

BS 6867:2013



BSI Standards Publication

Maintenance of electrical switchgear and controlgear for voltages above 36 kV – Code of practice

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Published by BSI Standards Limited 2013

ISBN 978 0 580 61300 5

ICS 29.130.10

The following BSI references relate to the work on this document:

Committee reference PEL/17/1

Draft for comment 13/30174947 DC

Publication history

First published October 1987

Second (present) edition, September 2013

Amendments issued since publication

Date	Text affected
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Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under license from the British Standards Institution and came into effect on 30 September 2013. It was prepared by Subcommittee PEL/17/1, *High-voltage switchgear and controlgear*, under the authority of Technical Committee PEL/17, *High-voltage switchgear and controlgear and HV-LV co-ordination*. A list of organizations represented on these committees can be obtained on request to their secretary.

Supersession

This British Standard supersedes BS 6867:1987, which is withdrawn.

Information about this document

This is a full revision of the standard, and introduces the following principal changes.

- The various types of maintenance approach are discussed, including preventative and condition based maintenance.
- Maintenance policies using PAS 55 philosophy have been introduced.
- Maintenance considerations for modern plant and equipment, like gas insulated switchgear (GIS) and capacitive charged motor drive mechanisms, have been added.
- The standard has been restructured to create a dedicated clause on mechanisms (Clause 31).
- Text on use and handling of sulphur hexafluoride has been brought up to date.
- Recommendations for hard-gas interrupters are not given.

The purpose of this British Standard is to provide, in a convenient form, recommendations and guidance on those matters which technical knowledge and experience have shown to be important in keeping electrical switchgear and controlgear in an acceptable condition. It is intended for the guidance of those actually carrying out the maintenance work, as well as for administrative personnel.

The normally quiescent state of electrical switchgear and some controlgear does not automatically draw attention to incipient faults, deterioration or danger resulting from neglect and the consequent need for maintenance. It follows, therefore, that an organized system of maintenance is important to facilitate continued safe and acceptable operation of an electrical system with the minimum risk of failure and consequent interruption of supply.

Use of this document

As a code of practice, this British Standard takes the form of guidance and recommendations. It should not be quoted as if it were a specification and particular care should be taken to ensure that claims of compliance are not misleading.

Any user claiming compliance with this British Standard is expected to be able to justify any course of action that deviates from its recommendations.

It has been assumed in the preparation of this British Standard that the execution of its provisions will be entrusted to appropriately qualified and experienced people, for whose use it has been produced.

Hazard warnings

WARNING. Older switchgear might contain asbestos. Attention is drawn to the Control of Asbestos Regulations 2012.

Presentational conventions

The provisions in this standard are presented in roman (i.e. upright) type. Its recommendations are expressed in sentences in which the principal auxiliary verb is “should”.

Commentary, explanation and general informative material is presented in smaller italic type, and does not constitute a normative element.

Contractual and legal considerations

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

Compliance with a British Standard cannot confer immunity from legal obligations.

In particular attention is drawn to the statutory regulations listed in Annex A.

Section 1: General

1 Scope

This British Standard gives recommendations and guidance for the maintenance of electrical switchgear and controlgear having a rated a.c. or d.c. voltage above 36 kV.

NOTE This standard is not applicable to explosion protected switchgear and controlgear. Inspection and maintenance of electrical apparatus in explosive gas atmospheres is covered in BS EN 60079-17.

2 Normative references

The following documents, in whole or in part, are normatively referenced in this document and are indispensable for its application. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

BS 6423:1983+A1:1992, *Code of practice for maintenance of electrical switchgear and controlgear for voltages up to and including 1 kV*

BS EN 13306:2010, *Maintenance – Maintenance terminology*

BS EN 50110-1:2013, *Operation of electrical installations – Part 1: General requirements*

BS EN 60422, *Mineral insulating oils in electrical equipment – Supervision and maintenance guidance*

BS EN 60480, *Guidelines for the checking and treatment of sulphur hexafluoride (SF₆) taken from electrical equipment and specification for its re-use*

PD CLC/TR 62271-303, *High voltage switchgear and controlgear – Part 303: Use and handling of sulphur hexafluoride (SF₆)*

3 Terms and definitions

For the purposes of this British Standard the terms and definitions given in BS EN 13306:2010, BS EN 50110-1:2013 and the following apply.

