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RECONDITIONING PULP AND PAPER MILL GENERATORS FOR RELIABLE SERVICE

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Abstract - This paper presents the latest generator "reconditioning" techniques, important to maintaining high reliability for this specialized equipment. These techniques involve preventive and predictive maintenance testing and inspections that, if done consistently, will ensure reliable operation of this class of generators. Also included are three brief case histories that describe activities falling in the category of "major" reconditioning. The focus is on generators rated in the 10 MW to 100 MW range, manufactured in the 1950's and 1960's. Many of these machines are at or near the end of their life, and they should be reconditioned to provide additional extended service.

Index Terms — Generator, Stator, Rotor, Preventive maintenance, ground fault, electrical testing, Stator core iron restack, Rotor turn cracking

I. INTRODUCTION

For the most part, generators are very efficient, and are typically quite reliable. They do need attention from time to time, however, to prevent disastrous failures that could end up costing millions of dollars, and causing long wait times for replacement parts.

Before these units can be properly reconditioned, however, their existing condition needs to be diagnosed correctly. An extensive generator health assessment should be done to determine what problems are most severe and need priority attention. Running to failure can result in additional damage above and beyond the reconditioning cost, so it is critical to identify problems as early as possible and fix them before they cause extended damage.

In this paper, key preventive maintenance actions, along with recommended cycle times, are addressed. Items to be discussed initially are basic preventive maintenance tasks such as visual inspection of generator components, particularly the stator windings and wedge system. Important findings that indicate deterioration will be discussed. Others preventive maintenance tasks include vibration measurements, hydrogen purity, generator bearing oil analysis and temperature measurements. In addition, generator electrical tests, which are very important for reliable operation, will be described. Recommended values and frequencies will be included. Additional focus will be placed on advanced predictive maintenance tools used for this class of generators. These include PDA (Partial Discharge Analysis), rotor winding flux probe testing, infrared core loop testing, EL CID testing, and so on.

This paper should be valuable to all owners and users of industrial and utility electrical generators. In one place, a concise catalogue of all the important preventive and predictive maintenance activities for reliable electrical generator operating will be available for the owner and operator's use.

II. STANDARD GENERATOR PREVENTIVE MAINTENANCE

Visual Inspection

Visual inspection of any component or machine is undoubtedly the most cost-effective diagnostic tool. This is especially true for the generator, if adequate access to the unit is obtained. Miniature robotic inspection tools are becoming more prevalent, and provided the air gap is large enough, limited visual inspections and other tests on the generator can be done with the rotor in place. Of course, having the rotor out of the stator provides full access to the stator. Rotor inspection, however, is still somewhat limited until the retaining rings are removed. Listed below are important items to examine during a rotor out visual inspection of the generator. Much information can be gained about past and future performance with this type of inspection. Visual inspection of the generator should be performed each time the rotor is removed from the stator. Industry practice and this author's recommendations are to perform a rotor removal as part of a major turbine – generator outage, every 7 to 10 years.

A common concern on pulp and paper generators is partial discharge. Partial Discharge (PD), also called corona is more common on air-cooled generators, with machine voltages at 6,900 volts or higher. PD is often seen as a white power or substance on the stator coils, as shown in the Fig.1. PD is a partial breakdown of the coil insulation, and if left untreated, could lead to a failure of the insulation. It can be caused by incorrect coil spacing (coils of different phases too close), poor corona suppression treatment on the coil surface, internal voids in the coil insulation, and so on. Corona suppression treatments are used on the coil surface to effectively ground the coil surface to the stator core in the cell section, and more gradually distribute high voltage stress concentrations around the coil bend area. These surface treatments can greatly minimize PD, and the deterioration of the coil insulation from PD. PD is easily seen by a trained inspector during a routine visual inspection. Monitoring equipment can also be installed to trend PD activity over time.

Fig. 1. Extensive partial discharge activity in stator winding, shown by its white "powder-like" appearance, can deteriorate the insulation, eventually causing an electrical ground fault.

One of the other serious concerns with older stator windings is the age and degree of thermal degradation of the coil insulation system. Many of these machines had coils insulated with asphalt-based insulation. While asphalt can be flexible and somewhat forgiving, in terms of not cracking and failing, it is susceptible to electrical grounds at the end of the stator core. This condition is typically called "girth cracking" or "tape separation" and occurs in the location where the stator coil exits the stator core iron. It occurs in this location because of the relative difference in thermal expansion between the stator core iron, and the stator coil itself. Over years and repeated thermal cycles, the asphalt insulation begins to flow and crack. (Fig. 2.) Left unaddressed, girth cracking can result in more serious consequences. (Fig. 3.)

