BS EN 50541-1:2011

BSI Standards Publication

Three phase dry-type distribution transformers 50 Hz, from 100 kVA to 3 150 kVA, with highest voltage for equipment not exceeding 36 kV -

Part 1: General requirements

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National foreword

This British Standard is the UK implementation of EN 50541-1:2011. It supersedes BS 7844-1:1996 and BS 7844-2:1996 which are withdrawn

The UK participation in its preparation was entrusted to Technical Committee PEL/14, Power transformers.

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

This publication does not purport to include all the necessary provisions of a contract. Users are responsible for its correct application.

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Three phase dry-type distribution transformers 50 Hz, from 100 kVA to 3 150 kVA, with highest voltage for equipment not exceeding 36 kV - Part 1: General requirements

Transformateurs triphasés de distribution de type sec, 50 Hz, de 100 kVA à 3 150 kVA, avec une tension la plus élevée pour le matériel ne dépassant pas 36 kV - Partie 1: Prescriptions générales

Drehstrom-Trocken-Verteilungstransformatoren, 50 Hz, 100 kVA bis 3 150 kVA, mit einer höchsten Spannung für Betriebsmittel kleiner oder gleich 36 kV - Teil 1: Allgemeine Anforderungen

CENELEC

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

Management Centre: Avenue Marnix 17, B - 1000 Brussels

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Foreword

This European Standard was prepared by the Technical Committee CENELEC TC 14, Power transformers.

The text of the draft was submitted to the Unique Acceptance Procedure and was approved by CENELEC as EN 50541-1 on 2011-01-02.

This document supersedes HD 538.1 S1:1992 + A1:1995 and HD 538.2 S1:1995.

The following dates were fixed:

- latest date by which the EN has to be implemented at national level by publication of an identical national standard or by endorsement (dop) 2012-01-02
- latest date by which the national standards conflicting with the EN have to be withdrawn (dow) 2014-01-02

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1 Scope

This European Standard covers dry type transformers from 100 kVA to 3 150 kVA intended for operation in three phases distribution networks, for indoor continuous service, 50 Hz, natural cooling, with two windings:

- a primary (high voltage) winding with a highest voltage for equipment of 3,6 kV to 36 kV;
- a secondary (low voltage) winding with a highest voltage for equipment not exceeding 1,1 kV.

For outdoor application, special design or enclosure (enclosure with adapted IP and IK degrees protections) should be requested.

NOTE 1 This European Standard may be applied, as a whole or in part to transformers having windings with more than one rated voltage. In this case the rated power for each coupling ratio should be specified by the purchaser.

NOTE 2 For dry type transformers installed in power generating plants, additional requirements, not covered by this European Standard, and alternative requirements may be specified.

NOTE 3 For dry type transformers dedicated to wind turbines applications additive requirements are specified in EN 60076-16.

The object of this European Standard is to lay down requirements related to electrical characteristics, dimensions and designs of three phases distribution dry type transformers. These transformers should be in accordance with EN 60076-11 for general requirements.

2 Normative references

The following referenced documents are indispensable for the application of this document. For dated references, only the edition cited applies. For undated references, the latest edition of the referenced document (including any amendments) applies.

EN 60076-1	Power transformers - Part 1: General (IEC 60076-1)
EN 60076-3	Power transformers - Part 3: Insulation levels, dielectric tests and external clearances in air (IEC 60076-3)
EN 60076-10	Power transformers - Part 10: Determination of sound levels
EN 60076-11:2004	Power transformers - Part 11: Dry-type transformers (IEC 60076-11:2004)
EN 60076-16:201X [1)]	Power transformers - Part 16: Transformers for wind turbines application (IEC 60076-16)
EN 60529	Degrees of protection provided by enclosures (IP Code) (IEC 60529)
EN 62262	Degrees of protection provided by enclosures for electrical equipment against external mechanical impacts (IK code) (IEC 62262)
EN 62271-202:2007	High-voltage switchgear and controlgear - Part 202: High voltage/low voltage prefabricated substation (IEC 62271-202:2006)

1) At draft stage.

