Circuit Breaker Aging, Maintenance, & Modernization

Understanding the lifecycle of your circuit breakers and what they can tell you about their current condition.

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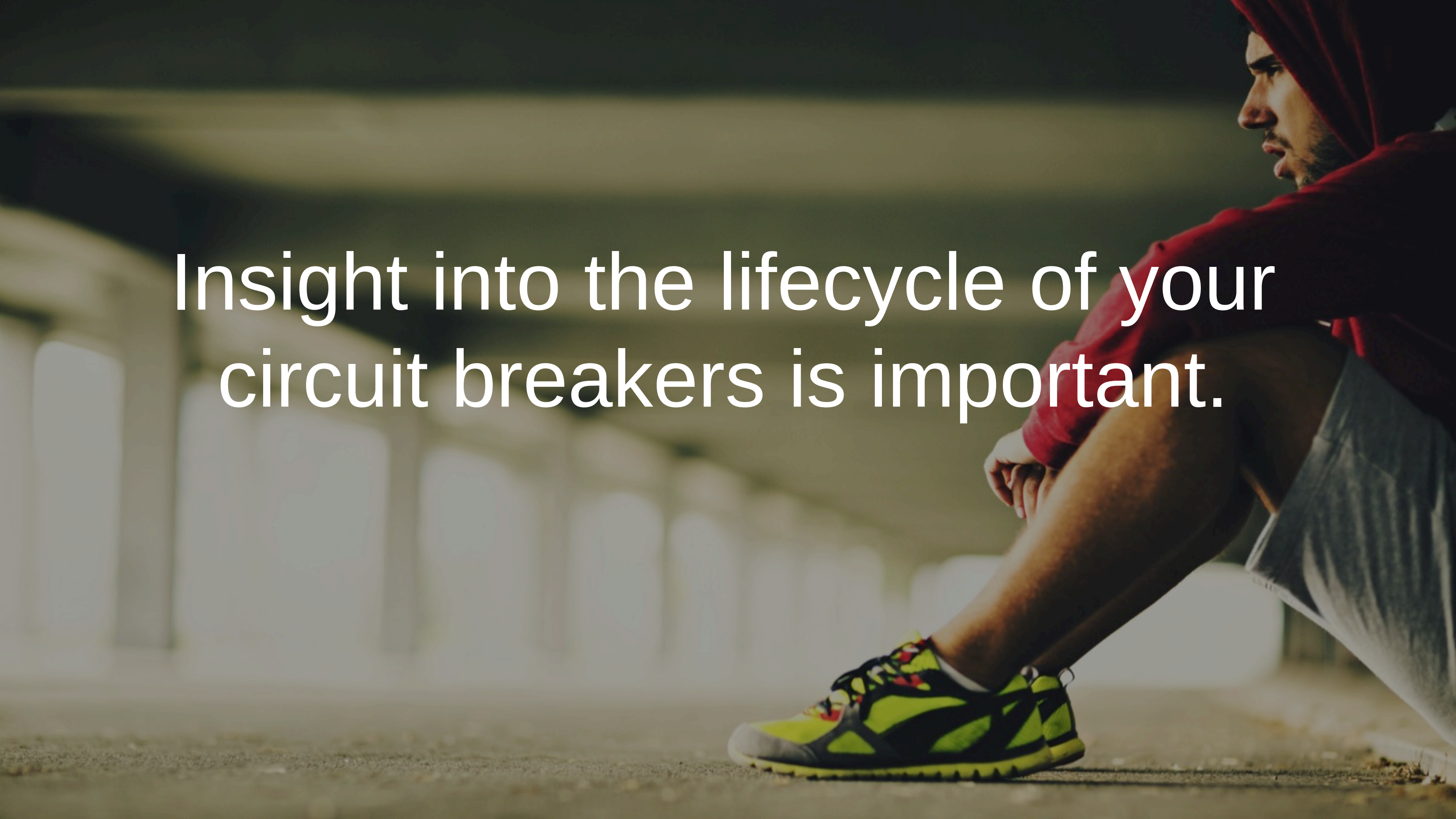
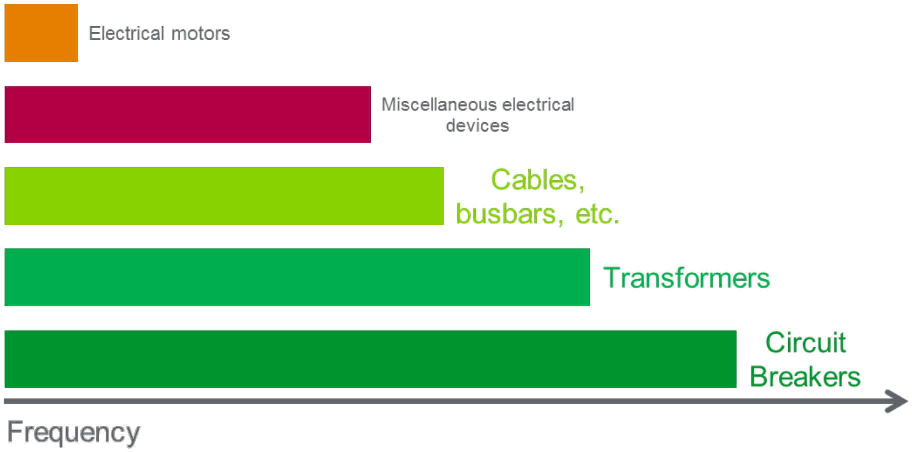
- Schneider Electric Services – Atlantic Canada
    - Past mechanical and electrical project management experience in the telecommunications industry.