Fig. 2. Evidence of coil girth cracking, often called tape separation, on a 1950s-vintage generator with asphalt-based insulation.

Fig. 3. Girth cracking in this particular machine, lead to a coil electrical ground fault that also damaged the stator core iron.

Stator Visual Inspection: Listed below is a detailed summary of visual checks that can be done during a routine stator inspection.

- Check all wedges. Depending upon the different wedging system, make a blank form showing slot numbers and wedge numbers from turbine end to exciter end.
- Record the condition of each wedge. Check its tightness, compression, or movement and alignment. Tap on each wedge in each slot. If wedges were tightened with top ripple springs, check the compression of ripple springs with depth gauges through wedge holes. Check each wedge for damage. Check filler material under the wedge for slippage or movement.
- Check wedge groove for dusting. Check separator strips between top and bottom coils for tightness. Pull on the strips with duck bill pliers to check looseness.
- Check the side fillers, if used, for tightness. They should not move when pulled with pliers.
- Check for debris between the coil end turns.
- Check the corona paint system. Carefully examine the top surface of the top coils after the wedges are removed to see if the corona suppression treatment is intact. If not, this surface should be retouched. The area where the cell portion of coil exits the stator core and around the cell bends should be carefully looked at for discoloration or chipping of the corona gradient paint.
- Check that the surge rings are tightly lashed to surge ring brackets and to the bottom coils. Make sure no ties are broken. Check that bracket holding bolts are tight with the frame.
- Visually check the condition of all lead cables and jumpers.
- Check to see that all vent ducts in the core are free and are not blocked or clogged.

- Check all blocking at the end turns to ascertain that they are in their proper positions and tightly lashed into place. Make sure no ties are loose or broken.
- Check the winding paint for discoloration or signs of overheating.
- Check for existence of oil on the end turns.
- Check the condition of the bus rings and bus ring support brackets. Check that the bus ring brackets are firmly supported and bolted to the frame. Also, check the bus rings to be tightly lashed to the support system and record if any dusting is observed.
- Check for any damaged lamination or signs of overheating. Also, check the core tightness with feeler gauges. Check for any signs of fretting between lamination and core bolts.
- Check all R.T.D. assemblies for continuity, resistance and meggar.

Fig. 4, **Fig. 5**, Fig. 6, and Fig. 7 are provided to orient those readers less familiar with the above-referenced stator components,

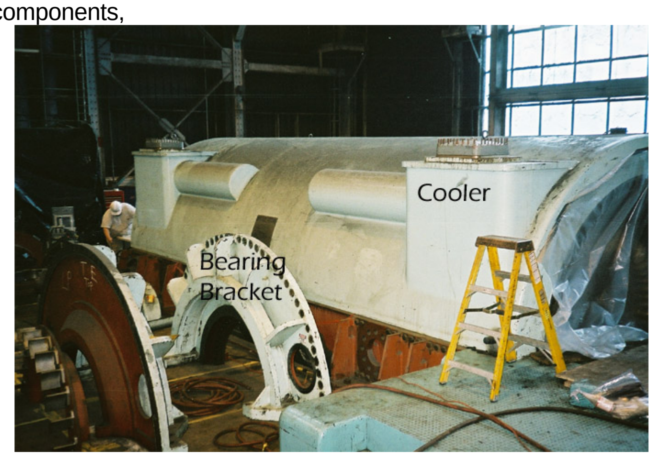

Fig. 4 shows bearing bracket and cooler. The generator frame holds the coolers and supports the bearing brackets that support the bearing, journals, and rotor.

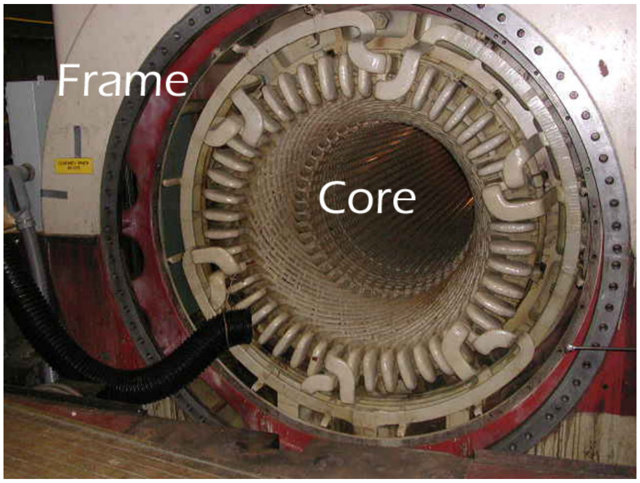

Fig. 5 shows location of the generator frame and core. Stator consists of the frame, core iron and coils. The frame holds everything together. The frame also houses the “lead box” area where the main terminals exit

