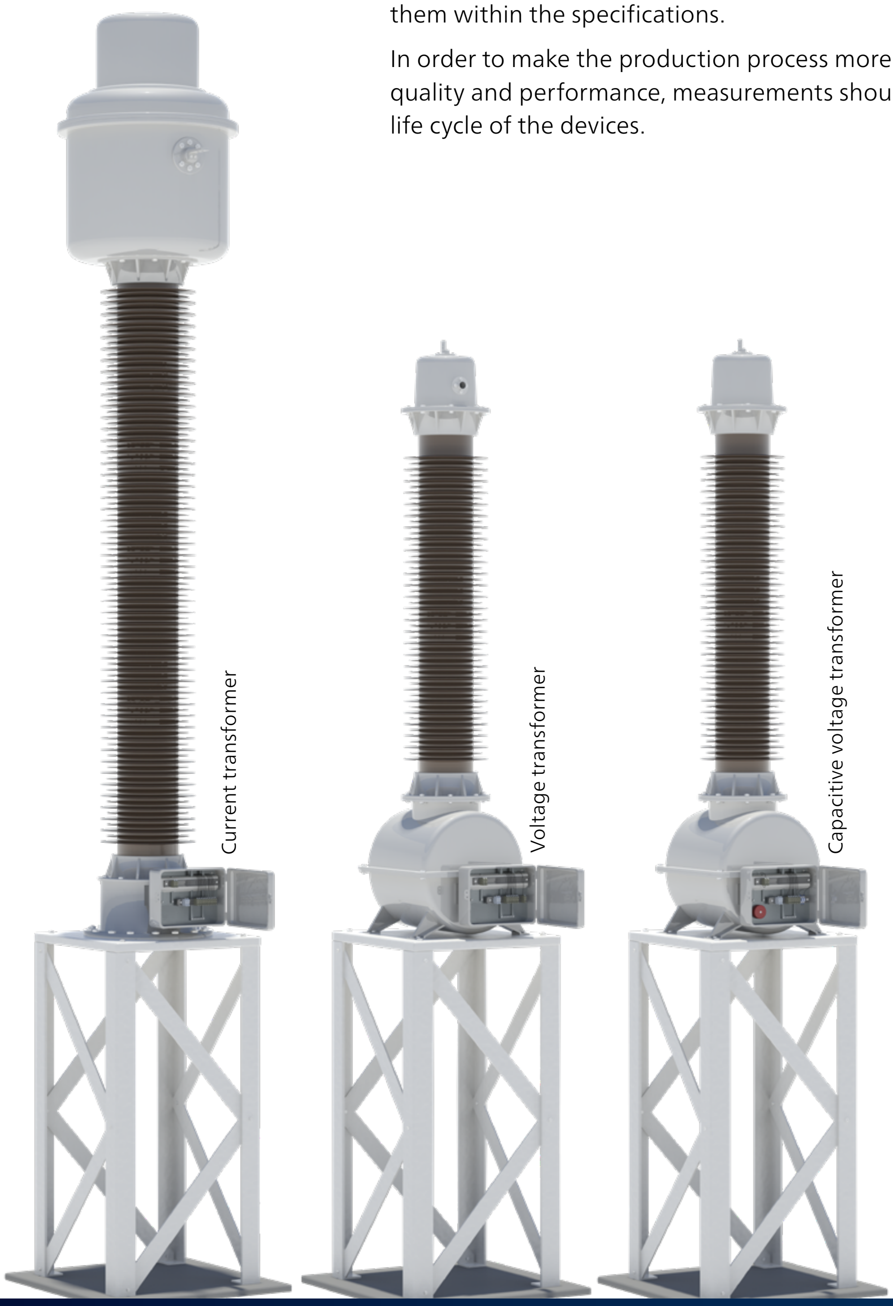
Diagnostic testing of instrument transformers

Ensure high quality and efficiency during the whole life cycle of your

Acting as the link between the primary and secondary system, instrument transformers (IT) are essential for a reliable and safe energy supply.

IT testing is of great importance as it helps to; ensure high quality in the production process, accurately install and commission the devices, and operate them within the specifications.

In order to make the production process more efficient and to ensure good IT quality and performance, measurements should be performed during the whole life cycle of the devices.



Typical IT failure sources

- **Design faults**
  Related to ratio, magnetic core, insulation
- **Manufacturing faults**
  Open/short circuits, insulation faults
- **Operation outside of specifications**
  Over/underburden, wrong currents/voltages
- **Electrical influences**
  Switching surges, lightning, overvoltages, short circuit currents
- **Aging/corrosion**
  Moisture, acids, oxygen, contamination, leakages

Design > **Manufacturing** > **Factory Acceptance Testing**

instrument transformers

Testing and corrective measures

> **During the production process**
> Determine the exact condition and performance data at defined stages within the production process in order to avoid processing of inaccurate or faulty devices and thus increasing efficiency of production process

> **After manufacturing**
> Know the actual performance of an IT according to the standards and provide useful fingerprint tests for further comparison

> **After transport**
> Perform tests after transportation to ensure that the transport didn't cause any mechanical failures in the IT and that it still works according to its specifications

> **During installation and commissioning**
> Ensure that the IT is installed properly and works according to the specifications in its operating environment

> **Regular maintenance**
> Know the condition of your IT in order to avoid failures, shut downs and long outages

Instrument transformer life cycle

Transport

Installation and Commissioning

Operation

Instrument transformer components and detectable faults

Component	Detectable faults
Insulation	Partial discharges
	Moisture in paper insulation
	Aging, moisture, contamination of insulation fluids
	Defects in the capacitive layers of the potential grading
Windings	Short circuits (interturn shorts)
	Open circuits
	Contact problems
Core	Mechanical deformation;
	Floating core ground;
	Loose clamping structure
	Magnetic short circuits
	Pre-magnetization / residual magnetism
Capacitive voltage divider	Partial breakdown of single capacitive layers
Compensation reactor (CVTs only)	Shorted turns
Whole electromagnetic circuit	Accuracy (ratio error and phase displacement)
	Ratio error (composite error)
	Polarity
	Wrong rating of IT
Burden	Wrong rating
	Wrong or faulty connection between IT and meter / relay

■[1]: Faults lead to changes of the IT's accuracy

■[2]: Often these faults cannot be clearly identified but comparisons to previous data help to find the failures.

OMICRON

Possible measurement methods	Accuracy (ratio error and phase displacement)	Ratio / Ratio error	Polarity	Excitation characteristics	Winding resistance	Burden	Partial discharge analysis	Dielectric (frequency) response analysis	Power factor / dissipation factor test	Accuracy limit factor (ALF) and terminal voltage (V_b)	Residual magnetism measurement	Transient CT parameters
							■					
								■				
								■	■			
									■			
	■[1]	■		■[2]	■							
	■[1]	■		■[2]	■							
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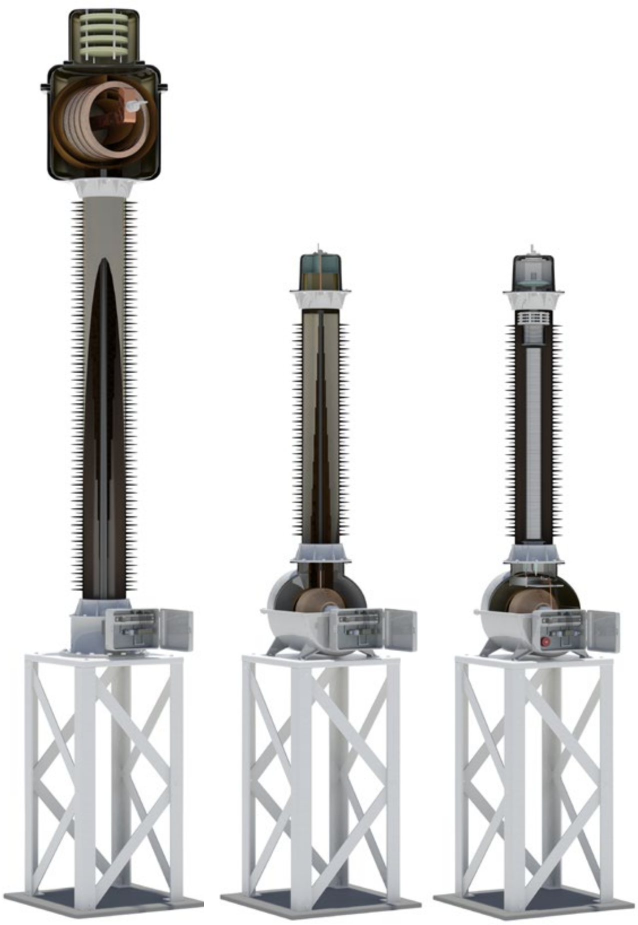
The ideal testing solution for your individual needs and requirements



	CT ANALYZER	VOTANO 100
Accuracy (ratio error and phase displacement)	■	■
Ratio / Ratio error	■[1]	■
Polarity	■	■
Excitation characteristics	■	■
Winding resistance	■	■
Burden	■	■
Partial discharge analysis		
Dielectric (frequency) response analysis		
Power factor/dissipation factor measurement:		
at 50 Hz or 60 Hz		
with variable frequency		
Accuracy limit factor (ALF) and terminal voltage (V_b)	■	
Residual magnetism measurement	■	
Transient CT parameters	■	

[1] Can measure CT and VT ratio
[2] CPC 100 can test the ratio of CTs and VTs; tests with higher amplitudes require CP TD12/15 and current booster
[3] Only possible for CTs
[4] Additional accessory CP TD12/15 required
[5] With limited accuracy
[6] Additional power supply and standard capacitor required

Highly accurate and lightweight test set for current transformer testing and calibration.

Highly accurate and mobile voltage transformer testing and calibration device.

/application

CPC 100	CPC 80 + CP TD12/15	COMPANO 100	DIRANA	MPD 800	TANDO 700
■[2]		■[5]			
■		■			
■[3]					
■					
■		■			
				■	
			■		
■[4]	■		■		■[6]
■[4]	■		■		■[6]
■					
Multi-functional test set for a comprehensive condition diagnosis and condition assessment of multiple high-voltage assets.	Power/dissipation factor and capacitance test set, (including source and reference capacitor) for various high-voltage assets.	Portable primary and secondary injection and basic protection test set.	Lightweight test set for fast and reliable moisture content determination of oil-paper insulated instrument transformers.	Universal partial discharge (PD) measurement and analysis system	Ultra-precise test set for dissipation/power factor and capacitance measurements on high-voltage assets (an external source and reference capacitor are required)
					

Electrical testing methods on instrument transformers

Direct electrical testing

Signals (voltage/current) are injected into the primary (HV) side of ITs and the corresponding value is measured at the secondary (LV) side. The determined parameters are ratio, accuracy, polarity, etc.

During accuracy tests, different test burdens need to be connected to the IT in order to consider their influence on its behavior. The method can be applied to both conventional and non-conventional ITs.

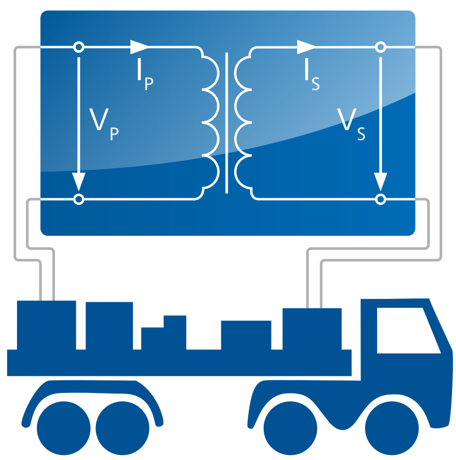
A test with this method at rated voltages / currents is mandatory for every IT as part of the routine tests.

Primary nominal injection

Test signals with nominal values (voltage/current) are used. During the test the operating burden is connected to the IT.

This method is used in calibration laboratories and sometimes on-site mounted on huge test trucks providing high accuracies.

Typically, the test systems are bulky, heavy and therefore not optimally suited for on-site tests, as their operation results in high efforts and costs.



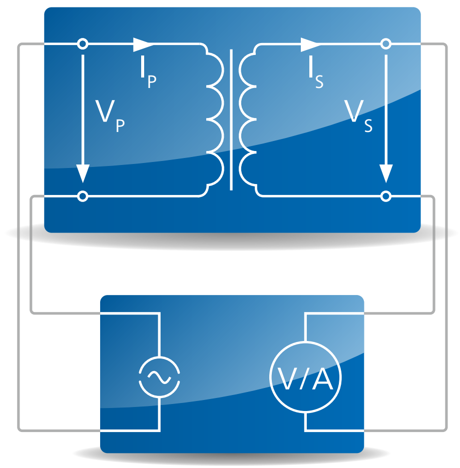
Primary nominal injection

Primary injection

Primary test signals (voltage/current) are used (not necessarily nominal values). It can only be used for a functional check of conventional ITs but not for calibration or class verification (non-linearity of the ITs).

For non-conventional instrument transformer (NCIT) testing, lower test signals may be suitable based on a linearity statement from the manufacturer.

Typically, the test systems are portable, but their accuracy is often limited. Therefore, this method is suitable for on-site commissioning tests.



Primary injection

Indirect electrical testing

With this method, an IT is tested from the secondary side with test signals differing from the primary values. The method is applicable to conventional ITs (CTs, VTs, CVTs).

