

NATIONAL STANDARD OF CANADA NORME NATIONALE DU CANADA

CAN/ULC-61481-1-15 (IEC 61481-1:2014 MOD)

La norme internationale IEC 61481-1:2014, (première édition, 2014-10), a été adoptée avec les exigences propres au Canada (MOD), et porte la désignation CAN/ULC-61481-1-15 la première édition. Elle a été approuvée comme Norme nationale du Canada par le Conseil canadien des normes.

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International Standard IEC 61481-1:2014 (First Edition, 2014-10), has been adopted with Canadian deviations (MOD) as the First Edition of CAN/ULC-61481-1-15, which has been approved as a National Standard of Canada by the Standards Council of Canada.

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Travaux sous tension – Comparateurs de phase – Partie 1: Type capacitif pour usage sur des tensions alternatives de plus de 1 kV

ICS 13.260, 29.240.20, 29.260.99

Live working – Phase comparators – Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.

ICS 13.260, 29.240.20, 29.260.99



Numéro de référence
Reference Number
IEC 61481-1:2014

**Commission Electrotechnique Internationale
International Electrotechnical Commission**

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Le but premier visé par cette norme est énoncé au paragraphe qui en définit le domaine d'application. Il importe de préciser qu'il incombe à l'utilisateur de décider si la norme convient à ses besoins particuliers.

The intended primary application of this Standard is stated in its scope. It is important to note that it remains the responsibility of the user of the Standard to judge its suitability for this particular application.

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Document ID: 61481-1-15 2015

NORME NATIONALE DU CANADA

NATIONAL STANDARD OF CANADA

CAN/ULC-61481-1-15
(IEC 61481-1:2014, MOD)

CAN/ULC-61481-1-15
(IEC 61481-1:2014, MOD)

**Travaux sous tension – Compérateurs
de phase – Partie 1: Type capacitif
pour usage sur des tensions
alternatives de plus de 1 kV**

**Live working – Phase comparators –
Part 1: Capacitive type to be used for
voltages exceeding 1 kV a.c.**

ICS 13.260, 29.240.20, 29.260.99

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International Electrotechnical Commission
Commission Électrotechnique Internationale



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Approuvée par le / Approved by



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Normes ULC

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Il s'agit de la liste des membres du comité au moment de l'approbation de présent document.
La composition du comité peut avoir changé depuis ce temps-là.

This list represents the membership at the time the Committee balloted on the final text of this edition. Since that time, changes in the membership may have occurred.

CAN/ULC-61481-1-15 (IEC 61481-1:2014, MOD)

Travaux sous tension – Comparateurs de phase – Partie 1: Type capacitif pour usage sur des tensions alternatives de plus de 1 kV

PRÉFACE NORMES ULC

Ce document constitue la première édition de la norme, CAN/ULC-61481-1-15 (IEC 61481-1:2014, MOD), Travaux sous tension – Comparateurs de phase – Partie 1: Type capacitif pour usage sur des tensions alternatives de plus de 1 kV, laquelle constitue une adoption, avec les exigences propres au Canada, de la norme internationale de la Commission Électrotechnique Internationale, IEC 61481-1 (première édition, 2014-10).

Au Canada, il y a deux langues officielles, le français et l'anglais. Tous les avertissements de sécurité doivent être en français et en anglais. Il importe de signaler que certaines autorités canadiennes peuvent exiger que des marquages et/ou des directives d'installation supplémentaires soient dans les deux langues officielles.

La première édition de cette norme ULC était fondée sur la première édition du document CAN/ULC-D61481 et le remplaçait.

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La révision de cette norme débutera dans les 5 ans suivant la date de publication, à moins que la norme soit désignée comme entrant dans une catégorie stabilisée, auquel cas la révision commencera dans le délai approprié défini par Normes ULC.

La présente norme est destinée à être utilisée à des fins d'évaluation de la conformité.

Une grande partie du financement nécessaire au processus d'adoption de cette Norme nationale du Canada a été assurée par l'association canadienne de l'électricité (ACE) que nous tenons à remercier.

Juin 2015

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CAN/ULC-61481-1-15 (IEC 61481-1:2014, MOD)

Live working – Phase comparators – Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.

ULC STANDARDS PREFACE

This is the First Edition of the Standard CAN/ULC-61481-1-15 (IEC 61481-1:2014, MOD), Live working – Phase comparators – Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c., with Canadian Deviations, of the international standard by International Electrotechnical Commission, IEC 61481-1:2014 (First Edition, 2014-10).

In Canada there are two official languages, English and French. All safety warnings must be in French and English. Attention is drawn to the possibility that some Canadian authorities may require additional markings and/or installation instructions to be in both official languages.

This First Edition National Standard of Canada is based on, and supercedes, the First Edition of CAN/ULC-D61481.

Attention is drawn to the possibility that some of the elements of this Canadian standard may be the subject of patent rights. ULC Standards shall not be held responsible for identifying any or all such patent rights.

The initiation of the review of this Standard will commence within 5 years of the date of publication, unless the Standard is identified as fitting within a stabilized category, whereby the review will commence within the appropriate time frame set out by ULC Standards

This Standard is intended to be used for conformity assessment.

Major funding in support of the adoption process of this National Standard of Canada was provided by the Canadian Electricity Association (CEA), whose assistance is acknowledged with thanks.

June 2015

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Exigences propres au Canada

GÉNÉRALITÉS

[Remplacez tous les références « IEC 61318 » dans le document avec « CAN/ULC-61318 »]

[Remplacez tous les références « IEC 61477 » dans le document avec « CAN/ULC-61477 »]

2 RÉFÉRENCES NORMATIVES

[Reviser les références IEC 61318 et IEC 61477 comme suit:

« CAN/ULC-61318-08, Travaux sous tension – Évaluation de la conformité applicable à l'outillage, au matériel et aux dispositifs (CEI/IEC 61318:2007, IDT)»

« CAN/ULC-61477-11, Travaux sous tension – Exigences minimales pour l'utilisation des outils, dispositifs et équipements (CEI/IEC 61477:2009, MOD)»]

4.5 MARQUAGE

[Supprimer la dixième point « - symbole IEC 60417-5216:2002-10... » et la REMARQUE connexe]

[Réviser le onzième point avec tiret comme suit :

« –numéro de la norme CAN/ULC applicable (CAN/ULC-61481-1). »]

[Réviser le deuxième et troisième paragraphes comme suit:

« Pour être marqué du numéro de la présente norme CAN/ULC, le produit doit satisfaire à toutes les exigences qui y sont spécifiées. »

« Avec chaque comparateur de phase ou avec chaque lot de comparateurs de phase à livrer, le fabricant doit fournir l'information relative au numéro de la norme CAN/ULC. »]

ANNEXE B

[Supprimer l'annexe B.]

Canadian Deviations

GENERAL

[Change all “IEC 61318” references in the document to read “CAN/ULC-61318”]

[Change all “IEC 61477” references in the document to read “CAN/ULC-61477”]

2 NORMATIVE REFERENCES

[Revise IEC 61318 and IEC 61477 to read:

“CAN/ULC-61318-08, Live Working – Conformity assessment applicable to tools, devices and equipment (CEI/IEC 61318:2007, IDT)”

“CAN/ULC-61477-11, Live Working – Minimum requirements for the utilizations of tools, devices and equipment (CEI/IEC 61477:2009, MOD)”]

4.5 MARKING

[Delete the tenth dash item regarding “- symbol IEC 60417-5216:2002-10...” and accompanying NOTE]

[Revise the eleventh dash item to state:

“– number of the relevant CAN/ULC standard (CAN/ULC-61481-1).”]

[Amend the second and third paragraph to reference CAN/ULC Standard:

“To be marked with the number of this CAN/ULC standard, the product shall satisfy all the requirements specified herein.”

“With every phase comparator or with every batch of phase comparators to be delivered, the manufacturer shall provide information related to the number of the CAN/ULC standard.”]