3.1 acceptable condition

condition in which an item is able to meet the requirements of the relevant specification and perform its required functions

3.2 controlgear

a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for the control of electric energy consuming equipment [IEC 60050-441:1984+A1, **441-11-03**]

3.3 dead working

work activity on electrical installations, which are neither live nor charged, carried out after having taken all measures to prevent electrical danger [BS EN 50110-1:2013, **3.4.8**]

3.4 diagnostic test

comparative measurement carried out to monitor the condition of an item

3.5 examination

inspection with the addition of partial dismantling as required, supplemented by means such as measurement and non-destructive tests in order to arrive at a reliable conclusion as to the condition of an item

3.6 failure

termination of the ability of an item to perform a required function
[BS EN 13306:2010, 5.1]

NOTE Failure can be gradual or sudden and partial or complete.

3.7 high voltage

voltage in excess of 1 kV

3.8 inspection

examination for conformity by measuring, observing, or testing the relevant characteristics of an item [BS EN 13306:2010, 8.1]

3.9 item

part, component, device, subsystem, functional unit, equipment or system that can be individually described and considered [BS EN 13306:2010, 3.1]

3.10 live working

all work in which a worker deliberately makes contact with live parts or reaches into the live working zone with either parts of his or her body or with tools, equipment or devices being handled [BS EN 50110-1:2013, 3.4.4]

3.11 low-maintenance equipment

equipment designed not to require frequent maintenance and, except when subject to very frequent operation, intended to need minimal examination or overhaul during the economic life of the equipment

3.12 maintenance

combination of actions carried out to retain an item in, or restore it to, an acceptable condition

3.13 manufacturer's handbook

written information issued by the manufacturer of the equipment which includes guidance and instructions concerning installation, commissioning, operation and maintenance of the equipment

3.14 non-routine maintenance

unplanned maintenance which is not the result of a failure

3.15 operational check

action carried out to determine whether an item functions correctly

3.16 overhaul

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

NOTE 1 Overhaul may be performed at prescribed intervals of time or number of operations.

NOTE 2 Overhaul may require a complete or partial dismantling of the item.

[BS EN 13306:2010, 8.6]

3.17 post-fault maintenance

maintenance which might be necessary after a specified number of fault clearance or making operations

3.18 preventive maintenance

maintenance carried out with the objective of preventing failure

NOTE It may include routine or non-routine maintenance.

3.19 routine maintenance

maintenance organized and carried out in accordance with a predetermined policy or plan to prevent failure or decide the likelihood of an item failing to be in an acceptable condition

3.20 servicing

work carried out to ensure that the equipment is kept in an acceptable condition, which usually does not involve any dismantling, and is typically limited to cleaning, adjustment and lubrication

3.21 switchgear

a general term covering switching devices and their combination with associated control, measuring, protective and regulating equipment, also assemblies of such devices and equipment with associated interconnections, accessories, enclosures and supporting structures, intended in principle for use in connection with generation, transmission, distribution and conversion of electric energy
[IEC 60050-441:1984+A1, **441-11-02**]

4 Maintenance policy

It is the asset owner's responsibility to ensure that there is an effective maintenance policy. An example of this is described in PAS 55. Whilst there is no legal requirement for maintenance at any particular interval, there is a legal requirement that the system and its parts continue to be safe.

NOTE Attention is drawn to the Electricity at Work Regulations 1989. See the Health and Safety Executive (HSE) publication HSR 25 Memorandum of guidance on the Electricity at Work Regulations 1989 [1].

