power completely de-energized and isolated for safety in accordance with local and national regulations. Observe the relevant Lockout/Tagout instructions. Wear appropriate PPE for entrance into energized cabinets. During the maintenance and the scheduled checks, isolate the voltage from all switchboard parts. Observe relevant Lockout/Tagout instructions. Before accessing the apparatus inside, make sure that

- the disconnect switch is open
- the earthing switch is positioned on "earth"
- the main switchgear (MVSG) has been de-energized

**Dangerous consequences for your health and the WTGS!**

Only adequately trained persons who are thoroughly familiar with the equipment and the instructions should maintain this equipment. Operations must be carried out by exerting a normal operating force. If proper function is hindered, do not force the mechanical interlocks and make sure that operations are executed in the correct sequence.

**Enclosure:**

- damaged or worn gaskets around door and moving parts
- standard visual inspections for cabinets
- correct component specific tools are attached to side of cabinet and in good condition
Power and Control Cables:
- standard visual inspections for electrical systems
Clean accumulated dust and dirt with vacuum cleaner or cloth. Do not use pressurized air!
- disconnect switch interlock prevents door opening
- ground switches properly engage/disengage
- door closes and properly latches

K1 Contactor Maintenance Visual Inspection
- Visual inspection for dust, dirt, rust, discoloration
- signs of arcing or overheating
- secure connection of all bolts, nuts, and screws

Lubrication Requirement (Vacuum Contacts):
Check female contactor pin connections to main bus to ensure adequate lubrication. Refer to the Lubrication List for appropriate material.
- Check for wear on the vacuum interrupter bottle. Refer to supplier manual for measurement procedure.

6.1.9 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 2.x Bolt Torque Specification document
• ensure cable glands are securely tight at generator junction box
• fastening stator connectors Pfisterer Plug (DFIG only)
• fire-blocking tape condition (if installed – DFIG only)

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.

Note: Physical check of Pfisterer plugs is not performed beyond initial installation unless Visual Inspection determines the fasteners worked loose.
6.1.10 Power Cable – Rotor (DFIG only)

- 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.

6.1.11 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.

6.1.12 Safety Chain

The safety chain is a series connection of contact points of various monitoring devices of the Wind Turbine Generator System. It serves to protect the WTGS from impermissible or dangerous operating states. The opening of just one of these contacts causes the interruption of the safety chain.

Note: Initiation of the emergency stop will initiate an emergency braking operation that brings the rotor to a standstill as quickly as possible. At the same time, the rotor blades are turned to the stop position of 87°, the disk brake is activated and the WTGS is disconnected from the grid by the opening of the circuit breaker of the generator. Ensure personnel are clear from these areas before initiating the emergency stop.

Refer to the appropriate GEI for correct work steps to complete the function tests associated with the safety chain.

ATTENTION

Dangerous consequences for the WTGS!
The WTGS must not start up with the safety chain opened.

Verify proper operation, including activation of the safety chain, for the following switches/devices:

Note: for instructions on completing these tests, please refer to the appropriate GEI.
• Emergency Stop
• Rotor Lock Switch (Low Speed)
• Vibration Switch
  o PMG equipped with pendulum style sensor
  o DFIG equipped with PCH - Shock Safety Detection – no test required
• Centrifugal Switch (if equipped)
• Over speed monitor

6.1.13 Generator Shear Plate (if equipped)
Perform standard visual inspection checks

6.1.14 Generator Support frame

**ATTENTION**
Failure to perform weld inspections may result in serious damage to the WTG. Additional hardware may need to be temporarily removed to fully inspect all weld points.

One piece welded bedframes that have shear plates must be inspected at GF 1, 2 and 6.

One piece welded bedframes without shear plates must be inspected at all of the locations specified in Figure below.
6.1.15  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

6.1.16 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.

