Precision power measurement for impedance measurements: Measurement under operating conditions

Impedance measurements are usually carried out with digital LCR measuring devices. Current, voltage and phase angle are measured on the test object. The impedance parameters can be determined from the values. The small signal impedance values obtained in this way are useful for many telecommunications applications. However, precision power meters are used for power engineering and power electronics test specimens, which also determine the current, voltage and phase angle via active and apparent power.

Precision power meters work according to the products to be measured in energy technology and power electronics from DC up to several MHz. Precise phase-correct measurement up to several MHz is required by power electronics for frequency-converting methods (PWM) and the control of modern lamps. If only the DC resistance had to be measured, an ohmmeter would suffice. The existing inductive and capacitive components with their frequency-dependent alternating current losses must also be measured.

Picture 1: Precision power measurement LMG500

The LCR impedance measuring devices in communications engineering work in the small signal range with a sinusoidal measurement voltage at one or more fixed frequencies. The small signal impedance values obtained in this way are used, for example, in production control for comparison with good samples. In most cases, no statement can be made about the actual use under operating conditions. Even the DC bias currents and voltages that can be added to high-quality impedance measuring devices only provide a sufficient approximation of the actual operation in exceptional cases.

The reasons are manifold

The large-signal behaviour (large-signal impedance values) and in particular the active component (corresponding to the losses) differ significantly from the small-signal behaviour due to a variety of non-linear influences. Level-dependent iron losses, temperature-dependent iron losses and temperature-dependent copper losses also influence the behaviour. Operation takes place with non-sinusoidal voltages and currents, i.e. with frequency mixtures. For this reason alone, it is not possible to measure the phase angle between current and voltage, as the phase angle only relates to a specific frequency. The usual equivalent circuit diagram, consisting of loss resistance and reactance, is also no longer applicable. Only a magnitude value of the impedance, calculated from the effective voltage and effective current, and the power factor describe the device under test. As the loss components contained in the power factor λ increase with different powers of the frequency depending on the physical cause, it is hardly possible to convert the losses to other frequencies and frequency mixtures.

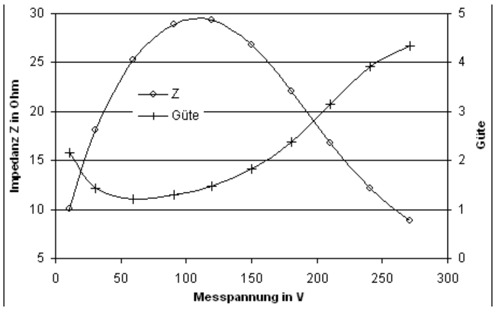
Picture 2: Filter circuit chokes as typical three-phase test specimens

Multiphase equipment as test specimen

Three-phase chokes, three-phase transformers and multiphase motors cannot be measured phase by phase due to the coupling of the phases via common iron paths. The properties that are important for operation can only be determined with three-phase measurements. The small-signal impedance is meaningful if there is only negligible self-heating of the component and the current and voltage values are so low that no significant distortions occur due to harmonics and thus new frequency components. However, the large-signal impedance is meaningful in all other cases. In particular, measurements under the planned operating conditions provide important information about the effective losses and their dependence on various influencing variables.

Measuring method for large signal impedance

Typical here is the separation between the supplying source and the measuring device. Adjustable current and voltage values of fixed frequency or non-sinusoidal signals of sufficient power are used as the source. As a measuring device, a modern power meter (e.g. the LMG series from ZES ZIMMER) is superior to all multimeters because the most important requirements of the application also fulfil the basic requirements of modern power meters. In particular, these are a wide measuring range for voltage and current, measurement of active power, multiphase measurement (if required by the device under test), galvanic isolation between the voltage and current inputs, a wide frequency range and high measuring accuracy. A display of the impedance value as a quotient of the effective voltage and effective current, convenient display and communication options and high device safety standards are also required. This also applies to accessories for measuring voltages and currents in the kV and kA range.



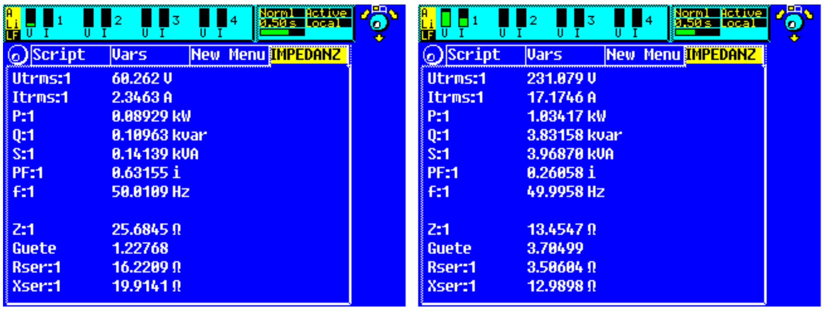
Picture 3: Magnitude and phase of the impedance as a function of the modulation

An example

Example measurements were carried out with sinusoidal variables, as this allows direct comparison of the measurement results with the data from an LCR measurement. The power factor then corresponds to cos ϕ and, in the case of low losses, approximately to the loss angle tan δ. The quality Q is calculated using the formula editor of the LMG500 and displayed in the user-defined customer menu. The measurement is intended to show the level dependence of the impedance values. With non-sinusoidal modulation, the deviation between small-signal and large-signal impedance is generally much more pronounced.

The user-defined impedance menu of the LMG500 power meter displays all the measurement and calculation values of interest at a glance. At a level of approx. 60V, the test specimen shows an impedance Z of 25.68 Ω and a quality factor of 1.22 (left); after increasing the level to 230V, the impedance Z falls by half (13.45 Ω) and the quality factor increases to three times the value (3.70) (right).

If the measurement is carried out with a sufficient number of operating points, the intermediate values can also be interpolated. This determines the entire non-linear course of the large-signal impedance in the operating range.



Picture 4: User-defined impedance menu of the LMG500 power meter

a) Level control with approx. 60V: high impedance, low Q factor

b) Level control with 230V: low impedance, high Q factor

Summary

It should be noted that the measurement of large-signal impedance poses major problems for commercially available LCR measuring devices. The use of modern precision power meters, on the other hand, enables amazingly simple solutions.

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