



CONDITION ASSESSMENT

FOR

HT MOTORS AND GENERATORS

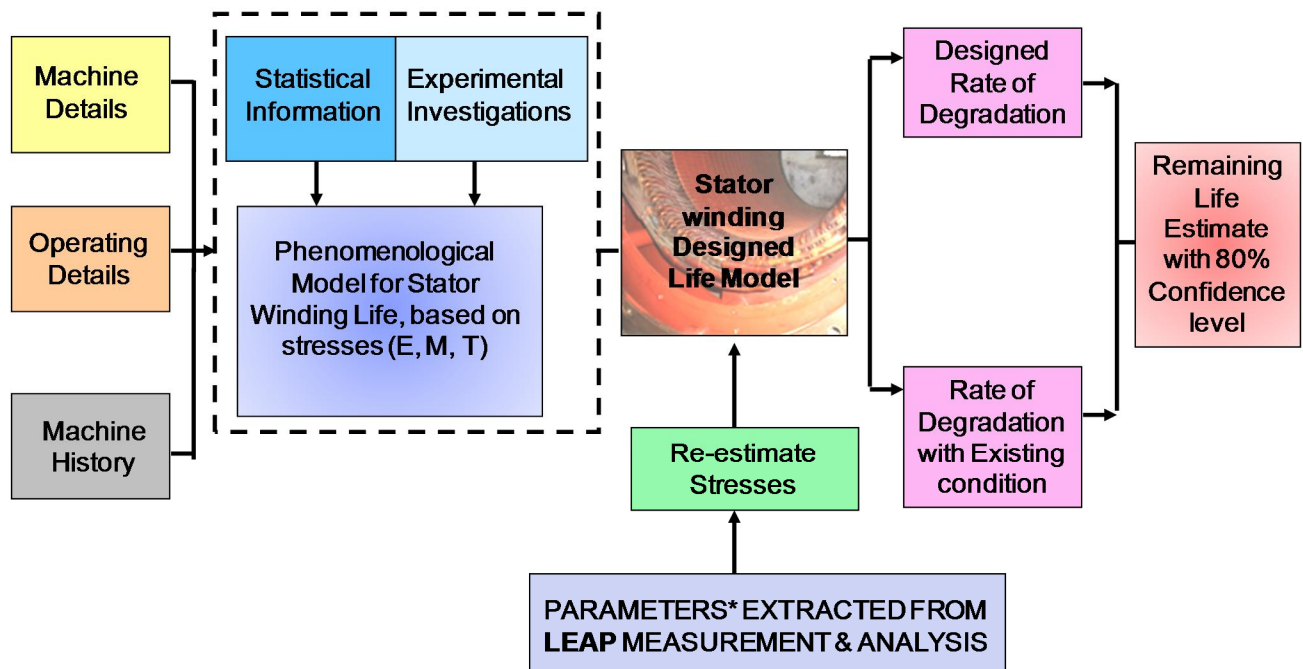
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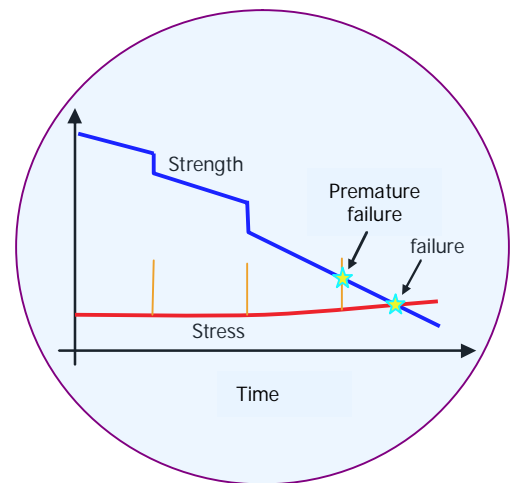
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LIFE EXPECTANCY ANALYSIS

A combined stress phenomenological model, that is based on one proposed originally by Simoni, Srinivas, et al, is used to assess the extent of degradation of the insulation and perform a lifetime expectancy analysis. The model accounts for thermal, electrical and mechanical stresses, whose relative effects on the life of the insulation are estimated on the basis of the analysis from the measurements performed, and from the operating and historical details made available.



The theory stems from the fact that when stresses act on the insulation of the stator windings, there is a progressive deterioration of the strength of the insulation. In other words, ageing is exhibited by a progressive deterioration of the physical properties of the insulation. Not all physical properties can give an indication of the progression of ageing, except perhaps those directly related to failure, e.g. electrical breakdown strength and mechanical strength. If stresses unable to produce a failure are considered such as temperature or chemical exposure, other failure criteria are selected that are related to electrical or mechanical breakdown strengths. In any case, failure essentially occurs when the selected property drops down to a limiting value, so that a unique definition can be adopted for remaining life – the time for the selected property to reach that point. This point is generally related to the stresses that are developed in the stator insulation during machine operation. In other words, when the strength of the insulation deteriorates to a point where it equals the developed stresses in the insulation, the insulation will fail.



The measurements performed during an inspection are converted into parameters that can be related to the stresses that are developed in the insulation, for example the extent to air space within insulation would affect thermal, mechanical and electrical properties of the insulation and thereby affect the thermal electrical and mechanical stresses that are developed in the insulation. This affects the rate of deterioration of the insulation.

To give another example, when the temperature of the insulation increases, the rate of deterioration of the mechanical strength of the insulation also increases. Therefore, based on the knowledge of how parameters derived from measurements can affect stresses, it is possible to estimate the rate of deterioration of the strength of the insulation.

▪ **Electrical Stress:**

$E = f(Q1, Q2, Q3, \text{Ageing Index}^*, \text{Volume Resistivity, Discharging Void Volume, Partial Discharge Inception, Nature of PD})$

▪ **Mechanical Stress:**

$M \text{ or } S = f(Q1, Q2, \text{Void volume content, Looseness Factor, Slot Discharge Factor})$

▪ **Temperature Stress:**

$T = f(\text{Winding Operating temperature, Discharging Void Content, Discharge Inception Voltage, Nature of PD})$

Phenomenological Life Estimation Formula:

$$L = L_0 K(T, S) \left[\frac{E^*}{E_0^*} \right]^b \left[\frac{E}{E_0} \right]^{-n} \left[\frac{E^{1/T}}{E_0^{1/T}} \right] \left[\frac{S}{S_0} \right]^{-m} \times \exp \left[\frac{\Delta GE}{K} \left(\frac{1}{T} - \frac{1}{T_0} \right) \right]$$

In the case of LEAP Standard measurements performed, the parameters that have been used as inputs from the analysis include the charge distribution parameters, the volume resistivity, the discharging void content parameters, partial discharge parameters and data from the non-linear analysis. These parameters are used together with operating data such as winding temperature and the number of starts, to draw the line describing the deterioration in insulation strength.

