BS EN 60990:2000
IEC 60990:1999

Methods of measurement of touch current and protective conductor current

The European Standard EN 60990:1999 has the status of a British Standard

ICS 13.260

National foreword

This British Standard is the official English language version of EN 60990:1999. It is identical with IEC 60990:1999.

The UK participation in its preparation was entrusted to Technical Committee EPL/74, Safety of information technology equipment including electrical business equipment, which has the responsibility to:

— aid enquirers to understand the text;

— present to the responsible international/European committee any enquiries on the interpretation, or proposals for change, and keep the UK interests informed;

— monitor related international and European developments and promulgate them in the UK.

A list of organizations represented on this committee can be obtained on request to its secretary.

From 1 January 1997, all IEC publications have the number 60000 added to the old number. For instance, IEC 27-1 has been renumbered as IEC 60027-1. For a period of time during the change over from one numbering system to the other, publications may contain identifiers from both systems.

Cross-references

Attention is drawn to the fact that CEN and CENELEC Standards normally include an annex which lists normative references to international publications with their corresponding European publications. The British Standards which implement international or European publications referred to in this document may be found in the BSI Standards Catalogue under the section entitled "International Standards Correspondence Index", or by using the "Find" facility of the BSI Standards Electronic Catalogue.

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Summary of pages

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Methods of measurement of touch current and protective conductor current (IEC 60990:1999)

Méthodes de mesure du courant de contact et du courant dans le conducteur de protection (CEI 60990:1999)

Verfahren zur Messung von Berührungsstrom und Schutzleiterstrom (IEC 60990:1999)

This European Standard was approved by CENELEC on 1999-10-01. CENELEC members are bound to comply with the CEN/CENELEC Internal Regulations which stipulate the conditions for giving this European Standard the status of a national standard without any alteration.

Up-to-date lists and bibliographical references concerning such national standards may be obtained on application to the Central Secretariat or to any CENELEC member.

This European Standard exists in three official versions (English, French, German). A version in any other language made by translation under the responsibility of a CENELEC member into its own language and notified to the Central Secretariat has the same status as the official versions.

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CENELEC

European Committee for Electrotechnical Standardization
Comité Européen de Normalisation Electrotechnique
Europäisches Komitee für Elektrotechnische Normung

Central Secretariat: rue de Stassart 35, B - 1050 Brussels

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Foreword

The text of document 74/518/FDIS, future edition 2 of IEC 60990, prepared by IEC TC 74, Safety and energy efficiency of IT equipment, was submitted to the IEC-CENELEC parallel vote and was approved by CENELEC as EN 60990 on 1999-10-01.

The following dates were fixed:

– latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement	(dop)	2000-07-01
– latest date by which the national standards conflicting with the EN have to be withdrawn	(dow)	2002-10-01

Annexes designated "normative" are part of the body of the standard.
Annexes designated "informative" are given for information only.
In this standard, annexes A, B, C, L and ZA are normative and annexes D, E, F, G, H, J, K and M are informative.
Annex ZA has been added by CENELEC.

Endorsement notice

The text of the International Standard IEC 60990:1999 was approved by CENELEC as a European Standard without any modification.

In the official version, for annex M, Bibliography, the following notes have to be added for the standards indicated:

IEC 60065	NOTE: Harmonized as EN 60065:1998 (modified).
IEC 60335-1	NOTE: Harmonized as EN 60335-1:1988 (modified), which is superseded by EN 60335-1:1994 (modified).
IEC 60364-3	NOTE: Harmonized as HD 384.3 S2:1995 (modified).
IEC 60601-1	NOTE: Harmonized as EN 60601-1:1990 (not modified).
IEC 60950	NOTE: Harmonized as EN 60950:1992 (modified).
IEC 61010-1	NOTE: Harmonized, together with its amendment A1:1992, as EN 61010-1:1993 (modified).

CONTENTS

Page

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 prepared under the safety pilot function assigned to TC 74, 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 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,
  - reaction,
  - let-go, 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.

* Terms in small capitals are defined in clause 3.

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 (e.g. one finger contact), a different model may be appropriate.

Of the four responses, perception, reaction and let-go 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, reaction and let-go currents 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, one in peak value for electric shock and a second in r.m.s. value for ELECTRIC BURNS.

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 471.3.3 of IEC 60364-7-707.

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.

METHODS OF MEASUREMENT OF TOUCH CURRENT AND PROTECTIVE CONDUCTOR CURRENT

1 Scope

This International Standard defines measurement methods for

– d.c. or a.c. 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 60479-1 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.

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,
– 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.

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 apply, unless specifically referred to or included in the relevant publications.

2 Normative references

The following normative documents contain provisions which, through reference in this text, constitute provisions of this International Standard. For dated references, subsequent amendments to, or revisions of, any of these publications do not apply. However, parties to agreements based on this International Standard are encouraged to investigate the possibility of applying the most recent editions of the normative documents indicated below. For undated references, the latest edition of the normative document referred to 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 60479-1:1994, *Effects of current on human beings and livestock – Part 1: General 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, *Guideline for the inclusion of safety aspects 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*

3 Definitions

For the purpose of this International Standard, the following 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 [IEV 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

3.4
grippable part
part of the equipment which could supply current through the human hand to cause muscular contraction round the part and an inability to let go. 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 [IEV 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 figures 6 to 14) shall be used and the main protective earthing terminal of the EQUIPMENT under test (EUT) earthed. Any capacitive leakage in the transformer must 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 J.

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 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.

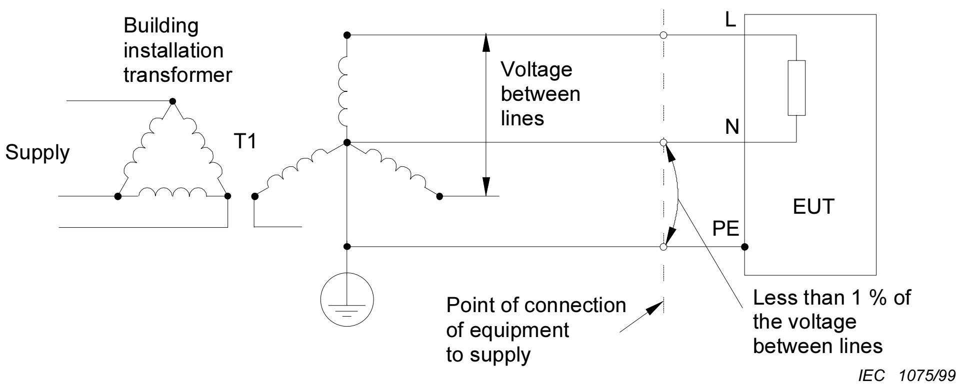


Figure 1 – Example of earthed neutral, direct supply

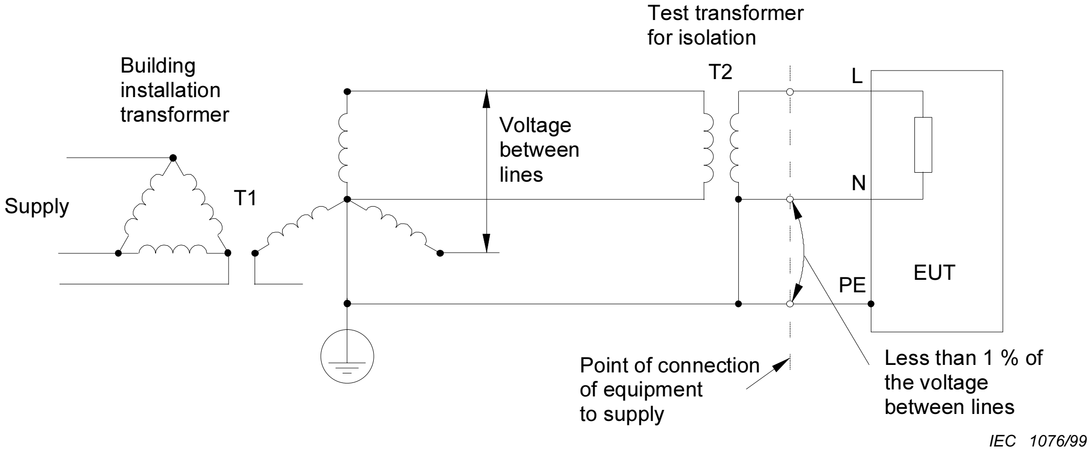


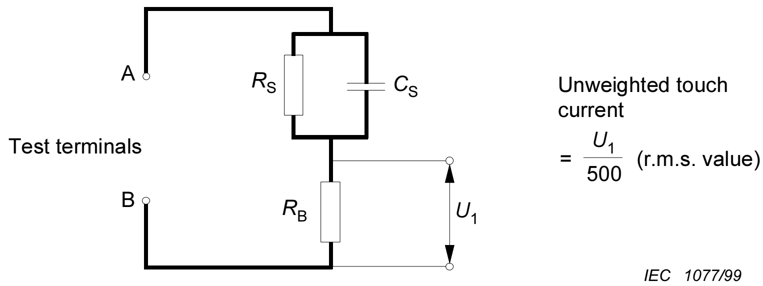
Figure 2 – Example of earthed neutral, with transformer for isolation