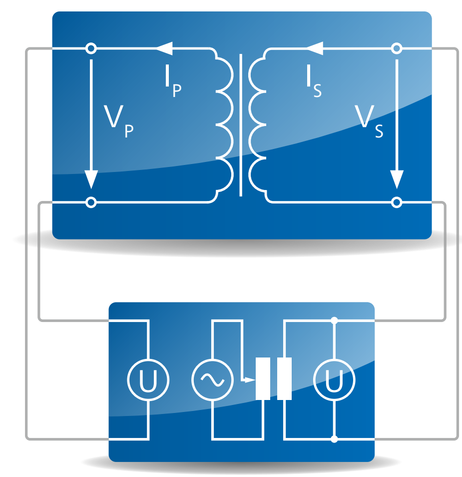
Secondary voltage injection

A dedicated test method for CTs where a voltage is injected via the secondary side. The test voltage is equivalent to the operating terminal voltage at rated burden.

The measured excitation curve complies to international standards.

The composite error can be determined by applying a voltage according to the CT's individual operational condition, measuring the corresponding excitation current, and calculating the error accordingly.

The great advantage of this method is that small, lightweight, test equipment can be used on site instead of bulky primary injection equipment.



Secondary voltage injection

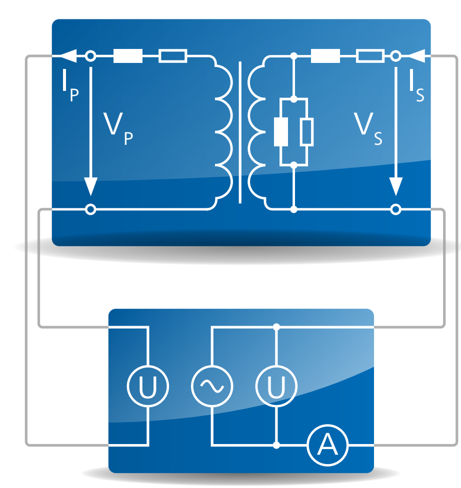
Model-based testing

The low-value test signals used allow for the design of small, lightweight and safe test equipment.

With this approach, ITs are modeled using their equivalent circuit diagrams (ECD). Based on all measured and determined ECD parameters, the necessary IT values, such as accuracy, ratio, polarity, are calculated.

This method can be used for calibration and diagnostics as the ECD parameters give accurate information about the device - even root cause analysis of a failure is facilitated.

The method is perfectly suited for on-site and laboratory applications (lightweight and accurate).



Model-based testing

Accuracy (according to IEC/IEEE standards)

What can be tested?

- Insulation
- ✓ Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- Burden

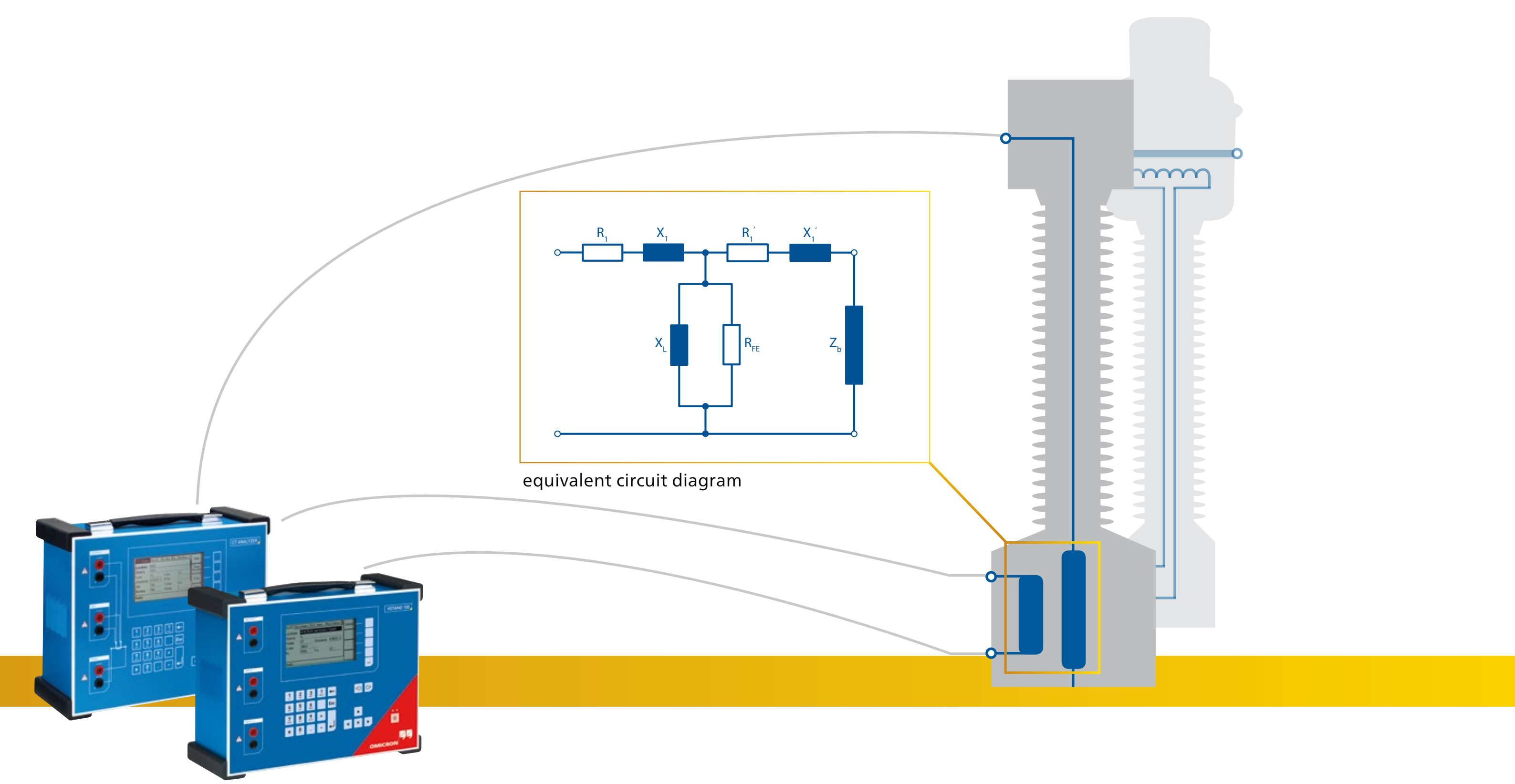
Why measure?

The measurement helps to guarantee a safe, stable and economic energy supply by evaluating the integrity of an IT. With the accurate performance of the IT under test, the operator can obtain an exact image of the system's voltages and currents.

Inductive current and voltage transformers (CT and VT) and capacitive voltage transformers (CVT) can develop ratio and phase deviations. An IT operation using different burdens, currents or voltages can change the ratio error and phase displacement, affecting an operation according to the specified accuracy. In addition, shorted turns in current transformers and shorted capacitive layers in the capacitor stack of a CVT are often undetected. This can lead to readings errors, loss in revenue, and in some cases, a complete breakdown. The accuracy measurements can be performed during the production process, in testing laboratories, or on site.

How does it work?

The transformer's accuracy (ratio and phase) is determined with a model-based approach. It models an IT by its equivalent circuit diagram using embedded mathematical algorithms. All circuit parameters are determined by software-guided on-site measurements where only low voltages are used. Afterwards, the transformer's accuracy is calculated on the basis of the measured parameters and the load condition.



CT Analyzer   VOTANO 100

Good to know ...

Only the model-based approach considers and simulates the influence of different burdens and operating ranges on the transformer's accuracy.

The accuracy measurement can also be performed using the primary injection method with connected burden. Other conventional test methods use high currents or high voltages.

The model-based accuracy measurements can also be used for further diagnostics, especially on CVTs. In addition to the ratio error and phase displacement, the circuit parameters are available after a measurement. The root cause of a possible drift in accuracy can be determined by examination of the parameters.

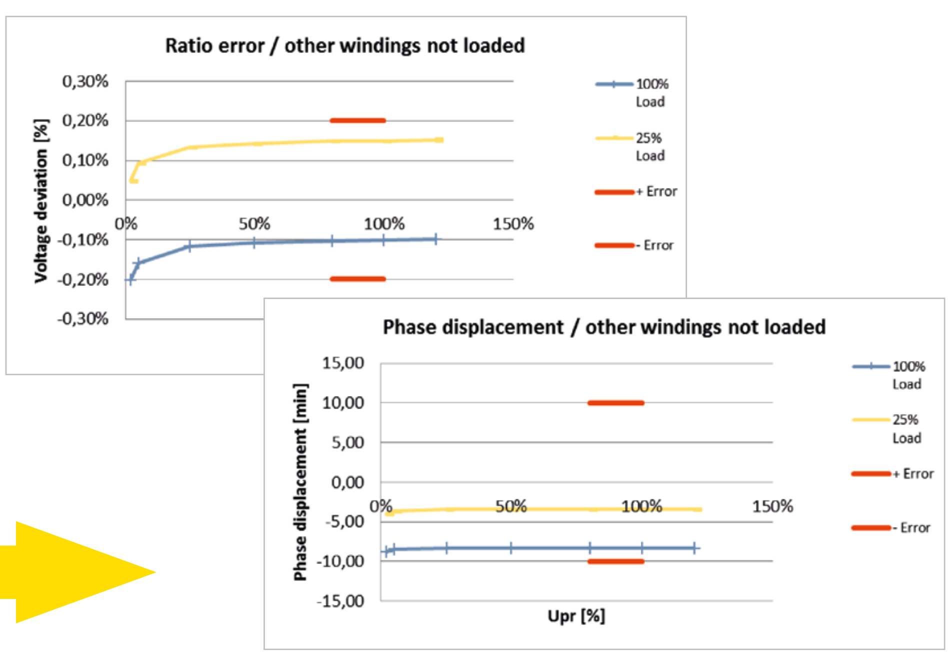
As only low voltages or currents are used for this method, it allows it to be used in the production process even without the main insulation.

Users can transfer the measured circuit parameters to simulation programs to simulate the system including a correct non-linear representation of current and voltage transformers.

Why use CT Analyzer / VOTANO 100?

- Provides all relevant information for mobile testing and calibration of protection and metering ITs
- Only existing measurement method using low and comparably safe test signals
- Much smaller, lighter, easy-to-use and safer than any existing primary test set
- Fast measurements without reference objects and with lightweight equipment
- Simulation of different operation modes possible after measurements
- With accessories, multi-ratio CTs and multi-tap VTs can also be measured
- Automated result assessment with values defined in selected IEEE, ANSI, or IEC standards

Ratio error and phase displacement of an IT



Ratio / Ratio error

What can be tested?

- Insulation
- ✓ Windings
- Core
- ✓ Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- Burden

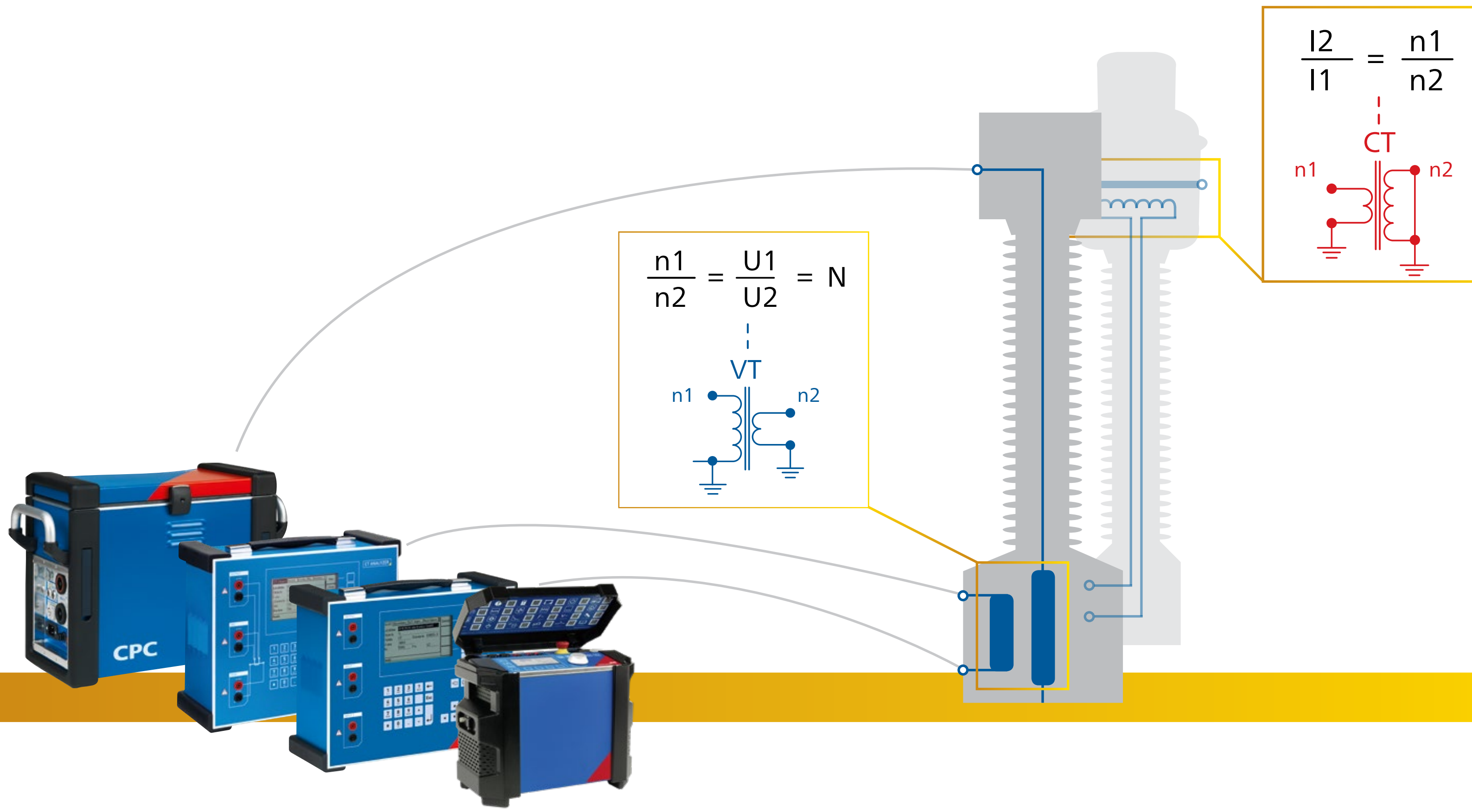
Why measure?