It is generally assumed that at the time of commissioning of the machine, there is no deterioration of the relevant properties of the insulation. An initial life estimate is made on the basis of “normal” expected parameters (as derived from operating data and the normal range values of measurements such as those specified for LEAP measurements) at an early part of the machine life.

The various LEAP packages are as described. Further details on some important tests are provided

LEAP PACKAGES:

LEAP ROTOR & BEARINGS (ABB MACHSense™)

This consists of various checks to determine faults or incipient faults in mechanical structure of rotor and bearing run/repair/replace decisions.

Scope of Work:

- Vibration Spectrum Analysis

- Motor Current Spectrum Analysis
- Acoustic Emission

Applicable for: HT Motors (mainly SCIM), limited form can be applied to Slip ring motors

Machine requirements:

- Sensors need to be placed on motor bearing pedestal or body or mounting.
- Special arrangements need to be made for vertical motors where these areas are inaccessible.
- Access to control panel for collection of current and voltage data required for MCSA through CTs and PTs.
- Motor should be running and load variations should be possible to achieve manually

LEAP PERFORMANCE EVALUATION

Purpose: Determination of runtime efficiency for motor in actual site conditions and conducts energy audit study.

Performance of the motor needs to be evaluated at site as part of the energy auditing or efficiency determination program. Most methods generally rely on models that does not account for dynamic variations of motor conditions. ABB has developed a special algorithm that uses information from LEAP Rotor & Bearings for accurate slip determination and simultaneous power quality measurements from the motor control panel (such as current and voltage) using a special ABB developed product called as MACHSense-P. This test is combined with LEAP Rotor & Bearings. The algorithms help to develop the equivalent model for the motor and all characteristics of the motor can then be determined at run-time. This includes variation of power factor and efficiency with load, effect of voltage variations, effect of load and slip variations.

Scope of Work:

- Vibration Spectrum Analysis (at no load and 1 or 2 load point)
- Motor Current Spectrum Analysis (at no load and 1 or 2 load point)
- Power Quality Measurements

Applicable for: HT Motors (only SCIM)

Machine requirements:

- Sensors need to be placed on motor bearing pedestal or body or mounting.
- Special arrangements need to be made for vertical motors where these areas are inaccessible.
- Access to control panel for collection of current and voltage data required for MCSA through CTs and PTs.
- Value of stator winding resistance needs to be provided
- Motor should be running and load variations should be possible to achieve manually

LEAP BASIC

Purpose: Screening of large fleet motors based on its operational details only to focus on further actions on machines that are critical and having low life.

Scope of Work:

A form will be circulated that captures information on operational hours, starts/stops, winding temperatures, ambient temperatures. Any historical information of repairs, maintenance actions is also required. Life analysis based on such operational and historical details only at 60 to 65 % confidence level.

Applicable for: HT Motors, HT Generators

Machine requirements: No requirements.

LEAP STANDARD

Purpose: Low and cost effective life assessment package. **Highly recommended!**

Consists of tests that give highly accurate physical information of various components of stator windings like insulation, stress grade and corona paint. The test assesses various anomalies and incipient faults like contamination, ageing, coil looseness and damage to various components. See details of each test for deliverables. Parameters from the test are vital for life analysis at 80 % confidence level. Note that by doing more LEAP Standard assessment on large generators, capital outages can be deferred and maximum savings through optimum maintenance can be achieved.

This package is ideal starting point as it is low priced compared to RLA assessment, does not require any dismantling and has low outage period.

Scope of Work:

- Polarization Depolarization Current Analysis
- Tan Delta and Capacitance Analysis
- Non-Linear Insulation Behaviour Analysis
- Partial Discharge Analysis and
- Stator Winding Resistance measurement

Applicable for: HT Motors, HT Generators

Machine requirements:

- Unit has to be offline with terminals disconnected from main cables/busbar.
- Unit has to cool down to ambient
- Large generators should be stopped from barring gear and hydrogen cooled units need to ensure that the hydrogen is out from the unit. Water cooled generators need to ensure removal of water from the unit.
- No dismantling is required except the terminal box.

LEAP ADVANCED

Purpose: Usually a part of Level 3 maintenance where end-caps are opened for overhauling

Package offers same benefits as LEAP Standard as all the tests are conducted with addition of visual inspections and tools like partial discharge localization using PD Probes. This is often recommended before and after overhauling to assess improvements due to overhauling that is done on overhangs. Life offerings are from 80 to 85 % confidence level.

Scope of Work:

- Polarization Depolarization Current Analysis
- Tan Delta and Capacitance Analysis
- Non-Linear Insulation Behaviour Analysis
- Partial Discharge Analysis and
- Stator Winding Resistance measurement
- Visual inspection of overhang and slot-exit section

Applicable for: HT Motors, HT Generators

Machine requirements:

- Unit has to cool down to ambient
- Unit has to be offline with terminals disconnected from main cables/busbar.
- The end-covers have to be opened to allow access to overhangs
- Large generators should be stopped from barring gear and hydrogen cooled units need to ensure that the hydrogen is out from the unit. Water cooled generators need to ensure removal of water from the unit.

LEAP PREMIUM

Purpose: Usually a part of Level 4 maintenance or capital outage for refurbishment and modernisation

Package offers more benefits than LEAP Standard it covers all parts like stator core, rotor, exciter, diodes, cooling circuit besides stator windings. It is a very thorough study of machine condition and life assessment also has FEM Multi-Stress modelling to achieve highest accuracy of 95 %. This is typically for large generators RLA.

