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BSI Standards Publication

Maintenance of electrical switchgear and controlgear for voltages above 1 kV and up to and including 36 kV – Code of practice

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Contents

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Summary of pages
This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 54, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI and came into effect on 31 August 2010. 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This British Standard supersedes BS 6626:1985, which is withdrawn.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 preventive and condition based maintenance.
- Maintenance policies using PAS 55 philosophy have been introduced.
- Maintenance considerations for modern plant and equipment like vacuum switchgear and actuators have been added.

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.

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 1 kV and up to and including 36 kV.

NOTE 1 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.

NOTE 2 This British Standard covers applications above 1 kV. Voltages below 1 kV are considered to be low voltage in line with the European Commission Directive 73/23/EEC [1], known as the "Low voltage directive".

2 Normative references

The following referenced documents are indispensable for the application of this document. 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 13306:2001, *Maintenance terminology*

BS EN 50110-1:2004, *Operation of electrical installations*

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 (SF_6) 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 13306:2001, BS EN 50110-1:2004 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 50110-1:2004, **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 13306:2001, **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
check for conformity by measuring, observing, testing or gauging the relevant characteristics of an item

NOTE Generally inspection can be carried out before, during or after other maintenance activity.

[BS EN 13306:2001, **8.1**]

3.9 item
part, component, device, subsystem, functional unit, equipment or system that can be individually considered [BS EN 13306:2001, **3.1**]

3.10 live working
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 50110-1:2004, **3.4.4**]

3.11 low-maintenance equipment
equipment designed not to require frequent maintenance and, except when subject to very frequent operation, intended not to need any 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

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3.16 overhaul
comprehensive set of examinations and actions carried out in order to maintain the required level of availability and safety 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 13306:2001, **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 *[2].*

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

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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.

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 the 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 manufacturers are no longer in business. Their equipment might be supported by other manufacturers, but such support can be limited.

Guidance concerning the decisions and available actions for maintenance are given in HSE publication HSG 230 *Keeping electrical switchgear safe* [3].

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 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

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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.

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Section 2: Safety

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

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 *[4] 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 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.

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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 areas such as switchrooms and/or 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 or build-up of debris in the location). 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 practice. 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 *[5] and HSR 25* Memorandum of guidance on the Electricity at Work Regulations 1989 *[2] 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 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 warning 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.

Voltage indicators should be proved before and after use. This should the 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. It is good practice to inspect earthing devices 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, warning 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

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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.

NOTE 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 *[6].*

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.

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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 Prevention Officer.

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 *[7] and EIS 37* Safety in electrical testing – Switchgear and controlgear *[8].*

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 (see Clause ***46****).*

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.

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 user.

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 preventive and condition based maintenance is necessary.

As the items in the system age various other faults and ways of failing 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.

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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 their original design capability. In modern business practice, where "sweating" assets is seen as a desirable practice, this can become a reality. 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) and failure modes, effects and criticality analysis (FMECA) 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

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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.

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 which, experience has shown, need post-fault maintenance, (see HSE publication HSG 230 *Keeping electrical switchgear safe* [3]).

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 made of relevant items each time maintenance is performed (see **19.2**). 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;

d) place where the manufacturer's handbook and list of recommended spare parts can be found;

e) date of last maintenance operation and note of the operation counter reading at that time, or an estimate of the number of operations;

f) record of maintenance work carried out – Maintenance records should be kept for all of the systems. These provide the evidence needed to assess the condition of the system and its equipment, enabling the scope and effectiveness of maintenance to be assessed. Trends in precursor conditions and failures can be used to inform policy. The policy can be justified using this evidence about what is done, when and by whom. Changes in content and timing of maintenance can be made with more confidence, and the records can assist other similar asset owners. Subsequently, assessment of maintenance effectiveness is aided. The records should allow handover to new workers in the event of loss of experienced operational persons. There is no overall legal requirement to keep records but such evidence does allow legal compliance to be demonstrated. Regulators, insurers, asset owners and maintainers will all have an interest in the existence of such records. There are some more specific requirements about maintenance logs in the PUWER R5(2);

g) record of any findings where the condition of the equipment varied from the expected, action taken and the condition of important components when the equipment was put back into service;

h) details of fuse-link type and ratings, and relay settings;

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i) details of the maximum system fault levels, and any changes to them;

j) any updates to the maintenance instructions and the manufacturer's handbook and recommendations, where possible.

Every significant fault or failure should be recorded and analysed with a view to taking action to prevent its recurrence.

20 Replacement parts

Care should be taken to ensure that all replacement parts are correct and suitable for the duty they are to perform, particularly when these parts are not available from the original manufacturer. Consumable spare parts and copies of manufacturer's component lists with exploded view drawings, where provided, should be kept readily available to maintenance staff. Legacy equipment manufacturers and other specialist companies might have bought rights to manufacture replacement parts from the original equipment manufacturer (OEM). Care should be taken with asking non-specialists to fabricate parts.

When ordering replacement parts it is advisable that nameplate particulars are quoted, including the serial number or other manufacturer's identification number.

To prevent the use of defective, or potentially defective, replacement parts, parts should be used that have been manufactured and supplied in accordance with a suitable quality standard.

Spare parts should be stored in conditions that prevent corrosion/degradation.

21 Cleanliness

For equipment to operate satisfactorily it is essential that natural or forced ventilation is not restricted (see also Clause **28**). However, care should be taken to avoid needlessly disturbing equipment. Before removing covers, inserting test probes, breaking gasketted joints or opening doors, precautions should be taken to prevent ingress of dirt, dust and loose objects.

Where the recommended maintenance procedures permit the use of solvents for cleaning or degreasing, it is essential that the liquids used are compatible with the equipment. Non-flammable and non-toxic solvents are preferable and precautions should be taken against fire and toxic effects.

Incorrect use and application of lubrication has been a major cause of mal-operation in switchgear and controlgear mechanisms. Some types of bearings should not be lubricated and can cause failure of the equipment if lubrication is applied.

If painting is necessary, care should be taken to avoid application of paint to pivots, bearings, insulating surfaces, labels and notices.

22 Marking of covers and connections

All covers, cable terminations, etc., should be marked carefully before removal to enable correct replacement. Electrical insulation tape should not be used for identification purposes because it could cause dielectric failure, for example within cable compartments.

Disturbed connections or temporary connections made for testing purposes should be clearly marked to facilitate reconnection. It is essential that the service connections be restored and the temporary connections and markings removed before the unit is returned to service.

23 Quality of connections

It is recommended that connections that have not been disturbed be checked for soundness. It might be possible to detect a bad connection by looking for signs of overheating or by using a contact resistance test set. In-service thermal imaging surveys are being increasingly used to verify the quality of high current carrying connections.

If it is necessary to break bolted joints, the section of the manufacturer's handbook dealing with installation should be consulted for guidance on remaking the joint. A contact resistance test set should be used to confirm that a satisfactory joint has been made.

Moveable contacts, e.g. plugs and sliding connections, should be inspected, as far as is reasonably practical, for correct functioning, cleanliness and signs of overheating.

Flexible connections, e.g. braids, should be inspected for signs of fraying and loss of flexibility, and renewed if necessary.

24 Maintenance and testing of insulation

24.1 General

It is important that insulation be inspected periodically. Modern insulation materials and systems are very reliable and stable but when equipment is made available for maintenance, where practicable, the opportunity should be taken to inspect the insulation. Where practicable, porcelain and moulded insulation should be inspected for cracks and other defects. Bonded and laminated fibrous insulation and other organic insulation should be inspected for signs of tracking, treeing, delamination and mechanical damage. An insulation resistance test may be carried out to determine the condition of the insulation.

24.2 Routine inspection and testing

Insulation resistance measurements between poles and between poles and earth are the most suitable for insulation testing under service conditions. In order to facilitate their proper interpretation, systematic testing and recording methods are essential. These tests are strictly comparative, in that for each item tested a judgement concerning any potential deterioration has to be made by experience based on earlier results. For this reason the test equipment and method used should be the same on each occasion, and the test values should be carefully logged, preferably on forms drawn up for this purpose, together with a record of the temperature and humidity conditions at the time of the test. Pass or fail criteria are sometimes stated by manufacturers.

The voltage which should be applied to primary insulation when making resistance tests varies according to the voltage rating of the equipment. Recommended test voltages are given in Table 1.

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Table 1 **Recommended test voltages**

3-phase voltage rating of primary insulation of equipment	**Test voltage recommended for insulation resistance test (to earth and between phases)** kV (d.c.)
Above 1 kV up to and including 3.6 kV	2
Above 3.6 kV up to and including 36 kV	5

After testing, conductors should be discharged to earth using an appropriate discharge rod.

