TECHNICAL CONSTRUCTION FILE
EN 60076-1:2011
Power transformers – Part 1: General
EN 60076-2:2011
Power transformers - Part 2: Temperature rise for liquid-immersed transformers
EN IEC 60076-11:2018
Power transformers – Part 11: Dry Type Transformers

Report Reference No..... :	TLZJ24082661457
Tested by (name + signature).....:	Kevin Liu
Approved by (name + signature)	Johnson Lai
Date of issue.....:	September 06,2024

Testing Laboratory.....:	Shanghai Global Testing Services Co., Ltd.
Address..... :	Floor 2nd, Building D-1, No. 128, Shenfu Road, Minhang District, Shanghai, China.
Applicant's name.....:	Hangzhou Easy Electric Wire and Cable Co., LTD.
Address..... :	Room 508, Building A5, No. 2-150, Yunlian Road, Hangzhou, Zhejiang, China
Manufacturer.....:	Hangzhou Easy Electric Wire and Cable Co., LTD.
Address ..... :	Room 508, Building A5, No. 2-150, Yunlian Road, Hangzhou, Zhejiang, China
Test specification:	
Standard.....:	EN 60076-1:2011, EN 60076-2:2011, EN IEC 60076-11:2018
Test procedure.....:	/
Non-standard test method……..:	N/A
Test Report Form No.....:	EN 60076
TRF Originator.....:	GTS
Master TRF.....:	Dated 2011

Test item description	Power Transformer
Test model/Type reference	35kV Power Transformer 500kVA~6300kVA, 10kV Distribution Transformer 30kVA~2500kVA S22-M, S20-M, S11-M, S13-M, S14-M S13-35KV, SZ13-35KV, S11-35KV, D14-M(R)-(10~160)/10KV, D13-M(R)-(10~160)/10KV, D11-M(R)-(10~160)/10KV SCB18-30~2500/10kV, SCB14-30~2500/10kV, SCB13-30~2500/10kV, SCB12-30~2500/10kV, SCB10-30~2500/10kV, SCB12-30~2500/35kV
Trade Mark	:/
Ratings	:/
Manufacturer	:Hangzhou Easy Electric Wire and Cable Co., LTD.
Factory location	: Room 508, Building A5, No. 2-150, Yunlian Road, Hangzhou, Zhejiang, China
Intend use	: 6kV, 6.3kV, 6.6kV, 10kV, 10.5kV, 11kV, Or other

Summary of testing:

Ambient temperature :20℃~25℃, humidity:50%~55%RH

Complete test was conducted on **S22-M**

A representative sample of the product covered by this re ort has been tested and complies with the applicable requirements of this standard.

General product information:

CE

Test item particulars..... :
Classification of installation and use ..... : /
Nature of supply .....: A.C
Class of protection against electrical shock ……..: Class Ⅰ
Degree of protection against moisture ..... : /
Possible test case verdicts:
- test case does not apply to the test object..... : N/A(N)
- test object does meet the requirement ..... : P(Pass)
- test object does not meet the requirement ..... : F(Fail)
Testing..... :
Date of receipt of test item..... : August 26,2024
Date (s) of performance of tests..... : August 26,2024 to September 06,2024
General remarks:
This report is not valid as a CE Test Report unless signed by an approved CE Testing Laboratory and appended to a CE Test Certificate issued.
The test results presented in this report relate only to the object tested. This report shall not be reproduced, except in full, without the written approval of the Issuing testing laboratory.
"(see Enclosure #)" refers to additional information appended to the report. "(see appended table)" refers to a table appended to the report. Throughout this report a comma (point) is used as the decimal separator.