Scope of Work:**STATOR WINDINGS**

- Polarization Depolarization Current Analysis
- Tan Delta and Capacitance Analysis
- Non-Linear Insulation Behaviour Analysis
- Partial Discharge Analysis and
- Stator Winding Resistance measurement
- Visual inspection of overhang and slot-exit section includes endoscope/boroscope inspections
- Coupling resistance
- Wedge Tightness Check
- Multi-stress Analysis
- Life Expectancy Analysis

STATOR CORE

- Digital EI CID test
- Visual inspection of core laminations, back of iron

ROTOR

- Visual inspection of rotor, slip rings, brush assembly, including endoscopy under retaining rings
- Rotor winding resistance/impedance
- Recurrent Surge Oscillograph
- Diode and RTD checks
- DP/UT on retaining rings, slip rings, shaft, fan blades, bearings

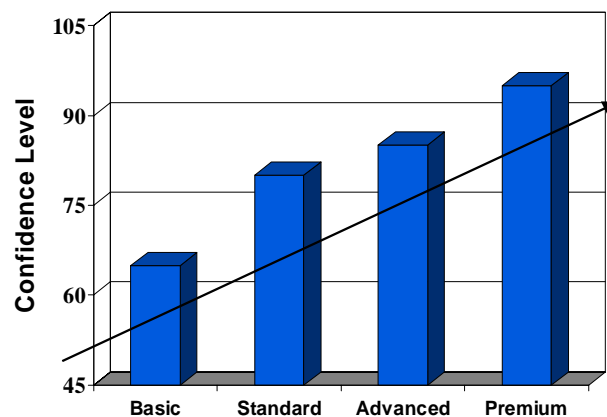
EXCITER

- Visual inspection of Exciter stator/rotor/PMG
- Winding resistance/impedance measurement of main and pilot exciter stator/rotor

Applicable for: HT Generators

Machine requirements:

- Unit has to cool down to ambient
- Unit has to be offline with terminals disconnected from main cables/busbar.
- Large generators should be stopped from barring gear and hydrogen cooled units need to ensure that the hydrogen is out from the unit. Water cooled generators need to ensure removal of water from the unit.
- Unit has to be dismantled and rotor has to be threaded out
- Diode ring disconnection is also required.
- Access to the rotor winding mid-point (for better analysis)



INDIVIDUAL TEST DESCRIPTION:

POLARIZATION DE-POLARIZATION CURRENT ANALYSIS (PDCA)

References:

- IEEE 43: 2000
- "Diagnosis of insulation health of rotating machines" by Cajetan Pinto, Maciej Wnek, CWIEME Proceedings, 2000.
- "An Improved Method of detecting contamination of HV stator windings In the field" by Pinto C 18th E/EIC conference proceedings - Chicago 1989

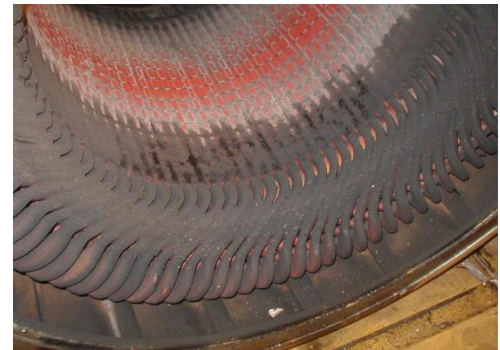
Note on PDCA:

This test has been an improvisation of the conventional IR/PI test, which was developed during the era where Class B insulation was being used. This was hygroscopic in nature and yielded a conductance current. However, all present day insulation used is Class F thermosetting type with further developments in epoxy-resin material and processes like Vacuum Pressure Impregnation. The conductance current is 0 and moreover the leakage currents are also very low. Hence, invariably the IR and PI values are always greater than the norms specified by IEEE 43:2000.

PDCA test, besides charging, also has a step of discharging through a known resistor value. It relies heavily on information obtained through regression and correlation analysis of the discharging current. Through several analytical parameters like charge distribution in air spaces and at interfaces, dispersion ratios, volume resistivity the test provides information on

Whether the stator/rotor windings are contaminated

- a) The severity of contamination
- b) The location of contaminants
- c) The type of contaminants
- d) Possibility of coils or wedges being loose
- e) Surface depolymerisation of resin
- f) Extent of contact of coil with core



Benefits to customer:

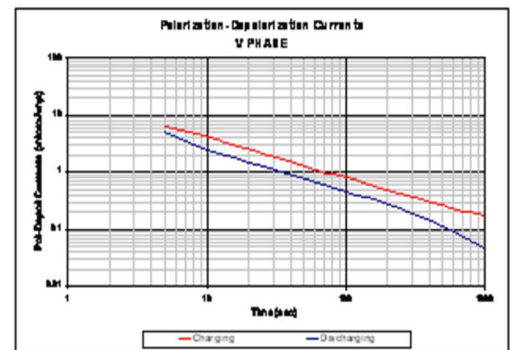
- More information and physically accurate information about contamination as compared to conventional IR/PI
- Decision making tool as it helps to assess schedule for cleaning (now or can be postponed)
- It helps estimate the resources – manpower, quantity of solvents or dry ice for overhauling through information of severity and nature of contaminants and size of the machine.
- Decide level of maintenance (eg. Is it sufficient to open end-caps or Should the rotor be removed?)

Tools Used:

5kV microprocessor based IR Tester, Resistor box, Digital Multimeter

Time taken:

3 hours (for U, V, W and UVW phase), 45 min (if only UVW phase)



MEASUREMENT OF CAPACITANCE AND TAN DELTA

References:

- IEC 60894/ IEEE 432: Guide for a test procedure for measurement of loss tangent of coils and bars for machine windings.
- "Estimation of void content in stator coils of high voltage rotating machines"., C. Pinto, Dr. A. D. Mokashi, 19TH EEIC/ ICWA CHICAGO, 1989

Note on TDCA:

Most standards for tan delta measurements are not actually standards but guides to do measurements and they all pertain to tests conducted on coils using guard electrodes. There is no standard for stator winding after the coils are assembled in the stator. Hence, tan delta magnitudes as a parameter of significance is a perception of individual and cannot be used to judge a machine condition. Also trending is often less meaningful if the value

itself is questionable. Often the guidelines specify “tip-up” criteria. This assumes tan delta variations with voltage to be an increasing trend due to partial discharges. Hence, all phenomena that can cause dielectric losses but do not result in significant PD are unaccounted. Also PD may not always cause rise in tan delta values. Contaminants like oil can cause drop in tan delta or its rate of increase in which case there may not be a tip-up.

