Hydro Generator Maintenance Testing Discussion

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Today's Discussion

• Industry changes
• Review testing fundamentals
• Concerns & trends
• Insight & references for future use
Industry Changes

- Loss of key people
  - Retirements
  - Promotions
  - Workforce Reductions

- Reduced spending

- Longer interval between outages

- Regardless of changes, and effective maintenance program is essential.
Key Elements Of An Effective Maintenance Program

- Standard Equipment Monitoring
- Visual Inspection
- Electrical Testing
- Documentation and Trending
Prior to Testing

• Establish Testing Protocol
• Isolation
  • Winding from iso phase bus
  • Phases from neutrals
  • Properly ground instrumentation
• Safety
  • LOTO
  • Clearances
  • Grounds
## Electrical Tests - Stator

<table>
<thead>
<tr>
<th>Maintenance Activity</th>
<th>Purpose/Findings</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>Insulation Resistance or “Megger” with PI</td>
<td>Determines presence of contamination</td>
<td>Minor and major outage</td>
</tr>
<tr>
<td>Winding Resistance</td>
<td>Integrity of brazed connections</td>
<td>Minor and major outage</td>
</tr>
<tr>
<td>Hipot</td>
<td>Proof test to “stress” insulation</td>
<td>Major outage</td>
</tr>
<tr>
<td>D.C. Ramp</td>
<td>Determines insulation condition / strength</td>
<td>Major outage</td>
</tr>
</tbody>
</table>
## Electrical Tests - Rotor

<table>
<thead>
<tr>
<th>Maintenance Activity</th>
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<tr>
<td>Pole Drop</td>
<td>Rotor shorted turns</td>
<td>Major outage</td>
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</table>
Insulation Resistance Testing

- 2500 vdc for stator
- 500 vdc for rotor
- PI (Polarization Index) - Compare 1 minute and 10 minute
  - One Min. (100 Megohms)
  - Ten Min. (300 Megohms)
  - PI = 300 / 100 = 3.0
- PI > 2.0 is good
Winding Resistance - DLRO

- DLRO – Digital Low Resistance Ohmmeter
- Should be capable of 4 or even 5 significant digits
- Compare all three phases of the stator winding – if not balanced within about 3% maximum, strand breakage or joint failure may be occurring
- Rotor value should be consistent outage to outage when corrected
Hipot Testing

- Hipot testing – high potential or over-potential testing - used as proof test
- Preferable to have a failure during a controlled test, during an outage, rather than at some unknown time, possibly when the unit is badly needed
- AC kV = (2*E) + 1
- Multiply by 1.7 for the DC value
- AC equipment, as shown at right, is large and heavy
Hipot Testing

- AC testing is more demanding than DC
- AC has higher risk of coil failure
- DC more commonly used as maintenance test (1.2 to 1.6 times $2 \times 10^1$)
- AC more commonly used as commissioning test for new winding
Documentation and Trending

• Consistency in reporting & central file
• Trending of key data
• Analyze trends that may lead to failure
• Once trends are established that indicate likely failure, determine steps to take and how soon they must be taken
## Specialty Tests - Stator

<table>
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<tr>
<th>Maintenance Activity</th>
<th>Purpose/Findings</th>
<th>Frequency</th>
</tr>
</thead>
<tbody>
<tr>
<td>ELCID – Electro-Magnetic Core Imperfection Detection</td>
<td>Shorted laminations</td>
<td>Major outage</td>
</tr>
<tr>
<td>Core Loop</td>
<td>Shorted laminations</td>
<td>After rewinds or core repair</td>
</tr>
<tr>
<td>Wedge Tightness</td>
<td>Loose wedges</td>
<td>Major outage</td>
</tr>
</tbody>
</table>
ELCID Test

• Excite core to only 4% of rated flux density
• Search coil on trolley detects any interlaminar circulating currents
• 100 milliamp action threshold
• Uses 110 vac – easy to set up and use
ELCID Test Plot

- ELCID test plot shows multiple locations with significant hot spots and “areas under the curve” as shown at the right.
- 100 milliamps or greater requires further investigation.
Full Flux AC Core Loop Testing Setup
Infrared Thermography

- Local hot spots in stator core can be seen through infrared thermography
Stator Core Damage
IEEE Trial-Use Guide to the Measurement of Partial Discharges in Rotating Machinery

Sponsor
Electric Machinery Committee
of the IEEE Power Engineering Society

Approved 26 April 2000
IEEE-SA Standards Board

Abstract: A review of the nature of partial discharge in machine windings, how it can be measured under both off-line and on-line conditions, how it can be measured for individual form-wound coils or bars, and the significance and limitations of the measured values are covered.

