A5. K-Factor Transformers - Routine Tests

Test standards and report additions for K-factor transformers

Brief note: On the IEC side, there is no standalone special IEC product standard only for “K-4 / K-13 / K-20”. The main transformer tests are carried out according to the product type through IEC/EN 60076-1, IEC/EN 60076-11 if it falls within the scope of dry-type power transformers, or IEC/EN 61558-1 for LV safety/isolation-type products. The most common special reference for K-factor/harmonic capacity verification is IEEE C57.110; this standard provides methods for evaluating the capability of dry-type and liquid-filled transformers under non-sinusoidal load currents.

1. Routine Tests

This section summarizes the basic headings that must be checked in K-factor transformers in addition to standard transformer routine tests, including harmonic load, neutral, screen, thermal design and verification of the declared K value.

1

Basic transformer routine tests

Main standard	IEC/EN 60076-1; IEC/EN 60076-11 for dry-type power transformers; IEC/EN 61558-1 for LV safety-type products
Construction / method standard	IEC 60076-1 / IEC 60076-11 / IEC 61558-1
Explanation for K-factor transformer	A K-factor transformer must first pass the normal electrical, dielectric and visual routine tests like a standard transformer.

2

Winding resistance and phase balance

Main standard	IEC/EN 60076-1; IEC/EN 60076-11
Construction / method standard	IEC 60076-1 winding resistance measurement method
Explanation for K-factor transformer	U-V-W phase resistances are compared. Since additional heating will occur under harmonic load, phase resistance unbalance must be evaluated more critically.

3

Ratio test

Main standard	IEC/EN 60076-1; IEC/EN 60076-11
Construction / method standard	IEC 60076-1 voltage ratio test
Explanation for K-factor transformer	The primary/secondary ratio is verified in each phase. If taps are present, all taps must be measured.

4 Connection group / vector group check

Main standard	IEC/EN 60076-1
Construction / method standard	IEC 60076-1 connection group and phase displacement check
Explanation for K-factor transformer	Dyn, Yyn, Dd or a special connection group is verified. In systems with harmonics, the star/neutral connection and third-harmonic behavior are especially important.

5 No-load loss and no-load current

Main standard	IEC/EN 60076-1; IEC/EN 60076-11
Construction / method standard	IEC 60076-1 no-load operation test; IEC 60076-19-1 as a supporting reference for measurement uncertainty
Explanation for K-factor transformer	Although the main risk in a K-factor transformer is load-related harmonics, core saturation, P0 and I0 must be shown in the routine report.

6 Load loss and short-circuit impedance

Main standard	IEC/EN 60076-1; IEC/EN 60076-11
Construction / method standard	IEC 60076-1 short-circuit test; IEC 60076-19-1 for measurement uncertainty
Explanation for K-factor transformer	Load loss must be corrected to the reference temperature. In harmonic loads, eddy-current and stray-loss effects are considered in addition to I2R loss.

7 Insulation resistance

Main standard	IEC/EN 60076-3; IEC/EN 60076-11; IEC/EN 61558-1 for LV products
Construction / method standard	IEC 60076-3 dielectric test preparation; IEC 61557-2 as a supporting reference for practical measurement
Explanation for K-factor transformer	Primary-secondary, primary-frame, secondary-frame and, if a screen is present, screen-frame are measured.

8 Dielectric withstand / applied voltage test

Main standard	IEC/EN 60076-3; IEC/EN 60076-11; IEC/EN 61558-1
Construction / method standard	IEC 60076-3 separate-source AC withstand test; IEC 61558-1 dielectric withstand test
Explanation for K-factor transformer	The main insulation is verified. The test level is determined according to the voltage class and customer specification.

9 Induced voltage / inter-turn insulation test

Main standard	IEC/EN 60076-3; IEC/EN 60076-11; IEC/EN 61558-1
Construction / method standard	IEC 60076-3 induced AC voltage test
Explanation for K-factor transformer	Inter-turn insulation is checked. In harmonic applications, the insulation system is exposed to greater thermal stress, so it is useful to show this test in the report.

