

TECHNICAL SPECIFICATION

**Electric energy supply networks – General aspects and methods for the
maintenance of installations and equipment**

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TECHNICAL SPECIFICATION

Electric energy supply networks – General aspects and methods for the maintenance of installations and equipment

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**ELECTRIC ENERGY SUPPLY NETWORKS – GENERAL ASPECTS
AND METHODS FOR THE MAINTENANCE OF INSTALLATIONS
AND EQUIPMENT**

FOREWORD

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Technical Specifications are subject to review within three years of publication to decide whether they can be transformed into International Standards.

IEC TS 63060, which is a Technical Specification, has been prepared by IEC technical committee 8: System aspects of electrical energy supply.

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

Enquiry draft	Report on voting
8/1470/DTS	8/1488/RVDTS

Full information on the voting for the approval of this Technical Specification can be found in the report on voting indicated in the above table.

This document has been drafted in accordance with the ISO/IEC Directives, Part 2.

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

- transformed into an International Standard,
- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

A bilingual version of this publication may be issued at a later date.

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INTRODUCTION

Maintenance (MA) and maintenance support provide an important contribution to ensure the reliability of components and electric installations throughout their operating life cycle. The correct functionality, performance, and reliability will be achieved by providing the necessary maintenance in conjunction with adequate design, construction, maintainability and installation quality, and by their proper usage. Other parameters besides maintenance affect the safe, secure, and reliable operation of electricity networks. For example: network topology, spare parts, new investment, technology, network conditions, know-how, staff, etc. The option(s) used is/are the responsibility of the company.

The extent and type of maintenance and maintenance support correspond to the type of equipment and installations, their constitution and required availability, as well as other factors such as operational and environmental condition, and operating experience.

Inappropriate, irregular or missing maintenance could lead to premature functional failures which reduce the availability of equipment and installations, could lead to consequential damage, and shorter asset life cycles. Functional failures can lead to operational consequences and need to be assessed accordingly. Safety aspects have to be considered at all times.

The purpose of this document is to describe, in general terms, the management methods, processes, and techniques with regard to the maintenance of installations and equipment, which are necessary to achieve public safety, reliable operation, and acceptable reliability for installations and equipment.

In this document, the term “network operator” and “system operator” are used for the network owner, asset manager, and maintenance provider.

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ELECTRIC ENERGY SUPPLY NETWORKS – GENERAL ASPECTS AND METHODS FOR THE MAINTENANCE OF INSTALLATIONS AND EQUIPMENT

1 Scope

This document provides guidance to develop maintenance requirements of installations and equipment in electric power networks. It is primarily meant for the operators of electric power networks, particularly those of public power supplies, including High-Voltage DC transmission (HVDC). This scope does not include:

- railway networks,
- installations of end consumer networks,
- installations for electric power generation.

Crises handling, e.g. in emergency situations, is not within the scope of this document.

NOTE Consumer networks (e.g. networks of chemical companies, traffic lights and street lighting) are installations which are not used to distribute electric energy to further consumers. The main scope covers public networks, but the general recommendations can be applied to other networks.

2 Normative references

There are no normative references in this document.

3 Terms and definitions

For the purposes of this document the following terms and definitions apply.

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

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

3.1

maintenance

combination of all technical and managerial actions intended to retain an object in, or restore it to, a state in which it can perform as required

[SOURCE: IEC 60050-192:2015, 192-06-01, modified – In the definition, "item" has been replaced with "object".] [1] ¹

3.2

maintenance concept

maintenance policy

definition of the maintenance objectives, line of maintenance, indenture levels, maintenance levels, maintenance support, and their interrelationships

¹ Numbers in square brackets refer to the Bibliography.

Note 1 to entry: The maintenance concept provides the basis for maintenance planning, determining supportability requirements, and developing logistic support.

[SOURCE: IEC 60050-192:2015, 192-06-02] [1]

3.3

corrective maintenance

maintenance carried out after fault detection to effect restoration

[SOURCE: IEC 60050-192:2015, 192-06-06, modified – Note 1 to entry has been deleted.] [1]

3.4

preventive maintenance

maintenance carried out to mitigate degradation and reduce the probability of failure

[SOURCE: IEC 60050-192:2015, 192-06-05, modified – The second term and Note 1 to entry have been deleted.] [1]

3.4.1

condition-based maintenance

preventive maintenance based on the assessment of physical condition

Note 1 to entry: Condition-based maintenance is derived from the analysis and determination of parameters which characterize the deterioration of the object

[SOURCE: IEC 60050-192:2015, 192-06-07, modified – Note 1 to entry has been changed.] [1]

3.4.2

periodic maintenance

time-based maintenance

maintenance carried out in accordance with a specified time schedule

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

[SOURCE: IEC 60050-192:2015, 192-06-12, modified – The terms defined have been changed.] [1]

3.5

reliability-centred maintenance

RCM

systematic method for determining the respective maintenance actions and associated frequencies, based on the probability and consequences of failure

Note 1 to entry: RCM studies may be conducted at any indenture level of a system.

Note 2 to entry: Data used may be derived from analysis (e.g. FMECA) and experience (e.g. FRACAS).

Note 3 to entry: RCM studies may provide feedback to initiate modifications of design or procedures to effect improvements.

[SOURCE: IEC 60050-192:2015, 192-06-08] [1]

3.6

maintenance task

maintenance action

sequence of elementary maintenance activities

EXAMPLE Fault localization, fault diagnosis, repair, and function checkout.

Note 1 to entry: Maintenance can be completely divided into the following tasks:

- inspection;
- routine maintenance;
- overhaul;
- repair;
- improvement.

