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Code of practice for maintenance of low-voltage switchgear and controlgear

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Contents

Summary of pages

This document comprises a front cover, an inside front cover, pages i to iv, pages 1 to 36, an inside back cover and a back cover.

Foreword

Publishing information

This British Standard is published by BSI Standards Limited, under licence from The British Standards Institution, and came into effect on 30 November 2014. It was prepared by Technical Committee PEL/17/3, *Low-voltage switchgear and controlgear assemblies* under the authority of Technical Committee PEL/17, *Switchgear, 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This British Standard supersedes BS 6423:1983, which is withdrawn.

Information about this document

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

- The structure has been revised to include separate clauses on preventive maintenance, corrective maintenance and post-fault maintenance.
- A new clause on fitness for purpose assessment and corrective actions has been added.
- A new clause on device substitution has been added.

The purpose of this standard is to provide guidance on the maintenance of low-voltage switchgear and controlgear where technical knowledge and experience are important in ensuring equipment is kept in an acceptable condition. It is intended to be suitable for people involved in all stages of the maintenance process, including those responsible for instigating work, establishing procedures for undertaking work and those actually completing the maintenance work. It also provides guidance on replacing devices within assemblies and on the administrative process required to achieve a successful outcome. It is strongly recommended that this standard is used, together with specific manufacturer's instructions, to develop a coherent maintenance strategy.

The normally quiescent state of electrical switchgear and controlgear does not automatically draw attention to incipient faults, deterioration or the potential danger that can result from neglect. The need for maintenance is often overlooked. An organized system of preventive maintenance will facilitate continued safe and acceptable operation of an electrical system with the minimum risk of breakdown and consequent interruption of supply.

Hazard warnings

WARNING. This British Standard calls for the use of substances and/or procedures that can be injurious to health if adequate precautions are not taken. It refers only to technical suitability and does not absolve the user from legal obligations relating to health and safety at any stage.

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 of 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.

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1 Scope

This British Standard gives recommendations and guidance for the maintenance of low-voltage switchgear and controlgear having a rated voltage up to and including 1 000 V a.c. or 1 500 V d.c.

This standard is applicable to stationary and movable switchgear and controlgear with or without an enclosure. It is also applicable to switchgear and controlgear for use under special service conditions, possibly with additional recommendations, for example in ships and rail vehicles.

This standard also gives recommendations on safety precautions for personnel carrying out maintenance. Guidance on the levels of maintenance necessary for and also procedures for the maintenance of the principal components within equipment is included. Guidance is also given on the assessment of the on-going suitability of equipment.

It also gives recommendations on the direct replacement of parts and, where this is not possible, guidance on device substitution.

This standard is not applicable to switchgear and controlgear used in potentially explosive atmospheres.

NOTE Inspection and maintenance of electrical apparatus in explosive gas atmospheres is covered in BS EN 60079-17.

2 Normative references

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

BS 7671:2008+A2:2013, *Requirements for electrical installations – IET Wiring Regulations. Seventeenth edition*

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

BS EN 60947-4-1:2010+A1:2012*, Low-voltage switchgear and controlgear – Part 4: Contactors and motor starters. Section 1: Electromechanical contactors and motorstarters*

BS EN 61439-1:2011*, Low-voltage switchgear and controlgear assemblies – Part 1: General rules*

BS EN 61439-2:2011*, Low-voltage switchgear and controlgear assemblies – Part 2: Power switchgear and controlgear assemblies*

BS EN 61439-3*, Low-voltage switchgear and controlgear assemblies – Part 3: Distribution boards intended to be operated by ordinary persons (DBO)*

BS EN 61439-4, *Low-voltage switchgear and controlgear assemblies – Part 4: Particular requirements for assemblies for construction sites (ACS)*

BS EN 61439-5, *Low-voltage switchgear and controlgear assemblies – Part 5: Assemblies for power distribution in public networks*

BS EN 61439-6, *Low-voltage switchgear and controlgear assemblies – Part 6: Busbar trunking systems (busways)*

IEC 60050-441:1984, *International Electrotechnical Vocabulary – Part 441: Switchgear, controlgear and fuses*

3 Terms and definitions

For the purposes of this British Standard, the following terms and definitions apply.

3.1 switchgear and controlgear
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

[IEC 60050-441:1984; 441-11-01]

3.2 switchgear
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; 441-11-02]

3.3 controlgear
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; 441-11-03]

3.4 low-voltage switchgear and controlgear assembly
combination of one or more low-voltage switching devices together with associated control, measuring, signalling, protective, regulating equipment, with all the internal electrical and mechanical interconnections and structural parts

[BS EN 61439–1:2011]

3.5 equipment
low-voltage switchgear, controlgear and switchgear and controlgear assemblies

3.6 item
any part of the equipment that can be individually considered

3.7 maintenance
combination of all technical and administrative actions, including supervision actions, intended to retain an item in, or restore it to, a state in which it can perform a required function

3.8 preventive maintenance
maintenance carried out at predetermined intervals or according to prescribed criteria and intended to reduce the probability of failure or the degradation of the functioning of an item

NOTE Also known in the industry as preventative maintenance.

3.9 corrective maintenance
maintenance carried out, after recognition of a failure, which intends to put an item into a state in which it can perform its required function

3.10 post-fault maintenance
maintenance which might be necessary after a circuit protective device has operated and, on switchgear, after a specified number of fault clearance operations

3.11 predictive maintenance
maintenance activity used to anticipate failures and allow corrective actions to be implemented on a planned basis

3.12 inspection
maintenance action comprising careful scrutiny of equipment or an item carried out without dismantling, supplemented by means such as measurement, in order to arrive at a reliable conclusion as to the condition of an item

3.13 examination
maintenance action comprising careful scrutiny of equipment or an item carried out with the addition of partial dismantling as required, supplemented by means such as measurement, in order to arrive at a reliable conclusion as to the condition of an item

3.14 overhaul
maintenance of an item including examination and replacement or rebuilding

NOTE Overhaul can be categorized as:

a) minor overhaul or servicing that is limited to lubrication and/or replacement of consumables;

b) major overhaul that includes major dismantling and/or replacement of items.

3.15 operational check
inspection and/or operational test carried out to determine whether an item functions correctly

3.16 failure
termination of the ability of the equipment or an item to perform its required function

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

3.17 duty holder
person who is responsible for the organisation, control or execution of maintenance activities on equipment

NOTE 1 Attention is drawn to the Electricity at Work Regulations [1] which place certain legal obligations on a 'duty holder'.

NOTE 2 Elements of this responsibility may be delegated to others as required.

3.18 instructed person
a person adequately advised or supervised by skilled persons to enable him/her to avoid dangers which electricity may create

[BS 7671:2008+A2:2013]

3.19 skilled person
a person with technical knowledge or sufficient experience to enable him/her to avoid dangers which electricity may create

[BS 7671:2008+A2:2013]

3.20 competent person
a person who possesses sufficient technical knowledge, relevant practical skills and experience for the nature of the electrical work undertaken and is able at all times to prevent danger and, where appropriate, injury to him/herself and others

NOTE Several years of practice in the relevant technical field may be taken into consideration in assessment of professional training.

[BS 7671:2008+A2:2013]

4 Safety

NOTE Attention is drawn to the Electricity at Work Regulations 1989 [1], the Work at Height Regulations 2005 (as amended) [2], and the Manual Handling Operations Regulations 1992 [3]. See also BS EN 50110-1 and BS EN 50110-2.

4.1 Appropriate skill level for maintenance

The duty holder should put in place a system to ensure that maintenance tasks are carried out by people with the appropriate level of competency, i.e. by instructed persons (see **3.18**), skilled persons (see **3.19**) or competent persons (see **3.20**), as applicable.

4.2 Rules and procedures for establishing a safe working environment

NOTE 1 Attention is drawn to the Management of Health and Safety at Work Regulations 1999 [4], which require risk assessment.

A risk assessment should be carried out prior to commencing work.

For maintenance activities on equipment there should be a written system of rules and procedures. Everybody involved with maintenance activities should be aware of their existence. The level of detail and complexity of the rules and procedures should be dependent on the organisation, personnel, working environment and equipment in use.

The risk assessment process should be used to ensure that hazards specific to maintenance activities have been adequately addressed in the development of the associated rules and procedures. For example, different working practices and competencies are required for work on d.c. systems than are required for a.c. systems.

NOTE 2 Different systems of work might be required for older equipment where equipment within a compartment might not be protected to Level IP2X, in accordance with BS EN 60529, and so present an increased risk of accidental contact with live parts.

