

8.3 Tests on auxiliary and control circuits

8.3.1 Inspection of auxiliary and control circuits, and verification of conformity to the circuit diagrams and wiring diagrams

The nature of the materials, the quality of assembly, the finish and, if necessary, the protective coatings against corrosion shall be checked. A visual inspection is also necessary to check the satisfactory installation of the thermal insulation, if any.

A visual inspection of actuators, interlocks, locks, etc., shall be made.

Components for auxiliary and control circuits inside enclosures shall be checked for proper mounting. The location of the means provided for connecting external wiring shall be checked to ensure that there is sufficient wiring space for spreading of the cores of multi-core cables and for the proper connection of the conductors.

The conductors and cables shall be checked for proper routing. Special attention shall be given to ensure that no mechanical damage can occur to conductors and cables due to the proximity of sharp edges or heating elements, or to the movement of moving parts.

Furthermore, the identification of components and terminals and, if applicable, the identification of cables and wiring shall be verified. In addition, the conformity of auxiliary and control circuits to the circuit diagrams and wiring diagrams shall be checked.

8.3.2 Functional tests

Functional tests are specified, where relevant, in the relevant IEC product standards. When specified, they shall be made on all auxiliary and control circuits to verify the proper functioning of auxiliary and control circuits in conjunction with the other parts of the switchgear and controlgear. The test procedures depend on the nature and the complexity of the auxiliary and control circuits of the device.

Operation tests on auxiliary and control circuits, subassemblies and components may be omitted if they have been fully tested during a test applied to the whole switchgear and controlgear.

8.3.3 Verification of protection against electrical shock

Protection against direct contact with the main circuit and safe accessibility to the auxiliary and control equipment parts liable to be touched during normal operation shall be checked. The preferred method is by visual inspection.

Where visual inspection cannot provide confirmation of the electrical continuity of earthed metallic parts, the alternative procedure defined in 7.4.3 shall be applied.

8.3.4 Dielectric tests

Only power frequency tests shall be performed. This test shall be made under the same conditions as those detailed in 7.10.5.

The test voltage shall be 1 kV with duration of 1 s.

8.4 Measurement of the resistance of the main circuit

For the routine test, the DC voltage drop or resistance of each pole of the main circuit shall be measured under conditions as nearly as possible similar, with regard to ambient air temperature and points of measurement, to those under which the corresponding measurement before the continuous current test was made. The test current shall be within the range stated in 7.4.4.

The measured resistance shall not exceed $1,2 \times R_u$, where R_u is equal to the resistance measured before the continuous current test.

In the case of assemblies it may be necessary to calculate the expected resistance based on relevant type tests.

8.5 Tightness test

8.5.1 General

Routine tests shall be performed to demonstrate the tightness criteria according to 6.16 at ambient temperature with the switchgear parts, components or subassemblies at or above the minimum functional pressure (or density) for insulation.

8.5.2 Controlled pressure systems for gas

The test procedure corresponds to 7.8.2.

8.5.3 Closed pressure systems for gas

The test may be performed at different stages of the manufacturing process or of assembling on site, on parts, components and subassemblies.

For parts or subassemblies tested in factory, the cumulative test is the preferred method.

For gas-filled systems tested in factory, the probing test using a sniffing device may be used. If any leak is detected, the test shall be considered to be failed or the leak shall be quantified by using a cumulative method.

For routine tests at site, the probing test using a sniffing device is the preferred method.

The sensitivity of the sniffing device shall be at least $10^{-8} \text{ Pa} \times \text{m}^3/\text{s}$.

8.5.4 Sealed pressure systems

Depending on the insulation medium two situations are considered:

a) Switchgear using gas

The preferred test procedure corresponds to 7.8.4, item a).

An alternative test procedure corresponds to the sealing tracer gas test with mass spectrometer, refer to IEC 60068-2-17:1994 [31].

b) Switchgear using vacuum interrupters

The vacuum tightness shall be demonstrated by a dielectric test according to 7.2.12 carried out after the mechanical routine test specified in the relevant product standards.

8.5.5 Liquid tightness tests

Routine tests shall be performed at normal ambient air temperature with the completely assembled switchgear and controlgear device. Testing of subassemblies is also permissible. In this case, a final check shall be performed at site.

