ZES ZIMMER
Precision Power Measurement

LMG600 Series Applications:

Transformers

ZES ZIMMER – THE EXPERTS IN PRECISION POWER ANALYSIS v1.0

Testing of Power Transformers with the LMG671 – Precision Measurement Technology for Type and Acceptance Tests

The efficiency of power transformers is a key factor in reducing energy losses within the power distribution network, not to mention the increasing regulatory pressure from energy-consuming facilities such as data centers. Inefficiencies in power transmission result in financial losses and elevated greenhouse gas emissions, both of which must be avoided. As part of type and acceptance testing, power transformers are both specified with respect to their essential electrical parameters and subsequently tested and certified for compliance with these and other regulatory requirements. High efficiency and full conformity are the ultimate objectives. To achieve this, all relevant electrical performance parameters must be measured and analyzed with the highest precision. In addition, manufacturers are increasingly required to perform special tests tailored to advanced and application-specific requirements.

Type Testing

- **Prior to series production**
- Assessment of the suitability of the transformer model for its intended applications
- Includes mechanical and **electrical testing**, insulation and thermal tests, among others

Acceptance Testing

- **After manufacturing**
- On-site or test laboratory
- Assessment of quality assurance and reliability
- Compliance with normative/regulatory requirements[1]
- Includes visual inspection, **electrical testing**, functional testing, among others

Topics

- Why are precision power analyzers particularly suitable?
- Which standards must be considered?
- Which electrical parameters are measured?
- What loss components does a transformer exhibit?
- What is the K-factor?
- What is “corrected” power and how is it measured?
- How does the LMG671’s internal script editor support the test procedure?
- How can measurement ranges be extended?
- Which parameters of a power analyzer must be taken into account?

[1] Standards and regulations that require precise measurements to ensure quality, safety, and compliance include, for example:
- **EU Regulation 548/2014**: Energy efficiency limits for no-load and load losses.
- **IEC 60076-1**: International test procedures and tolerances for parameters such as losses, voltages, and temperatures.
- **IEEE C57.12**: North American testing standards and methods.

A key aspect of electrical testing is the precise measurement of no-load and short-circuit losses, as well as other critical parameters such as active and reactive power, harmonic content, phase displacement, power factor, and many more. Both manufacturers and test laboratories face specific challenges during electrical testing. Challenges for which the use of **precision power analyzers such as the ZES ZIMMER LMG671** provides targeted, application-oriented solutions.

Challenges for manufacturers and test laboratories Solution through precision power measurement with the LMG671	
Acquisition of all required electrical parameters	**Reliable precision of measured electrical parameters**
▪ Comprehensive measurement of direct and derived electrical quantities ▪ Synchronized multi-channel measurement for advanced testing requirements ▪ Standards-compliant measurements acc. to, for example, IEC 60076-1, IEEE C57.12[2]	▪ Highest accuracy even at low power or current levels ▪ System-level temperature compensation and low long-term drift ▪ Traceable calibration certificate for audit-compliant test documentation
Application-oriented and user-optimized functionality	**Integration and remote control of test equipment used**
▪ Pre-configurable measurement profiles for no-load and short-circuit tests ▪ FFT analysis, k-factor calculation, power correction, and customizable measurement menus ▪ Flexible channel assignment for various transformer configurations	▪ Standardized interfaces: Ethernet, RS232 ▪ Fully remote-controllable for automated test procedures (SCPI commands) ▪ Direct data export from the instrument

Table 1: Testing challenges and measurement aolutions with the LMG671 Precision Power Analyzer

The following report outlines the central role of the LMG671 precision power analyzer in the testing of power transformers and demonstrates how the aforementioned solutions are practically applied. The measurement examples presented occur as mandatory elements in type and acceptance tests, as well as in supplementary, application-specific test procedures for particular use cases.

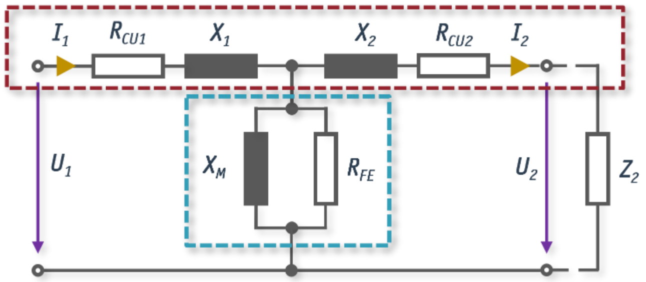
Learning

The efficiency of power transformers is essential for energy savings and regulatory compliance. Type and acceptance tests demand the highest measurement precision for electrical parameters such as no-load and short-circuit losses and the resulting efficiency. The LMG671 precision power analyzer from ZES ZIMMER offers an optimal testing solution with high accuracy, flexible multi-channel measurement, and standards-compliant data acquisition, serving both manufacturers and test laboratories. Reliable loss measurement with minimal uncertainty builds trust and reduces the potential for disputes.

[2] All electrical quantities - such as voltage, current, power, phase angle, power losses, and harmonic -, must be measured with standard-defined accuracy, under specified test conditions, over appropriate time intervals (stability windows), and with demonstrable traceability.

Efficiency and Loss Measurement – Precise Multi-Channel Testing of Three-Phase Transformers

Iron and copper losses are among the most critical loss components in a transformer. Precise measurement of these losses is a fundamental part of every type and acceptance test, providing the theoretical basis for the classification and physically traceable assignment of loss mechanisms—illustrated by the equivalent circuit model shown in Figure 1. Based on this model, both loss components are determined through no-load and short-circuit tests. The LMG671 enables high-precision, standards-compliant, and comprehensive measurement and analysis of both loss mechanisms.



R_{CU1}: Copper losses – primary side
X_1: Stray inductance – primary side
X_M: Main reactance / magnetizing inductance
R_{FE}: Iron losses
R_{CU2}: Copper losses – secondary side
X_2: Stray inductance – secondary side
---- : Cause copper losses (current-dependent)
---- : Cause iron losses (constant)

Figure 1: Simplified equivalent circuit of a loaded transformer

With up to seven measurement modules equipped with power measurement channels[3] and/or process signal interfaces, the LMG671 enables full connectivity for measuring the power of all phases as well as additional sensor signals - illustrated in Figure 2. The integration of a Process Signal Interface (PSI) allows parallel acquisition of further analog and/or digital signals relevant to the specific operating point, such as ambient and unit-under-test conditions including temperature, humidity, and vibration. Especially in applications involving power distribution and acoustic insulation in buildings - such as data centers - the vibration corresponding to the load operating point, i.e., the sound level, is of particular relevance.

