Life Expectancy Analysis Program for Electrical Machine Insulation

Cajetan Pinto, Global R&D Manager,
Presentation overview

- Life Cycle Management Approach
- Reliability and failure statistics
- Planning your Strategy
- LEAP Methodology & Use
- LEAP Standard
- Case Studies
- Benefits
Life Cycle Concept

Value to customer through maintenance

- Warranty Period
- Upgrade and Modernization Period
- Replacement & Recycle Period

Optimized Maintenance Line
- Maintenance
- Overhaul
- Repair

Continuous Upgrading/Replacement

Maintenance Period

Customer Project Lifecycle
Total cost of operation (TCO)*

TCO includes:
- Purchase price
- Specifications
- Transportation
- Storage
- Installation
- QA
- Reliability
- Electricity
- Repairs
- Administration
- Inventory
- etc

*Information provided by MachineMonitor™ based on survey of 6000 machines
Basis of Analysis: Stress & Strength v/s Time

Stress, strength

Strength

Transient faults

Premature Failure

Failure

Residual Life

Stress

Time
Life Expectancy Analysis: Benefits

Condition assessment and taking suitable actions at this point.

Adv. 1: No Premature Failure
 Adv. 2: Increase in Life

Stress

Strength

Transient faults

Failure

Residual Life
Reliability & Failure Statistics

Detection during Normal operation

- Bearing: 37%
- Winding: 33%
- Rotor: 11%
- Shaft/coupling: 5%
- Brushes/slipring: 6%
- External devices: 5%
- Not specified: 3%
- Other: 6%

Detection during maintenance or test

- Bearing: 61%
- Winding: 10%
- Rotor: 8%
- Shaft/coupling: 7%
- Brushes/slipring: 4%
- External devices: 2%
- Not specified: 8%
Out of 37% failures occurred during normal operation,

61% could be detected during maintenance/inspection.

Out of 33% failures occurred during normal operation,

only 8% could be detected during maintenance/inspection.
Failure Statistics: HT Motors Petrochemical Industry 1999

Distribution of Failures for motors below 2000KW

- Bearing: 57.40%
- Stator Windings: 2.80%
- Rotor Bars/rings: 14.60%
- Shaft or coupling: 5.60%
- External device: 1.20%
- Not Specified: 18.40%

Distribution of Failures for motors equal and above 2000KW

- Bearing: 18.42%
- Stator Windings: 60.53%
- Rotor Bars/rings: 7.89%
- Shaft or coupling: 5.26%
- External device: 0.00%
- Not Specified: 7.89%
Total Failure rate Vs Age

IEEE TRANSACTIONS ON INDUSTRY APPLICATIONS, VOL. 35, NO. 4, JULY/AUGUST 1999
Stator winding failures (link with TEAM)

FAILURE CONTRIBUTORS

Normal deterioration with age: 18%

Poor Ventilation/Cooling: 8%

Abnormal Moisture: 18%

Persistent Overloading: 7%

High Ambient Temperature: 8%

Abnormal Voltage: 5%

Abnormal Frequency: 1%

Poor Lubrication: 5%

Aggressive chemicals: 7%

High Vibration: 9%

Other: 14%
Planning your maintenance STRATEGY

Protection

- continuous, on-line, action taken in real time
- to limit the damage or prevent operation under abnormal conditions

Condition Monitoring

- on-line, but not necessarily continuous
- analysis and action is subsequent to data collection
- prevents failure by taking steps with short term planning for maintenance

MST, ARGUS, DLI, PD, Telemetry, etc

Life-time Estimation

- on-line + off-line
- analysis and action subsequent to data collection
- detects life limiting defects at the incipient stage, useful in both long term planning and short term planning for maintenance

LEAP
LEAP is not just a package of inspections; it is a systematic approach to managing Machine Maintenance

What is LEAP?

- Lifetime Expectancy Analysis Program or LEAP is a unique Maintenance Tool for the Stator Winding Insulation of Electric Machines.
- LEAP provides information on Machine winding and expected life, and will optimize the Machine Maintenance Plans
- LEAP developed by ABB Machines Service, India, is in use for over 12 years, with a database of measurements and analysis in excess of 4000 machines worldwide
- Measurements are performed by Local or Global ABB Service centers and data analyzed at the LEAP Center of Excellence
# Level Based Inspections

<table>
<thead>
<tr>
<th>Level</th>
<th>Opportunities for Inspections</th>
<th>Inspection Schedule</th>
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</thead>
<tbody>
<tr>
<td>Basic</td>
<td>When the machine is operating</td>
<td>Every 5% of the estimated lifetime</td>
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<tr>
<td>Standard</td>
<td>When the machine is stopped but assembled</td>
<td>Every 10% of the estimated lifetime</td>
</tr>
<tr>
<td>Advanced</td>
<td>When the machine is stopped and partially dismantled</td>
<td>Every 25% of the estimated lifetime</td>
</tr>
<tr>
<td>Premium</td>
<td>When the machine is stopped and rotor removed</td>
<td>Every 50% of the estimated lifetime</td>
</tr>
</tbody>
</table>

