Operating Instructions

HAEFELY TEST AG

2840 & 2820a

High-Precision
C, L & tan δ
Measuring Bridge

Version 2.04

4843256

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Date	Version	Author	Remarks
19.10.2013	2.0	TH	Revised for 2840/2820a LAN
13.11.2013	2.01	ThG	Detect Test Frequency
15.12.2015	2.02	ThG	Remote Current Comparator settable
02.05.2016	2.03	ThG	Peak/sqrt(2)/ Formulas
19.08.2016	2.04	SG	RS232 communications removed

Remember - Hazardous voltage can shock, burn or cause death !

This warning sign is visible on the equipment. Meaning: This unit should only be operated after carefully reading the user manual which is an integral part of the instrument.

HAEFELY TEST AG and its sales partners refuse to accept any responsibility for consequential or direct damage to persons and/or goods due to none observance of instructions contained herein or due to incorrect use of the equipment.

Further be aware that safety is the responsibility of the user !

Any correspondence regarding this instrument should include the exact type number, instrument serial number and firmware version number. With the exception of the firmware version number, this information can be found on the registration plate on the right panel of the instrument. The firmware version specified in the "About" menu.

The design of this instrument will be continuously reviewed and improved where possible. Therefore there may be small differences between the operating manual and the actual instrument. Although all efforts are made to avoid mistakes, no responsibility is accepted by HAEFELY TEST AG for the accuracy of this operating manual.

HAEFELY TEST AG accepts no responsibility for any damage that may be caused during use of this document. We reserve the right to amend the operation, functionality and design of this instrument without prior notice. If discrepancies are noticed between the on-line help provided by the instrument and the operating manual, then the on-line help should be followed.

Foreword

Welcome as a new user of the “High-Precision C, L & tanδ Measuring Bridge 2840” or the “C, L & tanδ Measuring Bridge 2820a”. Thank you for placing your confidence in our product.

With the purchase of this measuring instrument you have opted for all the advantages that have built a world-wide reputation for a Tettex Instrument: Robustness, performance and quality is assured. As a result this instrument provides a solution which achieves the optimal combination of traditional know-how and leading edge technology.

This operating manual is designed for completeness and easy location of the required information. Customers who already have experience with this kind of equipment will find this document to be of assistance as an extended help. A keyword index at the end of the operating manual greatly eases use.

If you find a mistake or inconsistency in the operating manual then please feel free to inform our Customer Support department with your corrections so that other users may benefit.

Abbreviations, definitions

Wherever possible the corresponding IEC definitions are used. The following abbreviations and definitions are used in this manual:

C_N	Standard capacitor (measurement reference)
C_X	Test object capacitance (e.g. power transformer, generator, motor etc.)
HV	High voltage
cos φ	Power factor
PF	Power factor
tan δ	Dissipation factor
DF	Dissipation factor
DUT	Device under test
ppm	Parts per million

Contents

1 Introduction

1.1 Receiving Instructions

When taking delivery, any possible transport damage should be noted. A written record should be made of any such damage. A suitable remark should be recorded on the delivery documents.

A claim for damage must be reported immediately to the transport company and to the Customer Support Department of HAEFELY TEST AG or the local agent. It is essential to retain the damaged packing material until the claim has been settled.

Check the contents of the shipment for completeness immediately after receipt (See chapter "Scope of Supply"). If the shipment is incomplete or damaged then this must be reported immediately to the transport company and the Customer Support Department of HAEFELY TEST AG or the local agent. Repair or replacement of the instrument can then be organised immediately.

1.2 General

The Dielectric-Loss Analyzing System is designed for measurement of very low dielectric losses and impedances (Dissipation Factor and Power Factor) of high-voltage apparatus (e.g. extruded insulation on power cables).

The instrument works on the principle of a combined bridge-vector-meter and is capable of analyzing capacitive and inductive loads – especially shunt reactors – with outstanding accuracy and stability certified by a leading metrology institute.

The Graphical User Interface of the instrument is highly intuitive, focussed on convenience with built-in useful programs (e.g. support tool for tuning the external High Voltage supply) and uses a large colour touch screen as the input device. The operator can choose between manual or automatic modes. While the manual mode provides quick measurements, the automatic test mode supports complete automated test sequences.

1.3 Hardware

This high precision measuring instrument (double vector meter) is fully automatically balanced by the built-in PC and the measurement values are calculated and displayed. Over 20 various parameters can be measured respectively calculated. The instrument , as a vector meter, recognises the type of test object (inductive / capacitive) and determines and displays its values automatically.

Advanced noise reduction is provided for field measurements where the measurement results might otherwise be falsified due to interferences.

1.4 Software

Advanced software functionalities such as insulation temperature correction, programmable test sequences with pass/fail limits, graphical visualization of measured data, etc. make this instrument a powerful tool for analysis of high-voltage equipment.

1.5 Scope of Supply

The standard scope of supply includes the following items:

Qty	Description
1	High-precision C, L & tanδ measuring bridge 2840 or 2820a
1	Mains cable (country specific)
1	Operating instruction
1	Test certificate
	Test cables corresponding to order

1.6 Optional Accessories

For details on optional accessories and test cable sets see product brochure and/or contact the Tettex customer support

2 Technical Data 2840

	Range	Max. Resolution	Accuracy
Dissipation Factor (tan δ) [1]	0 .. 100	1×10^{-6}	± 0.5 % rdg ± 1×10^{-5}
Power Factor (cos φ) [1]	0 .. 1	1×10^{-6}	± 0.5 % rdg ± 1×10^{-5}
Capacitance [2]	≥ 0.01 pF	0.001 pF	± 0.02 % rdg ± 0.01 pF
Inductance [2]	≤ 1000 kH	0.1 mH	± 0.1 % rdg ± 0.3 mH
Test Voltage	5V .. 2MV [5]	1 V	± 0.2 % rdg ± 1 V
Test Current @ Input Cn	20uA .. 300 mA	0.01 uA	± 0.1 % rdg ± 0.1 uA
Test Current @ Input Cx	20uA .. 15 A	0.01 uA	± 0.1 % rdg ± 0.1 uA
Test Frequency	15 .. 1000 Hz	0.01 Hz	± 0.1 % rdg ± 0.1 Hz
Apparent Power S [2]	≥ 1 mVA	0.1 mVA	± 0.5 % rdg ± 1 mVA
Real Power P [2]	≥ 1 mW	0.1 mW	± 0.5 % rdg ± 1 mW
Reactive Power Q [2]	≥ 1 mvar	0.1 mvar	± 0.5 % rdg ± 1 mvar

Recorded Values	DF (tanδ), DF (tanδ)$_{@20°C}$, DF (tanδ) [%], DF (tanδ) [%]$_{@20°C}$, PF (cosφ), PF (cosφ)$_{@20°C}$, PF (cosφ) [%], PF (cosφ) [%]$_{@20°C}$, QF (quality factor), QF (quality factor)$_{@20°C}$, C_P (Z_X= C_P || R_P), R_P (Z_X= C_P || R_P), C_S (Z_X= C_S + R_S), R_S (Z_X= C_S + R_S), L_S (Z_X= L_S + R_S), R_S (Z_X= L_S + R_S), L_P (Z_X= L_P || R_P), R_P (Z_X= L_P || R_P), Cn (Standard Capacitor Value), U_{RMS}, U/ √3, Ix $_{RMS}$, In $_{RMS}$, I_m, I_{fe}, Impedance Zx, Phase-angle φ (Zx), Admittance Yx, Frequency$_{Test}$, Frequency$_{Line}$, Apparent Power S, Real Power P, Reactive Power Q, Real Power$_{@2.5kV}$, Real Power$_{@10kV}$, Temperature$_{Ambient}$ [3], Temperature$_{Insulation}$ [3], Rel.Humidity [3], Temp.Corr.Factor K, Connection mode, Settings, Notes, Comments, Time, Date
Measuring Time	0.3 sec / measurement @ averaging = 1
Measuring Channels	2 (Cn & Cx)
Display	12" TFT, 800x600, integrated Touch-Screen
Operating System	Embedded Windows
Interfaces	4 x USB 1 x Ethernet 10/100 [4]
Data Format	XML, CSV
Operating Temperature	-10 .. 50°C
Storage Temperature	-20 .. 70°C
Humidity	5 .. 95 % r.h. non-condensing
Protection class	IP20
EMC standards	EMC directive 20004/108/EC, IEC61326-1 ed 1.0 (EN61000-3-2, EN61000-3-3, EN61000-4-2, EN61000-4-3; EN61000-4-4, EN61000-4-5, EN61000-4-6, EN61000-4-11, EN55011 +A1)
Safety Specification	Low voltage directive 2006/95/EC, IEC60010-1 :2001 ed 2.0
Vibration, Shock, Handling	IEC 60068-2-6 ed 7.0, IEC 600-2-27 ed 4.0, IEC 60068-2-31 ed 2.0
Supply	90 - 264 VAC, <100 VA, 50 / 60 Hz, PFC
Weight	16 kg (35 lbs)
W x H x D	48 x 27 x 44 cm (19" x 10.6" x 17.3")

1 Accuracy values @ 50/60Hz ; THD of power source <10%; for detailed range dispersion and preconditions for accuracy values see user manual.
2 Range limit is given by test current and voltage of used power source
3 These values are measured with an external device (option).
The values can be entered into the unit for temperature correction calculations and documentation purposes.
4 Allows communication respectively control of the unit
5 20uA/ωCn .. 300mA/ωCn

3 Technical Data 2820a

	Range	Max. Resolution	Accuracy
Dissipation Factor (tan δ) [1]	0 .. 100	1×10^{-5}	± 1 % rdg ± 1×10^{-4}
Power Factor (cos φ) [1]	0 .. 1	1×10^{-5}	± 1 % rdg ± 1×10^{-4}
Capacitance [2]	≥ 1 pF	0.01 pF	± 0.1 % rdg ± 0.1 pF
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Recorded Values	DF (tanδ), DF $(\tan\delta)_{@20°C}$, DF (tanδ) [%], DF (tanδ) $[\%]_{@20°C}$, PF (cosφ), PF $(\cos\varphi)_{@20°C}$, PF (cosφ) [%], PF (cosφ) $[\%]_{@20°C}$, QF (quality factor), QF $(\text{quality factor})_{@20°C}$, C_P $(Z_X= C_P \| R_P)$, R_P $(Z_X= C_P \| R_P)$, C_S $(Z_X= C_S + R_S)$, R_S $(Z_X= C_S + R_S)$, L_S $(Z_X= L_S + R_S)$, R_S $(Z_X= L_S + R_S)$, L_P $(Z_X= L_P \| R_P)$, R_P $(Z_X= L_P \| R_P)$, Cn (Standard Capacitor Value), U_{RMS}, U/√3, Ix_{RMS}, In_{RMS}, I_m, I_{fe}, Impedance Zx, Phase-angle φ (Zx), Admittance Yx, Frequency_{Test}, Frequency_{Line}, Apparent Power S, Real Power P, Reactive Power Q, $\text{Real Power}_{@2.5kV}$, $\text{Real Power}_{@10kV}$, $\text{Temperature}_{Ambient}$ [3], $\text{Temperature}_{Insulation}$ [3], Rel.Humidity [3], Temp.Corr.Factor K, Connection mode, Settings, Notes, Comments, Time, Date
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Remember - Hazardous voltage can shock, burn or cause death !

4.1 General

Safety is the most important aspect when working on or around high voltage electrical equipment.

Personnel whose working responsibilities involve testing and maintenance of the various types of high voltage equipment must have understood the safety rules written in this document and the associated safety practices specified by their company and government. Local and state safety procedures should also be consulted. Company and government regulations take precedence over Tettex recommendations.

If the instrument is damaged or it is possible that damage has occurred, for example during transportation, do not apply any voltage. The instrument may only be used under dry operating conditions.

Do not open the unit, it contains no user replaceable parts.

Do not switch on or operate the instrument if an explosion hazard exists.

People with heart pacemakers should not be in the vicinity of this system during operation.

4.2 Safety Precautions

A separate green/yellow earth cable is provided for the purpose of safety grounding the instrument. The earth cable should be connected to the earthing screw on the back of the unit at one end and to the station grounding system at the other end.

The earth cable should be the FIRST lead to be connected to the set.

All tests must be performed with the device under test completely de-energized and isolated from its power systems. The equipment, its tank or housing must be disconnected from all buses and properly earthed, so that all induced voltages or trapped charges are neutralized. Only when the measurement procedure is actually being performed the grounds should be temporarily removed.

The unit must be solidly earthed with the same ground as the device under test. When the unit is permanently housed in a vehicle, the ground should be bounded to the vehicle chassis, which in turn is grounded.

Exposed terminals of equipment should not normally be allowed to 'float'. They should be grounded directly or through the low voltage leads (INPUT V) of the unit, unless otherwise specified.

Testing of high voltage equipment involves energizing the equipment through a high voltage supply. This can produce dangerous levels of voltage and current. Care must be taken to avoid contact with the equipment being tested, its associated bushings and conductors. Especially the high voltage test cable should not be held during energization. Flashover of the test specimen can generate transient voltages of sufficient magnitude to puncture the insulating jacket of the high voltage test cable.

It is strongly recommended that the test crew make a visual check to ensure that the equipment terminals are isolated from the power system. If there is real possibility that the device under test fails precautions such as barriers or entrance restrictions must be taken against harm in the event of violent failure.

Proper clearance between the test equipment and the device under test must be ensured during the presence of high voltage. Barriers and safety tapes can be established around the test area to prevent unintentional entry into the live area. It must also be guaranteed that extraneous objects like ladders, buckets, etc. can not enter the test area.

After the unit is properly grounded, the remaining test leads and the High Voltage Test Cable are plugged into their receptacles. **Do not connect test leads to the DUT terminals until the leads are connected to the measuring bridge.**

The proper procedures for connecting the test leads to the device under test is described in detail in chapter “Test Procedure”.

The equipment operates from a single-phase mains supply. It has a three wire power cord and requires a two-pole, three terminal, live, neutral and ground type connector. Do not bypass the grounding connection. Any interruption of the grounding connection can create electric shock hazard.

After the tests are completed, all test leads should be disconnected first from the device under test and earthed before they are disconnected from the instrument.
The green / yellow safety ground cable should be the LAST lead to be disconnected from the set.

Do not disconnect the test cables from the DUT unless the high voltage is turned off. Attempts to disconnect leads while the DUT is energized may result in a serious and possibly lethal electrical shock.

4.3 Summary

Note: Many accidents that happen around high voltage equipment involve personnel who are familiar, and perhaps too familiar, with high voltage equipment. Staying alert and ever watchful requires constant training and awareness of the inherent hazards. The greatest hazard is the possibility of getting on a live circuit. To avoid this requires constant vigilance - for oneself and for one's fellow workers.

In addition to the obvious dangers, personnel should be alert to recognize subtle dangers as well. For example, during transformer excitation-current tests, the floating terminals may have significant voltages induced in them by simple transformer action. Therefore, **all terminals of a device under test, unless grounded, should be considered to be live while the test is in progress.**

When potential transformers or any transformers are interconnected, voltage can be back-fed through the secondary windings to produce high voltage on the primary although the primary is seemingly isolated from the power system. This entail a second important rule - **all terminals of a device under test should be completely isolated.**

Remember - Safety, FIRST, LAST, ALWAYS !

5 Theory

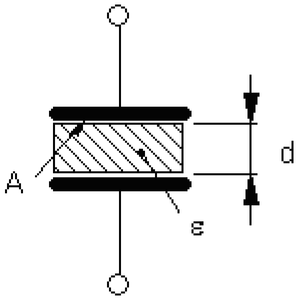
5.1 Loss Factor

Loss factor is the total energy that will be used by the equipment during normal service. In particular, the insulation loss factor is any energy that is taken by the flow of current through the resistive component of the insulation. The earth path varies according to the type of electrical equipment. For example, switchgear will probably develop tracking to earth at right angles to the floor connections. In transformers paths can develop in the insulation resistance between the windings or between the windings and housing (tank). In all cases the result is a loss factor in the form of heating.

Note: In this text loss factor (losses, watts) is referred to, in contrast with total loss factor. Total loss factor is normally used to describe the total losses of the transformer under load and should not be confused with the energy that is lost due to degradation of the insulation.

5.2 Dissipation Factor tan δ

To specify the insulation loss factor, the test object must be considered in the test arrangement as a capacitor. Consider all test objects e.g. transformers, bushings, bus bars, generators, motors, high voltage switchgear etc. are constructed from metal and insulation, and therefore possess associated capacitive properties. Every test object consists of various capacitances together with the insulation and the internal capacitance to earth. The figure shows the components that comprise a capacitance and the diagram for a simple disc capacitor.



Disc Capacitor

$$C = \frac{\varepsilon \cdot A}{d}$$

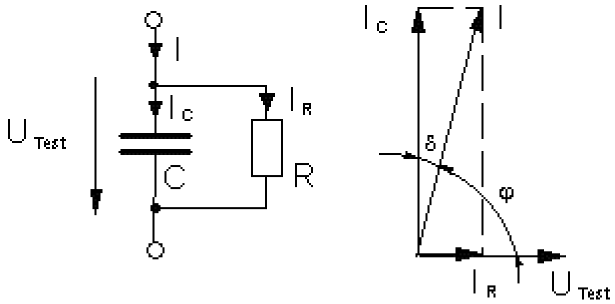
where:

A	electrode face
d	distance between the electrodes
C	capacitance
ε_0	dielectric constant of air (ε_0=8,8542•10^{-12} F/m)
ε_r	relative dielectric constant dependent upon material
ε	$\varepsilon = \varepsilon_0 \cdot \varepsilon_r$, dielectric constant

In an ideal capacitor the resistance of the insulation material (dielectric) is infinitely large. That means that, when an AC voltage is applied, the current leads the voltage by exactly 90° as it flows as pure current.

After further consideration it must be realized that every insulation material contains single free electrons that show little loss under DC conditions with $P= U^2/R$. Under AC a behaviour called dielectric hysteresis loss occurs which is analogous to hysteresis loss in iron.

As losses therefore occur in every insulation material, an equivalent diagram of a real capacitance can be constructed as follows:



Parallel equivalent diagram of a lossy capacitance with vector diagram

Loss factor (Dissipation Factor)

$$\tan\delta = \frac{P_R}{Q_C} = \frac{I_R}{I_C} = \frac{X_C}{R} = \frac{1}{\omega \cdot C \cdot R}$$

Power Factor

$$PF = \cos\varphi = \frac{I_R}{I} = \frac{P_R}{S_C} = \frac{\tan\delta}{\sqrt{1+\tan^2\delta}}$$

U_{Test}	applied test voltage
I_C	current through capacitance
I_R	current through resistance (insulating material)
C	ideal capacitance
R	ideal resistance

Because P = Q • tan δ, the losses which are proportional to tan δ, will usually be given as a value of tan δ to express the quality of an insulation material. Therefore the angle δ is described as loss angle and tan δ as loss factor.

5.3 The Difference between Power Factor and Dissipation Factor

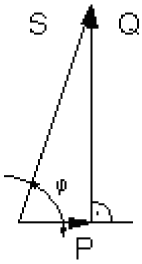
While “Dissipation Factor” tan δ is used in Europe to describe dielectric losses, the calculation used in the United States is „Power Factor“ cos φ.

The statistical data that have been collected in North America have been calculated using the loss factor cos φ (Power Factor) to specify the power losses in the insulation. Because the angles are complimentary it is unimportant whether tan δ or cos φ is used as with very small values the difference is negligible. However the conversion formulas are:

$$PF = \frac{\tan\delta}{\sqrt{1+\tan^2\delta}} \qquad \tan\delta = \frac{PF}{\sqrt{1-PF^2}}$$

5.4 Apparent Power, Real Power, Reactive Power

The relationship between the various types of power is clarified in the following equations.



Vector Diagram of Apparent Power,
Real power and Reactive Power

Apparent Power: $S = U \cdot I$ [VA]

Real Power: $P = U \cdot I \cos \varphi$ [W]

Reactive Power: $Q = U \cdot I \sin \varphi$ [var]

Because most test objects are not a pure resistance and therefore have a phase angle φ between the test voltage and current, this phase shift must also be taken into consideration in the power calculation.

5.5 Test Instruments

There are three basic kinds of capacitance, tan δ and Power Factor test instruments in use.

Although the high accuracy Schering Bridge must be balanced manually and the balance observed on a null indicator, it has been widely sold and used for decades up until this day. The capacitance and dissipation factor can be calculated by reading the position of the balance elements.

The automatically balanced C tan δ measuring instrument performs measurement by the differential transformer method. The automatic balancing makes operation very easy.

The double vector-meter method is essentially an improvement of the differential transformer method.

All three methods are in current use for accurate and repeatable measurements of C tan δ on various test objects. The differences basically lie in the resolution and accuracy. Different instruments are generally developed specially for field or laboratory measurement.

Field instruments are specially constructed for rugged field requirements and are equipped with a mobile high voltage source. In addition, such instruments provide noise suppression for onsite use.

Laboratory instruments have been constructed for indoor use where high accuracy specifications are required. These test systems are built in a modular construction for higher Test Levels. The systems may be used for daily routine testing, for high precision long duration tests or for acceptance tests.

5.6 Evaluation of Test Results

Significance of Capacitance and Dissipation Factor

A large percentage of electrical apparatus failures are due to a deteriorated condition of the insulation. Many of these failures can be anticipated by regular application of simple tests and with timely maintenance indicated by the tests. An insulation system or apparatus should not be condemned until it has been completely isolated, cleaned, or serviced. The correct interpretation of capacitance and dissipation factor tests generally requires a knowledge of he apparatus construction and the characteristics of the types of insulation used.

Changes in the normal capacitance of insulation indicate such abnormal conditions as the presence of a moisture layer, short circuits, or open circuits in the capacitance network. Dissipation factor measurements indicate the following conditions in the insulation of a wide range of electrical apparatus:

- Chemical deterioration due to time and temperature, including certain eases of acute deterioration caused by local overheating.
- Contamination by water, carbon deposits, bad oil, dirt and other chemicals.
- Severe leakage through cracks and over surfaces.
- Ionization.

The interpretation of measurements is usually based on experience, recommendations of the manufacturer of the equipment being tested, and by observing these differences:

- Between measurements on the same unit after successive intervals of time.
- Between measurements on duplicate units or a similar part of one unit, tested under the same conditions around the same time, e.g., several identical transformers or one winding of a three phase transformer tested separately.
- Between measurements made at different Test Levels on one part of a unit; an increase in slop (tip-up) of a dissipation factor versus voltage curve at a given voltage is an indication of ionization commencing at that voltage.

An increase of dissipation factor above a typical value may indicate conditions such as those showed above: If the dissipation factor varies significantly with voltage down to some voltage below which it is substantially constant, then ionization is indicated. If this extinction voltage is below the operating level, then ionization ma progress in operation with consequent deterioration. Some increase of capacitance (increase in charging current) may also be observed above the extinction voltage because of the short-circuiting of numerous voids by the ionization process.

An increase of dissipation factor accompanied by a marked increase of the capacitance usually indicates excessive moisture in the insulation. Increase of dissipation factor alone may be caused by thermal deterioration or by contamination other than water.

Unless bushing and pothead surfaces, terminal boards, etc., are clean and dry, measured values not necessarily apply to the insulation under test. Any leakage over terminal surfaces may add to the losses of the insulation itself and may give a false indication of its condition.

Dissipation Factor of Typical Apparatus Insulation

Values of insulation dissipation factor for various apparatus are shown in this table. These values are useful in roughly indicating the range to be found in practice; however, the upper limits are not reliable service values.

Equipment	**Dissipation factor @ 20°C**
Oil-filled transformer, New, HV (> 115kV)	0.15% .. 0.75%
Oil-filled transformer, Age 15 years, HV (> 115kV)	0.75% .. 2.0%
Oil-filled transformer, Age 15 years, LV, distribution	1.5% .. 5%
Circuit breakers, oil-filled	0.5% .. 2.0%
Oil-paper cables, "solid" (up to 27.6 kV) new	0.5% .. 1.5%
Oil-paper cables, HV, oil-filled or pressurized	0.2% .. 0.5%
Stator windings, 2.3 .. 13.8kV	2.0% .. 8.0%
Capacitors	0.2% .. 0.5%
Bushings, (solid or dry)	3.0% .. 10.0%
Bushings, compound-filled, up to 15kV	5.0% .. 10.0%
Bushings, compound-filled, 15 .. 46kV	2.0% .. 5.0%
Bushings, oil-filled, below 110 kV	0.8% .. 4.0%
Bushings, oil-filled, above 110 kV	0.3% .. 3.0%

Dissipation Factor and Dielectric Constant of Typical Insulation Materials

Typical values of 50/60Hz dissipation factor and permittivity (dielectric constant ε) of some typically used insulating materials.

Material	Dissipation factor @ 20°C	ε
Acetal resin (Delrin™)	0.5%	3.7
Air	0.0%	1.0
Askarels	0.4%	4.2
Kraft paper, dry	0.6%	2.2
Transformer oil	0.02%	2.2
Polyamide (Nomex™)	1.0%	2.5
Polyester film (Mylar™)	0.3%	3.0
Polyethylene	0.05%	2.3
Polyamide film (Kapton™)	0.3%	3.5
Polypropylene	0.05%	2.2
Porcelain	2.0%	7.0
Rubber	4.0%	3.6
Silicone liquid	0.001%	2.7
Varnished cambric, dry	1.0%	4.4
Water	100%	80
Ice	1.0% @ 0°C	88

Note: Tests for moisture should not be made at freezing temperatures because of the 100 to 1 ratio difference dissipation factor between water and ice.

Influence of Temperature

Most insulation measurements have to be interpreted based on the temperature of the specimen. The dielectric losses of most insulation increase with temperature. In many cases, insulations have failed due to the cumulative effect of temperature, e.g. a rise in temperature causes a rise in dielectric loss which causes a further rise in temperature, etc.

It is important to determine the dissipation factor temperature characteristics of the insulation under test, at least in a typical unit of each design of apparatus. Otherwise, all tests of the same spec should be made, as nearly as practicable, at the same temperature. On transformers and similar apparatus, measurements during cooling (after factory heat-run or after service load) can provide required temperature correction factors.

To compare the dissipation factor value of tests made on the same or similar type of equipment at different temperatures, it is necessary to correct the value to reference temperature base, 20°C (68°F). The unit does that automatically. See also chapter “Menu Conditions (Temperature correction)”.

The insulation material temperature for apparatus such as spare bushings, insulators, air or gas filled circuit breaker and lightning arresters is normally assumed to be the same as the ambient temperature. For oil-filled circuit breakers and transformers the insulation temperature is assumed to be the same as the oil temperature. The (transformer mounted) bushing insulation temperature can be assumed to be the midpoint between the oil and ambient temperatures.

The capacitance of dry insulation is not affected by temperature; however, in the case of wet insulation, there is a tendency for the capacitance to increase with temperature.

Dissipation factor-temperature characteristics, as well as dissipation factor measurements at a given temperature, may change with deterioration or damage of insulation. This suggests that any such change in temperature characteristics may be helpful in assessing deteriorated conditions.

Be careful making measurements below the freezing point of water. A crack in an insulator, for example, is easily detected if it contains a conducting film of water. When the water freezes, it becomes non-conducting, and the defect may not be revealed by the measurement, because ice has a volumetric resistivity approximately 100 times higher than that of water. Tests far the presence of moisture in solids intended to be dry should not be made at freezing temperatures. Moisture in oil, or in oil-impregnated solids, has been found to be detectable in dissipation factor measurements at temperatures far below freezing, with no discontinuity in the measurements at the freezing point.

Insulating surfaces exposed to ambient weather conditions may also be affected by temperature. The surface temperature of the insulation specimen should be above (never below) the ambient temperature to avoid the effects of condensation on the exposed insulating surfaces.

Influence of Humidity

The exposed surface of bushings may, under adverse relative humidity conditions, acquire a deposit surface moisture which can have a significant effect on surface losses and consequently on the results of a dissipation factor test. This is particularly true if the porcelain surface of a bushing is at temperature below ambient temperature (below dew point), because moisture will probably condense on the porcelain surface. Serious measurement errors may result even at a relative humidity below 50% when moisture condenses on a porcelain surface already contaminated with industrial chemical deposits.

It is important to note that an invisible thin surface film of moisture forms and dissipates rapidly on materials such as glazed porcelain, which have negligible volume absorption. Equilibrium after a sudden wide change in relative humidity is usually attained within a matter of minutes. This excludes thicker films which result from rain, fog, or dew point condensation.

Surface leakage errors can be minimized if dissipation factor measurements are made under condition where the weather is clear and sunny and where the relative humidity does not exceed 80%. In general, best results are obtained if measurements are made during late morning through mid afternoon. Consideration should be given to the probability of moisture being deposited by rain or fog on equipment just prior to making any measurements.

Influence of Surface Leakage

Any leakage over the insulation surfaces of the specimen will be added to the losses in the volume insulation and may give a false impression as to the condition of the specimen. Even a bushing with voltage rating much greater than the test voltage may be contaminated enough to cause a significant error. Surfaces of potheads, bushings, and insulators should be clean and dry when making measurement.

It should be noted that a straight line plot of surface resistivity against relative humidity for an uncontaminated porcelain bushing surface results in a decrease of one decade in resistivity for a nominal 15% increase in relative humidity.

5.7 Supplementary Test Methods

As of today there exists no other test method that can replace the currently used C & tan δ test. Nevertheless, several measurement methods exist which compliment dissipation factor measurement and assist in localization of defects in the test object.

Partial Discharge Measurement is unprotected against external electromagnetic disturbances and on-site measurement presents quite a lot of problems.

Oil Analysis Measurements provide useful information about the insulating oil in transformers and oil-paper insulation systems.

The Recovery Voltage Meter RVM provides information about the aging condition of the oil-paper insulation. This method cannot currently be used for testing synthetic insulation.

5.8 Standard Capacitor, Measuring Current

& Limits

To evaluate the expected values of test current, standard capacitor current, the corresponding limiting parameters and the resulting load range use these basic conditions and rules:

(1) Maximum test voltage shall be less than the nominal voltage of the standard capacitor.	$U_{Test\ max} \leq U_{CN}$
ⓘ Current through standard capacitor C_N	$I_{CN} = U_{Test} \cdot 2\pi \cdot f \cdot C_N$
(2) Minimum current through standard capacitor C_N *Note: Minimal current through C_N (internal or external) to ensure accuracy*	$I_{CN\ min} \geq 20\ \mu A$
(3) Maximum current through standard capacitor C_N *Note: Maximum input current of the "C_N INPUT" to avoid overload* *	$I_{CN\ max} \leq 250\ mA$
(4) Maximum test voltage *	$U_{Test\ max} = \dfrac{I_{CN\ max}}{2 \cdot \pi \cdot f \cdot C_N}$
(5) Minimum test voltage	$U_{Test\ min} = \dfrac{I_{CN\ min}}{2 \cdot \pi \cdot f \cdot C_N}$
ⓘ Test current I_X through test object C_X	$I_x = U_{Test} \cdot 2\pi \cdot f \cdot C_x$
(6) Maximum Test current through test object CX *Note: Maximum input current of the "Cx INPUT" to avoid overload*	$I_{X\ max} \leq 15$ A **
(7) Minimum Test current through test object CX *Note: Minimal input current of the "Cx INPUT" to ensure accuracy*	$I_{X\ min} \geq 20\ \mu A$
(8) Limitations based on "Technical Data" (e.g. max supply power, current etc.)	

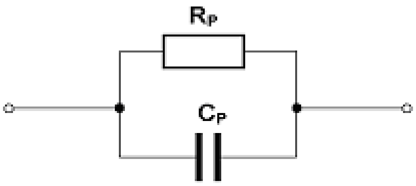
Note: These calculations are valid for capacitive test objects (tan $\delta = 0$). They can also be as a close approximation for test objects with a tan δ value < 0.01.

