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TECHNICAL REPORT

Maintenance of low voltage switchgear and controlgear and their assemblies

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MAINTENANCE OF LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR AND THEIR ASSEMBLIES

FOREWORD

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IEC TR 63482 has been prepared by IEC technical committee 121: Switchgear and controlgear and their assemblies for low voltage. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
121/160/DTR	121/165A/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1 and ISO/IEC Directives, IEC Supplement, available at www.iec.ch/members_experts/refdocs. The main document types developed by IEC are described in greater detail at www.iec.ch/publications.

The committee has decided that the contents of this document will remain unchanged until the stability date indicated on the IEC website under webstore.iec.ch in the data related to the specific document. At this date, the document will be

- reconfirmed,
- withdrawn, or
- revised.

INTRODUCTION

In the low-voltage domain, the evolution of the IEC 61439 series of standards (low-voltage switchgear and controlgear assemblies) incorporating devices according to IEC 60947 series (low-voltage switchgear and controlgear) have contributed significantly to improve safety, the performance and reliability of assemblies and power availability of low-voltage energy.

The IEC 61439 series is essentially dedicated to design and verification of assemblies up to the delivery to the customer. Most applications use assemblies to run 20 years or more. Over such long periods, without suitable maintenance, the performance of an assembly can be affected and unacceptably deteriorate with serious consequences for the safety of people and the application.

To minimize the risk of malfunction due to ageing of the low-voltage assemblies some type of maintenance is implemented depending on local rules, customer maintenance policy or assembly manufacturer instruction relating to the assembly or the built-in components within the assembly. Traditionally, maintenance is scheduled and has been predefined using a fixed schedule. To avoid malfunctions, the schedules are usually conservative.

As new technologies emerge, providing new functionalities and possibilities, for example measurement of equipment temperatures, loads including harmonic content, currents interrupted, climatic conditions, alternative and more effective maintenance approaches are possible. A preventive maintenance approach using such technologies can be more cost effective and less disruptive than the traditional schedule-based maintenance arrangements.

This document sets out the basic maintenance considerations for low-voltage switchgear, controlgear and their assemblies, which is supplemented by the assembly manufacturer's instructions. It recognises that the traditional basic approach of maintenance can be improved and enhanced. This document shows that it is possible to provide one suitable maintenance approach depending on the current customer's application, but it is also possible to move to a more advanced maintenance approach, if an assembly is suitably upgraded.

NOTE It is beneficial to refer to individual product standards and/or manufacturer instruction for further information on devices incorporated in an assembly.

MAINTENANCE OF LOW-VOLTAGE SWITCHGEAR AND CONTROLGEAR AND THEIR ASSEMBLIES

1 Scope

This document provides guidance for the specification and selection of the appropriate approach and for the planning and the execution of the maintenance of low-voltage switchgear and controlgear and their assemblies having a rated voltage up to and including 1 000 V AC or 1 500 V DC, and designed for a nominal frequency of the incoming supply or supplies not exceeding 1 000 Hz.

This document provides guidance on the safety precautions for personnel designed to carry out maintenance services, with the aim to minimize the safety risks, optimize service continuity (power availability) and contribute to the environment of a low-voltage switchgear and controlgear assemblies. It recognises there are different approaches to maintenance, e.g. scheduled maintenance, condition-based maintenance and predictive maintenance. This document does not consider specifically corrective maintenance but many of the recommendations included would apply when carrying out corrective maintenance. It provides additional recommendations to comply with validation requirements in IEC 60364-6.

This document explains how the use of preventive maintenance improves the efficiency and lifetime of built-in components and consequently the assemblies themselves. All parties (specifiers, owners, designers, manufacturers, maintenance personnel) involved with low-voltage switchgear and controlgear assemblies can benefit from this document.

This document applies to both stationary and movable switchgear and controlgear assemblies with or without an enclosure. It is also applicable to switchgear and controlgear assemblies intended for use under special service conditions, possibly with additional recommendations, for example in ships and rail vehicles. It also applies to low-voltage assembly upgrades which can have additional considerations to ensure modifications are fully verified to the appropriate assembly standard.

This document does not apply to low-voltage switchgear and controlgear assemblies used in potentially explosive atmospheres.