6.1.17 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>
</tr>
</thead>
<tbody>
<tr>
<td>Generator Bearings</td>
<td></td>
<td>Manual greasing:&lt;br&gt;Grease type: Kluberplex BEM 41-132</td>
<td>Approx 600 g (PMG) or Approx 400 g (DFIG)</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Automatic lubrication system (PMG Only):&lt;br&gt;Grease type: Kluberplex BEM 41-132</td>
<td>Approx 2.0 kg</td>
</tr>
<tr>
<td>Active Brake/Hydraulic system</td>
<td></td>
<td>Oil type: Mobil DTE 25</td>
<td>3 liters</td>
</tr>
<tr>
<td>Converter Cooling Circuit</td>
<td></td>
<td>60 Hz market:&lt;br&gt;Top up with premixed coolant per GE 108W1957P001&lt;br&gt;50 Hz market:&lt;br&gt;109W0166P001 (G05) and 109W0067P001 (distilled water)&lt;br&gt;Glycol in G05/Zerex G05</td>
<td>Single loop: Approx. 160 liters&lt;br&gt;Dual loop – inside: Approx. 120 liters&lt;br&gt;DFIG: Approx. 73 liters</td>
</tr>
<tr>
<td>Radiator Cooling Circuit – Dual Loop Cooling System (PMG only)</td>
<td></td>
<td>If necessary top up with liquid mixture of distilled water and propylene glycol per GE drawing 114W2675P001, Glycol in P44</td>
<td>Dual loop – outside: Approx. 420 liters</td>
</tr>
<tr>
<td>SSC K1 pin contactors</td>
<td></td>
<td>Grease Type: Mobilgrease 28</td>
<td>&lt;0.1 kg</td>
</tr>
<tr>
<td>Slip ring</td>
<td>Mersen</td>
<td>Manufacturer specified lubricant:&lt;br&gt;Cleaning set (art. no. 1600-45624)&lt;br&gt;GE part no.: 107W2195P001</td>
<td>N/A</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Manufacturer specified lubricant:&lt;br&gt;Spray lubricant (art. no. 1606-45620)&lt;br&gt;GE part no.: 107W2194P001</td>
<td>N/A</td>
</tr>
</tbody>
</table>

6.1.18 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.

6.1.19 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.

6.1.20 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.

### 6.1.21 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.

### 6.1.22 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

Build-up 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

Wear gloves and eye protection when using cleaning fluids and use them only in a well-ventilated area.

- 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).

Normal household cleaners may leave a salt residue behind and must not be used.
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 x 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 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,

6.3.3 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

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. ENHANCED TECHNICAL SUPPORT

7.1 GENERATOR CIRCUIT TESTING

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 Center. Data is collected, stored, trended and recalled to provide you with comprehensive reports.
On-line Generator Circuit Testing

GE provides on-line monitoring testing services including:
- Power condition tests - voltage level, un-balance, total harmonic distortion
- Generator performance tests - service factor, power factor, generator current, generator speed
- Generator efficiency studies
- Load condition test - load torque, torque ripple and profile
- Generator condition test - rotor bar test
- Trending - tracks all data over time
- Installation of a EP-1 Option, which is a port installed on the outer door of the MCC.

Off-Line Generator Circuit Testing

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. This testing offers the following advantages:
- Current testing technology
- Winding Condition - lead-to-lead resistance
- Winding Insulation Condition - resistance to ground (megger), insulation integrity (polarization index), insulation strength (hipot)
- Turn-to-Turn Condition - detects potential turn-to-turn short before it causes costly winding failure.
- Non-destructive testing

7.2 ADVANCED TESTING, MONITORING & DIAGNOSIS SOLUTIONS

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.
- Digital Diagnosis Management Solutions
- Vibration Analysis
- Thermographic Services
- Generator Reliability Program
- Generator performance monitoring with GE’s patented Condition Monitoring System
- Remote Monitoring and Diagnosis (RM&D) for Generators
- Cooling circuit test
- Short-circuited coil test
- Bearing Oil Analysis (Electrical & Mechanical)
- Arc flash hazardous analysis

7.2.1 Digital Diagnostic Management Solutions

GE’s Digital Diagnostic Management Solutions (DDMS) is a plant maintenance management program that utilizes the latest in predictive, assessment and maintenance technologies. DDMS offers digital diagnostics for condition assessment and correction of electrical apparatus and associated equipment.

Digital data will be collected in the field, synchronized under a unique identification, and transmitted to GE Energy’s global database/WAN Network for data analysis, trending and reporting of your critical equipment. This feature also offers our customers comparative trending of all similar equipment in the entire GE network.

DDMS provides condition monitoring by establishing practical evaluation criteria and routine monitoring to confirm equipment condition, detect developing problems, and to determine their nature and severity. The
program is also “solution based” and provides solutions and recommendations to equipment exceeding alarm limits.

7.2.2 Vibration Analysis

GE Energy offers a comprehensive condition monitoring program and extensive vibration troubleshooting services for your equipment. Our vibration analysis detects the following:

- Mechanical misalignment
- Excessive clearances
- Bearing defects
- Base and structural issues
- Belt issues
- Mechanical looseness
- Bent shaft/thermal bows
- Resonance issues
- Gear defects
- Rotor bar issues

7.2.3 Thermography Services

An infrared, or thermographic, inspection should be performed at least once every three years on all switchgear, distribution panels, cable and bus connections, generator control centers and starters, and other critical equipment. Infrared inspections are extremely beneficial in reducing electrical failures by identifying potentially dangerous conditions; such as, loose or dirty connections, overloaded or imbalanced circuits, or improperly installed equipment. By measuring the heat imbalance relative to the environment and to surrounding equipment, abnormal or adverse conditions can be uncovered that if left unattended would worsen to the point of failure.