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
5	Rating and general requirements		P
5.1	Rated power		P
5.1.1	General		P
	The rated power for each winding shall either be specified by the purchaser or the purchaser shall provide sufficient information to the manufacturer to determine the rated power at the enquiry stage		P
	The transformer shall have an assigned rated power for each winding which shall be marked on the rating plate. The rated power refers to continuous loading. This is a reference value for guarantees and tests concerning load losses and temperature rises		P
	If different values of apparent power are assigned under different circumstances, for example, with different methods of cooling, the highest of these values is the rated power.		N/A
	A two-winding transformer has only one value of rated power, identical for both windings		N/A
	For multi-winding transformers, the purchaser shall specify the required power-loading combinations, stating, when necessary, the active and reactive outputs separately.	Pass muter	P
	When the transformer has rated voltage applied to a primary winding, and rated current flows through the terminals of a secondary winding, the transformer receives the relevant rated power for that pair of windings.	Pass muter	P
	The transformer shall be capable of carrying, in continuous service, the rated power (for a multi-winding transformer: the specified combination(s) of winding rated power(s)) under conditions listed in Clause 4 and without exceeding the temperature-rise limitations specified in IEC 60076-2 for liquid immersed transformers	Pass muter	P
5.1.2	Preferred values of rated power		P
	For transformers up to 20 MVA, values of rated power should preferably be taken from the R10 series given in ISO 3:1973, *Preferred numbers – series of preferred numbers*: (...100, 125, 160, 200, 250, 315, 400, 500, 630, 800, 1 000, etc.) kVA.		P
5.1.3	Minimum power under alternative cooling modes		P
	Where the user has a particular requirement for a minimum power under a particular cooling mode other than the cooling mode for rated power, this shall be stated in the enquiry		P
	The transformer shall be capable of carrying, in continuous service, the specified minimum power (for a multi-winding transformer: the specified combination(s) of winding rated power(s) under conditions listed in Clause 4, and under the specified cooling mode, without exceeding the temperature-rise limitations specified in IEC 60076-2 for liquid immersed transformers.		P
5.1.4	Loading beyond rated power		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	A transformer and its component parts in accordance with this standard is able under some circumstances to carry loading beyond rated power. The method for calculating the permissible loading can be found in IEC 60076-7 for liquid immersed transformers and in IEC 60076-12 for Dry Type Transformers		P
	Any specific requirements for loading beyond rated power, operation at higher external cooling medium temperatures or reduced temperature rise limits shall be specified by the purchaser in the enquiry and the contract. Any additional tests or calculations required to verify compliance with these specific requirements shall also be specified		P
	The bushings, tap-changers, current transformers and other auxiliary equipment shall be selected so as not to restrict the loading capability of the transformer.		P
5.2	Cooling mode		P
	The user shall specify the cooling medium (air or water).		P
	If the user has particular requirements for the cooling method(s) or cooling equipment, this shall be stated in the enquiry		N/A
	For additional information see IEC 60076-2.		P
5.3	Load rejection on transformers directly connected to a generator		P
	Transformers intended to be connected directly to generators in such a way that they may be subjected to load rejection conditions shall be able to withstand 1,4 times rated voltage for 5 s at the transformer terminals to which the generator is to be connected		P
5.4	Rated voltage and rated frequency		P
5.4.1	Rated voltage		P
	The rated voltage shall either be specified by the purchaser or for special applications the purchaser shall provide sufficient information to the manufacturer to determine the rated voltage at the enquiry stage		P
	The transformer shall have an assigned rated voltage for each winding which shall be marked on the rating plate		P
5.4.2	Rated frequency		P
	The rated frequency shall be specified by the purchaser to be the normal undisturbed frequency of the network		P
	The rated frequency is the basis for the guaranteed values such as losses, impedance, and sound level		P
5.4.3	Operation at higher than rated voltage and/or at other than rated frequency		P
5.5	Provision for unusual service conditions		P
	The purchaser shall identify in his enquiry any service conditions not covered by the normal service conditions. Examples of such conditions are:		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	– external cooling medium temperature outside the limits prescribed in 4.2;		P
	– restricted ventilation		P
	– altitude in excess of the limit prescribed in 4.2;		P
	– damaging fumes and vapours		P
	– steam;		P
	– humidity in excess of the limit prescribed in 4.2		P
	– dripping water		P
	– salt spray		
	– excessive and abrasive dust		P
	– high harmonic content of the load current exceeding the requirements of 4.2;		P
	– distortion of the supply voltage waveform exceeding the limits of 4.2		P
	– unusual high frequency switching transients, see Clause 13;		P
	– superimposed DC current		P
	– seismic qualification which would otherwise require special considerations in the design, see 4.2		P
	– extreme mechanical shock and vibrations		P
	– solar radiation		P
	– regular frequent energisation in excess of 24 times per year		P
	– regular frequent short-circuits		P
	– V/Hz in excess of 5.4.3 above		P
	– if a generator step up transformer is intended to be used in back-feed mode when not connected to the generator without protection on the lower voltage side;		N/A
	– corrosion protection, according to the kind of installation and the installation environment (see 4.2), the purchaser should choose classes of protection in ISO 12944 or by agreement between purchaser and manufacturer		P
	– load rejection conditions for generator transformers more severe than those given in 5.3 above.		P
	Transformer specification for operation under such abnormal conditions shall be subject to agreement between the supplier and purchaser		P
	Supplementary requirements, within defined limits, for the rating and testing of transformers designed for other than normal service conditions listed in Clause 4, such as high temperature of cooling air or altitude above 1 000 m are given in IEC 60076-2.		P
5.6	Highest voltage for equipment *U*m and dielectric tests levels		P
	For line terminals, unless otherwise specified by the purchaser, *U*m shall be taken to be the lowest value that exceeds the rated voltage of each winding given in IEC 60076-3.		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	For transformer windings with a highest voltage for equipment greater than (>) 72,5 kV the purchaser shall specify whether any neutral terminals for that winding are to be directly earthed in service or not, and if not, the *U*m for the neutral terminals shall be specified by the purchaser		P
	Unless otherwise specified by the purchaser, dielectric test levels shall be taken to be the lowest applicable value corresponding to *U*m, given in IEC 60076-3.		P
5.7	Additional information required for enquiry		P
5.7.1	Transformer classification		P
	The kind of transformer, for example, separate winding transformer, auto-transformer or series transformer shall be specified by the user.		P
5.7.2	Winding connection and number of phases		P
	The required winding connection shall be specified by the user in accordance with the terminology given in Clause 7 to suit the application		P
	If a delta connected stabilizing winding is required, it shall be specified by the purchaser. For star-star connected transformers or autotransformers, if the design has a closed magnetic circuit for zero sequence flux and no delta winding is specified, then the requirement shall be discussed between the manufacturer and the purchaser (see IEC 60076-8).		N/A
	If there are requirements for high and low limits for the zero sequence impedance, this shall be stated by the purchaser and may influence the core configuration and the requirement for a delta winding. If the zero sequence requirements dictated the use of a delta connected winding that was not directly specified by the purchaser, then this shall be clearly stated by the manufacturer in the tender documents.		N/A
	The transformer manufacturer shall not use a delta connected test winding if no delta winding has been specified, unless specifically agreed by the purchaser		P
	If there is a particular requirement for either a bank of single phase transformer or a three phase unit, then this shall be specified by the user; otherwise the manufacturer shall make it clear in the tender document what type of transformer is being offered.		P
5.7.3	Sound level		P
	Where the purchaser has a specific requirement for a guaranteed maximum sound level, this shall be given in the enquiry and should preferably be expressed as a sound power level		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Unless otherwise specified, the sound level shall be taken as the no load sound level with all cooling equipment required to achieve rated power in operation. If an alternative cooling mode is specified (see 5.1.3) the sound level for each alternative mode may be specified by the purchaser and if specified shall be guaranteed by the manufacturer and measured on test		P
	The sound level in service is influenced by the load current (see IEC 60076-10). If the purchaser requires a load current sound level measurement test or a guarantee of the total noise level of the transformers, including load noise, this shall be stated in the enquiry.		P
	The sound level measured in the test according to IEC 60076-10 shall not exceed the guaranteed maximum sound level. The guaranteed maximum sound level is a limit without tolerance		P
5.7.4	Transport		P
5.7.4.1	Transport limitation		P
	If transport size or weight limits apply, they shall be stated in the enquiry		P
	If any other special conditions apply during transportation, they shall be stated in the enquiry. This might include a restriction on the transportation with insulating liquid or different environmental conditions expected to be experienced during transportation than those expected in service.		P
5.7.4.2	Transport acceleration		P
	The transformer shall be designed and manufactured to withstand a constant acceleration of at least 1 g in all directions (in addition to the acceleration due to gravity in the vertical direction) without any damage, demonstrated by static force calculations based on a constant value of acceleration		P
	If the transport is not the responsibility of the manufacturer and an acceleration in excess of 1 g is expected during transport, the accelerations and frequencies shall be defined in the enquiry. If higher accelerations are specified by the customer, the manufacturer shall demonstrate compliance by means of calculation		N/A
	If the transformer is intended to be used as a mobile transformer, this shall be stated in the enquiry		N/A
5.8	Components and materials		P
	All components and materials used in the construction of the transformer shall comply with the requirements of the relevant IEC standards where they exist unless otherwise agreed or specified. In particular bushings shall comply with IEC 60137, tap-changers shall comply with IEC 60214-1, and insulating liquid shall comply with IEC 60296 for mineral oil or as agreed for other liquids		P
6	Requirements for transformers having a tapped winding		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
6.1	General – Notation of tapping range		P
	The following subclauses apply to transformers in which only one of the windings is a tapped winding		P
	In a multi-winding transformer, the statements apply to the combination of the tapped winding with either of the untapped windings.		P
	For transformers specified in accordance with 6.4.2, the notation shall be as specified by the purchaser in item 3 of that subclause.		P
	In auto-connected transformers, tappings are sometimes arranged at the neutral which means that the effective number of turns is changed simultaneously in both windings. For such transformers, unless they are specified in accordance with 6.4.2, the tapping particulars are subject to agreement. The requirements of this subclause should be used as far as applicable		P
	Unless otherwise specified, the principal tapping is located in the middle of the tapping range. Other tappings are identified by their tapping factors. The number of tappings and the range of variation of the transformer ratio may be expressed in short notation by the deviations of the tapping factor percentages from the value 100 (for definitions of terms, see 3.5).		P
6.2	Tapping voltage – tapping current. Standard categories of tapping voltage variation. Maximum voltage tapping		P
	The short notation of tapping range and tapping steps indicates the variation range of the ratio of the transformer. But the assigned values of tapping quantities are not fully defined by this alone. Additional information is necessary. This can be given either in tabular form with tapping power, tapping voltage and tapping current for each tapping, or as text, indicating 'category of voltage variation' and possible limitations of the range within which the tappings are 'full-power tappings'.		P
6.3	Tapping power. Full-power tappings – reduced-power tappings		P
	The following shall apply unless the voltage and current at each tapping is otherwise specified		P
	All tappings shall be full-power tappings, that is, the rated tapping current at each tapping shall be the rated power divided by the rated tapping voltage at each tap except as specified below.		P
	In separate-winding transformers up to and including 2 500 kVA with a tapping range not exceeding ±5 %, the rated tapping current at all minus tappings shall be equal to the rated tapping current at the principal tapping. This means that the principal tapping is a 'maximum current tapping		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	In transformers with a tapping range wider than ±5 %, restrictions may be specified on values of tapping voltage or tapping current which would otherwise rise considerably above the rated values. When such restrictions are specified, the tappings concerned will be 'reduced-power tappings'. This subclause describes such arrangeme		P
	When the tapping factor deviates from unity, the tapping current for full-power tappings may rise above rated current on one of the windings. As Figure 1a illustrates, this applies for minus tappings, on the tapped winding, under CFVV, and for plus tappings on the untapped winding under VFVV (Figure 1b). In order to limit the corresponding reinforcement of the winding in question, it is possible to specify a maximum current tapping. From this tapping onwards the tapping current values for the winding are then specified to be constant. This means that the remaining tappings towards the extreme tapping are reduced-power tappings		P
	Under CbVV, the 'maximum voltage tapping', the change-over point between CFVV and VFVV shall at the same time be a 'maximum current tapping' unless otherwise specified. This means that the untapped winding current stays constant up to the extreme plus tapping		P
6.4	Specification of tappings in enquiry and order		P
6.4.1	General		P
	The purchaser shall specify the requirements for tapping either according to 6.4.2 or 6.4.3		P
	The purchaser shall specify if the tap changer or tap changers are intended to be operated on load or de-energized		P
	Where variable flux voltage variation VFVV is used, it is normally only possible for the design ratio to match the specified ratio at two positions over the regulation range. The purchaser shall specify where the design ratio shall match the specified ratio, e.g. extreme taps, principal and maximum tap or principal and mininimum tap. If not otherwise specified, the two extreme taps shall be the ratios to match		P
6.4.2	Constructional specification		P
	The following data are necessary to define the design of the transformer		P
	a) which winding shall be tapped		P
	b) the number of steps and the tapping step (or the tapping range and number of steps). Unless otherwise specified, it shall be assumed that the range is symmetrical around the principal tapping and that the tapping steps in the tapped winding are equal. If for some reason, the design has unequal steps, this shall be indicated in the tender		P
	c) the category of voltage variation and, if combined variation is applied, the change-over point		P