Topics covered

- Why understanding the health of your distribution Circuit Breakers is important
- Circuit Breaker basics
- Maintenance fundamentals
- Causes of accelerated aging
- Modernization possibilities
- What your Circuit Breaker can tell you about its health


Insight into the lifecycle of your circuit breakers is important.

Equipment Failures Blamed in Electrical Fires



*Source: FM Global Insurance Company

Costs of Neglecting Electrical Maintenance

- 69% of losses were in non-rotating equipment.
- $365.4M in gross losses in the US from 2001-2011.*

***Costs can not be placed on human lives.**

Electrical losses in the United States in which lack of electrical maintenance was a major contributing factor, 2001 to 2011*

Type of equipment	Number of losses	Losses, %	Total gross loss, US$(2011) millions	Gross loss, %	Average total gross loss, US$(2011) millions
Non-rotating electrical equipment — Switchgear	37	44	246.2	31	6.7
Motors†	4	5	178.8	22	44.7
Generators	15	18	162.9	20	10.9
Transformers	21	25	119.2	15	5.7
Mineral and metal process equipment	2	2	46.6	6	23.3
Pulp and paper process equipment (printing press)	1	1	25.2	3	25.2
Heating, ventilation, and air conditioning (HVAC)	2	2	11.7	1	5.9
Rubber/leather/plastic process equipment	2	2	9.6	1	4.8
Total	**84**	**100**	**800.2**	**100%**	**9.5**

**Data courtesy of FM Global.*
†Includes a single loss of US$(2011)123.8 million.

*Source: CSA Z463-13 & FM Global

Arc Flash Hazard

Definition (Z462-15)

–“A dangerous condition associated with the possible release of energy caused by an electric arc.”

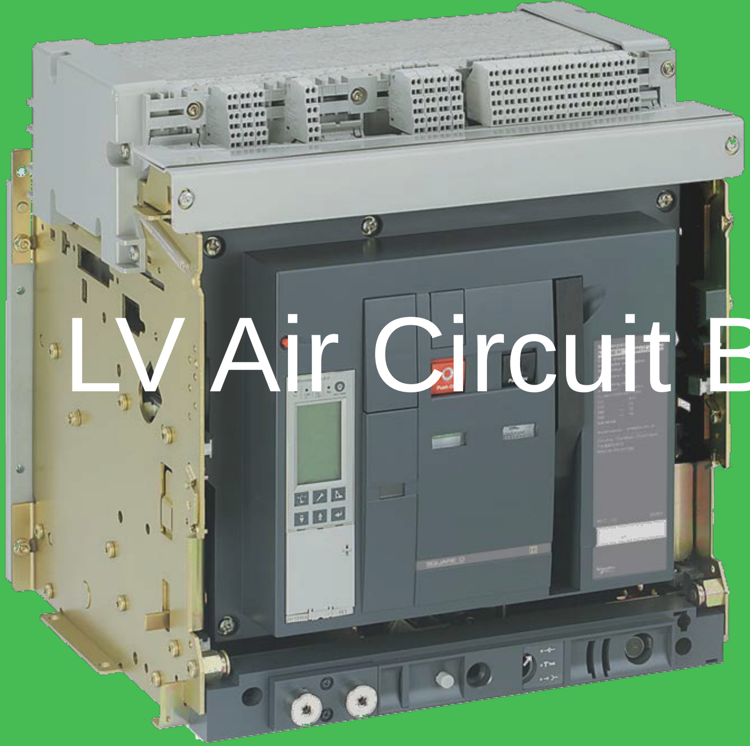
Arc flash hazard — a dangerous condition associated with the possible release of energy caused by an electric arc.

Notes:

(1) *An arc flash hazard can exist when energized electrical conductors or circuit parts are exposed or are within equipment in a guarded or enclosed condition, if a person is interacting with the equipment in a manner that could cause an electric arc. Under normal operating conditions, enclosed energized equipment that has been properly installed and maintained is not likely to pose an arc flash hazard.*

(2) *See Table 4A for examples of activities that could pose an arc flash hazard.*

- An arc flash hazard can exist when energized electrical conductors or circuit parts are exposed or are within equipment in a guarded or enclosed condition, if a person is interacting with the equipment in a manner that could cause an electric arc.
- Under **normal operating conditions**, enclosed energized equipment that has **been properly installed and maintained** is not likely to pose an arc flash hazard.



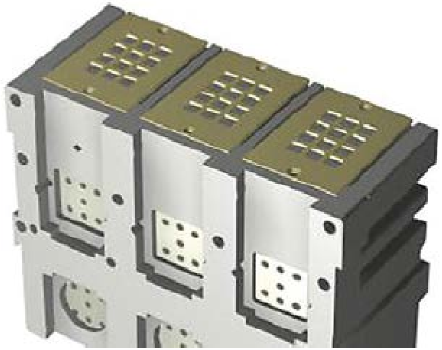
LV Air Circuit Breaker Basics

Circuit Breaker —

A device designed to open and close a circuit by non-automatic means and to open the circuit automatically on a predetermined overcurrent without damage to itself when properly applied within its ratings.