ANNEX B

[Delete Annex B]

AVADocuments

INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Live working – Phase comparators –
Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.**

**Travaux sous tension – Compérateurs de phase –
Partie 1: Type capacitif pour usage sur des tensions alternatives de plus de 1 kV**



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INTERNATIONAL STANDARD

NORME INTERNATIONALE

**Live working – Phase comparators –
Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.**

**Travaux sous tension – Compérateurs de phase –
Partie 1: Type capacitif pour usage sur des tensions alternatives de plus de 1 kV**

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INTERNATIONAL ELECTROTECHNICAL COMMISSION

**LIVE WORKING –
PHASE COMPARATORS –**
Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.**FOREWORD**

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International Standard IEC 61481-1 has been prepared by IEC technical committee 78: Live working.

This first edition, together with the first edition of IEC 61481-2, cancels and replaces the first edition of IEC 61481 published in 2001, Amendment 1:2002 and Amendment 2:2004. This edition constitutes a technical revision.

The major changes are:

- split of the standard in two parts;
- extension of the scope to include two-pole phase comparators operating with a wireless connection up to 245 kV a.c.;
- review of the requirements for indication;
- introduction of a requirement for a new marking “LU” for limited use;
- addition of requirements and tests for two-pole phase comparators operating with a wireless connection;
- clarification of the test procedures in case of additional contact electrodes, accessories and combination of accessories, as well as in case of family of phase comparators;
- addition of requirements and tests for electromagnetic compatibility (EMC);
- clarification of the test provisions for the function tests;
- clarification of the test procedure for clear perceptibility of audible indication;
- preparation of the elements of evaluation of defects, and general application of IEC 61318:2007;
- revision of existing annexes;
- change of existing normative Annex C in two new Annexes D and F giving the classification of defects (normative) and the rationale for the classification of defects (informative);
- deletion of existing Annex D, no longer needed following the specification of IEC 60068-2-75;
- deletion of existing Annex F, not applicable according to IEC 61318:2007;
- addition of a new informative Annex E giving additional information on the use of the limit mark and of a contact electrode extension.

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

FDIS	Report on voting
78/1051/FDIS	78/1087/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 terms defined in Clause 3 appear in *italics*.

A list of all parts of the IEC 61481 series, published under the general title *Live working – Phase comparators*, can be found on the IEC website.

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

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

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 has been prepared in accordance with the requirements of IEC 61477.

Taking into consideration the two different functioning principles of portable *phase comparators* of capacitive type available on the market, the maximum a.c. *nominal voltage* to be associated with each of them has been considered for delimiting the scope of this standard.

The following table presents the rationale for the resulting maximum *nominal voltage* to be associated with each functioning principle of *phase comparator of capacitive type*.

Functioning principle	Maximum nominal voltage kV rms	Rationale
Single-pole <i>phase comparators</i> operating with a memory system	36	– With this principle of functioning, the <i>clear indication</i> of the <i>phase comparator</i> is limited by the <i>memory holding time</i>. – With higher <i>nominal voltages</i>, the distance between phases of the installation increases and the time necessary to move the pole of the <i>phase comparator</i> between the two parts to be compared becomes the limitation.
Two-pole <i>phase comparators</i> operating with a wireless connection	245	– With this principle of functioning, there is no theoretical limit for the maximum <i>nominal voltage</i>. – The definition of 245 kV corresponds to the present limit of validation of the electric test set-up.

The product covered by this standard may have an impact on the environment during some or all stages of its life cycle. These impacts can range from slight to significant, be short-term or long-term, and occur at the global, regional or local level.

In terms of environmental improvement, this standard includes neither requirements nor test provisions for the manufacturers of the product nor recommendations to the users of the product. However, all parties intervening in its design, manufacture, packaging, distribution, use, maintenance, repair, reuse, recovery and disposal are invited to take account of environmental considerations.

LIVE WORKING – PHASE COMPARATORS –

Part 1: Capacitive type to be used for voltages exceeding 1 kV a.c.

1 Scope

This part of IEC 61481 is applicable to portable *phase comparators* of capacitive type to be used on electrical systems for voltages exceeding 1 kV a.c. and frequencies of 50 Hz and/or 60 Hz.

This standard is applicable to:

- single-pole *phase comparators* of capacitive type operating with a memory system up to 36 kV a.c.,
- two-pole *phase comparators* of capacitive type operating with a wireless connection up to 245 kV a.c.

This standard is applicable to *phase comparators* of capacitive type used in contact with the bare conductive parts to be compared:

- as a complete device including its *insulating element* or
- as a separate device, adaptable to an *insulating stick* which, as a separate tool, is not covered by this standard.

NOTE Some parts such as the *contact electrode* or the *insulating element* of a *phase comparator* as a complete device may be dismantled.

Some restrictions on their use are applicable in the case of factory-assembled switchgear and on overhead systems of electrified railways (see Annex A).

A device that is designed to provide other functions than phase comparison is a different device and is not covered by this standard. For example a device designed to be also used as a voltage detector is not covered by this standard (see Annex A).

Products designed and manufactured according to this standard contribute to the safety of users provided they are used by persons trained for the work, in accordance with the hot stick working method and the instructions for use.

Except when otherwise specified, all the voltages defined in this standard refer to phase-to-phase voltages of three-phase systems. In other systems, the applicable phase-to-phase or phase-to-earth (ground) voltages should be used to determine the operating voltage.

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.

CISPR 11, *Industrial, scientific and medical equipment – Radio-frequency disturbance characteristics – Limits and methods of measurement*

IEC 60060-1:2010, *High-voltage test techniques – Part 1: General definitions and test requirements*

IEC 60068-1, *Environmental testing – Part 1: General and guidance*

IEC 60068-2-6, *Environmental testing – Part 2-6: Tests – Test Fc: Vibration (sinusoidal)*

IEC 60068-2-14, *Environmental testing – Part 2-14: Tests – Test N: Change of temperature*

IEC 60068-2-31, *Environmental testing – Part 2-31: Tests – Test Ec: Rough handling shocks, primarily for equipment-type specimens*

IEC 60068-2-75, *Environmental testing – Part 2-75: Tests – Test Eh: Hammer tests*

IEC 60304, *Standard colours for insulation for low-frequency cables and wires*

IEC 60417, *Graphical symbols for use on equipment* (Available from: <http://www.graphical-symbols.info/equipment>)

IEC 60942, *Electroacoustics – Sound calibrators*

IEC 61000-4-2, *Electromagnetic compatibility (EMC) – Part 4-2: Testing and measurement techniques – Electrostatic discharge immunity test*

IEC 61000-4-3, *Electromagnetic compatibility (EMC) – Part 4-3: Testing and measurement techniques – Radiated, radio-frequency, electromagnetic field immunity test*

IEC 61260, *Electroacoustics – Octave-band and fractional-octave-band filters*

IEC 61318, *Live working – Conformity assessment applicable to tools, devices and equipment*

IEC 61326-1, *Electrical equipment for measurement, control and laboratory use – EMC requirements – Part 1: General requirements*

IEC 61477, *Live working – Minimum requirements for the utilization of tools, devices and equipment*

IEC 61672-1, *Electroacoustics – Sound level meters – Part 1: Specifications*

ISO 354, *Acoustics – Measurement of sound absorption in a reverberation room*

ISO 3744:2010, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Engineering method for an essentially free-field over a reflecting plane*

ISO 3745, *Acoustics – Determination of sound power levels and sound energy levels of noise sources using sound pressure – Precision methods for anechoic and hemi-anechoic rooms*

CIE 15, *Colorimetry*

3 Terms and definitions

For the purposes of this document, the terms and definitions given in IEC 61318, as well as the following apply.

3.1

accessory

supplementary item not necessary for the functioning of the *phase comparator* and provided by the manufacturer to facilitate its use under certain operating conditions

Note 1 to entry: An *accessory* is not considered as a part of a device. Without the *accessory*, the device is still functional. An item that is required each time a device is used is not an *accessory* but a part of the device which may be disassembled.

Note 2 to entry: For example an *accessory* is used to lengthen the handle, to improve the efficiency of the *contact electrode*, to enable the *contact electrode* to reach the parts to be compared, etc.

3.2

active signal

visual phenomenon, and optionally audible phenomenon, whose presence, absence or variation is considered as representing information on the condition “correct phase relationship” or “incorrect phase relationship”

Note 1 to entry: A signal indicating that the *phase comparator* is ready to operate is not considered as an *active signal*.