ABB uses special analysis algorithms to estimate the void content within total insulation volume that gives a more realistic parameter of significance. Other parameters like discharge inception voltage, effective phase shift and phase of discharge together with other checks like PDCA and PD measurements help in providing so much information about the insulation such as

- Contribution of contamination to dielectric losses
- Curing state of the resin
- Condition of the stress grading and corona protection shield
- Presence of partial discharges.
- Looseness of coils or wedges
- Impregnation issues.
- Insulation de-lamination



Benefits to customer:

- Verification of harmful effects of contamination
- Better assessment of partial discharges even if PD is extinguishing
- To decide actions like wedge tightness check or re-wedging.
- To decide on need for coil filling material during maintenance.
- Poor Impregnation information can help to decide actions like varnishing, resin filling.
- Warranty claims for new machines that have air voids due to bad VPI or manufacturing processes
- Plan maintenance levels.

Tools Used:

Deltamaxx-15, HV Power Source, inductor (for large machines)

Time taken:

30 min



PARTIAL DISCHARGES ANALYSIS

References:

- IEC 60034-27:2006
- IEEE Std 1434-2000 - Trial Use Guide to the Measurement of Partial Discharges in Rotating Machinery
- F.H. Kreuger, E.Gulski and A.Krivda, “Classification Of Partial Discharges”, IEEE Trans. On Electrical Ins., Vol. 28 No. 6, Dec 93
- B. Fruth, D. Gross, "Partial Discharge Signal Generation, Transmission and Acquisition", IEE Proc.-Sci. Meas. Technol., Vol. 142, No. 1, January 1995, Invited Paper following the Int. Conf. on Partial Discharge, University in Canterbury
- B. Fruth, L. Niemeyer, "The Importance of Statistical Characteristics of Partial Discharge Data", IEEE Trans. on Electrical Insulation, Vol.27, No.1, February 1992
- B. Fruth, J. Fuhr, "Partial Discharge Pattern Recognition - A Tool for Diagnosis and Monitoring of Ageing", CIGRE, paper 15/33-12, 1990

Note on PDA:

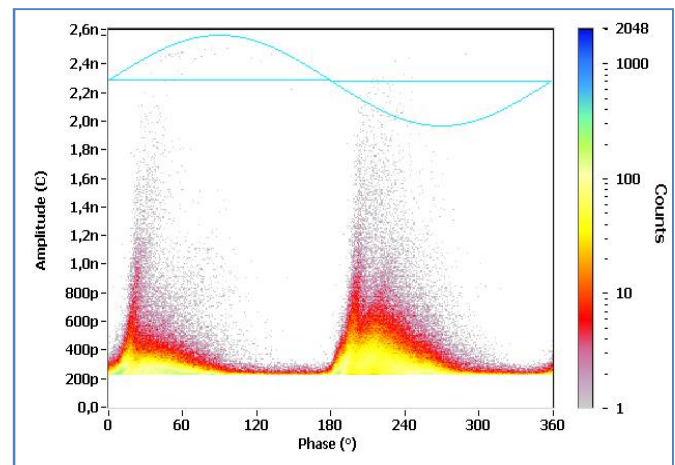
There are no standards that specify partial discharge measurements and its permissible magnitudes for rotating machines or stator windings. Most really on only the magnitude measurement of PD in pC which does not serve purpose. There are online methods to collect PD data using RFCTs or capacitive couplers. Systems with 8 bit data acquisition system and 80 pF capacitors do not give good PD data or information. Besides there are complications related to noise elimination, PD attenuation, and distance from the couplers, resolution, etc. Hence, ABB recommends offline PD during planned outages. Besides measurements of PD magnitudes (max and average), it also analyzes pulse magnitude vs count and importantly the phase resolved partial discharges collected with high speed data acquisition systems. This is integrated with TDCA, NLIBA and PDCA measurements to get more information on

- a) Partial discharge magnitudes
- b) Nature of partial discharge pulses
- c) Location of partial discharges
- d) Severity



Benefits to customer:

- Better assessment/classification of partial discharges
- Planning of outages for focussed maintenance
- Planning of maintenance actions like overhauling, taping of coils where PD has caused erosions
- Need for stress grade paint application at slot exits
- To decide actions like wedge tightness check or re-wedging.
- To decide on need for coil filling material during maintenance.
- Poor Impregnation information can help to decide actions like varnishing, resin filling.
- Warranty claims for new machines that have air voids due to bad VPI or manufacturing processes



Tools Used:

Deltamaxx-15, HV Power Source, inductor (for large machines)

Time taken:

30 min

NON-LINEAR INSULATION BEHAVIOUR ANALYSIS

References:

- C. Pinto, "A Generalized Approach For Study Of Non-Linear Behaviour Of Stator Winding Insulation". ICSD '98 - 6th International Conference On Conduction and Breakdown in Solid Dielectrics by IEEE.
- C. Pinto, "A generalized approach to study non-linear insulation behaviour of stator windings using ac measurements: - ELROMA 2008. 2nd prize winning paper.

Note on NLIBA:

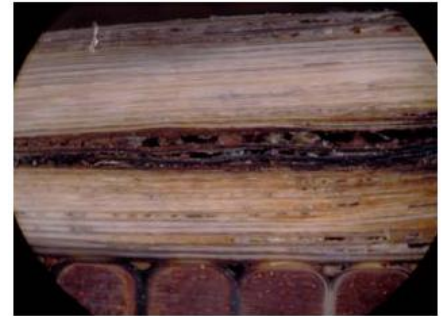
To study the non-linear behaviour and characteristics of insulation material. The tan delta and capacitance measurements vary with voltage even in absence of partial discharges and one of the most obvious reasons for such behaviour is the presence of non-linear field stress grading system at slot ends. Other reasons are space charge/interfacial polarization due to contamination, electrostatic forces on delaminated insulation, increased ionic mobility due to ageing, surface partial discharges etc. It is evident that both the voltage supply across insulation and the current passing through the insulation contain harmonics, which cause increase or decrease in

the measured tan delta and capacitance values. Thus, it becomes necessary to understand this time varying effect of insulation admittance on the capacitance and tan delta measured.