The test methods correspond to those of the type tests (refer to 7.8.5).

8.6 Design and visual checks

The switchgear and controlgear shall be checked to verify its compliance with the purchase specification, if any.

9 Guide to the selection of switchgear and controlgear (informative)

9.1 General

Clause 9 gives general guidance on the appropriate selection of ratings and parameters depending on the application to be covered by high-voltage switchgear and controlgear. A summary of the considerations for specifying the ratings of switchgear and controlgear is provided in Annex F (informative).

9.2 Selection of rated values

The rated values should be chosen in accordance with this document having regard for the characteristics of the system as well as its anticipated future development. A list of ratings is given in Clause 5.

For most of the rated voltages, several rated insulation levels exist to allow for application of different performance criteria or overvoltage patterns. The choice should be made considering the degree of exposure to fast-front and slow-front overvoltage, the type of neutral earthing of the system and the type of overvoltage limiting devices (see IEC 60071-2:1996). Other parameters, such as local atmospheric and climatic conditions and the use at altitudes exceeding 1 000 m, should also be considered.

The duty imposed by fault conditions should be determined by calculating the fault currents at the place where the switchgear and controlgear is to be located in the system. Reference is made to IEC 60909-0 [33] and IEC TR 60909-1 [34] in this regard.

9.3 Cable-interface considerations

For connection to cables, the maximum temperature at the terminals at full continuous current should be below the temperature limits of the cable insulation and cable termination.

9.4 Continuous or temporary overload due to changed service conditions

Equipment could be required to carry a load current above its rated continuous current during a short period of time or when ambient temperatures are favourable to do it provided the temperature does not exceed the maximum temperature value specified in Table 14; reference is made to IEC TR 62271-306 [4].

NOTE For certain devices (e.g. load break switches) the temporary overload could result in a load current that exceeds the switching capability of the switchgear.

9.5 Environmental aspects

9.5.1 Service conditions

Selected switchgear and controlgear and its associated operating devices and auxiliary equipment should be designed and validated to comply with at least the specific service conditions required by the user or appropriate arrangements should be made.

9.5.2 Clearances affected by service conditions

Where clearances may be compromised by environmental related changes in the service access level (for example accumulation of snow, sand, etc.) the use of increased clearances should be considered.

9.5.3 High humidity

For the normal service conditions present in 4.1.2 e), condensation may occasionally occur on, or in, indoor switchgear and controlgear.

To withstand the effects of high humidity and condensation, such as breakdown of insulation or corrosion of metallic parts, switchgear designed for such conditions should be used.

Condensation may be prevented by special design of the building or housing, by suitable ventilation and heating of the station or by the use of dehumidifying equipment. Other options include heaters with thermostats/humidistat inside the switchgear.

High humidity may also be due to ground level rainwater or for cable-connected applications of underground network applications from incoming cable raceways connected to switchgear.

9.5.4 Solar radiation

Under certain levels of solar radiation, appropriate measures, for example roofing, forced ventilation etc., may be necessary, or derating may be used, in order not to exceed the specified temperature and pressure rise limits. Tests with simulated solar gain may be used to demonstrate if measures or derating are needed.

10 Information to be given with enquiries, tenders and orders (informative)

10.1 General

The intention of this clause is to define information, which is necessary to enable the user to make an appropriate enquiry for equipment and to enable the supplier to give an adequate tender.

Furthermore, it enables the user to make a comparison and evaluation of offers from different suppliers.

NOTE The supplier can either be a manufacturer or a contractor.

When enquiring about or ordering an installation of switchgear and controlgear the following information as a minimum should be supplied by the enquirer.

Annex F (informative) provides similar information items in a tabular form for ease of use.

10.2 Information with enquiries and orders

The following information listed below, if applicable, should be given by the enquirer / user.

a) Particulars of the system:

Nominal and highest voltage, frequency, type of system neutral earthing.

b) Service conditions if different from normal (refer to Clause 4):

Any condition deviating from the normal service conditions or affecting the satisfactory operation of the equipment.