5 Measuring equipment

5.1 Selection of measuring network

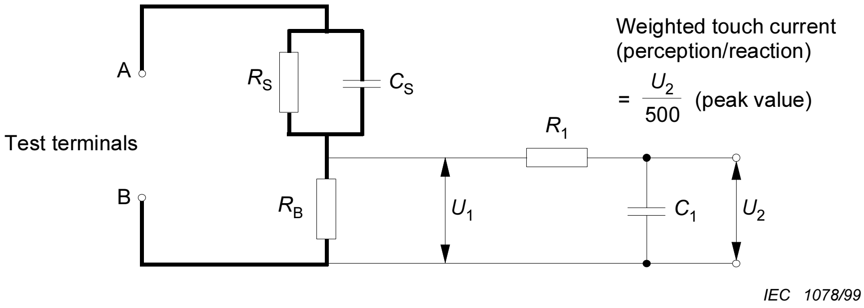
Measurements shall be made with one of the networks of figures 3, 4 and 5.

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



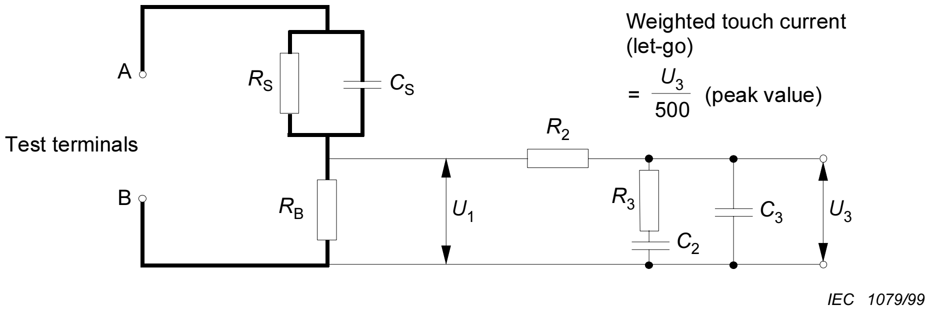
R_S	1 500 Ω
R_B	500 Ω
C_S	0,22 µF

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 reaction



R_S	1 500 Ω	R_3	20 000 Ω
R_B	500 Ω	C_2	0,0062 μF
C_S	0,22 μF	C_3	0,0091 μF
R_2	10 000 Ω		

NOTE – Use of this network is subject to special conditions (see 5.1.2).

Figure 5 – Measuring network, touch current weighted for let-go

5.1.1 Perception and reaction (a.c.)

The network of figure 4 shall be used.

5.1.2 Let-go (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.

5.1.3 Electric burn (a.c.)

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

5.1.4 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 (e.g. 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

NOTE – Examples of power distribution systems are given in annex J.

5.4.1 General

EQUIPMENT shall be connected as shown in figures 6 to 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), the protective conductors in figures 6 through 14 are ignored.

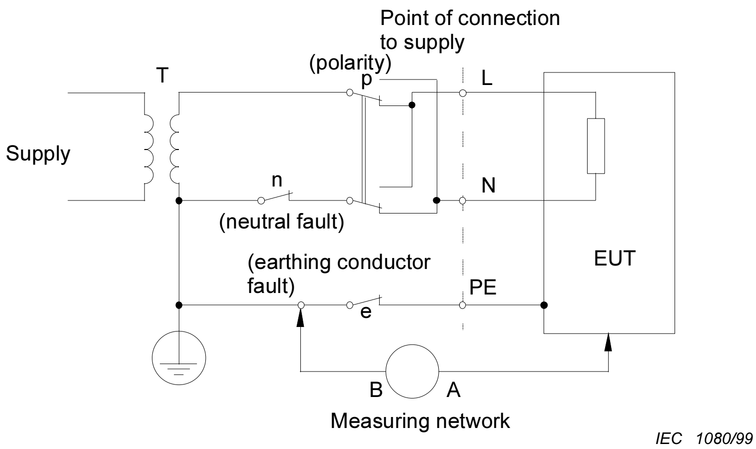
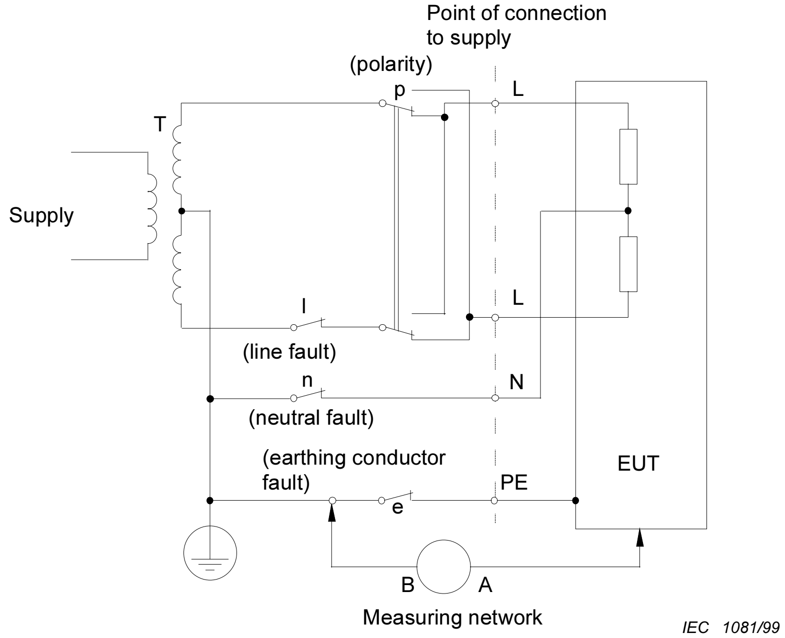