Ratio, or ratio error, is measured as a functional test of ITs' performance during manufacturing, factory acceptance, as part of commissioning tests, or as a performance test after an outage. The measured ratio of ITs is compared to the design and nameplate specifications and to previous measurement results. The error can be calculated for each testing point. Deviations from the specifications may indicate internal faults (for example, open or short circuits) or faults during production. Ratio errors may cause a malfunction of protection and false interpretation of the system voltage/current.

How does it work?

The device under test is a CT or VT with or without any connected burden. When no burden is connected to the IT, the CT's secondary side must be shorted and the VT's secondary side must be open. The test signal is applied to the primary or secondary side. The measurement is performed from the other side of the IT.

The turns ratio, ratio error or composite error can also be measured with the voltage method where the signal is applied to the secondary side. The secondary voltage, excitation current and the induced voltage on the primary side are measured.



CPC 100 | CT Analyzer | VOTANO 100 | COMPANO 100

Good to know ...

A ratio check is only a functional test which is generally not comparable to the accuracy tests according to the IEC /IEEE standards.

For capacitive VTs it makes sense to perform independent tests of the capacitive ratio and the ratio of the intermediate inductive VT. This helps to distinguish between a fault in the capacitive divider and in the electromagnetic circuit.

If the measuring results don't allow any clear interpretation, further examination of the ITs with a model-based approach should be performed.

The ratio of CTs can also be determined via the secondary side injection. In order to get very accurate turns ratio results, the voltage drop across the secondary winding resistance must be considered.

The very accurate phase measurement even allows the detection of magnetic short circuits (an advantage during the manufacturing process).

Why use CPC 100?

- Test signals up to 2 kA and 12 kV/15 kV
- Only test device for both primary injection (direct method) and secondary injection (indirect method)
- Can also test NCIT according to IEC 61850

Why use CT Analyzer?

- Ratio and complete accuracy measurement possible
- Nameplate parameter guessing if values are unknown
- Low test voltages guarantee safe measurements
- High-accuracy measurements (0.05%)

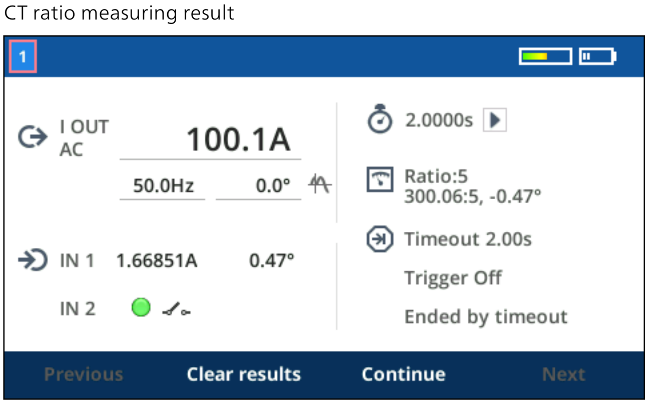
Why use VOTANO 100?

- Ratio and complete accuracy measurement possible
- Allows separate measurement of capacitive and inductive CVT ratio
- High-accuracy measurements (0.05% - 0.2%)

Why use COMPANO 100?

- Combines CT/VT ratio checks with circuit continuity, polarity checks and burden measurements
- Frequency-selective measurement

CT ratio measuring result



Polarity

What can be tested?

- Insulation
- ✓ Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- Burden

Why measure?

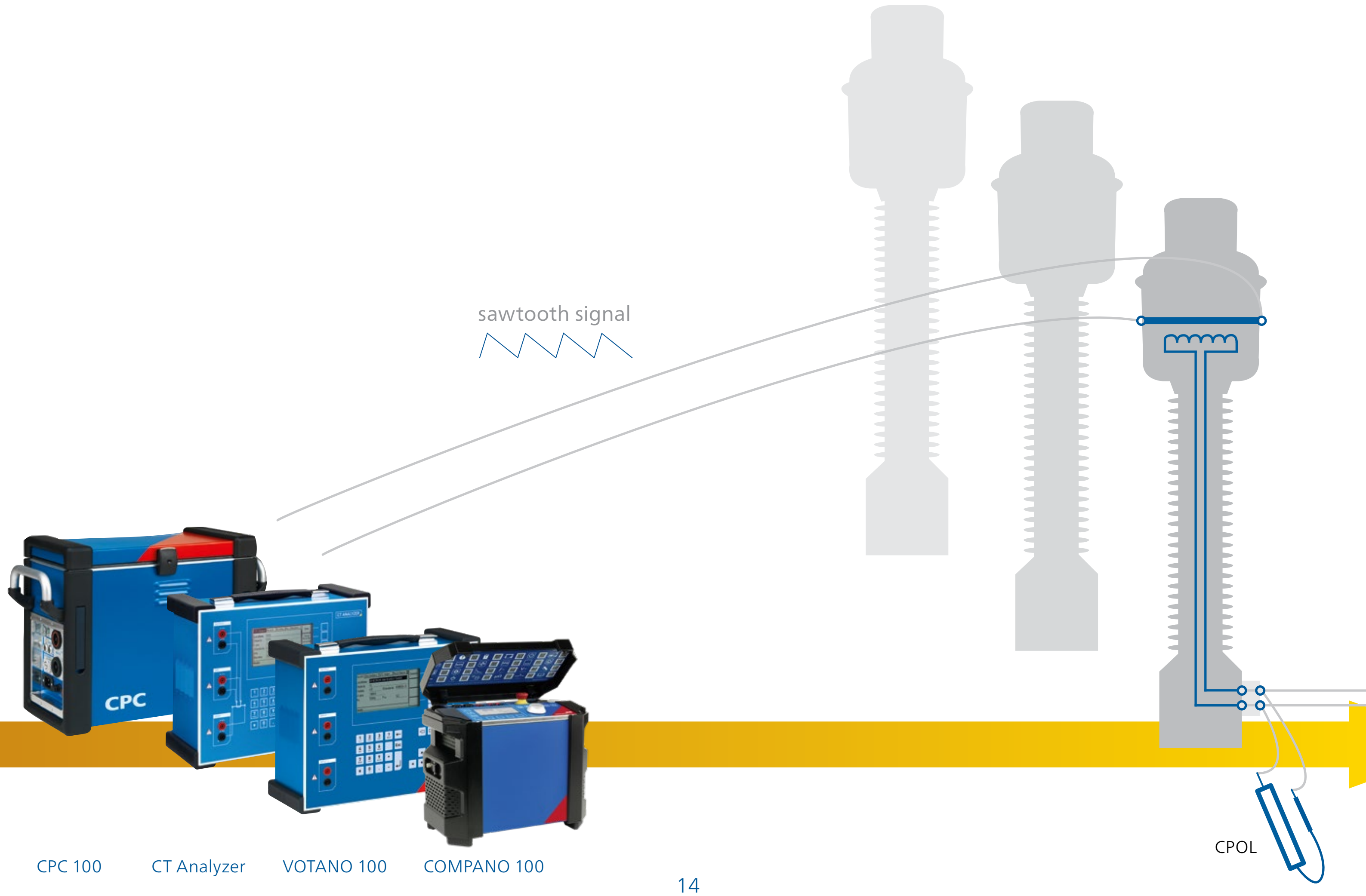
A polarity check makes sure that the polarity between the primary and secondary windings of an IT and thus, the direction of energy flow is correct. It prevents any maloperation of connected protection devices. Selective distance protection can only be guaranteed when the polarity is correct. The tests also make sure that the secondary devices are properly connected to the IT and with correct polarity.

How does it work?

Two different methods exist:

With the first method, a sawtooth signal is injected into the system. This signal can be either a voltage or a current signal. A polarity checker (CPOL), tests the polarity of the injected signal along the circuit and provides a clear indication as to whether the polarity is correct or not. ITs or connected cables can be checked.

The second method applies a sinusoidal voltage to the IT, measures the signal on the other side, and compares the voltage/current vectors of the primary and secondary side.



Good to know ...

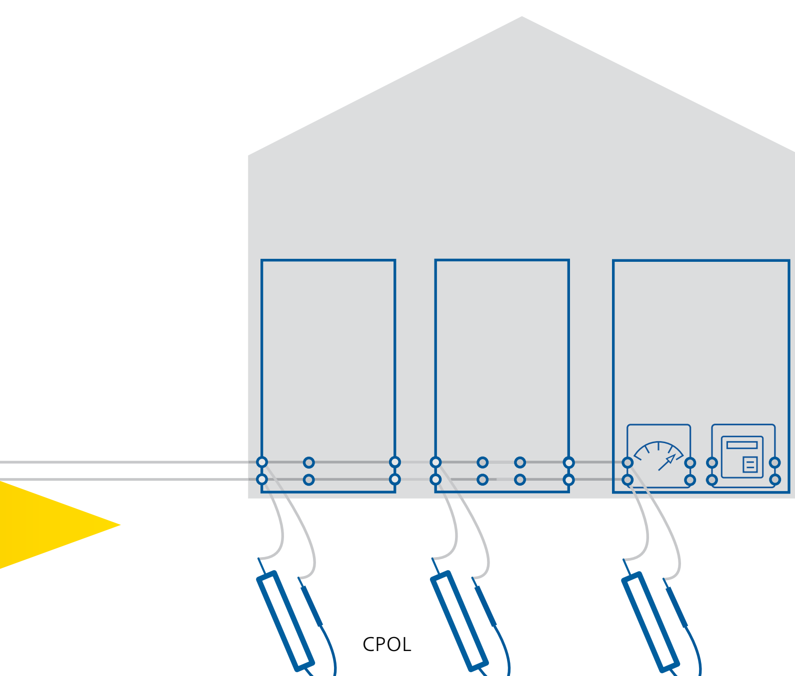
Polarity checks should be performed as part of commissioning tests to guarantee a proper function and the connections of newly installed ITs.

With CTs in power equipment, the check makes sure that the CTs are connected and installed properly.

In the past, the polarity has often been checked with batteries and conventional multimeters. As a result, core saturation and a subsequent maloperation of the protection could be seen. This cannot happen when an AC or sawtooth signal is used.

If there is any short circuit in the connection of a VT this leads to a VT failure, because a VT must not be operated under short circuit conditions.

If there is any open circuit in the connection of a CT this leads to a CT failure, because a CT must not be operated with open circuits.



Why use CPC 100?

- Checks polarity of complete process chain including CTs, VTs and connected cables
- Very easy operation with hand-held CPOL
- Sawtooth signal of up to 2 kV or 800 A can be generated
- Can also test NCIT according to IEC 61850

Why use CT Analyzer?

- Determines CT polarity with a comparison of the sinusoidal voltage vectors
- Also determines further important parameters such as ratio and phase displacement
- Allows generation of a sawtooth signal in order to check the connected wires

Why use VOTANO 100?

- Checks polarity of VTs without CPOL using a sinusoidal voltage
- Simultaneously measures ratio and polarity
- Exclusive test set for VTs

Why use COMPANO 100?

- Checks polarity of complete process chain including CTs, VTs, connection cables and direction setting of relays
- Uses a DC free asymmetrical test signal together with CPOL

Excitation characteristics

What can be tested?