In this case high-voltage switchgear and controlgear and associated operating devices and auxiliary equipment should be designed and validated to comply with any special service conditions required by the user, or appropriate arrangements should be made.

c) Particulars of the installation and its components:

- 1) indoor or outdoor installation;
- 2) number of phases;
- 3) number of busbars, as shown in the single-line diagram;
- 4) rated voltage;
- 5) rated frequency;
- 6) rated insulation level (U_d , U_p , U_s when applicable);

- 7) rated continuous currents of busbars and feeder circuits;
 - 8) rated short-time withstand current (I_k);
 - 9) rated duration of short-circuit (if different from 1 s);
 - 10) rated peak withstand current (if different from 2,5 I_k or 2,6 I_k);
 - 11) rated values of components (e.g. for VTs or CTs in an assembly, for individual functional units of an assembly.);
 - 12) degree of protection for the enclosure and partitions;
 - 13) circuit diagrams.
- d) Particulars of the operating devices:
- 1) type of operating devices;
 - 2) rated supply voltage (if any);
 - 3) rated supply frequency (if any);
 - 4) rated supply pressure (if any);
 - 5) special interlocking requirements;
 - 6) number of available auxiliary contacts required (the user should state the contact performance needed).

In addition to these items the enquirer should indicate every condition which might influence the tender or the order, for example special mounting or installation conditions, the location of the external high-voltage connections or any specific rules for pressure vessels, requirements for cable testing and, if applicable, whether functionality shall be maintained after a seismic event or during and after a seismic event.

Information should be supplied if type test reports or any other conformity assessment related document are requested.

10.3 Information with tenders

The following information listed below, if applicable, should be given by the manufacturer with descriptive material and drawings.

- a) Rated values and characteristics as enumerated in item c) of 10.2.
- b) Constructional features, for example:
 - 1) mass of the heaviest transport unit;
 - 2) overall dimensions of the installation;
 - 3) arrangement of the external connections;
 - 4) future extensions if applicable;
 - 5) facilities for transport and mounting;
 - 6) mounting provisions;
 - 7) accessible sides;
 - 8) instructions for installation, operation and maintenance;
 - 9) type of gas-pressure or liquid-pressure system;
 - 10) filling level / pressure and minimum functional level / pressure;
 - 11) volume or mass of fluid for the different compartments;
 - 12) specification of fluid.
- c) Particulars of the operating devices:
 - 1) types and rated values as enumerated in item d) of 10.2;
 - 2) current or power for operation;

- 3) operating times.
- d) List of recommended spare parts that should be procured by the user.
- e) Any other document or information requested in the enquiry.

11 Transport, storage, installation, operating instructions and maintenance

11.1 General

It is essential that the transport, storage and installation of switchgear and controlgear, as well as their operation and maintenance in service, is performed in accordance with instructions given by the manufacturer.

Consequently, the manufacturer shall provide the appropriate version of the instruction manual for the transport, storage, installation, operation and maintenance of switchgear and controlgear. The instructions for the transport and storage should be given at a convenient time before delivery, and the instructions for the installation, operation and maintenance should be given by the time of delivery at the latest. It is preferable that the operation manual be a separate document from the installation and maintenance manual.

It is impossible, here, to cover in detail the complete rules for the installation, operation and maintenance of each one of the different types of apparatus manufactured, but the following information is given relative to the most important points to be considered for the instructions provided by the manufacturer.

11.2 Conditions during transport, storage and installation

A special agreement should be made between manufacturer and user if the service conditions of temperature and humidity defined in the order cannot be guaranteed during transport, storage and installation. Special precautions may be essential for the protection of insulation during transport, storage and installation, and prior to energizing, to prevent moisture absorption due, for instance, to rain, snow or condensation. Vibrations during transport should be considered. Appropriate instructions should be given by the manufacturer.

Special packaging should be proposed by the manufacturer for long term storage of parts for maintenance needs according to customer specifications.

11.3 Installation

11.3.1 General

For each type of switchgear and controlgear the instructions provided by the manufacturer shall include at least the items listed below.

11.3.2 Unpacking and lifting

Each complete equipment shall be provided with adequate lifting facilities and labelled (externally) to show the correct method of lifting. The equipment shall be labelled (externally) to indicate its maximum mass, in kg, when fully equipped. Special lifting devices shall be capable of lifting the mass of each transport unit and special precautions shall be detailed in the installation manual (for example lifting brackets/bolts that are not intended to be left outdoors shall be removed at site).