Finally, this document is not a substitute for national regulations regarding the safety of electrical equipment and for the manufacturer's maintenance instructions. These are required to complement the overall principles defined in this document.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document, the terms and definitions given in the IEC 61439 series, the IEC 60947 series and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
maintenance
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

Note 1 to entry: Management is assumed to include supervision activities.

[SOURCE: IEC 60050-192:2015, 192-06-01]

3.2
corrective maintenance
maintenance carried out after fault detection to effect restoration

[SOURCE: IEC 60050-192:2015, 192-06-06]

3.3
preventive maintenance
maintenance carried out to mitigate degradation and reduce the probability of failure (of an item)

[SOURCE: IEC 60050-192:2015, 192-06-05]

3.3.1
scheduled maintenance
preventive maintenance carried out in accordance with a specified time schedule

Note 1 to entry: Scheduled maintenance may identify the need for some corrective maintenance action.

[SOURCE: IEC 60050-192:2015, 192-06-12, modified: the term preventive has been added]

3.3.2
condition-based maintenance
preventive maintenance based on the assessment of physical condition

Note 1 to entry: The condition assessment may be by operator observation, conducted according to a schedule, or by condition monitoring of system parameters.

[SOURCE: IEC 60050-192:2015, 192-06-07]

3.3.3
predictive maintenance
advanced form of preventive maintenance using data analysis tools and techniques to predict anomalies in operation and anticipate malfunction to extrapolate the residual time before the failure

3.4
digital twin
virtual representation in a digital format of a product or a system

Note 1 to entry: In this document, digital twin can be used for design, simulation, optimization or maintenance purposes using real time data throughout lifetime of product or system.

3.5
mean time to restoration
MTTR
DEPRECATED: mean time to repair
DEPRECATED: mean time to recovery
expectation of the time to restoration

[SOURCE: IEC 60050-192:2015, 192-07-23]

4 Recommended safety measures

4.1 Local regulations

Local regulations can differ from country to country. When local regulations and legal obligations are in place, they take precedence over this document and the manufacturer's maintenance instructions.

See Annex B for list of notes concerning certain countries.

4.2 Appropriate skill level for maintenance

Unless required otherwise by national or local regulations, maintenance tasks are carried out by people with the appropriate level of competency: instructed persons, skilled persons or skilled persons mandated by the assembly manufacturer. See Table 1.

4.3 Good practice and procedures for establishing a safe working environment

4.3.1 Working procedures

The risk assessment prior to commencing work is the recognized method of identifying safety risks. For maintenance activities on equipment, there is usually a written system of rules and procedures and all personnel involved with maintenance activities are aware of their existence. The level of detail and complexity of the rules and procedures is dependent on the organisation, personnel, working environment and equipment to be used. The risk assessment process is used to ensure that hazards specific to maintenance activities have been adequately addressed in the development of the associated rules and procedures. For example, different working practices and competencies are required for work on DC systems than are required for AC systems. Safety rules set out the principles and practices expected clearly and in a format that can be understood by those expected to use them. The rules and procedures reflect the requirements of an overall electrical safety policy. In most circumstances a policy for working on electrical equipment requires equipment to be deenergised and isolated prior to work commencing.

Safety rules addressing specific issues such as circuits associated with:

– interlocking and padlocking supplies;
– auto-reclosing devices;
– alternative supplies including generators, battery supplies, photovoltaic (PV), wind power;
– mechanically stored energy;
– capacitively stored energy; and/or
– control supplies (AC and DC).

All personnel are made aware to take notice of warning signs and follow instructions provided by the assembly manufacturer.

Product standards are recommended to include minimum requirements for the maintenance instructions to be provided by the manufacturer.

4.3.2 Emergency exits

Emergency exits are checked prior to carrying out maintenance work to ensure that they are clear.

4.3.3 Fire extinguishing equipment

When carrying out maintenance on equipment where there is a fire risk, fire-fighting equipment is readily available. Training is provided in the use of such appliances; personnel are made aware of the limitations of their use and how to raise the alarm and summon help.

The type of fire extinguishing equipment provided for use on electrical equipment is compatible with the equipment and not dangerous to use in the situation.

Where automatic fire extinguishing installations are provided, systems are in place to safeguard people against danger from the extinguishing medium when entering the protected area.