Figure 6 – Test configuration: single-phase equipment on star TN or TT system



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

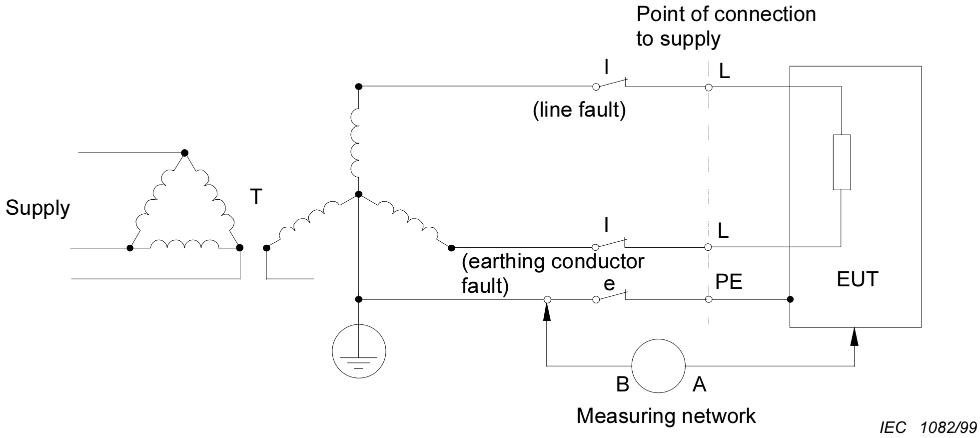
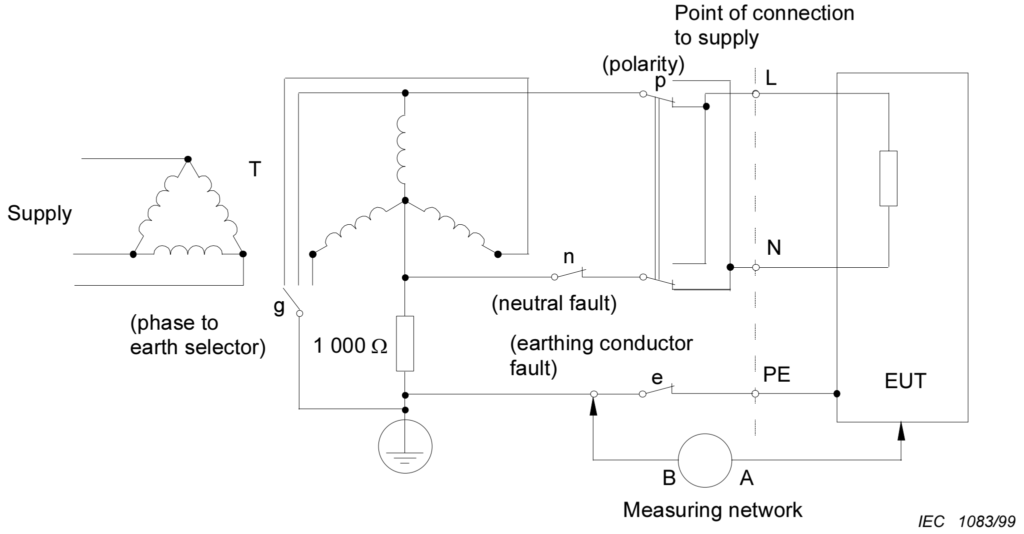
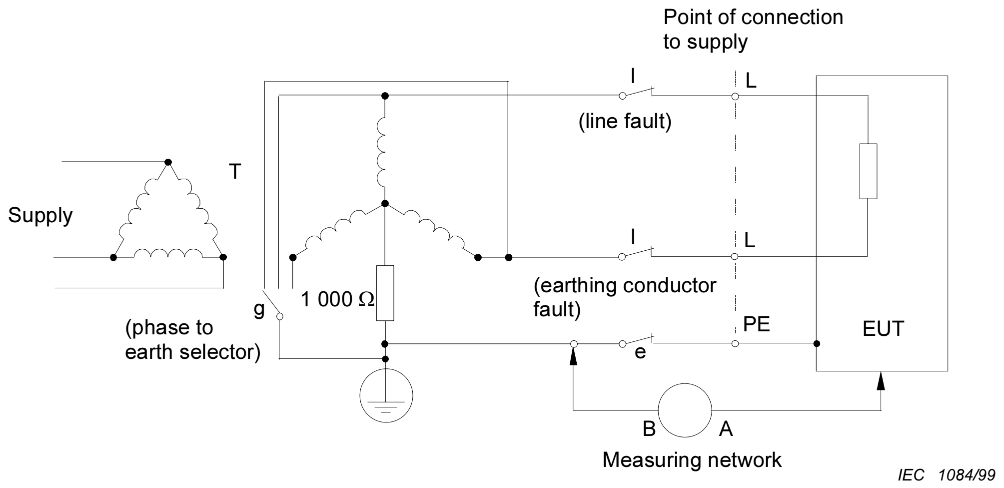


Figure 8 – Test configuration: single-phase equipment connected line-to-line on star TN or TT system



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

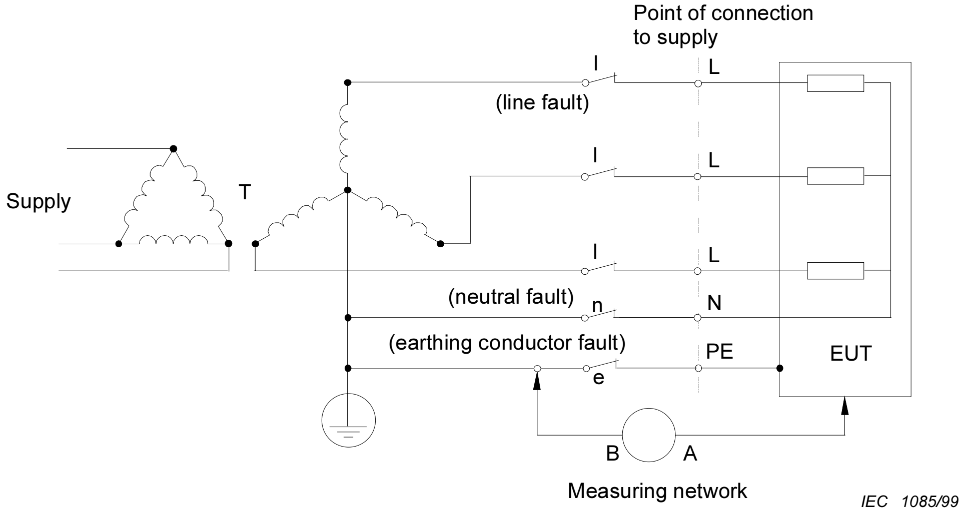
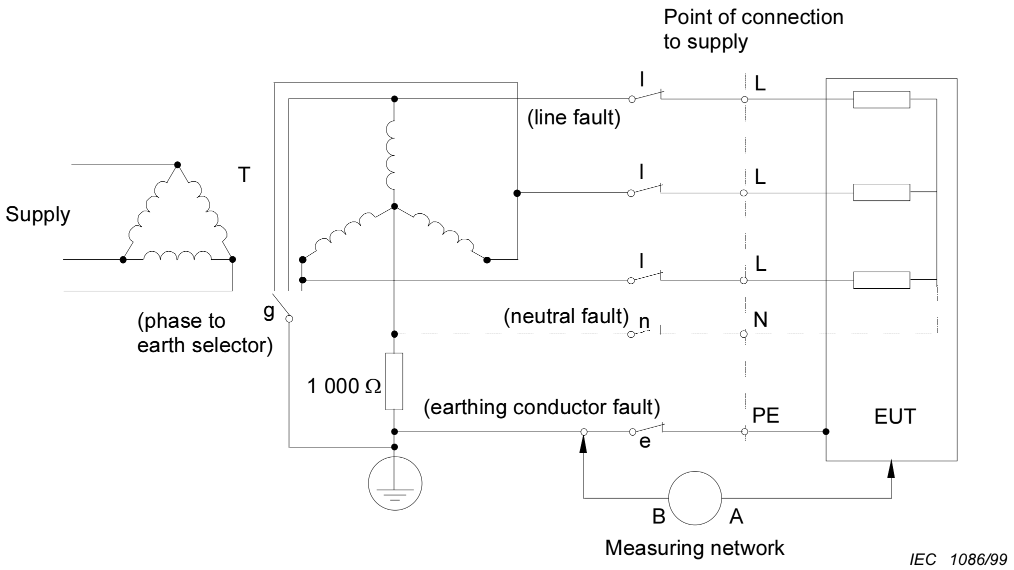