3 Electrical characteristics

3.1 Rated power

The values of the rated power are:

100–160–200–250–315–400–500–630–800–1 000–1 250–1 600–2 000–2 500–3 150 kVA

The underlined values are preferred.

3.2 Highest voltages for equipment of windings

Insulation levels and dielectric tests shall be in accordance with the requirements of EN 60076-3 and EN 60076-11.

The values of the highest voltage for equipment are:

- for the high voltage winding:

  3,6 – 7,2 – 12 – 17,5 – 24 – 36 kV;

- for the low voltage winding:

  1,1 kV.

3.3 Rated voltages of windings

3.3.1 For the high-voltage winding

The rated value of the high voltage winding is above 1,1 kV up to and including 36 kV.

3.3.2 For the low voltage winding

The rated voltage shall be chosen among the following preferred values:

400 – 410 – 415 – 420 – 433 V

NOTE This European Standard may be applied either as a whole or in part, to transformers with rated voltage below 400 V and above 433 V.

3.4 Tapping

The high voltage windings can be provided with tapping.

The preferred tapping range is either ± 2,5 % or ± (2 × 2,5) % unless otherwise specified, but in any case maximum taps shall not exceed seven positions and the total maximum range shall not exceed 10 %.

The tapping range has to be specified by the purchaser or by agreement between manufacturer and purchaser.

Tapping selection shall be made off-circuit by the use of bolted links or off-circuit tap changer.

3.5 Connections

Vector group: connection shall be Dyn.

Clock hour figure shall be 5 or 11.

Connection and clock hour figure shall be specified by the purchaser at the enquiry stage in accordance with EN 60076-1.

NOTE This European Standard may be applied, either as a whole or in part, for transformers having connections other than those mentioned above.

3.6 Dimensioning of neutral connection of the low voltage winding

The neutral conductor and terminal of the low voltage winding shall be dimensioned for rated current and earth fault current, unless otherwise specified.

3.7 Short-circuit impedance

The preferred values of the short-circuit impedance at reference temperature are according to Table 2 to Table 6.

The reference temperature for the short-circuit impedance and load-loss shall be the permitted average winding rise as given in column 2 of Table 2 plus 20 °C.

NOTE Other values of short-circuit impedance may be specified by the purchaser for particular system service conditions, e.g. in the case of parallel options

3.8 Load loss, no load loss, sound power level and short-circuit impedance

3.8.1 General purpose

For transformers having preferred values of rated power in accordance with 3.1 the values of load loss (P_K), no load loss (P_O), short-circuit impedance and sound power level (L_{WA}) are stated in Table 2 to Table 6.

3.8.2 Load loss aspect

The reference temperature for the short-circuit impedance and load-loss shall be the permitted average winding rise as given in column 2 of Table 2 plus 20 °C.

Table 1 − Example of performance according to the standard reference temperature

Insulation System Temperature (IST)	**155 °C** Standard reference	**105 °C** Banned reference
Reference temperature	120 °C	75 °C
LV Ri² loss	4 600 W	4 000 W [a]
LV Eddy loss	140 W	160 W [a]
LV Stray loss	340 W	390 W
Total LV loss	5 080 W	4 550 W
HV RI² loss	5 300 W	4 600 W [a]
HV Eddy loss	660 W	760 W [a]
HV Stray loss	40 W	46 W
Total HV loss	6 000 W	5 406 W
Total calculated load loss LV+HV	**11 080 W**	**9 956 W**

[a] If reference temperature 75 °C is used for the calculation of 155 °C insulation system temperature instead of load loss reference temperature of 120°C then the errors on the results of measurement and therefore the guaranties are ~ 11 %.

For copper and aluminium conductors the method to correct the I²R loss from 75 °C to 120 °C according to the reference temperature is:

- K= (120+235)/(75+235)=1,145 for copper;
- K= (120+225)/(75+225)=1,15 for aluminium.

For EDDY Loss and Stray Loss the method to correct the loss from 75 °C to 120 °C according to the reference temperature is: K'=1/K.

Above Table 1 show if the banned temperature reference is used the announced guaranty of load loss is reduced by 11 % for the chosen example compared to the real load loss produced in service by the transformer at full load.