10 Neutral connection check

Main standard	IEC/EN 60076-1; IEC/EN 61558-1; UL 1561 if UL is required
Construction / method standard	Connection diagram, continuity measurement, terminal/busbar check
Explanation for K-factor transformer	In three-phase four-wire systems, the 3rd, 9th and 15th harmonics may accumulate in the neutral. Therefore, the neutral connection must be checked separately.

11 Neutral cross-section check

Main standard	IEC/EN 60076-1; customer specification; UL 1561 for the UL market
Construction / method standard	Design drawing, conductor cross-section, busbar and terminal capacity check
Explanation for K-factor transformer	In K-factor transformers, the neutral cross-section may be selected larger than in a conventional transformer. The neutral busbar, terminal and connection cable must be compared with the design file. UL 1561 is the U.S. standard used for dry-type general-purpose and power transformers.

12 Screen winding continuity - if present

Main standard	IEC/EN 60076-1; IEC/EN 61558-1
Construction / method standard	Continuity measurement, connection diagram check
Explanation for K-factor transformer	If an electrostatic screen is present, it is verified that the screen lead is brought out to the correct terminal.

13 Screen-frame connection - if present

Main standard	IEC/EN 60076-1; IEC/EN 61558-1; IEC 61000 series as a supporting reference for EMC evaluation
Construction / method standard	Low-resistance continuity measurement
Explanation for K-factor transformer	The screen frame/PE connection is checked. This is important for reducing common-mode noise and interference.

14 K value check on the nameplate

Main standard	IEC/EN 60076-1 marking approach; IEEE C57.110 / UL specification for K value
Construction / method standard	Cross-check of nameplate, technical datasheet and test report
Explanation for K-factor transformer	The K-4 / K-13 / K-20 value must be clearly stated on the nameplate. The K value is not a value measured directly by a routine test device; it is a design verification declaration.

15 Harmonic current assumption check

Main standard	IEEE C57.110; customer specification
Construction / method standard	Harmonic spectrum table, THDi assumption, RMS current and K calculation
Explanation for K-factor transformer	The report or technical file should state according to which harmonic spectrum the K value was selected. IEEE C57.110 is used to evaluate the effect of non-sinusoidal load currents on transformer capability.

16 Neutral current design parameter check

Main standard	IEEE C57.110; UL 1561 if UL is required; customer specification
Construction / method standard	Design calculation, neutral conductor/terminal capacity and connection check
Explanation for K-factor transformer	In routine testing, the actual harmonic neutral current is often not measured; however, the neutral current assumption and neutral capacity must be verified in the design file.

17 Temperature rise class check

Main standard	IEC/EN 60076-11; IEC/EN 61558-1; IEEE C57.110 as supporting reference
Construction / method standard	Check of nameplate, insulation class, thermal design and type test report, if available
Explanation for K-factor transformer	The purpose of a K-factor transformer is not to exceed the permitted temperature rise despite additional harmonic losses.

18 Conductor cross-section check

Main standard	IEC/EN 60076-1; IEC/EN 60076-11; IEEE C57.110
Construction / method standard	Verification of production drawing, winding recipe, conductor cross-section and parallel conductors
Explanation for K-factor transformer	Due to skin effect, proximity effect and harmonic-related eddy losses, the conductor cross-section may be selected differently from a conventional transformer.

19

Cooling duct and mechanical tightness check

Main standard	IEC/EN 60076-11; IEC/EN 61558-1
Construction / method standard	Visual inspection, air-duct opening check, mechanical tightness check
Explanation for K-factor transformer	Because of the risk of harmonic-related heating, air ducts, coil tightness and loose connections must be checked especially carefully.

2. Optional / Special Tests

These tests may be recommended for projects with data centers, UPS, drives, intensive SMPS loads, high THDi, U.S./UL specifications or special customer performance expectations.

1

Temperature rise test under harmonic current

Main standard	IEC/EN 60076-11 or IEC/EN 61558-1; IEEE C57.110 for harmonic capability
Construction / method standard	Temperature rise measurement with a current source containing THD or with an equivalent loss/injection method
When is it recommended?	It is recommended where there is a high harmonic claim such as K-13 / K-20; and for data centers, UPS, drives and intensive SMPS loads.