[SOURCE: IEC 60050-192:2015, 192-06-11, modified – Note 1 to entry has been added.] [1]

3.6.1

inspection

activities to determine and assess the actual condition of an object, including the determination of the causes of wear and deriving the necessary conclusions for future use

Note 1 to entry: The term "condition determination" is described in detail in Clause B.1.

3.6.1.1

operational inspection

on-site inspection

activities carried out by pure visual observation with the aim of checking the recognizable condition of the object from outside

Note 1 to entry: Operational inspections are to be understood as checks to fulfil the legal duty to maintain safety. The inspection may be made by car or from the air (surveying flying).

Note 2 to entry: Operational inspection is the simplest form of inspection.

3.6.1.2

visual inspection

activities carried out by observation with the human senses and by recording simple condition variables

Note 1 to entry: Obvious function defects are recorded.

Note 2 to entry: Observation with the human senses can include simple tools like cameras and drones.

3.6.1.3

online monitoring

continuous or periodic detection, under energized condition, to verify that the parameters of an object lie within formulation limits

3.6.1.4

function check

action to confirm that an object is able to perform the required function

3.6.1.5

condition investigation

activities carried out by defined measurements, which can be a routine measurement or specific test, to make an assessment of the actual condition of the considered equipment

Note 1 to entry: Diagnostic indicators that may be used for the condition investigation can be derived from the operational experience that is the analysis of fault situations and causes of faults.

Note 2 to entry: Condition investigation within the scheduled inspection ensures that occurring defects can be detected and corrected at components.

3.6.2

routine maintenance

regular or repeated simple preventive maintenance activities

Note 1 to entry: Routine maintenance may include for example cleaning, tightening of connections, replacement of connectors, checking liquid levels, lubrication, etc.

Note 2 to entry: Activity to delay the degradation of the existing degree of wear. The degree of wear is the reserve of the possible functional compliances under specified conditions which an object does possess due to the construction as well as service activities.

[SOURCE: EN 13306:2010, 8.5] [2]

3.6.3

overhaul

comprehensive set of preventive actions carried out, in order to maintain the required level of performance of an object

Note 1 to entry: Overhaul may be performed at prescribed intervals of time or number of operations.

Note 2 to entry: Overhaul may require a complete or partial dismantling of the object.

[SOURCE: EN 13306:2010, 8.6] [2]

3.6.4

repair

direct action taken to effect restoration

Note 1 to entry: Repair includes fault localization (IEV 192-06-19), fault diagnosis (IEV 192-06-20), fault correction (IEV 192-06-21), and function checkout (IEV 192-06-22).

[SOURCE: IEC 60050-192:2015, 192-06-14] [1]

3.6.5

improvement

combination of all technical, administrative and managerial actions, intended to ameliorate the reliability and/or the maintainability and/or the safety of an object, without changing the original function

Note 1 to entry: Improvements can be useful if, for example, operating experience and inspection results identify systematic problems that demonstrate that the previous function security is not sufficient.

[SOURCE: EN 13306:2010, 8.12] [2]

3.7

failure

termination of the ability of an object to perform a required function

Note 1 to entry: After failure the object has a fault, which may be complete or partial.

Note 2 to entry: "Failure" is an event, as distinguished from "fault", which is a state.

[SOURCE: EN 13306:2010, 5.1] [2]

3.8

reliability

ability to perform as required, without failure, for a given time interval, under given conditions

Note 1 to entry: Reliability is used only for general descriptions in non-quantitative terms.

[SOURCE: IEC 60050-192:2015, 192-01-24, modified – The notes to entry have been deleted and a new note to entry has been added.] [1]

3.9

functional security

defined degree of reliability and reserve of wear of an object

3.10**maintenance object
object**

particular equipment, particular installation or a group of equipment or installations which in general are considered jointly with respect to the maintenance plan

EXAMPLE The equipment of a switching bay at a specific location.

3.11**maintenance object type**

particular equipment, particular installation or a group of equipment or installations which in general are considered jointly with respect to the maintenance concept or inspections

EXAMPLE Power transformers with certain properties, such as, size, design, manufacturer, and age.

3.12**maintainability**

ability to be retained in, or restored to a state to perform as required, under given conditions of use and maintenance

[SOURCE: IEC 60050-192:2015, 192-01-27, modified – The notes to entry have been deleted.] [1]

3.13**maintenance support**

provision of resources to maintain an object

[SOURCE: IEC 60050-192:2015, 192-01-28, modified – In the definition, "item" has been replaced with "object".] [1]

3.14**testability**

degree to which an object can be tested

[SOURCE: IEC 60050-192:2015, 192-09-20, modified – In the definition, "item" has been replaced with "object".] [1]

3.15**reserve of wear**

<of an object> ability to withstand a cumulative deterioration caused by the stresses imposed without losing its function while in use