Safety rules should set out the principles and practices expected clearly and in a format that can be understood by those expected to use them.

The rules and procedures should reflect the requirements of an overall electrical safety policy. In most circumstances a policy for work on electrical equipment requires equipment to be isolated and proven dead prior to work commencing. Safety rules might need to address specific issues such as circuits associated with:

- interlocked supplies;
- auto-reclosing devices;
- alternative supplies, including generators;
- mechanically stored energy;
- capacitively stored energy;

- battery supplies;
- photo-voltaic (PV) generator; and/or
- control supplies (a.c. and d.c.).

All personnel should be made aware of the need to take notice of warning signs and follow instructions provided by the equipment manufacturer.

NOTE 3 Factors that affect the safe operation of equipment might change during the life of an installation. The rules and procedures should be reviewed regularly and revised when necessary.

NOTE 4 Attention is drawn to the Management of Health and Safety at Work Regulations 1999 [4], which require that risk assessments are reviewed if there has been a significant change to the hazards associated with the equipment.

Where there are significant risks or where the control measures necessary for safety are complex or require careful co-ordination, it might be appropriate to use a Permit to Work system.

NOTE 5 For guidance on permit to work systems see HSG 85 [5].

4.3 Emergency exits

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

4.4 Fire extinguishing equipment

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

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

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

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

4.5 First aid

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

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

NOTE A poster Electric shock: First Aid Procedures [6] is available from the Health and Safety Executive.

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

4.6 Lighting

Lighting should be provided to ensure safe access and working. Temporary lighting, either battery powered or from generators, should be provided where normal supplies are not available.

4.7 Access

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

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

4.8 Isolation before and during maintenance work

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

a) accidental or inadvertent re-energization is prevented;

b) equipment is proved dead using a suitable voltage indicator.

Any switch, disconnector or other device used to provide disconnection should be secured. The use of "safety locks" i.e. a lock having a unique key controlled by those undertaking the work should be used to secure the point of disconnection. A notice or label should be applied at the place of isolation to inform others who might also be performing maintenance work that someone is working on the equipment.

The following recommendations should be followed.

1) Disconnectors should be intended for isolation.

   NOTE Appropriate isolators are usually marked in accordance with BS EN 60947-1:2007+A1:2011, ***5.2****.*

2) Where provision is made for so doing, disconnectors should be locked in the OFF position and/or caution notices should be exhibited at the points of isolation.

3) Where possible, devices with earthing facilities should be placed in EARTH position and locked.

4) Any shutters covering live or potentially live isolating contacts should be locked closed or other precautions taken to ensure safety.

5) Safety locks should be used and a system put in place to ensure that locks and notices are available and that the keys to locks in use are controlled.

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

7) Contactors should never be considered as a means of isolation.

8) Reliance should never be placed on control circuit isolation, switching or electrical interlocks to prevent accidental or inadvertent re-energization of the main or other auxiliary circuits, i.e. emergency stops.

9) It is not always possible to observe the contacts of a device used as a disconnector and the operation of an external handle or control should not be assumed to have opened all contacts of the connected device. Tests using voltage indicator should be carried out prior to working on any equipment made dead. These should include tests between phases and to earth to guard against the possibility of wrong connection. Voltage indicators should be proved before and after use. See HSE Guidance Note GS 38 *Electrical test equipment for use by electricians for suitable types of voltage proving instruments* [7].

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

4.9 Working on live equipment

The increased risk of accident and the severity of injuries that can occur due to electric shock and burns when undertaking work on or near live equipment are such that live working should rarely be permitted.

NOTE 1 Attention is drawn to Regulation 14 of the Electricity at work Regulations 1989 [1].

Where it is decided that it is unreasonable for equipment to be made dead, special precautions need to be observed. The special precautions depend on the design of the equipment, the nature of the task and the outcome of a risk assessment. The person carrying out the work should be competent to do so. The level of supervision required and the need for accompaniment should be taken into account.

NOTE 2 Further guidance can be found in HSE publication HSG85 Electricity at work. Safe working practices [5].

4.10 Insulating equipment

Permanent and/or portable insulating stands or screens, insulated tools and insulating gloves should be provided and used where necessary. All these items should be maintained in sound condition and periodically inspected.

The person responsible for the maintenance task should verify, prior to use, that all these items and any test equipment needed are suitable and serviceable.

4.11 Earthing equipment

Earthing equipment, where required, should be available and maintained in good working order.

4.12 Stored electrical energy

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

4.13 Associated plant

When performing functional testing on switchgear and controlgear care should be taken to ensure that danger is not caused by energizing the connected load. It might be necessary to disconnect motors or other items of mechanical plant before testing the functionality of the control equipment. Advice should be sought from the plant operator.

4.14 Portable electric tools and lamps

Portable electric tools and inspection lamps should be operated at extra-low-voltage. System voltages not greater than 110 V with either the star point of three phase or the midpoint of single phase transformer earthed are recommended. In confined conducting spaces, apparatus with an operational voltage of 25 V to earth or lower should be used. Where mains voltage portable tools are used, they should be of all insulated or double insulated construction and protected by a residual current device with an operating current not exceeding 30mA and an operating time not exceeding 40m·s at a residual current of five times the operating current.

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

4.15 Testing

CAUTION. Electrical equipment can be damaged by the application of test voltages and currents. Some electronic equipment is particularly vulnerable.

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

NOTE Further advice on electrical testing is given in Health and Safety General Guidance Leaflet INDG 354 Safety in electrical testing at work *available from the Health and Safety Executive [8].*

4.16 Use of test instruments

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 that is normally floating. It is recommended that the instrument casings are earthed at all times but, where the nature of test precludes this, specific care should be taken by the operator to secure their own safety and that of others by the adoption of a safe system of work. Suitably protected test leads should be used at all times.

The calibration of all measuring instruments used for preventive maintenance should be traceable to national or international standards of measurement which, in the UK, are the responsibility of the National Physical Laboratory (NPL).

NOTE Calibration laboratory accreditation. Users of this British Standard are advised to consider the desirability of selecting calibration laboratories that are accredited to BS EN ISO/IEC 17025 by a national or international accreditation body.

4.17 Avoidance of contamination

The ingress of moisture, dust, vermin, etc. into electrical equipment can cause malfunction and danger. During maintenance operations inspection should be carried out for evidence of these, including after a period out of service or changes in ambient or load conditions.

5 Preventive maintenance

5.1 General

NOTE 1 The purpose of preventive maintenance is to reduce the likelihood of failure of circuits within the equipment and the equipment itself.

Throughout its working life, equipment should undergo preventive maintenance at appropriate intervals and levels.

NOTE 2 Maintenance requirements are typically detailed in the manufacturers' instructions.

Many items within the equipment might not be suitable for maintenance more intrusive than inspection; such items should not be dismantled for examination or overhaul purposes and might have to be renewed periodically. For older equipment containing items that are no longer commonly used, the recommendations given in Annex A should be followed.

Preventive maintenance should be organized on the basis of inspections supplemented with operational checks followed by examination. The inspections and checks should be of such a frequency to ensure that no undue damage or excessive wear has been sustained in the course of operations since the last maintenance action. Examinations should be carried out to determine whether there is any need for reconditioning of the contact systems, lubrication and adjustment of mechanisms or deterioration of insulation. The appropriate interval for examination should be determined from the outcome of inspections or operational checks or be based on manufacturers recommendations, taking into account operating duty, environmental conditions and the potential effects of failure. Inspection and testing of insulation should be undertaken during examination.

NOTE 3 Diagnostic testing might be possible before preventive maintenance is undertaken. Comparison of test results with previous, similar tests might provide a measure of deterioration against which the need to perform preventive maintenance can be evaluated.

NOTE 4 Where equipment is in continuous use, opportunities for the completion of preventive maintenance actions might be restricted by commercial, process or production needs. It might be necessary to coordinate maintenance with the demands of the operational programme by completing maintenance during periods when plant is shut down or disruption minimised. It is important that maintenance is not neglected and that the intervals between maintenance activities are appropriate for the equipment. Undertaking preventive maintenance in a planned way is generally more effective than corrective maintenance as a result of failure.

Throughout the life of the equipment there might be a need to replace components that have worn out as a result of normal use. Wherever possible, components should be replaced with identical new parts to ensure the original performance of the equipment is maintained. However, items can become obsolete and therefore identical replacement components might not always be available. It might not always be practical to replace the whole assembly and/or the need to complete a repair might be urgent. In such cases, suitable alternative devices should be installed in accordance with Clause **9.**

5.2 Frequency of maintenance

Equipment should be inspected for signs of distress e.g. abnormal noise, vibrations or smell shortly after putting it into service.

