SWAPs Maintenance

The maintenance program for a successful and lasting use of your assets
Agenda

Customer needs
Maintenance
Failure trend and possible failures
Asset health management
SWAPs maintenance
Equipment’s conditions
SWAPs maintenance plan
Major maintenance activities
Condition based maintenance
End of life and retrofitting
Health & Safety
Recap
Customer needs

- Minimum downtime
- Lower costs
- High Reliability
- Avoid failures
- Be environmentally friendly!
- Less maintenance
- High availability
- Be safe!
- Be fast!
What is maintenance?

Mindset-changing

“Maintenance is a combination of all technical and management actions intended to retain an item in, or restore it to, a state in which it can perform as required”¹

Performing a correct and periodic maintenance is essential to:

- Maximize productivity
- Protect the assets
- Optimize investments
Myths and facts
Common misconceptions

Widespread myths

- Electrical equipment does not need maintenance
- Maintenance is just dusting down
- No need to take care of electrical equipment, being very static

Proven facts

- Periodical checks on functionality and maintenance are required to guarantee the original performance level
- Maintenance consists of checking the integrity of all the electrical and mechanical components to limit aging effects on components and prevent faults
- Aging and environmental conditions wear down the equipment over time
Myths and facts
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Why maintaining?
Failure rates and related effects

Causes of failure

- Environmental Conditions: 30%
- Inadequate Maintenance: 54%
- Others: 16%

Indirect costs

- Higher risk in Health & Safety
- Reduction of products lifetime
- Management of urgencies
- Poor quality
- Energy consumption
- Environmental impact
- Resources availability
- Inefficiency in personnel
- Insurance policies
- Production losses
- Losses in market share
Failure trend
Through the equipment’s life

First phase:
- **Infant mortality** – widely ranging failure rate due to manufacturing and commissioning defects

Second phase:
- **Random failures** – constant failure rate caused only by random failures

Third phase:
- **Wear out** – increasing failure rate due to aging and wearing of the equipment
Possible failures
Switchgear

**MV switchgear**
- Earthing switch
- Low voltage compartment components
- Shutters
- Door interlocks
- Panel frame and power circuit
- Switches
- Cable connections
- Measuring transformers
- Circuit breaker
- Relay

**LV switchgear**
- Operating handles
- Interlocks
- Cable Connections
- Measuring transformers
- Module Assembly Failure due to Short-circuit
- Contactors, MCCBs
- Circuit Breaker
- Relay
Possible failures
Circuit breakers

**MV circuit breaker**

- Operating mechanism
- Coils
- Spring charging motor
- Truck
- Poles
- Interlocks
- Tulip contacts
- Auxiliary plug
- Dumper

**LV circuit breaker**

- Operating Mechanism
- Coils
- Spring charging motor
- Interlocks
- Auxiliary Contacts
- Embedded Protection Relay
- Contacts
- Truck
Possible failures
Relays

Electronic cards
Plastic connectors
Software
Human Machine Interface (HMI)
Asset health management

Maintenance strategies

1. Run to failure
2. Time-based
3. Usage-based
4. Condition-based
5. Predictive

Proactive, predictive vs. Value, savings
SWAPs maintenance

Starting point

1. Run to failure
2. Time-based
3. Usage-based
4. Condition-based
5. Predictive

Proactive, predictive

Value, savings

SWAPs maintenance

Inputs

- Environmental and Operational Conditions
- Monitoring and Diagnostic solutions
- Age of the equipment
- Previous Maintenance

SWAPs maintenance

Reference Standards

- IEC, IEEE and GB Standards for electrical Equipment
- IEC, Classification of environmental conditions – Part 3-3: Classification of groups of environmental parameters and their severities – Stationary use at weather protected locations, IEC Standard 60721-3-3, Part 3-3, 10/2002
- NFPA, Recommended practices for electrical equipment maintenance, NFPA Standard 70B, 2019 (U.S. National Standard)
- IEC, Low-voltage switchgear and controlgear assemblies - Part 1: General rules, IEC Standard 61439-1, Part 1, 05/2020
Equipment’s conditions
Environmental and operational