* The max. output power can also limit the maximum test voltage

** Test current higher than 15A can be measured with external current dividers (current comparators). With them a range extension of up to 100 kA is possible. For more information please refer to the section 'Tab Sheet Setup – Menu Settings – Standard Capacitor'.

5.9 Parallel & Series Equivalent Circuits

The measuring bridge measures and displays both - the parallel and/or series equivalent circuit values.
The following formulas describe the calculation of the value conversion parallel – series :

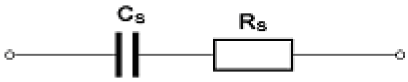


Parallel equivalent circuit

Parallel Equivalent Circuit C_p-R_p

$$Rp = \frac{1}{\omega \cdot \tan\delta * \cdot Cp *}$$

* measured values



Series equivalent circuit

Series Equivalent Circuit C_S-R_S

$$Cs = Cp * \cdot (1 + \tan^2 \delta *)$$

$$Rs = Rp \cdot \frac{\tan^2 \delta *}{1 + \tan^2 \delta *}$$

* measured values

6 Functional Description

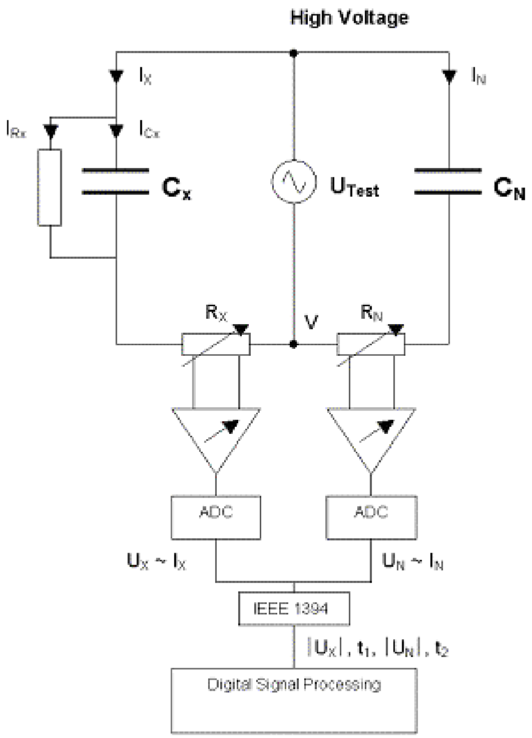
6.1 System Overview

⚠ To be able to execute correct and reproducible measurements it is essential to understand how the measuring system works.

The measuring system is based on the double vector-meter method which relies upon the measurement of the current I_N through the known reference capacitor C_N and the measurement of the current I_X through the unknown test object C_X.

Both branches are energized by an external HV AC power source (U_{Test}) and both currents are measured by the adjustable high accurate shunts R_X and R_N and then digitised. By using IEEE 1394 "fire wire" data bus technology each digitised value is time stamped. With this technology not only the values but also the time information (phase displacement) between I_N and I_X can be measured very fast and highly accurate.

The digitised data streams are fed into the built-in PC and over the known standard capacitor all other desired measuring values can now be determined online.



I_X	Current trough Device Under Test C_X
I_N	Current trough known Standard Capacitor C_N
I_{RX}	Losses of the Device Under Test C_X
C_X	Test Object (ideal capacitance)
C_N	Standard capacitor (with $\tan\delta < 10^{-5}$)
R_X	Measuring shunt for I_X, C_X
R_N	Measuring shunt for I_N, C_N
V	Low voltage point of the HV supply and reference point of the measurement
ADC	Analogue to Digital Converter
t_1, t_2	Time stamps of the measured values

6.2 V(Common) point and Guarding

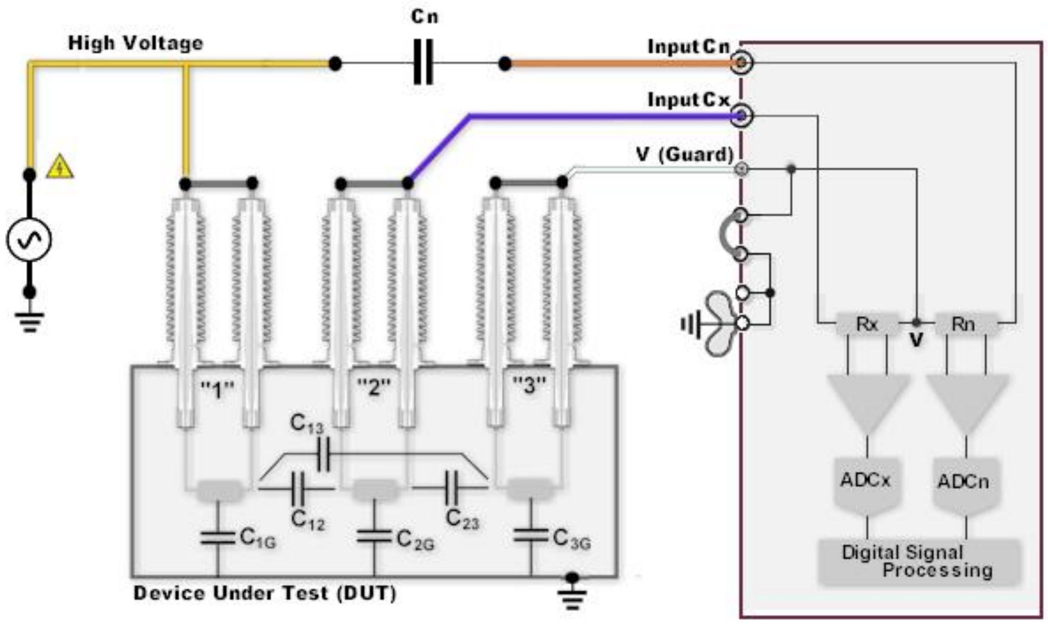
This measuring system is able to measure capacitances with highest accuracy to determine trending analysis of insulating materials. In the range of normal insulation capacitances the always existent stray capacitances - measured together wit the DUT – can influence the measuring values significant. So these unwanted stray capacitance effects have to be eliminated.

This is realized by the so called "guarding" of the relevant elements. That means that the complete high voltage source, the supply and measuring cables have to be shielded with the so called "V(Common)" which is the low voltage point (reference) of the high voltage supply. All capacitances connected to this reference point are bypassed and are therefore not influencing the measuring value. Several parts have to be double shielded (Guard and Ground) to compensate other side effects and to ensure the specified measuring accuracy. Due to this guarding concept the supplied shielded coax measuring cables (for High Voltage Supply, Input Cn and Input Cx) have to be used always. If the system is connected with normal unshielded cables the measuring values will be incorrect.

To keep in mind for the user of the system is that capacitances related to the V(Common) -point are bypassed. Make sure that all unwanted capacitances are related to the V(Common) point and their current is flowing directly into the V(Common) -point and not through the measuring shunt R_X.

This has to be evaluated for every measuring setup. The most common ones are described in this manual – for the other ones the user has to make sure that only the desired capacitances are measured with the chosen test setup.

The V(Common) point is accessible over 4mm plugs on the instruments back panel where the user can connect external parts of his test setup.



Guarding example: Bypass the unwanted inter-winding capacitances with connecting to V-potential.

Normal connection to measure capacitance C12 between high voltage winding "1" to low voltage winding."2". Capacitance C13 will be bypassed by connection to V(Common).

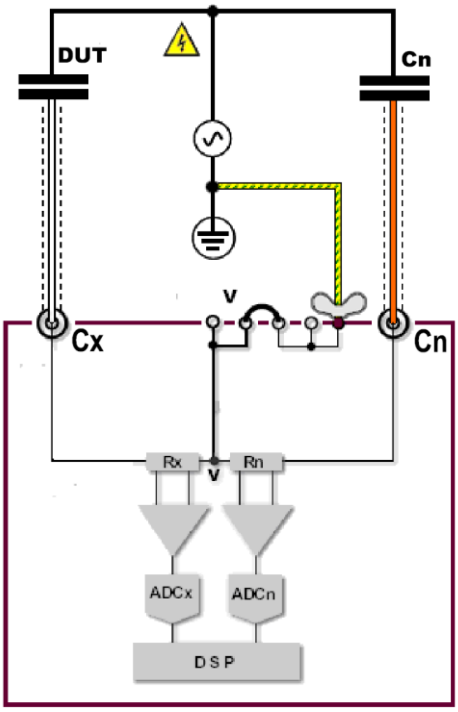
6.3 Standard test circuits

In this chapter the standard measuring methods are explained. It is important to understand how the current is flowing in the specific measuring application to avoid leakage currents which lead to inaccurate measurement results. These circuits are also applicable to Inductances.

6.3.1 Ungrounded Specimen Test (UST) with grounded HV Supply

This test mode is the most common situation when measuring capacitance and dissipation factor. Various ungrounded capacitances can be measured using this mode, providing that the maximum test current of the measuring instrument is not exceeded.
When measuring power transformers and HV current transformers, this configuration determines the capacitance and dissipation factor between the various winding groups.

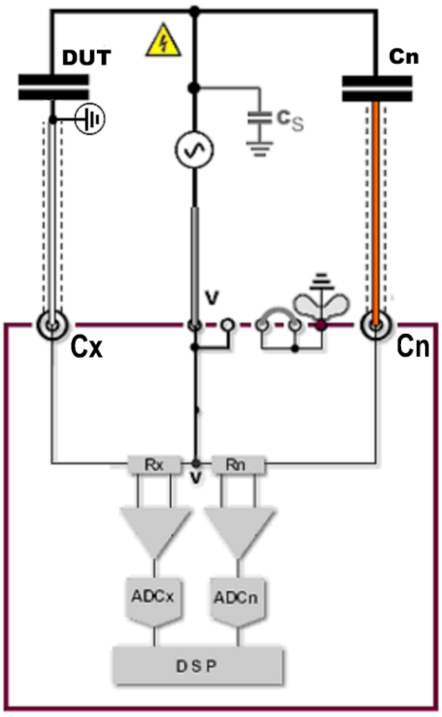
In this mode the highest measurement accuracy is reached.



Standard UST test circuit

6.3.2 Grounded Specimen Test (GST) with floating HV Supply

This test mode enables the measurement of capacitances that are normally earthed on one side when in operation. When measuring transformers, this configuration measures the capacitance and dissipation factor between the HV winding and all other windings and the transformer housing.



Standard GST test circuit

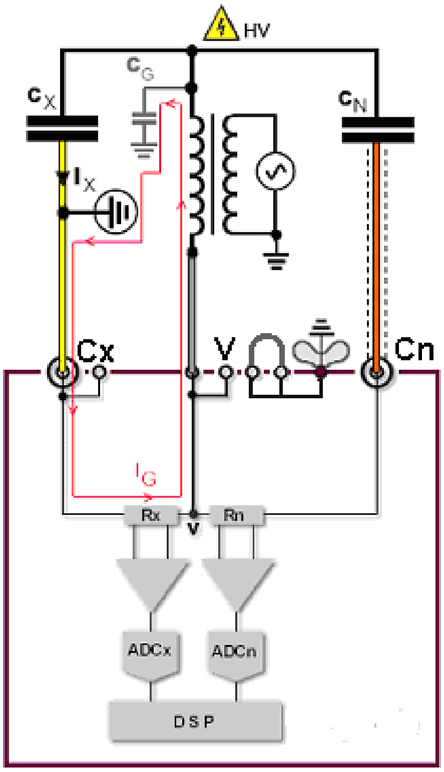
Note: The wing nut earth terminal is used for Safety Ground Connection.

In the GST mode the inter-winding capacitance of the HV source interferes the measurement. It should be as small as possible. Special double-shielded HV sources can be used to minimize this influence. Other test processes can be used to calculate the effect out of the measuring values.

See also next chapter.

6.4 Interference Correctives

6.4.1 Stray Capacitance HV-Earth of power source in GST mode.



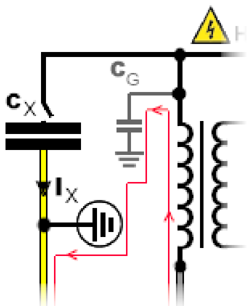
Interference:

The HV-Earth stray capacitance CG between the high voltage side (source & connection cables) and earth creates the path for the error current IG .

This current will be measured over the measuring shunt Rx together with the desired measuring current Ix and falsifies the measurement of CX .

$$C_{meas} = C_G + C_x$$

$$\tan\delta_{meas} = \frac{\tan\delta_G \cdot C_G}{C_G + C_x} + \frac{\tan\delta_x \cdot C_x}{C_G + C_x}$$



Corrective:

Compensation measurement : The capacitance C_G has to be measured first and put in calculation for further measuring of C_X.

The high-voltage cable has to be put very close to the test object connection point, but **without** connecting to test object C_X.

Now apply the required test voltage, measure and safe the value of the capacitance and the dissipation factor tan δ of the disturbing capacitance C_G.

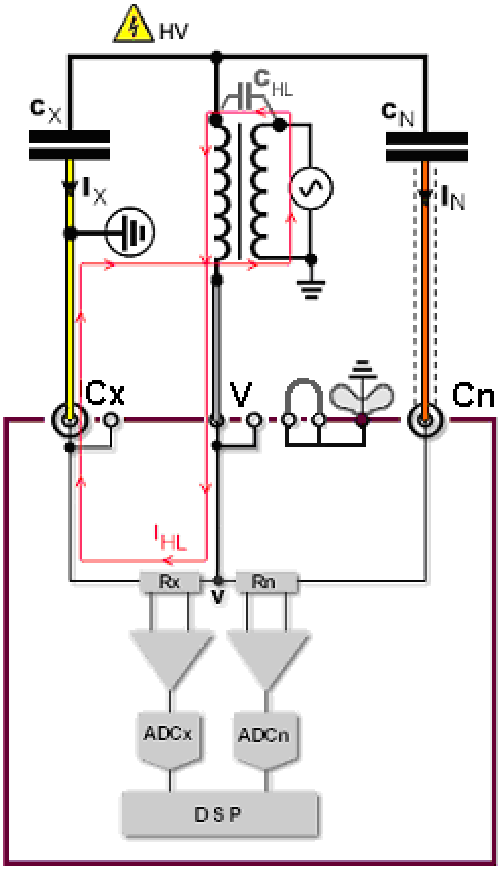
Now connect the high-voltage cable to the test object and the measured values will be automatically corrected according the following formulas :

$$C_x = C_{meas} - C_G$$

$$\tan\delta_x = \frac{\tan\delta_{meas} \cdot C_{meas}}{C_{meas} + C_G} - \frac{\tan\delta_G \cdot C_G}{C_G + C_x}$$

See also chapter “Software/Tab sheet SETUP/Menu Settings/Extended GST Accuracy” for C_G compensation measurement handling.

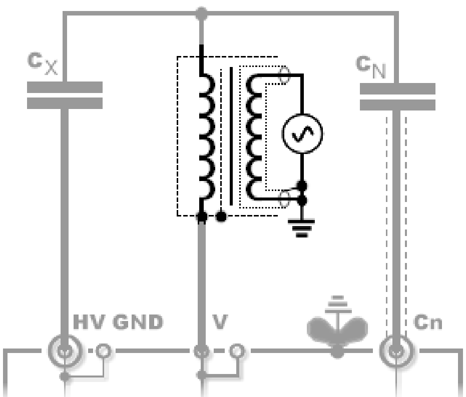
6.4.2 Coupling Capacitance LV-HV of power source in GST mode



Interference:

The coupling capacitance CHL from the low voltage side of the transformer to the high voltage side creates the path for the disturbance current IHL .

The current IHL will be measured over the measuring shunt Rx together with the desired measuring current Ix and falsifies the measurement.

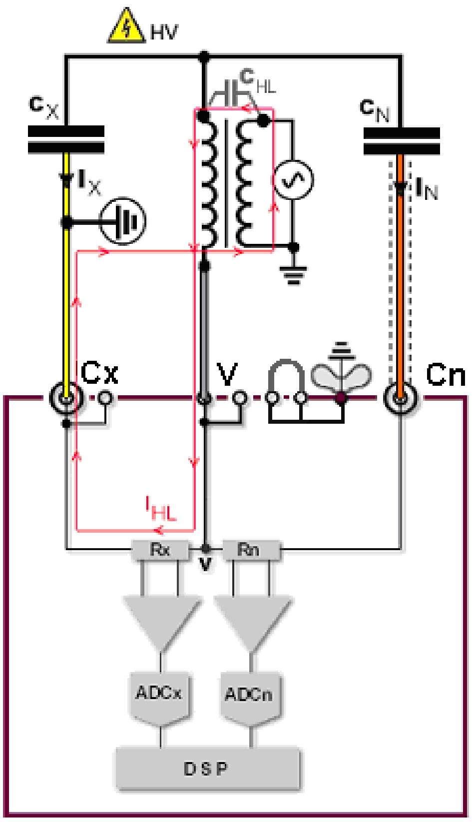


Corrective 1:

To eliminate the impact of this coupling capacitance of the power source TETTEX Instruments offers special double shielded high-voltage sources which reach minimal coupling capacitances and therefore lowest influence of the measuring accuracy.

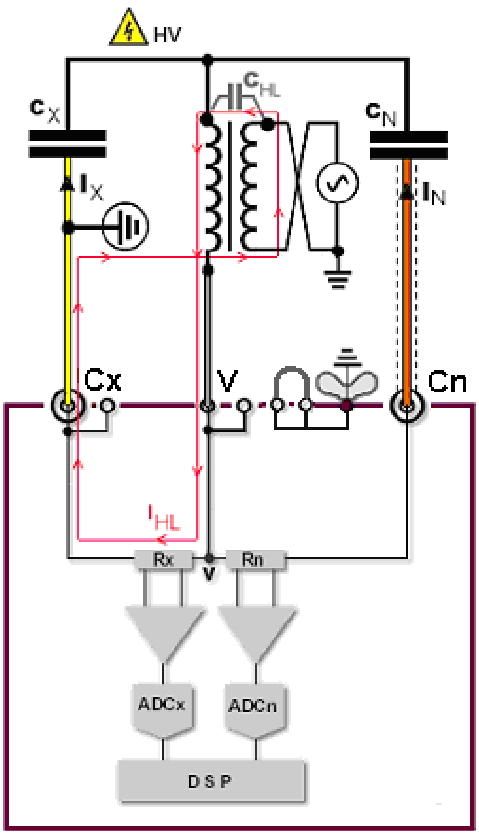
Contact our sales department for a quote. sales@haefely.com.

If you already have a HV source that has to be used, follow the Corrective 2 method.



Corrective 2:

#1 Measure the test object in the normal configuration and safe the measuring values (Measurement 1) .



#2 Change the polarity of the High Voltage source as shown in the left figure. Measure the test object in this configuration and safe these measuring values as well (Measurement 2).

The disturbance current I_{HL} keeps its polarity while the polarity of the measuring currents I_X and I_N will change by 180°. Due to that fact the correct values can be calculated out of the values of these two measurements.

#3 Calculate the average from measurement 1 and measurement 2

$$Cx_{act} = \frac{Cx_1 + Cx_2}{2}$$

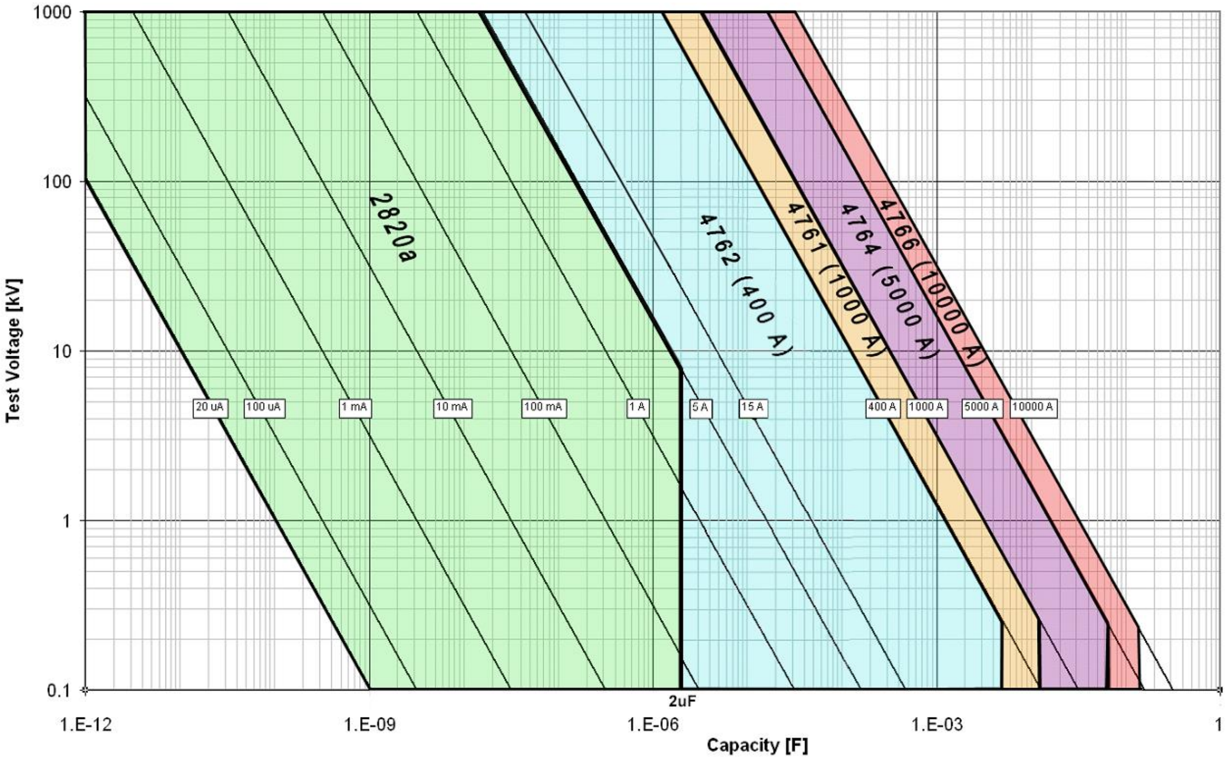
$$\tan\delta_{xact} = \tan\left(\frac{\arctan(\tan\delta_{X1}) + \arctan(\tan\delta_{X2})}{2}\right)$$

6.5 Use of Current Comparator CC

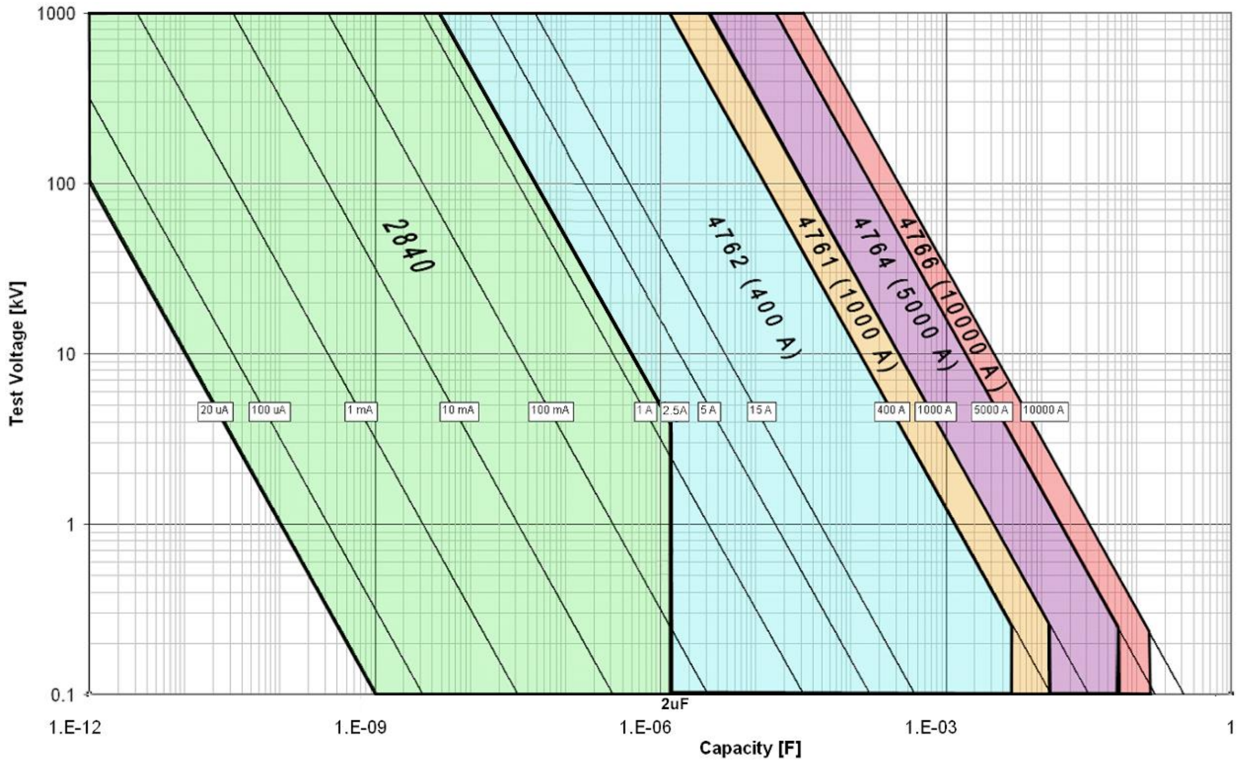
Power Capacitors and Shunt Reactor are tested with currents from some 10 A up to above 1000 A and with DF / tan δ from approximately 0.00005 .. 0.005.

The basic measuring bridge can handle measuring currents up to 15 A. For higher currents a current comparator (a high precision current divider transformer) CC is used for range extension

See in the following diagrams (for 2820a and 2840 unit) the max. currents within you reach the specified maximal accuracy and were an additional current comparator should be used.



*Max currents of the unit **2820a** and with the use of an additional Tettex current comparator.*



*Max currents of the unit **2840** and with the use of an additional Tettex current comparator.*

Principally the current comparator is a highly accurate current transformer which divides the current and therefore creates a measuring range extension. The accuracy of the complete measurement is reduced by the uncertainty of the used current comparator. Tettex offers high precision current comparators for current range extensions up to 10’000 A.

In this chapter several different measuring methods are explained. It is important to understand how the current is flowing in the specific measuring application to avoid leakage currents which can lead to inaccurate measurement results.

Following paragraphs will give a brief overview how to connect and setup the unit for different measuring application with current comparators. (Configuration A..D). The same circuits are also applicable to inductances.

If a Tettex current comparator is used follow these rules:

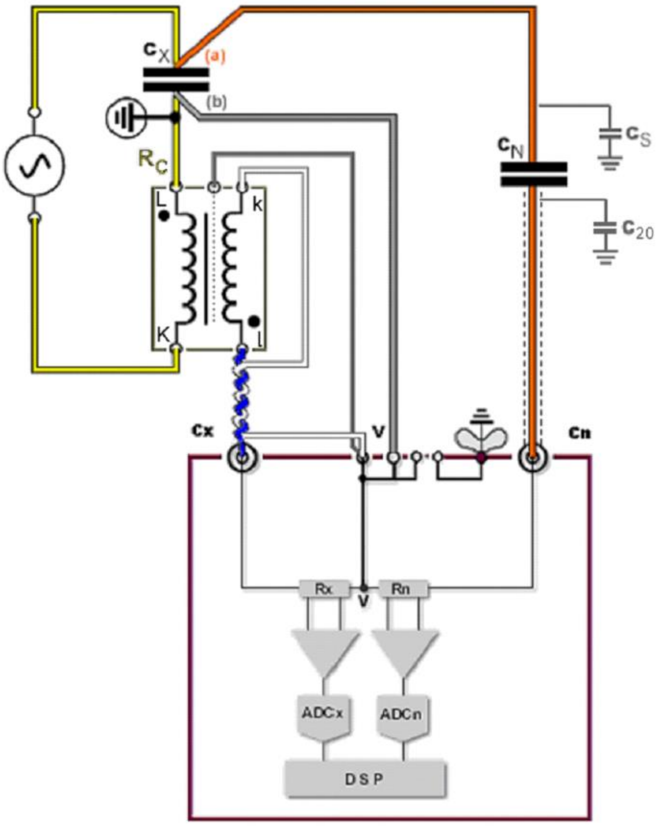
- In min should be > 600 µA (on the standard capacitor path without the current comparator)
- Select a ratio n (on the current comparator) that Ix current (into the measuring unit) is around 1A
- Select a ratio n (on the current comparator) of 10 : 1 or higher

For all circuits it is important that the used configuration is also set in the setup of the software and thus the software activates the related correction algorithms ! (see section Software “Menu Settings”).

The following test circuits “Configs” are used with the Tettex bridges and Current Comparators:

6.5.1 Configuration “A” Grounded DUT, Ungrounded HV Source

Used for earthed test objects (a shielded power supply should be used)



For this “4 wire Kelvin measurement” it is important, that the (a) wire to CN and (b) the wire from V to Cx are connected very close to the DUT. This reduces the voltage difference caused by the huge current through the resistance of the supply cable.

The reference current (C_N current) flows on his way back to the high voltage supply through the primary winding of the current comparator (CC which influences the measured capacitance C_X. The instrument compensates internally this measurement error so that the displayed measurement value only includes the C_X impedance. (But the actual used setup has to be set correctly to “A”)

Any stray capacitance C_S between high voltage and ground is parallel to the DUT and influences the measurement. For huge currents this stray capacitance is negligible.
But for small currents it is therefore strongly recommended to perform a stray error correction before this measurement configuration is used (see section “Extended GST Accuracy”).

A screened power supply should be used.

Advantage

- The voltage drop over Rc and CC has no influence (compared to Config ”C”)

- Stray capacitance C_{20} (Low - Earth) has very low influence

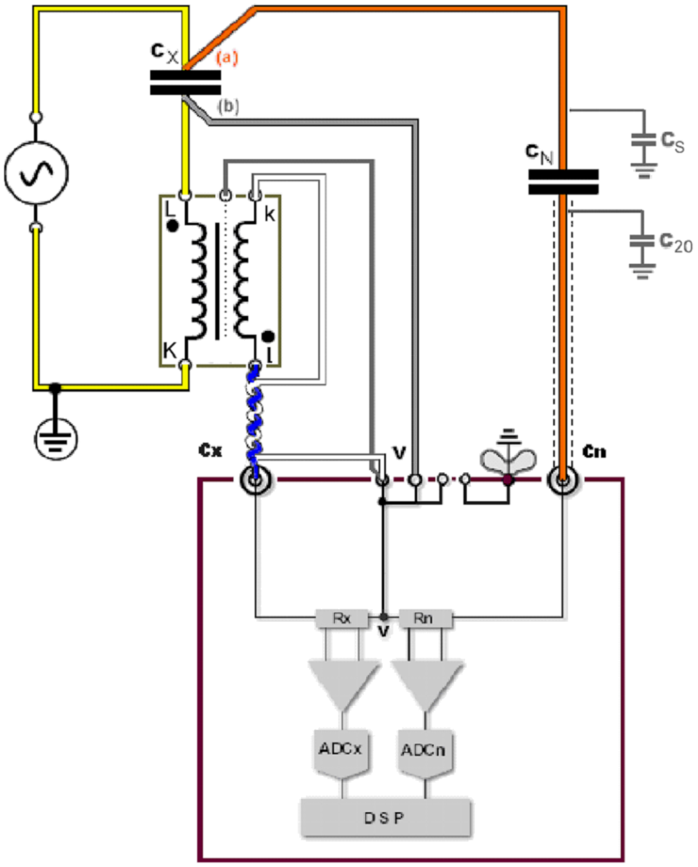
Disadvantage

- Cs has big influence

- Power supply has to be earth-free and should be shielded

6.5.2 Configuration "B" Ungrounded DUT, Grounded HV Source

Mainly used for power capacitors with small tan δ (approx. < 0.001) and Shunt Reactors with small ohmic resistance (approx. < 1 Ω)



The measurement of ungrounded specimen as illustrated in the figure above is principally the same as the measurement configuration described in Option A. All remarks are also applicable in this measurement application.

