UN environment

SUPPLEMENT TO THE TRANSFORMERS POLICY GUIDE:
«ACCELERATING THE GLOBAL ADOPTION OF ENERGY-EFFICIENT TRANSFORMERS»

PROCUREMENT GUIDELINES

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MODEL LIQUID IMMERSED DISTRIBUTION TRANSFORMER TECHNICAL SPECIFICATION

U4E United for Efficiency

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United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)

MODEL LIQUID IMMERSED DISTRIBUTION TRANSFORMER TECHNICAL SPECIFICATION

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Foreword

These Procurement Guidelines are a supplement to the UN Environment United for Efficiency (U4E) Transformers Policy Guide "Accelerating the Global Adoption of Energy-Efficient Transformers."[1] It is intended for use by liquid immersed distribution power transformer purchasers in developing and emerging economies[2] with 50 – 60 Hz power.

This model technical standard is a supplement to the Transformer Policy Guide[1] which is one of a series of United for Efficiency reports along with lighting, room air conditioners, residential refrigerators and electric motors. As is described further in the Transformers Policy Guide, United for Efficiency encourages countries to implement an integrated policy approach, which includes the following components:

- Standards and regulations;
- Supporting policies (e.g. communication campaigns);
- Finance and financial delivery mechanisms;
- Monitoring, verification and enforcement; and
- Environmentally sound management.

Please visit http://united4efficiency.org/ for more information about United for Efficiency.

[1] Please visit the "United for Efficiency Policy Guide on Energy-Efficient Transformers" for more information. (https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-transformers/)

[2] This model regulation is not intended for governments that already have effective regulations and policy processes for energy-efficient transformers in their country or region.

For more information about this document or other energy-efficient transformer related topics, contact:

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Disclaimer

Introduction

This model technical specification is a supplement to the UN Environment United for Efficiency (U4E) Transformers Policy Guide "Accelerating the Global Adoption of Energy-Efficient Transformers". It is intended to guide transformer purchasers like utilities as well as other purchasers on how to specify distribution power transformers in their national and international markets.

This document is based on U4E's Integrated Policy Approach, which has been used around the world to bring about sustainable energy market transformations.

The very first step towards owning transformers that offer maximum value to the purchaser is preparing clear and concise specifications. While writing any specifications, the challenge always lies in striking the right balance between being specific and generic, besides ensuring its accuracy and practicability. Too generic or inaccurate or impractical specifications lead to confusion during the bidding stage, which can ultimately snowball into disputes and procurement of transformers that don't fully comply with utility's requirements. To a large extent, clarity and effectiveness of specifications also depend on the formatting of the specification document. Well-structured specifications aid in readers' understanding, thereby improving the prospects of compliance or frank discussion about non-compliances.

Providing manufacturers with a set of clear, current and correct specifications is the key to procuring high-quality, optimum energy performing transformers.

This document guides transformer purchasers like utilities as well as other stakeholders on how to specify distribution transformers in their national and international markets.

This document comprises this introductory main part and two annexes providing sample specifications (Annexes B and C) for the type of transformer included in the scope of the U4E model regulation guideline that purchasers can adopt, either as they are or to use as a baseline to adjust to their own unique specifications.

The sample technical specifications are almost ready to be used, but additional comments and suggestions to each clause of the annexed technical specifications are reported in the following paragraphs with the same corresponding clause or sub-clause number. To keep consistency between clause numbering sometime there are empty clauses.

The words/terms/figures highlighted in grey indicate that the purchaser should pay special attention to these areas and amend or complete to suit their own requirements.

A general guideline on procurement is also provided with this document (Annex A).

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Acronyms

ANSI	American National Standards Institute
ASTM	American Society for Testing and Materials
BOM	Bill of Materials
C2H2	Acetylene
C2H4	Ethylene
C2H6	Ethane
CGO	Cold Grain Oriented
CH4	Methane
CO	Carbon Monoxide
CO2	Carbon Dioxide
DETC	De-Energized Tap Changer
EPA OPPTS	Environmental Protection Agency Office of Prevention, Pesticides and Toxic Substances
FAT	Factory Acceptance Test
H2	Hydrogen
HV	Highest Voltage
Hz	Hertz
IEC	International Electrotechnical Commission
IEEE	Institute of Electrical and Electronics Engineers
ISO	International Organization for Standardization
ITP	Inspection and Test Plan
kV	Kilovolt
LCC	Life Cycle Cost
LI	Lightning Impulse Withstand Voltage
LL	Load Loss
LMSH	Measurement of Load Loss
LV	Low Voltage
MV	Medium Voltage
NEC	National Electric Power Authority
NFPA	National Fire Protection Association
NL	Non-Load Loss
OECD	Organisation for Economic Cooperation and Development
OLTC	On-Load Tap Changer
ONAN	Oil Natural Air Natural
ONAF	Oil Natural Air Forced
PCB	Polychlorinated Biphenyls
RH	Relative Humidity
SAT	Site Acceptance Tests
SI	System of Units
TCO	Total Cost of Ownership
TOR	Terms of Reference
U4E	United for Efficiency
UN	United Nations

1. Scope

In order to provide the full specification information for distribution power transformers needed while maintaining consistency and maintainability, additional prescriptions or integration to the main common part of these specifications are to be reported in the 'Local Sections' with the same corresponding clause or sub-clause number.

2. Reference Laws and Standards

IEC 60076 and ANSI/IEEE C57 are the two leading international standards applicable to power transformers across the world. Of the two, most utilities follow the IEC standard.

The set of technical specifications in Annex A is based on the IEC 60076 standard while the ones in Annex B are based on ANSI/IEEE C57.

Users should add to the provided list of international standards, their local technical standards and laws as applicable.

3. Definitions

Empty paragraph.

4. General Requirements

Empty paragraph.

5. Service Conditions

According to IEC 60076-1 the normal service conditions are the ones listed in the following table. In case of deviations from normal service conditions, the correction factors described hereunder shall be applied.

Table 1 – Normal service condition according to IEC 60076-1

Description		**Data/Information**
Altitude		Not exceeding 1000 m
Air temperature	Maximum ambient air temperature (°C)	Not exceeding 40 °C
	Maximum average monthly ambient air temperature (°C)	Not exceeding 30 °C
	Maximum average yearly ambient air temperature (°C)	Not exceeding 20 °C
	Minimum ambient air temperature (°C)	Not below -25 °C (outdoor) / - 5 °C (indoor)

Description		Data/Information
Relative Humidity (RH)	Maximum RH (%)	Not Specified
	Minimum RH (%)	Not specified
	Yearly average RH (%)	98
Wave shape of supply voltage		**A sinusoidal supply voltage with a total harmonic content not exceeding 5 % and an even harmonic content not exceeding 1 %.**
Load current harmonic content		Total harmonic content of the load current not exceeding 5 % of rated current.

For altitudes higher than 1000 m correction factors shall be applied. Applicable values are reported in the table below.

Altitude correction factors – selected altitudes

Altitude (m/ft)											
Characteristic	1,000 3,280	1,200 3,940	1,400 4,600	1,500 4,920	1,600 5,250	1,800 5,900	2,000 6,560	2,500 8,200	3,000 9,840	3,500 11,500	4,000 13,125
Voltage	1.00	.98	.96	.95	.94	.92	.90	.85	.80	.75	.70
Current	1.00	.996	.992	.990	.988	.984	.980	.970	.960	.950	.940

Figure 1: Altitude correction factors

For a maximum average yearly ambient air temperature higher than 20 °C correction factors shall be applied. Applicable values are reported in the table below.

Permissible continuous symmetrical loading capacity at different ambient air temperatures for ONAN distribution transformers.

Constant ambient air temperature °C	0	+10	+20	+30	+40	+50	+60
Permissible continuous load factor, % Temperature rise 60/65 °C	116	108	100	91	82	72	-
Permissible continuous load factor, % Temperature rise 50/55 °C	-	119	110	100	89	77	64

Figure 2: Permissible continuous symmetrical loading capacity at different ambient air temperatures for ONAN distribution transformers

When the sinusoidal supply voltage with a total harmonic content exceeds 5 % or an even harmonic content exceeds 1 % correction factors shall be applied.

When the total harmonic content of the load current exceeds 5 % of rated current, correction factors shall be applied.

When one or more of the following special conditions is applicable, the purchaser has to indicate the details of same and add it/them in the technical specification:

- Tropical climate
- Restricted ventilation
- Installation near sea shore
- Seismic area
- Solar radiation
- Pollution

6. Design Criteria and Ratings

6.1. Type

Empty paragraph.

6.2. Number of phases

Empty paragraph.

6.3. Number of windings

Empty paragraph.

6.4. Vector group

Empty paragraph.

6.5. Cooling

The designation of cooling types of the oil distribution transformers depends on the fire point of the liquid being used:

- Mineral oils have fire point is below 300°C and are designated with "O"
- Non-mineral liquids such as silicone oil, Synthetic Ester and Natural Ester (vegetable oils) have fire point above 300°C and are designated with "K".

Non-mineral oils are more expensive but they have different advantages based on the application area of the transformers asked. Non-mineral oils can be divided into two types: synthetic ones and natural ones. Both have higher flashing points and thus are more safe to use in explosive areas defined as Zone 1 and Zone 2. KNAN transformers do have a bigger footprint compared to a mineral oil filled transformer. The heat dissipation factor for mineral oil compared to a non-mineral oil is higher; thus, the tank design is kept bigger. Higher-temperature-withstanding-active parts can be designed with non-mineral oils. Mineral oils are suitable for A-class design. (IEC-60076-14-2009)

Ester-based fluid are classified as fire safe, are readily biodegradable, are free from corrosive sulphur compounds, and have excellent moisture tolerance. These attributes are important for environmental impact especially in areas such as Africa with pole- and ground-mounted

transformers installed in remote areas without oil containment facilities. Ester fluids have also been shown to extend the life of electrical insulation, which prolongs the service life of the transformer.

Ester is a reaction product from the combination of an acid and an alcohol. Esters come in many forms, but the ester based fluids used in transformers can be split into two groups, synthetic and natural.

Synthetic esters are manufactured from carefully selected raw materials to give a finished product that is tailored to the specific application. Natural esters are derived directly from renewable natural sources, primarily seed oils such as soya bean, rapeseed oil or sunflower oil. The base oil is chosen to give the best possible fit to the application; however, unlike synthetic esters the properties of these base oils cannot be modified significantly. Thus to get a natural ester dielectric fluid that remains liquid at low temperatures, a compromise must be made, and a base oil with relatively poor oxidation stability is usually chosen.

This means natural esters are only suitable for sealed equipment. Natural esters are best suited to temperate locations or indoor applications.

6.6. Rated power

The values of rated power should be expressed in volt-ampere and 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, 1000 etc.

6.7. Rated frequency

The rated frequency shall be specified by the purchaser to be the normal undisturbed frequency of the network: 50 or 60 Hz.
The rated frequency is the basis for the guaranteed values such as losses, impedance, and sound level.

6.8. HV winding rated voltage

To be selected according with local network values. 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.

6.9. Highest voltages for equipment for winding with *U*m > 1,1 kV

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

The values of the highest voltage Um for equipment are: 3,6 kV– 7,2 kV – 12 kV – 17,5 kV – 24 kV – 36 kV

6.10. LV winding rated voltage

To be selected according with local network values. For Um ≤ 1,1 kV, the preferred rated voltage value shall be chosen in the hereunder list: 400 V – 410 V – 415 V – 420 V – 433 V – 690 V

6.11. Highest voltages for equipment for winding with *U*m ≤ 1,1 kV

*U*m = 1,1 kV

6.12. Voltage regulation

Taps can be provided with OCTC or OLTC devices:
— OCTC (DETC): De-energized tap changer;
— OLTC: On load tap changer.

For OCTC, the preferred tapping ranges are ± 2,5 % with 3 tap positions and ± 2 x 2,5 % with 5 tap positions. On special request ± 4 x 2,5 % with 9 tap positions can be provided. Tapping ranges greater than ± 10 % or with more than 9 tap positions are unusual and subject to specific agreement.

For OLTC, the tapping range shall be smaller than ± 15 % with a maximum of 17 tap positions. Tapping ranges greater than ± 15 % or with more than 17 tap positions are unusual and subject to specific agreement.

6.13. Short duration induced withstand voltage

The values for short duration power frequency withstand and/or for the lightning impulse withstand test between windings and earth need to be stated by the purchaser. Typical values are respectively 10 kV and 30 kV.

6.14. Lightning impulse withstand voltage (LI)

See clause 6.13.

6.15. Short circuit impedance

For 50 to 3200 kVA rating, the nominal value should range from 4% to 6%. Purchaser should agree the value with the manufacturer.

6.16. Energy performance level

IEC 60076-20 provides two levels of minimum energy performance

- Level 1 is for basic energy performance
- Level 2 is for high energy performance

IEC 60076-20 provides guidance on how to specify and evaluate energy performance for transformers. According to that IE, energy performance can be calculated based on either input power (Method A) or output power (Method B)

Method A: Ratio of the transmitted apparent power of a transformer minus electrical losses including the power consumed by the cooling, to the transmitted apparent power of the transformer for a given load factor

Method B: Ratio of the transmitted apparent power of a transformer to the transmitted apparent power of the transformer plus electrical losses for a given load factor

Table 2: Method A and Method B for Efficiency Calculation

Method A (IEC practice)	**Method B (IEEE practice)**
Efficiency = (S-Losses)/S	Efficiency = S/(S+Losses)
S: Input power	S: Output power

According with guidelines provided by U4E, this specification is based on Maximum load losses and Maximum no-load losses.

6.17. Maximum losses

6.18. Transformer losses

The efficiency of a typical distribution transformer is in excess of 97%. In other words, up to 3% of all electrical power generated is wasted in transformer losses. Since transformers handle large amounts of energy and operate continuously over 20 - 50 years, the transformer losses are far from negligible; the cumulative cost of losses can be more than double the original purchase price of a transformer.

The total energy loss of a transformer comprises two types of losses: no-load losses and load losses. No-load losses remain constant once the transformer is energised whereas load losses vary roughly as the square of the load on the transformer.