Main Elements of an LV ACB

- The case

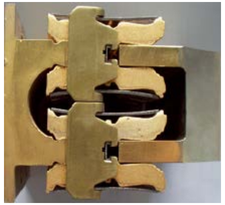


- Arc chutes

- Main contacts

- Chassis and mechanisms

- Connections



- Trip Unit and accessories

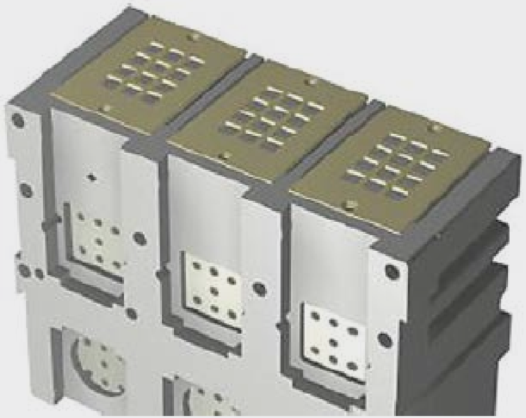
The Case

The case is an essential element in the circuit breaker.

First of all, it performs a number of safety functions:

- functional insulation between the phases themselves and between the phases and the exposed conductive parts in order to resist transient over-voltages caused by the distribution system
- a barrier avoiding direct user contact with live parts
- protection against the effects of electrical arcs and overpressures caused by short-circuits.

Secondly, it serves to support the entire pole operating mechanism as well as the mechanical and electrical accessories of the circuit breaker.



Arc chutes

During a short-circuit, the arc chute serves to extinguish the arc and to absorb the high level of energy along the entire path of the short-circuit. It also contributes to arc extinction under rated current conditions. An arc chute that is not in good condition may not be capable of fully clearing the short-circuit and ultimately result in the destruction of the circuit breaker.

Main contacts

The contacts make and break the current under normal conditions (rated current for the installation) and under exceptional conditions (overloads and short-circuits). The contacts are eroded by the many opening and closing cycles and can be particularly deteriorated by short-circuit currents.

Worn contacts may result in abnormal temperature rise and accelerate device aging. It is imperative to remove the arc chutes and visually check contact wear at least once a year and following each short-circuit..

Chassis and mechanism

Mechanical operation of the circuit breaker may be hindered by dust, knocks, aggressive atmospheres, no greasing or excessive greasing. Operating safety is ensured by dusting and general cleaning, proper greasing and regular opening and closing of the circuit breaker.

Connections

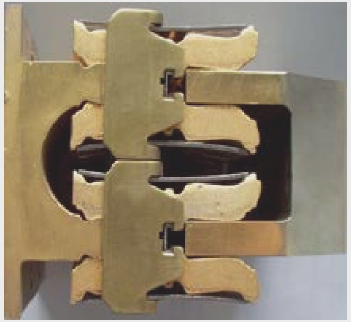
The connections between the various distribution systems in a switchboard (busbars, cables) and the switchgear are a major element. These vary between sliding connections as part of a rack-able system, or the fixed connections of a fixed mount breaker.

Sliding connections (chassis)

- They are made up of two parts, the clusters and disconnecting contacts. This type of connection is critical and requires periodic cleaning in compliance with the described procedures. The grease facilitates the connection between the clusters and the disconnecting contacts and avoids damaging the silver-coated surface by reducing the racking-in friction.

Fixed connections

- Connections using lugs or bars.



Sliding connections

Fixed connections

Trip unit and accessories

Control auxiliaries
MX and XF shunt releases are respectively used to remotely open and close the circuit breaker using an electrical order or by a supervisor via a communication network.

The MN under-voltage release is used to break the power circuit if the distribution system voltage drops or fails in order to protect life (emergency off) or property.

Electronic trip unit
If an electric fault occurs in the installation, the electronic trip unit detects the fault and orders the circuit breaker to open and thus protect life and property.

Gear motor
The gear motor (MCH) automatically recharges the operating-mechanism springs as soon as the circuit breaker is closed. The gear motor makes it possible to instantaneously reclose the device following an opening. This function may be indispensable for safety reasons. The charging lever serves simply as a backup means if the auxiliary voltage fails.