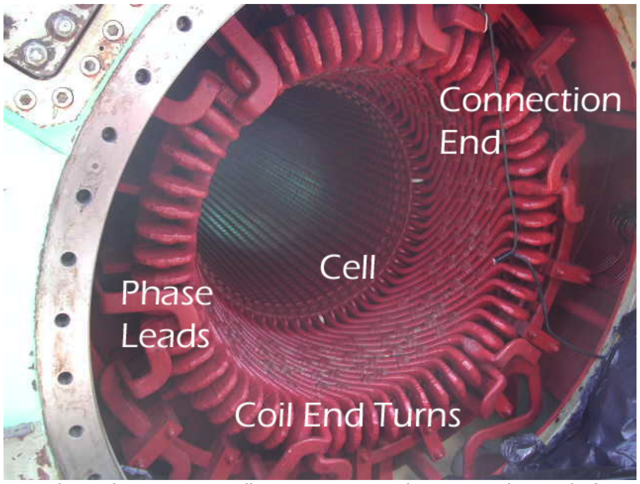

Fig. 6 shows stator coil components at the connection end of the machine. Core Iron provides a magnetic path for the flux. The coils carry the current generated by the **i**nduced voltage. A high-voltage stator (also called an armature) will range from 13.8 to 24 kVac.

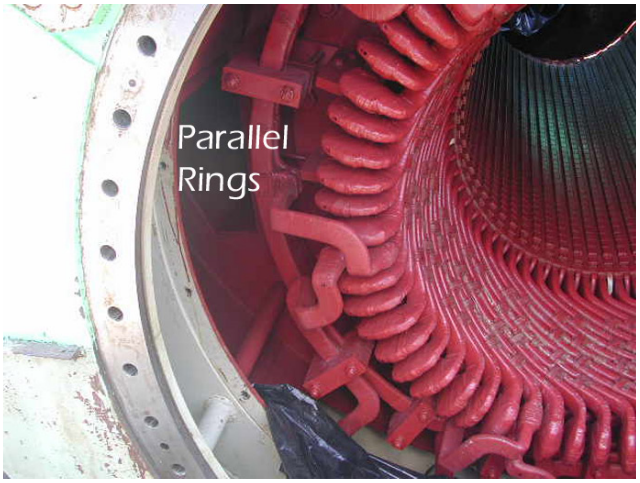

Fig. 7 show s the location of the parallel rings.

Rotor Visual Inspection: The generator rotor is best inspected after it is pulled out of the stator. A Visual inspection of the rotor, without removing the retaining rings, is usually very restrictive. Usually, only the following visual checks can be made:

- Check under the retaining rings to see end winding and main lead for out of place end turn blocking and insulation damage/debris.
- Inspect retaining ring vent holes, if present, for obstructions.
- Check the collector ring insulation and connection leads for signs of insulation deterioration, burning, discoloration, or fraying. Insulation that has not been impregnated with enough resin or has not cured properly may fray and eventually unravel or pieces may break off.
- Look for any signs of motoring faults in terms of rotor body heating or debris/residue coming out of slot.
- Look for any signs of overheating of end wedges and outer diameter of the retaining ring, close to fit surface.
- Check rotor journals for scratches, indentations or markings of any kind.

- Check the rotor body for signs of foreign object damage.
- Check the balance weights and slot wedges to assure they are properly staked.
- Examine the collector ring surface, looking for evidence of uneven wear or irregular grooving.

Fig. 8 is provided to orient readers less familiar with some of the above-referenced rotor components,

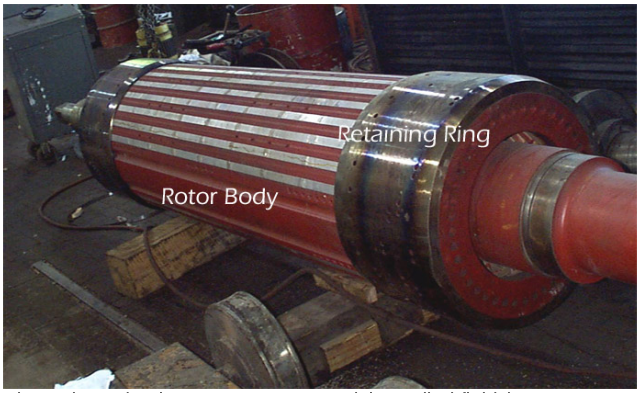

Fig. 8 shows basic rotor parts. Rotors (also called fields) can range in voltage from 125 to 375 vdc.