IEC 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	d) whether maximum current limitation (reduced power tappings) shall apply, and if so, for which tappings		P
	Instead of items c) and d), tabulation of the same type as used on the rating plate may be used to advantage (see example in Annex B).		P
6.4.3	Functional specification		P
	This type of specification is intended to allow the purchaser to specify operational requirements and not the category of voltage variation or which winding is to be tapped		P
	This method of specification is not applicable to separate-winding transformers up to and including 2 500 kVA with a tapping range not exceeding ±5 %.		P
	The following information shall be given by the purchaser in the enquiry in addition to the rated voltage and rated power defined in Clause 5:		P
	a) Direction of power flow (can be both directions).		P
	b) The number of tapping steps and the size of the tapping step expressed as a percentage of the rated voltage at the principal tapping. If the tapping range is not symmetrical about the principal tapping then this shall be indicated. If the tapping steps are not equal across the range then this shall be indicated		P
	c) Which voltage shall vary for the purpose of defining rated tapping voltage		P
	d) Any requirements for fixing the ratio of turns between two particular windings on a more than two winding transformer		P
	e) Minimum full load power factor (this affects the voltage drop of the transformer).		P
	f) Whether any tapping or range of tappings can be reduced power tappings		P
	The manufacturer will choose the arrangement of windings, the winding or windings that are tapped. The transformer shall be able to supply the rated current on the secondary winding on all tapping positions consistent with the above operating conditions, without exceeding the temperature rise requirements defined by IEC 60076-2		P
	The transformer shall be designed to withstand without damage the voltages and fluxes arising from the above specified loading conditions (including any specified overload conditions). A calculation showing that this condition is satisfied shall be supplied to the purchaser on request		P
	An example is given in Annex B (example 4).		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	Alternatively, the user may submit a set of loading cases with values of active and reactive power (clearly indicating the direction of power flow), and corresponding on-load voltages. These cases should indicate the extreme values of voltage ratio under full and reduced power (see “the six-parameter method” of IEC 60076-8). Based on this information, the manufacturer will then select the tapped winding and specify rated quantities and tapping quantities in his tender proposal. An agreement shall be reached between the manufacturer and the purchaser on the design tapping quantities		P
6.5	Specification of short-circuit impedance		P
	For transformers with no tappings exceeding a voltage variation of ±5 % from the principal tapping, the short-circuit impedance of a pair of windings shall be specified at the principal tapping only, either in terms of ohms per phase *Z* or in percentage terms *z* referred to the rated power and rated voltage of the transformer (see 3.7.1). Alternatively, the impedance may be specified in accordance with one of the methods below		P
	For transformers with tappings exceeding a voltage variation of ±5 % from the principal tapping, impedance values expressed in terms of *Z* or *z* shall be specified for the principal tapping and the extreme tapping(s) exceeding 5 %. On such transformers, these values of impedance shall also be measured during the short-circuit impedance and load losses test (see 11.4) and shall be subject to the tolerances given in Clause 10. If the impedance is expressed in percentage terms *z*, this shall be referred to the rated tapping voltage (at that tapping) and the rated power of the transformer (at the principal tapping).		P
	Alternatively maximum and minimum impedances in terms of *z* or *Z* may be specified for each tapping across the whole tapping range. This may be done with the aid of a graph or a table. (See Annex C). The boundaries should where possible be at least as far apart as to permit the double-sided tolerances of Clause 10 to be applied on a median value between them. Measured values shall not fall outside the boundaries, which are limits without tolerance		P
6.6	Load loss and temperature rise		P
	a) If the tapping range is within ±5 %, and the rated power not above 2 500 kVA, load loss guarantees and temperature rise refer to the principal tapping only, and the temperature rise test is run on that tapping		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	b) If the tapping range exceeds ±5 % or the rated power is above 2 500 kVA, the guaranteed losses shall be stated on the principal tapping position, unless otherwise specified by the purchaser at the enquiry stage. If such a requirement exists, it shall be stated for which tappings, in addition to the principal tapping, the load losses are to be guaranteed by the manufacturer. These load losses are referred to the relevant tapping current values. The temperature-rise limits are valid for all tappings, at the appropriate tapping power, tapping voltage and tapping current		P
7	Connection phase displacement symbols		P
7.1	Connection and phase displacement symbols for three-phase transformers and for single phase transformers connected in a three phase bank		P
7.1.1	Connection symbol		P
7.1.2	Phase displacement in clock number notation		P
7.1.3	Windings not intended to be loaded		P
7.1.4	Reconnectable windings		P
7.2	Connection and phase displacement symbols for single phase transformers not in three phase bank		P
7.2.1	Connection symbol		P
	The connection of a set of phase windings of single-phase transformers is indicated by the capital letter I for the high-voltage (HV) winding and small letter i for the intermediate and lowvoltage (LV) windings		P
	Letter symbols for the different windings of a transformer are noted in descending order of rated voltage independently of the intended power flow. The winding connection letter for any intermediate and low-voltage winding is immediately followed by its phase displacement 'clock number'		P
	For an auto-connected pair of windings, the symbol of the lower voltage winding is replaced by the letter a		P
7.2.2	Phase displacement in clock number notation		P
	The clock number of single-phase transformers is determined as for three phase transformers but can only be 0 if both windings are in phase or 6 if they are in opposition		P
7.2.3	Windings not intended to be loaded		P
7.2.4	Reconnectable windings		P
8	Rating plates		P
8.1	General		P
	The transformer shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the appropriate items indicated below. The entries on the plate shall be indelibly marked		P
8.2	Information to be given in all cases		P
	a) Kind of transformer (for example transformer, auto-transformer, series transformer, etc.).		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	b) Number of this standard		P
	c) Manufacturer's name, country and town where the transformer was assembled		P
	d) Manufacturer's serial number.		P
	e) Year of manufacture		P
	f) Number of phases		P
	g) Rated power (in kVA or MVA). (For multi-winding transformers, the rated power of each winding shall be given. The loading combinations shall also be indicated unless the rated power of one of the windings is the sum of the rated powers of the other windings.)		P
	h) Rated frequency (in Hz).		P
	i) Rated voltages (in V or kV) and tapping range		P
	j) Rated currents (in A or kA).		N/A
	k) Connection and phase displacement symbol		P
	l) Short-circuit impedance, measured value in percentage. For multi-winding transformers, several impedances for different two-winding combinations are to be given with the respective reference power values. For transformers having a tapped winding, see also 6.5 and item b)		P
	m) Type of cooling. (If the transformer has several assigned cooling methods, the respective power values may be expressed as percentages of rated power, for example ONAN/ONAF 70/100 %.)		P
	n) Total mass		P
	o) Mass and type of insulating liquid with reference to the relevant IEC standard.		P
	p) Maximum system short-circuit power or current used to determine the transformer withstand capability if not infinite		P
	If the transformer has more than one set of ratings, depending upon different connections of windings which have been specifically allowed for in the design, the additional ratings shall all be given on the rating plate, or separate rating plates shall be fitted for each set		P
8.3	Additional information to be given when applicable		P
	The information listed below shall be included on the rating plate when it is applicable to a particular transformer		P
	a) For transformers having one or more windings with 'highest voltage for equipment' *U*m equal to or above 3,6 kV		P
	– short notation of insulation levels (withstand voltages) as described in IEC 60076-3		P
	b) Tapping designationsc) Guaranteed maximum temperature rises of top liquid and windings (if not normal values).		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
	d) Connection diagram (in cases where the connection symbol will not give complete information regarding the internal connections). If the connections can be changed inside the transformer, this shall be indicated either on the same plate, a separate plate or with duplicate or reversible rating plates. The connection fitted at delivery shall be indicated. Where non-linear resistors or fuses are employed within the transformer, the location and connection of such equipment shall be shown on the connection diagram plate with terminal markings. An indication of any built-in current transformers when used shall be presented on the diagram.		P
	e) Transportation mass (if different from total mass).		P
	f) Untanking mass (for transformers exceeding 5 t total mass).		P
	g) Vacuum withstand capability of the tank, conservator, tap-changers and cooling equipment		P
	h) For multi-winding transformers, any restriction on power-loading combinations		P
	i) For transformers equipped with winding temperature indicators (WTI), the settings for each WTI. This is normally the difference between the winding hot-spot temperature at rated power and the top liquid temperature calculated from temperature rise test results. If more than one cooling method is specified, different settings may be required for each cooling method		P
	j) For all current transformers installed inside the transformer, the location, ratio(s), accuracy class and rated output (VA rating) of the current transformer		P
	k) Minimum temperature of cooling medium if not –5 °C for indoor transformers or –25 °C for outdoor transformers		P
	Plates with identification and characteristics of auxiliary equipment according to standards for such components (bushings, tap-changers, current transformers, special cooling equipment) shall be provided either on the components themselves or on the transformer		P
9	Safety, environmental and other requirements		P
9.1	Safety and environmental requirements		P
9.1.1	Liquid leaks		P
9.1.2	Safety considerations		P
9.2	Dimensioning of neutral connection		P
	The neutral conductor and terminal of transformers intended to carry a load between phase and neutral (for example, distribution transformers) shall be rated for the appropriate load current and earth-fault current		P
	The neutral conductor and terminal of transformers not intended to carry load between phase and neutral shall be designed to carry earth-fault current as if the transformer was directly earthed		P

