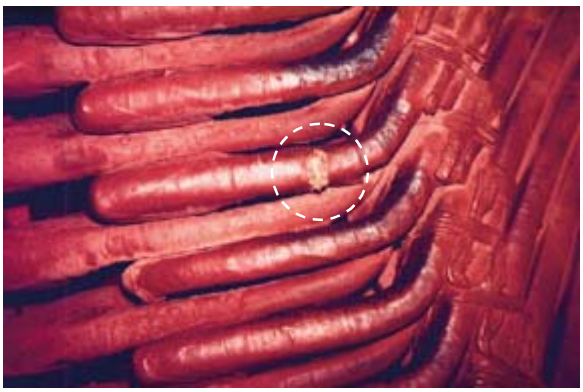
National Electric Coil Coil Talk Bulletin

November 12, 1999

Why Generators Fail

Many failure modes are common, predictable and preventable

By William G. Moore, P.E., Engineering Manager, NEC Columbus

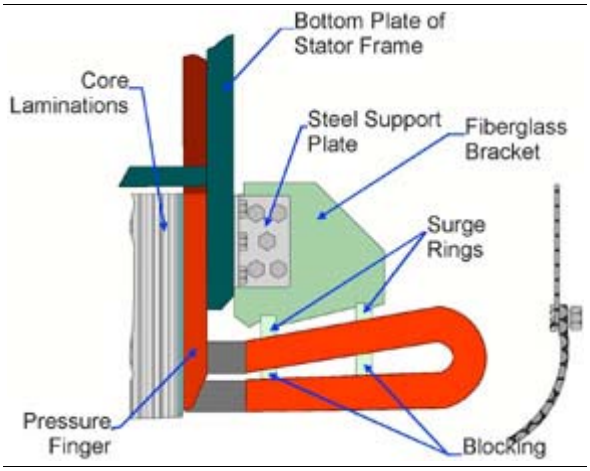


FOREIGN OBJECT DAMAGE

Problem: A generator operates in a carefully controlled environment. Entrance of objects into the machine can be disastrous. Objects can come from external sources or from the failure of internal components. Once inside, objects pick up energy from the spinning rotor and do extensive damage.

Prevention: Inspect, on a regular basis, all internal parts that are prone to failure or those which can be dislodged. Common objects of this type include fan blades, balance weights and pantleg washers, and items left inside the generator during a previous inspection always present a potential danger. Inspection tests can be a combination of visual examination and final crawl through, along with ultrasonic or magnetic particle tests on rotating components.

Photos: (top left) Damage from a foreign object to a coil's ground wall insulation can lead to coils failures. (top right) Schematic drawing of stator end turn area showing additional support and bracing for a new winding.



STATOR WINDING VIBRATION

Problem: Stator winding vibration is primarily a design-related problem that affects gas-cooled generators above 300 MWs. As these units were scaled up from their smaller predecessors, they had insufficient end winding bracing to limit the movement of end turns. Consequently, these machines experience a greater share of stator end winding vibration problems. Winding vibration can lead to turn to turn shorts, transposition shorts, phase to phase shorting and ground faults.

Prevention: Proper bracing of the end winding is required to limit motion caused by steady state and transient electromagnetic forces. Basket and coil consolidation and support can be provided through components such as bracing cones, surge rings, brackets, tie cords, and spacer blocks. Bump testing of the end winding can be done to determine if its natural frequency is close to double the operating frequency.

ROTOR WINDING DISTORTION

Problem: Many air-cooled rotors develop severe rotor winding distortion and displacement, which results in shorted turns or an electrical ground. Distortion can be caused by poor design of end turn blocking supports or by foreshortening of the rotor coils. Foreshortening is caused by a combination of rotational and axial thermal forces, causing ratcheting or compression of the rotor coils as the unit is cycled.

Prevention: Proper design of the rotor coils and bracing, so it supports the coils under axial loads, is essential. Upgrading the existing blocking design provides improved coil support. In some instances, if only the top turn is distorted, it can be moved back into its proper position. Rotors should be tested at operating speed for turn to turn shorts.