There are several aspects of the risk assessment concerning the scope, content and timing of the maintenance. Evidence is necessary to make a judgement of what maintenance is required, ranging from functional checks to complete replacement. The performance of the system, operational history, environmental exposure, physical condition, age and consequences of failure all provide evidence. Experience from similar systems gives useful guidance on potential performance. Manufacturers can be expected to provide guidance about maintenance, but clearly different practical applications over the lifetime of the system can give rise to failure modes that the manufacturer might not be aware of. Further guidance is provided by competent organizations [e.g. the Health and Safety Executive (HSE) or electrical consultants], standards and industry recommendations. The initial maintenance interval and its content should be as advised by this guidance unless the owner has developed technical and risk assessments which justify an alternative interval.

Subsequent experience should be recorded and used to update maintenance policy. It is key to the continued safe operation of the system and its parts that there is adequate evidence to justify the maintenance policy. This may involve progressive sampling of the equipment to assess the continuing condition of equipment and understand potential failures. If the maintenance interval is extended and a system failure or fault can have significant consequences, then adequate precautions should be taken to ensure that such faults can be anticipated and the consequences prevented so far as is reasonably practicable. Thus it is essential that any maintenance policy takes into consideration the application of the equipment, its use, environment, changes in operation and consequences of failure.

Options for maintenance can be restricted by lack of available parts. Many original equipment manufacturers are no longer in business. Their equipment might be supported by other manufacturers, but such support can be limited. (See Clause 20.)

5 Operational policy

A documented overall design, operation, maintenance, examination, inspection and testing scheme for the electrical installation, including fixed installations, switchgear, plant, machinery and equipment should be developed, with competent electrical workers employed to complete this work on site. A communications process should be established between the electrical workers employed to complete work on site and the organization's electrical engineering specialists. This should be reviewed periodically to ensure continued adequate installation, design, construction, integrity and operation and to confirm that the organization's policy, risk assessments and procedures are being complied with. This may include contingency planning in the event of the electrically competent workers being unavailable. Any identified remedial work should be completed in a prioritized programme, including inspection and testing. Clear instructions should be given, as appropriate, to site workers and contractors to ensure that they understand the job requirements, safe working procedures and their duties, limitations and responsibilities, all confirmed in writing as necessary. Appropriate training of staff, and supervision, monitoring and auditing of qualifications, competence and work should be undertaken.

6 Competence

Successful maintenance requires competent people. Training and experience sufficient for their tasks is essential for competent fitters and engineers. They should also be capable of recognizing danger and taking suitable action to prevent injury and damage to equipment. Those persons require appropriate information about the work and instructions about what to do. They should be familiar with the systems and equipment that they are responsible for. Changes in technology result in constant changes in the equipment and familiarity with the practical operational systems will require knowledge and experience of many different types of equipment from several generations using differing technologically diverse principles. As less experienced persons become responsible for maintenance, experience can be lost and this can adversely affect the quality of decisions and the condition of the equipment. This is particularly true where there are long intervals between interventions. Maintenance experience can become limited. It is important that relevant knowledge of maintenance and defects is documented such that staff experience is captured. This is particularly important to consider in instances of mergers, re-organization, redundancy and retirement.

According to their level of experience workers will require varying levels of supervision and support. Some form of recognition of competence and the extent of work that individual workers are expected to perform is usually necessary. This should be part of an authorization procedure, allowing the worker to challenge when work might exceed this expectation.

Experienced supervision capable of identifying procedural and technical failures is required to forestall potentially serious failures. Procedural drift and wilful neglect can result from inadequate assessment of policy and inadequate supervision to ensure compliance.

Section 2: Safety

7 Personal protective equipment and treatment of persons suffering from electric shock

A risk assessment should be carried out and the requirement for suitable personal protective equipment (PPE) should be considered before maintenance commences.

A notice giving instructions for the treatment of persons suffering from electric shock may be affixed in a prominent position in the vicinity in which work on electrical installations will be carried out. It is strongly recommended that all electrical maintenance personnel be trained in the application of resuscitation and know how to summon medical help.