NOTE Any measurements taken at this time could form the basis for comparative measurements taken and recorded during the life of the equipment, as a means of determining the equipment's condition.

Manufacturers' recommendations regarding maintenance should be obtained to identify the maximum recommended interval between maintenance activities. The actual intervals used should be determined by taking the following factors into account:

a) service experience;

b) the conditions under which the equipment operates;

c) the severity of duty;

d) the number of operations performed;

e) the ageing characteristics of the equipment;

f) the importance of the load.

Care should be taken to avoid needlessly disturbing equipment.

5.3 Equipment, tools, spares and test instruments

Equipment, tools, spares and test instruments required for the operation or maintenance of equipment, such as an air circuit-breaker (ACB) racking handle or earthing device, should be available and maintained.

5.4 Diagnostic aids

Where diagnostic aids, such as wear indicators, are incorporated in the equipment, they should be used to assist in the effective maintenance of the equipment.

NOTE 1 Any diagnostic aids of this form are likely to be detailed in the manufacturer's maintenance manual. They are usually some type of basic indication or marking that confirms, without a subjective judgement having to be made, that a part has reached the end of its useful life.

NOTE 2 Other types of diagnostic equipment may also be used on a range of equipment.

Equipment should not be used if wear indicators show that it has reached the end of its useful life.

NOTE 3 A typical example of a wear indicator is an air circuit breaker, where the erosion of its contacts due to interrupting current is indicated by a line on the moving contact coinciding with a fixed mark.

NOTE 4 Information about diagnostic aids is given in Annex B.

5.5 Cleanliness

For equipment to operate satisfactorily it is essential that it is kept free from contaminants that could impair its function. Natural or forced ventilation should not be restricted. Before removing covers, breaking gasketted joints or opening doors, precautions should be taken to prevent ingress of dirt, dust and loose objects.

For internal cleaning a suction cleaner should be used and cleaning should be carried out with the equipment made safe.

It is advisable when cleaning insulation to wipe across the likely tracking path and not in line with it.

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.

Where the preventive maintenance procedures recommended by the manufacturer permit the use of solvents for cleaning or degreasing, it is essential that the solvents used are compatible with the equipment.

WARNING. Non-flammable and non-toxic solvents should be chosen where possible or suitable precautions against fire and toxic effects should be observed.

5.6 Enclosures, busbar systems and earthing systems

*COMMENTARY ON **5.6***

The structure of an assembly is designed to provide a supporting system for the internal components including busbar systems, allow for ventilation, a barrier for ingress and to enable safe use. During a short circuit, the magnetic forces between the busbars can results in loads of several tons oscillating at 50 times per second (ac 50Hz). For this reason, structural changes to the assembly can have detrimental effects.

5.6.1 Environmental conditions

NOTE The environmental conditions in which the equipment is situated can have an impact on the life of the equipment. Equally, over the life time of the equipment, the environment it is located in may change.

The equipment should be checked periodically to determine if the area in which it is located has changed, with specific attention paid to its environment. Corrective action should be taken where necessary. The following list, which is not exhaustive, identifies changes that could impact on the equipment:

a) increased likelihood of physical damage due to change of use of area or removal of barriers;

b) possible exposure to water damage due to changes in the building's design or condition;

c) increase of dust or fumes due to change of building use or use of area;

d) change in ventilation due to building modifications or addition of adjacent equipment;

e) changes in ambient temperatures due to additional local heat sources or reduction of cooling facilities.

5.6.2 Provision of user instructions/information

The labelling of the equipment should remain clear and legible during the lifetime of the equipment. The user instructions and appropriate manuals should be confirmed to be suitable and complete. During the maintenance process the following should be checked and recorded:

a) that the safety and warning labels are present, legible and in line with legislation;

b) circuit designations and device/trip settings are present, correct and legible;

c) the operating instructions, manual and other user information is present, complete and up to date with the equipment's configuration.

5.6.3 The integrity of enclosure structure

The structure of the enclosure should be in a serviceable condition. The enclosure should be checked for the following:

a) any damage to structural parts including protective coatings and glazed covers;

NOTE Indentations to the structure can reduce clearance to internal live parts.

b) the security of fixings, including hinges, foundation bolts, and wall mountings;

c) missing or damaged gaskets, covers and internal barriers;

d) the correct functioning and security of interlock systems;

e) the integrity and functioning of ventilation systems including grills, louvres, fans and filters;

f) the freedom from dust and debris.

Care should be taken when cleaning to ensure dust or debris does not enter equipment or adjacent compartments.

5.6.4 Busbar systems

*COMMENTARY ON **5.6.4***

Busbars and associated connections can reach temperatures of 145 °C during normal operation. Manufacturers' designs incorporate features to address thermal expansion of conductors, stress on insulators and thermal cycling of joints.

5.6.4.1 General

When carrying out preventive maintenance on busbar systems, care should be taken not to compromise specific design features of the original equipment. For example, some busbar connections are fitted with maintenance-free bolts and no attempt should be made to re-torque or tighten them.

NOTE Replacement or alteration of busbar support structures might require reference to the original manufacturer or, if not available, a specialist organization to avoid compromising the design.

5.6.4.2 Conductor supporting structure

Supports and insulators should be inspected for damage, including cracks and/or burn marks. Dust and debris should be removed.

NOTE Vacuuming, working from the top down to the bottom of the assembly, would be the preferred method.

Damaged supports and insulators should be replaced if the damage impairs the function of the item. The cause of the damage should be ascertained in consultation with a specialist and any appropriate corrective action taken.

5.6.4.3 Busbar conductors including connections to circuit devices

Busbars should be inspected for damage, including the effects of excessive heat typically seen as thermal tarnishing or erosion and soot caused by electrical discharge.

Where busbars are covered by an insulating material, the insulation should be inspected for damage including missing parts, shrinkage, cracks, the effects of heat and local burning. Any insulation provided to supplement creepage and clearance distances should be inspected.

Dependent on the nature of any damage, specialist advice should be sought.

Busbar connections systems are designed to exert a pressure on the busbars that is critical to the performance of the connection. In some types of equipment these connections require no adjustment, therefore no adjustment should be attempted, details of which can be found in the manufacturers' instructions. Other systems might require adjustment in which case reference should be made to the manufacturer's instructions. Incorrect torque settings can have a detrimental effect on the integrity of a connection.

If any repair or modification to the busbars is required specialist advice should be sought.

5.6.4.4 Earthing system

The earth bar including joints, supports and fixings should be inspected in in accordance with **5.6.4.3.**

Flexible protective conductors should be examined; and replaced if damaged or showing signs deterioration.

Earth continuity of all exposed conductive parts including doors and covers should be checked in accordance with BS EN 61439-1:2011,**10.5.2**.

5.7 Quality of connections

Connections that have not been disturbed should be checked for soundness, including looking for signs of overheating.

After disturbance, the bolts, screws and locking devices of all current-carrying and earth connections should be correctly and securely replaced. It is not sufficient for nuts and bolts or screws to appear to be tight; a bolt may not be threaded far enough or too long a bolt or screw may have been used in a blind tapped hole, so giving the impression of a tight connection when, in fact, the connection is loose. A contact resistance test (commonly known as a 'ductor test'), should be used to measure the integrity of connections.

The current carrying capacity of a connection is dependent on contact pressure. Where this pressure derives from a threaded assembly, the assembly should be tightened using the manufacturer's recommended torque setting.

Connecting aluminium to aluminium, copper or brass satisfactorily requires care and the manufacturer's instructions should be followed.

Moveable power connections, e.g. plugs or sliding connections, should be inspected if possible, 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.

5.8 Circuit breakers

5.8.1 General

Many circuit breakers, such as moulded case circuit breakers (MCCBs) and miniature circuit breakers (MCBs), are not intended to be internally maintained; such items should not be dismantled for examination or overhaul purposes and might have to be renewed periodically.

Where maintenance is possible, the following safety precautions should be taken:

- for solenoid closed or motor closed gear the solenoid or motor supply should be isolated;

- for spring closed gear the spring should be discharged. In the case of a motor wound spring closing mechanism, the motor supply should first be isolated;

> **WARNING.** There is considerable stored energy within a charged spring mechanism. Accidental discharge of this energy can cause serious injury.