OVERHEATING

Problem: Overheating of the rotor or stator can lead to loss of insulation life, shorting of turns, and eventual ground faults. In many cases, the tendency to overheat results from problems in the original machine, which cause insufficient coolant flow. In other cases, however, short-term overheating results from blocked ventilation passages, caused by shifting insulation components or slot wedges.

Prevention: Make sure rotor wedges with cooling vents are "locked" in place, preventing their migration and causing blockage of the cooling passage. Slot pressure should be sufficient to prevent axial migration of components and potential misalignment of cooling holes. Class F insulation and components should be specified for all rewinds.

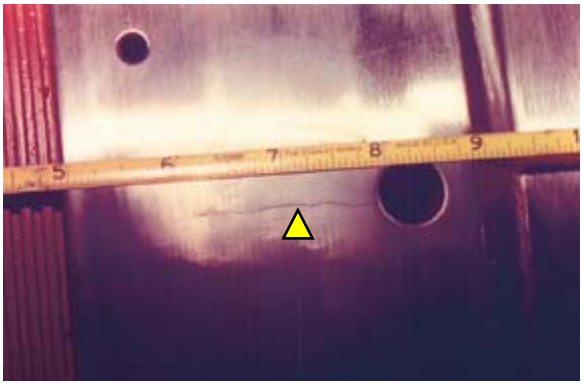
Photos: (top left) Distortion of the top layer of rotor end turn coils. (top right) Transient faults caused this rotor to overheat.

CONTAMINATION

Problem: Contamination from dirty oil or other chemicals can wreak havoc on the turbine generator system. For hydrogen-cooled generators, gas purity is critical to efficient operation and cooling of the generator. Oil leaks into the generator can easily drop hydrogen purity levels, tripping the machine off line. For air-cooled machines, dirt and dust are more of a problem. Electrical grounds caused by dirt or dust tracking along the creepage path is a common occurrence.

Prevention: Good maintenance practices are the rule here. Hydrogen driers must be checked regularly, with the desiccant replaced when needed. Generator leak detectors must be checked each shift, searching for initial signs of oil or water leakage. Filters for air-cooled machines must be checked and cleaned regularly. Polarization Index (PI) tests give a good indication of the overall cleanliness of the rotor winding.

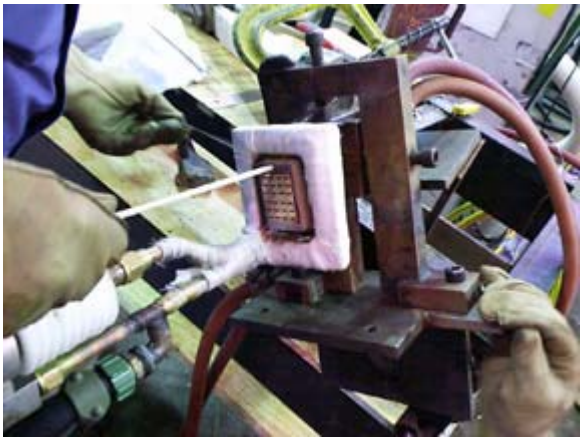
Photos: (top left) Dust and dirt found adhering to rotor winding end turns, after removal of retaining ring. (top right) Retaining ring forging cracks such as these can be the start of more serious problems.

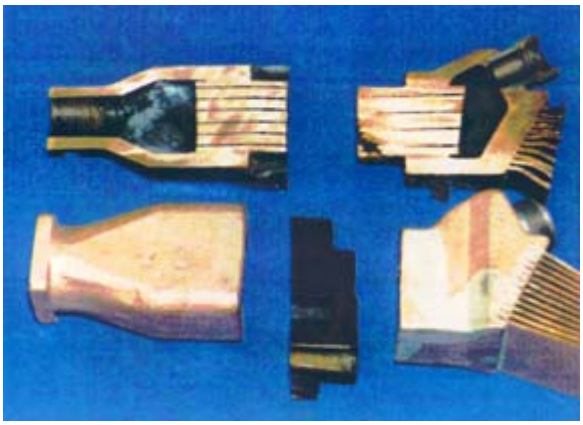


FORGING CRACKS

Problem: Forging cracks have become increasingly more common as the world generator fleet ages. Cracks are often found in older rotor forgings, which were made before advances in steel making. Common locations for cracks are sections of rotor shafts under large shrink-fitted hubs, rotor bores (highest stress area), tooth tops and ventilation holes. Cracks due to stress corrosion are also common in non-magnetic retaining rings and can occur when moisture or corrodants are present.