- Insulation
- ✓ Windings
- ✓ Core
- Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- Burden

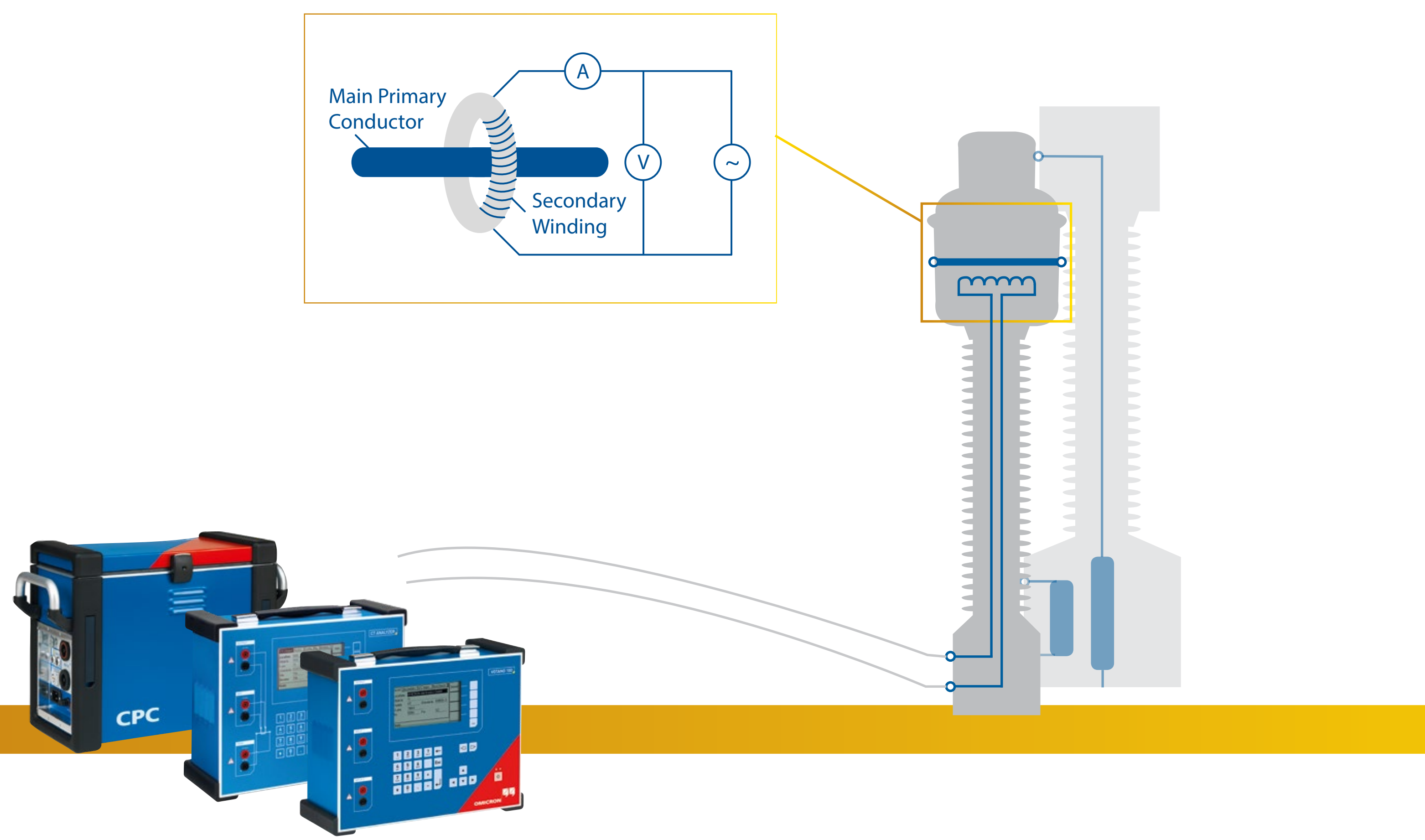
Why measure?

The excitation current is responsible for the IT error and defines the IT performance. The knee point voltage is important for the correct function of the connected protection device. For metering CTs, the excitation curve can be used to analyze the instrument security factor (FS). Protection CTs according to IEC and IEEE standards can be specified considering the excitation characteristics. The excitation curve of VTs can be used for a ferroresonance analysis, for network simulation and it gives an indication of shorted turns and core faults.

How does it work?

Excitation measurements are performed "indirectly" from the secondary side of the IT. A voltage is applied to the secondary side and the excitation current is measured. The test is performed with rated frequency or with variable frequency to decrease testing time and to be able to measure knee point voltages up to several kV with low applied voltages.

The knee points for CTs are subsequently calculated based on the specifications of the IEC or IEEE standards.



CPC 100 CT Analyzer VOTANO 100

Good to know ...

All possible test methods lead to similar information, even if the testing methodologies are different.

The variable frequency approach has a large advantage as lower testing voltages can be used, the testing time can be reduced, and CTs with comparably high knee points, up to 40 kV, can be tested.

It is very important to demagnetize ITs before and after the test in order to make sure that no residual magnetism affects their performance.

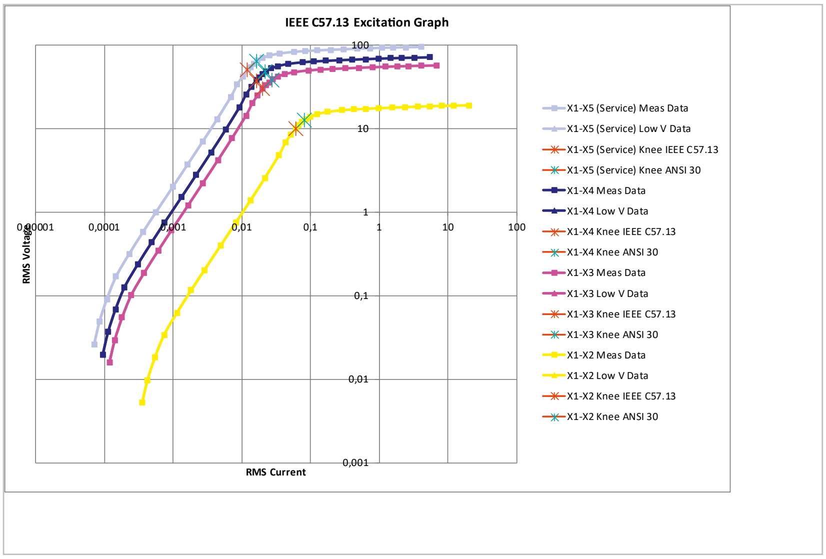
Why use CPC 100?

- Higher test voltages can be used for tests from 0 to 2 kV
- Trending and data analysis with the Primary Test Manager software
- Measurements can be performed with variable test frequencies from 15 Hz to 400 Hz

Why use CT Analyzer / VOTANO 100?

- Safe test due to relatively low test voltage of a maximum 120 V
- Reduction of testing time when using the variable frequency method
- Excellent noise immunity against disturbances from energized power lines close by
- Integration of excitation measurement in complete CT measurement workflow
- High knee points of up to 40 kV can be measured with the variable frequency method
- Direct comparison of excitation curve to an existing reference curve (trending)

Excitation curves of a multi-ratio current transformer



Winding resistance

What can be tested?

- Insulation
- ✓ Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- Burden

Why measure?

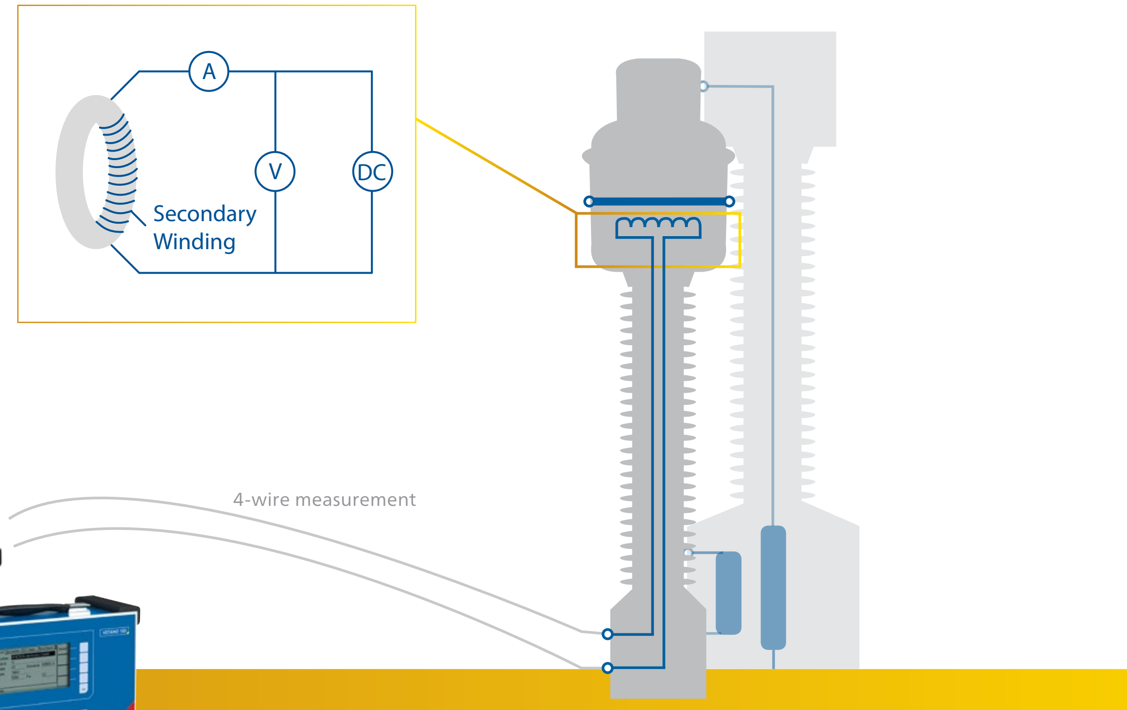
The measurement is performed to find possible electrical damage in windings or contact problems. The induction level of CTs depends on the secondary winding resistance. The voltage drop across the secondary winding resistance, together with the burden, defines the induction. If the secondary winding resistance is not according to specification due to manufacturing or connection issues or due to operational aspects, the induction might be too high resulting in overheating or operational restrictions.

The CT accuracy and accuracy limit factor (ALF) depend on the secondary winding resistance. The higher the winding resistance, the smaller the ALF. Shorted turns change the winding resistance and endanger IT operation (usually in VTs). Open circuits in CT secondary windings are dangerous and may result in high voltages or overheating and subsequently CT failure.

How does it work?

A DC current or voltage is applied to the secondary IT winding. For integrity checks, winding resistance measurements might also be of interest for the primary winding found on wound primary CTs.

After core saturation, a stable value for the measured current is reached. The winding resistance is then calculated as the ratio of applied voltage and measured current.



CPC 100 CT Analyzer VOTANO 100

Good to know ...

The measurement helps check the correct installation of built in CTs in larger assets such as power transformers or circuit breakers.

For certain standards, winding resistance of a CT is part of the specification.

A DC measurement will saturate the magnetic core, therefore it is absolutely necessary to demagnetize the core after a DC winding resistance measurement.

During DC magnetization, a stable resistance value will never be achieved. Thus, it is necessary to define a certain allowed deviation R_{dev}. If the measured value is within the defined deviation for a certain time, this value can be used for the measurement (see graphic below).

Why use CPC 100?

- The test is embedded in a multi-functional test set
- Stable measurement as core influence is considered
- Strong immunity against external noise
- High measuring accuracy

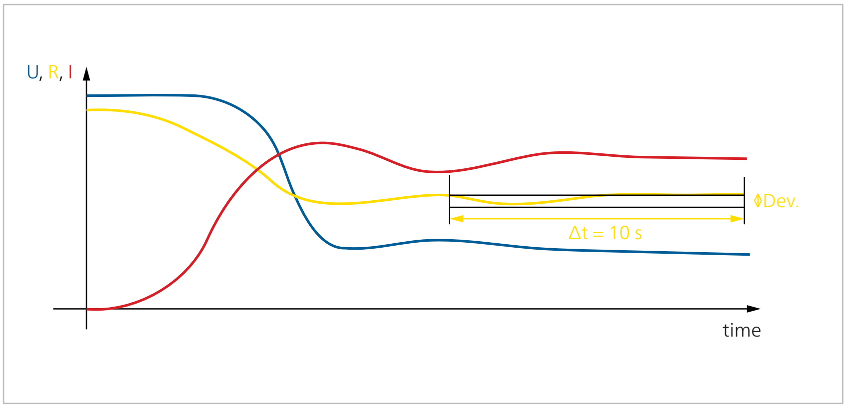
Why use CT Analyzer?

- Measurement can be integrated into complete CT test which includes accuracy, excitation and ALF, etc.
- High accuracy of typically 0.05 % + 1 mΩ with a resolution of 1 mΩ

Why use VOTANO 100?

- Together with the mandatory external connection and switching box VBO2, the test can be performed from a safe area without the need for long testing leads which influence the measurement
- Integrated in test workflow for VTs

Winding resistance profile over time



Burden measurement

What can be tested?

- Insulation
- Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- ✓ Burden

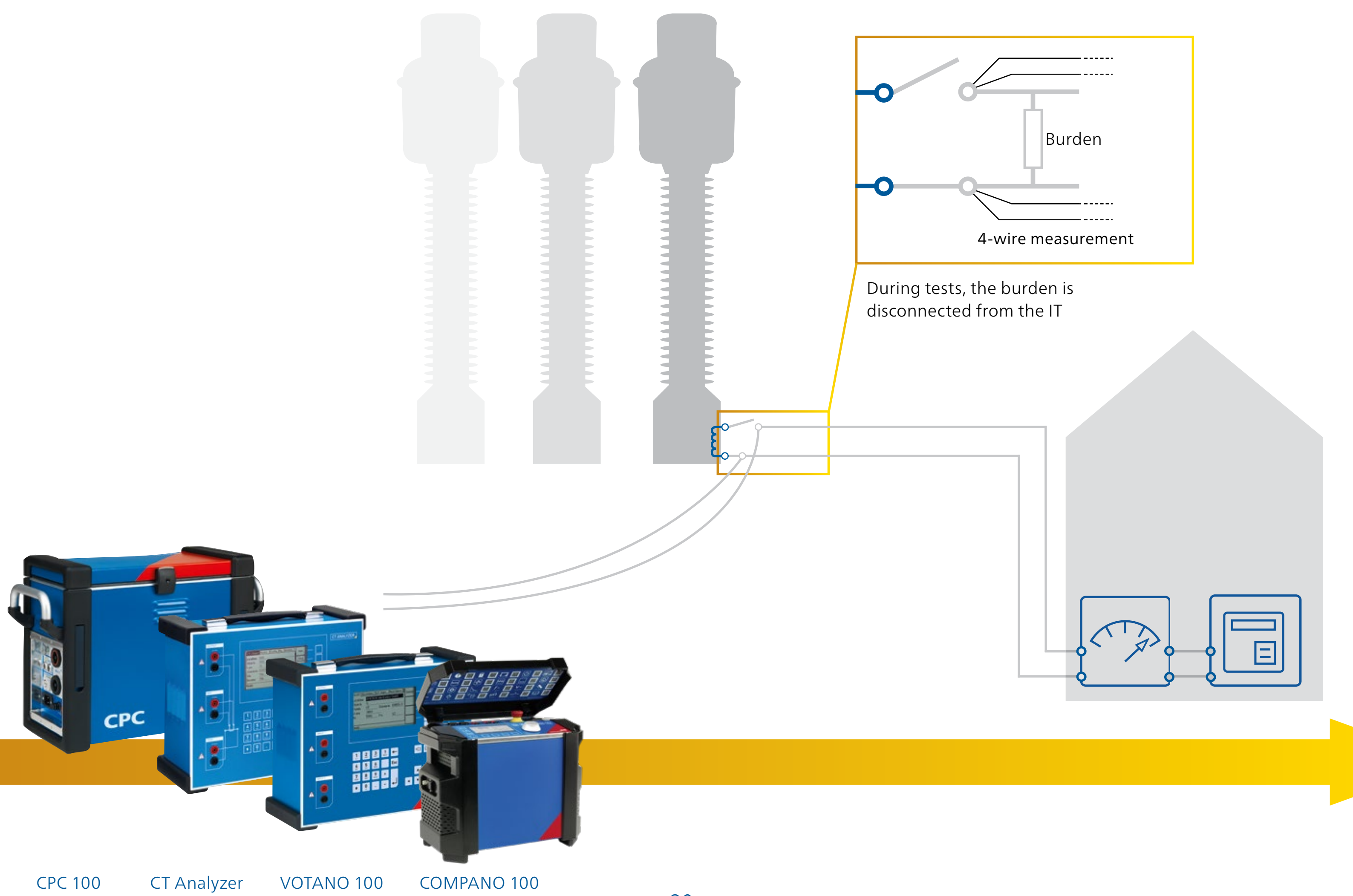
Why measure?