NOTE A poster Electric shock. First aid procedures [2] is available from the Health and Safety Executive.

8 Operational experience

Equipment related issues identified through operational experience should be recorded to provide evidence for future consideration. A robust procedure for reporting and recording abnormal events and faults, and acting upon them, is important in justifying continued operation. It is essential that these actions and changes are effectively communicated. It is also essential that maintenance policies are frequently reviewed and revisions in procedures implemented. All round communication is a vital aspect of effective maintenance.

There might be experience available from elsewhere. There are commercially available databases which record incidents of equipment failures.

9 Safety rules and procedures for safe systems of work

It is recommended that for all premises, the dutyholder/asset owner should formulate, and update as necessary during the life of the equipment, a set of safety rules and procedures, appropriate to the type of electrical installation, covering safe access for the purposes of maintenance to, and operation of, the equipment on the premises. An example of the issues to consider when formulating a set of safety rules is given in Annex B. Where the dutyholder/asset owner is not competent to do this, the formulation of a set of safety rules may be contracted out to a competent authority.

It is extremely important that competent persons who have adequate technical knowledge and experience of maintaining the particular types of switchgear and controlgear carry out the maintenance and that it is done in accordance with documented maintenance procedures. This also applies to any authorized persons or subcontractors who may undertake the work.

Where switching or maintenance work has to be done on equipment fed directly from a source of supply not under the control of the asset owner or the persons actually carrying out the work special care is essential. It is necessary for all parties (including the owner of the source of supply not under the control of the asset owner) to mutually agree procedures and methods of work in order to ensure the safety of persons carrying out the work, and for these agreed procedures to be incorporated in the rules and procedures for the installation.

Care should also be taken to prevent equipment being worked on becoming energized due to the automatic or inadvertent starting of standby or emergency generators or other locally connected generation plant and sources of supply. In particular, the possibility of backfeeds from embedded generation should be taken into consideration.

In addition, the asset owner should ensure that safety rules and working procedures are based on the manufacturer's handbook, as applicable, and operational knowledge gathered over the lifetime of the asset, for the safe handling, maintenance and testing of the equipment. The asset owner should also make arrangements for monitoring to ensure that these procedures are performed effectively.

Those concerned with the organization of the maintenance of the equipment should familiarize themselves with the plant it controls and take account of any changes which might affect the operation or maintenance of the equipment. During maintenance work all personnel should pay particular attention to warning notices and/or instructions on the equipment or set up temporarily during the maintenance procedures.

10 Equipment location

Switchgear is generally located in substations. These locations are normally separated from the routine activity of the premises and visited infrequently. Such locations should be kept locked and access restricted to authorized personnel. Periodic inspection of such locations is considered good practice to ensure that deterioration is not occurring which could affect the equipment (e.g. water ingress, build-up of debris in the location, or presence of vegetation or vermin). Documented procedures should be in place to detect and rectify such faults as soon as possible.

11 Isolation and access for maintenance

11.1 General

The policy to be followed in making equipment available for maintenance should always be that it should be isolated (with a means of securing the isolation utilized), proved dead where possible and immediately earthed. Dead working procedures should be the normal practise. Where live working is to be carried out, attention is drawn to Regulation 14 of the Electricity at Work Regulations 1989.

NOTE See HSE publications HSG 85 Electricity at work – Safe working practices [3] and HSR 25 Memorandum of guidance on the Electricity at Work Regulations 1989 [1] for further information.

11.2 Procedures

No electrical conductor should be regarded as being safe unless it has been isolated, proved dead where practicable, discharged to earth and, where necessary, earthed at all points of supply. It is essential that manually applied earth(s) are applied only after the conductor has been proved dead at the point of application.

Precautions should be taken to ensure that the isolated equipment cannot be re-energized from a high voltage or a lower voltage source of supply (e.g. backfeeds from transformers or other connected generation equipment). Precautions should be taken to ensure that any earth connection, applied as part of the safe system of work, is not inadvertently removed. This can be achieved with caution notices or, preferably, locks. If locks are used, they should have a unique key and the key should be under the control of the person carrying out the work.