Figure 11 – Test configuration: three-phase equipment on star TN or TT system



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

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

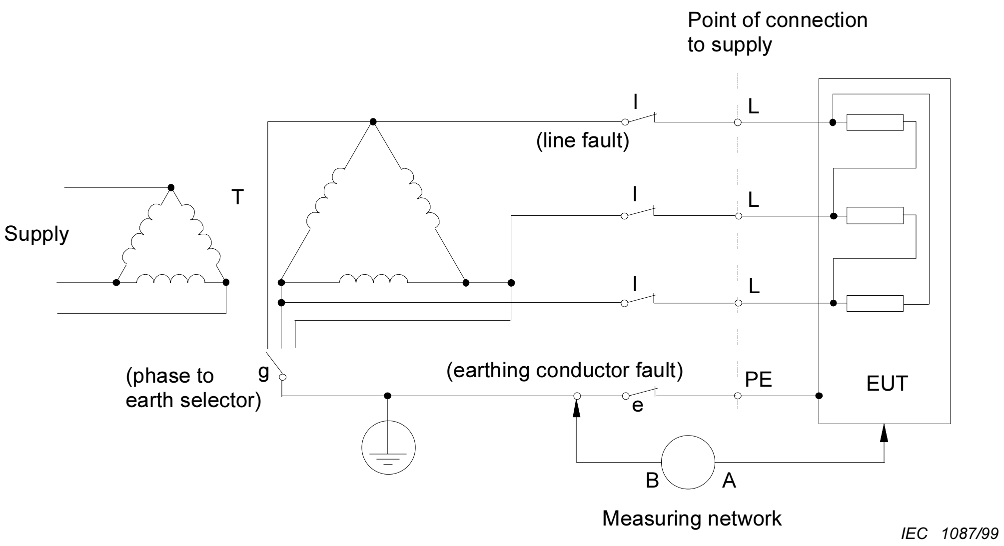
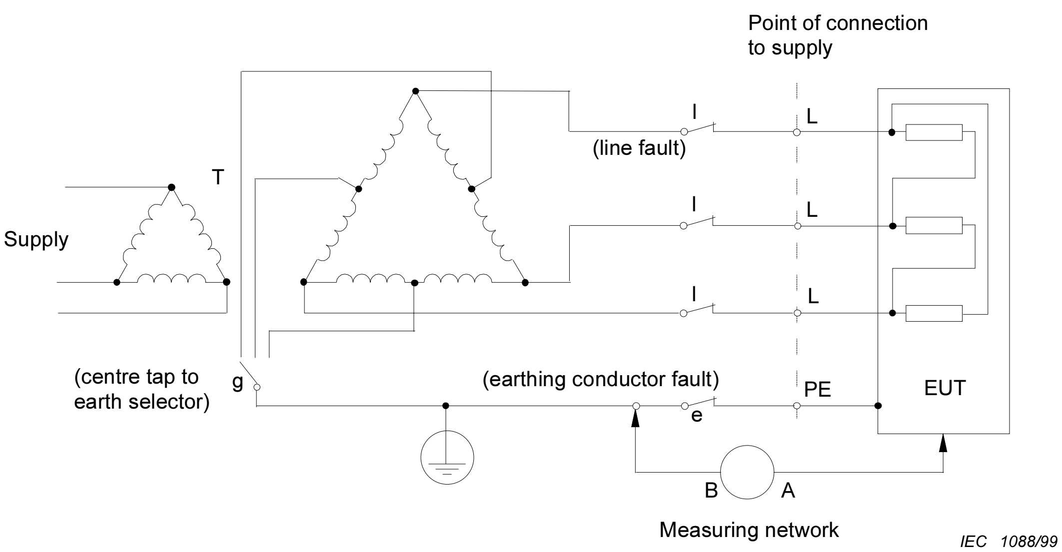


Figure 13 – Test configuration: unearthed delta system



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 figures 6, 8 and 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 figures 9, 10, 12 and 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 figures 7 and 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.

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 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 (e.g. 0 %, +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

EQUIPMENT 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 this clause.

Concern for ELECTRIC BURN effects may arise with d.c. or at high frequencies (e.g. above 30 kHz for 3,5 mA TOUCH CURRENT). At lower frequencies, reaction and let go 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 reaction (figure 4), or ability to let go (figure 5).

6.1.1 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 figures 6 to 14 shall be manipulated as described in 6.2, while the conditions listed in 6.1.2 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 committees shall make an appropriate selection of these variables.

6.1.2 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 figures 6 to 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

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 is connected to the EQUIPMENT earthing terminal of the EUT.

Measurements shall be made with each of the applicable fault conditions specified in 6.2.2.1 to 6.2.2.8. 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 (i.e. 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 (6.2.2.1).

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.

6.2.2.1 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 committee, the requirements of 6.2.2.1 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 (e.g. connectors specified in IEC 60309-1 or a comparable national standard).

6.2.2.2 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).

6.2.2.3 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).

6.2.2.4 Fault condition No. 4

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

6.2.2.5 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).

6.2.2.6 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.

6.2.2.7 Fault condition No. 7

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

6.2.2.8 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, reaction and let-go

Voltages U_2 and U_3 of figures 4 and 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 reaction and let-go specified for the EQUIPMENT (e.g. 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 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 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 (e.g. 0,5 Ω) 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.

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 (e.g. solar or battery power).

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

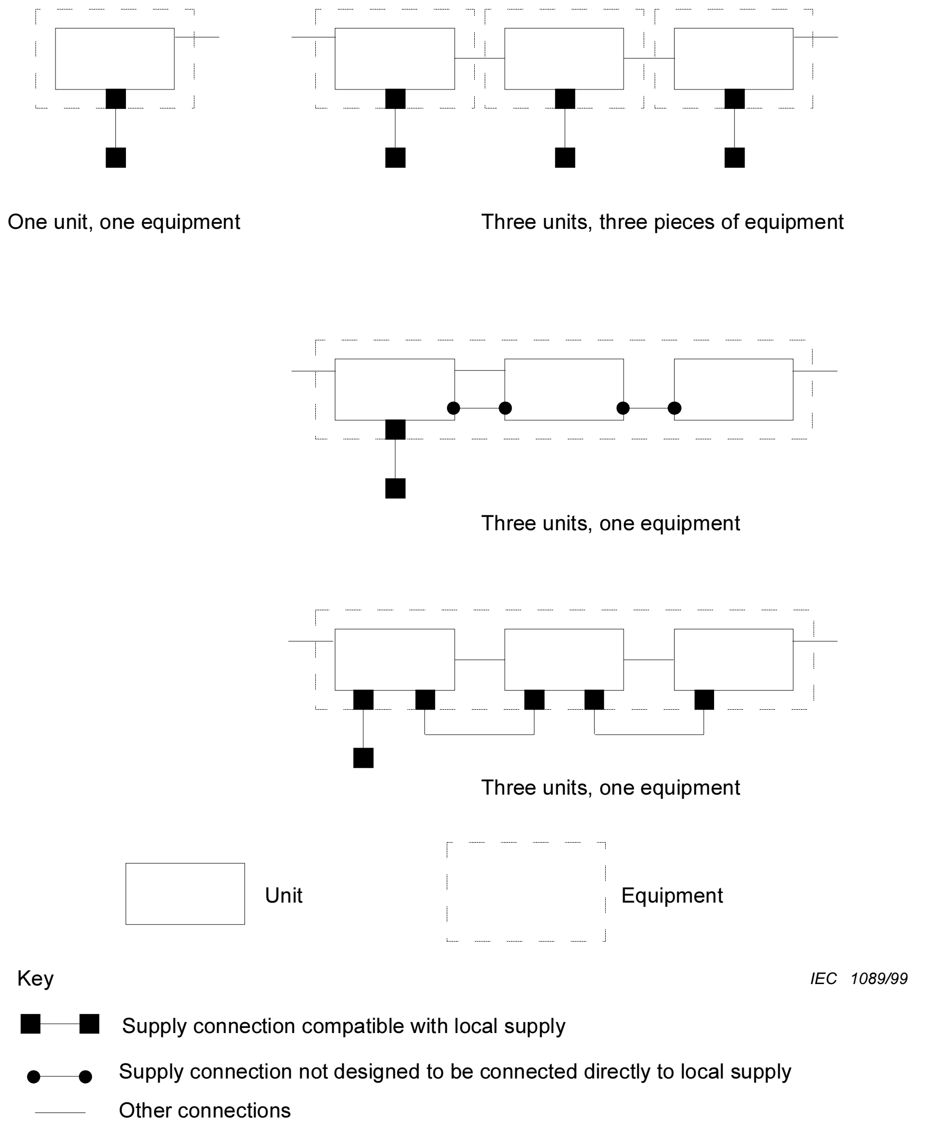


Figure A.1 – Equipment

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 (e.g. 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.

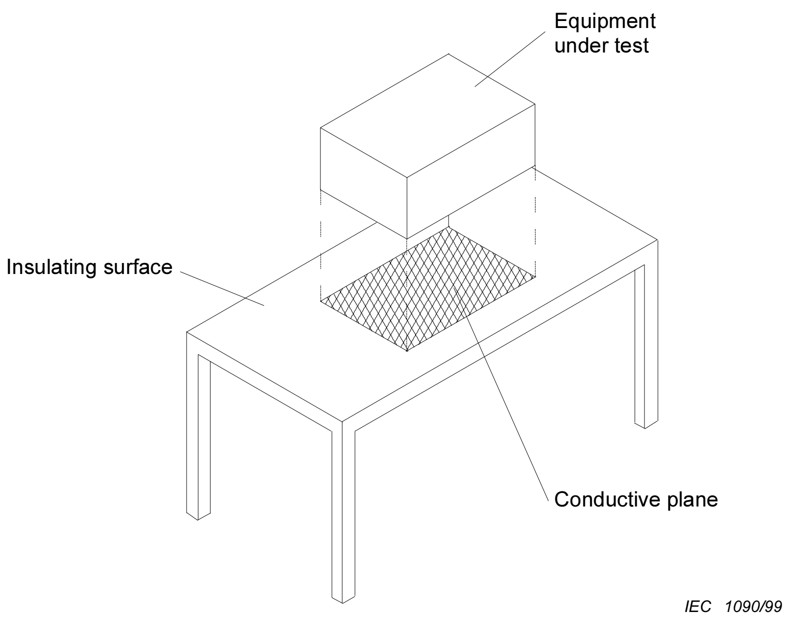


Figure B.1 – Equipment platform

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 (e.g. 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 worse case. However, where the predominant frequency is below 100 Hz, the worse case is most likely to be that in which the incidentally connected part is connected to the other parts.