EN 60076-1			
Clause	Requirement - Test	Result - Remark	Verdict
9.3	Liquid preservation system		P
9.4	DC currents in neutral circuits		P
9.5	Centre of gravity marking		P
	The centre of gravity of the transformer in the transport configuration shall be permanently marked on at least two adjacent sides of the transformer for transformers with a transport mass in excess of 5 tonnes		P
10	Tolerances		P
	It is not always possible, particularly in large, multi-winding transformers with relatively low rated voltages, to accommodate turns ratios which correspond to specified rated voltage ratios with high accuracy. There are also other quantities which may not be accurately explored at the time of tender, or are subject to manufacturing and measuring uncertainty.		P
	Therefore tolerances are necessary on certain specified and design values		P
	A transformer is considered as complying with this part when the quantities subject to tolerances are not outside the tolerances given in Table 1. Where a tolerance in one direction is omitted, there is no restriction on the value in that direction		P
	This clause is for the purposes of acceptance or rejection only and does not replace the purchasers' prescribed guarantees for economic evaluation purposes (for example penalties on losses). It does not take precedence over any limits specified in the enquiry		P
11	Tests		P
12	Electromagnetic compatibility (EMC)		P
	Power transformers shall be considered as passive elements in respect to emission of, and immunity to, electromagnetic disturbances		P
13	High frequency switching transients		P
	Switching lightly loaded and/or low power factor (inductively loaded) transformers with vacuum and SF6 interrupters may subject the transformer to potentially damaging voltage transients with frequencies up to the MHz range and voltages exceeding the transformer impulse withstand. Mitigation measures, while not part of the transformer, might include means to increase damping through resistor-capacitor snubbers, pre-insertion resistors within the switches, or switching under load. If specified by the purchaser, the manufacturer shall provide details of natural resonant frequencies and/or high frequency model parameters of the transformer		P