The error of the current through C_N will be corrected inside the instrument and the influence of higher currents (cable resistance) is reduced by connecting measuring point V directly to the test object.

The reference current (C_N current) flows on his way back to the high voltage supply through the primary winding of the current comparator (CC) which influences the measured capacitance C_X. The instrument compensates internally this measurement error so that the displayed measurement value only includes the C_X impedance. (But the actual used setup has to be set correctly to "B")

Any stray capacitance C_S between high voltage and ground is parallel to the DUT but the current flow back goes directly to the Ground of the HV source and not through the current comparator and therefore does not influence the measurement in this configuration.

Advantage

The voltage drop from Low of DUT (b) to Earth caused by the cable resistance and the CC is nearly eliminated compared to Config "C".

Disadvantages

- Stray capacitances from the Cn input to earth influences the measurement more or less depending on the voltage drop from LOW of the DUT against earth.
This stray capacitances are the C20 of the standard capacitor (Low-Earth) as well as any stray capacitances Cin in the input of the measuring bridge.

- Guard (Screen) capacitance in the CC to secondary winding influences the measurement more or less depending on the voltage drop from LOW of the DUT against earth.

Correctives to overcome the main disadvantages:

(a) Try to work with an isolated standard capacitor Cn. (maybe use a separate protection unit, spark gaps with minimized capacitance)

(b) Take care that the voltage drop from LOW of DUT to Earth is as low as possible, using wires with appropriate cross section.

(c) Use a Cn with a higher value to reduce the influence of C20

(d) If (a) is not possible, use test configuration “C” compensating the resistance from LOW of DUT to Earth supported by the software.

Even if (a) can be realized, some small residual influences from the CC shielding (Guard) might exist, especially at lower primary current (up to approx. 50 A) and using the 1 A Tap. Connecting the CC shielding (Guard) to Earth instead to v might decrease this influence.

Troubleshooting Test Configuration “B”

Problem: Negative values for tanδ are displayed

a. The cables from secondary side of CC are erroneously interchanged at the CC.

→ Connect the cables correct.

b. The tanδ value of the used standard capacitor is worse than the tanδ of the DUT.

→ Use better Cn or enter the Cn tanδ value in the setup field so it will be corrected.

Problem: Strange values for tanδ and fairly different value in Cx / Lx

a. Probably the Sense cable is not connected or not at the right position (LOW of DUT)

→ Check and connect according diagram

b. The v-Point is erroneously earthed somewhere

→ Disconnect cable (b) at the LOW of the DUT but all other cables connected according the diagram and measure with an Ohmmeter the resistance between v and Earth. It should be approx. > 500 kΩ, if not - search for the short circuit and eliminate it. (Especially check the screen of the Cn cable).

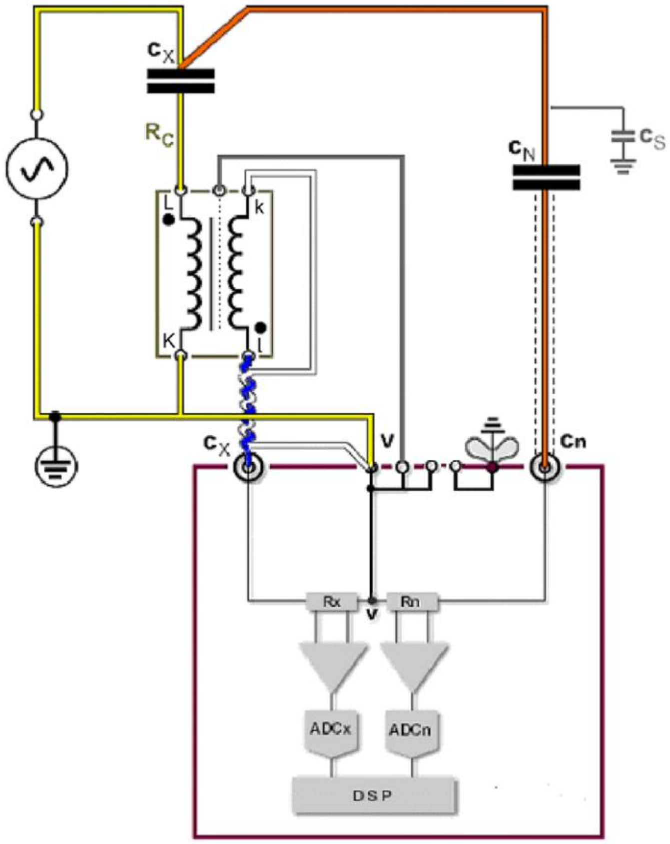
Problem: Negative values or values fairly smaller than expected are measured

a. Probably stray capacitance C20 and/or Cin are big and/ or voltage LOW of DUT to Earth is big.

→ see Recommendations to overcome the disadvantages

6.5.3 Configuration "C"
Ungrounded DUT, Grounded HV Source and CC

Mainly used for power capacitors with greater tan δ (approx. > 0.002) and Shunt Reactors with higher ohmic resistance (approx. > 1 Ω), respectively for application where the influence of the resistance between the Low of the DUT and Earth is smaller.



In this circuit the middle point V is connected to ground. So the stray capacitance between ground and high voltage U has no influence.

But on the other hand it is not possible to determinate quite accurate the additional influence of the R_C cable between the DUT and the current comparator and the impedance of the current comparator itself. And these uncertainties are not exactly known.

Advantage:

No influence of stray capacitances.

Disadvantages:

Errors eventually caused by wire resistances from DUT-Low to CC and Earth is difficult to correct accurately for DUT with very low equivalent serial resistance.

The resistance to be corrected can be calculated by measuring the voltage drop from DUT-Low to Earth and divide them by the displayed current.

Troubleshooting, Test configuration “C”

Problem: Negative values for tan δ are displayed

a. The cables from secondary side of CC are erroneously interchanged at the CC.

→ Connect the cables correct.

b. The tan δ value of the used standard capacitor is worse than the tan δ of the DUT.

→ Use better Cn or enter the Cn tan δ value in the setup field so it will be corrected.

Problem: Very strange values for tan δ

The correction value of the resistance to be compensated might be not correct.

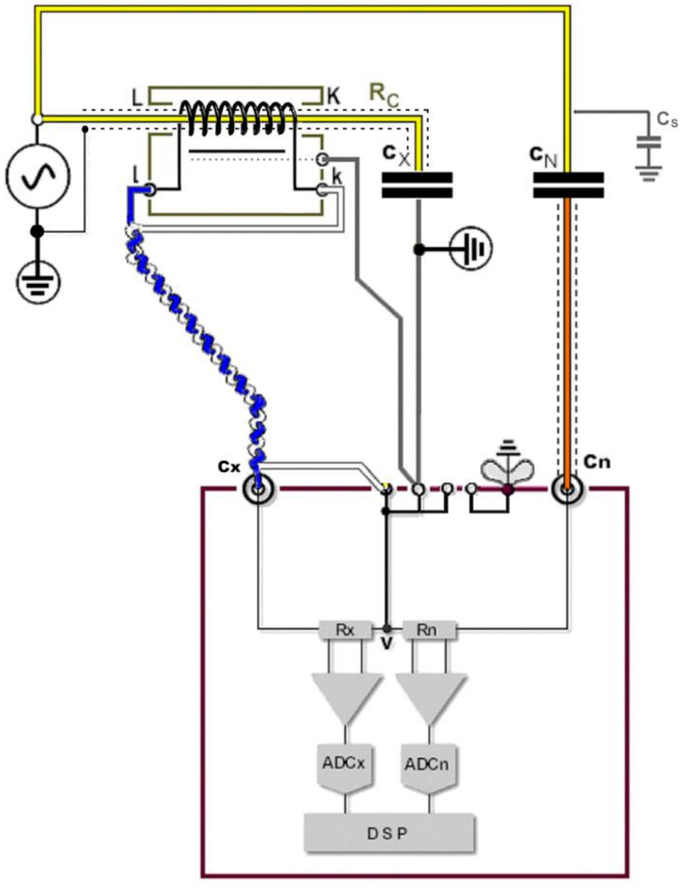
→ Measure and set the correct value.

6.5.4 Config "D" Grounded DUT, Grounded HV Source, CC on HV

For earthed test objects from approx. 20 mA to 20 A. No screened power supply is necessary but a screened high voltage cable.

The current comparator 4761 is used in this circuit, designed to be used as a trough hole type only.

Ratio according the number of turns of the HV-cable.



In this circuit the current is measured on the high voltage side with a current comparator(CC). This configuration allows a measurement with a non shielded power source as described in Chapter 6.4.2.

But due to the possible high current, the voltage drop over cable resistance (Rc) has to be compensated. By entering the Rc value in the software setup the influence is compensated.

Advantage

No influence of stray capacitances.

Disadvantages

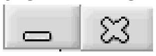
Resistance of HV cable has to be known quite well for good correction.

7 Operation Elements

7.1 Touch screen

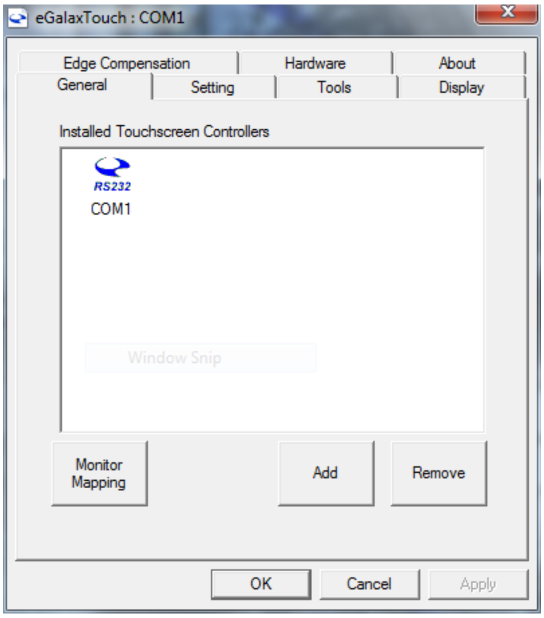
To calibrate the touch screen positioning follow these steps:

Close or minimize the application software by pressing
the Minimize Button or the Close Button

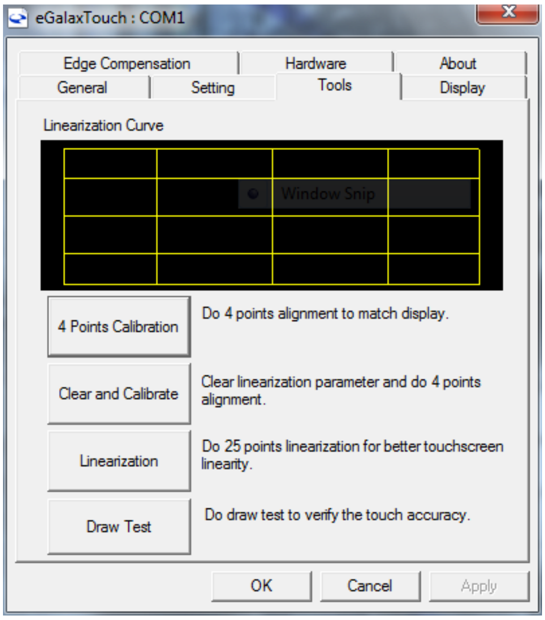


Start “All Programs” / “eGalaxTouch”.

The following screen will appear.



Click on tap “Tools”



Press “4 Points Calibration” and follw the instructions shown on the screen.

7.2 Front Panel

1 Touch screen interface

2 USB Interface 1

3 USB Interface 2

4 Mains Power Switch

7.3 Rear Panel

1 **Measurement Input Cx**

2 **Measurement Input Cn**

3 **V(Common) (Reference Point of the bridge)**

4 **$V_{(Common)}$ can be connected to Earth with the Black Jumper**

5 **Earth connection**

6 **Ext. HV Supply (Low Voltage Point) Connection (internally connected to 4)**

7 **Ethernet Interface**

8 **USB Interface 3**

9 **USB Interface 4**

10 **Safety Ground Connection**

For safety reasons this earth cable should be the FIRST lead to be connected to the set and the LAST to be disconnected.

11 **Mains Power Switch**

12 **Mains Fuse**

13 **Mains input socket**

14 **Auxiliary interface (not in use; for future enhancements)**

Note: When the unit is permanently housed in a vehicle, it should be bounded to the vehicle chassis, which in turn is grounded.

8 Software

The Software is running on a embedded Microsoft Windows Operation System. The software is designed to control all operation and inputs by a touch screen. For additional operation like installing LAN connectivity, printer etc, an USB mouse or an USB keyboard can be connected to the system for easier operating.

The software part is described for the type 2840.
The only software difference to the 2820a is the resolution of some displays (according to the technical data) and of course the shown unit type in the start-up screen.

8.1 General

8.1.1 Start-up

Once the program has been started following startup window appears:

The startup window contains some important information like software version, last calibration date, instrument serial number and product number. For any correspondence with Haefely Test AG please keep this information ready.

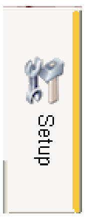
At the bottom of the startup window three buttons could be selected for different operations.

	to start the system in Manual Mode. The default file for storing measuring data will be used.
	to launch the file manager in which you have the possibility to select a file for operation, to load a previous file, or to create a new file. See section “File Manager“ for more information.
	to start the online help.

8.1.2 Main Window

The main window consists of four parts accessible over the related tabs on the right-hand side.

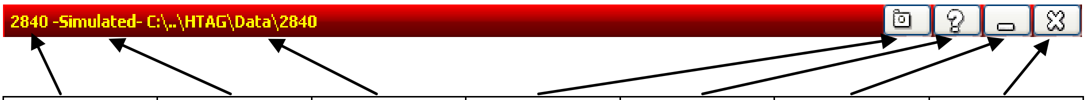
The function of these tab sheets are:

	**Setup** Pressing this button provides access to the definition of the Device under Test (DUT), measuring conditions and auxiliary information. See section “S” for details.

	**Manual** This sheet is used for manual operation, such as setting the measuring connection, voltage and frequency and storing the measuring results in a spreadsheet. See section “M” for details.
	**Sequence** This tab sheet defines the test sequence and create complex test cycles. The measured data are automatically stored in a spreadsheet, which can be used for additional analysis afterwards. See section “Sequence Mode“ for details.
	**Analysis** This sheet is used to sort and analyse the measured data in a graphical way. Trends or different comparisons can be generated without an extraordinary effort. As a result, you may predict the actual state of your equipment. See section “Tab sheet ANALYSIS” for details.

8.1.3 Title bar

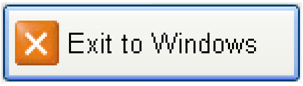
The title bar (header line) has following structure:



Device Name	Status if operation mode is “Simulated”	Path and name of the actual active file	Screen Shot Button	Help Button	Minimize Button	Close /ShutDown Button

The functional descriptions of the title bar elements are:

	**Device Name** Name of the device (2840 or 2820a). The colour of the title bar will change to red, if the currents exceeds 50 uA.
	Simulation Mode If the OFFICE software is used on a standalone PC or laptop to prepare sequences, connection diagrams, display measurements etc. the “Simulated” status is shown in the title bar. The “Simulated” mode provides the same functionality as on the unit itself, but no system hardware is needed. The measuring values are simulated.
	Document Name The actual active (loaded) test file and its path is shown here. All data are stored in this file.
	Alarm Message In this field you find the actual status of the system.

	**Screen Shot** This button can be used to generate and save a screenshot. If pressed a dialog pops up which asks where to store the picture file.
	Help Pressing this button an explorer with help screen will open
	Minimize The display of the software will be minimized and you have access to the Windows OS desktop. This button can only be pressed while the HV is switched off.
 	Exit By pressing this button you can select between “Exit to Windows” and “Shut Down”. Press “Exit to Windows” button to terminate the application software and exit to Windows Operating System. Press “Shut Down” button to terminate the application software and shut down the system. It’s strongly recommend to shut down the system correctly before switching the main power off.

8.1.4 Alarm Messages

Alarm messages of the system are displayed in the status field.

The alarm messages can be described as follow:

	Ext. Averaging If the system was not able to get stable values with the standard averaging routine this alarm will appear. The “Extended Averaging Mode” is reset to normal averaging after the High Voltage is switched off. Note: If the normal averaging mode can not create stable values the user is asked to enable the “Extended Average Mode”.

8.2 File Manager

Always save your files and data on the D:/ drive.

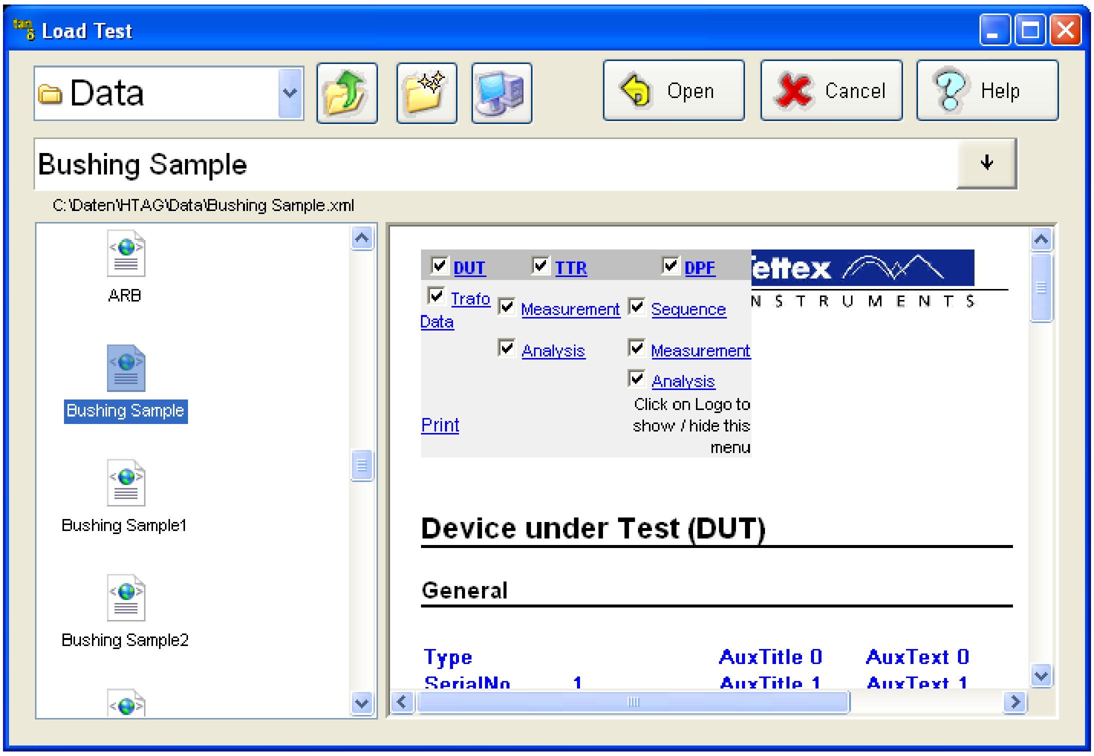
Do NOT save data on the C:/ drive. In case of a recovery (see page) the C:/ drive will be deleted and set to factory defaults. All data saved on the C:/ drive will be deleted.

The File Manager window will appear by pressing the button either in the start-up window or in the key bar at the bottom of the main window.

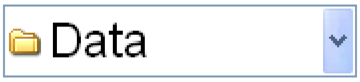
New	New The File Selector Dialog pops up where you can enter a name for the new file. All further measured data will be stored in this file.
New based on Template	New based on Template The File Selector Dialog pops up and a new test file can be generated which will be based on an existent file. The sequence data will be used from the source file, the measuring data will be deleted. All further operations will be stored in this file.
Load	Load Load an existing file to continue your work.
Save	**Save** To save the actual test file.
Save As	Save As The actual file can be saved with a different filename.
Copy to USB Stick	**Copy to USB Stick** To copy the actual file to your USB stick.
Report	Report The internet explorer with the actual test file will open. There you can print the file and configure the appearance of the document. See section“ Report “ for more information.
C:\..\HTAG\Data\XLPE cable 500 kV-04	Previous Test(s) Last three used files are displayed for quick access.

8.2.1 File Selector Dialog

The dialog is used for storing, loading, previewing and moving files inside the directory.



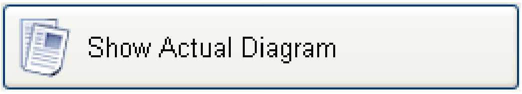
The function of the elements can be described as follow:

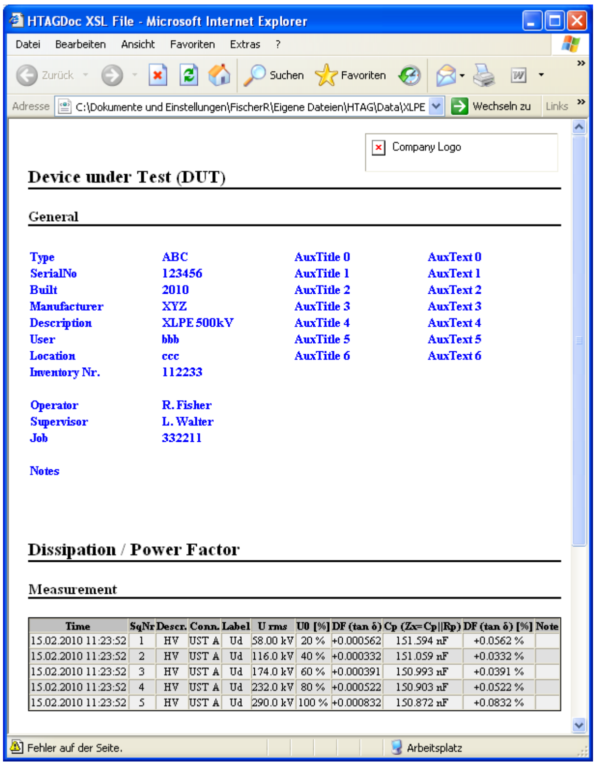
	**Directory** Drop-down list to select the actual directory.
	Files The selected file is displayed or a new filename can be entered. It is also possible to choose from the last four loaded files by pressing
	**Directory Up** Go up one directory in the hierarchy.
	New Directory Create a new directory.
	**My Computer** The root of the file system is displayed. There you can select for example the USB memory stick for storage.

	Context Menu With this button a context menu of the selected file is opened. It has the same function as the right mouse button in Microsoft Explorer. By using this menu, you can easily process a selected file, for example, copy the file to floppy, check it's properties and so on.
	Open Open a selected file. Select the file, or enter the name of a new file.
	Save Tthe current active file is stored under the actual "filename" in XML and CSV format.
	Open Cancel an close file manager window.

8.2.2 Report

Once the Report button is pressed in the File Manager Dialog two possibilities will arise.

	**Show Report** The actual report will pop up.
	**Show Actual Diagram** The actual analysis diagram is displayed.



At the top of the explorer window a small header with three boxes and a print link is placed. With this menu the appearance of the printout can be controlled. It is possible to hide or display the test sequences, the measurement values and the analysis window. Clicking on the Logo on the right side of the explorer window will show or hide the menu. The "Print" Command will hide the menu and open the print dialog.

Change of Printout Logo

If you want to use your own logo, the only thing you have to do is to replace the file "`C:\company.jpg`" by your own logo.

Data Files

All measurement and sequence data are stored in both XML and CSV format:

CSV (**C**omma **S**eparated **V**alues) files can be used to export data to Microsoft Excel.

XML (e**X**tended **M**arkup **L**anguage) files have a hierarchical structure and can be easily displayed by any computer with a Web Browser.

To exchange data or move files to another computer you have to copy one or more of the following files:

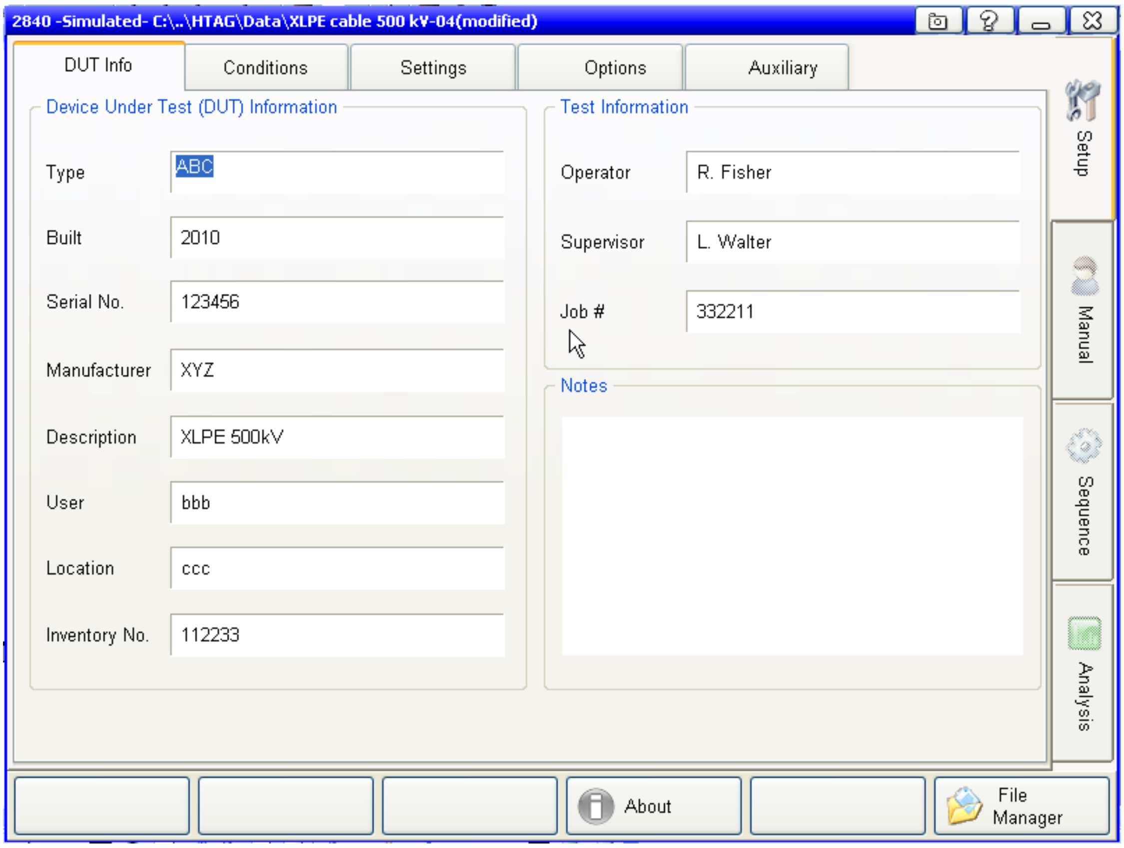
`*****.xml`	The XML file, which you want to look at.
`*****.csv`	The CSV file with DUT Information and all measuring data.
`*****.jpg`	All JPEG Files from the analysis part.
HTAGDoc.xsl	All information of the appearance of printing and showing are stored in this file. This file you have to copy only once into the root directory. For example if you want to copy the file anywhere on drive D, you should copy HTAGDoc.xsl to D:\HTAGDoc.xsl.

8.3 Setup

This tab sheet consists of following sub chapters.

DUT Info	DUT Info The general information about the device under test can be entered. See chapter6.3 for more information.
Conditions	Conditions In this panel, you should enter the actual type of the insulation of the DUT, such as the current ambient temperature and humidity. This allows that the measured Power Factor and C & tan δ are normalized to 20°C, which allows a comparison between values, measured at different temperatures. See chapter " Conditions (Temperature correction) " for more information.
Settings	Settings Enter the current measuring settings, such as cable length used, the parameters of an external capacitor connected and so on. See chapter 6.3.3 Settings for more information.
Options	Options Temperature unit (Celsius or Fahrenheit), start up unit, keyboard mode, user input, remote access, data directory, factory settings, mandatories and languages. Currently the user interface is available in English and Chinese. See chapter 8.3.3 Settings for more information.
Auxiliary	Auxiliary Additional information for special purpose can be entered. This information will be included when to the print out of the document.

8.3.1 DUT Info

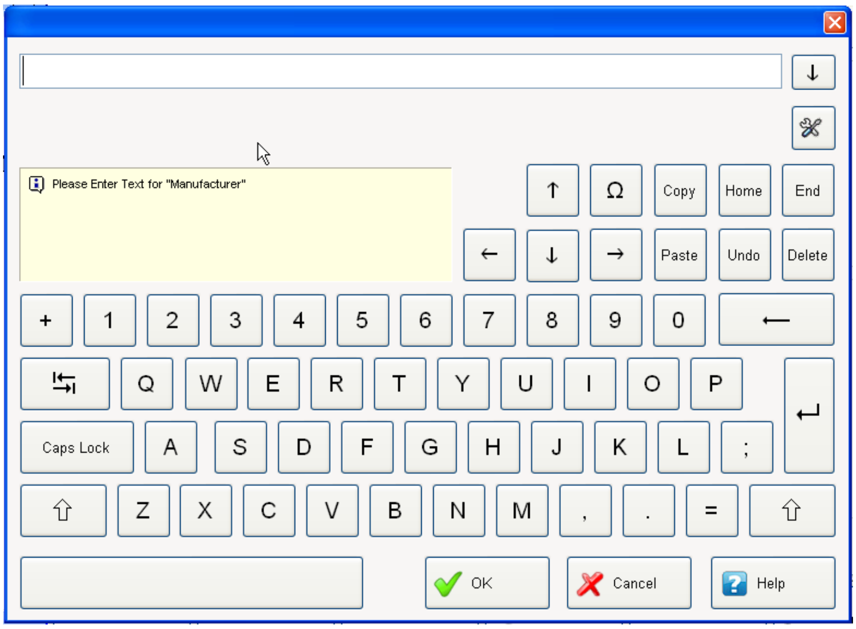


By pressing any of the input fields (white areas) the text input dialog pops up with a touch-screen ASCII keyboard to fill in the desired information.

Text Input Dialog

You can enter a text quick and easy by using this on-screen keyboard.

Once you have entered a few characters, a list of text, which was entered before and including similar characters, is shown in the dialog automatically. This speeds up the input of recurring text.



The behaviour of the text input and its list could be controlled by a pop-up menu which is triggered by pressing the button.