NLIBA provides a detailed understanding of such non-linear behaviour, and thereby supplements the tan delta analysis. The analysis provides additional insights into the aging of insulation.

The machine insulation is tested by applying a known voltage across the insulation and monitoring the voltage and the current flowing through the insulation, by capturing several waveform cycles of the voltage and the current on a digital storage oscilloscope. The insulation is tested at predetermined voltage levels up to a maximum of rated phase voltage only. The instantaneous admittance of the insulation is calculated and the admittance patterns analysed for specific harmonic patterns. The extent of harmonics, predominance of odd or even harmonics, high or low frequency harmonics is analysed to provide information on:

- The integrity of the stress grading system used at the slot ends
- The contribution of the slot stress grading system, contamination and ageing to the non-linear behaviour
- To confirm that observed anomalous tan delta variations can be physically related to the above non-linear phenomena
- Ageing of the insulation



Benefits to customer:

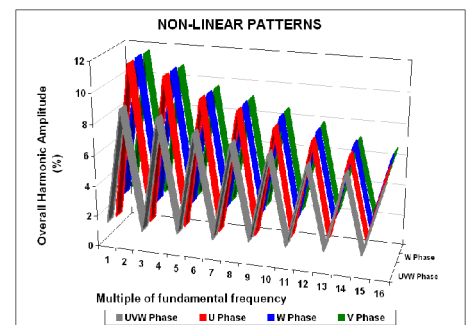
- Accurate information on aging status of insulation
- Assists in taking replace or rewind decisions
- Determining state of resin cure post varnishing
- No need for harmful stress inducing and costly tests like HVDC or HVAC

Tools Used:

Deltamaxx-15, HV Power Source, inductor (for large machines)

Time taken:

30 min



MEASUREMENT OF WINDING RESISTANCE

References:

- BS 4999 Part 60 : 1976

Note that for large motors and generators that are being assessed for condition in planned outage but are in running condition otherwise, there is no reason to suspect any inter-turn shorting and winding resistance may not pick this small change in resistance. If such interturn exists, the windings will just burn. However, this test is used to assess unbalance that can help in derating of the machine.

For motors, however, stator and rotor winding resistance is most important parameter to be measured if the performance of motor (energy losses and efficiency) is required to be determined. This is also applicable for exciter stator, rotor, PMG stators. Often resistances of RTDs, diodes, thermostats and other such components are measured using digital multimeters.

Tools Used:

Micro-ohm meter, multimeter

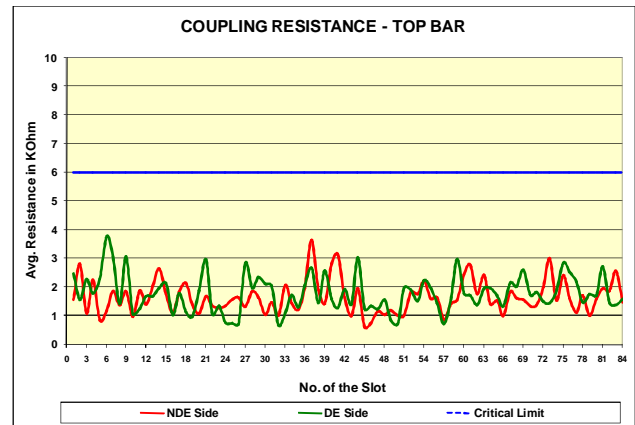
COUPLING RESISTANCE MEASUREMENT

Contact resistance will be measured between the stator bar insulation and the ground (core wall) in slot portion for both the top and bottom bars by inserting a measuring probe through the ventilating ducts. A chart showing the coupling resistance reading at each slot will be prepared. This should be less than 6 to 10 KOhm.

This is applicable for large generators and is used to decide the co-efficient of friction between coil and core that is input parameter to the stress modelling of coils and further to determine the life.

Tools Used:

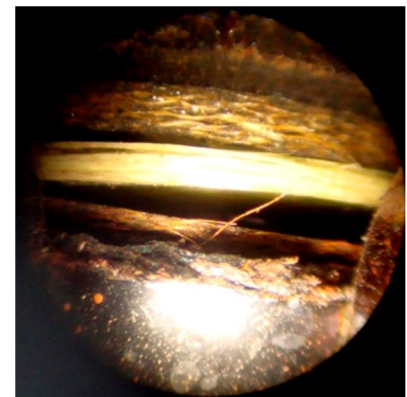
Coupling resistance probe, multimeter



VISUAL INSPECTIONS

Visual inspection is often the best condition assessment tool and provides ample evidence of any anomalies in the unit. Surface conditions like contamination, cracks, tracking marks, white powder, greasing paste, rust, foreign particles etc. are used to identify the phenomena behind it or root cause. Eg. White powder at slot exits is associated with partial discharges. Inner effects like wear of coil sides or heating of insulation are also visually identified through discoloration etc.

The surface of the windings will be inspected in critical areas with magnifying lenses, for surface cracks and for tape girth at the slot ends on top coils sides. The radial vent duct spaces are inspected with a rigid endoscope (provided the vent duct space available is greater than 7mm) along the depth of the coil. This gives information on coil side erosion, blockages within vent ducts.



Endoscopic/Borosopic inspections are also used in rotor vent ducts and under the retaining rings to check for contamination, blockages, tape migration and other effects.

Besides stator and rotor, visual inspection for large generators also includes several other components like bearings, shafts, cooler tubes, pipings, terminals, bushings, leads, exciter, diode rings, brushes etc.

Tools Used:

Endoscope with lens tips, Light source optically coupled to endoscope, video-camera, digital camera.

WEDGE TIGHTNESS CHECK

Besides the information obtained from PDCA, TDCA on condition of coil or wedge looseness, the capital outage on large motors and generators where the rotor is threaded out gives opportunity to physically check the wedges for tightness.