Control auxiliaries

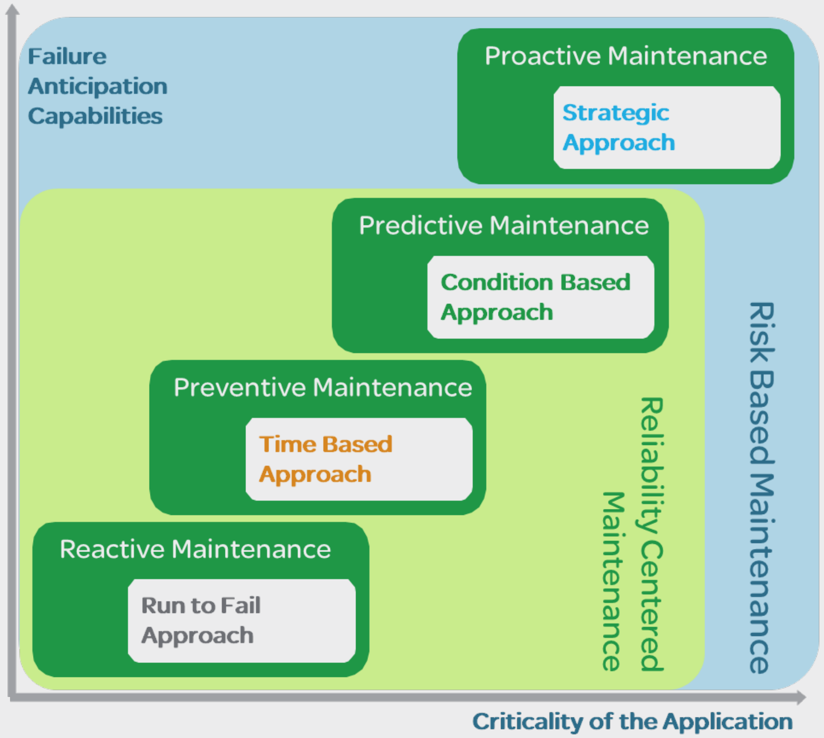
Electronic trip unit

Gear (charging) motor

Maintenance Fundamentals

What maintenance is required, and when?

Maintenance maturity curve



Maintenance Program Strategies

- Your partner should work with you to determine the appropriate maintenance strategy for your electrical distribution assets.

What pieces make up the right maintenance strategy for you?

The Changing Market Dynamics

Aging Infrastructure & Equipment

Leading cause of unscheduled downtime

- Aging equipment (45%)
- Insufficient maintenance (28%)

Aging Workforce

36% of the population base is over 50

Lack of available Technical Experience

68% of workplace shortages are due to lack of qualified applicants among the new work force

Challenging Economic Conditions

Canadian economy continues to struggle due to recession and low spending

- low Canadian $
- Canadian GDP growth down
- O&G Market

Need for Regional Support

Global, National and Regional customers are looking for seamless support

Want a partner to be their trusted adviser.

Power Reliability | Loss of Expertise and Experience | Limited Budgets | Competitive

Reactive Maintenance

Run to Fail

From CSA Z463-13

…appropriate in circumstances where equipment shutdowns do not affect production… if a machine is expected to be used only for a short duration, the reactive approach can be acceptable.

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- The advantage of RM is that resources are not expended until something breaks, which can be seen as a way to keep costs for maintenance and related staffing low and to limit production interruptions

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- Increased costs associated with unpredictable downtime
- Additional costs and collateral damage due to secondary equipment failures
- Shorter equipment life, resulting in more frequent replacement
- Increased demand for spare parts

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Preventive Maintenance

Time Based

From CSA Z463-13

…is most usefully applied to equipment that does not run continuously… and in circumstances where personnel have the knowledge, skills, and time to perform the PM work.

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- Flexibility that allows for adjustment of maintenance periods
- Increase in component and serviceable part life cycles
- Lower costs by performing PM as intended by the equipment designer, which extends equipment life
- Minimizing failures, which translates into maintenance and capital cost savings. It is estimated that PM saves from 12% to 18% annually over RM

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- It is a labour-intensive process
- It can result in unnecessary maintenance

What maintenance is required, and when?

Maintenance Fundamentals: Following manufacturers' recommendations

Preventive maintenance intervals

Typically, the manufacturer recommended intervals for maintenance varies based on environmental and operating conditions. By understanding your application, you can choose the interval which is most appropriate for time based interventions. These conditions can be classified as:

- **Normal**
- **Favourable**
- **Severe**

Normal conditions

The maintenance program (1) that must be carried out every one, two or five years on Masterpact NT/NW subassemblies and the level of competence required on the part of service agents are described in the tables on pages 12, 13 and 14.
At the end of each five year period, the maintenance program must be systematically repeated.
These maintenance operations apply for normal operating and environment conditions as defined below.

Normal operating and environment conditions	
Temperature	Average annual temperature < 25 °C outside the switchboard (Ta (1))
Percent load	< 80 % of In 24/24 hours
Harmonics	Harmonic current per phase < 30 % of In
Relative humidity	< 70 %
Corrosive atmosphere	Device installed in environment category 3C1 or 3C2 (IEC 60721-3-3)
Salt environment	No salt mist
Dust	Low level Device protected in switchboard equipped with filters or ventilated IP54 enclosure
Vibration	Permanent vibration < 0.2 g

Favourable conditions or device protected

The time interval between two preventive-maintenance visits can be doubled **if all the conditions** presented below are met.
The only exception is the check-up program which should be run in the 5th year.

Favourable operating and environment conditions or device protected	
Temperature	Average annual temperature < 25 °C outside the switchboard (Ta (1)). The device is installed in an air-conditioned room or in a ventilated enclosure
Percent load	< 50 % of In 8/24 hours or 24/24 hours
Relative humidity	< 50 %
Corrosive atmosphere	Device installed in environment category 3C1 or in a protected room (air is conditioned and purified)
Salt environment	None
Dust	Negligible Device protected in switchboard equipped with filters or ventilated IP54 enclosure
Vibration	None

(1) (Ti)–(Ta), see the definition in the Masterpact catalogue.

Example depending on the conditions:
- normal: check on charging time = 2 years
- favourable: check on charging time = 2 x 2 = 4 years

Severe conditions and device not protected

The time interval between two preventive-maintenance visits must be reduced by half **if any of the conditions** presented below are present.

