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REDLINE VERSION

INTERNATIONAL STANDARD



BASIC SAFETY PUBLICATION

Methods of measurement of touch current and protective conductor current

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REDLINE VERSION

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BASIC SAFETY PUBLICATION

Methods of measurement of touch current and protective conductor current

INTERNATIONAL
ELECTROTECHNICAL
COMMISSION

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**METHODS OF MEASUREMENT OF TOUCH CURRENT
AND PROTECTIVE CONDUCTOR CURRENT**

FOREWORD

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This redline version of the official IEC Standard allows the user to identify the changes made to the previous edition. A vertical bar appears in the margin wherever a change has been made. Additions are in green text, deletions are in strikethrough red text.

International Standard IEC 60990 has been prepared by TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition cancels and replaces the second edition published in 1999. It constitutes a technical revision.

The principal changes in this edition as compared with the second edition are as follows:

- the effects names have been updated to reflect increased understanding of the range of effects and is in concert with present usage;
- the conditions of use invoking a GRIPPABLE PART have been reduced in the application of the requirements based upon the current understanding of this effect;
- the references to ISO 10012-1, which has been replaced by management standard of the same number, have been replaced with explanatory text, where needed to maintain the sense of the document;
- former informative Annex H (GRIPPABLE PART) has been deleted from this update as it does not properly represent the full set of conditions under which immobilization can occur. A new informative Annex H (Analysis of frequency filtered touch current circuits measurement) has been added;
- the Bibliography (formerly Annex M) has been updated with additional references for completeness.

It has the status of a basic safety publication in accordance with IEC Guide 104.

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

FDIS	Report on voting
108/630/FDIS	108/640/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.

In this standard, the following print types or formats are used:

- requirements proper and normative annexes: in roman type;
- compliance statements and test specifications: *in italic type*;
- notes/explanatory matter: in smaller roman type;
- normative conditions within tables: in smaller roman type;
- terms defined in Clause 3: SMALL CAPITALS.

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

reconfirmed,

withdrawn,

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INTRODUCTION

This International Standard was developed as a response to concerns arising from the advent of electronic switching techniques being broadly applied to power systems and within EQUIPMENT^{*}, giving rise to high-frequency harmonic voltages and currents.

This standard is intended for the guidance of EQUIPMENT committees in preparing or amending the test specifications in their standards for measurement of leakage current. However the term "leakage current" is not used for reasons explained below.

This standard was initially prepared under the basic safety ~~pilot~~ function assigned to TC 74 (now TC 108), as follows:

Methods of measuring leakage current

This includes, for various types of EQUIPMENT, all aspects of what is referred to as "leakage current", including methods of measurement of current with regard to physiological effects and for installation purposes, under normal conditions and under certain fault conditions.

The methods of measurement of leakage current described herein result from the review of IEC TS 60479-1 and other publications, including descriptions of earlier methods of measurement.

The following conclusions were derived from a review of the effects of leakage current:

- the primary concern for safety involves possible flow of harmful current through the human body (this current is not necessarily equal to the current flowing through a protective conductor);
- the effect of electric current on a human body is found to be somewhat more complex than was assumed during the development of earlier standards in that there are several body responses which should be considered. The most significant responses for setting limits for continuous waveforms are
 - perception,
 - ~~startle~~-reaction,
 - letgo-~~immobilization~~, and
 - ELECTRIC BURN.

Each of these four body responses has a unique threshold level. There are also significant differences in the manner in which some of these thresholds vary with frequency.

Two types of current have been identified as needing separate measuring methods: TOUCH CURRENT and PROTECTIVE CONDUCTOR CURRENT.

TOUCH CURRENT only exists when a human body or a body model is a current pathway.

It was also noted that the term "leakage current" has already been applied to several different concerns: TOUCH CURRENT, PROTECTIVE CONDUCTOR CURRENT, insulation properties, etc. Therefore, in this standard, the term "leakage current" is not used.

Measurement of TOUCH CURRENT

In the past, EQUIPMENT standards have used two traditional techniques for measurement of leakage current. Either the actual current in the protective conductor was measured, or a

* ~~Terms in small capitals are defined in clause 3.~~

simple resistor-capacitor network (representing a simple body model) was used, the leakage current being defined as the current through the resistor.

This standard provides measuring methods for the four body responses to the electric current noted above, using a more representative body model.

This body model was chosen for most common cases of electric shock in the general sense. With respect to the path of current flow and conditions of contact, a body model approximating full hand-to-hand or hand-to-foot contact in normal conditions is used. For small areas of contact (for example, ~~one~~ small, finger contact), a different model may be appropriate **but is not covered here**.

Of the four responses, ~~perception~~ **startle-reaction** and ~~let-go~~ **immobilization** are related to the peak value of TOUCH CURRENT and vary with frequency. Traditionally, concerns for electric shock have dealt with sinusoidal waveforms, for which r.m.s. measurements are most convenient. Peak measurements are more appropriate for non-sinusoidal waveforms where significant values of TOUCH CURRENT are expected, but are equally suitable for sinusoidal waveforms. The networks specified for the measurement of ~~perception~~ **startle-reaction** and ~~let-go currents~~ **let-go-immobilization** are frequency-responsive and are so weighted that single limit power-frequency values can be specified and referenced.

ELECTRIC BURNS, however, are related to the r.m.s. value of TOUCH CURRENT, and are relatively independent of frequency. For EQUIPMENT where ELECTRIC BURNS may be of concern (see 7.2), two separate measurements are ~~required~~ **made**, one in peak value for electric shock and a second in r.m.s. value for ELECTRIC BURNS **each using the appropriate test circuit**.

EQUIPMENT committees should decide which physiological effects are acceptable and which are not, and then decide on limit values of current. Committees for certain types of EQUIPMENT may adopt simplified procedures based upon this standard. A discussion of limit values, based upon earlier work by various IEC EQUIPMENT committees, is provided in Annex D.

Measurement of PROTECTIVE CONDUCTOR CURRENT

In certain cases, measurement of the PROTECTIVE CONDUCTOR CURRENT of EQUIPMENT under normal operating conditions is required. Such cases include:

- selection of a residual current protection device,
~~— compliance with 474.3.3 of IEC 60364-7-707.~~
- **determination when a high integrity protective earth circuit is required,**
- **prevent excessive PROTECTIVE CONDUCTOR CURRENT overload in the electrical installation.**

The PROTECTIVE CONDUCTOR CURRENT is measured by inserting an ammeter of negligible impedance in series with the EQUIPMENT protective earthing conductor.

~~A bibliography of related documents is given in annex M.~~

~~This second edition has been prepared on the basis of comments provided by users of the first edition.~~

~~Principal changes include the following:~~

- ~~— provision of an earthing alternative for testing, in order to accommodate some test situations;~~
- ~~— provision of a more detailed description of the design and calibration of the measurement network, thus allowing deletion of component tolerances from the network diagrams;~~

- ~~— a minor inaccuracy in one measurement method has been corrected by the inclusion of an additional calculation;~~
- ~~— the discussion of the physiological effects has been clarified.~~

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METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

1 Scope

This International Standard defines measurement methods for

- d.c. or a.c. **current** of sinusoidal or non-sinusoidal waveform, which could flow through the human body, and
- current flowing through a protective conductor.

The measuring methods recommended for TOUCH CURRENT are based upon the possible effects of current flowing through a human body. In this standard, measurements of current through networks representing the impedance of the human body are referred to as measurements of TOUCH CURRENT. These networks are not necessarily valid for the bodies of animals.

The specification or implication of specific limit values is not within the scope of this standard. IEC TS 60479-4 **series** provides information regarding the effects of current passing through the human body from which limit values may be derived.

This standard is applicable to all classes of EQUIPMENT, according to IEC ~~60536~~ **61140**.

The methods of measurement in this standard are not intended to be used for

- TOUCH CURRENTS having less than 1 s duration,
- patient currents as defined in IEC 60601-1,
- a.c. at frequencies below 15 Hz, and
- ~~– a.c. in combination with d.c. The use of a single network for a composite indication of the effects of combined a.c. and d.c. has not been investigated,~~
- currents above those chosen for ELECTRIC BURN limits.

This basic safety publication is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51. It is not intended for use by manufacturers or certification bodies **independent of product standards**.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication ~~will not only apply, unless when~~ specifically referred to or included in the relevant publications.

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.

~~Members of IEC and ISO maintain registers of currently valid International Standards.~~

~~IEC 60050(195): International Electrotechnical Vocabulary (IEV) — Chapter 195: Earthing and protection against electric shock~~

~~IEC 60050(604): International Electrotechnical Vocabulary (IEV) — Chapter 604: Generation, transmission and distribution of electricity — Operation~~

~~IEC 60309-1:1997, Plugs, socket-outlets and couplers for industrial purposes — Part 1: General requirements~~

~~IEC 60364-4-41:1992, Electrical installations of buildings — Part 4: Protection for safety — Chapter 41: Protection against electric shock~~

~~IEC 60364-7-707:1984, Electrical installations of buildings — Part 7: Requirements for special installations or locations — Section 707: Earthing requirements for the installation of data processing equipment~~

IEC TS 60479-1:1994 2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC TS 60479-2:2007, *Effects of current on human beings and livestock – Part 2: Special aspects*

~~IEC 60536:1976, Classification of electrical and electronic equipment with regard to protection against electric shock~~

~~IEC 60536-2:1992, Classification of electrical and electronic equipment with regard to protection against electric shock — Part 2: Guidelines to requirements for protection against electric shock~~

IEC 61140:1997, *Protection against electric shock – Common aspects for installation and equipment*

ISO/IEC Guide 51:1990 2014, *Safety aspects – Guidelines for their inclusion in standards*

~~IEC Guide 104:1997, Guide to the drafting of safety standards and the role of committees with safety pilot functions and safety group functions~~

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

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

3.1

TOUCH CURRENT

electric current through a human body or through an animal body when it touches one or more accessible parts of an installation or of EQUIPMENT

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.2

PROTECTIVE CONDUCTOR CURRENT

current which flows in a protective conductor

3.3

EQUIPMENT

~~as defined in the relevant equipment standard. If not defined in the relevant equipment standard, see annex A~~

organized collection of electromechanical component parts and features to accomplish a defined task (as specified in the relevant product standard).

Note 1 to entry: If not specified in the relevant standard, see Annex A.

3.4

GRIPPABLE PART

part of the EQUIPMENT which could supply current through the human hand to cause muscular contraction around the part and an inability to let go

Note 1 to entry: Parts which are intended to be gripped with the entire hand are assumed to be grippable without further investigation ~~(see annex H)~~.

3.5

ELECTRIC BURN

burning of the skin or of an organ, caused by passing an electric current across or through the surface

[SOURCE: IEC 60050-604:1987, 604-04-18]

4 Test site

4.1 Test site environment

Test site environmental requirements shall be as specified in the EQUIPMENT standard. If limit values of less than 70 μA r.m.s. or 100 μA peak are specified, or if the EQUIPMENT contains large shields which may be driven by high-frequency signals, product committees shall refer to Annex B.

4.2 Test transformer

The use of a test transformer for isolation is optional. For maximum safety, a test transformer for isolation (T2 in Figure 2, T in Figure 6 to Figure 14) shall be used and the main protective earthing terminal of the EQUIPMENT under test (EUT) earthed. Any capacitive leakage in the transformer ~~must~~ shall then be taken into account. As an alternative to earthing the EUT, the test transformer secondary and the EUT shall be left floating (not earthed), in which case the capacitive leakage in the test transformer need not be taken into account.

If transformer T is not used, the EUT shall be mounted on an insulating stand and appropriate safety precautions taken, in view of the possibility of the body of the EUT being at hazardous voltage.

4.3 Earthed neutral conductor

EQUIPMENT intended for connection to a TT or TN power distribution system shall be tested with minimum voltage between neutral and earth.

NOTE Descriptions of various power distribution systems are given in Annex I.

The protective conductor and the earthed neutral conductor for the EUT should have a voltage difference of less than 1 % of line-to-line voltage (see example in Figure 1).

A local transformer, see 4.2, will achieve this requirement.

Alternatively, if the voltage difference is 1 % or more, the following are examples of methods which, in some cases, will avoid measurement errors due to this voltage:

- connecting the terminal B electrode of the measuring instrument **network** to the neutral terminal of the EUT instead of the protective earthing conductor (see 6.1.2) of the supply;
- connecting the earthing terminal of the EUT to the neutral conductor, instead of the protective earthing conductor, of the supply.

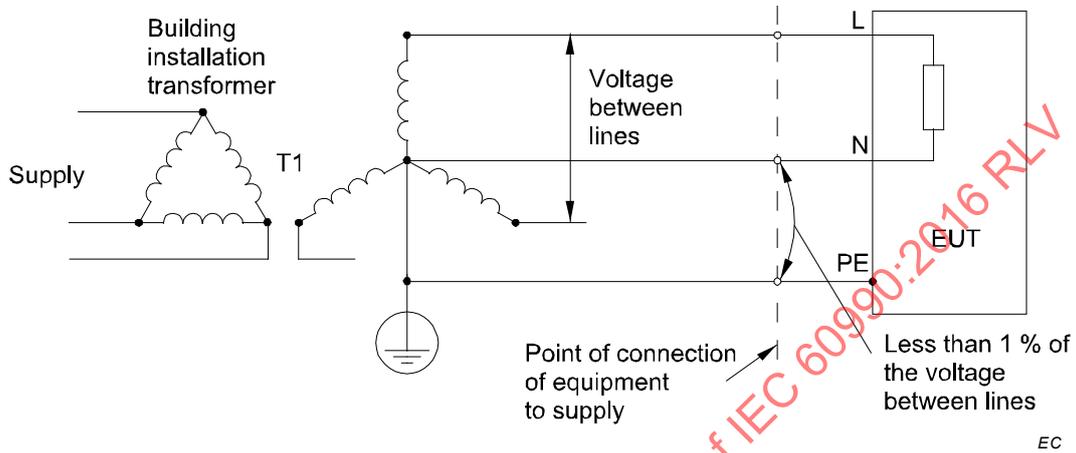


Figure 1 – Example of earthed neutral, direct supply

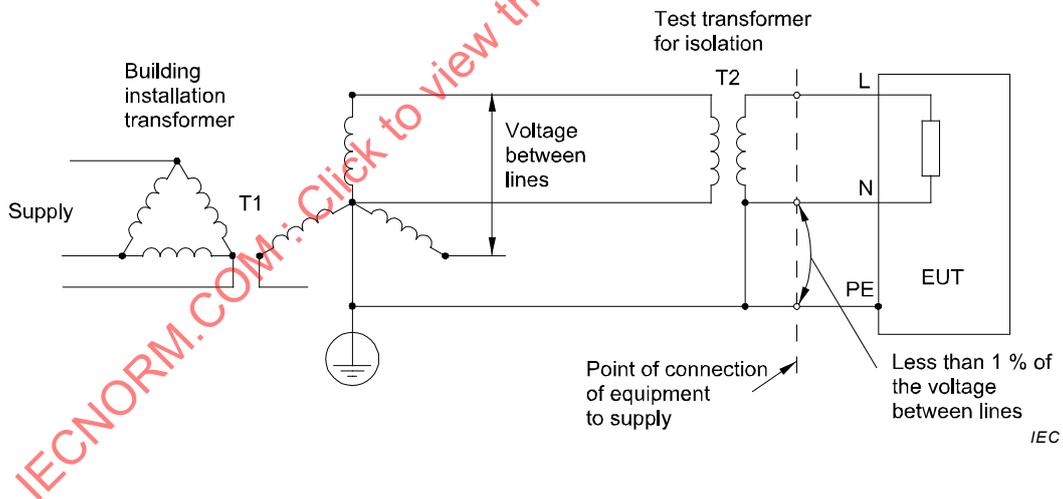


Figure 2 – Example of earthed neutral, with transformer for isolation

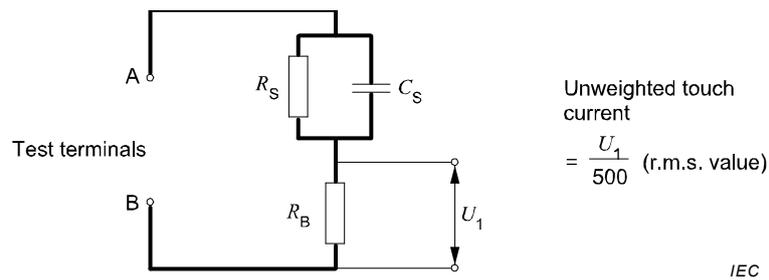
5 Measuring equipment

5.1 Selection of measuring network

5.1.1 General

Measurements shall be made with one of the networks of Figure 3, Figure 4 and Figure 5.

NOTE See Annexes E, F and G for further explanation of the three networks.

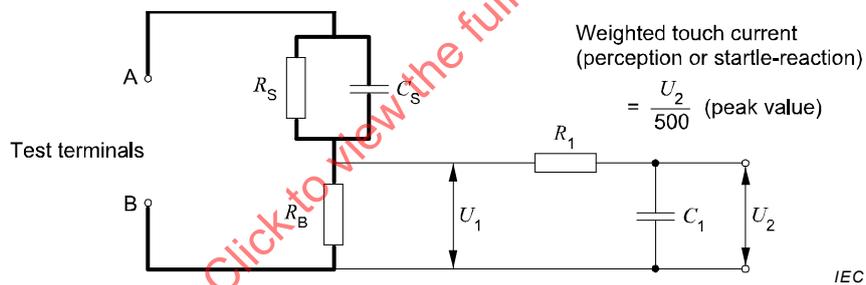


$$R_S = 1\,500 \, \Omega$$

$$R_B = 500 \, \Omega$$

$$C_S = 0,22 \, \mu\text{F}$$

Figure 3 – Measuring network, unweighted touch current



$$R_S = 1\,500 \, \Omega$$

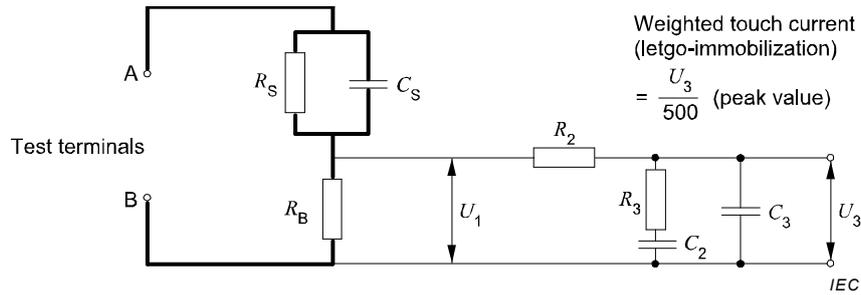
$$R_B = 500 \, \Omega$$

$$C_S = 0,22 \, \mu\text{F}$$

$$R_1 = 10\,000 \, \Omega$$

$$C_1 = 0,022 \, \mu\text{F}$$

Figure 4 – Measuring network, touch current weighted for perception or **startle-reaction**



R_S	1 500 Ω	R_3	20 000 Ω
R_B	500 Ω	C_2	0,006 2 μF
C_S	0,22 μF	C_3	0,009 1 μF
R_2	10 000 Ω		

NOTE For special conditions on the use of this network, see 5.1.2.

Figure 5 – Measuring network, touch current weighted for letgo-immobilization

5.1.2 Perception and ~~startle-reaction (a.c.)~~

The network of Figure 4 shall be used for low level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is up to 2 mA r.m.s. or 2,8 mA peak.

5.1.3 Letgo-immobilization ~~(a.c.)~~

~~The network of figure 5 shall be used, but only if inability to let go is a significant consideration, i.e. if all of the following conditions are met:~~

- ~~— the available current is a.c. and the limit value in the product standard is more than 2,0 mA r.m.s. or 2,8 mA peak;~~
- ~~— the EQUIPMENT has a GRIPPABLE PART;~~
- ~~— it is anticipated that it would be difficult to let go of the GRIPPABLE PART due to current flow through the hand and the arm (see E.3 and annex H for further information).~~

~~Otherwise, the network of figure 4 shall be used.~~

The network of Figure 5 shall be used for higher level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is more than 2 mA r.m.s. or 2,8 mA peak.

5.1.4 Electric burn (a.c.)

The unweighted TOUCH CURRENT network of Figure 3 shall be used.

5.1.5 Ripple-free d.c.

Any one of the three networks shall be used. Unless otherwise specified in the EQUIPMENT standard, ripple-free d.c. means less than 10 % peak-to-peak ripple.

5.2 Test electrodes

5.2.1 Construction

Unless otherwise specified in the EQUIPMENT standard, the test electrodes shall be

- a test clip, or
- a 10 cm × 20 cm metal foil to represent the human hand. Where adhesive metal foil is used, the adhesive shall be conductive.

5.2.2 Connection

Test electrodes shall be connected to test terminals A and B of the measuring network.

5.3 Configuration

The EQUIPMENT under test (EUT) shall be fully assembled and ready for use in the maximum configuration; it shall be connected to external signal voltages where applicable, as specified by the manufacturer for a single EQUIPMENT.

EQUIPMENT which is designed for multiple power sources, only one of which is required at a time (for example, for backup), shall be tested with only one source connected.

EQUIPMENT requiring power simultaneously from two or more power sources shall be tested with all power sources connected but with not more than one connection to protective earth.

5.4 Power connections during test

5.4.1 General

NOTE Examples of power distribution systems are given in Annex I.

EQUIPMENT shall be connected in a test configuration as shown in Figure 6 to Figure 14, according to 5.4.2, 5.4.3 or 5.4.4, as appropriate.

EQUIPMENT committees should consider the possible need for the manufacturer to identify the power distribution system (TN, TT, IT) to which an EQUIPMENT is intended to be connected in its final application.

If the EUT is specified by the manufacturer for use only on certain power distribution systems, the EUT shall be tested only when connected to those systems.

EQUIPMENT to be connected only to TN or TT systems shall comply with 5.4.2. EQUIPMENT to be connected to IT systems shall comply with 5.4.3 and may also be connected to TN or TT systems.

For Class 0 and Class II EQUIPMENT (see IEC-60536-2 61140), the protective conductors in Figure 6 through Figure 14 are ignored.

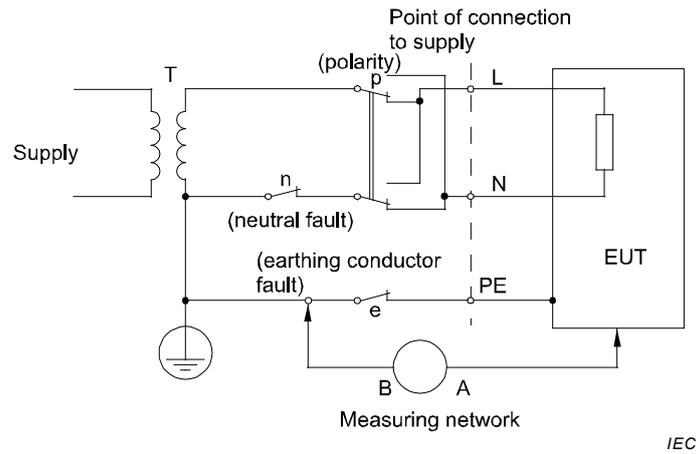
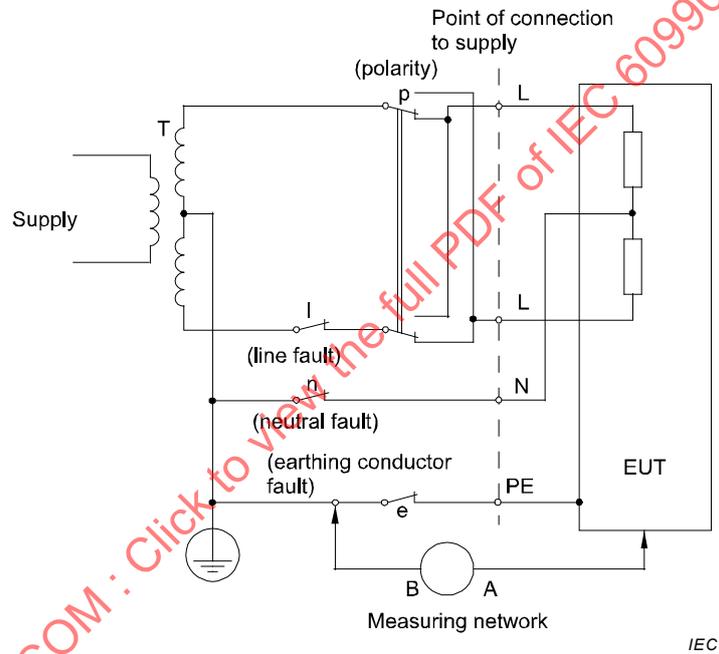


Figure 6 – Test configuration: Single-phase equipment on star TN or TT system



NOTE The centre-tapped winding may be one leg of a delta supply.

Figure 7 – Test configuration: Single-phase equipment on centre-earthed TN or TT system

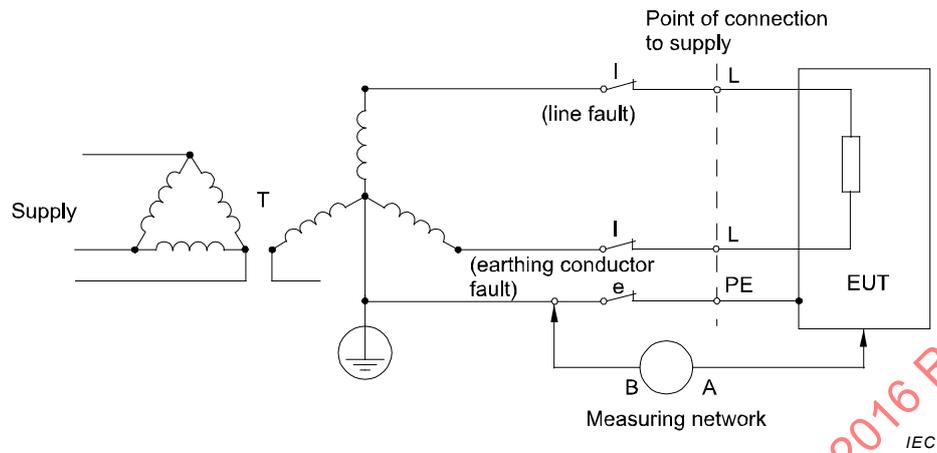
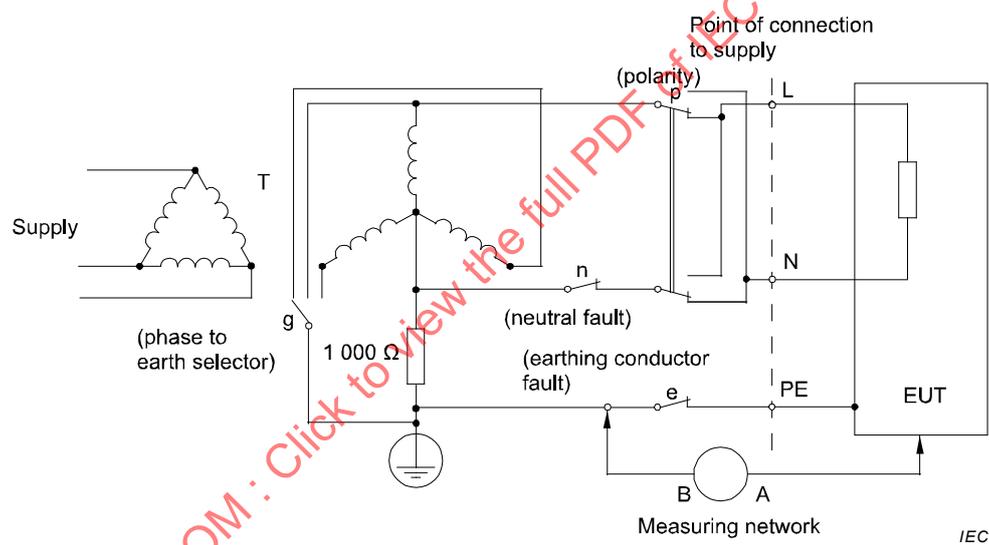
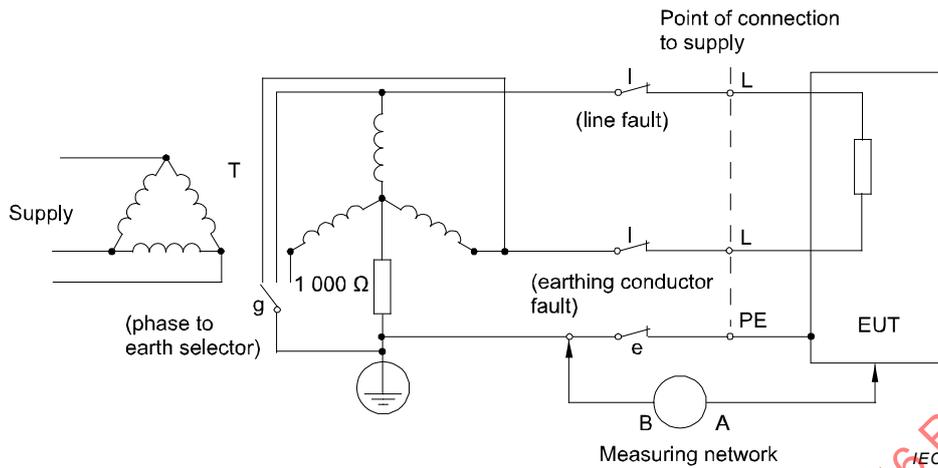


Figure 8 – **Test configuration:** Single-phase equipment connected line-to-line on star TN or TT system



NOTE The 1 000 Ω resistor should be rated for supply system faults.

Figure 9 – **Test configuration:** Single-phase equipment connected line-to-neutral on star IT system



NOTE The 1 000 Ω resistor should be rated for supply system faults.

Figure 10 – Test configuration: Single-phase equipment connected line-to-line on star IT system

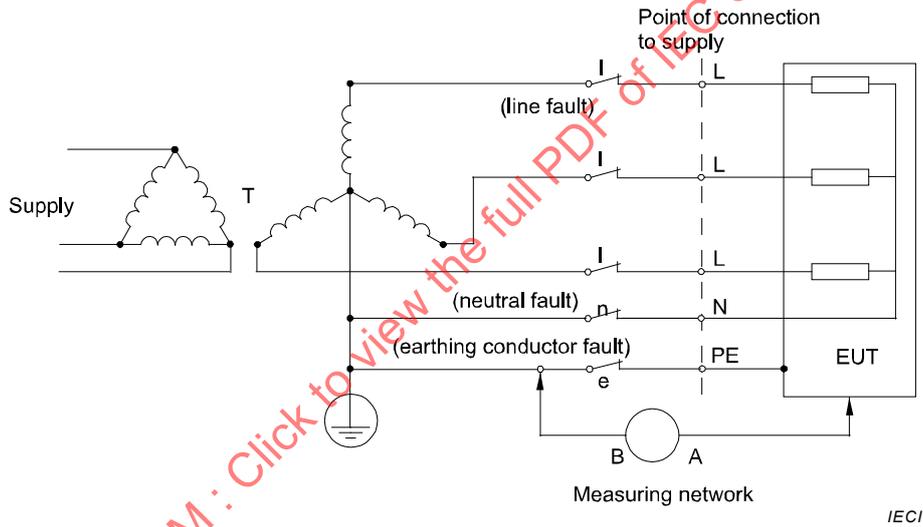
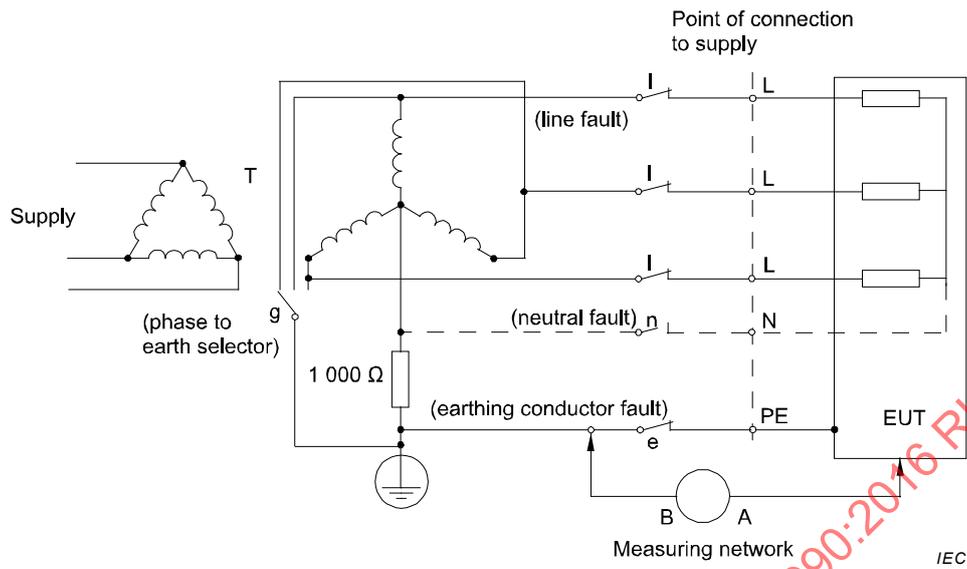


Figure 11 – Test configuration: Three-phase equipment on star TN or TT system



NOTE The 1 000 Ω resistor should be rated for supply system faults.

Figure 12 – Test configuration: Three-phase equipment on star IT system

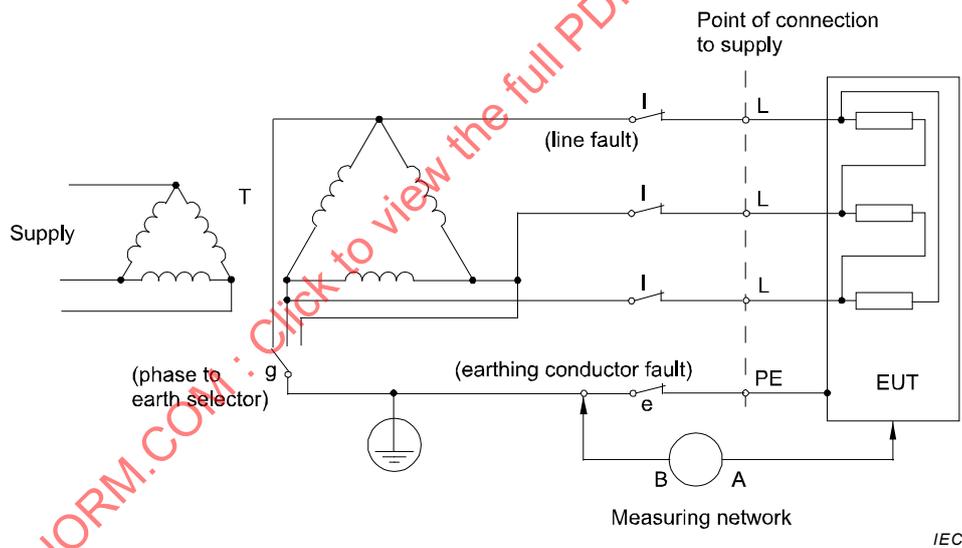
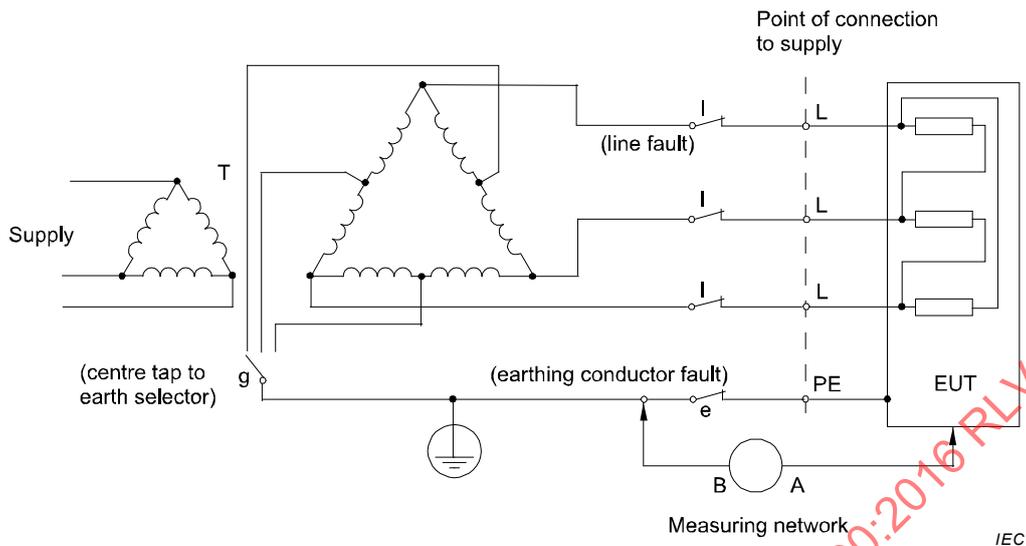


Figure 13 – Test configuration: Unearthed delta system



NOTE Where an EQUIPMENT contains both a three-phase load and a centre-earthed single-phase load, and the earthed side is identified, switch g shall remain in the position identified as the earthed side.

Figure 14 – Test configuration: Three-phase equipment on centre-earthed delta system

5.4.2 Equipment for use only on TN or TT star power distribution systems

Three-phase EQUIPMENT shall be connected to a three-phase star power distribution system, with earthed neutral. Single-phase EQUIPMENT shall be connected between phase and neutral of an earthed neutral power distribution system or, where specified by the manufacturer to operate in such a manner, line-to-line on a centre-earthed three-phase star power distribution system (see Figure 6, Figure 8 and Figure 11).

5.4.3 Equipment for use on IT power distribution systems including unearthed delta systems

Three-phase EQUIPMENT shall be connected to an appropriate three-phase IT power supply system. Single-phase EQUIPMENT shall be connected between phase and neutral or, where specified by the manufacturer to operate in such a manner, line-to-line (see Figure 9, Figure 10, Figure 12 and Figure 13).

5.4.4 Equipment for use on single-phase centre-earthed power supply systems or on centre-earthed delta power supply systems

Single-phase EQUIPMENT shall be connected to a supply having its centre tap earthed (see Figure 7 and Figure 14).

Three-phase EQUIPMENT shall be connected to the appropriate delta supply (see Figure 14).

5.5 Supply voltage and frequency

5.5.1 Supply voltage

Supply voltage shall be measured at the EQUIPMENT supply terminals.

Traditionally, TOUCH CURRENT was at its maximum at the highest supply voltage. Modern electronic power supplies will not always provide maximum TOUCH CURRENT under this supply condition. TOUCH CURRENT may be maximized at the lowest voltage, i.e. maximum current draw, or under some other condition. Electric shock protection shall be provided under the worst case operating condition.

EQUIPMENT rated for a single voltage shall be tested at its rated voltage plus an appropriate working tolerance to allow for supply variations.

EQUIPMENT rated for a nominal voltage range shall be tested at the ~~highest~~ extremes of the voltage ~~in that~~ range, plus an appropriate working tolerance to allow for supply variations. The working tolerance is determined by the EQUIPMENT committee or by the manufacturer if necessary (for example, 0 %, -10 %/+6 % or +10 %).

EQUIPMENT rated for different nominal voltages or voltage ranges, using a voltage selector, shall be set for the highest nominal voltage or voltage range and then treated as above. Where voltage selection involves more complex switching than a rearrangement of transformer windings, additional tests may be necessary to determine the worst case.

If it is inconvenient to test EQUIPMENT at the specified voltage, it is permitted to test it at any available voltage within the rating of the EQUIPMENT and then calculate the results.

5.5.2 Supply frequency

Supply frequency shall be the maximum rated nominal frequency, or alternatively, measurements may be corrected by calculation for estimation of the worst case current.

6 Test procedure

6.1 General

6.1.1 Touch current measurements

~~EQUIPMENT~~ Product committees may wish to exclude measurement of TOUCH CURRENT at some accessible parts, based upon the principle of limitation of voltage (see IEC 60364-4-41). If so, measurements shall be made for accessible voltage and then, if required, for weighted or unweighted TOUCH CURRENT according to Clause 6.

Concern for ELECTRIC BURN effects may arise with d.c. or at high frequencies (for example, above 30 kHz for 3,5 mA TOUCH CURRENT). At lower frequencies, ~~startle~~-reaction and letgo-~~immobilization~~ will be the dominant considerations. Where there is such a concern, the unweighted r.m.s. value of TOUCH CURRENT shall be measured (Figure 3), in addition to measurement for either ~~perception or~~ ~~startle~~-reaction (Figure 4), or ~~ability~~ inability to let go (Figure 5).

6.1.2 Control switches, equipment and supply conditions

During TOUCH CURRENT measurements, the test environment, configuration, earthing and supply system shall be according to 5.3, 5.4 and 5.5.

In order to maximize the current values during measurements, the configuration shall be varied by connection and disconnection of units that are part of the EQUIPMENT, as permitted by the manufacturer's operating and installation instructions.

Control switches e, g, l, n and p in Figure 6 to Figure 14 shall be manipulated as described in 6.2, while the conditions listed in this subclause and 6.2.1 are independently varied so as to give the maximum measured value or values. ~~Not all these conditions and points of application of the measuring network apply to all EQUIPMENT, and EQUIPMENT~~ Product committees shall make an appropriate selection of these variables. Recent addition of ABNORMAL OPERATION as an operating condition in product standards as related to the electrical installation (e.g. the loss of PE or the inability to ensure polarity of supply) clarifies the test conditions under NORMAL operation and FAULT CONDITIONS to then be applied.

6.1.3 Use of measuring networks

Appropriate measuring electrodes (see 5.2), measuring network (see 5.1) and measuring device (see G.4) shall be used in accordance with the appropriate systems of Figure 6 to Figure 14 (see 5.4) to make measurements of TOUCH CURRENT between simultaneously accessible parts, and between accessible parts and earth.

The terminal A electrode shall be applied to each accessible part in turn.