For smaller generating units up to 60 to 70 MW, this consists of tapping the wedges using mallet and hearing the emanating sound. Hollow sounds indicate looseness while flatter tones indicate tightness. Wedges are marked accordingly as loose, semi-loose or tight and color

Slot No.	Wedge No -->			
	1	2	3	4
1	1	1	1	0.5
2	1	1	0	0.5
3	1	0.5	0.5	0.5
4	0	1	0	0.5
5	0	1	0	1
6	0	1	0	1
7	0.5	0.5	0.5	0.5
8	0	0	1	1
9	1	0	0	1
10	0.5	0.5	0.5	0.5
11	1	1	0	0.5
12	1	1	0	0.5
13	0	0.5	0.5	0
14	0	1	0	0.5
15	1	0.5	0.5	1
16	0	1	0.5	0.5
17	0.5	0	0.5	0
18	1	0	0	0
19	1	0.5	0	1
20	0	0	0.5	0
21	0.5	1	0	0.5
22	1	0.5	0	0.5
23	0	0	0.5	0
24	1	1	1	0
25	0.5	0	0	0
26	0.5	0.5	1	1
27	1	0	0	0
28	0	0	0.5	1

coded. At ABB, we also give the wedges a score of looseness, which is used to judge the slot which has more than 3 adjacent wedges that are loose and to get average score per slot or from complete core.

For larger units, the wedges are placed on ripple springs which hold the coil under pressure. Tapping in such cases can break this springs and is not recommended. In such cases, a dial gauge is used through test holes to check for peak to peak displacement. In constructions where the test holes are not present, a known pressure is applied based on wedge dimensions and its displacement is measured. This is not done on all wedges but is done on certain % of wedges and in spiral fashion.

Tools Used:

- Mallet (for wedge tightness check)
- Hydraulic jack, dial gauge, weights (for wedge deflection)

HI-POT TEST/HVDC TEST/HV AC TEST

The Hi-POT test voltage or HV AC voltage as is applicable, will be applied in steps, each voltage being applied for 1 min duration. The maximum test voltage to be applied will be mutually decided between ABB and customer and after the IR/PI values suggests it is safe enough to proceed with the test. A plot of leakage current will be plotted and the leakage current will be measured at various voltage levels.

Note that the test can induce harmful and irreversible ageing effects within insulation and ABB does not recommend the test unless there have been some repair actions like partial repairs to the stator bars, rewedging or rewinding.

Benefits to customer:

- Identifying nature of leakage currents and its potential to cause damage.
- Identifying whether it flows through insulation material or contaminants
- Determining the permittivity for overall insulation system

Tools Used:

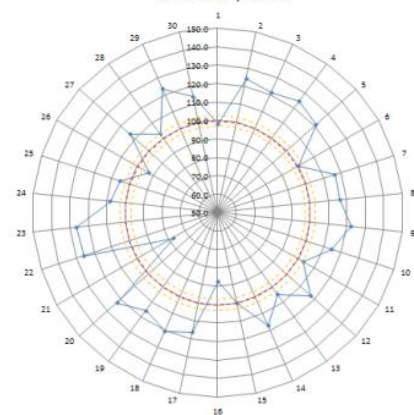
- 75 kV HVDC kit

NATURAL FREQUENCY TEST

The overhang section of the stator coils are tapped using a mallet or a calibrated hammer. An accelerometer is placed on the knuckle section and the vibration signal is picked up using a vibration analyzer. The FFT signal of vibration is analyzed for presence of peaks near the 2 x line frequency range. If such peaks are present, it can lead to catastrophic damages



Mapping of End Winding Natural Frequency
Exciter Side, Radial



Benefits to customer:

- Determining the mechanical integrity of the stator coil assembly.
- Determine need for adding stiffness to stator coils
- Helps in arresting high stresses on coils and in effect reduce breakage or water leakage for hollow conductors.
- Lowering stress levels of stator coil and in effect increasing the life of the unit.

Tools Used:

- Vibration analyzer, accelerometer sensor, calibrated hammer

DIGITAL ELCID TEST

The generator stator core is built from thousands of thin steel sheets (laminations). These laminations are coated with a thin layer of varnish for prevention of circulating induced currents also known as eddy currents, which are induced because of rotating magnetic flux produced by the rotor. Hence, it can be envisaged that any defects in the inter-laminar insulation causes fault currents to flow locally in core. These circulating currents can thus cause localized overheating and hot spots in the damaged areas and this may further damage the core. In extreme cases, sufficient heat is generated to cause melting of small parts of core and premature failure of the winding insulation. Thus these hot spots should be detected and corresponding repair works must be carried out before the condition worsens. Unlike the core ring flux test that had several disadvantages like running of high current/voltage, mechanical stresses etc, the digital ELCID test uses only a fraction (4%) of rated flux level to generate fault currents within the core body. These currents are then sensed by a pick-up coil. The digital ELCID test helps in assessing the condition of Generator/motor core and gives vital information in the development of trend analysis, for use in diagnostic and predictive maintenance.

Benefits to customer:

- Early detection of core faults.
- Core faults require long time and money for rectification, which can be avoided.
- Fault location is pin-pointed accurately for ease of repair action like chemical etching.

RSO CHECK

A fast fronted step voltage is repeatedly applied using a Recurrent Surge Oscillograph (R.S.O.) to the rotor winding and the terminal voltage waveform is examined for reflections. The test is applicable for turbo rotors (cylindrical 2 pole rotors only) and is not valid for synchronous rotors that have salient pole construction.

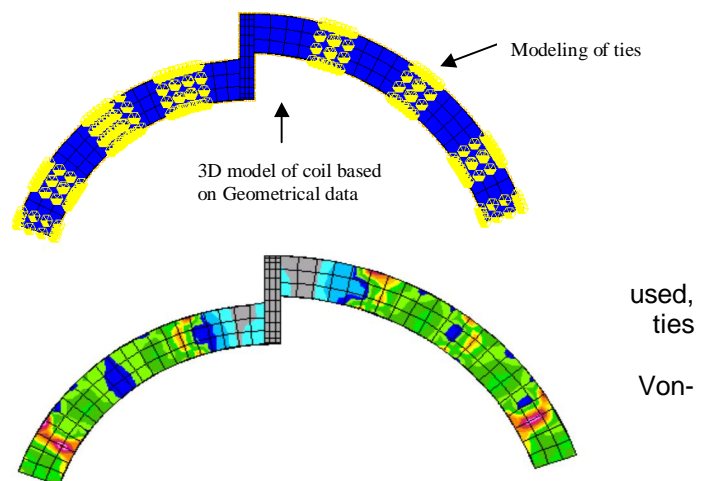
Benefits to customer:

- Early detection of rotor faults like interturn and prevent escalation to ground fault.
- Only test for determining issues with rotor

FEM MULTI-STRESS ANALYSIS

During operation, an electrical rotating machine is subjected to Thermal, Electrical, Mechanical and Ambient stresses (TEAM Stresses) either singly or in combination, ultimately resulting in aging of insulation. These stresses can be evaluated using Finite Element Modelling techniques.