Keywords: electrical insulation, form-wound bars, form-wound coils, partial discharge, rotating machine windings
## Testing Summary

BE SURE ALL CIRCUITS ARE DE-ENERGIZED

<table>
<thead>
<tr>
<th>MAINTENANCE ACTIVITY</th>
<th>SHOWS</th>
<th>FREQUENCY</th>
</tr>
</thead>
<tbody>
<tr>
<td>Dielectric Absorption</td>
<td>Winding cleanliness</td>
<td>Major Outage</td>
</tr>
<tr>
<td>Polarization Index (PI)</td>
<td>Winding cleanliness/moisture</td>
<td>Major and Minor Outage Cycles</td>
</tr>
<tr>
<td>Power Factor</td>
<td>Insulation integrity</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Partial Discharge (PD)</td>
<td>Coil tightness; insulation integrity</td>
<td>On-line or Outage Cycle</td>
</tr>
<tr>
<td>Megger</td>
<td>Integrity of Insulation</td>
<td>Major and Minor Outage Cycles</td>
</tr>
<tr>
<td>Blackout</td>
<td>Corona suppression integrity</td>
<td>Rewind</td>
</tr>
<tr>
<td>Resistance</td>
<td>Integrity of joints and connections</td>
<td>Major and Minor Outage Cycles</td>
</tr>
<tr>
<td>Flux Probe</td>
<td>Rotor winding shorts</td>
<td>On-line, Rewind</td>
</tr>
<tr>
<td>Rotor Impedance</td>
<td>Rotor winding shorts</td>
<td>Rewind</td>
</tr>
<tr>
<td>Ground Fault</td>
<td>Rotor Ground</td>
<td>Continuous</td>
</tr>
<tr>
<td>Split Voltage</td>
<td>Location of rotor grounds</td>
<td>As Needed</td>
</tr>
<tr>
<td>Voltage Drop</td>
<td>Presence of shorted turns</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>El Cid</td>
<td>Integrity of stator core</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Core Loop</td>
<td>Integrity of stator core</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Bolt Torque</td>
<td>Stator core looseness</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Ultrasonic</td>
<td>Cracks, defects in forgings</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Temperature Monitoring</td>
<td>Normal/abnormal operation</td>
<td>On-line and Continuous</td>
</tr>
<tr>
<td>Dye Penetrant</td>
<td>Cracks, defects in forgings</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Eddy Current</td>
<td>Cracks, defects in forgings</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Magnetic Particle</td>
<td>Cracks, defects in forgings</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Wedge Mapping</td>
<td>Stator winding tightness</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Hi-Pot</td>
<td>Insulation integrity</td>
<td>Major Outage Cycle</td>
</tr>
<tr>
<td>Vibration</td>
<td>Rotor imbalance</td>
<td>Monthly and On-line</td>
</tr>
<tr>
<td>Visual Inspection</td>
<td>Normal/Abnormal Performance</td>
<td>As Available</td>
</tr>
<tr>
<td>Oil Chemistry and Count</td>
<td>Bearing oil contamination</td>
<td>Twice Yearly</td>
</tr>
</tbody>
</table>
Sources of Guidance

• Vender Technical Staff
• IEEE
• Published Books:
  – *Operation and Maintenance of Large Turbo-Generators*  Klempner& Kerszenbaum
• IGTC
IGTC Forum

INTERNATIONAL GENERATOR TECHNICAL COMMUNITY
Become a member of the IGTC Technical Forum

Qualified members can participate in the only online technical forum devoted solely to maintaining and repairing power plant turbogenerators and hydrogenators.

www-generatortechnicalforum.org
Summary

• Electrical testing is a critical element of an effective maintenance program.
• To realize the greatest benefit of electrical testing, the proper tests and protocol must be applied, at reasonable intervals, by trained personnel, and the data must be properly documented and trended.
Hydro Generator Maintenance Testing Discussion

Questions