For each application of the terminal A electrode, the terminal B electrode shall be applied to earth, then applied to each of the other accessible parts in turn.

For power systems with an earthed power conductor, the terminal B electrode may be connected directly to the earthed power conductor at the interface of the EUT and the power supply, instead of being connected to the protective conductor. This connection may be used even though the voltage difference between the protective conductor and the earthed power conductor is more than 1 % of the line-to-line voltage (see 4.2).

6.2 Normal and fault conditions of equipment

6.2.1 Normal operation of equipment

The test is carried out with terminal A of the measuring network connected to each unearthed or conductive accessible part and circuit in turn, with all test switches l, n and e closed.

Measurements shall be made in all applicable conditions of normal operation.

Examples of normal operation include mains switch on, mains switch off, standby, start-up, heating and any setting of operator controls except supply-voltage-setting controls.

Single-phase EQUIPMENT shall be tested in normal and reverse polarity (switch p).

Three-phase EQUIPMENT shall be tested with phase reversals, unless EQUIPMENT operation is dependent on phasing.

6.2.2 Equipment and supply fault conditions

6.2.2.1 General

For EQUIPMENT having no connection to earth, 6.2.2 does not apply.

For EQUIPMENT having a protective earthing connection or a functional earthing connection, terminal A of the measuring ~~instrument~~ network is connected to the EQUIPMENT earthing terminal of the EUT.

Measurements shall be made with each of the applicable fault conditions specified in 6.2.2.2 to 6.2.2.9. The faults shall be applied one at a time, but shall include any faults which are a logical result of the first fault. Before applying any fault, the EQUIPMENT shall be restored to its original condition (for example, without faults or consequential damage).

Where a balanced line filter is used on three-phase EQUIPMENT, the net current to earth is theoretically zero. However, it is normal for component and voltage unbalance to produce a finite value of net current, the maximum value of which may not be measured during type testing. Larger unbalanced currents will result from a failed capacitor in one phase. EQUIPMENT committees should consider including a test for such EQUIPMENT, involving the substitution of a deliberately faulted filter (one capacitor removed), together with a loss of protective earth connection (see 6.2.2.2).

Similar considerations apply to a balanced arrangement of other components, such as surge arrestors, connected between mains and earth.

Three-phase EQUIPMENT shall be tested with phase reversals unless EQUIPMENT operation is dependent on phasing.

6.2.2.2 Fault condition No. 1

Depending on the kind of EQUIPMENT, several safety degrees of the protective conductor are to be distinguished (see IEC 61140).

Single-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e) in combination with normal and reverse polarity (switch p).

Three-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e).

Unless decided otherwise by the ~~EQUIPMENT~~ product committee, the requirements of this subclause do not apply to reliably earthed EQUIPMENT ~~(e.g. see IEC 60364-7-707)~~ which is connected to the supply either permanently, or by means of plugs and sockets which are of industrial grade (for example, connectors specified in IEC 60309-1 or a comparable national standard).

6.2.2.3 Fault condition No. 2

Single-phase EQUIPMENT shall be tested with neutral open (switch n), with earth intact and in normal polarity, and again in reverse polarity (switch p).

6.2.2.4 Fault condition No. 3

EQUIPMENT for use on IT systems shall be tested with each phase conductor faulted to earth, one at a time (switch g).

6.2.2.5 Fault condition No. 4

Three-phase EQUIPMENT shall be tested with each phase conductor open, one at a time (switches l).

6.2.2.6 Fault condition No. 5

Single-phase EQUIPMENT for use on IT power systems or on three-phase delta systems shall be tested with a three-phase power system, with each phase faulted to earth, one at a time (switch g), in combination with normal and reverse polarity (switch p) and separately with each phase conductor open one at a time (switches l), and in combination with normal and reverse polarity (switch p).

6.2.2.7 Fault condition No. 6

Three-phase EQUIPMENT for use on centre-earthed delta supply systems shall be tested on a delta supply system with each delta-leg centre-earthed, one at a time (switch g).

EQUIPMENT containing both three-phase and centre-earthed circuits which cannot be installed independently and which have an identified earthed leg shall be tested with switch g on the identified earth-leg position only.

6.2.2.8 Fault condition No. 7

Other faults as specified by the ~~EQUIPMENT~~ product committee shall be simulated if they are likely to increase TOUCH CURRENT.

6.2.2.9 Fault condition No. 8

Accessible conductive parts which are only incidentally electrically connected to other parts shall be tested both when connected electrically to the other part(s) and when disconnected electrically from the other part(s). See Annex C regarding incidentally connected parts.

7 Evaluation of results

7.1 Perception, ~~startle~~-reaction and letgo-~~immobilization~~

Voltages U_2 and U_3 of Figure 4 and Figure 5 are frequency-weighted values of U_1 , such that a single, low-frequency equivalent indication of TOUCH CURRENT results for all frequencies present above 15 Hz. These weighted values of TOUCH CURRENT are taken as the highest values of U_2 and U_3 measured during the procedure of Clause 6, divided by 500 Ω . The maximum values are compared with the limits for perception or ~~startle~~-reaction and letgo-~~immobilization~~ specified for the EQUIPMENT (for example, a 50 Hz or 60 Hz limit value).

Measurements for d.c. limits are made in a like manner, but taken as U_1 divided by 500 Ω (see also Annex G).

7.2 Electric burn

Where there is concern for ELECTRIC BURN effects (see 6.1), the unweighted r.m.s. or d.c. value of TOUCH CURRENT is measured. This is calculated from the r.m.s. voltage U_1 , measured across the 500 Ω resistor of the measuring network of Figure 3.

The effect of TOUCH CURRENT is also related to the area of contact with the human body and the duration of contact. The relationship between these parameters and the establishment of TOUCH CURRENT limits are not in the scope of this standard (see also Clause D.3).

NOTE ELECTRIC BURNS result from the power dissipated as current flows through the resistance of the human skin and body. Other forms of burn ~~may~~ can result from electrical EQUIPMENT, for example due to arcing or the by-products of arcing.

8 Measurement of protective conductor current

8.1 General

Current requirements and values for protective conductors are not related to TOUCH CURRENT concerns and, therefore, such limits and methods of measurement are dealt with separately.

8.2 Multiple equipment

Within any shared earthing system, the PROTECTIVE CONDUCTOR CURRENTS of individual EQUIPMENT combine in a non-arithmetic manner. Therefore, THE PROTECTIVE CONDUCTOR CURRENT of a group OF EQUIPMENT earthed by a single protective earthing conductor cannot be reliably predicted from knowledge of individual EQUIPMENT PROTECTIVE CONDUCTOR CURRENTS. Consequently, measurements made on individual EQUIPMENT are of limited use, and the PROTECTIVE CONDUCTOR CURRENT for that group of EQUIPMENT shall be measured in the shared protective earthing conductor.

8.3 Measuring method

The installation PROTECTIVE CONDUCTOR CURRENT shall be measured after installation by inserting an ammeter of negligible impedance (for example, $0,5\ \Omega$) in series with the protective conductor. Measurement of PROTECTIVE CONDUCTOR CURRENT is made with the EQUIPMENT and power distribution system running in all normal operating modes.

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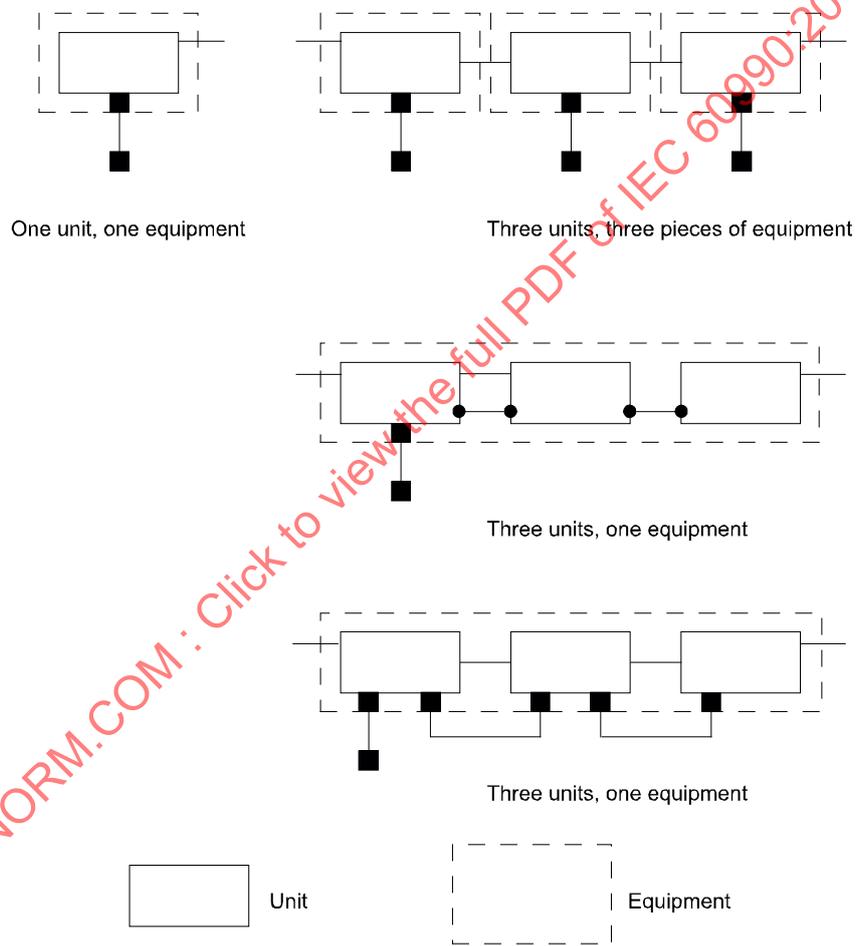
Annex A (normative)

Equipment

Unless otherwise defined in the EQUIPMENT standard, an EQUIPMENT is identified as having a single connection to a supply of electricity.

An EQUIPMENT may be a single unit or may consist of physically separate, electrically interconnected units (see Figure A.1). The source of electricity may be contained within the EQUIPMENT (for example, solar or battery power).

The connection of signal cables shall be considered as part of the EQUIPMENT, in accordance with 5.4.



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Key

- — ■ Supply connection compatible with local supply
- — ● Supply connection not designed to be connected directly to local supply
- Other connections

Figure A.1 – Equipment

Annex B (normative)

Use of a conductive plane

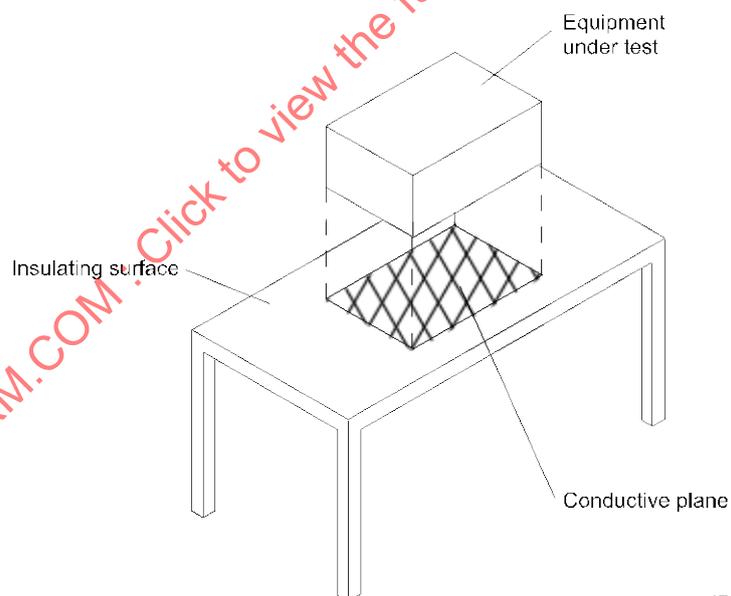
Where limits for TOUCH CURRENT (with or without frequency weighting) less than 70 μA r.m.s. or 100 μA peak are specified, or where an EQUIPMENT is tested that has large capacitive coupling to outer surfaces which may be driven at high frequencies (for example, high-frequency signal generators and voltage measuring instruments), it is appropriate to measure the current which is coupled capacitively into a conductive surface placed beneath or against a surface of the EQUIPMENT. If the EQUIPMENT is to be tested in this manner, it shall be placed on a conductive plane which is in turn placed on an insulating surface (see Figure B.1).

The conductive plane shall be equal to or greater than the adjacent EQUIPMENT surface in area and perimeter.

Measurements shall be according to Clause 6, with the conductive plane tested as an accessible part.

The measurements shall be repeated with the conductive plane placed against any other surface of the EQUIPMENT which may become adjacent to an outside conductive plane.

For purposes of isolation from electromagnetic interference, it may be necessary to place the EQUIPMENT (including the conductive plane, if used) 0,5 m or more from other conductors or EQUIPMENT.



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Figure B.1 – Equipment platform

Annex C (normative)

Incidentally connected parts

Incidentally connected parts are accessible conductive parts which are neither reliably connected to, nor positively isolated from, earth or any specified voltage.

Examples of incidentally connected parts include

- doors and assemblies attached by metal hinges,
- adhesively-bonded labels which have an accessible conductive part (for example, metal foil),
- parts which are attached to painted or anodised surfaces,
- control handles.

Some production samples of the EQUIPMENT may have an incidentally connected part effectively connected to earth or to another circuit. In other samples, the same part may be isolated from earth and other circuits. Since, in general, it is not clear which case will produce the higher TOUCH CURRENT, 6.2.2 requires TOUCH CURRENT to be measured for both cases in order to find the worst case. However, where the predominant frequency is below 100 Hz, the worst case is most likely to be that in which the incidentally connected part is connected to the other parts.

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Annex D (informative)

Choice of current limits

D.1 General

When drafting the procedures specified in this standard, certain assumptions were made about the current limits which ~~EQUIPMENT~~ product committees would use. This was necessary in order to select the appropriate data from IEC TS 60479-1 for design of the measuring networks in Figure 3, Figure 4 and Figure 5.

These assumptions were based on earlier IEC publications. Current values given in this annex are examples only. They are given below for the assistance of ~~EQUIPMENT~~ product committees when selecting current limits.

D.2 Limit examples

D.2.1 Ventricular fibrillation

No limit assumed.

It is assumed that the limits chosen for TOUCH CURRENTS will be well below the threshold for ventricular fibrillation.

D.2.2 Inability to letgo-immobilization

The method of measurement is specified in this standard.

IEC TS 60479-1 assumes 10 mA r.m.s. as the approximate average threshold level of letgo-immobilization current, whereas 5 mA r.m.s. as proposed for IEC TS 60479-1, would include the entire adult population. See Figure F.3 for the effects of frequency.

D.2.3 Startle-reaction

The method of measurement is specified in this standard.

The ~~startle~~-reaction threshold given in IEC TS 60479-1 is approximately 0,5 mA r.m.s. for low frequencies. Various limits are in use between the thresholds for ~~startle~~-reaction and letgo-immobilization.

D.2.4 Perception threshold

TOUCH CURRENT can be perceived at levels as low as a few microamperes. Unless the current is high enough to produce involuntary ~~startle~~-reaction that might result in harmful effects, these small touch currents are not considered hazardous and not usually measured by these methods.

D.2.5 Special applications

The method of measurement specified in this standard can be used, unless otherwise specified in the applicable standard for the particular product.

0,25 mA r.m.s. (one half of the ~~startle~~-reaction threshold) is used for Class II EQUIPMENT in product standards such as IEC 60065, IEC 60335-1, IEC 60950-1 and IEC 62368-1. See Figure F.2 for frequency effects.

Limits lower than 0,25 mA r.m.s. are specified for some medical applications. For such applications the method of measurement in this standard may not provide an ~~accurate~~ appropriate body impedance model (see Clause E.1).

D.3 Choice of limits

Consideration should be given to the need to specify different limits for (1) normal operating conditions and (2) fault conditions.

See IEC TS 60479-4 series for guidance on the effects of current passing through the human body.

Limits are normally expressed in terms of maximum values of d.c. and a.c. at frequencies up to 100 Hz. The methods of measurement specified in this standard are the same for letgo-immobilization, startle-reaction and some special applications. Measuring networks take into account the effect of higher-frequency current on the body and simulate lowering of body impedance as frequency increases. Letgo-immobilization, startle-reaction and perception are determined by peak values of current, weighted for frequency. For ELECTRIC BURN, r.m.s. values are significant. For the scope of this standard, the effects of frequency on ELECTRIC BURNS are negligible, since the predominant effect at low frequency is startle-reaction or letgo-immobilization.

Limits based upon ventricular fibrillation (see D.2.1) are not necessary for most EQUIPMENT, since the lower TOUCH CURRENT limits for startle-reaction or letgo-immobilization almost always prevent ventricular fibrillation. An exception (discussed in IEC TS 60479-1) is where a short-duration current impulse can flow through the body (too short an impulse to cause inability to let go), and startle-reaction from the current impulse is not considered hazardous.

~~For GRIPPABLE PARTS, the highest limit value for continuous current is the same as let go (D.1.2), except for consideration of ELECTRIC BURN.~~

Inability to let-go has traditionally focused on GRIPPABLE PARTS but this is now understood to be a simplistic view. Under this condition the highest limit value for continuous current is the same as letgo-immobilization (see D.2.2), except for consideration of ELECTRIC BURN. However, ELECTRIC BURN only becomes the predominant factor at high frequencies. ~~Between the limits for reaction and let go~~ In the range of the limits for startle-reaction and letgo-immobilization, there may be a secondary safety hazard due to surprise or involuntary muscle reaction, but no direct injury is expected due to current through the body. Such a current may be considered acceptable under single fault conditions ~~(e.g. a defective earthing connection)~~, if so product committees should specifically provide an exemption.

For short-duration current, a limit value higher than that for letgo-immobilization is sometimes used, provided that it is sufficiently below the ventricular fibrillation and ELECTRIC BURN threshold. The network of Figure F.3 ~~should be used for such measurements until a specific body impedance model for small area contacts is developed (future work)~~ might be specified by product committees for such a.c. measurements where small area contact is expected.

~~The perception/ startle-reaction network of Figure 4 should be used for measurements where the startle-reaction limit is used until a specific body impedance model for small area contacts is developed (future work)~~ for small area contact.

It is understood that the limit values for low-frequency TOUCH CURRENT in other IEC publications are based upon the following considerations.

- Limits for startle-reaction and lower limits:
 - need to avoid involuntary startle-reaction, where severe consequences may result (for example, falling from a ladder or dropping EQUIPMENT);

- the limit for **startle**-reaction is generally 0,5 mA r.m.s. or 0,7 mA peak for a sinusoidal current;
 - a limit lower than 0,25 mA r.m.s. (0,35 mA peak) is indicated where the user is particularly sensitive or at risk due to environmental or biological reasons.
- **Let-go limit** **Letgo-immobilization**:
- **perception startle** and some reaction are acceptable as an indication of a first fault, when the **letgo-immobilization** limit is applied;
 - men and women are estimated to have an average **letgo-immobilization** threshold of 16 mA r.m.s. and 10,5 mA r.m.s. respectively;
 - some people have a lower threshold, for example the 99,5 percentiles of men and women have been reported as 9 mA r.m.s. and 6 mA r.m.s. respectively, and the threshold values for children are expected to be lower;
 - certain single fault conditions may justify **letgo-immobilization** limits, with **startle**-reaction limits applying for normal (non-fault) conditions.

Certain EQUIPMENT types may have high initial TOUCH CURRENT when first switched on, which diminishes rapidly as EQUIPMENT is operated. This is normally ignored in setting EQUIPMENT limits when specified by the product committee.

D.4 Electric burn effects of touch current

There is no generally accepted limit value of TOUCH CURRENT which will prevent ELECTRIC BURNS in all cases. Other parameters, such as the area of contact with the human body and the duration of contact, are known to be relevant. The relationship between these parameters needs further study. When safe limits are established, they may be in terms of two or more of these parameters.

The method of measurement of TOUCH CURRENT for consideration of ELECTRIC BURN effects is specified in this standard (see 7.2).

The following limit has been used in an IEC standard:

- IEC 61010-1: 500 mA r.m.s. (under fault conditions).

It is reported that skin burns begin to occur at current densities of about 300 mA r.m.s./cm² to 400 mA r.m.s./cm² (Becker, Malhotra and Hedley-Whyte).

Analysis of conditions leading to ELECTRIC BURN has shown that there is a crossover frequency where ELECTRIC BURN exceeds **letgo-immobilization** and product requirements should reflect the need for making the correct measurement to provide the proper protection. IEC 62368-1 reflects one approach to defining such a requirement.

Annex E (informative)

Networks for use in measurement of touch current

E.1 General

Current values given in this annex are only examples.

The networks of Figure 3, Figure 4 and Figure 5 are intended for TOUCH CURRENT measurements using limits in general use by ~~EQUIPMENT~~ product committees: for example, from 100 μA r.m.s./140 μA peak up to approximately 10 mA r.m.s./14 mA peak for a.c. and d.c. currents, and covering a frequency range to 1 MHz for sinusoidal, mixed frequency and non-sinusoidal waveforms.

E.2 Body impedance network – Figure 3

The purpose of the network of Figure 3 is to

- simulate the impedance of the human body,
- provide a measurement indicating the level of current which can flow through a human body if the body contacts the EQUIPMENT in a like manner.

R_B models the internal impedance of the human body.

R_S and C_S model the total skin impedance of two points of contact. The value of C_S is determined from the area of skin contact. For larger areas of contact, a larger value (for example, 0,33 μF) may be used.

NOTE The human body model of Figure 3 with the R and C values used herein has traditionally been used in product safety standards for 50 years or more; it has a long history of adequacy for this measurement.

TOUCH CURRENT with regard to ELECTRIC BURN is equal to U_1 r.m.s. divided by 500 Ω .

E.3 ~~Perception, Startle~~-reaction (and body impedance) network – Figure 4

~~Perception and Startle~~-reaction by the human body ~~are~~ is the result of current flowing in the internal portions of the body.

Consideration of, and compensation for, the frequency variation of ~~startle~~-reaction are required for accurate measurement of this effect. The network of Figure 4 simulates body impedance and provides weighting to follow the frequency characteristics of the body for current causing involuntary ~~startle~~-reaction. It has been assumed that the shape of the frequency characteristic is the same for reaction and ~~perception startle~~, and the data establishing the frequency characteristic was actually obtained through tests on the threshold of ~~perception startle~~.

The measurement network is usable ~~for current limits up to the let-go limit for 50 Hz and 60 Hz current, and at higher frequencies,~~ for current limits up to the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz. The use of this network for measurement of higher level limits is restricted by the consideration of letgo-immobilization and the need for different frequency weighting ~~if ability~~ where the inability to let go is of concern ~~above these levels~~ (see Clause E.4).

The a.c. or d.c. TOUCH CURRENT with regard to ~~perception or~~ ~~startle-reaction~~ is equal to U_2 peak divided by 500 Ω .

E.4 Letgo-immobilization (and body impedance) network – Figure 5

Immobilization or the inability to let go of an object is caused by current flow internal to the body (for example, through muscles). The measurement network is suitable for current limits above the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz.

The effect of frequency on letgo-immobilization limits is different from its effect on ~~perception or~~ ~~startle-reaction~~, or on ELECTRIC BURN. This is especially true for frequencies above 1 kHz where the filter design takes this into account.

The network of Figure 5 simulates body impedance and is weighted to follow the frequency response of the body to currents which can cause tetanization of muscles (involuntary muscular contraction) and, thereby, an inability to let go ~~of CRIPPABLE PARTS~~. TOUCH CURRENT with regard to the ~~let-go threshold~~ letgo-immobilization is equal to U_3 peak divided by 500 Ω .

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Annex F
(informative)

Measuring network limitations and construction

The networks of Figure 3, Figure 4 and Figure 5 are intended to produce a measurable voltage response which approximates the curves given in Figure F.1, Figure F.2 and Figure F.3. The networks and reference curves provided are in general agreement with those published in IEC TS 60479-1 and IEC TS 60479-2, except that, for simplicity of measurement circuits, slight deviations are allowed at the curve inflections between 300 Hz and 10 kHz.

Where limits for ELECTRIC BURN are specified, TOUCH CURRENT is also measured without frequency weighting. The criteria established for ELECTRIC BURN will override criteria for perception, startle-reaction or letgo-immobilization if the r.m.s. current limit for ELECTRIC BURN is exceeded before the weighted peak current limits for perception, startle-reaction and letgo-immobilization are reached. If this occurs, it will usually be in the range of 30 kHz to 500 kHz, depending upon the waveform of the current and limit values used. Unless such frequencies are predominant, no measurement for ELECTRIC BURN limit is necessary.

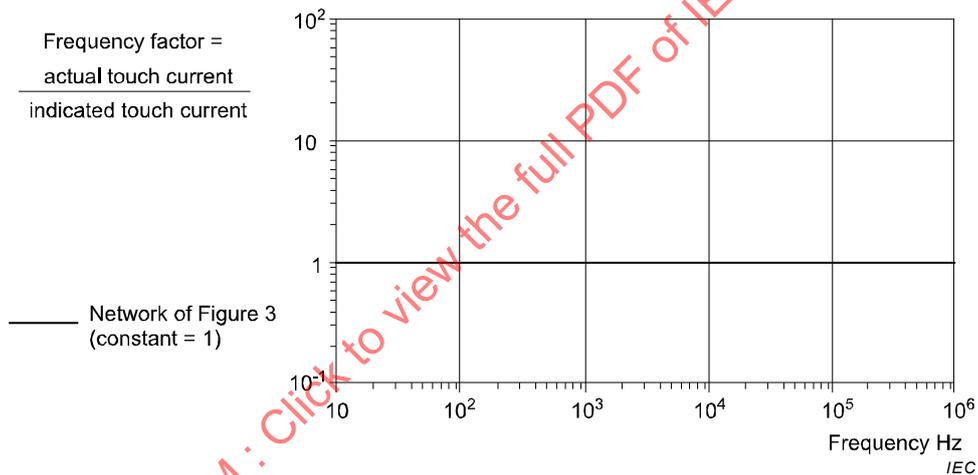


Figure F.1 – Frequency factor for electric burn

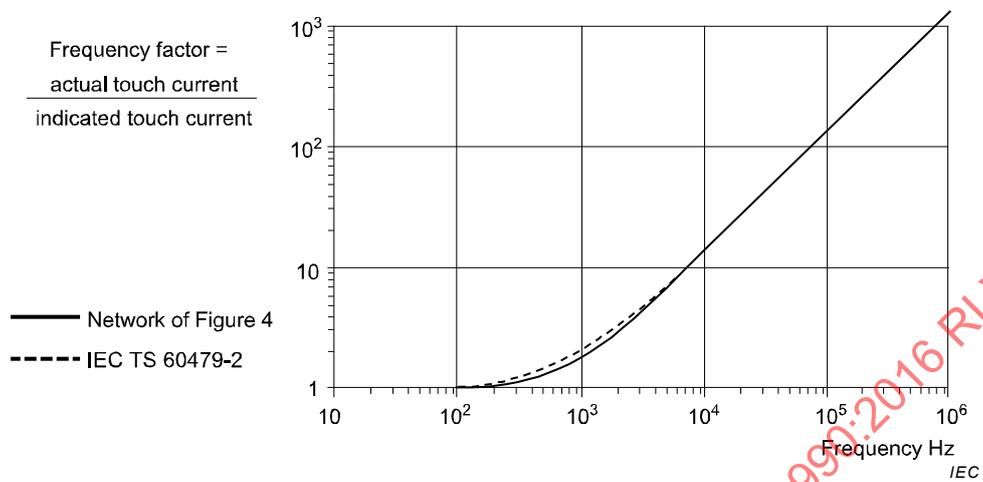


Figure F.2 – Frequency factor for perception or startle-reaction

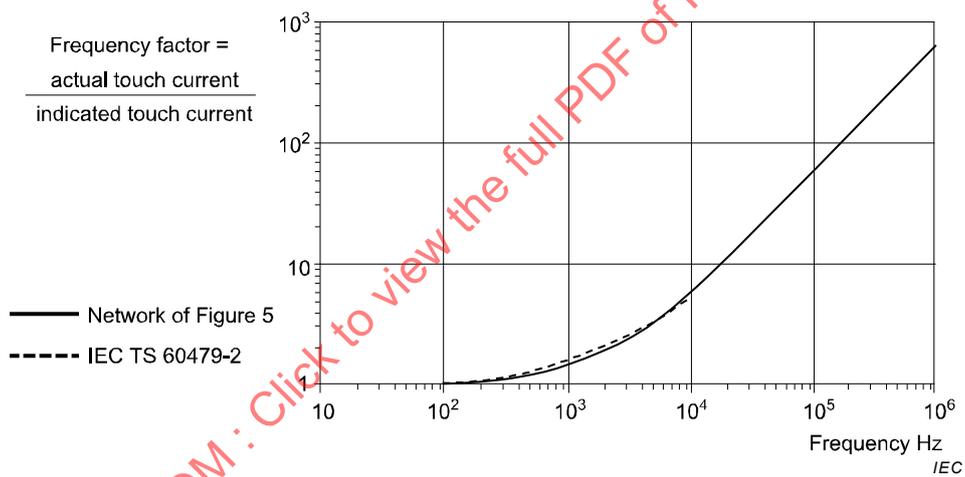


Figure F.3 – Frequency factor for letgo-immobilization

Annex G (informative)

Construction and application of touch current measuring instruments

G.1 Considerations for selection of components

G.1.1 General

The selection of components for the TOUCH CURRENT measuring networks in Figure F.3, Figure 4 and Figure 5 can be greatly affected by the application, for example, by the current levels and frequencies that are to be measured, and by the tolerances and power handling capability to be considered.

The measuring networks and instruments and the performance specifications discussed in this standard are appropriate for both sinusoidal TOUCH CURRENT waveforms from simple EQUIPMENT and for non-sinusoidal TOUCH CURRENT waveforms from sophisticated products that can generate high frequencies. However, for a limited application, it may not be necessary for a network to cover the complete range of d.c. to 1 MHz, nor to withstand power input levels that are unlikely in the particular application. Simpler current measuring networks and instruments can be substituted for the specified networks and instruments, provided that circuit conditions are such that the readings would be the same.

Information provided here is intended to point out the factors to be considered for each component, so that appropriate decisions can be made for particular applications.

G.1.2 Power rating and inductance for R_S and R_B

Power in R_S and R_B is determined by two factors. One is the possibility of overload at d.c. or low frequencies. If, for example, a 240 V 50 Hz/60 Hz overload capability is desired, R_S must shall tolerate 21,6 W and R_B 7,2 W for at least a short time, without shift in value. However, if overloads are not a concern, then 1/2 W or 1 W metal film resistors can provide adequate accuracy, together with a low temperature coefficient and long-term stability.

Based on the above choices, the measuring network should be appropriately marked, unless it is capable of withstanding continuous overloads.

R_B may also dissipate power from high-frequency currents in some applications. For example, if a current at a burn hazard of 500 mA is to be measured, a power of 125 W would be dissipated in R_B . Although this is unlikely, a resistor with this capability could be chosen.

Wire wound power resistors are available to handle the power, if other factors such as accuracy and inductive errors are controlled to acceptable levels for the application. Power resistors with an accuracy of $\pm 1\%$ and $\pm 5\%$ are readily available. Inductance has been measured on typical 12 W and 20 W wire wound resistors and found to be about 30 μH in a 1 000 Ω value. Two such resistors in parallel give 500 Ω and the inductance would cause a 2 % increase in impedance to 510 Ω at 1 MHz. The values of resistor R_S and capacitor C_S control the high-frequency performance of the R_S/R_B network. An inductance of 1 mH, which is much higher than would be expected, in series with R_S (1 500 Ω), causes less than 0,2 % at 1 MHz.

G.1.3 Capacitor C_S

Film capacitors with extended foil construction are recommended. Capacitor C_S may require a voltage rating capable of withstanding short-term overload, for example 250 V a.c., or perhaps 400 V d.c. or 600 V d.c. Film capacitors rated for d.c. will usually tolerate an a.c. peak voltage equal to the d.c. rating for short periods without failure. If the inductance of C_S

and its wiring is to be controlled for performance at 1 MHz, two or three capacitors in parallel may be necessary to achieve accuracy and frequency response.

0,1 μF film capacitors rated 250 V a.c. have been measured for resonance at about 3 MHz. Errors of approximately 3 % at 1 MHz can be expected due to the inductance of such components. Capacitors of lower value than 0,1 μF can be connected in parallel to reduce the inductive error.

G.1.4 Resistors R1, R2 and R3

Metal film resistors will give adequate performance under overload and at frequencies up to 1 MHz. If overload capability is desired (see G.1.2), R1 and R2 should be rated 1 W.

G.1.5 Capacitors C1, C2 and C3

Film type capacitors of extended foil construction are recommended. The inductance of capacitors in this range will generally not result in significant errors up to 1 MHz. Capacitors can be adjusted for tolerance by connecting two or more smaller capacitors in parallel.

G.2 Voltmeter

For full performance up to 1 MHz, the device used for measuring U_1 , U_2 , and U_3 should be a voltage measuring instrument which

- responds to
 - d.c. for d.c. measurements,
 - true r.m.s. for r.m.s. measurements, and
 - peak for peak measurements;
- has an input resistance not less than 1 M Ω ;
- has an input capacitance not more than 200 pF for a.c. measurements;
- has a frequency range for a.c. measurements from 15 Hz to 1 MHz, or more if higher frequencies are involved;
- has floating or differential input with common mode rejection of at least 40 dB up to 1 MHz.

See Clause G.1 regarding the use of simpler instruments for particular applications.

G.3 Accuracy

The overall accuracy of the TOUCH CURRENT measuring network and its voltmeter is influenced by the accuracy of resistors and capacitors, and the frequency response, impedance and accuracy of the voltmeter. Intercomponent capacity and lead inductance also affect the accuracy of a measurement.

NOTE Analysis of the effects of tolerances on the measured TOUCH CURRENT for the specified R and C components in the TOUCH CURRENT meter circuits shows that tolerance of the resistors R_S and R_B primarily affect the measurement results. The effects of the other component tolerances are an order of magnitude lower.

A voltmeter has both an input resistance and an input capacitance. At d.c. or low frequencies, a voltmeter having an input resistance of 1 M Ω used with the measuring network of Figure 4 or Figure 5 will indicate 1 % low due to voltage division with the 10 000 Ω resistor in the measuring network. At high frequencies, the input capacitance of the voltmeter, typically 30 pF, being directly in parallel with the output capacitor of the measuring network, can

cause an indication that is 0,15 % low in the network of Figure 4 and 0,33 % low in the network of Figure 5.

G.4 Calibration and application of measuring instruments

NOTE A definition of calibration is ~~given in 3.23 of ISO 10012-1~~ to correlate the readings of an instrument with those of a standard in order to check the instrument.

The performance of an assembled TOUCH CURRENT measuring network or TOUCH CURRENT measuring instrument can be determined by comparing its readings with calculated ideal values throughout the frequency range of interest (see Clause K.1). The error at each frequency of measurement should be noted for many specimens of each instrument. A compilation of error data should be used to establish guard bands within which future measurements are likely to occur. Statistical confidence in the statement regarding the width of the guard bands can be specified. If only one specimen of a particular design of instrument is built, the guard band can be the actual error data.

The establishment of guard bands ensures that measurements can reproducibly indicate whether the EQUIPMENT being tested is within the TOUCH CURRENT limits, when used in the following way.

For equipment manufacturers, the guard band should be added to the reading, and the sum compared to the limit. This ensures that EQUIPMENT indicated as complying with the TOUCH CURRENT limit will not be rejected by the testing laboratory. For testing laboratories, the guard band should be algebraically subtracted from the reading and the difference compared to the limit. This ensures that the testing laboratory will not reject EQUIPMENT that actually complies with the limit. The tolerances for instruments used by a testing laboratory should be sufficiently low to be accommodated by the difference between the limit value and the threshold of the unwanted physiological effect (see IEC TS 60479-1).

If necessary, the guard band of a measuring network can be made narrower, for example by

- selection of components,
- trimming of component values by connecting one or more components in parallel,
- minimizing lead length and sharp bends in leads (to reduce inductance),
- minimizing areas of parts in proximity (to reduce intercomponent capacitances).

It is recommended that equipment manufacturers minimize TOUCH CURRENT levels. The design of EQUIPMENT having current levels close to TOUCH CURRENT limit values is considered to be poor practice, due to the effects of component tolerance, ageing, use and environment on TOUCH CURRENT. When the TOUCH CURRENT from the EQUIPMENT is close to the limit value, special care should be taken in measurement precision and calibration of the test EQUIPMENT. If the TOUCH CURRENT is not close to the limit value, a wider guard band will be acceptable for instruments used by a manufacturer.

G.5 Records

For each measuring instrument, records should be established ~~in accordance with 4.8 of ISO 10012-1~~ containing periodic measurements of the measuring system. These records will provide data for subsequent ~~calibration in~~ confirmation systems (see Clause G.6) and about any limitations in use.

G.6 Confirmation systems

NOTE A definition of metrological confirmation (shortened to “confirmation” in this standard) is given in ~~3.1 of ISO 10012-1~~ many quality standards.

Measuring instruments used for EQUIPMENT certification should be subjected to routine confirmation of their accuracy (see Clause K.2).

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Annex H **(informative)**

Grippable part

H.1 Grippable part

In this standard, the concept of a GRIPPABLE PART is used (see the conditions for use of the measuring network of figure 5 in 5.1.2). A definition is given in 3.4, but no precise specification is given for determining whether or not a part is grippable in the meaning of the definition.

For most purposes, it is anticipated that the definition in 3.4 will be sufficient, but agreement on a specification is desirable.

No specification for a GRIPPABLE PART has yet been agreed in the IEC. To assist with further study and only as an example, a proposal is given in H.2. The use of such a device is not required by this standard.

H.2 Example of test device

To determine whether a part is a GRIPPABLE PART, accessibility measurements are made with the GRIPPABLE PART test device of figure H.1. The test device may be wrapped from either side, in any position that the hand may grip. The part is grippable if the following conditions apply:

- for parts which the hand wraps around in order to grip:
 - there is a hand access clearance of at least 12 mm between the part and any other part, and
 - the clearance is at least 60 mm wide to allow hand width access, and
 - the ends of the test device (figure H.1) meet or overlap;
- for parts such as large pipes or knobs which the hand may not completely enclose, the GRIPPABLE PART test device wraps lengthwise around the part with less than 30 mm of end gap, without regard to material in the end gap;
- where a plane surface is involved, the distance across the plane in the direction of gripping fingers does not exceed 100 mm.

H.3 Rationale

In determining a definition and criteria for a GRIPPABLE PART, the following items were considered:

H.3.1 Test device

A GRIPPABLE PART test device is needed to represent the hand for such parameters as hand thickness, minimum finger length, minimum palm width, minimum width including the thumb, maximum palm length and total overall length. In addition, the test device should be flexible from both sides to enable use for right and left hand gripping.

The test device of figure H.1, when made from flexible foam plastic of 12 mm thickness, should adequately fulfil the requirement from readily available material.

H.3.2 Contact length

A minimum contact of 60 mm length in the vicinity of the palm is considered to be necessary for involuntary gripping. A person should be able to pull away from small parts, such as a BNC connector, even though the voltage on the part could cause currents above the let-go level.

H.3.3 Wrap-around distance

The maximum wrap-around distance for inability to let go is considered to be the length of the hand plus 30 mm. Large parts which cannot be gripped with sufficient force to prevent let-go are thus not considered to be grippable.

H.3.4 Flat surfaces

Flat surfaces wider than the palm width of 100 mm are not considered to be grippable with enough force to prevent let-go.

H.3.5 Combinations of parts

When two or more parts are located together, the combination of parts can be considered to be a GRIPPABLE PART if all criteria are met.

H.3.6 Accessible parts

Accessible parts that do not meet the criteria for GRIPPABLE PARTS are evaluated as large or small area touchable parts. These may have somewhat higher TOUCH CURRENT levels because the condition of inability to let go does not occur.

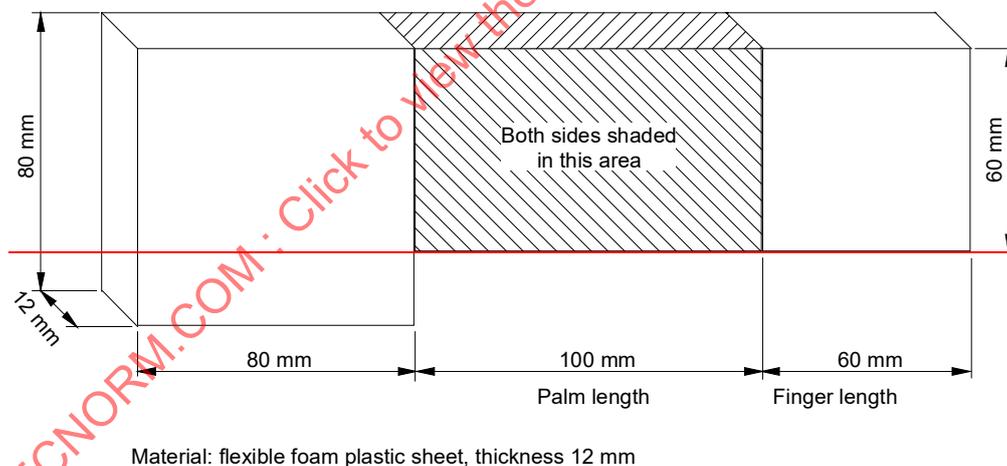


Figure H.1 – Grippable part test device

Annex H (informative)

Analysis of frequency filtered touch current circuit measurements

Annex H demonstrates the method of measurement of complex waveforms in accordance with IEC TS 60479 series.

Modern oscilloscopes provide accurate numeric value measurement information of waveforms during measurement. Common measurements are r.m.s., peak and peak-to-peak measurements of the waveforms. This annex will show how to use that data to properly develop the needed resulting value which is to be compared to the limit specified in the product standard.