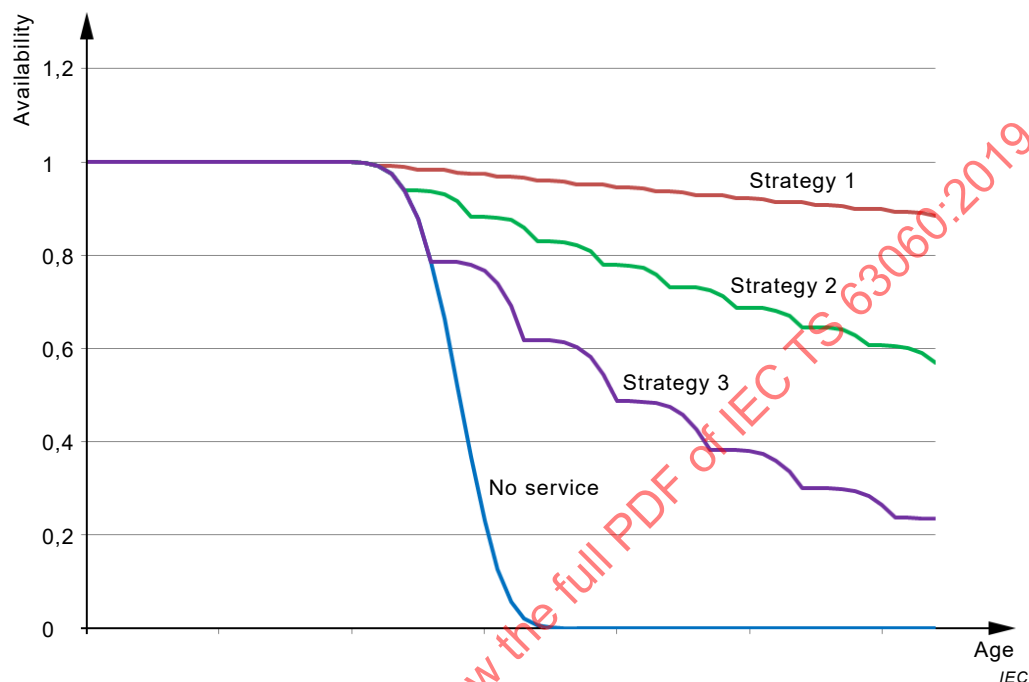
Note 1 to entry: Stresses can be mechanical, electrical, etc.

4 General aspects of maintenance and maintenance management

The availability and power quality of a network is influenced by several criteria, e.g. topology of the network, specification of components, maintenance, availability of spare parts, service know-how, environmental condition, application, etc. In consequence, the network operator has to consider which criterion (or criteria) is most influential to the performance of the network. During installations' design, the maintenance and the maintenance support should be considered in connection with the functionality and maintainability of power networks.

The network operator has to decide whether all required tasks for maintenance and maintenance support can be self-performed, or partly or fully commissioned to external contractors. A clear definition of aims and responsibilities for maintenance and maintenance support is important and has to be documented.

In a conception of a network, a required reliability is assigned to each component. The objective of maintenance is to ensure the required reliability over the entire life cycle of components. Maintenance and maintenance support have to be taken into account over the entire life cycle. Already, when planning installations and procuring equipment, decisions are taken that influence the effectiveness of maintenance activities in subsequent life cycle periods. Figure 1 shows an example of the availability of a component depending on the life time. Different maintenance cycles (marked as strategy 1, 2 and 3) will influence the availability of the components towards the end of the expected life time.



SOURCE: BALZER, G.; SCHORN, C [3]

Figure 1 – Influence of maintenance actions with different strategies on the availability of equipment

The optimal use of a maintenance strategy is occasionally obtained via the optimization of conflicting parameters. These parameters consist of: Investment costs (CAPEX), operating costs (OPEX), and energy not supplied or not transmitted, etc. The last parameter can be assessed, for example, by an appropriate indicator (for example, System Average Interruption Duration Index, SAIDI, refer to IEC 60050-692:2017, 692-08-03).

If condition-based maintenance is to be applied, it should be noted that additional investment costs for monitoring or diagnostics occur and the corresponding know-how shall be available. On the other hand, repair costs are avoided during the total operating period. In each case, the financial efficiency should be considered [3][4].

The maintenance targets are derived from business objectives, consumer needs, and legal requirements. The principles include:

- the realization of operational safety, particularly personal and third parties safety (including occupational safety),
- property protection, including fire protection and protection of goods of other parties,
- environmental protection,

as well as:

- functional security,

– value retention.

5 Management of maintenance

5.1 Structure of maintenance management

Maintenance management, in accordance with this specification, includes at least the following steps (see Table 1). These steps can be handled separately or combined.

Table 1 – Structure of maintenance management

System step	Result	Content	Clause
1 Definition of responsibility and principles	Principles, e.g. in the form of a guideline	- What are the objectives? - Assignment of responsibilities	5.2
2 Development of maintenance concept	Maintenance concept and basic structure of the documentation	Specification of maintenance object types - Assignment of maintenance types to the object types - Description of maintenance tasks regarding the object types - Identification of basic dates for inspections	5.3
3 Elaboration of maintenance plan	Maintenance plan	- Readout of the maintenance documentation - Arrangement of maintenance tasks to objects taking into account the available maintenance budget - Determine time frames for maintenance tasks	5.4
4 Planning of maintenance activities	Plan of action (date, location, resource)	- Allocate resources for maintenance activities taking into account availability of spare parts, human resources, subcontractors, etc. - Define schedule - Instruction of maintenance - Consideration of current operating and network states	6.2
5 Performing of maintenance activities	Object is maintained		6.3
6 Documentation of results	Documentation for each object	- What was done when? - What conditions were found? - Which additional maintenance action will be provided? - What will be the condition after the activity?	7
7 Analysis of results	Maintenance plan updated	- Were all tasks performed? - Was a maintenance task assigned? - Was an improvement assigned? - Was the maintenance plan updated?	
8 Assessment and improvement	Maintenance concept improved	Techno-economic analysis of the maintenance	8

NOTE Arrows indicate possible recursion.

5.2 Principles and roles

The network operator is responsible for planning and developing maintenance and maintenance support. The network operator has to ensure the proper implementation of maintenance activities. The organizational responsibilities have to be defined, assigned, and documented for all maintenance activities.

During the concept, design and definition stages of an installation, maintenance principles shall be defined that consider:

- general aims of maintenance and maintenance support,
- applicable laws and government regulations,
- required reliability, availability, maintainability (including testability), safety and health, environment, and costs,
- general specifications for maintenance and maintenance support.

The network operator is responsible for:

- defining maintenance principles,
- assuring that implementation and planning of maintenance is achieved,
- reviewing and adapting maintenance concepts with respect to operating experiences.