- fuses or links in the closing control circuits should be removed;
- before work is commenced, the circuit breaker should be opened and fuses and/or links in the tripping and auxiliary circuits removed.

For remote or power operated equipment it is important to also ensure that the equipment, together with any associated remote-controlling equipment, is made inoperative.

Before any work is carried out on the fixed isolating contacts of withdrawable type switchgear, they should be isolated and proved "dead" using a voltage indicator (see Clause **4**).

Shutters covering live or potentially live contacts should be locked closed.

5.8.2 Operational check

Circuit breakers with a tripping function should be tripped and reclosed at regular intervals. Tripping should be proven either using the protective relays to exercise the trip circuit and/or a trip button where provided.

NOTE Specialist test equipment might be required.

> **CAUTION.** Care should be taken when manipulating electro-mechanical relays, to avoid damage to the relay mechanism.

5.8.3 Inspection

A general inspection should be made to detect defects including corrosion, leakage of oil or compound, build-up of debris, contamination, unusual smells or discolouration, and damage to insulation.

5.8.4 Examination

Main and arcing contacts should be examined for burning or other damage. If damage is discovered, reconditioning or renewal might be required. Contact alignment and spring pressure should be checked in accordance with the manufacturer's instructions. Misalignment of contacts should be investigated further. When the cause of the misalignment has been determined, this should be rectified and the contacts realigned or replaced.

Slight discoloration or burning of copper or copper alloy contacts is not necessarily harmful. High-pressure point or line contacts normally carry their rated current satisfactorily even if there is some pitting of the surface. Large beads or ridges on the contacting members that would impede closing or opening should be removed. If the manufacturer's instructions recommend that contacts should be cleaned, emery cloth or carbon-based abrasives should not be used.

Arcing contacts are likely to show signs of burning and erosion. If erosion is excessive or the lead between the arcing and main contacts is incorrect, they should be replaced. Arc resisting tips should be checked to confirm that they are fixed securely.

In the case of tipped or faced contacts, it is usually undesirable to attempt to clean or dress the contacts. Silver contacts seldom require cleaning despite a black appearance.

Arc control devices and inter-pole barriers should be examined, and cleaned or renewed as appropriate. Items made from compressed fibrous materials should not be cleaned by abrasive methods.

Flexible braids should be examined for damage or fraying at the terminations and renewed if necessary.

Tripping and closing mechanisms should be cleaned and examined. Worn or damaged parts should be renewed. Rolling or sliding surfaces in the mechanisms should be free from dried up lubricant. Those parts which require lubrication should be re-lubricated sparingly, with the lubricant recommended by the manufacturer, and adjusted. Correct operation should be checked.

Auxiliary switches and contacts should be examined and cleaned or renewed if necessary. Where possible, the freedom of operating links and the timing of auxiliary contacts in relation to the circuit breaker contacts should be checked.

Indicating devices, such as mechanical on and off indicators, should be tested to check whether they are operating correctly.

Safety interlocks and locking devices should be examined and tested, as damaged or worn devices can result in dangerous conditions. It should be verified that incorrect operations are prevented. Isolating contacts should be examined for damage, overheating or corrosion and renewed as necessary. Correct alignment, movement and engagement should be checked.

Where safe to do so, safety shutters should be examined and subjected to a functional check.

Before the circuit breaker and its auxiliary apparatus are returned to service, an insulation resistance test should be carried out followed by an operational check (see **5.8.2**).

5.9 Disconnectors and main circuit switches (with or without fuses)

The necessary preventive maintenance procedures are dependent on the type of devices fitted. The following actions should be undertaken.

- The integrity of the contact gap (means by which a disconnector isolates a circuit or a switch to interrupt the flow of current) should be checked. Where a contact gap cannot be readily inspected, the integrity of the contact gap should be checked for all poles by a dielectric test.
- Actuating mechanisms should be checked for correct operation and fixing security. Interlocks, padlock/locking facilities, contact position indicators, operating handle shafts and any other functional features should be checked for correct operation and whether they register correctly.
- Contacts should be examined for wear, overheating, misalignment and defects. They should be cleaned, lubricated or renewed as appropriate.

5.10 Contactors and contactor relays

5.10.1 General

Contactor relays and some contactors are not intended to be maintained. These should not be dismantled for maintenance or overhaul purposes.

In many instances it may not be cost effective to replace contacts or other parts in standard contactor and contactor relays. The replacement of the complete item might be the most cost effective method of completing preventive maintenance or repair.

In the event of the contacts of a contactor or contactor relay becoming welded or if the associated protective device has operated on a power fault, the following should be performed prior to the contactor being returned to service:

a) investigate and rectify the cause of the fault;

b) examine the device according to the manufacturer's instructions, as the damage might have been sustained.

NOTE 1 Lightly welded contacts may be parted and potentially can continue in service. (see BS EN 60947-4-1:2010+A1:2012 and/or the original manufacturer's instructions).

Operations that should be carried out during preventive maintenance (for those devices designed to be maintained) include the following.

- Main and auxiliary contacts should be examined for wear, signs of overheating, misalignment or any other defects according to manufacturer's instructions, and reconditioned or renewed as appropriate.

  NOTE 2 Overheating may be caused by overloading, a loose connection, incorrect contact force or misalignment.

  NOTE 3 The correct treatment to recondition contacts depends on the material from which they are made as well as on the duty of the equipment.

- Contact areas on which arcing occurs should not be lubricated. Other parts of the contact surface should be lubricated where recommended in the manufacturer' instructions.

- Contact surfaces might appear pitted and discoloured, however dressing should only be carried out on those manufactured from plain copper. Either a fine file or glass paper should be used to remove any large projections. Emery or silicon carbide paper should not be used.

  NOTE 4 Excessive dressing of contacts will result in more rapid wear.

- Arc control features within devices should be examined and if they are cracked or badly eroded they should be replaced.

- Operating mechanisms should be inspected for freedom of movement, wear, and checked for effective operation.

NOTE 5 Where possible, the yoke faces of electromagnetic contactors should be examined for contamination. Care should be taken in the removal of contaminants, including oil or grease, to avoid damage to the yoke faces.

NOTE 6 Excessive noise from a.c. operated contactors and contactor relays when closed can be due to a number of causes including the following:

i) dirty yoke faces;

ii) broken shading ring;

iii) incorrect contact adjustment;

iv) incorrect alignment of yoke faces.

NOTE 7 The yoke faces of new contactors and relays are often provided with a protective coating to prevent corrosion during storage and this can cause excessive humming during the first few operations.

- For pneumatic contactors the mechanisms should be inspected for air leakage or other defects.

With d.c. operated contactors, the anti-residual magnetism devices, such as throw-off springs, should be checked for correct operation. Coil economizing circuits, suppression devices, etc. should also be examined.

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.

5.10.2 Vacuum contactors

The recommendations given in **5.10.1** should be followed except in the case of the main contacts. The main contact assemblies are sealed and no internal inspection or repair can be undertaken.

5.10.3 Overload protective devices

Many overload protective devices should not be dismantled for preventive maintenance or overhaul purposes. The manufacturer's instructions should be followed.

NOTE 1 Where maintenance is possible it is likely that specialist support will be required for all but the most basic of functional checks.

Where accessible, contacts should be examined. If possible a functional test should be performed by simulating tripping by use of a test button or purpose designed fault simulation equipment.

Where dashpots are present, oil should be maintained at the correct level and only the oil recommended by the manufacturer should be used.

NOTE 2 Different viscosities can vary the other characteristics of the overload protection, and degradation of oil can cause sludge which can prevent operation of the dashpot.

For overload protective devices protecting main power circuits or critical equipment, if an overload device has been dismantled or replaced, the accuracy of its setting should be checked. This can be achieved using a low-voltage current injection test, or by secondary injection for current transformer fed devices. Following a through fault, the opportunity should be taken to inspect and carry out preventive maintenance or replacement as necessary, since damage might have occurred.

5.11 Liquid starters and controllers

*COMMENTARY ON **5.11***

Liquid starters and controllers incorporate an electrolyte (usually an aqueous solution of sodium carbonate) as the resistance element. They also include motor shorting devices or shorting contactors and might include driven electrodes. Periodic inspection and preventive maintenance needs to be undertaken for reliable operation.

Electrolyte levels should be monitored and topped up if necessary to replace evaporation losses. The frequency at which this should be carried out is dependent on the duty of the liquid starters or controllers, and ambient temperature conditions. Deionized water should be used for topping up unless the manufacturer's instructions indicate otherwise. If electrolyte has been lost by leakage, the leak should be repaired and the lost electrolyte should be replaced. The electrolyte should be replaced periodically in accordance with the manufacturer's recommendations or if motor starting becomes problematic.