When a transformer has windings of different insulation system temperatures, the reference temperature relating to the winding having the higher insulation system temperature shall be used, see EN 60076-11:2004, Clause 17.

NOTE 1 LV winding designed with 130 °C insulation system temperature and HV winding designed with 155 °C insulation system temperature, in this case the reference temperature for the load loss will be 120 °C (insulation system temperature 155 °C) see EN 60076-11:2004, Clause 17.

NOTE 2 The guaranteed load loss at reference temperature as indicated in EN 60076-11:2004, Clause 17 for different insulation system temperature used in LV and HV windings gives a value in excess.

3.8.3 Sound power level

The sound pressure measurement (L_{PA}) under rated frequency and rated voltage and no load condition is base for sound power level (L_{WA}) calculation (see EN 60076-10). The calculated value (sound power level) is the maximum admitted value, no tolerance is allowed.

3.9 Tables of load loss, no load loss, sound level power and short-circuit impedance

3.9.1 Rated voltage ≤ 12 kV short-circuit impedance 4 %

Table 2 − Load loss, no load loss and sound power level

U_M	S_R	P_K	P_K	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}
		A_k	B_k	A_o		B_o		C_o	
kV	kVA	W	W	W	dB (A)	W	dB (A)	W	dB (A)
12	100	1 800	2 000	260	51	330	51	440	59
	160	2 500	2 700	350	54	450	54	610	62
	250	3 200	3 500	500	57	610	57	820	65
	400	4 500	4 900	700	60	880	60	1 150	68
	630	6 700	7 300	1 000	62	1 150	62	1 500	70

NOTE This European Standard applies also to transformers having Insulation System Temperature (IST) with temperature rise higher than IST of 180 °C. According to EN 60076-11:2004, Table 2; in this case the load loss will be calculated with proper temperature correction factors for rated temperature rises, for load loss guaranty and impedance voltage temperature reference (see 3.8).

3.9.2 Rated voltage ≤ 12 kV short-circuit impedance 6 %

Table 3 − Load loss, no load loss and sound power level

U_M	S_R	P_K	P_K	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}
		A_k	B_k	A_o		B_o		C_o	
kV	kVA	W	W	W	dB (A)	W	dB (A)	W	dB (A)
	100	1 800	2 000	260	51	330	51	440	59
	160	2 600	2 700	350	54	450	54	610	62
	250	3 400	3 500	500	57	610	57	820	65
	400	4 500	4 900	700	60	880	60	1 150	68
12	630	7 100	7 300	1 000	62	1 150	62	1 500	70
	800	8 000	9 000	1 100	64	1 300	65	1 800	71
	1 000	9 000	10 000	1 300	65	1 500	67	2 100	73
	1 250	11 000	12 000	1 500	67	1 800	69	2 500	75
	1 600	13 000	14 500	1 800	68	2 200	71	2 800	76
	2 000	15 500	18 000	2 200	70	2 600	73	3 600	78
	2 500	18 500	21 000	2 600	71	3 200	75	4 300	81
	3 150	22 000	26 000	3 150	74	3 800	77	5 300	83

NOTE 1 This European Standard applies also to transformers having Insulation System Temperature (IST) with temperature rise higher than IST of 180 °C; According to EN 60076-11:2004, Table 2; in this case the load loss will be calculated with proper temperature correction factors for rated temperature rises, for load loss guaranty and impedance voltage temperature reference (see 3.8).

3.9.3 Rated voltage 17,5 and 24 kV impedance voltage 4 %

Table 4 − Load loss, no load loss and sound power level

U_M	S_R	P_K	P_K	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}
		A_k	B_k	A_o		B_o		C_o		D_o	
kV	kVA	W	W	W	dB (A)	W	dB (A)	W	dB (A)	W	dB (A)
	100	1 350	1 750	330	51	360	51	400	59	600	59
	160	1 800	2 500	450	54	490	54	580	62	870	62
	250	2 700	3 450	640	57	660	57	800	65	1 100	65
	400	3 800	4 900	850	60	970	60	1 100	68	1 450	68
	630	5 300	6 900	1 250	62	1 270	62	1 600	70	2 000	70

NOTE This European Standard applies also to transformers having Insulation System Temperature (IST) with temperature rise higher than IST of 180 °C; according to EN 60076-11:2004, Table 2; in this case the load loss will be calculated with proper temperature correction factors for rated temperature rises, for load loss guaranty and impedance voltage temperature reference (see 3.8).