For this purpose, the network operator has to provide adequate resources (e.g. budget, staff, and spare parts). The general procedure for performing maintenance is defined by maintenance principles that serve as a guideline for planning, implementation, benchmarking, analysis, and improvement of maintenance. The principles have to be documented.

The principles for planning maintenance activities are defined by the network operator. With regard to grid development and grid planning, the planning of maintenance is oriented on long, medium, and short term operational objectives, as well as regularly occurring condition changes of equipment and installations.

The specifications of maintenance and maintenance support have to be verified on a regular basis to consider changes in legal frameworks, operational requirements, and the development of maintenance procedures. Corresponding changes may be necessary due to the age of the object or based on the results of diagnostic tests, if available. If new equipment or installations are added or modifications are implemented, required adjustments in maintenance and maintenance support should be considered.

If training is required, training documents, tools, and equipment have to be identified and provided, before entering the operational and planning phase. The training also has to be performed during the phase of operation and maintenance.

Technical manuals and technical documentation should contain the information and procedures that are necessary for the correct, safe, effective and economic implementation of maintenance tasks.

5.3 Maintenance concept

The maintenance concept defines the precise procedure for maintenance types based on maintenance principles.

The maintenance activities derived from a condition assessment (e.g. replacement, repair, service, and overhaul) are not defined in this document but are the responsibility of the network operator. Test cycles are not the subject of this document, but are to be defined by the system operators in self-responsibility.

The maintenance concept of an electric supply network includes the following:

- structuring of equipment and installations regarding maintenance object types;
- assignment of the types of maintenance to the maintenance object types and description of associated maintenance tasks, possibly dependent on operating conditions, environmental conditions, or other circumstances – see Annex A;
- defining of parameters dealing with criticality of equipment, e.g. impact on global quality and reliability of the network;
- defining of parameters for the specification of the maintenance types, e.g. as appropriate deadlines/frequencies for the execution of maintenance activities, depending in particular on the useful life, fault rate, and operational experience.

NOTE Details are described in Annex B

The following aspects have to be taken into account in the maintenance concept:

- operating experiences with installations and equipment (degradation mode, efficiency of maintenance tasks, etc.);
- recommendations of the manufacturer as appropriate, taking into account factors such as official regulations, safety considerations, environmental conditions and economic consequences of a failure;
- analysis of installations and equipment using a structured procedure to ensure functionality (possible criteria are condition, reliability, etc.);
- analysis of criticality of equipment on quality and reliability of the network.

5.4 Maintenance plan

Based on the maintenance concept, the characteristic of the respective types of maintenance for each equipment and installation are defined in terms of the content of the activities, the time frame, and the available budget.

The maintenance plan contains the following maintenance tasks:

- inspection (operational inspection, visual inspection, online monitoring, functional check and condition investigation);
- routine maintenance;
- overhaul;
- repair;
- improvement.

The result of this planning process is to create a maintenance plan that contains all common maintenance tasks to be performed for a sufficiently long time period.

The maintenance plan has to be issued in a way that guarantees the implementation of the maintenance concept in terms of both time and content. Statistically foreseeable events, whose respective time of occurrence is unknown, are also to be taken into account. The management of such events requires provision of dedicated maintenance resources to be kept on call. As appropriate, planning with a priority system may improve efficiency.

The maintenance plan is the basis for commission and implementation of the particular maintenance activities. It defines location, time frame, form and extent of tasks for each object and the associated maintenance support.

6 Conducting maintenance tasks

6.1 General

It shall be ensured that the planned maintenance tasks are performed completely and in accordance with the concept. To ensure the implementation of the planned maintenance tasks,

documents have to be provided – such as work orders, work instructions, checklists, report forms, inspection lists, etc., as applicable – which take the requirements of this document into account. It is the responsibility of the network operator to decide which level of qualification is required.

Maintenance activities shall only be executed by qualified personnel according to the requirements of the maintenance plan. Different qualifications of the instructed persons are required depending on the scope and difficulty of the assigned maintenance tasks.

6.2 Planning of maintenance activities

The implementation of specific maintenance activities has to be planned with adequate lead time to ensure that necessary resources are available. These include:

- organization of operational availability (including, for example, coordination of switching operations, consumer information, getting necessary permits, etc.),
- determining and allocating staff,
- acquisition of material and spare parts from external sources or stocks,
- ensuring that tools, transportation, lifting and support facilities are available,
- preparation of necessary procedures for operation, maintenance, safety, and environment and work plans,
- identification and advance booking of external resources,
- specification of means of communication,
- provision of necessary training.

Before starting the maintenance activities, personal protection equipment and tools have to be provided.

Dates, locations and resources for the maintenance activities are documented in the plan of action. The operational plan has to be adjusted accordingly, if its implementation conflicts with current operating or network conditions.

6.3 Instructions of maintenance activities

In order to instruct, supervise, and document individual maintenance activities, suitable assignments have to be implemented. An instruction is triggered either by IT-support or manually.

NOTE The IT-supported inducement is triggered by the maintenance IT-system using predetermined triggers, e.g. calendar time, time since the last activity, operating hours of objects, or by combining with other orders in accordance with the maintenance schedule.

7 Documentation and analysis

7.1 Documentation

The maintenance documentation should cover the following data.

- One-time documentation in the sense of a guideline:
 - principles of maintenance,
 - catalogue of maintenance support,
 - maintenance concept (mandatory),
 - catalogue of maintenance plans,
 - benchmark criteria for the condition of installations and equipment (mandatory),
 - description of maintenance tasks for each maintenance object type,

- skill requirements,
- confirmation of course attendance.
- Annual documentation in the sense of an object-inventory:
 - portfolio of installations and equipment.
- Current documentation of the maintenance performed:
 - catalogue of implemented maintenance activities (mandatory),
 - inspection documents, detected defects and damage (mandatory).