Annex D
(informative)

Choice of current limits

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

D.1 Limit examples

D.1.1 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.1.2 Inability to let go

– The method of measurement is specified in this standard.

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

D.1.3 Reaction

– The method of measurement is specified in this standard.

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

D.1.4 Perception threshold

– TOUCH CURRENT can be perceived at levels as low as a few microamperes. Unless the current is high enough to produce involuntary reaction that might result in harmful effects, these small TOUCH CURRENTS are not considered hazardous.

D.1.5 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 reaction threshold) is used for Class II EQUIPMENT in IEC 60065, IEC 60950 and IEC 60335-1. 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 body impedance model (see E.1).

D.2 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 60479-1 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 let-go, 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. Let-go, 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 reaction or let-go.

Limits based upon ventricular fibrillation (D.1.1) are not necessary for most EQUIPMENT, since the lower TOUCH CURRENT limits for reaction or let-go almost always prevent ventricular fibrillation. An exception (discussed in IEC 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 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. However, ELECTRIC BURN only becomes the predominant factor at high frequencies. Between the limits for reaction and let-go, 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).

For short-duration current, a limit value higher than that for let-go is sometimes used, provided that it is sufficiently below the ventricular fibrillation and ELECTRIC BURN threshold. The network of figure 3 should be used for such measurements until a specific body impedance model for small area contacts is developed (future work).

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

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

– Limits for reaction and lower limits:
  - need to avoid involuntary reaction, where severe consequences may result (e.g. falling from a ladder or dropping EQUIPMENT);
  - the limit for 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:
  - perception and some reaction are acceptable as an indication of a first fault, when the let-go limit is applied;
  - men and women are estimated to have an average let-go 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 let-go limits, with 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.

D.3 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./cm^2 to 400 mA r.m.s./cm^2 (Becker, Malhotra and Hedley-Whyte).

Annex E
(informative)

Networks for use in measurement of touch current

Current values given in this annex are only examples.

The networks of figures 3, 4 and 5 are intended for TOUCH CURRENT measurements using limits in general use by EQUIPMENT 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.1 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 (e.g. 0,33 µF) may be used.

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

E.2 Perception, reaction (and body impedance) network – Figure 4

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

Consideration of, and compensation for, the frequency variation of 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 reaction. It has been assumed that the shape of the frequency characteristic is the same for reaction and perception, and the data establishing the frequency characteristic was actually obtained through tests on the threshold of perception.

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 let-go and the need for different frequency weighting if ability to let go is of concern (see E.3).

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

E.3 Let-go (and body impedance) network – Figure 5

The inability to let go of an object is caused by current flow internal to the body (e.g. through muscles).

The effect of frequency on let-go limits is different from its effect on perception or reaction, or on ELECTRIC BURN. This is especially true for frequencies above 1 kHz.

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 GRIPPABLE PARTS. TOUCH CURRENT with regard to the let-go threshold is equal to U_3 peak divided by 500 Ω.

Annex F
(informative)

Measuring network limitations and construction

The networks of figures 3, 4 and 5 are intended to produce a measurable voltage response which approximates the curves given in figures F.1, F.2 and F.3. The networks and reference curves provided are in general agreement with those published in IEC 60479-1, 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, reaction or let-go if the r.m.s. current limit for ELECTRIC BURN is exceeded before the weighted peak current limits for perception, reaction and let-go 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.

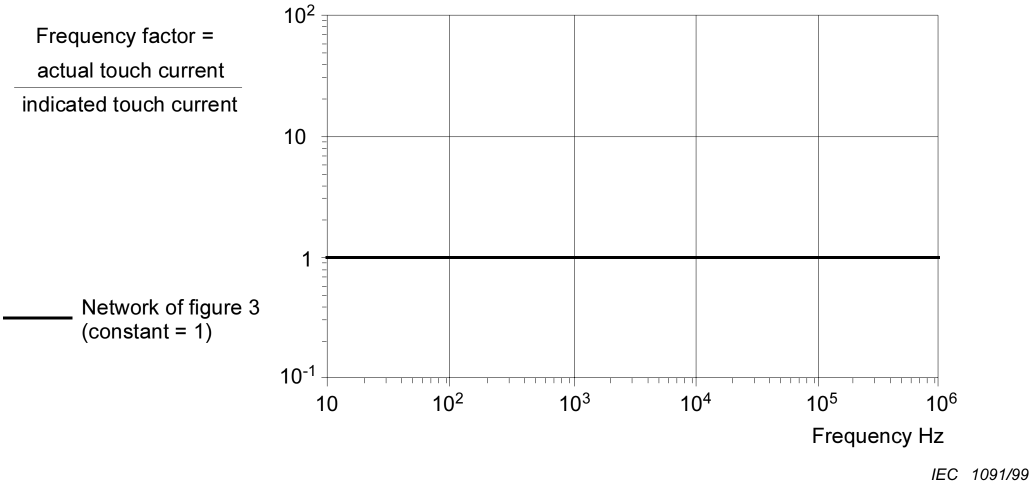


Figure F.1 – Frequency factor for electric burn

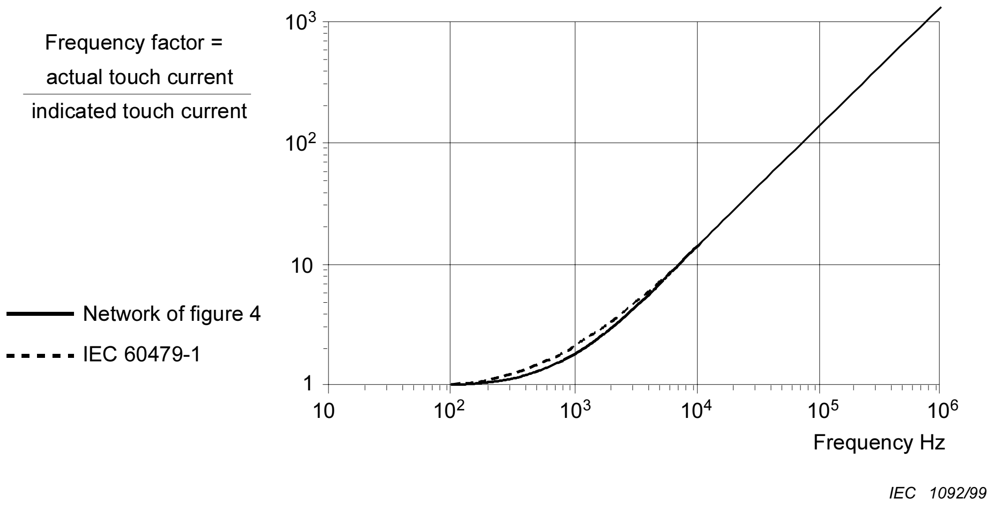


Figure F.2 – Frequency factor for perception or reaction

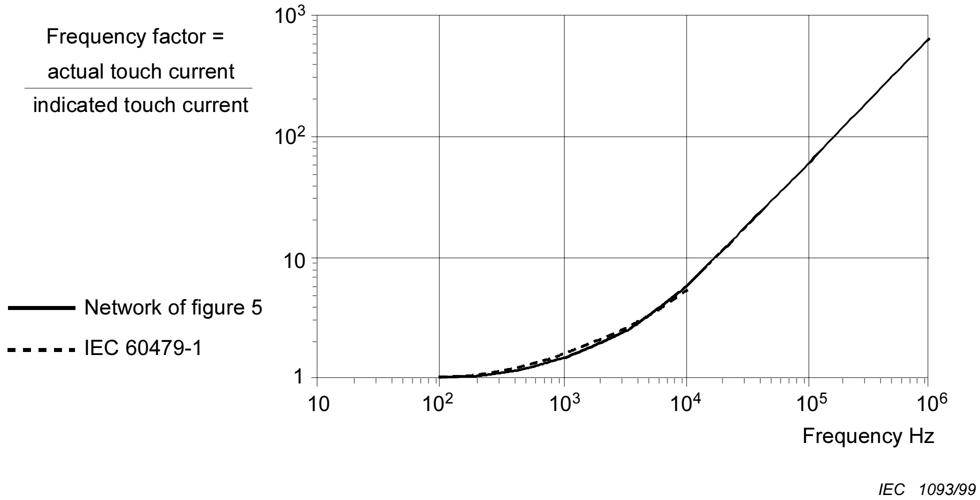


Figure F.3 – Frequency factor for let-go

Annex G
(informative)

Construction and application of touch current measuring instruments

G.1 Considerations for selection of components

The selection of components for the TOUCH CURRENT measuring networks in figures 3, 4 and 5 can be greatly affected by the application, i.e. 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.1.1 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 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 ±1 % and ±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.1.2 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.1.3 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.1.1), R1 and R2 should be rated 1 W.