The insulation resistance of small wiring and ancillary components should be tested at a voltage not exceeding 500 V d.c.

NOTE Certain types of equipment, e.g. apparatus incorporating semiconductors, might not withstand this test voltage and measures should be taken to protect these during the test.

A steady fall in insulation resistance over a period of time is indicative of insulation deterioration. However, a relatively low value which remains reasonably constant might be acceptable.

Additional diagnostic insulation tests such as polarization index (PI) and step voltage (SV) could also be used. Such tests are not comparative and, therefore, do not rely upon earlier results.

The types of insulation usually met with on distribution switchgear comprise moulded resin, laminated material and (increasingly rarely) porcelain. With all these materials, the results of the resistance measurements are mainly governed by the surface condition of the material and the humidity. Therefore the insulation tests should be accompanied by a careful visual inspection of the insulation surface, as already indicated. In laminated insulation, tracking, which tends to start at the edges of metalwork, often occurs beneath the surface of the insulation, and is indicated as a surface blister.

24.3 Insulating oil

WARNING. Excessive handling of insulating oil can cause dermatitis. Precautions should be taken to protect personnel from contact with insulating oil.

Adverse environmental and operational conditions can have a detrimental effect on insulating oil and special attention should be paid to equipment operating under such conditions, for example by making checks initially at fairly frequent intervals until experience has been gained.

In normal use the interval between tests of oil should be made dependent on the nature and frequency of use of the equipment. The optimum period between tests should be based on experience and/or consultation with the manufacturer.

The contamination of insulating oil can be a limiting factor on the allowable time between maintenance operations.

Testing in accordance with BS EN 60422 is recommended. These tests include testing of oil properties such as breakdown voltage, acidity, water content and flashpoint.

*NOTE 1 In equipment where the oil is used for arc extinction, the presence of carbon particles is a normal expectation in operation and does not necessarily indicate that the oil is in an unacceptable condition (see **34.2.2.1**).*

NOTE 2 To ensure satisfactory service, the utmost care in handling the oil is essential and guidance on this is given in BS EN 60422.

For oil handling it is good practice to segregate clearly the handling of clean oil and dirty oil, and for the arrangements to be clearly marked. All containers, pipework and pumps used with clean oil should be kept clean and free from moisture. Before use they should be carefully inspected and preferably flushed with clean oil.

24.4 Bushings on open-terminal equipment

The oil level on oil-filled terminal bushings should be periodically checked and, if any marked change occurs, particularly if accompanied by signs of oil leakage, the manufacturer should be consulted.

With compound-filled bushings a resistance measurement will not necessarily indicate the presence of moisture. Where practicable, the space above the compound should be inspected for signs of moisture ingress. If the presence of moisture is suspected, the bushing should be returned to the manufacturer for checking. Where covers are removed, care should be taken on re-assembly to ensure that all joints are properly made. During inspection it should be verified that the earth connection is satisfactory.

24.5 Sulphur hexafluoride (SF_6)

*COMMENTARY ON **24.5***
Sulphur hexafluoride is inert, colourless, tasteless, non-flammable, non-toxic, heavier than air (relative density = 5.11) and chemically stable in the normal conditions of use of electrical equipment.

At high temperatures (above 800 °C) and when exposed to an electric arc, sulphur hexafluoride is decomposed, with the formation of other SF compounds and, with the inevitable tiny traces of moisture and oxygen, with the formation of some oxyfluorides. In equipment where the gas is used for arc extinction, molecular sieves, activated alumina or charcoal are provided, which can easily absorb these decomposition products. The solid products resulting from the decomposition of sulphur hexafluoride exist in the form of a whitish powder which hydrolyses in the presence of moisture to form a sticky grey deposit. This powder has an irritating action on the skin, eyes and respiratory mucous membranes. However experience has shown that in the rare event of any of these products being present in the atmosphere within a substation, warning indications are likely to be apparent, at very low concentrations, in the form of a strong and nauseous odour. This is likely to be evident well before any toxic effects can take place.

Sulphur hexafluoride (SF_6) is listed as a fluorinated greenhouse gas in European Union Regulation EC 842/2006 [9] (on certain fluorinated greenhouse gases), the requirements of which are referred to in the Fluorinated Greenhouse Gases Regulations 2009. As such, SF_6 is subject to strict requirements governing its use, which are intended to prevent and minimize any release into the atmosphere.

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EC Regulation 305/2008 [10], which is also referred to in the Fluorinated Greenhouse Gases Regulations 2009, requires individuals who carry out recovery of SF_6 gas from high voltage switchgear to be appropriately trained and assessed and to hold a written qualification issued by a certification body.

24.5.1 General

Personnel working on equipment containing SF_6 should work in accordance with PD CLC/TR 62271-303.

24.5.2 Risks presented by sulphur hexafluoride leaks in normal operation

Gas loss from the equipment can lead to the introduction of air and moisture resulting in dielectric failure.

At distribution voltages the amount of gas present in the switching device is quite small, a maximum of a few hundred litres at atmospheric pressure, and experience has shown that leakage is rare. Any arcing by-products are likely to be absorbed by the reagents mentioned in the commentary on **24.5**, so these are unlikely to leak from the container. Even in the very unlikely event of a total loss of gas, the resultant layer of gas in the average substation cannot exceed a few centimetres at floor level, and this cannot be considered to present a risk of anoxia. Special consideration should be given to extremely low lying confined areas e.g. cable trenches or substation basements where, for example, it might be necessary to install temporary or permanent SF_6 alarms.

24.5.3 Risks presented by sulphur hexafluoride leaks due to abnormal occurrences producing rupture

In the very unlikely event of a failure of a sulphur hexafluoride switchgear or controlgear enclosure as a result of an internal arcing fault, there is a risk that some of the potentially toxic arcing products might be released into the substation. As mentioned in the commentary on **24.5**, the presence of these products can be detected at levels of concentration well below the danger level and it is recommended that personnel who would be concerned with such a substation, but not be working on the equipment, be given the following advice.

a) If a disagreeable smell is detected on opening the door of the premises or near the place where the plant is installed, the area should be thoroughly ventilated.

b) As far as possible, entering the premises should be avoided until the ventilation has dispersed the nauseous products.

c) When the area has been ventilated, it is possible to proceed with the removal of the damaged equipment and the cleaning of the cubicle and its surroundings. The solid deposits to be removed can have an irritating effect on the skin, so it is imperative that suitable goggles, gloves and a mask fitted with an approved filter be worn. After use, the mask filter should be carefully disposed of, and the goggles and gloves should be washed and copiously rinsed using a solution of sodium carbonate/bicarbonate.

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24.5.4 Prevention of release of gas to the atmosphere

As the venting of SF_6 to the atmosphere is strictly prohibited, if it is necessary to examine the interior of the equipment, all SF_6 should be removed and stored in a suitable cylinder using SF_6 gas handling equipment, in accordance with PD CLC/TR 62271-303.

24.5.5 Health and safety

On opening up equipment for inspection of the interior, personnel should take particular care to avoid exposure to possible breakdown products, and suitable protective clothing should be worn. This should include suitable overalls, thin rubber gloves, chemical type box goggles and a respirator incorporating a dust filter and activated charcoal. Users should draw up a written procedure covering the opening and inspection of the equipment and this should be strictly followed.

24.6 Arc gaps

Arcing horns should be secure and the gap dimensions correct.

25 Maintenance of safety earthing continuity

All exposed metal work should be effectively earthed. It is very important to ensure that earthing connections are mechanically and electrically sound and that all contact screws are tight and good contact is maintained. Particular care should be taken to reinstate fully all bolts and screws, together with any locking devices that might have been disturbed during the maintenance operation.

26 Shutters, locking devices, etc.

The mechanical features should be particularly checked for correct functioning and the inhibiting of incorrect actions under all conditions. Mechanisms should be free from corrosion and freely operating with all nuts, locking devices, etc., secure.

Unless otherwise stated in the manufacturer's instructions, and only if deemed essential, lubrication should be applied to bearings, shafts, pivots, actuating levers and rollers.

27 Interlocks

27.1 Types and purpose

Equipment interlocks are of two types which are for different purposes, as follows:

a) standard interlocks incorporated in the design of the equipment and associated with its safe manipulation;

b) application interlocks associated with the safe operation of the connected plant.

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27.2 Knowledge of interlocking requirements

The person, or persons, responsible for checking or maintaining any interlock system should have a thorough understanding of the extent, nature, function and purpose of the interlocks, together with the necessary knowledge and experience of the plant.

