
Guide on

High-voltage testing techniques

Part 2. Test procedures

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Part 2. Test procedures]

Guide pour les techniques des essais à haute tension
Partie 2. Modalités d'essais

Anleitung zu Hochspannungsprüfmethoden
Teil 2. Prüfverfahren

National foreword

This British Standard has been prepared under the direction of the Power Electrical Engineering Standards Committee. With Parts 1, 3 and 4 it is a revision of BS 923 : 1972, which is therefore withdrawn, and the four Parts are identical with Parts of IEC Publication 60 'High-voltage test techniques' published by the International Electrotechnical Commission (IEC). This Part is identical with IEC Publication 60-2 : 1973 'Test procedures'.

Terminology and conventions. The text of the international standard has been approved as suitable for publication, without deviation, as a British Standard. Some terminology and certain conventions are not identical with those used in British Standards.

Where page numbers are quoted in the text, they refer to IEC page numbers, which are shown in square brackets at the foot of each page.

Cross-references

International standard	Corresponding British Standard
IEC 60	BS 923 Guide on high-voltage testing techniques
IEC 60-1 : 1973	Part 1 : 1980 General requirements (Identical)
IEC 60-3 : 1976	Part 3 : 1980 Measuring devices (Identical)
IEC 60-4 : 1977	Part 4 : 1980 Application guide for measuring devices (Identical)
IEC 52 : 1960	BS 358 : 1960 Method for the measurement of voltage with sphere-gaps (one sphere earthed) (Technically equivalent)

NOTE. As IEC 60-2 was published before IEC 60-3 and IEC 60-4, certain references in the text should be read as follows.

Clause 2. The last sentence should be read as '... checking methods are given in IEC Publication 60-3 and in the Application Guide, IEC Publication 60-4.'

The references to IEC Publication 60 in subclauses 4.3.1, 7.3.1, 10.5.1, 13.3, 16.3 and 16.4 should be read as references to IEC Publication 60-3.

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British Standard Guide on

High-voltage testing techniques

Part 2. Test procedures

SECTION ONE — GENERAL

1. Scope

This recommendation is applicable to:

- dielectric tests with direct voltage;
- dielectric tests with alternating voltage;
- dielectric tests with impulse voltage;
- tests with impulse current.

2. Object

The object of this recommendation is:

- to define terms specifically relating to the above tests;
- to describe methods for generation and measurement of test voltages and currents;
- to describe test methods;
- to describe methods for the evaluation of test results and to indicate criteria for acceptance or refusal.

Definitions of general applicability, general requirements regarding test objects, and test procedures of general applicability are given in IEC Publication 60-1, High-voltage Test Techniques, Part 1: General Definitions and Test Requirements. Requirements concerning approved measuring devices and checking methods will be given in the future IEC Publication 60-3 and in an Application Guide (revision of Section Eight and of the Appendix of IEC Publication 60).

SECTION TWO — TESTS WITH DIRECT VOLTAGE

3. Definitions for direct voltage tests

3.1 *Ripple*

Ripple is the periodic deviation from the arithmetic mean value of the voltage. The amplitude of the ripple is defined as half the difference between the maximum and minimum values. The ripple factor is the ratio of the ripple amplitude to the arithmetic mean value.

3.2 *Value of the test voltage*

The value of the test voltage is defined by its arithmetic mean value.

4. Test voltage

4.1 *Requirements for the test voltage*

The test voltage, as applied to the test object, should be a direct voltage with not more than 5% ripple factor, unless otherwise specified by the relevant Technical Committee. Note that the presence of the test object may affect the ripple factor.

4.2 *Generation of the test voltage*

The test voltage is generally obtained by means of rectifiers, but sometimes by electrostatic generators. The requirements to be met by the test voltage source depend considerably upon the type of apparatus which shall be tested and on the test conditions. These requirements are determined mainly by the values and nature of the test current to be supplied, the important constituents of which are indicated in Sub-clause 4.4.

The output current rating of the source should be sufficient to charge the capacitance of the test object in a reasonably short time. In the case of objects having high capacitance, charging times of several minutes must, however, sometimes be accepted. The source, including the storage capacitance, should also be adequate to supply the leakage and absorption currents and any internal and external partial discharge currents without excessive voltage drops which might influence the test results. In tests on internal insulation, these currents are usually small; but when testing wet insulators, leakage currents of the order of some tens of milliamperes, or pre-discharge pulses of the order 10^{-2} coulomb may occasionally be encountered.

For tests on polluted insulators, special circuits giving large output currents are necessary. Provisionally, it is recommended that the source should be such that when a pulse current of 500 mA is drawn for a duration of 500 ms the voltage drop during each pulse or a sequence of pulses should not exceed 5% when the repetition rate is once per second.

4.3 *Measurement of the test voltage*

4.3.1 *Measurement with devices approved under IEC Publication 60*

The measurement of the arithmetic mean value, the maximum value, the ripple factor, and any transient drop in the test voltage should, in general, be made with devices which have passed the approval procedure referred to in IEC Publication 60, High-voltage Test Techniques. Attention is drawn to the requirements on response characteristics of devices used for measuring ripple or transients.