Losses in the core of a transformer are called “no-load losses” or “iron losses”. These losses are present whenever the transformer is energised and are independent of transformer load.

No-load losses form mainly out of two sources: hysteresis losses and eddy current losses. These two account for over 99% of the no-load losses.

No-load losses are constant for each transformer design, being dependent on the core steel characteristics and design. High-efficiency transformers have cores made of low-loss silicon steel or amorphous steel with copper windings. Copper windings have a lower resistance per cross-sectional area than aluminium windings, which in turn means smaller cores that produce lower no-load losses.

Transformer’s load losses are due to the resistance of the primary and secondary conductors to the flow of current and eddy currents. Also known as I 2R losses, these losses vary according to the square of transformer loading. A fully loaded transformer has four times the load loss

compared to the one operating at 50% load. To minimise load losses, copper windings are preferable due to very high conductivity.

Procurement policies should set a minimum energy performance (i.e. a maximum amount of losses) of the transformer and include Total Cost of Ownership (TCO) based evaluation of the bids. A brief explanation follows.

TCO, also known as life cycle cost (LCC), is the sum of all the costs incurred by the owner over the lifetime of a transformer. It includes purchase cost, installation cost, maintenance cost, and decommissioning cost. In the case of transformers, TCO also includes the "cost of energy losses" or simply "transformer losses".

The total capital and estimated lifetime operating and maintenance costs (TCO) are also significant considerations in determining the most suitable transformer for the intended application and may lead to the selection of more economical solutions when taking into account the lifetime of the transformers.

In practice, however, the following three components of TCO don't vary much unless different types of transformers are compared (e.g., oil-cooled vs. air-cooled):

- Installation cost
- Maintenance cost
- Decommissioning cost

So practically, the three cost components above can be ignored. So TCO = Initial Purchase Price + Transformer Losses.

To minimize TCO of the transformer, a loss capitalisation method should be used with all methods in addition to the minimum requirements.

TCO can be calculated with the following formula:

$$\mathrm{TCO} = C_I + A \times P_O + B \times P_K$$

Where:

- TCO: Total Cost of Ownership
- C_I: Initial cost of a transformer (including all taxes) as quoted by the bidder
- A: Factor for capitalising no-load loss of a transformer ($/W)
- P_O: No-load loss of a transformer per year (W)
- B: Factor for capitalising load loss of a transformer ($/W)
- P_K: Load losses from a transformer per year (W)

The user should compute values of factors A and B on the basis of the values of individual parameters (I, n, C_{kWh} and L outlined below). Basically these values cannot be standardised and are user-specific and can be calculated with the following equations:

$$A = \frac{(1+i)^n - 1}{i\,(1+i)^n} \times C_{kWh} \times 8760 \qquad B = \frac{(1+i)^n - 1}{i\,(1+i)^n} \times C_{kWh} \times 8760 \times L^2$$

Where:

- i: Discount rate or cost of capital (10%)
- n: Lifetime of a transformer (25 years)[3]
- C_{kWh}: Electricity price ($/kWh)
- L: Transformer loading (0.5 for rural areas / 0.7 for urban areas)
- 8760: Hours in a year

The value of losses (i.e. the ones minimizing the TCO) to the specified transformer in the technical specification should be defined on the basis of these calculations.

Factors A and B are to be used also for bid evaluation and penalties in the case of deviation of losses from tolerances.

6.18.1 Power rating according with IEC 60076-1

The given losses can be weighted by the correction factors given in table 3, in order to take care of variations related to the highest voltage for equipment values.

The level of losses given in table 9 and 10 of Annex B shall be weighted by the correction factors given in table 4 below, in order to take into account variations related to dual voltage windings.

For transformers having dual voltage on both windings for which both voltages on one winding are fully rated in combination with one of the voltages on the other winding, the levels of losses shall be based on the highest power and the values indicated in Table 9 and 10 of Annex B can be increased by 15 % for no load losses and by 10 % for load losses. The level of losses shall refer to the highest voltages of both windings. This remains valid even if further voltage combinations are available.

For a transformer having an insulation level according to table 3 and having dual voltage according to table 4 the loss level shall take into account both corrections.

[3] Please visit the "Guidelines for Specifications of Energy Efficient Outdoor Type Transformers" of the Government of India for more information.

Table 3: Correction of load loss and no load loss applicable to other insulation levels

Ref	Highest voltage for equipment values	Correction of load loss and no load loss
1	One winding with 1,1 kV < U_m ≤ 24 kV and the other with 1,1 kV < U_m ≤ 24 kV	The maximum losses indicated in Table 1 and 2 can be increased by 10 % for no load loss and by 10 % for load loss.
2	One winding with 24 kV < U_m ≤ 36 kV and the other with U_m ≤ 1,1 kV	The maximum losses indicated in Table 1 and 2 can be increased by 15 % for no load loss and by 10 % for load loss and short circuit impedance unless otherwise specified should be increased by adding a value of 0,5 %.
3	One winding with 24 kV < U_m ≤ 36 kV and the other with U_m > 1,1 kV	The maximum levels of losses indicated in Table 1 and 2 can be increased by 20 % for no load loss and by 15 % for load loss and short circuit impedance unless otherwise specified should be increased by adding a value of 0,5 %.

Table 4: Correction of load loss and no load loss applicable to dual voltage

Ref	Dual voltage	Correction of load loss and no load loss
A	One winding	In the case of power transformers with one high-voltage winding and two voltages available from tapped low-voltage winding, losses shall be calculated based on the higher low-voltage and shall comply with the levels indicated in Table 1 and 2. The maximum available power on the lower low-voltage on such transformers shall be no more than 0,85 times its rated power. In the case of power transformers with one high-voltage winding with two voltages available from a tap, the maximum available power on the lower high-voltage on such transformer shall be limited to 0,85 of its nominal rated power. In the case where the full rated power is available regardless of the combination of voltages, the levels of losses indicated in Table 1 and 2 can be increased by 15 % for no load loss and by 10 % for load loss. Such levels of losses shall refer to the highest voltage.
B	Both windings	The maximum allowable losses indicated in Table 1 and 2 can be increased by 20 % for no load losses and by 20 % for load losses for transformers with dual voltage on both windings if the rated power is the same regardless of the combination of voltages. The level of losses shall refer to the highest voltages of both windings. This remains valid even if further voltage combinations are available.

6.19. Power rating according with IEEE C57.12.80

Minimum energy performances referred to distribution transformers rated according to IEEE C57.12.80 do not foresee any correction factor.

6.20. Sound level

Transformers to be installed in close proximity to public facilities such as hospitals, schools, etc. shall be designed to keep the noise level within 58 to 68 decibels or less.

6.21. Temperature rise

Temperature rise limits at rated power are specified in IEC 60076-2.

Table 5: Temperature rise limits at rated power according to IEC 60076-2

Applicable Item	Temperature Rise Limits (K)
Top oil	60
Average winding	65
Hot-spot winding	78

Temperature rise limits for transformers having higher temperature resistant insulation systems and immersed in a less flammable liquid (code letter K) are subject to agreement.

The values specified in IEC 60076-2 are based on 40 °C maximum, 20°C yearly average and 20 °C monthly average ambient temperatures. For other ambient temperatures, the values shown above need to be adjusted.

For example, referring to IEC 60076-2, in the case of 50 °C maximum, 40°C yearly average and 30 °C monthly average ambient temperatures the values in the table are to be reduced by 10 K.

6.22. Overload

Empty paragraph.

6.23. Short circuit apparent power

The short-circuit apparent power of the system at the power transformer location is to be indicated. If unknown and in the case of transformers with a rated power up to 2,500 kVA, the contribution of system impedance shall be neglected (i.e. infinite short-circuit apparent power of the system shall be assumed in the design and calculations).

Transformers shall be suitable to withstand, without being permanently damaged, the thermal and dynamic effects of a secondary winding short-circuit, in the conditions specified in IEC 60076-5, for 2 s or 3 s.

Short-circuit withstand capability can be adversely affected by the cumulative effects of repeated short circuits which cause mechanical and thermal overstressing.

Short-circuit duration is 2 seconds unless otherwise specified by the user.

6.24. Penalties

In the case of average losses exceeding guarantee values within tolerances, the methodology described at clause 6.18 is to be used for calculating the capitalization factors A and B for compensating the increased Total Cost of Ownership (TCO) of that transformer batch and thus the penalties to be applied.

6.25. Overall dimensions

If required by the application, the overall following dimensions have to be specified.

Table 6: Overall dimensions

Description	UM
Height	mm
Length	mm
Width	mm
Insulating liquid Volume	m3
Total Mass	kg

7. Construction and Material Requirements

7.1. Core

Empty paragraph.

7.2. Windings

Empty paragraph.

7.3. Bushings and terminals

Empty paragraph.

7.4. Insulating liquid

The IEEE C57.91 Guide for Loading Transformers defines transformer insulation life versus temperature for thermally upgraded Kraft paper and pressboard in insulating liquids in terms of “A” and “B” factors in an exponential model, which defines the thermal class. The fluid shall have its A and B factors and thus its thermal class determined by the test procedure defined in IEEE C57.100. Both the sealed tube test and the C57.100 test, using actual oil-immersed distribution transformers, shall be used to determine the suitability of an insulation system for transformer applications. Data shall be submitted upon request.

All characteristics, definitions and terminology, except those specifically covered in this specification shall be in accordance with the latest revisions of the following documents.

IEEE / ANSI Design / FM Datasheets

- IEEE C57.12.00 – General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
- IEEE C57.147 – Acceptance and Maintenance of Natural Ester Fluids in Transformers
- IEEE C57.154 – Design, Testing, and Application of Liquid-Immersed Distribution, Power, and Regulating Transformers Using High-Temperature Insulation Systems and Operating at Elevated Temperatures
- FM Global DS 5-4 - Property Loss Prevention Data Sheets
- FM 3990 – Approval Standard for Less or Non-flammable Liquid-Insulated Transformers
- UL Standard 340 - Standard for Tests for Comparative Flammability of Liquids
- NEC or NFPA 70 - Article 110 – Requirements for Electrical Installations

IEC Design

- IEC 60076-1 – Power Transformers – Part 1: General
- IEC 60076-14 – Power transformers – Liquid-immersed power transformers using high-temperature insulation materials
- IEC 62770 – Fluids for electro-technical applications – Unused natural esters for transformers and similar electrical equipment
- IEC 62975 (work in progress) – Natural Ester insulating oils in electrical equipment – Supervision and maintenance guidance
- IEC 61936-1 Power installations exceeding 1 kV a.c. – Part 1: Common rules (note: volumes of fluid are not completely aligned with FM Global statements)

7.5. Tank and cover

Empty paragraph

7.6. Transformer nameplate

Empty paragraph.

7.7. Accessories

Empty paragraph.

8. Factory and Testing Inspection

This section deals with the all the mandatory tests to be carried out by the manufacturer and the production process and in-process inspections to be carried out by the purchaser.

8.1. Factory acceptance tests

Thorough testing at the factory as per applicable standards and specifications ensures transformers meet the manufacturing and customer's specifications.

IEC standard 60076-1 specifies the following three types of tests:

1. tine tests: These are mandatory tests that need to be carried out on each transformer.
2. e tests: These tests are not conducted on each transformer and instead conducted on one transformer, which is a representative of a group of the other transformers.
3 ecial tests: These are additional tests to be conducted in addition to the routine and type tests as per the agreement between manufacturer and customer.

8.1.1. General requirements

- Testing shall be done at an ambient temperature between 10–40 °C.
- Transformer shall be complete with all components and fittings that can affect transformer's performance.
- Tapped windings shall be connected to their principal tapping unless agreed otherwise.
- The test basis for all characteristics other than insulation is at rated conditions unless agreed otherwise.
- All measuring systems used for the tests shall have certified, traceable accuracy and be subjected to periodic calibration, according to the rules given in ISO 9001.
- Additional general requirements apply as mentioned in IEC 60076-1.
- Temperature rise test shall be as per IEC 60076-2.

8.1.2. Routine tests

Routine tests, applicable to each transformer, shall include:

- Measurement of winding resistance
- Measurement of voltage ratio and checking of phase displacement
- Measurement of short-circuit impedance and load loss
- Measurement of no-load loss and current
- Dielectric routine tests
- Test on on-load tap-changers, where appropriate
- Leak testing with pressure for oil-immersed transformers (tightness test)
- Check for the ratio and polarity of built-in current transformers
- Check for core and frame insulation for oil-immersed transformers with core or frame insulation

8.1.3. Type tests

Type testing is carried on a transformer that is representative of other transformers to demonstrate that these transformers comply with the specified requirements that are not covered by routine tests. A transformer is considered to be representative of others if it is

built to the same drawings using the same techniques and materials in the same factory. Type tests include:

- Temperature-rise test
- Dielectric type tests
- Determination of the sound level
- Measurement of power taken by the fan and liquid pump motors
- Measurement of no-load loss and current at 90% and 110% of rated voltage

8.1.4. Special tests

In addition to the routine and types tests, the following special tests can be carried out with a prior agreement between a supplier and a utility/customer. As per IEC 60076-1, these tests include:

- Dielectric special tests
- Winding hot-spot temperature-rise measurements
- Determination of capacitances winding-to-earth and between windings
- Measurement of dissipation factor (tan δ) of the insulation system capacitances
- Determination of transient voltage transfer characteristics
- Measurement of zero-sequence impedance(s) on three-phase transformers
- Short-circuit withstand test
- Measurement of d.c. insulation resistance — each winding to earth and between windings
- Vacuum deflection test on oil-immersed transformers
- Pressure deflection test on oil-immersed transformers
- Vacuum tightness test on site on oil-immersed transformers
- Measurement of frequency response (Frequency response Analysis or FRA)
- Check of external coating
- Measurement of dissolved gases in dielectric liquid
- Mechanical test or assessment of tank for suitability for transport
- Determination of weight with transformer arranged for transport

8.1.5. Loss measurements

8.1.5.1. Measurement of No-Load Loss

Accurate measurement of No-Load Losses is a critical step with far-reaching effects as these losses represent a sizable cost over the long lifespan of a transformer.