The manufacturer's handbook and any relevant plant diagrams should be available for reference.

27.3 Maintenance of interlock systems

Maintenance of interlock systems should include implementation of the following recommendations, depending on the types of interlock installed.

a) *Mechanical aspects*. All moving parts should be clean, adequately lubricated and be free to move as intended. Any evidence of wear or excessive free play should be investigated and, if necessary, reference made to the manufacturer. All fixing devices should be secure.

b) *Electrical aspects*. Where accessible, control wiring should be inspected for signs of damage, and terminations checked for tightness. If in doubt concerning the condition of the insulation it is recommended that an insulation resistance test be carried out (see **24.2**).

27.4 Functional test

Where it is reasonably practicable for the relevant busbar and/or feeder circuits to be made dead, all interlocks should be functionally tested before the equipment is restored to service. These checks should be carried out in both the positive and negative modes to ensure that the interlock system not only permits fulfilment of the intended operational sequence, but also prevents, when necessary, unintended or unsafe action.

When an interlock is found to be defective and remedial action cannot be implemented immediately, steps need to be taken to ensure safety by other adequate means.

28 Ventilation

Ventilated equipment should be examined and any restriction to the airflow removed. In the case of forced ventilation, the operation of any airflow interlock should be checked and corrected if necessary. Filters, if any, should be cleaned or renewed as necessary.

29 Equipment heating and lighting

WARNING. Circuits associated with equipment heating and lighting often remain live when the equipment is otherwise isolated.

The operation of heaters, lights, emergency lighting installation and changeover equipment for alternative low voltage (LV) supplies, where fitted, should be checked.

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30 Lifting devices

The maintenance of lifting devices should be carried out at regular intervals. In some types of equipment these form an integral part of the item and should be dealt with during the maintenance of the equipment. Some lifting devices are portable and these should be separately maintained in accordance with the manufacturer's instructions.

NOTE Attention is drawn to the Lifting Operations and Lifting Equipment Regulations 1998.

31 Tripping and closing supplies

It is particularly important that tripping and closing supplies be maintained in good order. Compressed air plant and battery installations should be regularly maintained, including associated indicators and alarms, in line with the manufacturer's instructions. (See also Clause **53** and BS 6423:1983+A1, Clause **63**.)

32 Equipment tools, spares and test instruments

Tools, spares and test instruments (including test probes) associated with a particular item of equipment should be regularly checked against an inventory. If calibration is required this should also be verified.

33 Conclusion of maintenance

After maintenance, equipment should be restored to a correct working condition, with particular attention to items and settings which have been disturbed, and it should be ensured that there is no potential hazard from loose or extraneous equipment, tools or wiring. Safety barriers and shrouds should be reinstated, all covers, including those of instruments and relays, replaced with all securing bolts properly tightened and all doors resecured and locked, where locks are fitted, to achieve the original degree of protection.

Any procedures required under plant safety rules should be carried out.

Section 4: Additional recommendations relating to the maintenance of specific items

NOTE The clauses in this section relate mainly to items operating at voltages above 650 V. For recommendations on maintenance of ancillary items operating at lower voltages in control and auxiliary circuits see BS 6423.

34 Circuit breakers

34.1 General

34.1.1 Safety

In addition to following the safety recommendations given in Section **2**, the following precautions should be taken when working on circuit breakers.

a) Before work is commenced care should be taken to discharge and isolate all stored energy devices, e.g. closing and tripping mechanisms. Where power racking devices are provided these should be isolated. The manufacturer's handbook should be consulted for information as to how this is to be achieved in each individual case.

b) When maintenance opening and closing devices are in use, the manufacturer's instructions on their operation and application to the circuit breaker should be carefully followed.

c) No smoking or naked flames should be permitted where oil is, or has been, directly exposed to the atmosphere.

d) In the event of internal maintenance being considered necessary to any part of the equipment which is, or has been, in contact with sulphur hexafluoride (SF_6) or associated compounds, the use of personal protective equipment and special handling techniques are essential. Any sulphur hexafluoride taken from the equipment should be checked and treated in accordance with BS EN 60480, and reference should also be made to the manufacturer's handbook for instructions.

34.1.2 Diagnostic testing

Where reasonably practicable, the maximum use should be made of diagnostic testing techniques to indicate the condition of the equipment and to prolong the intervals between examinations and overhauls. It is important to keep detailed records of diagnostic test results so that comparisons can be made and trends estimated.

The following diagnostic tests should be used, as applicable.

a) Timing and travel tests and the measurement of minimum operating voltages of both closing and tripping functions should be used to indicate any deterioration in the operation of the mechanism. Valuable information can be derived from the first trip operation, which should be captured wherever possible.

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b) Millivolt drop or resistance tests between the terminals of each pole or across individual series connected components, together with insulation resistance tests, should be used to indicate the electrical condition.

c) Measurements of contact engagement should be used to give information on the condition of the contacts in low-maintenance equipment.

d) Partial discharge testing, using both transient earth voltage (TEV) and ultrasonic methods, should be used to test for dielectric integrity.

e) Thermal imaging should be used to help locate highly resistive connections.

34.1.3 Routine maintenance

34.1.3.1 Inspection and operation check

A general inspection should be made to detect signs of corrosion, leakage of oil or compound, any unusual smell which might denote overheating and any noise which might indicate electrical discharge or looseness of components. Where possible, any external insulation, trip mechanism, shutter mechanism, earth connection and other visible parts should be inspected for any signs of abnormality. The integrity of the enclosure should be checked to determine whether distortion of any component has reduced the degree of protection intended to apply to the equipment. Partial discharge detection may be used to indicate deterioration of insulation which could be potentially hazardous.

The inspection should include the cleanliness of the equipment and the surrounding area and, in particular, any fire resisting barriers or seals provided on cable access points and any other provision made to prevent the passage of flame, smoke, gas or liquid. When measures have been taken to contain possible oil spillage, the catchment area should be checked to determine whether it is effective and whether any porous bed is clear. Where arc relief vents are used it is recommended that the vent outlet is checked to ensure that it is not obstructed.

Following the inspection it is recommended that the circuit breaker be tripped and re-closed a number of times. The tripping should preferably be by the electrical operation of the release coil and the associated relays.

It is extremely important that gaskets are seated correctly, are not degraded and have the appropriate compression.

34.1.3.2 Servicing

With particular reference to low-maintenance equipment, recommendations from the manufacturer's handbook as applicable, and operational knowledge gathered over the lifetime of the asset should be used to define recommendations concerning the inspection, cleaning, adjustment and lubrication of the circuit breaker and its mechanism and these recommendations should be strictly followed.

34.1.3.3 Examination and overhaul

If the inspection procedures give rise to any doubts concerning the internal condition of the equipment, then an examination of the

suspect part of the equipment should be carried out. This may include dismantling and the use of diagnostic testing procedures (see **34.1.2**).

The manufacturer's handbook and the maintenance instructions should be consulted as to how to gain access to the components in question and for guidance on the condition to be expected, allowable tolerances and the overhaul action that should be taken to rectify any deviation.

34.1.4 Post-fault maintenance

Depending on the design and duty of the switchgear or controlgear, inspection might be necessary after operation on fault (see **18.3**). When such an inspection is necessary, particular attention should be given to the following points.

a) *Cleaning*. Insulation and other parts liable to deposition of metal vapour should be cleaned and inspected for signs of cracking, burning or other damage. An inspection for signs of tracking should also be made.

b) *Contacts and arc-control devices*. Where accessible, contacts should be inspected for burning or other damage and reconditioned or renewed if necessary. Adequacy of contact force, alignment and wipe should be checked. Contact wear should be checked either by direct examination or by means of wear indicators on sealed equipment such as vacuum or SF_6 circuit breakers.

c) *Mechanisms*. The mechanism should be checked for correct operation and particular attention should be paid to settings and clearances after contacts or arc-control devices are replaced.

d) *General mechanical inspection*. A general inspection for mechanical damage or distortion of the general structure and mechanism should be made.

e) *Final verification*. Before the circuit breaker and its auxiliary apparatus is returned to service, an insulation resistance test should be carried out (see Clause **24**) followed by an operation check (see **34.1.3.1**).

34.2 Oil circuit breakers

*NOTE The following recommendations are specific to oil circuit breakers and are additional to those given in **34.1**.*

34.2.1 Routine examination and overhaul

34.2.1.1 Venting and gas seals

The venting system should be inspected, and cleared if necessary, to ensure that a free passage for oil and gases exists. Where there is a joint between fixed and moveable portions of the equipment, it should be ensured that it is in sound condition. In no circumstances should the vents be made larger than the design allows.