IEC TS 60479-2, special aspects, deals with the complexity of waveforms developed by modern electronic EQUIPMENT that easily switches significant voltages to develop voltages or current adapted for specialized use within EQUIPMENT.

IEC TS 60479-2:2007, 5.2 excerpt: 'Most physiological effects are related to the filtered peak current (in magnitude and duration) with the natural body filter defined by the frequency factor F . The peak value of the current should be used in all cases except ... (when) pure sinusoidal current.'

The frequency factor filters developed for IEC 60990 fit the frequency factor curves of IEC TS 60479-2 extended to 1 MHz, the long standing dividing frequency between electrical safety and EMC, as shown in Annex F. This extension is based upon a general medical understanding of the conduction of current within the body by including a continual increase in the allowed current to the end frequency carrying on the same reduction in effects specifically measured. These filters are implemented as an inverse of the frequency factor curves to aid in simplifying the measurements.

To implement the measurement of TOUCH CURRENT according to IEC TS 60479 series, including the frequency factor provisions, IEC 60990 provides two TOUCH CURRENT measurement circuits which meet the frequency factor curves of IEC TS 60479-2 under the following conditions:

- A circuit weighted for startle-reaction (formerly called perception-reaction) – Figure 4.
- A circuit weighted for letgo-immobilization (formerly called let-go) – Figure 5.

SPICE analysis was done for the frequency filtered circuits of Figure 4 and Figure 5 using common waveshapes straightforward for analysis and the results are discussed below. Although only a couple of cycles are shown, this analysis applies to continuous TOUCH CURRENT waveforms. The TOUCH CURRENT is calculated in the analysis and is $V(\text{output}) / 500 \Omega$ which is shown in the plot. The calculation leads to the mV/Ω units (=mA) attached to the TOUCH CURRENT Y / vertical / ordinate axis.

NOTE SPICE output waveform naming explained: $(V(\text{output})/500 \Omega) = \text{weighted touch current}$ and $\text{xmV}/\Omega = \text{xmA}$ touch current calculated using the voltage output from the startle-reaction/Figure 4 or the letgo-immobilization/Figure 5 filtered circuit.

Bipolar waveform examples

Bipolar alternating current waveforms include:

- sinusoidal waves (the most common example); and
- non-sinusoidal waveforms developed by electronic switching within products for power distribution and utilization.

A simple example is that of a 50 Hz (20 ms) triangular waveform shown in Figure H.1 and Figure H.2.

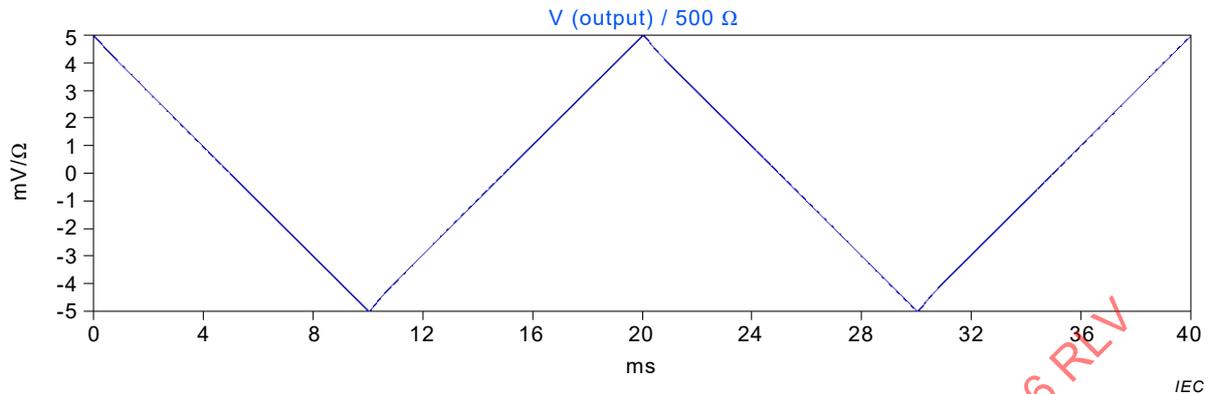


Figure H.1 – Triangular waveform touch current, startle-reaction

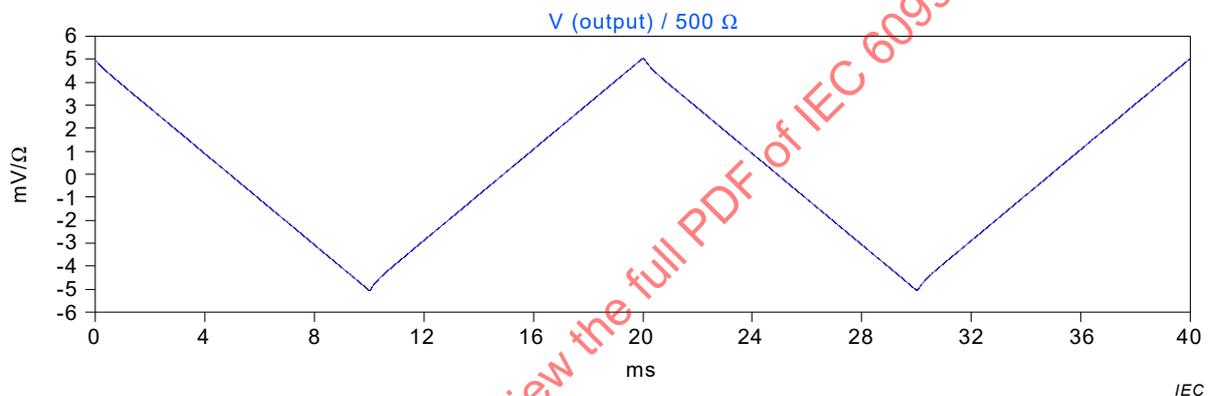


Figure H.2 – Triangular waveform touch current, letgo-immobilization

The input conditions are the same as for an equivalent sinusoidal waveform the results are not the same. The peak value shown in Table H.1 is the peak-to-peak value divided by 2. The peak current is at the 5 mA peak level but the r.m.s. value is below the 3,5 mA level of the example above. The peak measurement be used to adequately compare the level of TOUCH CURRENT hazard to the body. In this case the r.m.s. value when used as a measure of adequacy would indicate a margin below that of a sinusoidal limit value which is an unwarranted sense of protection available.

Table H.1 – Triangular waveform response comparison

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	4,98 mA	2,868 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	5,05 mA	2,869 mA

The filter circuit component of the TC circuits properly acts on the high frequency components of each waveform.

Another simple circuit of interest is a 50 Hz square wave shown in Figure H.3 and Figure H.4.

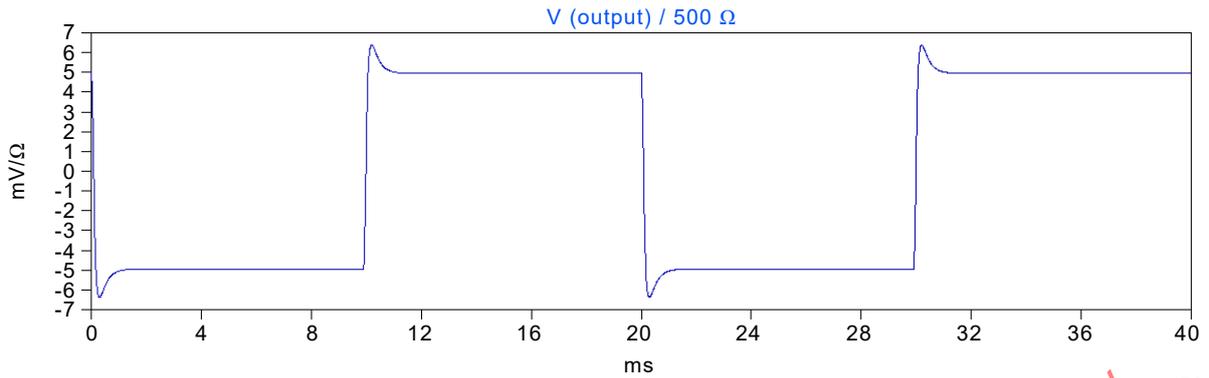


Figure H.3 – 1 ms rise time pulse response, startle-reaction

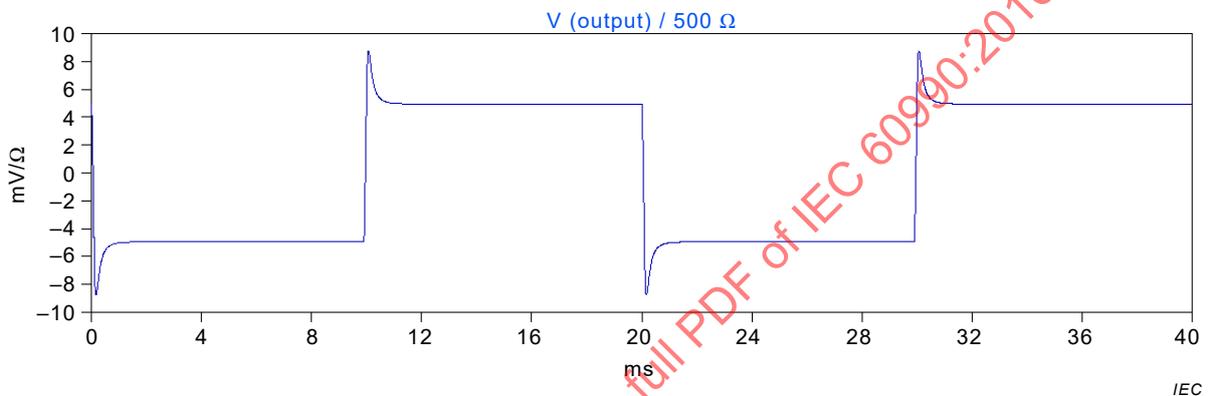


Figure H.4 – 1 ms rise time pulse response, letgo-immobilization

The steady value is 5 mA but the peak value (= peak-to-peak / 2) is higher in each case as shown in Table H.2.

Table H.2 – Square wave touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	6,39 mA	4,991 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,758 mA	5,054 mA

The letgo-immobilization circuit allows more high frequency current through the filter, therefore the peak value is higher.

The rise time is a key factor in the peak TOUCH CURRENT for a fast rising waveform. For this type of waveform, the rise time affects the TOUCH CURRENT by up to a factor of 2 as shown in the TOUCH CURRENT versus rise time plot as shown in Figure H.5.

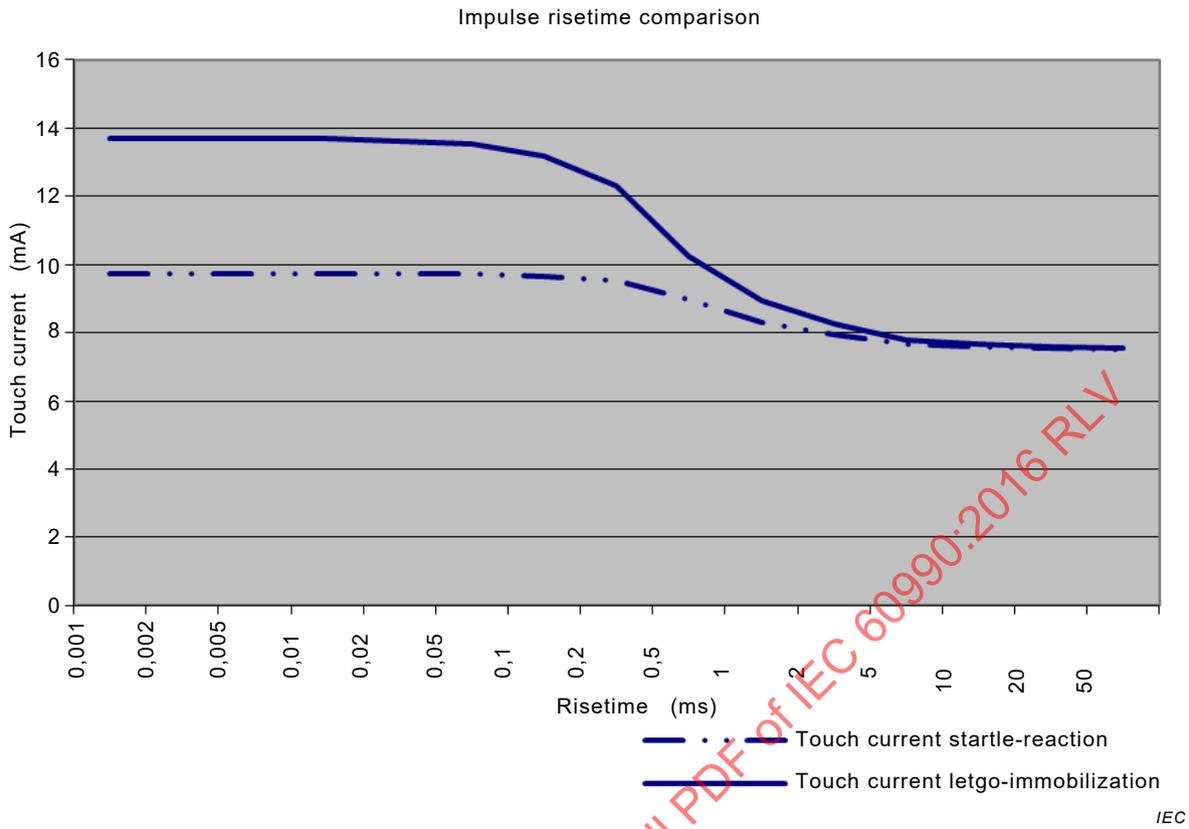


Figure H.5 – Touch current vs. rise time plot, 20 ms square wave

TOUCH CURRENT waveforms have been published for dozens of pieces of modern EQUIPMENT¹. The use of mains switching devices including efforts to restore sinusoidal input current (power factor correction = PFC) and, more recently, to add higher energy efficiency to Switch Mode Power Supplies (SMPS) has led to more complicated TOUCH CURRENT waveforms. One of the more complicated waveforms that has been seen is shown in waveform A of Figure H.6.

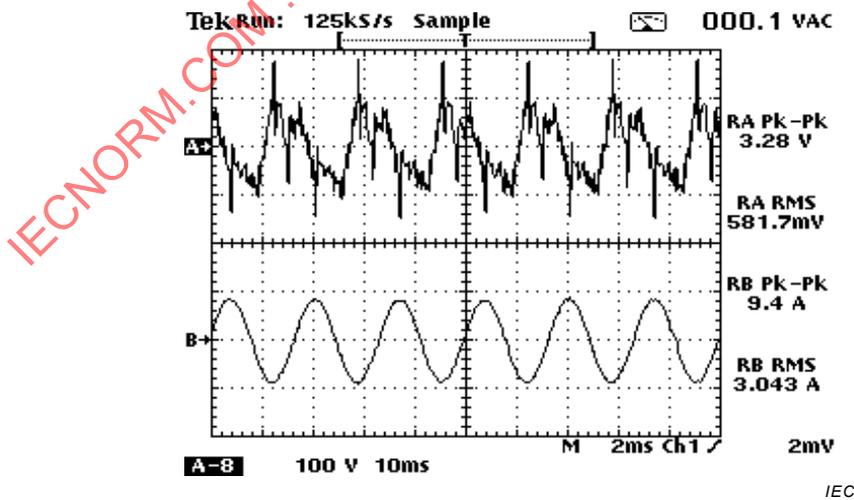
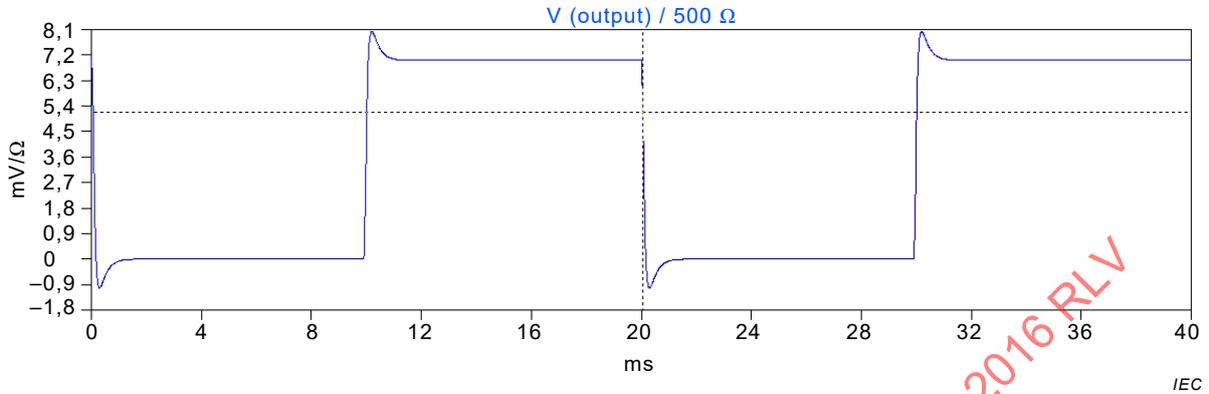


Figure H.6 – PFC SMPS touch current waveform

¹ 'Touch current comparison data'; Perkins, 2006. A collection of more than two dozen touch current waveforms from a variety of equipment; posted on www.safetylink.com, search on perkins.

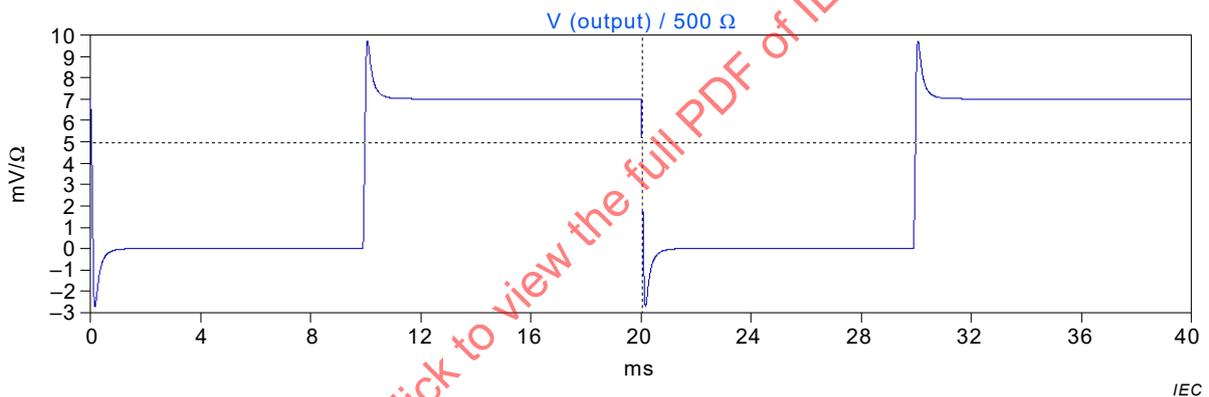
Monopolar waveform example

DC applications are the most common examples of monopolar waveforms. Of specific interest are switched d.c. applications that are discussed here and shown in Figure H.7 and Figure H.8.



r.m.s. value indicated

Figure H.7 – 50 Hz square wave, 0,1 ms rise time, startle-reaction



r.m.s. value indicated

Figure H.8 – 50 Hz square wave, 0,1 ms rise time, letgo-immobilization

For monopolar waveforms the peak value of the TOUCH CURRENT is used. The overshoot on top of the d.c. pulse is included in the measurement, the undershoot is not included.

Table H.3 – Square wave monopolar touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s.
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,031 mA	5,006 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	9,716 mA	5,037 mA

As before, the rise time of the waveform affects the overshoot and the peak value of the TOUCH CURRENT as shown in Table H.3.

Mixed a.c./d.c. examples

IEC TS 60479-2:2007, Figure 7 shows the let-go threshold expressed in peak mA for the combinations of 50/60 Hz sinusoidal alternating current and direct current. The peak of the

composite a.c. and d.c. wave in mA at the let-go threshold estimated for the population of humans including children is shown as a function of the direct current component in mA.

IEC TS 60479-2:2007, Figure 7 is represented by the equation for the composite current:

$$ACpk+DC = 7,176^{(-0,1434 \times DC)} - 0,1061 + DC$$

These effects are related to the peak value of the current and they have to be combined frequency per frequency to estimate the total effect. A measurement circuit is described in this standard.

Herein is shown to the use of IEC 60990 circuits to make measurement of mixed a.c./d.c. TOUCH CURRENTS and properly evaluate them against the equation above. The IEC TS 60479-2:2007, Figure 7 is repeated in Figure H.9 and annotated with some additional data from the waveforms discussed in this annex.

NOTE The composite waveform shown in IEC TS 60479-2:2007, Figure 7 is named ACpknDC in the plot of Figure 9 below. The examples are ACpknDCex1 and ACpknDCex2; the DC values are similarly named as explained in the text following.

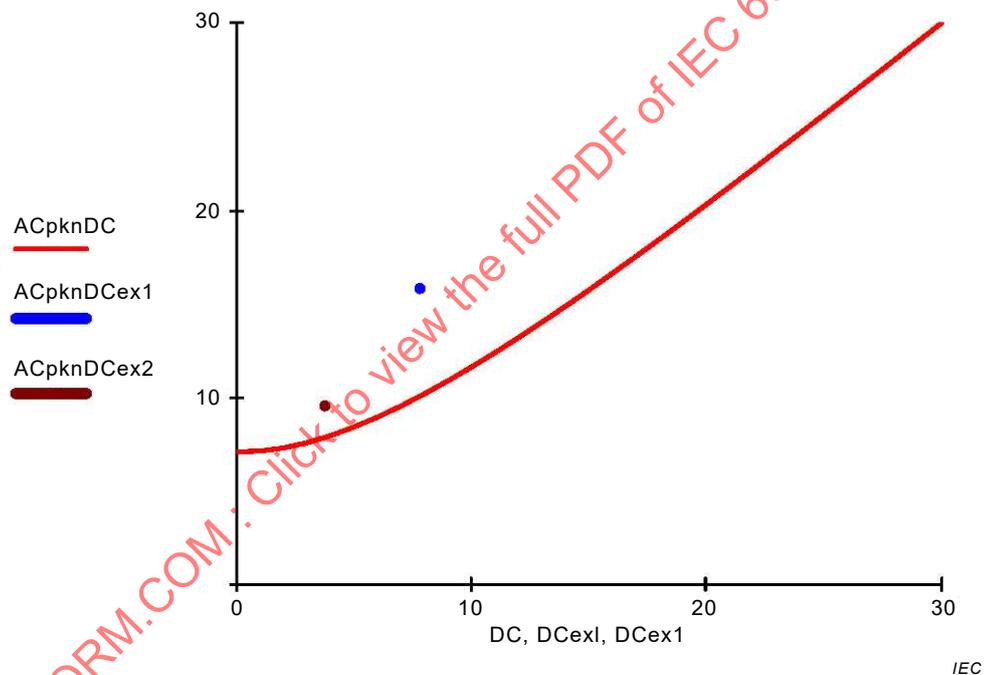


Figure H.9 – IEC TS 60479-2 let-go threshold for AC and DC combinations augmented by additional data, mA each axis

The procedure is as follows. The maximum peak absolute value of the composite waveform is selected (**bold values** of TOUCH CURRENT in the tables) to be plotted as ACpknDC. The peak-equivalent (pk-ev) value is calculated from the r.m.s. value; this is subtracted from the maximum peak value to get the DC value needed for the plot. The values derived from the measurements can be plotted on the same graph as the curve to compare as is done here or, alternatively, the DC value can be entered into the equation for the composite current to calculate the ACpk+DC and compared to the measurement derived value called ACpknDC.

Example 1 (ex1):

The first example (shown in Figure H.10) analyzed for letgo-immobilization.

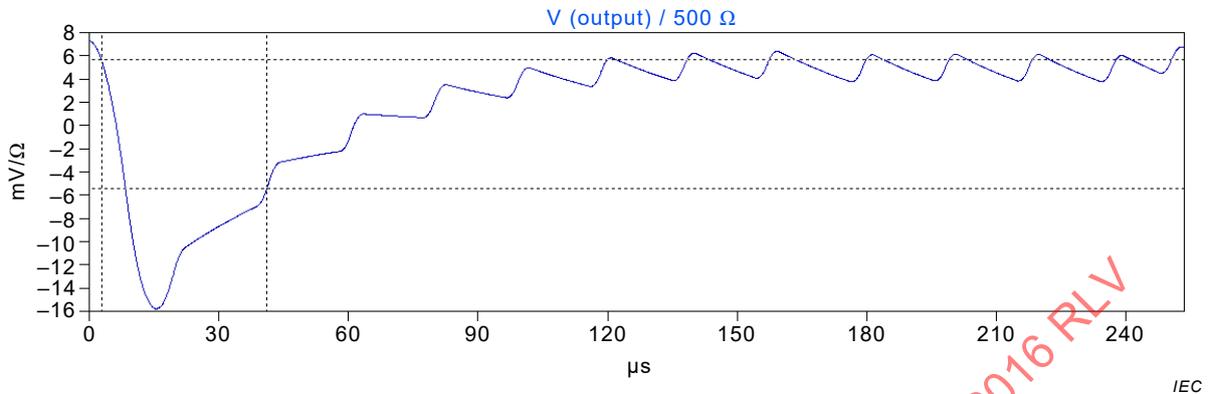


Figure H.10 – Ex1 case: showing r.m.s. window

For the ex1 case shown above, see Table H.4.

Table H.4 – Mixed ACnDC waveform evaluation, ex1

	TOUCH CURRENT peak	TOUCH CURRENT r.m.s.
Letgo-immobilization case	+7,281 96 / -15,788 2 mA peak	5,644 6 mA r.m.s. Pk-ev: 5,644 6 × 1,414 = 8 mA peak 15,79 – 8 = 7,79 mA d.c.
The values in bold in the table correspond to the plotted values (with rounding included in the latter) of Figure H.10.		

The values to be plotted for graphical evaluation are:

ACpknDCex1 = 15,8, DCex1 = 7,79

Example 2 (ex2):

Another mixed case, ex2, is shown in Figure H.11 and Table H.5.

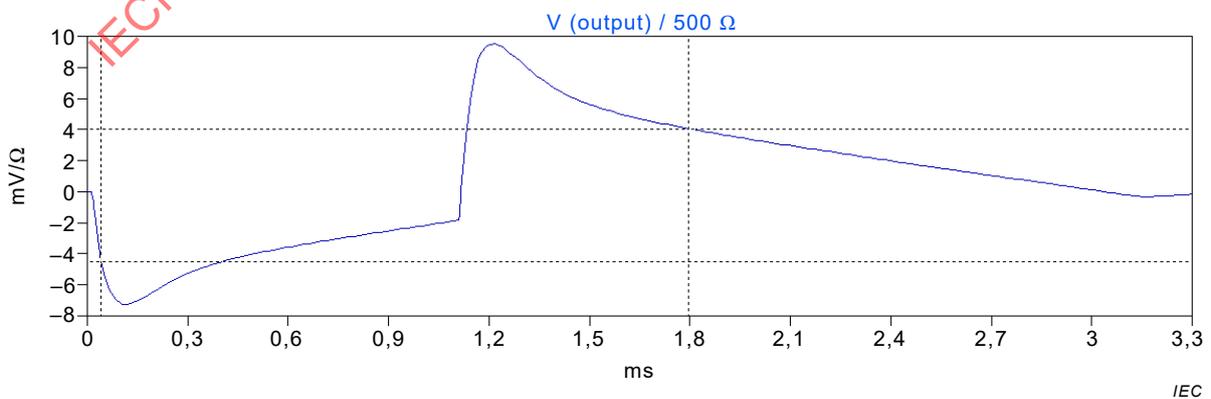


Figure H.11 – Waveform ex2 case: showing r.m.s. window

Table H.5 – Mixed ACnDC waveform evaluation, ex2

	TOUCH CURRENT peak	TOUCH CURRENT r.m.s
Letgo-immobilization case	9,524 69 / -7,247 19 mA peak	4,085 4 mA r.m.s. Pk-ev: $4,085\ 4 \times 1,414 = 5,777\ 6$ mA peak $9,524\ 7 - 5,777\ 6 = 3,747\ 1$ mA d.c.
The values in bold in the table correspond to the plotted values (with rounding included in the latter) of Figure H.11.		

The values to be plotted for graphical evaluation are:

$$\mathbf{ACpknDCex2 = 9,52, \quad DCex2 = 3,75}$$

Each example falls above the letgo-immobilization curve and fails to meet a letgo-immobilization TOUCH CURRENT limit of 5 mA r.m.s. / 7 mA peak as described in IEC TS 60479-2.

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Annex I (informative)

AC power distribution systems (see 5.4)

I.1 Introduction General

In IEC ~~60364-3~~ 60364-1, a.c. power distribution systems are classified TN, TT and IT, depending on the arrangement of current-carrying conductors and on the method of earthing. The classes and codes are explained in this annex. Some examples of each class are given in the Figure I.1 to Figure I.8; other configurations also exist.

In the figures:

- in most cases, the power systems apply for single-phase and three-phase EQUIPMENT but, for simplicity, only single-phase EQUIPMENT is illustrated;
- the power sources may be transformer secondaries, motor-driven generators or uninterruptible power systems;
- for transformers within a user's building, some of the figures apply, and the building boundary represents a floor of the building;
- some power systems are earthed at additional points, for example at the power entry points of users' buildings (see IEC 60364-4-41:2005, 413.1.3.1, note 1).

The following types of EQUIPMENT connection are taken into account; the numbers of wires mentioned do not include conductors used exclusively for earthing:

- single-phase, 2-wire;
- single-phase, 3-wire;
- two-phase, 3-wire;
- three-phase, 3-wire;
- three-phase, 4-wire.

The system codes used have the following meaning.

- First letter: relationship of the power system to earth
 - T means direct connection of one pole to earth;
 - I means system isolated from earth, or one point connected to earth through an impedance.
- Second letter: earthing of the EQUIPMENT
 - T means direct electrical connection of the EQUIPMENT to earth, independently of the earthing of any point of the power system;
 - N means direct electrical connection of the EQUIPMENT to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).
- Subsequent letters, if any: arrangement of neutral and protective conductors
 - S means the protective function is provided by a conductor separate from the neutral or from earthed line (or, in a.c. systems, earthed phase) conductor;
 - C means the neutral and protective functions are combined in a single conductor (PEN conductor).

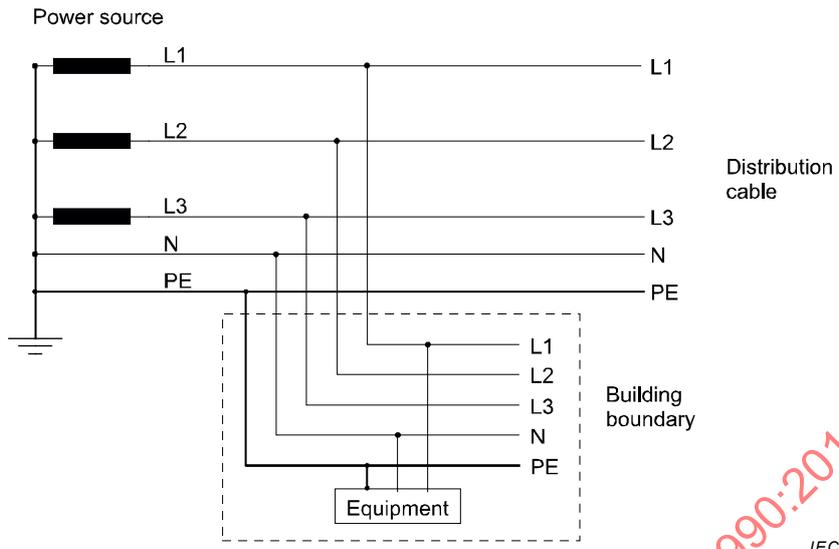
I.2 TN power systems

TN power systems are directly earthed, the parts of the EQUIPMENT required to be earthed being connected by protective earthing conductors. Three types of TN power systems are considered:

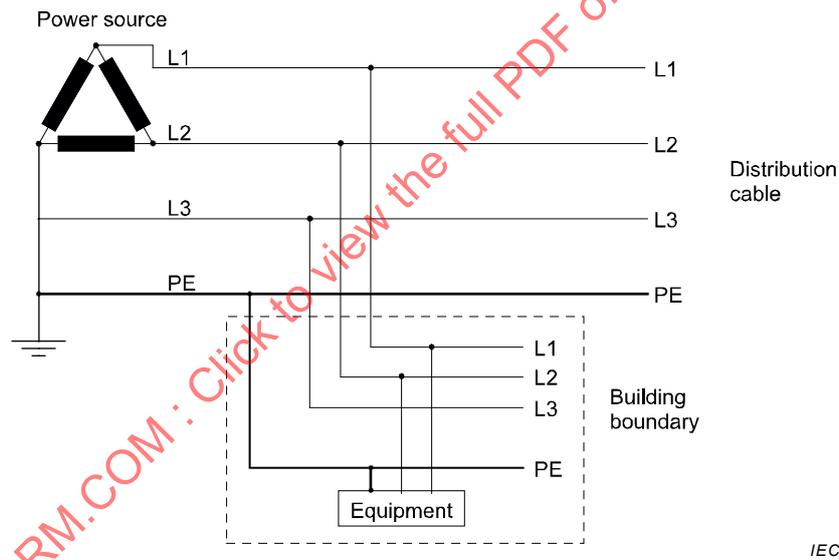
- TN-S power system: in which a separate protective conductor is used throughout the system;
- TN-C-S power system: in which neutral and protective functions are combined in a single conductor in part of the system;
- TN-C power system: in which neutral and protective functions are combined in a single conductor throughout the system.

Some TN power systems are supplied from a secondary winding of a transformer that has an earthed centre tap (neutral). Where the two phase conductors and the neutral conductor are available, these systems are commonly known as single-phase, 3-wire power systems.

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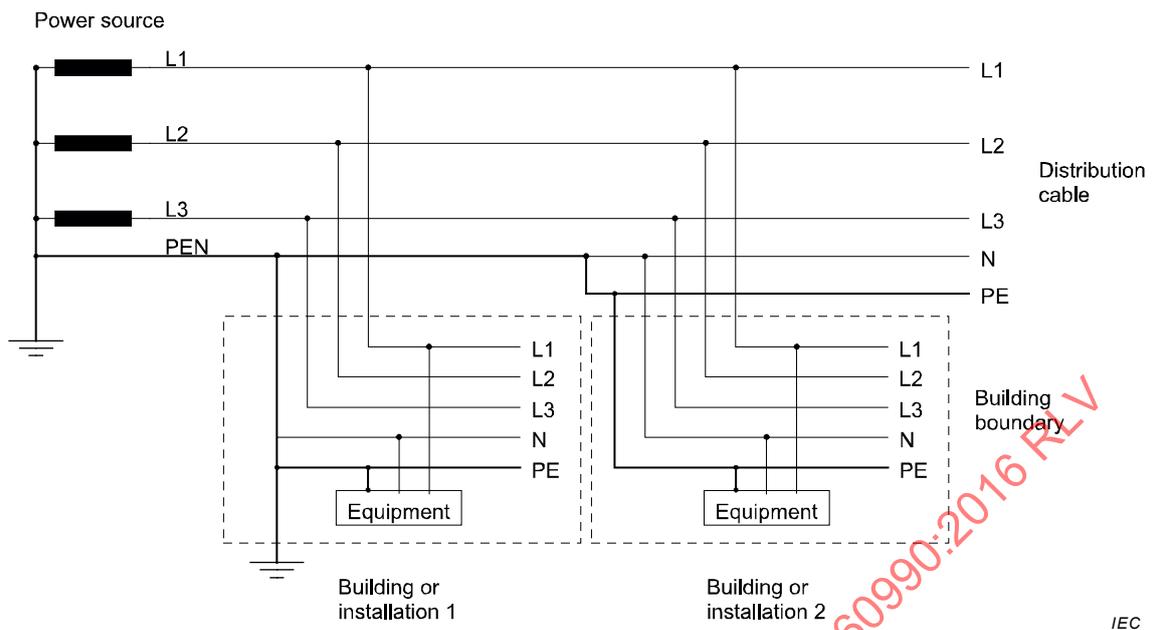


Separate neutral and protective conductors



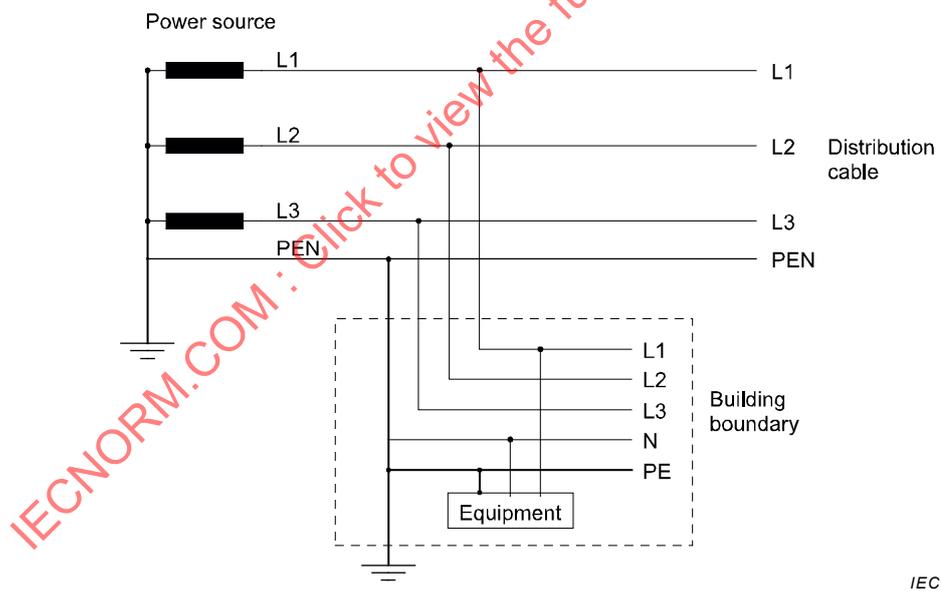
Earthed line conductor

Figure I.1 – Examples of TN-S power system



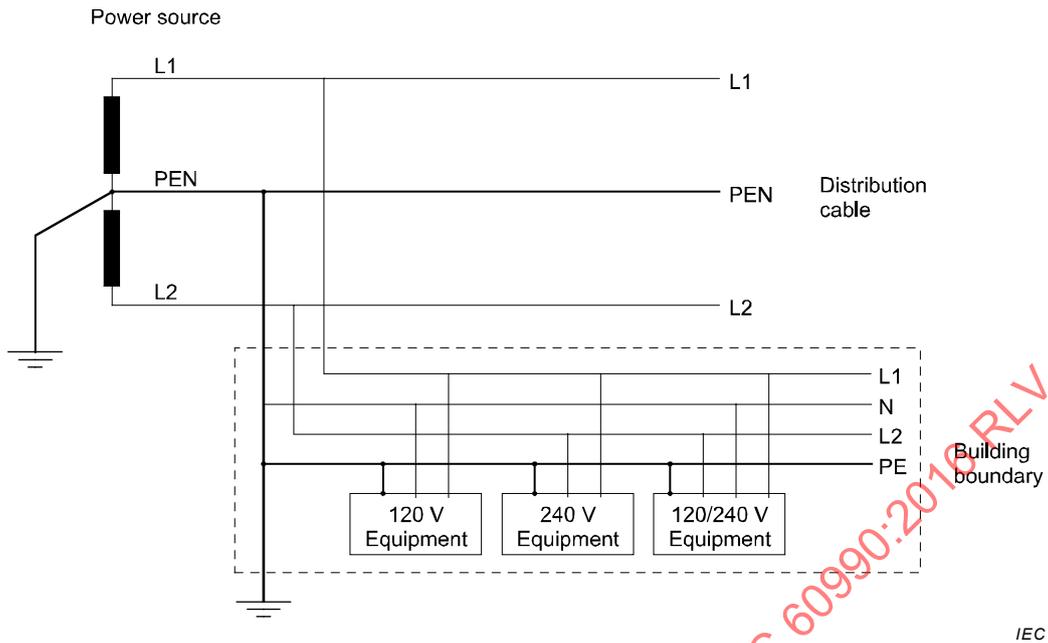
NOTE The point at which the PEN conductor is separated into protective earth and neutral conductors may be at the building entrance or at distribution panels within the building.

Figure I.2 – Example of TN-C-S power system



Neutral and protective functions combined in one conductor (PEN)

Figure I.3 – Example of TN-C power system



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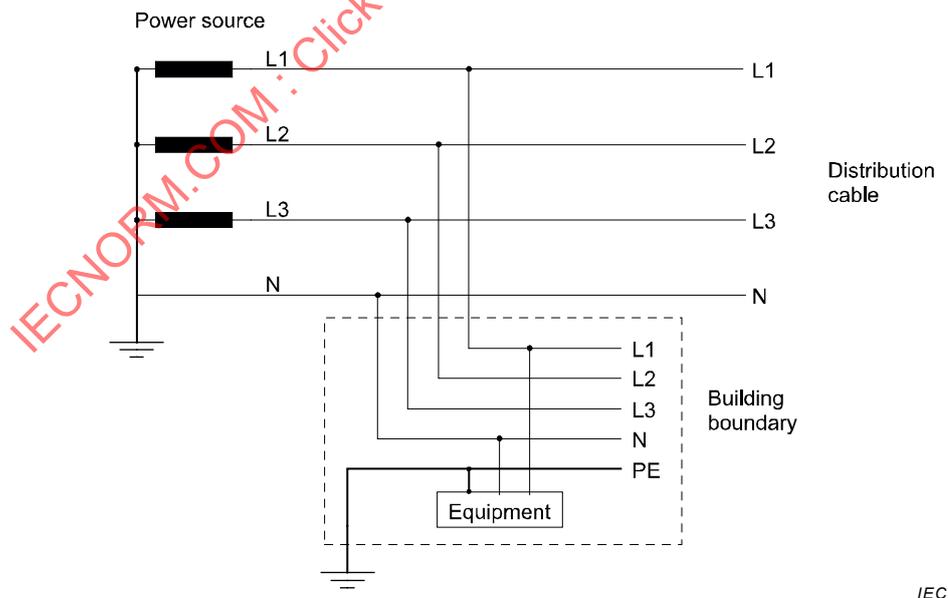
Protective and neutral functions combined in one conductor (PEN)

This system is widely used in North America at 120/240 V.

