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INTERNATIONAL STANDARD

NORME INTERNATIONALE

Dielectric and resistive properties of solid insulating materials – Part 1: General

Propriétés diélectriques et résistives des matériaux isolants solides – Partie 1: Généralités

IEC 62631-1:2011

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 1: General

FOREWORD

1) The International Electrotechnical Commission (IEC) is a worldwide organization for standardization comprising all national electrotechnical committees (IEC National Committees). The object of IEC is to promote international co-operation on all questions concerning standardization in the electrical and electronic fields. To this end and in addition to other activities, IEC publishes International Standards, Technical Specifications, Technical Reports, Publicly Available Specifications (PAS) and Guides (hereafter referred to as "IEC Publication(s)"). Their preparation is entrusted to technical committees; any IEC National Committee interested in the subject dealt with may participate in this preparatory work. International, governmental and non-governmental organizations liaising with the IEC also participate in this preparation. IEC collaborates closely with the International Organization for Standardization (ISO) in accordance with conditions determined by agreement between the two organizations.
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International Standard IEC 62631-1 has been prepared by IEC technical committee 112: Evaluation and qualification of electrical insulating materials and systems.

This International Standard, together with its future parts, is intended to replace certain standards as set out and explained in the Introduction.

Such standards will, however, remain valid until the respective part of IEC 62631 is published.

The text of this standard is based on the following documents:

FDIS	Report on voting
112/169/FDIS	112/176/RVD

Full information on the voting for the approval of this standard can be found in the report on voting indicated in the above table.

This publication has been drafted in accordance with the ISO/IEC Directives, Part 2.

The committee has decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC web site under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

- reconfirmed,
- withdrawn,
- replaced by a revised edition, or
- amended.

INTRODUCTION

The IEC 62631 series is divided into four main parts, which are further subdivided into component parts. The present Part 1 of IEC 62631 considers, general aspects related to the measurement of dielectric and resistive properties of solid electric insulating materials. Parts 2 and 3 outline basic procedures for the measurement of dielectric and resistive properties by means of AC and DC methods. These parts will gradually replace hitherto existing International Standards. Part 4 will cover special methods of measurement and computational methods.

Table 1 shows the planned future structure of IEC 62631, together with the standards it will replace.

Table 1 – Planned structure of IEC 62631

Main title	**DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS**	
Part number	**Part title**	**Remarks**
IEC 62631-1	**– General**	Amends and replaces IEC 60093, IEC 60167, IEC 60250, IEC 60345
IEC 62631-2	**– Permittivity and dielectric dissipation factors (AC methods)**	New
IEC 62631-2-1	– Technical frequencies (1 Hz to 100 MHz)	Replaces IEC 60250
IEC 62631-2-2	– High frequencies (1 MHz to 300 MHz)	Replaces IEC 60250
IEC 62631-2-3	– Very high frequencies (above 300 MHz)	Replaces IEC 60377-1 and IEC 60377-2
IEC 62631-2-4	– Low frequencies (1 MHz to 1 kHz)	New
IEC 62631-3	**– Resistive properties (DC methods)**	New
IEC 62631-3-1	– Volume resistance and volume resistivity	Replaces IEC 60093
IEC 62631-3-2	– Surface resistance and surface resistivity	Replaces IEC 60093
IEC 62631-3-3	– Insulation resistance	Replaces IEC 60167
IEC 62631-3-4	– Special requirements for the determination of resistive material properties at elevated temperatures	Replaces IEC 60345
IEC 62631-4	**– Special methods**	New
IEC 62631-4-1	– Computational methods for the evaluation of data gained by the use of broadband dielectric spectrometers	New
IEC 62631-4-2	– Thermal analysis by means of observation of dielectric properties	New

Measured values of dielectric and resistive properties of solid insulating materials are dependent upon different factors such as the magnitude and time of voltage application, frequency, the nature and geometry of the electrodes, the surface condition, contamination, temperature and humidity of the ambient atmosphere and of the specimens during conditioning and measurement and, in certain cases, on electric field strength also.

Therefore, the electrical and dielectric properties covered by the IEC 62631 series may only be comparable as far as the circumstances of the measurement's parameters are stipulated. The test specimen's shape and dimensions, as well as the measurement parameters, may be defined in product standards or the relevant parts of this series of standards dealing with test procedures, depending on the requirements to be considered for a certain demand of measurement. Care should be taken when using measured values from the IEC 62631 series for the purposes of designing an electric product.

NOTE It is not possible to give a comprehensive overview covering the dielectric and resistive properties of solid electrical insulating materials within a framework of an International Standard. Therefore, the user is encouraged to read up on the literature such as that recommended in the bibliography.

DIELECTRIC AND RESISTIVE PROPERTIES OF SOLID INSULATING MATERIALS –

Part 1: General

1 Scope

This part of IEC 62631 gives general guidelines for the determination of dielectric and resistive properties of solid electrical insulating materials.

2 Normative references

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

IEC 60050-212, *International Electrotechnical Vocabulary – Part 212: Electrical insulating solids, liquids and gases*

NOTE For IEC 60050, free online access is provided by www.electropedia.org.