3.9.4 Rated voltage 17,5 kV and 24 kV impedance voltage 6 %

Table 5 − Load loss, no load loss and sound power level

U_M	S_R	P_K	P_K	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}
		A_k	B_k	A_o		B_o		C_o	
kV	kVA	W	W	W	dB (A)	W	dB (A)	W	dB (A)
17,5 and 24	100	1 800	2 050	280	51	340	51	460	59
	160	2 600	2 900	400	54	480	54	650	62
	250	3 400	3 800	520	57	650	57	880	65
	400	4 500	5 500	750	60	940	60	1 200	68
	630	7 100	7 600	1 100	62	1 250	62	1 650	70
	800	8 000	9 400	1 300	64	1 500	64	2 000	72
	1 000	9 000	11 000	1 550	65	1 800	65	2 300	73
	1 250	11 000	13 000	1 800	67	2 100	67	2 800	75
	1 600	13 000	16 000	2 200	68	2 400	68	3 100	76
	2 000	16 000	18 000	2 600	70	3 000	70	4 000	78
	2 500	19 000	23 000	3 100	71	3 600	71	5 000	81
	3 150	22 000	28 000	3 800	74	4 300	74	6 000	83

NOTE This European Standard applies also to transformers having Insulation System Temperature (IST) with temperature rise higher than IST of 180 °C; according to EN 60076-11:2004, Table 2; in this case the load loss will be calculated with proper temperature correction factors for rated temperature rises, for load loss guaranty and impedance voltage temperature reference (see 3.8).

3.9.5 Rated voltage 36 kV impedance voltage 6 %

Table 6 − Load loss, no load loss and sound power level

U_M	S_R	P_K	P_K	P_K	P_O	L_{WA}	P_O	L_{WA}	P_O	L_{WA}
		A_k	B_k	C_k	A_o		B_o		C_o	
kV	kVA	W	W	W	W	dB (A)	W	dB (A)	W	dB (A)
36	160	2 500	2 700	2 900	850	57	900	62	960	66
	250	3 500	3 800	4 000	1 000	59	1 100	64	1 280	67
	400	5 000	5 400	5 700	1 200	61	1 300	65	1 650	69
	630	7 000	7 500	8 000	1 400	63	1 600	68	2 200	71
	800	8 400	9 000	9 600	1 650	64	1 900	69	2 700	72
	1 000	10 000	11 000	11 500	1 900	65	2 250	70	3 100	73
	1 250	12 000	13 000	14 000	2 200	67	2 600	72	3 600	75
	1 600	14 000	16 000	17 000	2 550	68	3 000	73	4 200	76
	2 000	17 000	18 500	21 000	3 000	72	3 500	74	5 000	78
	2 500	20 000	22 500	25 000	3 500	73	4 200	78	5 800	81
	3 150	25 000	27 500	30 000	4 100	76	5 000	81	6 700	83

NOTE This European Standard applies also to transformers having Insulation System Temperature (IST) with temperature rise higher than IST of 180 °C; according to EN 60076-11:2004, Table 2; in this case the load loss will be calculated with proper temperature correction factors for rated temperature rises, for load loss guaranty and impedance voltage temperature reference (see 3.8).

3.10 Tolerances and penalties

Within the limits of tolerances (EN 60076-1) the application of penalties/bonus with regard to loss is left to the agreement between manufacturer and purchaser at the time of enquiry and order.

4 Tests

4.1 Routine tests

EN 60076-11 applies including partial discharge test.

4.2 Type tests

EN 60076-11 applies.

4.3 Special tests

EN 60076-11 applies.

4.4 Insulation levels and dielectric tests

EN 60076-11 applies

5 Design requirements

5.1 Normal or/and abnormal service conditions

The normal or/and abnormal service conditions are those described in EN 60076-11:2004, 4.2/4.4 and have to be confirmed at the enquiry stage.