EN 60076-11			
Clause	Requirement - Test	Result - Remark	Verdict
4	Service conditions	Pass muter	P
4.1	General		P
	The requirements of IEC 60076-1 apply to Dry Type Transformers only in so far as they are referred to in this standard.		P
4.2	Normal service conditions		P
4.2.1	General		P
	Unless otherwise stated, the service conditions in 4.2.2 to 4.2.6 apply. When transformers are required to operate outside the normal service conditions, de-rating in accordance with 11.2 and/or 11.3 applies		P
4.2.2	Altitude		P
	A height above sea level not exceeding 1 000 m		P
4.2.3	Temperature of cooling air		P
4.2.4	Wave-shape of supply voltage		P
	A supply voltage of which the waveshape is approximately sinusoidal		P
4.2.5	Symmetry of polyphase supply voltages		P
	For three-phase transformers, a set of three-phase supply voltages which are approximately symmetrical		P
4.2.6	Humidity		P
	The relative humidity of the surrounding air shall be less than 93 %. No drops of water shall be present on the surface of the coils		P
4.3	Electromagnetic compatibility (EMC)		P
	Transformers shall be considered as passive elements in respect to emission and immunity to electromagnetic disturbances		P
4.4	Provision for unusual service conditions		P
	The purchaser shall identify in his enquiry any service conditions not covered by the normal service conditions in 4.2. Examples of such conditions are	Pass muter	P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
4	Cooling methods		--
4.1	Identification symbols		--
	Transformers shall be identified according to the cooling method employed. For liquid-immersed transformers, this identification is expressed by a four-letter code as described below. First letter: Internal cooling medium: • O: mineral oil or synthetic insulating liquid with fire point ≤ 300 °C; • K: insulating liquid with fire point > 300 °C; • L: insulating liquid with no measurable fire point. Second letter: Circulation mechanism for internal cooling medium: • N: natural thermosiphon flow through cooling equipment and in windings; • F: forced circulation through cooling equipment, thermosiphon flow in windings; • D: forced circulation through cooling equipment, directed from the cooling equipment into at least the main windings. Third letter: External cooling medium: • A: air; • W: water. Fourth letter: Circulation mechanism for external cooling medium: • N: natural convection; • F: forced circulation (fans, pumps).		P
4.2	Transformers with alternative cooling methods		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	A transformer may be specified with alternative cooling methods. In this case, the specification and the rating plate shall then carry information about the power values at which the transformer fulfils the temperature rise limits when these alternatives apply, see IEC 60076-1 . The power value for the alternative cooling methods with the highest cooling capacity is the rated power of the transformer (or of an individual winding of a multi-winding transformer, see IEC 60076-1). The alternatives cooling methods are conventionally listed in rising order of cooling capacity. Examples: • ONAN/ONAF. The transformer has a set of fans which may be put into service as desired at high loading. The insulating liquid circulation is by thermosiphon effect only, in both cases. • ONAN/OFAF. The transformer has cooling equipment with pumps and fans but is also specified with a reduced rated power under natural cooling (for example, in case of failure or reduction of auxiliary power).		P
5	Normal cooling conditions		--
5.1	Air-cooled transformers		--
	Normal ambient temperature limits for power transformers are given in IEC 60076-1 . With regard to normal temperature rise requirements, the temperatures at the intended installation site should not exceed: + 40 °C at any time; + 30 °C monthly average, of the hottest month; + 20 °C yearly average.		P
5.2	Water-cooled transformers		--
	Normal cooling condition for water cooled transformers is a temperature of cooling water at the inlet not exceeding 25 °C at any time or a 20 ° C yearly average. If the operating water temperature is higher than this, then a lower temperature rise should be specified (see IEC 60076-1).		P
6	Temperature rise limits		--
6.1	General		--
	Temperature rise requirements are specified according to different options: • a set of requirements which refer to continuous rated power (see 6.2). • an additional set of explicitly specified requirements, that relate to a prescribed loading cycle (see 6.4).		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	It is assumed throughout this part that the service temperatures of different parts of a transformer can each be described as the sum of the external cooling medium temperature (ambient air or cooling water) and the temperature rise of the transformer part. Normal temperature rise limits apply unless other service conditions are specified. In such cases, the limits of temperature rise shall be modified as indicated in 6.3. No plus tolerance is permitted on temperature rise limits.		P
6.2	Temperature rise limits at rated power		--
	For transformers up to 2 500 kVA (833 kVA single-phase) with a tapping range not exceeding ± 5 %, the temperature rise limits shall apply to the principal tapping corresponding to the rated voltage (see IEC 60076-1). For transformer rated power larger than 2 500 kVA or if the tapping range exceeds ± 5 %, the temperature rise limits shall apply to every tapping at the appropriate tapping power, tapping voltage and tapping current.		P
	For a multi-winding transformer, when the rated power of one winding is equal to the sum of the rated powers of the other windings, the temperature rise requirements refer to rated power in all windings simultaneously. If this is not the case, one or more particular loading combinations have to be selected and specified for the temperature rise limits. In the case of a transformer with two or more separate winding sections one above the other, the winding temperature limit shall apply to the average of the measurements of the stacked sections, if they are of equal size and rating. The temperature rise limits given in Table 1 are valid for transformers with solid insulation designated as class 1 05 °C according to IEC 60085, and immersed in mineral oil or synthetic liquid with a fire point not above 300 °C (first code letter: O). The limits refer to steady state conditions under continuous rated power, and 20 °C average yearly temperature of the external cooling medium. If not otherwise agreed between manufacturer and purchaser, the temperature rise limits given in Table 1 are valid for both Kraft and upgraded paper (see also IEC 60076-7).		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	No numerical limits are specified for the temperature rise of magnetic core, bare electrical connections, electrical or magnetic shields and structural parts in the tank. However, a self-evident requirement is that they shall not reach a temperature which will cause damages to adjacent parts or undue ageing of the insulating liquid. If considered necessary, a temperature rise limit for the magnetic core surface may be agreed between manufacturer and Purchaser On windings of very low resistance with numerous bolted connections (e.g., low voltage winding of furnace transformers), the determination of the average winding temperature rise by resistance variation may be difficult and subjected to a large uncertainty. As an alternative and by agreement between manufacturer and purchaser, the winding temperature rise requirements may be limited to the hot-spot winding temperature rise which shall be determined by direct measurement in this case. Temperature rise limits for transformers having higher temperature resistant insulation systems and immersed in a less flammable liquid (code letter K or L) are subject to agreement.		P
6.3	Modified requirements for special cooling conditions		--
6.3.1	General		--
	If the service conditions at the intended installation site do not fall within the limits of normal cooling conditions given in Clause 5, then the limits of temperature rise for the transformer shall be modified in accordance with the rules indicated below.		P
6.3.2	Air-cooled transformers		--
	If the temperature of the external cooling medium at site exceeds one or more of the normal values given in 5.1 , all the temperature rise limits indicated in Table 1 shall be corrected by the same amount as the excess. The obtained values shall be rounded to the nearest whole number of degrees kelvin. Recommended ambient temperature reference values and relevant temperature rise limit corrections are given in Table 2.		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	If the installation site is more than 1 000 m above sea-level but the factory is not, then the allowable temperature rises during the test in the factory shall be reduced as follows: • for a naturally cooled transformer (....AN), the limit of top-liquid, average and hot-spot winding temperature rises shall be reduced by 1 K for every interval of 400 m by which the installation's altitude exceeds 1 000 m; • for a forced-cooled transformer (…. AF), the reduction shall be 1 K for every 250 m exceeding 1 000 m. A corresponding reverse correction may be applied in cases where altitude of the factory is above 1 000 m and the altitude of the installation site is below 1 000 m. Any altitude correction shall be rounded to the nearest whole number of degrees kelvin. When the specified temperature rise limits of a transformer have been reduced, either because of high cooling medium temperature or because of high-altitude installation, this shall be indicated on the rating plate (see IEC 60076-1).		P
6.3.3	Water-cooled transformers		--
	If the maximum and/or the yearly cooling water temperature at site exceeds the values indicated in 5.2, all the prescribed temperature rise limits shall be reduced by the same amount as the excess. The values shall be rounded to the nearest whole number of degrees. The influence of differing ambient temperature or altitude on the air cooling of the tank shall be disregarded.		P
6.4	Temperature rise during a specified load cycle		--
	By agreement between manufacturer and purchaser, temperature rise limits can be guaranteed and/or a special test regarding load cycle operation specified (see IEC 60076-7).		P
7	Temperature rise tests		--
7.1	General		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The following subclauses describe the procedures for the determination of temperature and temperature rise values during factory testing and also the methods for substituting service loading conditions by equivalent test procedures. During the temperature rise test, the transformer shall be equipped with its protective devices (for example, Buchholz relay). Any indication from these devices during the test shall be noted and the case investigated. In the case of a transformer with more than one value of rated power (for example, when two or more cooling methods are provided), a temperature rise test shall be in principle performed for each rated power, but by agreement between manufacturer and purchaser the number of tests can be reduced		P
7.2	Temperature of the cooling media		--
7.2.1	Ambient temperature		--
	For the temperature rise test, the cooling air temperature should be in the range between 1 0 °C and the maximum ambient temperature for which the transformer is designed. The interpretation of the test results shall be subject to agreement if the external cooling medium temperature during the test is outside the limits indicated. At least four sensors shall be provided and the average of their readings shall be used to determine the ambient temperature for the evaluation of the test results. NOTE For tests on large power transformers, the number of sensors should be increased up to six in order to reduce the uncertainty that can affect the average of the readings. Readings should be taken at regular intervals (e.g., every ten minutes), or automatic continuous recording may be used. Around an ONAN transformer, the ambient sensors shall be placed at a level about halfway up the cooling surfaces		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The sensors shall be distributed around the tank, about 2 m away from the perimeter of tank and cooling surfaces, and protected from direct heat radiation. For a forced-air-cooled transformer, the sensors shall be placed in the air at about 0,5 m from the intake of the coolers. In the case of separate cooling equipment placed at a distance of at least 3 m from the transformer tank, the ambient temperature shall be measured around the cooling equipment applying the same rules given above. Attention shall be paid to possible recirculation of hot air. The transformer should be placed so as to minimize obstructions to the air flow and to provide stable ambient conditions. Precautions should be taken to minimize variations of cooling-air temperature, particularly during the last part of the test period when steady state conditions are approached. Rapid variation of readings due to turbulence should be prevented by appropriate means such as heat sinks for the temperature sensors of thermal time constant similar to the transformer thermal time constant.		P
7.2.2	Water temperature		--
