ABB Air Gap Inspector

In-situ visual inspections for motors and generators
In-situ robotic visual inspections

Overview

- Introduction, benefits and values
- Key features of inspections
- Visual inspection service offering
  - for internal inspections during minor outages
  - for ABB preventive maintenance level L3
  - for ABB LEAP Advanced
- System components
- Main stator/rotor defects
- Traditional approach vs in-situ visual inspection
- Summary
In-situ robotic visual inspections
What, Why, How

• **What:** A robot crawler – ABB Air Gap Inspector - to visually inspect the stators and rotors of motors and generators without removing the rotor.

• **Why:** Robotic inspection greatly extends the scope of motor and generator maintenance. It can be used during planned outages without removing the rotor, and in cases where removal of the rotor is not possible.

• **How:** The robot crawler moves in the air gap between the rotor and stator. It is equipped with five cameras and its modular reconfigurable design ensures it will fit in a wide variety of motors and generators.
## In-situ robotic visual inspections

**Benefits and values**

<table>
<thead>
<tr>
<th>Differentiators</th>
<th>Benefits</th>
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“Visual inspection of the stator core, rotor core and winding is now possible without removing the rotor.”

- Super-slim design means the crawler can be used on motors and generators with air gaps as small as 10 mm.
- Multiple camera views provide rich inspection information about stator/rotor core, winding, wedges, stator teeth, air ducts and rotor support blocks.
- Easily reconfigurable on-site to support a wide range of stator designs.
In-situ robotic visual inspections
Benefits and values

- Allows faults to be localized by recording their severity and position, all without the need to remove the rotor.
- Significantly extends the scope of the ABB L3 preventive maintenance program, with only a minimal increase in the time required.
- Increases confidence in the overall results of ABB LEAP (ABB Life Expectancy Analysis Program) Advanced, bringing them much closer to those of ABB LEAP Premium.
- Optimizes maintenance planning and increases the availability of motors and generators by reducing the number of outage days where removal of the rotor is required.
In-situ robotic visual inspections

Key features of inspections

- 100% uniform, high-resolution coverage of the whole length of the stator core is captured, with the entire inspection recorded for later use. In-depth assessment and expert evaluation available as required.
- Provides in-depth view, allowing for insights into critical areas of the ventilation duct, compared to limited views with conventional inspection tools.
- Multiple inspections can be carried out by the robot, using different camera angles within the stator and rotor body.
- Can capture still images as required.
- Consistent, repeatable inspections.
- Voice-over feature records inspector’s comments for later use during expert evaluation.
In-situ robotic visual inspections

Visual inspection service offering

In-situ robotic visual inspections performed by ABB Air Gap Inspector can be used for different purposes:

- Internal inspections during minor outages on any motor/generator.
- In combination with ABB preventive maintenance level L3 on ABB synchronous motors and generators.
- Can also be used as part of L4 maintenance in special cases where the rotor cannot be removed.
- To support ABB LEAP Advanced.

By allowing the inspection of stator and rotor cores without removing the rotor, ABB robotic visual inspections deliver reduced outage days and, as a result, reduced maintenance costs.
In-situ robotic visual inspections
For internal inspections during minor outages

• A major outage on larger motors and generators can last up to 20 days, with most of this time spent removing the rotor.
• An ABB robotic visual inspection using ABB Air Gap Inspector can eliminate the need to remove the rotor. This cuts outage time, with significant cost savings for the plant.
• ABB Air Gap Inspector can be used on any motor/generator with an air gap of 10 mm or more.
# In-situ robotic visual inspections

For internal inspections during minor outages

## Types of activities performed during major and minor outages on a typical generator.

<table>
<thead>
<tr>
<th></th>
<th>Minor outage</th>
<th>Major outage</th>
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<tbody>
<tr>
<td></td>
<td>Traditional approach</td>
<td>PLUS visual inspection with ABB Air Gap Inspector</td>
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<tr>
<td><strong>STATOR</strong></td>
<td></td>
<td></td>
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<tr>
<td>Stator wedge tightness</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Bar movement</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Stator winding leaks</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Stator winding insulation inspection</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Core Insulation inspection</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Blocked vent ducts</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Greasing</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Cracked connections/integrity</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Oil contamination</td>
<td>■</td>
<td>■</td>
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<tr>
<td>HV connection bolts</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td><strong>ROTOR</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Field coil distortions</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Field coil loose blocks</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Field wedge migration</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Blocked vent ducts</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Rotor winding insulation</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Rotor surface heating</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Pole coils interconnection</td>
<td>■</td>
<td>■</td>
</tr>
<tr>
<td>Pole tips screws (where applicable)</td>
<td>■</td>
<td>■</td>
</tr>
</tbody>
</table>
In-situ robotic visual inspections
For ABB preventive maintenance level L3

ABB preventive maintenance level L3 involves a larger outage, normally performed every 32,000 - 40,000 operating hours\(^{(1)}\) when several parts of the motor/generator, including the end-shields, are removed but the rotor is left in place.