Three Major Rotor Concerns for Machines 10 to 100 MW

Three major rotor concerns with this class of machines, units 10 to 100 MW and manufactured in the 1950s and 1960s, are the (1) retaining rings, (2) top turn cracking on spindle mounted rings, and (3) deteriorating rotor winding insulation.

Retaining Rings: Depending on the manufacturer, many of these style machines have non-magnetic retaining ring material that is susceptible to stress corrosion cracking. Two common materials are Gannalloy and 18Mn 5Cr. Retaining rings with severe stress corrosion cracking (SCC) should be replaced with 18Mn 18Cr material, which is resistant to stress corrosion cracking in the presence of moisture. (Fig. 9.)

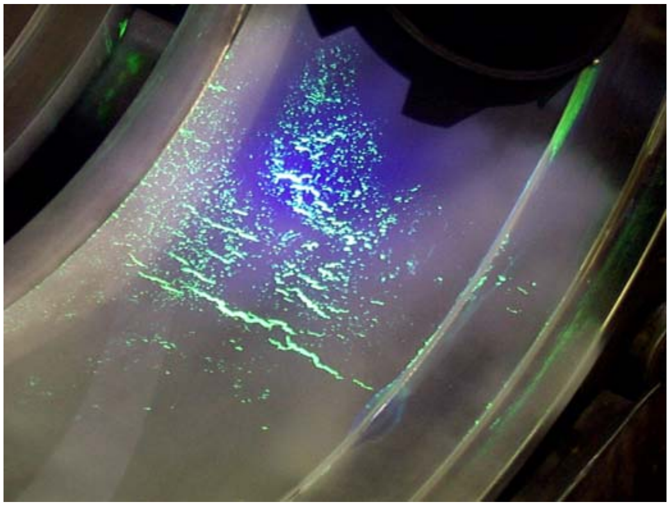

Fig. 9. A fluorescent penetrant test reveals severe stress corrosion cracking in an 18Mn 5Cr alloy retaining ring.

Rotor Top Turn Cracking: Many machines of the 1950s-1960s vintage have spindle mounted retaining rings, a style of retaining ring mounted and supported off of its back end, instead of having its nose shrunk on the rotor shaft. As a result, there is an unsupported area of rotor turn copper, just as the copper exits from the rotor forging. When the rotor is repeatedly cycled, the spindle mounted retaining ring imposes additional fatigue stresses on the copper in this area. Cracks can develop in the copper turns in this area. The copper turns will fatigue, eventually cracking the ground insulation slot liner and creating a ground fault in the process. Damage to the winding and forging can occur when this happens. (Fig. 10.)

Fig. 10. Two top copper rotor turns with breaks, which have occurred as the coils leave the slot, and the results of the subsequent electrical ground.

Deteriorating Rotor Winding Insulation: The third major problem with generator rotors of this size and age is the deterioration to the rotor winding insulation system. Time and temperature, along with repeated start and stop cycles of the generator rotor, gradually break down the insulation system. Many of these insulation components have a mica and shellac makeup. The shellac binder disintegrates over time, leaving only the mica flakes. If disturbed, as when the retaining rings are removed, the mica flakes separate, and their insulating properties are lost. Extensive rotor end turn deterioration in an older machine, as show in Fig. 11, makes a rewind necessary, in order to restore insulation to the copper turns.