Where maintenance is planned on an electrical switchgear or controlgear assembly connected to the electrical supply to the fire-fighting installation, attention is paid to the possible impact of that maintenance on the availability of the fire-fighting equipment. Where necessary, additional fire-fighting equipment is provided.

4.3.4 First aid

Rapid action can save life in the event of electric shock. Personnel working in the vicinity of exposed live parts is normally accompanied by someone who has the necessary competence to avoid injury and sufficient knowledge to be able to disconnect the supply. Personnel carrying out maintenance are aware of how to obtain assistance and who to contact in the event of an emergency.

A notice giving instructions for the treatment of persons suffering from electric shock is affixed in a prominent position in the vicinity in which work on electrical installations will be carried out. The training of electrical maintenance personnel or those who might accompany them in resuscitation is recommended.

Arrangements are in place to ensure immediate attention is available in the event that someone is taken ill or injured at work. As a minimum a suitably stocked first aid kit is available. It is important that the arrangements for seeking assistance or calling the emergency services are understood.

4.3.5 Lighting

Lighting is provided to ensure safe access and working. Temporary lighting, either battery powered or from generators, is provided where normal supplies are not available. Special attention is given to the continuity of lighting for emergency exits.

4.3.6 Access

Working space and access ways are kept free from obstruction. Particular consideration is given where live conductors are exposed within the work environment. There is space to allow people to move away from the conductors without hazard and if necessary for people to pass one another.

NOTE See 729.410.3.7 of IEC 60364-7-729:2007 for further information.

Where equipment to be worked on is located in a general work area, special attention is paid to prevent access by unqualified personnel, especially whilst covers are open.

4.3.7 Isolation before and during maintenance work

Whenever it is possible to do so, equipment is isolated before maintenance work commences. Isolation procedures ensure that:

a) accidental or inadvertent re-energization is prevented;

b) equipment is proven to be deenergized e.g. using a suitable voltage indicator.

A device suitable for isolation is provided to prevent any equipment from being unintentionally energized. Such precaution includes usually a selection of device suitable for padlocking in the OFF position as well as a notice or label applied at the place of isolation to inform others who might also be performing maintenance work that someone is working on the equipment.

The following recommendations can be considered:

– Use any device suitable for isolation.

– Where provision is provided, this device is locked in the OFF position and/or caution notices are exhibited at the points of isolation.

– Where possible, devices with earthing facilities are placed in EARTH position and locked.

– Any shutters covering live, or potentially live isolating contacts are locked closed or other precautions taken to ensure safety.

– Safety locks are used, and a system put in place to ensure that locks and notices are available and that the keys to locks in use are controlled.

– Where removal and retention of fuse links or bolted links are used as the only means of isolation, then precautions are taken to prevent duplicates being inserted.

– Contactors are never considered as a means of isolation.

– Reliance is never placed on control circuit isolation, switching or electrical interlocks to prevent accidental or inadvertent re-energization of the main or other auxiliary circuits, e.g. emergency stops.

– It is not always possible to observe the contacts of a device used as a disconnector and the operation of an external handle or control is not assumed to have opened all contacts of the connected device. Tests using voltage indicator are carried out prior to working on any deenergized equipment. These tests include verifying voltages between live parts and earth to guard against the possibility of a wrong connection. The equipment used for checking voltage are to be tested, in a safe manner, for example against a known voltage source to confirm that it is working correctly.

– Equipment often contains circuits having sources of supply different from those of the main circuits. Examples include alarm and sequence interlocks, heating and lighting circuits, battery supplies. Such circuits are not always isolated when the main disconnector is in the OFF position. These are identified with warning notices and ideally shrouded to prevent inadvertent contact. Particular care is taken to avoid danger from reverse energization of voltage/control transformers or the open circuiting of current transformer secondaries.

– Where a form of internal separation is used to facilitate access to one functional unit for maintenance or other operations, while adjacent function units are in service, suitable additional precaution are in place, e.g. use of appropriate personal protective equipment (PPE), adequately skilled personnel to ensure the work can be undertaken safely.

4.3.8 Working on live equipment

The likelihood of an occurrence and the severity of injuries that can occur due to electric hazards when undertaking work on or near live equipment are such that working on live equipment is rarely permitted.

