Virtual IRIS Rotation Machine Conference

Overview of Various Machine Online Condition Monitoring Techniques based on On-site Testing and Inspection

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Outline

An overview of presentation

- Introduction
- Types of In-service Aging Stresses
- Online Monitoring Techniques
- Selected Field Case Studies
- Conclusions
- Future Recommendations
- Acknowledgments

Introduction

Benefits and effectiveness of online condition monitoring

- **Condition Assessment**
- **Online Monitoring**
- **Type of Stresses**
- **Effective Planning**
- **Shutdown Losses**
- **Production Losses**

- *Several online techniques and test methods have been established for rotor and stator winding condition monitoring and assessment.*
- *End-users always prefer an online monitoring technique as no outage is needed or required.*
- *The key benefit of online testing is to assess condition under real stresses (thermal, mechanical, environmental, and electrical), while they are present.*
- *Reliable assessment of machines will certainly help to plan outages or downtime more effectively.*
- *Various on-line condition assessment methods for motors and generators have been discussed along with case studies to help in preventing unplanned shutdown and production losses.*

Types of In-service Aging Stresses

TEAM stresses

- Historical and recent research work clearly defines that there are several stresses that can affect the rate of insulation deterioration in stator and rotor windings. These are also called TEAM stresses.

  A. Thermal, B. Electrical

  C. Ambient, D. Mechanical

- ***Thermal:*** *The operating temperature of motors can impose thermal stresses due to losses in the copper conductors and by generating heat.*
- ***Electrical:*** *During the service life PD can cause slow degradation and weakness in the insulation leading to failure, especially if an over-voltage or a lightening impulse occurs.*
- ***Ambient or Environmental:*** *Moisture or surface contamination if present in the environment can affect the rotor and stator insulation when combined with other stresses.*
- ***Mechanical:*** *In rotating machines, rotor insulation is exposed to high centrifugal force which can distort the insulation during service life.*

Online Monitoring Techniques

In-service condition monitoring

#	Monitoring & Diagnostics Overview		
	Monitoring Description/Technique	****Predominant Aging Stress***	***Comments***
1	RTD Data Comparison	T	Stator Temperature Trending
2	High Sensitivity CT	T, E, A	Stator Insulation Health
3	Proximity Probes	M	Vibration Trending
4	Electrical Signature Analysis	M	Vibration Trending
5	Rotor Telemetry	T, M, A	Rotor Insulation Health
6	Electrical Signature Analysis – Rotor	M	Rotor Cage Health
7	Electrical Signature Analysis – Bearings	M	Bearings Misalignment
8	Partial Discharge (HF)	E	Stator Winding Health
9	Partial Discharge (LF)	E	Stator Winding Health
10	Power GuardII+	E	Rotor Shaft Current and Voltage Monitoring

#	Monitoring & Diagnostics Overview		
	Monitoring Description/Technique	****Predominant Aging Stress***	***Comments***
11	Cross-coupled Impedance Measurement	E	Stator Inter-Turn Fault Detection
12	Negative Sequence Current Monitoring	E	Stator Inter-Turn Fault Detection
13	Thermal Capacity Used (TCU)	T	Assess Thermal Stresses
14	Thermography	T	Identify Hotspots
15	Ozone Detectors	E	Stator Winding Corona Discharge
16	Accelerometers	M	Endwinding Vibration Monitor
17	Flux Probe for Rotor Flux Monitoring	E	Rotor Turn-to-Turn Shorts
18	Capacitive Sensors	M	Airgap Monitoring System
19	Piezo-Electric Accelerometers	M	Bearing Vibrational Analysis
20	Leak Detectors	E	Water Leak Inside Machine