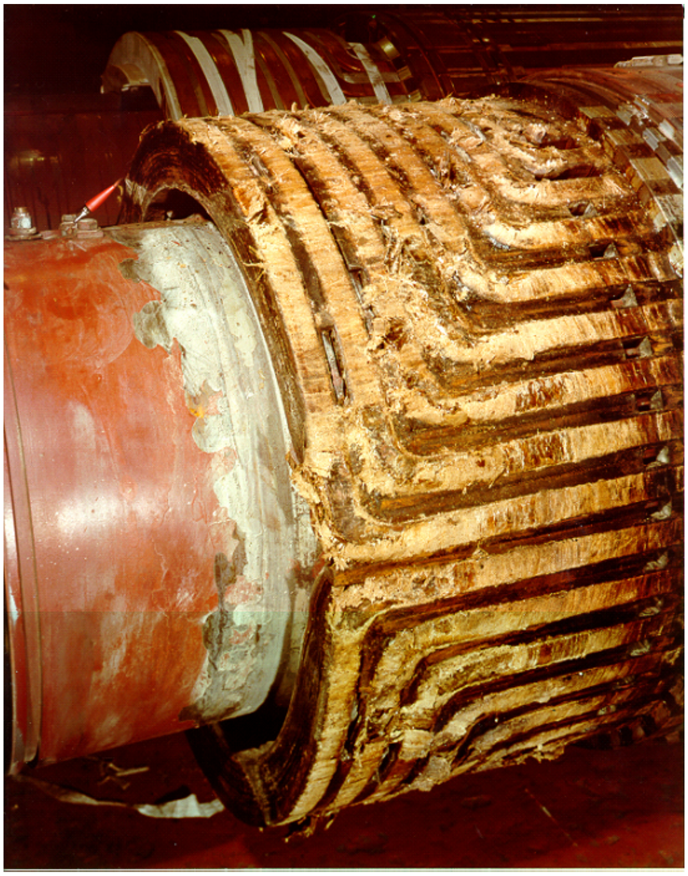

Fig. 11. After the removal of its retaining rings, a 1950s-vintage conventional generator rotor showed obvious deterioration of the end turn insulation.

Continuous Monitoring

There are a number of different tests and monitoring devices that assist in maintaining reliability of these generators. These would be useful in addition to regular visual inspections mentioned earlier. A general listing and description is found below. In addition to key parameters to monitor, important generator electrical tests are listed and briefly described. These tests, when done on a routine outage basis, can help to trend and even predict upcoming problems.

Typically, a number of standard, on-line, continuous monitoring devices are a part of any new generator package and many older ones. These include devices for measuring or monitoring indicators such as:

- vibration at the generator bearings and stator winding
- hydrogen gas purity
- bearing oil analysis
- generator stator coil temperature
- bearing oil temperature
- cooler temperatures
- gas temperatures
- field temperature
- rotor ground detection
- voltage
- current
- power factor
- seal oil temperature and differential pressure
- liquid level detectors
- hydrogen gas pressure
- frame differential expansion.
- coil cooling water flow

A few comments are in order about the nature of data generated by monitoring and measuring devices. Voltage, current and power factor are fundamental parameters of the generator operation and the generator is designed to operate within certain "design" parameters. Operation outside of these given values typically means the generator is undergoing some type of malfunction, which can jeopardize the reliability of the machine. Most generators have a design capability curve that defines many of these parameters, and lets the operator know what his boundaries and limits are. It would be too involved and beyond the scope of this paper to elaborate further on each of these parameters and what problems can affect each one of them.

Information gathered over time about these indicators provides a basic foundation for keeping a generator operating reliably. As the reader can see, this is a tremendous amount of information of which to keep track. Fortunately, for the control room operator, computers generally record all this data, and alarms and trips are set up to protect the generator, in case any one indicator deviates to an unacceptable level.

Manufacturers' instruction books typically have detailed descriptions of each of these indicators, describing their overall functions and importance, along with normal, alarm and trip levels. A brief description follows of some of the most useful indicators and measurements.

Vibration Measurements: A generator is usually fairly stable in vibration levels, unless some type of disturbance has occurred that upsets the steady state operation of the unit. When a unit is running smoothly, and a step change in balance is reported, look for some type of mechanical unbalance such as loss of a balance weight, or a forging crack that has relieved residual stresses. Bearing wipe, a situation where the rotor journal comes in direct contact with the bearing Babbitt, is usually, indicated by a step change in bearing oil temperature and can also cause a sudden step change in generator unbalance.[1]

If the high vibration is reversible, (that is, it can be decreased back to acceptable levels by changing loading conditions), the problem may be related to the rotor winding. The free expansion of the rotor winding in the slot may be inhibited or restricted. Coils on opposite poles may expand differently, causing a bowing force on the rotor, leading to unbalance. Adequate clearance at the end of the coils should be left for the total expansion of the rotor winding. Rotor shorted turns cause a temperature unbalance between coils of opposite poles and can cause the rotor to bend, increasing the vibration to higher levels. Shorts can be caused by failure of the turn insulation or by contamination of the winding with dirt, debris or other foreign material.

Blockage of cooling passages can also upset the balance of a smooth running machine. Uneven cooling of one coil versus another can cause differences in thermal expansion of the rotor winding, leading to rotor bowing and unbalance.

Vibration level changes, after the rotor is out of the generator for service, are not uncommon. Many times, this is caused by improper alignment when the rotor is re-installed back into the machine. Also, trim balance shots may be necessary, if the rotor is rewound in the field and not balanced in a high-speed balance facility with an overspeed run. For generator rotor rewinds, specific design considerations can be incorporated that minimize problems with vibration.[2]

Vibration of the stator end windings is an industry problem and can be measured by the use of special, fiber optic instrumentation. Excessive vibration of the stator coils can cause turn to turn shorts and insulation deterioration leading to a ground fault.[3]

Temperature Measurements: RTDs (Resistance Temperature Detectors) or thermocouples are used to continuously monitor temperatures inside an operating unit. For generators, RTD's are usually sandwiched between top and bottom coils, in an attempt to monitor stator coil operating temperature. Air or gas inlet and outlet temperatures, to and from coolers, are also important temperatures to record and evaluate. Bearing oil temperatures are critical indicators of reliable operation of all units.