Required information for unpacking should be given.

11.3.3 Assembly

When the switchgear and controlgear is not fully assembled for transport, all transport units should be clearly marked. Drawings showing assembly of these parts should be provided with the switchgear and controlgear.

11.3.4 Mounting

Instructions for the mounting of switchgear and controlgear, operating device and auxiliary equipment should include sufficient details of locations and foundations to enable site preparation to be completed.

These instructions should also indicate:

- the total mass of the apparatus inclusive of extinguishing or insulating fluids;
- the mass of extinguishing or insulating fluids;
- the mass of each unit to be lifted separately.

11.3.5 Connections

Instructions should include information on:

- connection of conductors, comprising the necessary advice to prevent overheating and unnecessary strain on the switchgear and controlgear and to provide adequate clearance distances;
- connection of auxiliary circuits;
- connection of liquid or gas systems, if any, including size and arrangement of piping;
- connection for earthing;
- auxiliary contacts available to the user.

11.3.6 Information about gas and gas mixtures for controlled and closed pressure systems

For controlled and closed pressure systems filled with gas mixture, the percentage of the different gases and their associated tolerances shall be defined by the manufacturer taking into account handling and uncertainty of measurement. Appropriate gas filling procedures are defined in IEC 62271-4.

During commissioning or maintenance, the maximum allowable humidity content within gas-filled switchgear and controlgear filled with gas at the filling pressure (density) for insulation shall be checked by dew point measurement. Appropriate correction factors shall be used for measurements performed at temperatures other than 20 °C according to the manufacturer's instruction manual.

The maximum allowable humidity content for equipment filled or re-filled with new or used gas should be such that the dew point inside the switchgear compartment is not higher than

- –10 °C for equipment with adsorber material;
- –15 °C for equipment without adsorber material

during commissioning or after maintenance for a measurement at filling pressure (density) for insulation and at 20 °C.

NOTE 1 These dew point values during commissioning are expected to give a dew point value lower than -5 °C during service life, for a measurement at 20 °C.

NOTE 2 The measurement of the dew point is specified at a given temperature due to the possible exchange of water between gas and solid materials when the temperature changes, which could change the measured value.

NOTE 3 An example of measurement and determination of the dew point is given in IEEE C37.122.5 [35].

11.3.7 Final installation inspection

Instructions should be provided for inspection and tests which should be made after the switchgear and controlgear has been installed and all connections have been completed.

These instructions should include:

- a schedule of recommended site tests to establish correct operation;
- procedures for carrying out any adjustment that may be necessary to obtain correct operation;
- recommendations for any relevant measurements that should be made and recorded to help with future maintenance decisions;
- a procedure for qualitative gas tightness test at site (sniffing test) on all field assembled connections for closed pressure systems, reference is made to 8.5.3;
- instructions for final inspection and putting into service.

Guidance for electromagnetic compatibility site measurements is given in Annex H (informative).

11.3.8 Basic input data by the user

These data should include:

- a) access limitations to the local site;
- b) local working conditions and any restrictions that may apply (for example, safety equipment, normal working hours, union requirements for supervisor, manufacturer's and local installation crew, etc.);
- c) availability and capacity of lifting and handling equipment;
- d) availability, number and experience of local personnel;
- e) specific pressure vessel rules and procedures that may apply during installation and commissioning tests;
- f) interface requirements for high-voltage cables and transformers;
- g) in the case of extensions to existing switchgear and controlgear:
 - 1) provisions for the extension available within existing primary and secondary equipment;
 - 2) in-service conditions or operating restrictions that apply;
 - 3) safety regulations that locally apply.

11.3.9 Basic input data by the manufacturer

These data should include:

- a) space necessary for installation and assembly;
- b) size and weight of components and testing equipment;
- c) site conditions regarding cleanliness and temperature for clean installation and preparation area;
- d) number and experience of local personnel required for installation;
- e) time and activity schedules for installation and commissioning;
- f) electric power, lighting, water and other needs for installation and commissioning;
- g) proposed training of installation and service personnel;
- h) in case of extension to existing switchgear and controlgear:
 - 1) out-of-service requirements of existing components related to the installation schedule;

2) safety precautions.

i) gas filling procedure (mixed gases) and dew point verification, if necessary.