Where the manufacturer recommends the use of specially formulated oil on the electrolyte to reduce evaporation, the oil should be checked and replenished if necessary.

Electrodes should be inspected, and any scale that has accumulated on them removed. If the electrodes are badly worn or corroded they should be replaced. Under such circumstances the electrolyte should also be replaced.

Integral short-circuiting contacts (in air) should be inspected, cleaned, checked for alignment and smeared with petroleum jelly. If the contacts have been eroded by arcing they should be replaced. The cause of arc damage should be investigated as it might be an indication that the resistance characteristics of the electrolyte are not correct. Preventive maintenance on contactors should be carried out in accordance with **5.10**.

The operation of the equipment should be functionally checked including any timers, control relays and auxiliary switches. Mechanical parts should be lubricated as necessary.

The cooling system should be inspected for leaks and all valves inspected and operated.

Electrolyte coolers should be inspected for corrosion. Corroded components should be replaced or repaired as necessary and the electrolyte should be renewed.

NOTE 1 This can be more cost effective that analysing the electrolyte for the formation of corrosive elements.

Tanks should be inspected for the presence of corrosion and sludge. If significant corrosion or deposits of sludge are found, the tank should be emptied, cleaned, corroded areas repaired, and the electrolyte replaced.

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

Where thermostatically controlled heaters are fitted, their operation should be checked.

A record should be kept of the strength of electrolyte required for each starter and controller.

NOTE 2 The strength of the electrolyte is important to achieve the correct starting or speed control performance of the associated motor and this information is useful if it becomes necessary to make good significant losses by leakage, etc.

5.12 Battery powered control systems

*COMMENTARY ON **5.12***

Switchgear and controlgear systems have progressively contained more intelligent electronic devices and systems communicating between the separate supply systems, including MV (medium-voltage) switchgear, transformers, LV (low-voltage) switchgear and standby supplies, providing signalling, safety interlock functions, as well as the tripping relays of the low-voltage system. Frequently electronic equipment is powered by DC extra low-voltage derived from a battery system. Battery systems are also employed in emergency systems such as alarms, lighting and the auto start of a standby generator. There are several types of battery all having maintenance requirements and routine test or status facilities.

Batteries integral to electronic equipment should be replaced in accordance with the manufacturer's instructions.

When switchgear and controlgear dependent on tripping batteries is maintained, the battery maintenance records should be checked to determine whether battery maintenance has been completed, including load testing where applicable.

NOTE Batteries have been known to fail despite maintaining their output voltage under no-load conditions.

A functional test of any signal or tripping activity using a battery system should be undertaken during the post maintenance commissioning.

5.13 Conclusion of maintenance

Prior to return to service, a visual inspection should be completed along with appropriate tests in accordance with the manufacturer's instructions to confirm that the equipment is suitable for service.

5.13.1 Removal of defective parts

Defective or potentially defective parts removed from equipment should be clearly marked to prevent unintentional reuse.

5.13.2 Re-energization

The equipment should be re-energized in line with the appropriate procedures in accordance with the site operations instructions. After the equipment has been put under load it should be re-inspected to check that it is working correctly.

5.14 Documentation and records

Work undertaken should be recorded and any recommendations should be reported for appropriate action.

6 Corrective maintenance

*COMMENTARY ON CLAUSE **6***

*Well maintained low-voltage switchgear and controlgear that is appropriate for the application rarely requires corrective maintenance as a result of a breakdown. However, in the event of breakdown, there might also be a need to carry out post-fault maintenance (see Clause **7**) when a switching device has functioned and interrupted a large fault somewhere downstream in the system*

In a critical applications, carrying out corrective maintenance brings pressures not present in preventive maintenance. There are likely to be significant consequences that result in pressure to restore supplies and minimize down time.

*The occurrence of, and/or the consequences of breakdowns and the need for corrective maintenance or post fault maintenance can be minimized when the owner of an assembly adheres to good practises and has in place the appropriate procedures, generally as outlined in **6.1**.*

6.1 Reducing the need for corrective maintenance

6.1.1 Preventive maintenance

In order to reduce the need for corrective maintenance, a management procedure should be put in place to ensure that preventive maintenance in accordance with Clause **5** is carried out in a timely manner and in accordance with the manufacturer's instructions.

6.1.2 Anticipation of faults

The results of ageing studies, maintenance trends and predictive techniques should be analysed at timely intervals in order to reduce the need for corrective maintenance.A management procedure should be put in place, for example use of failure modes and effect analysis (FMEA), to enable faults to be anticipated. When some form of deterioration or a potential issue is identified, a plan of corrective action should be implemented, prior to any fault occurring.

6.2 Emergency recovery plan

The possible need for emergency corrective maintenance on an assembly should be recognized. Owners of an assembly should undertake a study of the possible failures and determine critical components and likely failure modes. An emergency recovery plan that sets out procedures for possible emergency corrective maintenance and the restoration of supplies in a timely manner should be in place throughout the life of the assembly.

6.3 Spare parts

As determined by the criticality of the application and the likelihood of spare parts being required, appropriate spare parts should be readily available. All spare parts should be correctly identified and suitably stored. Appropriate installation instructions should be readily available to ensure the parts can be correctly installed.

6.4 Undertaking corrective maintenance

Undertaking corrective maintenance is likely to require a higher level of competency in comparison to preventive maintenance. Plans should be in place to ensure that people with the appropriate level of skill and competence are available to conduct any corrective maintenance activities in a timely manner.

Corrective maintenance should be carried out using the same procedures as for preventive maintenance (see Clause **5**).

6.5 Completion of corrective maintenance

Completion of corrective maintenance should be carried out in accordance with **5.13**.

6.6 Review of corrective maintenance

Following the completion of corrective maintenance, a review should be undertaken to determine the root cause of the breakdown or failure. Where appropriate, procedures should be put in place to enable any future occurrence to be anticipated and dealt with during preventive maintenance.

7 Post-fault maintenance

7.1 General

After the occurrence of an electrical fault in which equipment might have carried significant fault energy, the equipment should be inspected to determine whether additional actions are required before it can be restored to service. It is important that the location of the fault is identified, as the actions required are significantly different if the fault has occurred within the equipment or external to the equipment. In either case, the faulted equipment or components should be repaired or isolated from the system before the supply is restored.

7.2 Gathering of information

After a fault has occurred, information to assist with fault location and post-fault analysis should be obtained from an immediate examination of the equipment. The following should be recorded:

a) where in the system the fault originated;

b) any work going on in the area which might have caused it;

NOTE For example, cable damage causing electrical faults is often the result of other work activities

c) which devices have tripped or operated and which remain on (or which fuses have operated and require replacement);

d) fault or status indications from protection devices, particularly from mechanical relays before they are reset;

e) abnormal conditions in the equipment environment such as smoke, heat, soot deposits, distortion of casings or covers, or odour;

f) any load information that can be obtained from recording devices such an energy meters.

7.3 Internal equipment faults

If it is determined that a fault has occurred within an item of equipment, then the actions and procedures identified in Clause **6** should be followed.

7.4 External faults

If the equipment has operated to clear an external fault, it is likely that it will have been subject to electrical, thermal and magnetic stress during the fault clearance. Where practical, all components that have carried fault current in the equipment (including cables, connections and busbars) should be inspected to identify any signs of distress (see Clause **5**).

Switching devices that have operated to clear the fault might require maintenance before being returned to service. Fault limiting devices, used with some circuit breakers, might require replacement. High fault currents might also alter the characteristics of thermal devices such as motor overload protection relays. Heating elements might require replacement. The manufacturer's recommendations should be referred to for guidance, as testing of such characteristics it not usually practicable.

7.5 Circuit Breakers

The procedures for post-fault maintenance depend on the type of equipment and magnitude of the fault current interrupted. For circuit breakers, the following actions should be undertaken.

a) Insulation and other parts liable to deposition from 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 should be inspected for burning or other damage and reconditioned or renewed if necessary. Adequacy of contact force, alignment and wipe should be checked.

c) Arc control devices should be removed, and reconditioned or renewed as recommended in **5.8.4.**

d) All mechanisms should be checked for correct operation, and particular attention should be paid to settings and clearances after contacts or arc control devices are replaced.

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

f) A final verification should be carried out in accordance with **5.8.4**.