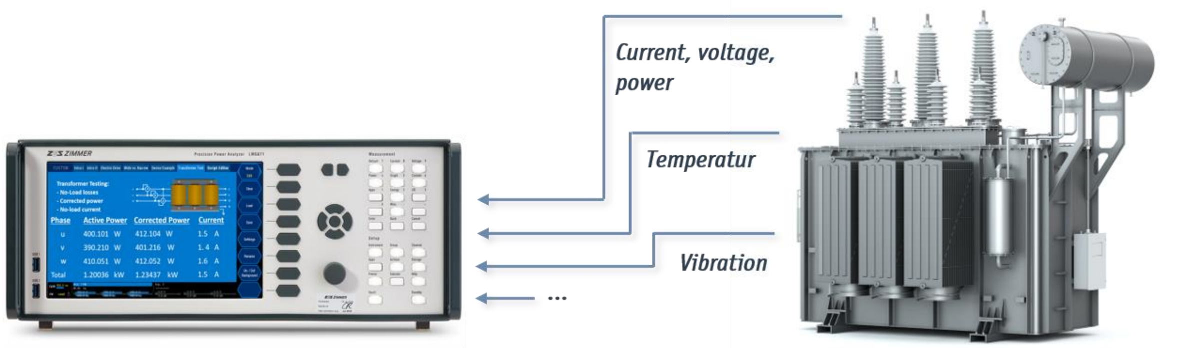


Figure 2: Acquisition of all relevant parameters with the LMG671 for power and efficiency testing

Especially for standard-required corrections of measured electrical quantities - arising from deviations between actual test conditions and specified nominal values - the measurement of ambient and winding temperatures can be crucial. Calculating the corrected short-circuit power[4] may be necessary when significant temperature variations affect copper losses. A complete connection of the input and output phases enables direct measurement of the load-dependent efficiency, which can be presented in addition to the results of the loss power tests, as illustrated in Figure 11.

[3] Power measurement channel: Consisting of current and voltage measurement inputs, adjusted for minimum time offset.
[4] The corrected power loss of a transformer is a mathematically standardised value that is often used to standardise the loss evaluation to reference conditions (typically to a reference temperature, e.g. 75 °C in accordance with IEC 60076). It is particularly relevant for copper/short-circuit losses, as these are temperature-dependent.

No-Load Test – Measurement of Iron Losses, No-Load Current, and Corrected Power

The no-load test is carried out under realistic conditions by measuring the three-phase power on the primary side of the transformer - i.e., the high-voltage side - while keeping the secondary side open, as shown in Figure 3.

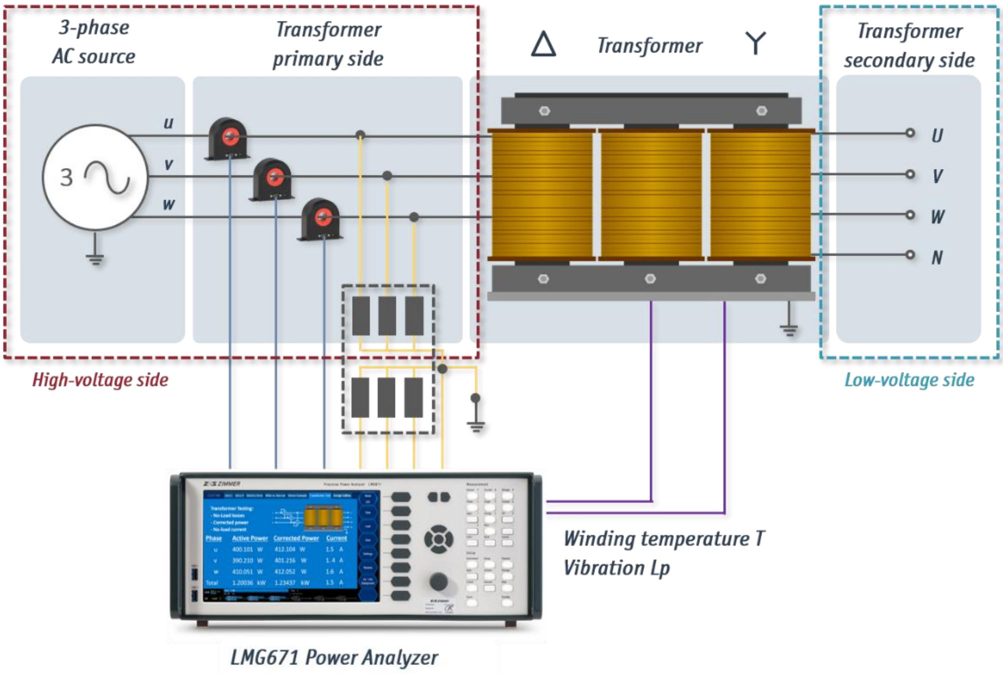


Figure 3: Transformer no-load test and connection to the LMG671 power analyzer

In this example, we consider a delta-star transformer, which is commonly used in data center or building power distribution applications. On the primary side, we measure the line-to-line voltages and the phase currents directly. For accurate conversion into individual phase powers[5], the LMG671 offers a corresponding built-in computation feature via the software option L6-OPT-SDC.

In a single measurement setup, we therefore directly capture the following for each phase and the overall system:

- **Power**: Measurement of no-load power, i.e., no-load or iron losses
- **Currents**: Measurement of the magnetizing current
- **Voltages**: Verification of test conditions under nominal voltage operation
- **Frequency**: Measurement of the frequency at the test operating point

Especially during no-load tests, low power factors occur, requiring power analyzers and external current sensors to measure with the highest phase accuracy. While amplitude accuracy of the measurement system is important, phase accuracy is absolutely essential!

Typical no-load power factors range between 0.1 and 0.4 - for example, with core laminations of grade M4 or M5. As transformer power ratings increase, and especially in loss-optimized core designs such as high-efficiency transformers with amorphous core laminations, power factors can drop as low as 0.008. See the exemplary dependency illustrated in Figure 4.

[5] Due to the amplitude factor of √3 (ideal) and a 30° phase shift between star and delta voltages, a conversion to the star system is required in order to obtain accurate phase power values when combining with the phase current.

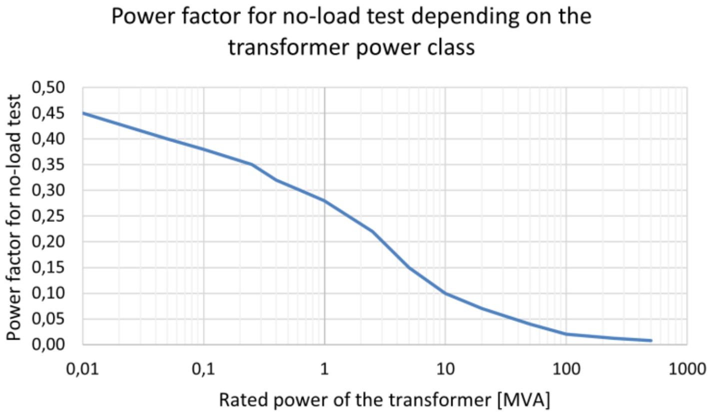


Figure 4: Power factors for no-load tests as a function of the transformer power class

Learning

In addition to amplitude accuracy, phase accuracy plays a critical role in no-load tests - particularly due to the very low power factors that may occur. The LMG671 features an inherently precise, nanosecond-level internal timing adjustment between current and voltage measurement paths across all channels. This enables unambiguous and highly accurate power measurements even at extremely low power factors down to ≤ 0.001. In line with practical needs, the power measurement tolerances of the LMG671 are specified across the full power factor range from PF = 0 to 1, avoiding potential pitfalls such as additional complex error terms or hidden error components that might otherwise arise in low-power-factor conditions.