The data regarding geometry of the coil, materials operating temperatures, arrangement of blocks and etc are collected by ABB engineer. These are later modelled using FEM software that calculates the Mises stresses (i.e. cumulative stresses including bending, shear, fatigue and other such mechanical stresses acting on coil)



VIBRATION SIGNATURE ANALYSIS

Data collection is based on solid engineering and is collected through accelerometer. A mounting pad technology is used to ensure right data collection. ABB expertise ensures the right location or points from where the data is collected in several special configurations. It is preferred that the reading be taken in coupled condition at full rated load. If it is possible to also run the motor at no load or at a different load, it would provide greater insights into the vibrations and allow for better segregation of electrical and mechanical origin of any incipient fault.

This data is collected using portable analyzer with 4 channels. It has capability to perform a four channel, simultaneous FFT analysis of the analogue input channels up to 16 kHz span. Moreover it offers an FFT resolution of 25600 lines, which gives accurate slip estimation and hence analysis accuracy. It supports extremely good digital signal processing as mentioned under:

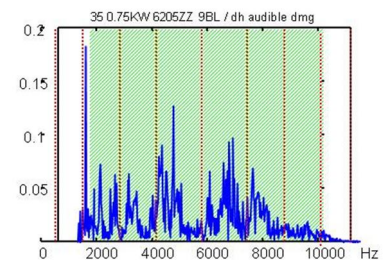
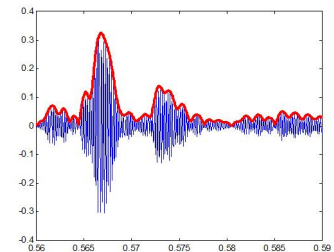
- Four-channel 16 Bit A/D conversion
- Simultaneous sampling of all four inputs up to 50 KS/sec
- Anti-aliasing via an analog RC filter plus a 64th order digital FIR filter
- Dynamic range greater than 85 dB
- Signal to noise ratio greater than 76 dB
- Overall RMS amplitude detection.

The superior high resolution data collection is analyzed by **Automated Rule based intelligent software**, and each machine is further individually scrutinized by ABB Experts. We would highlight that our greatest strength and uniqueness lies in analyzing the vibration data for accurate prognosys and special algorithms called as BEAM and BEACON for detection of bearing faults at a much earlier stage than conventional vibration analysis.

Thus, our way of vibration monitoring ensures that there is absolutely no “wrong diagnosis” or “false negatives” or “false positives”

Some of the faults that are identified very accurately through Vibration Signature Analysis are as listed.

- Motor and/or Driven Component Imbalance
- Motor Imbalance
- Motor Mounting Flexibility
- Foundation Flexibility
- Motor Cooling Fan Blade Damage
- Motor Bearing Wear
- Motor Thrust Bearing Wear
- Motor Bearing Looseness
- Motor Thrust Bearing Looseness
- Motor Bearing Misalignment
- Motor Lamination Looseness
- Motor Free End Bearing Wear
- Motor Drive End Bearing Wear
- Motor Free End Bearing Looseness
- Line Phase Voltage Imbalance
- Motor Air Gap Problem
- Motor Journal Bearing Wear
- Motor Bearing Noise
- Motor Free End Bearing Noise
- Motor Drive End Bearing Noise
- Motor Free End Journal Wear
- Motor Drive End Journal Wear
- Foundation Vibration
- Motor Foundation Resonance or
- Mounting Looseness
- Motor Bearing Fit Problem
- Indication of Bent Motor Shaft

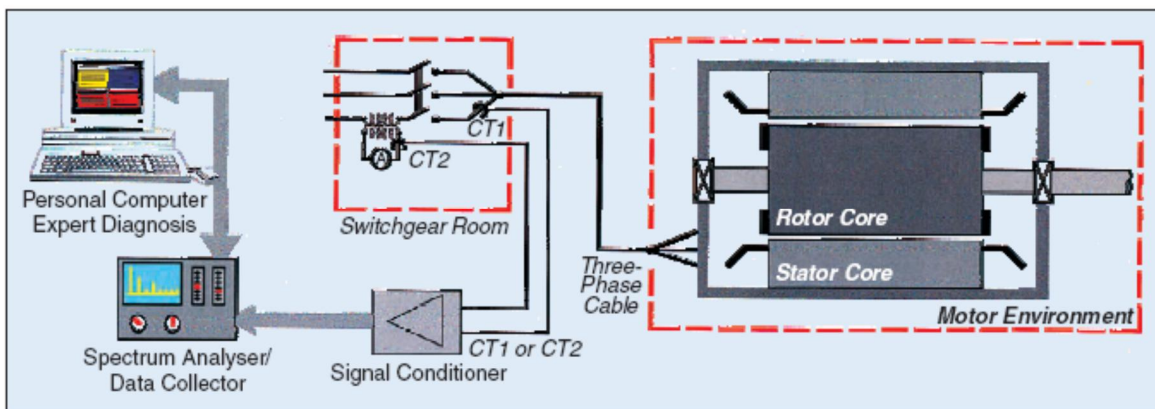


MOTOR CURRENT SIGNATURE ANALYSIS

Motor current signature analysis or MCSA is a condition monitoring technique that is widely used to diagnose problems such as broken rotor bars, abnormal levels of eccentricity – both static and dynamic, shorted turns in LV stator windings and certain mechanical problems. This is done by sensing an electrical signal that contains current components caused by faults as mentioned.

ABB uses MCSA differently. Besides its capability to identify the faults, ABB uses it as a condition monitoring tool to identify an incipient fault several months/years before it develops into a fault and hence provides the asset owner with a maintenance action along with a schedule as to when the problem should be attended that can help the plant to plan a shutdown in their busy process requirements.

Unlike other MCSA programs, ABB performs 3 phase measurements simultaneously. This implies monitoring 3 phase voltage signals through probes connected to PT secondary and 3 phase line currents through CT or clamps. For HT motors, these connections are made at the motor control centre panel and are thus safe.