7.6 Motor protection devices and contactors

NOTE Depending on the classification of the components, the energy let through by the motor protection device during a short circuit fault might result in permanent damage to the contactor.

Contactors should be checked for freedom of movement to ensure that contacts have not welded. Where possible, the condition of the contacts should be inspected.

On multi-phase systems, all fuses should be replaced if any of the fuses have operated. Remaining fuses might have been stressed by the passage of fault current and can be prone to premature failure if not replaced.

8 Fitness for purpose assessment and corrective actions

8.1 General

NOTE 1 The service life of low-voltage switchgear can be very long; forty plus years are not uncommon. Throughout this time the service environment and what is expected of the equipment can change.

To ensure that low-voltage equipment continues to be fit for purpose, a wide-ranging assessment of low-voltage switchgear and controlgear should be undertaken at timely intervals, for example every five years, or in anticipation of a major change in operating circumstance. The assessment should include, but not be limited to, the items covered in **8.2** to **8.9**, taking into account any likely changes prior to the next assessment.

NOTE 2 Factors that affect the safe operation of equipment might change during the life of an installation. The rules and procedures should be reviewed regularly and revised when necessary.

8.2 Changes to the operating environment

8.2.1 General

Over time the operating environment for low-voltage switchgear and particularly low-voltage assemblies is likely to change. Networks, load and supply requirements change as building use and/or processes change. To ensure that the low-voltage switchgear and controlgear continues to be suitable for its current and foreseeable application, as a minimum, assessments should be carried out in accordance with **8.2.2** to **8.2.8**.

8.2.2 Prospective short circuit current

Electrical networks are from time to time upgraded or reinforced resulting in an increase in prospective short circuit current.

The prospective short circuit current available at the incoming terminals of equipment should be checked and actions taken to ensure that it does not exceed the capability of the equipment. Specifically, it should be confirmed that the making and breaking requirements of every device are not exceeded. Back-up protection, selectivity should continue to be provided when prospective short circuit currents have increased. Where doubt exists, measures should be implemented to reduce the prospective short circuit current to an acceptable level, or, equipment should be upgraded or replaced.

8.2.3 Load

*COMMENTARY ON **8.2.3***

As applications within a building or an electrical network evolve, so too does the load on low-voltage switchgear and controlgear. The load on an individual circuit may increase or decrease significantly. A single-shift manufacturing operation might progress to continuous operation on three shifts, significantly increasing the duration of operation on full load of an assembly supplying the electrical power. Alternatively the time at which circuits operate at full load might change from being phased to coinciding.

Each individual circuit should be checked to confirm that it is capable of carrying its actual load current.

NOTE In some instances devices might have an 8-hour current rating and a lesser continuous current rating.

In the case of an assembly, it should be confirmed that the simultaneous loading of circuits is within the rated diversity factor of the assembly. Where the load demand exceeds the rating of the equipment, the network should be reconfigured or upgraded or equipment should be replaced as appropriate to ensure that the current rating of all low-voltage switchgear and controlgear is not exceeded.

8.2.4 Harmonics

*COMMENTARY ON **8.2.4***

With the progression towards more static switching, variable speed drives, switch mode power supplies and the wider use of d.c. including UPS equipment, the harmonic content of loads is increasing. A high harmonic content within a load can increase skin and proximity effects that necessitate some de-rating of equipment. An increase in third harmonic, and multiples thereof, can also have a particular impact on equipment supplied with the traditional half rated neutral.

The harmonics present in the load should be checked to confirm that they do not result in devices and/or circuits being overloaded. The harmonic currents should be checked and actions should be taken to ensure that they do not result in the current carrying capacity of the neutral circuit being exceeded. Where doubts exist, equipment should be upgraded or replaced as appropriate.

8.2.5 Transient over voltages

*COMMENTARY ON **8.2.5***

All low-voltage equipment is capable of withstanding a particular level of transient over voltage as defined in the product standards. Historically it has been generally assumed that transient voltages emanate from the mains supply and that the level of transient over voltage will decrease with increased distance from the source of supply. With changes in switching techniques and wider use of embedded generation this might not be the case.

The network, loads and switching arrangements should be assessed to confirm that the low-voltage equipment is capable of withstanding the likely transient over voltages. Where this is not the case, surge arrestors should be installed as appropriate.

8.2.6 Protection

*COMMENTARY ON **8.2.6***

Changes in network topology can require different protection setting.

Protective devices should be checked to confirm that they afford sufficient overcurrent and earth fault protection as applicable, with discrimination as appropriate to the application. Where deficiencies are identified, protective devices should be upgraded or replaced, as appropriate.

8.2.7 Installation conditions

*COMMENTARY ON **8.2.7***

Throughout the life of low-voltage equipment the installation conditions might change. Access routes might be blocked off; the risk of flooding might increase; other services might have been added which pass through or above the substation, that might leak and cause damage. Different facilities might be adjacent to the equipment, for example the added presence of sulfur can prompt the growth of whiskers on silver-plated surfaces.

The equipment should be checked to determine whether it is suitable for the conditions in which it is installed. If it is not, it should either be upgraded to suit the prevailing conditions, or the installation conditions should be restored to those of the original installation.

8.2.8 Opportunities for maintenance

NOTE As the living and working environment is increasingly dependent on a secure power supply, it is often very inconvenient to de-energize equipment for preventive or corrective maintenance. As an alternative, equipment offering more redundancy, longer maintenance intervals and better maintenance opportunities (e.g. more draw out circuits), might be more appropriate.

The opportunities for maintenance should be assessed and it should be determined whether the equipment can be effectively maintained within its working environment.

8.3 Maintenance records

*COMMENTARY ON **8.3***

Maintenance records for low-voltage switchgear and controlgear are a useful source of information when determining whether equipment is fit for purpose.

Maintenance records should be examined for trends. For example, a progressive decrease in insulation resistance indicates a general deterioration of the equipment. An increase in the number of breakdowns can indicate that more frequent maintenance is required or that the end of useful life is approaching.

8.4 Age-related deterioration

*COMMENTARY ON **8.4***

The ageing of low-voltage switchgear and controlgear is dependent on its application. Electro-mechanical components wear depending on the number of operations, switching duty, etc. Insulating materials age due to time, temperature, and in some instances, dielectric stress. If left unaddressed, ageing can result in equipment failure, particularly when the stresses associated with extreme operating conditions, such as short circuits, occur.

It should be determined, where practical, whether low-voltage switchgear and controlgear equipment has undergone significant age-related deterioration. The maintenance records should be checked for trends in occurrence of failure. The manufacturer's instructions should be checked for the intended design life, taking into account the intended electro-mechanical life of components versus the estimated number of devices in service. The actual loading compared with the design loading should be considered and if equipment has been lightly loaded and installed in a low ambient temperature, the insulation will have aged at a lower rate than for a heavily loaded application. To assist with this, condition monitoring and predictive techniques are available, usually from specialist organisations.

When equipment is determined to be reaching the end of its useful life, components and/or the complete equipment should be replaced as appropriate.

8.5 Skill and knowledge

*COMMENTARY ON **8.5***

The level of skill and knowledge that is required to operate and maintain low-voltage switchgear and controlgear to ensure that it remains fit for purpose depends on the equipment, its installation and application, and on current safety practices.

An assessment should be carried out of the equipment to determine whether people who are to operate and maintain it have the appropriate level of skill and knowledge to carry out all intended operations. Where this is not the case staff should be retrained or new, appropriately trained staff should be recruited and/or the equipment should be modified or replaced as necessary.

NOTE Examples of modifications include additional shrouding, interlocks, barriers and covers.

8.6 Criticality

*COMMENTARY ON **8.6***

Over time the consequences of an unexpected interruption in supplies can change and become more onerous compared with those related to the original installation.

The features of the low-voltage equipment should be reviewed in relation to its application taking into account all risks that could lead to an untimely loss of supply. An assessment should be made as to whether the equipment is optimum for the application or whether justifiable benefits might be gained from:

- use of a different design of equipment with increased reliability;
- installing additional monitoring equipment to assist in anticipating problems and allowing timely corrective actions;
- increasing the frequency of predictive maintenance;
- greater redundancy and more automation to reduce down time as a result of breakdowns.

In some instances, the conclusion might be that changes to the equipment cannot be justified. However, an upgrade to or replacement of the equipment could reduce the risk of failures and bring significant benefits.

8.7 Overview

Once the review is complete, all the findings should be considered in the light of the application of the equipment. A single finding or a combination of findings might indicate the necessity for changes in processes, and/or the equipment.