[SOURCE: IEC 60050-101:1998, 101-12-02, modified – the definition of “signal” has been modified to fit the specific context of diagnostic of phase relationship and Note 1 to entry has been added.]

3.3

adaptor

part of a *phase comparator* as a separate device which permits attachment of an *insulating stick*

3.4

clear indication

unambiguous detection and indication of “incorrect phase relationship” and/or “correct phase relationship” between the parts to be compared

3.5

clear perceptibility

case when the indication is unmistakably discernible by the user under specific environmental conditions when the *phase comparator* is in its operating position

3.6

contact electrode

bare conductive part of the *phase comparator* which establishes the electric connection to the part to be compared

3.7

contact electrode extension

externally insulated conductive part to enable the *contact electrode* to reach the parts of the installation to be compared

Note 1 to entry: For a certain installation configuration, the *contact electrode extension* is used to increase the *insertion depth* (see Figure 1d).

Note 2 to entry: The *contact electrode extension* is an *accessory* of the *phase comparator*.

3.8

end fittings

part of an *insulating stick* permanently fitted to the end of an insulating tube or rod

[SOURCE: IEC 60050-651:2014, 651-22-02]

3.9

family of phase comparators

for testing purposes, a group of *phase comparators*, delimited by a minimum and a maximum *rated voltage* and/or by the two frequencies (50 Hz and 60 Hz), that are identical in design (including dimensions) and only differ by their *nominal voltages* or *nominal voltage ranges* and/or their nominal frequency

3.10

hand guard

distinctive physical guard separating the handle of a *phase comparator* as a complete device from its *insulating element*

Note 1 to entry: The purpose of a *hand guard* is to prevent the hands from slipping and passing into contact with the *insulating element*.

3.11

indicator

part of the *phase comparator* that indicates the status of the phase relationship between two parts to be compared

Note 1 to entry: In the case of single-pole *phase comparators*, the *indicator* also indicates that the *phase comparator* is ready to be moved to the second part to be compared ("memory ready").

Note 2 to entry: In the case of two-pole-wireless *phase comparators*, the *indicator* also indicates the communication status.

3.12

indicator unit

additional unit of a two-pole *phase comparator* with wireless connection, normally intended to be hand-held and which is either an indicator or repeater that brings the indication and possibly other information close to the user

3.13

indoor type

phase comparator designed for use in dry conditions, normally indoors

3.14

insertion depth

A_i

distance between the *limit mark* and the top of the *contact electrode* for a *phase comparator* as a complete device

3.15

insulating element

part of a *phase comparator* as a complete device that provides adequate safety distance and insulation to the user

3.16

insulating stick

insulating tool made essentially of an insulating tube and/or rod with *end fittings*

Note 1 to entry: For phase comparison, an *insulating stick* is intended to be attached to a *phase comparator* as a separate device in order to provide the length to reach the installation to be tested and adequate safety distance and insulation to the user.

[SOURCE: IEC 60050-651:2014, 651-22-01, modified – the Note 1 to entry has been added.]

3.17

interference field

superposed electric field which may affect the indication

Note 1 to entry: The *interference field* may result from the parts to be compared or other adjacent parts and may have any phase relationship.

Note 2 to entry: The extreme cases for the tests are:

- an in-phase *interference field*. This occurs as a result of the dimensions and/or configuration of the parts of the installation to be compared or of adjacent parts of the installation having voltages in the same phase as the parts to be compared;
- an *interference field* in phase opposition. This occurs as a result of the adjacent parts of the installation having voltages in phase opposition to the parts to be compared.

3.18

limit mark

distinctive location or mark to indicate to the user the physical limit to which the *phase comparator* may be inserted between live parts or may touch them

3.19

maintenance test

test carried out periodically on a device or equipment to ascertain and, if necessary, make certain adjustments to ensure that its performance remains within specified limits

[SOURCE: IEC 60050-151:2001, 151-16-25, modified – the definition has been modified to fit the specific context of maintenance of device or equipment.]

3.20

memory holding time

for a single-pole *phase comparator*, maximum available time to contact the second part to be compared, after the indication “memory ready” appears when the *phase comparator* is in contact with the first part to be tested

3.21

nominal voltage

U_n

suitable approximate value of voltage used to identify a system or device

Note 1 to entry: The *nominal voltage* of the *phase comparator* is a parameter associated with its *clear indication*. When a *phase comparator* has more than one *nominal voltage*, or a *nominal voltage* range the limit values of the *nominal voltage* range are named $U_{n \min}$ and $U_{n \max}$.

[SOURCE: IEC 600500-601:1985, 601-01-21, modified – the definition has been modified to fit the specific context of device or equipment and Note 1 to entry has been added.]

3.22

outdoor type

phase comparator designed for use in wet conditions, either indoors or outdoors

3.23

permanent contact electrode extension

externally insulated conductive element located between the *indicator* and the *contact electrode* of some designs of *phase comparator* to move back the *indicator* from the live part to be compared

Note 1 to entry: The *permanent contact electrode extension* may contain impedances.

Note 2 to entry: The *permanent contact electrode extension* is not an *accessory*.

3.24

phase comparator

portable device used to provide clear evidence of the presence or the absence of the correct phase relationship between two energized parts at the same *nominal voltage* and frequency

[SOURCE: IEC 60050-651:2014, 651-24-03, modified – the definition has been modified to specify that the device herein defined is a portable device.]

3.25

phase comparator of capacitive type

capacitive phase comparator

device whose operation is based on the current passing through the stray capacitance to earth

Note 1 to entry: *Phase comparators* of capacitive type are either two-pole *phase comparators* operating with a wireless connection or single-pole *phase comparators* operating with a memory system.

Note 2 to entry: *Phase comparators* of capacitive type mainly work on the basis of angle measurement (frequency-based).

3.26

protection against bridging

protection against flashover or breakdown, when the insulation between the parts of the installation, at different potentials, is reduced by the presence of the *phase comparator*

3.27

rated voltage

U_r

value of voltage to which certain operating specifications are referred

Note 1 to entry: The *rated voltage* of the *phase comparator* is the voltage selected from IEC 60071-1:2006, Tables 2 and 3, column 1, which should either be equal to the *nominal voltage* (or the highest *nominal voltage* of its *nominal voltage* range), or the next higher voltage selected from those tables.

3.28

response time

delay between the time when the *phase comparator* makes contact with the second part to be compared and the relevant *clear indication*

3.29

testing element

built-in element or separate device, by means of which the functioning of the *phase comparator* can be checked by the user

[SOURCE: IEC 60743:2013, 11.3.7, modified – the definition has been modified to specify its application to the *phase comparator*.]

3.30

threshold parameter

minimum phase angle ϕ_p between the two parts to be compared which gives a change of the status of the *active signal*

3.31

wireless connecting system

communication system used to exchange information between the different units of a *phase comparator* without physical link

4 Requirements

4.1 Indication

The *phase comparator* shall clearly indicate the state "incorrect phase relationship" and/or "correct phase relationship" by means of the change of the status of one or more *active signals*.

The indication shall be visual. An audible indication may be additional.

For a *phase comparator* with *nominal voltage* above 36 kV it is recommended to have both visual and audible indication.

In the case of a single-pole *phase comparator*, the state “memory ready” shall be indicated.

In the case of a two-pole *phase comparator* operating with wireless connection the communication status shall be indicated.

4.2 Functional requirements

4.2.1 Clear indication

4.2.1.1 General

The following requirements apply when both parts to be compared have the same *nominal voltage* and frequency.

The indication “incorrect phase relationship” shall not appear for an angle difference up to $\pm 10^\circ$.

The indication “correct phase relationship” shall not appear for an angle difference above $\pm 30^\circ$, $\pm 60^\circ$ or $\pm 110^\circ$ according to the class of the *phase comparator*.

To fulfil the above requirements, the *threshold parameter* shall satisfy the following relationship:

Class A: $\pm 10^\circ < \varphi_p \leq \pm 30^\circ$

Class B: $\pm 10^\circ < \varphi_p \leq \pm 60^\circ$

Class C: $\pm 10^\circ < \varphi_p \leq \pm 110^\circ$, see Note 1.

Class D: If it is not possible to use any of the above-mentioned classes, the manufacturer and the customer shall reach an agreement to set the appropriate value of the phase-angle difference. In such a case the upper limit of the *threshold parameter* shall exceed the one of class C.

