STATOR INSULATION SYSTEM AGING MECHANISMS

AND

BAR VIBRATION

"The single most important parameter influencing the reliability of a rotating machine is the electrical insulation. If the insulation fails to maintain its integrity during operation, the equipment will fail. In practice, insulation does not fail at once. Multiple stresses acting on the insulation - voltage stress, mechanical forces, thermal effects - all combine to induce a slow but steady change in its nature over years."

B. S. Bernstein, Project Manager,
Electrical Systems Division
Electric Power Research Institute

The "Stator Insulation System Aging Mechanisms" Table from EPRI's Handbook To Assess Rotating Machine Insulation Condition lists aging mechanisms, failure modes, and common symptoms for most winding and core insulation system types. The majority of these problems are associated with the movement of the bar due to shrinkage, slackness or loosening. This is why the SBV system was developed : to monitor bar movement from its offset to prevent insulation system failures **(see the EPRI Table on reverse.)**

Stator Insulation System Aging Mechanisms

Table 3.9.1 from "Handbook to Assess Rotating Machine Insulation Condition"

Name	***Affected Insulation Types***	***Mechanism Description***	***Failure Mode***	***Common Symptoms***
Thermal Deterioration				
- Thermoplastic	Asphaltic-mica, micafolium	Operating at high temperature (RTD > 100°C) causes binding materials to flow and/or evaporate, creating delamination, **slackness**, tape migration; accelerated by reduced thermal conductivity	Strand or turn shorts **due to movement**; groundwall puncture due to discharges and abrasion	**Groundwall puffiness**, high internal partial discharge activity, discoloring of strand/turn insulation, high winding temperatures
- Thermoset	Epoxy-mica, polyester-mica	Operation at high temperature causes reduction in physical strength, **shrinkage**; accelerated by reduced thermal conductivity	Leads to other mechanisms such as slot discharge	**Slackness in slot**, discoloring of strand/turn insulation, high winding temperatures, insulation embrittlement
Girth Cracking	Primarily asphaltic and micafolium	Thermal cycling causing tape separation, **relative movement between copper and groundwall**	Cracking of insulation just outside the slot, leading to puncture	Groundwall puffiness, high internal partial discharge activity, **loosening of endwinding blocking and bracing**
Scarf Joint Failure	Windings with scarf joints	As above, with the scarf joint between the slot insulation and endwinding insulation opening up	Electrical puncture at scarf joint	As above
Slot Discharge				
- Mechanical	Epoxy-mica, polyester-mica, mainly air-cooled machines	Poor installation or **insulation and support system shrinkage leads to looseness and abrasion** of semicon and insulation, resulting in partial discharge	Reduction of groundwall thickness, electrical puncture	Powdering caused by abrasion, l**oose side packing and wedges**, high partial discharge activity between core and winding (slot discharges), high semicon resistance
- Electrical	As above	Poor semicon application or grounding, causing partial discharge, leading to reduced insulation wall and abrasion	As above	As above
Delamination Discharge	All types, but thermoplastic most susceptible	Partial discharge within groundwall make voids larger; original voids due to poor impregnation, thermal cycling, operation at high temperature	Groundwall puncture; turn-to-turn short if turn insulation fails first	Moderate to high internal partial discharge activity, **puffiness in thermoplastic insulation**
Endwinding Discharge	All types	Small end arm spacing less than 0.060" clearance, poor electric field grading coatings, and/or contamination of endwindings with pollution, allowing high electric stresses at surface of endwindings	Erosion of insulation by discharges, electric tracking, leading to puncture	Low insulation resistance and/or polarization index, high partial discharge, band of deterioration at grading/semicon interface, powder at blocking and bracing
Moisture Attack	All types, but polyester-mica most sensitive	Moisture from cooling system or condensation combining with binder to **reduce electrical and mechanical strength of insulation**	**Increased sensitivity to mechanical vibration**, higher losses leading to puncture	Low polarization index, higher dissipation factor
Abrasive Material Attack	All types of open machines	Abrasive dust from cooling air erodes insulation	Puncture due to reduced wall thickness	Insulation powder, **loosening of winding**
Radiation	All types, in radioactive environment	In very radioactive area, **insulation degrades, losing electrical and physical strength**; similar to thermal deterioration	Puncture, often during a shock such as mal-synchronization, motor start or a surge	**Shrinkage, winding looseness**, discoloration, insulation embrittlement
120 Hz Vibration	All types, but epoxy-mica most sensitive	**Magnetic forces cause vibration between the winding and the slot** (leading to slot discharge) or at blocking points in endwinding; resulting in insulation abrasion	Reducing insulation wall, partial discharges leading to phase-to-phase or phase-to-ground puncture; turn insulation failure may also occur	Powdering of insulation, especially at blocking and bracing; broken binding ties; high partial discharge if in slot; **broken ripple springs**
Mechanical Shock	All types, but especially motors	High inrush currents during motor starting or generator mal-synchronization create high mechanical forces which exceed insulation system strength	Broken ties and **loose blocking in endwinding** lead to abrasion of insulation and puncture	**Loose bracing and blocking**; broken ties in endwinding; insulation powdering