For wind turbines transformers service conditions are described in EN 60076-16.

5.2 Climatic, environmental and fire behaviour classes

Dry type transformers are normally installed indoor. Outdoor installation is possible with weather protection by enclosures or special design.

Climatic, environmental and fire behaviour classes for design of dry type transformers are listed in EN 60076-11:2004, Clause 13 and in EN 60076-16, 7.5.2.

5.2.1 Climatic classes

Class C1: The transformer is suitable for operation at ambient temperature not below - 5 °C but may be exposed during transport and storage to ambient temperatures down to - 25 °C.

Class C2: The transformer is suitable for operation, transport and storage at ambient temperatures down to - 25 °C.

Special tests according to EN 60076-11:2004, Clause 27 shall confirm the conformity of C1 and C2 class transformers.

5.2.2 Environmental classes

Environmental conditions for dry-type transformers are identified in terms of humidity, condensation, pollution and ambient temperature.

NOTE These environmental classes are important not only during service but also during storage before installation.

Class E0: No condensation occurs on the transformers and pollution is negligible. This is commonly achieved in a clean, dry indoor installation.

Class E1: Occasional condensation can occur on the transformer (for example, when the transformer is de-energised). Limited pollution is possible.

Class E2: Frequent condensation or heavy pollution or combination of both.

Special tests according to the procedure of EN 60076-11:2004, Clause 26 shall confirm the conformity of E1 or E2 class transformers.

Class E3: Is defined in EN 60076-16, 7.5.2 for wind turbine transformers or very frequent condensation or very heavy pollution or combination of both.

The manufacturer shall declare the climatic, environmental, and fire behaviour class in the tender and shall mark them on the rating plate.

5.2.3 Fire behaviour classes

Class F0: Unspecified fire performance. Except for the characteristics inherent in the design of the transformer, no special measures are taken to limit flammability. Nevertheless, the emission of toxic substances and opaque smoke shall be minimized.

Class F1: Transformers subject to a fire hazard. Restricted flammability is required. The emission of toxic substances and opaque smokes shall be minimised.

Special tests according to the procedure of EN 60076-11:2004, Clause 28 shall confirm the conformity of class F1 transformers.

6 Terminals

HV and LV terminals could be located on the upper side or lower side.

For easy understanding HV connecting leads side are fixed and used as reference side.

LV terminals could be on the same or on the opposite side referred to the HV leads.

Tapping could be on the same side or on the opposite side referred to the HV leads; preferred side is on the same HV side.

At the enquiry stage the exact positions of HV leads/terminals, LV leads/terminals and tapping shall be stated.

If in respect of leads with special dimensions and/or precise-exact dimensions and locations are needed, this needed information has to be given at the enquiry stage and agreed between manufacturer and purchaser.

7 Enclosure

When the transformer is to be delivered with an enclosure, this shall be specified in the enquiry and the tender with details about the requirements of protection degrees of enclosure according to the relevant standards (EN 60529, code IP and EN 62262, code IK).

The rated power of transformer and transformer with enclosure delivery shall be indicated on the enclosure and fitted in a visible position (see EN 62271-202:2007, Annex D).

The thermal class according to EN 62271-202 of the enclosure shall be indicated on the rating plate fixed on the enclosure.

If the enclosure is provided by other or later, the transformer manufacturer shall be consulted in respect of reduction of rated power of the transformer installed in the enclosure.

8 Overall dimensional indications and accessories

This drawing gives the ways in which dimensions of transformer should be given at the enquiry stage.