The implementation of maintenance and the detected defects and damage on installations and equipment have to be documented. The maintenance plan has to be updated.

7.2 Statistics

If appropriate, the network operator has to use a standardized, repeatable procedure for collecting and analysing data for the assessment of results. It should be based on corporate and sector-related factors, if applicable. The results should be used to support and to justify improvements. Possibly, a computer based maintenance information system for data management and analysis is needed.

NOTE The exchange of information between different system operators regarding the results of maintenance is not covered by this document.

Statistics of failure and, if appropriate, damage are to be kept in order to draw conclusions about the behaviour of equipment or components. Thus, the volume and timing of maintenance work can be oriented on statistical quantities. The maintenance plan is adjusted, if necessary.

The effectiveness of maintenance and maintenance support has to be monitored. For this purpose, selected properties have to be detected at certain objects, such as:

- availability, functionality, and maintainability,
- mean time between failures,
- mean time to repair.

7.3 Additional analysis

In addition to scheduled inspections, it may be necessary to perform additional testing and complementary analysis in particular cases, e.g. for improvement purposes, such as:

- Extraordinary incidents (e.g. caused by flood or terror attack)
After extraordinary incidents, inspection of equipment may be required due to potential damage or overload. The testing is event-oriented.
- Damaging events (e.g. due to aging)
After damaging events, failure analysis and additional investigations may be necessary. The testing is event-oriented.
- Justified information from third parties
If, for example, during inspections or by information from third parties (suppliers, other system operators, etc.) indications are known that indicate possible defects, tests have to be conducted, if required. The inspections are event-oriented.

Appropriate material oriented analysis may be conducted to obtain information on condition and aging behaviour of equipment and components.

8 Assessment and improvement of maintenance concepts

It is to ensure that maintenance concepts are regularly reviewed and improved where necessary to facilitate the analysis of the effectiveness and possible improvement of the activities for servicing and maintenance support.

If, for example, appropriate experience has been gained, other operating situations arise and equipment ages unexpectedly or new techniques become available, the requirements during the operation and maintenance phase should be checked. The maintenance concept has to be adapted and evolved optionally.

The observation of maintenance contains, if appropriate, the following assessments:

- the rate of planned activities versus unplanned activities,
- work that has not been completed in time,
- deviation of actual used resources from budgeted amount,
- availability of spare parts,
- utilization of workforce and their skill level.

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Annex A (informative)

Notes on types of maintenance

A.1 Types of maintenance

The types of maintenance described below can be combined. The analysis of maintenance results and statistics of failures and damage can be used for cost-benefit analysis to identify savings potential. The findings can however only be included in an optimization process with time delay when, for example, the operational behaviour is influenced by additional aging effects.

A.2 Corrective maintenance

A.2.1 General

The corrective maintenance usually produces the least costs related to the actual maintenance activities, because costs only arise in case of a failure. However, possible consequential costs of outage and replacement are often difficult to predict and higher. Therefore, this type of maintenance will only be used when the consequences of equipment outages are assessable and regional, and restoration of supply is possible by suitable repair, replacement or renewal activities in the short term. Another reason for this type of maintenance may be the variety of items used, which does not justify a planned maintenance activity for economic reasons.

In case of corrective maintenance, the actual condition is not systematically collected by inspections. Services and repairs are conducted after the occurrence of a malfunction, other event or outage.

A.2.2 Maintenance after the occurrence of a malfunction

This maintenance approach is applied with high reliability in case of low-maintenance and maintenance-free components. The requirement is that the consequences due to a malfunction are limited. The maintenance task is usually initiated immediately after the limitation of functionality of the equipment.

A.2.3 Repair after failure

This maintenance approach takes the limitation of the availability into account as well as temporarily and locally limited supply outages. If no (n-1)-security or the possibility of switching operation is present, the necessary maintenance activities are generally implemented immediately after the failure or the replacement power supply is installed so that the supply is not inadmissibly restricted.

A.3 Preventive maintenance

A.3.1 General

Preventive maintenance has set the goal to initiate the maintenance activities in time at the equipment before the reserve of wear is consumed. After the expiry of the maintenance cycle, the wear of the equipment is restocked independently of the condition or components of the equipment which are replaced. In this case, the maintenance activities are performed according to a predetermined maintenance plan. The contents of the maintenance plans are mainly based on experience due to tests during the development phase, tests of prototypes, previous maintenance activities, and operating experience. Maintenance plans may incorporate know-how gained from RCM or FMEA-studies carried out in the past. This type of maintenance is

more or less based on statistics and derives activities from these findings for a particular collective of equipment.

This type of maintenance is used if sufficient information is available due to operational experiences of particular pieces of equipment and unique equipment is not or partly equipped with devices for condition monitoring.

A.3.2 Condition-based maintenance

An efficient maintenance can be achieved for certain equipment by aligning the activities more on the properties and requirements of the considered equipment. In this case, timing and extent of the activities to be taken depend on the condition of the respective objects. In order to perform such a condition-based maintenance successfully, sufficient information concerning the components shall be available. Afterwards, the condition can be qualified and reliably assessed. This information can be obtained in the context of condition monitoring, by condition and diagnostic measurements or by samples. Condition-based maintenance enables to provide the maintenance more efficiently from the technical and economical point of view by reducing the expense and frequency. In addition, it has a positive effect on the availability and the useful life. Unplanned failures will rarely occur. The condition information allows a high degree of utilization of the useful life.

The aforementioned type of maintenance should be applied to components which are equipped with devices for condition monitoring and assessment or where a condition assessment by inspection or diagnostic measurements is possible.