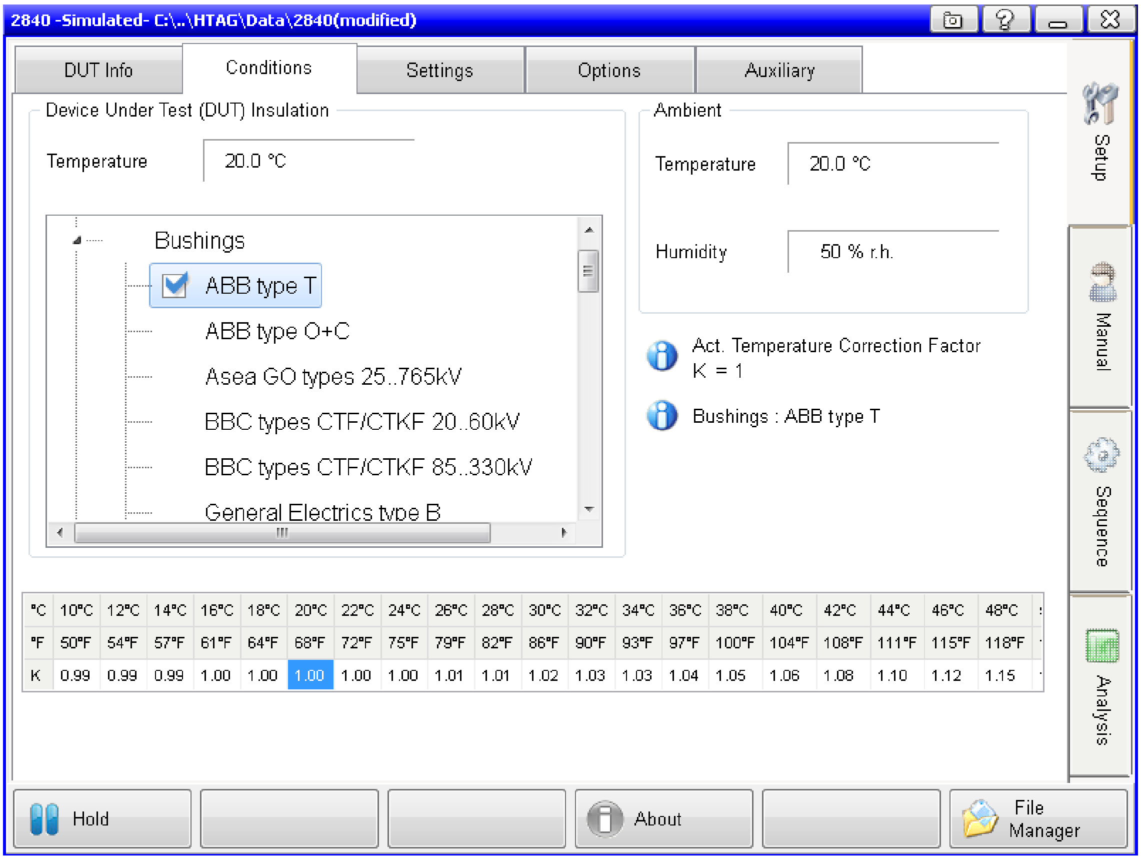
Pop-up menu description:

Add Entry	Add Entry Adds the actual text to the list.
Clear Entry	Clear Entry The actual selected input will be removed from the list. You have to confirm this operation.
Clear All	Clear All The whole list will be cleared after a confirmation process.
Ask Insert	Ask Insert If this option is activated and you enter a new text which is not in the list, you will be asked to add it to the list.
Auto Insert	**Auto Insert** If this option is inactivated and you enter a new text which is not in the list, the actual input will be automatically stored in the list. If you enter for example a misspelled text in the list, you can remove it by pressing the “Clear Entry” button.
No Insert	No Insert If this option is activated, nothing will be inserted to the text list.
No Selection List	No Selection List If this option is checked, there will be no list for the text input.

8.3.2 *Conditions (Temperature correction)*

The electrical characteristics of practical all insulation materials vary with temperature. In order to compare the results of periodic tests on the same equipment it is necessary that the manner in which the results vary with temperature must be known. The results can then be converted to the reference temperature of 20°C (68°F). Temperature correction data are average values and therefore subject to some error. The error is minimized if tests are performed at or near to reference temperature. This is not always possible in the field. But when questionable tan δ values are measured at very high or very low temperatures the equipment should be retested closer to the reference temperature.

In this menu the actual type and temperature of the DUT **insulation** has to be defined. Additionally the actual ambient temperature and humidity can be entered.



With these temperature factors the measured Power Factor and C & tan δ values are normalized to 20°C (68°F), which allows the comparison of results of periodic tests on the same equipment.

Several insulation types are already prepared for use. You can select the type of the insulation in the directory tree.

After a type and actual insulation temperature have been entered, you can find the actual calculated compensation factor “K” in the information fields.

The temperature corrections are calculated according to ANSI / IEEE C 57.12.80-1999, see following extract.

Extracts from standard ANSI/IEEE C57.12.90 –1999

Formula for recalculation at 20°C

The temperature correction factors for tan δ or power factor PF of insulation is dependent upon the insulating material, the material structure, the moisture content etc. The values for the correction factors are typical values and are sufficient for use in the following equation:

$$PF_{20} = \frac{PF_{mt}}{K} \quad \text{or}$$

$$\tan\delta_{20} = \frac{\tan\delta_{mt}}{K}$$

PF20	Power factor at 20°C
PFmt	Power factor measured at test object temperature T
tan δ 20	tan δ at 20°C
tan δ mt	tan δ measured at test object temperature T
K	Correction factor

Temperature correction factors

Conversion table for mineral oil as insulating fluid:

Test object temperature T [°C]	10	15	20	25	30	35	40	45	50	55	60	65	70
Correction factor K	0.80	0.90	1.00	1.12	1.25	1.40	1.55	1.75	1.95	2.18	2.42	2.70	3.00

Note: The correction factors given above are valid for insulation systems that use mineral oil as the insulating fluid. Other insulating fluids may require different correction factors.

Modify the Temperature Correction File

If you have equipment with known correction curves you can modify the basic standard data by yourself.

The temperature correction data is stored in the file “TempCorrFactors.csv” which is located in the same directory as the executable application file. The file format is “comma separated values” (.csv), which can be imported / modified / exported in Microsoft Excel.

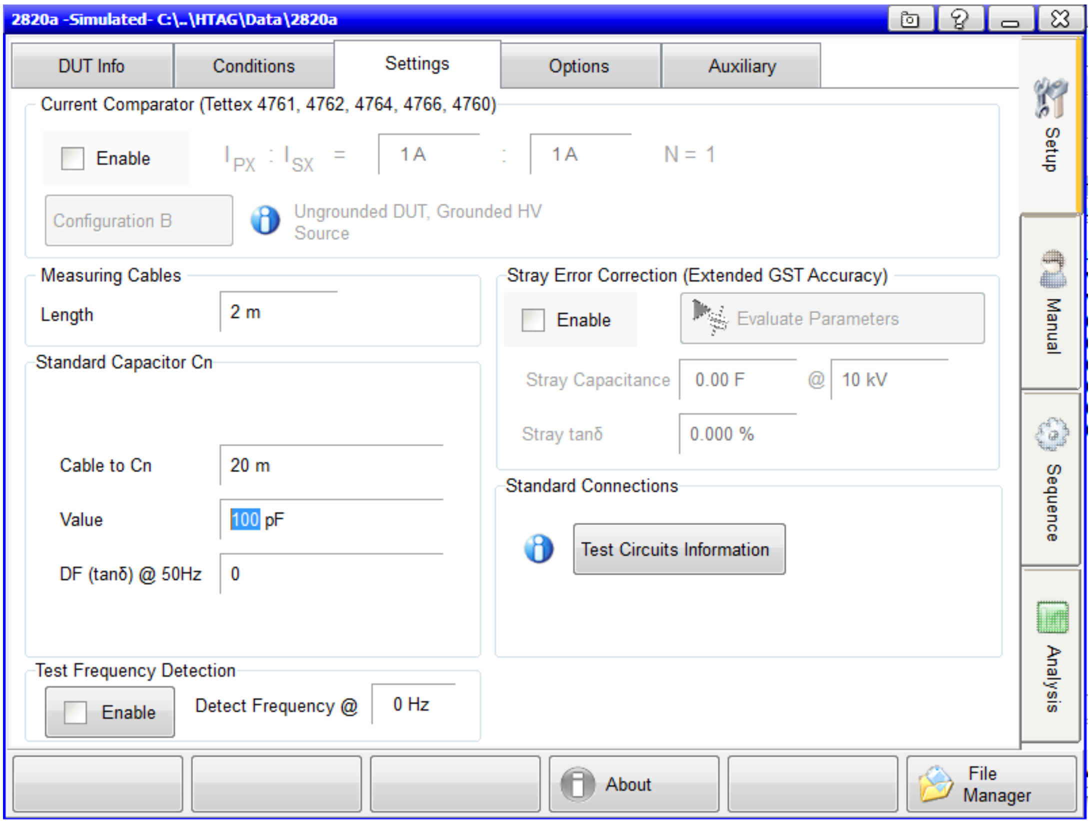
After opening the file “TempCorrFactors.csv”, you should select the first column “A” and choose from the menu-bar “Data” and then “Text in columns”. A pop-up window will ask you; ”Separate” or “Fixed width”, choose “Separate”. Then mark “Tab” and “Semicolon”. Press “OK” if the message appears; “…will overwrite the cell size”. After editing the Temperature Correction File it should be “Saved as” and the data type: “CSV” should be chosen. The file structure should be self explaining.

Example:

		0°C	2°C	4°C	6°C	8°C	10°C	12°C	14°C	16°C	18°C	20°C	22°C	24°C	..
		32°F	36°F	39°F	43°F	46°F	50°F	54°F	57°F	61°F	64°F	68°F	72°F	75°F	..
Liquids	Conventional Insulating Oil	0.64	0.66	0.68	0.69	0.7	0.72	0.76	0.81	0.86	0.93	1	1.1	1.2	..
	Askarel											1	1.11	1.23	..
	Silicon Oils - New											1	1.23	1.52	..
..	..														..

8.3.3 Settings

This menu is used to specify the external standard capacitor, the length of measuring cables and to activate a current comparator if necessary. Beside this the Settings Menu allows the user to compensate any stray capacitance which may influence the measurement results.



Current Comparator

According to the description in section “Current Comparator” four different measurement configuration are applicable with a current comparator. This configuration must be selected by pressing the button “Configuration A” which pops up a list with the four dedicated measurement configurations. The right measurement configuration can be chosen by clicking the appropriate picture.

Measuring Cables

Length	Input “Length of Measuring Cable [m, ft]” Length and type of measuring cables influence the measurement data, so it is important to set the right length for measuring cable connected to input Cx and Cn. Only supplied cables can be used. The standard length is 20m, 66 ft.

Standard Capacitor Cn

The external standard capacitor which is used as measuring reference has to be specified in this section. Haefely Tettex offers air and gas insulated standard capacitances (refer to section “Introduction – Optional Accessories”).

Following fields has to be set correctly. Once this has been done the values will be stored and can be recalled when the booster is reselected.

Cable to Cn	Length of measuring cable Cn Length and type of the cable influences the measurements so it is important to enter the cable length. Only supplied cables shall be used.
Value	Value of external Standard Capacitor Cn According to the formula presented in the section "Theory – Standard Capacitor, Measuring Current and Limits" he maximal current should be less then 1 A.
DF (tanδ) @ 50Hz	DF (tan δ) @ 50 Hz In general, only accurate standard capacitor can be used. If the connected external capacitor has a known error, you should correct the error setting in this field.

Stray Error Correction (Extended GST Accuracy)

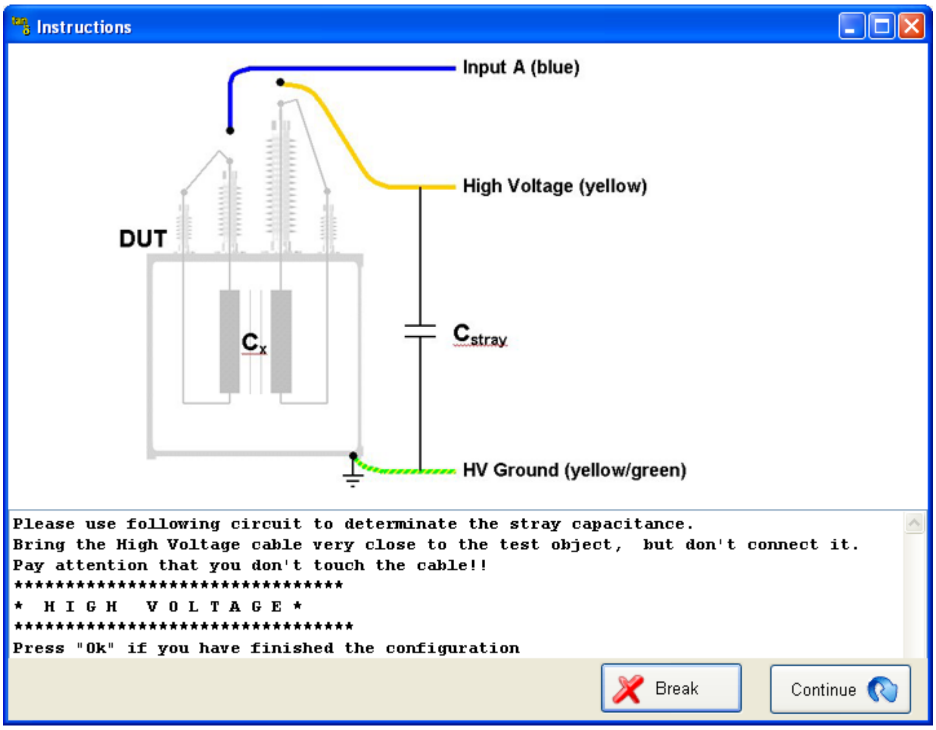
Pay attention to not touch the cable during energizing

The stray capacitance between high voltage cable and earth influences the measurements, because the capacitance is parallel to the capacitance of the test object. To get higher accurate test results the instrument offers the possibility to measure the stray capacitance and then compensate it.

For standard test operation this procedure is not necessary. By activating the capacitance and dissipation factor of the cable stray capacitors will be considered for further measurements.

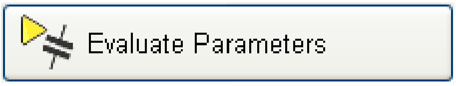
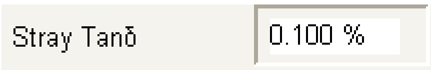
Standard Connections

Over the button the two standard connections (UST & GST) are visualized as an information.
No settings are done in the bridge in this section.



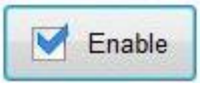
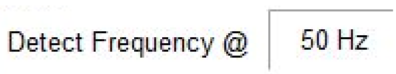
Bring the HV cable very close to the test object where it shall be connected but **don't** connect it.

After the cable will be energized with the set voltage the capacitance and the dissipation factor of the stray capacitance will be measured.

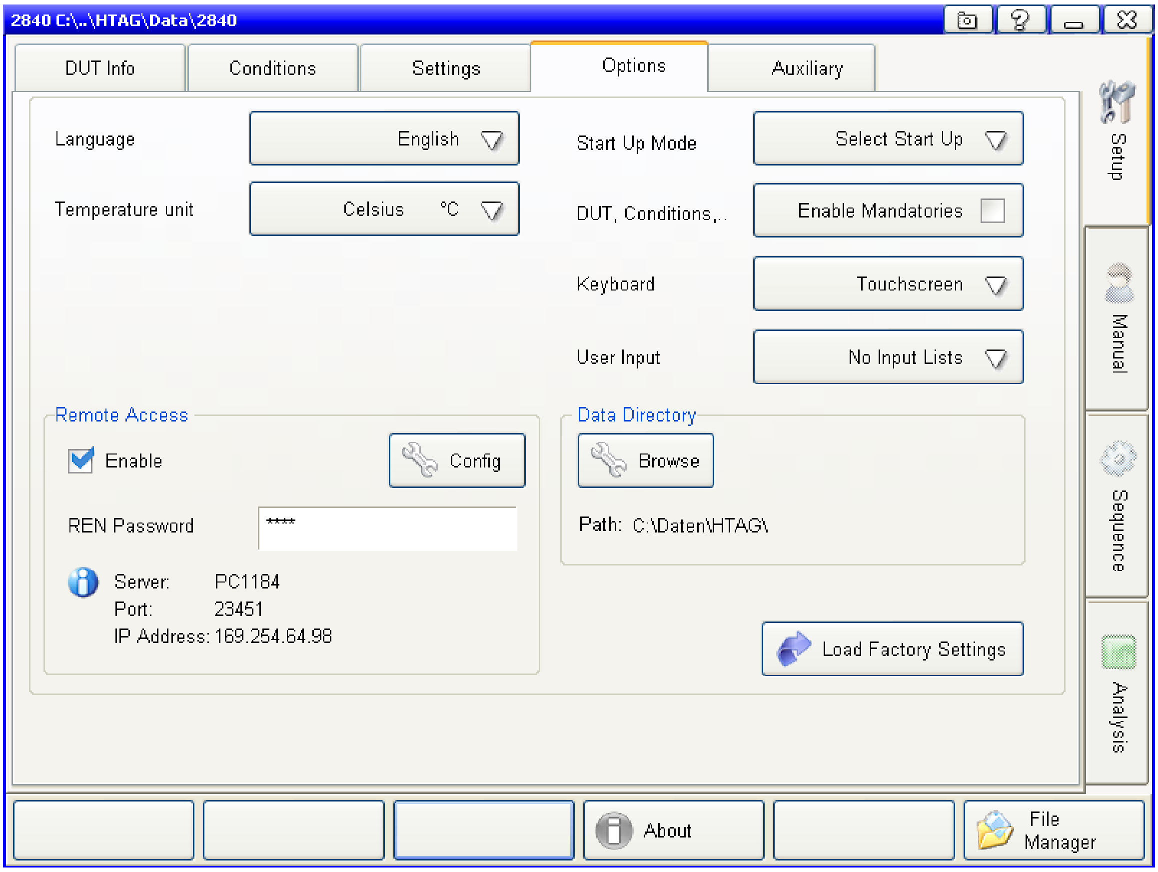
	Test Voltage Stray Capacitance At this voltage the stray capacitance will be measured.
	Evaluate Parameters The evaluation procedure to determinate the parameters of the stray capacitance will be started. You are guided with the connection diagram: See picture above.
Measured Values	
	Stray Capacitance After successful measuring of the stray capacitance this field will be filled by the capacity of the stray capacitance.
	Stray DF (tan δ) The Dissipation Factor of the measured stray capacitance will be displayed in this field.

Test Frequency Detection

Due to harmonics on the voltage signal it not is always possible to detect the test frequency automatically. In such a situation it is possible to set the test frequency manually. If Test Frequency Detection is enabled, the frequency of the strongest signal around +/- 5 % of this frequency will be used for calculation.

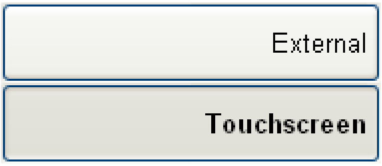
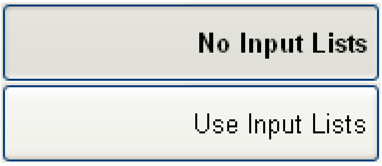
	Enable / Disable Test Frequency Detection
	Range for Frequency Detection Frequency will be detected inRange of +/- 5 % of 50 Hz

8.3.4 Options



In this menu you can set some general options

English	Language Select the operating language. At the moment English and Chinese is supported. Please contact our sales department for further languages.
Select Startup Quick Startup FileManager Load Last File	**Start up Mode** Select Start up: This button allows you to select the start-up of the system. By pressing this button a list appears, where you can select your start-up mode. Quick Start-up: System will start directly in manual mode. File Manager: System will start automatically with File Manager dialogue Load Last File: The file with which you have worked the last time will be automatically loaded. The system will continue at the same place, where you have left it.
Celsius °C Fahrenheit °F	Temperature Unit Here you can select the unit for temperature, if you choose “Celsius °C” the unit meter “m” will be automatically used for lengths. If “Fahrenheit °F” is selected the unit feet “ft” will be used.

	Enable Mandatory If this option is activated certain inputs in Menu Setup has to be filled before measuring. See chapter 8.3.4.1 Mandatory Inputs for details
	**Keyboard** With "Standard" user interfaces all inputs are windowslike. For numerical inputs the engineering unit like kilo, nano a.s.o. can be set by pressing 'G' Giga 'M'. Mega 'k' Kilo 'm' milli 'u' mikro 'n' nano 'p' pico after the number. The Unit like Volt will be automatically added. For "Touchscreen" a menu will popup,
	**User Input** If "Use Input Lists" is selected all inputs where stored in a file. After pressing first few character all window will popup with all stored values. So it is very easily to make you inputs.
	Load Factory Settings After leaving the factory or after a recalibration, the values of standard capacitor or cable length are tested and stored. By clicking this button you will be asked, if you want to use these settings.

8.3.4.1 Mandatory Inputs

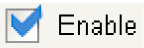
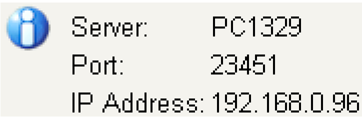
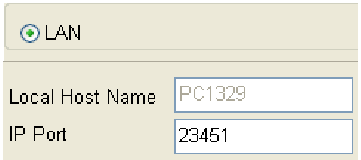
All inputs which are preceded with a red asterisk (*) are mandatory fields. That means at least one character has to be filled in. This "lock-functionality" can be disabled. See section "Settings" for more information.

If there is an mandatory input field which has to be filled in, the tab sheet button at the top is marked with a red asterisk.

When all marked mandatory fields are filled, the red asterisk in the tab sheet button will switch to a green hook.

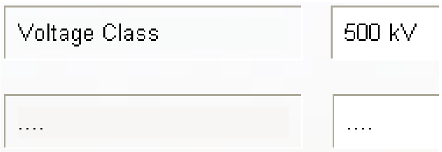
8.3.4.2 Remote Access

If this option is set the system is opened to be controlled from a host computer. Remote access is granted.

	Remote Access
	"REN Password" Here the user has to enter a password to set the system into "Remote controlled" status (together with command REN) from a remote location. This is for safety reasons to ensure that nobody (without the password) can accidentally take over control.
	Setup Remote Interface Here can you set the interface for controlling the unit by remote. It can be controlled by LAN. Be aware, that the set parameters of the interface correspond with the host computer ones.
	This field displays information about the actual **LAN Settings** (interface parameters). PORT: The port number used to remote control the unit. IP ADRESS: Actual IP address of the unit. SERVER: The actual computer name of the unit.
	This field displays information about the actual **LAN Settings** (interface parameters) if this interface is set. Local Host Name, IP Port of the host computer.

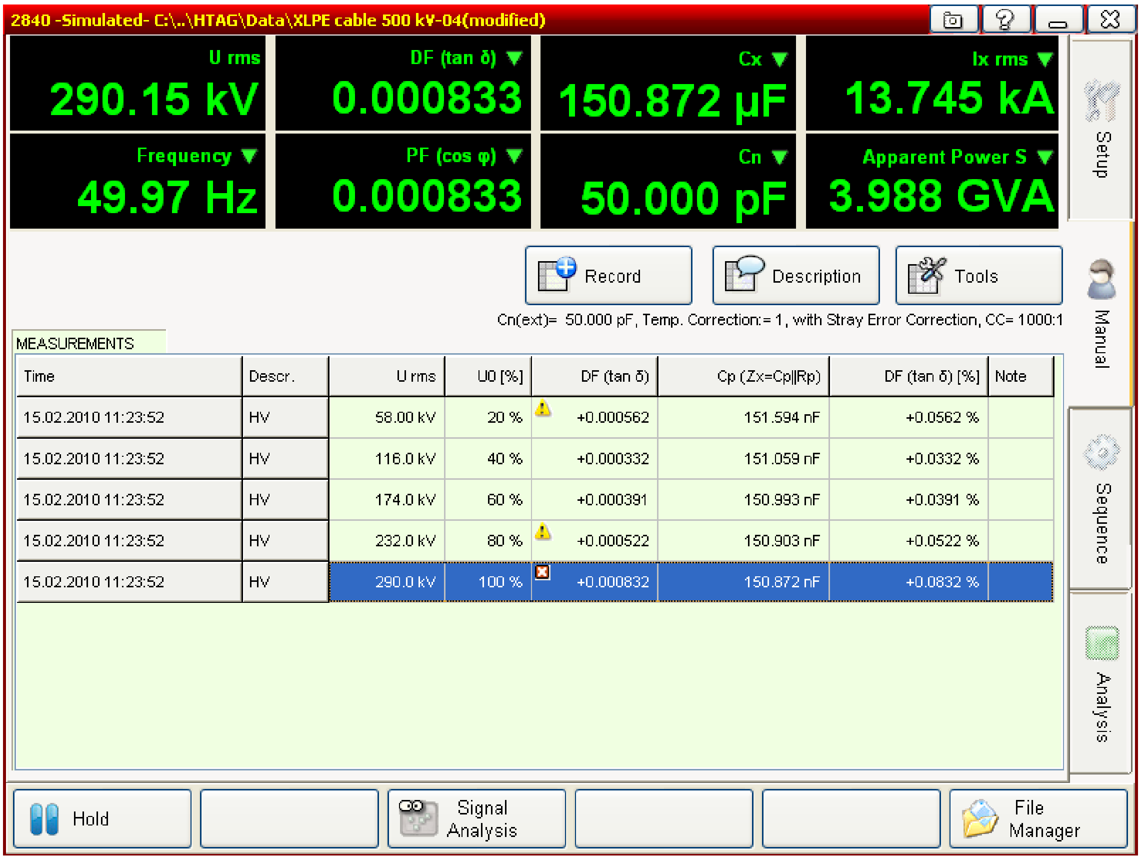
8.3.5 Auxiliary

Here you can enter your own documentation. The title of each field can be changed. All titles and text are shown in the printed document.



8.4 Manual Mode

The manual mode is used to perform single measurements straight away. It displays all necessary values at a glance and allows to capture a measurement by a single mouse click.



At the top of the tab sheet ight measurement elements are displayed. Different font colors are used to identify the actual status and validity:

Color	Meaning
Light green	The measured values are not yet stable. The built-in averaging routine is still calculating a mean value. Normally during fast voltage changes the values are displayed in dark green.
Bright green	The value is now stable and has the correct accuracy. In an automatic sequence mode the value will be recorded now and the next voltage step will be set.
Dark yellow	Signal Overflow error. This case should not be seen during normal operation. Anyway, it may occurs if the automatic ranging is switched off (expert mode).

Except the first element (U rms) all other measurement displays can be customized by clicking the arrow ▼ in the top right corner of the element.

Following measuring values can be selected:

Value	Description
DF (tan δ)	DF (tan δ) Actual measured Dissipation Factor.
DF (tanδ) @ 20°C	DF (tan δ) @ 20°C Dissipation Factor, temperature corrected to 20°C with the selected Temperature Correction Table
DF % (tan δ)	DF% (tan δ) Actual measured Dissipation Factor in percentage format
DF % (tanδ) @ 20°C	DF% (tan δ) @ 20°C Dissipation Factor in percentage format, temperature corrected to 20°C with the selected Temperature Correction Table
PF (cos φ)	PF (cos φ) Actual measured Power Factor.
PF (cosφ) @ 20°C	PF (cos φ) @ 20°C Power Factor, temperature corrected to 20°C with the selected Temperature Correction Table
PF % (cos φ)	PF% (cos φ) Actual measured Power Factor in percentage format
PF % (cosφ) @ 20°C	PF% (cos φ) @ 20°C Power Factor in percentage format, temperature corrected to 20°C with the selected Temperature Correction Table
QF	QF Actual measured Quality Factor [1/ DF (tan δ)]
QF @ 20°C	QF @ 20°C Quality Factor, temperature corrected to 20°C with the selected Temperature Correction Table [1/ DF (tan δ)@20°C]
U rms	U rms Effective voltage applied to the test object
U rms sqrt(3)	U rms sqrt(3) Effective voltage applied to the test object multiplied by √3. E.g. to get Line-Line voltage from the Line-Ground value.
U rect.mean	U rect. mean Rectified mean voltage applied to the test objects. If U rect. Mean value is similar to Urms then the test voltage has a small distortion
U Peak/√2 ▼	U Peak/√2 U Peak/√2 will be calculated according the measurement of the harmonics. This value will most used synchronize the sequence steps with an external power source. The weighting of each harmonics can be set. See 8.5.6
In rms	In rms Effective Current through CN

Ix rms	Ix rms Effective Current through CX
Frequency	Frequency Measured frequency of applied voltage
Zx	ZX Complex Impedance of the test object. Shown in absolute value and phase-angle φ
Yx	YX Complex Admittance of the test object. Shown in absolute value and phase-angle φ
φ(Zx)	φ (Zx) Phase-angle of the complex Impedance of the test object
I mag (Lp)	I mag (Lp) Effective magnetization current
I fe (Rp)	I fe (Rp) Effective iron loss current
Cx Cp (Zx=Cp||Rp)	Cx or Cp (ZX= CP || RP) Capacitive part of the test impedance (capacitance) ZX in parallel equivalent circuit
Rp (Zx=Cp||Rp)	Rp (ZX= CP || RP) Resistive part of the test impedance (capacitance) ZX in parallel equivalent circuit
Cs (Zx=Cs+Rs)	Cs (ZX= CS+ RS) Capacitive part of the test impedance (capacitance) ZX in serial equivalent circuit
Rs (Zx=Cs+Rs)	Rs (ZX= CS+ RS) Resistive part of the test impedance (capacitance) ZX in serial equivalent circuit
Ls (Zx=Ls+Rs)	Ls (ZX= LS+ RS) Capacitive part of the test impedance (inductance) ZX in serial equivalent circuit
Rs (Zx=Ls+Rs)	Rs (ZX= LS+ RS) Resistive part of the test impedance (inductance) ZX in serial equivalent circuit
Lp (Zx=Lp||Rp)	Lp (ZX= LP || RP) Capacitive part of the test impedance (inductance) ZX in parallel equivalent circuit
Rp (Zx=Lp||Rp)	Rp (ZX= LP || RP) Resistive part of the test impedance (inductance) ZX in parallel equivalent circuit
Cn	Cn Actual Standard Capacitor Cn (internal or external)
Apparent Power S	S Apparent Power energized complex impedance ZX

Real Power P	P Real Power energized complex impedance ZX
Reactive Power Q	Q Reactive Power energized complex impedance ZX
Real Power @ 2.5kV	Real Power @ 2.5kV Real Power (losses, watts) on the test object, normalized to a test voltage of 2.5kV. Real Power @ 2.5kV = PAct.voltage ∗ 2.5kV2 / (Act. voltage) 2
Real Power @ 10kV	Real Power @ 10kV Real Power (losses, watts) on the test object, normalized to a test voltage of 10kV. Real Power @ 10kV = PAct.voltage ∗ 10kV2 / (Act. voltage) 2
Ambient Temperature	Ambient Temperature Ambient Temperature. This value is manually set in Menu “Setup: Conditions”
Insulation Temperature	Insulation Temperature Insulation Temperature This value is set in Menu “Setup: Conditions”
Relative Humidity	Relative Humidity Relative Humidity. The value is manually set in Menu “Setup: Conditions”.
Temperature Correction	Temperature Correction Temperature correction factor. Multiplier for the temperature correction calculation. This value depends on the actual insulation temperature and the selected type of insulation
Scope	Scope Waveform display. The voltage value applied at the shunts in function of the time. This selection is only available at the fourth rightmost field.

The middle section of the tab sheet MANUAL contains

Element	Description
Record	Record The actual selection of measured data will be stored in the spreadsheet. The “description” field will be copied from the previous line.
Description	Description Click this button to modify the description field of the selected row. It is also possible to select more than one row and change them simultaneously.
Tools	Tools Clicking this button will open a list with elements described below. This list will also pop up if you click the right mouse button somewhere in the tab sheet.

Define Columns

Choose, which measured value should be recorded and at which position displayed.

Edit Note

Comment the field of the selected row. It is also possible to select more than one row and change them simultaneously.

New Measurement Serie

Creates a new measurement section (empty line). All Measurements in a section are interpreted as one measurement series. In Menu Analysis each series can be selected and is displayed in the same colour.

Delete Row(s)

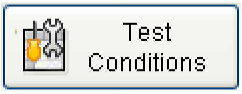
Deletes the selected rows in the list

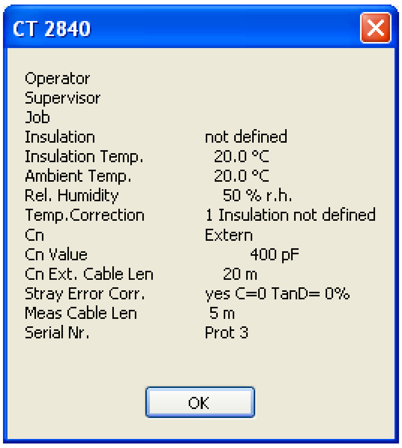
Delete All Rows

Delete all rows in the list

Signal Analysis

Pressing this button will open a window, where you get more information about the measured signal.