Where it is not possible and/or acceptable for an equipment to be deenergized, special precautions are usually applied. The special precautions depend on the design of the equipment, the nature of the task and the outcome of a risk assessment. The working area is restricted to authorised personnel (skill level 1 or 2; see Table 1). The level of supervision and the accompaniment is taken into account. Further information for selection of tools and clothes is given in IEC 61482-2:2018.

4.3.9 Insulating equipment

Permanent and/or portable insulating stands or screens, insulated tools and insulating gloves are provided and used where necessary. All these items are maintained in sound condition and periodically inspected. The personnel responsible for the maintenance task verify, prior to use, that all these items and any test equipment are suitable and serviceable.

4.3.10 Earthing equipment

Earthing equipment, where required, is available and maintained in good working order. Earthing is performed by wearable accessories compliant to IEC 61230 or dedicated switching device compliant to the relevant IEC 60947 standard. Suitable earthing equipment outside the assembly adjacent to relevant loads or circuits can be used when maintenance is being carried out.

4.3.11 Stored electrical energy

Measures are taken to discharge sources of stored energy, such as cables or capacitors and to ensure that they do not become charged during the execution of maintenance work. Suitably designed equipment is used to discharge stored energy. Earth leads might be used to prevent charge accumulating during the work activity.

4.3.12 Associated section of the installation

When performing functional testing on switchgear and controlgear assemblies care is taken to ensure that danger is not caused by energizing the connected load. It might be necessary to disconnect motors or other items of the electromechanical loads before testing the functionality of the control equipment. This could be achieved with the installation of an enclosed load break switch disconnector close to the motor. Advice from the plant operator is also considered. The use of earthing equipment (4.3.10) is highly recommended when stored electrical energy is present.

4.3.13 Portable electric tools and inspection lamps

Portable electric tools and inspection lamps are operated at extra-low voltage. For system voltages, see IEC 60364-4-41:2005, 414. In confined conducting spaces, apparatus with an operational voltage of 25 V to earth or lower are used, see IEC 60364-7-706. Where mains voltage portable tools are used, they are all insulated or double insulated construction and protected by a residual current device with an operating current not exceeding 30 mA and without intentional delay.

Cable connectors are designed for the environment in which they are operating. All portable electrical equipment is regularly inspected and tested. It is a good practice for the user to inspect portable electrical equipment before each occasion of use.

4.3.14 Testing instrument

Care is taken when applying test voltages to ensure that these are the lowest value required for the purpose with the minimum current output. Where equipment is capable of storing a charge, this equipment is safely discharged after every test.

Instruments are of a type suitable for the measurements that are to be made so that a malfunction or the introduction of transients and/or reversed polarities into the connected circuits is avoided. The manufacturer's instructions are followed.

An earthed instrument lead can create danger if it is applied to an active signal circuit that is normally floating. The instrument casings are usually earthed at all times but, where the nature of the test precludes this, specific care is taken by the operator to secure their own safety and that of others by the adoption of a safe system of work. Suitably protected test leads are used at all times.

4.3.15 Avoidance of contamination

The ingress of moisture, dust, vermin, etc. into an electrical equipment can occur during normal operation or periods when the assembly is out of service. This contamination can cause malfunction and danger. Maintenance includes an inspection for such contamination and appropriate action to remove it from the assembly.

4.3.16 Temporary safety signs or labels

Legible temporary safety signs and/or labels are placed as necessary.

5 Maintenance contributes to circular economy

5.1 General

Equipment maintenance is well recognized to be an important aspect of power availability, electrical safety and reliability of equipment. Maintenance can also be considered as a major topic for circular economy. A good management of category of maintenance can extend the service life of built-in components of an assembly and consequently the assembly itself, but also optimize material usage and reduce waste. See also IEC 63058 dealing with environmental aspects.

5.2 Maintenance to extend lifetime

5.2.1 General

Circular economy brought a new approach to the use of components and/or devices. Consideration of production / consumption / end of life is being substituted by a new approach where the product life cycle is fully considered from its initial concept to its end of life as applicable.

5.2.2 Maintenance to reduce carbon footprint

Performing the relevant maintenance on a device reduces it replacement by new parts and decreases the waste of material. Carbon footprint is becoming a differentiator of increasing importance for specifiers and an additional performance criterion in the choice of an electrical equipment.