As the connected burden has a strong influence on the IT's performance, the exact operating burden must be known for correct IT operation. The measurement can determine the influence of cables and connections on the burden impedance. As the burden defines and / or affects the accuracy of ITs, the burden values should be known and the specified burden should not be exceeded or undercut.

The burden measurement can also indicate wrong connections or failures in the connection, preventing a CT from open circuit operation and a VT from short circuit operation.

How does it work?

The burden is connected to the measuring device instead of the IT. The burden is then measured with a complex impedance measurement (with magnitude and phase). The burden value is displayed in VA and as impedance. The VA rating always refers to the nominal secondary voltage or current.



Good to know ...

Due to a changed operation point, the burden can influence the ALF of protection CTs as the CTs saturate too early. In the case of metering CTs, the core saturation as a protection function for the connected measuring instruments can be compromized when a burden with either wrong polarity or wrong value is connected.

In relation to VTs, the burden current together with the excitation current are responsible for the VTs' error. As the influence of the excitation current is generally smaller and can be compensated during manufacturing, the burden current is dominating. Therefore, the operational burden is of interest.

If the connection includes short circuits (VTs) or open circuits (CTs) the IT may be destroyed.

Why use CPC 100?

- Multi-functional use for CTs and VTs and for burdens of all values and designs
- Measuring accuracy of 0.1 % of the automatically selected range (0 - 0.3 / 3 / 30 / 300 V AC)
- Existing measurement data can be loaded to the measuring device at any time
- The output specifications allow tests with nominal currents and voltages and higher values

Why use CT Analyzer and VOTANO 100?

- Burden measurement can be integrated into workflow of complete IT test including all standard relevant parameters
- Recalculation/simulation of IT accuracy for different burdens and primary currents/voltages is possible
- Existing measurement data can be loaded to the measuring device at any time

Why use COMPANO 100?

- Combination of wiring checks with burden measurements
- Can be easily moved around due to battery power and light weight

Burden dependence on the accuracy of VTs

Power			Voltage ratio error in % at % of rated voltage				
VA	**cos Phi**	**Burden in %**	**2%**	**5%**	**80%**	**100%**	**120%**
15	0.8	100	0.088%	0.123%	0.177%	0.177%	0.176%
3.75		25	0.033%	0.362%	0.415%	0.417%	0.415%
15	0.8	100	4.825	4.287	3.180	3.186	3.245
3.75		25	2.802	2.263	1.155	1.161	1.220
15	0.8	100	-0.57%	-0.54%	-0.482%	-0.481	-0.483%
3.75		25	-0.33%	-0.30%	-0.246%	-0.245	-0.246%
15	0.8	100	2.320	1.7825	0.678	0.683	0.737
3.75		25	0.302	-0.235	-1.340	-1.335	-1.300

Burden dependence on the accuracy of CTs

POWER			Current ratio error in % at % of rated current							
VA	**cos Phi**	**Burden in %**	**1%**	**5%**	**10%**	**20%**	**50%**	**100%**	**120%**	**200%**
15	**0.8**	100	-0.023	-0.023	-0.021	-0.018	-0.013	-0.010	-0.009	-0.008
		25	-0.023	-0.023	-0.021	-0.018	-0.013	-0.010	-0.009	-0.008
7.5	**0.8**	100	-0.008	-0.010	-0.010	-0.008	-0.006	-0.004	-0.003	-0.002
		25	-0.008	-0.010	-0.010	-0.008	-0.006	-0.004	-0.003	-0.002
3.75	**1**	100	0.005	0.001	0.000	-0.001	0.000	0.000	0.001	0.001
		25	0.005	0.001	0.000	-0.001	-0.000	0.000	0.001	0.001
0	**1**	100	0.007	0.005	0.004	0.003	0.003	0.003	0.004	0.004
		25	0.007	0.005	0.004	0.003	0.003	0.003	0.004	0.004

Partial discharge analysis

What can be tested?

- ✓ Insulation
- Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- Burden

Why measure?

Partial discharge (PD) can damage the insulation of ITs. PD can be caused by voids or air pockets in resin-impregnated ITs or due to local hot spots, sharp surfaces or moisture ingress in ITs (regardless of insulation type). Also design faults might lead to local high field strength and thus PD activity. This can lead to IT failure and costly outages.

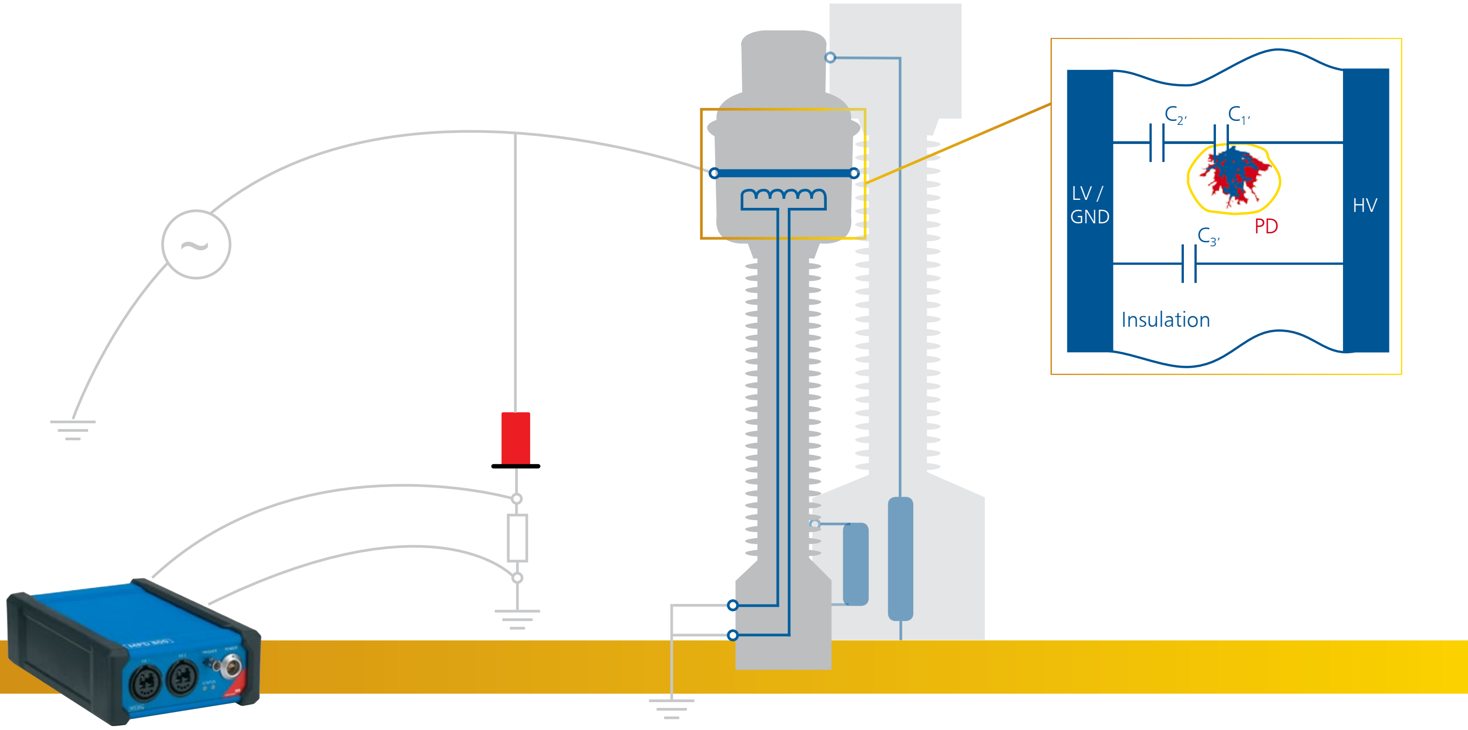
PD can also appear if the insulation material between different voltage potentials is aged, contaminated or faulty.

PD measurement is a reliable and non-intrusive method used to diagnose the condition of an IT's insulation system. It can be used for diagnosis in the laboratory (during factory acceptance) as well as for on-site tests to detect critical defects and assess risks.

How does it work?

When measuring and analyzing PD activity in ITs, the particular tests and test set-ups are defined by the IT type and the standard the measurements are performed to. Depending on the IT type, the PD analysis system is connected either to an external coupling capacitor or to the ground path of the IT.

PD is typically measured in pC. Advanced noise suppression techniques are commonly deployed in high-interference environments to minimize irrelevant data.



MPD 800

Good to know ...

PD is a localized electrical discharge that only partially bridges a solid or liquid electrical insulation system under high-voltage (field) stress.

A test circuit is installed so the shorted capacitance is reloaded from the coupling capacitor. The current during reloading can be measured and correlated to the discharge level.

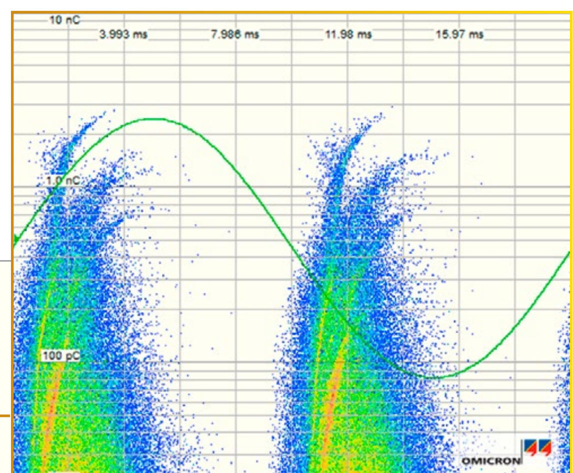
With pattern interpretation, internal and external PD as well as surface discharges or floating potential can be separated.

The multi-spectral PD measurement, called 3CFRD, can be used to separate different PD sources by analyzing the different frequency responses of the PD with only one measurement channel.

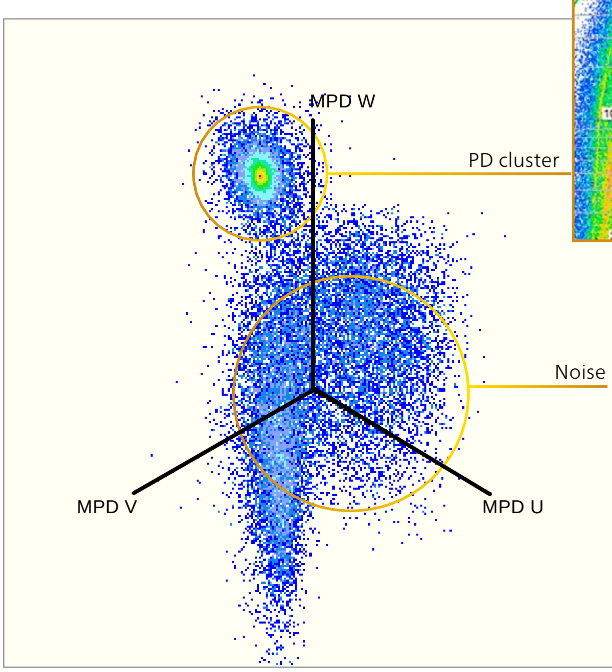
A measurement balanced bridge (MBB1) enables single-phase PD testing and can be used in both AC and DC test set-ups in the laboratory and on site. This is especially helpful for environments with heavy interference.

Why use MPD 800?

- IEC standard-compliant PD measurements on instrument transformers.
- Galvanic isolation via fiber optic cables ensures safe operation.
- Synchronous, multi-channel PD measurement and gating capabilities.
- PD data set recording and playback for later analysis.
- Active noise suppression and gating methods for optimal accuracy despite high interference.
- Customizable software allows uses to select only the PD analysis tools they need.



The detected PD cluster can be visualized in detail by using the PRPD histogram.



A 3PARD (3-Phase Amplitude Relation Diagram) separates PD sources from noise

Dielectric (frequency) response analysis

What can be tested?

- ✓ Insulation
- Windings
- Core
- Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- Burden

Why measure?