Rotor Ground Fault Detection: Damage to groundwall insulation, such as the slot liner in the rotor slot, can open a path for the current to flow to ground potential. With a ground in only one location, no circulating current will flow through the ground. With a second ground, however, current will flow through the path of least resistance, namely the rotor forging. Serious damage can result from the overheating of forging components. Because of the seriousness and possible consequential damages associated with this type of fault, it is recommended that the rotor be removed from service and repaired when one ground is identified. Ground fault detection can be done continuous, on-line, or as a minimum, once per shift, depending upon the setup. Some units are setup to trip automatically, even if only one ground occurs. Most systems, however, leave that decision up to the operating staff.

Standard Generator Electrical Tests – Predictive and Preventive

Next to visual inspections, routine generator electrical tests are important diagnostics for providing information about the generator's condition and suitability for future service. This type of information is not attainable by other methods. Listed below are the most common types of tests, along with a brief description. Where applicable, the appropriate IEEE standard is also referenced.

Dielectric Absorption: This test is performed per IEEE 95. There are two ways to perform this test, time graded or fixed DC voltage steps. This is a non-destructive test and provides critical information about the conducting current and the absorption current. This test, if done at regular outage intervals, shows the degree of deterioration of insulation over a specified period of time and helps to determine the remaining life of the insulation system.

Insulation Resistance Test: This test determines the condition of either the rotor or stator groundwall insulation. For rotors, typically a 500 volt dc source is applied for up to 10 minutes to the rotor winding. For stator windings, depending upon the units rated voltage, a typical test value may be 2500 vdc. The ratio between the 10-minute and one-minute value insulation resistance values is called the Polarization Index, or PI. For a dry and clean stator winding, the PI ratio should be greater than or equal to 2.0. If the PI is lower than 2.0, it is generally recommended the winding be cleaned and/or dried out, before any additional testing is done, especially for a Hi-Pot test. For rotor windings, a PI of at least 1.5 is recommended.

Blackout: Blackout tests should be performed on individual new coils, or in the machine, particularly after a rewind. Essentially, the winding is energized, and at the same time, all the lights in the immediate area are turned out. If corona, also called partial discharge (PD), is present, it is visible. The amount visible charge seen is an indication of the amount of partial discharge present.

Resistance: Winding resistance measurements can be used, primarily, to look for poorly brazed joints or for shorted or open strands. Failed joints can lead to overheating and subsequent winding failure. The stator winding phases can each be measured and compared one to another. A difference of more than two percent indicates a problem. For rotors, resistances can be trended over time. It is important to measure the ambient temperature, and then adjust the resistance value accordingly. This test is performed according to IEEE 115 and IEEE 118 with the help of a Kelvin Bridge or low resistance ohmmeter.

Flux Probe: Flux probe testing is used to identify shorted turns in a rotor winding. Rotor shorts can lead to thermal sensitivity and rotor unbalance. Testing should be done in the factory after a rewind to verify the winding is short free. Testing can be continued on-line while the machine is operating. A probe can be inserted through the generator frame, through a vent duct, in close proximity to the rotor winding. The coil and pole, in which the short is located, can be identified. The exact turn number, or axial location of the short, generally can not be identified.

Rotor Impedance: An impedance test of a rotor winding also checks for winding shorts. The impedance of the winding can be checked on a stand still rotor or even on a running rotor. The running impedance test is helpful in finding speed sensitive turn to turn shorts. Impedance is the ratio between applied voltage and current. This ratio is plotted against speed. If a short exists, the induced current in that shorted turn will flow in the opposite direction to the normal current flow. This sets up an opposing flux, reducing the rotor winding impedance. A step change in the impedance is evident at the speed the short occurs.

Split Voltage: This test is used to determine the location of the ground. A known AC low voltage is applied to the slip rings and voltage is measured from each slip ring to the body of the rotor by means of a high impedance voltmeter. The ratio of the voltages will give approximate distance from each slip ring.

Voltage Drop: This test is performed to check turn to turn shorts but requires that one retaining ring be removed. AC voltage is applied to the slip rings and voltage is checked between adjacent turns. A significant voltage difference between turns is evidence that there is a shorted turn.

Core Loop: The core loop test is used to test for and identify the same type of core problems as the below-mentioned EL

CID test. The core loop test, however, uses a completely different method to come to the same conclusion. For this test, the stator core is energized up to its rated voltage. Shorted laminations will again allow fault currents to flow, causing localized overheating of the shorted iron. Usually, after a period of about one hour, an infra red scan is done of the entire stator core, marking and measuring the local hot spots.