34.2.1.2 Mechanisms

Uncontrolled closing and opening operations with the tank removed or empty of oil are undesirable and should be avoided unless the manufacturer's instructions specifically indicate otherwise.

34.2.1.3 Insulating oil

A representative sample of oil should be taken and electric strength, water content and acidity tests which should be carried out in accordance with BS EN 60422 with suitable variation for high viscosity oil. Oil that does not meet the recommendations given in BS EN 60422 should be replaced with oil that does. The oil level should be maintained at the level specified by the equipment manufacturer.

For internal cleaning, high pressure spraying is recommended, using clean oil (several times) and removing it using a suction cleaner. Wipes should only be used if the contamination is difficult to remove. If using such wipes, it is advisable when cleaning insulation to wipe across the likely tracking path and not in line with it. Damage to insulating material should be avoided because surface damage can lead to early failure by making the insulation more susceptible to tracking.

Suitable proprietary wipes may be used when cleaning oil compartments. Cotton waste should not be used for cleaning. If cloths are used they should be chemically clean and free from loose fibres, metallic threads and similar particles. It is extremely important that wipes should be lint free and that they do not release fibres.

Before filling switchgear tanks with oil it is a good practice to clean the interior of the tank and the immersed part with clean oil. It is essential that the tank and the surfaces of conductors and insulators be kept free from fibres and from moisture as contamination lowers the dielectric strength of the oil.

There should be as little aeration of the oil as possible during the filling of the tank, and a good practice is to fill from the bottom of the tank. A standing time should be allowed after the tank is filled before commissioning the equipment. Hot oil should not be used to fill switchgear or controlgear.

In addition to this routine maintenance, where practicable a more frequent inspection should be made of oil levels, or for signs of loss of oil.

34.2.1.4 Tank and tank linings

Tank linings should be inspected for evidence of burning or other damage, paying special attention to the edges for signs of separation of the laminae, which often indicates the presence of moisture. Damp or damaged linings should be reconditioned or renewed as necessary. They should not be refitted until the tank has been thoroughly cleaned and dried using fibreless cleaning material.

Gaskets should be inspected for cracking, where they might allow moisture ingress, and for appropriate compressibility. They should be renewed where necessary.

It should be ensured that all tank bolts are properly tightened in the correct sequence when replacing the tank.

The tank compartment should, when practicable, be flushed with clean oil prior to filling.

Special care should be taken to avoid damage to interpole barriers when replacing tanks, since this could obstruct the opening of the circuit breaker.

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34.2.1.5 Tank lifting mechanism

Where the tank lifting mechanism is integral with the circuit breaker, the rope (where fitted) and operating mechanism should be inspected for wear, corrosion and freedom of moving parts. This inspection should be carried out before attempting to lower the tank.

Lifting mechanisms should be lubricated sparingly and the hydraulic system topped up as necessary.

34.2.2 Post-fault maintenance

WARNING. Fault operation of circuit breakers can produce quantities of smoke and flammable gases, and the isolation of withdrawable circuit breakers should be delayed to allow for dispersal of these.

34.2.2.1 Insulating oil

If the oil is badly discoloured or shows evidence of excessive contamination by carbon particles in suspension it might require changing. If the oil requires changing this should be done in accordance with the procedure given in **34.2.1.3**.

34.2.2.2 Joints and seals

All joints and seals should be inspected for tightness and particular attention should be paid to tank gaskets where these are fitted.

34.3 Air circuit breakers examination and overhaul

In addition to the recommendations given in **34.1**, it is essential that any air-puffer device be inspected for correct operation. Care needs to be exercised with equipment containing old components e.g. arc chutes which may contain asbestos. Attention is drawn to the Control of Asbestos Regulations 2006.

34.4 Vacuum circuit breakers

*NOTE 1 The following recommendations are specific to vacuum circuit breakers and are additional to those given in **34.1**.*

NOTE 2 Vacuum circuit breakers are long life devices with a typical vacuum life of at least 20 years and typical switching capabilities of tens of short-circuit interruptions and thousands of load switching operations.

A vacuum interrupter is a sealed unit on which no internal maintenance can be carried out. Contact wear is not normally a problem, however circuit breakers often have a method for indicating contact erosion. The minimum vacuum life of the vacuum interrupter can be expected to be stated by the manufacturer as this is specified in BS EN 62271-1 and is from the date of seal-off not the date of start of service; however, experience indicates that the actual lifetime is well in excess of the stated minimum value. During this period, vacuum integrity can be confirmed by methods recommended by the manufacturer. These normally consist of voltage withstand tests which can confirm the loss of vacuum but cannot predict future life expectancy. If a voltage withstand test confirms loss of vacuum it is essential that the unit is replaced.

Once the vacuum life (also known as the shelf life) has expired, the continuing integrity of the vacuum interrupter should be determined by a revalidation process, e.g. by a risk assessment process and/or a vacuum assessment.

Where the recommended method involves the application of a high voltage to the vacuum interrupter, careful attention should be paid to the relevant instructions in the manufacturer's handbook for avoiding electric shock and possible emission of X-radiation.

34.5 Circuit breakers containing sulphur hexafluoride gas

*NOTE The following recommendations are specific to sulphur hexafluoride circuit breakers and are additional to those given in **34.1**.*

Many SF_6 circuit breakers are sealed for life devices and as such there are no user serviceable components located internally. In this case examination and overhaul should be restricted to the areas of the circuit breaker external to the gas zone.

35 Switches

35.1 General

The maintenance of switches, switch-disconnectors, switch-fuses and fuse-switches should be carried out in accordance with Clause **34**.

NOTE Switches are not designed to break fault current and consequently, arc control devices, where fitted, can be simpler than circuit breakers.

In addition, on open type outdoor switches, flexible connections should be inspected for fraying, especially at the terminations, and for deterioration of any protective oversheaths. Protective compound should be applied as recommended in the manufacturer's instructions to protect bare copper flexible connections. Arc horns should be inspected for damage and the security of fixings checked. It should be ensured that the horns wipe lightly through the opening stroke and do not foul during the closing stroke.

Fuses in switch-fuses and fuse-switches should be checked in accordance with Clause **38**.

35.2 Hard-gas interrupters

These are air interrupter units designed so that the arc deliberately acts on a polymeric component which releases gaseous products into the arc assisting in the interruption process.

Detailed examination and overhaul should be carried out in accordance with the manufacturer's instructions for the particular unit. An inspection and minor overhaul may be carried out in the following way.

a) External insulation should be cleaned.

b) External wiping or sliding contacts should be cleaned and an appropriate contact lubricant applied.

c) Where applicable, the interrupter vent should be removed and inspected. The presence of metal particles and carbonized material might denote excessive contact erosion and, in that case, further examination is needed. If necessary, the unit should be changed and maintenance carried out in the workshop or by the manufacturer.

d) A check should be made on the interrupter to check whether it operates freely and positively to the open and closed positions; lubrication of the interrupter mechanism is not normally required.

Operational checks should be carried out in accordance with the manufacturer's instructions since it is essential for satisfactory performance that the contacts operate in the correct sequence.

36 Disconnectors and earthing switches

The maintenance of disconnectors and earthing switches should be carried out in accordance with Clause **34**.

NOTE With the exception of some earthing switches which have a fault-making rating, disconnectors and earthing switches are not designed to make or break any more than negligible currents. Consequently, contacts and mechanisms are simpler than for circuit breakers.

Where open-type disconnectors and earthing switches are installed in an unfavourable environment, it might be necessary to use a dry type lubricant on contacts that would otherwise normally be greased, in order to avoid a build up of contaminants.

Some types of disconnectors and fault-making earthing switches rely on contact friction to decelerate the moving parts without bounce. It is essential that contact lubricant is not applied in these cases.

37 Busbars and busbar chambers

Air insulated busbars and busbar chambers, and their supports, should be examined, as far as is reasonably practicable, for signs of overheating and for deterioration of the insulation. This could include use of a number of non-invasive techniques e.g. thermal, partial discharge. Open type busbars can be scanned with infra-red detection equipment in order to indicate any hot spots which are caused by high resistance connections.

NOTE 1 Protective barriers, although they might be clear, can affect the transmission of infra-red and thus the reading of infra-red detection equipment.

Compound and oil filled busbar chambers should be inspected for leakage. Insulation should be checked as detailed in Clause **24**.

Sulphur hexafluoride filled busbar chambers which are giving satisfactory service should not be disturbed as contamination might be introduced during examination.

