IEC/IEEE 60076-57-1202

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INTERNATIONAL STANDARD

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Power transformers –
Part 57-1202: Liquid immersed phase-shifting transformers

Transformateurs de puissance –
Partie 57-1202: Transformateurs déphaseurs immergés dans un liquide

IEC/IEEE 60076-57-1202:2017-05(en-fr)

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International Standard IEC/IEEE 60076-57-1202 has been prepared by IEC technical committee 14: Power transformers, in cooperation with the Transformers Committee of the IEEE Power & Energy Society[1], under the IEC/IEEE Dual Logo Agreement.

This publication is published as an IEC/IEEE Dual Logo standard.

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

FDIS	Report on voting
14/892/FDIS	14/902/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.

International Standards are drafted in accordance with the rules given in the ISO/IEC Directives, Part 2.

The IEC Technical Committee and IEEE Technical Committee have decided that the contents of this publication will remain unchanged until the stability date indicated on the IEC website under "http://webstore.iec.ch" in the data related to the specific publication. At this date, the publication will be

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- withdrawn,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

[1] A list of IEEE participants can be found at the following URL: http://standards.ieee.org/downloads/60076/60076-57-1202-2017/60076-57-1202-2017_wg-participants.pdf

POWER TRANSFORMERS –

Part 57-1202: Liquid immersed phase-shifting transformers

1 Scope

This part of IEC 60076 covers the requirements for phase-shifting transformers of all types. The scope excludes transformers with an unregulated phase shift.

This document is limited to matters particular to phase-shifting transformers and does not include matters relating to general requirements for power transformers covered in existing standards in the IEC 60076 series or IEEE Std C57.12.00™ and IEEE Std C57.12.10™.

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.

2.1 IEC references

IEC 60050-421, *International Electrotechnical Vocabulary – Chapter 421: Power transformers and reactors* (available at: www.electropedia.org)

IEC 60076-1, *Power transformers – Part 1: General*

IEC 60076-2, *Power transformers – Part 2: Temperature rise for liquid-immersed transformers*

IEC 60076-3, *Power transformers – Part 3: Insulation levels, dielectric tests and external clearances in air*

IEC 60076-5, *Power transformers – Part 5: Ability to withstand short circuit*

IEC 60076-10, *Power transformers – Part 10: Determination of sound levels*

IEC 60076-18, *Power transformers – Part 18: Measurement of frequency response*

ISO 2178, *Non-magnetic coatings on magnetic substrates – Measurement of coating thickness – Magnetic method*

ISO 2409, *Paints and varnishes – Cross-cut test*

2.2 IEEE references

IEEE Std C57.12.00™, *IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers*

IEEE Std C57.12.10™, *IEEE Standard Requirements for Liquid-Immersed Power Transformers*

IEEE Std C57.12.70™, *IEEE Standard for Standard Terminal Markings and Connections for Distribution and Power Transformers*

IEEE Std C57.12.80™, *IEEE Standard Terminology for Power and Distribution Transformers*

IEEE Std C57.12.90™, *IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers*

3 Terms and definitions

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

ISO and IEC maintain terminological databases for use in standardization at the following addresses:

- IEC Electropedia: available at http://www.electropedia.org/
- ISO Online browsing platform: available at http://www.iso.org/obp

For the purposes of this document, the terms and definitions given in IEC 60050-421 and IEC 60076-1 apply to IEC specified phase shifting transformers. For IEEE specified phase shifting transformers the terms and definitions given in IEEE Std C57.12.80 apply. For all phase shifting transformers the following apply and take precedence.

3.1
phase-shifting transformer
PST
transformer (or combination of transformers designed to work together) with two sets of line terminals (S and L) which is capable of varying the voltage phase-angle relationship between the S terminals and the L terminals

Note 1 to entry: The rated voltage of the S terminals and the L terminals may be the same or different. In addition the PST may also be capable of varying the in-phase voltage.

Note 2 to entry: This note applies to the French language only.

3.2
S terminal
terminal that is used as the fixed reference point when measuring the voltage phase angle of a phase-shifting transformer

3.3
L terminal
terminal that is used to measure the voltage phase angle when compared to the S terminal of the phase-shifting transformer

Note 1 to entry: The designations of S and L to the terminals do not imply any particular direction of power flow.