EL CID: An EL CID[4] or "ELectromagnetic Core Imperfection Detection" test is used to identify shorted iron laminations. With this test, the core is energized only to about four percent of its normal operating voltage. If laminations are shorted together, circulating fault currents occur. These fault currents can cause overheating in local areas, generating hot spots and eventual core damage. A specially wound coil, called a "Chattock" coil, can sense these fault currents at very low values. Once identified, these fault locations can be repaired or monitored, as appropriate.

Hi-Pot: Hi-Pot or High Potential testing is commonly used in the industry as a final proof test for the usability of a winding. DC Hi-Pot testing is more commonly done, because of the smaller and more portable test equipment. A multiplier of 1.7 is commonly used over AC test values. The Hi-Pot test can be destructive, and the owner of the machine should be prepared to replace a coil or rewind the machine, if a coil fails. Standard A. C. test values after a rewind are two times the rated machine voltage plus 1000. There are many cases where a 40- to 50-year old asphalt winding has successfully taken a (2E + 1000) kV Hi-Pot test, where "E" is the rated machine voltage.

Partial Discharge: Many new machines are equipped with on-line partial discharge monitoring equipment. This equipment is specially designed to be mounted on the phase or circuit rings or the slot wedge of pre-selected coils or slots. Partial discharge occurs when an electro-magnetic charge sparks across an air gap. The discharge does not reach ground potential because of other insulation, hence the name "partial" discharge. These signals can be recorded and evaluated, and do give an indication of insulation deterioration. Partial discharge for one machine should not be compared to another, and there are no absolute standards for this test.[5] However, it is useful to trend PD data for each machine over time.

III. Reconditioning Activities

Once a generator's condition is well diagnosed, the proper reconditioning must be performed in order to return it to a reliable state. Reconditioning can take on many forms and varying in degrees, from minor end winding tightening, which will minimize vibration, to full stator rewinds and core restacks.

In general, the earlier that preventive maintenance is done, and done with a greater frequency, the less major reconditioning is required. The following are some of the most common reconditioning activities for machines of this age and rating:

- Rotor rewind with the existing copper to restore the winding insulation system
- Stator rewind with new coils to eliminate potential for ground fault failures and possibly provide generator uprate capability
- Stator core restack to eliminate lamination shorting and the potential for core melt down and damage

Three brief case histories of each of the above reconditioning activities follow below. As is typical for every generator, work scopes vary depending upon the range of problems that need to be addressed.

Case History 1 -- Rotor Rewind: A General Electric rotor, rated at 13,500 kVA, had failed to ground three previous times. In each of the cases, a previous supplier completely rewound the rotor, using the existing copper but adding new insulation. Each time the unit failed again shortly after being put back in service.

After the third failure, the owner sought a "second opinion." Upon receipt by the author's company, inspection showed a classic case of top turn cracking (Fig. 12), compounded by the fact that the entire copper winding had been completely annealed "dead soft." As a consequence of the softness of the copper, the top turns were breaking as they exited the rotor forging core, causing an electrical ground fault that would trip the unit off line. (Fig. 13)

Fig. 12. A close up of the actual turn break in the copper turn.

Fig. 13. Rotor top turn cracking caused an electrical ground fault from the rotor turn, through the ground insulation and to the rotor forging.

In this instance, the author's company rewound the rotor with new, hard copper, to eliminate the root cause of the fatigue cracking of the top copper turns. The unit now has been back in service over one year, running reliably.

Case History 2 -- Stator Core Iron Restack: This 44,118 kVA Elliott generator was inadvertently energized in standstill condition. Extensive damage occurred to the stator and rotor. The stator core iron had to be replaced, and a new stator winding installed. Fig. 14 shows the up-righting of the stator frame in preparation for restacking it with new iron laminations.

Fig. 14 shows up-righting of generator stator in preparation for a restack of the stator core laminations.

After the new laminations were installed in the vertical position, the stator was lowered and the new stator winding was installed.

Case History 3 -- Stator Rewind:

This 15,625 kVA General Electric paper mill generator required replacement of its core iron laminations and a new stator winding. This particular design was particularly challenging in that it had a very small stator bore inner diameter, approximately 29 inches. A replacement winding using half turn bars might have been an option but more time would have been needed to braze connections. Instead, new multi turn coils were manufactured with flexible end turns, as shown in Fig. 15. The multi turn coils reduced the number of brazes needed and the unit was back to reliable service more quickly.