2

Neutral current heating test

Main standard	IEEE C57.110; UL 1561 if UL is required
Construction / method standard	Three-phase four-wire harmonic load simulation; temperature measurement of neutral busbar/terminal
When is it recommended?	It is recommended in systems with intensive single-phase non-linear loads. The neutral terminal, star point and busbar connections must be monitored in particular.

3

Load simulation with THD

Main standard	IEEE C57.110; IEC 61000-4-7 and IEC 61000-4-30 for measurement
Construction / method standard	Creating a harmonic spectrum with a programmable load or power-electronic load; measuring THDi, THDv and individual harmonics with a power analyzer
When is it recommended?	It is applied when the customer specifies a particular THDi or harmonic spectrum. IEC 61000-4-7 is used for harmonic/interharmonic measuring instruments and methods, while IEC 61000-4-30 is used for power quality measurement methods.

4 Thermal camera test

Main standard	IEC/EN 60076-11 or IEC/EN 61558-1 thermal performance approach
Construction / method standard	IR thermography under load; manufacturer procedure
When is it recommended?	Hot spots are checked at terminals, the neutral busbar, screen connection, tap connection, winding surface and core clamping points.

5 Sound level test

Main standard	IEC/EN 60076-10
Construction / method standard	IEC 60076-10
When is it recommended?	Harmonic load, magnetic operating point and mechanical looseness may affect sound behavior. It is recommended for indoor, hospital, office and data center applications.

6 K-factor design verification calculation report

Main standard	IEEE C57.110; UL 1561 if UL is required
Construction / method standard	Harmonic spectrum, K calculation, RMS current, neutral current, eddy/stray loss, temperature rise and derating calculation
When is it recommended?	The K value is not measured directly in routine testing; it is verified by design calculation and, where necessary, by thermal testing.

7 IEEE/UL customer specification compliance file

Main standard	IEEE C57.110; UL 1561; NEC/NFPA 70 if necessary
Construction / method standard	Compliance matrix, design calculation, test report, material and nameplate check
When is it recommended?	It is recommended for the U.S. market, data centers, UPS manufacturers and projects with UL/IEEE specifications. UL 1561 is used for dry-type general-purpose and power transformers.

8 Harmonic loss separation / additional loss analysis

Main standard	IEEE C57.110; IEC/EN 60076-1 as supporting reference
Construction / method standard	Fundamental-frequency load loss + calculation of eddy and stray losses caused by harmonic currents
When is it recommended?	It is recommended especially for high K classes such as K-20 and systems with high THDi.

9 Partial discharge test - in special applications

Main standard	IEC 60270; IEC/EN 60076-11 for dry-type power transformers
Construction / method standard	IEC 60270
When is it recommended?	It may be applied in projects with cast-resin construction, high reliability, rail systems, medical applications or special insulation expectations.

10 On-site power quality verification

Main standard	IEC 61000-4-30; IEC 61000-4-7 for harmonic measurement
Construction / method standard	Measurement of THDi, THDv, individual harmonics, neutral current and load profile with an on-site power quality analyzer
When is it recommended?	It is recommended before design or after commissioning when the actual harmonic spectrum is unknown.

3. Lines Recommended to Be Added to the Test Report

Adding the following lines to the classic routine test report for K-factor transformers makes the technical declaration and customer-side verification clearer.

1 K value declaration
K-4 / K-13 / K-20

2 Design harmonic assumption
THDi %, dominant harmonics, load type

3 Neutral design capacity
Neutral cross-section, neutral busbar/terminal capacity

4 Screen winding
Present/not present, continuity, screen-frame connection

5 Load loss
Measured Pk, Pk corrected to reference temperature

6 Impedance
Z% / Uk%, tolerance check

7 **Thermal class**
Insulation class F/H, temperature rise target

8 **K-factor calculation file**
Calculation reference according to IEEE C57.110 or customer specification

9 **Measuring instruments**
Power analyzer, harmonic analyzer, calibration date