8.1.5.1.1 Prerequisites

According to the referenced IEC standards, the following conditions are applicable for no-load testing:

- Voltage is equal to rated voltage unless specified otherwise.
- Frequency is equal to the rated frequency.

- Measurements are reported at the reference temperature.
- The voltage applied to the voltmeters is proportional to that across the energized winding.
- The transformer shall be approximately at factory ambient temperature.
- power source shall be made to provide, as far as possible, symmetrical and sinusoidal

8.1.5.1.2 List of equipment and instruments

Referenced IEC standards require the following equipment and instruments:

- Current transformer with 1% accuracy
- Potential transformer with 1% accuracy
- Power meter with 0.5% accuracy

8.1.5.1.3 Acceptance criterion

Measured no-load losses and current shall be lower than guaranteed values or within a tolerance of +15% of no-load loss guaranteed values and +30% of no-load current guaranteed values.

8.1.5.1.4 Test description

Figure below shows the test circuit and apparatus for no-load loss testing.

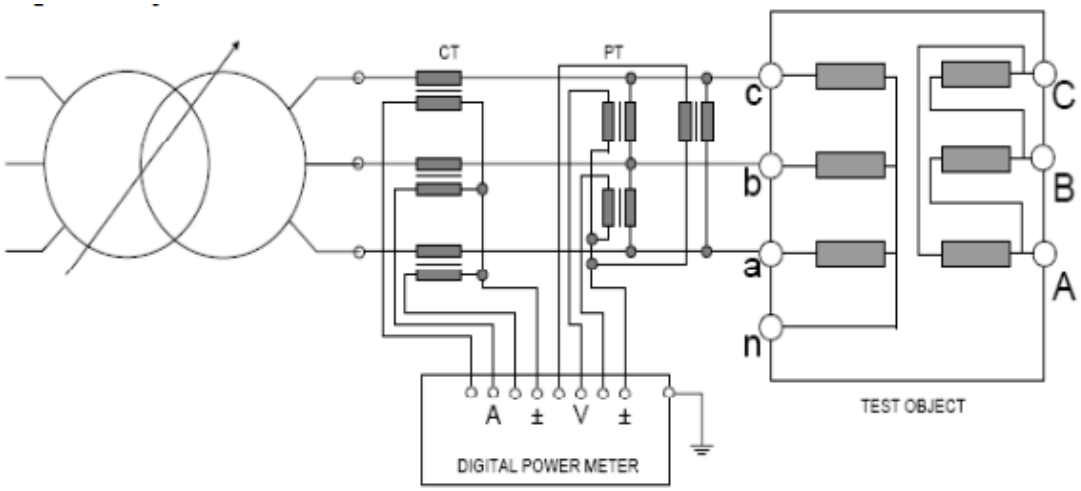

Figure 3 - Test Circuit and Apparatus for No-Load Loss Measurement

The no-load loss and current can be measured on one of the windings at rated frequency and voltage on principal tapping.

Transformers may be subjected to a distorted sine-wave voltage, which can lead to inaccurate measurements. To achieve the required measuring accuracy, the instrumentation should respond to the power frequency harmonics encountered in these measurements. In addition, the measured values need to be corrected to account for the effect of the voltage harmonics on the magnetic flux in the core—for both the hysteresis and eddy current loss components.

The hysteresis loss component is a function of the maximum flux density in the core and practically independent of the waveform of the flux. The maximum flux density corresponds to the average value of the voltage (not the rms value), and, therefore, if the test voltage is adjusted to be the same as the average value of the desired sine wave of the voltage, the hysteresis loss component will be equal to the desired sine wave value.

The eddy-current loss component varies approximately with the square of the rms value of the core flux. When the test voltage is held at rated voltage with the average-voltage voltmeter, the actual rms value of the test voltage is generally not equal to the rated value.

8.1.5.2. Measurement of load loss (LMSH)

Transformer load losses or copper losses include I^2R losses in windings due to the load current, stray losses due to stray fluxes in the windings, core clamps, magnetic shields, tank wall, etc. and losses due to circulating current in parallel windings and parallel conductors within windings.

8.1.5.2.1 Prerequisites

According to the referenced IEC standards, the following conditions are applicable for load testing.

The supplied current should be equal to the relevant rated current (tapping current) but shall not be less than 50 % thereof. The measurements shall be performed quickly so that temperature rises do not cause significant errors. The difference in temperature between the top liquid and the bottom liquid shall be small enough to enable the mean temperature to be determined accurately. The difference in temperature between the top and bottom liquid shall not exceed 5 K. To obtain this result more rapidly, the liquid may be circulated by a pump.

8.1.5.2.2 List of equipment and instruments

Referenced IEC standard require the following equipment and instruments:

- Current transformer 1% accuracy
- Potential transformer with 1% accuracy
- Power meter with 0.5% accuracy

8.1.5.2.3 Acceptance criteria

The transformer load loss shall be lower than the guaranteed values or within a tolerance of +15% of guaranteed values and voltage impedance shall be ±10% of guaranteed values.

8.1.5.2.4 Test description

Figure below shows the test circuit and apparatus for load loss testing.

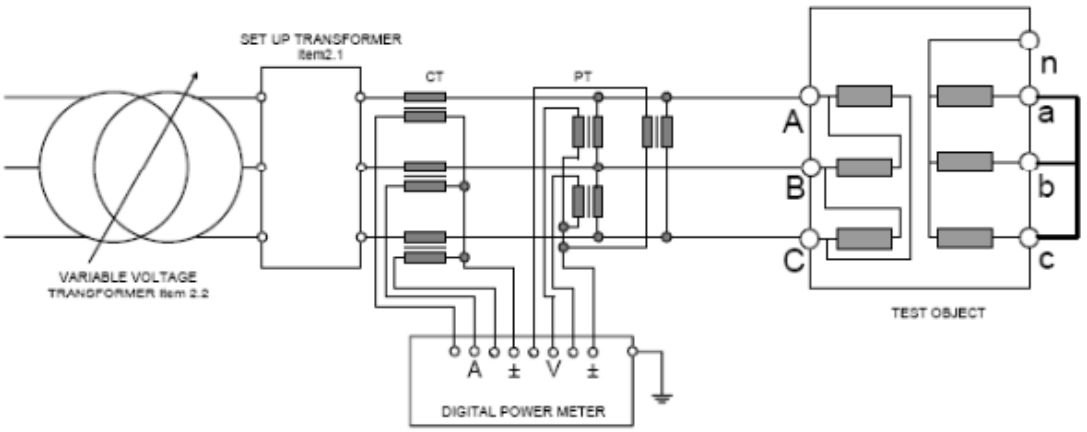

Figure 4 - Test Circuit and Apparatus for Load Loss Measurement

Load losses are normally measured by short circuiting one winding of a transformer—usually the low voltage winding. And then applying sufficient voltage (referred to as impedance voltage) on the high voltage winding to cause rated current to circulate in the high voltage winding. Measurements to be taken include Input voltage, current and power.

The short-circuit impedance and load loss of winding are measured at rated frequency and relevant rated current (tapping current) not less than 50% with an approximately sinusoidal voltage applied to one winding. The temperature of the winding to be recorded to rated current and the reference temperature of 75°C or 85°C.

8.1.6. Special situations and precautions

Measurement at a lower than rated current: According to the reference standards load losses should be measured at a load current equal to the rated current for the corresponding tapping position. However, if it is not exactly equal to the rated current, the measured load loss value will be corrected by the square of the ratio of the rated current to the test current (average of the measured phase current in three-phase transformers).

- Duration of the load loss measurement test: During load loss measurement, the current in the winding increases its temperature, which in turn increases winding I^2R losses. To minimise this impact on measurements, keep the duration of the test as small as possible.
- Optimizations of measuring range of instrumentation: Instruments should be used within their optimum operating range to minimize the errors.
- Other precautions with the use of instrument transformers: Use the proper burden, clean connections, and demagnetize the current transformer after every use to achieve a better measuring accuracy.

8.2. Production process and in-process inspections

Until the award of a contract for supplying transformers, purchasers need to pay attention to suppliers' documentary submissions to ensure that theoretically proposed equipment comply with the technical specifications and commercial and contractual conditions. But once the

contract is awarded, the responsibility to manufacture those transformers shifts to the factory where both parties—supplier and purchaser—have important roles to play.

Manufacturing of a transformer involves several function- and cost-sensitive materials, processes, inspections and tests, and there are many points during the whole process when inspections and testing are required to ensure equipment complies with the specifications. Purchasers need to be prepared to participate in the manufacturing process to ensure the quality of transformers, which will form their assets for decades to come.

From the purchaser's side, the key steps during the manufacturing phase include appointing a factory inspection team, preparing for factory inspections, understanding the manufacturing processes involved and tests to be done, and witnessing tests.

Well-planned and carefully executed factory inspections are critical to ensuring the material and functional quality of transformers and overall compliance with the applicable standards and specifications.

8.2.1. Planning factory inspections

The two key components of successful factory inspections are the forming of an inspection team and providing the team all the relevant and latest documents.

8.2.2. Appointing the factory inspection team

Forming a well-represented factory inspection team is required to ensure that transformers are inspected from all the important angles, such as design/technical specifications, maintenance, operations, contractual, etc. The following departments should preferably be represented during factory inspections:

- Electrical engineering department, which is responsible for the technical specifications or terms of reference (TOR).
- Service department, which maintains transformers' maintenance, characteristics and performance monitoring data and records.
- Testing division or Maintenance department, which is experienced in testing and preventive maintenance on the transformers.
- Purchasing or Contract department, which deals with all the contractual documents, starting from the quotation, technical and commercial condition agreement and the transformer drawings.

The factory inspection team should be authorised by the top management to make the right decisions on behalf of the utility/customer.

8.2.3. Preparing for inspection

The quality and effectiveness of a factory inspection directly rest on the prior preparation by an inspection team.

A Factory Acceptance Test (FAT) protocol should be prepared by the supplier, and it should be carefully reviewed and approved by the authorised personnel on the utility/customer side. At the minimum, the protocol should include:

- Reference documents used for preparing the protocol
- Number of transformers to be tested
- Types of tests to be carried out
- Methods of testing
- Instruments used
- Acceptance criteria
- Test forms for recording the observations, results and deviations during the testing

In addition to the approved FAT protocol, all members of the inspection team should be provided with the latest approved specifications, drawings and any supporting documents (e.g., applicable standards).

The engineers and technicians responsible for the inspection should study the documents well in advance before arriving at the factory for inspection.

Members of the inspection team should know their respective roles in advance to ensure factory testing proceeds as planned.

On the supplier's side, free access to the facilities, people and documents should be provided to enable the team to verify that materials, processes and equipment conform to the specifications and drawings.

Finally, the plan should allow for sufficient time for the inspection and testing; the classic pitfall of rushing through a factory inspection should be avoided.

8.2.4. Inspection guidelines

The figure below shows the complete process of manufacturing a transformer along with the recommended stages of in-process inspection.

Overall, the production process starts with receipt of raw materials and splits into four main activities: covering building a core, preparing insulation, building windings and fabricating tank, cover, and accessories. Broadly, the following main processes are involved in the manufacturing of a transformer:

- Receipt—raw materials
- Silicon steel cutting
- Core stacking process
- HV, LV Coil Winding
- Insulation preparation
- Tank, Cover, Equipment and Accessory Preparation
- Core & coil assembly, Tap changer installation, Wire connection
- Drying, Vacuum and Oil Filling

- Accessory assembly, colour paint
- Packing

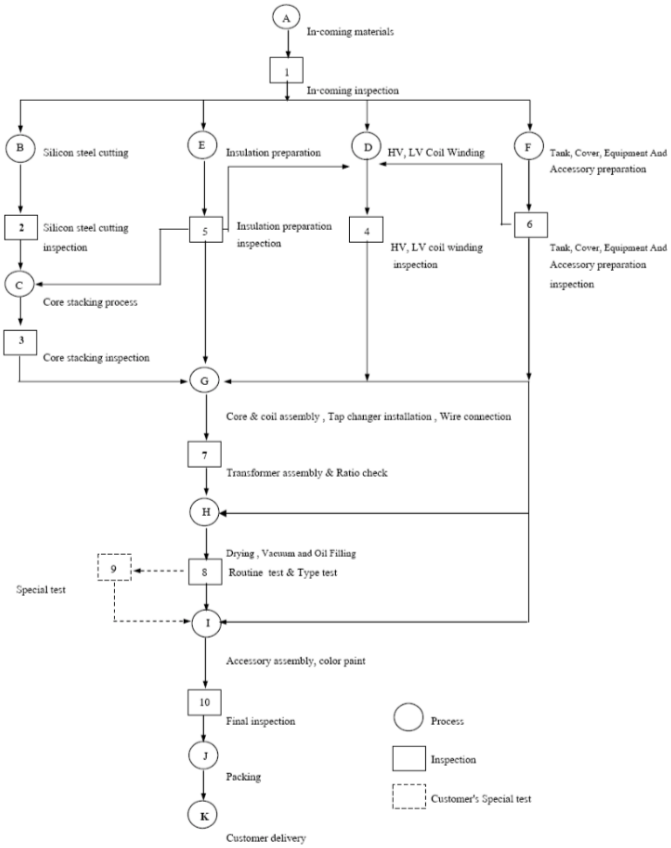

Figure 5 - Transformer Production Process and Inspection Flow[4]

The manufacturer should provide the utility with an overview of the complete manufacturing process plan along with the clear plan for inspections. The inspections can fall into three categories:

1. Witnessed by manufacturer's internal quality control team with documentary results not to be reviewed by utility's/customer's factory inspection team.
2. Witnessed by manufacturer's internal quality control team with documentary results to be reviewed by utility's/customer's factory inspection team.
3. Jointly witnessed by manufacturer's quality control team and customer's inspection team.

Results of all the tests should be recorded in pre-determined formats and available for customer's review and acceptance.

8.2.5. Loss transformer verification guidelines

To ensure low losses in a transformer, the Factory Inspection Team should pay attention to the following elements that directly affect transformer losses:

- Core (material)

[4] Please visit the ICA "Distribution Transformer Handbook" for more information.