Dielectric response analysis, also known as dielectric frequency response analysis, is used for inductive oil-paper insulated ITs to assess the moisture content of the cellulose insulation and, thus, determine its condition.

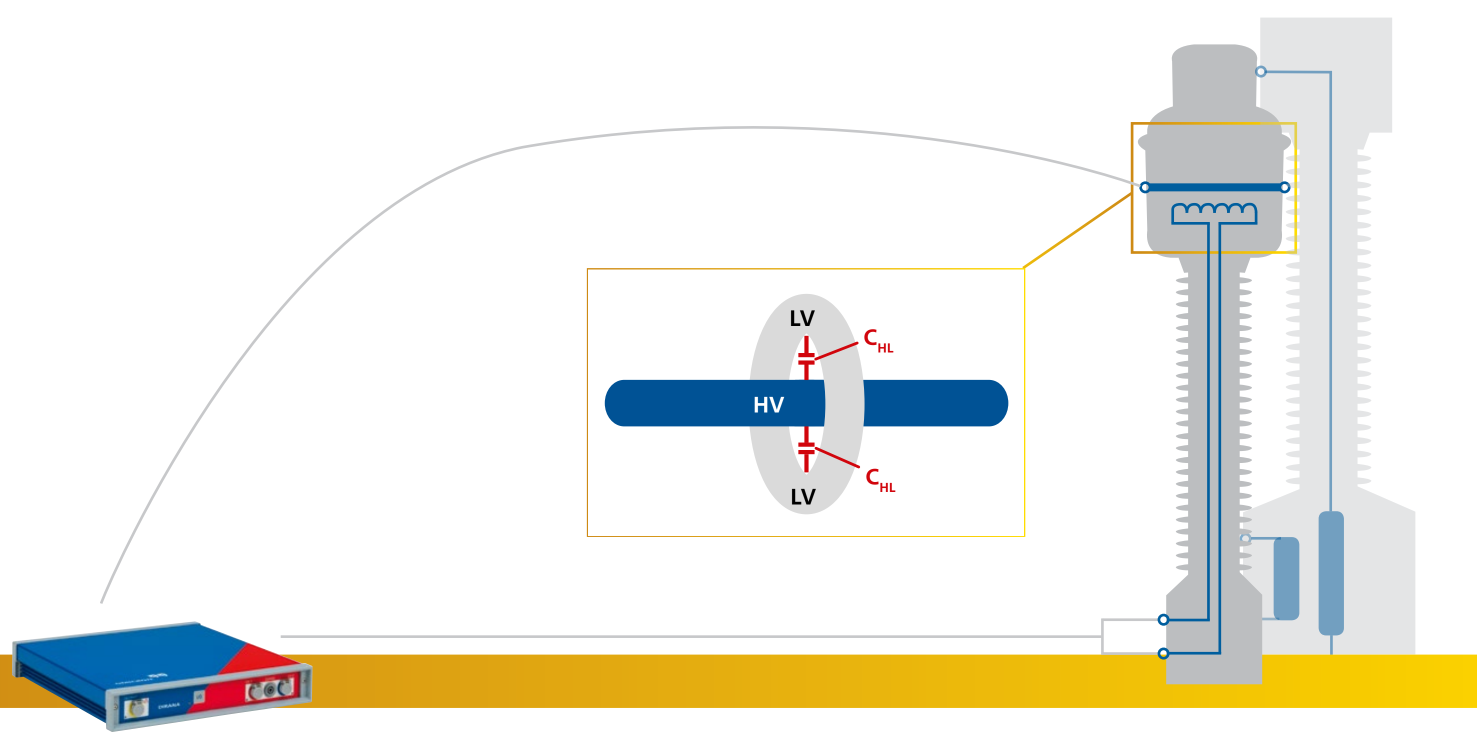
The reason for moisture in oil-paper insulated ITs can either be insufficient drying during manufacture or leaks. It leads to a reduced breakdown strength and increased losses.

A high moisture content in the insulation of oil-paper insulated ITs can lead to failures culminating in complete destruction of the IT. Therefore, the moisture content in the insulation is an important factor during condition assessment.

How does it work?

The main insulation of CTs is directly accessible for measurements. In the case of a VT, direct access to the complete main insulation is difficult, as it is the sum of the insulation of all individual primary winding turns. However, the dielectric response can be measured between the primary and secondary winding, as well as between the primary winding and ground.

The power factor/dissipation factor of this insulation is measured over a wide frequency range. The resulting curve contains information about the insulation condition.



Good to know ...

There are no other non-invasive ways to assess moisture in an IT which provide comparable accuracy.

The moisture content is directly determined in the cellulose and not deduced from the moisture in the oil. Thus, the method is applicable at all temperatures and there is no need to wait until moisture equilibrium between paper and oil has been reached.

In order to increase the reliability of the measured results, it is always good to take several measurements from single devices and also measure as many "sister" devices as possible and then compare the results (reference results).

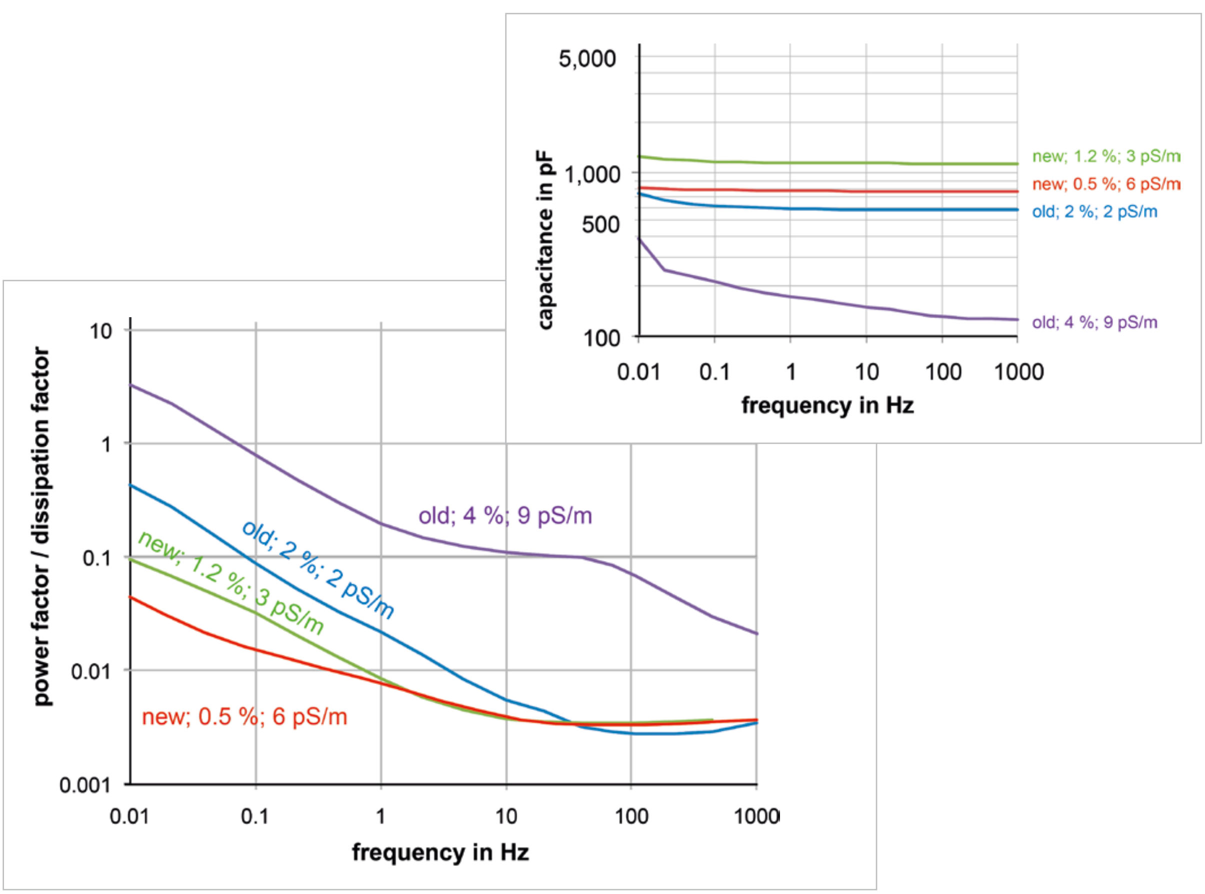
Capacity measurements over frequency can also be used to determine aging of insulation. With new ITs the capacity value stays the same, with old ITs it decreases with increasing frequency.

Why use DIRANA?

> Reliable moisture determination of instrument transformers

> Provides extremely short measurement times by combining measurement methods (FDS and PDC)

> Wide frequency range (10 µHz ... 5 kHz)



Dielectric response and capacitive ratio of instrument transformers of different age and condition

Capacitance and power factor / dissipation factor measurement

What can be tested?

- ✓ Insulation
- Windings
- Core
- ✓ Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- Burden

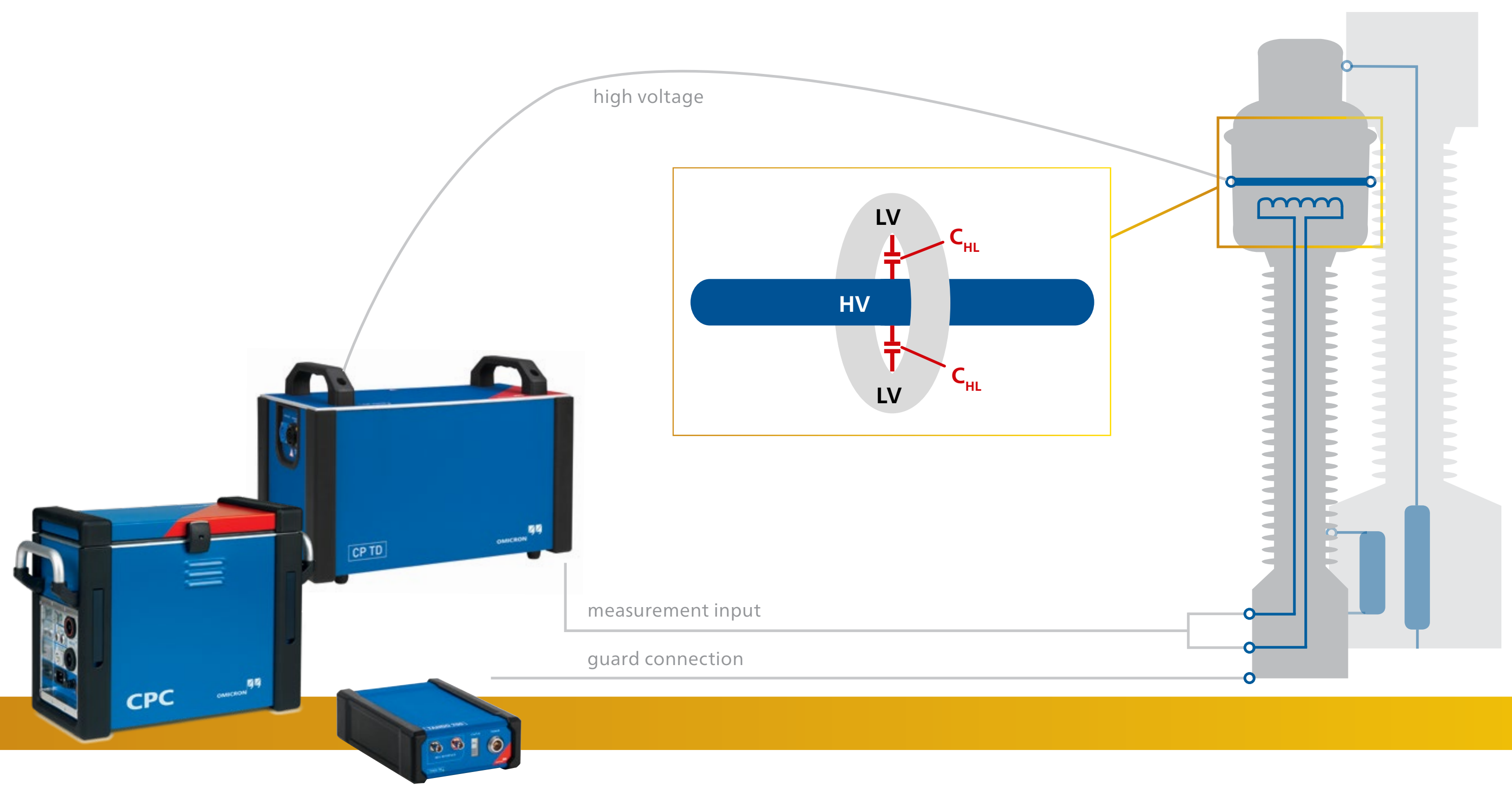
Why measure?

Power factor/dissipation factor (PF/DF) measurements are performed to investigate the insulation condition of ITs which is essential for reliable IT operation.

Water ingress results in an increase of dielectric losses, which can be quantified by PF/DF measurements. Performed on the capacitive stack of a CVT, the measurement can reveal shorted capacitive layers. One of the major causes of IT malfunction is an insulation failure.

How does it work?

The measurements are performed on the IT's main insulation which can be accessed between the primary and secondary conductor. For CTs, the windings are shorted and the test voltage is applied to one winding while the current through the insulation is measured on the opposite winding. For VTs, direct access of the full main insulation is difficult, however, the measurement can be performed between the primary and secondary winding, as well as between the primary winding and ground.



CPC 100 + CP TD12/15

TANDO 700
(Voltage source required)

Good to know ...

In order to assess the measurement results, it is beneficial to compare the values to previous results, to results of "sister" units, and to reference values mentioned in the relevant standards for the asset under test.