	For the temperature rise test, the cooling water temperature should be in the range between 5 °C and the maximum water temperature for which the transformer is designed. The interpretation of the test results shall be subject to agreement if the water temperature is outside the limits indicated above. The temperature shall be measured at the intake of the cooling equipment. Readings of temperature and rate of water flow should be taken at regular intervals (e.g., every ten minutes), or automatic continuous recording may be used. Precautions shall be taken to minimize the variations of water cooling flow and temperature during the test period.		P
7.3	Test methods for temperature rise determination		--
7.3.1	General		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The standard method for the determination of the steady-state temperature rises on the test floor is the equivalent test in short-circuit connection according to 7.3.2 below. In special cases, if agreed, the test can be performed applying rated voltage and current by connection to a suitable load. This is mainly applicable to transformers with low rated power. A back-to-back method may also be agreed. In this method, two transformers, one of which is the transformer under test, are connected in parallel and excited at the rated voltage of the transformer under test. By means of different voltage ratios or an injected voltage, rated current is made to flow in the windings of the transformer under test.		P
7.3.2	Test by short-circuit method for two winding transformers		--
	During this test the transformer is not subjected to rated voltage and rated current simultaneously, but to the calculated total losses, previously obtained by two separate determinations of losses, namely load loss at reference temperature and no-load loss (see IEC 60076-1). The purpose of the test is to establish: • the top-liquid and average liquid temperature rises in a steady-state condition with dissipation of total losses; • the average winding temperature rise at rated current for the average liquid temperature rise as determined above; • the hot-spot winding temperature rise at rated current and for the top-liquid temperature rise as mentioned above.		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	This is achieved in two testing steps: a) Total loss injection The top-liquid and average liquid temperature rises are established when the transformer is subjected to a test current corresponding to the total losses of the transformer (see IEC 60076-1). The test current will be above rated current to the extent necessary for producing an additional amount of loss equal to the no-load loss at rated voltage, and the winding temperature rise will be correspondingly elevated. The top-liquid temperature and cooling medium temperature are monitored, and the test is continued until steady-state liquid temperature rises are established. The first part of the test may be terminated when the rate of change of top-liquid temperature rise has fallen below 1 K/h and has remained there for a period of 3 h. If discrete readings have been taken at regular intervals, the mean value of the readings during the last hour is taken as the result of the test. If continuous automatic recording is applied, the average value during the last hour is taken. b) Rated current injection After the top-liquid temperature rise has been established, the test shall be continued without a break with the test current reduced to rated current for the winding combination connected. This condition is maintained for 1 h, during which time continuous temperature records of top-liquid, winding hot-spot (if measured) and external cooling medium should be taken at least every 5 min. At the end of the hour, the resistances of the windings are measured, either after a rapid disconnection of the supply and short circuits (see 7.8 and Annex C) or, without switching off the supply, by means of the superposition method which consists of injecting into the windings and measuring direct current of low value superimposed on the load current. The values of average temperature of the two windings are determined from the resistance variations, and in addition by taking into account the liquid temperature decrease when the current is reduced to the rated value, as well as the variation of the external cooling medium temperature.		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	If the direct measurement of the hot-spot winding temperature is provided, the corresponding temperature rise is obtained by taking the highest reading before disconnection and applying the correction indicated in 7.1 0.3 because the liquid temperature decreases when the current is reduced to the rated value. By agreement, the two steps of the test may be combined in one single application of power at a level between load loss and total loss. For liquid immersed transformers, the temperature rise values for top-liquid, average liquid and for the windings shall then be determined using the correction rules given in 7.1 3. The power injected during the test shall however be at least 80 % of the total loss value.		P
7.3.3	Test modification for particular transformers		--
	Two-winding transformer with a tapping range larger than ± 5 %, or having a rated power exceeding 2 500 kVA. Unless otherwise specified, the temperature rise test is conducted with the transformer connected on the maximum current tapping (see IEC 60076-1) and the tapping current for that tapping is used during the later part of the test (see 7.3.2 b)). The total losses to be injected during the first part of the test (see 7.3.2 a)), shall be equal to the highest value of total loss appearing at any tapping (corresponding to its tapping quantities). This tapping is also often, but not always, the maximum current tapping. This part of the test determines the maximum top-liquid temperature rise. For the determination of winding temperature rise at the maximum current tapping, the value of liquid temperature rise to be used in the evaluation shall correspond to the total losses of that tapping. The value from the first part of the test will be recalculated if obtained with other data. Multi-winding transformer When the rated power of one winding is equal to the sum of the rated powers of the other windings, for the first part of the test, a total loss shall be developed which corresponds to rated power (or tapping power) in all windings.		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	If this does not apply, there are specified loading cases with different combinations of individual winding loads. That case which will be associated with the highest total loss shall determine the test power for the determination of liquid temperature rise. The temperature rise value for an individual winding above liquid shall be obtained with rated current in the winding. In the determination of winding temperature rise above medium cooling medium, the liquid temperature rise for the relevant loading case will be recalculated from the total loss injection test, according to 7.1 3, and likewise the winding temperature rise above liquid for each winding, as applicable. Guidance for recalculation of losses in multi-winding transformers is given in IEC 60076-8. The injection of total loss for the determination of liquid temperature rise may be made: • either in a manner as near as possible to the actual loading case, by injecting the current corresponding to the total losses in one winding, the other ones being simultaneously short-circuited or connected to an impedance; • or in an approximate manner by not short-circuiting or closing certain windings; for example if one of the windings has a relatively low rated power and low contribution to the total loss of the transformer, it may be acceptable to leave it open and raise the current in the other windings concerned until the correct total loss is obtained. If none of the methods above can be applied in full, because of limitations of test facilities, it may be agreed to perform the test with reduced loss, down to 80 % of the correct value. Then the measured temperature value shall be corrected according to 7.1 3. The details of the temperature rise test for a multi-winding transformer should, as a rule, be presented and agreed already at the tender stage. For multi-core transformers with windings that do not have external connections, the temperature rise test method should be agreed at the tender stage. The use of additional test bushings may be appropriate		P
7.4	Determination of liquid temperatures		--
7.4.1	Top-liquid temperature		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The top-liquid temperature (θ_o) is conventionally determined by one or more sensors immersed in the insulating liquid at the top of the tank or, in pockets in the cover. The recommended number of pockets is the following: − rated power ≥ 1 00 MVA: 3 pockets; − rated power from 20 MVA to <1 00 MVA: 2 pockets; − rated power < 20 MVA: 1 pocket. The position of the sensors should be chosen to present the top-liquid temperature possibly in correspondence to the wound columns. If more than one pocket is used, the readings of the sensors shall be averaged in order to obtain a representative temperature value. By agreement between manufacturer and purchaser, the top-liquid temperature can be determined assuming as the average of the indications of the pockets placed on the cover and the temperature of the liquid of the inlet of the cooling equipment.		P
7.4.2	Bottom and average liquid temperatures		--
	Bottom liquid is the term which actually means the temperature of liquid entering the windings at the bottom. For practical reasons, it is identified with the temperature of the liquid returning from the cooling equipment to the tank. The bottom liquid temperature (θ_b) shall be determined by sensors placed at the return headers from coolers or radiators. If several batteries of cooling equipment are fitted, more than one sensor should be used and the reading average assumed as bottom liquid temperature. The average liquid temperature is in principle intended to be the average temperature of the cooling liquid in the windings. Average liquid temperature (θ_{om}) is used for the calculation of the average winding gradient and for correction of certain temperature rise test results (see 7.1 3). The average liquid temperature is: $\theta_{om} = (\theta_o + \theta_b)/2$		P
7.5	Determination of top, average and bottom liquid temperature rises		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The top-liquid temperature rise $(\Delta\theta_o)$ shall be determined by difference between the top-liquid temperature measured at the end of the test period with total losses (θ_o) and the external cooling medium temperature at the end of the test period with total losses (θ_a), that is: $\Delta\theta_o = \theta_o - \theta_a$ The average liquid temperature rise $(\Delta\theta_{om})$ shall be determined by difference between the average liquid temperature (θ_{om}) calculated according to 7.4.2 and the external cooling medium temperature (θ_a), that is: $\Delta\theta_{om} = \theta_{om} - \theta_a$ The bottom liquid temperature rise $(\Delta\theta_b)$ shall be determined by difference between the bottom liquid temperature (θ_b) defined according to 7.4.2 and the external cooling medium temperature (θ_a), that is: $\Delta\theta_b = \theta_b - \theta_a$		P
7.6	Determination of average winding temperature		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The average winding temperature is determined by measurement of winding resistance. On three-phase transformers, the measurement should be normally performed including the middle phase of the windings. For star connected, low voltage and high current windings, the measurement should be made between line terminals in order to exclude the neutral connection from the test circuit. A reference measurement (R_1, θ_1) of all winding resistances is made with the transformer at ambient temperature, in a steady-state condition (see IEC 60076-1). When the resistance (R2)is measured after disconnection of the power supply, extrapolated to the instant of shutdown, this yields the temperature value: $\theta_2 = \frac{R_2}{R_1}(235 + \theta_1) - 235$ for copper $\theta_2 = \frac{R_2}{R_1}(225 + \theta_1) - 225$ for aluminium Where θ_2 is the average temperature of the winding at the instant of shutdown. In the formula, the temperatures are expressed in Celsius degrees.		P
7.7	Determination of winding resistance at the instant of shutdown		--
	The winding resistance (R2) before shutdown shall be determined using the rules indicated below. Immediately after disconnection of the test power supply and removal of the short-circuiting connection, a direct current measuring circuit shall be connected across the winding terminals corresponding to the resistance to be measured. As the resistance of the winding varies with time as the winding cools down, it shall be measured for a sufficient time to permit extrapolation back to the instant of shutdown. As the windings have a large electrical time constant (L/R), accurate readings are therefore obtained only after a certain delay. The delay can be reduced by minimizing as much as possible the time between the shutdown and the switching on the resistance circuit, as well as reducing the electrical time constant by an adequate choice of the parameters of the circuit.		P