- Windings (material)
- Welding

As shown in Figure 6 below, transformer's core losses depend on two key factors: core material and thickness of core laminations. Core losses can be reduced by upgrading core material from Cold Grain Oriented (CGO) silicon steel to Irradiated Hi-B silicon steel. To differentiate between the two steels, inspectors should know that Hi-B silicone steel surface has a dotted line whereas the CGO silicone steel is plainly visible. Further, loss reduction is possible by utilizing less thick pieces/laminations of silicon steel.

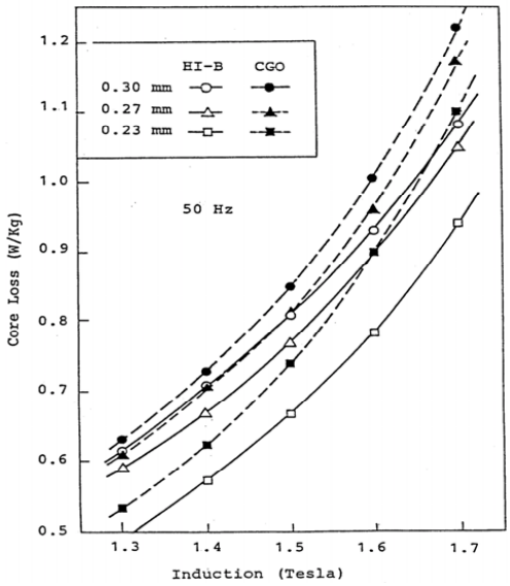

Figure 6 - Silicon Steel Core Loss Curve

For low load loss transformers, the copper winding having a "high-temperature class" shall be selected in order to avoid the risk of deformation of the enamel coat on the copper material.

The welding of windings to make tappings and connections is also important as it directly affects transformer losses and risk of failure. Care must be taken to ensure welding quality and highest working area cleanliness and orderliness.

There should be testing prior to the production of the core staking and winding process. Samples of core staking with some designed turns of copper winding assembly should be tested to verify the no-load loss value. If the value is over the guaranteed no-load loss, the core shall be investigated and redesigned to meet the contract agreement. This will be done in order to convince the inspection team that the low loss transformers will be able to meet the contractually guaranteed values.

8.2.6. Insulating liquids verification guidelines

To ensure the quality of insulating materials used in a transformer, the Factory Inspection Team should pay attention to manufacturer quality controls as follow.

8.2.6.1. Shipment and receiving

Every shipment received shall be visibly inspected for container integrity, and that no leaks are visible.

Samples shall be taken from containers per IEC 60475 or ASTM D-923 Section 2.2, as follows:

Table 7: Sampling

Lot Size (Litres)	Number of Containers Sampled
2275 or less	1
2276 to 11,360	2-6
11,361 or more	6 minimum (10% of quantity of containers recommended)

When material will be combined for production, samples may be mixed together in equal proportions to create a composite sample for testing. Minimum tests required are dielectric strength and visual inspection. Dissipation factor testing is highly recommended, although not essential.

8.2.6.2. Storage

Avoid storing drums and totes outdoors. Extreme temperature variations can stress the integrity of container protective seals. Exposure of totes to sunlight can cause fluid discoloration.

Insulating liquids cannot be stored at temperatures lower than -4*C.

8.2.6.3. Fluid Transfer

When transferring electrical insulating fluid from its original container, take care to prevent contamination with moisture, dust, and foreign matter. These impurities can cause deterioration of the dielectric strength and electrical performance.

8.2.6.4. Partial Containers

Provide nitrogen blanket for partially filled containers, and properly seal to prevent contamination.

8.2.6.5. Processed oil for installation in transformer

In accordance with IEC 62770 except as indicated below:

1. Oxidation inhibitor content: As recommended by oil manufacturer.
2. Combustible gases: Natural Ester Oil: In accordance with IEEE C57.147 or as listed in Table 1, whichever is more stringent. Test methods in accordance with applicable ASTM standards referenced in IEEE C57.147.
3. List and describe each oil quality and dissolved gas test performed.

Table 8: Dissolved Gas Concentrations – Natural Ester Oil

Gas	Gas Maximum Value
Acetylene (C2H2)	0.0 ppm
Carbon Dioxide (CO2)	100.0 ppm
Carbon Monoxide (CO)	20.0 ppm
Ethane (C2H6)	10.0 ppm
Ethylene (C2H4)	2.0 ppm
Hydrogen (H2)	10.0 ppm
Methane (CH4)	2.0 ppm
Total Dissolved Combustible Gas	35.0 ppm

8.2.6.6. Deviations during inspection

Inspection team members and manufacturer's representatives should objectively record any deviations from the specifications, drawings and contractual obligations. These deviations should be recorded as and when they arise in a pre-defined document— a Punch List. All records of deviations should form part of the factory inspection report.

PUNCH LIST									
Project Title:									
Contract No:									
Customer Name:									
Punch list last updated on (Date):									
Item No.	Description of Deviation	Picture (if applicable)	Date of Inspection / Testing	Responsible for Correction	Scheduled Date of Completion	Date of Completion	Picture—After Completion	Approved	Remarks

Figure 7 - Sample Punch List for Use during Factory Inspection

9. Transportation, Receipt, Installation, Energising and Testing

Empty paragraph.

10. Documentation Requirements

Empty paragraph.

11. Informative and Guaranteed Values

Empty paragraph.

MODEL LIQUID IMMERSED DISTRIBUTION TRANSFORMER TECHNICAL SPECIFICATION

ANNEX A

PROCUREMENT GUIDELINES

U4E United for Efficiency

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Foreword

This technical specification model is a supplement to the UN Environment United for Efficiency (U4E) Transformers Policy Guide "Accelerating the Global Adoption of Energy-Efficient Transformers."[5] It is intended for use by liquid immersed distribution transformer purchasers in developing and emerging economies[6] with 50 – 60 Hz power.

This model technical standard is a supplement to the Transformer Policy Guide[1] which is one of a series of United for Efficiency reports along with lighting, room air conditioners, residential refrigerators, and electric motors. As is described further in the Transformers Policy Guide, United for Efficiency encourages countries to implement an integrated policy approach, which includes the following components:

- Standards and regulations;
- Supporting policies (e.g. communication campaigns);
- Finance and financial delivery mechanisms;
- Monitoring, verification, and enforcement; and
- Environmentally sound management.

Please visit http://united4efficiency.org/ for more information about United for Efficiency.

For more information about this document or other energy-efficient transformer related topic, contact:

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E-mail: u4e@unep.org
http://united4efficiency.org/

[5] Please visit the "United for Efficiency Policy Guide on Energy-Efficient Transformers" for more information. (https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-transformers/)

[6] This model regulation is not intended for governments that already have effective regulations and policy processes for energy-efficient transformers in their country or region.

1. Introduction

These guidelines should enable utilities and other power transformer customers to carry out the procurement process with due diligence and efficiency.

2. Procurement guidelines

Bids should only be invited from pre-qualified suppliers and manufacturers.

After the issuance of the tender, sufficient time should be allowed for the bidders to understand the specifications and quote with all the required details and documents. If the utility doesn't give reasonable time to bidders for the bid preparation, they are likely to submit bids based on inadequate understanding of the specifications and may also submit incomplete and/or incorrect bids. This can lead to substantial wastage of time further down the process of procurement.

Sufficient time should be allowed for the utility's/customer's Procurement Team to review the bids and seek clarifications from the suppliers.

Bids received with total compliance to the specifications without any deviations should be scrutinised even more carefully, for bidders sometimes tend to agree with the specifications at the bidding stage only to dispute them later after the award of contract.

The complete bidding process should be transparent and all the correspondence should be traceable.

All-important verbal discussions and meetings with suppliers should be followed up with written memos to record the key decisions and agreements for future reference.

If required, utility/customer personnel should visit the supplier's works to check the manufacturing and testing facilities.

To ensure that bids are reviewed and evaluated objectively, the Procurement Team should identify criteria (and their relative weight) for the evaluation of bids. The key items in the list of criteria can include:

Compliance with the technical specifications and

- Total Cost of Ownership
- Manufacturer's safety and environmental record
- Compliance with commercial and contractual conditions
- Legacy issues considering the fleet of existing transformers
- Quality of service

MODEL LIQUID IMMERSED DISTRIBUTION TRANSFORMER TECHNICAL SPECIFICATION

ANNEX B

TRANSFORMERS RATED ACCORDING WITH IEC PRACTICES

U4E United for Efficiency

UN environment

IEC

gef

Endorsements

Please visit the United for Efficiency website to see the organisations that have endorsed these Model Regulation Guidelines for power transformers. The endorsing organisations encourage governments who do not currently have up-to-date energy efficiency regulations for transformers to consider adopting these requirements in order to fast-track energy performance requirements for these products in their economies.

http://united4efficiency.org/

Foreword

This model regulation is a supplement to the UN Environment United for Efficiency (U4E) Transformers Policy Guide "Accelerating the Global Adoption of Energy-Efficient Transformers."[7] It is intended for use by liquid immersed distribution transformer purchasers in developing and emerging economies[8] with 50 – 60 Hz power.

This model technical standard is a supplement to the Transformer Policy Guide[1] which is one of a series of United for Efficiency reports along with lighting, room air conditioners, residential refrigerators, and electric motors. As is described further in the Transformers Policy Guide, United for Efficiency encourages countries to implement an integrated policy approach, which includes the following components:

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[7] Please visit the "United for Efficiency Policy Guide on Energy-Efficient Transformers" for more information. (https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-transformers/)

[8] This model regulation is not intended for governments that already have effective regulations and policy processes for energy-efficient transformers in their country or region.

1. Scope

The scope of this document is to provide minimum technical requirements for the supply of MV/LV liquid-immersed distribution power transformers

This document is applicable to liquid immersed transformers, three-phase, bi-phase and single phase for indoor, outdoor, pole mounted and inbox installation.

2. Reference Laws and Standards

The transformers should comply with the latest editions of the following IEC publications:

Table 9: List of Technical Standards (As of February 2019)

Standard	Title
IEC 60076-1 ed3.0 (2011-04)	Part 1: General
IEC 60076-2 ed3.0 (2011-02)	Part 2: Temperature rise for liquid-immersed transformers
IEC 60076-3 ed3.0 (2013-07)	Part 3: Insulation levels, dielectric tests and external clearances in air
IEC 60076-4 ed1.0 (2002-06)	Part 4: Guide to the lightning impulse and switching impulse testing-Power transformers and reactors
IEC 60076-5 ed3.0 (2006-02)	Part 5: Ability to withstand short circuit
IEC 60076-7 ed1.0 (2005-12)	Part 7: Loading guide for oil-immersed power transformers
IEC 60076-8 ed1.0 (1997-10)	Part 8: Application guide
IEC 60076-10 ed1.0 (2001-05)	Part 10: Determination of sound levels
IEC 60076-10-1 ed1.0 (2005-10)	Part 10-1: Determination of sound levels - Application guide
IEC 60076-13 ed1.0 (2006-05)	Part 13: Self-protected liquid-filled transformers
IEC 60076-14 (2013-09)	Part 14: Design and application of liquid-immersed power transformers using high-temperature insulation materials
IEC/TS 60076-19 ed1.0 (2013-03)	Part 19: Rules for the determination of uncertainties in the measurement of losses in power transformers and reactors
IEC/TS 60076-20 ed1.0	Energy efficiency
IEC 60137 (2008)	Insulated bushings for alternating voltages above 1000 V
IEC 60296 (2003)	Fluids for electro technical applications – Unused mineral insulating oils for transformers and switchgear

3. Definitions

Terms used in this specification refer to the definitions stated in IEC Standards.

For the purposes of the present specification:

- the word “shall” indicates (or is relevant to) a “mandatory requirement” for the supply;
- the word “should” indicates (or is relevant to) a “recommended requirement” for the supply.

4. General requirements

4.1. Units of measurement

The International System of Units (SI) shall be used.

4.2. Tolerances

IEC tolerances apply.

4.3. Document Priority

In case of discrepancies between provisions laid down in documentation, the priority that shall be applied is the following:

- Codes and Laws
- This technical specification
- Reference standards
- Manufacturer technical documentation.

4.4. Languages

The languages shall comply with the following table.

Table 10: Languages used

Document	Language
Drawings	English or local language.
Technical documents	English or local language.
Operative manual	English or local language.
Rating plate	See IEC 60076-1
Markings	--
Warning labels, inscriptions, etc.	--

4.5. Quality assurance

Transformers shall be manufactured according to a well-established quality assurance system that complies with ISO 9000 or equivalent national standard. The bid should include a valid ISO 9000 certificate.

4.6. Scope of supply

Supplier shall include in its scope the design, manufacturing, factory testing, delivery, installation, energizing and on-site performance testing.

4.7. Spare parts

Manufacturer to submit a list of recommended spare parts.

4.8. Warranty

The manufacturer shall provide a warranty against any defects and non-performance for 24 months from the date of receipt at the stores of the purchaser or in the event of a breakdown within the warranty period, the manufacturer shall immediately investigate, repair or replace the unit at no cost to the purchaser.

The outage period (the period from the date of failure until the unit is repaired or replaced) shall not be counted for deriving the guarantee period.

Unless otherwise agreed, all replacements shall be made within 30 working days from the first written notice otherwise the utility/customer reserves the right to the forfeit of the equipment performance guarantees and any relevant security.

5. Service Conditions

The following service conditions apply.

Table 11: General conditions

Description		Data/Information
Altitude		≤ 1000 m asl
Location		Outdoors
Air temperature	Maximum ambient air temperature (°C)	50 °C
	Maximum average monthly ambient air temperature (°C)	40 °C
	Maximum average yearly ambient air temperature (°C)	Not exceeding 20 °C
	Minimum ambient air temperature (°C)	Not below -25 °C
Relative Humidity (RH)	Maximum RH (%)	Not Specified
	Minimum RH (%)	Not specified
	Yearly average RH (%)	Not exceeding 98
Wave shape of supply voltage		A sinusoidal supply voltage with a total harmonic content not exceeding 5 % and an even harmonic content not exceeding 1 %.
Load current harmonic content		Total harmonic content of the load current not exceeding 5 % of rated current.