GE offers infrared services to detect thermally related issues on your power distribution systems. This infrared scanning technology allows our service technicians to scan and store up to 500 images per visit. By utilizing GE’s uncooled camera, the speed of scanning and collecting data has increased dramatically. The lightweight camera has voice annotation, which permits 30 seconds of verbal notes per image. Issues detected in our survey include:

- Localized heating
- Electrical overloads
- Corona tracking
- Defective electrical components
- Arcing
- Loose connections
- Dirty connections

Effective infrared surveys require specialized equipment and should be performed only by qualified technicians. Experience and training is required to accurately identify problem conditions and possible causes so that specific recommendations can be made to correct the situation. It is imperative that these recommendations be implemented in a timely manner to benefit from an infrared inspection. Knowing a problem exists does not help avoid an electrical failure unless corrective actions are employed.
7.2.4 Generator Reliability Program

GE Energy, a leader in the generator industry, understands the costs associated with plant downtime. Because generators are a key link in production systems, maximizing the reliability and life-cycle of a generator can have significant financial benefits to plant operators. To help monitor and maintain the performance of your critical generators, GE Energy now offers the Generator Reliability Program.

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.

By offering an outstanding selection of service options from repairs and refurbishment to new units, GE can help you keep your operation "up and running" with experience you can trust.

This unique program combines two valuable services:

- Performance monitoring with GE’s patented Condition Forecaster™ system
- Comprehensive maintenance and repair services

The Condition Forecaster system provides advanced notice of probable failures and statistically forecasts the remaining life of a generator. Using this in-depth information, GE Energy can proactively plan repair or replacement timing for critical process equipment, reducing downtime and improving the efficiency of asset management in your organization.

With limited capital investment required, the Generator Reliability Program includes a Condition Forecaster system for each generator specified in the service contract. GE also provides all necessary generator repair services, whether in-shop or on-site, in response to system alerts.

7.2.5 Generator Performance with GE patented Condition Forecaster™ Monitoring System

Condition Forecaster is a unique and easy-to-use monitoring system that analyzes industry historical generator data and predicts not only specific upcoming failures, but also the expected time before the failure occurs.

GE’s patented, leading-edge Condition Forecaster technology offers significant advantages over other types of monitoring systems:

- Uses industry-standard monitoring system data collection such as mechanical, electrical, and ambient measurements.
- Analyzes information in conjunction with other historical data compiled by GE (database includes more than 40,000 maintenance activities to reference).
- Estimates generator residual life through multi-parameter regression analysis, Bayesian belief networks, and Weibull reliability curves.
- Takes advantage of the wide variety of continuous monitoring hardware that may already be in use at customer sites or supplied through other sources.

GE can set up Condition Forecaster in a stand-alone format or remotely monitor equipment status for you. The system sends alerts and time-to-failure estimates via phone, e-mail, or pager when components are under stress.

7.2.6 Remote Monitoring & Diagnostics (RM&D) for Generators

GE’s comprehensive generator monitoring strategy enhances the ability of industrial customers to reduce downtime and identify generator failure before it happens. Elements of GE’s solution include:
• Continuous technical support through the GE Monitoring & Diagnostic Center (M&D)
• GE engineers analyze your generator’s condition data to identify potential failures
• Advanced technology products that retrofit easily into existing equipment and provide the highest levels of protection and reliability
• Prompt installation and commissioning services built on GE’s years of field engineering experience and OEM product knowledge

Industrial customers who use generator equipment can lose time and money from periodic maintenance and equipment removal efforts. RM&D provides them with the engineering and service expertise of GE Energy.

RM&D is a complete industrial machine-monitoring package that samples voltage, current, temperature and vibration data and transmits the values via a secure, cellular network connection to the GE Energy M&D Center. At the M&D Center, experienced industrial engineers identify and report erratic machine behavior, which allows for preventive maintenance, condition-based service or halting dangerous operation. RM&D also enables customers to analyze generator operating trends through our secure web connection, which displays all condition data in real time.

GE surveys industrial machine health through the remote monitoring of the key process indicators such as Stator voltage, Stator current, Stator temperature, Bearing temperature, Bearing vibration, Calculation of torque, speed and efficiency, and energy usage, Current signature analysis, Harmonics analysis (current and voltage)

RM&D is applicable to all industrial generators that are attached to a control device that outputs data via Modbus; e.g., GE MultiLine 369, 469, M60 or various other manufacturers’ relays.

GE Energy can provide a complete generator monitoring solution:
• Comprehensive generator condition monitoring
• Text message/email alerts
• 24-hour monitoring support
• 24-hour engineering support
• Warehoused condition data
• Web-based access for customer visualization of data
• Wireless transmission of data
8. **REPAIR & REFURBISHMENT WORKS**

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

Note: Renewals and spares (or those not under warranty) should be ordered by contacting the nearest GE Sales or Service Office, or an authorized GE Sales Representative.