G.1.4 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 MΩ;
- 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 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.

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 MΩ used with the measuring network of figure 4 or 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.

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 L.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 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 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. These records will provide data for subsequent calibration in confirmation systems (see 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.

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

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.

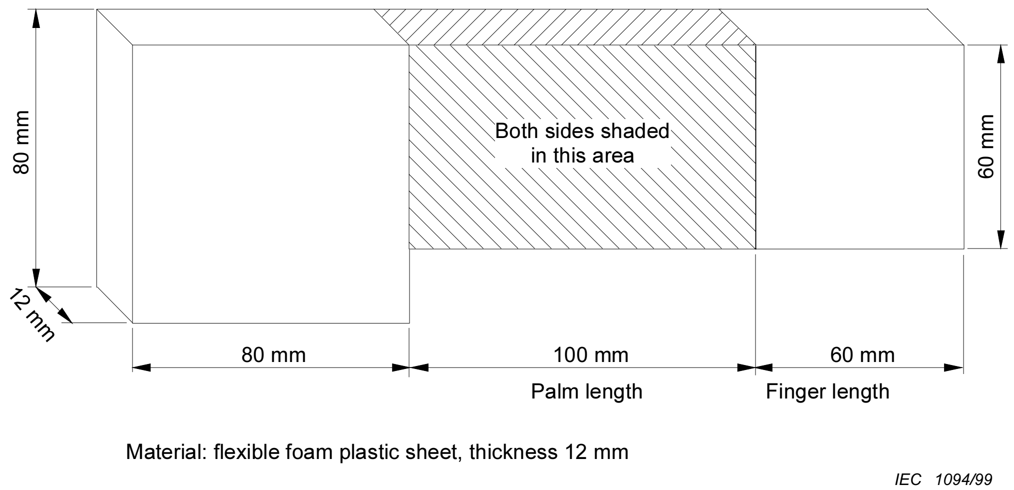


Figure H.1 – Grippable part test device

Annex J
(informative)

AC power distribution systems
(see 5.4)

J.1 Introduction

In IEC 60364-3, 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 figures; 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, 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;

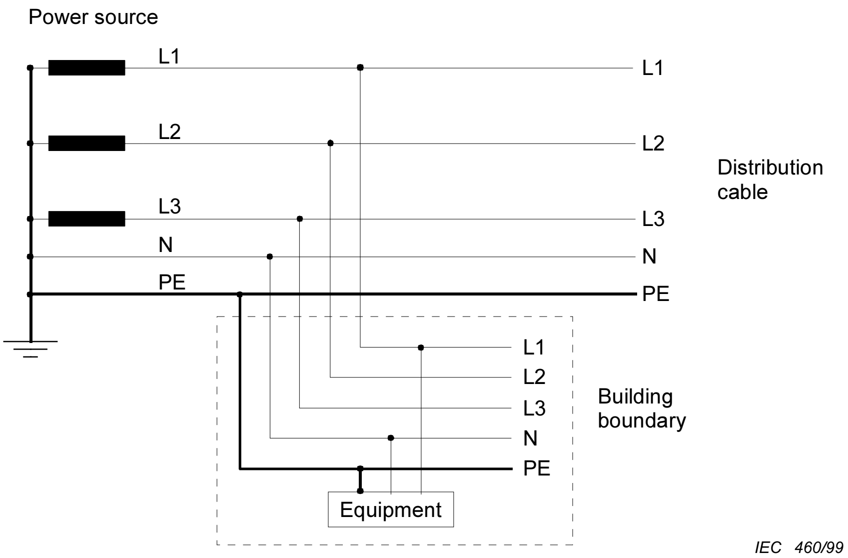
  C means the neutral and protective functions are combined in a single conductor (PEN conductor).

J.2 TN power systems

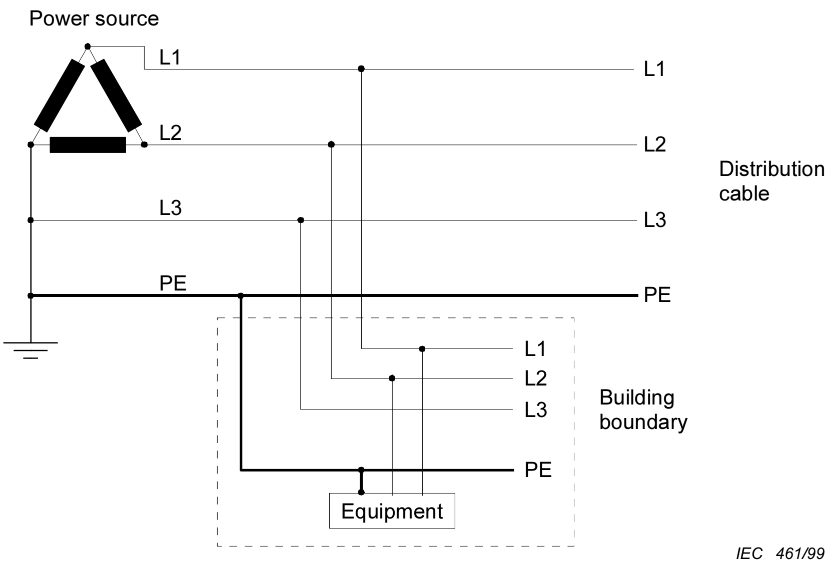
TN power systems are directly earthed, the parts of the EQUIPMENT required to be earthed being connected by protective earthing conductors. Three types of TN power systems are considered:

- 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.