**Environmental**
- Temperature
- Humidity
- Rate of Change of temperature
- Condensation, formation of ice
- Heat radiation
- Flora and fauna
- Chemicals (salt, sulphur dioxide, chlorine, etc.)
- Presence of dust and sand
- Vibration and shock
- Altitude
- Pollution degree

**Operational**
- Age
- Number of operations
- Loading
- Short Circuit current interruptions
- Frequency of operation (inactivity time)
Equipment’s conditions

Classes of conditions

**Optimal**
Favorable range within the Normal conditions, based on ABB experience
Allow the deferral of the equipment’s aging

**Normal**
Defined by Standards from IEC, IEEE and GB

**Severe**
Outside the Normal range
Require higher attention
One parameter might influence the whole performance
Can cause premature aging and wearing
Higher safety risks due to higher probability of failure
Equipment’s conditions

Example of optimal and severe conditions

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Optimal</th>
<th>Normal</th>
<th>Severe</th>
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<tbody>
<tr>
<td>Temperature [°C]</td>
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<tr>
<td>Humidity [%]</td>
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<tr>
<td>Number of operations [%]</td>
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<tr>
<td>More than 10 other parameters considered</td>
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Effects of the equipment's condition

Costs and downtime comparison

- Normal
- Optimal
- Severe

+100%
-20%
## SWAPs maintenance

### Maintenance levels

<table>
<thead>
<tr>
<th>See</th>
<th>Watch</th>
<th>Act</th>
<th>Perform</th>
<th>Secure</th>
</tr>
</thead>
<tbody>
<tr>
<td>Overall visual Inspection</td>
<td>In-depth Inspection De-energized Panel</td>
<td>Basic Maintenance Cleaning, lubrication and functional testing of the equipment</td>
<td>Advanced Maintenance In-depth analysis of the asset and immediate corrective actions</td>
<td>Special maintenance for critical situations (It will not be included in maintenance plan)</td>
</tr>
</tbody>
</table>

Trained personnel
Dedicated ABB trainings

ABB certified technician
Support by ABB
Why ABB Technicians?

Safety ① Safety is the first priority for all ABB services

Quality and performance ② ABB Technicians have a deep knowledge of the product

Certification ③ All ABB technicians are registered and certified

Warranty ④ Warranty is granted on repaired components
**SWAPs maintenance plan**

Example for Medium Voltage equipment

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<tr>
<th>Conditions</th>
<th>Device/Year</th>
<th>0.5</th>
<th>1</th>
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**Legend**
- See
- Watch
- Act
- Perform

**Frequency of SWAPs intervals:**
- Optimal conditions allow to extend them by 30%
- Severe ones imply reducing them by 50%
SWAPs maintenance plan

Example for Low Voltage equipment

Frequency of SWAPs intervals:
- Optimal conditions allow to extend them by 30%
- Severe ones imply reducing them by 50%
Major maintenance activities
For MV and LV equipment

Complete list of maintenance activities can be found in the SWAPs brochure, for both MV and LV equipment.
Condition – based maintenance

A step further

1. Run to failure
2. Time-based
3. Usage-based
4. Condition-based
5. Predictive

Value, savings

Proactive, predictive
Monitoring and Diagnostic solutions
Enabling condition – based maintenance

**ABB Ability™ Asset Manager** enables ABB service engineers and operations teams to deploy continuous monitoring of remote assets and performance trends to define the correct maintenance procedures at the right time.

ABB Ability™ Asset Manager collects diagnostic information from sources like **MySiteCare, SWICOM** and **CMES**

ABB Service specialists monitor the asset condition and define the right action.

Maintenance is planned in relation to the real asset condition.