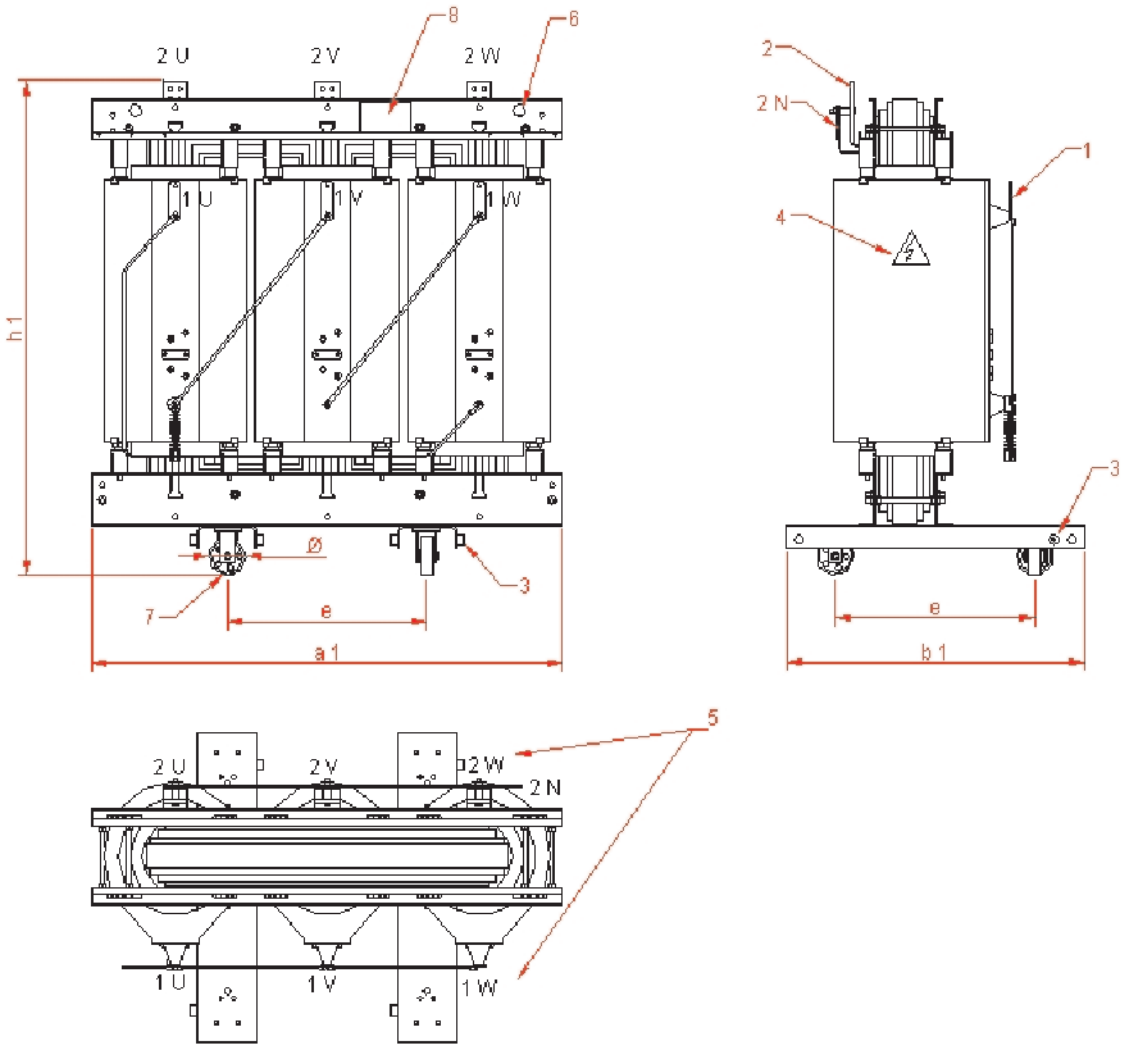

Figure 1 – Transformer dimensions

Transformers shall normally be fitted with the accessories listed in Table 7.

Table 7 − List of accessories

Position number in Figure 1	Designation
1	Terminal HV
2	Terminal LV
3	Earthing terminals
4	Warning plate
5	Terminal markings [a]
6	Lifting devices
7	Rollers
8	Rating plate

[a] Terminal markings should preferably be in accordance with IEC/TR 60616, unless otherwise covered in national standards.