6. Design criteria and Ratings

The transformers shall comply with the following requirements.

Table 12: Main characteristics

Characteristic	Requirement
Type	Liquid immersed, hermetically sealed (bolted type)
Number of phases	3 or 1
Number of windings	Minimum 2 as applicable
Vector group	Dyn 11 or as applicable
Cooling	Naturally cooled

Table 13: Rated values

Rated value	UM	Requirement
Rated power	kVA	As applicable
Rated frequency	Hz	50 or 60
HV winding rated voltage	kV	As applicable
Highest voltage for the equipment HV (Um)	kV	As applicable
LV winding rated voltage	kV	As applicable
Highest voltage for the equipment LV (Um)	kV	As applicable
Voltage regulation	--	3 phase recommended OLTC 5 positions ±2 x 2.5% single no tapping
Short duration induced withstand voltage	kV	As applicable
Lightning impulse withstand voltage (LI)	kV	As applicable
Short circuit impedance	%	Recommended 4% or 6% or as applicable
Energy perfomance level (IEC 60076-20)	--	Level 2 - high energy performance
Maximum no load losses	W	See table 15
Maximum load losses	W	See **Error! Reference source not found.**
Sound level	dB(A)	IEC 60076-10
Temperature rise	K	IEC 60076-2
Overload	%	IEC 60076-7
Short-circuit apparent power	MVA	Infinite short-circuit apparent power

Table 14: Penalty factors for loss capitalization

Factor	UM	Value
A- No-load loss	($/kW)	10,697
B - Load loss	($/kW)	4,424

6.1. Type

Empty paragraph. See table 12.

6.2. Number of phases

Empty paragraph. See table 12.

6.3. Number of windings

Empty paragraph. See table 12.

6.4. Vector group

Empty paragraph. See **Error! Reference source not found.**.

6.5. Cooling

Empty paragraph. See table 12.

6.6. Rated power

Transformer shall be capable of supplying its rated power (kVA) as defined in IEC 60076-1.

6.7. Rated frequency

Empty paragraph. See table 13.

6.8. HV winding rated voltage

Empty paragraph. See table 13.

6.9. Highest voltages for equipment for winding with *U*m > 1,1 kV

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

6.10. LV winding rated voltage

Empty paragraph. See table 13.

6.11. Highest voltages for equipment for winding with *U*m ≤ 1,1 kV

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

6.12. Voltage regulation

Each transformer shall be fitted with a tap changer for voltage variation as specified in table 13.

Tap changing shall be done in de-energised condition. An externally operated self-positioning tapping switch shall be provided.

Provision shall be made for locking the tapping switch handle in required position.

Tap changer shall meet the requirements of the following standard

- IEC 60214-1 ed1.0 (2003-02) - Tap-changers - Part 1: Performance requirements and test methods
- IEC 60214-2 ed1.0 (2004-10) - Tap-changers - Part 2: Application guide

- IEC/TR 60616 ed1.0 (1978-01) - Terminal and tapping markings for power transformers

6.13. Short duration induced withstand voltage

Empty paragraph. See table 13.

6.14. Short circuit impedance

Empty paragraph. See table 13.

6.15. Lightning impulse withstand voltage (LI)

Empty paragraph. See table 13.

6.16. Short circuit impedance

Empty paragraph. See table 13.

6.17. Energy performance level

Energy performance level is given in accordance with IEC 60076-20. This specification is based on Maximum load losses and maximum no-load losses.

6.18. Maximum losses

Each unit shall comply with the maximum allowed load and no-load losses values set out in the following tables.

If not otherwise specified, three phase or single phase transformers shall be evaluated against the rated power of the individual transformer.

Maximum allowable losses rated powers that fall in between the given values shall be obtained by linear interpolation.

Table 15: Liquid immersed power transformers – Maximum load losses (LL) and no-load losses (NL)

Single or three phase, 50 or 60 Hz 2 windings, MV Um≤24kV, LV Um ≤1.1kV, OLTC range ≤ 5%						
Rated Power	**Level 1**			**Level 2**		
IEC 60076-1	**LL**	**NL**	**EIA50**	**LL**	**NL**	**EIA50**
kVA	**W**	**W**	**%**	**W**	**W**	**%**
≤25	900	70	97,640	600	63	98,296
50	1100	90	98,540	750	81	98,926
100	1750	145	98,835	1250	130	99,115
160	2350	210	99,003	1750	189	99,217
250	3250	300	99,110	2350	270	99,314
315	3900	360	99,152	2800	324	99,350
400	4600	430	99,210	3250	387	99,400
500	5500	510	99,246	3900	459	99,426
630	6500	600	99,294	4600	540	99,463
800	8400	650	99,313	6000	585	99,479
1000	10500	770	99,321	7600	693	99,481
1250	11000	950	99,408	9500	855	99,483
1600	14000	1200	99,413	12000	1080	99,490
2000	18000	1450	99,405	15000	1305	99,495
2500	22000	1750	99,420	18500	1575	99,504
3150	27500	2200	99,424	23000	1980	99,509

The losses given in table 15 above can be weighted by the correction factors given in 16 below, in order to take account of variations related to the highest voltage for equipment values.

The level of losses given in table 15 above shall be weighted by the correction factors given in table 17 below, in order to take account of variations related to dual voltage windings.

For power transformers having dual voltage on both windings for which both voltages on one winding are fully rated in combination with one of the voltages on the other winding, the levels of losses shall be based on the highest power and the values indicated in table 15 above can be increased by 15 % for no load losses and by 10 % for load losses. The level of losses shall refer to the highest voltages of both windings. This remains valid even if further voltage combinations are available.

For a power transformer having an insulation level according to table 16 below and having dual voltage according to table 17 below the loss level shall take into account both corrections.

Table 16: Correction of load loss and no load loss applicable to other insulation levels

Ref	Highest voltage for equipment values	Correction of load loss and no load loss
1	One winding with 1,1 kV < U_m ≤ 24 kV and the other with 1,1 kV < U_m ≤ 24 kV	The maximum losses indicated in Table 9 and 10 can be increased by 10 % for no load loss and by 10 % for load loss.
2	One winding with 24 kV < U_m ≤ 36 kV and the other with U_m ≤ 1,1 kV	The maximum losses indicated in Table 9 and 10 can be increased by 15 % for no load loss and by 10 % for load loss and short circuit impedance unless otherwise specified should be increased by adding a value of 0,5 %.
3	One winding with 24 kV < U_m ≤ 36 kV and the other with U_m > 1,1 kV	The maximum levels of losses indicated in Table 9 and 10 can be increased by 20 % for no load loss and by 15 % for load loss and short circuit impedance unless otherwise specified should be increased by adding a value of 0,5 %.

Table 17: Correction of load loss and no load loss applicable to dual voltage

Ref	Dual voltage	Correction of load loss and no load loss
A	One winding	In the case of power transformers with one high-voltage winding and two voltages available from tapped low-voltage winding, losses shall be calculated based on the higher low-voltage and shall comply with the levels indicated in Table 9 and 10. The maximum available power on the lower low-voltage on such power transformers shall be no more than 0,85 times its rated power. In the case of power transformers with one high-voltage winding with two voltages available from a tap, the maximum available power on the lower high-voltage on such power transformer shall be limited to 0,85 of its nominal rated power. In the case where the full rated power is available regardless of the combination of voltages, the levels of losses indicated in Table 9 and 10 can be increased by 15 % for no load loss and by 10 % for load loss. Such levels of losses shall refer to the highest voltage.
B	Both windings	The maximum allowable losses indicated in Table 9 and 10 can be increased by 20 % for no load losses and by 20 % for load losses for power transformers with dual voltage on both windings if the rated power is the same regardless of the combination of voltages. The level of losses shall refer to the highest voltages of both windings. This remains valid even if further voltage combinations are available.

6.19. Sound level

- Transformers to be installed in close proximity to public facilities such as hospitals, schools, etc. shall be designed to keep the noise level within 58 to 68 decibels or less.
- The sound level shall be as per IEC 60076-10.

6.20. Temperature rise

Empty paragraph. See table 13.

6.21. Overload capacity

Transformer shall be capable of overloading as per the guidelines and limitations in IEC 60076-7.

6.22. Short circuit apparent power

The short circuit apparent power the transformer shall be able to withstand the thermal and dynamic effects of a short circuit in accordance with IEC 60076-1 and IEC 60076-5.

6.23. Penalties

Supplier shall guarantee the load and no-load losses individually. Individual transformers with losses beyond the guarantee values plus positive tolerances shall be rejected.

When the average losses of all transformers of the same rated power exceed the guarantee value but remain within tolerance, the penalty will be as follows:

- No-load loss: A / kW X Number of transformers
- Load loss: B / kW X Number of transformers

The maximum value of the transformer shall be used to calculate tolerance limits relating to higher guarantee value. In this case, the supplier shall bear all the calculated penalties. Penalties are to be calculated over a period of 20 years.

6.24. Overall dimensions

Empty paragraph.

7. Construction and Material Requirements

7.1. Core

The main characteristics required for the core are listed in the following table:

Table 18: Main core characteristics

Core material	High permeability silicon steel having low loss and good grain properties coated with hot oil proof insulation
Type of core	Wound core / stacked core
Maximum flux density	not exceed 1.65 T when a transformer is connected to centre tap and operating at normal voltage and frequency
Over fluxing	up to 12.5% without injurious heating at full load conditions and not getting saturated

It will be firmly fixed to the tank and designed to avoid core strips becoming loose due to vibrations during transportation and handling.

Adequate cooling facilities shall also be provided at the oil ducts.

The core and coil assembly shall have the core and coils rigidly connected to the tank and suitable closed lugs shall be provided for removing the core and coil assembly from the tank.

Design of the core must ensure the permanency of the core loss considering the continuous working requirement of power transformers.

The bidder shall offer the core for inspection and approval by the purchaser during manufacturing.

7.2. Windings

The main characteristics required for the windings are listed in the following table:

Table 19: Main winding characteristics

Winding material	The HV and LV windings shall be super enamel covered/double paper covered high conductivity copper
Type of winding	LV elical/layer/Foil HV layer crossed
Current density	Less than 2.8 Ampere per sq. mm for copper

The windings shall be designed to withstand thermal and mechanical effects caused by external short circuits.
The winding clamping arrangement and clamping rings shall be designed to withstand forces due to short circuit.

The windings shall be designed and assembled to handle temperature increase specified in the tender specification.
The insulation of winding and connections shall not be likely to soften, loose, shrink or collapse during service.
The neutral formation will be at the top (LV windings).
Winding construction: Single HV coil wound over LV coil.
Proper bonding of the inner layer of insulation with the copper conductor shall be ensured.

7.3. Bushings and terminals

The main characteristics required for bushings and terminals are listed in the following table:

Table 20: Main bushing characteristics

Reference standards	IEC 60137, DIN 42530 and DIN 42531
Creepage distances	not less than 25 mm/kV for the maximum phase to phase system voltage

Bushings and terminals shall be designed and constructed to facilitate smooth installation, monitoring and maintenance of a transformer. Bushings shall be installed so that these are easy to check and remove without removing the tank cover and piping.

To maintain current integrity, the connectors shall be made with solderless tin-plated copper.

Two belleville spring washers, corn-disk types shall be supplied to provide adequate pressure on the conductor during thermal cycling.

The size of LV and HV terminals shall be according to the transformer's capacity rating.

The bushing cover shall be made of ultra-violet radiation resistance and track resistant plastic or rubber to protect equipment from potential impairments by external objects, such as birds, squirrels, snakes, etc.

All bushings shall be designed to avoid excessive stressing of any parts due to temperature changes. Adequate means shall be provided to accommodate conductor expansion.

The insulation levels for bushings shall be at least equal to those specified for the windings.

Both HV and LV bushings shall be complete with brass terminals suitable for copper conductors according to transformer rating.

7.4. Insulating liquid

Transformers shall be supplied with:

- Mineral oil or
- Natural Ester Less-Flammable Transformer Dielectric Coolant

Insulating liquid shall not contain polychlorinated biphenyls (PCB).

Use of recycled liquids is not allowed.

7.4.1. Mineral oil

Mineral oil shall conform to IEC 60296. Mineral oil should be filtered and tested with a dielectric strength not less than 30 kV before filling the transformer tank. Test method shall comply with IEC 60156.

The manufacturer shall submit detailed specifications of the proposed oil.

7.4.2. Natural Ester Less-Flammable Transformer Dielectric Coolant

The dielectric coolant shall meet or exceed all acceptance limits outlined in IEC 62770. The fluid shall also be biobased and readily biodegradable, be Factory Mutual Global Approved less flammable fluid, and be UL® Classified EOVK transformer fluid. The fluid shall meet the property limits listed in tables 21 and 22 below. The base fluid shall be 100% derived from seed oils. The fluid shall have published Dissolved Gas data by either IEC or IEEE.

The manufacturer shall provide AC and lightning impulse breakdown and withstand curves for both fluid gap and insulation creep interfaces from 3mm to 150 mm and 3 mm to 35mm respectively.