Maintenance Responsible

Substation
## Maintenance plan

Standard conditions with condition monitoring: example for Medium Voltage equipment

| Device/Year | 0.5 | 1   | 1.5 | 2   | 2.5 | 3   | 3.5 | 4   | 4.5 | 5   | 5.5 | 6   | 6.5 | 7   | 7.5 | 8   | 8.5 | 9   | 9.5 | 10  | 10.5 | 11  | 11.5 | 12  | 10   | 13  | 13.5 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Circuit breaker | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   | A   | P   |
| Relay         | W   | A   | W   | W   | W   | W   | A   | W   | P   | W   | A   | P   | W   | A   | P   | W   | A   | P   | W   | A   | P   | W   | A   | P   | W   | A   | P   | W   |

Intervals can be increased by 30%\(^1\)

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November 20, 2020  |  Slide 28  | 1. Independently of the equipment’s conditions
## Maintenance plan

Standard conditions with condition monitoring: example for Low Voltage equipment

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<th>Device/Years</th>
<th>0.5</th>
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</table>

Intervals can be increased by 30%<sup>1</sup>
Condition-based maintenance
Benefits of condition monitoring

<table>
<thead>
<tr>
<th>Asset type</th>
<th>SWAPs level</th>
<th>Activities duration (h)</th>
<th>Activities duration with M&amp;D (h)</th>
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<td>Perform</td>
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</table>

30% Maintenance activities duration’s reduction
Up to 40% Maintenance activities’ cost reduction

Standard conditions

| Device/Year | 0.5 | 1   | 1.5 | 2   | 2.5 | 3   | 3.5 | 4   | 4.5 | 5   | 5.5 | 6   | 6.5 | 7   | 7.5 | 8   | 8.5 | 9   | 9.5 | 10  | 10.5 | 11  | 11.5 | 12  | 12.5 | 13 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Circuit breaker | A   | P   |     |     | A   |     |     | P   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Switchgear   | S   | W   | S   | A   |     | A   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Relay        | W   | A   | W   | W   | A   | W   | P   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Standard conditions with M&D

| Device/Year | 0.5 | 1   | 1.5 | 2   | 2.5 | 3   | 3.5 | 4   | 4.5 | 5   | 5.5 | 6   | 6.5 | 7   | 7.5 | 8   | 8.5 | 9   | 9.5 | 10  | 10.5 | 11  | 11.5 | 12  | 12.5 | 13 |
|-------------|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|-----|
| Circuit breaker | A   | P   |     |     | A   |     |     | P   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Switchgear   | W   | S   | A   |     |     | S   | W   | P   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |
| Relay        | W   | A   | W   | W   | A   | W   | P   |     |     |     |     |     |     |     |     |     |     |     |     |     |     |

Reduction of unplanned labor cost maximizing uptime

- **$1.2M per hour**
  Average downtime costs for an automotive industry

- **$740K per outage**
  Average downtime costs for data centers

- **$4.4M per day**
  120,500 barrels of oil lost per day oil&gas segment

- **$150M per outage**
  Airline lost a switchgear with 3.7% stock drop in 2 condition months in 2016

- **$100K per panel**
  Steel works loss per year per panel

- **$20K per panel**
  Annual loss in semi-conductor production

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How to further extend equipment’s lifetime

Switchgear modernization

Upgrade solutions
- Arc fault protection
- Remote breakers racking
- Auxiliary equipment renewal
- Interlocking and safety features
- Condition monitoring

Retrofit solutions
- Relay replacement
- Circuit breaker replacement
## End of life and retrofitting

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<tr>
<td>Switchgear</td>
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</tbody>
</table>

**Legend**

- **R**: Relay retrofitting
- **EOL**: End of life

Dedicated preventive maintenance programs are available as an alternative for some Relays lines.
Health and safety
How to carry out maintenance in a safe way

Training & certification
Only trained and certified personnel should carry out maintenance

ABB offers different solutions:
– Training for your own personnel
– Trained ABB personnel to perform maintenance

Maintenance with de-energized panel
Maintenance plans mean preserving your equipment integrity

Reduces the risk of internal arc faults

Remote racking
TruckMaster (MV) and RRD Remote Racking Device (LV Emax2)

Reduces the risk for personnel on site

Active Arc Protection
UFES (Ultra Fast Earthing Switch)

Safety for personnel and equipment is the first priority
Reducing the risk of failure