Figure I.4 – Example of single-phase, 3-wire TN-C power system

I.3 TT power systems

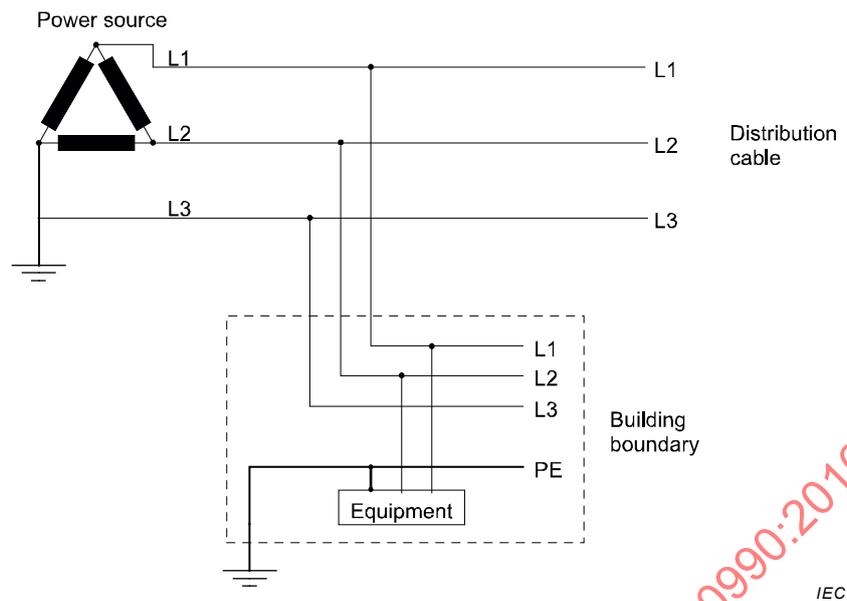
TT power systems have one point directly earthed, the parts of the equipment required to be earthed being connected at the user's premises to earth electrodes that are electrically independent of the earth electrodes of the power distribution system.



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Earthed neutral and independent earthing of EQUIPMENT

Figure I.5 – Example of 3-line and neutral TT power system



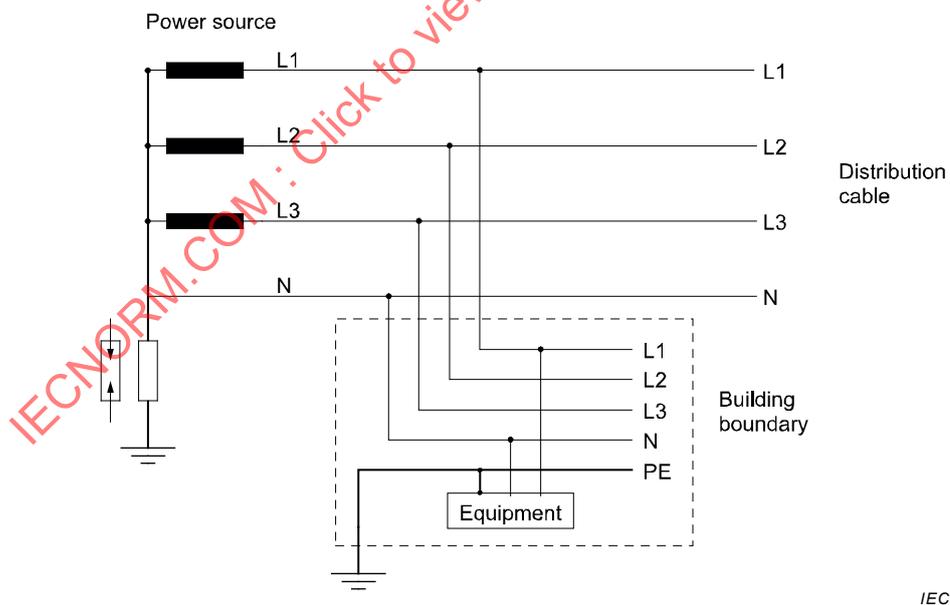
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Earthed line and independent earthing of EQUIPMENT

Figure I.6 – Example of 3-line TT power system

I.4 IT power systems

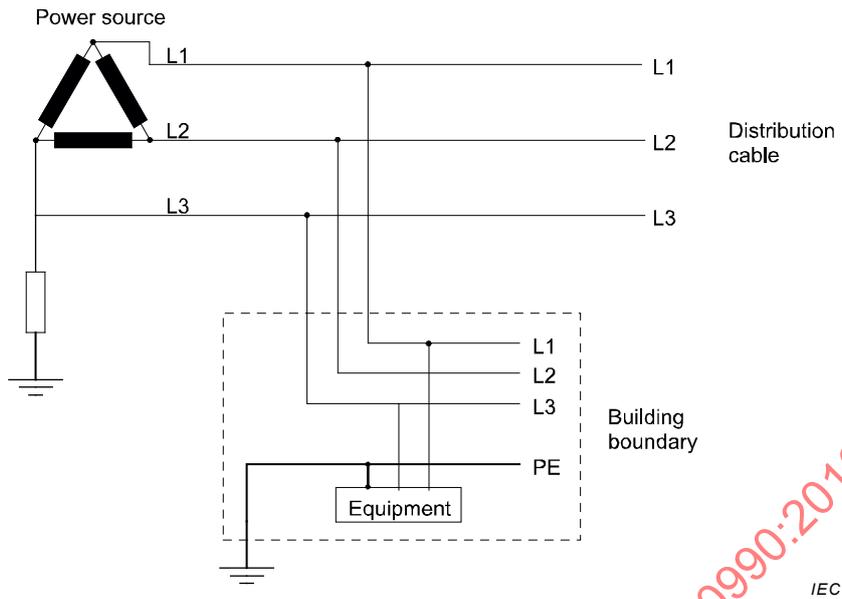
IT power systems are isolated from earth, except that one point may be connected to earth through an impedance or a voltage limiter. The parts of the EQUIPMENT required to be earthed are connected to earth electrodes at the user's premises.



The neutral may be connected to earth through an impedance or a voltage limiter, or isolated from earth.

This system is widely used isolated from earth, in some installations in France, with impedance to earth, at 230/400 V, and in Norway, with a voltage limiter, neutral not distributed, at 230 V line-to-line.

Figure I.7 – Example of 3-line (and neutral) IT power system



The system may be isolated from earth.

Figure I.8 – Example of 3-line IT power system

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Annex J (informative)

Routine and periodic touch current tests, and tests after repair or modification of mains operated equipment

This annex defines methods and procedures to perform tests which reverify TOUCH CURRENT according to design requirements from the product standard, during production (routine test), after repair or modification and at periodic intervals during use.

The objective is to have the test performed by technicians or other instructed persons, using simple procedures to achieve sufficient accuracy. Measuring results should be easy to interpret. Measuring equipment should be economical and easy to use under practical field conditions.

Method

Tests are to be carried out using the procedures of this standard with the appropriate measuring network ~~of figure 4~~. Tests are to be performed under the environmental conditions of an appropriate field or factory location.

The EQUIPMENT is to be tested in a stand-alone configuration without external connections, except for the mains supply.

TOUCH CURRENT is to be measured and shall be at or below the limit defined in the EQUIPMENT standard as follows:

- if the limit is given as d.c. current, measure the d.c. and compare with the limit;
- if the limit is given in peak current, measure the ~~r.m.s.~~ peak current and ~~multiply the result by 1,414, and~~ compare with the peak limit;
- if the limit is given in r.m.s. current, measure the r.m.s. current and compare with the r.m.s. limit.

No routine or periodic test is required for ELECTRIC BURN currents unless specified by the EQUIPMENT standard.

Annex K
(normative)

Network performance and calibration

K.1 Network or instrument performance and initial calibration

Measured ratios of input voltage to input current (input impedance) and output voltage to input current (transfer impedance or network response) are compared with ideal values calculated from the nominal component values specified in Figure 3, Figure 4 and Figure 5. Care is taken in the arrangement of the test equipment circuitry so that intercomponent capacitance, lead inductance and characteristics of the voltage measuring device do not significantly affect the voltage-current ratios.

A guard band indicating the uncertainty of measurement at various frequencies is specified for each instrument. The performance of measuring networks can, if necessary, be adjusted to make the guard band narrower.

NOTE 1 A definition of uncertainty of measurement is ~~given in 3.7 of ISO 10012~~ the characterization of the range within which the true value of a measurement is estimated to lie; this is a common term in metrology and calibration.

NOTE 2 Guidance on adjusting the performance of measuring networks is given in G.4.

The performance of a measuring network is checked by passing variable frequency sinusoidal current through the input of the instrument, test terminals A and B in Figure 3, Figure 4 and Figure 5. The input current (I), input voltage (U) and output voltage (U_1 , U_2 or U_3) are measured at various frequencies. If possible, the output voltage is measured by the same voltmeter as will be used during all measurements on the EQUIPMENT for product certification purposes and for all confirmation procedures (see Clause K.2).

Table K.1 – Calculated input impedance and transfer impedance for unweighted touch current measuring network (Figure 3)

Frequency Hz	Input impedance U / I	Transfer impedance U_1 / I
20	1 998	500
50	1 990	500
60	1 986	500
100	1 961	500
200	1 857	500
500	1 434	500
1 000	979	500
2 000	675	500
5 000	533	500
10 000	509	500
20 000	502	500
50 000	500	500
100 000	500	500
200 000	500	500
500 000	500	500
1 000 000	500	500

Table K.2 – Calculated input impedance and transfer impedance for ~~perception~~ or ~~startle~~-reaction touch current measuring network (Figure 4)

Frequency Hz	Input impedance U / I	Transfer impedance U_2 / I
20	1 998	500
50	1 990	499
60	1 986	498
100	1 961	495
200	1 857	480
500	1 433	405
1 000	973	284
2 000	661	162,9
5 000	512	68,3
10 000	485	34,4
20 000	479	17,21
50 000	477	6,89
100 000	476	3,45
200 000	476	1,722
500 000	476	0,689
1 000 000	476	0,345

Table K.3 – Calculated input impedance and transfer impedance for letgo-immobilization current measuring network (Figure 5)

Frequency Hz	Input impedance U / I	Transfer impedance U_3 / I
20	1 998	500
50	1 990	499
60	1 986	499
100	1 961	496
200	1 858	484
500	1 434	427
1 000	976	340
2 000	667	251
5 000	515	144,3
10 000	487	79,9
20 000	479	41,2
50 000	477	16,63
100 000	476	8,32
200 000	476	4,16
500 000	476	1,666
1 000 000	476	0,833

K.2 Calibration in a confirmation system

K.2.1 General

NOTE A definition of metrological confirmation (shortened to “confirmation” in this standard) is ~~given in 3.1 of ISO 10012-1~~ a set of operations required to ensure that a measuring equipment is in a state of compliance with requirements for its intended use.

Each instrument that is used to determine acceptability for the purpose of certification of EQUIPMENT shall be routinely calibrated in a confirmation system, ~~according to ISO 10012-1~~, to ensure that no drift of its performance outside the limits of permissible error has occurred. Reference is necessary to the guard band and other data recorded for the particular measuring instrument during its initial calibration (see Clause K.1).

If a particular measuring instrument has drifted outside permissible limits, measurements made on the EQUIPMENT with that instrument since the last confirmation calibration shall be reviewed to check their validity.

Calibration in a confirmation system is carried out in two steps.

K.2.2 Measurement of input resistance

The d.c. input resistance is measured and its value is checked against the ideal value (2 000 Ω) and the value determined during initial calibration.

NOTE This measurement guards against the possibility that a shift in input impedance has occurred at the same time that a shift occurs in the instrument response, resulting in addition or cancellation of errors.

K.2.3 Measurement of instrument performance

The input voltage and the output voltage (or milliamperes as indicated on the meter) are measured at various frequencies and the ratios compared to the data in Table K.4, Table K.5 or Table K.6, as appropriate. If possible, the output voltage is measured by the same voltmeter as will be used for initial calibration and during all measurements on the EQUIPMENT for product certification purposes. It is sufficient to carry out the measurements at a few frequencies over the whole frequency range of interest **as long as attention is given to the higher frequencies**. The input voltages used should be such as to produce output indications in the range of the TOUCH CURRENT limit values for which the measuring instrument is intended, subject to observing the power rating of internal components.

NOTE Table K.4, Table K.5 and Table K.6 are derived from Table K.1, Table K.2 and Table K.3 respectively but, in order to simplify the confirmation procedure, the presentation of the data avoids the need to measure input current at high frequencies.

Table K.4 – Output voltage to input voltage ratios for unweighted touch current measuring network (Figure 3)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,98	1,99
60	0,252	3,97	1,99
100	0,255	3,92	1,96
200	0,269	3,72	1,86
500	0,349	2,87	1,43
1 000	0,511	1,96	0,979
2 000	0,740	1,35	0,675
5 000	0,937	1,07	0,533
10 000	0,983	1,02	0,509
20 000	0,996	1,00	0,502
50 000	0,999	1,00	0,500
100 000	1,00	1,00	0,500
200 000	1,00	1,00	0,500
500 000	1,00	1,00	0,500
1 000 000	1,00	1,00	0,500

**Table K.5 – Output voltage to input voltage ratios for ~~perception~~
or ~~startle~~-reaction measuring network (Figure 4)**

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,99	2,00
60	0,251	3,99	1,99
100	0,252	3,96	1,98
200	0,259	3,87	1,93
500	0,282	3,54	1,77
1 000	0,292	3,43	1,71
2 000	0,246	4,06	2,03
5 000	0,133	7,50	3,75
10 000	0,070 8	14,1	7,06
20 000	0,036 0	27,8	13,9
50 000	0,014 5	69,2	34,6
100 000	0,007 23	138	69,1
200 000	0,003 62	277	138
500 000	0,001 45	691	346
1 000 000	0,000 723	1 382	691

**Table K.6 – Output voltage to input voltage ratios
for letgo-immobilization measuring network (Figure 5)**

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliamperere indication
20	0,250	4,00	2,00
50	0,251	3,99	1,99
60	0,251	3,98	1,99
100	0,253	3,95	1,98
200	0,261	3,83	1,92
500	0,298	3,36	1,68
1 000	0,348	2,87	1,44
2 000	0,377	2,65	1,33
5 000	0,280	3,57	1,79
10 000	0,164	6,09	3,04
20 000	0,086 0	11,6	5,81
50 000	0,034 9	28,7	14,3
100 000	0,017 5	57,2	28,6
200 000	0,008 74	114	57,2
500 000	0,003 50	286	143
1 000 000	0,001 75	572	286

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Annex M
(informative)

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Methods of measurement of touch current and protective conductor current

Méthodes de mesure du courant de contact et du courant dans le conducteur de protection

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

FOREWORD

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International Standard IEC 60990 has been prepared by TC 108: Safety of electronic equipment within the field of audio/video, information technology and communication technology.

This third edition cancels and replaces the second edition published in 1999. It constitutes a technical revision.

The principal changes in this edition as compared with the second edition are as follows:

- the effects names have been updated to reflect increased understanding of the range of effects and is in concert with present usage;
- the conditions of use invoking a GRIPPABLE PART have been reduced in the application of the requirements based upon the current understanding of this effect;
- the references to ISO 10012-1, which has been replaced by management standard of the same number, have been replaced with explanatory text, where needed to maintain the sense of the document;

- former informative Annex H (GRIPPABLE PART) has been deleted from this update as it does not properly represent the full set of conditions under which immobilization can occur. A new informative Annex H (Analysis of frequency filtered touch current circuits measurement) has been added;
- the Bibliography (formerly Annex M) has been updated with additional references for completeness.

It has the status of a basic safety publication in accordance with IEC Guide 104.

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

FDIS	Report on voting
108/630/FDIS	108/640/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.

In this standard, the following print types or formats are used:

- requirements proper and normative annexes: in roman type;
- compliance statements and test specifications: *in italic type*;
- notes/explanatory matter: in smaller roman type;
- normative conditions within tables: in smaller roman type;
- terms defined in Clause 3: SMALL CAPITALS.

The committee has decided that the contents of this publication will remain unchanged until the maintenance result date indicated on the IEC website 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.

IMPORTANT – The 'colour inside' logo on the cover page of this publication indicates that it contains colours which are considered to be useful for the correct understanding of its contents. Users should therefore print this document using a colour printer.

INTRODUCTION

This International Standard was developed as a response to concerns arising from the advent of electronic switching techniques being broadly applied to power systems and within EQUIPMENT, giving rise to high-frequency harmonic voltages and currents.

This standard is intended for the guidance of EQUIPMENT committees in preparing or amending the test specifications in their standards for measurement of leakage current. However the term "leakage current" is not used for reasons explained below.

This standard was initially prepared under the basic safety function assigned to TC 74 (now TC 108), as follows:

Methods of measuring leakage current

This includes, for various types of EQUIPMENT, all aspects of what is referred to as "leakage current", including methods of measurement of current with regard to physiological effects and for installation purposes, under normal conditions and under certain fault conditions.

The methods of measurement of leakage current described herein result from the review of IEC TS 60479-1 and other publications, including descriptions of earlier methods of measurement.

The following conclusions were derived from a review of the effects of leakage current:

- the primary concern for safety involves possible flow of harmful current through the human body (this current is not necessarily equal to the current flowing through a protective conductor);
- the effect of electric current on a human body is found to be somewhat more complex than was assumed during the development of earlier standards in that there are several body responses which should be considered. The most significant responses for setting limits for continuous waveforms are
 - perception,
 - startle-reaction,
 - letgo-immobilization, and
 - ELECTRIC BURN.

Each of these four body responses has a unique threshold level. There are also significant differences in the manner in which some of these thresholds vary with frequency.

Two types of current have been identified as needing separate measuring methods: TOUCH CURRENT and PROTECTIVE CONDUCTOR CURRENT.

TOUCH CURRENT only exists when a human body or a body model is a current pathway.

It was also noted that the term "leakage current" has already been applied to several different concerns: TOUCH CURRENT, PROTECTIVE CONDUCTOR CURRENT, insulation properties, etc. Therefore, in this standard, the term "leakage current" is not used.

Measurement of TOUCH CURRENT

In the past, EQUIPMENT standards have used two traditional techniques for measurement of leakage current. Either the actual current in the protective conductor was measured, or a simple resistor-capacitor network (representing a simple body model) was used, the leakage current being defined as the current through the resistor.

This standard provides measuring methods for the four body responses to the electric current noted above, using a more representative body model.

This body model was chosen for most common cases of electric shock in the general sense. With respect to the path of current flow and conditions of contact, a body model approximating full hand-to-hand or hand-to-foot contact in normal conditions is used. For small areas of contact (for example, small, finger contact), a different model may be appropriate but is not covered here.

Of the four responses, startle-reaction and letgo-immobilization are related to the peak value of TOUCH CURRENT and vary with frequency. Traditionally, concerns for electric shock have dealt with sinusoidal waveforms, for which r.m.s. measurements are most convenient. Peak measurements are more appropriate for non-sinusoidal waveforms where significant values of TOUCH CURRENT are expected, but are equally suitable for sinusoidal waveforms. The networks specified for the measurement of startle-reaction and letgo-immobilization are frequency-responsive and are so weighted that single limit power-frequency values can be specified and referenced.

ELECTRIC BURNS, however, are related to the r.m.s. value of TOUCH CURRENT, and are relatively independent of frequency. For EQUIPMENT where ELECTRIC BURNS may be of concern (see 7.2), two separate measurements are made, one in peak value for electric shock and a second in r.m.s. value for ELECTRIC BURNS each using the appropriate test circuit.

EQUIPMENT committees should decide which physiological effects are acceptable and which are not, and then decide on limit values of current. Committees for certain types of EQUIPMENT may adopt simplified procedures based upon this standard. A discussion of limit values, based upon earlier work by various IEC EQUIPMENT committees, is provided in Annex D.

Measurement of PROTECTIVE CONDUCTOR CURRENT

In certain cases, measurement of the PROTECTIVE CONDUCTOR CURRENT of EQUIPMENT under normal operating conditions is required. Such cases include:

- selection of a residual current protection device,
- determination when a high integrity protective earth circuit is required,
- prevent excessive PROTECTIVE CONDUCTOR CURRENT overload in the electrical installation.

The PROTECTIVE CONDUCTOR CURRENT is measured by inserting an ammeter of negligible impedance in series with the EQUIPMENT protective earthing conductor.

METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

1 Scope

This International Standard defines measurement methods for

- d.c. or a.c. current of sinusoidal or non-sinusoidal waveform, which could flow through the human body, and
- current flowing through a protective conductor.

The measuring methods recommended for TOUCH CURRENT are based upon the possible effects of current flowing through a human body. In this standard, measurements of current through networks representing the impedance of the human body are referred to as measurements of TOUCH CURRENT. These networks are not necessarily valid for the bodies of animals.

The specification or implication of specific limit values is not within the scope of this standard. IEC TS 60479 series provides information regarding the effects of current passing through the human body from which limit values may be derived.

This standard is applicable to all classes of EQUIPMENT, according to IEC 61140.

The methods of measurement in this standard are not intended to be used for

- TOUCH CURRENTS having less than 1 s duration,
- patient currents as defined in IEC 60601-1,
- a.c. at frequencies below 15 Hz, and
- currents above those chosen for ELECTRIC BURN limits.

This basic safety publication is primarily intended for use by technical committees in the preparation of standards in accordance with the principles laid down in IEC Guide 104 and ISO/IEC Guide 51. It is not intended for use by manufacturers or certification bodies independent of product standards.

One of the responsibilities of a technical committee is, wherever applicable, to make use of basic safety publications in the preparation of its publications. The requirements, test methods or test conditions of this basic safety publication only apply when specifically referred to or included in the relevant publications.

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.

IEC TS 60479-1:2005, *Effects of current on human beings and livestock – Part 1: General aspects*

IEC TS 60479-2:2007, *Effects of current on human beings and livestock – Part 2: Special aspects*

IEC 61140, *Protection against electric shock – Common aspects for installation and equipment*

ISO/IEC Guide 51:2014, *Safety aspects – Guidelines for their inclusion in standards*

IEC Guide 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications*

3 Terms and definitions

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

3.1

TOUCH CURRENT

electric current through a human body or through an animal body when it touches one or more accessible parts of an installation or of EQUIPMENT

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.2

PROTECTIVE CONDUCTOR CURRENT

current which flows in a protective conductor

3.3

EQUIPMENT

organized collection of electromechanical component parts and features to accomplish a defined task (as specified in the relevant product standard).

Note 1 to entry: If not specified in the relevant standard, see Annex A.

3.4

GRIPPABLE PART

part of the EQUIPMENT which could supply current through the human hand to cause muscular contraction around the part and an inability to let go

Note 1 to entry: Parts which are intended to be gripped with the entire hand are assumed to be grippable without further investigation.

3.5

ELECTRIC BURN

burning of the skin or of an organ, caused by passing an electric current across or through the surface

[SOURCE: IEC 60050-604:1987, 604-04-18]

4 Test site

4.1 Test site environment

Test site environmental requirements shall be as specified in the EQUIPMENT standard. If limit values of less than 70 μA r.m.s. or 100 μA peak are specified, or if the EQUIPMENT contains large shields which may be driven by high-frequency signals, product committees shall refer to Annex B.

4.2 Test transformer

The use of a test transformer for isolation is optional. For maximum safety, a test transformer for isolation (T2 in Figure 2, T in Figure 6 to Figure 14) shall be used and the main protective earthing terminal of the EQUIPMENT under test (EUT) earthed. Any capacitive leakage in the transformer shall then be taken into account. As an alternative to earthing the EUT, the test transformer secondary and the EUT shall be left floating (not earthed), in which case the capacitive leakage in the test transformer need not be taken into account.

If transformer T is not used, the EUT shall be mounted on an insulating stand and appropriate safety precautions taken, in view of the possibility of the body of the EUT being at hazardous voltage.

4.3 Earthed neutral conductor

EQUIPMENT intended for connection to a TT or TN power distribution system shall be tested with minimum voltage between neutral and earth.

NOTE Descriptions of various power distribution systems are given in Annex I.

The protective conductor and the earthed neutral conductor for the EUT should have a voltage difference of less than 1 % of line-to-line voltage (see example in Figure 1).

A local transformer, see 4.2, will achieve this requirement.

Alternatively, if the voltage difference is 1 % or more the following are examples of methods which, in some cases, will avoid measurement errors due to this voltage:

- connecting the terminal B electrode of the measuring instrument network to the neutral terminal of the EUT instead of the protective earthing conductor (see 6.1.2) of the supply;
- connecting the earthing terminal of the EUT to the neutral conductor, instead of the protective earthing conductor, of the supply.

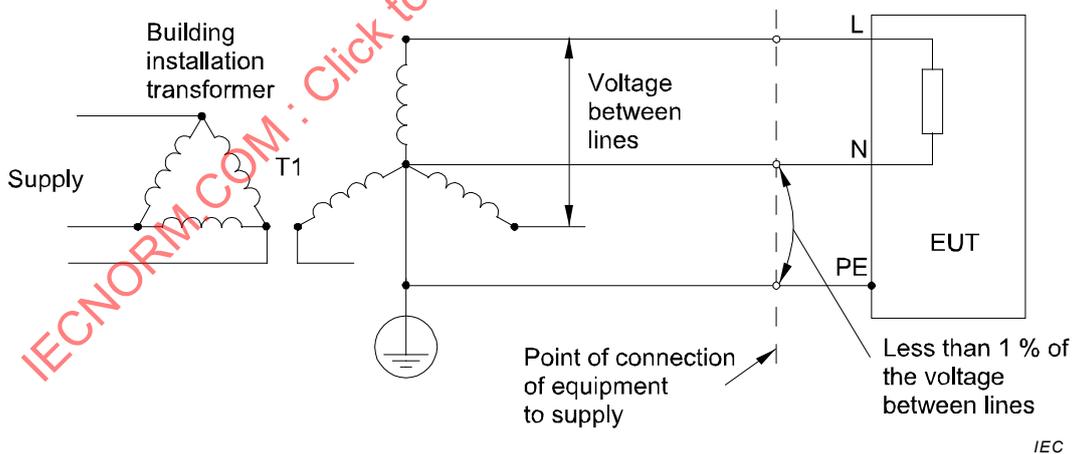


Figure 1 – Example of earthed neutral, direct supply

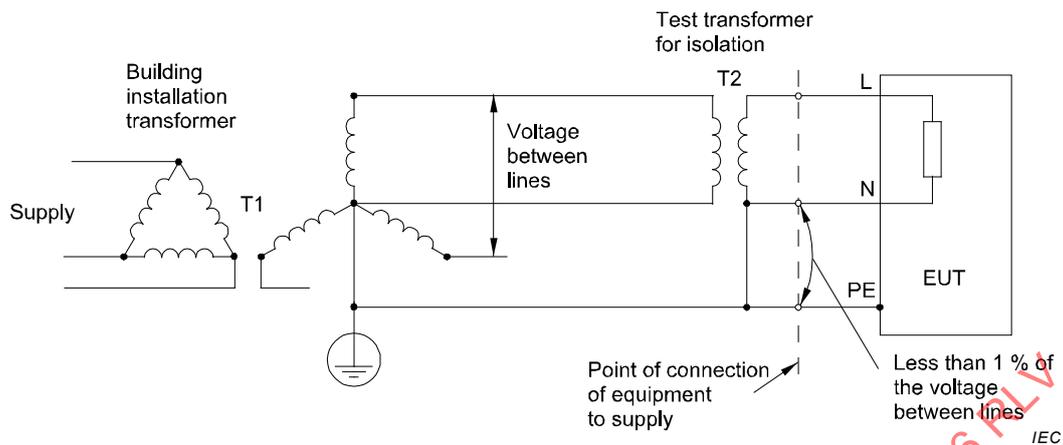


Figure 2 – Example of earthed neutral, with transformer for isolation

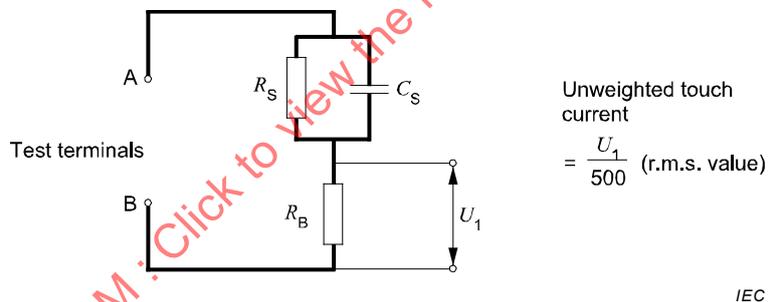
5 Measuring equipment

5.1 Selection of measuring network

5.1.1 General

Measurements shall be made with one of the networks of Figure 3, Figure 4 and Figure 5.

NOTE See Annexes E, F and G for further explanation of the three networks.

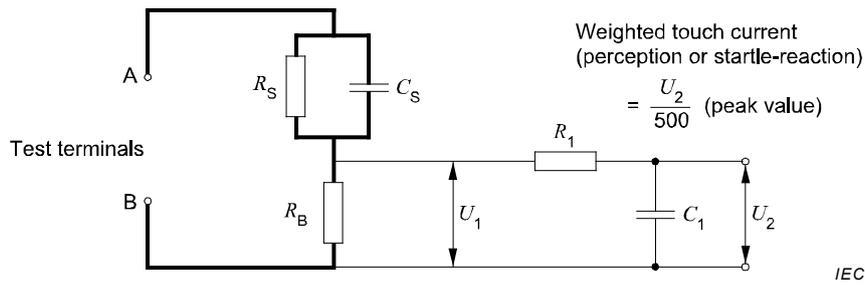


$$R_S = 1\,500 \, \Omega$$

$$R_B = 500 \, \Omega$$

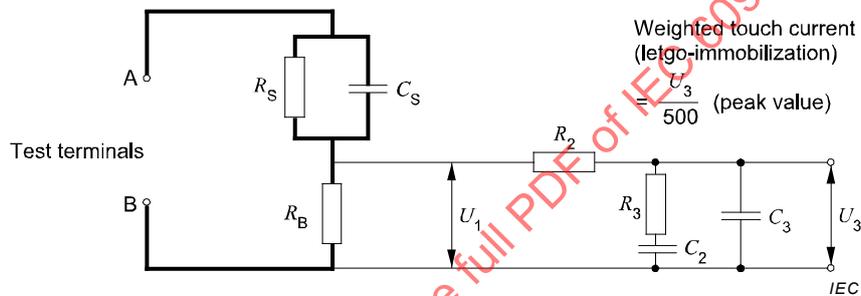
$$C_S = 0,22 \, \mu\text{F}$$

Figure 3 – Measuring network, unweighted touch current



R_S	1 500 Ω	R_1	10 000 Ω
R_B	500 Ω	C_1	0,022 μF
C_S	0,22 μF		

Figure 4 – Measuring network, touch current weighted for perception or startle-reaction



R_S	1 500 Ω	R_3	20 000 Ω
R_B	500 Ω	C_2	0,006 2 μF
C_S	0,22 μF	C_3	0,009 1 μF
R_2	10 000 Ω		

NOTE For special conditions on the use of this network, see 5.1.2.

Figure 5 – Measuring network, touch current weighted for letgo-immobilization

5.1.2 Perception and startle-reaction

The network of Figure 4 shall be used for low level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is up to 2 mA r.m.s. or 2,8 mA peak.

5.1.3 Letgo-immobilization

The network of Figure 5 shall be used for higher level electric shock limits. This circuit is to be applied where the a.c. limit value in the product standard is more than 2 mA r.m.s. or 2,8 mA peak.

5.1.4 Electric burn (a.c.)

The unweighted TOUCH CURRENT network of Figure 3 shall be used.

5.1.5 Ripple-free d.c.

Any one of the three networks shall be used. Unless otherwise specified in the EQUIPMENT standard, ripple-free d.c. means less than 10 % peak-to-peak ripple.

5.2 Test electrodes

5.2.1 Construction

Unless otherwise specified in the EQUIPMENT standard, the test electrodes shall be

- a test clip, or
- a 10 cm × 20 cm metal foil to represent the human hand. Where adhesive metal foil is used, the adhesive shall be conductive.

5.2.2 Connection

Test electrodes shall be connected to test terminals A and B of the measuring network.

5.3 Configuration

The EQUIPMENT under test (EUT) shall be fully assembled and ready for use in the maximum configuration; it shall be connected to external signal voltages where applicable, as specified by the manufacturer for a single EQUIPMENT.

EQUIPMENT which is designed for multiple power sources, only one of which is required at a time (for example, for backup), shall be tested with only one source connected.

EQUIPMENT requiring power simultaneously from two or more power sources shall be tested with all power sources connected but with not more than one connection to protective earth.

5.4 Power connections during test

5.4.1 General

NOTE Examples of power distribution systems are given in Annex I.

EQUIPMENT shall be connected in a test configuration as shown in Figure 6 to Figure 14, according to 5.4.2, 5.4.3 or 5.4.4, as appropriate.

EQUIPMENT committees should consider the possible need for the manufacturer to identify the power distribution system (TN, TT, IT) to which an EQUIPMENT is intended to be connected in its final application.

If the EUT is specified by the manufacturer for use only on certain power distribution systems, the EUT shall be tested only when connected to those systems.

EQUIPMENT to be connected only to TN or TT systems shall comply with 5.4.2. EQUIPMENT to be connected to IT systems shall comply with 5.4.3 and may also be connected to TN or TT systems.

For Class 0 and Class II EQUIPMENT (see IEC 61140), the protective conductors in Figure 6 through Figure 14 are ignored.

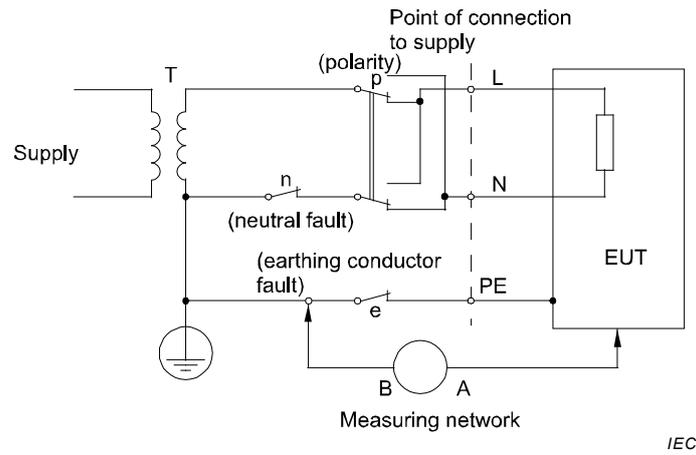
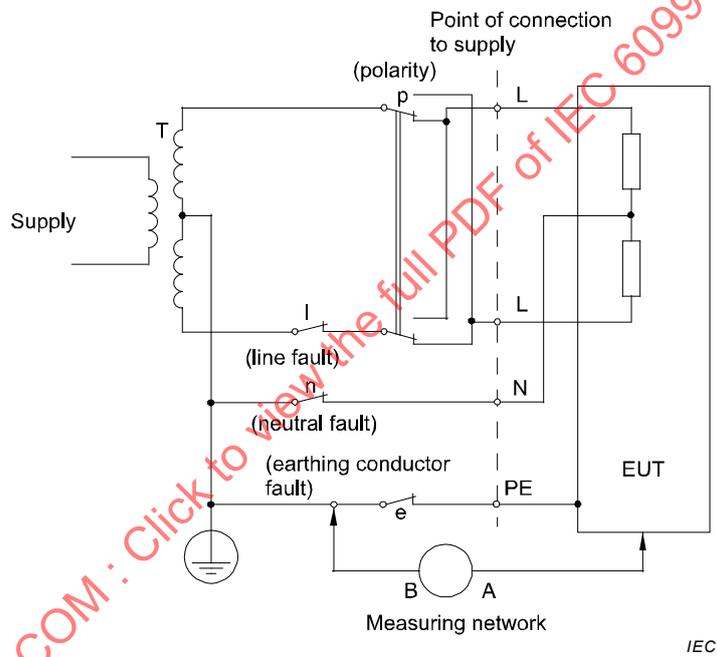


Figure 6 – Single-phase equipment on star TN or TT system



The centre-tapped winding may be one leg of a delta supply.

Figure 7 – Single-phase equipment on centre-earthed TN or TT system

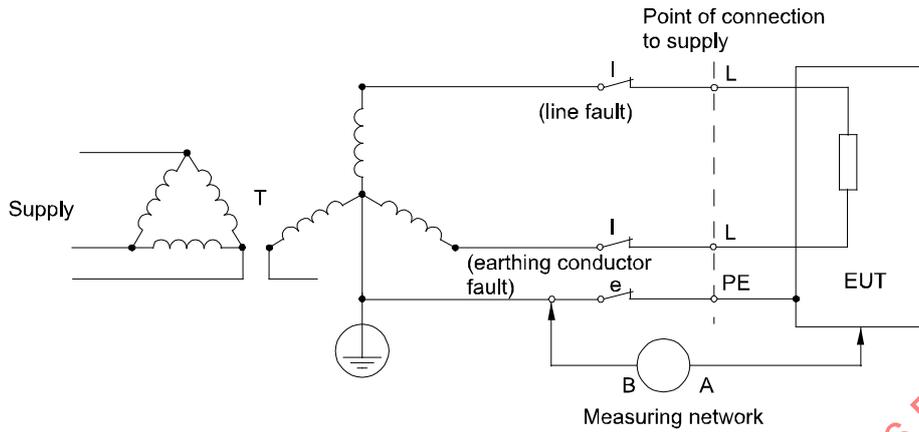
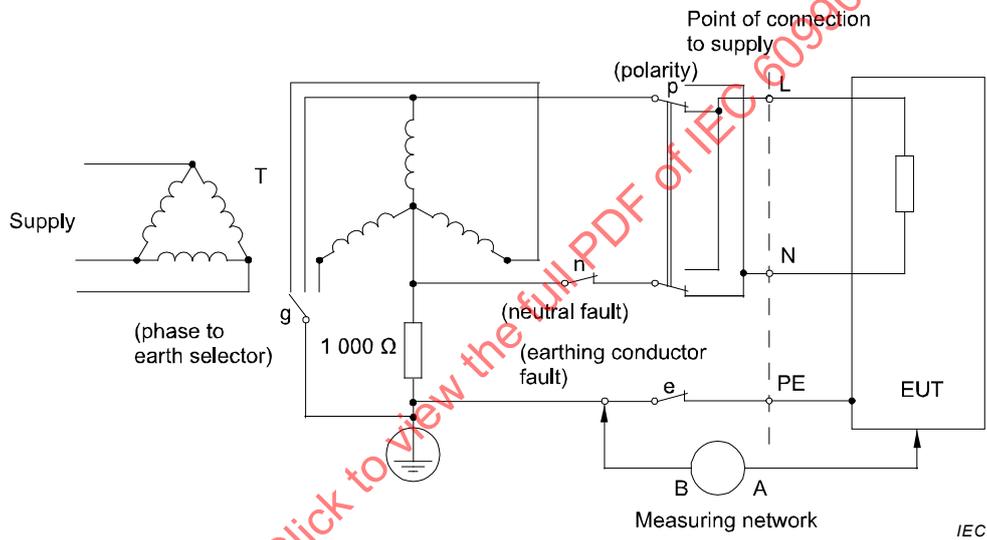
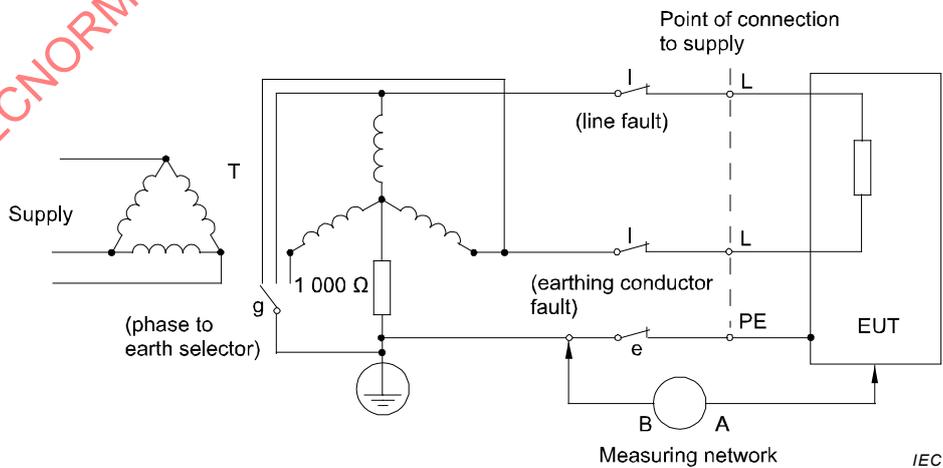


Figure 8 – Single-phase equipment connected line-to-line on star TN or TT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 9 – Single-phase equipment connected line-to-neutral on star IT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 10 – Single-phase equipment connected line-to-line on star IT system

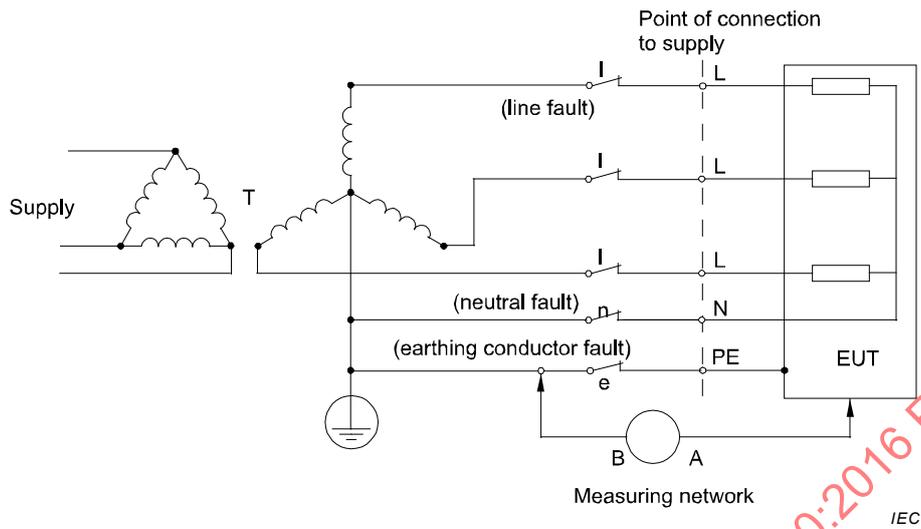
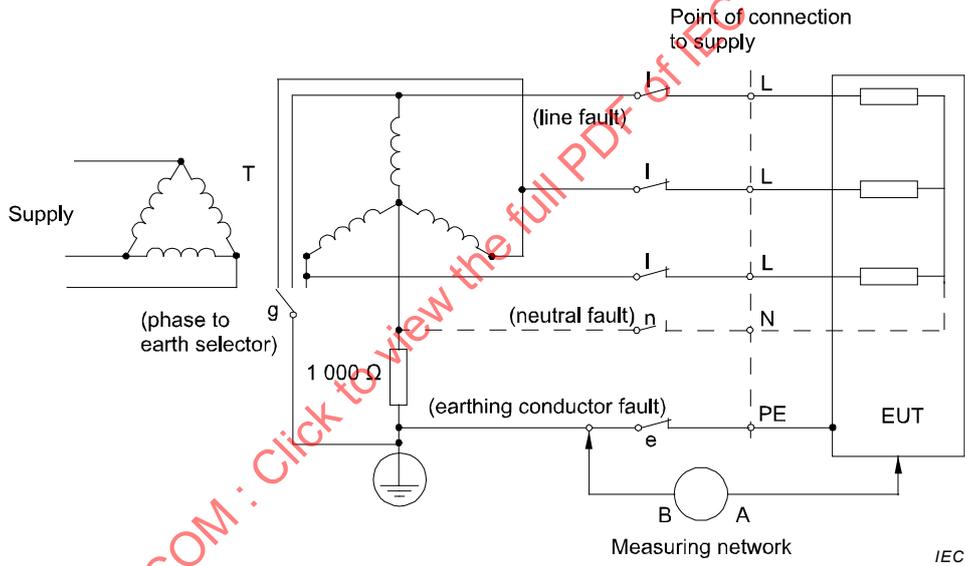


Figure 11 – Three-phase equipment on star TN or TT system



The 1 000 Ω resistor should be rated for supply system faults.