If a circuit breaker is used to provide the earth connection, it is imperative that all trip facilities are disabled. This should include all facilities for remote operation.

Voltage indicators should be proved before and after use. This should be done by means of a proving unit with low power output. If live circuits are to be used to prove instruments, adequate precautions against electric shock and short circuits should be taken. A formal system of inspection and maintenance on all earthing harnesses and test bushings should be established. Such equipment should be inspected before every use. However, this might not be practicable for some devices where an integral earthing device is used. Earthing connections including leads and associated terminations need to be of adequate capacity for the duty at the point of application. The integrity of the earth connection should be verified before work commences.

Barriers preventing access to enclosures containing live conductors should normally be kept locked.

Where one person isolates and another does the work, the person responsible for isolating should demonstrate effectively to the other that the equipment is in fact dead and safe and that there are adequate safeguards to prevent re-energization.

Adequate quantities of suitable locks, cautionary notices and temporary barriers should be available for use to facilitate safe working and to prevent conductors from being accidentally electrically charged when persons are working on them, and also to warn of the presence of any live conductors. Such notices should be clearly legible, prominently displayed, made from durable material and kept up to date. Suitable precautions should be taken to identify circuits and equipment at the front and back of switchboards, where such identification does not already exist. Where locks are used as part of the safe system of work, they should have a unique key and the key(s) should be under the control of the person carrying out the work.

Any disconnectors used for isolation should be locked to prevent movement to the ON position. Any shutters giving access to live conductors should also be padlocked in the CLOSED position.

Equipment enclosures frequently contain circuits which have sources of supply different from that of the main circuit, such as interlocks, alarms, and heating and lighting circuits, and these secondary circuits are not always isolated when the main circuit is disconnected. Where reasonably practicable, separate isolation of these secondary circuits should be provided and used. Conductors and terminals associated with these circuits should be shrouded where necessary to prevent accidental contact and identified with warning notices. Particular care should be taken to avoid danger from reverse energization of voltage/control transformers or the open-circuiting of current transformer secondaries.

Removal and retention of fuse links or bolted links should only be used as a means of isolation when suitable precautions are taken to prevent duplicates being inserted.

Contactors and power electronic switching devices should never be considered as a means of isolation.

Where the component to be maintained is completely withdrawn from the equipment, and thus from all sources of electrical supply and discharged to earth, that component may be regarded as an electrically safe piece of equipment for maintenance purposes.

In the case where power capacitors are included in the component to be maintained, care should be taken to ensure that these are discharged to earth and are in a safe condition.

12 Preparing for maintenance work

Working space, entry ways and exit ways provided to apparatus and to equipment which is to be maintained should be kept clean and free from obstructions. Spare parts, tools, instruments, insulating screens, insulated tools, portable earthing devices and gloves associated with the equipment or the work to be performed should be housed in receptacles provided for the purpose, as necessary.

Adequate lighting, either fixed, portable, or a combination of both, should be provided as necessary to ensure safe access and working.

Portable electrical tools and inspection lamps should preferably be battery operated or operated from a system with a voltage no greater than 110 V with either the star point of a three-phase or the mid-point of a single-phase transformer low voltage winding earthed. If portable tools operating at a higher voltage need to be used, they should be of all-insulated or double-insulated construction and the use of a residual current device is recommended. All portable electrical equipment should be regularly inspected and tested.

NOTE 1 Further advice on maintaining portable tools is available in HSE publication HSG 107 Maintaining portable and transportable electrical equipment [4].

The ingress of moisture, vegetation, dirt, vermin, etc. into electrical equipment can cause malfunction and danger. Care should be taken to prevent such ingress whilst work is in progress, and covers should be replaced as soon as access to the particular part or the chamber is no longer required.

When work is being carried out with adjacent pneumatically operated or air-blast circuit breakers in service, precautions should be taken to protect personnel from the effects of noise caused by these circuit breakers should they operate. Consideration should be given to the use of ear protectors even where silencers are fitted.