4.3.2 *Measurement with a sphere-gap, in accordance with IEC Publication 52, 1960*

The measurement only of the maximum value of the test voltage can be made with a sphere-gap. The procedure usually consists in establishing a relationship between the spacing at which disruptive discharges occur and some other circuit variable related to the test voltage, see IEC Publication 52 (1960), Recommendations for Voltage Measurement by Means of Sphere-gaps (one sphere earthed). (The relationship between the supply voltage and the output voltage may not be sufficiently stable for measuring purposes.)

The relationship may be dependent on the presence of the test object and the sphere-gap, the precipitation in wet tests, etc. Hence, it is important that these conditions are the same during the sphere-gap calibration and the actual test, except that during the test, the sphere-gap may be opened sufficiently to prevent sparkover. Attention is drawn also to the possibility of erratic sphere-gap measurements with direct voltage due to pollution in the atmosphere.

The calibration is preferably made at 100% of the test voltage, but for tests on objects with non-self-restoring insulation, extrapolation may be made from a value not lower than 80% of this voltage. Extrapolation may be unsatisfactory if the current in the test circuit varies non-linearly with the applied voltage.

4.4 *Measurement of the test current*

When measurements of current through the test object are made, a number of separate components may be recognized which differ from each other by several orders of magnitude for the same test object and test voltage. They are:

- the capacitance current, due to the initial application of the test voltage and to any ripple or other fluctuations imposed on it;
- the dielectric absorption current, due to slow charge displacements within the insulation and persisting for periods of a few seconds up to several hours. This process is partially reversible; currents of opposite polarity being observed when the test object is discharged and short-circuited;
- the continuous leakage current, which is the final steady direct current attained at constant applied voltage after the above components have decayed to zero;
- partial discharge currents.

Measurement of the first three components necessitates the use of instruments covering a wide range of current magnitudes. It is important to ensure that the instrument, or the measurement of any one component of the current, is not adversely affected by the other components. From the observed current variation with time, in non-destructive tests, information may sometimes be obtained concerning the condition of the insulation.

The relative magnitude and the importance of each component of current depend on the type and the condition of the test object, the purpose for which the test is being made and the duration of the test. Accordingly the measurement procedures should be specified by the relevant Technical Committee, especially when it is required to distinguish a particular component.

Measurements of partial discharge pulse currents are made with special instruments which are dealt with in IEC Publication 270 (1968), Partial Discharge Measurements.

5. **Test procedures**

The disruptive discharge voltage of a test object is subject to statistical variations. Some guidance on methods for determining voltages giving a specified disruptive discharge probability is presented in Appendix A.

5.1 *Rated withstand voltage tests*

The voltage should be applied to the test object starting at a value sufficiently low to prevent any effect of overvoltage due to switching transients. It should be raised sufficiently slowly to permit accurate reading of the instruments, but not so slowly as to cause unnecessary prolongation of stressing of the test object near to the test voltage. These requirements are in general met if the rate of rise above 75% of the estimated final voltage is about 2% per second of this voltage. It should be maintained for the specified time and then reduced by discharging the smoothing capacitor through a suitable resistor. The requirements of the test are generally satisfied if no disruptive discharge occurs on the test object.

The polarity of the voltage or the order in which voltages of each polarity are applied, and any deviation required from the above specification, should be specified by the relevant Technical Committee.

5.2 *Assured disruptive discharge voltage tests*

The voltage should be applied and raised in the manner described in Sub-clause 5.1 until a disruptive discharge occurs on the test object. The value of the test voltage reached just prior to the disruptive discharge should be recorded. The requirements of the test are generally satisfied if this voltage is not higher than the assured disruptive discharge voltage on each one of a specified number of voltage applications.

SECTION THREE — TESTS WITH ALTERNATING VOLTAGE

6. Definitions for alternating voltage tests

6.1 *Peak value*

The peak value of an alternating voltage is the maximum value, except that small high-frequency oscillations arising for instance from partial discharges, are disregarded.

6.2 *R.M.S. value*

The r.m.s. value of an alternating voltage is the square root of the mean value of the square of the voltage values during a complete cycle.

6.3 *Value of the test voltage*

The value of the test voltage is defined by its peak value divided by $\sqrt{2}$.

Note. — The relevant Technical Committee may require a measurement of the r.m.s. value of the test voltage instead of the peak value for cases where the r.m.s. value may be of importance. Such cases are for instance when thermal effects are under investigation.

7. Test voltage

7.1 *Requirements for the test voltage*

The test voltage should be an alternating voltage generally having a frequency in the range 40 Hz to 62 Hz. Special tests may be required at frequencies considerably below or above this range, as specified by a Technical Committee.

The voltage shape shall approximate to a sinusoid with both half-cycles closely alike and shall have a ratio of peak to r.m.s. values equal to $\sqrt{2}$ within $\pm 5\%$. The results of a high-voltage test are thought to be unaffected by deviations from a sinusoid if these requirements are met.