Figure 12 – Three-phase equipment on star IT system

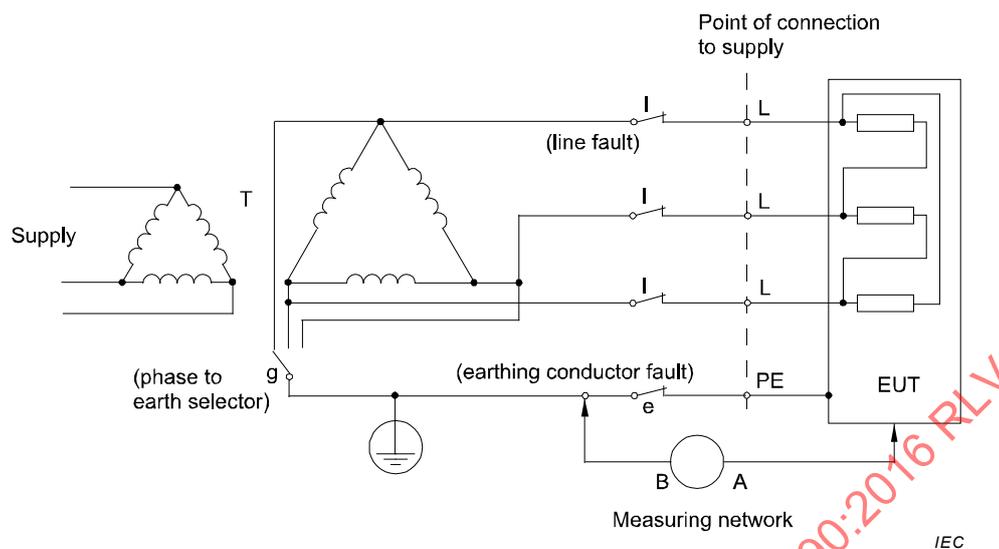
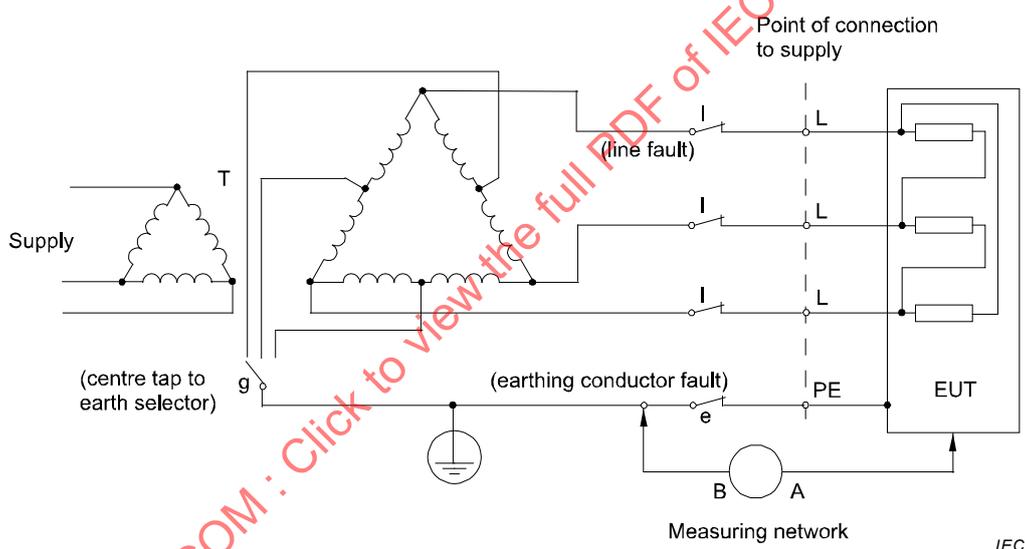


Figure 13 – Unearthed delta system



Where an EQUIPMENT contains both a three-phase load and a centre-earthed single-phase load, and the earthed side is identified, switch g shall remain in the position identified as the earthed side.

Figure 14 – Three-phase equipment on centre-earthed delta system

5.4.2 Equipment for use only on TN or TT star power distribution systems

Three-phase EQUIPMENT shall be connected to a three-phase star power distribution system, with earthed neutral. Single-phase EQUIPMENT shall be connected between phase and neutral of an earthed neutral power distribution system or, where specified by the manufacturer to operate in such a manner, line-to-line on a centre-earthed three-phase star power distribution system (see Figure 6, Figure 8 and Figure 11).

5.4.3 Equipment for use on IT power distribution systems including unearthed delta systems

Three-phase EQUIPMENT shall be connected to an appropriate three-phase IT power supply system. Single-phase EQUIPMENT shall be connected between phase and neutral or, where specified by the manufacturer to operate in such a manner, line-to-line (see Figure 9, Figure 10, Figure 12 and Figure 13).

5.4.4 Equipment for use on single-phase centre-earthed power supply systems or on centre-earthed delta power supply systems

Single-phase EQUIPMENT shall be connected to a supply having its centre tap earthed (see Figure 7 and Figure 14).

Three-phase EQUIPMENT shall be connected to the appropriate delta supply (see Figure 14).

5.5 Supply voltage and frequency

5.5.1 Supply voltage

Supply voltage shall be measured at the EQUIPMENT supply terminals.

Traditionally, TOUCH CURRENT was at its maximum at the highest supply voltage. Modern electronic power supplies will not always provide maximum TOUCH CURRENT under this supply condition. TOUCH CURRENT may be maximized at the lowest voltage, i.e. maximum current draw, or under some other condition. Electric shock protection shall be provided under the worst case operating condition.

EQUIPMENT rated for a single voltage shall be tested at its rated voltage plus an appropriate working tolerance to allow for supply variations.

EQUIPMENT rated for a nominal voltage range shall be tested at the extremes of the voltage range, plus an appropriate working tolerance to allow for supply variations. The working tolerance is determined by the EQUIPMENT committee or by the manufacturer if necessary (for example, 0 %, -10 %/+6 % or +10 %).

EQUIPMENT rated for different nominal voltages or voltage ranges, using a voltage selector, shall be set for the highest nominal voltage or voltage range and then treated as above. Where voltage selection involves more complex switching than a rearrangement of transformer windings, additional tests may be necessary to determine the worst case.

If it is inconvenient to test EQUIPMENT at the specified voltage, it is permitted to test it at any available voltage within the rating of the EQUIPMENT and then calculate the results.

5.5.2 Supply frequency

Supply frequency shall be the maximum rated nominal frequency, or alternatively, measurements may be corrected by calculation for estimation of the worst case current.

6 Test procedure

6.1 General

6.1.1 Touch current measurements

Product committees may wish to exclude measurement of TOUCH CURRENT at some accessible parts, based upon the principle of limitation of voltage (see IEC 60364-4-41). If so, measurements shall be made for accessible voltage and then, if required, for weighted or unweighted TOUCH CURRENT according to Clause 6.

Concern for ELECTRIC BURN effects may arise with d.c. or at high frequencies (for example, above 30 kHz for 3,5 mA TOUCH CURRENT). At lower frequencies, startle-reaction and letgo-immobilization will be the dominant considerations. Where there is such a concern, the unweighted r.m.s. value of TOUCH CURRENT shall be measured (Figure 3), in addition to measurement for either startle-reaction (Figure 4), or inability to let go (Figure 5).

6.1.2 Control switches, equipment and supply conditions

During TOUCH CURRENT measurements, the test environment, configuration, earthing and supply system shall be according to 5.3, 5.4 and 5.5.

In order to maximize the current values during measurements, the configuration shall be varied by connection and disconnection of units that are part of the EQUIPMENT, as permitted by the manufacturer's operating and installation instructions.

Control switches e, g, l, n and p in Figure 6 to Figure 14 shall be manipulated as described in 6.2, while the conditions listed in this subclause and 6.2.1 are independently varied so as to give the maximum measured value or values. Product committees shall make an appropriate selection of these variables. Recent addition of ABNORMAL OPERATION as an operating condition in product standards as related to the electrical installation (e.g. the loss of PE or the inability to ensure polarity of supply) clarifies the test conditions under NORMAL operation and FAULT CONDITIONS to then be applied.

6.1.3 Use of measuring networks

Appropriate measuring electrodes (see 5.2), measuring network (see 5.1) and measuring device (see G.4) shall be used in accordance with the appropriate systems of Figure 6 to Figure 14 (see 5.4) to make measurements of TOUCH CURRENT between simultaneously accessible parts, and between accessible parts and earth.

The terminal A electrode shall be applied to each accessible part in turn.

For each application of the terminal A electrode, the terminal B electrode shall be applied to earth, then applied to each of the other accessible parts in turn.

For power systems with an earthed power conductor, the terminal B electrode may be connected directly to the earthed power conductor at the interface of the EUT and the power supply, instead of being connected to the protective conductor. This connection may be used even though the voltage difference between the protective conductor and the earthed power conductor is more than 1 % of the line-to-line voltage (see 4.2).

6.2 Normal and fault conditions of equipment

6.2.1 Normal operation of equipment

The test is carried out with terminal A of the measuring network connected to each unearthed or conductive accessible part and circuit in turn, with all test switches l, n and e closed.

Measurements shall be made in all applicable conditions of normal operation.

Examples of normal operation include mains switch on, mains switch off, standby, start-up, heating and any setting of operator controls except supply-voltage-setting controls.

Single-phase EQUIPMENT shall be tested in normal and reverse polarity (switch p).

Three-phase EQUIPMENT shall be tested with phase reversals, unless EQUIPMENT operation is dependent on phasing.

6.2.2 Equipment and supply fault conditions

6.2.2.1 General

For EQUIPMENT having no connection to earth, 6.2.2 does not apply.

For EQUIPMENT having a protective earthing connection or a functional earthing connection, terminal A of the measuring network is connected to the EQUIPMENT earthing terminal of the EUT.

Measurements shall be made with each of the applicable fault conditions specified in 6.2.2.2 to 6.2.2.9. The faults shall be applied one at a time, but shall include any faults which are a logical result of the first fault. Before applying any fault, the EQUIPMENT shall be restored to its original condition (for example, without faults or consequential damage).

Where a balanced line filter is used on three-phase EQUIPMENT, the net current to earth is theoretically zero. However, it is normal for component and voltage unbalance to produce a finite value of net current, the maximum value of which may not be measured during type testing. Larger unbalanced currents will result from a failed capacitor in one phase. EQUIPMENT committees should consider including a test for such EQUIPMENT, involving the substitution of a deliberately faulted filter (one capacitor removed), together with a loss of protective earth connection (see 6.2.2.2).

Similar considerations apply to a balanced arrangement of other components, such as surge arrestors, connected between mains and earth.

Three-phase EQUIPMENT shall be tested with phase reversals unless EQUIPMENT operation is dependent on phasing.

6.2.2.2 Fault condition No. 1

Depending on the kind of EQUIPMENT, several safety degrees of the protective conductor are to be distinguished (see IEC 61140).

Single-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e) in combination with normal and reverse polarity (switch p).

Three-phase EQUIPMENT not reliably earthed shall be tested with loss of protective earth connection (switch e).

Unless decided otherwise by the product committee, the requirements of this subclause do not apply to reliably earthed EQUIPMENT which is connected to the supply either permanently, or by means of plugs and sockets which are of industrial grade (for example, connectors specified in IEC 60309-1 or a comparable national standard).

6.2.2.3 Fault condition No. 2

Single-phase EQUIPMENT shall be tested with neutral open (switch n), with earth intact and in normal polarity, and again in reverse polarity (switch p).

6.2.2.4 Fault condition No. 3

EQUIPMENT for use on IT systems shall be tested with each phase conductor faulted to earth, one at a time (switch g).

6.2.2.5 Fault condition No. 4

Three-phase EQUIPMENT shall be tested with each phase conductor open, one at a time (switches l).

6.2.2.6 Fault condition No. 5

Single-phase EQUIPMENT for use on IT power systems or on three-phase delta systems shall be tested with a three-phase power system, with each phase faulted to earth, one at a time

(switch g), in combination with normal and reverse polarity (switch p) and separately with each phase conductor open one at a time (switches l), and in combination with normal and reverse polarity (switch p).

6.2.2.7 Fault condition No. 6

Three-phase EQUIPMENT for use on centre-earthed delta supply systems shall be tested on a delta supply system with each delta-leg centre-earthed, one at a time (switch g).

EQUIPMENT containing both three-phase and centre-earthed circuits which cannot be installed independently and which have an identified earthed leg shall be tested with switch g on the identified earth-leg position only.

6.2.2.8 Fault condition No. 7

Other faults as specified by the product committee shall be simulated if they are likely to increase TOUCH CURRENT.

6.2.2.9 Fault condition No. 8

Accessible conductive parts which are only incidentally electrically connected to other parts shall be tested both when connected electrically to the other part(s) and when disconnected electrically from the other part(s). See Annex C regarding incidentally connected parts.

7 Evaluation of results

7.1 Perception, startle-reaction and letgo-immobilization

Voltages U_2 and U_3 of Figure 4 and Figure 5 are frequency-weighted values of U_1 , such that a single, low-frequency equivalent indication of TOUCH CURRENT results for all frequencies present above 15 Hz. These weighted values of TOUCH CURRENT are taken as the highest values of U_2 and U_3 measured during the procedure of Clause 6, divided by 500Ω . The maximum values are compared with the limits for perception or startle-reaction and letgo-immobilization specified for the EQUIPMENT (for example, a 50 Hz or 60 Hz limit value).

Measurements for d.c. limits are made in a like manner, but taken as U_1 divided by 500Ω (see also Annex G).

7.2 Electric burn

Where there is concern for ELECTRIC BURN effects (see 6.1), the unweighted r.m.s. or d.c. value of TOUCH CURRENT is measured. This is calculated from the r.m.s. voltage U_1 , measured across the 500Ω resistor of the measuring network of Figure 3.

The effect of TOUCH CURRENT is also related to the area of contact with the human body and the duration of contact. The relationship between these parameters and the establishment of TOUCH CURRENT limits are not in the scope of this standard (see also Clause D.3).

NOTE ELECTRIC BURNS result from the power dissipated as current flows through the resistance of the human skin and body. Other forms of burn can result from electrical EQUIPMENT, for example due to arcing or the by-products of arcing.

8 Measurement of protective conductor current

8.1 General

Current requirements and values for protective conductors are not related to TOUCH CURRENT concerns and, therefore, such limits and methods of measurement are dealt with separately.

8.2 Multiple equipment

Within any shared earthing system, the PROTECTIVE CONDUCTOR CURRENTS of individual EQUIPMENT combine in a non-arithmetic manner. Therefore, THE PROTECTIVE CONDUCTOR CURRENT of a group OF EQUIPMENT earthed by a single protective earthing conductor cannot be reliably predicted from knowledge of individual EQUIPMENT PROTECTIVE CONDUCTOR CURRENTS. Consequently, measurements made on individual EQUIPMENT are of limited use, and the PROTECTIVE CONDUCTOR CURRENT for that group of EQUIPMENT shall be measured in the shared protective earthing conductor.

8.3 Measuring method

The installation PROTECTIVE CONDUCTOR CURRENT shall be measured after installation by inserting an ammeter of negligible impedance (for example, $0,5 \Omega$) in series with the protective conductor. Measurement of PROTECTIVE CONDUCTOR CURRENT is made with the EQUIPMENT and power distribution system running in all normal operating modes.

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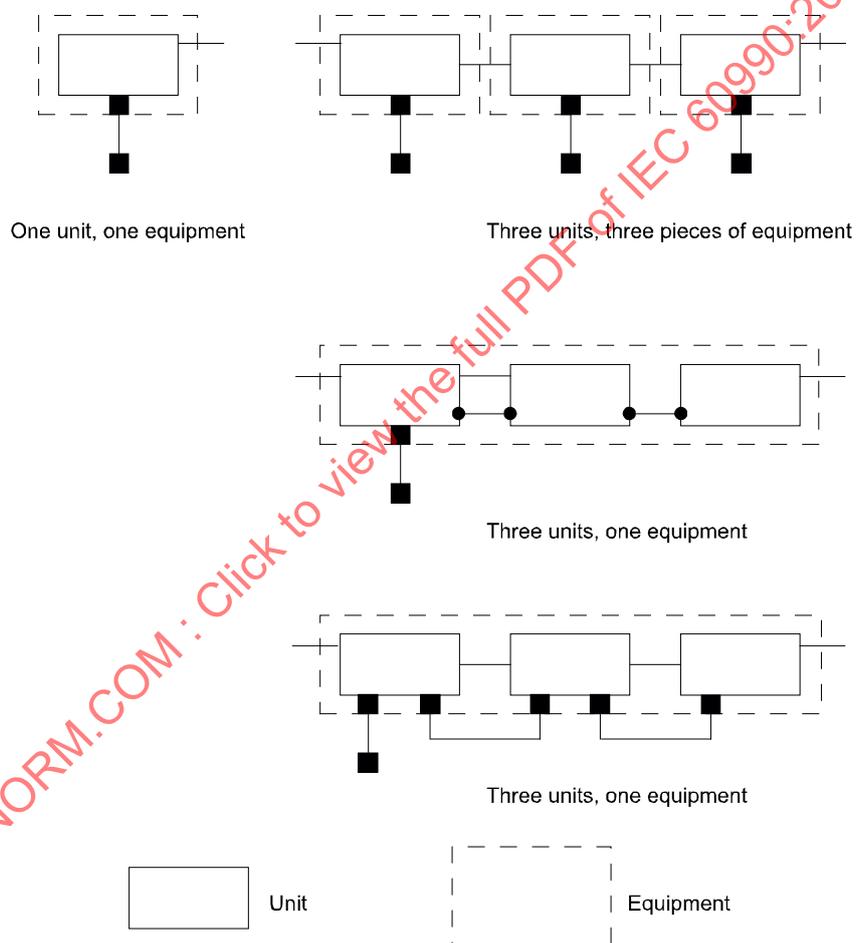
Annex A (normative)

Equipment

Unless otherwise defined in the EQUIPMENT standard, an EQUIPMENT is identified as having a single connection to a supply of electricity.

An EQUIPMENT may be a single unit or may consist of physically separate, electrically interconnected units (see Figure A.1). The source of electricity may be contained within the EQUIPMENT (for example, solar or battery power).

The connection of signal cables shall be considered as part of the EQUIPMENT, in accordance with 5.4.



IEC

Key

- — ■ Supply connection compatible with local supply
- — ● Supply connection not designed to be connected directly to local supply
- Other connections

Figure A.1 – Equipment

Annex B (normative)

Use of a conductive plane

Where limits for TOUCH CURRENT (with or without frequency weighting) less than 70 μA r.m.s. or 100 μA peak are specified, or where an EQUIPMENT is tested that has large capacitive coupling to outer surfaces which may be driven at high frequencies (for example, high-frequency signal generators and voltage measuring instruments), it is appropriate to measure the current which is coupled capacitively into a conductive surface placed beneath or against a surface of the EQUIPMENT. If the EQUIPMENT is to be tested in this manner, it shall be placed on a conductive plane which is in turn placed on an insulating surface (see Figure B.1).

The conductive plane shall be equal to or greater than the adjacent EQUIPMENT surface in area and perimeter.

Measurements shall be according to Clause 6, with the conductive plane tested as an accessible part.

The measurements shall be repeated with the conductive plane placed against any other surface of the EQUIPMENT which may become adjacent to an outside conductive plane.

For purposes of isolation from electromagnetic interference, it may be necessary to place the EQUIPMENT (including the conductive plane, if used) 0,5 m or more from other conductors or EQUIPMENT.

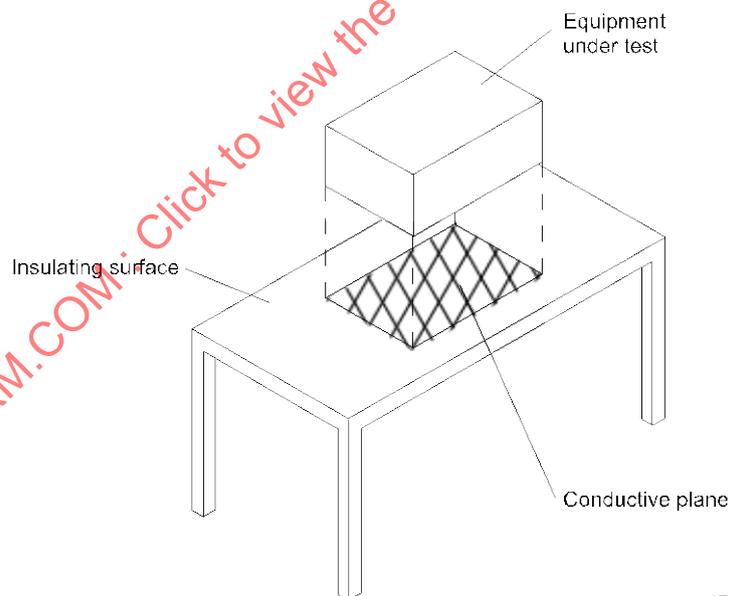


Figure B.1 – Equipment platform

Annex C (normative)

Incidentally connected parts

Incidentally connected parts are accessible conductive parts which are neither reliably connected to, nor positively isolated from, earth or any specified voltage.

Examples of incidentally connected parts include

- doors and assemblies attached by metal hinges,
- adhesively-bonded labels which have an accessible conductive part (for example, metal foil),
- parts which are attached to painted or anodised surfaces,
- control handles.

Some production samples of the EQUIPMENT may have an incidentally connected part effectively connected to earth or to another circuit. In other samples, the same part may be isolated from earth and other circuits. Since, in general, it is not clear which case will produce the higher TOUCH CURRENT, 6.2.2 requires TOUCH CURRENT to be measured for both cases in order to find the worst case. However, where the predominant frequency is below 100 Hz, the worst case is most likely to be that in which the incidentally connected part is connected to the other parts.

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Annex D (informative)

Choice of current limits

D.1 General

When drafting the procedures specified in this standard, certain assumptions were made about the current limits which product committees would use. This was necessary in order to select the appropriate data from IEC TS 60479-1 for design of the measuring networks in Figure 3, Figure 4 and Figure 5.

These assumptions were based on earlier IEC publications. Current values given in this annex are examples only. They are given below for the assistance of product committees when selecting current limits.

D.2 Limit examples

D.2.1 Ventricular fibrillation

No limit assumed.

It is assumed that the limits chosen for TOUCH CURRENTS will be well below the threshold for ventricular fibrillation.

D.2.2 Inability to letgo-immobilization

The method of measurement is specified in this standard.

IEC TS 60479-1 assumes 10 mA r.m.s. as the approximate average threshold level of letgo-immobilization current, whereas 5 mA r.m.s. as proposed for IEC TS 60479-1, would include the entire adult population. See Figure F.3 for the effects of frequency.

D.2.3 Startle-reaction

The method of measurement is specified in this standard.

The startle-reaction threshold given in IEC TS 60479-1 is approximately 0,5 mA r.m.s. for low frequencies. Various limits are in use between the thresholds for startle-reaction and letgo-immobilization.

D.2.4 Perception threshold

TOUCH CURRENT can be perceived at levels as low as a few microamperes. Unless the current is high enough to produce involuntary startle-reaction that might result in harmful effects, these small touch currents are not considered hazardous and not usually measured by these methods.

D.2.5 Special applications

The method of measurement specified in this standard can be used, unless otherwise specified in the applicable standard for the particular product.

0,25 mA r.m.s. (one half of the startle-reaction threshold) is used for Class II EQUIPMENT in product standards such as IEC 60065, IEC 60335-1, IEC 60950-1 and IEC 62368-1. See Figure F.2 for frequency effects.

Limits lower than 0,25 mA r.m.s. are specified for some medical applications. For such applications the method of measurement in this standard may not provide an appropriate body impedance model (see Clause E.1).

D.3 Choice of limits

Consideration should be given to the need to specify different limits for (1) normal operating conditions and (2) fault conditions.

See IEC TS 60479 series for guidance on the effects of current passing through the human body.

Limits are normally expressed in terms of maximum values of d.c. and a.c. at frequencies up to 100 Hz. The methods of measurement specified in this standard are the same for letgo-immobilization, startle-reaction and some special applications. Measuring networks take into account the effect of higher-frequency current on the body and simulate lowering of body impedance as frequency increases. Letgo-immobilization, startle-reaction and perception are determined by peak values of current, weighted for frequency. For ELECTRIC BURN, r.m.s. values are significant. For the scope of this standard, the effects of frequency on ELECTRIC BURNS are negligible, since the predominant effect at low frequency is startle-reaction or letgo-immobilization.

Limits based upon ventricular fibrillation (see D.2.1) are not necessary for most EQUIPMENT, since the lower TOUCH CURRENT limits for startle-reaction or letgo-immobilization almost always prevent ventricular fibrillation. An exception (discussed in IEC TS 60479-1) is where a short-duration current impulse can flow through the body (too short an impulse to cause inability to let go), and startle-reaction from the current impulse is not considered hazardous.

Inability to let-go has traditionally focused on GRIPPABLE PARTS but this is now understood to be a simplistic view. Under this condition the highest limit value for continuous current is the same as letgo-immobilization (see D.2.2), except for consideration of ELECTRIC BURN. However, ELECTRIC BURN only becomes the predominant factor at high frequencies. In the range of the limits for startle-reaction and letgo-immobilization, there may be a secondary safety hazard due to surprise or involuntary muscle reaction, but no direct injury is expected due to current through the body. Such a current may be considered acceptable under single fault conditions, if so product committees should specifically provide an exemption.

For short-duration current, a limit value higher than that for letgo-immobilization is sometimes used, provided that it is sufficiently below the ventricular fibrillation and ELECTRIC BURN threshold. The network of Figure F.3 might be specified by product committees for such a.c. measurements where small area contact is expected.

The startle-reaction network of Figure 4 should be used for measurements where the startle-reaction limit is used for small area contact.

It is understood that the limit values for low-frequency TOUCH CURRENT in other IEC publications are based upon the following considerations.

- Limits for startle-reaction and lower limits:
 - need to avoid involuntary startle-reaction, where severe consequences may result (for example, falling from a ladder or dropping EQUIPMENT);
 - the limit for startle-reaction is generally 0,5 mA r.m.s. or 0,7 mA peak for a sinusoidal current;
 - a limit lower than 0,25 mA r.m.s. (0,35 mA peak) is indicated where the user is particularly sensitive or at risk due to environmental or biological reasons.
- Letgo-immobilization:

- startle and some reaction are acceptable as an indication of a first fault, when the letgo-immobilization limit is applied;
- men and women are estimated to have an average letgo-immobilization threshold of 16 mA r.m.s. and 10,5 mA r.m.s. respectively;
- some people have a lower threshold, for example the 99,5 percentiles of men and women have been reported as 9 mA r.m.s. and 6 mA r.m.s. respectively, and the threshold values for children are expected to be lower;
- certain single fault conditions may justify letgo-immobilization limits, with startle-reaction limits applying for normal (non-fault) conditions.

Certain EQUIPMENT types may have high initial TOUCH CURRENT when first switched on, which diminishes rapidly as EQUIPMENT is operated. This is normally ignored in setting EQUIPMENT limits when specified by the product committee.

D.4 Electric burn effects of touch current

There is no generally accepted limit value of TOUCH CURRENT which will prevent ELECTRIC BURNS in all cases. Other parameters, such as the area of contact with the human body and the duration of contact, are known to be relevant. The relationship between these parameters needs further study. When safe limits are established, they may be in terms of two or more of these parameters.

The method of measurement of TOUCH CURRENT for consideration of ELECTRIC BURN effects is specified in this standard (see 7.2).

The following limit has been used in an IEC standard:

- IEC 61010-1: 500 mA r.m.s. (under fault conditions).

It is reported that skin burns begin to occur at current densities of about 300 mA r.m.s./cm² to 400 mA r.m.s./cm² (Becker, Malhotra and Hedley-Whyte).

Analysis of conditions leading to ELECTRIC BURN has shown that there is a crossover frequency where ELECTRIC BURN exceeds letgo-immobilization and product requirements should reflect the need for making the correct measurement to provide the proper protection. IEC 62368-1 reflects one approach to defining such a requirement.

Annex E (informative)

Networks for use in measurement of touch current

E.1 General

Current values given in this annex are only examples.

The networks of Figure 3, Figure 4 and Figure 5 are intended for TOUCH CURRENT measurements using limits in general use by product committees: for example, from 100 μA r.m.s./140 μA peak up to approximately 10 mA r.m.s./14 mA peak for a.c. and d.c. currents, and covering a frequency range to 1 MHz for sinusoidal, mixed frequency and non-sinusoidal waveforms.

E.2 Body impedance network – Figure 3

The purpose of the network of Figure 3 is to

- simulate the impedance of the human body,
- provide a measurement indicating the level of current which can flow through a human body if the body contacts the EQUIPMENT in a like manner.

R_B models the internal impedance of the human body.

R_S and C_S model the total skin impedance of two points of contact. The value of C_S is determined from the area of skin contact. For larger areas of contact, a larger value (for example, 0,33 μF) may be used.

NOTE The human body model of Figure 3, with the R and C values used herein has traditionally been used in product safety standards for 50 years or more; it has a long history of adequacy for this measurement.

TOUCH CURRENT with regard to ELECTRIC BURN is equal to U_1 r.m.s. divided by 500 Ω .

E.3 Startle-reaction (and body impedance) network – Figure 4

Startle-reaction by the human body is the result of current flowing in the internal portions of the body.

Consideration of, and compensation for, the frequency variation of startle-reaction are required for accurate measurement of this effect. The network of Figure 4 simulates body impedance and provides weighting to follow the frequency characteristics of the body for current causing involuntary startle-reaction. It has been assumed that the shape of the frequency characteristic is the same for reaction and startle, and the data establishing the frequency characteristic was actually obtained through tests on the threshold of startle.

The measurement network is usable for current limits up to the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz. The use of this network for measurement of higher level limits is restricted by the consideration of let-go-immobilization and the need for different frequency weighting where the inability to let go is of concern above these levels (see Clause E.4).

The a.c. or d.c. TOUCH CURRENT with regard to startle-reaction is equal to U_2 peak divided by 500 Ω .

E.4 Letgo-immobilization (and body impedance) network – Figure 5

Immobilization or the inability to let go of an object is caused by current flow internal to the body (for example, through muscles). The measurement network is suitable for current limits above the weighted equivalent of about 2 mA r.m.s. at 50 Hz and 60 Hz.

The effect of frequency on letgo-immobilization limits is different from its effect on startle-reaction, or on ELECTRIC BURN. This is especially true for frequencies above 1 kHz where the filter design takes this into account.

The network of Figure 5 simulates body impedance and is weighted to follow the frequency response of the body to currents which can cause tetanization of muscles (involuntary muscular contraction) and, thereby, an inability to let go. TOUCH CURRENT with regard to the letgo-immobilization is equal to U_3 peak divided by 500 Ω .

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Annex F (informative)

Measuring network limitations and construction

The networks of Figure 3, Figure 4 and Figure 5 are intended to produce a measurable voltage response which approximates the curves given in Figure F.1, Figure F.2 and Figure F.3. The networks and reference curves provided are in general agreement with those published in IEC TS 60479-1 and IEC TS 60479-2, except that, for simplicity of measurement circuits, slight deviations are allowed at the curve inflections between 300 Hz and 10 kHz.

Where limits for ELECTRIC BURN are specified, TOUCH CURRENT is also measured without frequency weighting. The criteria established for ELECTRIC BURN will override criteria for startle-reaction or letgo-immobilization if the r.m.s. current limit for ELECTRIC BURN is exceeded before the weighted peak current limits for startle-reaction and letgo-immobilization are reached. If this occurs, it will usually be in the range of 30 kHz to 500 kHz, depending upon the waveform of the current and limit values used. Unless such frequencies are predominant, no measurement for ELECTRIC BURN limit is necessary.

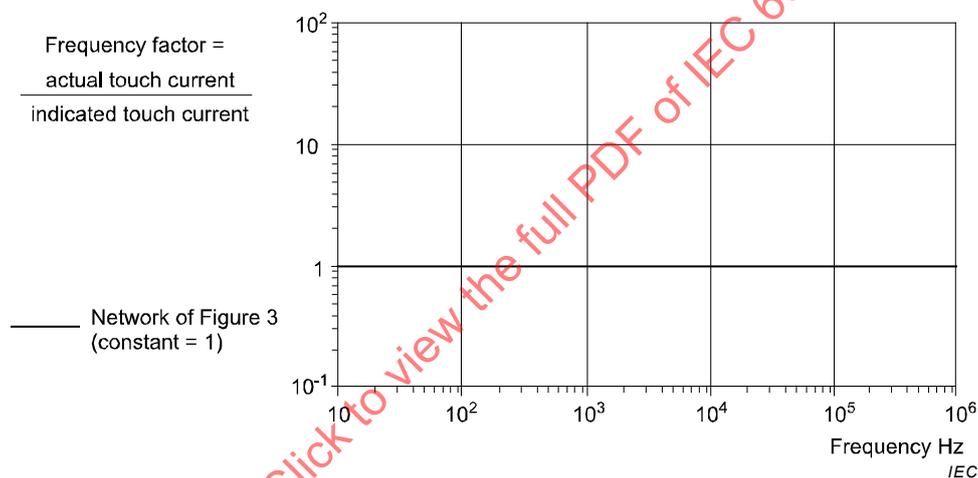


Figure F.1 – Frequency factor for electric burn

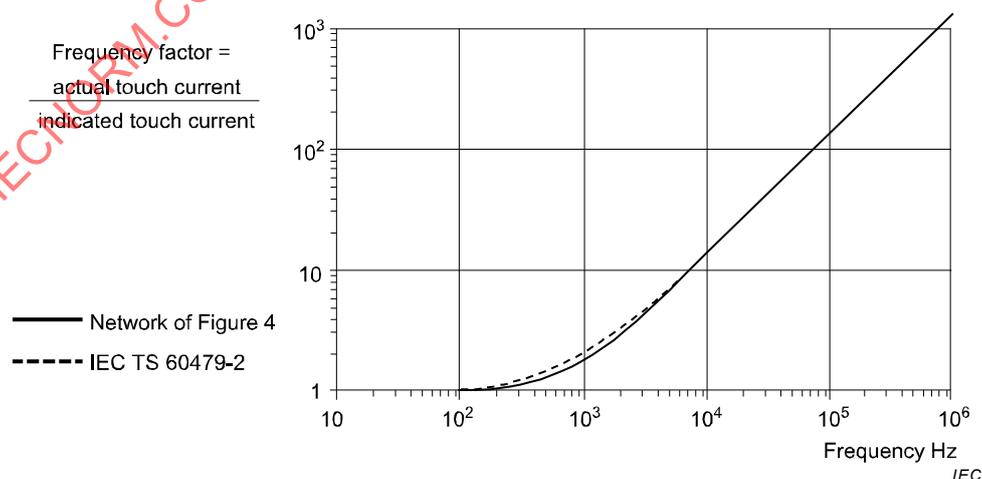


Figure F.2 – Frequency factor for perception or startle-reaction

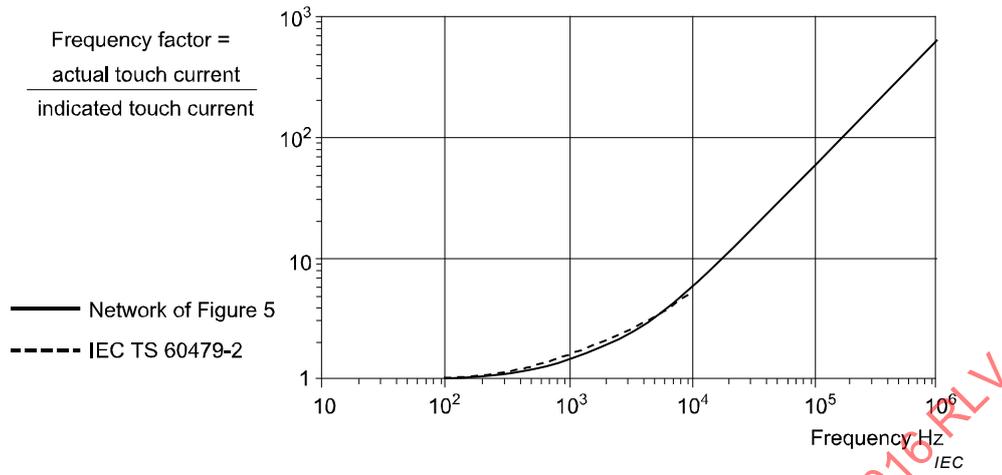


Figure F.3 – Frequency factor for letgo-immobilization

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Annex G (informative)

Construction and application of touch current measuring instruments

G.1 Considerations for selection of components

G.1.1 General

The selection of components for the TOUCH CURRENT measuring networks in Figure F.3, Figure 4 and Figure 5 can be greatly affected by the application, for example, by the current levels and frequencies that are to be measured, and by the tolerances and power handling capability to be considered.

The measuring networks and instruments and the performance specifications discussed in this standard are appropriate for both sinusoidal TOUCH CURRENT waveforms from simple EQUIPMENT and for non-sinusoidal TOUCH CURRENT waveforms from sophisticated products that can generate high frequencies. However, for a limited application, it may not be necessary for a network to cover the complete range of d.c. to 1 MHz, nor to withstand power input levels that are unlikely in the particular application. Simpler current measuring networks and instruments can be substituted for the specified networks and instruments, provided that circuit conditions are such that the readings would be the same.

Information provided here is intended to point out the factors to be considered for each component, so that appropriate decisions can be made for particular applications.

G.1.2 Power rating and inductance for R_S and R_B

Power in R_S and R_B is determined by two factors. One is the possibility of overload at d.c. or low frequencies. If, for example, a 240 V 50 Hz/60 Hz overload capability is desired, R_S shall tolerate 21,6 W and R_B 7,2 W for at least a short time, without shift in value. However, if overloads are not a concern, then 1/2 W or 1 W metal film resistors can provide adequate accuracy, together with a low temperature coefficient and long-term stability.

Based on the above choices, the measuring network should be appropriately marked, unless it is capable of withstanding continuous overloads.

R_B may also dissipate power from high-frequency currents in some applications. For example, if a current at a burn hazard of 500 mA is to be measured, a power of 125 W would be dissipated in R_B . Although this is unlikely, a resistor with this capability could be chosen.

Wire wound power resistors are available to handle the power, if other factors such as accuracy and inductive errors are controlled to acceptable levels for the application. Power resistors with an accuracy of $\pm 1\%$ and $\pm 5\%$ are readily available. Inductance has been measured on typical 12 W and 20 W wire wound resistors and found to be about 30 μH in a 1 000 Ω value. Two such resistors in parallel give 500 Ω and the inductance would cause a 2 % increase in impedance to 510 Ω at 1 MHz. The values of resistor R_S and capacitor C_S control the high-frequency performance of the R_S/R_B network. An inductance of 1 mH, which is much higher than would be expected, in series with R_S (1 500 Ω), causes less than 0,2 % at 1 MHz.