A.3.3 Periodic maintenance

The periodic maintenance is characterized by the maintenance activities conducted according to regular time intervals (e.g. operating hours counter) regardless of the condition of the components. The scope of the maintenance is agreed in advance. For example, based on the operating experience and regulations by law, the maintenance cycles are chosen so that the functionality of the equipment is not endangered.

The periodic maintenance is used on all the voltage levels in the areas where a high requirement is demanded on the reliability or availability of equipment and wear of equipment components can be expected during the operation.

A.3.4 Maintenance after extraordinary operating conditions

Here, maintenance activities are initiated after the occurrence of special operating conditions or events. As a rule, these are operational events with increased stresses of equipment, e.g. short circuits, which consume the degree of wear above average.

Preventive maintenance requires that the operating conditions with higher stresses are detected. The extent of the required one-time or cyclical maintenance activities shall be determined on the basis of operating experience, depending on the equipment.

Furthermore, equipment outages (malfunctions or failures) due to "faulty design/hidden defect" also lead to the preventive maintenance. In this context, the required maintenance is conducted as a specific activity at the equipment or equipment group.

A.4 Reliability-centred maintenance

The reliability-centred maintenance combines data of the current condition investigation supplemented by further information such as age, technology, availability of spare parts, experience of operating and service personnel, etc. with the importance of equipment for the network. The combination of the condition and the importance leads to the prioritization of the maintenance activities.

A.5 Risk-based maintenance

Risk-based maintenance is a development from reliability-centred maintenance based on FMEA-analysis. The main idea is to multiply the probability of occurrence of a failure with its expected consequences. Several drivers can be separately taken into account. Examples of drivers are:

- costs,
- power quality,
- environmental impact,
- image,
- etc.

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Annex B (informative)

Condition assessment of equipment and installations

B.1 Information for use

Annex B identifies exemplary activities to determine the actual condition of equipment/installation of electricity supply networks for the purpose of a selection catalogue. The activities listed are not differentiated by voltage levels nor the type of maintenance and specified deadlines as this is the responsibility of the network operator. Which activities for the condition determination are applicable for various equipment/installations including the termination have to be defined and documented by the operator of the electricity supply network according to 5.3.

The following circumstances apply for the listed activities for the condition determination of an object and its respective components.

- The listed activities are responsible for personal safety, operational and environmental security as well as functional security.
- If equipment/installations are not listed, the condition determination shall be made in accordance with this specification by own specifications.
- If activities cannot be performed, for example due to the design, this should be considered when determining the type of maintenance or the selected strategy.
- The condition determination is made by operational inspection, visual inspection, online monitoring, functional check, and condition investigation. The condition investigation can be carried out, e.g., by a measurement (continuous or discontinuous), optionally by a representative random sample.
- The listed measurements can represent routine measurements as well as special investigations which can be performed for condition investigation in special cases.

The activities for the condition determination are listed in Clause B.2 in tabular form. The following definitions apply.

- Component: Part of equipment or a functional group for which a condition assessment is performed.
- Criterion: Which property of the component is analysed due to the operating experience.
- Activity: Description of the procedure for the condition determination, such as measurement, visual inspection. Even reading of a fixed measuring device is part of the visual inspection.
- Additional information: Related standards with additional information.

As part of the maintenance concept (see 5.3), the exemplary mentioned activities (see Clause B.2) should be taken into consideration in case of the definition of the maintenance strategy (periodic, corrective, condition-based, reliability-centred) for the objects or components. The activities can be selected for this reason. The selection catalogue according to Clause B.2 shall be specified depending on the type of maintenance and be completed, if necessary. The order of the activities listed does not represent a weighting.

In general, the condition of equipment/installation depends also on the location, the operational mode, the technology and the manufacturing, so that these constraints have to be considered. For this reason, manufacturers' recommendations and operating experience of the user should be additionally considered.

B.2 Selection catalogue for activities to determine the actual condition of equipment/installations of electrical supply systems

B.2.1 Substations/installations

B.2.1.1 General facilities

Component	Criterion	Activity	Additional information
Entries, ways, areas, external boundary fence	Insularity of the electric premises, distance to live parts, distance to trees and bushes, safe usage, no hazardous positions (holes, unevenness)	Operational and visual inspection	
Inscriptions (warning, indicating, safety labels, identification plates), safeguard (barriers)	Existing, valid, complete, clear, and readable	Visual inspection	
General building condition (doors, windows, gates, roofs, walls, corridors, etc.)	Safe usage, no hazard positions (holes, unevenness)	Operational and visual inspection	
Standard and emergency lighting	Safe functionality	Functional check	
Traffic, escape routes	Accessibility, identification, functional check of panic locks	Operational and visual inspection	
Notice, regulations	Existing, complete, correct, clear, readable	Visual inspection	
Supporting structures, fundaments, terminal construction (e.g. steel, concrete)	Load capacity: Tilting (mining subsidence), damage, corrosion prevention (layer thickness, cracks, consistency), spalling (laid open armouring), cracks, vegetation	Visual inspection, condition investigation	
Power transformer fundament, collecting vat with separated container	Tightness of the surface, manhole and pipe connections	Visual inspection, condition investigation	
Power transformer fundament, collecting vat with integrated container	Tightness of the surface, filling level, cover panel (fire safety)	Visual inspection, condition investigation	
Fire-protection appliance	Safe functionality, proper condition	Visual inspection, condition investigation	

B.2.1.2 Grounding system/ground conductor

Component	Criterion	Activity	Additional information
Junction points	Damage, corrosion	Visual inspection	
Ground conductor	Corrosion, cracks, grounding resistance	Visual inspection, condition investigation	