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	The cooling conditions should preferably not be disturbed during the time the resistance measurements are made. If pumps are operating during the temperature rise test, they should be maintained during the measurements. Recommendations for the detailed execution of the measurement are given in Annex C.		P
7.8	Determination of average winding temperature rise at the instant of shutdown		--
	The average winding temperature rise shall be determined using the value of resistance at the instant of shutdown determined as indicated in 7.6. The measured values of winding average temperature shall be raised by the same amount as the average liquid temperature has fallen from the correct value obtained as given in 7.4.2 to that at the end of the 1 h with rated current. The corrected winding average temperature rise of the winding $(\Delta\theta_w)$ is then: $\Delta\theta_w = \theta_2 + \Delta\theta_{ofm} - \theta_a$ where θ_2 is the average winding temperature at the instant of shutdown, θ_a is the external cooling medium temperature at the end of the test period with total losses, $\Delta\theta_{ofm}$ the fall of the temperature of the average liquid during the 1 h test at rated current. Recommendations for the detailed execution of the measurement are given in Annex C.		P
7.9	Determination of the average winding to liquid temperature gradient		--
	The average winding to average liquid temperature gradient (g) shall be determined as the difference between the uncorrected average winding temperature (θ_2) and the average liquid temperature θ_{om} at shutdown: $g = \theta_2 - \theta_{om}$		P
7.10	Determination of the hot-spot winding temperature rise		--
7.10.1	General		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	For transformers having rated power 20/3 MVA/phase and above, the determination of the hot-spot winding temperature rise shall be always determined through calculation based on the result of a temperature rise test, applying a method agreed between manufacturer and purchaser. As a special test and by agreement between manufacturer and purchaser, the hot-spot winding temperature rises can be determined by direct measurement. For transformers having the rated power per phase lower than 20/3 MVA/phase, neither direct measurements nor calculations are required, as the average winding temperature rise requirement is considered sufficient to also meet the hot-spot winding temperature rise requirement. For a strategic asset or specific operating conditions (e.g., nuclear power plant) for which more severe requirements are to be applied, the hot-spot winding temperature rise can be determined both by calculation and direct measurement and the obtained results compared. For auto-connected transformers, the indicated limit refers to the rated power of the equivalent double wound transformer.		P
7.10.2	Determination by calculation		--
	The manufacturer shall submit to the purchaser the results of a study concerning the location of the hot-spots and the estimation of their temperature rise. The study should be based on: • the results of the temperature rise test during which the measurement of the hot-spot winding temperatures were not directly measured; • the knowledge of the leakage flux field to determine the additional loss distribution; • the knowledge of the insulating liquid circulation patterns inside the windings in the regions in which the additional loss is higher. For transformers having rated power between 20/3 MVA and 1 00/3 MVA per phase and short-circuit impedance not exceeding 1 4 %, simplified methods for calculating the hot-spot winding temperature rise can be agreed between manufacturer and purchaser (see also Annex B)		P
7.10.3	Direct measurement during the temperature rise test		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	A number of thermal sensors (e.g., optical fibre sensors) shall be mounted inside the windings in positions where it is supposed the hot-spots are located. When more than one sensor is used on the same winding, the maximum reading shall be taken as the hot-spot winding temperature. The hot-spot winding temperature rise $(\Delta\theta_h)$ is then obtained by: $\Delta\theta_h = \theta_h + \Delta\theta_{of} - \theta_a$ where θ_h is the temperature reading at shutdown, $\Delta\theta_{of}$ the fall of the top-liquid temperature during the 1 h test at rated current, and θ_a the ambient temperature at the end of the total loss test period.		P
7.11	Uncertainties affecting the results of the temperature rise test		--
	The results of the temperature rise test are affected by uncertainties related to the test method and instrumentation used. In the test report, estimates should be given of the uncertainties that affect the temperature rises General criteria for evaluating the uncertainties are given in the IEC Guide 1 1 5 and in the bibliography. As a general recommendation, the extended uncertainties should be related to a confidence level of 95 %.[8] 1		P
7.12	Dissolved gas-in-oil analysis		--
	For large mineral oil-immersed power transformers, in which additional flux effects are potential risk factors, a chromatographic analysis of dissolved gas-in-oil may allow the detection of possible local overheating. If agreed between manufacturer and purchaser, the analysis should be performed as a special test before and after the temperature rise test. Details of the test method and acceptance criteria for evaluating the DGA results are given in Annex D.		P
7.13	Corrections		--