G.1.3 Capacitor C_S

Film capacitors with extended foil construction are recommended. Capacitor C_S may require a voltage rating capable of withstanding short-term overload, for example 250 V a.c., or perhaps 400 V d.c. or 600 V d.c. Film capacitors rated for d.c. will usually tolerate an a.c. peak voltage equal to the d.c. rating for short periods without failure. If the inductance of C_S

and its wiring is to be controlled for performance at 1 MHz, two or three capacitors in parallel may be necessary to achieve accuracy and frequency response.

0,1 μF film capacitors rated 250 V a.c. have been measured for resonance at about 3 MHz. Errors of approximately 3 % at 1 MHz can be expected due to the inductance of such components. Capacitors of lower value than 0,1 μF can be connected in parallel to reduce the inductive error.

G.1.4 Resistors R1, R2 and R3

Metal film resistors will give adequate performance under overload and at frequencies up to 1 MHz. If overload capability is desired (see G.1.2), R1 and R2 should be rated 1 W.

G.1.5 Capacitors C1, C2 and C3

Film type capacitors of extended foil construction are recommended. The inductance of capacitors in this range will generally not result in significant errors up to 1 MHz. Capacitors can be adjusted for tolerance by connecting two or more smaller capacitors in parallel.

G.2 Voltmeter

For full performance up to 1 MHz, the device used for measuring U_1 , U_2 , and U_3 should be a voltage measuring instrument which

- responds to
 - d.c. for d.c. measurements,
 - true r.m.s. for r.m.s. measurements, and
 - peak for peak measurements;
- has an input resistance not less than 1 M Ω ;
- has an input capacitance not more than 200 pF for a.c. measurements;
- has a frequency range for a.c. measurements from 15 Hz to 1 MHz, or more if higher frequencies are involved;
- has floating or differential input with common mode rejection of at least 40 dB up to 1 MHz.

See Clause G.1 regarding the use of simpler instruments for particular applications.

G.3 Accuracy

The overall accuracy of the TOUCH CURRENT measuring network and its voltmeter is influenced by the accuracy of resistors and capacitors, and the frequency response, impedance and accuracy of the voltmeter. Intercomponent capacity and lead inductance also affect the accuracy of a measurement.

NOTE Analysis of the effects of tolerances on the measured TOUCH CURRENT for the specified R and C components in the TOUCH CURRENT meter circuits shows that tolerance of the resistors R_S and R_B primarily affect the measurement results. The effects of the other component tolerances are an order of magnitude lower.

A voltmeter has both an input resistance and an input capacitance. At d.c. or low frequencies, a voltmeter having an input resistance of 1 M Ω used with the measuring network of Figure 4 or Figure 5 will indicate 1 % low due to voltage division with the 10 000 Ω resistor in the measuring network. At high frequencies, the input capacitance of the voltmeter, typically 30 pF, being directly in parallel with the output capacitor of the measuring network, can

cause an indication that is 0,15 % low in the network of Figure 4 and 0,33 % low in the network of Figure 5.

G.4 Calibration and application of measuring instruments

NOTE A definition of calibration is to correlate the readings of an instrument with those of a standard in order to check the instrument.

The performance of an assembled TOUCH CURRENT measuring network or TOUCH CURRENT measuring instrument can be determined by comparing its readings with calculated ideal values throughout the frequency range of interest (see Clause K.1). The error at each frequency of measurement should be noted for many specimens of each instrument. A compilation of error data should be used to establish guard bands within which future measurements are likely to occur. Statistical confidence in the statement regarding the width of the guard bands can be specified. If only one specimen of a particular design of instrument is built, the guard band can be the actual error data.

The establishment of guard bands ensures that measurements can reproducibly indicate whether the EQUIPMENT being tested is within the TOUCH CURRENT limits, when used in the following way.

For equipment manufacturers, the guard band should be added to the reading, and the sum compared to the limit. This ensures that EQUIPMENT indicated as complying with the TOUCH CURRENT limit will not be rejected by the testing laboratory. For testing laboratories, the guard band should be algebraically subtracted from the reading and the difference compared to the limit. This ensures that the testing laboratory will not reject EQUIPMENT that actually complies with the limit. The tolerances for instruments used by a testing laboratory should be sufficiently low to be accommodated by the difference between the limit value and the threshold of the unwanted physiological effect (see IEC TS 60479-1).

If necessary, the guard band of a measuring network can be made narrower, for example by

- selection of components,
- trimming of component values by connecting one or more components in parallel,
- minimizing lead length and sharp bends in leads (to reduce inductance),
- minimizing areas of parts in proximity (to reduce intercomponent capacitances).

It is recommended that equipment manufacturers minimize TOUCH CURRENT levels. The design of EQUIPMENT having current levels close to TOUCH CURRENT limit values is considered to be poor practice due to the effects of component tolerance, ageing, use and environment on TOUCH CURRENT. When the TOUCH CURRENT from the EQUIPMENT is close to the limit value, special care should be taken in measurement precision and calibration of the test EQUIPMENT. If the TOUCH CURRENT is not close to the limit value, a wider guard band will be acceptable for instruments used by a manufacturer.

G.5 Records

For each measuring instrument, records should be established containing periodic measurements of the measuring system. These records will provide data for subsequent confirmation systems (see Clause G.6) and about any limitations in use.

G.6 Confirmation systems

NOTE A definition of metrological confirmation (shortened to "confirmation" in this standard) is given in many quality standards.

Measuring instruments used for EQUIPMENT certification should be subjected to routine confirmation of their accuracy (see Clause K.2).

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Annex H (informative)

Analysis of frequency filtered touch current circuit measurements

Annex H demonstrates the method of measurement of complex waveforms in accordance with IEC TS 60479 series.

Modern oscilloscopes provide accurate numeric value measurement information of waveforms during measurement. Common measurements are r.m.s., peak and peak-to-peak measurements of the waveforms. This annex will show how to use that data to properly develop the needed resulting value which is to be compared to the limit specified in the product standard.

IEC TS 60479-2, special aspects, deals with the complexity of waveforms developed by modern electronic EQUIPMENT that easily switches significant voltages to develop voltages or current adapted for specialized use within EQUIPMENT.

IEC TS 60479-2:2007, 5.2 excerpt: 'Most physiological effects are related to the filtered peak current (in magnitude and duration) with the natural body filter defined by the frequency factor F . The peak value of the current should be used in all cases except ... (when) pure sinusoidal current.'

The frequency factor filters developed for IEC 60990 fit the frequency factor curves of IEC TS 60479-2 extended to 1 MHz, the long standing dividing frequency between electrical safety and EMC, as shown in Annex F. This extension is based upon a general medical understanding of the conduction of current within the body by including a continual increase in the allowed current to the end frequency carrying on the same reduction in effects specifically measured. These filters are implemented as an inverse of the frequency factor curves to aid in simplifying the measurements.

To implement the measurement of TOUCH CURRENT according to IEC TS 60479 series, including the frequency factor provisions, IEC 60990 provides two TOUCH CURRENT measurement circuits which meet the frequency factor curves of IEC TS 60479-2 under the following conditions:

- A circuit weighted for startle-reaction (formerly called perception-reaction) – Figure 4.
- A circuit weighted for letgo-immobilization (formerly called let-go) – Figure 5.

SPICE analysis was done for the frequency filtered circuits of Figure 4 and Figure 5 using common waveshapes straightforward for analysis and the results are discussed below. Although only a couple of cycles are shown, this analysis applies to continuous TOUCH CURRENT waveforms. The TOUCH CURRENT is calculated in the analysis and is $V(\text{output}) / 500 \Omega$ which is shown in the plot. The calculation leads to the mV/Ω units (=mA) attached to the TOUCH CURRENT Y / vertical / ordinate axis.

NOTE SPICE output waveform naming explained: $(V(\text{output})/500 \Omega) = \text{weighted touch current}$ and $\text{xmV}/\Omega = \text{xmA}$ touch current calculated using the voltage output from the startle-reaction/Figure 4 or the letgo-immobilization/Figure 5 filtered circuit.

Bipolar waveform examples

Bipolar alternating current waveforms include:

- sinusoidal waves (the most common example); and
- non-sinusoidal waveforms developed by electronic switching within products for power distribution and utilization.

A simple example is that of a 50 Hz (20 ms) triangular waveform shown in Figure H.1 and Figure H.2.

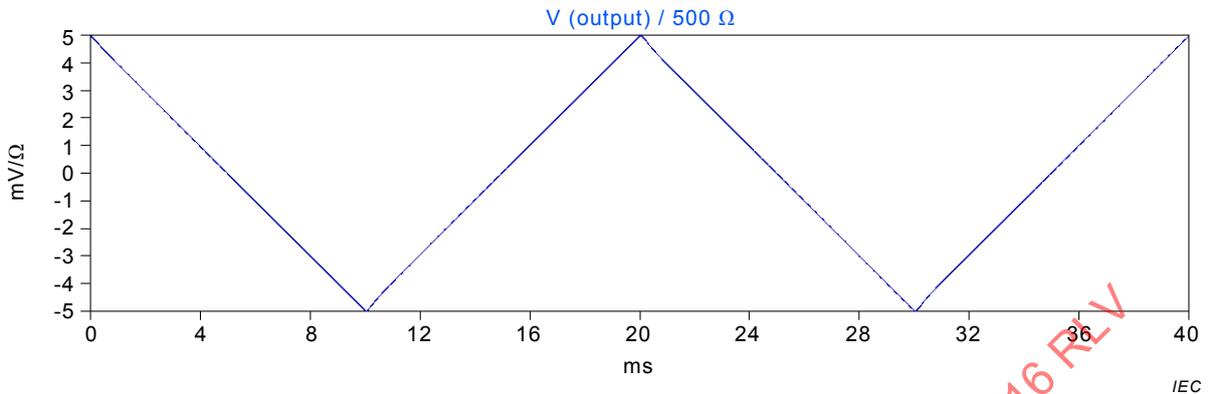


Figure H.1 – Triangular waveform touch current, startle-reaction

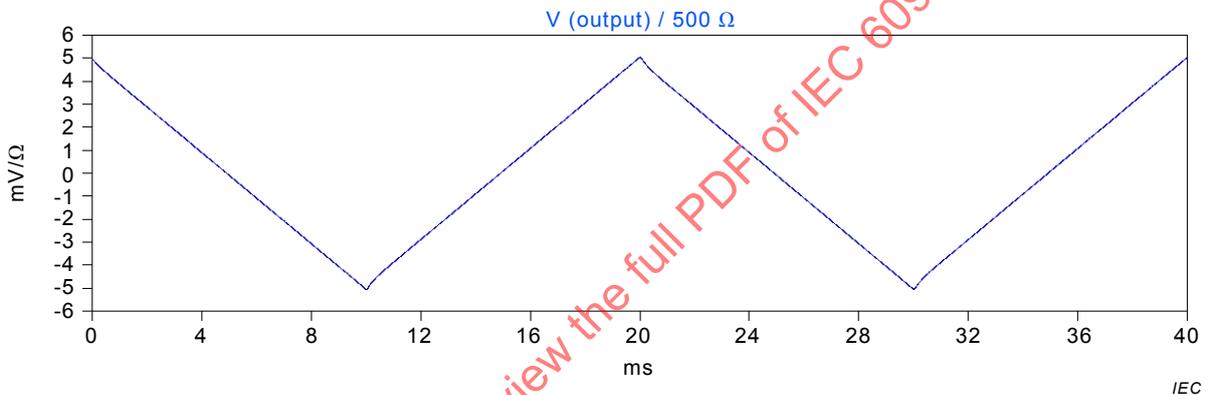


Figure H.2 – Triangular waveform touch current, letgo-immobilization

The input conditions are the same as for an equivalent sinusoidal waveform the results are not the same. The peak value shown in Table H.1 is the peak-to-peak value divided by 2. The peak current is at the 5 mA peak level but the r.m.s. value is below the 3,5 mA level of the example above. The peak measurement be used to adequately compare the level of TOUCH CURRENT hazard to the body. In this case the r.m.s. value when used as a measure of adequacy would indicate a margin below that of a sinusoidal limit value which is an unwarranted sense of protection available.

Table H.1 – Triangular waveform response comparison

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	4,98 mA	2,868 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	5,05 mA	2,869 mA

The filter circuit component of the TC circuits properly acts on the high frequency components of each waveform.

Another simple circuit of interest is a 50 Hz square wave shown in Figure H.3 and Figure H.4.

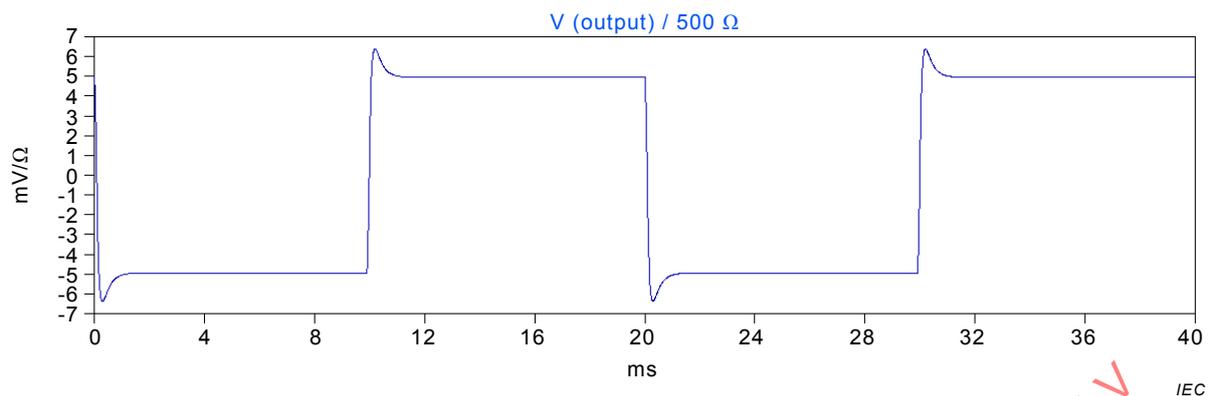


Figure H.3 – 1 ms rise time pulse response, startle-reaction

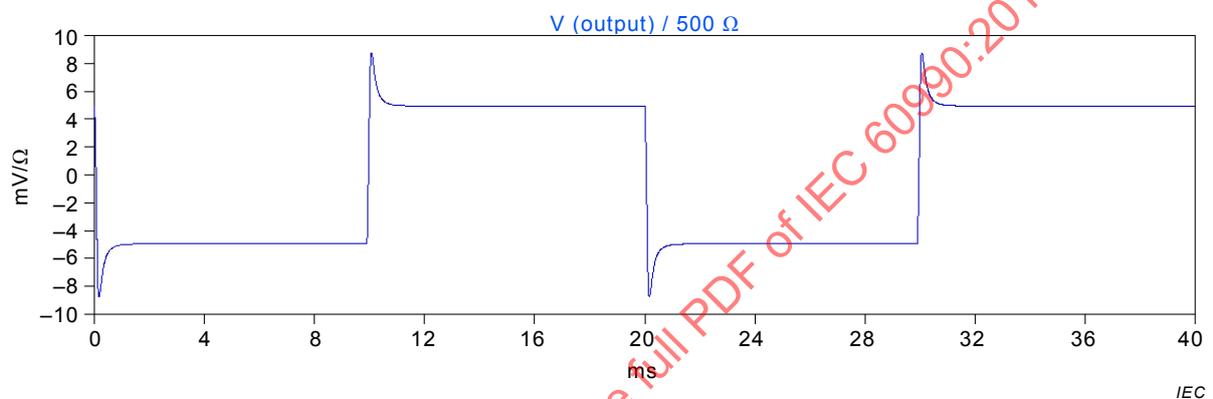


Figure H.4 – 1 ms rise time pulse response, letgo-immobilization

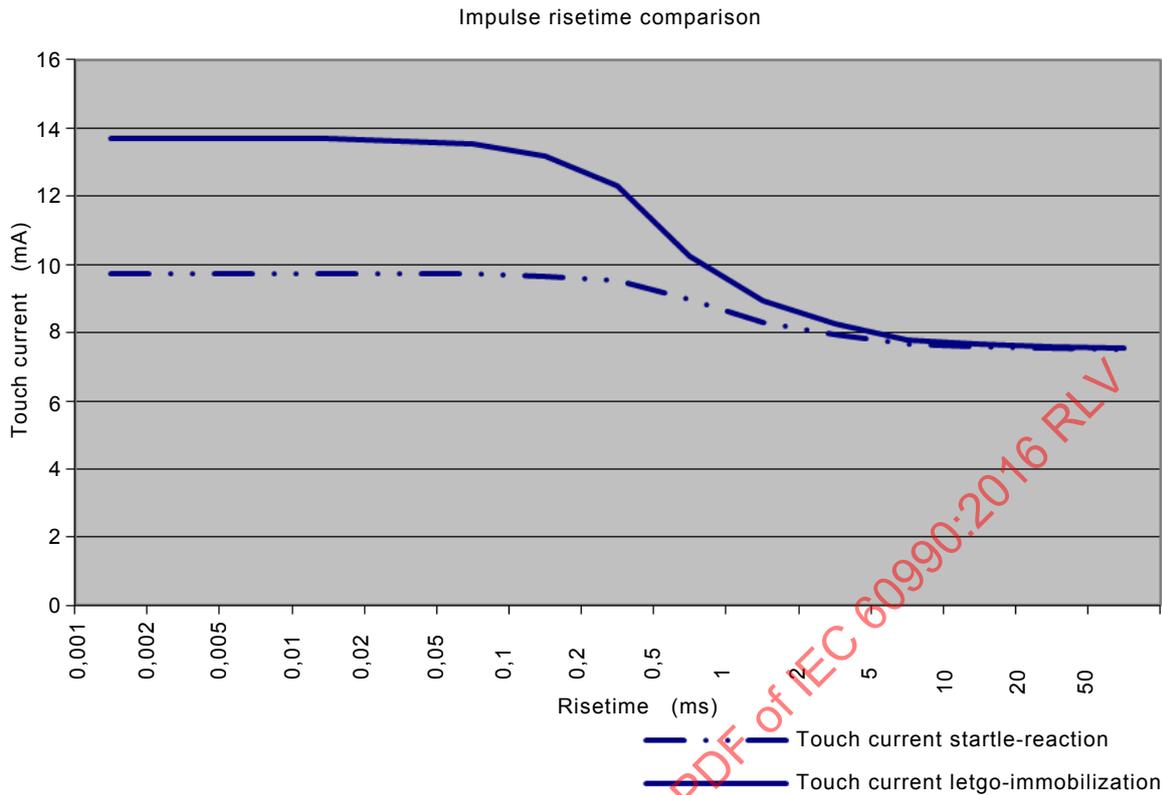
The steady value is 5 mA but the peak value (= peak-to-peak / 2) is higher in each case as shown in Table H.2.

Table H.2 – Square wave touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	6,39 mA	4,991 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,758 mA	5,054 mA

The letgo-immobilization circuit allows more high frequency current through the filter, therefore the peak value is higher.

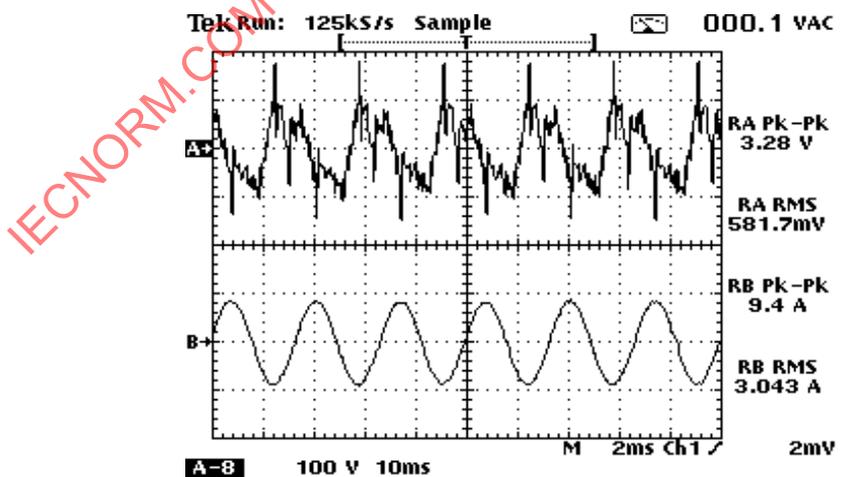
The rise time is a key factor in the peak TOUCH CURRENT for a fast rising waveform. For this type of waveform, the rise time affects the TOUCH CURRENT by up to a factor of 2 as shown in the TOUCH CURRENT versus rise time plot as shown in Figure H.5.



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Figure H.5 – Touch current vs. rise time plot, 20 ms square wave

TOUCH CURRENT waveforms have been published for dozens of pieces of modern EQUIPMENT¹. The use of mains switching devices including efforts to restore sinusoidal input current (power factor correction = PFC) and, more recently, to add higher energy efficiency to Switch Mode Power Supplies (SMPS) has led to more complicated TOUCH CURRENT waveforms. One of the more complicated waveforms that has been seen is shown in waveform A of Figure H.6.



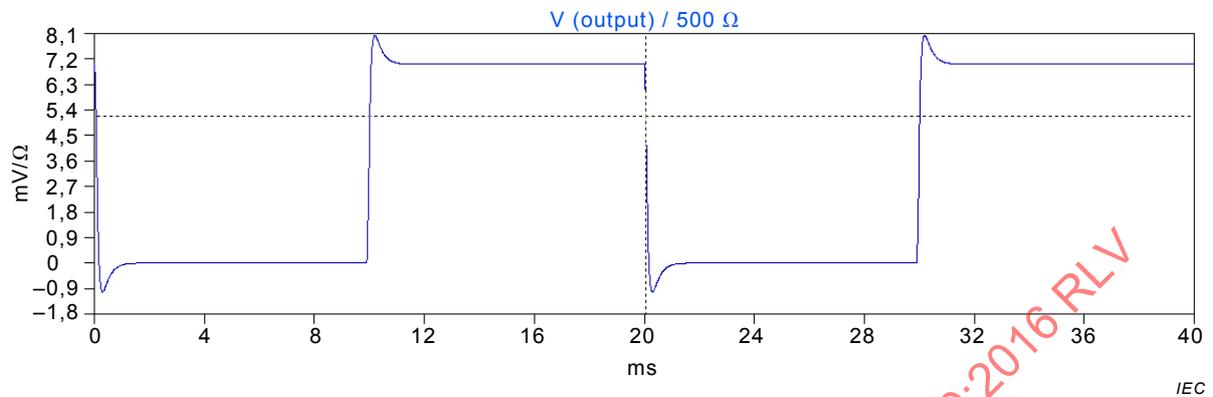
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Figure H.6 – PFC SMPS touch current waveform

¹ 'Touch current comparison data'; Perkins, 2006. A collection of more than two dozen touch current waveforms from a variety of equipment; posted on www.safetylink.com, search on perkins.

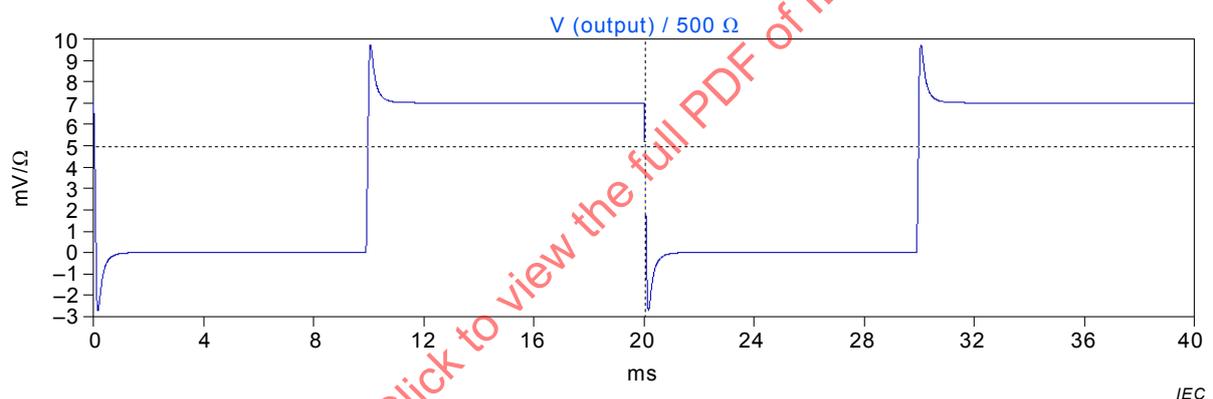
Monopolar waveform example

DC applications are the most common examples of monopolar waveforms. Of specific interest are switched d.c. applications that are discussed here and shown in Figure H.7 and Figure H.8.



r.m.s. value indicated

Figure H.7 – 50 Hz square wave, 0,1 ms rise time, startle-reaction



r.m.s. value indicated

Figure H.8 – 50 Hz square wave, 0,1 ms rise time, letgo-immobilization

For monopolar waveforms the peak value of the TOUCH CURRENT is used. The overshoot on top of the d.c. pulse is included in the measurement, the undershoot is not included.

Table H.3 – Square wave monopolar touch current response

Circuit / TOUCH CURRENT response	Peak	r.m.s.
Startle-reaction circuit TOUCH CURRENT I [V(output) / 500 Ω]	8,031 mA	5,006 mA
Letgo-immobilization circuit TOUCH CURRENT I [V(output) / 500 Ω]	9,716 mA	5,037 mA

As before, the rise time of the waveform affects the overshoot and the peak value of the TOUCH CURRENT as shown in Table H.3.

Mixed a.c./d.c. examples

IEC TS 60479-2:2007, Figure 7 shows the let-go threshold expressed in peak mA for the combinations of 50/60 Hz sinusoidal alternating current and direct current. The peak of the

composite a.c. and d.c. wave in mA at the let-go threshold estimated for the population of humans including children is shown as a function of the direct current component in mA.

IEC TS 60479-2:2007, Figure 7 is represented by the equation for the composite current:

$$ACpk+DC = 7,176^{(-0,1434 \times DC)} - 0,1061 + DC$$

These effects are related to the peak value of the current and they have to be combined frequency per frequency to estimate the total effect. A measurement circuit is described in this standard.

Herein is shown to the use of IEC 60990 circuits to make measurement of mixed a.c./d.c. TOUCH CURRENTS and properly evaluate them against the equation above. The IEC TS 60479-2:2007, Figure 7 is repeated in Figure H.9 and annotated with some additional data from the waveforms discussed in this annex.

NOTE The composite waveform shown in IEC TS 60479-2:2007, Figure 7 is named ACpknDC in the plot of Figure 9 below. The examples are ACpknDCex1 and ACpknDCex2; the DC values are similarly named as explained in the text following.

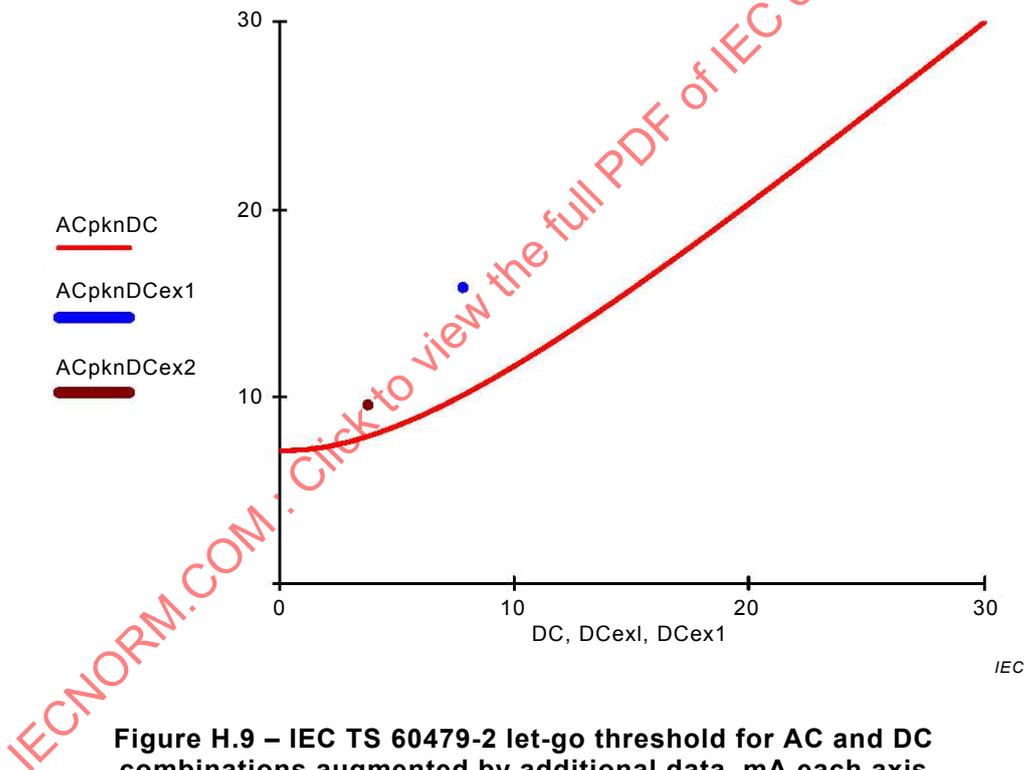


Figure H.9 – IEC TS 60479-2 let-go threshold for AC and DC combinations augmented by additional data, mA each axis

The procedure is as follows. The maximum peak absolute value of the composite waveform is selected (**bold values** of TOUCH CURRENT in the tables) to be plotted as ACpknDC. The peak-equivalent (pk-ev) value is calculated from the r.m.s. value; this is subtracted from the maximum peak value to get the DC value needed for the plot. The values derived from the measurements can be plotted on the same graph as the curve to compare as is done here or, alternatively, the DC value can be entered into the equation for the composite current to calculate the ACpk+DC and compared to the measurement derived value called ACpknDC.

Example 1 (ex1):

The first example (shown in Figure H.10) analyzed for letgo-immobilization.

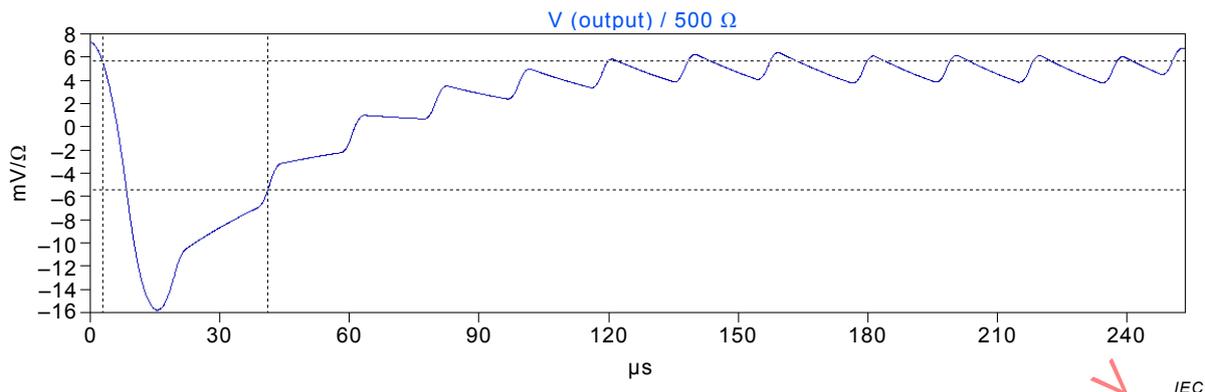


Figure H.10 – Ex1 case: showing r.m.s. window

For the ex1 case shown above, see Table H.4.

Table H.4 – Mixed ACnDC waveform evaluation, ex1

	TOUCH CURRENT peak	TOUCH CURRENT r.m.s.
Letgo-immobilization case	+7,281 96 / -15,788 2 mA peak	5,644 6 mA r.m.s. Pk-ev: 5,644 6 × 1,414 = 8 mA peak 15,79 – 8 = 7,79 mA d.c.
The values in the table correspond to the plotted values (with rounding included in the latter) of Figure H.10.		

The values to be plotted for graphical evaluation are:

ACpknDCex1 = 15,8, DCex1 = 7,79

Example 2 (ex2):

Another mixed case, ex2, is shown in Figure H.11 and Table H.5.

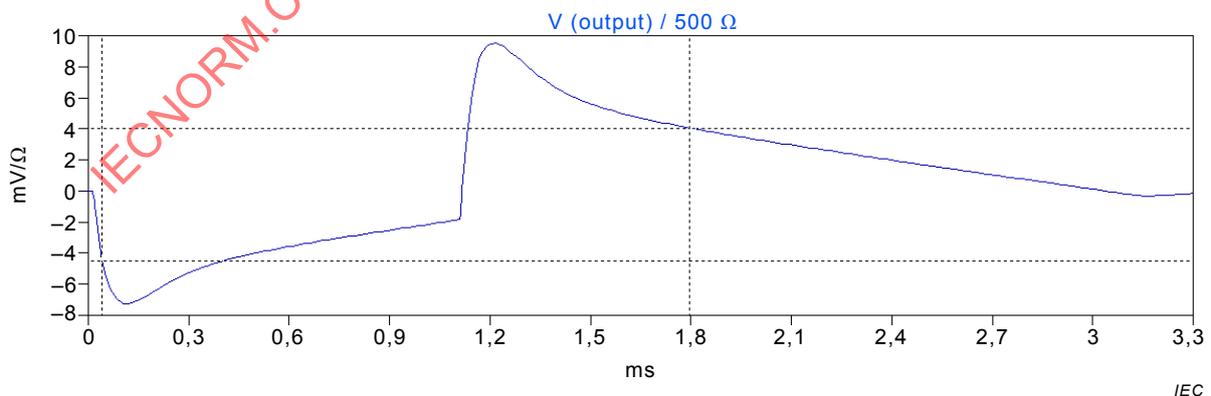


Figure H.11 – Waveform ex2 case: showing r.m.s. window

Table H.5 – Mixed ACnDC waveform evaluation, ex2

	TOUCH CURRENT peak	TOUCH CURRENT r.m.s
Letgo-immobilization case	9,524 69 / -7,247 19 mA peak	4,085 4 mA r.m.s. Pk-ev: 4,085 4 × 1,414 = 5,777 6 mA peak 9,524 7 – 5,777 6 = 3,747 1 mA d.c.
The values in bold in the table correspond to the plotted values (with rounding included in the latter) of Figure H.11.		

The values to be plotted for graphical evaluation are:

$$\text{ACpknDCex2} = 9,52, \quad \text{DCex2} = 3,75$$

Each example falls above the letgo-immobilization curve and fails to meet a letgo-immobilization TOUCH CURRENT limit of 5 mA r.m.s. / 7 mA peak as described in IEC TS 60479-2.

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Annex I (informative)

AC power distribution systems (see 5.4)

I.1 General

In IEC 60364-1, a.c. power distribution systems are classified TN, TT and IT, depending on the arrangement of current-carrying conductors and on the method of earthing. The classes and codes are explained in this annex. Some examples of each class are given in the Figure I.1 to Figure I.8; other configurations also exist.

In the figures:

- in most cases, the power systems apply for single-phase and three-phase EQUIPMENT but, for simplicity, only single-phase EQUIPMENT is illustrated;
- the power sources may be transformer secondaries, motor-driven generators or uninterruptible power systems;
- for transformers within a user's building, some of the figures apply, and the building boundary represents a floor of the building;
- some power systems are earthed at additional points, for example at the power entry points of users' buildings (see IEC 60364-4-41:2005).

The following types of EQUIPMENT connection are taken into account; the numbers of wires mentioned do not include conductors used exclusively for earthing:

- single-phase, 2-wire;
- single-phase, 3-wire;
- two-phase, 3-wire;
- three-phase, 3-wire;
- three-phase, 4-wire.

The system codes used have the following meaning.

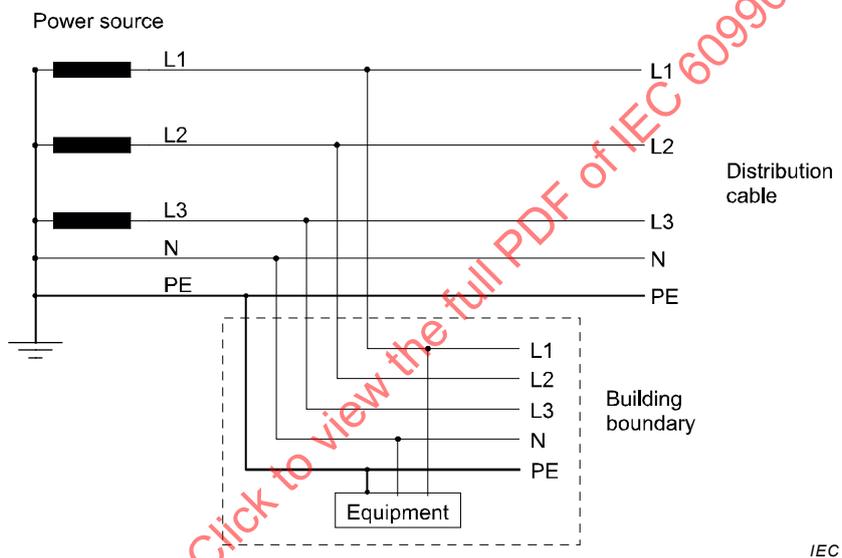
- First letter: relationship of the power system to earth
 - T means direct connection of one pole to earth;
 - I means system isolated from earth, or one point connected to earth through an impedance.
- Second letter: earthing of the EQUIPMENT
 - T means direct electrical connection of the EQUIPMENT to earth, independently of the earthing of any point of the power system;
 - N means direct electrical connection of the EQUIPMENT to the earthed point of the power system (in a.c. systems, the earthed point of the power system is normally the neutral point or, if a neutral point is not available, a phase conductor).
- Subsequent letters, if any: arrangement of neutral and protective conductors
 - S means the protective function is provided by a conductor separate from the neutral or from earthed line (or, in a.c. systems, earthed phase) conductor;
 - C means the neutral and protective functions are combined in a single conductor (PEN conductor).

I.2 TN power systems

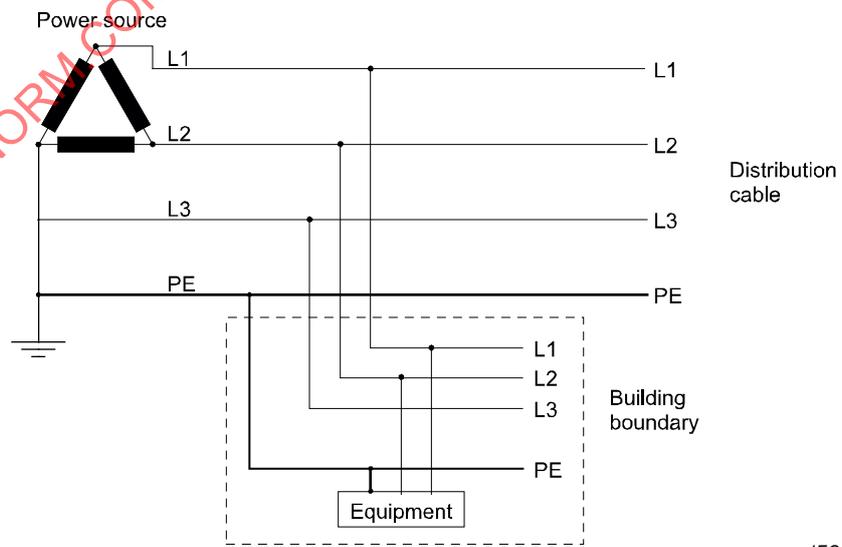
TN power systems are directly earthed, the parts of the EQUIPMENT required to be earthed being connected by protective earthing conductors. Three types of TN power systems are considered:

- TN-S power system: in which a separate protective conductor is used throughout the system;
- TN-C-S power system: in which neutral and protective functions are combined in a single conductor in part of the system;
- TN-C power system: in which neutral and protective functions are combined in a single conductor throughout the system.

Some TN power systems are supplied from a secondary winding of a transformer that has an earthed centre tap (neutral). Where the two phase conductors and the neutral conductor are available, these systems are commonly known as single-phase, 3-wire power systems.

