GEK 103566c
Revised, July 2005

GE Energy

Creating an Effective Maintenance Program

I. BACKGROUND

Implementing a thorough maintenance program is the most effective way to retain generator reliability and avoid major failure expenses. However, it must be cost effective in that there are demonstrated savings in improved availability & reliability to offset the cost of implementing the program. The three important elements of a thorough program are maintenance frequency, electrical testing and visual inspection. It is the intent of this instruction to provide information on each of these elements, which will aid the owner/operator to establish a thorough and cost effective maintenance program.

II. MAINTENANCE FREQUENCY

There are a number of components, which require routine maintenance or inspections between scheduled outages. The operator will find these recommendations in various equipment sections, and should also include additional maintenance tasks as operating experience indicates. Results of this routine maintenance should be retained in well-organized files readily available for reference. These routine maintenance records coupled with the information from the monitored operating data are a good indicator of pending service or operating problems that should be addressed at the next scheduled outage. The monitored information alone is usually not sufficient for tracking or highlighting trends.

During the first several months of operation, the stator winding support system and some of the other generator components experience a break-in period with more severe duty/wear than normal. Therefore, the first major maintenance inspection is recommended for one year after it is placed in service. For the purposes of the first major inspection, one year is defined as 8760 operating hours; or 300 starts. Regardless of the generator's duty, the first inspection should not be deferred beyond two (2) calendar years from COD. If the unit's operating experience has been unusual because of misoperation or very limited in-service hours, etc. you may wish to discuss your particular circumstances with your local GE Field Service Office for recommendations specific to your circumstances.

Subsequent planned outages must also be performed in a timely fashion. Experience has shown that regularly scheduled maintenance outages are one of the most important steps in retaining unit reliability and reducing major repair/failure expenses. A minor maintenance outage is recommended every 30 months. During these outages the end shields or end plates are removed to permit inspection from the end winding area, but the field remains in place. A major outage is recommended every 60 months. This includes removing the field from the stator or using MAGIC (Miniature Air Gap Inspection Crawler) to permit a thorough inspection of the core section of the stator and field. To inspect the field and stator using MAGIC requires the removal of a few entrance gap baffles to allow access to the air gap with the field in place. The inspection must include a comprehensive series of electrical tests and a thorough visual inspection. Each has their particular advantage and neither alone is sufficient. See Section V for a brief description of the capabilities of MAGIC and MAGIC Jr.

Older generators with asphalt insulated stator windings and core lengths greater than 150 inches are subject to girth crack failures in the stator bars, and therefore, these generators should be reinspected twice as often (Minor Outage - 18 months; Major Outage - 36 months).

These recommended outage intervals have proven themselves over many years of use. However, high equipment reliability and outage costs, have lead to increasing interest in extending the time between major inspections. Condition Based Maintenance (CBM) is one method in development to do this, and is the focus of considerable attention in the industry. CBM relies on availability of reliable on-line instrumentation and evaluation techniques. As these evaluation methods become proven and practical, they will be incorporated into recommended operation and maintenance packages such that maintenance outages can be scheduled based on the condition of the unit.