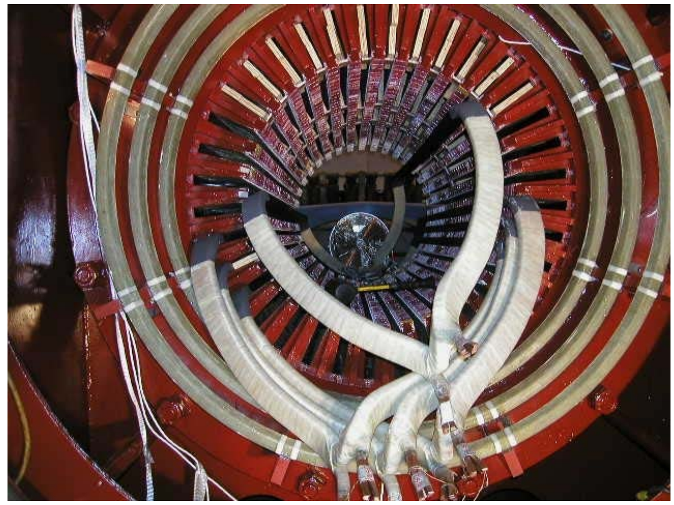

Fig. 15 shows installation of the some of the first stator coils in a paper mill generator rewind.

IV. SUMMARY

It is impossible to list and describe every possible reconditioning activity and identification test to ensure generator reliability. Also, there are other important tests for special classes of machines. For instance, for larger water cooled stator windings, capacitance tests on stator bars can determine if the stator bar insulation is wet, indicating a leak. Other tests for finding leaks on water cooled bars are vacuum and pressure decay tests. For conventional generators with magnetic retaining rings, hardness testing can be used to determine if the ring might become embrittled, due to the presence of hydrogen gas. Many industry papers have been written and are available on each of the inspection techniques and tests described above.

The Table 1 lists typical tests for identifying reconditioning activities, along with their recommended frequencies.

TABLE 1
RECONDITIONING ACTIVITIES & RECOMMENDED INTERVALS

Maintenance Test	**Shows**	**Frequency of Test**
Dielectric Absorption	Winding cleanliness	Major Outage
Polarization Index (PI)	Winding cleanliness / moisture	Major and Minor Outage Cycle
Power Factor	Insulation integrity	Major Outage Cycle
Partial Discharge (PD)	Coil tightness; insulation integrity	On line or Outage Cycle
Blackout	Corona suppression integrity	Rewind
Resistance	Integrity of joints & connections	Major and Minor Outage Cycle
Flux Probe	Rotor winding shorts	On-line, Rewind
Rotor Impedance	Rotor winding shorts	Rewind
Ground Fault	Rotor ground	Continuous
Split Voltage	Location of rotor grounds	As Needed
Voltage Drop	Presence of shorted turns	Major Outage Cycle
EL CID	Integrity of stator core	Major Outage Cycle
Core Loop	Integrity of stator core	Major Outage Cycle
Bolt Torque	Stator core looseness	Major Outage Cycle
Ultrasonic	Cracks, defects in forgings	Major Outage Cycle
Temperature Monitoring	Normal / abnormal operation	On-Line & Continuous
Dye Penetrant	Cracks, defects in forgings	Major Outage Cycle
Eddy Current	Cracks, defects in forgings	Major Outage Cycle
Magnetic Particle	Cracks, defects in forgings	Major Outage Cycle
Wedge Mapping	Stator winding tightness	Major Outage Cycle
Hi-Pot	Insulation integrity	Major Outage Cycle
Vibration	Rotor imbalance	Monthly & On-Line
Visual Inspection	Norma l/ abnormal Performance	As Available
Oil Chemistry & Count	Bearing oil contamination	Twice Yearly

[1] "Manual of Bearing Failures and Repair in Power Plant Rotating Equipment," EPRI GS-7352, July 1991.
[2] W.G. Moore, "Improvements for Generator Rotor Unbalance," International Joint Power Generation Conference, Baltimore, MD, August 24-26, 1998.
[3] J. Foley & J. Butler, "Improvements in the Reliability of Stator Windings for Large Turbine Generators," EPRI Generator Workshop, Scottsdale, AZ, 1987.
[4] J. Shelton, M. Fisher, D. Paley, "Introduction and Qualification of Digital Electromagnetic Core Imperfection Detector (EL CID) Test Equipment and Associated Robotic Delivery and Inspection Systems, American Power Conference, Chicago, IL, April 25-27, 1994.
[5] G.C.Stone, "Partial Discharge Part XXV: Why PD Calibration is Difficult in Motors and Generators," IEEE Electrical Insulation Magazine, Jan/Feb 1998, pp. 9-12.