B.2.1.3 Lightning protection

Component	Criterion	Activity	Additional information
Junctions	Corrosion, cracks	Visual inspection	

B.2.1.4 Substation (air and solid insulated, GIS)

Component	Criterion	Activity	Additional information
Housing, bay (open)	External defects, corrosion, pollution	Visual inspection	
Enclosure (metal)	External defects, corrosion, pollution	Visual inspection	
Solid enclosure	External defects, pollution, partial discharge	Visual inspection, condition investigation	
Flanges, flange joints	External defects, corrosion, pollution	Visual inspection	
Conduction/bus bars/joints (open)	External defects, corrosion, pollution	Visual inspection	
Monitoring equipment (signalling device, voltage test system, filling pressure system)	Functionality	Functional check, condition investigation	
Locking	Functionality	Functional check	
Grounding	External defects, grounding resistance (see B.2.1.2)	Visual inspection, condition determination	
Inscriptions, barriers	External defects, completeness, correctness	Visual inspection	
Clamps, conductor, joints	Pollution, damage, corrosion, heating	Visual inspection, condition investigation (e.g. thermography)	

B.2.1.5 Switchgears

B.2.1.5.1 Circuit-breaker (SF₆, air-blast, minimum oil, vacuum)

B.2.1.5.1.1 Live parts

Component	Criterion	Activity	Additional information
Porcelain (arcing chamber), cement, flanges, terminations, pole pillar (air insulated substation)	Pollution, damage	Visual inspection	
Flange joints (outdoor circuit-breaker)	Corrosion (not flange corrosion)	Visual inspection	
Contacts	Contact resistance	Condition investigation (e.g. resistance measurement)	
Arcing chamber	Clearing time, switching speed	Condition investigation (e.g. travel-time measurement, switching time)	
Insulating and extinguishing medium	Pressure, density, humidity, dissociation products, filling level, breakdown voltage	Visual inspection, condition investigation	IEC 62271-4:2013 [5]
Embedding pole parts (vacuum circuit-breaker, withdrawable switch)	Crack formation	Visual inspection	
Switch (general)	Number of switching cycles	Visual inspection	
Moving contacts	Deterioration contact system	Visual inspection	

B.2.1.5.1.2 Drive

Component	Criterion	Activity	Additional information
Drive, general	Corrosion, number of switching cycles, tightness	Visual inspection	
Magnetic drive	Damage	Visual inspection	
Hydraulic	Oil level, oil pressure, number of pump starts	Visual inspection	
Mechanic (spring stored-energy drive)	Deterioration of latching mechanism	Visual inspection	
Pneumatic (air pressure drive)	Number of compressional starts	Visual inspection	
Charging device, hydraulic pump, winding motor for spring drive	Functionality	Functional check	

B.2.1.5.1.3 Secondary and auxiliary installations

Component	Criterion	Activity	Additional information
Anti-condensation heater	Functionality	Functional check	
Alarm and warning indication devices	Functionality	Functional check	
Control	Functionality	Functional check	
Test and monitoring device	Functionality	Functional check	

B.2.1.5.2 Load switch**B.2.1.5.2.1 Live parts**

Component	Criterion	Activity	Additional information
Outer insulation	Damage, pollution	Visual inspection	
Contact system	Burn-off	Visual inspection	
Flange joints	Corrosion	Visual inspection	

B.2.1.5.2.2 Drive

Component	Criterion	Activity	Additional information
Drive (general)	Damage, corrosion, water condensation	Visual inspection	
Drive, mechanical (spring stored-energy drive)	Deterioration of latching mechanism	Visual inspection	

B.2.1.5.2.3 Secondary and auxiliary installations

Component	Criterion	Activity	Additional information
Anti-condensation heater	Functionality	Functional check	
Alarm and warning indication devices	Functionality	Functional check	
Control, position switch	Functionality	Functional check	
Test and monitoring device	Functionality	Functional check	

B.2.1.5.3 Disconnecter and earthing switch (open air)

B.2.1.5.3.1 Live parts

Component	Criterion	Activity	Additional information
Contacts	Burn-off, damage, pollution, abrasion	Visual inspection, condition investigation (e.g. resistance measurement)	
Pivot bearing connection	Damage	Visual inspection	
Supporter, slewing column, outer insulation, cement	Damage, pollution	Visual inspection	
Flanges, flange joints	Corrosion	Visual inspection	

B.2.1.5.3.2 Drive

Component	Criterion	Activity	Additional information
Drive (general)	Corrosion	Visual inspection	
Hinges	Greasing	Visual inspection	
Leverage	Pollution, damage	Visual inspection	
Motor (pneumatic)	Running time	Condition investigation	
Motor	Power consumption, torque	Condition investigation	
Pneumatic	Tightness	Visual inspection	

B.2.1.5.3.3 Secondary and auxiliary installations

Component	Criterion	Activity	Additional information
Anti-condensation heater	Functionality	Functional check	
Outer secondary wiring, position switch, auxiliary switch	Damage, wiring	Visual inspection, functional check	

B.2.1.6 HVDC converter station

Component	Criterion	Activity	Additional information
Converter building	Room temperature, freedom from dust, humidity	Condition investigation, operational and visual inspection	
Air conditioning	Functionality	Functional check	
Cooling system (superior)	Corrosion, porosity, tightness, coolant level, system pressure	Visual inspection	
Valves	Reverse voltage, tightness, arc traces, pollution, discoloration	Condition investigation, visual inspection	
Cooling (valves)	Functionality	Functional check	
Control, signalling and monitoring devices	Functionality	Functional check	
Smoothing reactor	See B.2.4		
Harmonic filter	See B.2.1.9 and B.2.4		