Prevention: Knowledge of where and when these cracks typically occur is probably the best prevention. Most are design-related and can be detected with the proper inspection techniques such as, the use of dye penetrants, and with magnetic particle, ultrasonic, and eddy current tests. For nonmagnetic retaining rings, a dry clean atmosphere, at all times, is essential

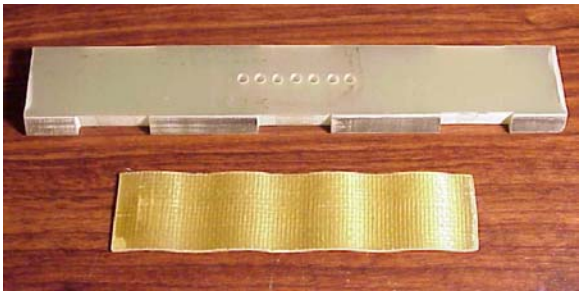




WATER-COOLED COIL LEAKS

Problem: Stator coils carrying water can develop leaks that allow water to enter the machine, leading to insulation damage and winding failures. Leaks are caused by porosity in water box connection components and braze materials, in conjunction with crevice corrosion and problems with water chemistry.

Prevention: Replacement of the water box/clip connection is the best alternative. New components should be machined, rather than cast, and brazing done in a manner that eliminates previous porosity issues. The water box/clip connection can be replaced alone, or as part of a stator coil rewind. The rewind provides more integrity, since all brazes are done in the factory under more controlled conditions.