The fluid shall meet the following test limits:

Table 21: Natural ester main characteristics

Property	Specification Limits	Test Method
Aquatic Biodegradation [%]	>99	EPA OPPTS 835.3100
Ready Biodegradation [%]	>99	EPA OPPTS 835.3110 (ii) or OECD 301 B, C or F
Acute Aquatic Toxicity	Non-toxic	OECD 203
Acute Oral Toxicity	Non-toxic	OECD 420
Bio-based material content	>95%	P3***

* Per OECD 203 Method B and OECD 420

** Per US PA OPPTS 835.3100 and US EPA OPPTS 835.8110 (ii)

*** Per OECD Sustainable Manufacturing Indicator P3 – Renewable materials content of products 2011

Table 22: Natural ester properties (IEC 62770 "Specification for unused natural esters for transformers and similar equipment")

Property	Ref. Test Standard	Value
Physical		
Flash Point PMCC (°C)	ISO 2719	≥ 250
Fire Point (°C)	ISO 2592	> 300
Pour Point (°C)	ISO 3016	≤ -10
Density at 20 °C (g/ml)	ISO 3675	≤ -1
Viscosity (mm/sec)	ISO 3104	
100°C		≤ 15
40°C		≤ 50
Visual Examination	IEC61099 9.2	Clear, free from sediment and suspended matter
Biodegradation	OECD 301C,B,F	Readily biodegradable
Electrical		
Dielectric Breakdown (kV)	IEC 60156	
2.5mm gap		≥ 35
Dissipation Factor (%)	IEC 60247	
(tan delta) 90 °C		≤ 0,05
Chemical		
Corrosive Sulfur	IEC 62697	non-corrosive
Water Content (mg/kg)	IEC 60814	≤ 200
Acid Number(mg KOH/g)	IEC 62021.3	≤ 0,06
PCB Content (ppm)	IEC 61619	Free from PCB's
Performance after oxidation stability test in accordance with IEC 61125C 1		
Total acidity (mg KOH/g)	IEC 62021.3	≤ 0,06
Viscosity at 40°C(mm2/sec)	ISO 3104	≤ 30 % increase over the initial value
Dissipation Factor at 90°C (tan delta)	IEC 60247	≤ 0,5
Note - oxidation tested per IEC 61125C for 48 hours at 120°C		

7.5. Tank and cover

The main characteristics required for tank and cover are listed in the following table.

Table 23: Tank and cover main characteristics

Tank walls/bottom/top thickness	No requirements
Type of wall	No requirements
Tank walls coating thickness	The external protective coating must be realized by means of the following treatments: · A base coat; · Any intermediate coat; · A coat to finish. The thickness of the bottom will be equal to 80 µm ± 10% and the thickness of the coat to finish it will be equal to 80 µm ± 10%. The total thickness of the cycle, measured after 48 hours from the application of the finishing coat, must be equal to 160 µm ± 10%.
Tank material	Mild steel
Testing standard	IEC 60076 / IEC 60071-1

Inside to be painted with varnish /hot oil resistant paint.

Rust-preventive finishing shall be provided.

The tank shall be of rigid construction, leak-free and shall be designed so that the complete transformer can be lifted and transported without permanent deformation or oil leakage.

No bulging of the tank is allowed during service.

Transformer tank and cover shall be designed to avoid any external pockets for water or dust deposits.

Tank cover shall be bolted type and fitted with neoprene bonded cork seals suitable for temperatures as per this specification.

The cooling surface shall be oil-filled fins or radiators. Cooling surfaces shall be attached to the larger face of the transformer.

All pipes and radiators, which are welded to the tank wall, shall be welded externally.

Colour of tank shall be as per utility's/customer's preferred colour choice.

7.6. Transformer nameplate

According to IEC 60067-1, transformers should be provided with a rating plate of weather-proof material, which should be fitted in a visible and accessible location. The plates should include the following details with legible and indelible markings:

- Kind of transformer (for example transformer, auto-transformer, series transformer, etc.).
- Number of this standard.
- Manufacturer's name, country and town where the transformer was assembled.
- Manufacturer's serial number.
- Year of manufacture.
- Number of phases.
- 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.)
- Rated frequency (in Hz).
- Rated voltages (in V or kV) and tapping range.
- Rated currents (in A or kA).
- Connection and phase displacement symbol.
- 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.
- 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 %).
- Total mass.
- Mass and type of insulating liquid with reference to the relevant IEC standard.
- Maximum system short-circuit power or current used to determine the transformer withstand capability if not infinite.
- Energy perfomance level (IEC 60076-20)
- Maximum load losses (in W, kW)
- Maximum no load losses (in W, kW)

7.7. Accessories

Tank shall be fitted with the following attachments and fittings according with IEC 60076-1 IEC 60076-22 series, IEC 60214 series and EN 50216 series:

- Tap changer (off-circuit with pad lockable switch)
- HV bushing assemble
- LV bushings assembly
- Oil filling and drain valves

- Main earthing terminal
- Lifting eyes, pulling eyes and jacking pads
- Pressure relief valve
- Protection irons
- Oil level indicator
- Terminal markings

All gaskets shall be able to withstand hot liquid of extremely high temperatures and have a lifespan of more 20 years.

To protect the transformer from damage by lightning strike, the transformer cover should have provision to install three lightning arrestors.

8. Factory Inspection and Testing

The bidder shall submit a detailed Inspection and Test Plan (ITP) with an overview of the manufacturing process, and all the inspections and tests.

The customer reserves the right to witness any tests at the manufacturer's works and to conduct production process and in-process inspections in accordance with the following sections:

8.1. Factory Acceptance Tests (FAT)

All transformers shall be:

- fully routine tested
- type tested
- special tested

as per the relevant IEC and other applicable standards and as shown in the following sections. All the tests shall be conducted in accordance with IEC 60076 and other applicable standards. Test certificates and records of all tests shall be submitted for purchaser's review before despatch of transformers.

The routine and type testing of 10% of transformers (minimum of one) or sample size as per the following table may be witnessed by the purchaser at the manufacturer's works.

Table 24: Factory Acceptance Tests

Number of transformers per lot (Unit)	Sample size of transformers for acceptance test (Unit)	Maximum number of samples failing in the acceptance test (Unit)
2 to 15	2	0
16 to 25	3	0
26 to 90	5	0
91 to 150	8	0
151 to 500	13	1
More than 500	20	1

The FAT shall be carried out as per an approved FAT protocol.

8.1.1. Routine tests

Routine tests shall be carried out on all units.

The following routine tests shall be carried out:

- Measurement of winding resistance
- Measurement of voltage ratio and check of phase displacement
- Measurement of short-circuit impedance
- Measurement of load losses
- Measurement of no-load losses and no-load current
- Dielectric routine tests
- Leak testing with pressure for oil-immersed transformers (tightness test)
- Check of the ratio and polarity of built-in current transformers
- Check of core and frame insulation for oil-immersed transformers with core or frame insulation

8.1.2. Type tests

The following type tests shall be carried out:

- Temperature-rise test
- Dielectric type tests
- Determination of sound level
- Measurement of power taken by fan and liquid pump motors
- Measurement of no-load loss and current at 90% and 110% of rated voltage

8.1.3. Special tests

The special tests shall be carried out by agreement between purchaser and manufacturer.

8.2. Production process and in-process inspections

The manufacturer should provide the utility/customer with an overview of the complete manufacturing process plan along with the clear plan for inspections. The inspections can fall into three categories:

4. Witnessed by the manufacturer's internal quality control team with documentary results not to be reviewed by the purchaser's factory inspection team.
5. Witnessed by the manufacturer's internal quality control team with documentary results to be reviewed by the purchaser's factory inspection team.
6. Jointly witnessed by the manufacturer's quality control team and the purchaser's inspection team.

The results of all the tests should be recorded in pre-determined formats and available for purchaser's review and acceptance.

9. Transportation, Receipt and SITE Testing

The manufacturer shall be responsible to provide the loading of vehicles. This applies even in the case where transports are made using vehicles belonging to the purchaser. More information may be given in other specific documents.

The transformers shall be delivered without any packing/ or packing included to be agreed.

The purchaser reserves the right to conduct all tests on a sample of transformers after their receipt on site.

The site acceptance tests (SAT) shall be carried out to an approved SAT protocol.

10. Documentation requirements

Documents/drawings required with the bid are:

- Dimensional drawings of proposed transformers
- Bill of materials (BOM)
- Inspection and Test Plan (ITP)
- Organisational chart with contact details of key responsible persons
- Quality assurance plan
- Schedule of manufacturing and inspection
- Details of manufacturing and testing facilities
- Completed schedules as specified in this specification
- Submittals required after award of contract

All required documents are to be submitted electronically by the bidder to the purchaser according with the following table.

Table 25: Required documents

S. No.	Description	Submission Time	Objective
1	Schedule for production	Within two weeks of award of contract	Approval
2	Inspection and testing plan with a list, description and methods of all tests to be performed		Approval
3	Design drawings – General arrangement drawings, component drawings, assembly drawings, mounting arrangements, etc.	Within three weeks of award of contract	Approval
4	Technical data sheets		Approval
5	Material catalogues and certificates		Approval
6	Test reports of all routine, type and special tests	Progressively and immediately after completion of tests	Approval
7	As-built drawings, technical data sheets, and material catalogues and certificates	One month before delivery	Approval
8	Installation and commissioning instructions		
9	Operating and maintenance manual		
10	Spare parts list		
11	Warranty certificate		

11. Informative and guaranteed values

Bidders shall submit the following forms duly filled with the bid.

Table 26: Technical data

S. No.	Description	Unit	Information / Data
1	International standards transformer complies with	NA	
2	Nominal frequency	Hz	
3	Rated power	kVA	
4	Nominal primary voltage	kV	
5	Nominal secondary voltage	V	
6	Rated primary voltage	kV	
7	Rated secondary voltage	V	

S. No.	Description		Unit	Information / Data
8	Type of cooling		NA	
9	Vector group		NA	
10	Tap changing	Number of steps	± steps	
		Tapping range	± %	
11	Rated short circuit current and withstanding duration	Current	kA	
		Duration	s	
12	Impedance measured at 75°C and centre tap		%	
13	X/R ratio		NA	
14	Duration of overload	25% overload	°C	
			minutes	
		50% overload	°C	
			minutes	
15	Design maximum outdoor temperature		°C	
16	Design continuous ambient temperature		°C	
17	Thermal characteristics	Avg. winding temp. rise	°C	
		Max. avg. temp. rise	°C	
		Max. hot spot temp. rise	°C	
		Hot-spot to top-oil temp. gradient	°C	
18	Magnetic flux density		Tesla	
19	No load losses		W	
20	Load losses		W	
21	No load current		A	
22	Regulation: full load	PF=1	%	
		PF=0.85	%	
23	Silicon steel	Manufacturer	NA	
		Type and grade	NA	
		Operating flux density	Tesla	
		Losses at operating flux density	kW/kg	
		Manufacturer's data sheet supplied	Yes/No	
24	Conductor for HV windings	Manufacturer/Supplier and type	NA	
		Conductor material	NA	
		Shape and cross section area	NA	
25	Conductor for LV windings	Manufacturer and type	NA	
		Conductor material	NA	

S. No.	Description		Unit	Information / Data
		Shape and cross section area	NA	
26	HV Bushing	Manufacturer/Supplier	NA	
		Type and grade	NA	
		Bushing catalogue number	NA	
27	LV Bushing	Manufacturer/Supplier	NA	
		Type and grade	NA	
		Bushing catalogue number	NA	
28	Bushing basic impulse level	HV Bushing	kV	
29	Bushing power frequency withstand voltage	HV Bushing	kV	
		LV Bushing	kV	
30	Terminals	Type and metal used in HV terminal	NA	
		Type and metal used in LV terminal	NA	
		Type and metal used in earth terminal	NA	
31	Minimum phase to phase clearance		mm	
32	Minimum phase to earth clearance		mm	
33	Spring and lock washers included		Yes/no	
34	Tap changer	Manufacturer/Supplier		
		Type		
		Catalogue details attached	Yes/No	
		Manufacturer's data sheet attached	Yes/No	
35	Can tap changer switch be locked		Yes/No	
36	Tank fabrication	Tank material	NA	
		Thickness of metal sheet	mm	
		Painting method details attached	Yes/No	
37	Tank dimensions	Width	mm	
		Height	mm	
		Depth	mm	
38	Transformer weights	Weight- core and windings	kg	
		Weight – tank	kg	

S. No.	Description		Unit	Information / Data
		Weight of oil at 20 °C	kg	
		Total weight of transformer	kg	
		Shipping weight of transformer	kg	

Note: Mention NA if a particular item is not applicable.

Table 27: Non-compliance with this specification. Each non-compliance shall refer to a specific clause in the specifications.

S. No.	Clause No.	Non-Compliance	Alternative Proposal

MODEL LIQUID IMMERSED DISTRIBUTION TRANSFORMER TECHNICAL SPECIFICATION

ANNEX C

TRANSFORMERS RATED ACCORDING WITH IEEE PRACTICES

U4E United for Efficiency

IEEE PES Power & Energy Society®

gef

Foreword

This model regulation is a supplement to the UN Environment United for Efficiency (U4E) Transformers Policy Guide "Accelerating the Global Adoption of Energy-Efficient Transformers."[9] It is intended for use by liquid immersed distribution transformer purchasers in developing and emerging economies[10] with 50 – 60 Hz power.

This model technical standard is a supplement to the Transformer Policy Guide[1] which is one of a series of United for Efficiency reports along with lighting, room air conditioners, residential refrigerators, and electric motors. As is described further in the Transformers Policy Guide, United for Efficiency encourages countries to implement an integrated policy approach, which includes the following components:

- Standards and regulations;
- Supporting policies (e.g. communication campaigns);
- Finance and financial delivery mechanisms;
- Monitoring, verification, and enforcement; and
- Environmentally sound management.

Please visit http://united4efficiency.org/ for more information about United for Efficiency.

For more information about this document or other energy-efficient transformer related topic, contact:

UN Environment - United for Efficiency
Economy Division
Energy and Climate Branch
1 Rue Miollis, Building VII
75015, Paris
FRANCE
Tel: +33 (0)1 44 37 14 50
Fax: +33 (0)1 44 37 14 74
E-mail: u4e@unep.org
http://united4efficiency.org/

[9] Please visit the "United for Efficiency Policy Guide on Energy-Efficient Transformers" for more information. (https://united4efficiency.org/resources/accelerating-global-adoption-energy-efficient-transformers/)

[10] This model regulation is not intended for governments that already have effective regulations and policy processes for energy-efficient transformers in their country or region.

1. Scope

The scope of this document is to provide minimum technical requirements for the supply of MV/LV distribution power transformers liquid-immersed transformers

This document is applicable for liquid immersed transformer, three-phase, bi-phase and single phase for indoor, outdoor, pole mounted and inbox installation.

