A4. High-efficiency / low-loss transformers

Test standards for high-efficiency and low-loss transformers

High-efficiency and low-loss transformers

For this product group, the main standard is selected according to the product type. For products with the character of power transformers, IEC/EN 60076-1 is the main framework standard; IEC 60076-1 covers three-phase and single-phase power transformers. For dry-type power transformer products, IEC/EN 60076-11 is used; however, IEC 60076-11 applies to dry-type power transformers in which at least one winding operates above 1.1 kV, so for fully LV/LV products it should be evaluated together with the customer specification. For the energy efficiency declaration and efficiency index, IEC TS 60076-20 is a supporting reference; this technical specification proposes methods for the energy efficiency index and energy performance evaluation for transformers within the scope of IEC 60076-1.

1. Routine Tests

This section summarizes the basic test items recommended for post-production verification of loss, efficiency, impedance, regulation and guaranteed values in high-efficiency / low-loss products.

1

Basic transformer routine tests

Main standard	IEC/EN 60076-1; IEC/EN 60076-11 for dry-type power units; IEC/EN 61558-1 for LV safety-type products
Implementation / method standard	Routine test sequence according to IEC 60076-1, IEC 60076-11 or IEC 61558-1
Note for high-efficiency product	Winding resistance, ratio, connection group/phase check, insulation resistance, dielectric withstand, induced voltage, no-load/load measurements and visual-mechanical checks should be included in the basic FAT scope. In the OMSAN FAT procedure, these steps are listed as winding resistance, TTR, insulation, hipot, induced voltage, no-load loss, load loss and output check.

2

No-load loss measurement - P0

Main standard	IEC/EN 60076-1; IEC TS 60076-20 for energy performance
Implementation / method standard	IEC 60076-1 no-load loss measurement method; IEC 60076-19-1 for uncertainty
Note for high-efficiency product	This is one of the most critical sales and guarantee parameters for a high-efficiency transformer. Core loss should be compared with the guaranteed value. Instrument class, calibration date and measurement uncertainty should be included in the report. IEC 60076-19-1 defines procedures for evaluating the uncertainty affecting no-load and load loss measurements in routine tests.

3 No-load current measurement - I0

Main standard	IEC/EN 60076-1; IEC/EN 60076-11 for dry type
Implementation / method standard	IEC 60076-1 no-load test
Note for high-efficiency product	Measured at nominal voltage. If required, measurements at 90% / 100% / 110% voltage points are useful for showing the core saturation trend and the behavior of low-loss electrical steel. The OMSAN technical glossary states that magnetizing current rises rapidly and heating increases under core saturation.

4 No-load loss guarantee comparison

Main standard	IEC/EN 60076-1; IEC TS 60076-20; customer specification
Implementation / method standard	Comparison of the measured P0 value with the quotation/project guarantee table
Note for high-efficiency product	It is recommended to add the columns "Guaranteed P0 / Measured P0 / Deviation % / Pass-Fail" to the routine report. For low-loss products, not only the measurement but also the guarantee comparison is important for sales.

5 Load loss measurement - Pk / Pcu

Main standard	IEC/EN 60076-1; IEC/EN 60076-11 for dry type
Implementation / method standard	IEC 60076-1 short-circuit test; IEC 60076-19-1 for uncertainty
Note for high-efficiency product	Load loss is measured at nominal current, or under the measurement conditions permitted by the standard, and is reported after correction to the reference temperature. The OMSAN technical glossary states that load losses are the sum of copper losses and additional stray losses and increase approximately with the square of the current as load increases.

6 Load loss reference temperature correction

Main standard	IEC/EN 60076-1; IEC/EN 60076-11 for dry type
Implementation / method standard	IEC 60076-1 temperature correction rules; IEC 60076-19-1 for measurement uncertainty
Note for high-efficiency product	The report should not contain only the instantaneous measured loss; it should include the load loss corrected to the reference temperature. This enables comparability under different test environments.

7 Short-circuit impedance - Uk% / Z%

Main standard	IEC/EN 60076-1
Implementation / method standard	IEC 60076-1 short-circuit impedance measurement
Note for high-efficiency product	Efficiency is directly related to losses; however, Z% is also a critical parameter for voltage drop, short-circuit current and parallel operation. The OMSAN technical glossary states that impedance voltage limits short-circuit current and is a basic criterion in selecting parallel transformers.

8 Efficiency calculation verification

Main standard	IEC TS 60076-20; IEC/EN 60076-1
Implementation / method standard	Calculation from measured P0, Pk, load ratio and power factor
Note for high-efficiency product	Calculated efficiency at 25%, 50%, 75% and 100% load points can be added to the report. IEC TS 60076-20 recommends energy efficiency index and energy performance evaluation methods for transformers within the scope of IEC 60076-1. The OMSAN technical glossary states that efficiency is the ratio of output power to input power and that no-load loss, load loss, cooling performance and operating profile should be evaluated together in efficiency optimization.

9 Low-load efficiency calculation verification

Main standard	IEC TS 60076-20; customer specification
Implementation / method standard	Calculation through loss separation
Note for high-efficiency product	If high efficiency at low load is claimed, especially the 25% and 50% load points should appear in the report. At low load, the effect of no-load loss within total loss becomes greater.