NOTE 2 Use of a leakage detection device may be considered.

Following maintenance, it is particularly important that an inspection is made to ensure that no loose equipment or wiring is left in the vicinity of the busbars which could subsequently cause a fault.

38 Fuses

An inspection should be carried out for correct type and rating, security, engagement, overheating and correct location/orientation. If the fuses are of the striker-pin type, it should be verified that they are correctly installed and that the striker-pin trip arrangements and indications are in good functional order.

Devices are available which fit in the fuse holder to simulate the action of the fuse striker pin and enable its action on automatic tripping to be checked. The action of the striker pin should be checked in each phase of the equipment separately, and it should be ensured that they are inserted in the correct orientation.

Where motor-starting fuses conforming to BS EN 60644 are used, particular care should be exercised if replacing by another brand, since characteristics vary for fuses of the same nominal rating. In these circumstances, protection co-ordination with the switching device, etc., as well as the ability to withstand the repeated motor starting currents without deterioration (ageing) should be checked by reference to manufacturer's data. These aspects are even more important where distribution fuses conforming to BS EN 60282-1 are used for motor circuits since they do not have the same ability to withstand repeated motor starting currents.

Subsequent to a fuse operating on fault, it is recommended that all fuse links of the same rating apparently subjected to the fault should be destroyed and replaced by new fuse links.

NOTE Some constructions of equipment permit the safe renewal of fuse links with the equipment live.

The availability and use of correct replacement fuse links should be ensured.

Confusion between fuse links and solid links should be guarded against.

39 Contactors

39.1 Air contactors

Some auxiliary contacts are not intended to be maintained. Such items should not, therefore, be dismantled for maintenance or overhaul purposes.

The correct operation and setting of latching mechanisms should be checked. Should the main contacts ever become welded or the protective fuse or circuit breaker operate on a power fault, then, as well as investigating and rectifying the cause, the contactor should be examined according to the manufacturer's handbook before returning the equipment to service, since damage might have occurred.

The following list gives operations that should to be carried out during maintenance.

a) *Contacts: main and auxiliary*. These should be examined or inspected for wear (according to the manufacturer's handbook) and for overheating, misalignment, failure to disengage correctly and other defects, and reconditioned or renewed as required.

   NOTE 1 Overheating can be caused by overloading, a loose connection, insufficient contact force or misalignment.

   For correct treatment of contacts the manufacturer's handbook should be referred to as it depends on the material from which they are made as well as on the duty of the equipment. Particular attention should be given to plated contacts, to ensure that the plating is not removed, as the rated characteristics of the switchgear could be compromised.

Contact areas on which arcing occurs should be lubricated only in accordance with the manufacturers' instructions. Other parts of the contact surface might also require lubrication and the recommendations given in the manufacturer's handbook should be followed.

In spite of the frequent pitted and discoloured appearance of contacts, dressing should only be carried out on those of plain copper, using a fine file or glass paper to remove any large projections (emery or carborundum paper should not be used). Excessive dressing of contacts should be avoided and it is important that the contact profile is maintained.

Lightly welded contacts should be parted and, subject to examination as above, can continue in service.

b) *Arc-control devices*. These should be examined and replaced if cracked or badly eroded.

The free operation of the contactors should be checked. Contacts should not foul arc chutes or barriers. The cleaning of barriers should be carried out accordingly. Users should be aware that, particularly on older designs, some of these barriers can contain asbestos.

NOTE 2 Attention is drawn to the Control of Asbestos Regulations 2006.

c) *Operating mechanisms*. Mechanisms should be inspected for freedom of movement, wear and effective operation as follows.

1) *Electromagnetic*. Where possible the pole faces should be examined for the collection of material in the gaps, and care taken to remove it and any oil or grease without damaging the pole faces, otherwise "sticking" might occur.

With d.c. operated contactors, if the magnet remains closed when the coil is de-energized, the anti-residual device and throw-off springs, if fitted, should be examined. Coil economizing circuits, suppression devices, etc., should be inspected.

Excessive noise from a.c. operated magnets when closed might be due to a number of causes of which the following are examples:

i) dirty magnet faces;

ii) broken shading ring;

iii) incorrect contact adjustment;

iv) incorrect alignment of magnet faces.

NOTE 3 The magnet faces of new contactors are often provided with a protective coating to prevent corrosion during storage and this can cause excessive humming during the first few operations only.

2) *Pneumatic*. The mechanism should be inspected for air leakage and other defects.

The care of electrically operated valves, power operating cylinders and pneumatic supply systems will differ according to construction and the manufacturer's instructions should be followed. Valve leakage is usually due to dirt on the valve seat but can be caused by wear. Sluggishness can be due to a sticky valve stem or insufficient travel. Recommended solvents may be used to clean valve parts when necessary.

39.2 Oil contactors

In addition to inspection and maintenance in accordance with **39.1**, inspection should be made for oil leaks, and the correct level and condition of the oil in accordance with **24.3**.

39.3 Vacuum contactors

The recommendations given in **39.1** should be followed, except in relation to the main contacts. The contact assemblies are sealed and no internal maintenance can be carried out.

When recommended by the manufacturer, an examination should be made for the integrity of the vacuum and also for contact wear and alignment which might require adjustment (see also **34.4**). In the event of a fuse blowing, the manufacturer's instructions should be carefully followed. Depending on the rating and fuse co-ordination the main contacts might have suffered class C damage (as defined in BS EN 60470) which would require their replacement.

39.4 Sulphur hexafluoride contactors

Maintenance should be carried out in accordance with **39.1**c) and **34.5**. These are sealed units and no internal maintenance can be carried out.

40 Overload protective devices

40.1 General

Many overload protective devices are not intended to be maintained or are designed for maintenance by specialists. Such items should not, therefore, be dismantled for maintenance or overhaul purposes. In certain cases, special purpose relays might be employed (see Clause **41**).

Where accessible, contacts should be inspected and, if possible, tripping simulated by mechanical means, e.g. by operating the test button.

When replacing heaters of thermal overload devices, correct alignment and soundness of connections should be ensured.

The fluid in dashpots of magnetic overload devices should be maintained at the correct level with clean fluid at all times. It is most important that only the fluid recommended by the manufacturer should be used both to give the correct delay and to minimize sludging.

Whenever an overload device has been dismantled or replaced, the accuracy of setting should be verified where relevant by a low voltage current injection test. Following a through fault, the opportunity should be taken to inspect and carry out maintenance or replacement as necessary, since damage might have occurred.

40.2 Time fuses

The contacts of time fuses if allowed to deteriorate can affect fuse performance. These should be regularly inspected and cleaned.

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Where time fuses of a rewireable type are used, attention is drawn to the possibility of mechanical damage to, or deterioration of, the fuse wire or of high resistance contacts.

NOTE It is important that fuse wire of the correct rating and material is used.

A continuity test gives a useful indication of the condition of a fuse but it should be noted that rewireable fuse links can deteriorate in time due to the passage of high load currents.

41 Relays

*NOTE 1 General purpose relays, such as contactor relays (maintenance of which is covered in BS 6423), overload protective devices (see Clause **40**) and timing devices (see Clause **42**) are not covered by the recommendations in this clause.*

Particular note should be taken of any relay associated with plant safety (see also PD 5304). A periodic check should be devised and used to prove the operational capability of the device. Any maintenance on relays should be carried out in accordance with the manufacturer's instructions and should be incorporated in the maintenance programme which should include operational checking of protective and interlock features.

NOTE 2 See HSE publication HSG 230 Keeping electrical switchgear safe *[3].*

42 Timing devices

There are many types of timing device and most are designed for specialist maintenance. Such items should not be dismantled for maintenance or overhaul purposes unless this is recommended in the manufacturer's instructions.

Where possible, actual timing periods should be verified against the set values and application requirements, particularly if the timing device has been dismantled or replaced.

43 Protective, measuring and control transformers

43.1 General

In general any maintenance on protective, measuring and control transformers should be carried out in accordance with the manufacturer's instructions.

43.2 Current transformers

WARNING. Steps should be taken to ensure that a current transformer is dead and isolated and discharged to earth before it is examined. Attention is drawn to the dangerous voltage which could result if the secondary circuit of a current transformer is opened with the primary circuit on load. It is essential to ensure that any connection removed for the purpose of carrying out tests is correctly replaced and securely tightened.

When current transformers are installed in cells or other locations in which they are accessible, maintenance should consist of a general inspection and verification that all main and secondary connections are tight. All exposed insulation should be cleaned and examined thoroughly for any damage such as cracks or tracking marks.