**Data Nameplate**

Each exciter line up, cabinet (panel/case), and core unit has a unique identifying catalog number, also called the part or ML number. The data nameplate provides the ML number, which links the equipment to its requisition, drawings, components, materials, specification item, and shipping documents. The data nameplate is located on the back of the cabinet door.

**Evaluating replacement part needs**

During production of Power Conversion generators, a list of replacement parts is generally drawn up consistent with the specific features of each machine.

Backed by our extensive experience in design and construction, Power Conversion's generators are able to meet the high-reliability requirements demanded by the operating conditions of our customers, and the applicable standards governing construction of generators.

8.1 **GENERATOR MAINTENANCE AND REPAIR SERVICES**

Another important feature of the Generator Reliability Program is GE's expert generator maintenance and repair services. 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

By offering an outstanding selection of service options from repairs and refurbishment to new units, GE can help you keep your operation "up and running".
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

1. 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?
2. 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 increases abruptly.
   e) The variation of load will cause the temperature of generator to go up.

9.7 LEAKAGE OF OIL

3. Self-contained bearings
   a. Is the bearing overfilled with oil?
4. Bearings with external oil supply
   a. Is the oil exit pipe flowing freely?
   b. Is the specified oil flow rate being exceeded?
5. Both kinds of bearing
   a. Windage from the coupling can cause a local depression, adjacent to the DE bearing, which
      will draw oil out of the bearing. If this is occurring, the coupling guard arrangement may have
      to be modified.

9.8 BRUSH HEATING
1. Measure and compare line current with that given on generator nameplates.
2. Check whether brushes are not bedding or sticking in holders – carefully re-bed or clean brushes and
   adjust pressure, check the spring tension.
3. Check grades of brush material – ensure grade recommended by manufacturer is being used.
4. In case sparking of brush is noticed, polish slip ring surface and apply pressure on brush.
5. We however, do not recommend the dismantling of machines by clients themselves during the
   guarantee period. In case of any trouble the matter should be immediately communicated to GEPC.

9.9 COOLERS

CACA (IC6A1A6)
1. Is the load normal, with balanced line currents and the expected power factor?
2. Is the cooling system working properly?
3. Are both fans running?
4. Is the external air flow normal and not blocked by tarpaulins, polythene sheets or rubbish?

CACW (IC8A1W7)
1. Is the load normal, with balanced line currents and the expected power factor?
2. Is the cooling system working properly?
3. Is the water on and are the flow and temperature levels normal?
4. Is the water outlet flowing freely?
5. Is air trapped in any of the stacks?
6. If there are two stacks in parallel, are they both at the same temperature?

NOTE
Stacks in series will NOT be at the same temperature

Screen Protected, Drip Proof
7. Is the load normal, with balanced line currents and the expected power factor?

Duct-Ventilated Cooling System with or without Filters
8. Is the load normal, with balanced line currents and the expected power factor?
9. Is the cooling system working properly?
10. Is the duct blocked at its remote end?
11. If there are dampers, are the working properly?

Filtered
12. Are filters blocked or in need of cleaning? Lack of filter maintenance can restrict ventilation and
    cause overheating.
10. **RECOMMENDED MAINTENANCE TOOLS**

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

10.1 **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

10.2 **TYPICAL MAINTENANCE TOOLS**

<table>
<thead>
<tr>
<th>Maintenance Job</th>
<th>Required Tools</th>
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<tbody>
<tr>
<td>General</td>
<td>Camera, Laptop computer, Handheld</td>
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<tr>
<td>Door/outer area</td>
<td>Hand brush, standard screw driver set, ratchet set &amp; torque wrench</td>
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<tr>
<td>Foundation</td>
<td>Tape meter &amp; go no go gauges</td>
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<tr>
<td>Anchor bolts</td>
<td>Tensioning cylinder, hydraulic power unit or hydraulic manual pump</td>
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<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>
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<tr>
<td>Bedplate</td>
<td>Hydraulic/electronic torque tool, power unit</td>
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<tr>
<td>Generator frame</td>
<td>Hydraulic/electronic torque tool, power unit</td>
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<tr>
<td>High speed coupler</td>
<td>Torque wrench</td>
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<tr>
<td>Generator bearings</td>
<td>Grease gun &amp; scraper (spatula)</td>
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<tr>
<td>Generator alignment</td>
<td>Alignment set/toolbox, alignment tools</td>
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<tr>
<td>Generator to bedplate attachment</td>
<td>Torque wrench</td>
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<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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## 11. MAINTENANCE SCHEDULE