IEC 60093:1980, *Methods of test for volume resistivity and surface resistivity of solid electrical insulating materials*

IEC 60167:1964, *Methods of test for the determination of the insulation resistance of solid insulating materials*

IEC 60250:1969, *Recommended methods for the determination of the permittivity and dielectric dissipation factor of electrical insulating materials at power, audio and radio frequencies including metre wavelengths*

IEC 60345:1971, *Method of test for electrical resistance and resistivity of insulating materials at elevated temperatures*

IEC 60377-1:1973, *Recommended methods for the determination of the dielectric properties of insulating materials at frequencies above 300 MHz – Part 1: General*

IEC 60377-2:1977, *Recommended methods for the determination of the dielectric properties of insulating materials at frequencies above 300 MHz – Part 2: Resonance methods*

ISO 291, *Plastics – Standard atmospheres for conditioning and testing*

ISO 558, *Conditioning and testing – Standard atmospheres – Definitions*

3 Terms and definitions

For the purposes of this document, the following terms and definitions, as well as those given in IEC 60050-212, apply.

3.1 General definitions

3.1.1
electrical insulating material
solid material with negligibly low electric conductivity, used to separate conducting parts at different electrical potentials

NOTE In English, the term "electrical insulating material" is sometimes used in a broader sense to also designate insulating liquids and gases. Insulating liquids are covered by IEC 60247.

3.2 Definitions for resistive properties

The resistive properties of an insulating material are those comprehensive materials whose behaviour can be measured with a DC in a time domain. Five examples are given below.

3.2.1
insulation resistance
resistance under specified conditions between two conductive bodies separated by the insulating material

NOTE Insulation resistance includes parts of volume resistivity and surface resistivity with respect to a given geometric shape of the test specimen.

3.2.2
volume resistance
quotient of a direct voltage applied between two electrodes in contact with an insulating medium and the current through it at a given duration of voltage application

NOTE Within this definition, current along the surface is excluded and possible polarization phenomena at the electrodes are neglected.

3.2.3
volume resistivity
quotient of a DC electric field strength and the current density within an insulating medium at a given time of voltage application

NOTE 1 According to IEC 60050-212, "conductivity" is defined as "the scalar or matrix quantity whose product by the electric field strength is the conduction current density" and "resistivity" as "the reciprocal of the conductivity". The volume resistivity is an average of this quantity over possible heterogeneities in the volume incorporated in the measurement, and includes the effect of possible polarization phenomena at the electrodes.

NOTE 2 Usually, volume resistivity in practice is taken as the volume resistance reduced to a cubical unit volume.

3.2.4
surface resistance
that part of the insulation resistance which is due to conduction along the surface

NOTE The surface current generally depends strongly on the time of voltage application and often varies in an erratic manner.

3.2.5
surface resistivity
surface resistance reduced to a square area

NOTE The numerical value of the surface resistivity is independent of the size of the square.

3.3 Definitions for dielectric properties

The dielectric properties of an insulating material are those comprehensive materials whose behaviour can be measured with an AC in a given frequency domain. Four examples are given below.

3.3.1
absolute permittivity
electric flux density divided by the electric field strength

NOTE The measured permittivity (formerly known as dielectric constant) ε of an insulating material is the product of its relative permittivity ε_r and the permittivity of a vacuum ε_0:

$$\varepsilon = \varepsilon_0 \times \varepsilon_r \qquad (1)$$

The permittivity is expressed in farad per meter (F/m); the permittivity of vacuum ε_0 has the following value:

$$\varepsilon_0 = 8{,}854 \times 10^{-12}\ F/m \qquad (2)$$

3.3.2
relative permittivity
ratio of the absolute permittivity to the permittivity of a vacuum, ε_0

NOTE 1 In the case of constant fields and alternating fields of sufficiently low frequency the relative permittivity of an isotropic or quasi-isotropic dielectric is equal to the ratio of the capacitance of a capacitor, in which the space between and around the electrodes is entirely and exclusively filled with the dielectric, to the capacitance of the same configuration of electrodes in a vacuum.

NOTE 2 In practical engineering, it is usual to employ the term 'permittivity' when referring to relative permittivity.

NOTE 3 The relative permittivity ε_r of an insulating material is the quotient of capacitance C_x of a capacitive test specimen (capacitor), in which the space between the two electrodes is entirely and exclusively filled with the insulating material in question, and the capacitance C_0 of the same configuration of electrodes in vacuum:

$$\varepsilon_r = \frac{C_x}{C_0} \qquad (3)$$

The relative permittivity ε_r of dry air free from carbon dioxide, at normal atmospheric pressure, is equal to 1,000 53, so that in practice, the capacitances C_a of the configuration of electrodes in air can normally be used instead of C_0 to determine the relative permittivity ε_r with sufficient accuracy.

3.3.3
relative complex permittivity
permittivity in a complex number representation, under steady sinusoidal field conditions expressed as

$$\underline{\varepsilon}_r = \varepsilon_r' - j\varepsilon_r'' = \varepsilon_r \times e^{-j\delta} \qquad (4)$$

where ε'_r and ε''_r have positive values.