2. Reference Laws and Standards

The relevant lists of reference laws and standards to be complied with are provided below

The transformers should comply with the latest editions of the following IEEE publications:

Table 28: List of Standards for IEEE power transformer standards (May 2016)

Standard	Title
IEEE C57.12.90 (2015)	Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.00 (2015)	IEEE Standard for General Requirements for Liquid-Immersed Distribution, Power, and Regulating Transformers
IEEE C57.12.10 (2010)	IEEE Standard Requirements for Liquid-Immersed Power Transformers
IEEE C57.12.20 (2011)	IEEE Standard for Overhead-Type Distribution Transformers 500 kVA and Smaller: High Voltage, 34 500 V and Below; Low Voltage, 7970/13 800Y V and Below
IEEE C57.12.40 (2011)	IEEE Standard for Network, Three-Phase Transformers, 2500 kVA and Smaller; High Voltage, 34 500 GrdY/19 920 and Below; Low Voltage, 600 V and Below; Subway and Vault Types (Liquid Immersed)

3. Definitions

Terms used in this specification refer to the definitions stated in IEEE Standards.

For the purposes of the present specification:

- the word “shall” indicates (or is relevant to) a “mandatory requirement” for the supply;
- the word “should” indicates (or is relevant to) a “recommended requirement” for the supply.

4. General requirements

4.1. Units of measurement

The International System of Units (SI) shall be used.

4.2. Tolerances

IEEE tolerances apply.

4.3. Document Priority

In case of discrepancies between provisions laid down in documentation, the priority that shall be applied is the following:

- Codes and Laws
- This technical specification
- Reference standards
- Manufacturer technical documentation.

4.4. Languages

The languages shall comply with the following table.

Table 29: Languages used

Document	Language
Drawings	English or local language.
Technical documents	English or local language.
Operative manual	English or local language.
Rating plate	See IEEE C57.12
Markings	--
Warning labels, inscriptions, etc.	--

4.5. Quality assurance

Transformers shall be manufactured according to a well-established quality assurance system that complies with ISO 9000 or equivalent national standard. The bid should include a valid ISO 9000 certificate.

4.6. Scope of supply

Supplier shall include in its scope the design, manufacturing, factory testing, delivery, installation, energizing and on-site performance testing.

4.7. Spare parts

Manufacturer to submit a list of recommended spare parts.

4.8. Warranty

The manufacturer shall provide a warranty against any defects and non-performance for 24 months from the date of receipt at the stores of the purchaser or in the event of a breakdown within the warranty period, the manufacturer shall immediately investigate, repair or replace the unit at no cost to the purchaser.

The outage period (the period from the date of failure until the unit is repaired or replaced) shall not be counted for deriving the guarantee period.

Unless otherwise agreed, all replacements shall be made within 30 working days from the first written notice otherwise the utility/customer reserves the right to the forfeit of the equipment performance guarantees and any relevant security.

5. Service Conditions

The following service conditions apply.

Table 30: General conditions

Description		**Data/Information**
Altitude		≤ 1000 m asl
Location		Outdoors
Air temperature	Maximum ambient air temperature (°C)	50 °C
	Maximum average monthly ambient air temperature (°C)	40 °C
	Maximum average yearly ambient air temperature (°C)	Not exceeding 20 °C
	Minimum ambient air temperature (°C)	Not below -25 °C
Relative Humidity (RH)	Maximum RH (%)	Not Specified
	Minimum RH (%)	Not specified
	Yearly average RH (%)	Not exceeding 98
Wave shape of supply voltage		**A sinusoidal supply voltage with a total harmonic content not exceeding 5 % and an even harmonic content not exceeding 1 %.**
Load current harmonic content		Total harmonic content of the load current not exceeding 5 % of rated current.

6. Design criteria and Ratings

The transformers shall comply with the following requirements.

Table 31: Main characteristics

Characteristic	Requirement
Type	Liquid immersed, hermetically sealed (bolted type)
Number of phases	3 or 1
Number of windings	Minimum 2 as applicable
Vector group	Dyn 11 or as applicable
Cooling	Naturally cooled

Table 32: Rated values

Rated value	UM	Requirement
Rated power	kVA	As applicable
Rated frequency	Hz	50 or 60
HV winding rated voltage	kV	As applicable
Highest voltage for the equipment HV (Um)	kV	As applicable
LV winding rated voltage	kV	As applicable
Highest voltage for the equipment LV (Um)	kV	As applicable
Voltage regulation	--	3 phase recommended OLTC 5 positions ±2 x 2.5% single no tapping
Short duration induced withstand voltage	kV	As applicable
Lightning impulse withstand voltage (LI)	kV	As applicable
Short circuit impedance	%	Recommended 4% or 6% or as applicable
Energy perfomance level (IEC 60076-20)	--	Level 2 - high energy performance
Maximum no load losses	W	See Table 34
Maximum load losses	W	See **Error! Reference source not found.**
Sound level	dB(A)	IEC 60076-10
Temperature rise	K	IEC 60076-2
Overload	%	IEC 60076-7
Short-circuit apparent power	MVA	Infinite short-circuit apparent power

Table 33: Penalty factors for loss capitalization

Factor	UM	Value
A- No-load loss	($/kW)	10,697
B - Load loss	($/kW)	4,424

6.1. Type

Empty paragraph. See table 31.

6.2. Number of phases

Empty paragraph. See table 31.

6.3. Number of windings

Empty paragraph. See table 31.

6.4. Vector group

Empty paragraph. See table 31.

6.5. Cooling

Empty paragraph. See table 31.

6.6. Rated power

Transformer shall be capable of supplying its rated power (kVA) as defined in IEEE C57.12.80 and IEC 60076-1.

6.7. Rated frequency

Empty paragraph. See table 32.

6.8. HV winding rated voltage

Empty paragraph. See table 32.

6.9. Highest voltages for equipment for winding with Um > 1,1 kV

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

6.10. LV winding rated voltage

Empty paragraph. See table 32.

6.11. Highest voltages for equipment for winding with Um ≤ 1,1 kV

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

6.12. Voltage regulation

Each transformer shall be fitted with a tap changer for voltage variation as specified in table 32.

Tap changing shall be done in de-energised condition. An externally operated self-positioning tapping switch shall be provided.

Provision shall be made for locking the tapping switch handle in required position.

Tap changer shall meet the requirements of the following standard

- IEC 60214-1 ed1.0 (2003-02) - Tap-changers - Part 1: Performance requirements and test methods
- IEC 60214-2 ed1.0 (2004-10) - Tap-changers - Part 2: Application guide
- IEC/TR 60616 ed1.0 (1978-01) - Terminal and tapping markings for power transformers

6.13. Short duration induced withstand voltage

Empty paragraph. See table 32.

6.14. Short circuit impedance

Empty paragraph. See table 32.

6.15. Lightning impulse withstand voltage (LI)

Empty paragraph. See table 32.

6.16. Short circuit impedance

Empty paragraph. See table 32.

6.17. Energy performance level

Energy performance level is given in accordance with IEC 60076-20. This specification is based on Maximum load losses and maximum no-load losses.

6.18. Maximum losses

Each unit shall comply with the maximum allowed load and no-load losses values set out in the following tables (preferred). Alternatively, each unit shall comply with the minimum allowed EIB50 values set out in the following tables.
If not otherwise specified, three phase or single phase transformers shall be evaluated against the rated power of the individual transformer.

Table 34: Liquid immersed power transformers – Maximum load losses (LL) and no-load losses (NL). Maximum allowable losses rated powers that fall in between the given values shall be obtained by linear interpolation.

Single or three phase, 50 Hz 2 windings						
Rated Power	**Level 1**			**Level 2**		
IEEE C57.12.80	**LL**	**NL**	**EIB50**	**LL**	**NL**	**EIB50**
kVA	**W**	**W**	**%**	**W**	**W**	**%**
≤25	563	140	97,849	411	102	98,429
50	703	175	98,657	521	130	99,004
100	1125	281	98,925	860	215	99,178
160	1544	386	99,078	1221	305	99,271
250	2159	539	99,175	1675	418	99,36
315	2592	648	99,214	1998	499	99,394
400	3070	767	99,267	2345	586	99,44
500	3664	916	99,3	2806	701	99,464
630	4327	1081	99,344	3305	826	99,499
800	5327	1331	99,364	4062	1015	99,515
1000	6575	1643	99,372	5047	1261	99,518
1250	7185	1796	99,451	6282	1570	99,52
1600	9130	2282	99,455	7941	1985	99,526
2000	11539	2884	99,449	9842	2460	99,53
2500	14057	3514	99,463	12068	3017	99,539
3150	17613	4403	99,466	15040	3760	99,544

Single phase 60 Hz 2 windings						
Rated Power	**Level 1**			**Level 2**		
IEEE C57.12.80	**LL**	**NL**	**EIB50**	**LL**	**NL**	**EIB50**
kVA	**W**	**W**	**%**	**W**	**W**	**%**
≤10	137	34	98,62	130	32	98,7
15	185	46	98,76	177	44	98,82
25	272	68	98,91	262	65	98,95
37,5	371	92	99,01	356	89	99,05
50	459	115	99,08	445	111	99,11
75	622	155	99,17	607	151	99,19
100	769	192	99,23	749	187	99,25
167	1252	313	99,25	1118	279	99,33
250	1700	425	99,32	1525	381	99,39
333	2131	532	99,36	1898	474	99,43
500	2900	725	99,42	2550	637	99,49
667	3601	900	99,46	3201	800	99,52
833	4248	1062	99,49	3748	937	99,55

Three phase 60 Hz 2 windings						
Rated Power	**Level 1**			**Level 2**		
IEEE C57.12.80	**NL**	**LL**	**EIB50**	**NL**	**LL**	**EIB50**
kVA	**W**	**W**	**%**	**W**	**W**	**%**
≤15	246	61	98,36	202	50	98,65
30	413	103	98,62	351	87	98,83
45	557	139	98,76	486	121	98,92
75	817	204	98,91	727	181	99,03
112,5	1113	278	99,01	1001	250	99,11
150	1380	344	99,08	1260	315	99,16
225	1867	466	99,17	1732	433	99,23
300	2309	577	99,23	2190	547	99,27
500	3749	937	99,25	3250	812	99,35
750	5100	1275	99,32	4499	1124	99,4
1000	6399	1599	99,36	5699	1424	99,43
1500	8700	2175	99,42	7799	1949	99,48
2000	10800	2700	99,46	9799	2449	99,51
2500	12750	3187	99,49	11750	2937	99,53

6.19. Sound level

- Transformers to be installed in close proximity to public facilities such as hospitals, schools, etc. shall be designed to keep noise level within 58 to 68 decibels or less.
- The sound level shall be as per IEC 60076-10.

6.20. Temperature rise

Empty paragraph. See table 32.

6.21. Overload capacity

Transformer shall be capable of overloading as per the guidelines and limitations in IEC 60076-7.

6.22. Short circuit apparent power

The short circuit apparent power the transformer shall be able to withstand the thermal and dynamic effects of a short circuit in accordance with IEC 60076-1 and IEC 60076-5.

6.23. Penalties

Supplier shall guarantee the load and no-load losses individually. Individual transformers with losses beyond the guarantee values plus positive tolerances shall be rejected.

When the average losses of all transformers of the same rated power exceed the guarantee value but remain within tolerance, the penalty will be as follows:

- No-load loss: A / kW X Number of transformers
- Load loss: B / kW X Number of transformers

The maximum value of the transformer shall be used to calculate tolerance limits relating to higher guarantee value. In this case, the supplier shall bear all the calculated penalties.

6.24. Overall dimensions

Empty paragraph.

7. Construction and Material Requirements

7.1. Core

The main characteristics required for the core are listed in the following table:

Table 35: Main core characteristics

Core material	High permeability silicon steel having low loss and good grain properties coated with hot oil proof insulation
Type of core	Wound core / stacked core
Maximum flux density	not exceed 1.65 T when a transformer is connected to centre tap and operating at normal voltage and frequency
Over fluxing	up to 12.5% without injurious heating at full load conditions and not getting saturated

It will be firmly fixed to the tank and designed to avoid core strips becoming loose due to vibrations during transportation and handling.

Adequate cooling facilities shall also be provided at the oil ducts.

The core and coil assembly shall have the core and coils rigidly connected to the tank and suitable closed lugs shall be provided for removing the core and coil assembly from the tank.

Design of the core must ensure the permanency of the core loss considering the continuous working requirement of power transformers.

The bidder shall offer the core for inspection and approval by the purchaser during manufacturing.

7.2. Windings

The main characteristics required for the windings are listed in the following table.

Table 36: Main winding characteristics

Winding material	The HV and LV windings shall be super enamel covered/double paper covered high conductivity copper
Type of winding	LV elical/layer/Foil HV layer crossed
Current density	Less than 2.8 Ampere per sq. mm for copper

The windings shall be designed to withstand thermal and mechanical effects caused by external short circuits.

The winding clamping arrangement and clamping rings shall be designed to withstand forces due to short circuit.

The windings shall be designed and assembled to handle temperature increase specified in the tender specification.

The insulation of winding and connections shall not be likely to soften, loose, shrink or collapse during service.

The neutral formation will be at the top (LV windings).

Winding construction: Single HV coil wound over LV coil.

Proper bonding of the inner layer of insulation with the copper conductor shall be ensured.

7.3. Bushings and terminals

The main characteristics required for bushings and terminals are listed in the following table:

Table 37: Main bushing characteristics

Reference standards	IEC 60137, DIN 42530 and DIN 42531
Creepage distances	not less than 25 mm/kV for the maximum phase to phase system voltage

Bushings and terminals shall be designed and constructed to facilitate smooth installation, monitoring and maintenance of a transformer. Bushings shall be installed so that these are easy to check and remove without removing the tank cover and piping.

To maintain current integrity, the connectors shall be made with solderless tin-plated copper.

Two belleville spring washers, corn-disk types shall be supplied to provide adequate pressure on the conductor during thermal cycling.

The size of LV and HV terminals shall be according to the transformer's capacity rating.

The bushing cover shall be made of ultra-violet radiation resistance and track resistant plastic or rubber to protect equipment from potential impairments by external objects, such as birds, squirrels, snakes, etc.

All bushings shall be designed to avoid excessive stressing of any parts due to temperature changes. Adequate means shall be provided to accommodate conductor expansion.

The insulation levels for bushings shall be at least equal to those specified for the windings.

Both HV and LV bushings shall be complete with brass terminals suitable for copper conductors according to transformer rating.