A rise in capacitance of more than 10 % compared to previous results is normally considered to be dangerous. It indicates that a part of the insulation is shorted and the dielectric stress to the remaining insulation is too high.

Standard PF/DF measurements at 50 Hz or 60 Hz can only detect the effects of moisture and aging at an advanced stage. By performing the measurement across a wider frequency range, these effects can be detected at an earlier stage allowing for a longer reaction time to schedule corrective action.

If a high PF/DF is detected, dielectric response analysis can be used as a supplementary diagnostic method. This broadband dielectric measurement can be used to determine whether the high PF/DF is caused by moisture.

Why use CPC 100 + CP TD12/15?

> General condition diagnosis of multiple assets on site and during manufacturing

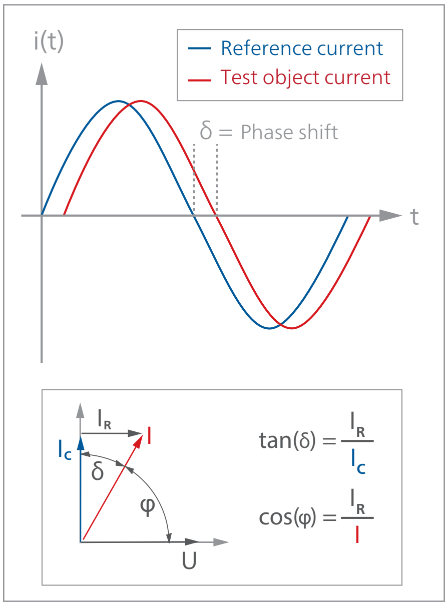
Why use CPC 80 + CP TD12/15?

> Dedicated dissipation factor testing of multiple assets on site and during manufacturing

Why use TANDO 700?

> High-voltage laboratory tests, for example, for routine and type tests or material tests of multiple assets

The dielectric losses cause a phase shift



Accuracy limit factor (ALF) and terminal voltage (V_b)

What can be tested?

- Insulation
- ✓ Windings
- ✓ Core
- Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- ✓ Burden

Why measure?

CT accuracy varies under different operating conditions due to the non-linearity of the magnetic core. When the inductance of the core decreases due to saturation, the error increases. Therefore, the accuracy changes during overcurrent conditions. The ALF (IEC) and terminal voltage (IEEE) indicate whether a protection CT can measure fault currents with sufficient accuracy considering the specified/connected burden.

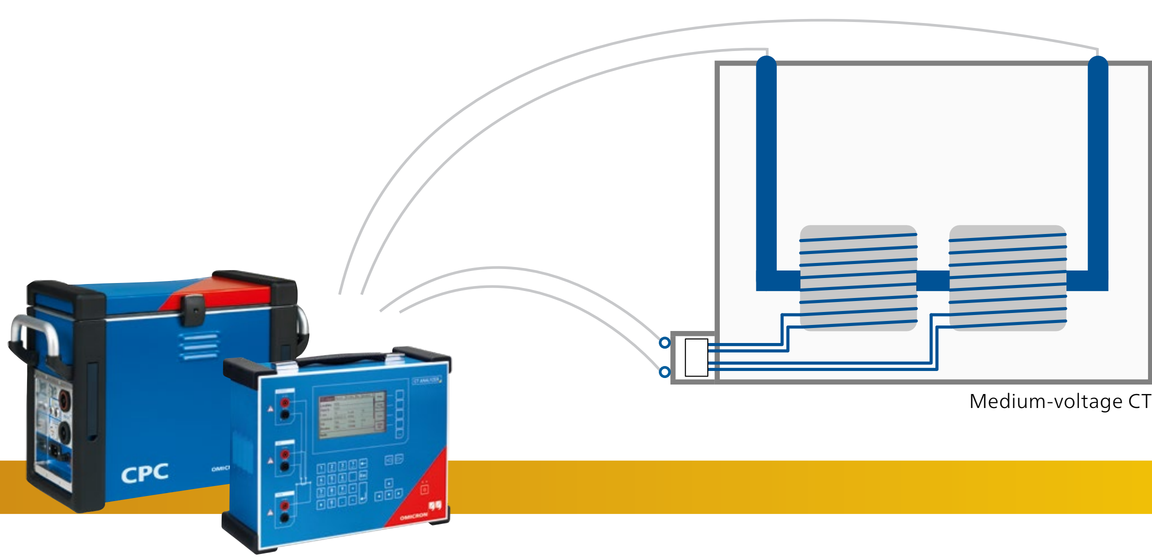
The ALF can be defined as the operational current related to the nominal current where the accuracy is still within the defined limits. The terminal voltage V_b is the voltage across the standard burden at 20 times rated current without exceeding 10 % composite error.

How does it work?

Using the indirect method as per IEC, winding resistance, burden and excitation curve are directly measured. Based on the results, the ALF can be derived based on the simplified equivalent circuit diagram.

In order to verify if an IEEE C-Class CT fulfills the requirements regarding the terminal voltage (for example, 400 V), the ratio correction or composite error is calculated based on the excitation curve and the burden for 20 times rated secondary current. If the error is below 10 % the CT is satisfactory.

With the direct method, a sinusoidal current is applied to the CT's primary side which equals the accuracy limit primary current. The secondary side is connected to the rated burden and the accuracy should be determined.



CPC 100 CT Analyzer

Good to know …

The parameter IPL is the rated instrument limit primary current for a measuring and the accuracy limit current for a protection transformer. The ratio of the current IP_L to the rated primary current IP_R is known as the Accuracy Limit Factor (ALF) for protection CTs and Instrument Security Factor (FS) for measurement CTs.

Protection and metering CTs have different requirements. Metering CTs are operated in the linear range and should saturate at overcurrents in order to protect the connected devices. Protection CTs, however, should operate correctly at both nominal and overcurrents with a higher saturation.

In order to validate the terminal voltage V_b if unknown, the voltage across the burden must be determined where the error is exactly 10 %. If this voltage is, for example, 480 V the CT is rated as a C 400 CT.

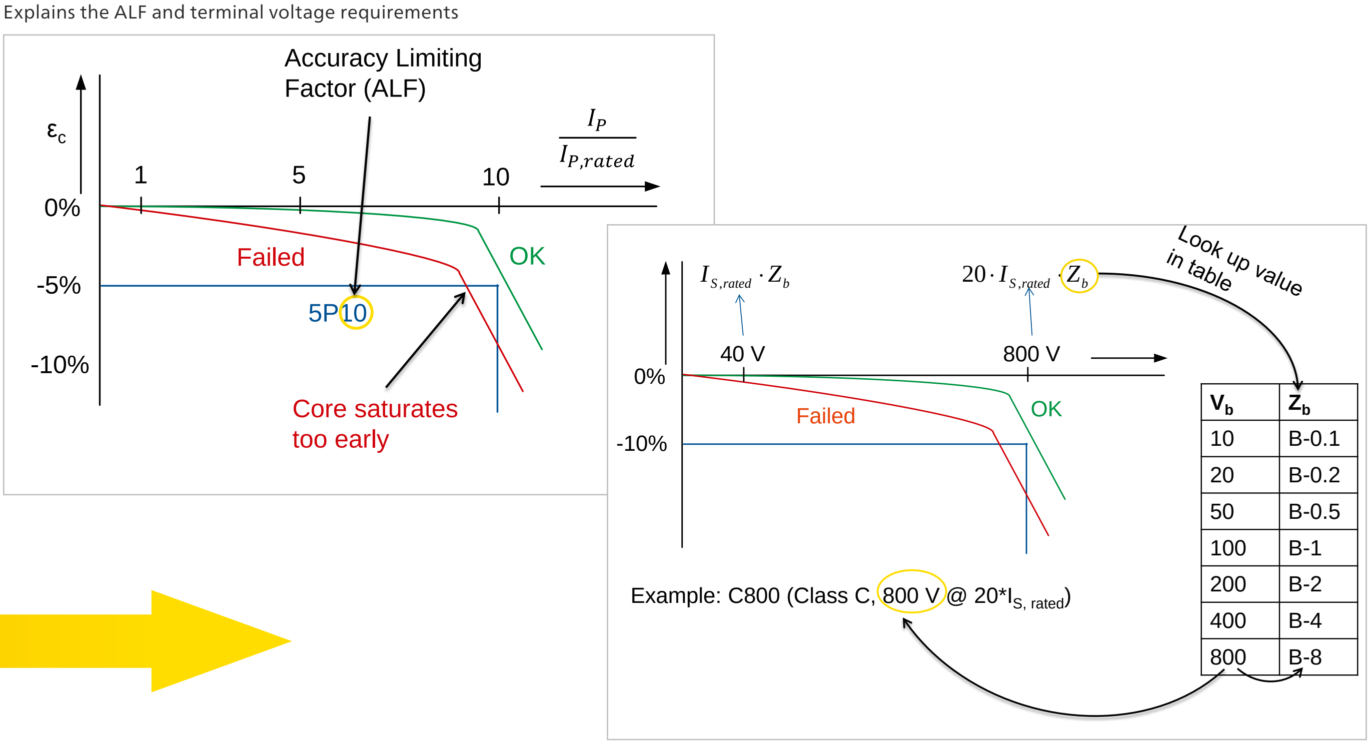
Why use CPC 100?

- Primary test set for primary injection tests of CTs
- With the ALF template the ALF can be additionally calculated using the indirect method

Why use CT Analyzer?

- Derivation of ALF via the direct method is possible (described in IEC 60044-1 and IEC 61869-2)
- Measurement is part of the complete CT test with low voltage
- Indirect ALF and direct ALF can be determined
- The terminal voltage can be validated if it is unknown
- An overall assessment of the CT can be made when it performs according to the standard requirements

CT errors related to primary current:
Explains the ALF and terminal voltage requirements



Residual magnetism measurement

What can be tested?

- Insulation
- Windings
- ✓ Core
- Capacitive voltage divider
- Compensation reactor
- Whole electromagnetic circuit
- Burden

Why measure?

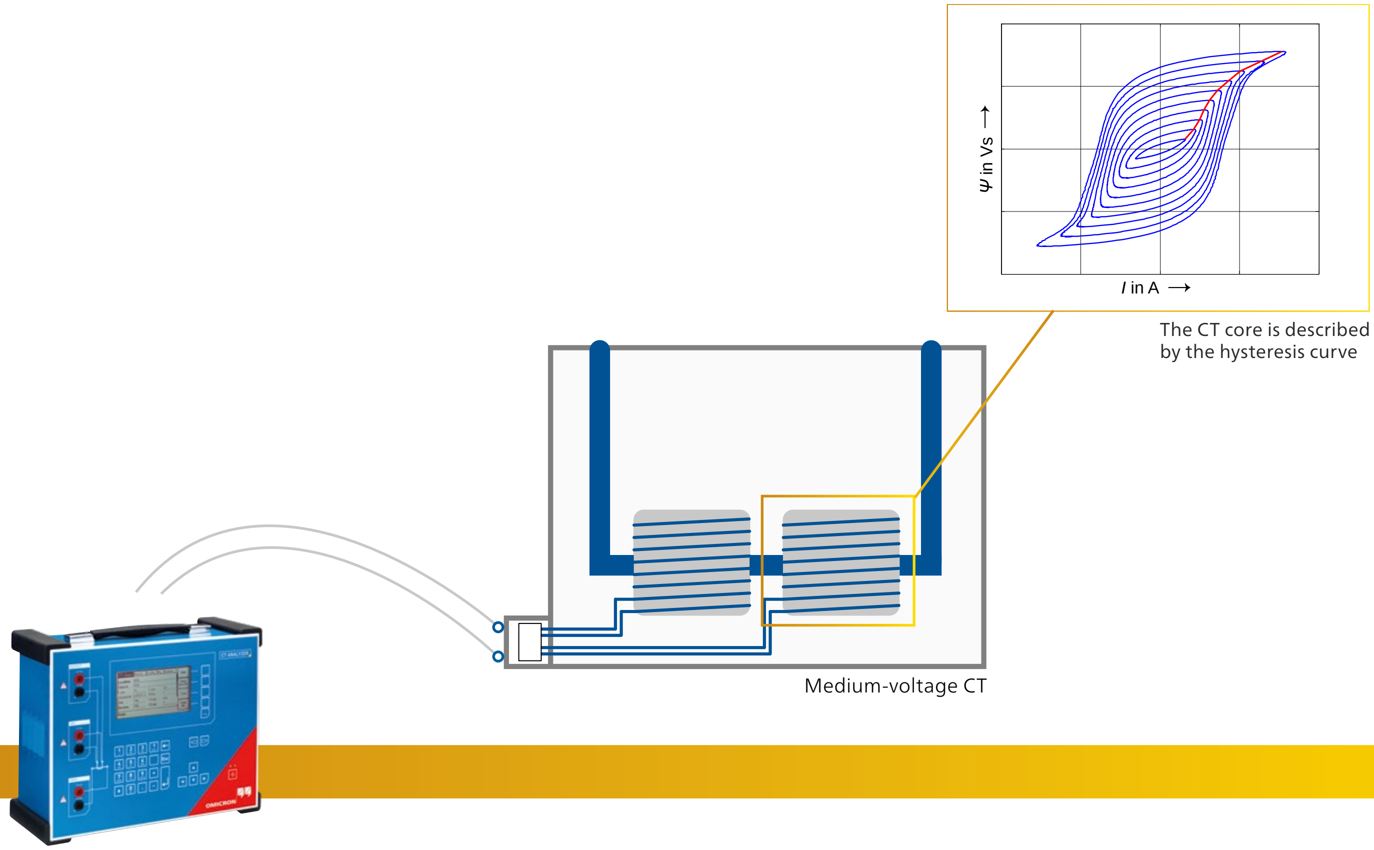
The measurement detects residual magnetism in the magnetic core due to fault currents, DC components during switching, DC measurements or lightning.

