Life Cycle Management of Motors and Generators
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Global presence
Global service products, local service centers

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ABB Machines Service in Indonesia

- Part of global ABB Machines Service network
- Established in 1987
- Workshops located in Tangerang, Surabaya, Balikpapan;
- Hazardous motor certification for workshops and engineers.
- Certified by ISO 9000 series since 1996
- Certified ISO 14001 and OSHAS 18001 (since Dec 2003);
- Member of Electrical Apparatus & Service Association (EASA)
Testing facilities

In order to achieve high quality service, our workshop has

- Test bench with 350 kVA with voltage 0–6600 volts, ac/dc;
- Dynamometer for load test up to 300 hp.
- Surge comparison test up to 30 kV with computerized software
- High Voltage Insulation Resistance
- Shaft align laser alignment
- RSO
- MACHsense
- EMPATH
- LEAP
- Vibration analyzer and balancer (VibXpert II)
Life Cycle Management

- Replacement of the M&G
- Reception at the plant
- Mounting, alignment, and commissioning
- M&G operation at customer plant
- Troubleshooting
  - Diagnostic: Technical
  - Diagnostic: Economic
- Dismounting
- Transport
- Overhaul & repair
- Modernization
- Spare parts
- Rotable Management
- Proactive Maintenance
- Predictive Maintenance
- Systematic Preventive Maintenance
Life Cycle Curve

Value to customer through maintenance

Installation & Commissioning

Optimized Maintenance Line

Aging + TEAM (Thermal, Electrical, Ambient, Mechanical)

Warranty Period

Upgrade and Modernization Period

Replacement & Recycle Period

Maintenance Period

Training for Skill Improvement

Proactive Maintenance

Predictive Maintenance

Preventive Maintenance

Overhaul

Asset Monitoring

Condition Monitoring

Continuous Maintenance & Spares Holding

Troubleshoot

Repair

Reactive Maintenance

Continuous Maintenance & Spares Holding

Training for Skill Improvement

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2014 EASA Research

Methodology

EASA solicited the services of CFE Media, publishers of Plant Engineering and Control Engineering, to conduct the studies. Topics and specific questions used in the study were developed by EASA. Because the number of different topics and questions was too large for one survey, two separate survey instruments were developed. In March 2014, invitations with a link to each online survey were e-mailed by CFE Media to subscribers of Plant Engineering and Control Engineering magazine. Recipients were unaware the surveys were being conducted for EASA.

Electric Motors Purchase & Repair Practices Study

* Deployment date: March 14, 2014
* A qualifying question limited survey respondents to those who are involved in decisions relating to repairs or replacement of electric motors used in their facilities.
* By the closing date of March 28, 2014, completed surveys had been submitted by 256 qualified respondents.
* The survey’s margin of error at the 95% confidence level is +/-6.1%.

Maintenance Practices Study

* Deployment date: March 28, 2014
* A qualifying question limited survey respondents to those who are involved in decisions relating to maintenance policies or practices for their facilities.
* By the closing date of April 9, 2014, completed surveys had been submitted by 205 qualified respondents.
* The survey’s margin of error at the 95% confidence level is +/-6.8%.
2014 EASA Research

**Estimate your annual purchases of MRO electric motors.**

How many electric motors are operating or are in use within your facility?

<table>
<thead>
<tr>
<th>Annual MRO spend</th>
<th>&lt; 10 hp</th>
<th>10 to 100 hp</th>
<th>101 to 300 hp</th>
<th>&gt; 300 hp</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>Average</td>
<td>$62,965</td>
<td>255</td>
<td>105</td>
<td>48</td>
<td>34</td>
</tr>
<tr>
<td>Median</td>
<td>$15,000</td>
<td>50</td>
<td>20</td>
<td>3</td>
<td>0</td>
</tr>
<tr>
<td>Maximum</td>
<td>$3 million</td>
<td>15,000</td>
<td>3,000</td>
<td>3,000</td>
<td>2,500</td>
</tr>
</tbody>
</table>

Over the past three years, has your overall maintenance budget increased, decreased, or remained the same?