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<thead>
<tr>
<th>S. No</th>
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<th>2nd Level</th>
<th>3rd Level</th>
<th>PERSONNEL</th>
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<td>Generator Shear Plate (if equipped)</td>
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<td>Generator Support frame</td>
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<td>Frame and Stator core physical inspection</td>
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<td>Generator Circuit Testing</td>
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<td>Turn-to-turn Test</td>
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<td>Air-gap Test</td>
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<td>Special Measures related to Generators installed in Explosion Hazard Areas</td>
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<td>Arc Flash Hazard Analysis</td>
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<td>Cleaning of windings with Solvents</td>
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<td>Cleaning of Brush Gear and Slip-rings</td>
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<td>Bolt Torque Tightening Procedure</td>
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<td>Check for shaft alignment</td>
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<td>Connection of bushed bearings lubricated by force-feed lubrication</td>
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<td>80</td>
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Table 8: Preventive Maintenance Schedule for Generators
12. **GLOSSARY OF TERMS**

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<th>Abbreviation</th>
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<tr>
<td>AC</td>
<td>Alternating Current</td>
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<tr>
<td>CACA</td>
<td>Closed Air Circuit, Air cooled</td>
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<tr>
<td>CACW</td>
<td>Closed Air Circuit, Water cooled</td>
</tr>
<tr>
<td>CMS</td>
<td>Condition Monitoring System</td>
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<tr>
<td>CT</td>
<td>Current Transformer</td>
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<td>DC</td>
<td>Direct Current</td>
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<td>DE</td>
<td>Drive End</td>
</tr>
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<td>EHS</td>
<td>Environment, Health and Safety</td>
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<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>
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<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>
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<tr>
<td>RTD</td>
<td>Resistance Temperature Detector</td>
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<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>
<tr>
<td>WTGS</td>
<td>Wind Turbine Generator System</td>
</tr>
</tbody>
</table>
## 13. APPENDIX A