9 Efficiency and drop voltage at reference temperature

9.1 Efficiency

The efficiency of a power transformer is given for any load conditions by the ratio between the output power (P_2) and the input power (P_1).

$$\eta = 100 \times \frac{P_2}{P_1} \quad (\%)$$

Because of the difficulty to determine the efficiency by direct measurements, it can be evaluated conventionally through the guaranteed or measured loss as follows:

$$\eta = 100 \times \left(1 - \frac{\alpha^2 \times P_{cc} + P_0}{\alpha \times S + \alpha^2 \times P_{cc} + P_0} \right) \quad (\%)$$

where

P_{cc} is the load loss at rated current, rated frequency, and reference temperature;

P_o is the no load loss at rated voltage and frequency;

S is the rated power;

α is the load factor (p.u.).

9.2 Voltage drop (Δu%)

The voltage drop for any load condition (Secondary current and power factor) is given by the following relation:

$$\Delta u\% = (I_2 / I_{2n}) \times (R\% \times \cos\varphi_2 + X\% \times \sin\varphi_2) + (1/200) \times \{(I_2 / I_{2n}) \times (X\% \times \cos\varphi_2 - R\% \times \sin\varphi_2)\}^2$$

where

R% is the active component of short-circuit impedance in % of the transformer rated impedances*;*

X% is the reactive component of short-circuit impedance in % of the transformer rated impedances;

I_2 is the load secondary current (A);

I_{2n} is the secondary rated current (A);

(I_2 / I_{2n}) is the load factor;

φ_2 is the phase angle between secondary voltage and current.

Annex A
(informative)

Capitalisation evaluation

A transformer produces loss due to the magnetisation of the core (no load loss P_0) and due to the current carrying windings (load loss P_k).

No load loss are generated whenever the transformer is energised and usually are considered for 8 760 h per year. They are independent of the load while load loss relate to the square of the current ($P_k \equiv I^2$).

The load loss shall be referred with its insulation system temperature as indicated in 3.8.2.

The sum of both losses represent a loss of energy translated into heat which has to be dissipated by the cooling system of the transformer.

Since energy has a certain cost, it is important to be aware of the financial value of the loss generated during the lifetime of the transformer in addition to the initial purchase cost.

The loading profile, the transformer loss and the energy cost should be taken into account in order to select the optimal no load loss and load loss, therefore different lists of no load loss and load loss are presented in this standard.

However, this evaluation may change over time and can be different in each country or for each user, depending on local investment or energy policies.

Therefore, transformers can be requested or offered with no load loss and/or load loss different from those tabled in this standard to satisfy particular requirements.

Therefore capitalisation evaluation should be done for each transformer in enquiry stage.

The sum of purchase cost and energy cost (load loss and no load loss) is called capitalised cost and represents an important part of the investment for the purchaser.

This analysis may be done by using a capitalisation formula as follows:

$$C_C = C_T + A \times P_0 + B \times P_K$$

where

- C_C is the capitalised cost;
- C_T is the purchase cost of transformer;
- A is the value indicated by the purchaser in the enquiry expressed in local currency per watt (e.g. €/W) corresponding to no load loss;
- P_0 is the guaranteed no load loss in watts;
- B is the value indicated by the purchaser in the enquiry expressed in local currency per watt (e.g. €/W) corresponding to load loss;
- P_k is the guaranteed load loss in watts.

If another capitalisation evaluation method is made by the purchaser, this method has to be declared at the enquiry stage.

Bibliography

EN 50180 Bushings above 1 kV up to 52 kV and from 250 A to 3,15 kA for liquid filled transformers

EN 50181 Plug-in type bushings above 1 kV up to 52 kV and from 250 A to 2,50 kA for equipment other than liquid filled transformers

EN 50216 series Power transformer and reactor fittings

EN 50386 Bushings up to 1 kV and from 250 A to 5 kA, for liquid filled transformers

EN 50387 Busbar bushings up to 1 kV and from 1,25 kA to 5 kA, for liquid filled transformers

EN 60076-2 Power transformers - Part 2: Temperature rise for liquid-immersed transformers (IEC 60076-2)

EN 60076-4 Power transformers - Part 4: Guide to the lightning impulse and switching impulse testing - Power transformers and reactors (IEC 60076-4)

EN 60076-5 Power transformers - Part 5: Ability to withstand short-circuit (IEC 60076-5)

IEC 60076-12 Power transformers - Part 12: Loading guide for dry-type power transformers

IEC/TR 60616 Terminal and tapping markings for power transformers

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