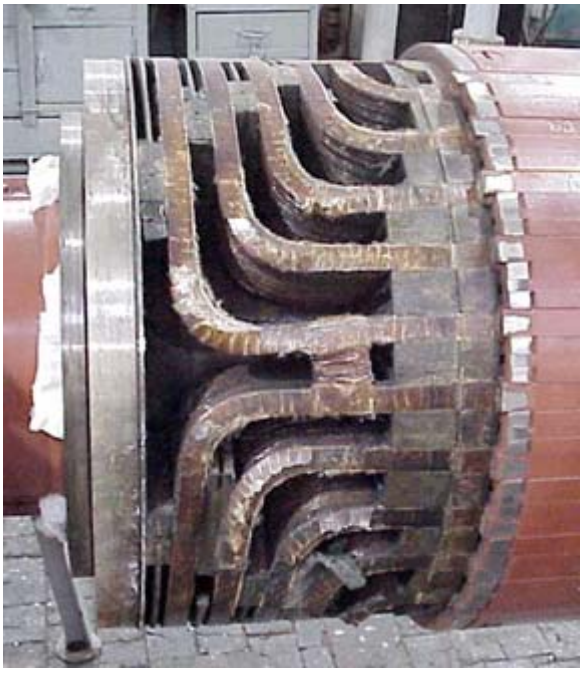
STATOR WEDGE LOOSENESS

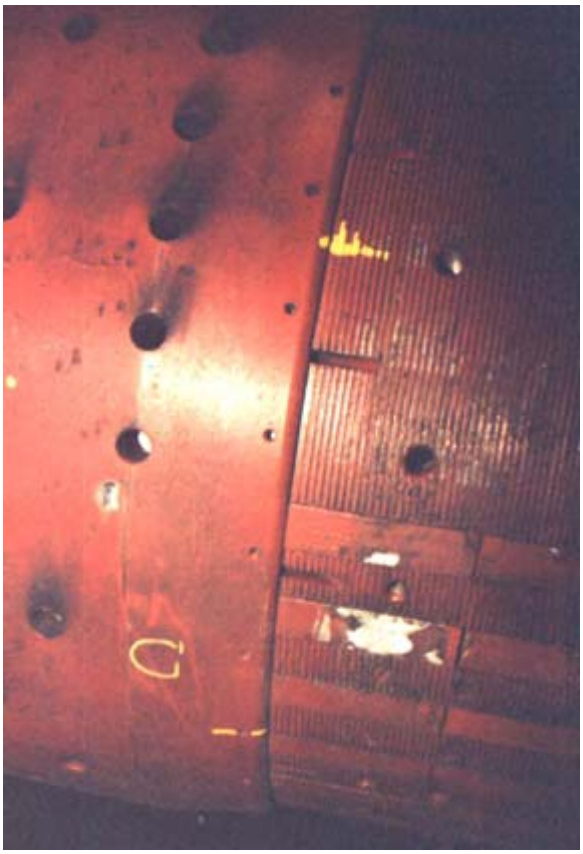
Problem: Stator wedges are essential for holding stator coils tight in the slots and minimizing vibration from steady state related excitation forces. When these wedges become loose, coils can vibrate, causing wear of the ground wall and turn insulation and leading to ground failure or turn to turn shorts.

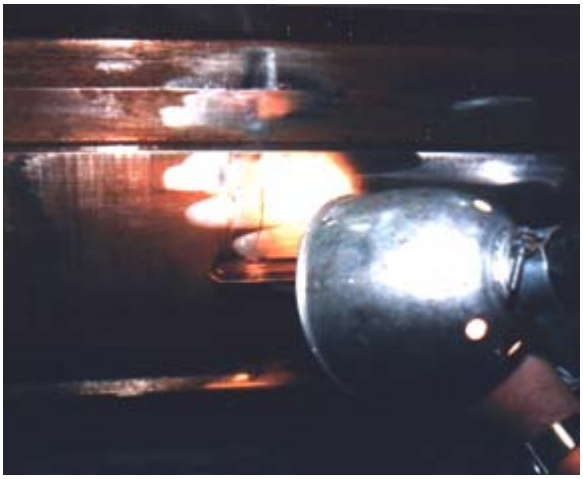
Prevention: The problem of loose wedges can be minimized with the proper initial design and installation. Top and side ripple springs, can allow a pre-load to be applied to the coil, so that compression is maintained in any operating condition. During regular maintenance activities, periodic checks of wedge tightness are worthwhile. Also, the prevention of oil seepage into the machine can prolong wedge tightness, as well as insulation integrity.

Photos: (top left) Brazing MD&A patented two-piece water box, made of machined copper, to new wind replacement coils in NEC's Brownsville factory. (bottom left) Cross section of one of the machine's original cast copper water boxes. (top right) Typical wedge and ripple spring used for seating stator coils in core iron.*

** National Electric Coil and Mechanical Dynamics & Analysis have partnered to manufacture and install replacement windings for water-cooled generators experiencing winding leakage problems.*