### 13.1 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>
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<tr>
<td>2</td>
<td><strong>LOTO</strong></td>
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<tr>
<td></td>
<td>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</td>
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</tr>
<tr>
<td>3</td>
<td><strong>STANDARD VISUAL INSPECTION</strong></td>
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</tr>
<tr>
<td></td>
<td>Prior to start up the Maintenance; discuss with the customer any existing/previous issues with the generator.</td>
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<tr>
<td></td>
<td>Perform Mechanical disassembly of the following:</td>
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</tr>
<tr>
<td></td>
<td>Electrical disconnection of main stator &amp; excitation stator</td>
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<tr>
<td></td>
<td>Disconnection of bearing instrumentation &amp; pipe work</td>
<td></td>
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<tr>
<td></td>
<td>Removal of bearing covers, shells &amp; seals</td>
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<tr>
<td></td>
<td>Disconnect the rotor earth fault (REFM) (If fitted)</td>
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<tr>
<td>4</td>
<td><strong>Visual Checks (Mechanical)</strong></td>
<td></td>
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<tr>
<td></td>
<td>Inspection should look for:</td>
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<tr>
<td></td>
<td>Evidence of damage caused by dirt, loose parts, or foreign objects.</td>
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<td></td>
<td>Verification that air inlets are not blocked</td>
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<td></td>
<td></td>
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<tr>
<td></td>
<td>Evidence of moisture and/or dirt build-up</td>
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<td></td>
<td>Unusual noises, leaking oil seals, or high vibration</td>
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<td></td>
<td>Oil level gages (if present) should be checked</td>
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<td></td>
<td>Evidence of degradation of foundation, bed plates, anchor bolts</td>
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<td></td>
<td>Evidence of oil rings turning (if applicable)</td>
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<td></td>
<td>Evidence of leaking oil and water piping and connections</td>
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<tr>
<td>5</td>
<td><strong>Visual Checks (Electrical)</strong></td>
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<tr>
<td></td>
<td>Insulation damage, soft or degraded insulation</td>
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<tr>
<td></td>
<td>Short circuit damage over the coil or windings exposed</td>
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<td></td>
<td>Partial discharge activity</td>
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<tr>
<td>6</td>
<td><strong>Terminal Cubicle Inspection</strong></td>
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<tr>
<td></td>
<td>Check Line/Neutral Side Cubicles. Clean out and check tightness of the links (if not taped)</td>
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<tr>
<td></td>
<td>Check neutral earthing resistor/transformer.</td>
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<tr>
<td></td>
<td>Clean out and check tightness of the links (if not taped)</td>
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<tr>
<td></td>
<td>Functional checks on cubicle heaters (if fitted)</td>
<td></td>
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<tr>
<td></td>
<td><strong>Converter Cabinets (PMG only) (Threads, PDP, MCP)</strong></td>
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<td>7</td>
<td>Converter Cabinets (DFIG only)</td>
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<tr>
<td>8</td>
<td>Main Control Cabinet (MCC) – (PMG only)</td>
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<tr>
<td>9</td>
<td>Main Control Cabinet (MCC) (DFIG only)</td>
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</tr>
<tr>
<td>10</td>
<td>Low Voltage Distribution Panel (DFIG only)</td>
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<tr>
<td>11</td>
<td>Low Voltage Distribution Panel (DFIG only)</td>
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<tr>
<td>12</td>
<td>Power Cables – Stator</td>
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<tr>
<td>13</td>
<td>Power Cable – Rotor (DFIG only)</td>
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<tr>
<td>14</td>
<td>Bus bar and Power Cables Inspection</td>
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<td>15</td>
<td>Safety Chain</td>
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<tr>
<td>16</td>
<td>Generator Shear Plate (if equipped)</td>
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<tr>
<td>17</td>
<td>Generator Support frame</td>
<td></td>
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<tr>
<td>#</td>
<td>Description</td>
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<tr>
<td>18</td>
<td><strong>Frame and Stator core physical inspection</strong>&lt;br&gt;Check the paintwork for damage and recommend course of action&lt;br&gt;Inspect enclosure for contaminants ingress (water, dust...)&lt;br&gt;Check mechanical guards - Coupling/shaft protection (if fitted)&lt;br&gt;Inside frame contamination (oil ingress, fallen parts, debris...)&lt;br&gt;Borescope Inspection of other accessible areas (stator and rotor internals)&lt;br&gt;For any coil movement, plugged vent holes, coil bracing adequate and intact, lamination damage, tightness of wedges, etc.&lt;br&gt;Stator core: Check and clean the stator core within reach</td>
<td></td>
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<tr>
<td>19</td>
<td><strong>Rotor and Field physical inspection</strong>&lt;br&gt;Check and clean all reachable rotor components&lt;br&gt;Check all rotor components out of hands reach&lt;br&gt;Check and clean rotating excitation equipment (all components fitted)&lt;br&gt;Check the rotor mounted suppression resistors&lt;br&gt;Check rotor shaft grounding brush &amp; brush older&lt;br&gt;Rotor earth fault (REFM) components check (if fitted)&lt;br&gt;Visually inspect rotor mounted fans&lt;br&gt;balance weights properly secured&lt;br&gt;signs of bar movement&lt;br&gt;signs of rotor/stator rub or lamination damage&lt;br&gt;cooling ducts clear&lt;br&gt;rubbing marks on shaft&lt;br&gt;keyway distortion</td>
<td></td>
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</tr>
<tr>
<td>20</td>
<td><strong>Bearing Inspection &amp; Re-lubrication</strong>&lt;br&gt;Note the bearing oil flow, vibration and temperature levels (if generator is found running and sensors are operative)&lt;br&gt;Visual inspection of bearing housing, pipework and related hardware&lt;br&gt;Check bearing oil inspection glass&lt;br&gt;Check tightness of oil flange bolts&lt;br&gt;Bearing RTD resistance check and insulation resistance test&lt;br&gt;Inspect oil filters and check operation of filter blockage sensor (if fitted)&lt;br&gt;Check jacking oil lift and record data (if fitted)&lt;br&gt;Check bearings insulation</td>
<td></td>
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</tr>
<tr>
<td>21</td>
<td><strong>Bearing Sealing Inspection</strong>&lt;br&gt;Visual inspection of bearings journal and seals&lt;br&gt;Check bearing seal clearances</td>
<td></td>
<td></td>
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<tr>
<td></td>
<td>Stator Winding Inspection</td>
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<tr>
<td></td>
<td>The following electrical tests shall be conducted in the stator as well as in the exciter windings.</td>
<td></td>
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<tr>
<td></td>
<td>10-minute insulation resistance with polarization index</td>
<td></td>
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<tr>
<td></td>
<td>Winding copper resistance</td>
<td></td>
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<tr>
<td></td>
<td>Winding RTD resistance check and insulation resistance test</td>
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<tr>
<td></td>
<td>Air RTD resistance check and insulation resistance test</td>
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<tr>
<td></td>
<td>Stator space heater function checks</td>
<td></td>
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<tr>
<td></td>
<td>Check whole rectifier plate for continuity and break insulation</td>
<td></td>
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<tr>
<td></td>
<td>Individual checks on diodes (not included, except when a problem has been detected)</td>
<td></td>
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</tbody>
</table>

<table>
<thead>
<tr>
<th></th>
<th>Cooling circuit &amp; Heat Exchanger Inspection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Check generator air inlet filters (if fitted)</td>
</tr>
<tr>
<td></td>
<td>Check generator air inlet pressure switch (if fitted and accessible)</td>
</tr>
<tr>
<td></td>
<td>Check general status and operation of cooling air fan generators</td>
</tr>
<tr>
<td></td>
<td>Visual inspection of heat exchangers</td>
</tr>
<tr>
<td></td>
<td>Check for excessive vibration.</td>
</tr>
<tr>
<td></td>
<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></td>
<td>Check the winding temperatures</td>
</tr>
<tr>
<td></td>
<td>Check for oil leaks from bearings, seals, sight-glasses and pipework.</td>
</tr>
</tbody>
</table>

|   | Generator Cooling Fan (if equipped) |

|   | Generator Air Outlet Ducts |
### 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.