On oil filled current transformers the oil level should be inspected and the required quantity of the correct oil added if necessary. At longer intervals the oil might require testing (see **24.3**). As the oil is used as a coolant, acidity and electric strength tests in accordance with BS EN 60422 might also be necessary.

Current transformers insulated by sulphur hexafluoride under pressure should be inspected to determine if the correct gauge pressure is being maintained. If attention is necessary, the manufacturer's maintenance handbook should be consulted.

Current transformers enclosed in metal clad gear, or otherwise inaccessible, are usually safe against mechanical damage and only electrical testing can determine whether they are in good order. Where test windings are provided, these tests can be carried out without difficulty. Where such provision is not made, however, special means might have to be devised; an insulation resistance and continuity test of the secondary winding should be regarded as an essential minimum.

43.3 Voltage and control transformers

Steps should be taken to ensure that a voltage transformer is dead and isolated and discharged to earth before it is examined. Where protective fuses are fitted, particular care should be taken to ensure that the voltage transformer is discharged to earth.

Particular care should always be taken to ensure that a voltage transformer is not liable to be made live inadvertently due to a feedback via the secondary side.

Maintenance as described in **43.2** for current transformers is appropriate to voltage transformers. In addition, the isolating contacts of withdrawable transformers should be cleaned, inspected for damage, reconditioned as necessary and a film of contact lubrication sparingly applied. The correct operation of any safety shutters should be verified.

Certain oil filled voltage transformers might be fitted with a gas/oil actuated (Buchholz) relay which should be maintained in accordance with the manufacturer's instructions.

Protective fuses and current-limiting resistors, if provided, should be tested for continuity and general soundness.

44 Instruments including recorders

There are many types of instruments and most are designed for specialist maintenance. Such items should not be dismantled for maintenance or overhaul purposes unless this is recommended in the manufacturer's instructions.

Maintenance should usually only entail inspection except for renewal of consumable items and recalibration.

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45 Capacitors

WARNING 1. Before working on the capacitor or connections it should be ensured that the capacitor is discharged and subsequently all terminals earthed at the same time. Capacitors are often fitted with discharge devices designed to reduce the potential to a safe value after switching off. Time should be allowed for the capacitor to discharge and a voltage tester used to verify that the terminals are safe to handle.

WARNING 2. Special precautions should be taken when handling old capacitors since some might contain polychlorinated biphenols (PCBs). Guidance on the safe handling of PCBs can be found in HSE publication MSA 19 *PCBs and you. Do you know how to work safely with PCBs?* [11].

Apart from inspection in accordance with the manufacturer's instructions, additional maintenance is not normally required.

Electrolytic capacitors deteriorate if stored or not used for long periods (e.g. 12 months) and it is important that they are "re-formed" in line with the manufacturer's instructions.

46 Power electronic equipment

Before commencing work it should be ensured that there are no backfeeds, e.g. regenerative, capacitive, or from distributed generation.

The continuity of fuses should be verified if this can be safely done without disconnection.

Surge voltage absorbing or controlling circuits should be inspected.

Subsequent to the failure of a semiconductor device, or rupture of its associated fuse, the surge voltage absorbing or controlling circuit should always be examined.

Semiconductor devices can fail if subjected to voltages or currents in excess of their rating. In consequence great care should be taken during dielectric testing, when semiconductors should be protected, e.g. by short circuiting. Circuit continuity testers should be of types that do not generate damaging voltages or currents.

For thyristor phase determining circuits and semiconductor control equipment, it is essential to carry out any investigation into causes of malfunction in strict accordance with the equipment manufacturer's instructions. It is important to ensure that any connections removed are replaced in their correct positions. If the supply leads have been disturbed the phase sequence should be verified, as a wrong phase sequence might cause maloperation in addition to reversal of any connected rotating equipment.

It should be noted that anything connected to the gate of the thyristor is at main power circuit potential.

Various methods of cooling are used. It is essential that the cooling fins, ducts and heat exchangers are inspected regularly and cleaned as necessary.

Where an intermediate cooling medium is used this should be kept at the correct purity, flow rate and reservoir level.

When replacing semiconductors, their fuses or associated components, it is essential that the manufacturer's instructions are followed. This particularly applies to cleaning, preparation of mating surfaces, jointing and securing techniques.

Aluminium is extensively used in semiconductor equipment. Electrical connectors in this material require special treatment and the manufacturer's instructions should be followed.

47 Cable boxes and terminations

The security of mounting and of earthing, where appropriate, should be examined. Compound/oil filled boxes should be inspected for leakage. In the case of dry type terminations, exposed tails should be examined for the condition of insulation and freedom from moisture and tracking, particularly in the crutch area. This could include use of a number of non-invasive techniques e.g. partial discharge.

48 Control switches including pushbuttons and limit switches

Many mass-produced items are not intended to be maintained and it is not possible to inspect or gain access to operating mechanisms, contacts and associated insulation. Such items should not, therefore, be dismantled for maintenance or overhaul purposes.

When a new item or part has been fitted it is desirable to operate the equipment a few times before it is put back into service, to ensure its correct operation and that of associated plant.

Where accessible, contacts should be inspected and when refitted or renewed, contact force, alignment and wipe should be verified.

Where possible, and strictly in accordance with the manufacturer's recommendations, the mechanism should be cleaned and inspected, worn parts renewed, pivots lubricated and the security of retaining devices verified, e.g. circlips correctly seated and split-pins opened.

Any seals and gaskets that show signs of deterioration should be replaced.

49 Liquid starters, controllers and resistors

Liquid starters and controllers incorporate an electrolyte (usually an aqueous solution of sodium carbonate) as the resistance element and therefore require routine servicing to inspect the electrolyte level, which should be topped up as necessary to replace evaporation losses. The frequency at which this is required depends very much on the duty and the installation ambient conditions and could be daily for heavy duty controllers. Soft, purified or distilled water should be used for topping up. No additional sodium carbonate is needed unless electrolyte has been lost by leaks, etc.

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Periodic maintenance is also needed, as applicable, for the following items.

a) *Electrodes*. These should be inspected and any scale that has accumulated on them should be removed. If the electrodes are badly worn or corroded they should be replaced. Hard scale on the electrodes, accompanied by excessive wear on the unscaled portions, usually indicates that hard water has been used for making or topping up the electrolyte. In this event the electrolyte should be renewed.

b) *Insulators*. These should be cleaned and inspected (see Clause **24**).

c) *Integral short-circuiting contacts (in air)*. These should be inspected, cleaned and checked for alignment and smeared with petroleum jelly. If the contacts are eroded by arcing they should be replaced after investigating the cause (which might be too weak an electrolyte).

d) *Connections*. These should be examined for tightness and condition (see Clause **23**).

e) *Operation*. The operation of the equipment should be checked, including auxiliary switches, and mechanical parts lubricated as necessary.

f) *Electrolyte coolers*. If fitted, these should be inspected for corrosion from the electrolyte. If signs of abnormal corrosion are seen, an analysis of the electrolyte for contamination by, for example, chlorides or sulphates, might be worthwhile and if found, the electrolyte should be renewed. The cooling system should be inspected for leaks and all valves checked.

g) *Tanks*. These should be inspected, as far as practicable, for cleanliness and freedom from sludge which might cause corrosion in the bottom of the tank as well as restricting electrolyte circulation in some designs.

   If significant sludge is found, or if considerable electrode wear or scaling has taken place indicating the presence of sludge, the tank(s) should be emptied and cleaned.

h) *Electrolyte system*. The system should be inspected for leaks and all valves, etc. checked. If forced circulation is used, the pumps and associated gear should be checked to ensure that they are in good order and function correctly. Occasionally, the pump, pipework and valves in such systems should be examined for possible erosion/corrosion. Valve erosion can be due to running the pump with the valve partly open.

   Where thermostatically controlled heaters are fitted these should be checked for satisfactory operation.

i) *Electrolyte*. The electrolyte does not normally need frequent renewal. However, when it becomes necessary to empty the tank(s), e.g. to change electrodes or remove sludge, it is preferable to refill with fresh electrolyte.

   In order to save time in determining the strength of the new electrolyte, a record should be kept of the electrolyte strength for each starter and controller. This may be by mass of sodium carbonate crystals or by relative density related to temperature, of the made-up electrolyte. This information is also useful should it be necessary at any time to make good significant losses by leakage, etc.

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It should be noted that a given mass of anhydrous sodium carbonate (soda ash) has over 2.5 times the strength of crystalline sodium carbonate (washing soda).