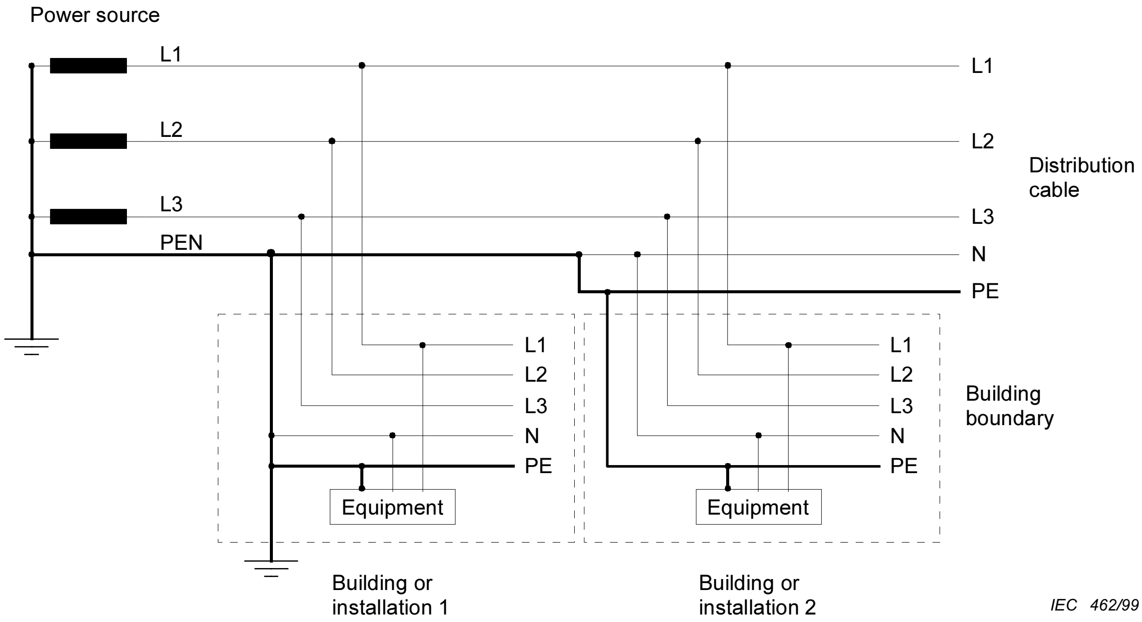


Separate neutral and protective conductors



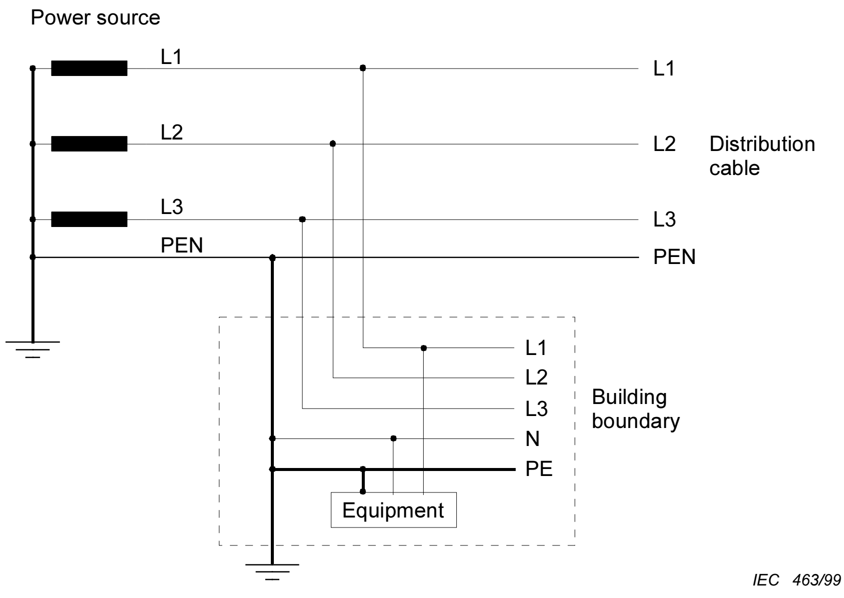
Earthed line conductor

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



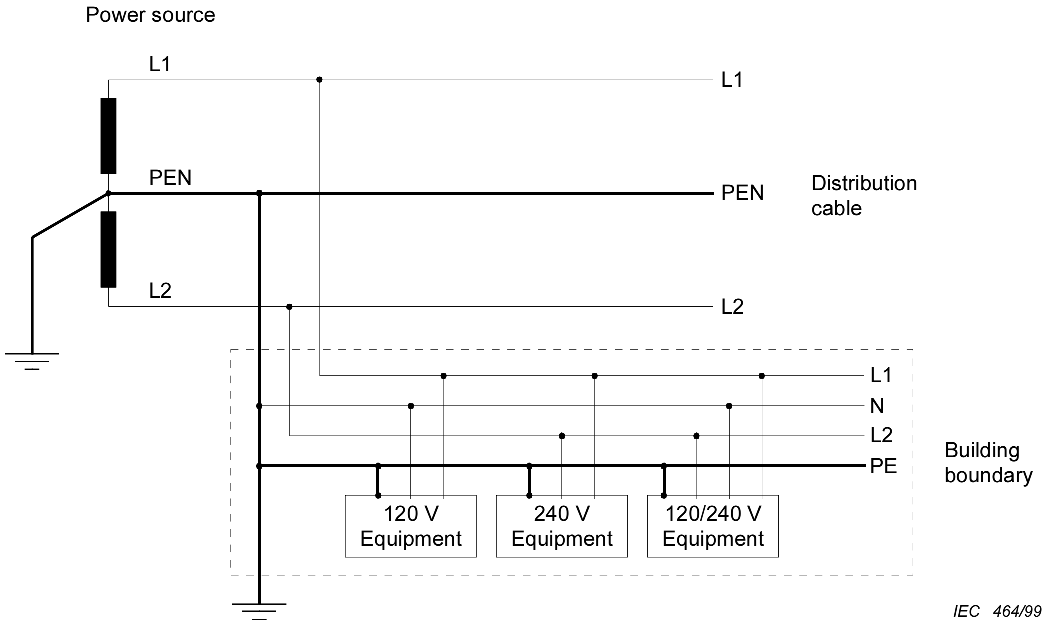
NOTE – The point at which the PEN conductor is separated into protective earth and neutral conductors may be at the building entrance or at distribution panels within the building.

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



Neutral and protective functions combined in one conductor (PEN)

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



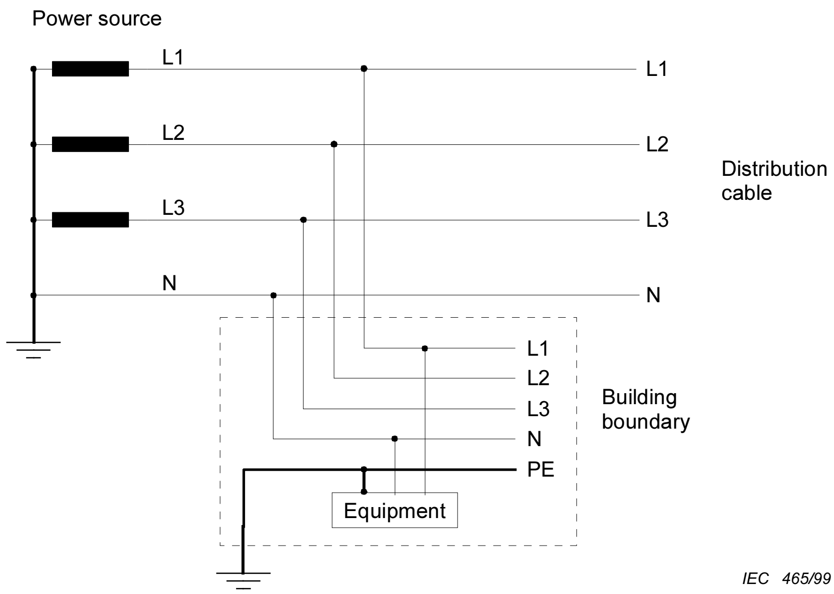
Protective and neutral functions combined in one conductor (PEN)

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

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

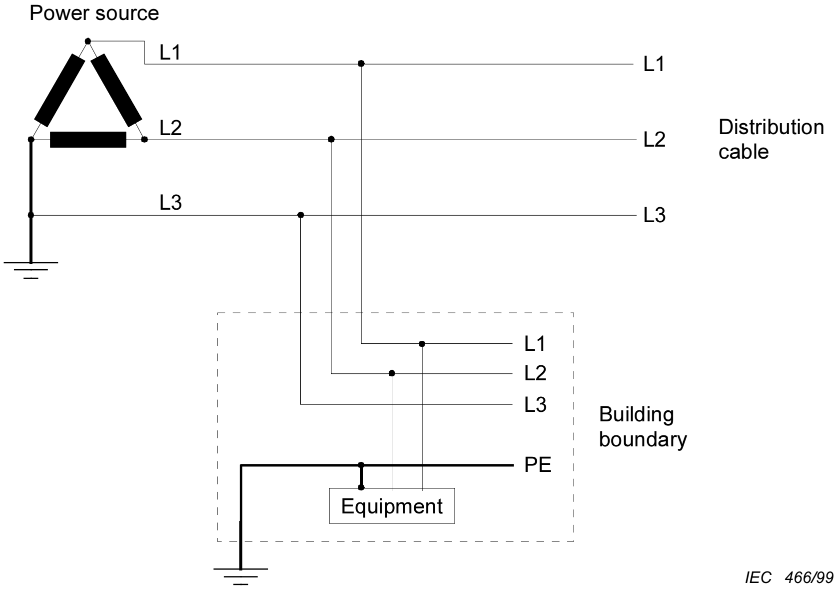
J.3 TT power systems

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.