Table 1. Recommended Standard Test

STATOR			AIR	HYD	LCSW	Minor	MAGIC/ RAC	Major
Test	**Component**	**Inspection Objectives & Assessment**						
RTD Element Res.	Gas & Winding RTD's	Checks for calibration & poor connections.	X	X	X	X		X
RTD Ground Insulation	Stator Winding RTD's	Insulation condition of RTD.	X	X	X	X		X
Winding Copper Res.	Stator Winding	Checks for poor connections & breaks.	X	X	X	X		X
Insulation Resistance (aka Megger)	CE Bearing	Contamination and/or deterioration of insulation.	X	X	X	X		X
	Hydrogen Seal Casing	Contamination and/or deterioration of insulation.		X	X	X		X
Polarization Index	Stator Winding	Contamination and/or deterioration of insulation.	X	X	X	X		X
DC Leakage Current	Stator Winding	Contamination and/or deterioration of insulation.	X	X	X	X		X
Over Potential/Hipot	Stator Winding	Ground wall insulation integrity	X	X	X	X		X
Wedge Tightness Map	Stator Wedges	Detect wedge tightness deterioration	X	X	X		X	X
Magnetic Scalar Potential (EL CID)	Stator Core Insulation	Weak or damaged core enamel.	X	X	X		X	X
Vacuum Decay	Water Cooled StatoCher Winding	Checks the hydraulic integrity of the entire winding.			X[1]	X		X
Pressure Decay	Water Cooled Stator Winding	Checks the hydraulic integrity of the entire winding.			X[1]	X		X
Capacitance Mapping	Water Cooled Stator Winding	Wet ground wall bar insulation			X[1]			X
Helium Tracer Gas	Water Cooled Stator Winding	Detects minute leaks in the hydraulic circuit.			X[1]			X
Visual Inspections	Core Laminations	Foreign Object Damage	X	X	X		X	X
	Space Blocks	Migration, cooling passage blockage	X	X	X		X	X
	Gas Gap Baffles	Cracked welds, looseness	X	X	X		X	X
	Stator Wedges	Evidence of abrasion or looseness	X	X	X		X	X
	Stator Bars	Evidence of abrasion or looseness	X	X	X		X	X
	End Windings and connection rings	Evidence of relative motion, loose/broken ties, hardware, corona activity	X	X	X		X	X
	Copper Flux Shield	Overheating, hardware looseness	X	X	X		X	X
	Overall cleanliness	Oil or other contamination	X	X	X		X	X
OPTIONAL TEST								
Partial Discharge Analysis	Stator Winding Insulation	Localized deterioration	X	X	X	R		R
Water Flow Verification	Water Cooled Stator Winding	Restrictions in hydraulic circuit			X			O
Core Ring Test	Stator Core Insulation	Weak or damaged core enamel	X	X	X			O
Dynamic Freq. Response	Stator End Winding	Potentially damaging resonance.	X	X	X			O
Bar Jacking	Slot Support System	Check slot clearance			X			O

FIELD			AIR	HYD	LCSW	Minor	MAGIC/ RAC	Major
Test	**Component**	**Inspection Objectives & Assessment**						
Winding Copper Res.	Field Winding	Checks for poor connections & breaks.	X	X	X	X		X
Polarization Index	Field Winding	Contamination and/or deterioration of insulation.	X	X	X	X		X
AC Impedance	Field Inter-Turn Insulation	Turn shorts & speed sensitive turn shorts	X	X	X	X		X
Visual Inspection	Field Surface	Heating, arcing, foreign object damage	X	X	X		X	X
	Body Weights	Looseness, staking	X	X	X		X	X
	Field Wedges	Arcing, migration, cracking	X	X	X		X	X
	Retaining Ring “Nose”	Wedge contact, arcing, foreign object damage	X	X	X		X	X
	Coil End Turns	Blocked ventilation, damaged insulation, coil distortion	X	X	X		X	X
	Overall cleanliness	Oil or other contamination	X	X	X	X	X	X
OPTIONAL TEST								
Over Potential/Hipot	Field Winding	Ground wall insulation integrity.	X	X	X	O		O
Air Gap Flux Probe	Field Inter-Turn Insulation	Shorted turns at operating speed.	X	X	X	R		R
Bore Pressure Test	Chevron Seals	Sealing capability of the Chevron seals.		X	X	O		O

O - Optional Test X^1 - Pertains only to water-cooled units   R - These test are performed while the unit is running.

Note: Gas cooled bars use the hydrogen column. During high voltage testing the hollow conductors should be shorted to copper strand

III. TESTING

Generator electrical testing is focused on the insulation systems. However, there are other tests used to monitor for degradation in other components. A list of the typical tests recommended and the test purpose is shown in Table 1. Historical records of test results should be maintained and compared to the new test results. Changes between outage test results may point to needed repairs/rework that may not be evident from the absolute test values themselves.

Many of the tests require special equipment. Test results may be misleading and useless if the right equipment is not used, or it has not been properly maintained and calibrated to assure accurate results.

IV. INSPECTION

A visual inspection performed by an experienced individual can disclose unit conditions not detected by monitoring equipment or indicated by tests. Even the stator and field insulation systems must be significantly degraded to be detected by electrical testing. Also, for example there is not a definitive test for contamination, rust or oil and water leaks, and yet the presence of any of these could significantly adversely affect reliability and operation. A typical inspection should include those items listed in Table 2.