3.4
zero phase shift tap position
tap position at which the no-load voltage phase angle is zero

3.5
rated power
output power at rated voltage and rated frequency that can be delivered at the L terminal continuously without exceeding the specified temperature rise

3.6
excitation winding
winding of a phase-shifting transformer (PST) that draws power from the source to energize the PST

3.7
excited winding
winding of the series unit that is excited from the exciting winding

3.8
quadrature booster
asymmetric design phase-shifting transformer with the excitation winding connected to the S terminal

3.9
symmetric design
phase-shifting transformer where the no-load voltage ratio between the S and L terminals is constant

3.10
asymmetric design
phase-shifting transformer where the no-load voltage ratio between the S and L terminals changes with the phase angle variation tap position

3.11
single-core PST
phase-shifting transformer that has all windings mounted on a single core

3.12
two-core PST
phase-shifting transformer consisting of a series unit and an exciting unit, located on two separate cores

3.13
extreme tap
tap for maximum absolute value of no-load phase angle in the advance or retard direction

3.14
phase angle
electrical phase angle expressed in degrees between the S and L terminals with a sign such that the angle is positive when the voltage at the L terminal leads the voltage at the S terminal

3.15
boost operation
operation when the PST is acting to increase the power flow in the circuit

3.16
buck operation
operation when the PST is acting to reduce or reverse the power flow in the circuit

Note 1 to entry: For example, in retard operation the load phase angle between the S and L terminals is made more negative in buck operation relative to the no-load phase angle at the same tap position because both the no-load phase angle and the phase angle change caused by the load are negative (see Annex E).

3.17
advance
mode of operation where the L terminal no-load voltage leads the S terminal no-load voltage, giving a positive no-load phase angle

3.18
retard
mode of operation where the L terminal no-load voltage lags the S terminal no-load voltage, giving a negative no-load phase angle

3.19
rated voltage
no-load phase-to-phase voltage at zero phase shift tap position to which operating and performance characteristics are referred

3.20
tapping voltage of the S terminal
<for asymmetric designs> no-load phase-to-phase voltage based on turns ratio appearing at the S terminal when rated voltage is applied to the L terminal at a particular tap position

Note 1 to entry: For an asymmetric design, the voltage at taps other than at the zero phase shift tap position will be lower at the S terminal than the L terminal. This definition is used so that the series unit rated current is constant with tap position to be compatible with the rating of the attached power system circuits.

3.21
series winding
winding connected between the S and L terminals

Note 1 to entry: The term series winding refers to any winding or set of windings that can be connected between the S and L terminals. For example, this term refers to the tap winding of a single-core phase shifting transformer where this winding is connected between the S and L terminals. In the case of a PST combined with a transformer or autotransformer, the series winding of the PST may be connected to the S or L terminal indirectly through the transformer or autotransformer series winding (see example 9.4.3.1).

3.22
series unit
core and windings of a two-core PST containing the series winding

3.23
exciting unit
core and windings of a two-core PST that provides excitation to the series unit

3.24
exciting winding
winding of a single-core PST or of the exciting unit of a two-core PST which supplies the voltage required to change the phase angle

3.25
tap winding
winding in which taps are changed to vary the phase angle

Note 1 to entry: The tap winding is referred to as the regulating winding in some countries.

3.26
design value
expected value given by the number of turns in the design in the case of turns ratio and no-load phase angle or calculated from the design in the case of impedance, no-load current or other parameters

3.27
advance-retard switch
ARS
switch separate from any change-over selector associated with the on-load tap-changer that allows a change of operation from advance to retard or from retard to advance at zero no-load phase angle without interrupting the load current or de-energizing the PST

Note 1 to entry: See Annex F.

Note 2 to entry: This note applies to the French language only.

4 Use of normative references

This standard can be used with either the IEC or IEEE normative references, but the references shall not be mixed. The purchaser shall include in the enquiry and order which normative references are to be used. If the choice of normative references is not specified, then IEC standards shall be used, except for PSTs intended for installation in North America where IEEE standards shall be used.

5 Service conditions

5.1 General

Unless otherwise specified by the purchaser, normal service conditions shall apply as stated in IEC 60076-1 or IEEE Std C57.12.00.

5.2 Usual service conditions

5.2.1 Switching arrangement

Unless otherwise specified, the PST shall be designed for use with an on-load bypass device connecting the respective L terminals and S terminals that will only be closed in service when the PST is on the zero phase shift tap position for the time taken to complete a switching sequence to place the PST into or out of service.

If the PST will never be used with the L and S terminals connected (no on-load bypass device), this can be specified and the double ended impulse test may be omitted (see 13.12.5).

If the PST is to be used in the condition where an on-load bypass is closed in service with the PST energized from both S and L terminals for longer than the time taken for switching, this shall be specified.

Unless otherwise specified, the PST shall not be energized or operated with the L and S terminals connected by a bypass unless it is on the zero phase shift tap position. If it is required that the PST can be bypassed at other than zero phase shift tap position, this shall be clearly stated by the purchaser in the enquiry.

The PST shall be suitable for energization from either the S or L terminals at any tap position.

5.2.2 Power flow

Unless otherwise specified, the PST shall be capable of transferring rated power in either direction provided that the phase angle between the S and L terminals does not exceed the maximum no-load phase angle.

NOTE If the PST is acting to reduce or reverse the power flow in the circuit, the phase angle will exceed the no-load phase angle and, unless otherwise specified, there will be no power flow capability at the extreme taps under these conditions. If this capability is required, see 6.3.

5.2.3 Operation with two or more PSTs in series or parallel

Unless otherwise specified, it may be assumed that the PST will not be installed in series or parallel with another PST connected to the same circuit. If series or parallel operation is required, this shall be stated by the purchaser in the enquiry and contract, and details of the PST which will be in series or parallel given.