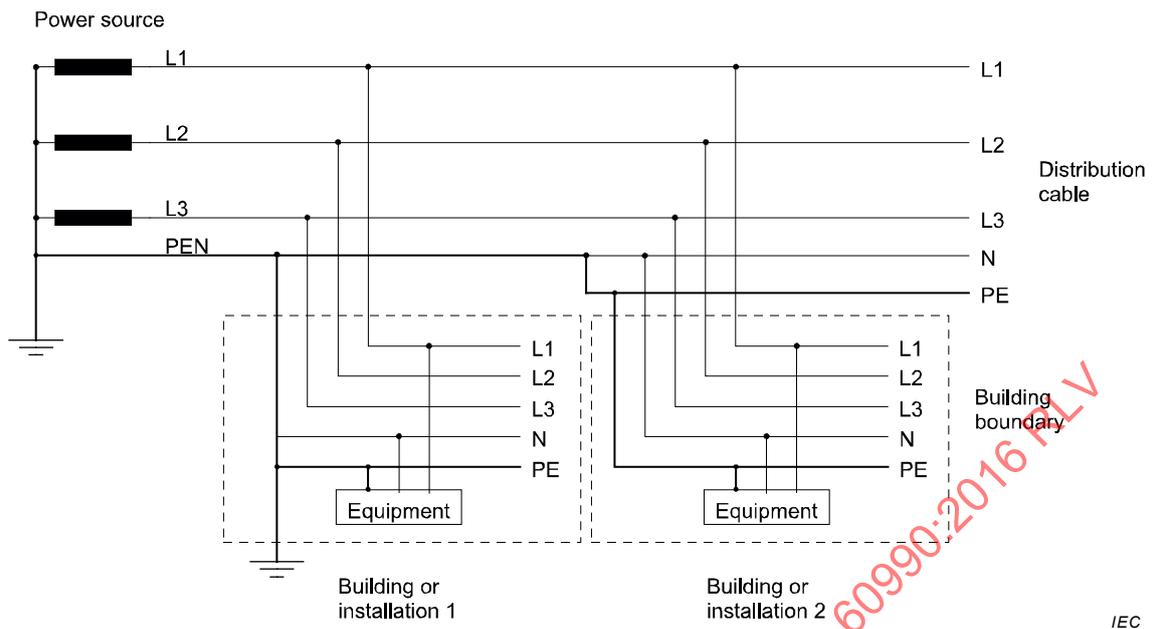


Separate neutral and protective conductors



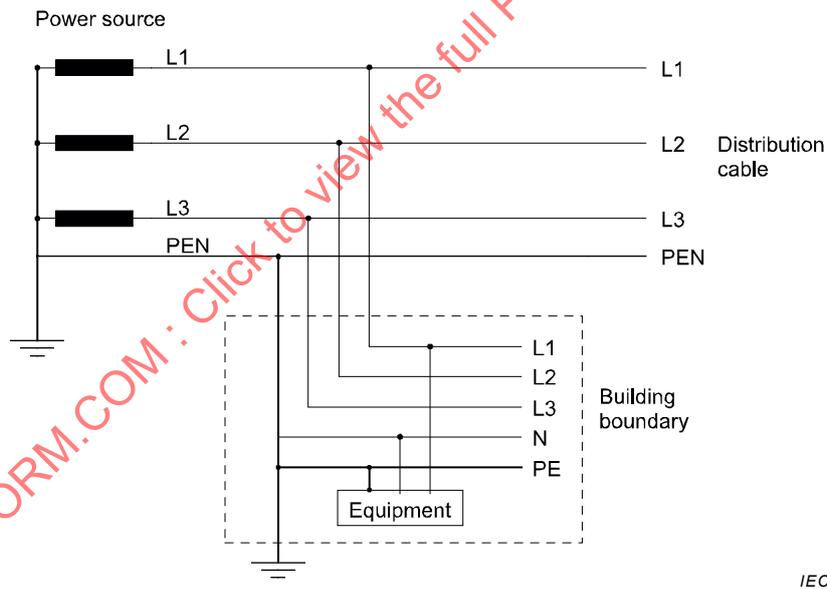
Earthed line conductor

Figure I.1 – Examples of TN-S power system



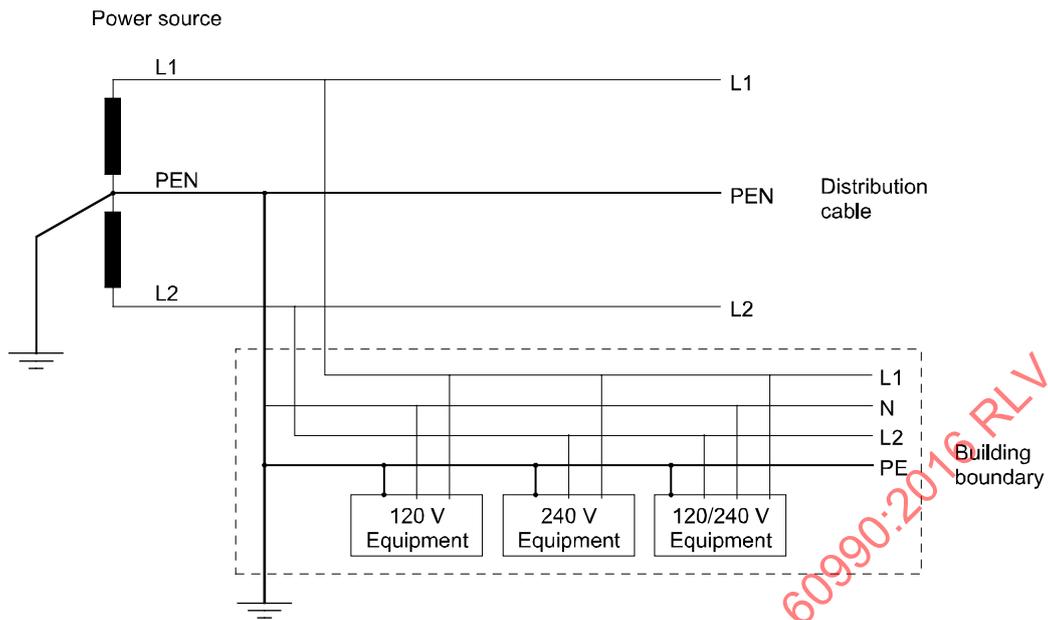
The point at which the PEN conductor is separated into protective earth and neutral conductors may be at the building entrance or at distribution panels within the building.

Figure I.2 – Example of TN-C-S power system



Neutral and protective functions combined in one conductor (PEN)

Figure I.3 – Example of TN-C power system



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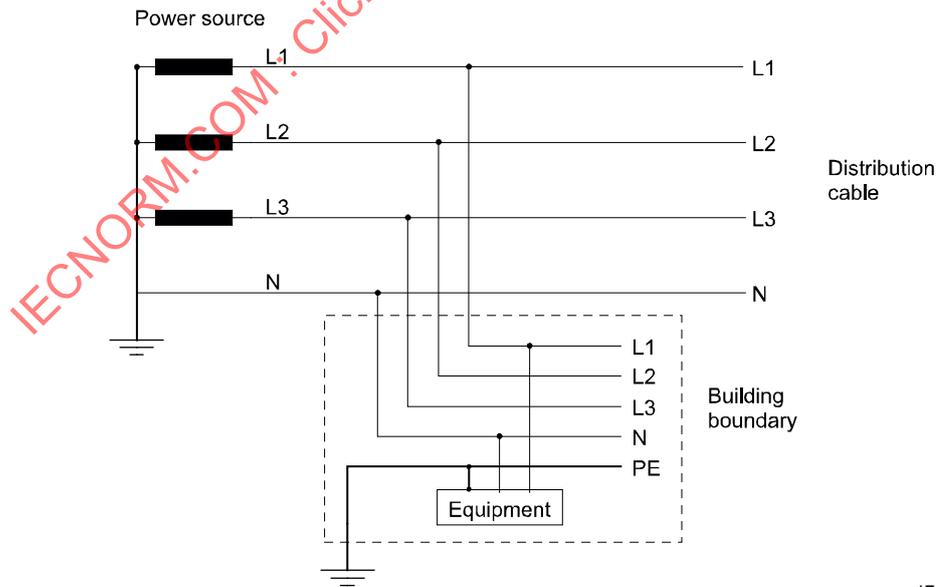
Protective and neutral functions combined in one conductor (PEN)

This system is widely used in North America at 120/240 V.

Figure I.4 – Example of single-phase, 3-wire TN-C power system

I.3 TT power systems

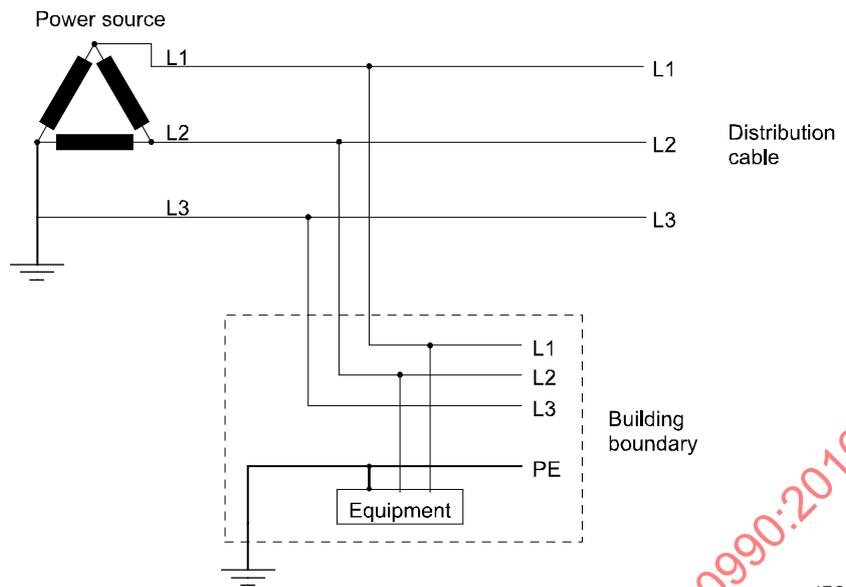
TT power systems have one point directly earthed, the parts of the equipment required to be earthed being connected at the user's premises to earth electrodes that are electrically independent of the earth electrodes of the power distribution system.



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Earthed neutral and independent earthing of EQUIPMENT

Figure I.5 – Example of 3-line and neutral TT power system



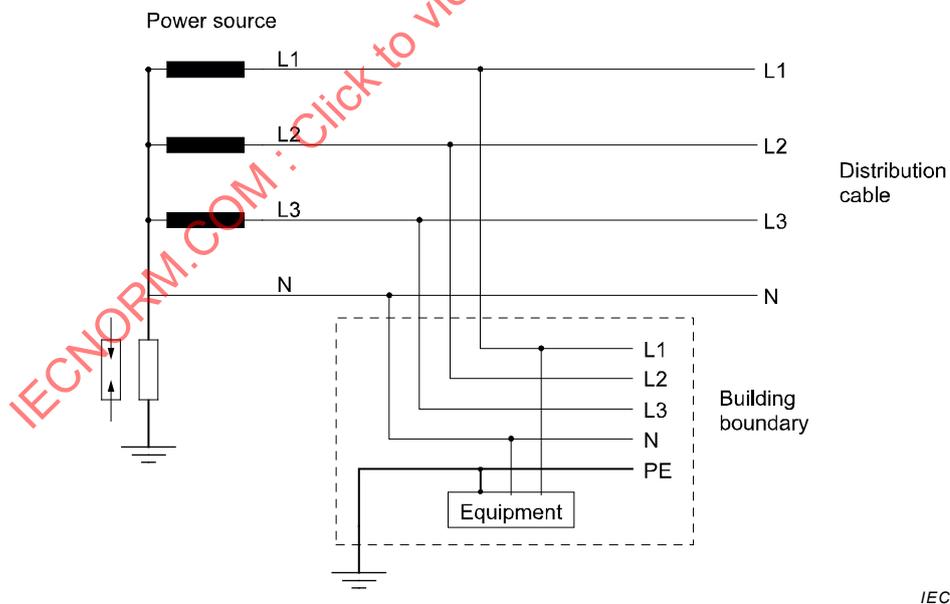
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Earthed line and independent earthing of EQUIPMENT

Figure I.6 – Example of 3-line TT power system

I.4 IT power systems

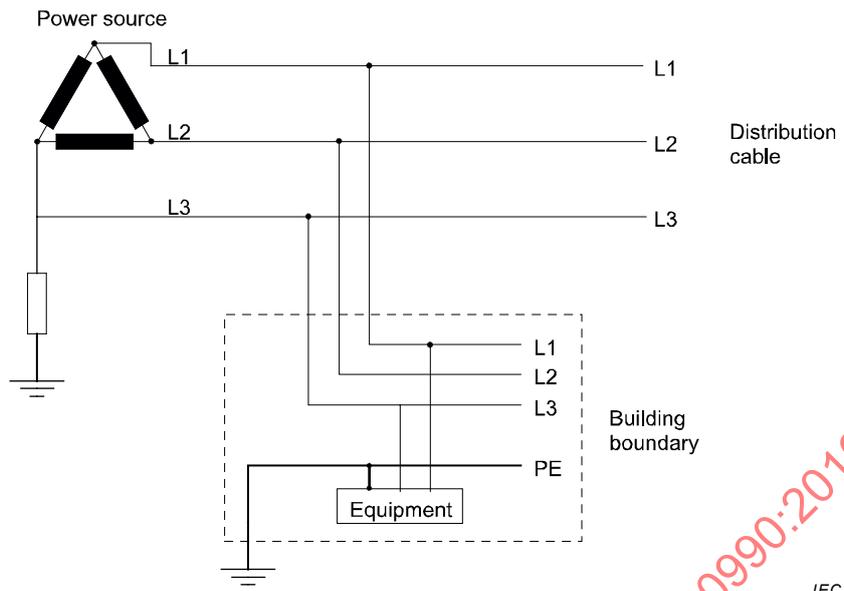
IT power systems are isolated from earth, except that one point may be connected to earth through an impedance or a voltage limiter. The parts of the EQUIPMENT required to be earthed are connected to earth electrodes at the user's premises.



The neutral may be connected to earth through an impedance or a voltage limiter, or isolated from earth.

This system is widely used isolated from earth, in some installations in France, with impedance to earth, at 230/400 V, and in Norway, with a voltage limiter, neutral not distributed, at 230 V line-to-line.

Figure I.7 – Example of 3-line (and neutral) IT power system



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The system may be isolated from earth.

Figure I.8 – Example of 3-line IT power system

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Annex J (informative)

Routine and periodic touch current tests, and tests after repair or modification of mains operated equipment

This annex defines methods and procedures to perform tests which reverify TOUCH CURRENT according to design requirements from the product standard, during production (routine test), after repair or modification and at periodic intervals during use.

The objective is to have the test performed by technicians or other instructed persons, using simple procedures to achieve sufficient accuracy. Measuring results should be easy to interpret. Measuring equipment should be economical and easy to use under practical field conditions.

Method

Tests are to be carried out using the procedures of this standard with the appropriate measuring network. Tests are to be performed under the environmental conditions of an appropriate field or factory location.

The EQUIPMENT is to be tested in a stand-alone configuration without external connections, except for the mains supply.

TOUCH CURRENT is to be measured and shall be at or below the limit defined in the EQUIPMENT standard as follows:

- if the limit is given as d.c. current, measure the d.c. and compare with the limit;
- if the limit is given in peak current, measure the peak current and compare with the peak limit;
- if the limit is given in r.m.s. current, measure the r.m.s. current and compare with the r.m.s. limit.

No routine or periodic test is required for ELECTRIC BURN currents unless specified by the EQUIPMENT standard.

Annex K (normative)

Network performance and calibration

K.1 Network or instrument performance and initial calibration

Measured ratios of input voltage to input current (input impedance) and output voltage to input current (transfer impedance or network response) are compared with ideal values calculated from the nominal component values specified in Figure 3, Figure 4 and Figure 5. Care is taken in the arrangement of the test equipment circuitry so that intercomponent capacitance, lead inductance and characteristics of the voltage measuring device do not significantly affect the voltage-current ratios.

A guard band indicating the uncertainty of measurement at various frequencies is specified for each instrument. The performance of measuring networks can, if necessary, be adjusted to make the guard band narrower.

NOTE 1 A definition of uncertainty of measurement is the characterization of the range within which the true value of a measurement is estimated to lie; this is a common term in metrology and calibration.

NOTE 2 Guidance on adjusting the performance of measuring networks is given in G.4.

The performance of a measuring network is checked by passing variable frequency sinusoidal current through the input of the instrument, test terminals A and B in Figure 3, Figure 4 and Figure 5. The input current (I), input voltage (U) and output voltage (U_1 , U_2 or U_3) are measured at various frequencies. If possible, the output voltage is measured by the same voltmeter as will be used during all measurements on the EQUIPMENT for product certification purposes and for all confirmation procedures (see Clause K.2).

**Table K.1 – Calculated input impedance and transfer impedance
for unweighted touch current measuring network (Figure 3)**

Frequency Hz	Input impedance U / I	Transfer impedance U_1 / I
20	1 998	500
50	1 990	500
60	1 986	500
100	1 961	500
200	1 857	500
500	1 434	500
1 000	979	500
2 000	675	500
5 000	533	500
10 000	509	500
20 000	502	500
50 000	500	500
100 000	500	500
200 000	500	500
500 000	500	500
1 000 000	500	500

Table K.2 – Calculated input impedance and transfer impedance for startle-reaction touch current measuring network (Figure 4)

Frequency Hz	Input impedance U / I	Transfer impedance U_2 / I
20	1 998	500
50	1 990	499
60	1 986	498
100	1 961	495
200	1 857	480
500	1 433	405
1 000	973	284
2 000	661	162,9
5 000	512	68,3
10 000	485	34,4
20 000	479	17,21
50 000	477	6,89
100 000	476	3,45
200 000	476	1,722
500 000	476	0,689
1 000 000	476	0,345

Table K.3 – Calculated input impedance and transfer impedance for letgo-immobilization current measuring network (Figure 5)

Frequency Hz	Input impedance U / I	Transfer impedance U_3 / I
20	1 998	500
50	1 990	499
60	1 986	499
100	1 961	496
200	1 858	484
500	1 434	427
1 000	976	340
2 000	667	251
5 000	515	144,3
10 000	487	79,9
20 000	479	41,2
50 000	477	16,63
100 000	476	8,32
200 000	476	4,16
500 000	476	1,666
1 000 000	476	0,833

K.2 Calibration in a confirmation system

K.2.1 General

NOTE A definition of metrological confirmation (shortened to “confirmation” in this standard) is a set of operations required to ensure that a measuring equipment is in a state of compliance with requirements for its intended use.

Each instrument that is used to determine acceptability for the purpose of certification of EQUIPMENT shall be routinely calibrated in a confirmation system to ensure that no drift of its performance outside the limits of permissible error has occurred. Reference is necessary to the guard band and other data recorded for the particular measuring instrument during its initial calibration (see Clause K.1).

If a particular measuring instrument has drifted outside permissible limits, measurements made on the EQUIPMENT with that instrument since the last confirmation calibration shall be reviewed to check their validity.

Calibration in a confirmation system is carried out in two steps.

K.2.2 Measurement of input resistance

The d.c. input resistance is measured and its value is checked against the ideal value (2 000 Ω) and the value determined during initial calibration.

NOTE This measurement guards against the possibility that a shift in input impedance has occurred at the same time that a shift occurs in the instrument response, resulting in addition or cancellation of errors.

K.2.3 Measurement of instrument performance

The input voltage and the output voltage (or milliamperes as indicated on the meter) are measured at various frequencies and the ratios compared to the data in Table K.4, Table K.5 or Table K.6, as appropriate. If possible, the output voltage is measured by the same voltmeter as will be used for initial calibration and during all measurements on the EQUIPMENT for product certification purposes. It is sufficient to carry out the measurements at a few frequencies over the whole frequency range of interest as long as attention is given to the higher frequencies. The input voltages used should be such as to produce output indications in the range of the TOUCH CURRENT limit values for which the measuring instrument is intended, subject to observing the power rating of internal components.

NOTE Table K.4, Table K.5 and Table K.6 are derived from Table K.1, Table K.2 and Table K.3 respectively but, in order to simplify the confirmation procedure, the presentation of the data avoids the need to measure input current at high frequencies.

Table K.4 – Output voltage to input voltage ratios for unweighted touch current measuring network (Figure 3)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,98	1,99
60	0,252	3,97	1,99
100	0,255	3,92	1,96
200	0,269	3,72	1,86
500	0,349	2,87	1,43
1 000	0,511	1,96	0,979
2 000	0,740	1,35	0,675
5 000	0,937	1,07	0,533
10 000	0,983	1,02	0,509
20 000	0,996	1,00	0,502
50 000	0,999	1,00	0,500
100 000	1,00	1,00	0,500
200 000	1,00	1,00	0,500
500 000	1,00	1,00	0,500
1 000 000	1,00	1,00	0,500

Table K.5 – Output voltage to input voltage ratios for startle-reaction measuring network (Figure 4)

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,99	2,00
60	0,251	3,99	1,99
100	0,252	3,96	1,98
200	0,259	3,87	1,93
500	0,282	3,54	1,77
1 000	0,292	3,43	1,71
2 000	0,246	4,06	2,03
5 000	0,133	7,50	3,75
10 000	0,070 8	14,1	7,06
20 000	0,036 0	27,8	13,9
50 000	0,014 5	69,2	34,6
100 000	0,007 23	138	69,1
200 000	0,003 62	277	138
500 000	0,001 45	691	346
1 000 000	0,000 723	1 382	691

**Table K.6 – Output voltage to input voltage ratios
for letgo-immobilization measuring network (Figure 5)**

Frequency Hz	Output voltage to input voltage ratio	Input voltage to output voltage ratio	Input voltage per milliampere indication
20	0,250	4,00	2,00
50	0,251	3,99	1,99
60	0,251	3,98	1,99
100	0,253	3,95	1,98
200	0,261	3,83	1,92
500	0,298	3,36	1,68
1 000	0,348	2,87	1,44
2 000	0,377	2,65	1,33
5 000	0,280	3,57	1,79
10 000	0,164	6,09	3,04
20 000	0,086 0	11,6	5,81
50 000	0,034 9	28,7	14,3
100 000	0,017 5	57,2	28,6
200 000	0,008 74	114	57,2
500 000	0,003 50	286	143
1 000 000	0,001 75	572	286

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COMMISSION ÉLECTROTECHNIQUE INTERNATIONALE

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Cette troisième édition annule et remplace la deuxième édition, parue en 1999. Cette édition constitue une révision technique.

Cette édition inclut les modifications majeures suivantes par rapport à la deuxième édition:

- les désignations des effets ont été mises à jour pour refléter la meilleure compréhension de la plage des effets et s'accorder avec l'utilisation actuelle;
- les conditions d'utilisation impliquant une PARTIE PREHENSIBLE ont été réduites pour l'application des exigences fondées sur la compréhension actuelle de cet effet;

- les références à l'ISO 10012-1, qui a été remplacée par une norme de management portant le même numéro, ont été remplacées par un texte explicatif, le cas échéant, afin de conserver le sens du document;
- l'ancienne Annexe H informative (PARTIE PREHENSIBLE) a été supprimée de cette mise à jour car elle ne représente pas de manière adéquate l'intégralité des conditions dans lesquelles une immobilisation est susceptible de se produire. Une nouvelle Annexe H informative (Analyse du mesurage de circuits de courant de contact avec filtre de fréquence) a été ajoutée;
- la Bibliographie (anciennement dénommée Annexe M) a été mise à jour avec des références supplémentaires par souci d'exhaustivité.

Elle a le statut d'une publication fondamentale de sécurité conformément au Guide IEC 104.

Le texte de cette norme est issu des documents suivants:

FDIS	Rapport de vote
108/630/FDIS	108/640/RVD

Le rapport de vote indiqué dans le tableau ci-dessus donne toute information sur le vote ayant abouti à l'approbation de cette norme.

Cette publication a été rédigée selon les Directives ISO/IEC, Partie 2.

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INTRODUCTION

La présente Norme internationale a été élaborée pour répondre à des préoccupations provenant de l'arrivée de nouvelles techniques de découpage à haute fréquence largement appliquées dans les systèmes d'alimentation et dans les MATÉRIELS, et qui provoquent des courants et tensions harmoniques à haute fréquence.

La présente norme est destinée à servir de guide aux comités traitant de MATÉRIELS lors de la préparation ou de la modification des spécifications d'essai dans leurs normes de mesure du courant de fuite. Toutefois, le terme «courant de fuite» n'est pas utilisé pour les raisons indiquées ci-après.

La présente norme a été initialement établie dans le cadre de la fonction fondamentale de sécurité assignée au comité d'études 74 (désormais comité d'études 108), comme suit.

Méthodes de mesure du courant de fuite

Ces méthodes incluent, pour divers types de MATÉRIELS, tous les aspects qui se rapportent à ce qui est désigné par le terme «courant de fuite», y compris les méthodes de mesure du courant en ce qui concerne les effets physiologiques et les questions d'installation, dans les conditions normales et dans certaines conditions de défaut.

Les méthodes de mesure du courant de fuite décrites ci-après proviennent de l'étude de l'IEC TS 60479-1 et d'autres publications, y compris les descriptions de méthodes de mesure précédentes.

Les conclusions suivantes sont déduites de l'étude des effets du courant de fuite:

- le principal intérêt pour la sécurité concerne le passage possible d'un courant nuisible à travers le corps humain (ce courant n'est pas nécessairement égal au courant traversant le conducteur de protection);
- l'effet du courant électrique traversant un corps humain s'est révélé être sensiblement plus complexe que dans les hypothèses retenues lors de l'élaboration des normes antérieures, dans la mesure où il convient de prendre en compte plusieurs réponses du corps. Les réponses les plus significatives pour établir les limites de sécurité pour des formes d'onde permanentes sont
 - la perception,
 - la réaction de tressaillement,
 - le non-lâcher/l'immobilisation, et
 - la BRÛLURE ÉLECTRIQUE.

Chacune de ces quatre réponses du corps a un niveau de seuil unique. D'importantes différences existent aussi dans la manière dont certains de ces seuils varient en fonction de la fréquence.

Deux types de courants ont été identifiés comme nécessitant des méthodes de mesure différentes: le COURANT DE CONTACT et le COURANT DANS LE CONDUCTEUR DE PROTECTION.

Le COURANT DE CONTACT existe uniquement lorsque le corps ou un modèle de corps humain est un chemin de passage du courant.

Il a été également noté que le terme «courant de fuite» a déjà été appliqué à plusieurs concepts différents: COURANT DE CONTACT, COURANT DANS LE CONDUCTEUR DE PROTECTION, propriétés d'isolement, etc. En conséquence, dans la présente norme, le terme «courant de fuite» n'est pas utilisé.

Mesurage du COURANT DE CONTACT

Dans le passé, les normes de MATERIELS ont traditionnellement utilisé deux techniques pour mesurer le courant de fuite. Soit le courant réel circulant dans le conducteur de protection était mesuré, soit un simple réseau résistance/condensateur (représentant un modèle simple du corps humain) était utilisé, le courant de fuite étant défini comme le courant traversant la résistance.

La présente norme fournit des méthodes de mesure pour les quatre réponses du corps au courant électrique indiqué ci-dessus, utilisant un modèle du corps humain plus représentatif.

Ce modèle du corps humain a été choisi pour les cas les plus courants de chocs électriques au sens général. En ce qui concerne le cheminement du courant et les conditions de contact, un modèle du corps humain est utilisé, représentant approximativement le contact complet main à main à pied en situation normale. Pour de petites surfaces de contact (par exemple un petit contact de doigt), un modèle différent peut être approprié, mais ce modèle n'est pas abordé ici.

Parmi les quatre réponses, la réaction de tressaillement et le non-lâcher/l'immobilisation sont liés à la valeur de crête du COURANT DE CONTACT et varient avec la fréquence. Traditionnellement, les questions concernant les chocs électriques ont traité des formes d'onde sinusoïdales, pour lesquelles les mesurages de valeurs efficaces conviennent le mieux. Les mesurages de valeurs de crête sont plus appropriés pour les formes d'onde non sinusoïdales, pour lesquelles il est prévu des valeurs significatives du COURANT DE CONTACT, mais sont également utilisables pour les formes d'onde sinusoïdales. Les réseaux spécifiés pour le mesurage de la réaction de tressaillement et du non-lâcher/de l'immobilisation ont une réponse en fréquence et sont pondérés de telle façon que des valeurs limites uniques puissance-fréquence puissent être spécifiées et référencées.

Toutefois, les BRULURES ELECTRIQUES sont liées à la valeur efficace du COURANT DE CONTACT et sont relativement indépendantes de la fréquence. Pour les MATERIELS pour lesquels les BRULURES ELECTRIQUES peuvent être significatives (voir 7.2), deux mesurages séparés sont effectués, un en valeur de crête pour les chocs électriques et un second en valeur efficace pour les BRULURES ELECTRIQUES, chacun utilisant le circuit d'essai approprié.

Il convient que les comités de MATERIELS décident des effets physiologiques qui sont acceptables et des effets qui ne le sont pas et, à partir de là, qu'ils décident des valeurs limites de courant. Des comités concernés par certains types de MATERIELS peuvent adopter des procédures simplifiées, fondées sur la présente norme. Une discussion des valeurs limites, issue de travaux antérieurs de différents comités de MATERIEL de l'IEC, est donnée à l'Annexe D.

Mesurage du COURANT DANS LE CONDUCTEUR DE PROTECTION

Dans certains cas, il est exigé de mesurer le COURANT DANS LE CONDUCTEUR DE PROTECTION des MATERIELS dans les conditions normales d'utilisation, notamment:

- pour le choix d'un dispositif de protection à courant résiduel,
- pour la détermination du moment auquel un circuit de terre de protection de haute intégrité de protection est exigé,
- pour prévenir toute surcharge excessive de COURANT DANS LE CONDUCTEUR DE PROTECTION dans l'installation électrique.

Le COURANT DANS LE CONDUCTEUR DE PROTECTION est mesuré par insertion d'un ampèremètre d'impédance négligeable en série avec le conducteur de mise à la terre de protection du MATERIEL.

MÉTHODES DE MESURE DU COURANT DE CONTACT ET DU COURANT DANS LE CONDUCTEUR DE PROTECTION

1 Domaine d'application

La présente Norme internationale définit des méthodes de mesure pour

- les courants continus ou les courants alternatifs de forme d'onde sinusoïdale ou non sinusoïdale qui peuvent traverser le corps humain, et
- les courants qui peuvent circuler dans un conducteur de protection.

Les méthodes de mesure recommandées pour le COURANT DE CONTACT sont basées sur les effets possibles provoqués par le passage du courant dans le corps humain. Dans la présente norme, les mesurages de courant à travers des réseaux représentant l'impédance du corps humain sont appelés mesurages du COURANT DE CONTACT. Les réseaux utilisés ne sont pas nécessairement valables pour des animaux.

La spécification ou l'implication de valeurs limites spécifiques ne fait pas partie du domaine d'application de la présente norme. La série IEC TS 60479 fournit des informations concernant les effets du courant traversant le corps humain, à partir desquelles des valeurs limites peuvent être déduites.

La présente norme est applicable à toutes les classes de MATÉRIELS, conformément à l'IEC 61140.

Les méthodes de mesure indiquées dans la présente norme ne sont pas destinées à être utilisées pour

- les COURANTS DE CONTACT de durée inférieure à 1 s,
- les courants patients tels qu'ils sont définis dans l'IEC 60601-1,
- les courants alternatifs de fréquence inférieure à 15 Hz, et
- les courants supérieurs aux courants choisis pour les limites de BRULURE ELECTRIQUE.

La présente publication fondamentale de sécurité est destinée principalement à être utilisée par les comités d'études lors de la préparation de normes conformément aux principes figurant dans le Guide IEC 104 et le Guide ISO/IEC 51. Elle n'est pas destinée à être utilisée par les fabricants ou les organismes de certification indépendants de normes de produit.

L'une des responsabilités d'un comité d'études est d'utiliser, pour la préparation de ses publications, les publications fondamentales de sécurité, lorsque celles-ci sont applicables. Les exigences, méthodes d'essai ou conditions d'essai de la présente publication fondamentale de sécurité s'appliquent uniquement lorsqu'elles sont incorporées ou spécifiquement mentionnées dans les publications appropriées.

2 Références normatives

Les documents suivants sont cités en référence de manière normative, en intégralité ou en partie, dans le présent document et sont indispensables pour son application. Pour les références datées, seule l'édition citée s'applique. Pour les références non datées, la dernière édition du document de référence s'applique (y compris les éventuels amendements).

IEC TS 60479-1:2005, *Effets du courant sur l'homme et les animaux domestiques – Partie 1: Aspects généraux*

IEC TS 60479-2:2007, *Effets du courant sur l'homme et les animaux domestiques – Partie 2: Aspects particuliers*

IEC 61140, *Protection contre les chocs électriques – Aspects communs aux installations et aux matériels*

Guide ISO/IEC 51:2014, *Aspects liés à la sécurité – Principes directeurs pour les inclure dans les normes*

Guide IEC 104:2010, *The preparation of safety publications and the use of basic safety publications and group safety publications* (disponible en anglais seulement)

3 Termes et définitions

Pour les besoins du présent document, les termes et définitions suivants s'appliquent.

3.1

COURANT DE CONTACT

courant électrique passant dans le corps humain ou dans le corps d'un animal lorsqu'il est en contact avec une ou plusieurs parties accessibles d'une installation ou de MATÉRIELS

[SOURCE: IEC 60050-195:1998, 195-05-21]

3.2

COURANT DANS LE CONDUCTEUR DE PROTECTION

courant circulant dans un conducteur de protection

3.3

MATÉRIEL

ensemble organisé de composants et de caractéristiques électromécaniques visant à réaliser une tâche définie (comme spécifié dans la norme de produit applicable)

Note 1 à l'article: S'il n'est pas spécifié dans la norme applicable, voir Annexe A.

3.4

PARTIE PREHENSIBLE

partie du MATÉRIEL qui peut fournir un courant dont le passage à travers la main humaine provoque des contractions musculaires autour de la partie et une incapacité de lâcher

Note 1 à l'article: Des parties qui sont destinées à être tenues avec la main entière sont considérées par hypothèse comme préhensibles, sans autre investigation.

3.5

BRÛLURE ÉLECTRIQUE

brûlure de la peau ou d'un organe, causée par le passage superficiel ou en profondeur d'un courant électrique

[SOURCE: IEC 60050-604:1987, 604-04-18]

4 Emplacement d'essai

4.1 Environnement de l'emplacement d'essai

Les exigences concernant l'environnement de l'emplacement d'essai doivent être conformes aux spécifications de la norme du MATERIEL. Si des valeurs limites inférieures à 70 μA en valeur efficace ou 100 μA en valeur de crête sont spécifiées, ou si le MATERIEL contient de larges écrans qui peuvent être parcourus par des signaux haute fréquence, les comités de produits doivent se référer à l'Annexe B.

4.2 Transformateur d'essai

L'utilisation d'un transformateur d'essai pour l'isolement est facultative. Pour une sécurité maximale, un transformateur d'essai pour l'isolement (T2 à la Figure 2, T de Figure 6 à la Figure 14) doit être utilisé et la borne principale de mise à la terre de protection du MATERIEL en essai (EUT – Equipment under test) doit alors être mise à la terre. Toute capacité de fuite dans le transformateur doit alors être prise en compte. En variante à la mise à la terre du MATERIEL en essai, le secondaire du transformateur d'essai et le MATERIEL en essai doivent être laissés flottants (non mis à la terre), auquel cas la capacité de fuite du transformateur d'essai n'a pas besoin d'être prise en compte.

Si le transformateur T n'est pas utilisé, le MATERIEL en essai doit être monté sur un support isolant et des précautions de sécurité appropriées doivent être prises étant donné que le corps du MATERIEL en essai peut se trouver à une tension dangereuse.

4.3 Conducteur neutre mis à la terre

Un MATERIEL prévu pour être connecté à un schéma de distribution d'énergie TT ou TN doit être soumis à l'essai avec une tension minimale entre neutre et terre.

NOTE Des descriptions des différents schémas de distribution d'énergie sont données à l'Annexe I.

Il convient que le conducteur de protection et le conducteur neutre mis à la terre pour le MATERIEL en essai aient une différence de potentiel inférieure à 1 % de la tension entre phases (voir exemple à la Figure 1).

Un transformateur local, voir 4.2, permet de satisfaire à cette exigence.

En variante, si la différence de potentiel est supérieure ou égale à 1 %, les exemples suivants donnent des méthodes qui, dans certains cas, permettent d'éviter les erreurs de mesure dues à cette différence de potentiel:

- connexion de l'électrode de la borne B du réseau de l'appareil de mesure à la borne de neutre du matériel en essai au lieu du conducteur de mise à la terre de protection (voir 6.1.2) de l'alimentation;
- connexion de la borne de terre du matériel en essai au conducteur de neutre, au lieu du conducteur de mise à la terre de protection, de l'alimentation.

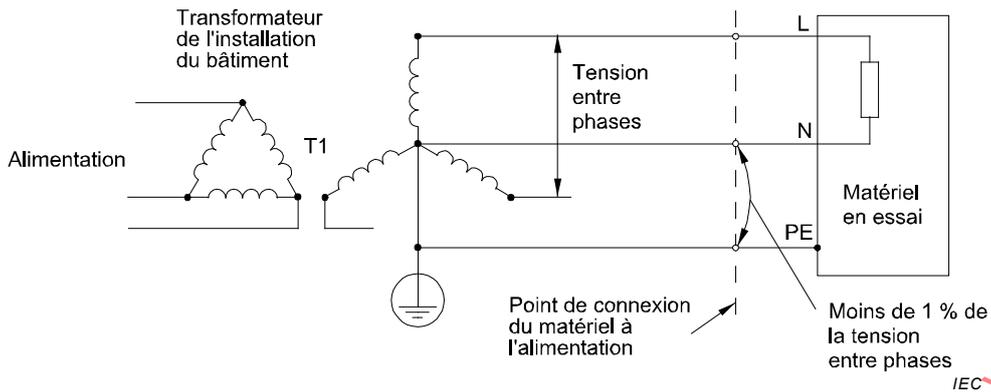


Figure 1 – Exemple de neutre mis à la terre, alimentation directe

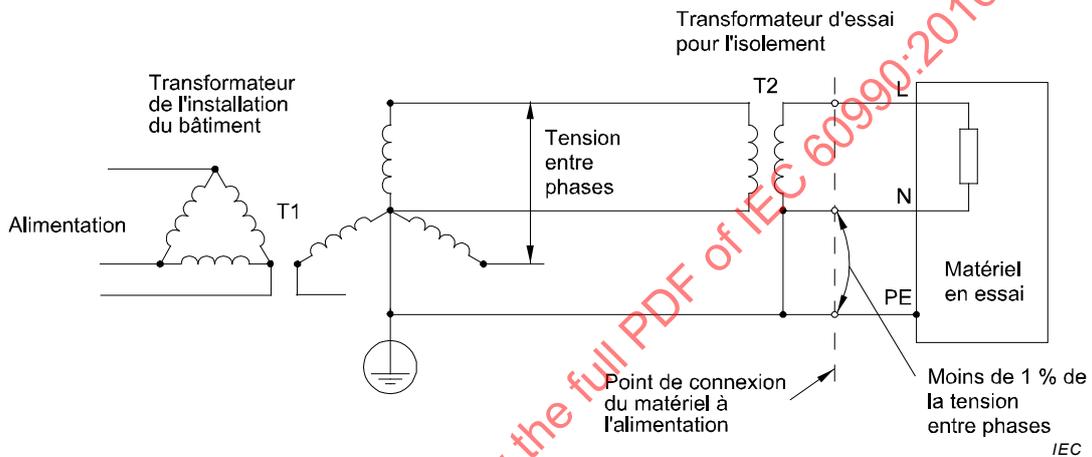


Figure 2 – Exemple de neutre mis à la terre, avec transformateur pour l'isolement

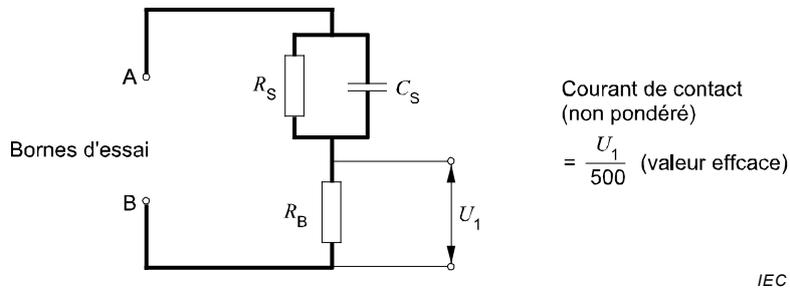
5 Matériel de mesure

5.1 Choix du réseau de mesure

5.1.1 Généralités

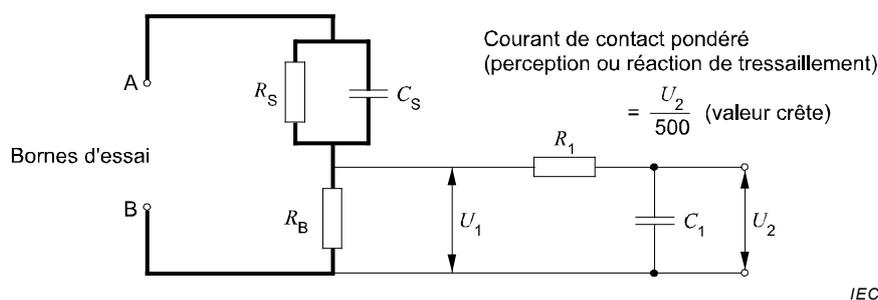
Les mesurages doivent être effectués à l'aide d'un des réseaux de la Figure 3, de la Figure 4 et de la Figure 5.

NOTE Voir les Annexes E, F et G pour de plus amples informations sur ces trois réseaux.



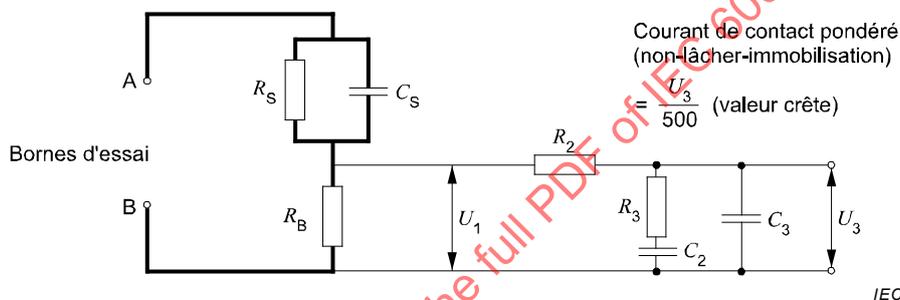
R_S	1 500 Ω
R_B	500 Ω
C_S	0,22 μF

Figure 3 – Réseau de mesure, courant de contact non pondéré



R_S	1 500 Ω	R_1	10 000 Ω
R_B	500 Ω	C_1	0,022 μF
C_S	0,22 μF		

Figure 4 – Réseau de mesure, courant de contact pondéré pour la perception ou la réaction de tressaillement



R_S	1 500 Ω	R_3	20 000 Ω
R_B	500 Ω	C_2	0,006 2 μF
C_S	0,22 μF	C_3	0,009 1 μF
R_2	10 000 Ω		

NOTE Pour les conditions spéciales d'utilisation de ce réseau, voir 5.1.2.