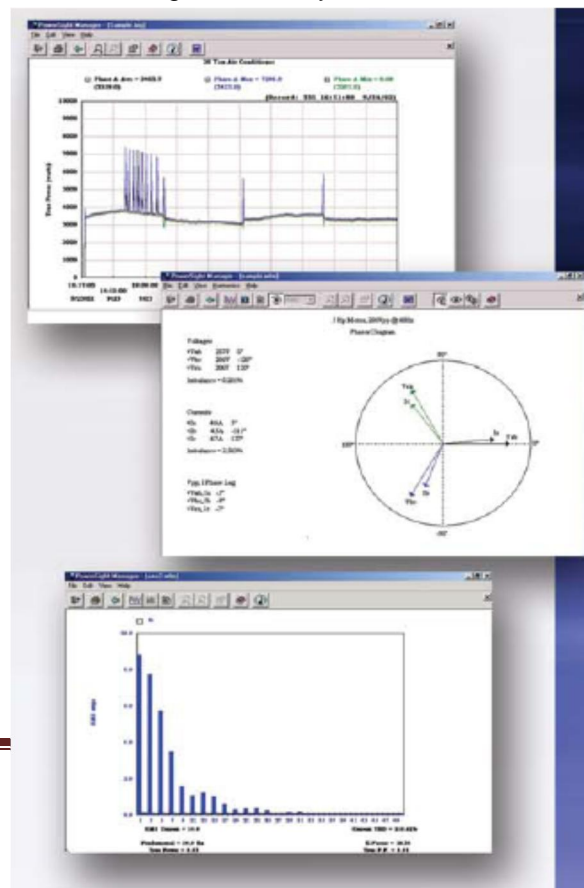


The data collection is backed up the Intelligent Automated Software that diagnoses a wide range of motor problems. Some of the faults that are identified through Motor Current Signature Analysis are as listed.

- Rotor bar deterioration
- Rotor eccentricity
- Stator phase imbalance
- Motor speed and slip
- Gear and belt imperfections
- Average running current, an indicator of motor torque
- Stroke time on assemblies with defined start and stop points
- Changing friction forces
- Torsional vibration and dynamic loading
- Bearing degradation

Furthermore, ABB also backs up the findings using our own high specialized **MACHSense™** software to ensure the correct diagnosis.

In addition, ABB can provide you with data captured by power monitor that can record



- RMS Volts, RMS Amps
- Watts, VA, VAR, power factor
- Total Harmonic Distortion
- Sags, swells, dips to ½ cycle
- Transients to 16 micro sec
- Frequency- 22 to 440 Hz
- DC Voltage and Current

This will also provide you with insights on unbalance (with phasor diagrams), load profiling, effect of harmonics, energy consumption, quality of power, run-time efficiency.

ACOUSTIC EMISSION ANALYSIS

Vibration Monitoring can help find faults pertaining to bearing which can also be reflected in MCSA measurements. However, for low speed machines, often vibration monitoring is not possible and does not help in accurate bearing problems. Acoustic Emission is however, a very sensitive test and is known to pick up bearing defects well in advance.

The power of Acoustic Emission (AE) lies in the fact that it directly detects the physical processes such as friction, impacts and metal removal which occur when machinery degrades. Because of this it can be applied to virtually all rotating machinery including those traditionally difficult areas such as slow speed machinery, plain bearings and complex gearboxes.

The key to the success of AE in the industrial environment lies not only in its high sensitivity to machine faults, but also in its inherent immunity to audible noise and low frequency vibrations. Because of this, AE is ideally suited to the shop floor where the background levels of noise and vibration are likely to be high and variable. The AE sensor is placed on bearings for 15 to 20 secs. AE analyzer is used to detect high frequency stress waves (~1MHz) generated by energy loss mechanisms (eg. friction) which are produced by rotating machinery in poor condition. The detected signal is characterized in terms of Distress & dB Level. Distress® is a proprietary parameter which sums all microscopic clicks, crunches & groans associated with faults. dB Level measures overall signal strength & is used to trend the rate of degradation of suspect machinery. It is very sensitive and can detect inadequate lubrication at an early stage allowing remedial action (eg. re-greasing or bearing replacement) before any significant damage takes place.

Thus Acoustic Emission can help the asset owner to:

- Identify Lubrication problems
- Instant health check without the need to know which bearing type, what speed and such other details.
- If any repair action (say re-greasing is carried out), the success of this action can be assessed immediately.
- The data can be trended (if previous data is provided or is available with customer or ABB).
- Identify and prioritize motors that need further attention.

PERFORMANCE EVALUATION PROGRAM (PEP)

Often a nameplate is derived from some factory test setup and no load and locked rotor tests conducted under ideal conditions. However site conditions may differ due to foundation or mounting issues, harmonics or disturbances in supply, load side variations. Besides, motor could be wrongly selected and may run at less than 50 % loads.

In this program, data from nameplate is assessed for its correctness after the motor is installed at site through online vibration and a model of induction motor is developed with the help of online measurements and the machine ratings.

This helps in identifying the stator and rotor resistances and inductances of the model using complex algorithms. The model once established can help to identify/estimate the various losses such as stator copper loss, rotor

copper loss and hence determine efficiency. It can help to redraw the torque-speed characteristic, variation of power factor and efficiency with load etc.

Thus, the model can help to identify what should be temperature rise for a given load and any comparison with actual can help identify the discrepancies and cause for it.

Benefits to customer:

- Motor characterization and determination of its characteristics (N-T, I-T etc.).
- Take decisions on overloading of required for process as behaviour and temperature rise can be predicted.
- Determining the losses and efficiency helps in taking decisions on replacement with energy efficient motors or usage of VFD to achieve potential savings in energy consumption.
- The above when clubbed with LEAP Standard and Premium will provide further benefits of adding a reliability perspective to the commercial benefits of increased efficiency. This can further modify the maintenance perspectives and help in deciding between rewinding and replacement options.
- The package also helps to compute commercial benefits like return on investment, payback values with efficiency alone, with efficiency and reliability and also considers hidden costs like cost of adaptation plate, half couplings, provides comparative analysis such as cost of maintenance, repair and operation of existing machine vis-à-vis cost of replacing the machine etc.