B.2.1.7 Bushings, insulators**B.2.1.7.1 Bushings**

Component	Criterion	Activity	Additional information
Insulator (general, open air), cement	Pollution, damage, arc effects	Visual inspection	
Composite insulator	Hydrophobia	Condition investigation	IEC TS 62073 [6]
Fittings	Damage, corrosion, deformation, cross-section changes	Visual inspection	
Sealing system of internal oil filling	Corrosion, aging (sealing ring), filling level	Visual inspection	
Sealing system of internal gas filling (as applicable)	Corrosion, aging (sealing ring)	Visual inspection	
Active component based on OIP (oil impregnated paper)	Aging, humidity	Condition investigation (e.g. C-tan measurement)	
Active component based on RBP (resin bonded paper bushings)	Aging	Condition investigation (e.g. C-tan measurement)	
Active component based on RIP (resin impregnated paper)	Aging	Condition investigation (e.g. C-tan measurement)	
Grounding	External defects (see also B.2.1.2)	Visual inspection	

B.2.1.7.2 Hollow insulator (porcelain, composite), support insulator (porcelain)

Component	Criterion	Activity	Additional information
Insulator (general, cement)	Pollution, damage, arc effects	Visual inspection	
Composite insulator	Hydrophobia	Condition investigation	IEC TS 62073 [6]
Armature	Damage, corrosion, deformation, cross-section changes	Visual inspection	

B.2.1.8 Instrument transformer

Component	Criterion	Activity	Additional information
Housing, terminal box	Tightness, corrosion, damage, pollution, ventilation	Visual inspection	
Porcelain, composite insulator	Damage, pollution, cement, hydrophobia	Visual inspection, condition investigation	
Insulating medium	Oil level, SF ₆ pressure, SF ₆ tightness, oil quality	Visual inspection, condition investigation	
Oil connector	Tightness	Visual inspection	
Anti-condensation heater	Functionality	Functional check	
Alarm and warning indication devices	Functionality	Functional check	
Test and monitoring device	Functionality	Functional check	

B.2.1.9 Capacitors, power capacitors, resistors

Component	Criterion	Activity	Additional information
Housing	Pollution, corrosion, deformation, tightness	Visual inspection	
Insulator/clamp	Pollution, damage, temperature	Visual inspection, condition investigation	
Discharge device	Thermal overload, functionality	Functional check	
Cubicle/room	Pollution, ventilation	Visual inspection	
Capacitor	Capacity, symmetry	Condition investigation	IEC 60831-1 [7] IEC 60871-1 [8]
Grading capacitor	Pollution, damage	Visual inspection	
Anti-condensation heater	Functionality	Functional check	
Alarm and warning indication devices	Functionality	Functional check	
Test and monitoring device	Functionality	Functional check	
Resistor	Pollution, overheating, damage	Visual inspection	

B.2.1.10 Auxiliary power, DC supply**B.2.1.10.1 Battery installation**

Component	Criterion	Activity	Additional information
Installation site	Room temperature, freedom from dust, intactness of retention areas	Visual inspection	
Venting system	Functionality	Visual inspection, functional check	
Charging device	Connection of power supply, condition	Visual inspection	
Battery housing	Damage, pollution	Visual inspection	
Battery cell	Battery, block and cell voltage, current, electrolyte (tightness, temperature, position), capacity	Condition investigation, visual inspection	
Ventilation plug (battery cells)	Functionality	Visual inspection	

B.2.1.10.2 Converter installation/converter

Component	Criterion	Activity	Additional information
Installation site	Room temperature, freedom from dust, humidity	Visual inspection	
Air conditioning	Functionality	Functional check	
Control room	Ventilation, pollution	Visual inspection, functional check	
Control, signalling and monitoring devices	Functionality	Functional check	
Housing, terminal clamp, switchboard, grounding, equipotential bonding	Pollution, strength, electric connection	Visual inspection, condition investigation (e.g. potential measurement)	
Voltage and current indication, function display	Indication error	Visual inspection, functional check	

B.2.1.10.3 Installation of auxiliary electric power supply

Component	Criterion	Activity	Additional information
General	Functionality	Functional check	

B.2.2 Low voltage installations

B.2.2.1 Switchgear and supply installations

Component	Criterion	Activity	Additional information
Housing, venting system, locking system	External defects, corrosion, pollution, accessibility, functionality	Visual inspection, functional check	
Interior	Pollution, small animals, vegetation, foreign body, protection against electric shock	Visual inspection	
Safeguarding, covering, enclosure	External defects, pollution	Visual protection	
Conductors, busbar, joints	External defects, insulation, corrosion, pollution	Visual inspection	
Switchgear (circuit-breaker, load switch, disconnector, switch-disconnector)	External defects	Visual inspection	
Grounding system, equipotential bonding	External defects, grounding resistance	Visual inspection, condition investigation	
Inscriptions, identification, barriers	External defects, existing, complete, correct, clear, readable	Visual inspection	

B.2.2.2 House service connection

Component	Criterion	Activity	Additional information
Housing, seal, joints	External defects, corrosion, pollution	Visual inspection	

B.2.2.3 Cable distribution box

Component	Criterion	Activity	Additional information
Installation site	Vegetation, foreign body, ground zone	Visual inspection	
Housing including base	External defects, ventilation, locking system	Visual inspection, functional check	
Inscriptions, identification	Existing, complete, correct, clear, readable	Visual inspection	
Interior	Pollution, small animals, vegetation, foreign objects, protection against electric shock	Visual inspection	
Switchgear (circuit-breaker, load switch, disconnector, switch-disconnector)	External defects	Visual inspection	
Conductors, busbar, joints	External defects, insulation, corrosion, pollution	Visual inspection	
Grounding system, equipotential bonding	External defects, grounding resistance	Visual inspection, condition investigation	