Severe operating and environment conditions	
Temperature (annual average)	Average annual temperature between [35 ° and 45 °C] around the switchboard (see definition in EN 60439-1)
Percent load	> 80 % of In 8/24 hours or 24/24 hours
Relative humidity	> 80 %
Corrosive atmosphere	Device installed in environment category 3C3 or 3C4 without any particular protection
Salt environment	Installation < 10 kilometers from seaside and device without any particular protection
Dust	High level Device not protected
Vibration	Continuous vibrations between 0.2 and 0.5 g

Severe environmental and operating conditions are encountered in marine and wind power applications, for example.
Example depending on the conditions:
- normal: check on charging time = 2 years
- severe: check on charging time = 0.5 x 2 = 1 year

This time interval reduction must be applied to all levels of maintenance operations and checks.

What maintenance is required, and when?

Maintenance Fundamentals: Following manufacturers’ recommendations

Level II preventive maintenance to be performed every year

Check	Year 1	2	3	4	5 (1)
Device					
Check the general condition of the device (escutcheon, control unit, case, chassis, connections)	■	■	■	■	■
Mechanism					
Open/close device manually and electrically	■	■	■	■	■
Charge device electrically	■	■	■	■	■
Check complete closing of device’s poles	■	■	■	■	■
Check number of device operating cycles	■	■	■	■	■
Breaking unit (arc chutes + contacts)					
Check the filters cleanlines and the fixing of the arc-chute chambers	■	■	■	■	■
Control auxiliaries					
Check auxiliary wiring and insulation	■	■	■	■	■
Control unit					
Trip control unit using test tool and check operation of contacts SDE1 and SDE2	■	■	■	■	■
Check earth-fault protection function (Micrologic 6.0) or earth-leakage protection function (Micrologic 7.0)	■	■	■	■	■
Device locking					
Open and close keylocks installed on device	■	■	■	■	■
Open and close padlocking system installed on device	■	■	■	■	■
Chassis (optional)					
Remove device from chassis and put it back	■	■	■	■	■
Check operation of position contacts (CE, CT, CD, EF)	■	■	■	■	■
Check operation of safety shutters	■	■	■	■	■
Chassis locking					
Open and close keylocks installed on chassis	■	■	■	■	■
Operate padlocking system	■	■	■	■	■

Level III preventive maintenance to be performed every 2 years

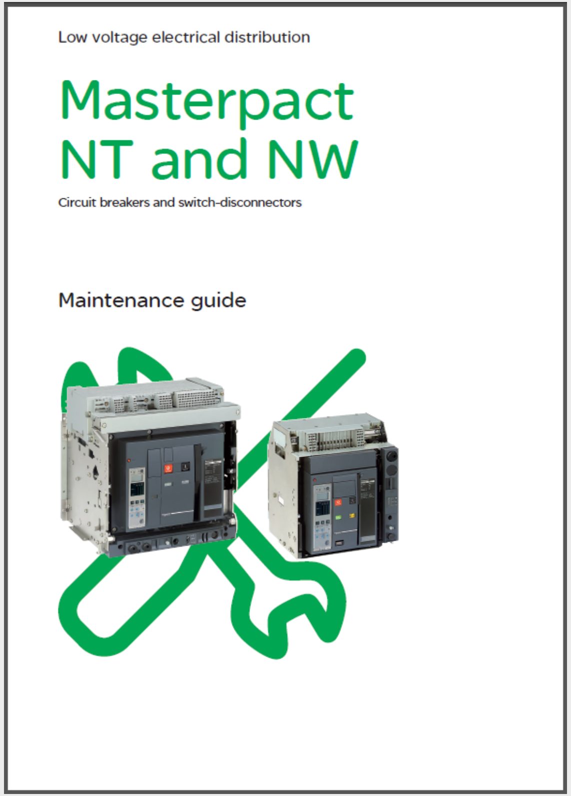
Check	Year 1	2	3	4	5 (1)
Mechanism					
Check gear-motor charging time at 0.85 Un		■		■	■
Check general condition of mechanism		■		■	■
Breaking unit (arc chutes + contacts)					
Check condition of breaking unit		■		■	■
Control auxiliaries					
Check operation of indication contacts (OF / PF / MCH)		■		■	■
Check closing operation of control auxiliary XF at 0.85 Un		■		■	■
Check opening operation of control auxiliary MX at 0.70 Un		■		■	■
Check operation of control auxiliary MN/MNR between 0.35 and 0.7 Un		■		■	■
Check delay of MNR devices at 0.35 and 0.7 Un		■		■	■
Check MX tripping time		■		■	■
Control unit					
Check tripping curves using test tool, signallling LED (tripped, overload) Save results on PC		■		■	■
Chassis (optional)					
Dust and regrease chassis		■		■	■
Regrease disconnecting-contact clusters and cluster supports (specific case of corrosive atmospheres)		■		■	■
Check the position of the key on the cluster		■		■	■
Power connections					
Check and tighten loose connections		■		■	■

Level IV manufacturer diagnostic and replacement of components to be performed every 5 years