There is insufficient information available to indicate whether the above requirements are generally met by test circuits in common use; hence, for some circuits or test objects greater deviations may have to be accepted. Note that the presence of the test object, especially if it has non-linear impedance characteristics, may considerably affect the deviation from a sinusoid.

Note. — It can generally be assumed that the above requirements on deviations from a sinusoid will be met if the r.m.s. value of the harmonics does not exceed 5% of the r.m.s. value of the fundamental.

7.2 Generation of the test voltage

The test voltage is generally supplied from a step-up transformer. Alternatively, it may be generated by means of a series resonant circuit.

Note. — Attention is drawn to the possibility that non-sustained disruptive discharges may cause large overswings of voltage between the terminals of the test object. This phenomenon may cause failure of the test object or of the testing transformer. A cure can usually be affected by changing the natural frequency of the voltage source or by introducing some attenuation into the system.

7.2.1 Requirements for the transformer test circuit

The voltage in the test circuit should be stable enough to be practically unaffected by varying leakage currents. Partial discharges, or pre-discharges in the test object, should not reduce the test voltage to such an extent and for such a time that the measured disruptive discharge voltage of the test object is affected.

This is usually achieved if, simultaneously:

- the total capacitance of the test object and any additional capacitor is not less than about 1 000 pF;
- the steady-state current delivered by the transformer, if the test object is short-circuited at the test voltage, is not less than 1 A r.m.s.

Note. — If any external protective series resistance does not exceed 1 k Ω , the effective terminal capacitance of the transformer may be regarded as being in parallel with the test object.

Exceptions for the requirement on steady-state short-circuit current are:

- for dry tests on small samples of solid insulation, insulating liquids, or combinations of the two, a short-circuit current of the order of 0.1 A r.m.s. may suffice;
- for tests under artificial pollution, the required short-circuit current depends on the ratio of series resistance R_s to the steady-state reactance X_s of the voltage source, including the generator or supply network at the test frequency, as indicated by Table I below.

TABLE I

R_s/X_s	Short-circuit current A r.m.s.
< 0.1	≥ 6
0.1-0.2	≥ 8
0.2-0.3	≥ 12

If the ratio R_s/X_s is greater than 0.3, higher values of short-circuit current than 12 A may be necessary.

7.2.2 The series resonant circuit

The series resonant circuit consists essentially of a capacitive test object or load in series with a variable inductance, connected to a medium voltage power source. By varying the inductance the circuit can be tuned to resonance at the supply frequency, when a voltage considerably greater than that of the source, and of substantially sinusoidal shape, will be applied to the test object. The stability of the resonance conditions and of the test voltage depends on the constancy of supply frequency and of the test circuit impedances.

The series resonant circuit is especially useful when testing objects such as capacitors or cables in which the leakage currents on the external insulation are very small in comparison with the capacitive currents through the test object. The circuit may be unsuitable if the resonance conditions are disturbed by non-linear leakage currents or discharges, for example in tests on external insulation under wet or polluted conditions.

7.3 *Measurement of the test voltage*

7.3.1 *Measurement with devices approved under IEC Publication 60*

The measurement of the peak value, the r.m.s. value and the deviation from a sinusoid should in general be made with devices which have passed the approval procedures referred to in IEC Publication 60 (under revision).

7.3.2 *Measurement with a sphere-gap, in accordance with IEC Publication 52, 1960*

The measurement only of the peak value of the test voltage can be made with a sphere-gap. The procedure usually consists in establishing a relationship between the spacing at which disruptive discharges occur and some other circuit variable related to the test voltage; see IEC Publication 52, 1960. (The relationship between the supply voltage and the output voltage may not be sufficiently stable for measuring purposes.)

The relationship may be dependent on the presence of the test object and the sphere-gap, the precipitation in wet tests, etc. Hence, it is important that these conditions are the same during the sphere-gap calibration and the actual test, except that during the test the sphere-gap may be opened sufficiently to prevent sparkover.

The calibration is preferably made at 100% of the test voltage, but for tests on objects with non-self-restoring insulation, extrapolation may be made from a value not lower than 80% of this voltage. Extrapolation may be unsatisfactory if the current in the test circuit varies non-linearly with the applied voltage, or if any changes occur in the voltage shape or frequency between the calibration and the 100% voltage levels.

8. **Test procedures**

The disruptive discharge voltage of a test object is subject to statistical variations. Some guidance on methods for determining voltages giving specified disruptive discharge probabilities is given in Appendix A.

8.1 *Rated withstand voltage tests*

The voltage should be applied to the test object starting at a value sufficiently low to prevent any effect of overvoltages due to switching transients. It should be raised sufficiently slowly to permit accurate reading of the measuring instrument but not so slowly as to cause unnecessary prolongation of the stressing of the test object near to the test voltage. These requirements are in general met if the rate of rise above 75% of the estimated final test voltage is about 2% per second of this voltage. It should be maintained for the specified time and then rapidly decreased, but not suddenly interrupted as this may generate switching transients which could cause damage or erratic test results. The requirements of the test are generally satisfied if no disruptive discharge occurs on the test object.

Deviations from the above recommendation may be specified by the relevant Technical Committee.