- Remained the same: 34.6%
- Increased: 39.0%
- Decreased: 26.3%

75% respondents have same or higher budget in past 3 years.
2014 EASA Research

More than 55% respondents experienced that **Predictive Maintenance** has less budget spend and time devoted.
### Cost Illustration

#### Design Life Time: 25 years

<table>
<thead>
<tr>
<th>Maintenance Type</th>
<th>Event</th>
<th>Cost / Event (USD)</th>
<th>Total Cost (USD)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>10 HP</td>
<td>100 HP</td>
</tr>
<tr>
<td>Overhaul</td>
<td>8</td>
<td>280</td>
<td>1,100</td>
</tr>
<tr>
<td>Corrective Action</td>
<td>4</td>
<td>480</td>
<td>2,050</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>4,160</strong></td>
<td><strong>17,000</strong></td>
</tr>
<tr>
<td>ABB MachSense-P</td>
<td>50</td>
<td>250</td>
<td>250</td>
</tr>
<tr>
<td>Corrective Action</td>
<td>25</td>
<td>45</td>
<td>180</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td><strong>13,625</strong></td>
<td><strong>17,000</strong></td>
</tr>
</tbody>
</table>

How if you calculate all related costs?

The iceberg

How if you have hundreds of motor?
Maintenance
Condition based predictive maintenance

Maintenance scheduling based on actual condition requires reliable condition monitoring and diagnostic services.

Benefits for customers
- Optimum Total Cost of Ownership
- Comfort in knowing condition
- Minimize unplanned and planned downtime
- Reduce operating risks
- Extend motors and generators lifetime

Performed by trained personnel

ABB Life Expectancy Analysis Program (ABB LEAP) – Offline
- Assesses the condition of the stator winding insulation in motors and generators >= 4 kV

ABB MACHsense P – Online Portable
- Offers a comprehensive analysis of electromagnetic and mechanical faults in motors like rotor winding defects, installation problems and bearing defects

ABB MACHsense R - Online remote service
- Continuously monitors key parameters related to the condition of the cage rotor, bearings of motors and generators, temperature issues.

Benefits for customers
- Optimum Total Cost of Ownership
- Comfort in knowing condition
- Minimize unplanned and planned downtime
- Reduce operating risks
- Extend motors and generators lifetime

Performed by trained personnel
ABB Life Expectancy Analysis Program
Condition and lifetime assessment of stator winding
ABB LEAP measurements
General information

- Can be applied on motors and generators from any manufacturer
- Time for data collection approximately 4 hours with motor/generator stopped (off-line tests)
- Not necessary to open covers/machine for data collection
- Only need access to the terminal boxes
- Non destructive tests
ABB Life Expectancy Analysis Program (ABB LEAP) Levels

Standard
All AC motors and generators
1. Condition assessment and life expectancy with 80% confidence
2. Machine stopped but not dismantled
3. During short stoppage (few days)

Advanced
Large synchronous motor and generator above 710 frame size
1. Condition assessment and life expectancy with 85% confidence
2. Machine stopped and partially dismantled (end covers removed)
3. During minor overhaul (1 week stoppage)

Premium
Large synchronous motor and generator above 710 frame size
1. Condition assessment and life expectancy with 90% confidence
2. Machine stopped and fully dismantled (rotor removed from stator)
3. During major overhaul (3 week stoppage)
# ABB Life Expectancy Analysis Program (ABB LEAP)

Tests carried out in each level

<table>
<thead>
<tr>
<th>Test</th>
<th>Standard</th>
<th>Advanced</th>
<th>Premium</th>
</tr>
</thead>
<tbody>
<tr>
<td>Polarization Depolarization Current Analysis (PDCA)</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Tan Delta and Capacitance Analysis</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Non-Linear Insulation Behaviour Analysis</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Partial Discharge Analysis</td>
<td>•</td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Visual inspection of end winding</td>
<td></td>
<td>•</td>
<td>•</td>
</tr>
<tr>
<td>Visual inspection of stator and rotor</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>ELCID</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Endoscopic test</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>RSO</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Natural frequency</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>Wedge tightness</td>
<td></td>
<td></td>
<td>•</td>
</tr>
<tr>
<td>FEM</td>
<td></td>
<td></td>
<td>•</td>
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</tbody>
</table>
ABB Life Expectancy Analysis Program

Reports

SUMMARY

There are indications of the presence of oil mixed contaminants on the surface of the end-windings. There is evidence of the initiation of de-polymerization of the resin in the insulation, and the advancement of depolymerization in localized areas. However, the extent of depolymerization in localized areas, is not large enough to cause the reduction in the volume resistivity of the insulation.