NOTE 2 Attention is drawn to the Control of Noise at Work Regulations 2005.

13 Fire extinguishing equipment

All personnel carrying out maintenance on equipment where there is a fire risk, or using flammable materials in processes requiring flame or other sources of heat, should have suitable fire fighting equipment available for ready use. This equipment may be installed permanently by an asset owner for use in the premises or it may be temporary equipment provided for the period of work. Employees should be trained in the use of the fire fighting equipment and know how to summon further assistance.

If a fixed automatic fire extinguishing installation is installed, a prominent warning notice should be displayed at the entry to the protected area. The notice should also include instructions for preventing automatic operation when persons are working within the protected area. The prevention and restoration of automatic operation should be subject to appropriate safety procedures, for example by including a reference on the relevant safety documentation.

The type of fire extinguishers provided for use on or near electrical equipment should be compatible with the equipment and safe to use. Further advice on fire prevention and fire fighting may be obtained from the local Fire and Rescue Service.

14 Testing

14.1 General

Care should be taken when applying test voltages to ensure that they are the lowest value required for the purpose with the minimum current output and should not exceed the equipment capability. Where equipment is capable of storing a charge this should be safely discharged before and after every test.

NOTE 1 Further advice on electrical testing is given in HSE publications INDG 354 Safety in electrical testing at work – General guidance [5] and EIS 37 Safety in electrical testing – Switchgear and controlgear [6].

NOTE 2 Electrical equipment can be damaged by the application of test voltages and currents of incorrect value and polarity. Some electronic equipment is particularly vulnerable.

14.2 Use of test instruments (oscilloscopes, etc.)

Instruments should be 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 should be followed.

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

15 Disposal of scrap

In the UK there are statutory requirements for the disposal of waste products. These make the holder of the waste responsible for its fate even after it has left their premises. In particular, attention is drawn to the statutory requirements listed in Annex A. In case of doubt, the local authority should be consulted.

NOTE 1 Prior to scrapping materials it is recommended that the asset owner's agreement is sought.

NOTE 2 Consideration should be given to recycling materials where appropriate.

Section 3: Common recommendations relating to maintenance

16 Manufacturer's instructions

It is essential that personnel engaged on maintenance of equipment ensure that they have access to the relevant and up-to-date documentation for the task being undertaken. This may include work instructions and/or the manufacturer's handbook. These should be used as the principal reference guide to methods of working, dismantling, reassembly and restoring to service. It is good practice to liaise with the manufacturers to establish that the version of the instructions that they hold is still valid and is the latest version. Other trade bodies might have additional operational information.

17 Newly commissioned equipment

All newly installed equipment should have a full and detailed inspection and a complete range of tests and operational checks as part of the commissioning procedure. The manufacturer's handbook and other information supplied with the equipment should be consulted for details the procedures to be followed. From a subsequent maintenance point of view the most important factor is to keep careful records of the condition of the equipment, including values of essential settings. Reference to these notes at future maintenance operations can help in deciding what interval of time should elapse between such operations (see Clause 18).

18 Frequency of maintenance

18.1 General

NOTE 1 Some items are not intended to be maintained and might have to be renewed periodically.

There are three approaches to maintenance:

- a) maintenance based on failure;
- b) preventive maintenance;
- c) maintenance based on condition monitoring.

The most appropriate approach to maintenance should be chosen by the duty holder, who should develop and document technical and risk assessments to justify the approach taken.

NOTE 2 This may be determined as part of the risk assessment for the equipment. The risk of continued operation can be assessed using evidence from several sources. Inspection and test of the items and the system allows the condition to be assessed, provided appropriate observations are made. These can be compared with manufacturers' recommendations and previous observations and trends. Further guidance might be available from standards, fellow operators, industry associations and regulators. Key information can be obtained from internal operational reporting, including faults and operator reports of abnormal or fault events. Such evidence should be actively sought and acted upon. All of this evidence should be used when deciding on maintenance policy. It is vital that such decisions are made by competent persons who have appropriate knowledge and experience.