EN 60076-2			
Clause	Requirement - Test	Result - Remark	Verdict
	If the specified values of injected power or current have not been obtained during the temperature rise test, the results shall be corrected according to the following relations valid within a range of ± 20 % of the target value of power and ± 1 0 % of the target value of current. By agreement, corrections may be applied over a wider range, but not lower than of –30 % of the target value of power and –1 5 % of the target value of current. The liquid temperature rises over the external cooling medium temperature at the end of the total loss injection shall be multiplied by: $\left(\frac{\text{Total losses}}{\text{Test losses}}\right)^{x}$ The average winding temperature rise over average liquid temperature at shutdown shall be multiplied by: $\left(\frac{\text{Rated current}}{\text{Test current}}\right)^{y}$ The hot-spot winding temperature rise over top-liquid temperature at the shutdown shall be multiplied by: $\left(\frac{\text{Rated current}}{\text{Test current}}\right)^{z}$ The exponents to be applied are given in Table 3 in accordance with the transformer type and cooling system. The corrections made using the exponent values given in Table 3 are conservative and intended only for reporting the temperature rise during a test in steady state conditions performed within the limits indicated above.		P

EN 60076-11			
Clause	Requirement - Test	Result - Remark	Verdict
	– high or low ambient temperature outside the limits prescribed in 4.2.3; – restricted ventilation; – altitude in excess of the limit prescribed in 4.2.2; – damaging fumes and vapours; – steam; – humidity in excess of the limit prescribed in 4.2.6; – dripping water; – salt spray – excessive and abrasive dust; – high harmonic content of the load current; – distortion of the supply voltage waveform; – fast transient overvoltages over the limits prescribed in 12.1 and Clause 21; – associated power factor correction and method of capacitor switching to limit inrush current; – superimposed DC current; – seismic qualification which would otherwise require special considerations in the design; – extreme mechanical shock and vibrations; – transport and storage conditions not covered by the normal condition described in 4.5.		P
	Transformer specification for operation under such abnormal conditions shall be subject to agreement between the supplier and purchaser		P
	Supplementary requirements, within defined limits, for the rating and testing of transformers designed for other than normal service conditions listed in 4.2, such as high temperature of cooling air or altitude above 1 000 m are given in 11.2 and 11.3.		P
4.5	Transport and storage conditions		P
	All transformers shall be suitable for transportation and storage at ambient temperatures down to –25 °C.		P
	The supplier shall be informed of anticipated high levels of shock, vibration and inclination during transportation to site		P
5	Tappings		P
6	Connections		P
	Unless otherwise specified by the purchaser, transformer connections shall be Dyn with clock hour figure 5 or 11 in accordance with Clause 6 of IEC 60076-1. The neutral connection shall be capable of carrying full phase rated current		P
7	Ability to withstand short circuit		P
	Transformers shall fulfil the requirements in IEC 60076-5. If the purchaser requires a test to demonstrate this fulfilment, this shall be stated in the contract		P
8	Rating		P
8.1	General		P

EN 60076-11			
Clause	Requirement - Test	Result - Remark	Verdict
	The manufacturer shall assign ratings to the transformer, which shall be marked on the rating plate, see Clause 9. These ratings shall be such that the transformer can deliver its rated current under steady loading conditions without exceeding the limits of temperature rise specified in Clause 11, assuming that the applied primary voltage is equal to the rated voltage and that the supply is at rated frequency.		P
8.2	Rated power		P
	The transformer shall have an assigned rated power for each winding which shall be marked on the rating plate. The transformer shall be fully rated when supplied in an enclosure. The rated power refers to continuous loading. This is a reference value for guarantees and tests concerning load losses, temperature rises and short-circuit impedance		P
	The rated power corresponds to continuous duty; nevertheless, Dry Type Transformers complying with this standard can be overloaded and guidance on overloads is given in IEC 60905		P
8.3	Preferred values of rated power		P
	The preferred values shall be in accordance with 4.3 of IEC 60076-1 starting from 50 kVA		P
8.4	Operation at higher than rated voltage		P
	Within the prescribed value of *U*m, a transformer shall be capable of service without damage under conditions of overfluxing where the ratio of voltage over frequency exceeds the corresponding ratio at rated voltage and rated frequency by no more than 5 %		P
8.5	Operation with fan cooling		P
	When additional cooling by means of fans is provided, the nominal power rating with and without fans shall be subject to agreement between purchaser and supplier		P
	The rating plate shall indicate both the power rating without fans and the maximum power rating with fan cooling		P
8.6	Operation in an enclosure		P
	For operation in an enclosure that is not provided or later provided by the manufacturer of the transformer, see Annex D of IEC 61330 and IEC 60905		P
9	Rating plate		P
9.1	Rating plate fitted to the transformer		P
9.2	Rating plate fitted to the transformer enclosure		P

EN 60076-11			
Clause	Requirement - Test	Result - Remark	Verdict
	Each transformer enclosure shall be provided with a rating plate of weatherproof material, fitted in a visible position, showing the items indicated in 9.1. The entries on the plate shall be indelibly marked (that is, by etching, engraving, stamping or by a photo-chemical process).		P
10	Identification according to cooling method		P
10.1	Identification symbols		P
	Transformers shall be identified according to the cooling method employed		P
10.2	Arrangement of symbols		P
	Transformers shall be identified by two symbols for each cooling method for which a rating is assigned by the manufacturer, typically as follows: – A transformer designed for natural air ventilation is designated AN. – A transformer designed for natural air ventilation up to specified rating and with forced cooling to a higher rating is designated AN/AF		P
11	Temperature-rise limits		P
12	Insulation levels		P
13	Climatic, environmental and fire behaviour classes		P
14	General requirements for tests		P
	New transformers shall be subjected to tests as specified in Clauses 15 to 23. Transformers which have been in service may be tested in accordance with this specification but dielectric test levels should be reduced to 80 %, however, the guarantee levels of the transformer when new do not apply		P
	Tests shall be made by the manufacturer or at an approved laboratory, unless otherwise agreed between the supplier and the purchaser at the tender stage.		P
	Dielectric tests in accordance with Clauses 19, 20 and 21 shall be made with the transformer at approximately the temperature of the test house		P
	Tests shall be performed on a completely assembled transformer including relevant accessories supplied		P
	Tapped windings shall be connected on their principal tapping unless the supplier and the purchaser agree otherwise		P
	The test basis for all characteristics other than insulation is the rated condition, unless the test Clause states otherwise		P
15	Measurement of winding resistance (routine test)		P
16	Measurement of voltage ratio and check of phase displacement (routine test)		P
17	Measurement of short-circuit impedance and load loss (routine test)		P
18	Measurement of no-load loss and current (routine test)		P

EN 60076-11			
Clause	Requirement - Test	Result - Remark	Verdict
19	Separate-source AC withstand voltage test (routine test)		P
20	Induced AC withstand voltage test (routine test)		P
	The test described in 12.2.1 of IEC 60076-3 applies		P
	The test voltage shall be twice the rated voltage.		P
21	Lightning impulse test (type test)		P
	The test described in Clause 13 of IEC 60076-3 applies		P
	The test voltage shall be in accordance with Table 3 or Table 4 for the specified insulation level of the transformer		P
	The test impulse wave shape shall be 1,2 µs ± 30 %/50 µs ± 20 %		P
	The test voltage shall be of negative polarity. The test sequence per line terminal shall be one calibration impulse at a voltage between 50 % and 75 % of the full voltage followed by three impulses at full voltage		P
22	Partial discharge measurement (routine and special test)		P
23	Temperature-rise test (type test)		P
24	Measurement of sound level (special test)		N/A
25	Short-circuit test (special test)		N/A
26	Environmental test (special test)		N/A
27	Climatic test (special test)		N/A
28	Fire behaviour test (special test)		N/A
29	Tolerances		P
30	Protection against direct contact		P
	Transformers in which constructive features do not provide for protection against direct contact, shall be supplied with a visible element (warning plate or special mark) indicating the danger, according to national rules.		P
31	Degrees of protection provided by enclosures		P
	The design of an enclosure will be dependent upon the location and environmental conditions in which the transformer is installed. The enclosure shall be specified by reference to IEC 60529.		P
32	Earthing terminal		P
	Transformers shall be fitted with an earth terminal for the connection of a protective conductor. All exposed metallic conductive non-live parts shall be connected to the earth terminal by construction or otherwise.		
33	Information required with enquiry and order		

PHOTO DOCUMENTATION:

Type of equipment: Model:	Power Transformer 35kV Power Transformer 500kVA~6300kVA, 10kV Distribution Transformer 30kVA~2500kVA S22-M, S20-M, S11-M, S13-M, S14-M S13-35KV, SZ13-35KV, S11-35KV, D14-M(R)-(10~160)/10KV, D13-M(R)-(10~160)/10KV, D11-M(R)-(10~160)/10KV SCB18-30~2500/10kV, SCB14-30~2500/10kV, SCB13-30~2500/10kV, SCB12-30~2500/10kV, SCB10-30~2500/10kV, SCB12-30~2500/35kV

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