11.4 Operating instructions

The operating instructions given by the manufacturer shall contain the following information:

- a general description of the equipment with particular attention to the technical description of its characteristics and operation so that the user has an adequate understanding of the main principles involved;
- a description of the safety features of the equipment and the operation of the interlocks and padlocking facilities;
- as relevant, a description of the action to be taken to manipulate the equipment for operation isolation, earthing, maintenance, and testing;
- as relevant, measures against corrosion should be given.

11.5 Maintenance

11.5.1 General

The effectiveness of maintenance depends mainly on the way instructions are prepared by the manufacturer and implemented by the user.

11.5.2 Information about fluids and gas to be included in maintenance manual

Where applicable, the following information shall be provided by the manufacturer:

- a) type and required quantity and quality of liquid to be used in switchgear and controlgear;
- b) type and required quantity and quality of gas to be used in switchgear and controlgear.

11.5.3 Recommendations for the manufacturer

The manufacturer should be responsible for ensuring the continued availability of spare parts required for maintenance for a period of not less than 10 years from the date of final manufacture of the switchgear and controlgear.

The manufacturer should inform the purchasers of a particular type of switchgear and controlgear about corrective actions required by systematic defects and failures detected in service.

The manufacturer's maintenance manual should include the following information listed below.

- a) Extent and frequency of maintenance. For this purpose the following factors should be considered:
 - 1) switching operations (current and number);
 - 2) total number of operations;
 - 3) time in service (periodic intervals);
 - 4) environmental conditions;
 - 5) activity after a seismic event (if applicable);
 - 6) measurements and diagnostic tests, (if any).
- b) Detailed description of the maintenance work:
 - 1) recommended place for the maintenance work (indoor, outdoor, in factory, on site, etc.);
 - 2) procedures for inspection, diagnostic tests, examination, overhaul;
 - 3) reference to drawings;

- 4) reference to part numbers;
 - 5) use of special equipment or tools;
 - 6) precautions to be observed (for example cleanliness and possible effects of harmful arcing by-products);
 - 7) lubrication procedures.
- c) Comprehensive drawings of the details of the switchgear and controlgear important for maintenance, with clear identification (part number and description) of assemblies, subassemblies and significant parts.

NOTE Expanded detail drawings which indicate the relative position of components in assemblies and subassemblies are a common illustration method.

- d) Limits of values, which can be measured during operation or routine maintenance and tolerances which, when exceeded, make corrective action necessary, for example:
- 1) pressures, density levels, gas mixtures tolerance;
 - 2) resistance and/or capacitance (of the main circuit);
 - 3) operating times;
 - 4) resistance of the main circuits;
 - 5) insulating liquid or gas characteristics;
 - 6) quantities and quality of liquid or gas (see IEC 60480 and IEC 62271-4 for SF₆);
 - 7) dew point inside gas-filled switchgear compartment according to 11.3.6;
 - 8) permissible erosion of parts subject to wear;
 - 9) torques;
 - 10) important dimensions.
- e) Specifications for auxiliary maintenance materials, including warning of known non-compatibility of materials:
- 1) grease;
 - 2) oil;
 - 3) fluid;
 - 4) cleaning and degreasing agents.
- f) List of special tools, lifting and access equipment.
- g) Tests after the maintenance work.
- h) List of the recommended spare parts (description, reference number, quantities) and advice for storage.
- i) Estimate of active scheduled maintenance time, carried out in accordance with an established time schedule.
- j) How to proceed with the equipment at the end of its operating life, taking into consideration environmental requirements.

11.5.4 Recommendations for the user

If the user wishes to perform maintenance, the maintenance manual of the manufacturer should be followed.

The user should record the following information:

- the serial number and the type of the switchgear and controlgear;
- the date when the switchgear and controlgear is put in service;
- the results of all measurements and tests including diagnostic tests carried out during the life of the switchgear and controlgear;
- dates and extent of the maintenance work carried out;