Check	Year 5	10	15	20	25
Case					
Measure insulation resistance	■	■	■	■	■
Mechanism					
Check tripping forces (crescent shaped part)	■	■	■	■	■
Breaking unit (arc chutes + contacts)					
Measure resistance of input/output contact	■	■	■	■	■
Control auxiliaries					
Check the service life of the auxiliaries XF, MX, MN	■	■	■	■	■
Control auxiliaries replacement XF, MX, MN (1)			■		
Micrologic control unit					
Save protection settings, log events (Micrologic P and H), and edit reports.	■	■	■	■	■
Check continuity of the tripping chain by primary injection for each phase	■	■	■	■	■
Check DIN/DINF tripping using performer test tool	■	■	■	■	■
Check operation of thumbwheels	■	■	■	■	■
Check the service life of control unit	■	■	■	■	■
Micrologic replacement (1) (2)			■		
Chassis (optional)					
Clean and regrease racking screw (NW only)	■	■	■	■	■
Check connection/disconnection torque	■	■	■	■	■
Communication module and accessories					
Test the device control, the uploading of contact status (OF, SDE, PF, CH) operation of optical link , by using the communication Bus	■	■	■	■	■
Test the uploading of chassis position contacts, the synchronisation of the address between BCM and CCM, the forced replication of the BCM address, by using the communication Bus	■	■	■	■	■
Test the writing of data into Micrologic by using the communication Bus	■	■	■	■	■

Maintenance Fundamentals

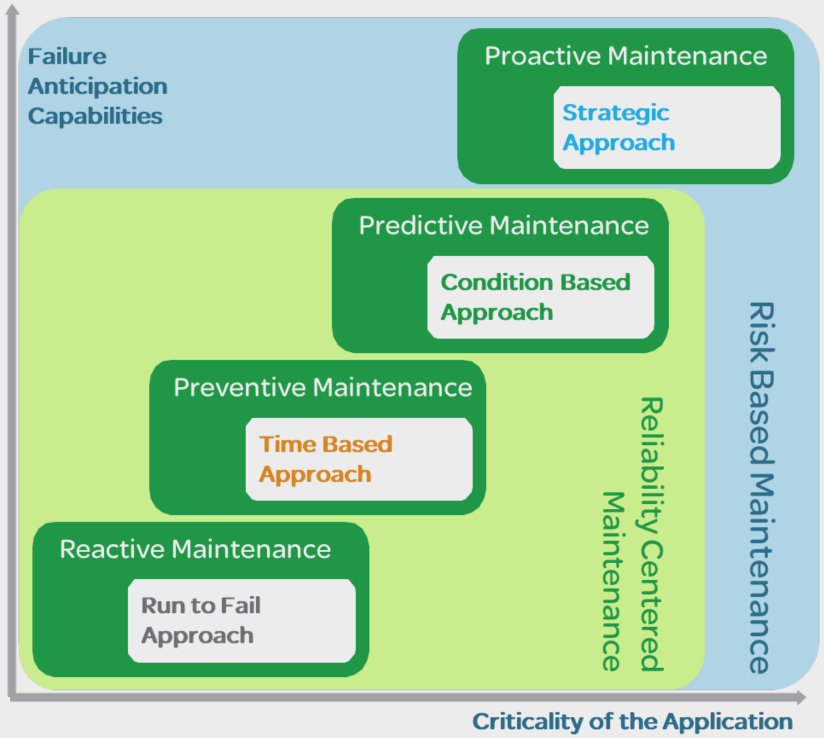
Full preventive maintenance schedules



Maintenance Fundamentals

Predictive maintenance of LV air circuit breakers

Maintenance maturity curve



Predictive Maintenance

Condition Based

From CSA Z463-13

…The fundamental difference between PdM and PM is that PdM is used to define necessary maintenance tasks based on quantifiable material or equipment conditions.

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- Perform maintenance where and when it's needed
- Minimize inventory by ordering parts on a timely (demand based) basis.
- Maintenance of downstream equipment can be optimized (not driven by the upstream shutdown schedule)
- Enable asset optimization through adaptation to operating and equipment conditions
- Avoid unnecessary maintenance and shutdowns

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- Increased initial investment in diagnostic equipment and staff training in the use of such equipment
- Savings can be hard to recognize by management, particularly in the short term
  - *Consider completing a cost/benefit analysis to communicate the potential savings*

Causes of Accelerated Aging

Influence of the environment

A device placed in a given environment is subjected to its effects.

The main environmental factors that accelerate device aging are:

- temperature
- percent load
- current harmonics
- relative humidity
- salt environment
- dust
- corrosive atmospheres
- vibration

….plus time can lead to

Thermal cycling stress

Corrosion/Oxidation

Gear/Linkage seizure

Grease Hardening

Fretting

Electro-migration

Etc..

Influence of operating conditions

Operating conditions directly affect the service life of switchgear due to the limited electrical and mechanical endurance levels of the various subassemblies.

Operating conditions include:

- **the number of operating cycles**
- **the interrupted currents**

Mechanical Wear & Electrical Wear

Circuit Breaker Modernization

Upgrading end-of-life infrastructure

Renew: Modernization

Why Upgrade?

Maintenance Costs

- Existing circuit breakers require periodic maintenance and overhaul
- Many components for the existing breakers are no longer supported