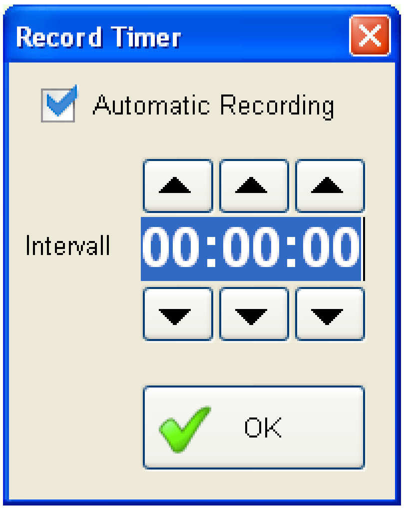




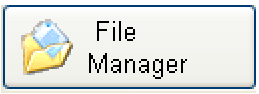
Test Conditions

When this button is clicked the actual test conditions of the measuring system is displayed.

Each recorded test series have their own test conditions, so it is possible to trace back test condition over years, even with different measuring devices and operators

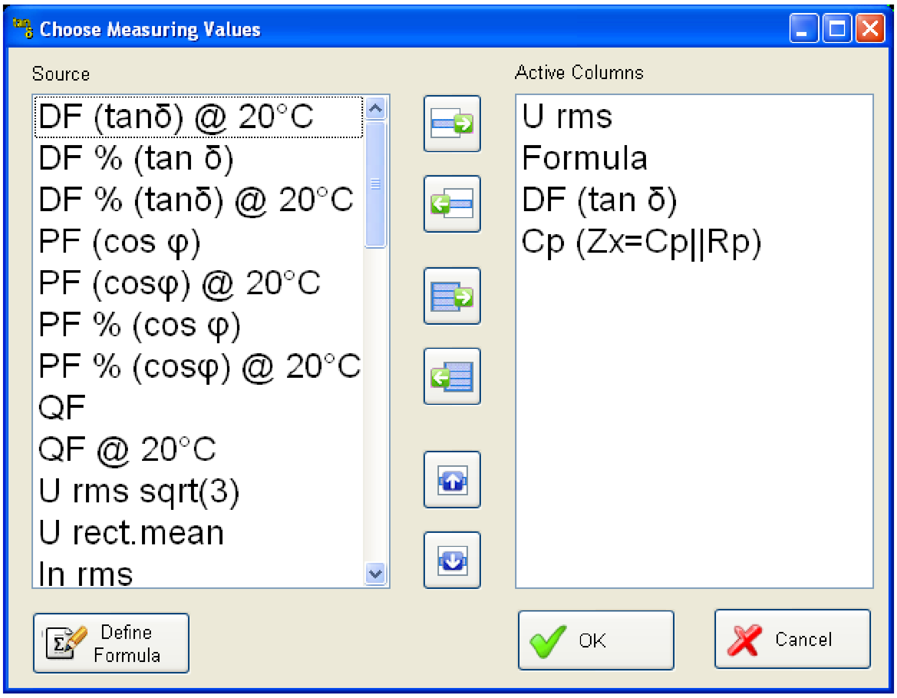
 	Record Timer Here it is possible to create a measurement series, where the data are logged in a settable interval. A dialog will popup to set the interval of logging. (min. 1 second) This activation of this options will be signalised by a running bar below the Button Record. The logging is only active while a signal is applied. To stop automatic recording press 

At the bottom of the tab sheet MANUAL a key bar is located with following buttons:

	Run By pressing this button the unit will start measuring.
	Hold When this button is pressed the measuring process will be stopped and the last captured measuring values will be displayed.
	Signal Analysis This button has the same functionality as the button found when clicking Tools -> Signal Analysis.
	File Manager With this button the file manger dialog is started (copy, save and load measuring files). See section “File Manager” for more information.

8.4.1 Definition of Columns for Measuring Spreadsheet

By pressing the button “Define Column” a dialog appears as following:



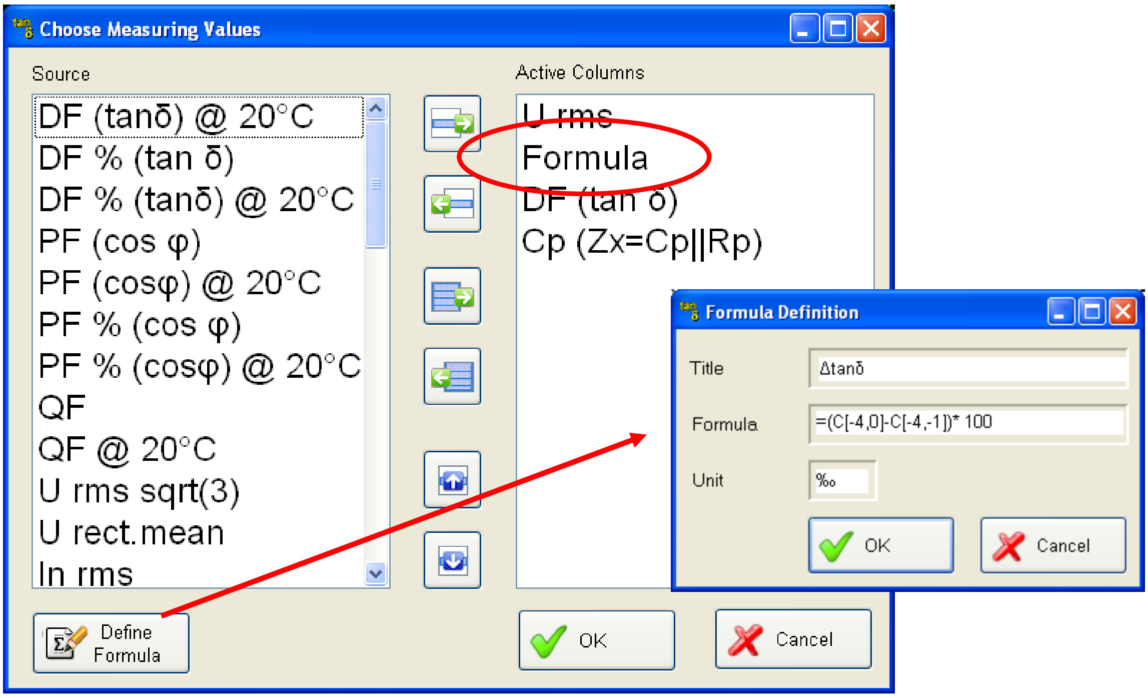
This dialog is used to define the recorded measured data. With  and  selected measuring values can be added or removed from the active spreadsheet. With  and  all data can be moved or removed.

With  and  you can move the position of a specific active column.

Note: The columns in the measuring spreadsheet itself can also be moved in position with simple drag and drop.

8.4.2 Formulas in Measuring Spreadsheet

Use **Tools:Define Columns** to choose the measuring values. By moving up or down the position of the column *Formula* can be changed



Use **Define Formula** to define the title, formula and the unit of the column *Formula*

Δtanδ =(C[-4,0]+C[-4,1])* 100‰

Title	column title
Formula	Enter the formula of the cell of column *Formula*, when a measurement is recorded. Where C[0,0] is the actual cell. C[-4,-1] means 4 columns left side of column *Δtanδ*. This is cell *DF(tanδ)* and one row above the actual row. All relations are relative to the actual row. If C$[Column, Row] is used, the relations are absolute in the grid. The cell of the first column and the first row will be addressed by C$[0,0]

Here the result:

Start Time	Descr.	U rms	Cp(Zx=Cp||Rp)	DF(tanδ)@20°C	Ieff Test	Ieff Ref	Frequency	Δtanδ	Note
24.09.2009 16:53:16	Manual	7.680 kV	100.122 pF	0.000004	250.200 µA	999.58 µA	51.79 Hz	0 ‰	
24.09.2009 16:53:16	Manual	9.409 kV	100.122 pF	0.000179	330.122 µA	1.31888 mA	55.77 Hz	0.0175 ‰	
24.09.2009 16:53:16	Manual	10.011 kV	100.122 pF	0.000353	351.216 µA	1.40315 mA	55.77 Hz	0.0174 ‰	

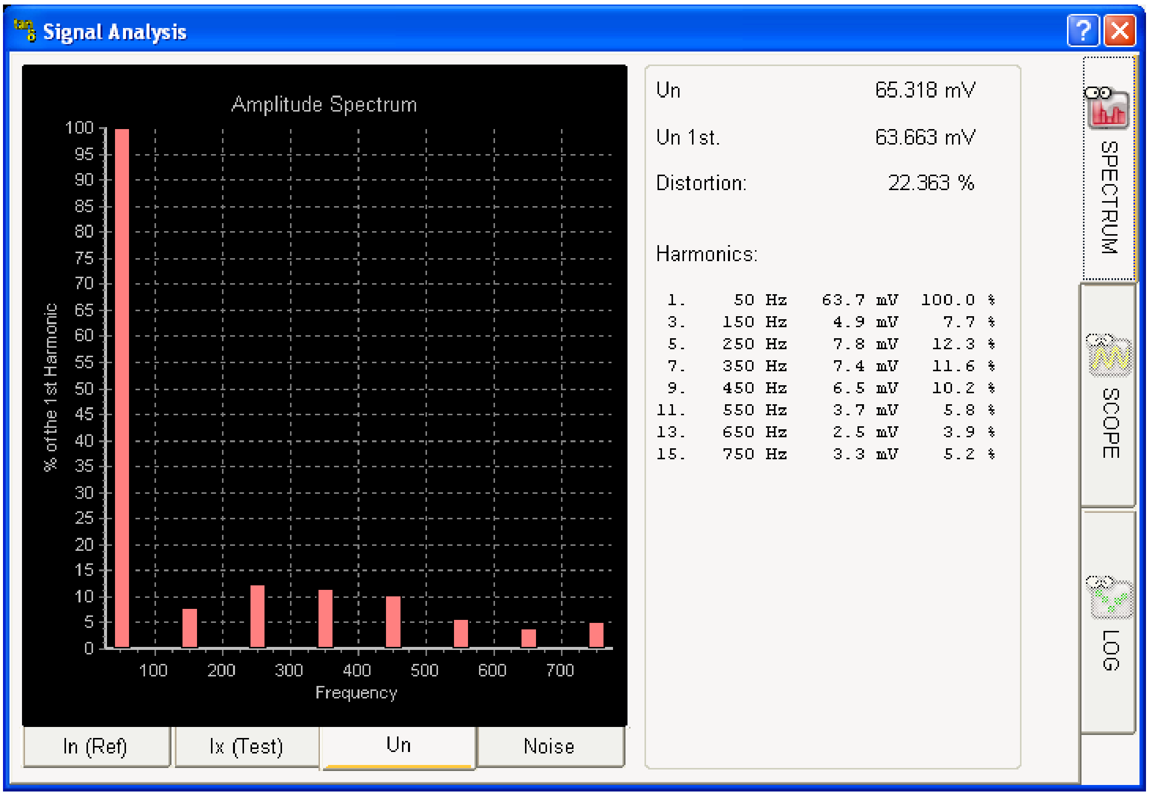
8.4.3 Signal Analysis

If you need more information about the signal wave shape and the spectrum of the measured signal you can use this menu. It is only for information purpose and has no importance for analysing the test object.

8.4.3.1 Spectrum

This tab sheet will show you the spectrum of the measured signals. The amplitudes are related to the amplitude of the first harmonic in Percent %.

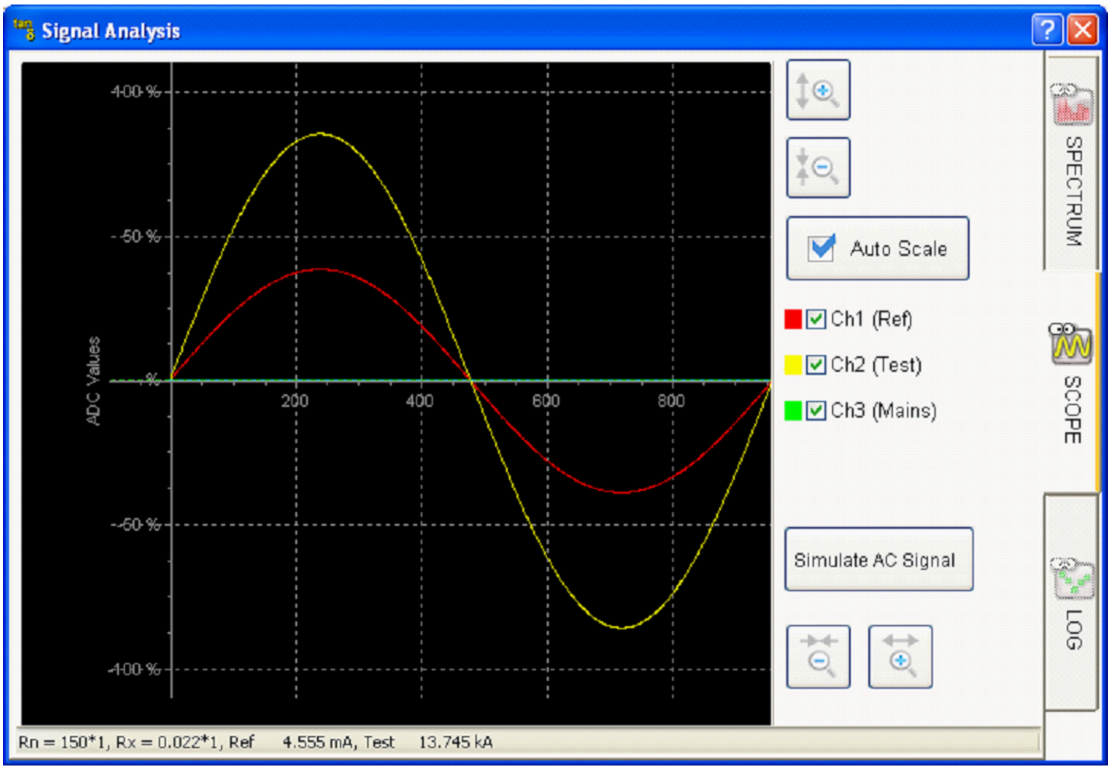
The first 15 harmonics are shown.



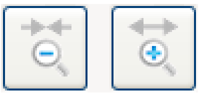
In (Ref)	In If this Tab Sheet is selected you can see the spectrum of the current through the nominal standard capacitor
Ix (Test)	Ix If this Tab Sheet is selected you can see the spectrum of the current through the test object
Un	Un The Spectrum of the integrated In(Ref) signal will be shown. This corresponds to the applied test voltage.
Noise	Noise The recorded data of measured noises are shown here. This is normally the line signal.

8.4.3.2 Scope

With this tab sheet you will get an impression of the real data, which is recorded by the Analogue Digital Converter (ADC). The amplitude of the signal corresponds with the degree of modulation of the ADC, where 2^{23} (6388608) is the maximum of modulation. The X – Axis shows the number of recorded samples. The Sampling rate is 48 kHz, it corresponds with the time, where the unit 1 is 20.83 µs

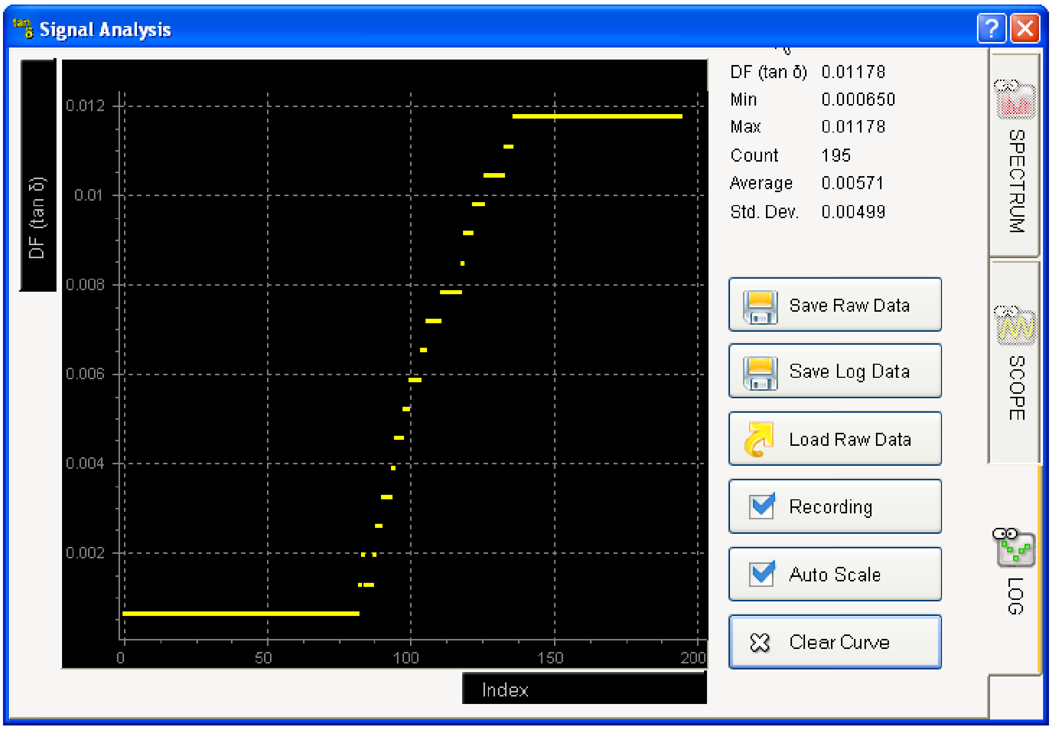


Button description:

	Up / Down Amplitude With Up, the signal amplitude is shown larger. The Auto Scale button will be automatically disabled. With Down, the signal amplitude is shown smaller, this increases the scale.
Auto Scale	Auto Scale Setting this option will show the signal well scaled.
Ch1 (Ref)	The voltage over the nominal standard capacitor will be shown
Ch2 (Test)	The voltage over the test object will be shown
Ch3 (Mains)	The mains input voltage will be shown
	Inc / Dec Time Base By pressing "ms" Button, the time scale will increased. As a result, there are more recorded data visible. By Pressing "µs" Button, the time scale will be decreased. As a result, there are less data will be shown.

8.4.3.3 Log

This menu records all measured data in function of the time. It displays some statistical data as average and standard deviation. Be aware that the recorded data looks very instable. This is caused by the automatic scaling of the scope, where the lowest and the highest value will be used for minimum and maximum y-axis. At maximum 1000 values are recorded.



Buttons description:

DF (tan δ)	X / Y Axis The measuring values for the x- or y-axis can be chosen.
Clear Curve	**Clear Curve** Clear recorded values.
Auto Scale	Auto Scale Enable/disable automatic scaling of the scope. If it is unchecked higher and lower values than the maximum range of the scope are not shown anymore
Recording	Recording If this option is deactivated, the recording of the measuring values will be stopped.
Save Raw Data	Save Raw Data Store recorded raw data of the ADC. Filename can be selected. The data are stored as CSV format (Comma Separated Values). Should only be used for debugging purpose.
Load Raw Data	Load Raw Data Load a stored data. This is only available with the Office Version of the software and it is only for debugging purpose.
Save Log Data	Save Log Data Pressing this button will save the logged measurement values as displayed in the scope at the left side.

8.5 Sequence Mode

Via this sheet a complete test cycle can be created. The whole process is designed in such a way that modifications can be done quick and straight forward.

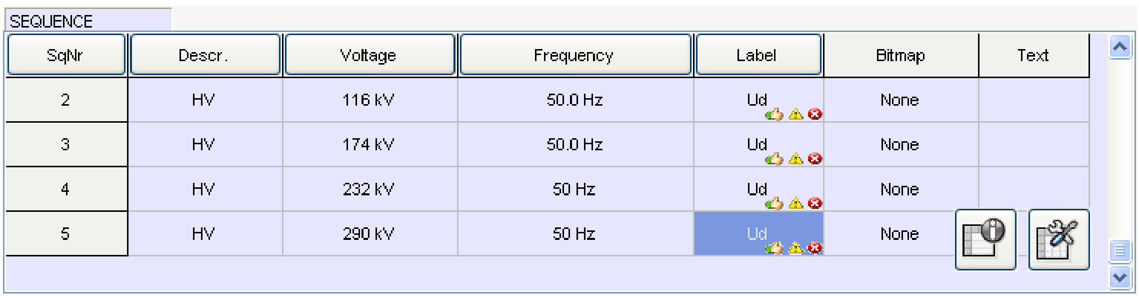
The tab sheet “SEQUENCE” consists of two sections. At the top half of the window a test sequence can be defined by the voltage applied, the test mode (UST or GST) and a picture with some comments. The bitmap and the text will be displayed before the test sequence will start.

At the bottom half of the window the measurement results are displayed.

For each measurement sequence, two pass and attention limiters can be applied, which define the acceptable and cautious range of a measured value.

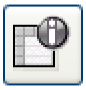
8.5.1 Definition of Spreadsheet Sequence

Description of Sequence Columns



Column	Description
SqNr	SqNr Identification number of the sequence.
Descr.	Description Description of measurement. For example the object where the High Voltage Source is connected.
Voltage	Voltage Voltage applied to the test object.
Frequency	Frequency Frequency of the AC voltage applied to the test object.
Label	Label In this field the measurement can be labeled. If the cell is signed with , the measurement sequence includes limiter definitions, which characterize the measurement as “Passed“, “Attention” or “Failed”.
Bitmap Text	Bitmap If these cells are filled with the filename of the bitmap or “None” is selected, a dialog with the corresponding bitmap and the comment of column “text” will appear before the measurement is performed. If “None” is selected as a bitmap, no image will be shown.

Button Sequence Info

	Sequence Info Pressing this button will open a dialog with the information contained in the column “Bitmap” and the column “Text”.

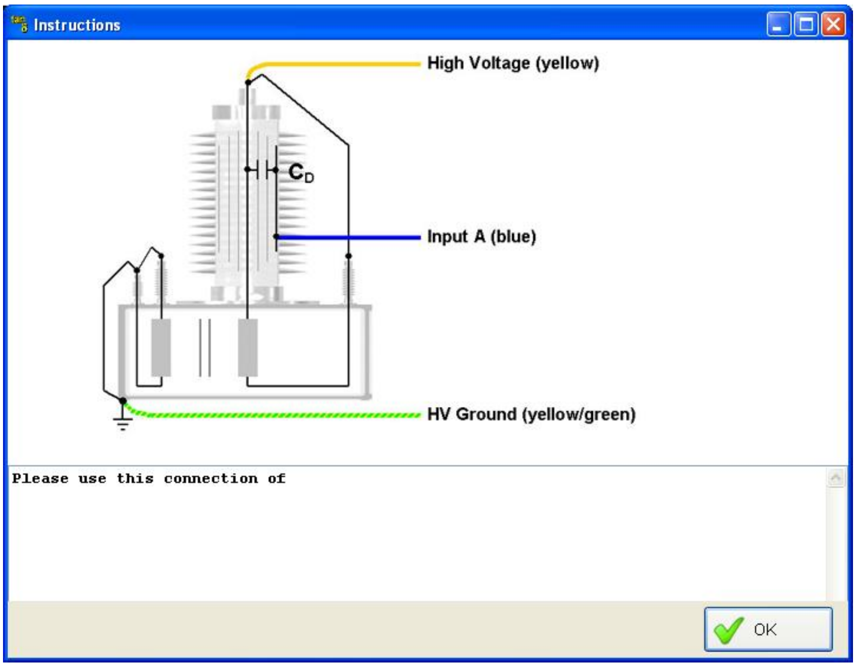
Button Sequence Tool

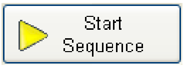
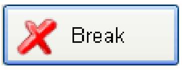
	Sequence Tool By pressing this icon a pop-up list appears with the following buttons.
Edit	Edit This button will open a numerical or alphanumerical input for editing the content of the cell. If more than one row of a column is selected, the changes will be applied to all of these rows. If this button is pressed on the selected column “Bitmap”, a file selection dialog will appear, where the desired picture can be chosen.
Edit Limit	Edit Limit(s) With this button the parameters of the limiters for the selected test mode can be selected.
Delete Limit(s)	Delete Limit(s) If this button is clicked the limits will be deleted. The sign will disappear.
Insert Row	Button Insert Row By pressing this button a new row with the same content as the row above will be inserted.

	Button Blank Row By pressing this button a blank row for better organization of the sequence will be added.
	Button Delete Row(s) By pressing this button the selected row(s) will be deleted.
	Settings Settings of 8.5.6

Sequence Dialog

With a valid bitmap and text, a dialog appears before the voltage is applied. An example is shown below.



This dialog pops up after pressing.  The sequence may be continued by pressing , or interrupted by  and the high voltage will be switched off.

8.5.2 *Sequence Measurement*

In the second half of the tab sheet SEQUENCE the measured values of a sequence are stored. All technical feasible data are recorded during a sequence. With the buttons in the top row of the window, the amount of displayed measuring data can reduced or enlarged.

MEASUREMENTS

Time	Descr.	U rms	U0 [%]	DF (tan δ)	Cp (Zx=Cp||Rp)	DF (tan δ) [%]	Note
15.02.2010 11:23:52	HV	116.0 kV	40 %	+0.000332	151.059 nF	+0.0332 %	
15.02.2010 11:23:52	HV	174.0 kV	60 %	+0.000391	150.993 nF	+0.0391 %	
15.02.2010 11:23:52	HV	232.0 kV	80 %	+0.000522	150.903 nF	+0.0522 %	
15.02.2010 11:23:52	HV	290.0 kV	100 %	+0.000832	150.872 nF	+0.0832 %	

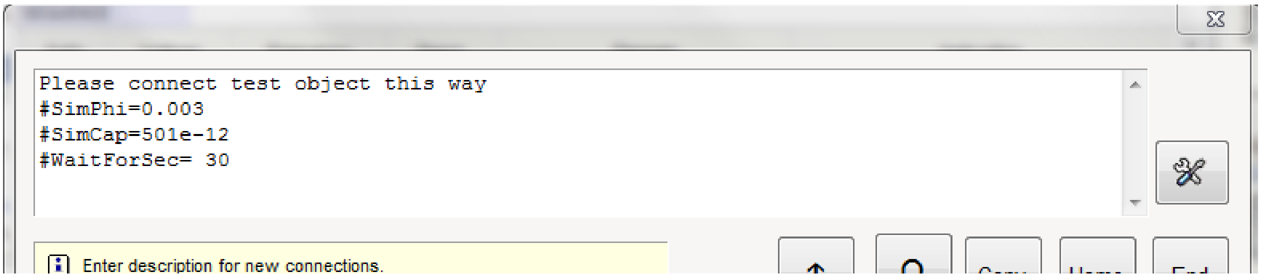
	Tool Sequence Measurement By pressing this button a menu with the following buttons will appear
Define Column	Define Columns This button can be used to define which data will be displayed.
Edit Note	Edit Note Pressing this button will open an alphanumerical dialog, where you can enter a comment for this measurement.
Show Note	Show Note Pressing this button will show the action of a limiter: whether the value exceeds the limiters or not.
New Series	New Measurement Serie Creates a new measurement section (empty line). All Measurements in a section are interpreted as one measurement serie. In Menu Analysis each serie can be selected and is displayed in the same color
Delete Row(s)	Delete Row(s) By pressing this button the actual selected data will be deleted.
Delete All Rows	Delete All Rows By pressing this button all rows will be deleted.
Signal Analysis	Signal Analysis This button has the same functionality as the button found when clicking Tools -> Signal Analysis.
Test Conditions	Test Condtions When this button is clicked the actual test conditions of the measuring system is displayed. Each recorded test series have their own test conditions, so it is possible to trace back test condition over years, even with different measuring devices and operators
Use as Limit	Use as Limit(s) Pressing this button will select the measurement signal you want to use for limits, for example DF (tan δ). To perform this operation the sequence number (SqNr) and the connection in table MEASUREMENTS must be equal to the values in table SEQUENCE.
+0.000522	Cell marked as attention A red cross in the right bottom corner of the field indicates that the measured value fails the assigned limit.
+0.000832	Cell marked as failed A yellow exclamation mark in the right bottom corner of the field indicates that the measured value exceed the assigned limit.

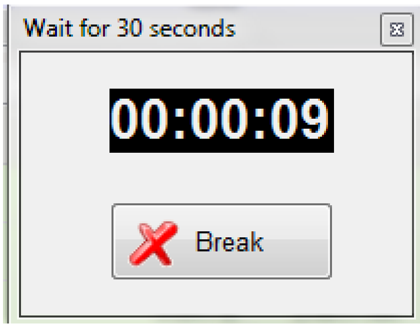
8.5.3 *Additional Sequence Control Commands*

Inside the cell called “Note” it is possible to add some sequence commands like “gotos”, “wait” a.s.o.

Use 

to enter desired commands.

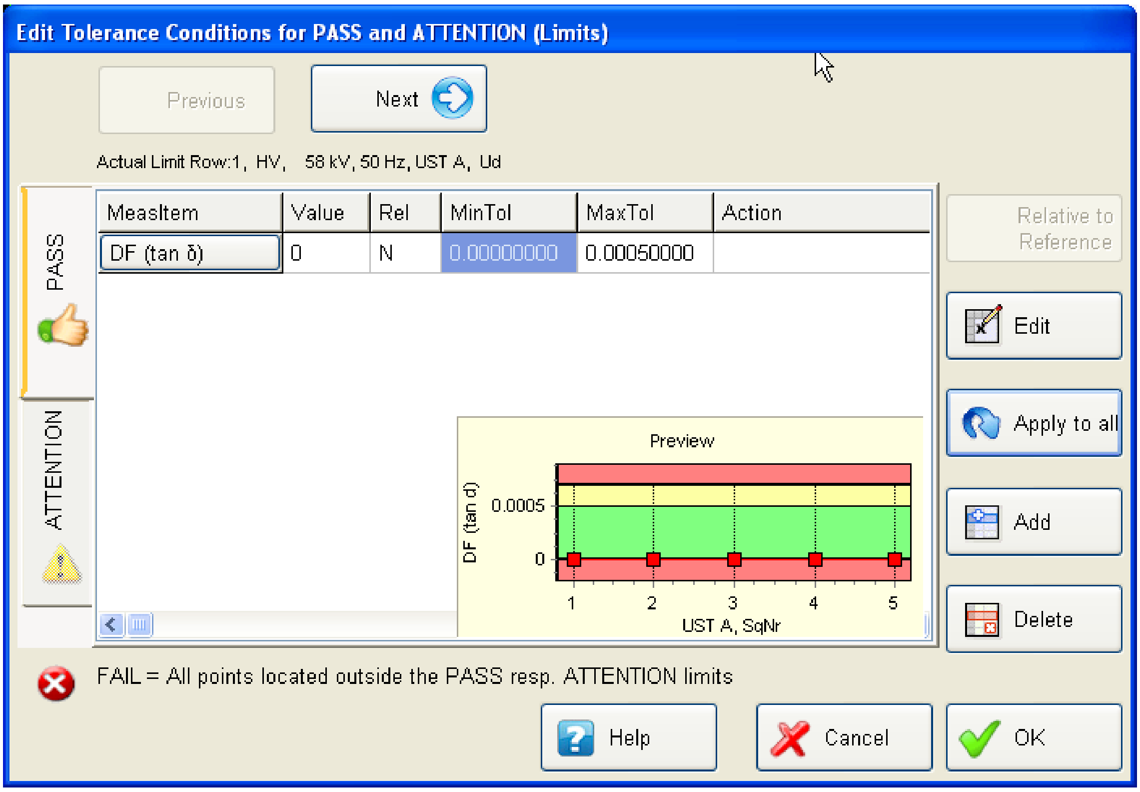


#JumpTo=<INTEGER>	Jump to Line
#SelectMenu=<INTEGER>	mnSetup = 0;
	mnManual = 1;
	mnSequence = 2;
	mnAnalysis = 3;
#SimCap=<FLOAT>	Simulation Capacitance[F]
#SimPhi=<FLOAT>	Simulation Phase[°]
#NewMeasSerie	New Measuring Serie
#WaitForSec=<INTEGER>	Wait <INTEGER> seconds for executing next commands. During this command following dialog will appear. With “Break” the sequence can be interrupted. 