*TEAM

Selected Field Case Studies

Case Study 1: RTDs Data Comparison

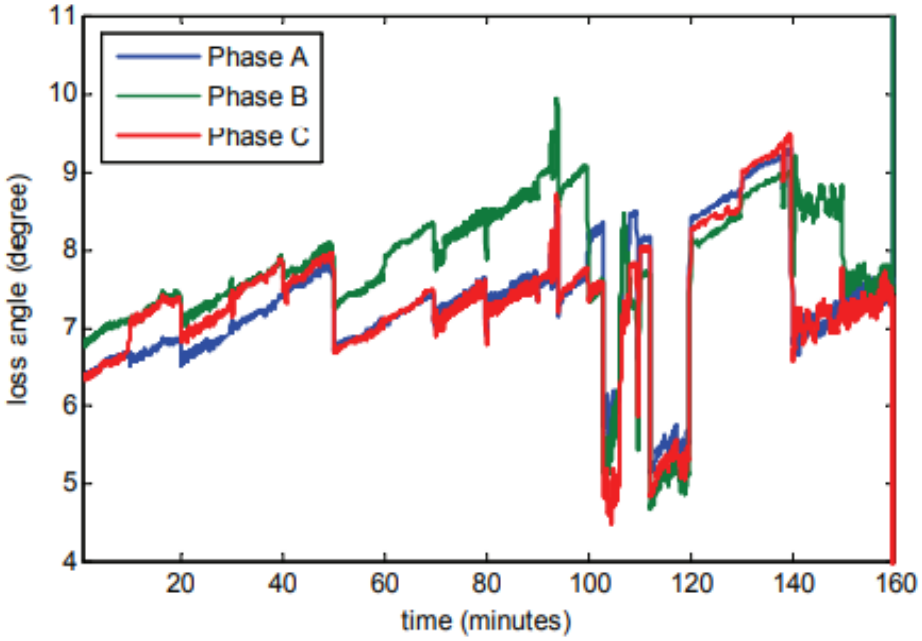
- Stator winding inspection of a generator rated at 28750 kVA/23000 kW revealed signs of insulation degradation mainly due to thermal aging.
- It was established that the overheating was likely due to insufficient circulation of cooling air inside the machine.
- Inspection of the generator enclosure revealed that the cooling air may have been restricted through the cooler air passages due to contamination.
- Clogged pipes in the water cooler further increased the temperature of the cooling air entering the stator which increased the temperature of the stator winding.

- *The comparison of the operational data received from 2007 and 2014 indicated that the stator RTDs temperature had increased up to 18˚C when the machine ran at full load.*

Selected Field Case Studies (cont.)

Case Study 2: Online C & DF Measurements using High Sensitivity CT (HSCT)

- A novel high sensitivity differential current transformer is used as a sensor for online monitoring of insulation capacitance and dissipation factor of motors.
- A 4160 V, 3-Phase form-wound induction motor was tested with different contaminants sprayed over its endwinding.
- The loss angle showed an upward trend during the test indicating gradual deterioration.
- Use of high sensitivity CTs for such indications can help prevent catastrophic failures of motors and can enhance overall reliability of the system .

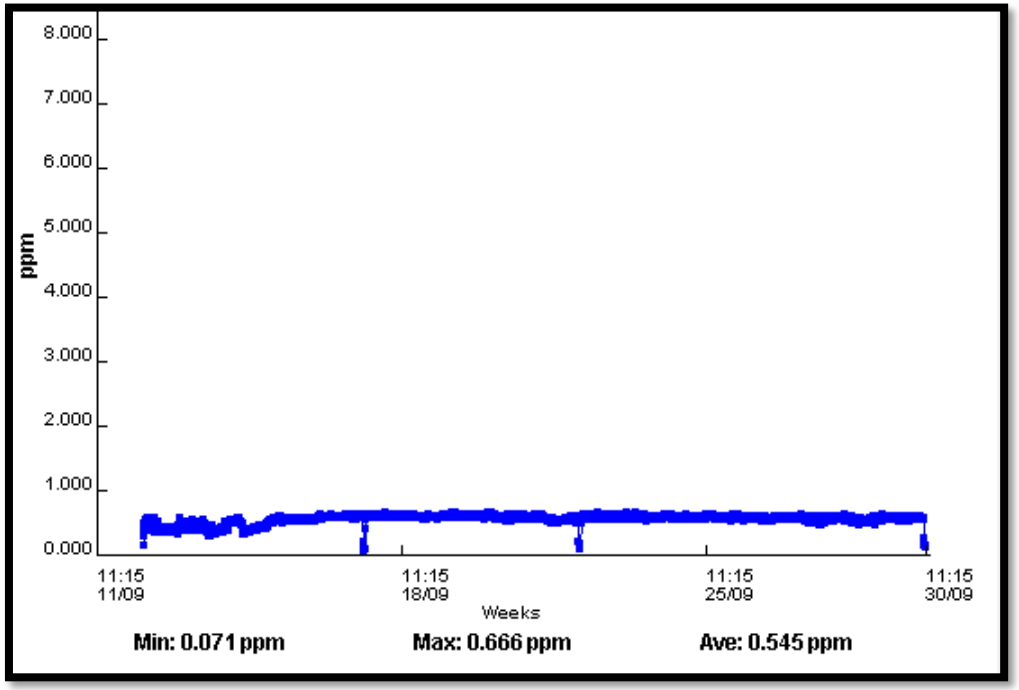


- *The capacitances and loss angles are calculated from the leakage current measured using HSCT, as shown on the right-side plot.*

Selected Field Case Studies (cont.)