Note

Measurement systems that allow flexible pairing of voltage and current inputs may introduce significant phase errors in this context. Compared to dedicated power analyzers with fixed, combined voltage and current measurement inputs - such as those in the LMG series - and calibrated power factor accuracy, such flexible systems should be considered with caution, especially in low power factor applications.

Corrected Power

To obtain standardized[6] and comparable measurement values, it is essential to account for the influences of the test environment as well as any deviations from the specified nominal supply conditions. This is achieved by calculating the so-called corrected power $P_{0,corr}$. The no-load power determined during the no-load test - i.e., the iron losses, which consist of hysteresis and eddy current losses - is not linearly dependent on voltage and frequency. In particular, eddy current losses are proportional to the square of the voltage. For factory acceptance, type testing, and conformity verification, the following formula is commonly applied in accordance with IEC 60076-19-1:

$$P_{0,corr} = P_0 \cdot \left(\frac{U_1}{U_{1,N}}\right)^2 \cdot \left(\frac{f_N}{f}\right)^{1.5}$$

P_0:	Measured no-load losses (active power in W)
U_1:	Effective primary voltage during measurement
$U_{1,N}$:	Rated voltage of the transformer
f:	Frequency during measurement
f_N:	Nominal frequency (usually 50 or 60 Hz)

The frequency correction in this case is based on an empirical approximation (hysteresis $\sim f^{1.5}$). The LMG671 power analyzer supports direct calculation of this corrected power via its integrated script editor, as shown in Figure 5. All measurement quantities and values relevant to the no-load test can be clearly consolidated into customized measurement menus tailored to the user's specific needs - providing a comprehensive overview at a glance, as illustrated in Figure 6.

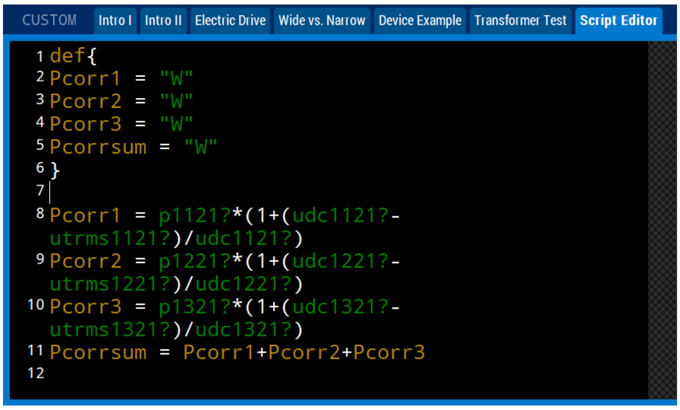


Figure 5: Script editor for calculating the corrected no-load power

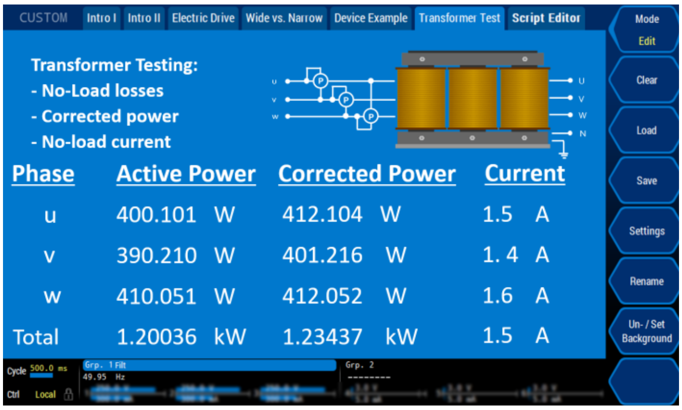


Figure 6: Exemplary LMG671 "Custom Menu" for the no-load test

Short-Circuit Test – Measurement of Copper Losses and Complex Short-Circuit Impedance

Following the no-load test, the short-circuit test is carried out, which - by principle - follows an inverse approach. The primary side is connected to the power analyzer in an equivalent manner, while the secondary side (all phases) of the transformer is short-circuited.

We therefore directly measure the following for each individual phase and the overall system in a single setup:

- **Power**: Measurement of the short-circuit power or short-circuit or copper losses
- **Currents**: Measurement of the set currents (reaching the rated current)
- **Voltages**: Measurement for checking until the rated current is reached
- **Impedance**: Measurement of the complex total impedance

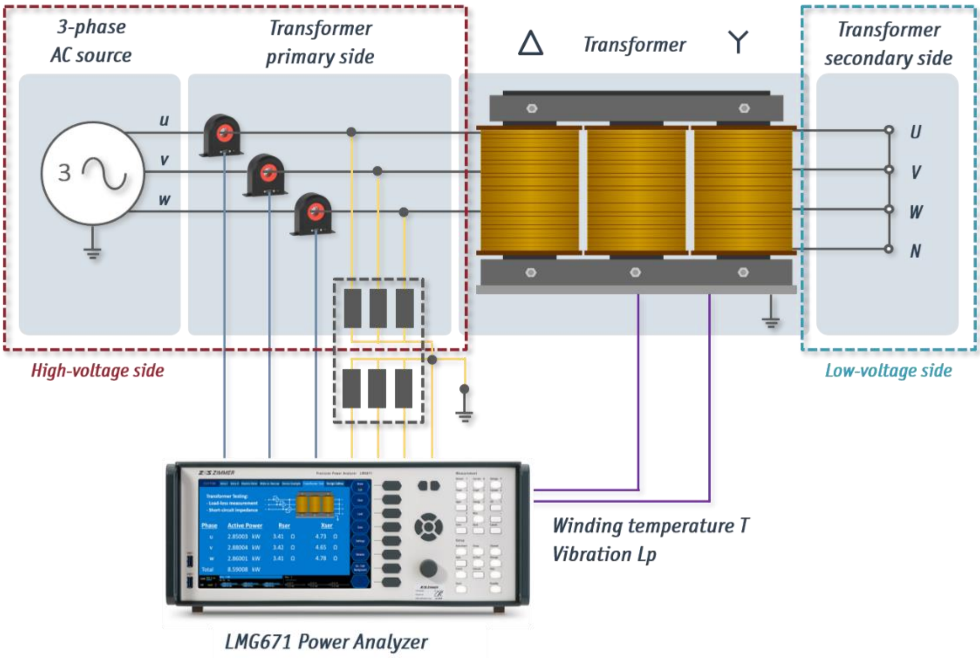


Figure 7: Transformer short-circuit test and connection to the LMG671 power analyzer

[6] Normative basis for corrected power: IEC 60076 and EU Regulation 548/2014

Short-circuit impedance

Another advantage of using modern power analyzers for transformer testing lies in the comprehensive range of measured values, which - during the short-circuit test - enable the simultaneous measurement and evaluation of both phase-specific and total impedance. The measured complex impedance is used to determine the series winding resistance and stray reactance in the equivalent circuit model (see red highlights in Figure 1). These values are essential for characterizing the transformer and are also required for calculating the short-circuit current - a critical factor for sizing fuses, circuit breakers, uninterruptible power supplies (UPS), and protective devices. IEC 60076 specifies minimum and maximum limits for this impedance.