The results indicate de-lamination between within the insulation, with evidence of separation between the conductor stack and the groundwall insulation in some areas.

On the basis of the analysis of the operating data and the measurements performed on the machine tested the expected life of the machine insulation is estimated to be an additional 22,000 to 28,000 hours. The above life expectancy analysis is done with a confidence level of 80%.

RECOMMENDATIONS

Inspection and Maintenance Planning:

Based on the lifetime expectancy analysis and the condition of the machine insulation, the machine has been in operation for a period of around 91.5% of its expected lifetime.

Considering that there is evidence of oil based contaminants on the endwinding, it is recommended to clean and dry the endwindings at the next available maintenance opportunity. Cleaning of the windings could help by extending the life of the machine by an additional 3600 operational hours.

Advice on spares

The two major phenomena contributing to the degradation of the stator winding insulation are de-lamination and de-polymerization of the resin in the areas of discharge activity. These are principally irreversible and therefore, based on the information that estimated remaining lifetime of the insulation is not more than 28,000 hours, it is recommended to consider the suitable spare options, also accounting for the maintenance time available. It is recommended that these steps be taken within a period of time that will not exceed 50% of the remaining estimated lifetime of the machines, i.e. within the next 11,000 to 14,000 hours.

Provides condition assessment of stator winding

- Helps make short term maintenance plan

Provides remaining lifetime of stator winding

- Helps make long term maintenance plan

Provides recommendation

- What maintenance needs to be done
- When maintenance needs to be done
- What winding areas to attend
- When to perform rewinding or buy new stator
## Reference List

<table>
<thead>
<tr>
<th>No</th>
<th>Customer</th>
<th>Brand</th>
<th>Power (kVA)</th>
<th>Year</th>
<th>Service</th>
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<td>1</td>
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<td>ABB</td>
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<tr>
<td>5</td>
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<td>206,100</td>
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<td>12</td>
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<tr>
<td>13</td>
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<td>ASEA</td>
<td>67,010</td>
<td>2013</td>
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<td>LEAP Standard</td>
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<td>16</td>
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<td>6,383 kW</td>
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<tr>
<td>17</td>
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<td>ABB</td>
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<td>2014</td>
<td>LEAP Standard</td>
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<td>18</td>
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<td>Fuji Electric</td>
<td>522 kW</td>
<td>2014</td>
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<td>2014</td>
<td>LEAP Standard</td>
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<td>GE</td>
<td>29,741</td>
<td>2014</td>
<td>LEAP Standard</td>
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<td>MEIDEN</td>
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<td>22</td>
<td>PKT Bontang, Kaltim STG#1</td>
<td>ABB</td>
<td>37,500</td>
<td>2014</td>
<td>LEAP Standard</td>
</tr>
</tbody>
</table>
ABB MACHsense-P
Online condition monitoring of complete shaft line
ABB MACHsense-P
Overview

- ABB MACHsense-P is unique diagnostic tool to assess condition of:
  - Motor
  - Gearbox (if any)
  - Load (pump, fan, compressor)
- Portable equipment is used to take periodic measurements with equipment in running condition
- Service performed by ABB local service centers
- Main benefit
  - Enables correct maintenance at correct time
  - Evaluates performance of motor in given environment
  - Provides report with specific maintenance plans
ABB MACHsense-P
Measurements and deliverables

- Electric motor
  - Measurements
    - Current
    - Voltage
    - Vibration
  - Deliverables
    - Rotor
    - Bearings
    - Installation
    - Power quality

- Gearbox
  - Measurements
    - Vibration
  - Deliverables
    - Gear wear
    - Gear looseness
    - Misalignment
    - Tooth faults
    - Shaft faults
    - Bearings
  - Load (pump, fan, compressor)
    - Measurements
      - Vibration
    - Deliverables
      - Misalignment
      - Looseness
      - Bearings
      - Cavitation
      - Flow turbulence
      - Blade faults
ABB MACHsense-P
1. Motor analysis

**Key functions**

- Vibration and electrical data (current and voltage) are **analyzed by same software**
- Uses specific motor related algorithms
- Uses multiple analysis tools (simultaneous measurement of current/voltage, torque analysis, vibration, etc.)