Case Study 3: Ozone Monitoring

- Ozone monitoring and trending was performed on four 13800 V synchronous machines that were installed at the same location within one building.
- Ozone monitoring performed at the customer site revealed levels around 0.2 ppm, with time weight average (TWA) values around 0.06-0.07 ppm. Overall, highest levels of ozone found near vicinity of machines were 0.6-0.7 ppm.
- As a preventative action, it was recommended to improve ventilation where the machines are installed to better remove ozone from the environment and bring it to a safe level.

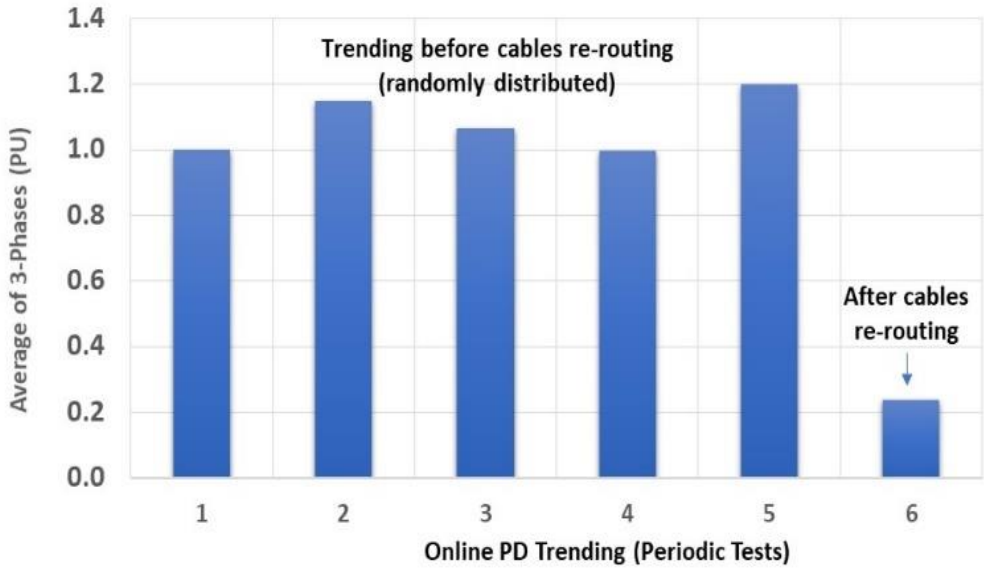


- *A better and continuous use of ventilation showed significant improvements in bringing ozone levels to acceptable limits.*

Selected Field Case Studies (cont.)

Case Study 4: Online PD Monitoring

- Online PD monitoring can be done periodically. Recommended periodic monitoring is at 6 to 12-month interval after settling-in period of 12 to 18-month.
- Online PD monitoring systems are presented in IEEE Std. 1434 and IEC 60034-27-2.
- Online PD monitoring of a synchronous machine with nameplate rating of 13800 V, 4-Pole, 1800 RPM, 17500 HP, TEWAC was performed over a period of time.
- Upon inspection, it was revealed that the elevated PD activity was due to corona discharges between two cables that belonged to different phases and which also had insufficient clearances to ground.