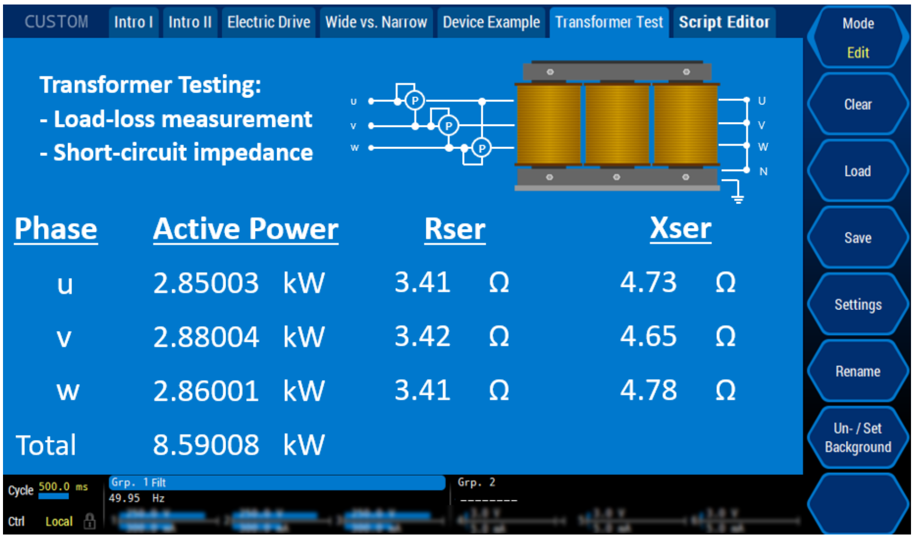


Figure 8: Exemplary LMG671 "Custom Menu" for the short-circuit test

In practice, the same type of measurement is also carried out in parallel during the no-load test, where the complex impedance - including both resistive and reactive components - represents the parallel branch of the equivalent circuit, as indicated by the blue marking in Figure 1.

All relevant measurement quantities and values for the short-circuit test can also be clearly displayed in a dedicated measurement menu, as shown in Figure 8.

Efficiency Test – Direct Measurement of Load-Dependent Efficiency and Derived Test Procedures

Efficiency measurement

The load-dependent efficiency of a transformer is often calculated based on the previously determined loss components from the no-load and short-circuit tests, using the formula below. This calculation is typically based on the rated apparent power, which also includes reactive components. Thanks to the capabilities of the power analyzer, the loss components expressed in terms of apparent power were measured in parallel during the tests.

$$\eta = \frac{S_N - (S_0 - S_{KS})}{S_N}$$

S_N: Nominal apparent power
S_0: Measured no-load apparent power
S_{KS}: Measured short-circuit apparent power

The challenge and drawback of this calculation method lies in the assumption that all measurements refer to exactly the same operating point. To obtain a plausible and precise calculated efficiency value, identical environmental conditions (especially temperature) and ideally minimal deviation between measured operating values and specified nominal values must be ensured. Moreover, if a load-dependent efficiency curve is to be generated, these requirements become even more demanding - posing a significant practical challenge. In many cases, this is difficult to implement reliably in a real test environment.

Solution: A more effective approach is the direct measurement of the actual active power involved in energy conversion on both the primary and secondary sides. By connecting a three-phase load[7] to the secondary side, a full efficiency curve across various load levels can be recorded in a single test sequence. This requires a power analyzer capable of performing group-separated power measurements on both sides—i.e., 2× 3-phase groups, requiring six power measurement channels. In the described test setup, the delta-star configuration once again becomes relevant: the transformer is operated in delta on the primary side and either star or delta on the secondary side. For the determination of total system power, however, it is irrelevant whether a delta-to-star or star-to-delta conversion is applied, as long as the correct method for calculating system power is used.

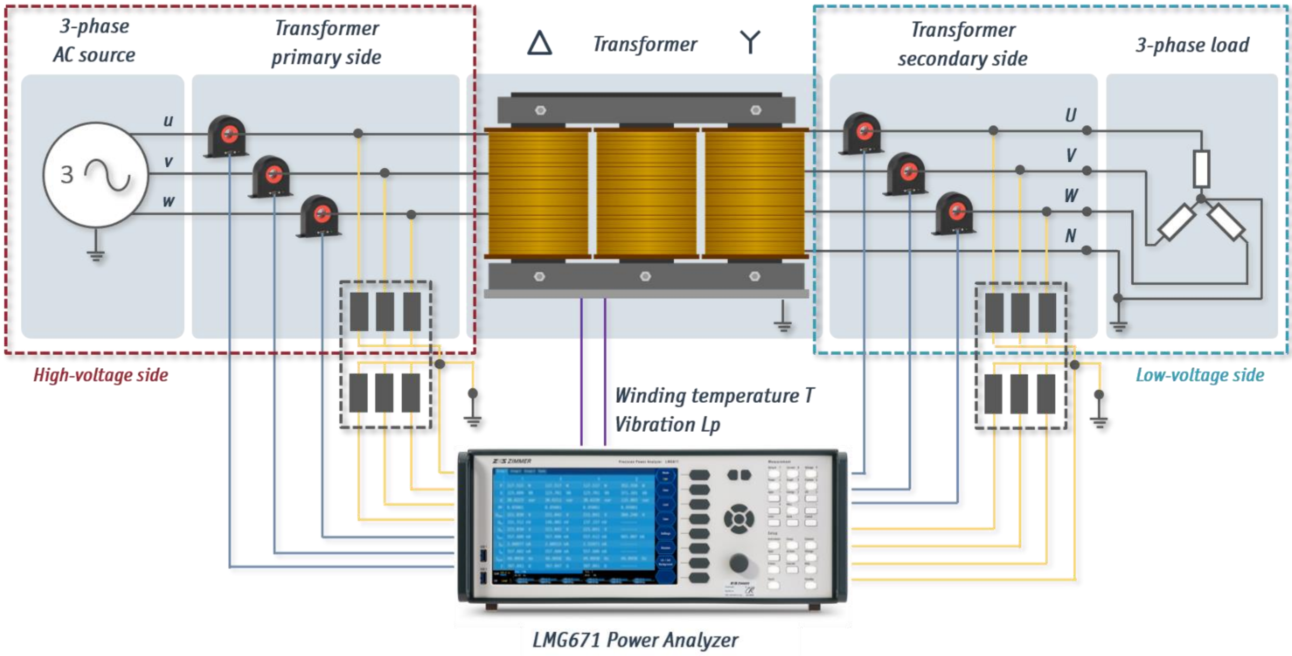


Figure 9: Transformer efficiency test and connection to the LMG671 power analyzer