Extending the service life of a device or assembly does not affect the carbon footprint of the construction phase but affects the carbon footprint value of the operation phase. Comparing with scheduled maintenance, the condition-based maintenance and predictive maintenance provide means of optimizing the carbon footprint, while maintaining the high level of electrical safety and power availability.

5.2.3 Maintenance to maximise material efficiency

Maintenance plays an essential role in extending the lifetime of equipment, thereby decreasing waste. When reliability becomes a priority, it is essential to adjust the maintenance strategy with that goal in mind.

Adapting maintenance actions to be performed based on the conditions of use brings value to the customer by saving time, reducing downtime and maximising the overall material efficiency.

Beyond ordinary schedule maintenance, condition-based and predictive maintenance contributes to adding value to the customer by saving time, reducing downtime but also enabling maximum the overall material efficiency. Thus, depending on demands, different type of maintenance can be analysed to determine the most suitable maintenance strategy. See 7.2.

5.3 Reused, refurbished and remanufactured products

Reused, refurbished and remanufactured products can be used both at one stage to build a new assembly or for any stage of any maintenance step.

Several levels of product quality service are possible, for example:

– Reused products: according to the documentation of original manufacturer the products have safety check up before being delivered to customers;
– Refurbished products: according to the documentation of original manufacturer the products have a safety check up with replacement of damaged parts before being delivered to customers;
– Remanufactured products: according to the documentation of original manufacturer the products have a safety check up with replacement of all accessories and all damaged parts. They are re-certified based on their latest product standard, e.g. IEC 60947-2 for a circuit-breaker. If they do not pass the test they are replaced by a new product.

6 Electrical preventive maintenance

6.1 General

Equipment ageing, part of its design life, is taken into account with a necessary maintenance activity to delay equipment failure. As soon as new equipment is installed, a process of normal deterioration begins. Unchecked, the deterioration process can cause malfunction or an electrical failure. Deterioration can be accelerated by factors such as a hostile environment, overload, or severe duty cycle. An effective electrical preventive maintenance program identifies and recognizes these factors and provides measures for coping with them.

6.2 Values and benefits of electrical preventive maintenance

An electrical preventive maintenance service reduces incidents and minimizes breakdowns and unplanned shutdowns of production equipment. Potential issues can be identified, and solutions applied, before they become major problems requiring more expensive, time-consuming solutions.

The benefits from preventive maintenance are twofold:

– Safety, as a result of documentation giving appropriate inspection, testing and repair procedures;
– Ensuring a better power availability by reducing the downtime of the equipment.

7 Maintenance category of assemblies

7.1 General

The three preventive categories of maintenance described in this document are sometimes joined with a fourth category, corrective maintenance. With a strategy to use only corrective maintenance, no regular verifications and maintenance are carried out on the equipment. This category is not included in this document since it is generally intended for equipment whose repair is quick and easy, and the MTTR does not result in a significant loss of production.

Maintenance incorporating remote monitoring is to determine deterioration and facilities for corrective adjustments carried out either locally or remotely.

7.2 Preventive maintenance categories

7.2.1 Scheduled maintenance

Scheduled maintenance is a type of maintenance, carried out at established intervals in time. It is a scheduled activity consisting of a series of systematic actions based on the assumed operating conditions and expected life of the assembly and its components.

Scheduled maintenance enables the planning of interruptions for maintenance, thereby minimising the costs associated with loss of production and allowing power to be available to the connected loads, when expected.

7.2.2 Condition-based maintenance

Condition-based maintenance is a flexible maintenance method that monitors the condition of equipment to determine the type and frequency maintenance task that can be carried out. Thanks to additional sensors in the equipment, they provide data to some forms of alarm/management system and allowing the time interval between two interventions to be reduced or extended as appropriate. For low-voltage switchgear and controlgear assemblies, the maintenance required can be based on one of a number of parameters, for example, the number of mechanical operations, the number of over-current trips, loading, ambient environment data (temperature, dust, salt content in the atmosphere, etc.), current harmonics, increase of residual current, low power quality.

7.2.3 Predictive maintenance

Predictive maintenance relies upon multiple sensors in and around the assembly frequently (hourly, daily) reporting data to a central processor able to simulate and trend ageing, based upon the real operating conditions of the assembly, to estimate the remaining time before failure and the new schedule of maintenance.