![Confidence Level Chart](chart.png)
# Level Based Inspections

<table>
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<tr>
<th>Solution Levels</th>
<th>Packages</th>
<th>Deliverables</th>
</tr>
</thead>
</table>
| **Basic**       | Data collection (on site or remote):  
  - Operational hours, voltage, current, power, slip,  
    Starts/Stops, Temperature (Winding, Coolant and Ambient),  
    Duty cycle & loading pattern, Failure and Maintenance  
    history, Information on power supply, breaker-cable  
    configuration, etc  
|                  | Life Expectancy Analysis 65% Confidence Level  
  - Condition Based Inspection and Maintenance Plan |
| **Standard**    | Basic Data Collection  
  - Polarization Depolarization Current Analysis PDCA  
  - Tan Delta & capacitance Analysis  
  - Non-Linear Insulation Behaviour Analysis  
  - Partial Discharge Analysis  
|                  | Condition Assessment of Stator Windings for Contamination, ageing, looseness,  
  delamination, stress grading system  
  - Life Expectancy Analysis 80% Confidence Level  
  - Condition Based Inspection and Maintenance Plan |
| **Advanced**    | Standard Data Collection  
  - Visual Inspection on end windings  
  - Partial Discharge Probe measurements & Dynamic  
    Mechanical Response of Windings  
  - Stress analysis of End-windings  
|                  | Condition Assessment of Stator Windings with Standard Package + End-winding assessment  
  - Life Expectancy Analysis 85% Confidence Level  
  - Condition Based Inspection and Maintenance Plan |
| **Premium**     | Advanced Data Collection  
  - Wedge Tightness Map & Coupling resistance measurements  
  - Visual inspection, including slot areas  
  - Stress analysis of Windings  
|                  | Condition Assessment of Stator Windings with Advanced Package + slot region assessment  
  - Life Expectancy Analysis 90% Confidence Level  
  - Condition Based Inspection and Maintenance Plan |
LEAP Methodology & Use of LEAP
LEAP methodology

- **Collection of Data**
  Operating data, test measurements and machine information

- **Analysis of Data**
  ABB has developed UNIQUE analytical tools aimed at life assessment

- **Calculation of Stresses**
  Life Expectancy Analysis is performed and factors and conditions that affect lifetime are identified

- **Estimating Life & Condition Based Maintenance**
  Lifetime is estimated with different Confidence levels depending on the LEAP package

  Possible further inspections, maintenance, replacements or even upgrades are drawn up
LEAP Standard
LEAP Standard package

- **DC Measurements**
  - Polarization De-Polarization Current Analysis

- **AC Measurements**
  - Non Linear Behavior Analysis
  - Tan δ and Capacitance Analysis
  - Partial Discharge Analysis

Remark: DC tests are sensitive to the surface condition, and AC tests give more information on the insulation volume.
DC measurements

Polarization - De-polarization Current Analysis

- Besides leakage and absorption current, PDCA test gives an idea of **quantity and location of charge storage** within the machine.
- Identifies contamination even when IR, PI values are “acceptable”.
- Determines state of the winding insulation, ageing, looseness, etc.

Remark:
Conventional IR & PI Measurements may have satisfactory values even with highly contaminated windings.

Parameters
Derived
Time constants T1, T2, T3
Charge storage Q1, Q2, Q3
Ageing Factor
Dispersion Ratio
(1+Q1+Q2+Q3) < 1.25
Volume Resistivity
AC measurements

Non Linear Behavior Analysis, Tan δ and Capacitance Analysis, Partial Discharge Analysis

- Confirm the results from DC Measurements
- Assess the condition of Corona protection shield
- Determine the extent of de-lamination or void content in terms of a percentage of discharging Air Volume to Insulation Volume
- Assess condition of the Stress Grading system at slot ends
- Trend Ageing effects

Remarks:
Conventional measurement interpretation is generally based on trends
LEAP – How is it different?

- Methodology is **not dependent on old records** of measurements performed. Single occasion of measurements will suffice for making decisions. Parameters are derived from measurements to quantify problems such as contamination, ageing and looseness.

- 65-72% of failures are related to Thermal and Ambient reasons which may not be detected by measurements that rely only on partial discharges. ABB’s measurements and analysis focuses also on **detection non-partial discharge** related problems.

- Analysis software is **UNIQUE** and parameters derived from analysis can be utilized in Life Expectancy Calculations.

- Sophisticated **FEM analysis** can be deployed in Level III and IV inspections.

- Can be related to time and **integrated into a Maintenance Plan**.
Towards a New Dimension

- We change the units!
- Machinery status is typically expressed in vague units (green, yellow, red)
- We change that into a measurable dimension: *time* that can be easily interpreted by other computerized systems and related to scheduling actions
LEAP - Value for the Customer

- Optimizes Maintenance Planning of Electrical Machines by moving from Scheduled Maintenance to Condition Based Maintenance
- Life Extension of machines would lead to increased earnings capability and thereby greater return on investment.
- Facilitate decision making (short and long term maintenance planning)
- Focus mainly on essential maintenance, and machines that are vulnerable, thereby reducing downtime at lower risk levels
- Provides important “lifetime ” inputs for more realistic estimates of Life Cycle Costing
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