10 Voltage regulation calculation verification

Main standard	IEC/EN 60076-1
Implementation / method standard	Calculation from measured impedance, load loss, resistance/reactance components and power factor
Note for high-efficiency product	Voltage regulation is the rate of change between no-load and loaded output voltage; lower regulation provides more stable load voltage. A report line such as "calculated regulation for cosphi 1.0 / 0.8" can be added.

11 Measuring instrument calibration control

Main standard	ISO 9001:2015 quality system; IEC 60076-19-1 supporting reference
Implementation / method standard	Calibration certificate, instrument class and measurement-chain uncertainty check
Note for high-efficiency product	Because loss differences are small in high-efficiency products, the power analyzer, current transformers, voltage transformers/probes and connection cables have a significant effect on measurement uncertainty. IEC 60076-19-1 should be used especially for loss measurement uncertainty.

12 Frequency and voltage accuracy control

Main standard	IEC/EN 60076-1
Implementation / method standard	Test source voltage/frequency verification
Note for high-efficiency product	No-load loss is sensitive to voltage and frequency. Therefore, the applied voltage, frequency and waveform during the P0 test should be stated in the report.

13 Label / guaranteed values check

Main standard	IEC/EN 60076-1; IEC TS 60076-20 for energy efficiency declaration; customer specification
Implementation / method standard	Cross-check of label, technical data sheet and test report
Note for high-efficiency	Power, voltage, frequency, connection group, cooling, insulation class, P0, Pk, Uk%, and any efficiency or energy performance declaration should be consistent across quotation, label and report.

2. Optional / Special Tests

These tests may be recommended depending on the customer specification, energy efficiency declaration, operating environment, acoustic sensitivity or special performance guarantee.

1 Temperature rise test

Main standard	IEC/EN 60076-11 for dry-type power transformers; IEC/EN 60076-2 for oil-immersed transformers; IEC/EN 61558-1 for LV safety-type products
Implementation / method standard	Temperature rise test method in the relevant product standard
When is it recommended?	It is a very strong test to demonstrate the thermal advantage of a low-loss design. IEC 60076-2 defines temperature rise limits and temperature rise test methods for oil-immersed transformers; for dry-type power transformers, IEC 60076-11 should be considered.

2 Efficiency verification test / third-party efficiency test

Main standard	IEC TS 60076-20; IEC/EN 60076-1; customer specification
Implementation / method standard	Accredited laboratory measurement; loss measurement uncertainty according to IEC 60076-19-1
When is it recommended?	Recommended for public tenders, energy efficiency guarantees, high-volume projects or contracts that include performance penalties/bonuses.

3 Sound level test

Main standard	IEC/EN 60076-10
Implementation / method standard	IEC 60076-10; IEC 60076-10-1 as an application guide
When is it recommended?	In low-loss core designs, flux density and steel quality affect sound behavior. IEC 60076-10 defines methods for determining sound power level through sound pressure/sound intensity methods for transformers and reactors.

4 Energy efficiency regulation compliance check

Main standard	For the EU market: Commission Regulation EU 548/2014 and its amendment EU 2019/1783; IEC TS 60076-20 for technical evaluation
Implementation / method standard	Comparison of P0, Pk, PEI or minimum efficiency against regulation limit tables
When is it recommended?	Applied when the EU/CE market, public tenders or customer specifications include an energy efficiency limit. EU 2019/1783 is based on the use of minimum efficiency or maximum loss values for transformers for product regulation purposes.

5 Thermal camera hot-spot check

Main standard	IEC/EN 60076-11 or IEC/EN 61558-1 thermal performance approach; IEC/TS 62478 may be used as a supporting thermography reference
Implementation / method standard	IR thermography under load in steady state; manufacturer procedure
When is it recommended?	Recommended as a special check rather than a routine test. Local heating is checked at terminals, busbars, tap connections, core clamping points and winding surfaces. The OMSAN technical glossary states that the hot spot is the critical region that determines insulation life.

6 Loss/heating evaluation under harmonic load

Main standard	IEC/EN 60076-1; IEC 61378-1 for converter transformers; K-factor/customer specification
Implementation / method standard	Loading with harmonic spectrum or calculation-supported verification
When is it recommended?	Recommended when the low-loss product supplies an inverter, UPS, drive or non-linear load. The OMSAN technical glossary states that harmonics can increase winding losses and cause additional heating.

7 Long-term load profile / life-cycle loss analysis

Main standard	IEC TS 60076-20; customer specification
Implementation / method standard	TCO calculation using annual operating hours, load profile, P0/Pk and energy unit price
When is it recommended?	Very useful for showing low carbon emission and operating-cost advantages in sales documentation. The justification of EU 2019/1783 states that capitalization of no-load and load losses is a common method for optimizing transformer designs.

3. Recommended Additional Lines for the Report Format

P0 guaranteed / measured	Guaranteed no-load loss, measured no-load loss, deviation %, conformity
I0 at nominal voltage	No-load current at nominal voltage; optional 90% / 100% / 110% points
Pk guaranteed / measured / corrected	Measured load loss, measurement temperature, Pk corrected to reference temperature
Uk%	Measured short-circuit impedance and tolerance check
Calculated efficiency	At 25%, 50%, 75%, 100% load; preferably at cosphi 1.0 and/or 0.8
Voltage regulation	Regulation calculated from measured impedance and losses
Measuring instruments	Power analyzer, current/voltage measuring equipment, calibration date
Energy/efficiency declaration	Conformity note according to IEC TS 60076-20 or customer specification