Figure 5 – Réseau de mesure, courant de contact pondéré pour le non-lâcher / l'immobilisation

5.1.2 Perception et réaction de tressaillement

Le réseau de la Figure 4 doit être utilisé pour les limites de choc électrique de faible niveau. Ce circuit doit être appliqué lorsque la valeur limite du courant alternatif indiquée dans la norme de produit est égale au maximum à 2 mA en valeur efficace ou 2,8 mA en valeur de crête.

5.1.3 Non-lâcher/immobilisation

Le réseau de la Figure 5 doit être utilisé pour les limites de choc électrique de niveau élevé. Ce circuit doit être appliqué lorsque la valeur limite du courant alternatif indiquée dans la norme de produit est supérieure à 2 mA en valeur efficace ou 2,8 mA en valeur de crête.

5.1.4 Brûlures électriques (courant alternatif)

Le réseau de COURANT DE CONTACT non pondéré de la Figure 3 doit être utilisé.

5.1.5 Courant continu sans ondulation

L'un quelconque des trois réseaux doit être utilisé. Sauf spécification contraire dans la norme du MATERIEL, le courant continu sans ondulation signifie moins de 10 % d'ondulation crête à crête.

5.2 Électrodes d'essai

5.2.1 Construction

Sauf spécification contraire dans la norme du MATERIEL, les électrodes d'essai doivent être

- un clip d'essai, ou
- une feuille de métal de 10 cm × 20 cm représentant la main humaine. Si une feuille adhésive est utilisée, l'adhésif doit être conducteur.

5.2.2 Connexion

Les électrodes d'essai doivent être connectées aux bornes A et B du réseau de mesure.

5.3 Configuration

Le MATERIEL en essai doit être complètement assemblé et prêt pour l'utilisation dans la configuration maximale; il doit être connecté à des tensions de signal externes lorsque cela est applicable, suivant les spécifications du fabricant pour un seul MATERIEL.

Les MATERIELS qui sont prévus pour des sources d'alimentation multiples et pour lesquels une seule alimentation est exigée à la fois (par exemple pour alimentation de secours) ne doivent être soumis à l'essai qu'avec une seule source connectée.

Les MATERIELS pour lesquels une alimentation simultanée à partir de deux sources ou plus est exigée doivent être soumis à l'essai avec toutes les sources connectées mais avec pas plus d'une connexion à la terre de protection.

5.4 Connexions à l'alimentation pendant l'essai

5.4.1 Généralités

NOTE Des exemples de schémas de distribution d'énergie sont donnés à l'Annexe I.

Le MATERIEL doit être connecté dans une configuration d'essai comme représenté de la Figure 6 à Figure 14, conformément à 5.4.2, 5.4.3 ou 5.4.4, selon le cas.

Il convient que les comités de MATERIELS considèrent le besoin éventuel pour le fabricant d'identifier les schémas de distribution d'énergie (TN, TT, IT) auxquels un MATERIEL est destiné à être relié dans son utilisation finale.

Si le fabricant spécifie que le MATERIEL en essai ne peut être utilisé que dans certains schémas de distribution d'énergie, le MATERIEL ne doit être soumis à l'essai que lorsqu'il est relié à ces schémas.

Un MATERIEL devant être connecté uniquement à des schémas TN ou TT doit satisfaire à 5.4.2. Un MATERIEL devant être connecté à des schémas IT doit satisfaire à 5.4.3 et peut aussi être connecté à des schémas TN ou TT.

Pour les MATERIELS de la classe 0 et de la classe II (voir IEC 61140), il n'est pas tenu compte des conducteurs de protection représentés de la Figure 6 à la Figure 14 incluses.

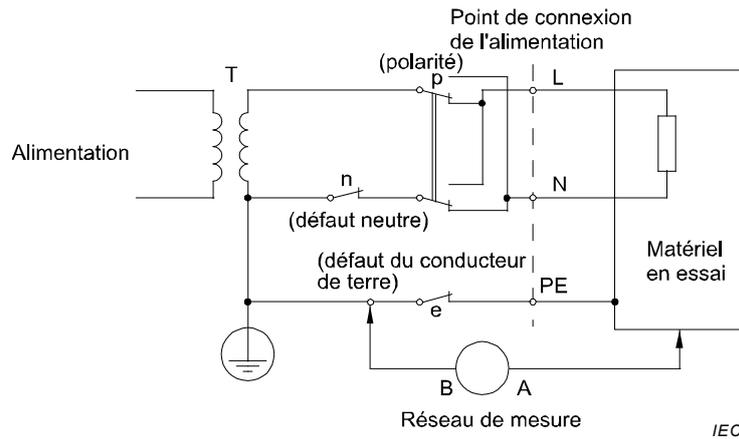
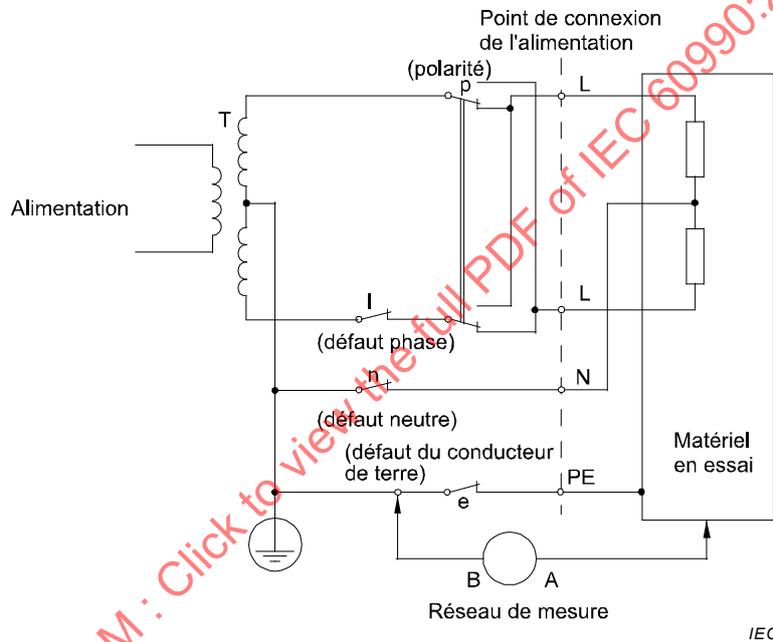


Figure 6 – Matériel monophasé dans un schéma étoile TN ou TT



L'enroulement à prise médiane peut être une branche d'une alimentation triangle.

Figure 7 – Matériel monophasé dans un schéma TN ou TT avec point milieu à la terre

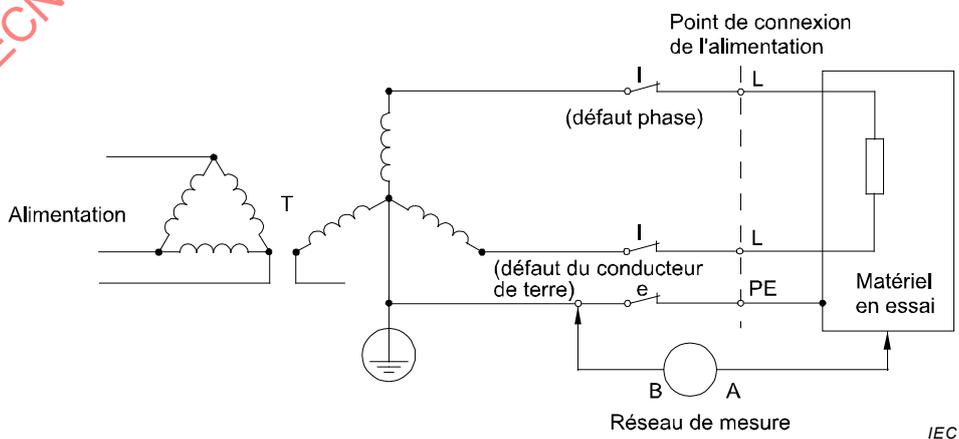
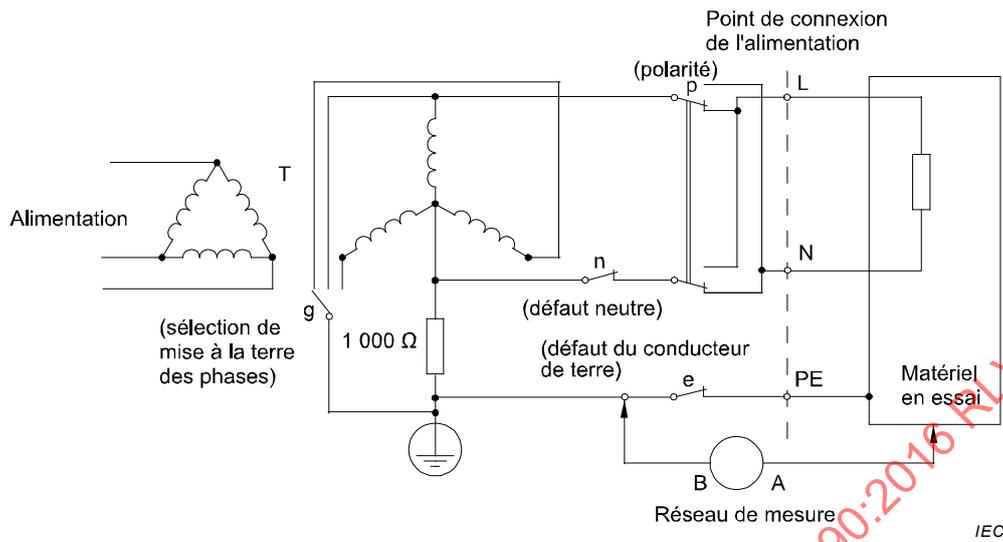
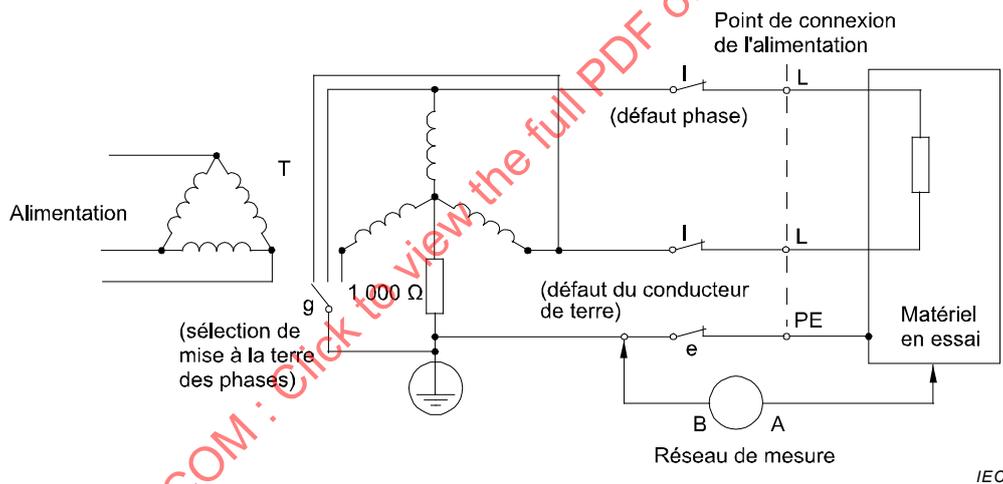


Figure 8 – Matériel monophasé connecté entre phases dans un schéma étoile TN ou TT



Il convient que la résistance de 1 000 Ω soit adaptée pour les défauts du système d'alimentation.

Figure 9 – Matériel monophasé connecté entre phase et neutre dans un schéma étoile IT



Il convient que la résistance de 1 000 Ω soit adaptée pour les défauts du système d'alimentation.

Figure 10 – Matériel monophasé connecté entre phases dans un schéma étoile IT

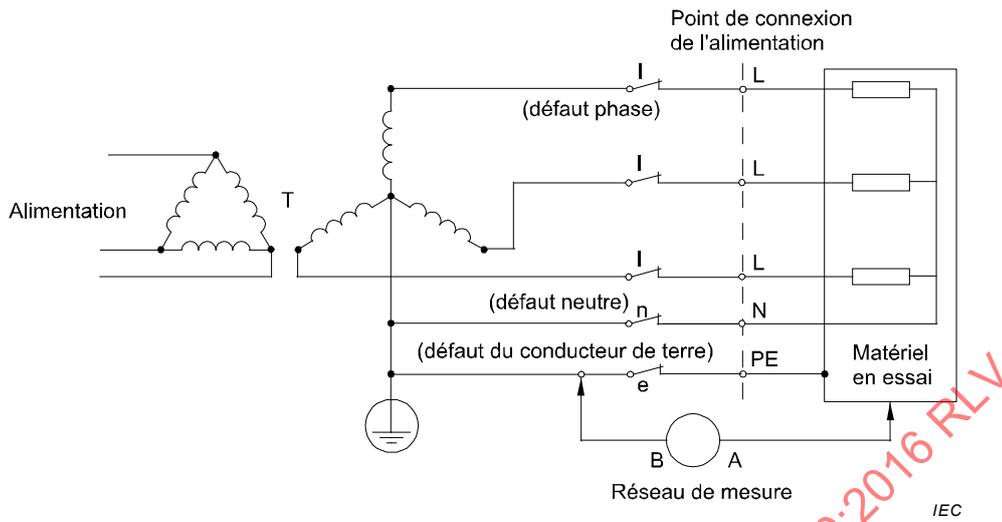
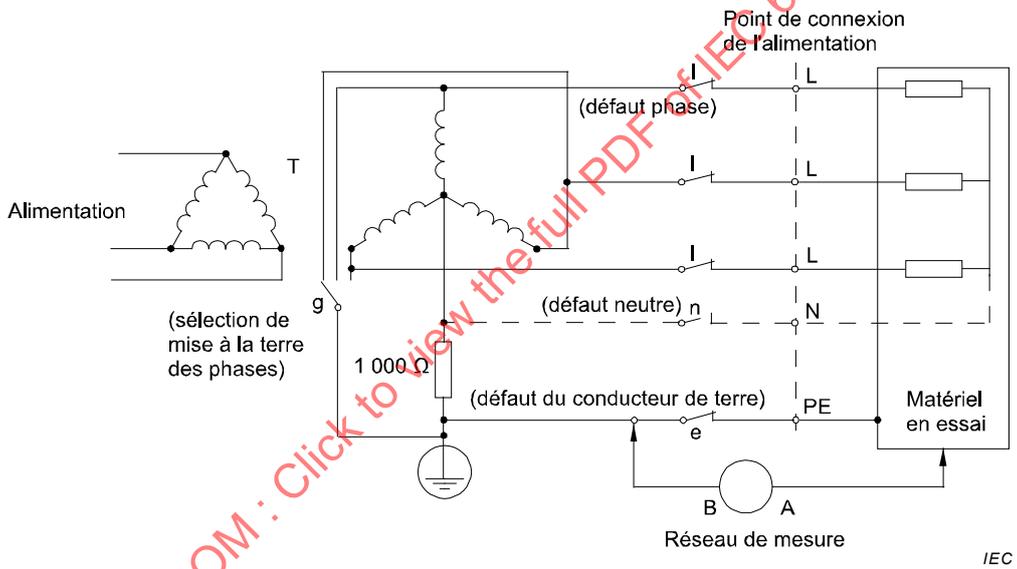


Figure 11 – Matériel triphasé dans un schéma étoile TN ou TT



Il convient que la résistance de 1 000 Ω soit adaptée pour les défauts du système d'alimentation.

Figure 12 – Matériel triphasé dans un schéma étoile IT

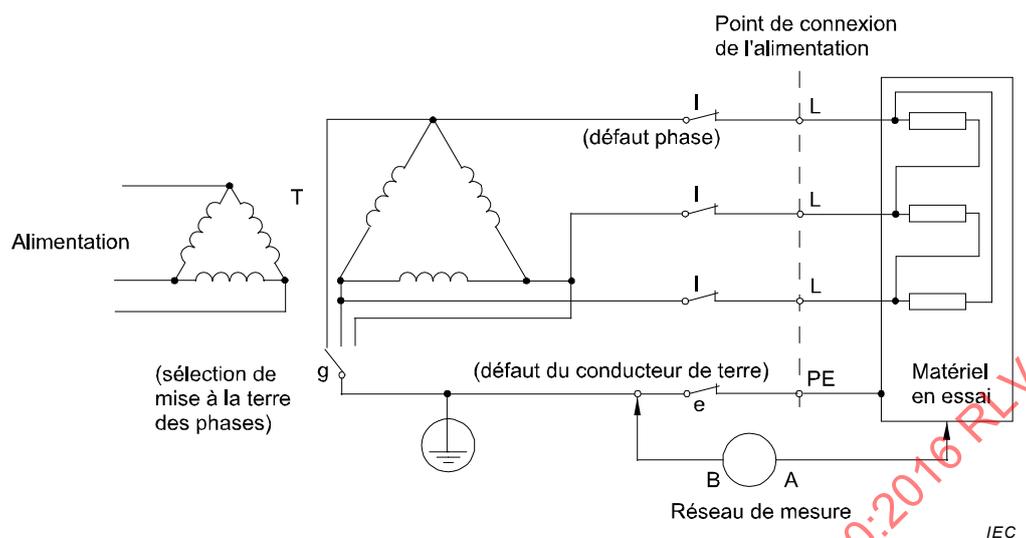
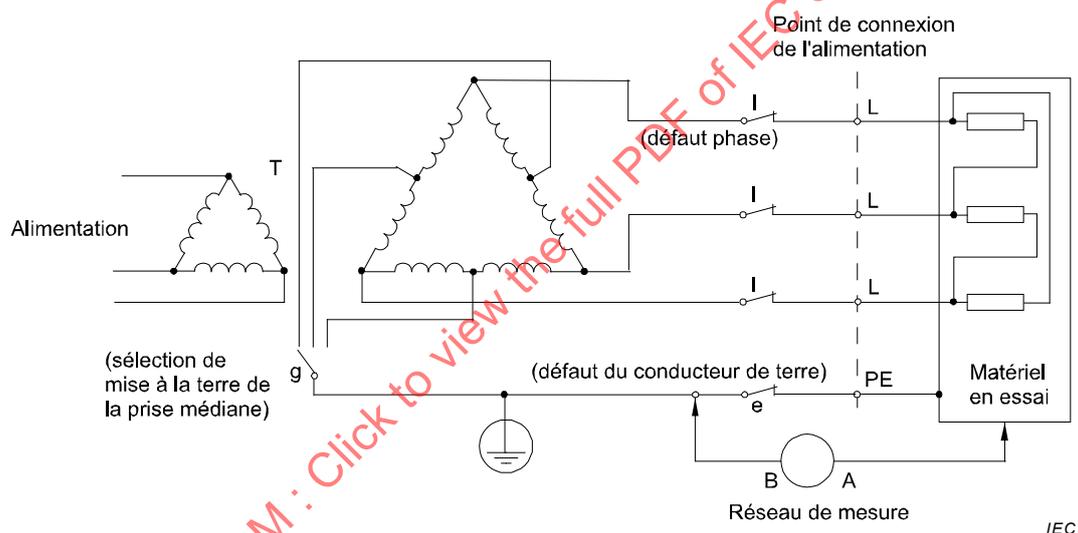


Figure 13 – Schéma triangle non mis à la terre



Lorsqu'un MATÉRIEL contient à la fois une charge triphasée et une charge monophasée dont le point milieu est relié à la terre, et lorsque le côté mis à la terre est identifié, le commutateur g doit rester dans la position identifiée comme correspondant au côté relié à la terre.

Figure 14 – Matériel triphasé dans un schéma triangle avec point milieu mis à la terre

5.4.2 Matériel pour utilisation uniquement dans des schémas de distribution d'énergie étoile TN ou TT

Un MATÉRIEL triphasé doit être connecté à un schéma de distribution d'énergie triphasé étoile avec le neutre à la terre. Un MATÉRIEL monophasé doit être connecté entre phase et neutre d'un schéma de distribution d'énergie ayant le neutre à la terre ou, s'il est spécifié par le fabricant comme pouvant être utilisé de cette manière, entre phases d'un schéma de distribution d'énergie étoile triphasé dont le point milieu est relié à la terre (voir Figure 6, Figure 8 et Figure 11).

5.4.3 Matériel pour utilisation dans des schémas de distribution d'énergie IT, y compris les schémas triangle non reliés à la terre

Un MATÉRIEL triphasé doit être connecté à un schéma d'alimentation triphasé IT approprié. Un MATÉRIEL monophasé doit être connecté entre phase et neutre ou, s'il est spécifié par le

fabricant comme pouvant être utilisé de cette manière, entre phases (voir Figure 9, Figure 10, Figure 12 et Figure 13).

5.4.4 Matériel pour utilisation dans des schémas d'alimentation monophasés dont le point milieu est à la terre ou dans des schémas d'alimentation triangle dont le point milieu est à la terre

Un MATERIEL monophasé doit être connecté à l'alimentation ayant sa prise médiane reliée à la terre (voir Figure 7 et Figure 14).

Un MATERIEL triphasé doit être connecté à l'alimentation triangle appropriée (voir Figure 14).

5.5 Tension et fréquence d'alimentation

5.5.1 Tension d'alimentation

La tension d'alimentation doit être mesurée aux bornes d'alimentation du MATERIEL.

Traditionnellement, le COURANT DE CONTACT était à son maximum à la tension d'alimentation la plus élevée. Les alimentations électroniques modernes ne fournissent pas toujours un COURANT DE CONTACT maximal dans ces conditions d'alimentation. Le COURANT DE CONTACT peut être maximisé à la tension la plus basse, c'est-à-dire l'appel de courant maximal, ou dans d'autres conditions. Une protection contre les chocs électriques doit être assurée dans les conditions de fonctionnement du cas le plus défavorable.

Un MATERIEL ayant une seule tension assignée doit être soumis à l'essai à sa tension assignée, majorée d'une tolérance de travail appropriée pour tenir compte des variations de l'alimentation.

Un MATERIEL ayant une plage de tensions nominales doit être soumis à l'essai aux valeurs extrêmes de la plage de tensions, majorée d'une tolérance de travail appropriée pour tenir compte des variations de l'alimentation. La tolérance de travail est déterminée par le comité de MATERIEL ou par le fabricant, si nécessaire (par exemple 0 %, -10 %, +6 % ou +10 %).

Un MATERIEL ayant différentes tensions nominales ou différentes plages de tensions nominales, par utilisation d'un sélecteur de tension, doit être réglé pour la tension nominale ou la plage de tensions nominales la plus élevée, puis traité comme ci-dessus. Lorsque le changement de tension implique des commutations plus complexes qu'un réaménagement des enroulements d'un transformateur, des essais complémentaires peuvent être nécessaires pour déterminer le cas le plus défavorable.

S'il n'est pas pratique d'effectuer l'essai sur un MATERIEL à la tension spécifiée, il est autorisé d'effectuer l'essai à une tension quelconque disponible, comprise dans la plage assignée du MATERIEL et, ensuite, de calculer les résultats.

5.5.2 Fréquence d'alimentation

La fréquence d'alimentation doit être la fréquence nominale maximale assignée ou, en variante, les mesurages peuvent être corrigés par calcul pour l'estimation du courant dans le cas le plus défavorable.

6 Procédure d'essai

6.1 Généralités

6.1.1 Mesurages du courant de contact

Les comités de produits peuvent souhaiter exclure les mesurages du COURANT DE CONTACT sur certaines parties accessibles, en se basant sur le principe de la limitation de la tension (voir IEC 60364-4-41). Dans ce cas, les mesurages doivent être effectués pour les tensions accessibles et ensuite, si nécessaire, pour des COURANTS DE CONTACT pondérés ou non pondérés, conformément à l'Article 6.

Les effets des BRULURES ELECTRIQUES sont à prendre en compte avec un courant continu ou à haute fréquence (par exemple fréquence supérieure à 30 kHz pour un COURANT DE CONTACT de 3,5 mA). À des fréquences plus basses, la réaction de tressaillement et le non-lâcher/l'immobilisation sont les phénomènes prédominants. Si de tels effets sont pris en compte, la valeur efficace non pondérée du COURANT DE CONTACT doit être mesurée (Figure 3), en plus des mesurages concernant la réaction de tressaillement (Figure 4) ou l'incapacité de lâcher (Figure 5).

6.1.2 Auxiliaires de commande, matériel et conditions d'alimentation

Pendant les mesurages du COURANT DE CONTACT, l'environnement d'essai, la configuration, la mise à la terre et le système d'alimentation doivent être conformes à 5.3, 5.4 et 5.5.

Afin d'obtenir les valeurs de courant les plus élevées possibles pendant les mesurages, on doit faire varier la configuration par la connexion et la déconnexion d'unités faisant partie du MATERIEL, comme l'autorisent les instructions du fabricant pour le fonctionnement et l'installation.

Les auxiliaires de commande e, g, l, n et p représentés de la Figure 6 à la Figure 14 doivent être actionnés comme décrit en 6.2, pendant que les conditions énumérées dans le présent paragraphe et en 6.2.1 font chacune, indépendamment les unes des autres, l'objet de variations de manière à obtenir la ou les valeurs maximales mesurées. Les comités de produits doivent faire une sélection appropriée des variables obtenues. L'ajout récent du FONCTIONNEMENT ANORMAL comme condition de fonctionnement dans les normes de produits liées aux installations électriques (par exemple, un défaut du conducteur de protection ou l'incapacité d'assurer la polarité de l'alimentation) clarifie les conditions d'essai en FONCTIONNEMENT NORMAL et dans les CONDITIONS DE DEFAUT à appliquer par la suite.

6.1.3 Utilisation des réseaux de mesure

Des électrodes de mesure (voir 5.2), un réseau de mesure (voir 5.1) et un dispositif de mesure (voir G.4) appropriés doivent être utilisés conformément aux schémas appropriés représentés de la Figure 6 à la Figure 14 (voir 5.4) pour effectuer les mesurages du COURANT DE CONTACT entre les parties simultanément accessibles, et entre les parties accessibles et la terre.

L'électrode de la borne A doit être appliquée successivement à chaque partie accessible.

Pour chaque application de l'électrode de la borne A, l'électrode de la borne B doit être appliquée à la terre, puis appliquée successivement à chacune des autres parties accessibles.

Pour les systèmes d'alimentation avec un conducteur d'alimentation mis à la terre, l'électrode de la borne B peut être reliée directement au conducteur d'alimentation mis à la terre à l'interface du MATERIEL en essai et de l'alimentation, au lieu d'être reliée au conducteur de protection. Cette connexion peut être utilisée même si la différence de potentiel entre le

conducteur de protection et le conducteur d'alimentation mis à la terre est supérieure à 1 % de la tension entre phases (voir 4.2).

6.2 Fonctionnement normal et conditions de défaut du matériel

6.2.1 Fonctionnement normal du matériel

L'essai est effectué avec la borne A du réseau de mesure reliée successivement à chaque circuit ou partie accessible conductrice ou non mise à la terre, avec tous les commutateurs d'essai I, n et e fermés.

Les mesurages doivent être effectués dans toutes les conditions applicables de fonctionnement normal.

Exemples de fonctionnement normal: mise sous tension, mise hors tension, régime de veille, démarrage, chauffage, tout réglage des commandes utilisables par l'opérateur à l'exception des commandes de réglage de la tension d'alimentation.

Un MATERIEL monophasé doit être soumis à l'essai en polarité normale et inverse (commutateur p).

Un MATERIEL triphasé doit être soumis à l'essai avec inversion des phases, à moins que le fonctionnement du MATERIEL ne dépende du phasage.

6.2.2 Conditions de défaut du matériel et de l'alimentation

6.2.2.1 Généralités

Pour les MATERIELS n'ayant pas de connexion à la terre, 6.2.2 ne s'applique pas.

Pour les MATERIELS ayant une connexion de terre de protection ou une connexion de terre fonctionnelle, la borne A du réseau de mesure est connectée à la borne de terre du MATERIEL en essai.

Les mesurages doivent être effectués avec chacune des conditions de défaut applicables spécifiées de 6.2.2.2 à 6.2.2.9 inclus. Les défauts doivent être appliqués l'un après l'autre mais doivent inclure tout défaut qui soit le résultat logique du premier défaut. Avant l'application d'un défaut, le MATERIEL doit être remis dans ses conditions initiales (par exemple, sans défaut ni dommage en résultant).

Si un filtre de ligne équilibré est utilisé dans un MATERIEL triphasé, le courant net à la terre résultant est théoriquement égal à zéro. Toutefois, il est normal qu'un composant et une tension déséquilibrés produisent une valeur finie du courant net, dont la valeur maximale peut ne pas être mesurée lors d'un essai de type. Des courants déséquilibrés plus importants résultent d'une défaillance d'un condensateur dans une phase. Il convient que les comités de MATERIELS envisagent l'introduction d'un essai pour de tels MATERIELS, prévoyant la substitution d'un défaut délibéré du filtre (un condensateur débranché) ainsi qu'un défaut de la connexion de terre de protection (voir 6.2.2.2).

Des considérations analogues s'appliquent à des dispositions équilibrées d'autres composants tels que parafoudres, reliés entre le réseau d'alimentation et la terre.

Un MATERIEL triphasé doit être soumis à l'essai avec inversion des phases, à moins que le fonctionnement du MATERIEL ne dépende du phasage.

6.2.2.2 Condition de défaut n° 1

En fonction du type de MATERIEL, plusieurs degrés de sécurité du conducteur de protection doivent être distingués (voir IEC 61140).

Un MATERIEL monophasé non relié de façon sûre à la terre doit être soumis à l'essai avec défaut de la connexion de terre de protection (commutateur e) en combinaison avec la polarité normale et inverse (commutateur p).

Un MATERIEL triphasé non relié à la terre de façon sûre doit être soumis à l'essai avec défaut de la connexion de terre de protection (commutateur e).

À moins d'une décision contraire du comité de produits, les exigences du présent paragraphe ne s'appliquent pas aux MATERIELS reliés de façon sûre à la terre qui sont connectés à l'alimentation soit de façon permanente, soit par l'intermédiaire de prises et de socles industriels (par exemple prises et socles spécifiés dans l'IEC 60309-1 ou dans une norme nationale équivalente).

6.2.2.3 Condition de défaut n° 2

Un MATERIEL monophasé doit être soumis à l'essai avec le neutre interrompu (commutateur n), avec la terre intacte et en polarité normale, et ensuite en polarité inverse (commutateur p).

6.2.2.4 Condition de défaut n° 3

Un MATERIEL destiné à être utilisé dans les schémas IT doit être soumis à l'essai en mettant, à tour de rôle, chaque conducteur de phase défectueux à la terre (commutateur g).

6.2.2.5 Condition de défaut n° 4

Un MATERIEL triphasé doit être soumis à l'essai en ouvrant, à tour de rôle, chaque conducteur de phase (commutateurs l).

6.2.2.6 Condition de défaut n° 5

Un MATERIEL monophasé destiné à être utilisé dans des schémas d'alimentation IT ou dans des schémas triphasés triangle doit être soumis à l'essai dans un schéma d'alimentation triphasé, chaque phase défectueuse mise à la terre à tour de rôle (commutateur g), en combinaison avec polarité normale et inverse (commutateur p) et séparément avec ouverture de chaque conducteur de phase à tour de rôle (commutateurs l), et en combinaison avec polarité normale et inverse (commutateur p).

6.2.2.7 Condition de défaut n° 6

Un MATERIEL triphasé destiné à être utilisé dans des schémas d'alimentation triangle dont le point milieu est relié à la terre doit être soumis à l'essai dans un schéma d'alimentation triangle, chaque point milieu de branche étant relié à la terre, à tour de rôle (commutateur g).

Un MATERIEL comprenant à la fois des circuits triphasés et des circuits dont le point milieu est relié à la terre, qui ne peuvent être installés indépendamment et dont une branche mise à la terre a été identifiée, doit être soumis à l'essai avec le commutateur g réglé uniquement sur la position correspondant à la branche mise à la terre identifiée.

6.2.2.8 Condition de défaut n° 7

D'autres défauts, comme spécifiés par le comité de produits, doivent être simulés s'ils sont susceptibles d'augmenter le COURANT DE CONTACT.

6.2.2.9 Condition de défaut n° 8

Les parties conductrices accessibles qui ne sont que fortuitement reliées électriquement à d'autres parties doivent être soumises à l'essai, d'une part, lorsqu'elles sont reliées électriquement à ces autres parties et, d'autre part, lorsqu'elles ne sont pas reliées électriquement à ces autres parties. Voir l'Annexe C pour ce qui concerne les parties connectées fortuitement.

7 Évaluation des résultats

7.1 Perception, réaction de tressaillement et non-lâcher/immobilisation

Les tensions U_2 et U_3 de la Figure 4 et de Figure 5 sont des valeurs de U_1 pondérées en fréquence de telle manière qu'une indication unique équivalente en basse fréquence soit le résultat du COURANT DE CONTACT pour toutes les fréquences supérieures à 15 Hz. Ces valeurs pondérées du COURANT DE CONTACT sont prises comme étant les plus fortes valeurs de U_2 et U_3 mesurées pendant la procédure de l'Article 6, divisées par 500Ω . Les valeurs maximales sont comparées aux limites pour la perception ou la réaction de tressaillement et le non-lâcher/l'immobilisation spécifiées pour le MATERIEL (par exemple valeur limite à 50 Hz ou 60 Hz).

Les mesurages pour les limites en courant continu sont réalisés de la même manière, mais en prenant U_1 divisé par 500Ω (voir aussi Annexe G).

7.2 Effets des brûlures électriques

Si les effets de BRULURES ELECTRIQUES sont à prendre en compte (voir 6.1), la valeur efficace non pondérée ou la valeur en courant continu du COURANT DE CONTACT est mesurée. Cette valeur est calculée à partir de la tension efficace U_1 , mesurée aux bornes de la résistance de 500Ω du réseau de mesure de la Figure 3.

L'effet du COURANT DE CONTACT dépend aussi de la surface de contact avec le corps humain et de la durée du contact. Le rapport entre ces paramètres et la fixation des limites du COURANT DE CONTACT ne relèvent pas du domaine d'application de la présente norme (voir aussi l'Article D.3).

NOTE Les BRULURES ELECTRIQUES proviennent de la puissance dissipée par le courant circulant à travers la résistance de la peau et du corps humains. D'autres formes de brûlures peuvent provenir du MATERIEL électrique, par exemple à cause d'un arc ou des dérivés d'un arc.

8 Mesurage du courant dans le conducteur de protection

8.1 Généralités

Les exigences et les valeurs du courant dans les conducteurs de protection n'ont pas de relation avec le COURANT DE CONTACT. Par conséquent, leurs limites et méthodes de mesure sont traitées séparément.

8.2 Matériels multiples

Dans le cadre de MATERIELS individuels mis à la terre de façon commune, les COURANTS DANS LES CONDUCTEURS DE PROTECTION se combinent de façon non arithmétique. C'est pourquoi le COURANT DANS LE CONDUCTEUR DE PROTECTION d'une installation mise à la terre par un seul conducteur de mise à la terre de protection ne peut être convenablement estimé à partir de la connaissance des COURANTS DANS LES CONDUCTEURS DE PROTECTION DES MATERIELS individuels. En conséquence, les mesurages sur un MATERIEL individuel sont de peu d'intérêt et le COURANT DANS LE CONDUCTEUR DE PROTECTION pour ce groupe de MATERIELS doit être mesuré dans le conducteur commun de mise à la terre de protection.

8.3 Méthode de mesure

Le COURANT DANS LE CONDUCTEUR DE PROTECTION doit être mesuré après l'installation de tous les MATERIELS, par insertion d'un ampèremètre d'impédance négligeable (par exemple $0,5 \Omega$) en série avec le conducteur de protection. Le mesurage du COURANT DANS LE CONDUCTEUR DE PROTECTION est effectué avec le MATERIEL et le schéma de distribution d'énergie fonctionnant dans tous les modes normaux de fonctionnement.

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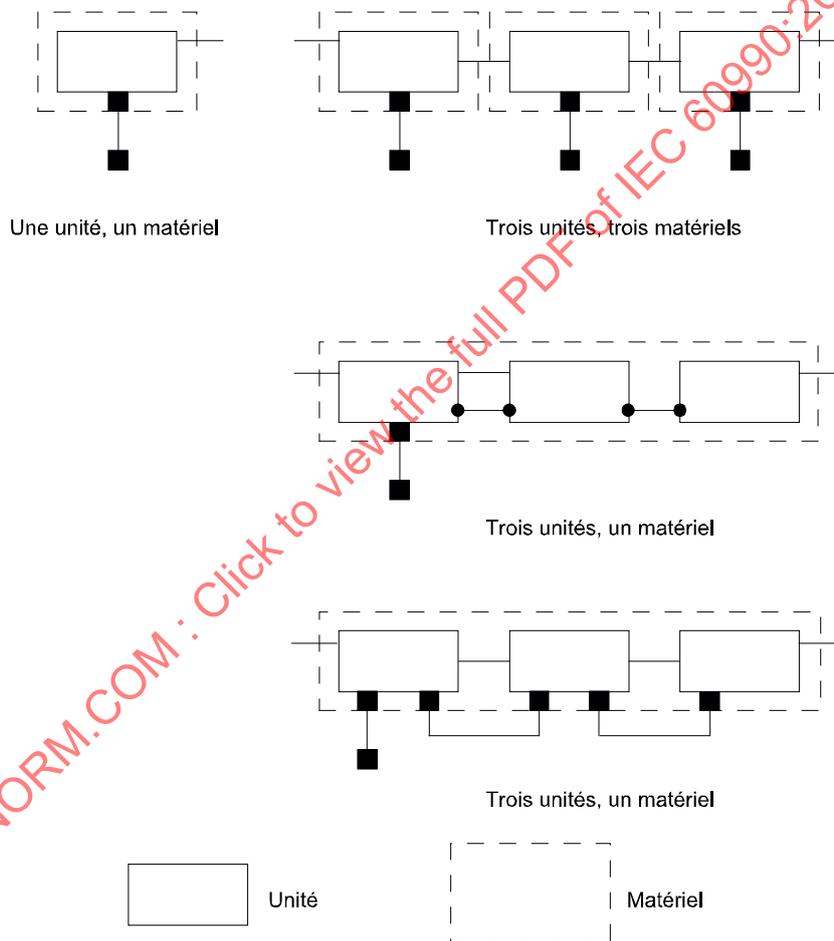
Annexe A (normative)

Matériel

Sauf indication contraire dans la norme de MATERIEL, le MATERIEL est identifié comme ayant une seule connexion à une source électrique.

Un MATERIEL peut être une seule unité ou peut être constitué d'unités physiquement indépendantes et électriquement interconnectées (voir Figure A.1). L'alimentation électrique peut être contenue dans le MATERIEL (par exemple, sources solaires ou batteries).

La connexion des câbles signaux doit être considérée comme faisant partie du MATERIEL, conformément à 5.4.



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Légende

- Connexion à l'alimentation compatible avec l'alimentation locale
- Connexion à l'alimentation non prévue pour être reliée directement à l'alimentation locale
- Autres connexions

Figure A.1 – Matériel

Annexe B (normative)

Utilisation d'un plan conducteur

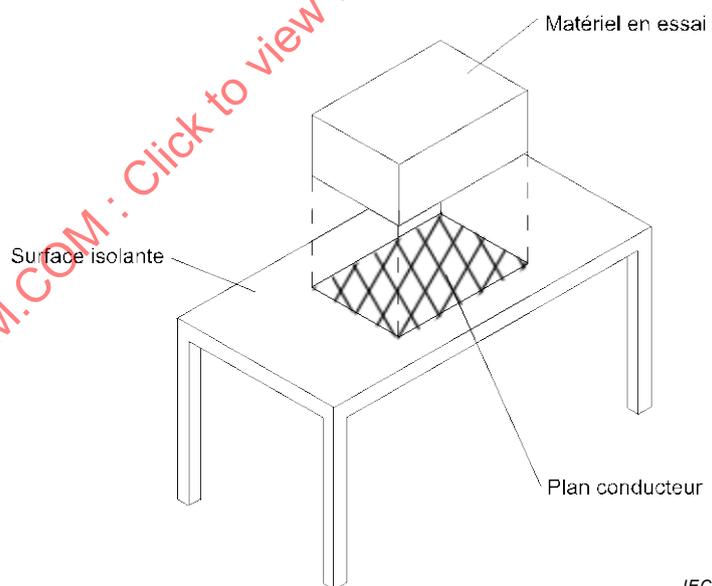
Lorsque des limites du COURANT DE CONTACT (avec ou sans pondération en fréquence) de moins de $70 \mu\text{A}$ en valeur efficace ou de $100 \mu\text{A}$ en valeur de crête sont spécifiées, ou lorsque le MATERIEL soumis à l'essai présente un important couplage capacitif avec des surfaces extérieures qui peuvent, de ce fait, être parcourues par des courants à haute fréquence (par exemple des générateurs de signaux à haute fréquence et des appareils de mesure de tension), il est approprié de mesurer le courant qui est couplé capacitivement dans une surface conductrice placée sous ou contre une surface du MATERIEL. Si le MATERIEL doit être soumis à l'essai de cette manière, il doit être placé sur un plan conducteur qui lui-même repose sur une surface isolante (voir Figure B.1).

La surface et le périmètre du plan conducteur doivent être égaux ou supérieurs à ceux de la surface adjacente du MATERIEL.

Les mesurages doivent être effectués conformément à l'Article 6, en considérant le plan conducteur comme une partie accessible.

Les mesurages doivent être répétés avec le plan conducteur placé contre toute autre surface du MATERIEL qui peut devenir adjacente à un plan conducteur extérieur.

Pour des raisons de protection contre les brouillages électromagnétiques, il peut être nécessaire de placer le MATERIEL (y compris le plan conducteur, s'il est utilisé) à au moins 0,5 m d'autres conducteurs ou d'autres MATERIELS.



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Figure B.1 – Plate-forme d'essai