Digital twins can use predictive models with/without machine learning including deep learning, and other technologies to predict when maintenance is necessary. Predictive maintenance generally reduces the amount of maintenance by limiting it to that which is necessary for the assembly in its actual working environment.

NOTE For other general definitions of maintenance see also EN 13306.

8 Implementation and management of maintenance

8.1 General

Throughout its working life an assembly will undergo appropriate maintenance. Subject to the manufacturer's documentation, maintenance of devices and assemblies is either scheduled, condition based, predictive or a combination of two or more the types of maintenance. For an example of a maintenance plan see Annex A.

It is good practice to make sure software is available and can be modified as necessary, throughout the necessary anticipated lifetime of the assembly. Equally, necessary spares are available when required.

Preventive maintenance is organized on the basis of inspections supplemented with operational checks followed by examination. The inspections and checks are of such a frequency to ensure that no undue damage or excessive wear is sustained in the course of operations since the last maintenance action. Examinations can be carried out to evaluate the possibly for reconditioning of the contact systems, lubrication and adjustment of mechanisms or deterioration of insulation. The appropriate intervals for examination are determined from the outcome of inspections or operational checks or are based on manufacturer's documentation, taking into account operating duty, environmental conditions and the potential effects of failure. Inspection and testing of insulation are undertaken during examination. The different maintenance operations are based on different level of skills.

8.2 Skill levels

8.2.1 General

Various levels of knowledge and skills are necessary for maintenance of devices and assemblies. For the tasks to be carried out, the level depends essentially upon the:

– Existing risk in the execution of the task (complexity);
– Specialist knowledge on devices, assemblies and software;
– Equipment and tools necessary to perform the maintenance.

Generally, this leads to three levels of skill, see Table 1, and as detailed in 8.2.2 to 8.2.4.

NOTE It is good practice for assembly manufacturer to provide maintenance documentation in line with maintenance activity and the three levels of skill detailed in 8.2.2, 8.2.3 and 8.2.4.

8.2.2 Skill level 1

Tasks are simple actions undertaken by an instructed person following simple instructions and without exposure to hazardous live parts. Examples of the tasks as:

– cleaning of the assembly;
– visual inspection of the operation of displays (indicator lights, actuators, mechanical indicators, etc.);
– visual inspection of barriers, shutters, covers doors and door locks;
– visual inspection of conditions (temperature, dust, humidity, etc.);
– visual inspection of mains and auxiliary cable conditions and their terminations;
– confirming protection settings are in accordance with the protection scheme;
– replacing fan filter in assemblies with forced ventilation.

8.2.3 Skill level 2

Tasks are complex, require knowledge, training, supporting information and engineering judgment. They are undertaken by a skilled person who understands the risks associated with partially energised equipment. Examples of the tasks as:

– they are undertaken by a skilled person who understands the risks associated with energised equipment;
– verification insulation, busbar joints according to maintenance documentation;
– verification of effective earth continuity according to maintenance documentation;
– reviewing the wear and of ageing of components, e.g. erosion of main contacts and arc chutes.

8.2.4 Skill level 3

Operations with procedures require the mastering of a particular technique or technology and / or the use of specialized supporting equipment. These tasks are carried out by personnel with specialist skills, for example the assembly manufacturer or an organisation with the same expertise, and include:

– Verification and update of software according to maintenance documentation;
– Incorporation of alternative devices when the original type is no longer available;
– Verification according to maintenance documentation of mechanical and/or electrical interlocks where applicable.

NOTE Due to the different specialist skill level, software related tasks and the installation of alternative devices are not necessarily carried out by the same person.

Table 1 classifies the maintenance operation in three levels in regard to their complexity and the necessary skills for each level.

Table 1 – Maintenance operation level

Maintenance skill level	Operation	People classification
Level 1	Simple actions undertaken by an instructed person following simple instructions and without exposure to hazardous live parts	Instructed person [a, b]
Level 2	Complex tasks requiring knowledge, training, supporting information and engineering judgment.	Skilled person [a, c]
Level 3	Operations with procedures requiring the mastering of a particular technique or technology and / or the use of specialized supporting equipment	Assembly manufacturer or skilled person mandated by the assembly manufacturer
[a] See IEC 61439-1. [b] The term instructed person can be considered with the term instructed person (BA4) referring to the IEC 60364. [c] The term skilled person can be considered with the term skilled person (BA5) referring to the IEC 60364.		