The right mix

Managing conditions
Depending on the location of the equipment it is not always possible to control environmental conditions

Right maintenance
Tailored to your assets, according to your equipment’s conditions
Safer electrical equipment – for everybody!
Lower overall downtimes
Higher lifetime of your equipment

Condition monitoring
Online monitoring
Remote support
Predictive algorithms

Modernization
Upgrades and retrofits
Equipment’s conditions – Normal
Environmental - MV equipment

**Climatic conditions**
- Temperature: -5°C... 40°C
- Humidity: 5%... 95%
- Temperature change: ≤ 0,5°C/min
- Possibility of condensation and ice formation

**Mechanically active conditions**
- Presence of dust minimized, ingress of sand prevented.
  Visible dust layer

**Mechanical conditions**
- Insignificant vibration and shock. No external vibrations source

**Altitude**
- ≤ 1000m

**Special conditions**
- No influence of heat radiation

**Biological conditions**
- The presence of flora and fauna is avoided

**Chemical conditions**
- Salt mist may be present in sheltered locations (coastal and offshore)
- Other chemicals limits¹

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¹ Sulphur dioxide 0.1 mg/m³, Hydrogen sulphide 0.01 mg/m³, Chlorine 0.01 mg/m³, Hydrogen chloride 0.01 mg/m³, Hydrogen fluoride 0.003 mg/m³, Ammonia 0.3 mg/m³, Ozone 0.01 mg/m³, Nitrogen oxides 0.1 mg/m³
Equipment’s conditions – Normal
Environmental - LV equipment

- Temperature, min and max values: -5°C... 40°C
- Temperature, average value over a period of 24h: ≤ 35°
- Humidity: 5%... 95%
- Temperature change: ≤ 0,5°C/min
- Possibility of moderate and occasional condensation
- No ice formation
- Pollution degree: conductive pollution occurs or dry, non – conductive pollution occurs which is expected to become conductive due to condensation
- Flora and fauna: avoided
- No dust
- No sand
- Insignificant vibration and shock
- Altitude: ≤ 2000m
Equipment’s conditions – Normal

Operational - MV and LV equipment

**Age**
- Relay: <15 years
- Circuit breaker: <20 years
- Switchgear: <30 years

**Number of operations**
- ≤ 50% of declared mechanical life

**Loading**
- ≤ 100% (current AND voltage)

**Short circuit currents interruptions**
- ≤ 50% of declared number of max SC interruptions
- ≤ 90% of interrupted \( I_{SC} \)

**Frequency of operation (inactivity time)**
- At least one operation every 6 months
Equipment’s conditions – Optimal

Environmental – MV equipment

**Climatic conditions**
- Temperature: 15°C... 30°C
- Humidity: 10%... 75%
- No condensation, no formation of ice

**Special and Biological conditions:** same as normal conditions

**Chemical conditions**
- Salt mist absence
- Other chemicals limits

**Mechanically active conditions**
- Present but not visible dust layer

**Mechanical conditions**, same as standard conditions

**Altitude** ≤ 1000m, same as standard conditions
Equipment’s conditions – Optimal
Environmental - LV equipment

- Temperature, min and max values: 15°C… 30°C
- Temperature, average value over a period of 24h: ≤ 30°C
- Humidity: 10%... 75%
- Temperature change: ≤ 0,5°C/min
- No condensation
- No ice formation
- Pollution degree: no pollution or non-conductive pollution occurs
- Flora and fauna: avoided
- No dust
- No sand
- Insignificant vibration and shock
- Altitude: ≤ 1000m
Equipment’s conditions – Optimal
Operational - MV and LV equipment

Age
- Relay <10 years
- Circuit breaker <15 years
- Switchgear <20 years

Number of operations:
- ≤ 25% of declared mechanical life

Loading
- ≤ 90% voltage AND ≤ 80% current

Short circuit interruptions
- ≤ 25% of declared number of max short circuit interruptions
- ≤ 80% of interrupted $I_{SC}$

Frequency of operation (inactivity time)
- Up to 100 operations per year (number of operation of circuit breaker)