As important as it is, visual inspection is limited to areas that can be accessed for view either directly or with mirrors, boroscopes, cameras, etc., and therefore, it must be combined with testing to give a complete picture of generator condition.

V. MAGIC INSPECTION

GE's MAGIC and MAGIC Jr. robots provides a thorough visual inspection of the stator and field using the robot's on-board high-resolution video cameras. Additionally, it is capable of providing quantitative wedge tightness and Electromagnetic Core Imperfection Detection (ELCID) assessments. Coupled with the Remote Access Camera (RAC), the MAGIC or MAGIC Jr inspection can provide a comprehensive stator and field inspection. The customer may opt to utilize the MAGIC robot to perform the recommended inspection tasks that normally require the removal of the rotor. As a result, the customer may substitute a MAGIC for a major inspection providing the minor inspection tasks outlined in Table 1 are performed during the outage as well.

In order to use MAGIC and MAGIC Jr., the generator must meet the following minimum entrance gap dimensions:

- MAGIC:
    - Retaining ring to core minimum gap 1.13 inches
    - Field to core minimum gap of 2.0 inches.
- MAGIC Jr.
    - Retaining ring to core minimum gap 0.5 inches.
    - Field to core minimum gap 0.75 inches.

TABLE 2 - VISUAL INSPECTION AREAS

		Foreign Material/Contamination	Cleanliness	Loose or Displaced Parts	Movement	Mechanical Damage	Deterioration (General)	Corrosion	Surface Condition and Wear	Water Leaks (Water-Cooled Winding)	Cracks	Worn Parts	Burning	Blocked Ventilation	Bar Sparking	Tape Migration	Broken Ties	Shorted Core Punchings	Core Tightness
Stator	All Components	X	X	X	X	X	X												
	Bars									X	X	X	X		X	X			
	EW Support System										X	X		X					
	Slot Support System											X		X	X				
	Conn. Rgs & Lower Lds.									X	X	X	X				X		
	High Voltage Bushings									X	X		X	X					
Core	All Components	X	X	X	X	X	X	X										X	X
	Core End										X		X	X					
	Ventilation Ducts													X					
	Laminations												X					X	X
	Key Bars																		X
Field	All Components	X	X	X	X	X	X	X	X										
	Body & Wedges										X		X	X					
	Retaining Rings										X		X						
	Fans										X								
	Spindles										X	X							
	Winding													X					
	Collectors											X	X						

VI. MAINTENANCE PLANNING

Major maintenance outages are usually scheduled well in advance of the actual outage date, and preparation for the outage should begin early. An important part of that is to review operational logs, previous inspection reports for any indication of work needed, and review recommendations from GE communicated by Technical Information Letters, Engineering Change Notices, etc. to integrate those items into your plans. Materials you expect to need should be ordered to have available at the start of the outage to avoid the risk of costly delays waiting for material.

The operational log should include the type of duty, any known incidents of misoperation. Operational events which should be carefully noted are:

- Errors in synchronizing
- Under or overfrequency operation
- Lightning surges or other transients
- Faults (such as short circuits) on system or adjacent machines
- Unbalanced load, including single phase operation
- Overload
- Overvoltage or undervoltage
- Loss of field
- Loss of cooling water without load run-back
- Out of synchronism operation.

Each of these events would have a different impact on the necessary planning for maintenance and inspection. Depending on the circumstances, some of them might dictate that the machine be shut down for immediate inspection, whereas with other events it would be reasonable to wait until the next schedule inspection.

Your maintenance program should reflect the level of acceptable risk for the unit. That will probably vary from unit to unit and plant to plant, and will change over time as the importance of the unit to the power system changes. In addition, new technologies are constantly being developed to improve unit reliability, performance, monitoring & inspection equipment, and otherwise provide more cost–effective means for maintaining the generator. The MAGIC Robot In-Situ Generator Inspection System is one example of a new technology developed by GE to provide a more cost-effective means of inspecting your generator. The owner/operator should be aware of these developments and modify the maintenance program accordingly. While this should be a continuous process, the “maintenance outage planning review” is an appropriate checkpoint.

Your local GE Field Service Office can assist you in your maintenance planning, and review of your overall maintenance program, incorporating any appropriate new maintenance and upgrade technologies available.

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