### 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.

### STANDARD FUNCTION TESTS

#### 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

<table>
<thead>
<tr>
<th>Generator voltage</th>
<th>Test voltage (VDC)</th>
<th>Acceptable reading</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt; 1000</td>
<td>500</td>
<td>&gt; 5 megohm</td>
</tr>
<tr>
<td>1000 – 2500</td>
<td>1000</td>
<td>&gt; 100 megohm</td>
</tr>
<tr>
<td>2501 – 5000</td>
<td>2500</td>
<td>&gt; 100 megohm</td>
</tr>
<tr>
<td>&gt;50000</td>
<td>5000</td>
<td>&gt; 100 megohm</td>
</tr>
</tbody>
</table>

#### Insulation Resistance (IR) Tests on Rotor

A 50V tester to be used, and the tester earth lead fixed to the rotor body.

Make sure that all diodes are temporarily short circuited to avoid damaging them, and make sure that the short circuits are removed when testing is complete.

#### Polarization Index (PI)

Ratio of the 10 minute IR to the 1 minute IR (10 min IR / 1 min IR)

Determines condition of ground insulation Test voltages similar to the IR test voltages Acceptance criteria ratio > 2
<table>
<thead>
<tr>
<th>No.</th>
<th>Test Description</th>
</tr>
</thead>
</table>
| 32  | High Voltage (HV) Test  
Megger readings must be taken before High Potential Tests. The test voltage must be of approximately sine wave form and during the application of the test the peak value as determined by a Peak reading voltmeter shall be not more than 1.45 times the R.M.S. Value. |
| 33  | Winding Resistance Test  
A comparison of the line to line resistances of the generator’s winding. This test should be done at the generator terminals using a meter capable of measuring low resistance (milliohms). A typical ohm meter does not have adequate accuracy. Record, temperate correct and trend. Each phase should be within +/- (3% - 5%) of the average of all three phases |
| 34  | Phase Rotation Test  
The correct rotation of the machine must first be checked in accordance with the outline drawing |
| 35  | Shaft Voltage Test  
The volts are to be measured by Avometer and recorded. |
| 36  | Voltage Balance Test  
A clamp-on ammeter to be used to take readings in each phase of a generator in actual operation under normal load. A Tachometer to be used to check the speed of a generator. |
| 37  | Winding Insulation Test  
The minimum insulation resistance to ground is 1 megohm per kv of rating plus 1 megohm at 40 degrees Celsius ambient. |
| 38  | Bearing Insulation Test  
Check for Cracks, Distortion, evidence of excessive heating, Oxidized or corrected conductor/stands, Loose connections. To Complete similar to other IR (megger) test. Used to verify condition of insulation on a bearing. Test voltage: 500 Vdc Acceptance criteria: 1 megohm |
| 39  | Cold Resistance Test  
The cold resistance of all windings must be measured and it is most important that this is done before any other test. |
<table>
<thead>
<tr>
<th>No.</th>
<th>Test Description</th>
</tr>
</thead>
</table>
| 40  | Voltage Drop Test  
"Acceptable" for most circuits is less than 0.4 volts, although 0.1 volts or less is preferred. Some starter circuits can allow up to 0.6 volts during a voltage drop test. |
| 41  | Final IR & HV Test  
Every machine or insulated part must pass an Insulation Resistance Test using an Insulation Tester, (normally referred to as a Megger). |
| 42  | End float and Magnetic Center check  
End float will normally be measured and marked before the machine is handed to Factory test. |
| 43  | Temperature Measurement |
| 44  | Vibration (generator frame, bearing housing) |
| 45  | Noise Level |
| 46  | Step Voltage Test |
| 47  | Waveform Analysis and OC Oscillogram at rated voltage test |

**Enhanced Technical Support for 2nd and 3rd Level Maintenance Tasks**

<table>
<thead>
<tr>
<th>No.</th>
<th>Test Description</th>
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</thead>
<tbody>
<tr>
<td>48</td>
<td>Generator Circuit Testing</td>
</tr>
<tr>
<td>49</td>
<td>Turn-to-turn Test</td>
</tr>
<tr>
<td>No.</td>
<td>Task Description</td>
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<tr>
<td>50</td>
<td>Air-gap Test</td>
</tr>
<tr>
<td>51</td>
<td>Bearing Oil Analysis (Mechanical &amp; Electrical)</td>
</tr>
<tr>
<td>52</td>
<td>Cooling Circuit Test</td>
</tr>
<tr>
<td>53</td>
<td>Temperature Monitoring on Bearings and Windings</td>
</tr>
<tr>
<td>54</td>
<td>Stator Winding – Wedge Insulation Tightness Measurements</td>
</tr>
<tr>
<td>55</td>
<td>Inter-laminar Insulation test</td>
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<tr>
<td>56</td>
<td>Special Measures related to Generators installed in Explosion Hazard Areas</td>
</tr>
<tr>
<td>57</td>
<td>Arc Flash Hazard Analysis</td>
</tr>
</tbody>
</table>