**Main benefits**

- Covers both mechanical and electrical problems in motor
- Increases reliability of analysis (automated slip calculation, load normalization, etc.)
- Helps specify source of fault

### Summary of findings

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power quality</td>
<td>Wait &amp; Watch</td>
</tr>
<tr>
<td>Rotor</td>
<td>Stop &amp; Inspect</td>
</tr>
<tr>
<td>Bearings</td>
<td>Wait &amp; Watch</td>
</tr>
<tr>
<td>Insulation</td>
<td>Keep running</td>
</tr>
</tbody>
</table>

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ABB MACHsense-P
2. Gearbox and load analysis

Key functions | Main benefits
--- | ---
- Time synchronous averaging of vibration signal | - Provides exact determination of gear faults such as tooth damage, gear wear, and others
- Time synchronous averaging of vibration signal without additional RPM measuring hardware | - No need to stop equipment to paste reflecting tape (for speed measurement)
- Combining data from different sources | - Helps combine signals from multiple sensors to determine probability of fault in each subsystem of drivetrain (motor – gearbox - load)

Summary of findings - Gearbox

<table>
<thead>
<tr>
<th>Gearbox Overview</th>
<th>Status</th>
</tr>
</thead>
<tbody>
<tr>
<td>Gearbox Overview</td>
<td>Wait &amp; Watch</td>
</tr>
<tr>
<td>Gearbox Overview</td>
<td>Wait &amp; Watch</td>
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<tr>
<td>Gearbox Overview</td>
<td>Stop &amp; Inspect</td>
</tr>
<tr>
<td>Gearbox Overview</td>
<td>Stop &amp; Inspect</td>
</tr>
</tbody>
</table>

Vibration
Installation and Commissioning

Benefits for customers

- Carry out by skilled personnel
- Reduction in installation and commissioning time
- Clearly defined procedures
- Safe and controlled start-up
- Standard reporting & parameters
- Warranty protection

Without a proper installation and commissioning no amount of maintenance will achieve the desired performance.
TEAM as aging effect

The majority of all rotor and stator failures are caused by combination of TEAM

<table>
<thead>
<tr>
<th>Thermal</th>
<th>Electrical</th>
<th>Ambient</th>
<th>Mechanical</th>
</tr>
</thead>
<tbody>
<tr>
<td>Operating</td>
<td>Terminal voltage</td>
<td>Contaminated air,</td>
<td>Vibration due to misalignment,</td>
</tr>
<tr>
<td>condition such</td>
<td>Harmonics</td>
<td>dust, chemicals</td>
<td>unbalance, air gaps, installation</td>
</tr>
<tr>
<td>as overload, etc</td>
<td>Transient, voltage</td>
<td>Humidity</td>
<td>Repeated starts</td>
</tr>
<tr>
<td>Starting</td>
<td>peaks in network,</td>
<td>High temperature</td>
<td>causing torsional</td>
</tr>
<tr>
<td>conditions</td>
<td>switching surge</td>
<td>Corrosion</td>
<td>effect and fatigue</td>
</tr>
<tr>
<td>such as long</td>
<td>Phase unbalance</td>
<td></td>
<td></td>
</tr>
<tr>
<td>start, stalking,</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>repeated starts</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Inadequate</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>cooling, fouling</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>of coolers of</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>filters</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Act alone or in combination leading to general weakening and ultimately failure
Maintenance
Time based preventive maintenance

Investing in preventing of failure, rather than living with its consequences, such as loss of production can make the company manage to retain its long-term competitiveness.
## Recommended Maintenance Program

<table>
<thead>
<tr>
<th>Level of inspection</th>
<th>Level 1 (L1)</th>
<th>Level 2 (L2)</th>
<th>Level 3 (L3)</th>
<th>Level 4 (L4)</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Interval</strong></td>
<td>Max. 10,000 hours (equivalent hours(^1)) of operation. Or annually.</td>
<td>Max. 20,000 hours (equivalent hours(^1)) of operation. Or max. 3 years operation.</td>
<td>Max. 40,000 hours (equivalent hours(^1)) of operation. Or max. 6 years operation.</td>
<td>Max. 80,000 hours (equivalent hours(^1)) of operation. Or max. 12 years operation.</td>
</tr>
<tr>
<td><strong>Expected downtime</strong></td>
<td>Approx. 1 day.</td>
<td>Approx. 2 days.</td>
<td>Approx. 5 days.(^3)</td>
<td>Approx. 10 days.(^3)</td>
</tr>
</tbody>
</table>