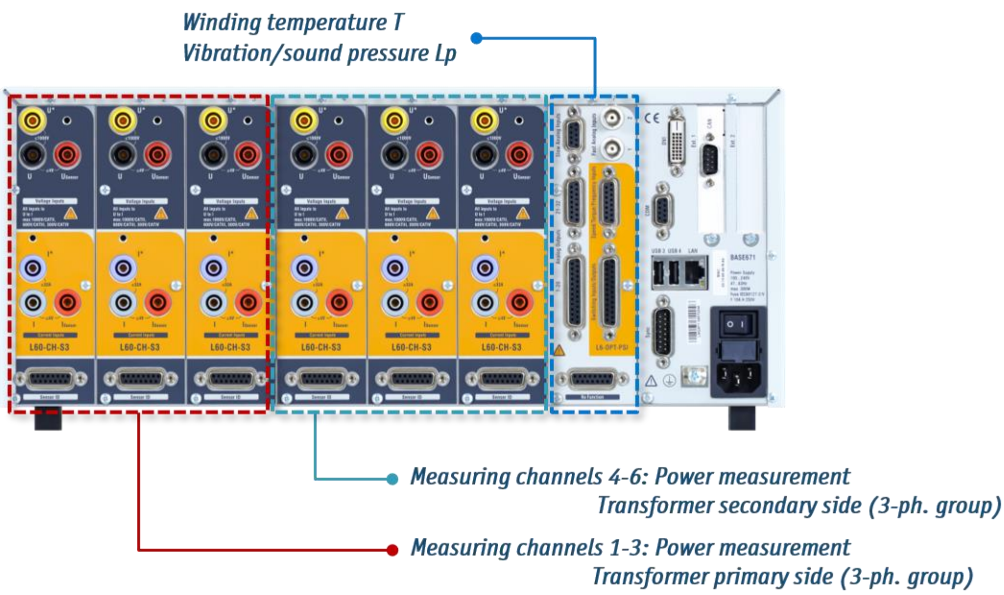


Figure 10: Connection of transformer primary and secondary side to the LMG671 power analyzer

[7] A three-phase load can be implemented using either a resistive load bank (uniform ohmic load, easy to control) or an electronic load (adjustable current/power control, optionally with phase shift capability). With programmable electronic loads, it is also possible to perform a realistic data center simulation (e.g., 3+N consumer configuration), providing highly application-relevant test conditions.

According to the wiring shown in Figure 9 and Figure 10, we directly measure the following quantities for each phase and the overall system in a single test sequence:

- **Power**: Measurement of primary and secondary active power
- **Currents**: Measurement of primary and secondary currents
- **Voltages**: Measurement of primary and secondary voltages
- **Frequencies**: Measurement of the fundamental frequency on both primary and secondary sides
- **Harmonics**: Measurement of harmonic content and evaluation of harmonic distortion (THD, derived TDD), distortion power (D), phase displacement, and phase symmetry

Based on these measured values, the LMG671 automatically and cyclically determines the power losses and efficiency, providing direct, real-time insight into the transformer's performance. The key advantage is that all measurements are performed under precisely identical operating conditions for each load point, inherently including all loss mechanisms. This results in a significantly more plausible and precise measurement, which is essential for reliably assessing compliance with increasingly strict energy efficiency standards and limit values. A typical measured efficiency curve of a power transformer is shown in Figure 11, which also highlights the influence of copper (short-circuit) and iron (no-load) losses. For this measurement setup as well, a custom display interface can be easily created using the LMG671's CUSTOM Menu, tailored specifically to the requirements of transformer efficiency testing.

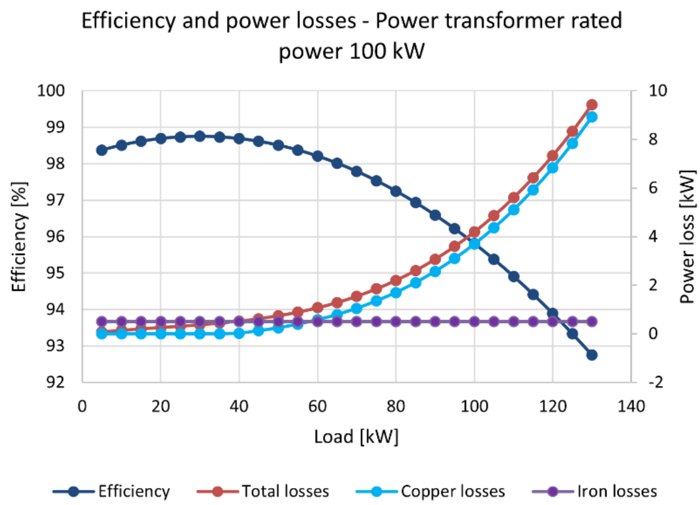
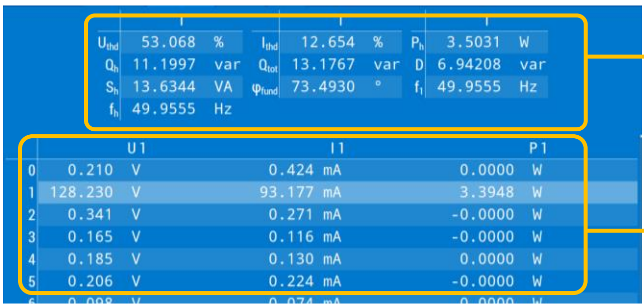


Figure 11: Typical efficiency curve of a transformer

Verification of Phase Symmetry

The LMG671 offers, in addition to the numerical display of current, voltage, and power harmonics (both in RMS value and phase angle), the direct graphical representation of voltages and currents as a vector diagram for the respective harmonic order - most importantly, the fundamental frequency.



Presence view of most of important measured values:
Harmonic distortion, distortion power, phase shift, harmonic power, harmonic phase, ...

Listing of the harmonics:
Harmonic effective values of current, voltage, power

Figure 12: LMG671 example display of measured harmonic values

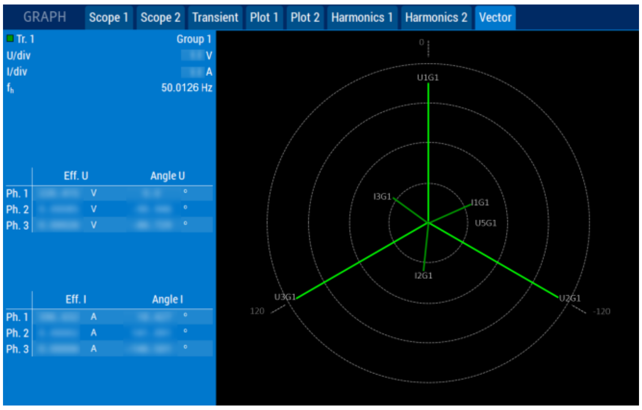


Figure 13: Vector diagram - extract from LMG671 Scope menu for checking phase symmetry