Reliability

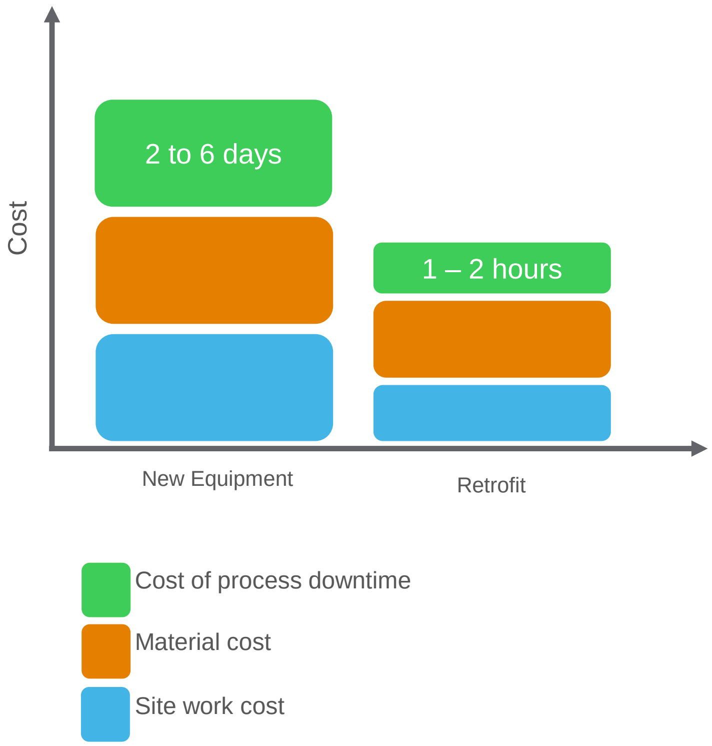
- Dash-pot style trip devices on existing breakers have high failure rates
- Failure of aging materials
- Existing breakers are more susceptible to foreign material contamination

Ratings/Performance

- Higher Fault Current Interruption
- Advanced Trip Units

Enhanced Safety Features

- Circuit Breaker Racking Thru-the-Door
- Arc Flash Limiting capability
- Shutter mechanism



A retrofit approach offers cost advantages in

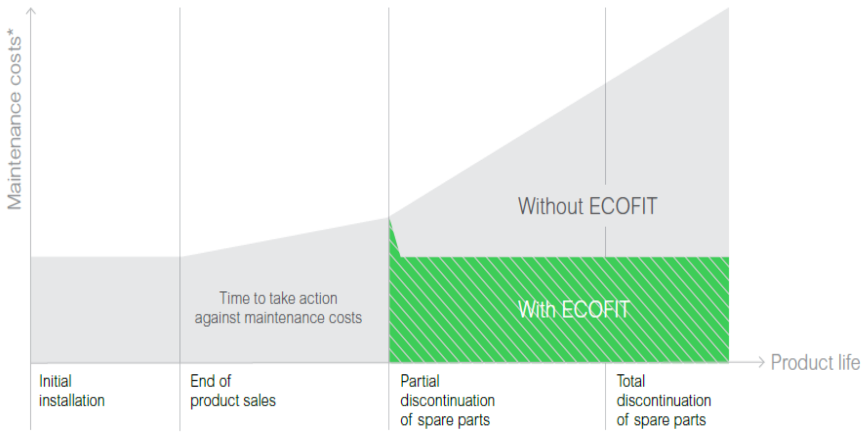
- Materials
- Lost production time
- Site preparation

Renew: Modernization

Why Retrofit instead of buy all new product?

- New Product requires
  - New switchgear
  - New footprint
  - Cabling
  - Resulting in extra cost and downtime
  - Must update to latest code requirements

- Retrofit allows you to
  - Buy only the equipment you need
  - Maintain existing switchgear footprint
  - Reduce downtime



*Based on previous data. Not a guarantee of future performance or performance in your particular circumstances.

Renew: Modernization

Benefits of a Direct Replacement or Retrofill Solution

- Enhances electrical system reliability
- Equipment footprint is not affected
- Requires minimal downtime for installation
- Lowers maintenance and operating expenses
- Eliminates the challenge of locating obsolete parts
- Each project is installed, tested and commissioned by experienced technicians

Renew: Modernization

Molded Case Circuit Breakers and Fuses

Retrofill Process:

- Retrofit existing breakers/Supply & Install Retrofill kit
- Reuse existing interior or Brand new interior with new breakers
- Installation then requires an extended bus outage which may range from 5 – 10 hours
- Switch-to-breaker conversions require a study for trip unit settings

Benefits:

- Improved functionality
- Improved electrical system reliability

* A brief outage to confirm key dimensions will be required

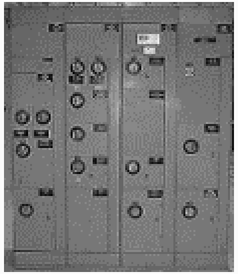
Renew: Modernization

Motor Control Center (MCC) Refurbish

In most cases, there is retrofit potential for MCC buckets of vintage and current style MCCs of all OEMs

- Square D Model 4
- Westinghouse and Cutler-Hammer: Type W
- Allen-Bradley: 2100 Centerline
- ITE – Gould – Telemecanique: 5600 Series, Imperial
- General Electric: 7700, 8000
- Klockner Moeller

Cutler-Hammer



ITE-Gould

Square D

Renew: Modernization

Motor Control Center Upgrade

- Solid-state overload
- Upgrade to an intelligent MCC with a multi-network overload
    - Digital Display can be mounted on the door to minimize need for opening door
- Solid-State Starter (Soft-Start)
- Variable Frequency Drives
    - Upgrade processes
    - Improve energy efficiency