For *phase comparators* with one *nominal voltage*, $U_{n \max}$ equals $U_{n \min}$.

NOTE 1 It has been recognized that for networks with small angle differences a device of class C could permit increasing the *memory holding time*.

NOTE 2 The required phase angle differences to give indication of incorrect phase relationship will depend on network situations.

NOTE 3 A *phase comparator* may not indicate properly in the presence of large harmonic and/or amplitude distortion (e.g. HV a.c./d.c. converters, non-linear loads, etc.). Relevant data, acceptable limits and performance requirements are under consideration.

4.2.1.2 Settings

The user shall not have access to the settings of the *indicator*.

A selector for different *nominal voltages* or different *nominal voltage* ranges is allowed, but for each position of the selector the user shall not have access to any settings.

On each unit of a wireless *phase comparator* there could be an accessible selector for setting a multi-channel connecting system (e.g.: radio communication).

4.2.1.3 Continuous indication

Once the *phase comparator* gives *clear indication* it shall continue to indicate as long as it is in direct contact with the live part.

4.2.1.4 Influence of interference fields

The presence of an *interference field* (adjacent live or earthed parts) shall not affect the indication when the *phase comparator* is used in accordance with the instructions for use.

NOTE The indication may not be reliable in the vicinity of large conductive parts that create equipotential zones.

4.2.1.5 Special marking in the case of limited use

In the case of a *phase comparator* that does not fulfil anyone of the tests of 5.2.2 or 5.2.5 when using the test set-up of Figure 4, it shall have a marking “LU” for limited use.

4.2.1.6 Electromagnetic compatibility (EMC)

Phase comparators shall comply with the requirements of class A for portable equipment according to IEC 61326-1.

NOTE In some countries additional requirements may be added to fulfil EMC regulations.

4.2.2 Distance range

Wireless operating *phase comparators* shall communicate properly within the limits of the distance range in free space (between the various units of the whole device) specified by the manufacturer in the instructions for use (see Annex A).

There are no radio communication requirements in this standard. Where relevant, the *phase comparator* should conform to the national radio communication regulations.

4.2.3 Clear perceptibility

4.2.3.1 Visual indication

The *phase comparator* shall give a clear visual indication to the user when in operating position and under normal light conditions.

When two or more visual *active signals* are used, the indication shall not rely solely on light of different colours for perceptibility. Additional characteristics, such as physical separation of the light sources, distinctive form of the light signals, or flashing light shall be used.

4.2.3.2 Audible indication (where relevant)

The *phase comparator* shall give a clear audible indication to the user when in the operating position and under normal noise conditions.

When two audible *active signals* are used, the indication shall not rely solely on sounds of different sound pressure level for perceptibility. Additional characteristics, such as tone or intermittence of the audible signals shall be used.

4.2.4 Temperature and humidity dependence of the indication

There are three categories of *phase comparators* according to the climatic conditions of operation: cold (C), normal (N) and warm (W). The *phase comparator* shall operate correctly in the temperature range of its climatic category, according to Table 1.

Table 1 – Climatic condition ranges

Climatic condition ranges (operation and storage)		
Climatic category	Temperature °C	Humidity %
Cold (C)	–40 to +55	20 to 96
Normal (N)	–25 to +55	20 to 96
Warm (W)	–5 to +70	12 to 96

4.2.5 Frequency dependence

4.2.5.1 General

At a given time the value of the frequency is considered to be the same all over a network. Then the following requirements apply when both parts to be compared have the same frequency.

4.2.5.2 Tolerance of nominal frequency

The *phase comparator* shall operate correctly at frequencies within a tolerance of at least $\pm 0,2$ % of the nominal frequency.

A *phase comparator* with two nominal frequencies shall operate correctly for each nominal frequency within a tolerance of at least $\pm 0,2$ %.

4.2.5.3 Frequency shift of single-pole phase comparator

Single-pole *phase comparators* shall operate correctly with variations of frequency up to 1 MHz/s during the *memory holding time* declared by the manufacturer after the indication "memory ready" appears.

The indication of a single-pole *phase comparator* shall not be assessed as "correct phase relationship" with variations of frequency above 10 MHz/s during at least 5 s after the indication "memory ready" appears.

The *memory holding time* shall be at least 5 s.

4.2.6 Response time

The *response time* of the *phase comparator* shall not be more than 1 s. In situations where the *response time* is above 1 s the phase comparator shall give a visual and/or audible indication that data processing is still running.

4.2.7 Power source dependability

The *phase comparator* with a built-in power source shall give a *clear indication* until a non-readiness signal appears or the device is automatically shut off, as mentioned in the instructions for use.

4.2.8 Testing element

The *testing element*, whether built-in or separate, shall be capable of testing all the electrical circuits, the *wireless connecting system*, the energy source and the functioning of the indication. When all circuits cannot be tested, any limitation shall be clearly stated in the instructions for use. These circuits shall be of high reliability construction. When there is a built-in *testing element*, the *phase comparator* shall give an indication of "ready" or "not ready".

4.2.9 Time rating

The *phase comparator* shall be able to perform during its specified time rating without failure and without giving incorrect indication when subjected to the maximum operating voltage.

The minimum time rating shall be:

- 5 min in the case of a *phase comparator* at a *nominal voltage* up to 36 kV;
- 15 min in the case of a *phase comparator* at a *nominal voltage* above 36 kV.

The manufacturer shall clearly state in the instructions for use the maximum time rating for the user.

4.3 Electrical requirements

4.3.1 Insulating material

The insulating materials shall be adequately rated (nature of material, dimensions) for the *nominal voltage* (or the maximum *nominal voltage* of the voltage range) of the *phase comparator*.

When tubes of insulating material with circular cross-section are used in the design of *phase comparators*, they should meet the requirements of IEC 60855-1 or IEC 61235, otherwise they shall demonstrate appropriate insulating performance by fulfilling the test of 5.3.1.

For a *phase comparator* as a complete device the user shall be provided with adequate insulation by means of an *insulating element*.

NOTE For a *phase comparator* as a separate device, the selection of an appropriate adaptable *insulating stick* will provide the user with adequate insulation.

4.3.2 Protection against bridging

Protection shall be such that the *phase comparator* cannot cause flashover or breakdown between live parts of an installation or between a live part of an installation and earth.

4.3.3 Resistance against sparking

The *phase comparator* shall be so constructed that the *indicator* cannot be damaged or shut-off as a result of a low energy electric arc.

4.3.4 Insulating element of phase comparator as a complete device

4.3.4.1 Dielectric strength

The *insulating element* shall be rated so that no flashover or breakdown occurs in use.

4.3.4.2 Leakage current

The *insulating element* of the *indoor type phase comparator* shall be so rated that leakage current shall be limited under dry conditions.

The *insulating element* of the *outdoor type phase comparator* shall be so rated that leakage current shall be limited under dry and wet conditions.

4.3.5 Indicator casing

The *indicator* casing shall be rated so that no flashover or breakdown occurs in use.

4.4 Mechanical requirements

4.4.1 General

For a *phase comparator* as a complete device the user shall be provided with adequate distance by means of an *insulating element*.

NOTE For a *phase comparator* as a separate device, the selection of an appropriate *insulating stick* will provide the user with adequate distance.

4.4.2 Design

The *phase comparator* shall be designed to allow operation by one person.