The residual magnetism in a CT can lead to a shift of the operation point, leading to maloperation of protection relays, or generally a misinterpretation of the system currents.

Measurements and analysis of remanence and residual magnetism should be performed before putting a CT into operation to ensure correct function, after an event and exposure to DC components and after a DC winding resistance measurement.

How does it work?

The software-based tool determines the residual magnetism in the core of CTs. An alternating DC voltage is applied to the secondary terminal in order to determine the saturation. Now the saturation flux is determined. Then the remanent flux is calculated through differences between the initial excitation characteristics and the characteristics derived after some alternating DC voltage cycles when the system is symmetrical again. After the measurement, the CT core is demagnetized.



CT Analyzer

Good to know ...

In the event of a system failure, the protection equipment connected to ITs shuts down the affected grid sections and thereby helps prevent more serious damage.

However, unselective tripping of the protection systems when there is no failure in the respective protection area (false tripping) interrupts regular grid operations and has negative effects on both availability and selectivity.

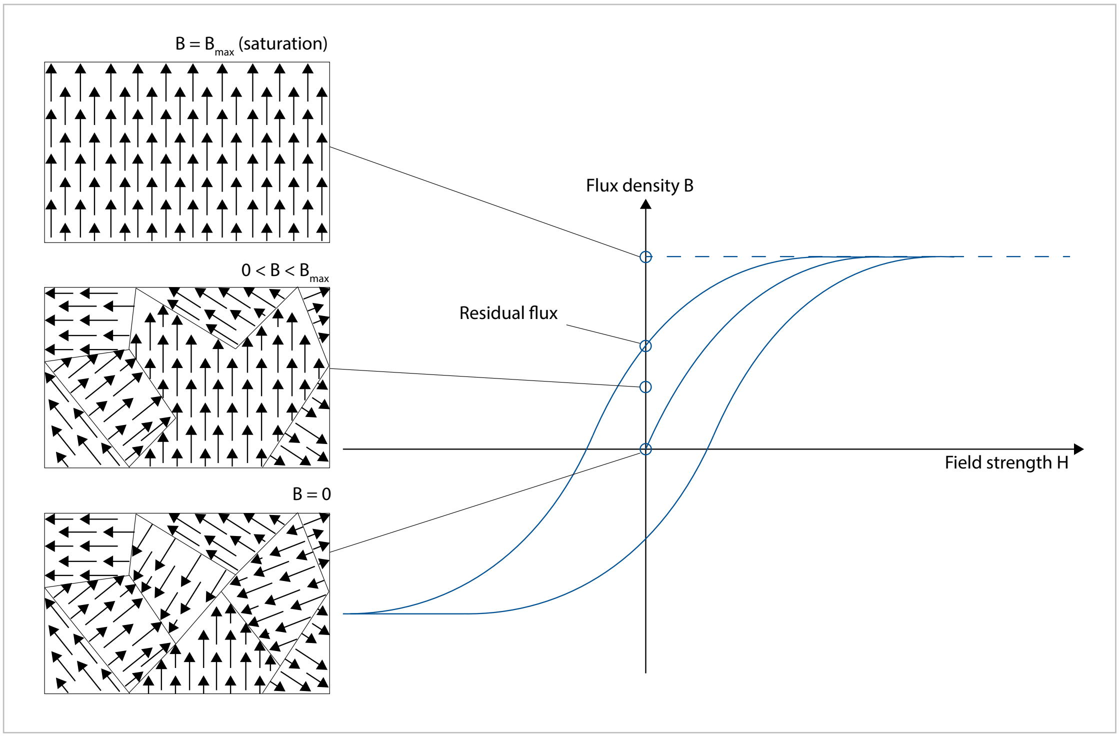
It is important to know if residual flux is present in the core of CTs as it reduces the available flux swing in one direction and makes it more difficult to avoid saturation during fault conditions.

In order to prevent a negative effect due to residual magnetism, CT cores can be either oversized or air gaps can be introduced. With installed air gaps, the hysteresis curve is flattened, core saturation will begin at higher magnetic fields, and the remanence can be reduced. The larger the air gaps, the smaller the remanence. Instead of having one air gap they may be distributed around the core.

Why use CT Analyzer?

- Exact measurement of remanence factors and residual magnetism
- Determination of remanence factor K_r and residual flux in one automated test cycle
- Demagnetization of the CT core after measurement makes sure that the CT is free of residual magnetism
- Results within seconds

Excitation / hysteresis curve corresponding to the internal magnetization processes of the magnetic core



Transient CT parameters

What can be tested?

- Insulation
- Windings
- ✓ Core
- Capacitive voltage divider
- Compensation reactor
- ✓ Whole electromagnetic circuit
- Burden

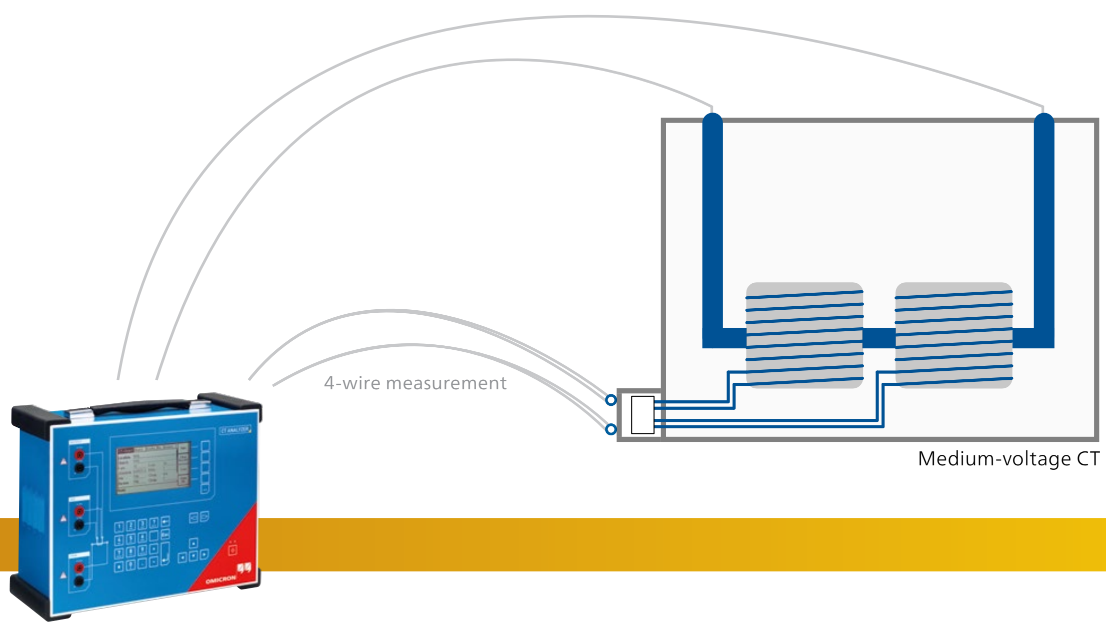
Why measure?

CTs are operated under symmetrical AC conditions but are also exposed to DC components due to operational, environmental, or maintenance influences. Transient events, for example, short circuits or switching, may expose the CTs to an exponentially decreasing DC component. This causes asymmetrical magnetization and thus, residual magnetism in the magnetic core. Asymmetrical magnetization and residual magnetism can lead to maloperation of the protection devices.

A protection CT must be "oversized" to be able to ensure a correct system interpretation under nominal and fault conditions, even when exposed to DC components. DC components magnetize and may saturate CT cores (depending on the core design and material). This results in unsymmetrical operation. Different parameters are defined in order to desensitize the behavior under these conditions. Important transient parameters are: K_{td}, t_{al}, K_{tf}, K_x, K_{ssc}

How does it work?

The transient CT parameters are obtained by measuring the CT equivalent circuit parameters and subsequently determine the transient parameters based on the input values and the applied secondary burden.



CT Analyzer

Good to know ...

The IEC standard defines different classes for protection CTs. The TPX, TPY and TPZ classes have special requirements regarding the transient performance. If a fault current occurs, the DC component must not affect correct CT performance for these classes during different duty cycles.

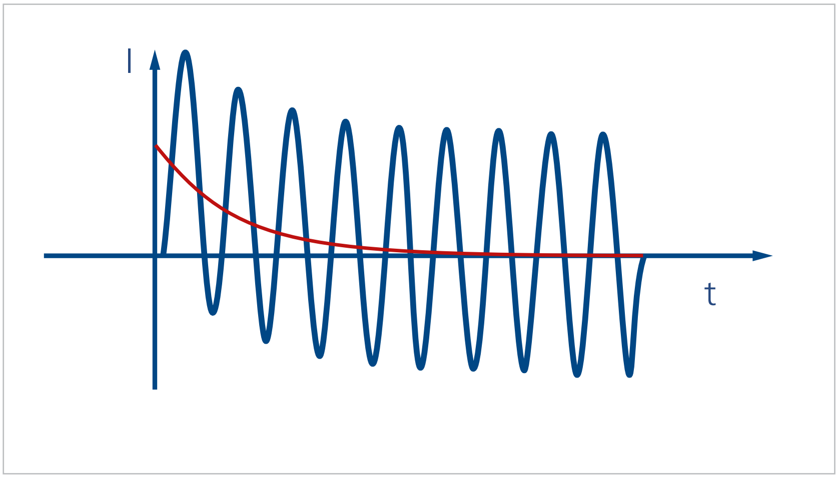
The criteria can be fulfilled by oversizing the CT core, using material with a small remanence induction, or by introducing air gaps. The latter results in a linear behavior. A DC component cannot be fully transformed and does not harm the CT.

In order to determine the residual flux in a CT core, a certain measurement must be performed (see "residual flux"). After every CT measurement the CT core must be demagnetized, especially after the DC winding resistance test.

Why use CT Analyzer?

- Know the capabilities of a CT in the event of a transient fault even at a very early production stage
- Decide whether or not a CT is suitable for a specific network with the expected fault currents
- Decide whether or not a CT is suitable for a defined duty cycle
- Know the transient parameters in order to be able to set the correct protection functions of the relays

Short circuit current with decreasing DC component (red line)



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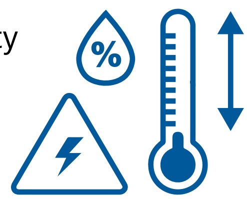

100%

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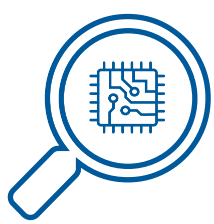

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More than

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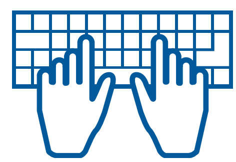

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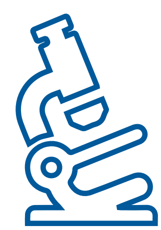

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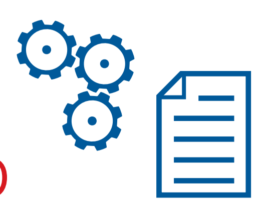
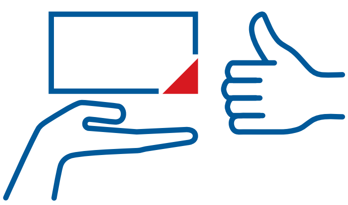
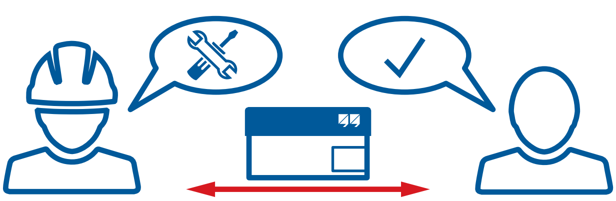


Support

Professional technical support at any time



Loaner devices help to reduce downtime



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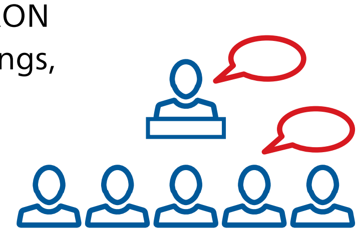
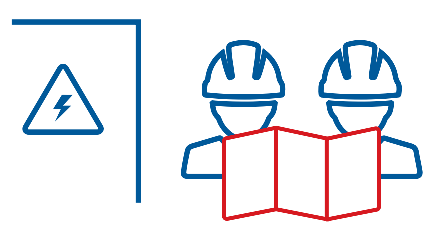


to thousands of technical papers and application notes



Extensive expertise in consulting, testing and diagnostics

OMICRON is an international company that works passionately on ideas for making electric power systems safe and reliable. Our pioneering solutions are designed to meet our industry's current and future challenges. We always go the extra mile to empower our customers: we react to their needs, provide extraordinary local support, and share our expertise.

Within the OMICRON group, we research and develop innovative technologies for all fields in electric power systems. When it comes to electrical testing for medium- and high-voltage equipment, protection testing, digital substation testing solutions, and cybersecurity solutions, customers all over the world trust in the accuracy, speed, and quality of our user-friendly solutions.

Founded in 1984, OMICRON draws on their decades of profound expertise in the field of electric power engineering. A dedicated team of more than 900 employees provides solutions with 24/7 support at 25 locations worldwide and serves customers in more than 160 countries.

For more information, additional literature, and detailed contact information of our worldwide offices please visit our website.

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