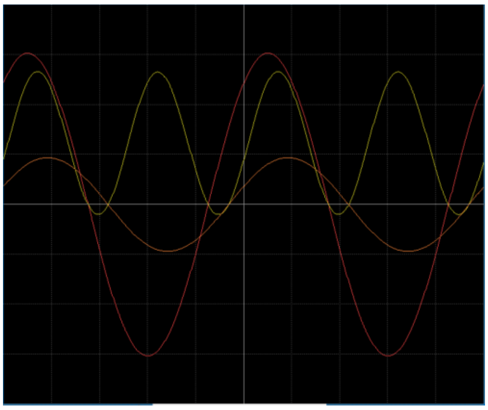


Figure 14: Measurement signals of a phase - extract from LMG671 Scope menu for checking the signal quality

Learning

Measuring the efficiency of power transformers is clearly preferable to calculating it from separate loss measurements - and with the LMG671 and its multi-channel capability, this process is seamless and highly accurate. The instrument enables direct, continuous efficiency measurement across multiple load operating points, all under identical measurement, DUT, and environmental conditions, allowing for the reliable representation of the complete efficiency curve. Additionally, this comprehensive measurement setup provides immediate verification of phase quality and symmetry, thanks to the integrated signal visualization (scope) and phase relationship display (vector diagram)—all performed in parallel and in real time.

Additional Tests and Special Measurements

Determination of Phase Displacement – Phase Shift Between Secondary and Primary Windings

Phase displacement in transformers refers to the difference in phase angle between the secondary to primary voltages or currents. This parameter is also a mandatory part of the type test (IEC 60076-1, section: Vector group) and, in simplified form, the routine (acceptance) test (IEC 60076-1, Routine tests).

The specific phase angle (e.g., 30°, 150°, or 330°) results from the winding configuration (e.g., delta-star or star-delta) and the relative physical arrangement of the windings within the core. In the previous example, a transformer with a delta-connected primary winding and a star-connected secondary winding with a neutral point would be designated Dyn11. This implies a phase displacement of 330°, meaning the secondary voltage lags the primary voltage by 30°. This phase displacement is part of the transformer specification and must be verified to ensure correct integration into the application or power distribution network.

By design, a power analyzer synchronizes to one voltage or current signal from each of the three phases within a given measurement group - independently for the primary and secondary sides. As a result, the fundamental phase angles of the selected reference phases in both the primary and secondary measurement groups are each defined as 0°, making direct determination of the phase displacement between them not inherently possible with standard power analyzers.

The LMG671 offers two direct measurement solutions for determining phase displacement:

- **Measuring solution 1: 6-channel measuring group:**

  As part of the previously described direct efficiency measurement (simultaneous acquisition of primary and secondary electrical quantities), the channel grouping within the user interface can be configured so that all six power channels are treated as a single 6-phase system, as illustrated in Figure 15. This configuration allows the use of the harmonics analysis function to determine the absolute phase displacement between the secondary and primary voltages. By defining the primary voltage of phase 1 (channel 1 u) as the reference (phase angle = 0°), the phase angle of the secondary voltage of phase 1 (Channel 4 U) can be directly measured relative to Channel 1 - thus enabling precise verification of the transformer's phase displacement.

$$\Delta\varphi_{ps} = \varphi_{u4} - \varphi_{u1}$$

$\Delta\varphi_{ps}$: Phase shift secondary to primary
φ_{u1}: Measured phase position primary voltage u
φ_{u4}: Measured phase position secondary voltage U

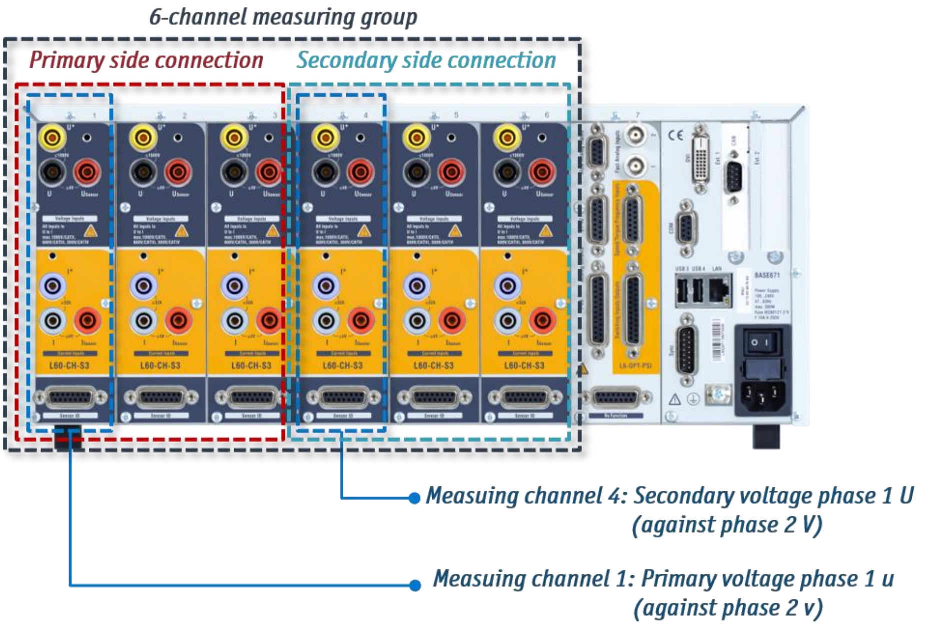


Figure 15: Connection and grouping of measuring solution 1 for testing the phase displacement

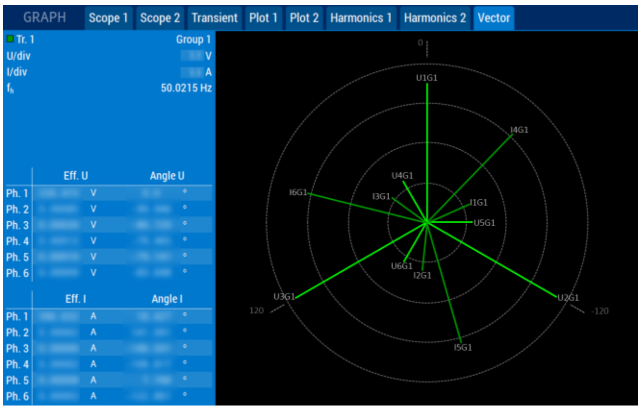


Figure 16: Vector diagram - phase displacement measuring solution with 6-channel measuring group

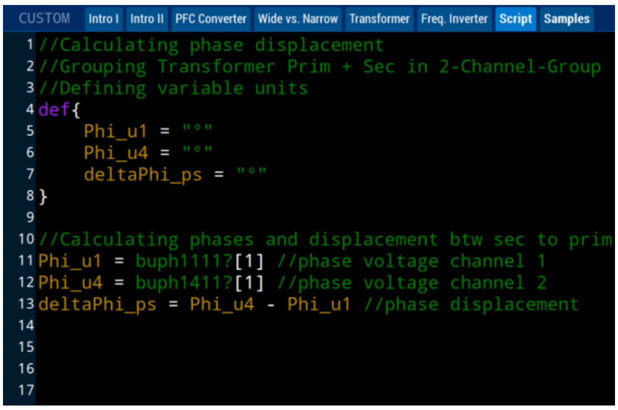


Figure 17: Calculation of phase displacement measuring solution with 6-channel measuring group with script editor