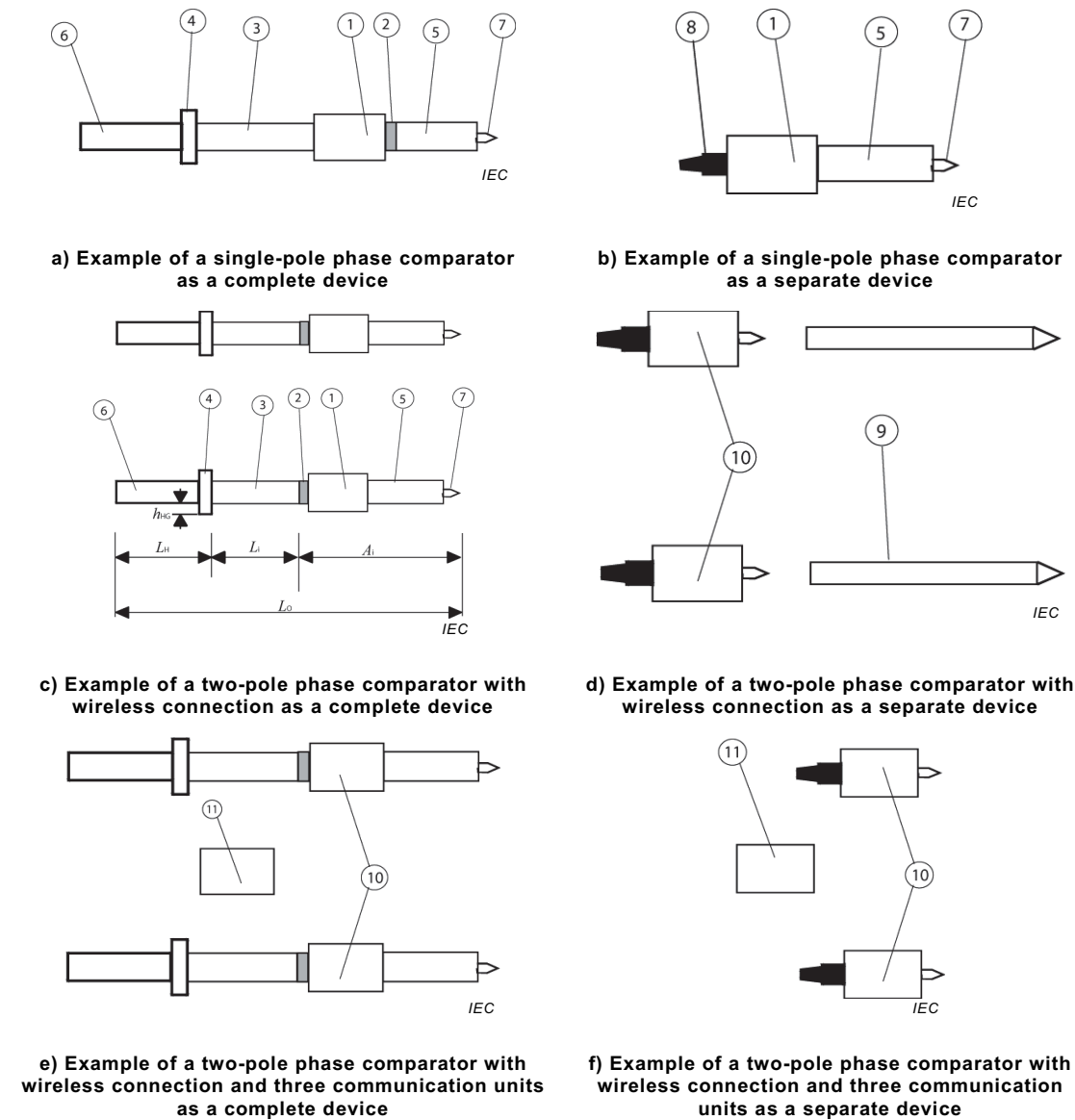
The *phase comparator* as a complete device shall include the following elements as a minimum:

- handle, *hand guard*, *insulating element*, *indicator*, *limit mark* and *contact electrode* (see Figure 1).

The position of the *limit mark* may be on either side of the *indicator*.

The *phase comparator* as a separate device shall include the following elements as a minimum:

- *adaptor*, *indicator* and *contact electrode* (see Figure 1).



Key

1	indicator	9	contact electrode extension (accessory)
2	limit mark	10	two basic communications units
3	insulating element	11	indicator unit
4	hand guard	h_{HG}	height of hand guard
5	permanent contact electrode extension	L_H	length of handle
6	handle	L_i	length of insulating element
7	contact electrode	L_O	overall length of phase comparator
8	adaptor (can be used as limit mark)	A_i	insertion depth

Figure 1 – Illustration of different elements and different principles of functioning of phase comparators

4.4.3 Dimensions, construction

The minimum length of the *insulating element* of a *phase comparator* as a complete device shall be in accordance with Table 2.

Table 2 – Minimum length of the insulating element (L_i) of a phase comparator as a complete device

U_r kV	L_i mm
$1 < U_r \leq 7,2$	320
$7,2 < U_r \leq 12$	360
$12 < U_r \leq 17,5$	370
$17,5 < U_r \leq 24$	470
$24 < U_r \leq 36$	520
$36 < U_r \leq 72,5$	830
$72,5 < U_r \leq 123$	1 300
$123 < U_r \leq 170$	1 700
$170 < U_r \leq 245$	2 300

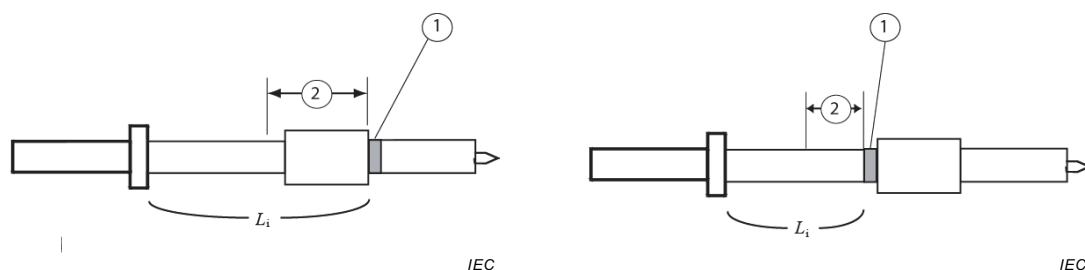
NOTE 1 The *nominal voltage* U_n is used when the parameters to be specified are related to the installation dimensioning or to the functional performance of the *phase comparator*, while the *rated voltage* U_r is used when insulation performance of the *phase comparator* is concerned.

NOTE 2 The L_i values of Table 2 correspond to the minimum distance in air (obtained from Tables 1 and 2 of IEC 61936-1:2010) plus an additional safety distance.

NOTE 3 The L_i values of Table 2 can be used as a guidance to determine the length of the *insulating stick* used with a *phase comparator* as a separate device. However, the length of the *insulating stick* for live working can be shortened for a *phase comparator* as a separate device taking into account the minimum approach distances or in accordance with national or regional regulations.

In the case of a *phase comparator* as a complete device and for L_i equal to or greater than 520 mm, conductive parts are allowed within the minimum length of the *insulating element* if they are completely externally insulated and are located immediately adjacent to the *limit mark* in one section of the *insulating element* not exceeding 200 mm (see Figure 2).

NOTE 4 The performance of the insulation covering the conductive parts is verified by the *protection against bridging* test of 5.3.2.



Key

- 1 *limit mark*
- 2 *section of the insulating element where conductive parts are allowed (≤ 200 mm)*
- L_i *minimum length of the insulating element*

Figure 2 – Location of allowed conductive parts within the minimum length of the insulating element of a pole of a phase comparator as a complete device

The *limit mark* shall be about 20 mm wide, permanent, and clearly recognizable by the user.

If there is no *limit mark* on a *phase comparator* as a separate device, the end of the *adaptor* can act as the *limit mark* (Figures 1b, 1d and 1f).

For a *phase comparator* as a complete device, the length of the handle (L_H) shall be 115 mm as a minimum.

NOTE 5 A longer handle facilitates two-hand operation.

For a *phase comparator* as a complete device, the *hand guard* shall be permanently fixed and have a minimum height (h_{HG}) of 20 mm.

In order to adapt the *phase comparator* to different uses, the *contact electrode* may readily be interchangeable with other types of *contact electrodes* depending on the type of installation to be compared and instructions for use.

When a *phase comparator* is intended to be disassembled by the user, the parts shall be clearly marked as belonging together.

4.4.4 Grip force and deflection

The *phase comparator* shall be designed to facilitate reliable operation with reasonable physical effort by the user.

The *phase comparator* shall be designed to allow a safe approach toward the parts of the installation to be compared. The deflection of the pole(s), under its(their) own weight, shall be as low as possible.

NOTE In the case of a *phase comparator* as a separate device, the choice of an *insulating stick* may greatly influence the grip force and deflection.

4.4.5 Vibration resistance

The *phase comparator* including the *indicator unit* (if any) shall be vibration resistant.