\(^1\) Equivalent hours = Total hours of operation + number of starts x 20.  
\(^2\) Option: Diagnostic insulation test of the stator winding  
\(^3\) Depending on the accessibility of the machine and lifting equipment
On site and workshop repair

The faster a fault can be repaired, the smaller the consequences.

Benefits for customers

- Access to technical documentation for ABB motors and generators
- Standardized repair with ISO & Hazardous Area Certified
- Supported by ABB’s world wide network & EASA
- 30 years experiences with high quality of work
- Range of repair depending of the situation and exact financial and operation needs

ABB Branch office will enabling of fast response of Customer inquiry
Spare-parts

Benefits for customers

Access to original spare-parts

Expert support in part and capital spares identification

Minimized down-time in case of failure

Ensure motor and generator availability

Single source / ABB Validated supplier (ISO Standard)

On line system – Business OnLine

Having spare parts at the customer site may reduce the downtime significantly when something breaks.
Replacement

When parts might not be available anymore or repair cannot be done at reasonable costs, replacement is the only solution

- New standard motors/generators with adaptations
- New standard motor/generator with specific electrical and/or mechanical design (e.g.: foot print)
- Upgrading or rebuilding of old motors/generators

Benefits for customers

- Reduction in life cycle costs
- Increase of reliability, availability and safety
- Selection based on energy calculations possible
- Access to latest technology
- Expert support in selecting and designing replacement
- Access to original ABB drawing and specification

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Engineering and consulting

Advisory services from experts for life cycle management of motors and generators

Energy efficiency and reliability appraisals show the savings that can be achieved by replacing an existing product with a more efficient and reliable unit

Transient mitigation services check the susceptibility of your network to transients which could damage the stator windings of motors

Other solutions are available for dealing with specific problems that may arise at the site.

Benefits for customers

Maximized availability and reliability

Single source for consulting services and implementation of solutions

Extended lifetime through use of most appropriate maintenance practices

Minimized unplanned downtime

Access to solutions based on patented and specialized technology

Controlled risks and costs associated with maintenance

Benefits for customers

Maximized availability and reliability

Single source for consulting services and implementation of solutions

Extended lifetime through use of most appropriate maintenance practices

Minimized unplanned downtime

Access to solutions based on patented and specialized technology

Controlled risks and costs associated with maintenance

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Technical support and Emergency field service resources

- Fast and competent
- Escalation to world leading experts

Benefits for customers

- Quick identification of the problem
- Possibility to optimize in-house maintenance staff.
- Direct service actions to prevent failure and minimize consequences
- To help minimize your downtime and bring back on line

Technical support through world wide network of service centers

Field engineers available on call out

Advantages for customers

- Quick identification of the problem
- Possibility to optimize in-house maintenance staff.
- Direct service actions to prevent failure and minimize consequences
- To help minimize your downtime and bring back on line
Training

- Provided trainings to ABB’s customers and end users
  - General motor and generator awareness
  - Maintenance and service
- Can be tailored to suit customers needs
  - Low voltage rewinding
  - Condition Monitoring

Benefits for customers

- Employee confidence and motivation
- Employee competence in maintenance and first-line trouble shooting
- Create competent employee to reduce risk of down-time
- Ability to interpret alarm warnings and undertake appropriate actions to avoid failures
- Gives ability to Customer to interact with expert technical support

Provided trainings to ABB’s customers and end users

General motor and generator awareness

Maintenance and service

Low voltage rewinding

Condition Monitoring
One or more services combined to achieve best possible solution for each customer

Service contract – customized solutions

Benefits for customers

- Full support of technical consulting & engineering
- Tailor made services based on condition, importance & needs
- Cost-effective delivery under one single contract
- Access to ABB ServIs for maintenance plan & history / record
- Fast response of delivery service request
- Cut the administration process of service order

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