In any switchgear or controlgear installation, a distinction can be made between the device which carries out the switching operation (e.g. circuit breaker, contactor) and the rest of the equipment which performs a supporting role of connection, containment, etc. The latter components are only likely to need periodic inspection and servicing to ensure that the equipment is free from dirt, damp and deterioration, such as corrosion of metalwork and contamination of insulation. The switching device and its operating mechanism have moving parts subject to wear after extended use, and contacts, arc control devices and arc extinguishing fluids that are subject to deterioration at a rate depending on the design of the device and the frequency of switching operations.

Modern equipment, generally, is designed for lower maintenance and might be sealed for life. Depending on the design of the switchgear or controlgear, where frequent switching is required (e.g. several operations per day) it might be necessary to perform more frequent maintenance and the manufacturer should be consulted. This guidance should be checked and supplemented by keeping careful records of inspections and operational checks so that user experience can be built up in the operational environment. The manufacturer's handbook should also be consulted for information as to how essential settings should be checked and on the acceptable range of values for continuing service.

Whilst abnormally frequent operation might necessitate an increase in maintenance frequency, the converse is not necessarily true.

Semiconductors for power and control purposes and similar items and assemblies should be left undisturbed since they are easily damaged inadvertently.

18.2 Maintenance based on failure

When they fail, equipment and systems are repaired or replaced. This approach can be followed where failure does not result in danger and the consequences of failure are otherwise acceptable. Often failure maintenance is used in the belief that is the cheapest and least difficult to organize. It is also the default when maintenance is not adequately considered. It can lead to unplanned outages and undisclosed failures with potentially severe consequences. This can lead to further pressures to restore the failed system in an uncontrolled and potentially dangerous way. The financial and personal cost of such situations can far outweigh any short term financial gain. This lack of knowledge about the condition and risk of failure of the system can make planning difficult. Thus, failure maintenance is only suitable where the failure and its serious consequences can be prevented by effective reporting of the precursors of the failure and suitable remedial action. If this is not possible then a more formal maintenance procedure involving planned preventative and condition based maintenance is necessary.

As the items in the system age, various other faults and modes of failure can become likely that do not apply in the newly supplied system. Operational experience might highlight the need for modifications or alterations in their assigned capability.

Also, as time passes the items can be subjected to changes in the way that they are applied. The systems that utilize the items can change and they might have to operate in new ways or with extra duties that are possibly beyond the intention of their original design. There are likely to be changes in the loading of systems due to changes in the layout of connected loads and installation of new loads. Failure modes can be affected by environmental factors and operational stresses. Basic good practice such as keeping substations and switchrooms clean, tidy and free from condensation can have a beneficial affect on the performance of the systems.

18.3 Preventive maintenance

This is carried out before failure occurs. This normally means that maintenance is planned and carried out at specified intervals. Reliability centred maintenance (RCM) (see BS EN 60300-3-11) and failure modes, effects and criticality analysis (FMECA) (see BS EN 60812) may be used to determine optimum maintenance frequencies. The content, scope, timing, availability of alternative systems, finance, replacement parts and competent maintenance staff can all be planned and made available. Thus the planned outages can be better controlled, less disruptive and safer. There are fewer pressures and less stress on those involved. Key to the effectiveness of this type of maintenance is the evidence that justifies the policy. If the intervals or content are changed to reduce the amount of maintenance without supporting evidence then it is potentially another form of failure maintenance with the shortcomings of that type of maintenance. Checking, inspection and testing should inform the policy to highlight potential failures. However it can have the drawback of unnecessary maintenance that can lead to the introduction of errors due to poor standards of work, incorrect replacement parts, or reduction in reliability due to intrusion, albeit correctly executed. Irrespective of the maintenance process used, the use of competent maintenance personnel and appropriate supervision is essential.