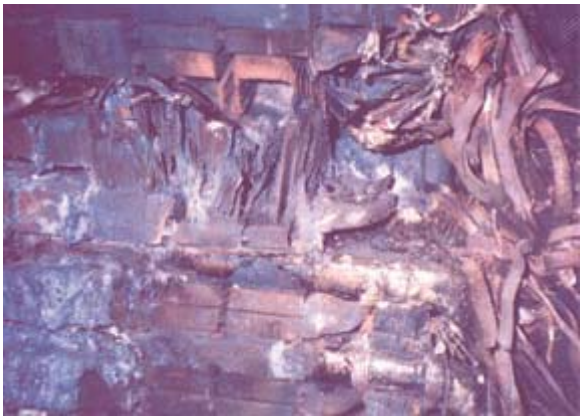


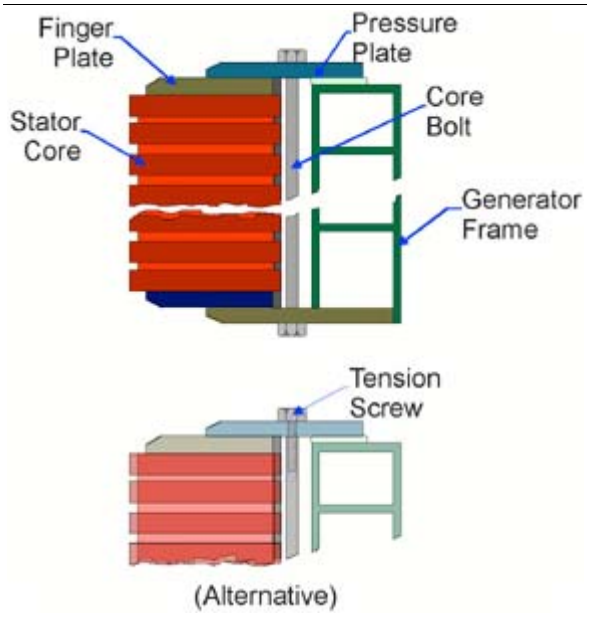
ROTOR VIBRATION

Problem: Rotor vibration problems, although usually not catastrophic, have caused many, many forced outage hours. The causes are almost too numerous to mention, but the most common reasons are: turn to turn shorts, rotor coil foreshortening, blocked ventilation passages, electrical grounds, mechanical imbalance, wedge stick-slip, coil stick-slip, loss of balance weights, overheating and bearing wipe.

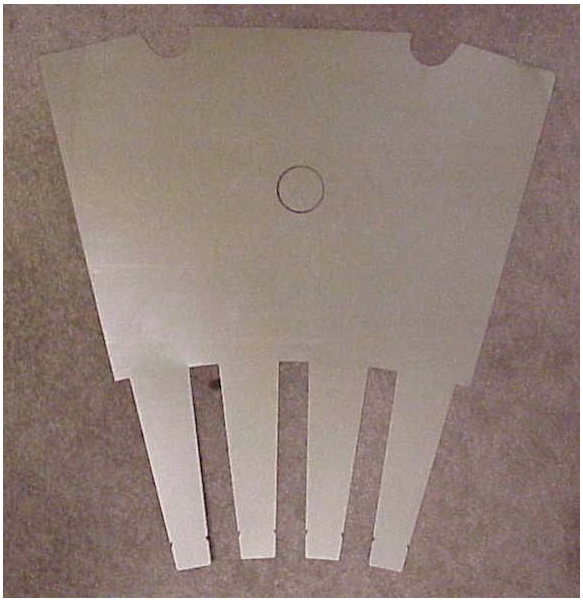
Prevention: With so many causes, it is nearly impossible to discuss all but a few key prevention techniques. However, two prevention methods take precedence over all others - good vibration measuring instrumentation and alert operators. Their value is obvious. Accurate instrumentation signals impending problems and is absolutely essential to prevent subsequent damage. Alert operators, who are well-trained and knowledgeable enough to take appropriate actions, such as tripping the unit, are an indisputable asset.

Photos: (top left) Rotor showing evidence of turn to turn shorts, resulting from winding end turn migration. (bottom left) Dark "burns" show evidence of blocked rotor ventilation passages. (top right) Hairline crack, barely visible, in rotor shaft.





Photos: (top left) Machine damage resulting from severe core displacement. (bottom left) Diagram shows location of through bolts relative to the laminations and stator frame. (top right) Section of a typical lamination. Stator cores are comprised of thousands of laminations, stacked into the machine frame, held into place by through bolts and compressed.



STATOR CORE DAMAGE

Problem: Stator core looseness may occur over time as pre-tensioned through bolts relax. A loose core can cause serious trouble to coils and laminations. If laminations vibrate relative to one another, they can cause wear to the surface insulation. This pattern of wear leads to lamination shorting, core hot spots and eventual core or coil-to-core failure.

Prevention: Inspection of through bolt tightness is recommended at regular intervals. Regular EL CID tests or loop test inspections of the stator core can also verify its continued integrity. If a company's regular maintenance technicians are not qualified to perform these tests, NEC can provide these services with its trained field service personnel.