Earthed neutral and independent earthing of EQUIPMENT

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

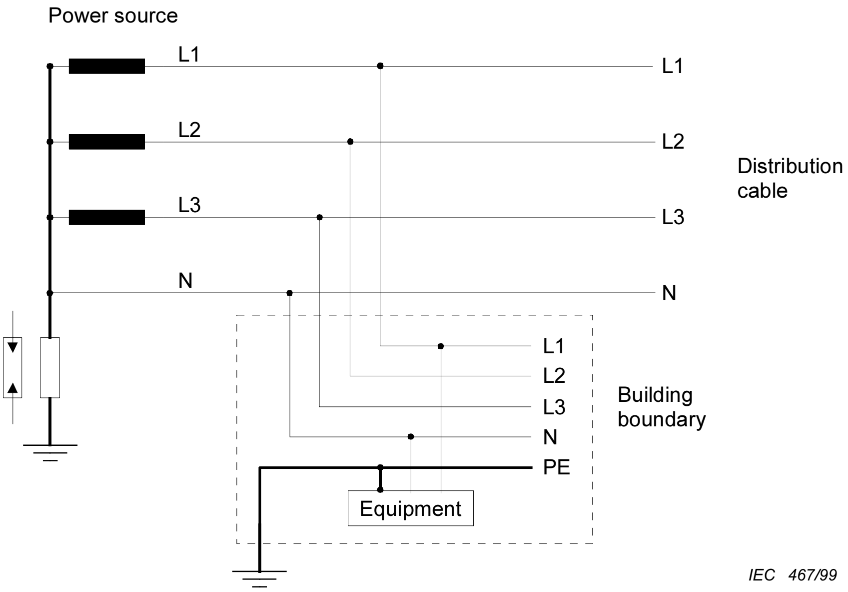


Earthed line and independent earthing of equipment

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

J.4 IT power systems

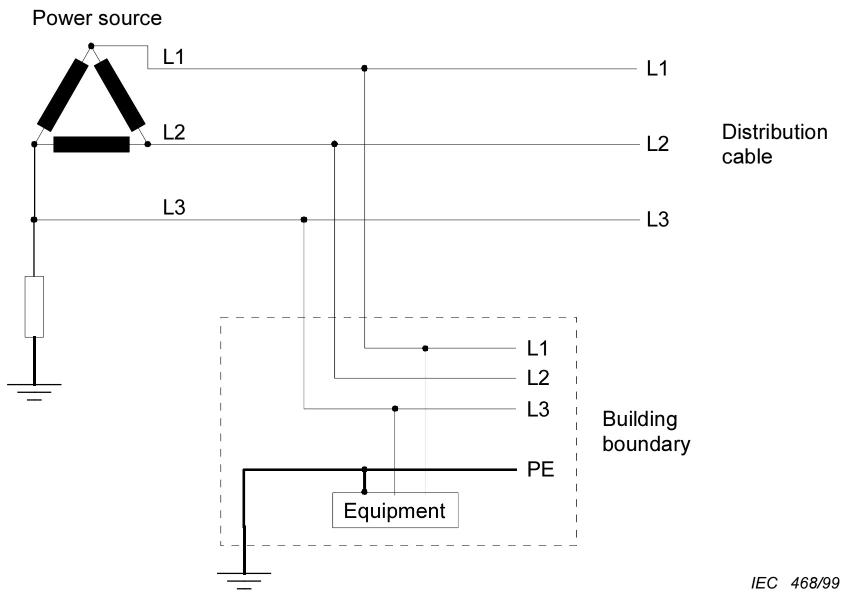
IT power systems are isolated from earth, except that one point may be connected to earth through an impedance or a voltage limiter. The parts of the EQUIPMENT required to be earthed are connected to earth electrodes at the user's premises.



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



The system may be isolated from earth.

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

Annex K
(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 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 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. 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 test is required for ELECTRIC BURN currents.

Annex L
(normative)

Performance and calibration

L.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 figures 3, 4 and 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 10012-1.

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 figures 3, 4 and 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 L.2).

Table L.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 L.2 – Calculated input impedance and transfer impedance for perception or 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 L.3 – Calculated input impedance and transfer impedance for let-go 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

L.2 Calibration in a confirmation system

NOTE – A definition of metrological confirmation (shortened to "confirmation" in this standard) is given in 3.1 of ISO 10012-1.

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 L.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.

L.2.1 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.

L.2.2 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 tables L.4, L.5 or L.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. 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 – Tables L.4, L.5 and L.6 are derived from tables L.1, L.2 and L.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 L.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 L.5 – Output voltage to input voltage ratios for perception or 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	0,0708	14,1	7,06
20 000	0,0360	27,8	13,9
50 000	0,0145	69,2	34,6
100 000	0,00723	138	69,1
200 000	0,00362	277	138
500 000	0,00145	691	346
1 000 000	0,000723	1382	691

Table L.6 – Output voltage to input voltage ratios for let-go 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	0,0860	11,6	5,81
50 000	0,0349	28,7	14,3
100 000	0,0175	57,2	28,6
200 000	0,00874	114	57,2
500 000	0,00350	286	143
1 000 000	0,00175	572	286

Annex M
(informative)

Bibliography

IEC 60065:1998, *Audio, video and similar electronic apparatus – Safety requirements*

IEC 60335-1:1976, *Safety of household and similar electrical appliances – Part 1: General requirements*

IEC 60364-3:1993, *Electrical installations of buildings – Part 3: Assessment of general characteristics*

IEC 60601-1:1988, *Medical electrical equipment – Part 1: General requirements for safety*

IEC 60950:1991, *Safety of information technology equipment, including electrical business equipment*

IEC 61010-1:1990, *Safety requirements for electrical equipment for measurement, control and laboratory use – Part 1: General requirements*

ISO 10012-1:1992, *Quality assurance requirements for measuring equipment – Part 1: Metrological confirmation system for measuring equipment*

Other publications:

Becker, Malhotra and Hedley-Whyte: *The distribution of radiofrequency current and burns,* Anesthesiology, Vol. 38, No. 2, Feb. 1973: 106-22

Biegelmeier and Miksch: *Über den Einfluss der Haut auf die Körper – Impedanz des Menschen,* E.u.M., Vol. 97, Heft 9, Sept. 1980, Österreich

Bridges, Ford, Sherman and Vainberg: *Electrical Shock Safety Criteria*. Pergamon, New York, 1985

Dalziel and Mansfield: *Effect of frequency on perception currents*, AIEE Transactions, Vol. 69, Part II, 1950: 1162-1168

Freiberger: *Der elektrische Widerstand des menschlichen Körpers gegen technischen Gleich- und Wechselstrom*, Verlag Julius Springer, Berlin, 1934

Geddes, Leslie A., editor: *Handbook of Electrical Hazards and Accidents*, CRC Press, 1995. ISBN 0-8493-9431-7

Reilly: *Electrical Stimulation and Electropathology*, Cambridge University Press, 1992

Wagner: *Über die Diagnostik von Stromeintrittstellen auf der menschlichen Haut,* Dissertation Universität Erlangen, 1961

Annex ZA (normative)

Normative references to international publications with their corresponding European publications

This European Standard incorporates by dated or undated reference, provisions from other publications. These normative references are cited at the appropriate places in the text and the publications are listed hereafter. For dated references, subsequent amendments to or revisions of any of these publications apply to this European Standard only when incorporated in it by amendment or revision. For undated references the latest edition of the publication referred to applies (including amendments).

NOTE: When an international publication has been modified by common modifications, indicated by (mod), the relevant EN/HD applies.

Publication	Year	Title	EN/HD	Year
IEC 60050-195	1998	International Electrotechnical Vocabulary (IEV) Chapter 195: Earthing and protection against electric shock	-	-
IEC 60050-604	1987	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	EN 60309-1 [1)]	1997
IEC 60364-4-41 (mod)	1992	Electrical installations of buildings Part 4: Protection for safety Chapter 41: Protection against electric shock	HD 384.4.41 S2	1996
IEC 60364-7-707	1984	Part 7: Requirements for special installations or locations Section 707: Earthing requirements for the installations of data processing equipment	-	-
IEC 60479-1	1994	Effects of current on human beings and livestock Part 1: General aspects	-	-
IEC 60536	1976	Classification of electrical and electronic equipment with regard to protection against electric shock	HD 366 S1	1977
IEC 60536-2	1992	Part 2: Guidelines to requirements for protection against electric shock	-	-
IEC 61140	1997	Protection against electric shock - Common aspects for installation and equipment	-	-

1) EN 60309-1 is superseded by EN 60309-1:1999, which is based on IEC 60309-1:1999.

Publication	Year	Title	EN/HD	Year
ISO/IEC Guide 51	1990	Guidelines for the inclusion of safety aspects in standards	-	-
IEC Guide 104	1997	The preparation of safety publications and the use of basic safety publications and group safety publications	-	-

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