NOTE 1 The complex permittivity $\underline{\varepsilon}_r$ is customarily quoted either in terms of ε'_r and ε''_r , or in terms of ε_r and tan δ. If $\varepsilon'_r > \varepsilon''_r$ then $\varepsilon_r \approx \varepsilon'_r$ which are both called relative permittivity.

NOTE 2 ε''_r is termed loss index.

3.3.4
dielectric dissipation factor tan δ (loss tangent)
numerical value of the ratio of the imaginary to the real part of the complex permittivity

$$\tan\delta = \frac{\varepsilon_r''}{\varepsilon_r'} \qquad (5)$$

NOTE 1 Thus, the dielectric dissipation factor tan δ of an insulating material is the tangent of the angle δ by which the phase difference φ between applied voltage and resulting current deviates from $\pi/2$ rad when the solid insulating material is exclusively used as dielectric in a capacitive test specimen (capacitor) (compare Figure 1).

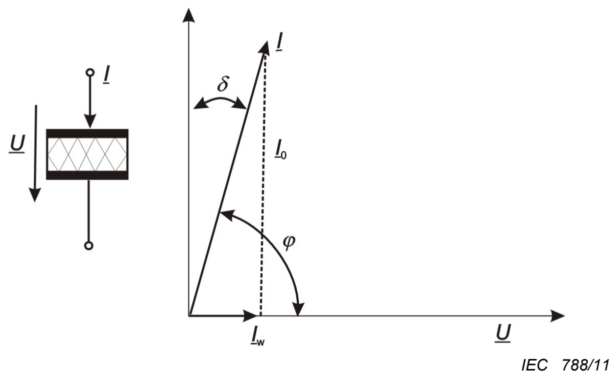

Figure 1 – Dielectric dissipation factor

The dielectric dissipation factor can also be expressed by an equivalent circuit diagram using an ideal capacitor with a resistor in series or parallel connection (see Figure 2).

$$\tan\delta = \omega C_S \times R_S = \frac{1}{\omega C_P \times R_P} \tag{6}$$

with

$$\frac{C_P}{C_S} = \frac{1}{1+\tan^2\delta} \tag{7}$$

and

$$\frac{R_P}{R_S} = 1 + \frac{1}{\tan^2\delta} \tag{8}$$

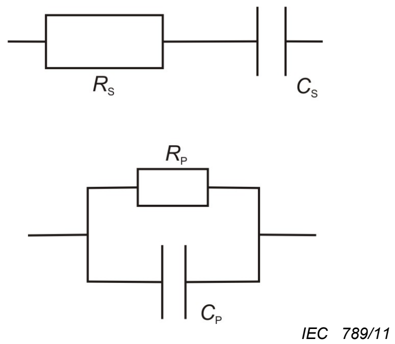

Figure 2 – Equivalent circuit diagrams

NOTE 2 R_S and R_P respectively are not directly related with but affected by the volume and the surface resistance of an insulating material. Therefore also the dielectric dissipation factor may be affected by these resistive materials properties.

3.4
capacitance
C
property of an arrangement of conductors and dielectrics which permits the storage of electrical charge when a potential difference exists between the conductors

NOTE *C* is the ratio of a quantity *q* of charge to a potential difference *U*. A capacitance value is always positive. The unit is farad when the charge is expressed in coulomb and the potential in volts.

$$C = \frac{q}{U} \tag{9}$$

3.5
voltage application
application of a voltage between electrodes

NOTE Voltage application is sometimes referred as electrification.

3.6
current after voltage application
current between two electrodes in contact with an insulating medium when direct voltage is applied between them

NOTE The current after voltage application is a function of time. Usually this current is determined 1 min after voltage application (1 min value).

3.7
conduction current
steady-state component of the current after voltage application

3.8
charging current
transient component of the current after voltage application which flows during the charging of the test specimen

3.9
electric field strength
vector field quantity E which exerts on any charged particle at rest a force F equal to the product of E and the electric charge Q of the particle:

$$F = Q \times E \tag{10}$$

3.10
electric flux density
vector quantity obtained at a given point by adding the electric polarization P to the product of the electric field strength E and the permittivity of vacuum ε_0:

$$D = \varepsilon_0 E + P \tag{11}$$

3.11
polarization
P
phenomenon of material that describes the direction of the transverse electric field. Electric polarization at a given point within a domain of quasi-infinitesimal volume, V, vector quantity equal to the electric dipole moment, *p,* of the substance contained within the domain divided by the volume V:

$$P = \frac{p}{\mathrm{V}} \tag{12}$$

NOTE 1 The polarization P satisfies Equation (11).

NOTE 2 Polarization may occur as a displacement of charged particles or as orientation of dipoles. It may also occur at boundaries, such as electrodes, as well as inner boundaries in the electrical insulating material. All polarization effects are strongly dependent on time and frequency respectively and on temperature as well. The effect of polarization therefore strongly affects the dielectric and resistive properties. Because of this, the time-dependent process of becoming polarized, which an electrical insulating material undergoes by the procedure of voltage application, is commonly understood as polarization when the resistive properties of an electrical insulating material are to be determined.