Unless specified to the contrary, the starter or controller will be supplied without electrolyte. Only sodium carbonate in soft, purified or distilled water should be used, unless otherwise approved by the manufacturer.

The strength of the solution required varies over a wide range and it may be necessary to use as much as 1 kg or more of the crystalline sodium carbonate per 10 L of solution.

NOTE Where separate phase tanks are incorporated, the electrolyte strengths should be correctly proportioned.

50 Manual controllers

50.1 General

Correct operation should be periodically verified as should the setting of any integral protective releases, e.g. undervoltage, overload.

Manual operating mechanisms should be examined giving particular attention to correct functioning of "dead man's" handle, spring/gravity return and condition of rope, chain or rod actuator, as appropriate.

*NOTE If the controller is oil immersed, see also **24.3**.*

50.2 Drum type

Shaft bearings require adequate lubrication and renewal as necessary.

Notching arrangement, contact alignment, pressure and follow-through should be checked.

It should be ensured that arc control devices and/or barriers are in the correct location and not cracked or badly eroded. Blow-out coils should be examined for signs of overheating and replaced as necessary. Thorough cleaning of finger and barrel insulation is essential, particularly where there is marked wear of segments and fingers and hence deposits of conductive dust.

50.3 Cam type

Maintenance should be similar to that for contactors (see Clause **39**) and maintenance of the working parts should be similar to that for controllers of the drum type (see **50.2**).

50.4 Faceplate type

Contacts should be examined or inspected for wear (according to the manufacturer's handbook) and for overheating, misalignment and defects. They should be reconditioned or renewed as required.

NOTE Overheating can be caused by inadequate ventilation, overloading, a loose connection, insufficient contact force or misalignment.

The correct treatment of contacts depends on the material of which they are made as well as on the duty of the equipment and reference should be made to the manufacturer's handbook.

51 Sealed switches

The term "sealed switch" is used here to describe a device in which two or more terminals occur on the outside of an envelope within which contacts operate in a controlled atmosphere.

A wide range of contact materials can be employed including mercury. Should contact materials become exposed as a consequence of envelope damage they should be regarded as potentially hazardous and treated and disposed of accordingly.

Envelope damage invalidates switch performance and immediate replacement is necessary. Visual inspection of contacts or of device operation is seldom possible. Doubts concerning performance should be resolved by replacement or by an operational check carried out in accordance with the manufacturer's information. The operational efficiency of any power or current-limiting component associated with the switch contacts should be ensured.

Some types of sealed switches can be damaged by the current pulses produced by simple forms of continuity indicators. Continuity testers should be of types that do not generate damaging voltages or currents.

Some devices combine switches with permanent magnets and should not be exposed to magnetic fields of significant level. Care should be taken when storing such devices to avoid close proximity with each other or with stray magnetic fields; alternatively each device should be provided with an individual magnetic keeper shroud.

52 Actuators

The following actuators types can be used in switchgear:

- spring;
- pneumatic;
- hydraulic;
- solenoid;
- permanent magnet.

WARNING 1. Circuit breaker actuators provide the movement necessary for the correct operation of the switchgear. As such, regardless of type, they are all stored energy devices and it is essential that they are treated with caution. The energy stored is significant and serious injury could result if an operator is caught in the moving mechanism.

The large variety of types makes reference to the manufacturer's instructions imperative but general inspection and maintenance, where appropriate, of brushes, bearings, ventilation, travel limits and mechanism will increase the device life. Pneumatic and hydraulic mechanisms should be checked for leakage, and solenoid and permanent magnet actuators should be checked for electrical connections. In the case of magnetic actuators it might be the case that the control and energy for the operation (normally in the form of capacitors) is combined with the relay unit.

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CAUTION. Some types of actuators can be damaged if operated whilst uncoupled from the driven item.

WARNING 2. Some designs of magnetic actuators use high voltages, which can be several hundred volts for operation, and these can constitute a safety hazard.

The special magnetic materials used in magnetic actuators are prone to corrosion and are normally covered in a protective lacquer. Corrosion can rapidly cause significant deterioration in the performance of the actuator and, where applicable, the magnets should be inspected for corrosion during maintenance.

53 Indicator devices

Many types of indicator devices are not intended to be maintained; such items should not therefore be dismantled for maintenance or overhaul purposes. Examples are visual devices such as lamps, light emitting diodes (LEDs) and semaphores, and audible devices such as bells and sirens.

An operational check should be carried out.

Only correct replacement lamps or LEDs should be used, as wrong selection can give rise to overheating and/or incorrect light intensity and can lead to premature failure.

Where the indicator device is used as a hazard warning, a procedure should be included in the safety rules to ensure that it is functioning efficiently.

54 Batteries

54.1 General

Operational experience has shown that that the maintenance and correct functioning of the ancillary battery equipment for switchgear is frequently overlooked. Failure to maintain such equipment can cause the switchgear not to operate under fault conditions as designed and can exacerbate the fault circumstances.

Batteries for switchgear tripping and closing supplies play a vital part in the overall performance of the equipment. The batteries and associated chargers need an appropriate maintenance regime in order to ensure consistent and reliable performance.

WARNING. As hydrogen produced during battery charging is flammable, the use of naked flames should be prohibited at all times in the immediate vicinity of battery installations. For the same reason, precautions should be taken to avoid causing sparks near to the battery.

A violent reaction will result if alkaline and acid substances are mixed, or if water is poured into concentrated acid.

Protective clothing should be worn and special care taken when handling electrolyte to prevent it coming into contact with the body. Should this occur, the affected area should be washed immediately with a copious supply of clean water. Means of doing this should be readily available. Medical attention should be obtained in the event of burns or if the eyes are involved.

Batteries are capable of producing very large currents with consequent risk of burns or fire. Particular care is therefore needed to avoid inadvertent short-circuits by hand tools, slings, etc. Insulated tools, etc. should be used.

No unnecessary metal objects should be worn or carried when working on batteries.

It is essential that personnel involved in work on, or close to, batteries are competent to carry out such work and trained in any special procedures necessary. It is also essential that appropriate tools are provided (see BS EN 60900 for guidance).

A major issue is establishing that the remaining battery life is sufficient for the maintenance interval. The battery room environment, charging regime and duty all play a part in determining battery life and the achievement of reliable performance over and above the maintenance practice. The practical lifetime can be less than the manufacturer's quoted figures, as these are based on optimum conditions in service at ideal temperatures.

Pertinent questions for the asset engineer are what test methods to use and what maintenance strategy to apply. The two are interrelated since decisions on one will affect the other. For example:

- a strategy of replacing batteries on the basis of condition requires diagnostic equipment that has the capability of reliably assessing battery condition and remaining life, and a commitment to regular testing;
- for a strategy of replacing batteries at a specific frequency based on experience of failure rates and lifetimes, the diagnostic equipment can be less sophisticated, but needs to be capable of identifying premature failure.

The type of battery in use is a major factor. One of the main problems with lead-acid cells is that their ageing is not linear and there is always a possibility of "sudden death" failure, particularly in the case of valve regulated lead-acid (VRLA) types. This makes it difficult to predict when they will need replacing. In contrast, the ageing of nickel-cadmium cells is linear and more predictable, allowing a lifetime to be reliably defined. In both situations some form of diagnostic testing is vital to avoid early failures going undetected, but can be less frequent for nickel-cadmium cells.

54.2 Primary cell(s)

The maintenance of this type of cell should be a simple inspection with replacement as required.

54.3 Secondary cell(s)

Where possible, battery systems using different types of secondary cells should be kept in separate rooms to prevent accidental contamination between the systems. It is important that separate, clean, battery utensils be kept for lead-acid type and for alkaline type batteries since any contamination by incorrect electrolyte can damage the battery. All utensils should be prominently identified for use on the particular type of battery and preferably kept in separate locations. Further guidance on safe operation of lead-acid batteries is given in BS 6133.

The means provided for safe and efficient dispersal of hydrogen should be inspected and kept clear.

Battery cells should, where practicable, be inspected for shedding of active material, sedimentation and buckling of the plates.

Measurements of cell voltage and relative density of the electrolyte should be taken. The electrolyte level should be inspected and, where necessary, topped up to the correct level with distilled water.

The terminal posts and connectors should be inspected for corrosion and tightness of the connections and, after cleaning as necessary, lightly greased with petroleum jelly or other corrosion inhibitor.

The manufacturer's instructions should be kept in a prominent position close to the batteries, where they can be read easily and the recommendations followed.

55 Compressed air plant

Compressed air plant should be inspected as part of the routine maintenance, at which time it is good practice also to carry out the periodic start/stop tests on the plant.