9 Device substitution

9.1 General

Where components need to be replaced, they should be replaced with identical new parts wherever possible to ensure the original performance of the equipment is maintained.

However, devices can become obsolete, so replacement components might not always be available. If it is not practical to replace the whole assembly and/or the need to complete a repair is extremely urgent, suitable alternative devices should be identified and installed in a manner that reduces all risks to an acceptable level.

9.2 Manufacturer's direct alternative

If an identical device is not available the first option should be to use an equivalent from the same manufacturer who made the original device. If the manufacturer of the original and replacement devices (same manufacturer) declares that the replacement part is a suitable substitute for the original device in all relevant respects (temperature rise, short circuit, dielectric, etc.), the replacement device can be installed without concern.

9.3 Device substitution without a manufacturer's declaration

9.3.1 General

When substituting an original device with an alternative, wherever possible, all of the design verifications set out in BS EN 61439 should be carried out. Alternatively, the approach given in **9.3.2 to 9.3.14** should be followed.

NOTE 1 Device substitution is a special maintenance operation, and requires the particular skills of a switchgear design specialist. Engineering judgement is necessary as some aspects of the change might not be fully proven.

NOTE 2 Device substitution might not provide the same performance of the original device, and in extreme circumstances, could give rise to hazards.

Before device substitution is carried out the person carrying out the substitution should inform the end user in writing of the limitations and potential risks.

For those occasions when the substitution of devices without a manufacturer's declaration cannot be avoided, the guidance given in **9.3.2** to **9.3.14** should be followed.

9.3.2 General conditions for device substitution

All of the requirements of the relevant part(s) of BS EN 61439 should be met, except aspects of Clause **10** in the relevant part, that are not practicable. Any that are not practicable, e.g. temperature rise verification, short circuit verification, should be in accordance with this standard.

NOTE 1 The methods detailed in this standard are based on industrial experience, comparison of component parameters, device characteristics, appropriate assessment of the device being substituted and the addition of safety margins where applicable. However, as in some instances the verification processes possible are less rigorous than those prescribed in BS EN 61439, the substitution process does not necessarily ensure the assembly continues to fully conform to BS EN 61439 or the preceding standards in the case of older assemblies.

To ensure acceptable device substitution:

- both the original device and the replacement device should be of the same generic type. E.g. MCCB replaced with MCCB; and

- both the original device and the replacement device should have similar performance characteristics;
- where appropriate, the Safety Integrity Level (SIL) of the substituted device should be equal or higher to the original device.

*NOTE 2 Guidance on the assessment of performance characteristics is given in **9.3.3.11,** a) to h).*

The guidance on device substitution given in this standard should not be used to increase any existing rating of the assembly, rated voltage and current, rated short circuit current, etc. Any recommendations made by the replacement device manufacturer, e.g. support for connections and safety clearance, should be adhered to together with the following recommendations. The design of the functional unit should remain unchanged except for the replacement of the device being considered.

The conductors connected to the replacement device should only be adapted to the necessary minimum extent for compatibility with the different geometries of the terminals, and to accommodate any additional bracing as recommended by the manufacturer of the replacement device. A reduction of terminal spacing greater than 10% should not be made. Any other changes, such as changes to the type and cross-sections of the conductors, type of conductor (front, rear, edge, etc.) should also not be made.

Where verification cannot be in accordance with BS EN 61439, a margin should be added to minimize any risk that might result from the less rigorous process detailed in **9.3.3**.

For adjustable speed electrical power drive systems, it is not currently possible to give recommendations for device substitution because of the complexity of the systems and key characteristics that are not readily comparable. Where substitution does take place, verification should be undertaken as in the case of a new assembly.

9.3.3 Design verification of the replacement device

9.3.3.1 General

Those responsible for carrying out device substitution should follow the design verification recommendations given in **9.3.3.2** to **9.3.3.14**, as listed in Table 1. The means of verification should be recorded together with the results. The record should be retained in the design file. An example of a suitable format is shown in Table 1.

9.3.3.2 Strength of materials and parts

The strength of materials and parts should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.3 Degrees of protection

If the device requires a change in the enclosure integrity, the degree of protection should be verified in accordance with the relevant part of BS EN 61439. In applications, such as retrofit, where this is not practical, the original manufactures' advice should be sought or a switchboard specialist employed to advise on the means of verification, which might include observation, use of test probes, etc.

9.3.3.4 Clearance and creepage distances

Clearance and creepage distances should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.5 Protection against electric shock and integrity of protective circuits

Depending on what changes have been made, the earth continuity should be measured in accordance with the relevant part of BS EN 61439. Any new or repositioned protective conductors specified by the device manufacturer should have a cross section in accordance with the relevant part of BS EN 61439.

9.3.3.6 Incorporation of switching devices and components

Switching devices and components should be incorporated in accordance with the relevant part of BS EN 61439.

9.3.3.7 Internal electric circuits and connections

Internal electric circuits and connections should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.8 Terminals for external conductors

Terminals for external conductors should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.9 Dielectric properties

Dielectric properties should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.10 Verification of temperature rise

The power loss of the replacement device at the rated current of the functional unit should not exceed 90% of the power loss of the original device in order to ensure acceptable temperature rise performance.

9.3.3.11 Short circuit withstand strength

Substitution of a device in a functional unit by a generically similar device from another series (from the same manufacturer as the original device, or a different manufacturer) may take place without the need of short circuit tests as specified in BS EN 61439, provided the following conditions are met:

- the internal wiring structure of the device remains substantially unchanged;
- any necessary adoptions to connections to enable them to connect to the replacement device terminals take place within a short distance;
- for a replacement device that needs to be coordinated with other devices (e.g. part of a motor starter combination, "conditional short circuit rating", back-up protection, selectivity with up and downstream protective devices) those responsible for the substitution have verified that coordination is maintained;
- the breaking capacity of the replacement device is not less than the short circuit rating of the assembly;
- the peak let through current and energy of the replacement device are not greater than those of the original device. For circuit breakers and switches having a short time withstand rating (I_{cw}) the replacement device should have an I_{cw} equal or greater than that of the original device;
- the volume of the device compartment is not be less than that specified by the replacement device manufacturer;

  *NOTE 1 For circuit breakers BS EN 60947-2, **5.2**, c) requires appropriate volume data to be given by the device manufacturer.*

- in the case of circuit breakers, unless the live terminals do not appear in the compartment where the gases are exhausted:

a) terminal shields or phase separators are to be provided on the line side of the circuit breaker; or

b) all live parts are fully insulated;

- Either:

a) the functional unit with the substituted device has been previously successfully tested to verify the short-circuit strength in accordance with the relevant part of BS EN 61439; or

b) installation of the replacement device confroms to the minimum safety parameters specified by the replacement device manufacturer, plus 20%.

NOTE 2 For circuit breakers BS EN 60947-2 requires appropriate data be given by the device manufacturer.

9.3.3.12 Fuse-links

Fuse-links can be replaced, provided they are manufactured to the same product standard as the original fuse-link and the following conditions are met:

NOTE The data needed can be taken from the standardized marking of the fuse-link.

- The rated voltage of the replacement fuse-link is the same or greater than the rated voltage of the original fuse-link.
- The rated current of the replacement fuse-link is the same as the rated current of the original fuse-link.
- The utilization category of the replacement fuse-link is the same utilization category as of the original fuse-link.
- The fuse-system of the replacement fuse-link is the same fuse-system as the original fuse-link.
- The size of the replacement fuse-link is the same size as the original fuse-link.
- The breaking capacity of the replacement fuse-link is the same or greater than the breaking capacity of original fuse-link.

For special applications (e.g. semiconductor protection) fuse links with the appropriate characteristics should be selected.

9.3.3.13 Electromagnetic compatibility (EMC)

Electromagnetic compatibility should be verified in accordance with the relevant part of BS EN 61439.

9.3.3.14 Mechanical operation

Mechanical operation should be verified in accordance with the relevant part of BS EN 61439.