7.4. Insulating liquid

Transformers shall be supplied with:

- Mineral oil or
- Natural Ester Less-Flammable Transformer Dielectric Coolant

Insulating liquid shall not contain polychlorinated biphenyls (PCB).

Use of recycled liquids is not allowed.

7.4.1. Mineral oil

Mineral oil shall conform to IEC 60296. Mineral oil should be filtered and tested with a dielectric strength not less than 30 kV before filling the transformer tank. Test method shall comply with IEC 60156.

The manufacturer shall submit detailed specifications of the proposed oil.

7.4.2. Natural Ester Less-Flammable Transformer Dielectric Coolant

The dielectric coolant shall meet or exceed all acceptance limits outlined in IEC 62770. The fluid shall also be biobased and readily biodegradable, be Factory Mutual Global Approved less flammable fluid, and be UL® Classified EOVK transformer fluid. The fluid shall meet the property limits listed in tables 38 and 39 below. The base fluid shall be 100% derived from seed oils. The fluid shall have published Dissolved Gas data by either IEC or IEEE.

The manufacturer shall provide AC and lightning impulse breakdown and withstand curves for both fluid gap and insulation creep interfaces from 3mm to 150 mm and 3 mm to 35mm respectively.

The fluid shall meet the following test limits:

Table 38: Natural ester main characteristics

Property	Specification Limits	Test Method
Aquatic Biodegradation [%]	>99	EPA OPPTS 835.3100
Ready Biodegradation [%]	>99	EPA OPPTS 835.3110 (ii) or OECD 301 B, C or F
Acute Aquatic Toxicity	Non-toxic	OECD 203
Acute Oral Toxicity	Non-toxic	OECD 420
Bio-based material content	>95%	P3***

* Per OECD 203 Method B and OECD 420

** Per US PA OPPTS 835.3100 and US EPA OPPTS 835.8110 (ii)

*** Per OECD Sustainable Manufacturing Indicator P3 – Renewable materials content of products 2011

Table 39: Natural ester properties (IEC 62770 "Specification for unused natural esters for transformers and similar equipment")

Property	Ref. Test Standard	Value
Physical		
Flash Point PMCC (°C)	ISO 2719	≥ 250
Fire Point (°C)	ISO 2592	> 300
Pour Point (°C)	ISO 3016	≤ -10
Density at 20 °C (g/ml)	ISO 3675	≤ -1
Viscosity (mm/sec)	ISO 3104	
100°C		≤ 15
40°C		≤ 50
Visual Examination	IEC61099 9.2	Clear, free from sediment and suspended matter
Biodegradation	OECD 301C,B,F	Readily biodegradable
Electrical		
Dielectric Breakdown (kV)	IEC 60156	
2.5mm gap		≥ 35
Dissipation Factor (%)	IEC 60247	
(tan delta) 90 °C		≤ 0,05
Chemical		
Corrosive Sulfur	IEC 62697	non-corrosive
Water Content (mg/kg)	IEC 60814	≤ 200
Acid Number(mg KOH/g)	IEC 62021.3	≤ 0,06
PCB Content (ppm)	IEC 61619	Free from PCB's
Performance after oxidation stability test in accordance with IEC 61125C 1		
Total acidity (mg KOH/g)	IEC 62021.3	≤ 0,06
Viscosity at 40°C(mm2/sec)	ISO 3104	≤ 30 % increase over the initial value
Dissipation Factor at 90°C (tan delta)	IEC 60247	≤ 0,5
Note - oxidation tested per IEC 61125C for 48 hours at 120°C		

7.5. Tank and cover

The main characteristics required for tank and cover are listed in the following table:

Table 40: Tank and cover main characteristics

Tank walls/bottom/top thickness	No requirements
Type of wall	No requirements
Tank walls coating thickness	The external protective coating must be realized by means of the following treatments: · A base coat; · Any intermediate coat; · A coat to finish. The thickness of the bottom will be equal to 80 µm ± 10% and the thickness of the coat to finish it will be equal to 80 µm ± 10%. The total thickness of the cycle, measured after 48 hours from the application of the finishing coat, must be equal to 160 µm ± 10%.
Tank material	Mild steel
Testing standard	IEC 60076 / IEC 60071-1

Inside to be painted with varnish /hot oil resistant paint.

Rust-preventive finishing shall be provided.

The tank shall be of rigid construction, leak-free and shall be designed so that the complete transformer can be lifted and transported without permanent deformation or oil leakage.

No bulging of the tank is allowed during service.

Transformer tank and cover shall be designed to avoid any external pockets for water or dust deposits.

Tank cover shall be bolted type and fitted with neoprene bonded cork seals suitable for temperatures as per this specification.

The cooling surface shall be oil-filled fins or radiators. Cooling surfaces shall be attached to the larger face of the transformer.

All pipes and radiators, which are welded to the tank wall, shall be welded externally.

Colour of tank shall be as per utility's/ customer's preferred colour choice.

7.6. Transformer nameplate

According to IEC 60067-1, transformers should be provided with a rating plate of weather-proof material, which should be fitted in a visible and accessible location. The plates should include the following details with legible and indelible markings:

- Kind of transformer (for example transformer, auto-transformer, series transformer, etc.).
- Number of this standard.
- Manufacturer's name, country and town where the transformer was assembled.
- Manufacturer's serial number.
- Year of manufacture.
- Number of phases.
- 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.)
- Rated frequency (in Hz).
- Rated voltages (in V or kV) and tapping range.
- Rated currents (in A or kA).
- Connection and phase displacement symbol.
- 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.
- 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 %).
- Total mass.
- Mass and type of insulating liquid with reference to the relevant IEC standard.
- Maximum system short-circuit power or current used to determine the transformer withstand capability if not infinite.
- Energy perfomance level (IEC 60076-20)
- Maximum load losses (in W, kW)
- Maximum no load losses (in W, kW)

7.7. Accessories

Tank shall be fitted with the following attachments and fittings according with IEC 60076-1 IEC 60076-22 series, IEC 60214 series and EN 50216 series:

- Tap changer (off-circuit with pad lockable switch)
- HV bushing assemble
- LV bushings assembly
- Oil filling and drain valves
- Main earthing terminal

- Lifting eyes, pulling eyes and jacking pads
- Pressure relief valve
- Protection irons
- Oil level indicator
- Terminal markings

All gaskets shall be able to withstand hot liquid of extremely high temperatures and have a lifespan of more 20 years.

To protect transformer from damage by lightning strike, the transformer cover should have provision to install three lightning arrestors.

8. Factory Inspection and Testing

The bidder shall submit a detailed Inspection and Test Plan (ITP) with an overview of the manufacturing process, and all the inspections and tests.

The customer reserves the right to witness any tests at the manufacturer's works and to conduct production process and in-process inspections according with the following sections:

8.1. Factory Acceptance Tests (FAT)

All transformers shall be:

- fully routine tested
- type tested
- special tested

as per the relevant IEC and other applicable standards and as shown in the following sections.

All the tests shall be conducted in accordance with IEC 60076 and other applicable standards.

Test certificates and records of all tests shall be submitted for purchaser's review before despatch of transformers.

The routine and type testing of 10% of transformers (minimum of one) or sample size as per the following table may be witnessed by the purchaser at the manufacturer's works.

Table 41: Factory Acceptance Tests

Number of transformers per lot (Unit)	Sample size of transformers for acceptance test (Unit)	Maximum number of samples failing in the acceptance test (Unit)
2 to 15	2	0
16 to 25	3	0
26 to 90	5	0
91 to 150	8	0
151 to 500	13	1
More than 500	20	1

The FAT shall be carried out as per an approved FAT protocol.

8.1.1. Routine tests

Routine tests shall be carried out on all units.
The following routine tests shall be carried out:

- Measurement of winding resistance
- Measurement of voltage ratio and check of phase displacement
- Measurement of short-circuit impedance
- Measurement of load losses
- Measurement of no-load losses and no-load current
- Dielectric routine tests
- Leak testing with pressure for oil-immersed transformers (tightness test)
- Check of the ratio and polarity of built-in current transformers
- Check of core and frame insulation for oil-immersed transformers with core or frame insulation

8.1.2. Type tests

The following type tests shall be carried out:

- Temperature-rise test
- Dielectric type tests
- Determination of sound level
- Measurement of power taken by fan and liquid pump motors
- Measurement of no-load loss and current at 90% and 110% of rated voltage

8.1.3. Special tests

The special tests shall be carried out by agreement between purchaser and manufacturer.

8.2. Production process and in-process inspections

The manufacturer should provide the utility/customer with an overview of the complete manufacturing process plan along with the clear plan for inspections. The inspections can fall into three categories:

7. Witnessed by the manufacturer's internal quality control team with documentary results not to be reviewed by the purchaser's factory inspection team.
8. Witnessed by the manufacturer's internal quality control team with documentary results to be reviewed by the purchaser's factory inspection team.
9. Jointly witnessed by the manufacturer's quality control team and the purchaser's inspection team.

The results of all the tests should be recorded in pre-determined formats and available for purchaser's review and acceptance.

9. Transportation, Receipt and SITE Testing

The manufacturer shall be responsible to provide the loading of vehicles. This applies even in the case where transports are made using vehicles belonging to the purchaser. More information may be given in other specific documents.

The transformers shall be delivered without any packing/ or packing included to be agreed.

The purchaser reserves the right to conduct all tests on a sample of transformers after their receipt on site.

The site acceptance tests (SAT) shall be carried out to an approved SAT protocol.

10. Documentation requirements

Documents/drawings required with the bid are:

- Dimensional drawings of proposed transformers
- Bill of materials (BOM)
- Inspection and Test Plan (ITP)
- Organisational chart with contact details of key responsible persons
- Quality assurance plan
- Schedule of manufacturing and inspection
- Details of manufacturing and testing facilities
- Completed schedules as specified in this specification
- Submittals required after award of contract

All required documents are to be submitted electronically by the bidder to the purchaser according with the following table.

Table 42: Required documents

S. No.	Description	Submission Time	Objective
1	Schedule for production	Within two weeks of award of contract	Approval
2	Inspection and testing plan with a list, description and methods of all tests to be performed		Approval
3	Design drawings – General arrangement drawings, component drawings, assembly drawings, mounting arrangements, etc.	Within three weeks of award of contract	Approval
4	Technical data sheets		Approval
5	Material catalogues and certificates		Approval
6	Test reports of all routine, type and special tests	Progressively and immediately after completion of tests	Approval
7	As-built drawings, technical data sheets, and material catalogues and certificates	One month before delivery	Approval
8	Installation and commissioning instructions		
9	Operating and maintenance manual		
10	Spare parts list		
11	Warranty certificate		

11. Informative and guaranteed values

Bidders shall submit the following forms duly filled with the bid.

Table 43: Technical data

S. No.	Description	Unit	Information / Data
1	International standards transformer complies with	NA	
2	Nominal frequency	Hz	
3	Rated power	kVA	
4	Nominal primary voltage	kV	
5	Nominal secondary voltage	V	
6	Rated primary voltage	kV	
7	Rated secondary voltage	V	
8	Type of cooling	NA	

S. No.	Description		Unit	Information / Data
9	Vector group		NA	
10	Tap changing	Number of steps	± steps	
		Tapping range	± %	
11	Rated short circuit current and withstanding duration	Current	kA	
		Duration	s	
12	Impedance measured at 75°C and centre tap		%	
13	X/R ratio		NA	
14	Duration of overload	25% overload	°C	
			minutes	
		50% overload	°C	
			minutes	
15	Design maximum outdoor temperature		°C	
16	Design continuous ambient temperature		°C	
17	Thermal characteristics	Avg. winding temp. rise	°C	
		Max. avg. temp. rise	°C	
		Max. hot spot temp. rise	°C	
		Hot-spot to top-oil temp. gradient	°C	
18	Magnetic flux density		Tesla	
19	No load losses		W	
20	Load losses		W	
21	No load current		A	
22	Regulation: full load	PF=1	%	
		PF=0.85	%	
23	Silicon steel	Manufacturer	NA	
		Type and grade	NA	
		Operating flux density	Tesla	
		Losses at operating flux density	kW/kg	
		Manufacturer's data sheet supplied	Yes/No	
24	Conductor for HV windings	Manufacturer/Supplier and type	NA	
		Conductor material	NA	
		Shape and cross section area	NA	
25	Conductor for LV windings	Manufacturer and type	NA	
		Conductor material	NA	
		Shape and cross section area	NA	
26	HV Bushing	Manufacturer/Supplier	NA	

S. No.	Description		Unit	Information / Data
		Type and grade	NA	
		Bushing catalogue number	NA	
27	LV Bushing	Manufacturer/Supplier	NA	
		Type and grade	NA	
		Bushing catalogue number	NA	
28	Bushing basic impulse level	HV Bushing	kV	
29	Bushing power frequency withstand voltage	HV Bushing	kV	
		LV Bushing	kV	
30	Terminals	Type and metal used in HV terminal	NA	
		Type and metal used in LV terminal	NA	
		Type and metal used in earth terminal	NA	
31	Minimum phase to phase clearance		mm	
32	Minimum phase to earth clearance		mm	
33	Spring and lock washers included		Yes/no	
34	Tap changer	Manufacturer/Supplier		
		Type		
		Catalogue details attached	Yes/No	
		Manufacturer's data sheet attached	Yes/No	
35	Can tap changer switch be locked		Yes/No	
36	Tank fabrication	Tank material	NA	
		Thickness of metal sheet	mm	
		Painting method details attached	Yes/No	
37	Tank dimensions	Width	mm	
		Height	mm	
		Depth	mm	
38	Transformer weights	Weight- core and windings	kg	
		Weight – tank	kg	
		Weight of oil at 20 °C	kg	
		Total weight of transformer	kg	

S. No.	Description		Unit	Information / Data
		Shipping weight of transformer	kg	

Note: Mention NA if a particular item is not applicable.

Table 44: Non-compliance with this specification. Each non-compliance shall refer to a specific clause in the specifications

S. No.	Clause No.	Non-Compliance	Alternative Proposal

UN environment

United Nations Environment Programme – Global Environment Facility | United for Efficiency (U4E)