NOTE For parallel operation of PSTs it should be considered that if the PST has a low impedance at or close to the no-load zero phase shift tap position then a short circuit or an extremely high circulating current can occur during tap-change operations if no additional reactance is connected to the circuit. See IEC 62032 [1] or IEEE Std C57.135 [2].[2]

5.2.4 Phase unbalance

PSTs are intended to be used in a system where the voltages and currents in the three phases are essentially balanced under normal conditions (see IEC 60076-1 or IEEE Std C57.12.00 for normal levels of voltage balance). If the PST is to operate in a system that has current unbalance of more than 5 %, the expected unbalance shall be stated by the purchaser in the enquiry and order.

5.2.5 Surge protection

The PST shall be installed with adequate surge protection on both S and L terminals irrespective of the characteristics of the connected system. Unless otherwise specified, this is the responsibility of the purchaser.

NOTE A through fault short circuit condition on one phase is likely to produce induced voltages on the other phases higher than the test voltage levels, see Annex B.

6 Rating and general requirements

6.1 Rated power

The rated power shall be specified by the purchaser and shall apply to the zero phase shift tap and any tap in boost mode, but see 6.3 for rated power in buck mode.

6.2 Loading at other than rated conditions

Any requirements for loading beyond rated power or at other than rated conditions shall be specified by the purchaser. See IEC 60076-7 [3] or IEEE Std C57.12.00, and IEEE Std C57.91 [6]. See also 6.3.

NOTE PSTs have loading limitations due to thermal, magnetic induction and tap-changer considerations.

6.3 Specification of buck capability

If operation of the PST in buck mode is required, the minimum required power at each tap position under buck loading conditions including any overloads shall be specified. Unless otherwise specified, unity power factor, rated frequency and rated voltage at the L terminal shall be assumed when calculating the PST capability. An example of such a specification is given in Annex C.

If the minimum required power at each tap position under buck loading conditions is not specified, then according to 5.2.2 the PST will have no buck loading capability at the extreme tap position. Some buck capability (below rated power) at other tap positions will be available depending on the no-load phase angle and impedance at that tap, but any capability will be determined by the manufacturer.

The impedance used as the basis for the buck loading capability assessment shall become the maximum guaranteed value (without tolerance) at that particular tap position. This figure may be lower than the maximum impedance, but shall be higher than the minimum impedance specified by the purchaser.

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2 Numbers in square brackets refer to the Bibliography.

6.4 Cooling modes

Requirements for cooling modes and minimum power under different cooling modes if any shall be stated in the enquiry and order. See IEC 60076-1 or IEEE Std C57.12.00.

6.5 Short circuit impedance and load phase angle capability

6.5.1 Specification

The purchaser shall specify the load phase angle capability of the PST in one of the following ways:

- the maximum and minimum impedance at the extreme taps and the minimum absolute no-load phase angle at the extreme taps;
- the minimum absolute boost and/or buck phase angle at rated power. In this case the manufacturer shall determine the no-load phase angle and impedance required to meet this requirement. The purchaser shall also specify either a maximum impedance or voltage drop (regulation) if required.

Unless otherwise specified, unity power factor, rated frequency and rated voltage at the L terminal shall be assumed when calculating the PST capability.

NOTE In the case of certain asymmetric designs with both voltage and phase angle variation, it can be more convenient by agreement to base the capability on the S terminal to avoid an apparent interaction between phase angle tap position and voltage variation range.

If there is a minimum impedance requirement at the zero phase shift tap position, this shall be specified by the purchaser. Otherwise the minimum impedance at the zero phase shift tap is at the discretion of the manufacturer.

If the purchaser requires any particular limits on zero sequence impedance, for example to avoid series resonance conditions, this shall be stated in the enquiry and order.

6.5.2 Short circuit impedance for asymmetric designs

In the case of an asymmetric design, the voltage ratio between the S terminal and the L terminal and consequently the tapping voltage of the S terminal will vary with tap position. Unless otherwise agreed, the impedance at each tap shall be based on the rated voltage and rated power at the L terminal.

6.6 Neutral earthing (grounding)

The purchaser shall specify the neutral earthing arrangement for each neutral terminal; whether directly connected to earth, earthed through an impedance or not earthed.

Any intermediate circuit or circuits that would otherwise have no galvanic connection to the S, L or neutral terminals shall be connected to earth. Unless otherwise specified, intermediate circuits shall be connected to earth externally to facilitate site testing. Unless otherwise agreed, the connection to the tank earth shall be provided by the manufacturer.

6.7 Rated voltage

The purchaser shall specify the rated voltage for the S and L terminals.

6.8 Voltage variation and asymmetric design

Unless otherwise specified, the PST shall be designed so that the voltage ratio between the S and L terminals does not vary with tap position. If an asymmetric design can be accepted by the purchaser, this should be stated in the enquiry together with any limits on the voltage variation at the L terminal.