ABB Air Gap Inspector can be used in combination with ABB preventive maintenance level L3 to provide a more effective visual inspection of the stator and rotor.

A visual inspection during L3 enables parts to be examined that are normally not accessible at this stage. This significantly enhances the scope of service through early detection of issues that might otherwise only be visible during L4.

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\(^{(1)}\) Equivalent operating hours in continuous operation duty \((H_{eq}) = Actual operating hours \((H_{op}) + (Number of starts \times 20h)\)
In-situ robotic visual inspections
For ABB preventive maintenance level L3

- The combination of visual inspection using ABB Air Gap Inspector and L3 maintenance can also be performed in cases where the rotor has to be left in place and scheduled L4 maintenance (involving rotor removal) cannot be executed as required, due to:
  - Space or access limitations
  - High downtime costs (with ABB’s approval to postpone L4 maintenance)
  - This cannot fully replace L4 maintenance, but the data produced can be used to plan future maintenance activities and support decision-making on the time and scope of possible major outages (i.e., in combination with a long plant stoppage).
In-situ robotic visual inspections
For ABB preventive maintenance level L3

- ABB LEAP provides information on the condition of the stator insulation with respect to:
  - Contamination
  - Condition of bonding resin
  - Aging
  - Void content
  - Partial discharges
- Predicts lifetime with accuracy of 80% and upward, depending the type of tests performed (ABB LEAP Standard, Premium; Advanced).
- Indicates the need for future inspections and maintenance.
- Undertaking visual inspections in conjunction with ABB LEAP Advanced can provide an improved lifetime estimation.
In-situ robotic visual inspections
For ABB LEAP Advanced

• ABB LEAP Advanced includes visual inspection of the end windings as part of the tests performed.
• With ABB Air Gap Inspector visual inspections, it is possible to undertake extensive inspection of the end winding conditions during minor outages.
• The added capability to make a full internal inspection without removing the rotor increases confidence in the overall results towards the higher levels obtained by ABB LEAP Premium (but note that ABB LEAP Premium includes additional tests not covered by the combination of ABB LEAP Advanced and in-situ visual inspection).
In-situ robotic visual inspections

ABB Air Gap Inspector: System components

- Modular robot crawler, equipped with
  - Five high-resolution cameras
  - Slot identification system
  - Encoders/accelerometers
  - Alarm system to allow crawler to move safely in proximity of stator core ends without falling
- Control cabinet including two large and three small monitors, digital video recorder and keyboard
- Control unit with joystick, lighting and speed control
- Tether connecting crawler to control cabinet
In-situ robotic visual inspections

ABB Air Gap Inspector overview

- Robot crawler moves along the stator core laminations using modular, magnetic tracks. Can be reconfigured for different motor and generator designs.
- Five cameras are mounted on the main body of the robot and oriented to provide the best and most complete view of the inspected areas.
  - One camera looking forwards along the air gap, provides visibility of the wedge, stator core and winding overhangs
  - One camera looks into the stator ventilation slots
  - One camera looks at the rotor main body
  - One pannable camera can look at the stator laminations in various angles
  - One camera aids in reversing the crawler, providing a rear-end view
In-situ robotic visual inspections

Stator defects detected during inspections

Problems that can be detected through visual inspection of stator (core and windings):

- Contamination/discoloration
- Broken laminations
- Damage/burning on core
- Blocking of vent ducts
- Red/white powder deposits in slots/core caused by looseness/spark erosion defects
- Migration of core/wedges/slot fillers
- Bulging/signs of movement at slot exit/in vent ducts.
In-situ robotic visual inspections
Images from ABB Air Gap Inspector cameras
## In-situ robotic visual inspections

Traditional approach vs in-situ visual inspection

<table>
<thead>
<tr>
<th>Activity</th>
<th>Traditional approach</th>
<th>With ABB Air Gap Inspector</th>
<th>Saving</th>
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</thead>
<tbody>
<tr>
<td>Opening covers (h)</td>
<td>16</td>
<td>16</td>
<td>0</td>
</tr>
<tr>
<td>Dismantling and reassembly, including rotor removal (h)</td>
<td>32</td>
<td>0</td>
<td>32</td>
</tr>
<tr>
<td>Time for visual inspection (h)</td>
<td>4</td>
<td>7.5</td>
<td>-3.5</td>
</tr>
<tr>
<td><strong>Total (h)</strong></td>
<td>52</td>
<td>23.5</td>
<td>28.5</td>
</tr>
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Savings/outage time and associated costs: 55%
In-situ robotic visual inspections

Summary

**ABB Air Gap Inspector**

- Inspections that would otherwise require major outages can be performed during minor outages.
- Easy and precise localization of defects.
- Planning for optimized maintenance can be better supported and facilitated.
- You can reduce:
  - Downtime
  - Inspection costs
  - The risk of secondary damage during rotor withdrawal