8.5.4 *Edit Sequence Limiters*

By pressing, 

the following dialog appears in which the limiters can be modified.



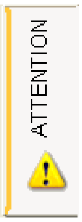
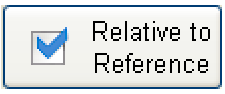
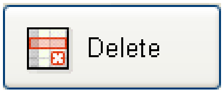
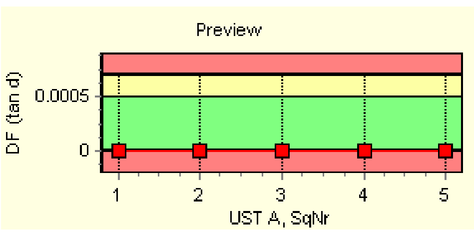
The user should keep in mind that you start with a red area, on top you put the yellow area (attention area) and on top of the yellow area, you put the green area (pass area). Example above:

Attention Limits; Min Tol is: 0.00 – Max Tol is: 0.00075 (Yellow Band)

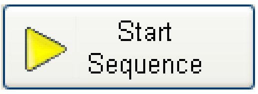
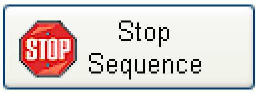
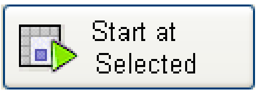
Pass Limits; Min Tol is: 0.00 – Max Tol is: 0.0005 (Green band)

The descriptions of the fields and buttons areas follows:

MeasItem DF (tan δ)	Measuring Item This is the limiter name. You can select any one of measured data.
Value 0	Value This data is the reference value of the limits
Rel N	Rel If the option [Relative to Reference] is activated “MinTol” and “MaxTol” are relative to the reference value [Value 0], otherwise the inputs are absolute.
MinTol 0.00000000	MinTol This field indicates the minimum tolerance level of the “Pass” or “Attention” range. Depending on the “Rel” field the value is relative or absolute.
MaxTol 0.00070000	MaxTol This field indicates the maximum tolerance level of the “Pass” or “Attention” range. Depending on the “Rel” field the value is relative or absolute.

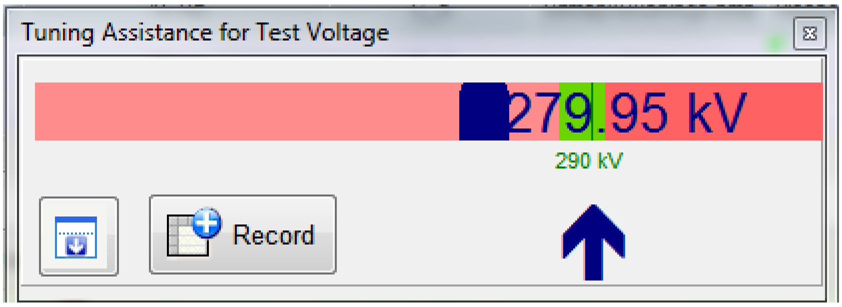
	Action This field describes the required action when the measured value exceeds the minimal or maximal tolerance
	Previous By pressing this button the previous limiter can be read. If there is a previous cell at the SEQUENCE spreadsheet, which is marked with a limiter sign, the limits of this cell is selected.
	Next By pressing this button the next limiter can be read. If there is a next cell at the SEQUENCE spreadsheet, which is marked with a limiter sign, the limits of this cell is selected
	Pass Criteria If this tab is clicked the limiters for pass the tolerance can be edited. You have to fill in the border of the green area.
	Attention Criteria If this tab is clicked the limiters for the attention tolerance can be edited. This is the border of the yellow area. All points located outside the attention limits are failed (red).
	Relative to Reference The minimum and maximum tolerance are relative if this box is checked, otherwise absolute.
	Edit By pressing this button the selected cells such as value, MinTol, MaxTol can be edited.
	Apply to all If this button is clicked, the current measured value with its limiters will be applied to all limiters.
	Add Pressing this button will add a line to the spreadsheet.
	Delete Pressing this button will delete one row in the spreadsheet.
	Graphic Preview All limits of the sequence spreadsheet with the same connection are shown in this graph

8.5.5 Starting Sequence

	Start Sequence Press this button to start the sequence from the first row of the sequence spreadsheet. If the column "Text" or "Bitmap" is filled with valid data, an info dialog will be shown. If all safety conditions ("Emergency Button" released, "Safety Switch pressed" etc.) are fulfilled, the high voltage with its specified voltage and frequency will be switched on. For the specified test mode all measurements are collected. After each changing of connection the system is switched off for calibrating the noise. See section “Extended GST Accuracy” for more information. The sequence will be executed starting from first connection in first row, then downwards one row until the last connection in the last row. After all is done, a message box will pop-up. This button is disabled if the condition for switching high voltage on are not fulfilled, such as "Emergency Button" released or "Safety Switch pressed".
	Stop Sequence The sequence can be interrupted and stopped anytime by pressing this button. With the button "Start at Selected" the sequence can be continued. With the button "Start Sequence" the sequence can be restarted.
	Start at Selected Pressing this button will start the sequence at the selected row of the spreadsheet SEQUENCE.

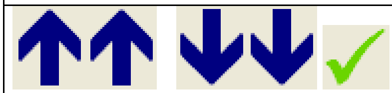
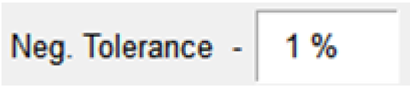
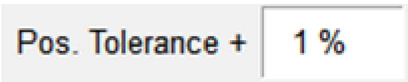
8.5.6 Sequence with external AC power source

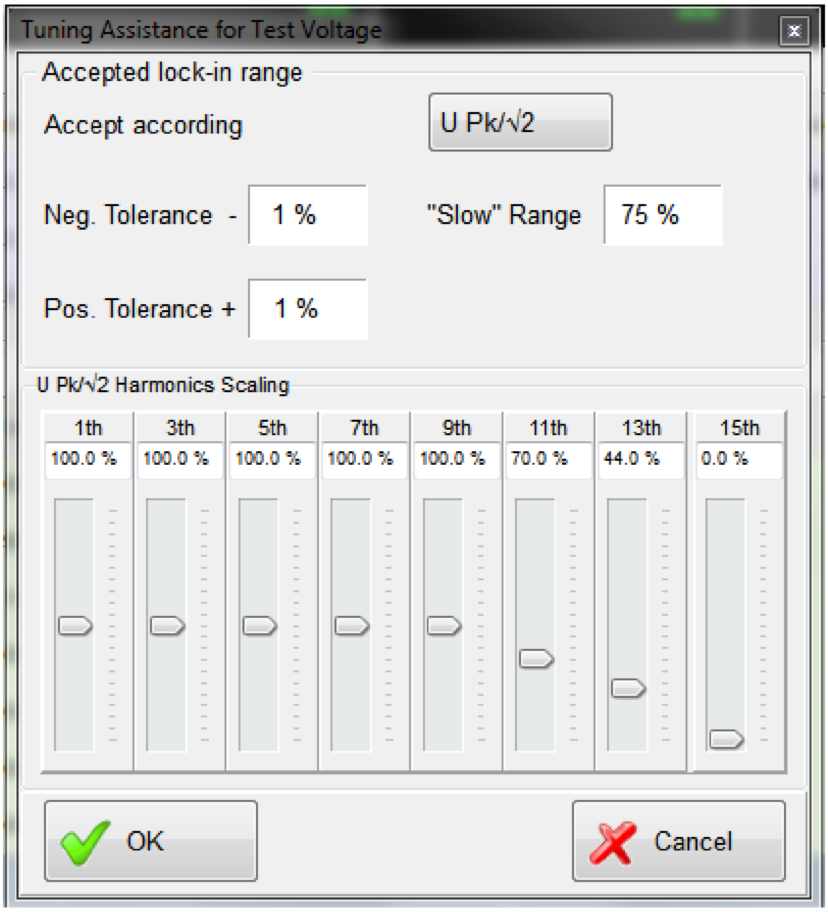
Because it is difficult to control the external power source accurate, the “catch value” dialog supports the user to set up the correct voltage. It is especially helpful when a sequence with different voltage levels must be performed. Before a new voltage level has to be established following pop up window will appear:



The descriptions of the elements in the “Catch Value” window are:

	Bar Finding Voltage If the blue needle is inside the pink colour area, the applied voltage is too low. You have to increase the voltage. If the needle is inside the red colour area, the applied voltage is too high. You have to decrease the voltage. If the needle is inside the green colour area, the voltage is close enough to the expected value (e.g. 2.00kV). The window will be automatically closed after reaching the required accuracy and the values will be recorded. After that the sequence will execute the next cell in the spreadsheet SEQUENCE. The actual measured voltage will be shown at the left or right hand side of the needle.

	Record Pressing this button will close the window and the actual measuring values will be recorded. The next cell of the spreadsheet SEQUENCE will be executed. Therefore you can continue the sequence without reaching the actual voltage step.
	Label Action This message is used to show you how you should control the voltage of the external AC Power Source.
	Additional Settings Pressing this button will scale up/down the dialog. Additional fields for defining the green area are getting visible/invisible.
	Negative Tolerance In this field the lower value of the green area can be defined in percent [%] of the applied voltage.
	Positive Tolerance In this field the higher value of the green area can be defined in percent [%] of the applied voltage.
	"Slow" Range This field is used to set the level of voltage when the message "Slow Up"  and "Slow Down"  appears. It is relative to "set voltage".



Accept according

These values

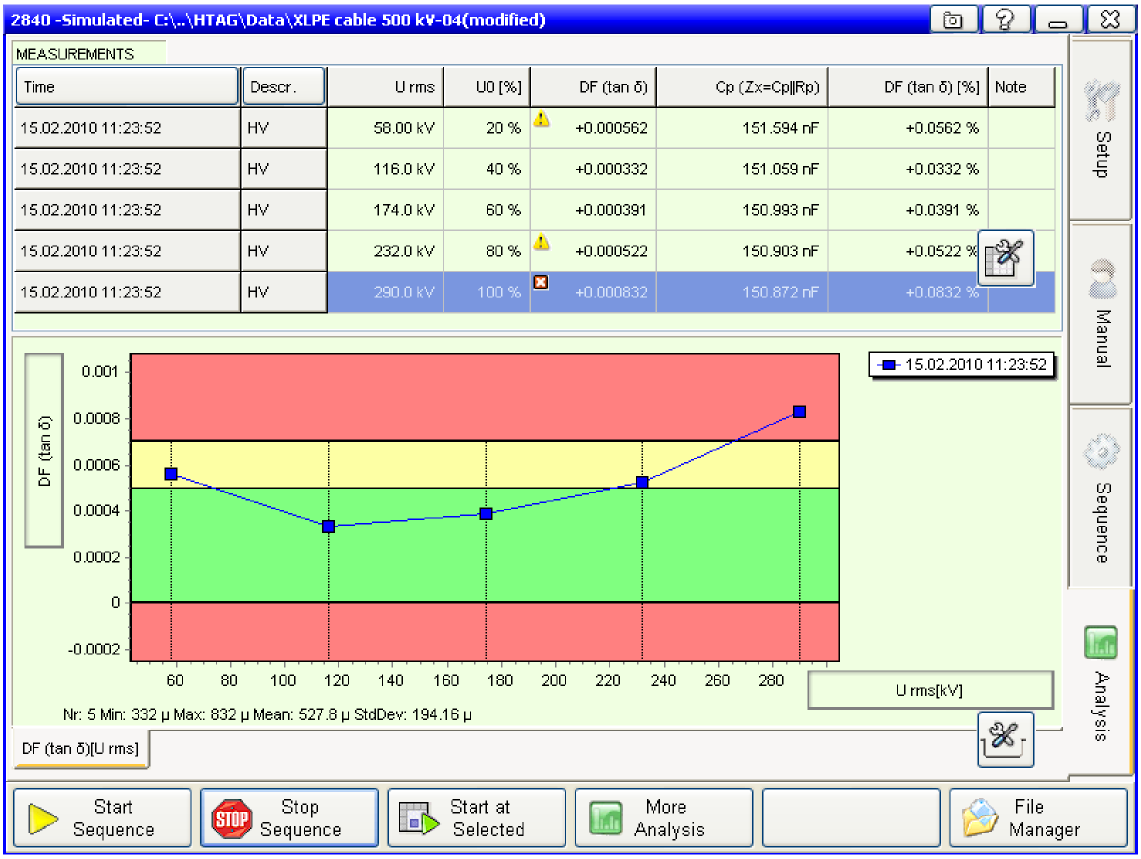
U rms

U Pk/√2

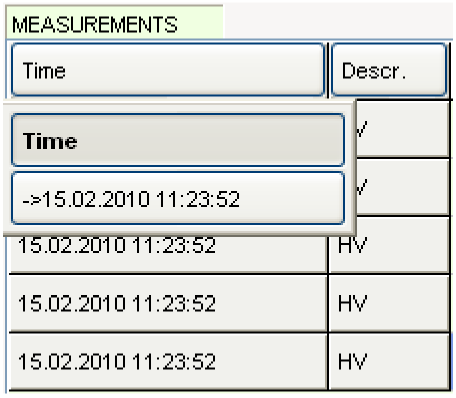
For U Peak/√2 each harmonics can be weighted to reach the measurement of the power source. So it is possible to synchronize the sequence steps without additional equipement according the set voltage. Leave 2840/2820a enough time to reach accurate values for each powersource voltage step.

8.6 Analysis Mode

In this sheet you can compare the new measured data with older ones for trending visualisation or display a measured value against another, for example dissipation factor against voltage.


2840 -Simulated- C:\..\HTAG\Data\XLPE cable 500 kV-04(modified)
MEASUREMENTS
Time
Descr.
U rms
U0 [%]
DF (tan δ)
Cp (Zx=Cp||Rp)
DF (tan δ) [%]
Note
15.02.2010 11:23:52
HV
58.00 kV
20 %
+0.000562
151.594 nF
+0.0562 %
116.0 kV
40 %
+0.000332
151.059 nF
+0.0332 %
174.0 kV
60 %
+0.000391
150.993 nF
+0.0391 %
232.0 kV
80 %
+0.000522
150.903 nF
+0.0522 %
290.0 kV
100 %
+0.000832
150.872 nF
+0.0832 %
DF (tan δ)
U rms[kV]
Nr: 5 Min: 332 µ Max: 832 µ Mean: 527.8 µ StdDev: 194.16 µ
DF (tan δ)[U rms]
Setup
Manual
Sequence
Analysis
Start Sequence
Stop Sequence
Start at Selected
More Analysis
File Manager

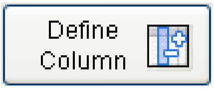
8.6.1 Spreadsheet Measurement

<table>
<tr><td></td><td>Analysis Columns

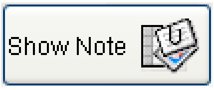
With the buttons at the top of the spreadsheet, you can change the amount of displayed measuring data. The graphical output is automatically adjusted.

By pressing the column header (“Time”), all data will be shown.</td></tr>
</table>

<table>
<tr><td></td><td>Tool Sequence Measurement

By pressing this button a menu with the following buttons will appear</td></tr>
<tr><td></td><td>Define Columns

This button can be used to define which data will be displayed.</td></tr>
<tr><td></td><td>Edit Note

Pressing this button will open an alphanumerical dialog, where you can enter a comment for this measurement.</td></tr>
<tr><td></td><td>Show Note

Pressing this button will show the action of a limiter: whether the value exceeds the limiters or not.</td></tr>
<tr><td></td><td>New Measurement Serie

Creates a new measurement section (empty line). All Measurements in a section are interpreted as one measurement series. In Menu Analysis each series can be selected and is displayed in the same colour</td></tr>
<tr><td></td><td>Delete Row(s)

By pressing this button the actual selected data will be deleted.</td></tr>
<tr><td></td><td>Delete All Rows

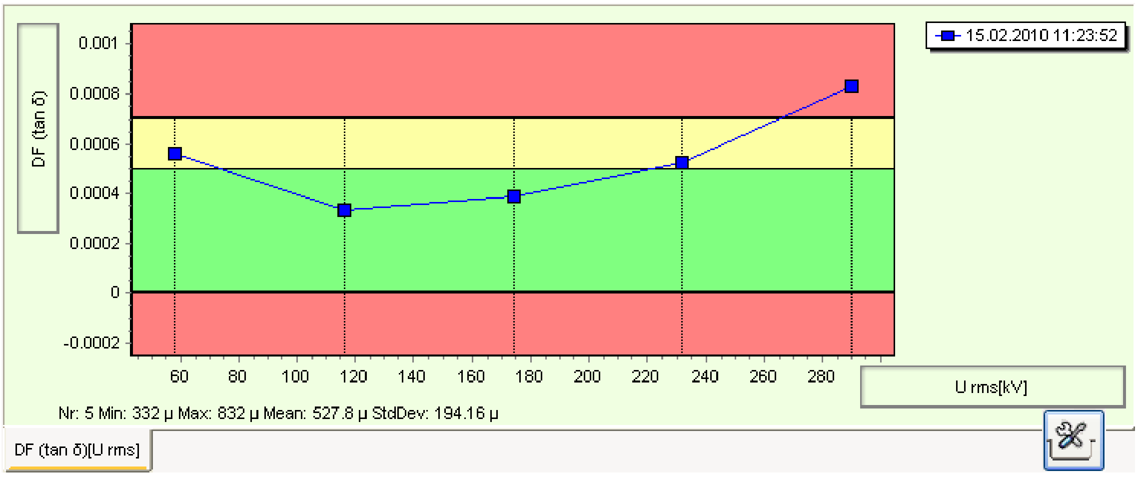
By pressing this button all rows will be deleted.</td></tr>
<tr><td></td><td>Signal Analysis

This button has the same functionality as the button found when clicking Tools -> Signal Analysis.</td></tr>
<tr><td></td><td>Test Condtions

When this button is clicked the actual test conditions of the measuring system is displayed.

Each recorded test series have their own test conditions, so it is possible to trace back test condition over years, even with different measuring devices and operators</td></tr>
</table>

8.6.2 Graphic Analysis



Description:

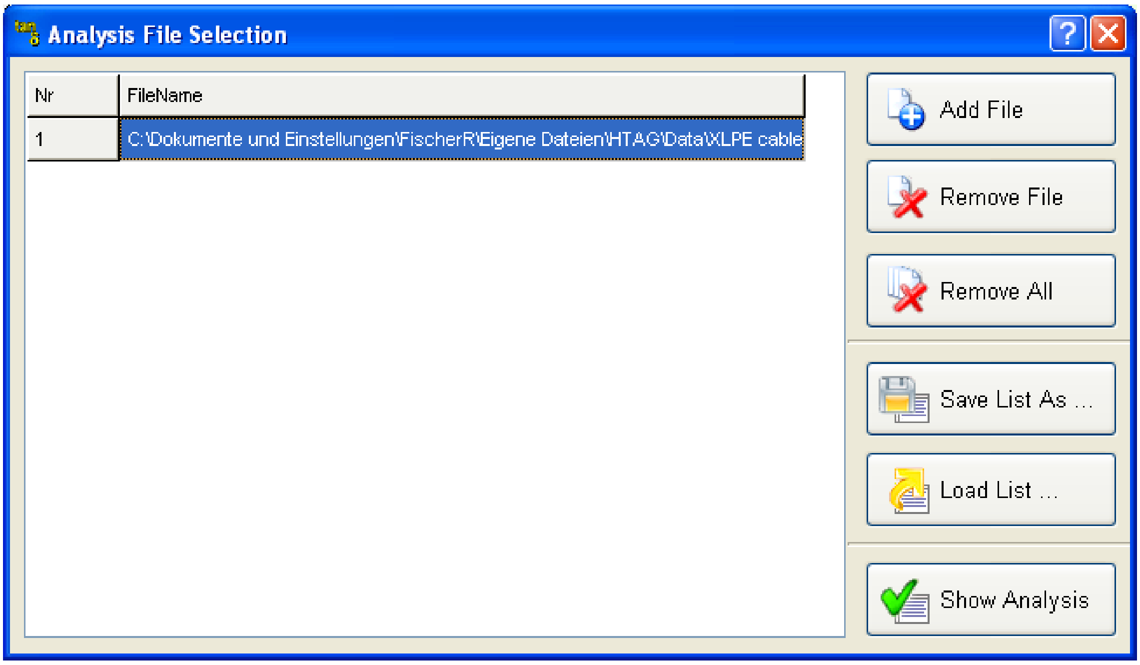
U rms[kV]	X- / Y - Axis By pressing the labels of the X or Y axes, a popup occurs where all possible axes values can be selected.
DF (tan δ)[U rms]	Predefined Views These buttons can be used to predefine a graphical view. The X- / Y- Axis and the selected measured data are stored under free definable name.
	Define View Pressing this button will pop-up a menu with the following buttons
Add View	Add View Pressing this button will store the actual graphic under a free definable name.
Delete View	Delete View Pressing this button will delete the actual selected view.
Rename View ...	Rename View Pressing this button will rename the actual view.
Save View	Save View Pressing this button will store the current view under the actual selected name.
Show Actual Diagram	Show Actual Diagram Shows the actual diagram, a JPEG File, with the associated program f.e. internet explorer.

8.6.3 More Analysis

This tool is used to analyze several files at the same time. The feature is especially helpful, if you want to analyze the measured data from different test objects.

Analysis File Selection

Pressing the  button will open the following dialog, where you can manage files for analyzing measuring data.

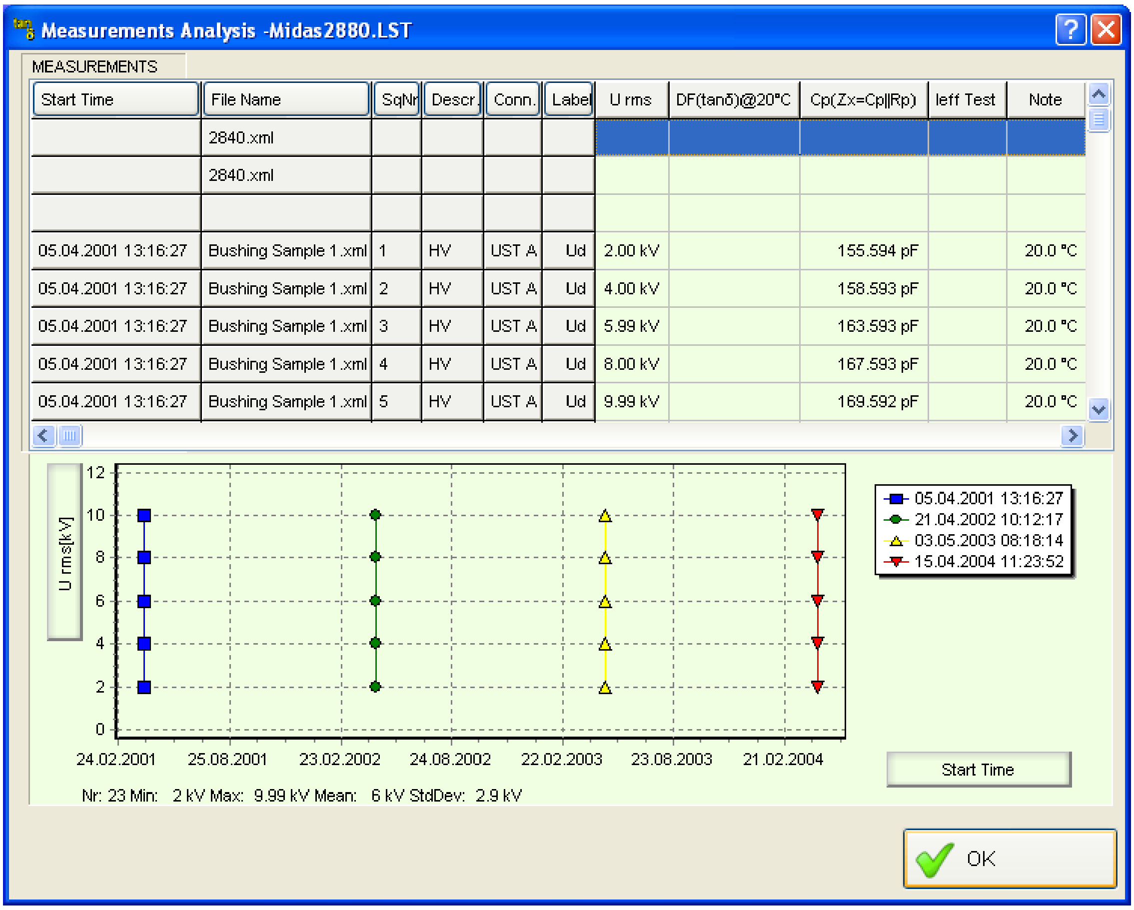


The descriptions of the buttons are as follow:

 Add File	Add File Pressing this button will add a file to the list.
 Remove All	Remove File Pressing this button will remove the current selected file from the list.
 Remove All	Remove All Pressing this button will remove all files from the list.
 Save List As ...	Save List As Pressing this button will store the actual list in a file.
 Load List ...	Load List Pressing this button will load a list from a file.
 Show Analysis	Show Analysis Pressing this button will open a dialog with all files from the list.

Analysis with data from different files

All selected measurement files are shown here. By pressing the column name “File Name”, you can manage this list. See related chapter for details.


Measurements Analysis -Midas2880.LST
MEASUREMENTS
Start Time
File Name
SqNr
Descr.
Conn.
Label
U rms
DF(tanδ)@20°C
Cp(Zx=Cp||Rp)
Ieff Test
Note
2840.xml
2840.xml
05.04.2001 13:16:27 Bushing Sample 1.xml 1 HV UST A Ud 2.00 kV 155.594 pF 20.0 °C
05.04.2001 13:16:27 Bushing Sample 1.xml 2 HV UST A Ud 4.00 kV 158.593 pF 20.0 °C
05.04.2001 13:16:27 Bushing Sample 1.xml 3 HV UST A Ud 5.99 kV 163.593 pF 20.0 °C
05.04.2001 13:16:27 Bushing Sample 1.xml 4 HV UST A Ud 8.00 kV 167.593 pF 20.0 °C
05.04.2001 13:16:27 Bushing Sample 1.xml 5 HV UST A Ud 9.99 kV 169.592 pF 20.0 °C
U rms[kV]
12
10
8
6
4
2
0
24.02.2001
25.08.2001
23.02.2002
24.08.2002
22.02.2003
23.08.2003
21.02.2004
05.04.2001 13:16:27
21.04.2002 10:12:17
03.05.2003 08:18:14
15.04.2004 11:23:52
Start Time
Nr: 23 Min: 2 kV Max: 9.99 kV Mean: 6 kV StdDev: 2.9 kV
OK

8.7 Remote Operation

This section first describes the basic characteristics of the built-in interface, the command syntax and the data format. Then detailed information is given about the registers and commands made available for remote controlling the unit.

To remote control the unit the LAN connection (Ethernet10/100) must be used.

8.7.1 Characteristics of the interface

The LAN settings can be seen in the tap sheet SETUP / Menu Options

Command Syntax

The command syntax corresponds to the IEEE 488.2 standard. The following list is an explanation of the terms, special characters and rules of syntax.

Terms, Characters	Explanation	Remarks
<EOS>	End character, sent as conclusion of a transmissions or serves to recognise the end of a transmission	Fix set to “CR + LF”
Command header	Specifies the command to be executed.	
Argument	Contains the value to be input; can be transferred in various formats (see also the “Data Format” section).	
<SPACE>	Separates the command header from the argument.	
Command	Command header and argument together.	
:	Separates command headers from one another.	
,	Separates arguments from one another.	
?	Attached to the command header for interrogating an argument	
;	Separates individual commands from one another.	
Command sequence	Several commands one after another.	
' or "	Marks the beginning and the end of a string argument.	
'' or ""	Immediate repetition of the ' or " character in a string argument. Accepts the character in the string without the argument being taken as closed.	

The unit can process command sequences, whereby only one query is allowed per sequence which must be positioned at the end of the sequence.

You can transmit upper and lower case letters when transmitting command headers and arguments.

Data Format

All numerical input and outputs are in SI units (Volts, Amperes, Ohms, etc.). The following summary shows the formats used:

Format	Description	Examples
<NR1>	Integer numbers	1, -8
<NR2>	Real numbers	1.4, -3.64
<NR3>	Real numbers with exponents	1.56E+1, -1.67E-12
<String>	Character sequences without CTRL (ASCII 13) and LF (ASCII 10) (see also the “Command Syntax” section).	'Test character sequence'
<ARBITRARY ASCII RESPONSE DATA>	Character sequences of indefinite length, closed by the end character.	abcdefg.......z and even more<EOS>
<DEFINITE LENGTH ARBITRARY BLOCK RESPONSE DATA>	Data byte sequence with definite length, closed by the end character	#10 0123456789<EOS>

Register

Various registers are used in order to interrogate the state of the device via the interface. Most registers are defined in the IEEE 488.2 Standard and are extended for the specific characteristics of the unit. The following table shows the relationship of all registers used together with the associated bit assignments and resulting values:

*STB Status Byte Register	Bit 7 Not in use, always '0' 6 RQS/MSS (Status of the RQS line) if queried over the serial connection MSS (Master Summary Status) if queried via the *STB? '1', if a message exists for the controller. 5 ESB (Standard Event Status Bit). Set, if since the last read or delete operation something has changed in the Event Status Register. 4 MAV (Message Available). Set if there is still data to read through the controller. 3 Not in use, always '0' 2 Not in use, always '0' 1 Not in use, always '0' 0 ISR. Set if the internal status register has a changed contents. The internal status can be queried with ISR?
*SRE Service Request Enabling Register	Used to mask the status byte bits (with the exception of bit 6). If a bit is set to '1' in this register, then the associated bit in the status register can be set as a collective alarm and initiate a request, otherwise nothing will happen.

*ESR Standard Event Status Register	Bit 15 - 8 Reserved— answer with '0' 7 PON Set to '1' when the unit is switched on 6 URQ Not used 5 CME Shows the processing errors that are stored in the CMR register and can be queried with CMR? 4 EXE Shows a execution error that is stored in the EXR register and can be queried with EXR? 3 DDE Shows that a unit-specific error has occurred and which can be queried with DDR? 2 QYE Shows a query error that is stored in the QYR register and can be queried with QYR? 1 RQC Always '0' because the unit is not able to take over bus control. 0 OPC Unused and always '1' if and *OPC is recognised because all commands are processed in a strictly one after another.
*ESE Event Status Enable Register	Is used to mask the ESR. If a bit is set to '1', an associated bit in ESR can be set and can initiate a collective alarm, otherwise nothing.
ISR Internal Status Register	Bit 7 0 6 0 5 0 4 0 3 2 1 Set if a transmission error (time out) occurs. 0 Set if the device is in the 'local' state.
ISE Internal Status Enable Register	Used to mask the bits in the ISR. If a bit is set to '1', then the associated bit in the ESR can be set and a collective alarm initiated, otherwise nothing.
CMR Command Error Register	Holds the last syntax error that occurred while processing the interface buffer. Bit 7 0 6 0 5 0 4 0 3 General error 2 Illegal syntax 1 Illegal argument 0 Unknown command
EXR Execution Error Register	Holds the last execution error 0 No error 1 Query in the 'Remote' state not allowed 2 A Query in the 'Local' state not allowed 3 Setting in the 'Remote' state not allowed 4 Setting in the 'Local' state not allowed 5 Argument outside the specified range 6 Too many or too few parameters 7 No data to transmit

DDR Device Dependent Register	Holds the last unit-specific error Bit 7 6 5 4 3 2 Illegal Insulation Type 1 File Error File does not exist. Illegal file name a.s.o. 0 Illegal State. To change a value the system is not in the state needed, as f.e. High Voltage Off State
QYR Query Error Register	Holds the last error queried. 0 No error 1 Buffer overflow either for input or output

Most of the commands have a short form and a long form. Short forms are written in upper case characters. The part of the command header written in upper case has to be transmitted so that the unit can recognize the command. The part of the command written in lower case letters can also be transmitted. It is only used for better understanding.