8.3 Maintenance instructions

As low-voltage assemblies are produced in many arrangements with a wide range of devices, it is not possible for this document to provide detailed maintenance instructions covering every arrangement of assembly. The assembly manufacturer makes available adequate maintenance instructions for each assembly produced in hard and/or soft copy. Access to maintenance instructions according to local regulation is facilitated by electronic means (QR Code, manufacturer website, etc.).

The maintenance instructions include, but are not limited to, the following details:

– technical details of the assembly including arrangement drawings and diagrams;
– recommended frequency of maintenance (fixed interval or variable depending on the type of maintenance);
– diagnostic aid supplied with the devices and assembly or provided separately;
– equipment and tools necessary to perform the maintenance;
– cleaning requirements;
– safety earthing arrangements;

- operational check to confirm satisfactory operation of the devices and assembly and all the included devices;
- how to determine the end of useful life of devices;
- service instructions for devices;
- repair instructions where applicable;
- on completion of maintenance, visual inspection and checks to be completed to confirm the devices and assembly are suitable for service;
- recommendation for installation of additional sensors if any, to respect the initial performances;
- spare parts and consumables.

8.4 Periodic verification

The frequency of periodic verification of devices depends on the criticality of the user application, environmental conditions and device operating condition. See Annex C.

8.5 Replacement parts

Many items within the assembly might not be suitable for more intrusive maintenance and better suited for visual inspection. Such items are not dismantled for examination or overhaul purposes and might be renewed periodically. Throughout the life of the equipment some components, that have worn out as a result of normal use, can be replaced. Wherever possible, components are replaced with identical new parts to ensure the original performance of the equipment is maintained. However, items can become obsolete and therefore identical replacement components are not always available. The manufacturer proposes, in some case, an alternative to maintain the original performance.

If identical replacement or manufacturer recommended alternatives are not available, it might not always be practical to replace the whole assembly and/or it might be urgent to complete a repair. In such cases, suitable alternative devices are installed by organisations/persons with the necessary specialist skills.

8.6 Re-energisation

Before re-energisation it is recommended to perform a dielectric test (power-frequency withstand test or an insulation resistance measurement) to ensure that no tools and/or parts are causing connection between live parts. The equipment is re-energized in line with the appropriate procedures in accordance with the site operations instructions. After the devices are put under load, they are re-inspected to check that they are working correctly.

8.7 Documentation and records

Work undertaken is recorded and any recommendations are reported for appropriate action.

9 Maintenance categories and associated functionalities

9.1 General

Clause 6 provides three approaches to a maintenance strategy for low-voltage switchgear and controlgear assemblies:

- category A: scheduled maintenance;
- category B: condition-based maintenance;
- category C: predictive maintenance.

The following details the steps necessary to achieve a defined level of performance over the lifetime of the assembly:

– selection of maintenance category;
– implementation of minimum functions associated with the selected category;
– verification of performances.

9.2 Maintenance category over lifetime of an assembly

To optimize the maintenance of an assembly, it is necessary to consider the overall life cycle. In fact, if the maintenance has not been considered at the design stage there is a little chance to optimize it in all other steps of the life cycle.

Example: lack of room to install additional sensors is an obstacle to optimize maintenance.

The main steps of the life cycle of an assembly can be summarized as design, build, commissioning, operation, maintenance and end of life. The necessary functions to assess a maintenance category are defined in 9.3.

9.3 Functions necessary to achieve a specific maintenance category

Table 2 specifies all the functions necessary to achieve the targeted maintenance category.

Table 2 – Functions associated with each category of maintenance

Category A	Category B	Category C
Scheduled maintenance	**Condition-based maintenance**	**Predictive maintenance**
Documentation (paper or digital) is available including the design documents of the original manufacturer and the assembly manufacturer. A maintenance schedule with maintenance reminders for the devices and the assembly is available	In addition to the scheduled maintenance (Category A): A flexible maintenance plan to the devices and assembly is available according to the measurements of sensors Monitored parameters can include but are not limited to: – Number of trips – Number of cycles – Temperature, current, t (estimated ageing) Type and number of acquisitions of information by circuit depend on the application and is subject to an agreement between the user and the manufacturer. End of life is estimated and refined according to sensors measurement values	In addition to the condition-based maintenance (Category B): Predict when maintenance is necessary on each circuit could be achieved by using: – Analysis from the output of sensors – Simulation, e.g. analysis using digital twin – Devices incorporating algorithms to predict failure and ageing behaviour Simulation of the equipment based on the architecture of the circuit. See 7.2.3. End of life is optimized and predicted based on equipment simulation

9.4 Details to be available for each category of maintenance

Table 3 provides a typical list of information available to maintenance personnel.