- **Measuring solution 3: 3-channel measuring group:**

The primary voltage of phase 1 (u) and the secondary voltage of phase 1 (U) are connected to two consecutive channels on the LMG671 and defined as a 2-channel measuring group, Figure 18. Measuring channel 1 serves as the synchronization reference, and in the harmonics analysis, the LMG671 determines the phase shift of measuring channel 2 (secondary voltage phase 1 U) relative to channel 1 (primary voltage phase 1 u), displayed numerically and graphically. Using the integrated script editor, the phase difference is automatically calculated and made available to the user as a derived measurement value.

$$\Delta\varphi_{ps} = \varphi_{u2} - \varphi_{u1}$$

$\Delta\varphi_{ps}$: Phase shift secondary to primary
φ_{u1}: Measured phase position primary voltage u
φ_{u2} Measured phase position secondary voltage U

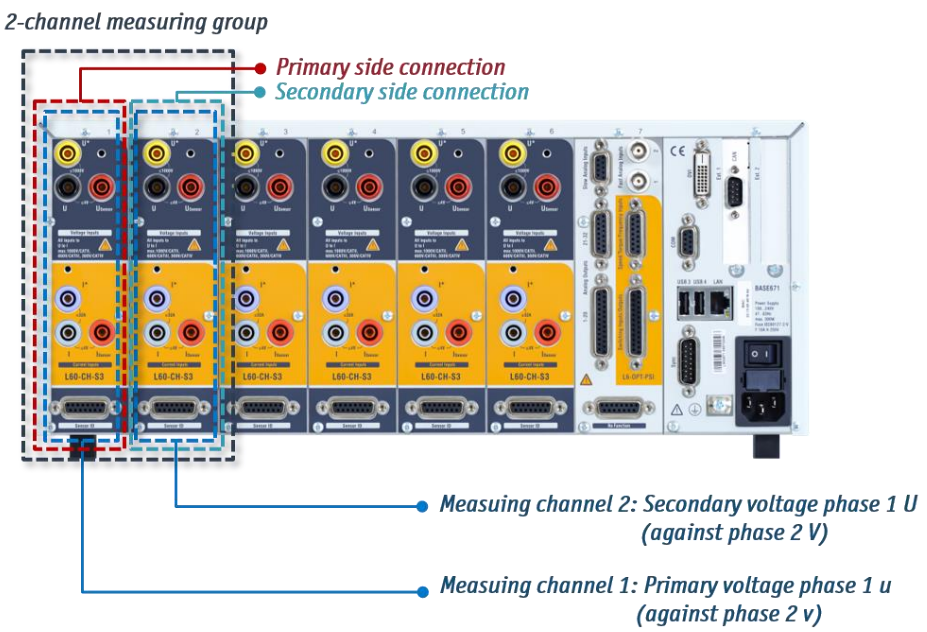


Figure 18: Connection and grouping of measuring solution 2 for testing the phase displacement

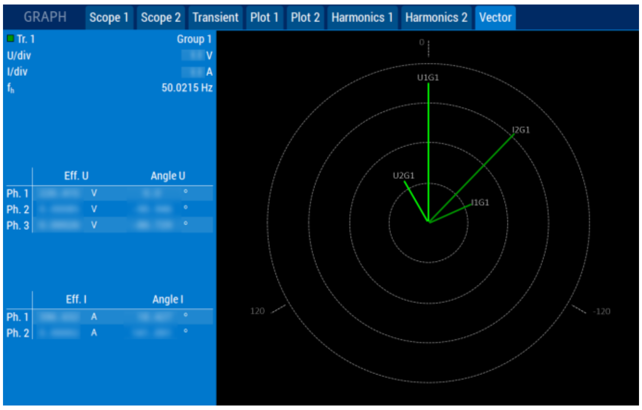


Figure 19: Vector diagram - phase displacement measuring solution with 2-channel measuring group

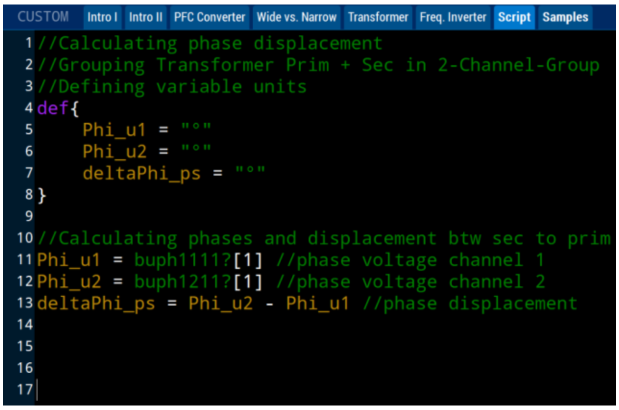


Figure 20: Calculation of phase displacement measuring solution with 2-channel measuring group with script editor

Learning

Phase displacements between the primary and secondary windings, whose verification is normatively required as part of type and acceptance testing, can be determined using the LMG671 during direct, comprehensive efficiency measurements with all six power measurement channels - without the need for any rewiring. The instrument's unique integrated script editor enables direct calculation based on the fundamental phase angles obtained from the harmonic analysis.

Note

Measuring solution 1 is preferable to solution 2 in this case, as it allows differential comparison across all phases - e.g., primary voltage Phase 2 v (channel 2) against secondary voltage Phase 2 V (channel 5), and so on - providing direct insight into phase symmetry.

Direct Measurement of the K-Factor – Assessment of Resistance to Current Harmonics

The K-Factor (load factor) is particularly important for high-efficiency transformers in the context of non-linear loads - such as in data centers, server infrastructure, or uninterruptible power supplies (UPS). Although it is not part of standard type testing (e.g., no-load or short-circuit tests), the K-Factor plays a critical role in modern application environments.

This parameter is typically not determined during factory testing but rather during operation, under simulation or load testing conditions with harmonic distortion, or within a dedicated special test setup using suitable power sources.

The K-Factor is a measure of the thermal stress a transformer experiences due to harmonic components in the load current. It was introduced to quantify the increased heating effect caused by high-frequency current harmonics. An example of how various harmonic components influence the K-Factor is illustrated in Figure 21. Transformers with a high K-Factor rating can therefore continue to operate efficiently and safely even under significant harmonic loading, maintaining performance within high-efficiency and energy-compliant operating ranges.