**GE SPECIALIZED MAINTENANCE SERVICES FOR 2ND AND 3RD LEVEL MAINTENANCE TASKS**

<table>
<thead>
<tr>
<th>No.</th>
<th>Task Description</th>
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<tbody>
<tr>
<td>58</td>
<td>ADVANCED CLEANING</td>
</tr>
<tr>
<td>59</td>
<td>Cleaning of windings and Interior of the generator</td>
</tr>
<tr>
<td>60</td>
<td>Cleaning of windings with Solvents</td>
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<tr>
<td></td>
<td>Maintenance Schedule Checklist for Wind Generators.docx</td>
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<td>---------------------------------------------------------</td>
</tr>
<tr>
<td>61</td>
<td>Cleaning of windings with Detergent Water</td>
</tr>
<tr>
<td>62</td>
<td>Cleaning of Brush Gear and Slip-rings</td>
</tr>
<tr>
<td>63</td>
<td><strong>MAINTENANCE OF BEARINGS</strong></td>
</tr>
<tr>
<td>64</td>
<td>Maintenance of Anti-friction Bearings</td>
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<tr>
<td>65</td>
<td>Maintenance of Sleeve Bearings</td>
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<tr>
<td>66</td>
<td><strong>BOLTED CONNECTIONS</strong></td>
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<td>67</td>
<td>Bolt Torque Tightening Procedure</td>
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<td>68</td>
<td>Check for shaft alignment</td>
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<tr>
<td>69</td>
<td>Compensation of thermal expansion during alignment</td>
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<tr>
<td>70</td>
<td>Systematic check of machine alignment</td>
</tr>
<tr>
<td>71</td>
<td>Barring speeds (In case of low speed generators)</td>
</tr>
<tr>
<td></td>
<td>Description</td>
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<td>-----------------------------------------------------------------------------</td>
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<tr>
<td>72</td>
<td>Cooling system alignment check (for generators equipped with air cooler)</td>
</tr>
<tr>
<td>73</td>
<td>Connection of bushed bearings lubricated by force-feed lubrication</td>
</tr>
<tr>
<td>74</td>
<td>Connections of the cooling circuit</td>
</tr>
<tr>
<td>75</td>
<td>High Voltage Connection Tightness Check</td>
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</table>

**ADVANCED TESTING, MONITORING & DIAGNOSIS SOLUTION FOR 2ND AND 3RD LEVEL MAINTENANCE TASKS**

<table>
<thead>
<tr>
<th></th>
<th>Description</th>
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<tbody>
<tr>
<td>76</td>
<td>GE patented Digital Diagnostic Management Solutions (DDMS)</td>
</tr>
<tr>
<td>77</td>
<td>Vibration Analysis</td>
</tr>
<tr>
<td>78</td>
<td>Thermography Services</td>
</tr>
<tr>
<td>79</td>
<td>Generator Reliability Program</td>
</tr>
<tr>
<td>80</td>
<td>Generator Performance Monitoring with GE's patented Condition Forecaster™ Monitoring System</td>
</tr>
<tr>
<td>81</td>
<td>Remote Monitoring &amp; Diagnostics (RM&amp;D)</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
14. 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>
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<tr>
<td>Germany</td>
<td>+49 69 6612 5588</td>
<td>Local costs / International</td>
<td>German / English</td>
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<tr>
<td>India</td>
<td>+91 44 496 80008</td>
<td>Local costs / International</td>
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</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>
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<tr>
<td>UK</td>
<td>+44 1788 56 3800</td>
<td>Local costs / International</td>
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<tr>
<td>NAM</td>
<td>+1 844 437 4474</td>
<td>Local costs / International</td>
<td>English</td>
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<tr>
<td>Iran</td>
<td>+33 619365696</td>
<td>Local costs / International</td>
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</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
## 15. MODIFICATION RECORD

<table>
<thead>
<tr>
<th>Revision</th>
<th>Date</th>
<th>Author</th>
<th>Approver</th>
<th>Details</th>
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<td>000</td>
<td>2017-04-07</td>
<td>S. Muthukkumaran</td>
<td>De-Camas, Luc</td>
<td>Initial Issue</td>
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<tr>
<td>001</td>
<td>2017-07-21</td>
<td>S. Muthukkumaran</td>
<td>De-Camas, Luc</td>
<td>General Update</td>
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