Rear view of bucket with stab assembly

Front view of MCC

Modernization: New Features

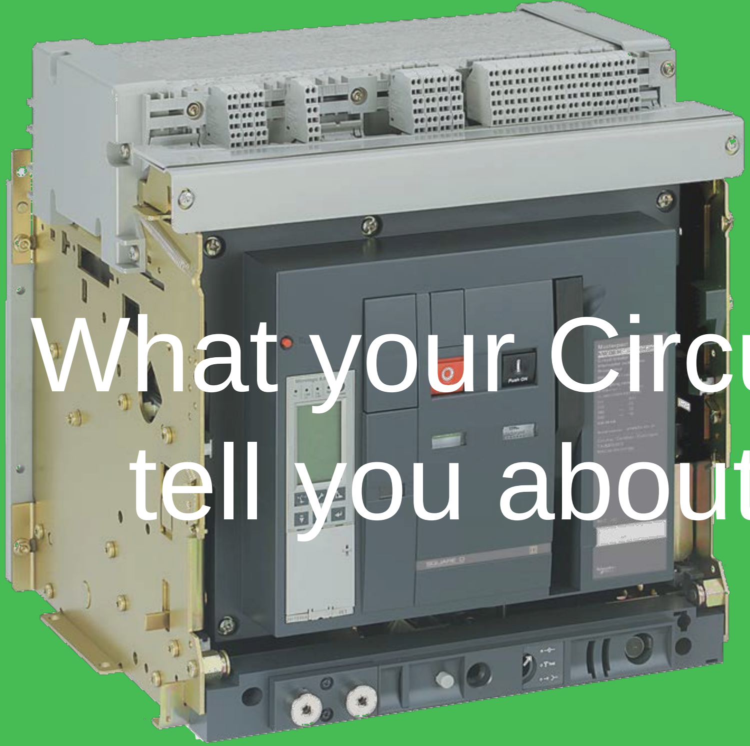
Cost-effective metering circuit breakers allow you to monitor, analyze, and adjust

- Reduce energy consumption:

- Identify large consumers of energy
- Break down costs
- Raise user awareness
- Report costs to management/accounting
- Choose utility contract best adapted to needs
- Control kVar consumption and avoid power factor penalties

- Optimize energy costs:

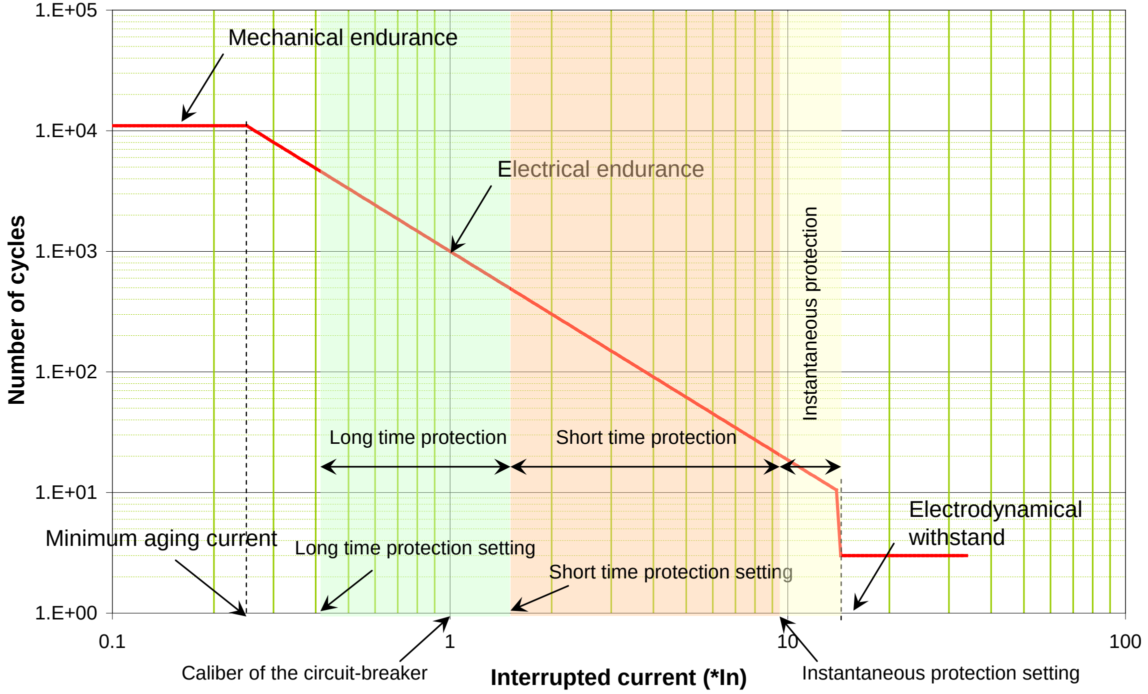
- Identify available power reserves
- Balance loads between various parts of the network
- Manage consumption peaks and avoid penalties



What your Circuit Breaker can tell you about its condition

Mechanical and Electrical Breaker Endurance

Defined by four parameters



- The mechanical endurance E_M
- The electrical endurance E_E
- The minimum aging current $I_{\min}$
- The electro dynamical withstand T_{ED}

The current is given as a fraction of the nominal current of the circuit-breaker.

When interrupted current is below I_{min}, we consider that aging is not impacted by current and the endurance is the mechanical endurance for the device.

When interrupted current is above T_{ED}, the endurance is the number of guaranteed short-circuits trips which is 3 operations.

Between these two values, the circuit-breaker endurance for a constant interrupted current is given by

$$E(I) = E_E \cdot \left(\frac{E_M}{E_E} \right)^{\frac{\ln I}{\ln I_{\min}}}$$

Life Is On | Schneider Electric