Table 3 – Details to be available for each category of maintenance

Category A	Category B	Category C
Scheduled maintenance	Condition-based maintenance	Predictive maintenance
Documentation: ☐ Manufacturer maintenance instruction ☐ Maintenance plan ☐ Historical maintenance records ☐…	Category A +☐ Flexible maintenance plan is available ☐ Check the parameters: ☐ Number of trips ☐ Number of cycles ☐ Temperature ☐ Current, (estimated ageing)	Category B +☐ Simulation results are available

9.5 Shift from one category to another

A move from one category of maintenance to another during lifetime of the assembly is possible. This can require integration of new devices, additional sensors, etc. For example, new software together with additional sensors could allow a move from a maintenance category A to a maintenance category B or C. Such a move usually relies upon documentation provided by the original manufacturer.

Annex A
(informative)

Maintenance plan according to maintenance level

The following Table A.1 give examples of maintenance operation related with the type of devices and the complexity of the operation of maintenance.

Table A.1 – Maintenance plan

Sub-component	Examples	Typical control and verification	Periodicity (recommended frequency of maintenance)		Level
			Category A	Category B/C	
Mechanical installation system	Panel, sub-section, drawer, barrier,	– locking mechanism efficiency	annual		1
		– barriers, separations, forms, connections, keys	annual		1
		– general aspect as cleanness, humidity, oxidation, etc.	annual		1
		– deformations (knock),	annual		1
		– dust removable	annual		1
Signalling devices	Luminous indicator, mechanical indicator, controlling devices	– lights efficiency	annual		1
		– value accuracy of measurements devices	each 2 years		2
Electrical installation system	Connections	– Temperature-rise	annual		2
		– Power joint connection: busbar, busbar connection, busbar insulating support	each 2 years		2
		– Aluminium joint connection • Bare aluminium • Coated aluminium	each 2 years		2
		– Outgoing connection: cables, terminals, mechanical wiring,…	annual		2
		– Connector, jaws, sliding contacts…	annual		2
		– Auxiliary connection	annual		2

Sub-component	Examples	Typical control and verification	Periodicity (recommended frequency of maintenance)		Level
			Category A	Category B/C	
Devices	Breakers, contactors,	– updating of equipment devices – updating of software	annual each 2 years		1 2
Equipment for measurement, analysis, and control			according to evolution of regulation or national code		3 3

Annex B
(informative)

List of notes concerning certain countries

Subclause	Text
4.1	In Canada several standards deal with maintenance and safe work on electrical equipment, this document provides additional information and guidance when read in conjunction with: Z460 Control of hazardous energy – lockout Z462 Workplace Electrical Safety Z463 Maintenance of electrical systems.
4.1	In the UK the Electricity at Work Regulations take precedence over this document. This document provides additional information and guidance when read in conjunction with the British Standard, BS 6423: Code of practice for maintenance of low-voltage switchgear and controlgear.
4.1	In RU, the “Rules for the technical operation of electrical assemblies, of consumers” and the “Rules for the installation of electrical assemblies, Ed 7” take precedence over this document.
4.1	In the United States of America this document provides additional information and guidance when read in conjunction with: NFPA 70B Standard for Electrical Equipment Maintenance NFPA 70E Standard for Electrical Safety in the Workplace
4.1	“DGUV Vorschrift 3 (BGV A 3) Unfallverhütungsvorschrift Elektrische Anlagen und Betriebsmittel“ and “DGUV Vorschrift 4 (GUV-V A 3) Unfallverhütungsvorschrift Elektrische Anlagen und Betriebsmittel mit Durchführungsanweisungen” take precedence over this document. This document provides additional information and guidance when read in conjunction with the German Standard, DIN VDE 0105-100: Operation of electrical installations – Part 100: General requirements

The assembly manufacturer provides recommendation of frequency maintenance program. See also 6.5.2 of IEC 60364-6: 2016.