Because of the widely varying conditions of operation of individual installations, it is not possible to give precise recommendations for the intervals between maintenance operations. These intervals can vary greatly depending upon the design of the equipment, the duty that it is required to perform and the environment in which it is situated. From experience and/or by consultation with the manufacturer, the person responsible for the maintenance strategy/policy should decide how long it would take for any item of equipment to deteriorate to an unacceptable state under normal conditions of use, and plan the maintenance schedule accordingly.

18.4 Maintenance based on condition monitoring

Maintenance based on condition monitoring requires the measurement of certain parameters of the equipment. Maintenance philosophies such as reliability centred maintenance (RCM) and failure modes, effects and criticality analysis (FMECA) may be used to determine optimum maintenance frequencies. It is very important that the switchgear and controlgear failure modes and degradation processes are understood. The role of condition based maintenance and condition monitoring in maintenance regimes to support maintenance decisions should be considered.

This type of maintenance does not rely on a policy of assessing a safe time interval for maintenance before failure. This extends the evidence available for the assessment by surveying the system and its parts to determine precursors of failures and faults. It assesses the reliability of systems and constituent parts. This might involve surveys using intrusive internal examination to assess the condition of equipment. Often periodic or continuous monitoring of relevant parameters is used to decide when some maintenance intervention is necessary. This monitoring can be non-invasive with sensors and instrumentation. The parameters measured can include temperature, leakage or operating currents, acoustics, partial discharge or thermographic surveys. The amount and effectiveness of maintenance can be better provided if the technique is effectively applied. It is essential that precursors of all significant failure modes are effectively monitored in this type of maintenance, even if they have not appeared yet. If the failure appears without sufficient warning to prevent its serious consequences then this type of maintenance is not suitable.

It is essential that the asset owner ensures that the designated condition monitoring parameters are measured by whoever undertakes the work. It is also essential that those undertaking the work follow the asset owner's requirements in order to ensure consistent application of the philosophy.

18.5 Routine maintenance

The appropriate maintenance approach for the equipment (see 18.1 to 18.4) should be used when carrying out routine maintenance. Examinations should be carried out to determine whether undue damage or excessive wear has been sustained in the course of operations and whether there is a need for overhaul of the contact systems or servicing of mechanisms, together with a more detailed inspection and testing of insulation.

Diagnostic testing can be a useful aid in establishing the frequency of maintenance, because a comparison with previous similar tests can provide an indication of possible deterioration and might indicate a need to vary maintenance intervals under the particular service conditions.

18.6 Post-fault inspection and maintenance

The need for, and extent of, post-fault inspection and maintenance should be determined by consulting the manufacturer's handbook and by past experience; it depends on a number of factors such as the magnitude of the fault current, the number of fault operations, the condition and type of the arc extinguishing medium and the effectiveness of the arc-control devices.

Particular attention should be given to some older classes of switchgear (e.g. air blast and oil) which, experience has shown, need post-fault maintenance.

It is also desirable to include on the service record reference to the number of fault operations, together with an indication of the likely fault current, if known (see also Clause 19). The cumulative fault current and duration of the fault (I^2t) is sometimes used to determine the requirement for post-fault maintenance.

19 Records and drawings

19.1 General

Records and drawings are of value in establishing the frequency of maintenance, therefore records should be updated each time maintenance is performed. It is recommended that records should be retained for the lifetime of the equipment.

19.2 Content of records and drawings

Records should be initiated, and initial drawings made, when the equipment is installed and should contain at least the following information:

- a) network diagram showing all switchgear including earthing switches;
- b) asset register – These records should also include operational information such as ownership schedules, interface agreements and cable records. Any master site electrical system and services diagrams should be checked and updated. Site installation, maintenance, inspection, test and examination records, including the system diagram, should be kept up to date and readily available on site for use at all times, along with relevant safety documentation and instructions for use of site equipment;
- c) manufacturer's details, including nameplate particulars of the equipment installed, its serial number and manufacturer's order number (if known) and the date of installation;