4.4.6 Drop resistance

The *phase comparator* including the *indicator unit* (if any) shall be drop resistant.

4.4.7 Shock resistance

The *phase comparator* including the *indicator unit* (if any) shall be shock resistant.

4.5 Marking

Each *phase comparator* shall have at least the following items of marking:

- nominal voltage and/or range of nominal voltages;
- nominal frequency or nominal frequencies;
- symbol for operational class (“A”, “B”, “C” or “D”);
- name or trade mark of the manufacturer;
- type reference, serial number;
- indication of type indoor or outdoor;
- symbol for climatic category or climatic categories (“C”, “N” or “W”);
- symbol “LU”, when relevant;
- year of production;

- symbol IEC 60417-5216 (2002-10) – Suitable for live working; double triangle (see Annex B);

NOTE The exact ratio of the height of the figure to the base of the triangle is 1,43. For the purposes of convenience, this ratio can be between the values of 1,4 and 1,5.

- number of the relevant IEC standard immediately adjacent to the double triangle symbol ("IEC 61481-1").

To be marked with the number of this IEC standard, the product shall satisfy all the requirements specified herein.

With every *phase comparator* or with every batch of *phase comparators* to be delivered, the manufacturer shall provide information related to the number of the IEC standard with the year of publication.

In the case of a *phase comparator* with a built-in energy source, the type of power supply shall be indicated either on the *indicator* or inside the compartment designed to house it, and the polarity when required.

The marking shall be legible and permanent. The characters shall be at least 3 mm high. The marking shall not impair the quality of the *phase comparator*.

4.6 Instructions for use

The manufacturer shall provide written instructions for use with each *phase comparator* covered by this standard.

The instructions for use shall include as a minimum the information of Annex A.

These instructions shall be prepared in accordance with the general provisions of IEC 61477.

4.7 Requirements in the case of reasonably foreseeable misuse during live working

4.7.1 Voltage selection

In the case of incorrect position of the voltage selector, if any, the *phase comparator* shall give no incorrect indication of phase relationship.

4.7.2 Frequency selection

In the case of incorrect position of the frequency selector, if any, the *phase comparator* shall give no indication of phase relationship.

4.7.3 Channel selection for wireless connection

In the case of incorrect setting of the channel selectors, if any, the *phase comparator* shall give no indication of a phase relationship.

5 Tests

5.1 General

5.1.1 Testing provisions

This standard provides testing provisions to demonstrate compliance of the product to the requirements of Clause 4. These provisions are primarily intended to be used as type tests for the validation of the design input. Where relevant, alternative means (calculation, examination, tests, etc.), are specified within the test subclauses for *phase comparators* having completed the production phase.

Tests shall be performed on a *phase comparator* which has been completely assembled, in accordance with instructions for use. Unless otherwise specified, for a *phase comparator* as separate device, the tests shall be performed with each pole equipped with an *insulating stick* complying with 4.3.1, 4.4.1 and 4.4.3.

NOTE It is essential that the tests are done by a competent test facility.

5.1.2 Atmospheric conditions

Except when otherwise stated, tests are carried out under the following standard atmospheric conditions of IEC 60068-1 for measurements and tests:

- ambient temperature 15 °C to 35 °C;
- relative humidity 25 % to 75 %;
- atmospheric pressure 86 kPa to 106 kPa.

For type tests, the *phase comparator* shall be subjected to these conditions for at least 4 h before being submitted to the group of tests.

5.1.3 Tests under wet conditions

Before the electrical tests, each *phase comparator* shall be cleaned with isopropanol ($\text{CH}_3\text{-CH(OH)-CH}_3$) and then dried in air for 15 min.

NOTE It is not part of this standard to ensure that the relevant legislation and safety requirements for the use of this chemical are complied with in their entirety.

The test under wet conditions shall be conducted in accordance with 4.4.1 of IEC 60060-1:2010 (wet test procedure), with the following exception: the openings in the collecting vessel designed to measure the wetting rate shall be less than, or equal to, the horizontal cross-section of the *indicator*.

5.1.4 Type test

5.1.4.1 Type test on basic configuration

The type test shall be performed on three complete *phase comparators* representative of the production and on three test pieces of each material providing high-voltage insulation except for 5.2.4 which is performed on only one *phase comparator*. If more than one *phase comparator* or test piece does not pass, the test has failed. If only one *phase comparator* or test piece fails, the entire sequence for the type test shall be repeated on three other *phase comparators* or test pieces. If any one of these three new *phase comparators* or test pieces does not pass, the type test is considered to have failed.

NOTE In the particular case of 5.2.4, if the *phase comparator* does not pass, the type test is considered to have failed.

Type tests shall be performed in the sequence defined in Annex C.

5.1.4.2 Type test on additional contact electrodes and accessories

The use of different *contact electrodes* or *accessories* or combination of *accessories* may affect the performance of the *phase comparator*.

When several *contact electrode extensions* or several *contact electrodes* are provided, the following tests shall be performed with each *contact electrode extension*, each *contact electrode* and each combination of them:

- vibration resistance (see 5.4.3),
- drop resistance (see 5.4.4),

- *clear indication* (see 5.2.2),
- influence of electric *interference fields* (see 5.2.5),
- *protection against bridging* for *indoor/outdoor type phase comparator* (see 5.3.2),
- *protection against bridging* for *outdoor type phase comparator* (see 5.3.3),
- spark resistance (see 5.3.4) and
- distance range (see 5.2.3).

These type tests can be done

- with the same set of *phase comparators*, these being equipped successively with the different *accessories* or combination of *accessories*, or
- with different sets of *phase comparators*, each set being equipped with a different *accessory* or combination of *accessories*.

In the case of different sets of *phase comparators*, for each set if more than one *phase comparator* does not pass the test the set has failed. For each set if only one *phase comparator* fails, the entire sequence for the relevant type test (see 5.1.4.1) shall be repeated on a new set of three *phase comparators*. If any one of these three new *phase comparators* fails, the type test of this configuration is considered to have failed.

5.1.4.3 Type test of a family of phase comparators

In the case of *phase comparators* of the same family the following applies.

- The type tests shall be performed at the lowest and at the highest *nominal voltages* delimiting the *family of phase comparators*. Within the limits of the family, bridging tests (5.3.2 and 5.3.3) shall be performed for each distance d_1 of Table 7 under the highest voltage of each voltage range. Mechanical tests shall be done only once covering the worst conditions.
- The test for *clear indication* (see 5.2.2) shall be carried out at each *nominal voltage* or each *nominal voltage* range. Each time the test set-up changes within the range of the *nominal voltages* of the *phase comparator* the corresponding test shall be carried out.

5.1.5 Test methods

Tests shall be carried out using an a.c. power source in accordance with the requirements given in IEC 60060-1.

The maximum test voltage value shall be reached within 10 s to 20 s.

All types of *phase comparators* (indoor and outdoor) shall be submitted to the tests in dry conditions.

Unless otherwise specified,

- a tolerance of $\pm 3\%$ is allowed for all required values,
- dielectric tests shall be carried out at a frequency of 50 Hz or 60 Hz,
- additional tests applicable to *outdoor type phase comparators* shall be performed under wet conditions.

No correction factor due to climatic conditions shall be applied to test voltages.

5.2 Function tests

5.2.1 Description of the test set-up and general pass criteria

The tests shall be performed using a test set-up made of two ball-and-ring arrangements as shown in Figure 3 and Figure 4 with the dimensions specified in Table 3. The distinction

between Figure 3 and Figure 4 is the relative position of the ball electrode and its associated ring electrode. Both test set-ups permit to simulate various installation configurations.

It is important to limit the influence of the elements that provide the mechanical support and the electrical connections to the test set-up on the electric field configuration around the test electrodes.

For this purpose, around each test electrode (ball and ring), a spherical zone is defined in which only the elements illustrated in Figure 3 or 4 are permitted.

For each ball electrode, the supporting element shall permit connection to the voltage source. The electrical connection shall consist of a cable with a conductor section of 2 mm^2 to 5 mm^2 inserted in an insulating tube to provide mechanical support and additional electrical insulation.

For each ring electrode, the element(s) providing mechanical support and the ones providing electrical connection shall be out of the spherical zone except for its fixing or connecting device(s) to the ring which shall be as small as possible.