Table 1 *(1 of 2)* **List of design verifications to be performed**

No.	Characteristic to be verified	Clause or subclause	Means of verification	Result	Comments
1	Strength of material and parts:	**9.3.3.2**			
	Resistance to corrosion	BS EN 61439-2, **10.2.2**			
	Properties of insulating materials:	BS EN 61439-2, **10.2.3**			
	Thermal stability	BS EN 61439-2, **10.2.3.1**			
	Resistance of insulating materials to normal heat	BS EN 61439-2, **10.2.3.2**			
	Resistance to abnormal heat and fire due to internal electric effects	BS EN 61439-2, **10.2.3.3**			
	Resistance to ultra-violet (UV) Radiation				
	Lifting	BS EN 61439-2, **10.2.4**			
	Mechanical impact	BS EN 61439-2, **10.2.5**			
	Degree of protection of enclosures	BS EN 61439-2, **10.2.6**			
	Clearances and creepage distances	BS EN 61439-2, **10.2.7**			
2	Protection against electric shock and integrity of protective circuits:	**9.3.3.3**			
	Effective continuity between the exposed conductive parts of the ASSEMBLY and the protective circuit				
	Effectiveness of the assembly for external faults				
3	Incorporation of switching devices and components	**9.3.3.4**			
4	Internal electrical circuits and connections	**9.3.3.5**			
5	Terminals for external conductors	**9.3.3.6**			

Table 1 *(2 of 2)* **List of design verifications to be performed**

No.	Characteristic to be verified	Clause or subclause	Means of verification	Result	Comments
6	Dielectric properties: Power-frequence withstand Voltage Impulse withstand voltage	**9.3.3.7**			
7	Temperature-rise limits:	**9.3.3.8**			
8	Short-circuit withstand strength	**9.3.3.9**			
9	Electromagnetic compatibility (EMC)	**9.3.3.10**			
10	Mechanical operation	**9.3.3.11**			
11	Electromagnetic compatibility (EMC)	**9.3.3.13**			
12	Mechanical operation	**9.3.3.14**			

Annex A (normative) Equipment no longer commonly used but which might be present in old installations

COMMENTARY ON Annex A

In this standard, effort has been made to identify commonly used components and make appropriate maintenance recommendations. It is realistic to consider that while new assemblies mainly contain new technology, old installations, which are still in operational condition, might have equipment that is no longer in volume production. For the purpose of providing assistance in those instances, recommendations given in BS 6423:1983 have been included in this Annex.

A.1 Oil circuit breakers

A.1.1 Examination and overhaul

A.1.1.1 Venting and gas seals

The venting system should be inspected to ensure that a free passage for oil and gases exists. Where there is a joint between fixed and moveable portions of the gear it should be ensured that it is in sound condition. Vents should not be made larger than the design allows.

A.1.1.2 Mechanisms

Uncontrolled closing or opening operations with the tank removed or empty of oil should not be made unless the manufacturer's instructions specifically indicate otherwise.

A.1.1.3 Insulating oil (see also A.1.2)

A representative sample of oil should be taken and tested in accordance with BS EN 60422, with suitable variation for high viscosity oil. Oil that does not meet the requirements of the tests should be replaced with oil that does meet requirements. The oil level should be maintained to the level specified by the equipment manufacturer.

Before filling switchgear tanks with oil it is a good practice to rinse the interior of the tank and the immersed parts with clean oil. The tank and the surfaces of conductors and insulators should be kept free from fibres and from moisture as contamination will lower 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.

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

A.1.1.4 Tank or 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 laminate, which often indicates the presence of moisture. If moisture is suspected, a sample of the lining should be immersed in oil heated to approximately 105 °C. The presence of moisture will be indicated by frothing. 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.

Gaskets should be inspected and renewed where necessary.

All tank bolts should be 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.

A.1.1.5 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 hydraulic systems topped up as necessary.

A.1.2 Insulating oil

The interval between tests of oil will depend on the nature and frequency of operation of the equipment. Adverse environmental conditions can have a detrimental effect on insulating oil and special attention should be paid to equipment operating under such conditions. The optimum period between tests should be based on experience and/or consultation with the manufacturer. Electrical strength tests and, where ingress of moisture is likely, water content tests should be carried out in accordance with BS EN 60422 .The contamination of insulating oil can be a limiting factor on the allowable time between maintenance operations. The presence of carbon particles in oil does not necessarily indicate that the oil is in an unacceptable condition (see **A.2.1.3**).

A.1.3 Post-fault maintenance

WARNING. Isolation of withdrawable circuit breakers can be delayed after operation on fault to allow for the dispersal of any flammable gases.

A.1.3.1 Insulating oil

If the oil is badly discoloured or shows evidence of excessive contamination by carbon particles in suspension it might require changing in accordance with the procedure referred to in **A.1.2**.

A.1.3.2 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.

A.2 Manual controllers

A.2.1 General

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

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

NOTE If the controller is oil immersed, refer also to ***A.2.1.***

A.2.1.3 Drum type

Shaft bearings should be lubricated and renewed as necessary.

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

It should be ensured that Arc control devices and/or barriers should be checked for cracks or erosion, and actions should be taken to ensure that they are in the correct location. Blow out coils should be examined for signs of overheating and replaced as necessary. Finger and barrel insulation should be cleaned thoroughly, particularly where there is marked wear of segments and fingers and hence deposits of conductive dust.

A.2.1.4 Cam type

Maintenance for the cam type should be similar to that of contactors (see **5.10**) and of the working parts of drum type (see **A.3.1.1**).

A.2.1.5 Faceplate type

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

NOTE Overheating may 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 (see manufacturer's instructions).

A.2.1.6 Sealed switches

A sealed switch is 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 the switch should be replaced immediately. 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.

A.3 Motorized items

There are many types of motorized items, e.g. programme timers, rheostats and liquid starters/controllers. This clause applies to the motorized part of these items.

The large variety of types means that manufacturer's instructions should be consulted. Inspection and maintenance, where appropriate, of brushes, bearings, ventilation, travel limits and gearbox/clutch should be performed.

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

Annex B (informative) Diagnostic aids

*COMMENTARY ON Annex **B***

Means are available to assist in identifying maintenance needs and/or predicting when maintenance is required for low-voltage switchgear and controlgear. These means can take several forms:

a) means of identifying during preventive maintenance that a part has reached the end of its useful life;

b) on-going surveillance that identifies the reason for a failure and/or predicts preventive maintenance will be requires;

c) supplementary specialist equipment that will determine deteriorations and a need for preventive maintenance.

Manufacturers might provide as a feature of the equipment diagnostic aids, such as wear indication or other visual indicators to allow the performance of the equipment to be monitored.

Means for identifying that a part has reached the end of its useful life are usually some type of basic indicator or marking that shows, without a subjective judgement having to be made, whether a part has reached the end of its useful life. A typical example is that of air circuit breaker contacts where, with erosion of the contacts due to interrupting currents, a line on the moving contact comes to coincide with a mark on another part; this indicating that the contacts have reached the end of their useful life.

B.1 On-going surveillance

On-going surveillance mechanisms take many different forms. The mechanism can be a simple mechanical operations counter, or a sophisticated self-check circuit within a digitally controlled circuit within an assembly, for example, the checking facilities within a variable speed drive. Alternatively, contact wear might be predicted on the basis of current interruption, thus giving an early warning of the need for maintenance given.

B.2 Supplementary specialist equipment

Some types of supplementary specialist equipment are offered by the particular device or assembly manufacturer for use with that device or assembly, typically a test kit for checking the correct operation of the protection that is integrated into a circuit breaker. Where this form of diagnostic aid is offered it is important that it is used in accordance with the manufacturer's maintenance manual.

There is also specialist equipment intended to be used with many different makes of switchgear. An example of this is a thermal imaging camera, used to determine hot spots within an assembly.

For an effective diagnosis, the user of this type of specialist equipment needs to have a good understanding of the equipment, and a detailed knowledge of the usual performance and/or operation of the switchgear or controlgear. For example, in the case of thermal imaging the following need to be taken into account:

a) whether all necessary areas can be accessed. With compact assemblies, or switchgear that was not designed for thermal imaging this might not be practical;

b) whether all necessary areas can be thermally imaged safely;

c) the load on the circuit in the hours preceding thermal imaging;

d) normal working temperature corresponding to the load current;

e) previous test results for trend analysis.

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For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

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

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[9] HEATH AND SAFETY EXECUTIVE Removing an asbestos- containing 'Arc shield' from asbestos electrical switchgear

Further reading

BS EN ISO/IEC 17025, *General requirements for the competence of testing and calibration laboratories*

BS EN 60204-1, *Safety of machinery – Electrical equipment of machines – Part 1: General requirements*

BS EN 60204-32, *Safety of machinery – Electrical equipment of machines – Part 32: Requirements for hoisting machines*

BS EN 60947-1:2007+A1:2011 – *Low-voltage switchgear and controlgear. Part 1: General rules*

BS EN 60947-2 – *Low-voltage switchgear and controlgear. Part: 2 Circuit-breakers*

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