In general, queries can be executed in local mode. However, most of the set operations have to be carried out using remote control operation first (remote mode).

The command tables give information about the allowable operations. An 'x' marked in a column means:

LS setting or executing is allowed in local mode operation,
LA querying in local mode operation is allowed,
RS setting or executing in remote control mode is allowed,
RA querying in remote control mode is allowed.

8.7.2 General Commands

This section describes the “common commands” defined in the IEEE 488 standard as well as register queries and miscellaneous memory and loading commands.

Command	Arg	LS	LA	RS	RA	Commentary.
*IDN?	<ARBITRARY ASCII RESPONSE DATA>		X		X	Return of device identification in the format: <Companyname>, <Model>, 0, <Software-Version>, i.e., HAEFELY TEST AG, 2840, 0, X.XX
*RST				X		Sets the standard configuration
*TST?	<NR1>		X		X	The unit returns a '1' for unavailable or defective hardware, otherwise a '0'
*OPC?	<NR1>		X		X	If all pending operations have been carried out, then the returned answer is ASCII 31 ('1'). The unit always returns a '1' because all commands are processed strictly one after another.
*OPC		X		X		Sets the OPC bit in the ESR status register to True. Has no further effect on the unit

*WAI		X		X		Does not affect the unit because all commands are processed strictly one after another.
*CLS		X		X		Clears all registers
*STB?	<NR1>		X		X	Calls up and then deletes, with exception of the MAV bit, the contents of the status register masked by the service request enable. Remotely controlled via the IEEE 488. Can also query the contents via serial poll. In this case bit 6 identifies the state of the RQS line instead of the Master Summary Status.
*SRE	<NR1>			X		Sets the Service Request Enable Register and determines which events initiate an RQS/MSS when using the IEEE 488 interface.
*SRE?	<NR1>		X		X	Returns the contents of the Service Request Enable Register.
*ESR?	<NR1>		X		X	Returns and then clears the contents of the Event Status Register.
*ESE	<NR1>			X		Sets the contents of the Event Status Enable Register and determines which events initiate a collective error.
*ESE?	<NR1>		X		X	Returns the contents of Event Status Enable Registers
ISR?	<NR1>		X		X	Returns and then clears the contents of the Internal Status Register
ISE	<NR1>			X		Sets the Internal Status Enable Register and determines which internal sequence should initiate a collective error.
ISE?	<NR1>		X		X	Returns the contents of the internal Status Enable Register.
CMR?	<NR1>		X		X	Returns and then clears the contents of the Command Error Register.
EXR?	<NR1>		X		X	Returns and then clears the contents of the Execution Error Register.
DDR?	<NR1>		X		X	Returns and then clears the contents of the Device Dependent Register
QYR?	<NR1>		X		X	Returns and then clears the contents of the Query Error Register.
REN	<String>	X		X		Change to remote control if <string> corresponds to the entered password. Otherwise this command will be ignored.
GTL		X		X		Change to local mode.

SET?	<ARBITRARY ASCII RESPONSE DATA>		X		X	Returns the current settings of the unit.
HELP?	<ARBITRARY ASCII RESPONSE DATA>		X		X	Returns the available command headers.
FILE?	<String>		X		X	Returns the actual working file.
SAVE	<String>			X		Stores the current working file under the name <String> . Sets bit 1 at the “Device Dependent Register” in case of an error. Example.: SAVE 'C:\ABC.XML'
LOAD	<String>			X		Loads the actual working file. If the file does not exist the “Device Dependent Register” Bit 1 will be set. Example.: LOAD 'C:\ABC.XML
RECord				X		Records actual measurement data into actual open working file.
SRQ SRQ?	ON OFF	X	X	X	X	Only functional if the IEEE 488 interface is used. In the 'ON' state a Service Request is initiated as soon as a bit changes in the Serial Poll Byte.
SIVALues	YES NO		X		X	The value measurement commands will be output as SI Values Default is NO f.e CAPX will answer as “"400E-10" instead of "400.00 pF"

8.7.3 System control commands

There are commands that can be activated only if the high voltage is switched off . The RHE (Remote High Voltage switched ON) and RHA (Remote HV switched OFF) columns give information about the necessary states of the system. If a command is executed in an incorrect state, bit 0 in the DDR Register is set.

Note: LA = Local Answer
RA = Remote Answer
LS = Local Set
RHE = Remote HV ON Set
RHA = Remote HV OFF Set

Command header 1	Command header 2 or Arg.	Command header 3 or Arg.	LA	RA	LS	RHE	RHA	Commentary

RefCAP	INTERN?	<Nx>	X	X				Returns the value of the internal reference capacitor in [F].
	EXTERN EXTERN?	<Nx>	X	X				Sets or returns the value of the external capacitor in [F].
	SWitCH SwitCH?	INTern EXTern	X	X			X	Sets or returns, if the external or the internal capacitor is used.
TEMPeratu re	UNIT	CELSius FAHRenhei t	X	X		X	X	Sets or returns the unit of temperature inputs. If the unit is "Celsius" all temperature units are in "°C", if "Fahrenheit" is set, the unit is "°F"
INSULation	TEMPeratu re TEMPeratu re?	<Nx>	X	X		X	X	Sets or returns the temperature of the insulation. The unit corresponds with the "TEMP:UNIT" set value.
	TYPE TYPE?	<string>	X	X		X	X	Sets or returns the type of the insulation. If you want to set the insulation type, <string> has to be a member of the temperature correction file. See section "*Menu Condition"* for more information. Otherwise the DDR Register will be set. Example INSUL:TYPE "Liquids :Askarel"
	CORRfacto r?		X	X				Returns the actual set temperature correction factor
AMBient	TEMPeratu re		X	X		X	X	Sets or returns the actual ambient temperature. The unit corresponds to the command "TEMP:UNIT".
	HUMidity		X	X		X	X	Sets or returns the actual ambient humidity.
CurrentCo mparator	XPATH	NO YES	X	X		X	X	Current Comparator is used. The entered ratio will be used for calibration.
	IPX	<Nx>	X	X		X	X	Value for IPX
	ISX	<Nx>	X	X		X	X	Value for ISX
	CONFigura tion	Conf_A Conf_B Conf_C Conf_D	X	X		X	X	Configuration of the Calculation. See the selected picture for more explanation.

8.7.4 Measurement commands

Note: All values are formatted in the same way as on the display as f.e
"12.44 kV" for Voltages

"99.43 pF" for Capacitances,
"0.0033" for Dissipation, Power Factor, a.s. o.

Following units are possible:

"p"	Pico	10^{-12}	"k"	Kilo	10^{3}
"n"	Nano	10^{-9}	"M"	Mega	10^{6}
"u"	Mikro	10^{-6}	"'G"	Giga	10^{9}
"m"	Milli	10^{-3}			

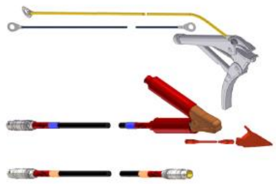
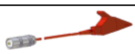
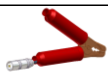
If the system is ranging the system will answer with "--"

Command header1	**Command header f2 or Arg.**	**L S**	**L A**	**R S**	**R A**	**Commentary**
ACCUracy?	YES NO		X		X	Returns "YES" if the accuracy of the measured signal is enough. This value corresponds with the colour displayed on the system. See section “Display of Measurement Values”
OVERflow?	YES NO		X		X	Returns "YES" if a signal has an overflow detected.
URMS?	<Nx>		X		X	Effective Voltage which is applied to the test object. Answer similar as "12.434 kV"
DF?	<Nx>		X		X	Dissipation factor without temperature correction. Answer similar as "0.0043 "
DF20?	<Nx>		X		X	Dissipation factor with temperature correction. Answer similar as "0.0043 "
PF?	<Nx>		X		X	Power factor without temperature correction. Answer similar as "0.0043 "
PF20?	<Nx>		X		X	Power factor with temperature correction. Answer similar as "0.0043 "
CAPX?	<Nx>		X		X	Test Capacitance C_X in parallel equivalent circuit Answer similar as "12.34 pF"
FREQ?	<Nx>		X		X	Measured frequency of applied voltage Answer similar as "50.04 Hz"
IREF?	<Nx>		X		X	Effective Current through C_N Answer similar as "35.30 uA"
ITEST?	<Nx>		X		X	Effective Current through C_X Answer similar as "5.304 mA"
RESX	<Nx>		X		X	Resistor parallel to Capacitance C_X in parallel equivalent circuit Answer similar as "1.20 kOhm"
PWRA?	<Nx>		X		X	Apparent Power Answer similar as "277.35 VA"
PWRP?	<Nx>		X		X	Real Power Answer similar as "399.55 mW"

PWRQ?	<Nx>		X		X	Reactive Power Answer similar as "278.85 VAR"
PWR25?	<Nx>		X		X	Real Power at test object normalized to a test voltage at 2.5 kV. Answer similar as "526.06 uW"
PWR10?	<Nx>		X		X	Real Power at test object normalized to a test voltage at 10 kV. Answer similar as "8.45 mW"
INDX	<Nx>		X		X	Test inductance L_X in serial equivalent circuit Answer similar as "54.5407 kH"
RINDX	<Nx>		X		X	Test Resistor serial to L_X (serial equivalent circuit) Answer similar as "54.5407 kH"
ZX?	<Nx>		X		X	Complex Impedance of the test object Answer similar as "|1.712E+07|-89.92°"
YX?	<Nx>		X		X	Complex Admittance of the test object Answer similar as "|5.841E-08|89.92°"
MeasSET	<String>		X	X	X	Allows to define a set of measuring data, which all be transferred by the command "MeasDATa". All data belong to one calculation and are recorded at the same time. Each values is separated by a comma. Following data are possible: URMS For description see above DF DF20 PF PF20 CAPX FREQ IREF ITEST RESX PWRA PWRP PWRQ PWR25 PWR10 INDX RINDX ZX YX f.e. you can send MSET "URMS, PF, CAPX, ITEST" and you will get with the command "MeasDATa" a similar string as "957 V, +0.00119 , 106.21 pF, 31.25 uA" for answer.

MeasDATa	<String>		X		X	A string of measuring data which are set by the command "MeasSet", which are separated by a comma.

9 Accessories

Order code	Length	Description	Picture
4843181	-	Office Software package. Used for PC test preparation, data visualisation, staff education	
4841882		Field kit including: Rugged field cases for instrument, Rugged field cases for cables	
4843321 4843322	10 m 20 m	Complete connection cable kit for large DUT (e.g. power transformer) connection, including: Earthing cable with gripper, V-point connection cable (black), 1 measuring cable (blue) with clamps, 1 small clamp adaptor for measuring cables, C_n cable with plugs (orange)	
4841868 4840203 2485791 4841869	2 m 10 m 20 m xx m	Shielded C_x measuring cable (blue), Lemo3 – Lemo3 plugs Custom length on request (max. 50m)	
4841872 4840206 4840041 4841873	2 m 10 m 20 m xx m	Shielded C_n cable (orange), Lemo3 – Lemo3 plugs Custom length on request (max. 50m)	
4841876 4840207 4840168 4841877	2 m 10 m 20 m xx m	V-point guard cable (black) with lugs Custom length on request (max. 50m)	
4840186	-	Connection Lemo3 – alligator clip	
4840169	-	Connection Lemo3 – clamp	
0107351	-	90° adaptor, Lemo3 – Lemo3 plug	
4841895		DUT Connection box Lemo3 – screw terminal	

Current Comparators

For current comparator types and specification please see
www.haefely.com

10 Care and Maintenance

The instrument is basically service free, as long as the specified environmental conditions are adhered to. As a result, service and maintenance is restricted to cleaning of the equipment and calibration at intervals stipulated by the application for which the instrument is used.

The insulation of all high voltage cables should be periodically checked for damage. If any damage to the insulation is detected then a new measuring cable should be ordered from HAEFELY TEST AG.

If the instrument is to remain unused for a long time then it is recommended that steps are taken to prevent ingress of dust inside the housing through air circulation (i.e. wrap or pack the instrument).

⚠ If the instrument is to be used in extreme environmental conditions (e.g. unclean, oily air with airborne metal or coal dust, high humidity etc.) then it should be protected by building into a suitable housing with forced air filtering or similar suitable protection. If such protective measures cannot be provided, then the instrument should be periodically checked for contamination and promptly cleaned with suitable cleanser when required. This kind of service work is particularly important if high voltages are to be measured and should be performed by an authorised service agent.

Cleaning the Instrument

The instrument should be cleaned with a lint free cloth, slightly moistened using mild household cleanser, alcohol or spirits. Caustic cleansers and solvents (Trio, Chlorothene, etc.) should definitely be avoided.

In particular, the protective glass of the display should be cleaned from time to time with a soft, moist cloth such as used by opticians.

Instrument Calibration

When delivered new from the factory, the instrument is calibrated in accordance with the calibration report provided. A periodical calibration of the instrument every two years is recommended.

As the calibration process is fairly extensive, the instrument can only be calibrated and, if necessary, adjusted at HAEFELY TEST AG's factory. An updated calibration report will then be issued.

Changing Fuses

Before changing the mains fuse, remove the mains power cord. Fuses should only be replaced with the same type and value.

11 Instrument Storage

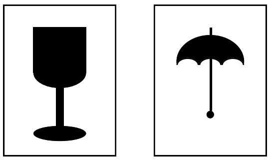
During day to day use the instrument can be switched off at the mains switch located above the mains socket on the rear panel of the instrument.

If the instrument is to remain unused for any length of time, it is recommended to unplug the mains lead. In addition, it is advisable to protect this high precision instrument from moisture and accumulation of dust and dirt with a suitable covering.

12 Packing and Transport

The packing of the Measuring instrument provides satisfactory protection for normal transport conditions. Nevertheless, care should be taken when transporting the instrument. If return of the instrument is necessary, and the original packing crate is no longer available, then packing of an equivalent standard or better should be used.

Whenever possible protect the instrument from mechanical damage during transport with padding. Mark the container with the pictogram symbols „Fragile“ and „Protect from moisture“.



Pictograms

13 Recycling

When the instrument reaches the end of its working life it can, if required, be disassembled and recycled. No special instructions are necessary for dismantling.

The instrument is constructed of metal parts (mostly aluminum) and synthetic materials. The various component parts can be separated and recycled, or disposed of in accordance with the associated local rules and regulations.

14 Trouble Shooting

All error messages appear on the display of the measuring instrument. If persistent problems or faulty operation should occur then please contact the Customer Support Department of HAEFELY TEST AG or your local agent.

The Customer Support Department can be reached at the following postal address:

HAEFELY TEST AG

Customer Service - Tettex

Birsstrasse 300

CH-4052 Basel

Switzerland

Tel: +41 61 373 4422

Fax: +41 61 373 4914

e-mail: tettex-support@haefely.com

14.1 Windows Recovery

The 2820a / 2840 has an integrated PC board and runs on Windows 7. In case of a damaged Windows operating system (corrupted files, damaged partition etc.) the integrated Windows recovery function can help to restore the instrument in the state it was delivery from the factory.

There are two drives available:

C:/ Contains the Windows installation and all system files

D:/ Contains the user data and installation files of the application software

During the recovery process all files, software, programs, etc. saved on partition C:/ will be deleted.

Any update of the 2840/2820a software that was installed after delivery have to be reinstalled after the recovery process

Follow these steps To recover the instrument to the factory defaults:

1. Switch off the instrument by the main switch on the front panel
2. Connect an external keyboard to one of the USB connectors
3. Switch on the instrument and press the F1 key
4. The instrument starts in the recovery mode and restores Windows
5. The instrument is now reset to factory defaults
6. Reinstall the application software if an update was once done after delivery

14.2 Software Updates 2840

Haefely Test AG runs an Internet Update Homepage where owners of our test instruments can download the newest firmware, software, manuals, related information etc.

http://update.haefely.com/Ct2840/

14.3 Software Updates 2820a

Haefely Test AG runs an Internet Update Homepage where owners of our test instruments can download the newest firmware, software, manuals, related information etc.

http://update.haefely.com/Ct2820a/

Do NOT try to install the 2840 software on a 2820a hardware or vice versa.
It won't work at all!

15 Conformity

HAEFELY TEST AG

Declaration of Conformity

Haefely Test AG
Lehenmattstrasse 353
4052 Basel
Switzerland

declare, under his own responsibility, that the below mentioned product complies with the requirements of the listed standards or other normative documents.

So, the product complies with the requirements of the EMC directive 2004/108/EC and the low voltage directive 2006/95/EC.

Product:	**C, L & tan δ Measuring Bridge type 2820a and 2840**
Description:	Fully automatic capacitance, inductance and dissipation factor measuring bridge type 2820a and 2840 is designed for determining impedances and dielectric losses of high-voltage equipment and liquid or solid insulation.
Standards:	EN 61010-1: 2001 EN 61326-1: 2006

R. Mäder
Quality Department Manager
Haefely Test AG
4052 Basel
Switzerland

Basel, May 6, 2010

....
(Signature)

Haefely Test AG, Lehenmattstrasse 353, CH-4052 Basel/Switzerland
www.haefely.com

Appendix

16 Applications Guide

This chapter contains important information regarding construction of the test circuit and the individual test modes depending on the device under test.

Selected circuits for specific test objects are presented for further information. Unfortunately it is not possible to provide a test circuit for every customer specific test object as this would exceed the capacity of this manual.

If this chapter is studied carefully, and the function of the measuring instrument with the individual test modes is understood, then it will be simple to find the relevant test circuit for a special application.

16.1 Bushings

The most important function of a bushing is to provide an insulated entrance for an energized conductor into an equipment tank or chamber. A bushing may also serve as a support structure for other energized parts of an equipment.

Generally two types of bushings are available:

Condenser type

- Oil-impregnated paper insulation with interspersed conducting (condenser) layers or oil-impregnated paper insulation, continuously wound with interleaved lined paper layers.
- Resin-bonded paper insulation with interspersed conducting (condenser) layers.

Non-condenser type

- Solid core, or alternate layers of solid and liquid insulation.
- Solid mass of homogeneous insulating material (e.g. solid porcelain).
- Gas filled.

The primary insulation of outdoor bushings is contained in a weatherproof housing, usually porcelain or silicone. The space between the primary insulation and the weather shed is usually filled with an insulating oil or a compound (plastic, foam, etc.). Bushings also may use gas such as SF_6 as an insulating medium between the center conductor and the outer weather shed.

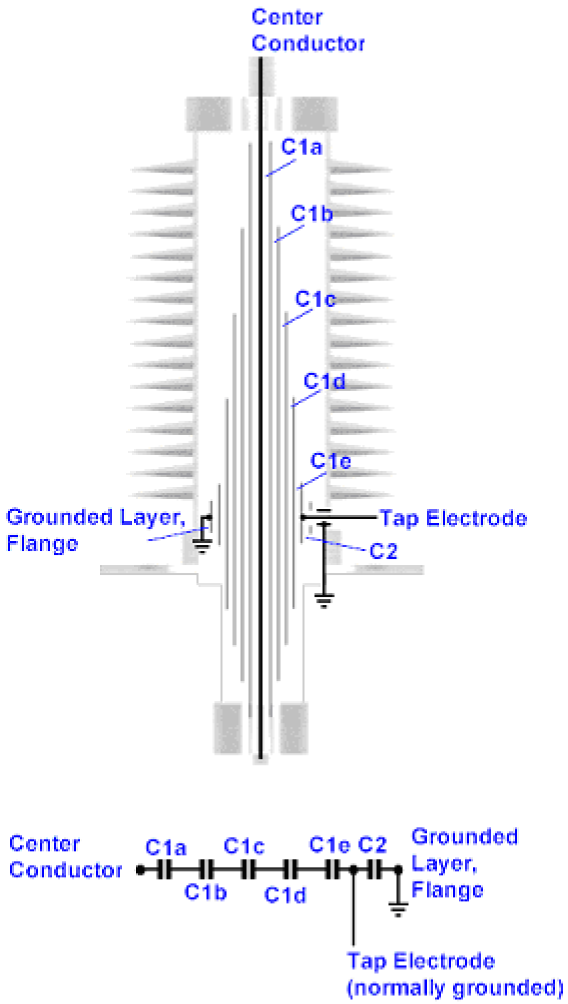
Bushings may be classified as being equipped or not equipped with a potential tap (sometimes also called "capacitance" or "voltage" tap) or a dissipation factor test tap (power factor tap). Usually high voltage bushings are fitted with potential taps while medium or low voltage bushings are equipped with dissipation factor taps.

In higher voltage designs, the potential tap may be utilized to supply a bushing potential device for relay and other purposes. Therefore these are capable of withstanding fairly high voltages.

Potential taps also serve the additional purpose of permitting a dissipation factor test on the main insulation of a bushing without the need to isolate the upper and lower terminals from the associated equipment and connected de-energized bus. Dissipation factor taps are not designed to withstand high potential since their purpose is solely to provide an electrode for making a dissipation factor test on the bushing C1 insulation.

The dissipation factor tap is normally designed to withstand only about 500V while a potential tap may have a normal rating of 2.5kV to 5kV. Before applying a test voltage to the tap, the maximum safe test voltage must be known and observed. An excessive voltage may puncture the insulation and render the tap useless.

A bushing without a potential tap or power-factor tap is a two-terminal device which is normally tested overall (center conductor to flange). If the bushing is installed on equipments like circuit breaker, transformers or cap banks the overall measurement will include all connected and energized insulating components between the conductor and ground.



Construction of a bushing

In principle a condenser bushing is a series of concentric capacitors between the centre conductor and ground sleeve or mounting flange.

A conducting layer near the ground sleeve may be tapped and brought out to a tap terminal to provide a three-terminal specimen.

The tapped bushing is essentially a voltage divider.

Note:

Equal capacitances (C1a..C1e) produce equal distribution of voltage from the energized centre conductor to the grounded condenser layer and flange.

The tap electrode is normally grounded in service except for certain designs and bushings used with potential device.

For bushings with potential taps, the C2 capacitance is much greater than C1 For bushings with power-factor tap , C1 and C2 capacitances may be the same order of magnitude.

In the dissipation factor tap design, the ground layer of the bushing core is tapped and terminated in a miniature bushing on the main bushing mounting flange. The tap is connected to the grounded mounting flange by a screw cap on the miniature bushing housing. With the grounding cap removed, the tap terminal is available as a low-voltage terminal for a UST measurement on the main bushing insulation, C1 conductor to tapped layer.

In some bushing designs the tapped layer is brought out into an oil-filled compartment. The potential tap is allowed to float in service. A special probe is inserted through an oil filling hole to make contact with the tapped layer, to permit a measurement.

A bushing is a relatively simple device and field test procedures have been evaluated to facilitate the detection of defective, deteriorated, contaminated or otherwise damaged insulation. The most important types of tests applicable to bushings are:

- Overall Test (Centre Conductor to Flange, C1/C2)
- Centre Conductor to Tap Test (C1)
- Tap Insulation Test (Tap to Flange, C2)
- Hot Collar Test (Collar to Center Conductor)

Due to the caution statement mentioned above, it is important to note that for tap-insulation tests the applied voltage should not exceed 5 kV for potential taps and 500 V for dissipation factor taps.

For the overall and the center conductor to tap test a convenient voltage at or below the bushing nameplate rating should be chosen.

The hot collar test should be performed at a test voltage of about 10kV.

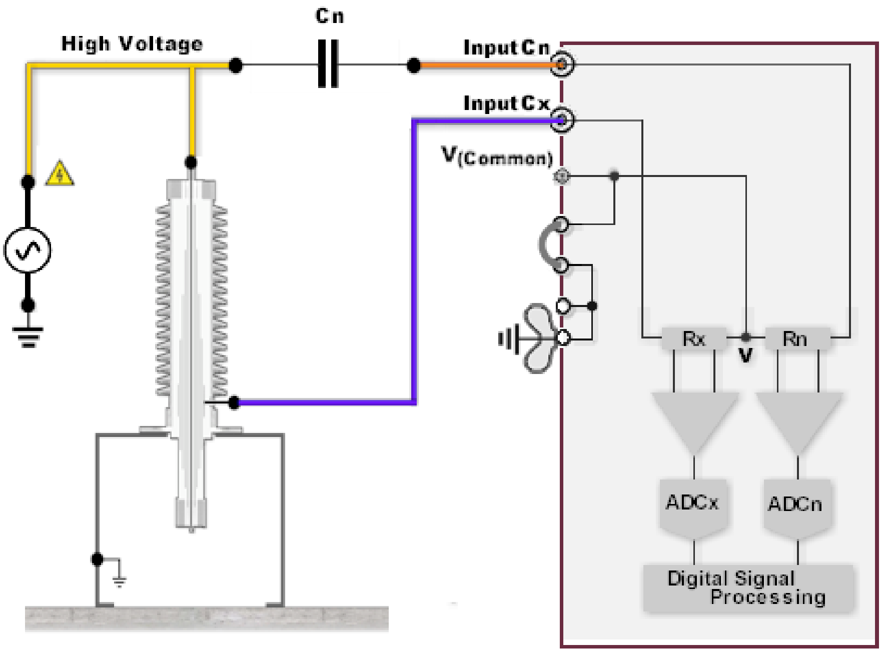
16.1.1 Spare Bushings

For testing a spare bushing care must be taken in the method used to hoist the bushing.

The bushing should be mounted in a grounded metal rack with nothing connected to the terminals. Tests should not be performed with the bushings mounted in wooden crates or lying on a floor. Otherwise the test results can be affected by the wood or the cement floor.

It is also important to ensure that the bushing centre conductor is not in contact with a foreign material (sling, rope, etc.).

With this test mode the Centre Conductor to Tap Test (C1) is measured:



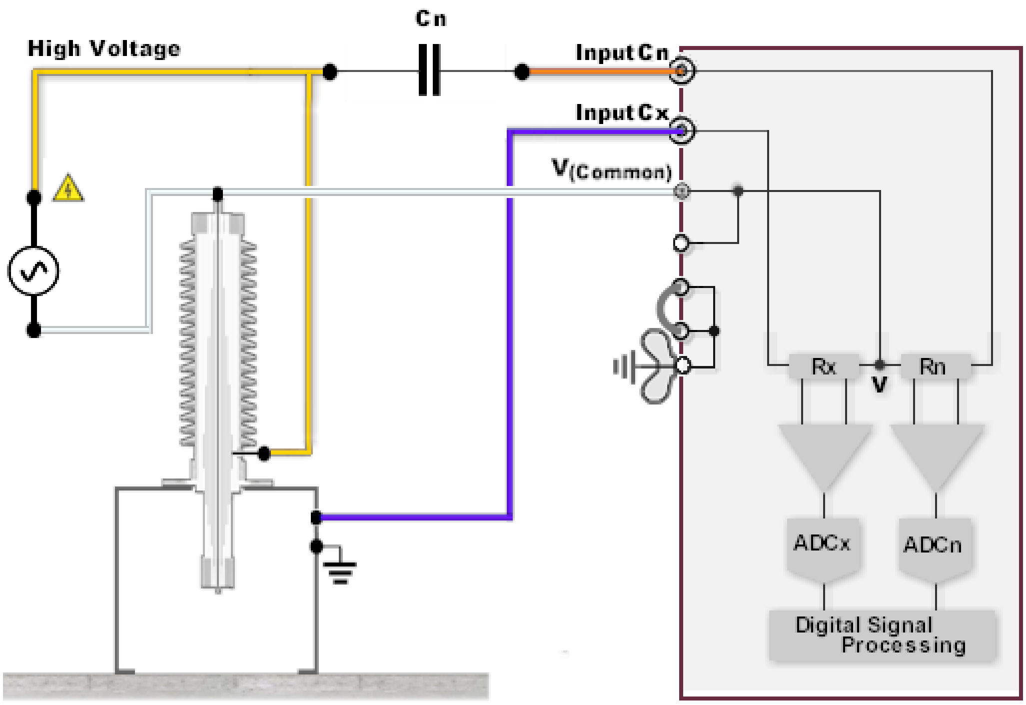
Spare Bushing Tap Insulation Test C1

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	Bridge	High Voltage to
C_1	Bushing Tap	-	UST	Closed	HV
C_{HG}	Tank GND	Bushing Tap	GST	Open	HV
C_2	Tank GND	HV	GST	Open	Bushing Tap*

** When HV is applied to the Bushing Tap, use reduced voltage, e.g. 500V, 2.5kV or 5kV depending on the type of Tap*

With this test mode the Tap Insulation Test (Tap to Flange, C2) is measured:



Spare Bushing Tap Insulation Test C2

Table with “Test connections” can be found on the previous page.

Warning: Check the manufacturer’s recommendation for maximum tap- test voltage before applying

16.1.2 Installed Bushings

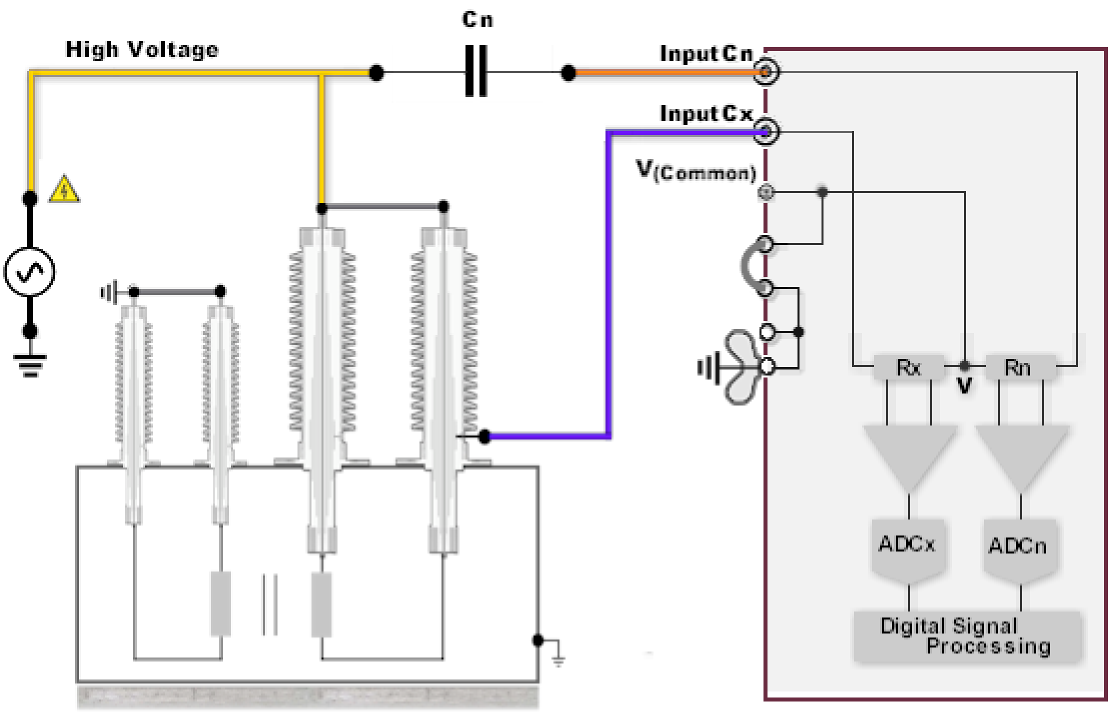
Overall Test (Centre Conductor to Flange) .

If a bushing is mounted on the equipment, the overall measurement method would include all conduction and insulation elements connected between the bushing center conductor and ground. Therefore the overall method is not recommended for separate tests on bushings, unless the bushing conductor can be completely isolated or the bushing has no tap.