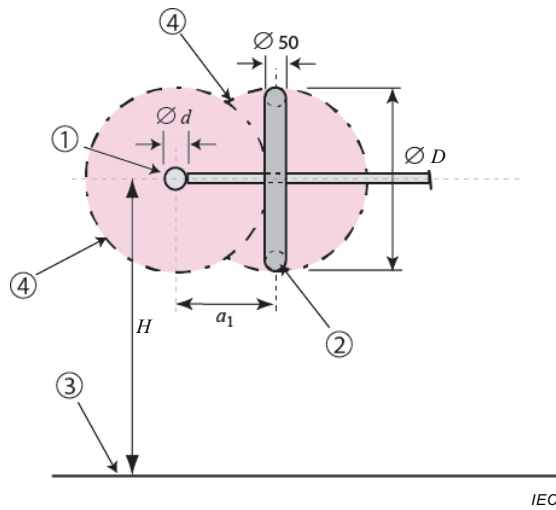
The floor of the test room shall be conductive or be laid out with conductive matting and connected to earth. The tests shall be conducted in a room which is free from unwanted foreign *interference fields*. No objects, except the insulating supporting element of the test set-up, shall be situated between the test set-up and the floor (ground) within a distance H and within a distance W in any direction from the test set-up according to Table 3.

The pole(s) of the *phase comparator* shall be fixed by means of an insulating support at the handle, in such a manner that its *contact electrode* touches the ball electrode, and the *indicator* is approximately concentrically located in relation to the associated ring electrode (in the horizontal axis) (see Figure 5). A suitable means shall be used for ensuring a good electrical connection as well as a mechanical pressure between the *contact electrode* of the *phase comparator* and the ball electrode without disturbing the local electric field. An example of such means is illustrated in Figure 6a. Likewise it is possible to modify the ball electrode without disturbing the local electric field. An example of such a modified ball electrode is illustrated in Figure 6b.

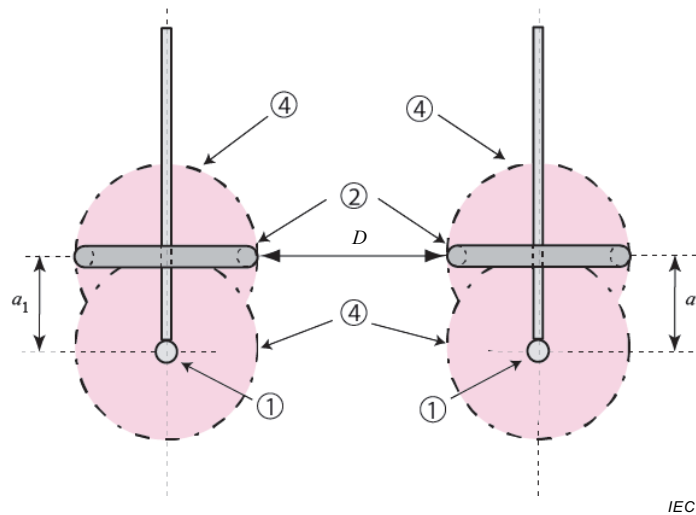
To be in accordance with this standard without any restriction, the *phase comparator* shall fulfil the tests performed with the test arrangements of Figures 3 and 4.

When the *phase comparator* without any *accessory* only fulfils the tests performed with the test arrangement of Figure 3, it shall be marked with “LU” (limited use).

Dimensions in millimetres



a) Side view



b) Top view

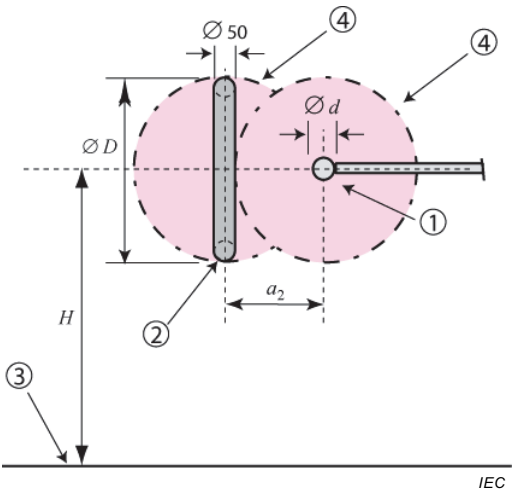
Key

- | | |
|---|---|
| 1 ball electrodes (B1 and B2) of $\varnothing d$ diameter with their supporting element | a_1 electrode separation distance |
| 2 ring electrodes (R1 and R2) of $\varnothing D$ diameter | D distance between the two ring electrodes |
| 3 ground | H distance between the test set-up and the ground |
| 4 spherical zone of $\varnothing D$ diameter around each test electrode | |

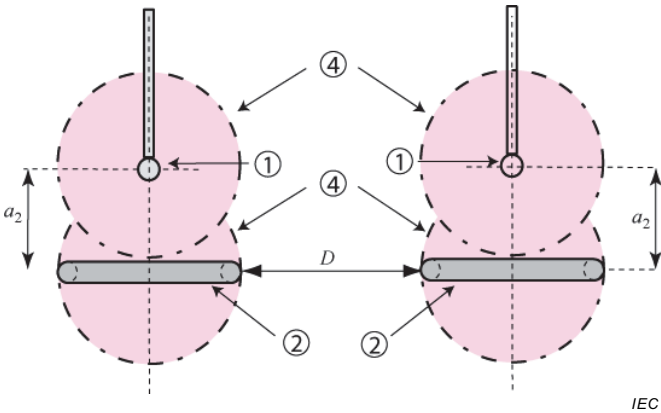
NOTE Diameter " D " and distance " D " are of the same value.

Figure 3 – Test set-up for clear indication with the ball electrode in front of its ring electrode

Dimensions in millimetres



a) Side view



b) Top view

Key

- | | |
|---|---|
| 1 ball electrodes (B1 and B2) with $\varnothing d$ diameter with their supporting element | a_2 electrode separation distance |
| 2 ring electrodes (R1 and R2) with $\varnothing D$ diameter | D distance between the two ring electrodes |
| 3 ground | H distance between the test set-up and the ground |
| 4 spherical zone of $\varnothing D$ diameter around each test electrode | |

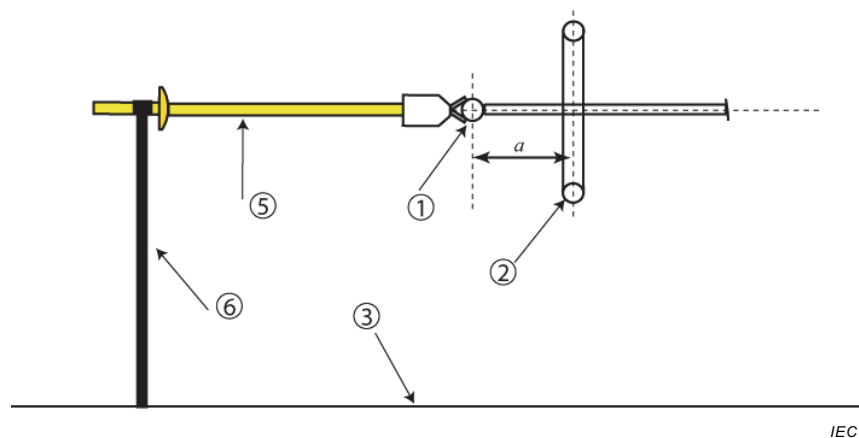
NOTE Diameter " D " and distance " D " are of the same value.