NOTE 1 The manufacturer's guidance on the maintenance of this equipment should be followed. There are statutory obligations to inspect, test and certify air receivers (pressure vessels) periodically, at which time pressure relief and reducing valves, if fitted, should also be inspected.

NOTE 2 Attention is drawn to the Pressure Systems Safety Regulations 2000.

Annex A (informative) Statutory requirements and related documents

Attention is drawn to the following statutory requirements.

NOTE This list is not exhaustive.

Control of Asbestos Regulations 2006

Control of Noise at Work Regulations 2005

Control of Substances Hazardous to Health Regulations 2002

Electricity at Work Regulations 1989

Electricity Safety, Quality and Continuity Regulations 2002 (as amended)

Environmental Protection Act 1990

Factories Act 1961

Fluorinated Greenhouse Gases Regulations 2009

Gas Safety (Installation and Use) Regulations 1998

Health and Safety at Work etc. Act 1974

Lifting Operations and Lifting Equipment Regulations 1998

Management of Health and Safety at Work Regulations 1999

Pressure Systems Safety Regulations 2000

Provision and Use of Work Equipment Regulations (PUWER) 1998

RoHS Regulations 2008

Work at Height Regulations 2005

The following documents also offer further guidance.

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Electrical maintenance, published by the Institution of Engineering and Technology (IET) [12].

MSA 19 *PCBs and you. Do you know how to work safely with PCBs?* Free leaflet. Published by HSE Books, 1995 [1)] [11].

1) Available from http://www.hse.gov.uk/pubns/msa19.htm

Annex B (informative)

Example of items to be covered in safety rules

COMMENTARY ON ANNEX B
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It is essential for every organization to have, and to work to, a detailed set of safety rules. This annex gives, as an example, some of the headings under which these rules need to be drafted and some of the principal topics which need to be covered.

The list of headings and topics is not exhaustive and asset owners/users should consider each element in turn and produce their own safety rules to suit their individual circumstances and the types of systems being worked upon.

NOTE Numbered paragraphs of text give advice which needs to be incorporated into the safety rules. The headings given are intended to be those under which safety rules specific to the particular organization can be drafted.

1. Introduction

1.1. Scope

1.1.1. Identify the full extent of the duty holder's electrical distribution system, including boundary points.

1.1.2. Safe systems of work must be established across boundary points.

1.2. Duties and Responsibilities (Generally)

1.2.1. The duty holder must allocate responsibility for the achievement of health and safety from the inherent dangers of the distribution system, plant and apparatus during the various stages of work or activity.

1.2.2. The duty holder must ensure effective systems and procedures are in place to safely manage the distribution network.

1.3. Training requirements

1.3.1. Duty holders must have in place:

(i) Adequate technical training;

(ii) Capability assessment;

(iii) Competency assessment;

(iv) Treatment of electric shock.

1.4. General 'safety rules housekeeping' requirements:

1.4.1. Change control process;

1.4.2. Ensure all relevant persons have copy of rules.

1.5. Identify which rules require approved plant and apparatus, and approved procedures (and/or Codes of Practice).

2. Definitions of terms

2.1. Terms used must be adequately defined to ensure correct application of the safety rules.

3. General Safety Rules

3.1. All tasks must start with a risk assessment.

3.2. Always assume apparatus is live.

3.3. Personal Protective Equipment shall be issued and worn.

3.4. If anyone is not sure, stop and seek clarification.

3.5. Don't do it unless you are suitably trained / competent / authorized.

3.6. What to do in unexpected situations while working e.g. failure of supply.

3.7. Confined Spaces.

3.8. Fire Protection.

3.9. Working above 2 metres:

3.9.1. Remain attached;

3.9.2. Unsound poles.

3.10. Do not patrol alone across country in darkness or poor weather conditions.

3.11. Voltage testing devices.

3.12. Use of mobile plant near overhead lines.

3.13. Restrictions for long objects and vehicles in substations.

3.14. HV Switching:

3.14.1. Assess the competency of persons;

3.14.2. Maintain control procedures.

3.15. Recording operational information.

3.16. Recording of accidents and incidents.

3.17. Every source of stored energy in the system to be worked on must be effectively controlled to minimize risk.

3.18. Equipment subject to the safety rules must be clearly and unambiguously identified.

3.19. Effective communication must be established and maintained between all relevant parties.

4. Precautions when working on or near HV systems

4.1. Work must not be carried out on an HV system unless it is dead, effectively isolated, efficiently earthed, screened to prevent danger, identified and released for work by the issue of appropriate documentation.

4.2. Isolation.

4.2.1. Isolation must be controlled and co-ordinated in the context of the network.

4.2.2. Devices used to perform isolation must provide adequate physical separation between the isolated and non-isolated equipment.

4.2.3. Adequate precautions must be in place to reduce risk of interference with points of isolation.

4.3. Earthing.

4.3.1. The positioning of earths relative to the zone of work.

4.3.2. Use lowest risk method to apply earths (via CB, switch, portable leads).

4.3.3. Check earthing lead equipment before use.

4.3.4. Use the lowest risk process to apply / remove portable earthing leads.

4.3.5. Control and recording of earths.

4.4. Safety distances and working and access clearances that must be maintained between exposed HV conductors and persons and / or objects.

4.5. Work in substations.

4.5.1. No one must work outside the delimited area.

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4.6. Safety documentation.

4.6.1. Safety documents must match standard company proformas.

4.6.2. Safety documents must be legible, and clearly and unambiguously identify:

(i) The equipment that can be worked on;

(ii) What precautions have been taken;

(iii) Any other precautions that need to be taken, including any residual site hazards or risks;

(iv) The work that can be carried out.

4.6.3. Safety documents must be signed at each key stage in their lifecycle to indicate that the specified actions have been taken and responsibilities have been accepted.

4.6.4. Where safety documents are not used, effective precautions must be applied to ensure work can proceed safely. Clear, unambiguous instructions must be issued.

5. Working on specific items of plant, equipment, and apparatus

5.1. Specific precautions to be taken when working on or adjacent to high voltage open terminal apparatus in substations.

5.2. Specific precautions to be taken when working on fully enclosed (metalclad) apparatus in substations.

5.3. Specific precautions to be taken when working on transformers, capacitors and other equipment.

5.4. Specific precautions to be taken when working on or adjacent to overhead networks:

5.4.1. Lightning risk;

5.4.2. Soundness of poles.

5.5. Specific precautions to be taken when working on or adjacent to cable networks:

5.5.1. Always presume cables to be live unless identified and proved dead by approved means at the point of work;

5.5.2. Key points to deal safely with damaged cables.

6. Live Line working

6.1. Requirement for additional training and authorization.

6.2. Tools and equipment must be approved and checked before use.

6.3. Control Engineer must be aware of work content.

6.4. Unauthorized re-energisation by manual, remote or automatic means is prohibited.

6.5. Apparatus must be checked before starting.

6.6. Precautions must be taken to prevent any steelwork becoming live.

6.7. Observe safe handling limits, including after conductors have been displaced.

6.8. Protect against out-of-control live conductor.

6.9. Defined weather restrictions.

6.10. Precautions for other members of the team and the public.

7. Safe working on LV systems

7.1. Personnel shall be adequately trained and authorized for the work to be done.

7.2. Apparatus shall always be presumed live unless proved dead by approved means.

7.3. Before starting work, always assess the risk.

7.4. If working dead:

(i) Apparatus shall be adequately isolated (including from consumers' generation), and;

(ii) Earthed where reasonably practicable, and;

(iii) Identified and proved dead at the point of work using approved means.

7.5. If working live:

(i) Adequate precautions shall be taken;

(ii) Approved procedures shall be followed;

(iii) Approved tools shall be used;

(iv) Electrical rubber gloves shall be worn;

(v) Only one live conductor in a cable shall be bared at a time, and;

(vi) When manipulating bare live conductors, the person must be accompanied.

7.6. Polarity and phase rotation shall be checked after working on a connection to a consumer.

7.7. Restrictions will apply when working on an LV overhead line in the vicinity of live HV overhead lines.

7.8. Identify precautions to ensure safe working on LV networks which are interconnected with HV networks.

7.9. Any unearthed steelwork supporting live LV overhead lines should be treated as live unless proved dead by approved means.

8. General precautions to be taken when testing HV Apparatus

8.1. Additional dangers require persons with special responsibilities.

8.2. Requirement for special processes with special proformas.

8.3. Requirement for maintaining clearances from live conductors.

9. Confirmation of the responsibilities of all persons who carry out duties under the safety rules

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