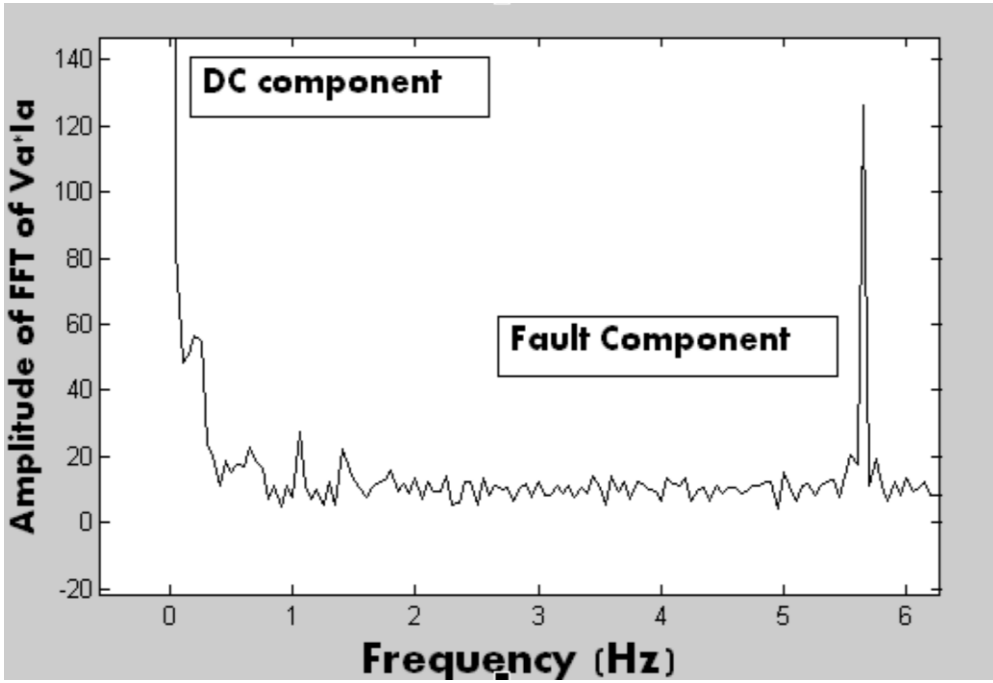


- *Re-adjustments of the cable lengths to achieve sufficient clearances resulted in a significant drop in PD level.*

Selected Field Case Studies (cont.)

Case Study 5: Broken Rotor Bar Detection

- A defect in an induction motor rotor bar causes the modulation of the stator current.
- The impact of broken rotor bars to the stator current can be determined by analyzing in the frequency domain to detect rotor bar failures and the approach is typically called a Motor Current Signature Analysis (MCSA).
- Advanced protection relays are now available to provide FFT analysis in order to detect failure of the rotor bars.
- The combination of a voltage and current signature provides a more accurate detection compared to the typical current based algorithm.



- *Fault component as shown in figure was successfully captured suggesting broken rotor bar detection which was later confirmed during visual inspection.*

Selected Field Case Studies (cont.)

Case Study 6: Thermal Capacity Used Modelling

- Advancements in motor thermal model to proactively monitor Thermal Capacity Used (TCU) in correlation with above presented parameters is used to give early warning on preventive maintenance due to thermal stress.
- This approach of TCU was utilized on a mining mill motor rated as 1900 V, 2082 A, 8750 HP with TEWAC enclosure and showed favorable results.

Case Study 7: Inter-turn Fault Detection

- Stator inter-turn fault detection can be performed using an online cross-coupled impedance measurement technique or by negative sequence current monitoring method.
- A model for 1 MVA, 2300 V motor with stator inter-turn fault in A-phase of the winding was developed.
- Analysis of results illustrated that during normal operating conditions, the learned Operating Quantity (OP) measured was 0.043, due to inherent imbalance in the machine windings. With stator inter-turn fault, the maximum OP quantity increased four times to 0.135 showing a significant change which can be used to initiate an alarm or to stop motor operation.

Conclusions

- Benefits of several online monitoring techniques were discussed to promptly initiate corrective measures preventing costly shutdowns and production losses.
- The major advantages that apply to large rotating machines are an early warning to schedule maintenance and outage to reduce process loss (outage time) and to limit loss of revenue.
- Other benefits of reducing end-users cost and time required for machines repair by optimising assets performance management cannot be ignored.
- It is already pointed out that initial investments could be higher to make machines capable for online monitoring due to installation of sensors and other monitoring devices. To reduce these investments, it is recommended to consult OEMs for selecting appropriate sensors and monitoring devices depending on site application and usage to minimize costly shutdowns and production losses.

Future Recommendations

Machines Condition Assessment

- Rotating machines health assessment is an important aspect of machine operation. There are twenty or more online tests and techniques available to assess machine condition while in-service.

- Reasonable cost to minimize principal investments
- Easy installation to reduce downtime
- Simple use interface design and display
- Easy data trending and interpretation
- Optimized alarm systems
- Automated reporting system

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Thank You