Figure 4 – Test set-up for clear indication with the ball electrode behind its ring electrode

Table 3 – Dimensioning of the ball and ring test set-up

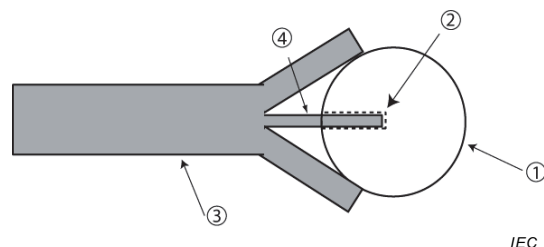
U_n	Electrode separation distance when the ball is in front of the ring a_1	Electrode separation distance when the ball is behind the ring a_2	H	Diameter “ $\varnothing D$ ” and distance “ D ”	d	W (3 times D) Clearance of the complete test set-up from any foreign objects mm
kV	mm	mm	mm	mm	mm	mm
$1 < U_n \leq 12$ $12 < U_n \leq 24$ $24 < U_n \leq 52$	300	100 270 430	1 500	550	$\varnothing 60$	$> 1\,650$
$52 < U_n \leq 170$ $170 < U_n \leq 245$	1 000	650 850	2 500	1 050	$\varnothing 100$	$> 3\,150$

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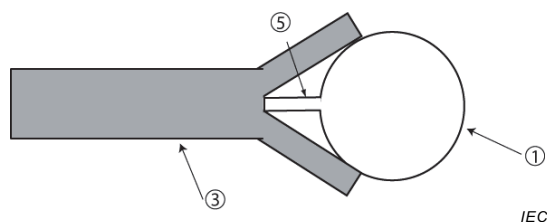
**Key**

- 1 ball electrode
- 2 ring electrode
- 3 ground
- 5 pole of the *phase comparator* (as a complete device or equipped with an *insulating stick*)
- 6 one insulating support for maintaining the pole horizontal to ground

Figure 5 – Positioning of a pole of the phase comparator in relation to a ball and ring test arrangement



a) Modification of a contact electrode used for testing



b) Modification of the ball electrode

Key

- 1 ball electrode
- 2 circular hole drilled in the ball electrode
- 3 Y shape *contact electrode*
- 4 cylindrical rod fixed to a Y shape *contact electrode* of a dimension to fit tightly into the hole of the ball electrode
- 5 cylindrical rod fixed to the ball electrode

Figure 6 – Examples of suitable means for ensuring appropriate contact between a contact electrode and the ball electrode

5.2.2 Clear indication

The description of the test set-up and the general pass criteria are those of 5.2.1.

For performing the *clear indication* tests, the two ring electrodes, designated as R1 and R2, shall be earthed.

In the case of a *phase comparator* with one *nominal voltage* U_n the test shall be performed at this *nominal voltage*.

In the case of a *phase comparator* with more than one *nominal voltage* the test shall be performed at every *nominal voltage*.

In the case of a *phase comparator* with one *nominal voltage* range the test shall be performed at the lowest ($U_{n \min}$) and the highest ($U_{n \max}$) value of the *nominal voltage* range.

In the case of a *phase comparator* with more than one *nominal voltage* range the test shall be performed at the lowest and the highest value of each *nominal voltage* range.

Each pole of the two-pole *phase comparator* shall be connected to one of the two ball electrodes of the test set-up. In the case of a single-pole *phase comparator*, the *contact electrode* shall touch successively the two ball electrodes according to the instructions for use.

For test series 1 and 2, the test electrodes shall have a voltage and phase relationship according to the relevant part of Table 4.

The test shall be considered as passed if the indication "incorrect phase relationship" does not appear or the indication "correct phase relationship" appears according to the type of indication of the *phase comparator*.

For test series 3 and 4, the test electrodes shall have a voltage and phase relationship according to the relevant part of Table 4.

The test shall be considered as passed if the indication "incorrect phase relationship" appears.

Table 4 – Test series and conditions for clear indication

Test series	Test voltage on the two ball-and-ring electrode arrangements (B1-R1 and B2-R2)				Required indication according to the type of indication	
	B1	R1	B2	R2	“Incorrect phase relationship”	“Correct phase relationship”
1	$0,45 U_{n \text{ min}}$	earth	$0,45 U_{n \text{ min}} 10^\circ \text{ }^a$	earth	no	yes
2	$0,63 U_{n \text{ max}}$	earth	$0,63 U_{n \text{ max}} 10^\circ \text{ }^b$	earth	no	yes
3	$0,45 U_{n \text{ min}}$	earth	$0,45 U_{n \text{ min}} 30^\circ \text{ }^a \text{ }^c$	earth	yes	no
4	$0,63 U_{n \text{ max}}$	earth	$0,63 U_{n \text{ max}} 30^\circ \text{ }^b \text{ }^c$	earth	yes	no

^a $0,45 U_n$ corresponds to $0,78 U_n / \sqrt{3}$.
^b $0,63 U_n$ corresponds to $1,1 U_n / \sqrt{3}$.
^c A phase difference according to the operational class of the *phase comparator* (see 4.2.1) shall be adjusted. In the table, operational class A is used as an example.

5.2.3 Distance range for two-pole phase comparators with wireless connection

With all various communication units of the whole *phase comparator* separated each one from the other in free space by the maximum distance declared by the manufacturer, the communication between all these units shall be activated.

The test shall be considered as passed if all various units communicate properly according to the instruction for use.

5.2.4 Electromagnetic compatibility (EMC)

5.2.4.1 Type test

The *phase comparator* shall be submitted to and shall fulfil the relevant tests of IEC 61326-1 for:

- immunity requirements for portable equipment powered by battery or from the circuit being measured with the following test parameters:

Description	Port	Test	Parameters
Electrostatic discharge (ESD)	Enclosure	IEC 61000-4-2	4 kV/8 kV (contact/air)
RF electromagnetic field immunity	Enclosure	IEC 61000-4-3	3 V/m for 80 MHz to 1 GHz (level 2) 3 V/m for 1,4 GHz to 2 GHz (level 2) 1 V/m for 2 GHz to 2,7 GHz
Power frequency magnetic field	Enclosure	IEC 61000-4-8	Not applicable

NOTE 1 Level 2 corresponds to a moderate electromagnetic radiation environment. This happens in presence of Global System for Mobile Communications (GSM), for example fixed transceivers, like microwave antenna for cell phones, installed in transmission structures or substations.

NOTE 2 *Phase comparators* of capacitive type are magnetically non sensitive devices.

With the following performance criteria for all the EMC tests:

Function	Criteria
Functioning of <i>phase comparator</i>	B
Data communication (if any)	B
Functioning of the <i>testing element</i>	B

- emission limit requirements for equipment intended for use in industrial locations with the following test parameters:

Description	Port	Test	Parameters
Radio disturbances characteristics	Enclosure	CISPR 11	Class A

The *phase comparator* shall be configured in a mode that represents normal working conditions according to the instructions for use.

The test shall be considered as passed if the relevant indications are not affected.

5.2.4.2 Alternative means for phase comparators having completed the production phase

After completing the production phase, it is not practical to perform EMC tests for checking the conformity to the relevant requirements. Nevertheless, the manufacturer shall prove that it has followed the same documented assembly procedure as per the type tested device.

5.2.5 Influence of electric interference fields

5.2.5.1 General

The description of the test set-up and the general pass criteria are those of 5.2.1.

The test consists of the test series and conditions given in Table 5.

Table 5 – Test series and conditions for influence of electric interference fields

Test series	Test voltage on the two ball-and-ring electrode arrangements (B1-R1 and B2-R2)				Required indication according to the type of indication	
	B1	R1	B2	R2	“Incorrect phase relationship”	“Correct phase relationship”
Influence of in-phase interference electric field						
1	0,45 $U_{n \text{ min}}$	0,45 $U_{n \text{ min}}$	0,45 $U_{n \text{ min}}$ 10°	earth	no	yes
2	0,63 $U_{n \text{ max}}$	0,63 $U_{n \text{ max}}$	0,63 $U_{n \text{ max}}$ 10°	earth	no	yes
3	0,45 $U_{n \text{ min}}$	0,45 $U_{n \text{ min}}$	0,45 $U_{n \text{ min}}$ 30° ^a	earth	yes	no
4	0,63 $U_{n \text{ max}}$	0,63 $U_{n \text{ max}}$	0,63 $U_{n \text{ max}}$ 30° ^a	earth	yes	no
Influence of phase opposition interference electric field						
1	0,63 $U_{n \text{ max}}$	earth	0,63 $U_{n \text{ max}}$ 10°	0,63 $U_{n \text{ max}}$	no	yes
2	0,63 $U_{n \text{ max}}$	earth	0,63 $U_{n \text{ max}}$ 30° ^a	0,63 $U_{n \text{ max}}$	yes	no
^a A phase difference according to the operational class of the <i>phase comparator</i> (see 4.2.1) shall be adjusted. In the table, operational class A is used as an example.						