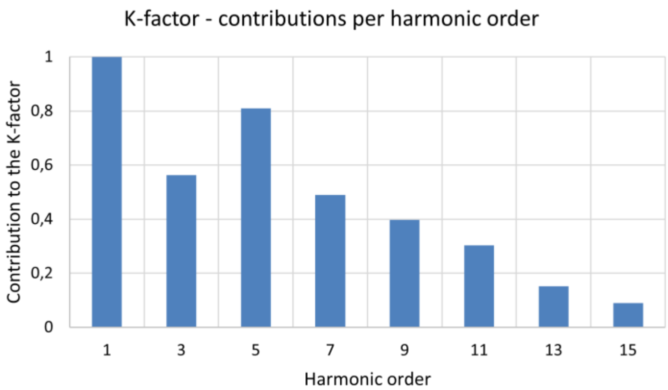


Figure 21: Diagram of the contributions per harmonic to the K-factor of approx. 3.8

K-Factors under highly distorted load conditions typically range between:

- 13 (K-13): For loads with elevated harmonic content
  (e.g., server rooms, data centers).
- 20 (K-20): For loads with very high harmonic content
  (e.g., industrial facilities with numerous frequency converters).

The K-Factor is based on the following formula, in accordance with IEEE C57.110 and IEC 60076-1:

$$K = \sum_{n=1}^{N} \left(\frac{I_n}{I_1}\right)^2 \cdot n^2$$

I_n: Current of the nth harmonic
I_1: Current at fundamental frequency (e.g. at 50 Hz)
n: Harmonic order (e.g. n = 3 -> 150 Hz)

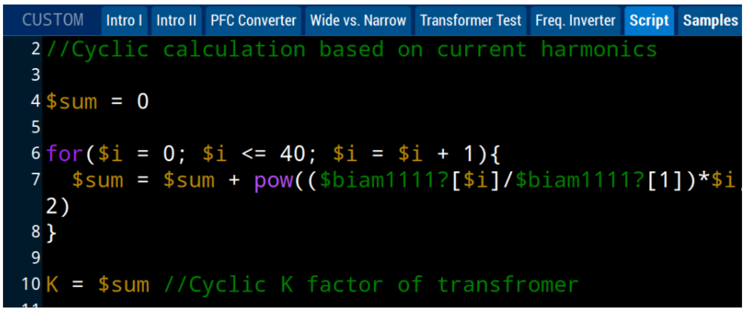


Figure 22: Calculation of the K-factor using the LMG671 integrated script editor

The LMG671, with its harmonics analysis capability up to the 2000th order (resp. up to 150 kHz), provides an exceptionally wide spectrum for the direct measurement of current harmonics using FFT. By additionally utilizing the integrated script editor, as illustrated in Figure 22, the real-time, synchronized calculation of the K-Factor during cyclic measurement is made possible.

Learning

The LMG671, with its harmonics analysis capability of up to the 2000th order (resp. up to 150 kHz), offers a very broad range for the direct measurement of current harmonics using Fast Fourier Transformation (FFT). By additionally using the integrated script editor, the real-time, cycle-synchronized calculation and output of the K-Factor is enabled.

LMG671 as Measuring Solution – Typical Device Configuration, Calibrated Accuracy, Recommended Accessories

LMG671 Precision Power Analyzer – Typical Device Configuration for Transformer Testing

For the most accurate, comprehensive, and time-efficient testing of power transformers, we recommend our LMG671 Precision Power Analyzer with the following configuration:

- **3 to 6× L60-CH-S:** High-end power measuring channels, Type S (quantity acc. number of measured phases)
- **1× L6-OPT-PSI:** Process Signal Interface
- **1× L6-OPT-SDC:** Delta-Star conversion option
- **1× L6-OPT-HRM:** Harmonics analysis up to 150 kHz (2000th order)
- **1× L6-OPT-EVT:** Transient trigger and recorder option

Thanks to its very wide current measurement range, the LMG671 with S-type channels allows for accurate measurements in both very low-current conditions (e.g. no-load test) and high-current scenarios (e.g. short-circuit test) - without the need to compromise between the two.

What the LMG671 power measurement channel type S offers

Electrical specifications for the highest femands:

- **Bandwidth:** DC, 0.05 Hz … 10 MHz
- **AC power accuracy (45 Hz … 65 Hz):** ± (0.015 % of reading + 0.01 % of range)
- **Voltage inputs:** 300 mV – 1000 V direct
- **Current inputs:** 500 µA – 32 A direct

Outstanding AC current measurement fynamics:

- **Measuring ranges:** 500 µA to 32 A across 14 ranges
- **Crest factors:** Factors up to 28 (RMS to peak ratio)
- **Measuring range extension:** Extendable up to 10 kA using precision current transducers from the PCT/Dx series or precision AC transformers from the LMG-Z5x2 series, without compromising amplitude or phase accuracy

Test bench integration and automated remote control:

- **Remote control interfaces:** Gigabit Ethernet, RS232, CAN
- **Data logging and export:** 8 GB internal SSD or external USB mass storage device
- **Software:** LMG600 Control PC software with plugin tools LMG600 Remote (GUI remote control, standard) und LMG600 SampleVision (sample value analysis tool, optional)

Current Measurement Range Extension

In professional test environments - particularly for type and acceptance testing according to IEC 60076 - fluxgate current sensors are increasingly replacing conventional current transformers for extending the measurement range, especially in the following areas:

- **Low current levels:** e.g., during no-load testing with typically only around 1–10% of rated current
- **High accuracy requirements**: with measurement tolerances below 0.1% and excellent thermal stability
- **Wideband measurement needs**: capturing harmonic components in test setups affected by grid distortions or non-sinusoidal test sources

Figure 23: Fluxgate-based precision current transducer from the PCT or Dx series

What PCT and Dx series current sensors offer

Electrical specification – uncompromising accuracy:

- **Bandwidth:** DC … 10 MHz (up to 600 A), … 400 kHz (up to 2000 A), … 100 kHz (up to 10 kA)
- **AC accuracy** (e.g. 5000 A sensor): ± (0.002 % of reading + 0.00002% of range)
- **Phase accuracy** (e.g. 5000 A sensor): ± 0.02 ° (even ± 0.01° with e.g. 2000 A sensor)
- **Features:** Direct supply from the LMG671 possible via LMG600 Plug'n'Measure interface; integrated ASPC protection electronics to safeguard against common fault scenarios (e.g., loss of sensor supply during active measurement, overcurrent events, etc.)

Note

For high-power transformers operating at correspondingly higher voltages, additional insulation within the current sensor aperture supports the required voltage withstand capability, if demanded by the measurement setup. With our LMG671 precision power analyzer, we make no compromises in amplitude or phase accuracy. That's why we rely on high-quality fluxgate current sensors, such as those from the PCT or Dx series (Danisense) - as illustrated in Figure 23.

Author:
M.Sc. Patrick Fuchs, Head of Business Development at ZES ZIMMER

Tel. +49 6171 88832-91
E-Mail: pfuchs@zes.com

Contact us

For further information on ZES ZIMMER products, applications or services, please contact us at:

ZES ZIMMER Electronic Systems GmbH
Pfeiffstraße 12
61440 Oberursel
Germany

Tel. +49 6171 88832-0
Fax +49 6171 88832-28
E-Mail: info@zes.com
Web: www.zes.com