Centre Conductor to Tap, C1

Most high-voltage condenser-type bushings are equipped with either potential or power-factor test taps. These permit separate tests on the main bushing insulation (commonly referred to as C1) without the need to disconnect a bushing from the equipment or bus to which it is connected.

The C1 insulation is measured via the UST mode. The connection is shown in the figure below.



C1 Insulation test of bushing in transformer

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	Bridge	High Voltage to
C_1	Bushing Tap	-	UST	Closed	HV
C_2	Tank GND	HV	GST	Open	Bushing Tap*

** When HV is applied to Bushing Tap, use reduced voltage, e.g. 500V, 2.5kV or 5kV depending on the type of Tap*

The values are measured in the conventional manner, and the dissipation factor is calculated and corrected for temperature. For a bushing in a power or distribution transformer the average temperature of the transformer top-oil and ambient air temperature should be used. For bushings mounted in oil circuit breakers the C1 dissipation factor should be corrected using the air temperature.

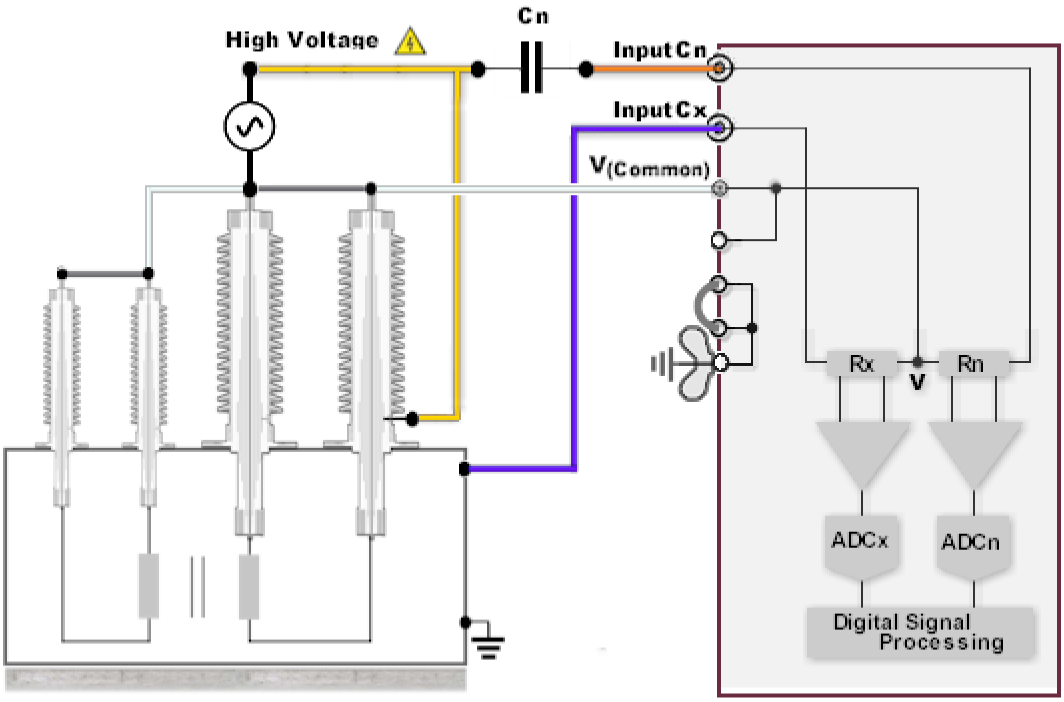
During measurements on bushings in transformers, all terminals of the windings to which the bushings are connected must be tied together electrically. Otherwise higher-than-normal losses may be recorded due to the influence of the winding inductance. Also, for safety the bushings associated with all windings not energized should be grounded and not left floating.

Tap-Insulation Test (Tap to Flange, C2)

Before starting any measurements the test engineer must carefully consider the type of tap and its corresponding maximum rated voltage. The maximum permissible test voltage is usually designated by the manufacturer (generally between 500 V and 2 kV).

Warning: Check the manufacturer's recommendation for max. tap test voltage

In analogy to the tap insulation test on spare bushings the C2 insulation is measured by the GST mode. The connection is shown below.

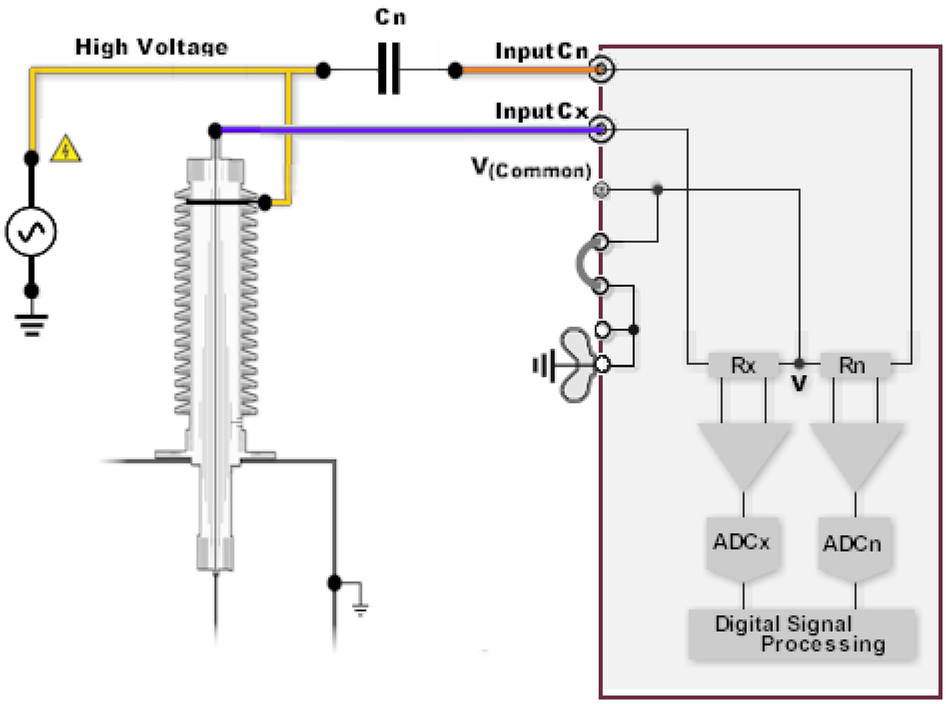


C2 Insulation test of bushing in transformer

For the capacitance C2 (tap to flange) the dissipation factor is calculated but normally not corrected for temperature.

Hot Collar Test

The dielectric losses through the various sections of any bushing or pothead can be investigated by means of a hot collar test which generates localized high-voltage stresses. This is accomplished by using a conductive hot collar band designed to fit closely to the porcelain surface, usually directly under the top petticoat, and applying a high voltage to the band. This test provides a measurement of the losses in the section directly beneath the collar and is especially effective in detecting conditions such as voids in compound filled bushings or moisture penetration since the insulation can be subjected to a higher voltage gradient than can be obtained with the normal bushing tests.



Hot Collar test on bushing in transformer.

The Hot Collar Test is made via UST mode and the bushing does not need to be disconnected from other components or circuits. Make sure that the collar band is drawn tightly around the porcelain bushing to ensure a good contact and eliminate possible partial discharge problems at the interface.

16.1.3 Measuring Data Interpretation

Condenser Bushings

The dissipation factor and capacitance recorded are compared with one or more of the following:

- Nameplate data.
- Results of prior tests on the same bushing.
- Results of similar tests on similar bushings.

Dissipation factors for modern condenser bushings are generally in the order of 0.5% after correction to 20°C. (0.55% for resin bonded, 0.30% for oil impregnated and 0.32% for resin impregnated types) They should be within twice the nameplate value. Increased dissipation factors indicate contamination or deterioration of insulation.

Capacitances should be within +/- 5 .. +/- 10% of nameplate value, depending upon the total number of condenser layers. Increased capacitance indicates the possibility of short-circuited condenser layers. Decreased capacitance indicates the possibility of a floating ground sleeve, or open or poor test tap connection.

Negative dissipation factors accompanied by small reductions in capacitance or charging current are experienced occasionally, and may result from unusual conditions of external surface leakage or internal leakages resulting from carbon tracks.

On bushings equipped with taps, the measurement on C1 is supplemented by a Tap-Insulation test on C2. Test potential may have to be reduced from 2.5 kV depending upon the tap rating. The dissipation factor of tap insulation is normally not corrected for temperature. Dissipation factors recorded for tap insulation are generally on the order of 1%. Results should be compared with those of earlier tests or with results of tests on similar bushings.

Capacitances recorded for tests on potential taps should also be checked against nameplate values, if available. Decreased capacitance indicates the possibility of a floating ground sleeve, or poor test tap connection.

Dry-Type Porcelain Bushings

Bushings of this design may be used in circuit breakers or transformers, or as roof or wall bushings. They are not equipped with special test electrodes or facilities, so that the only test applicable is the Overall method, conductor to mounting flange.

The test results are analysed and graded on the basis of comparison of results among similar . bushings and with results recorded for previous tests. Abnormally high losses and dissipation factor result from:

- Cracked porcelain
- Porous porcelain which has absorbed moisture (not common in modern porcelain)
- Losses in the secondary insulations, such as varnished cambric
- Corona around the centre conductor.
- Conducting paths over the insulation surfaces to ground.
- Improper use or bonding of resistance coatings or glazing on internal porcelain surfaces.

Cable-Type Bushings

Overall dissipation factor and Hot-Collar losses are relatively high because of inherently high losses in the cambric insulation. Test results should be compared among similar bushings and with those recorded for previous tests. Abnormally high losses can result from moisture entering the top of the bushing and contaminating cambric and compound, migration of oil into the compound through a bottom seal, cracked porcelain, etc.

Hot-Collar Test

The losses recorded should be less than 100mW. If the current or watts-loss is appreciably higher than normal, then a second test is made after moving the collar down one petticoat. This procedure can be followed as far down the bushing as necessary to determine how far down the fault has progressed.

16.2 Transformers

16.2.1 Power and Distribution Transformers

The dissipation factor test for distribution transformers (rated ≤ 500kVA) and power transformers (rated > 500kVA) is a very comprehensive test for detecting moisture, carbonization, and other forms of contamination of windings, bushings, and liquid insulations.

Power and distribution transformers exist as single-phase or three-phase design. For insulation purposes transformers can be further classified as dry type which have air or gas as insulation and cooling medium, or as liquid-filled constructions which have mineral oil, Askarel® or other synthetic materials.

The scope of the dissipation factor test for transformers is to determine the capacitance (insulation) between the individual windings and between the windings and ground.

To eliminate any effect of winding inductance on the insulation measurements all terminals of each winding, including neutrals, must be connected together. Check also for possible arrester elements in the tap changer.

Before any measurement is performed the transformer must be deenergized and completely isolated from the power system. The transformer housing must be properly grounded.

References and standards for the dissipation factor tests can be found in:

- IEC60076-1 (2000) clause 10.1.3 "Measurement of the dissipation factor of the insulation"
- IEEE Std C57.12.90-1999 clause 10.10 "Insulation power-factor tests"

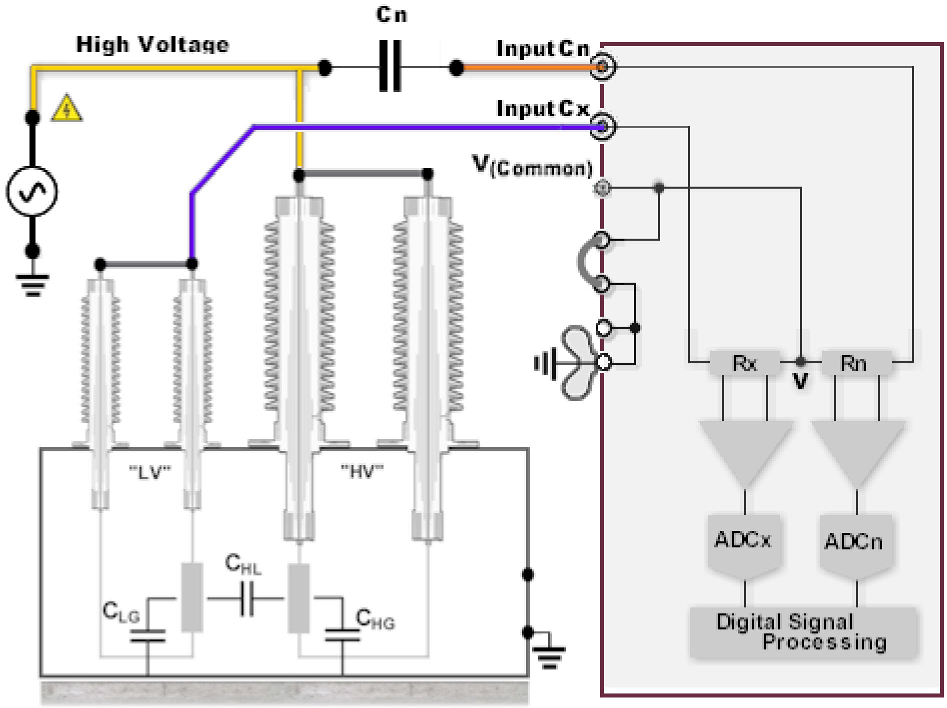
Test Levels

The decision about the applied test voltage is in most cases easy since the tested equipment is generally rated above 15 kV. In case of equipment rated 15 kV or lower, consideration should be given to include testing at slightly above (10..25%) the operating line-to-ground voltage.

IEEE C57.12.90 recommends that, for insulation dissipation factor tests, the voltage should not exceed one-half the low-frequency test voltage given in IEEE C57.12.00. The lowest low-frequency test voltage given in C57.12.00 is 10 kV which correspond to a nominal system voltage of 1.2 kV. Therefore, in accordance with IEEE, an insulation dissipation factor test voltage of 5 kV could be applied to 1.2 kV transformer.

The following sections try to illustrate three typical applications of testing the insulation properties of transformers. First an ordinary two winding transformer is presented, then an autotransformer is visualized and finally a three winding transformer is explained.

Two Winding Transformers (3 phase and single-phase)



Measurement connections of a two windings transformer for measurement of C_{HL}

Test Connections

DUT	INPUT Cx to	V(Common) to	Test Mode	Bridge	High Voltage to
C_{HL}	LV	Tank GND	UST	Closed	HV
C_{HG}	Tank GND	LV	GST	Open	HV
C_{LG}	Tank GND	HV	GST	Open	LV
C_{LG} + C_{HG}	Tank GND	-	GST	Open	LV + HV

Note: Test line #4 can be used to inter-check the measurement results. (#4 = #2 + #3). Additional measurements in other test modes can be executed to inter-check the measurements results.

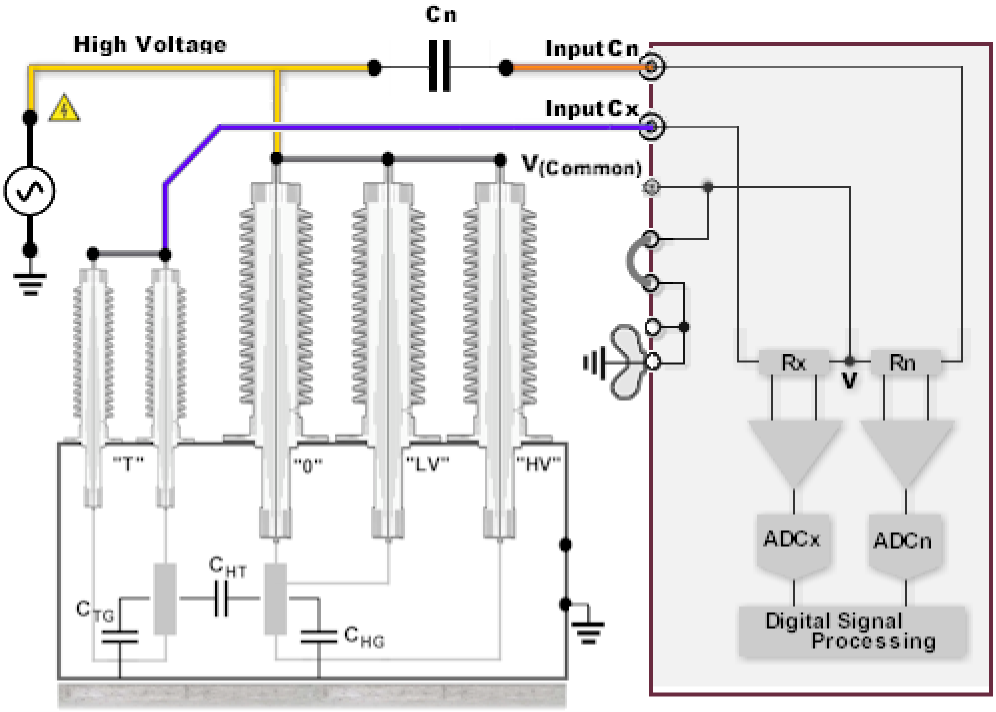
Autotransformers (3 phase and single-phase)

Contrary to the two-winding transformer the windings of an autotransformer can not be separated. The winding of an autotransformer is a combination of the high- and low-voltage windings (HV and LV, see figure below).

For testing the insulation of an autotransformer all seven bushings (three bushings for a single-phase unit) have to be connected together (HV1+HV2+HV3+LV1+LV2+LV3+0).

For a conventional autotransformer without a tertiary winding only an overall test to ground can be performed (C_{HG}).

If an autotransformer is equipped with a tertiary winding which is accessible, the test procedure is exactly the same as described in section “Two Winding Transformer”.



Measurement connections of an autotransformer with tertiary winding for measurement of C_{HT}

Test Connections

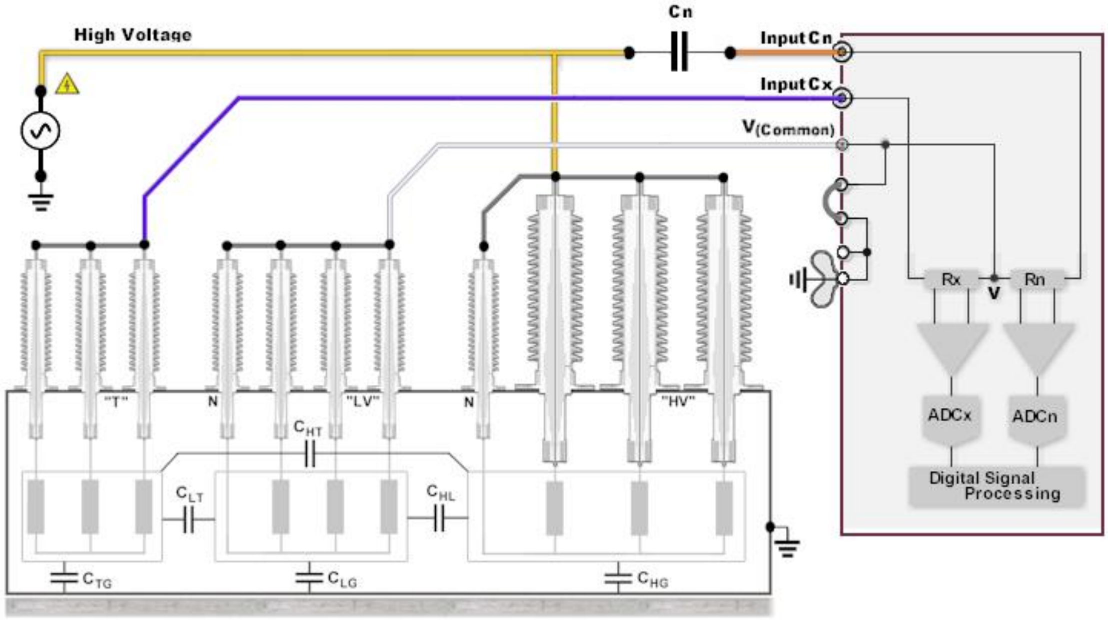
DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	Bridge	High Voltage to
C_{HT}	T	Tank GND	UST	Closed	HV+LV+0
C_{HG}	Tank GND	T	GST	Open	HV+LV+0
C_{TG}	Tank GND	HV+LV+0	UST	Closed	T
C_{TG} + C_{HG}	Tank GND	-	GST	Open	HV+LV+0+T

Note: Test line #4 can be used to inter-check the measurement results. (#4 = #2 + #3). Additional measurements in other test modes can be executed to inter-check the measurements results.

Three Winding Transformers (3 phase and single-phase)

The test technique for a three-winding transformer is an extension of the two-winding transformer test procedure.

In some cases a three-winding transformer is so constructed that one of the interwinding capacitances is practically non-existent. This condition may be the result of a grounded electrostatic shield between two windings, or of a concentric-winding arrangement which places one winding between two others. The effect of the grounded shield of the sandwiched winding is to effectively eliminate the interwinding capacitance except for stray capacitances between bushing leads.



3 phase, 3 winding transformer in Yn-Yn formation with tertiary winding. Connections for measurement of C_{HT}

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	High Voltage to
C_{HT}	T	LV, Tank GND	UST	HV
C_{HG}	Tank GND	LV, T	GST	HV
C_{HL}	LV	T, Tank GND	UST	HV
C_{LG}	Tank GND	HV, T	GST	LV
C_{TG}	Tank GND	LV, HV	GST	T
C_{LT}	LV	HV, Tank GND	UST	T
C_{HG+} C_{LG} C_{TG}	Tank GND	-	GST	HV+LV+T

For the **GST** test mode the **HV supply must not be grounded** ! Connect the Low of the HV supply with $V_{(Common)}$ and **open the bridge** between Earth and $V_{(Common)}$ on the back panel.

Note: Test line #7can be used to inter-check the measurement results. (#7= #2 + #4 + #5) additional measurements in other test modes can be executed to inter-check the measurements results.

Measuring Data Interpretation

If available the dissipation factor and the capacitances should be compared with factory data, with previous test results and with test results on similar units.

Capacitance is a function of winding geometry, and is expected to be stable with temperature and age. A change of capacitance is an indication of winding movement or distortion such as might occur as a result of a through fault. Such a fault affects mainly the C_{LG} and C_{HL} insulations.

Increased dissipation factor values normally indicate some general condition such as contaminated oil. An increase in both dissipation factor and capacitance indicates that contamination is likely to be water.

Modem oil-filled power transformers should have insulation power factors of 0.5% or less at 20°C. There should be a justification by the manufacturer for higher values, and assurance that they are not the result of incomplete drying. Older power and distribution transformers may have power factors higher than 0.5%.

Abnormal power factors are occasionally recorded for inter-winding insulations of two-winding transformers. These may be the result of improper (high-resistance) grounding of the transformer tank, or the use of grounded electrostatic shielding between transformer windings. In this case, as a result of the ground shield, the inter-winding capacitance is practically non-existent except for stray capacitances between bushing leads.

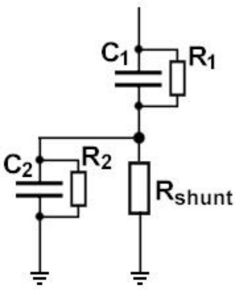
Although the bushings are included in C_{LG}, C_{HG}, the effect of a single bushing on the measuring value may be small, depending upon the relative capacitance of the bushing and the overall C_{LG}, C_{HG} component. It is possible that a defective bushing may go undetected in an overall test because of the masking effect of the winding capacitance. It is imperative that separate tests should be performed on all transformer bushings.

The Transformer windings must remain short-circuited for all bushing tests and all bushings connected to deenergized windings shall be connect to the V-point (if not done by the test mode).

Bushings with potential or dissipation factor taps may be tested separately. See also section “Test Procedure Bushings”.

Note: For regular comparison measurements normal UST- mode measurements should be sufficiently accurate and are reproducible when measured directly afterwards or after a longer period of time.

To obtain the exact dissipation factor of the capacitance C1 obtained by a UST- measurement on a transformer, an additional calculation should be made to correct for the dissipation factor error.



This dissipation factor error is caused by the physical phenomenon, that there is always the influence of one or more parallel capacitances C2 to Rshunt (e.g. CLG or CHG on a two winding transformer), which can not be excluded during an UST- mode measurement.

The dissipation factor error caused by the influence of the always parallel capacitance C2 to Rshunt (e.g. CLG or CHG), is in most cases negligible.

Only in the rare cases that the Rshunt will switch to the highest value of 200 Ω and the parallel capacitance (C2) to the Rshunt is relatively high, the error becomes significant. The Rshunt will switch to the highest value of 200 Ω, when the current measured through the Rshunt is smaller than 3mA. This will only occur when the capacitance C1 to be measured has a very low value (e.g. 50~100pF) or when the test voltage applied to the capacitance to be measured C1 is very low.

Therefore the following formula may be used to calculate the dissipation factor error :

Dissipation factor error = $R_{shunt} * \omega * C2$.

The exact dissipation factor will be the dissipation factor as displayed by the unit subtracted by the dissipation factor error :

$\tan\delta$ (exact) = $\tan\delta$ (2880) - $R_{shunt} * \omega * C2$.

16.2.2 Current Transformers

Current transformers (CTs) convert high transmission line current to a lower, standardized value to be handled by instrumentation. The measures are used for network control, protection and revenue metering.

Current transformers have voltage ratings from several kilovolts up to the highest system voltages now in operation. Conventional CTs are oil-filled but since several years CTs are also available as a dry type version, normally filled with SF_6.

Test Voltage

For current transformers a convenient test voltage should be chosen, which is equal to or below the nameplate rating.

For dry type CTs a the test voltage of 10% to 25% above line-to-ground operating voltage can be applied.

Sometimes it might be useful to investigate abnormal results on the units by making a series of tests at several voltages to determine if the condition causing the abnormal result is nonlinear or voltage sensitive within the range of possible Test Levels. For example a test sequence of 2 kV, 10kV and 12kV may be used.

Test Procedure

Current transformers are tested in the same manner as two winding transformers (see section "Power and Distribution Transformers").

As for all transformer tests, the device under test must first be isolated, deenergized and grounded. For the dissipation factor test the high voltage cable should be applied to the shorted terminals of the primary winding. The secondary winding should be shorted and grounded.

For current transformers which are tested in storage, the frame must be grounded externally.

Some HV CTs are equipped with taps similar to those on bushings. For these units a supplementary test can be performed, in addition to the overall test. The main insulation C1 (between tap and conductor) and the tap insulation C2 (between tap and ground) can be tested separately. Current transformers with such taps often have nameplate values of dissipation factor and capacitance C1, C2.

As already indicated in section "Bushings", the test potential applied to the tap must not exceed the voltage rating of the tap.

Measuring Data Interpretation

CT dissipation factors are corrected based on the ambient temperature at the time of test. Oil-filled units use the curve "Oil-Filled Instrument Transformers" while askarel-filled units are corrected using the curve "Askarel". Dry-type units are not corrected for temperature.

The corrected dissipation factors should be compared with previous test results, with data recorded for other similar units on the system and against factory or nameplate data.

Dry-type CTs can be further analyzed base on dissipation-factor tip-up.

16.2.3 Voltage Transformers

A huge variety of different kinds of voltage (or potential) transformers makes a complete disquisition in this manual impossible. Therefore only one of the most famous and widespread voltage transformer is presented here. It is the capacitor voltage transformer (CVT) as available for example by ABB (type CPA) or by Trench (type WE).

A capacitor voltage transformer consists basically on a capacitor voltage divider and an inductive/electromagnetic unit. The electromagnetic unit includes a transformer and a reactor whose inductance is adjusted in resonance to the equivalent capacitance of the voltage divider. The secondary voltage of the electromagnetic unit is proportional to the primary voltage and differs in phase from it by an angle which is approximately zero.

The appropriate standard for testing capacitor voltage transformers are IEC 600186 and IEC 600358.

Test Procedure

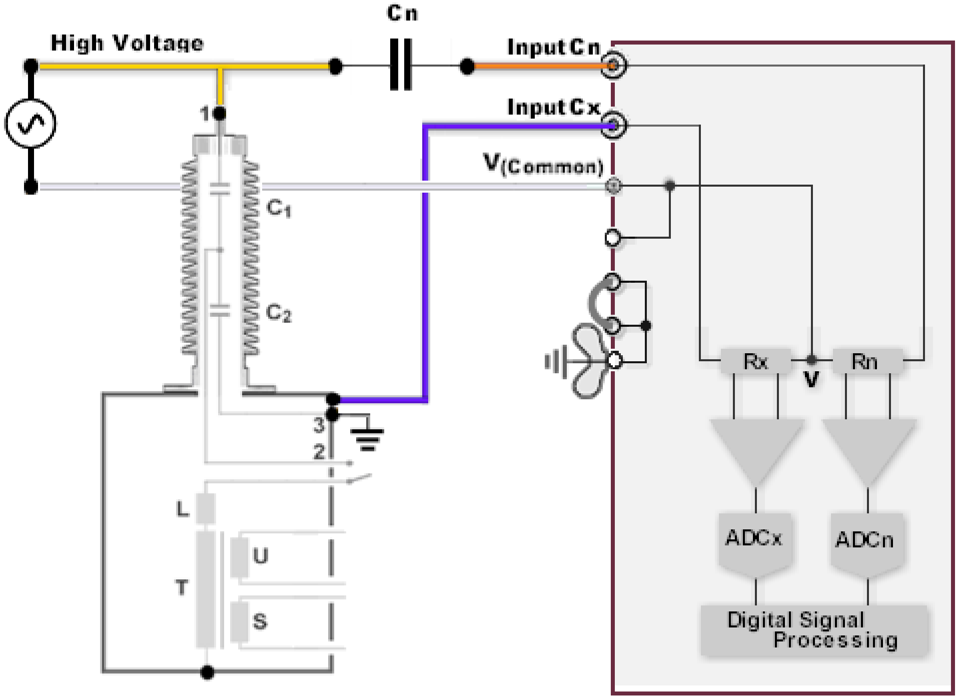
Before any attempt is made to measure a voltage transformer, the unit should be isolated, deenergized and grounded effectively.

For test purpose the inductive unit of a capacitor voltage transformer can be disconnected from the capacitor voltage divider. This allows beside the overall test (voltage ratio, phase displacement) separate measurements about the condition of the voltage divider and the electromagnetic unit.

A test procedure with the corresponding test modes is shown in the figure below. The connection between the intermediate voltage of the voltage divider and the tuning reactor must be opened. Then the capacitance and the loss factor of the capacitor voltage divider can be measured as outlined in the table below.

Since the high voltage winding of the transformer is not capacitive graded, a measurement of the loss angle (tan δ) will give no significant results. More meaningful tests would be secondary/ adjustment winding resistance measurements and oil sample analysis.

The applied test voltage for the capacitor voltage divider should be chosen between 90 – 110% of the rated voltage. In order to reveal any change in capacitance due to the puncture of one or more elements, a preliminary capacitance measurement can be made at a sufficiently low voltage (less than 15% of rated voltage). If the rated voltage exceeds the maximum available test voltage, measurements should be performed at the maximum test voltage.



Capacitor voltage transformer test procedure

C1, C2	Capacitor voltage divider
L	Tuning reactor
T	Primary winding
S	Secondary winding
U	Ferro resonance damping winding

Test Connections

DUT	Test Mode	High Voltage to	INPUT Cx to	$V_{(Common)}$ to
$C_1 \| C_2$	GST	1	3	Supply Low

Measuring Data Interpretation

Measurement results should be compared with earlier measurements on the same apparatus, on similar units and with manufacturer data.

Generally the measured capacitance value should not differ from the rated capacitance by more than –5% to +10%. The ratio of the capacitances of any two units forming a part of a capacitor stack shall not differ by more than 5% from the reciprocal ratio of the rated voltages of the units.

The capacitor losses (tanδ) should be agreed upon between manufacturer and purchaser.

If the dielectric system of the capacitor divider varies with the voltage, it can be meaningful to perform measurements at several voltages to determine if the effect is nonlinear or voltage sensitive.

16.3 Shunt Reactors

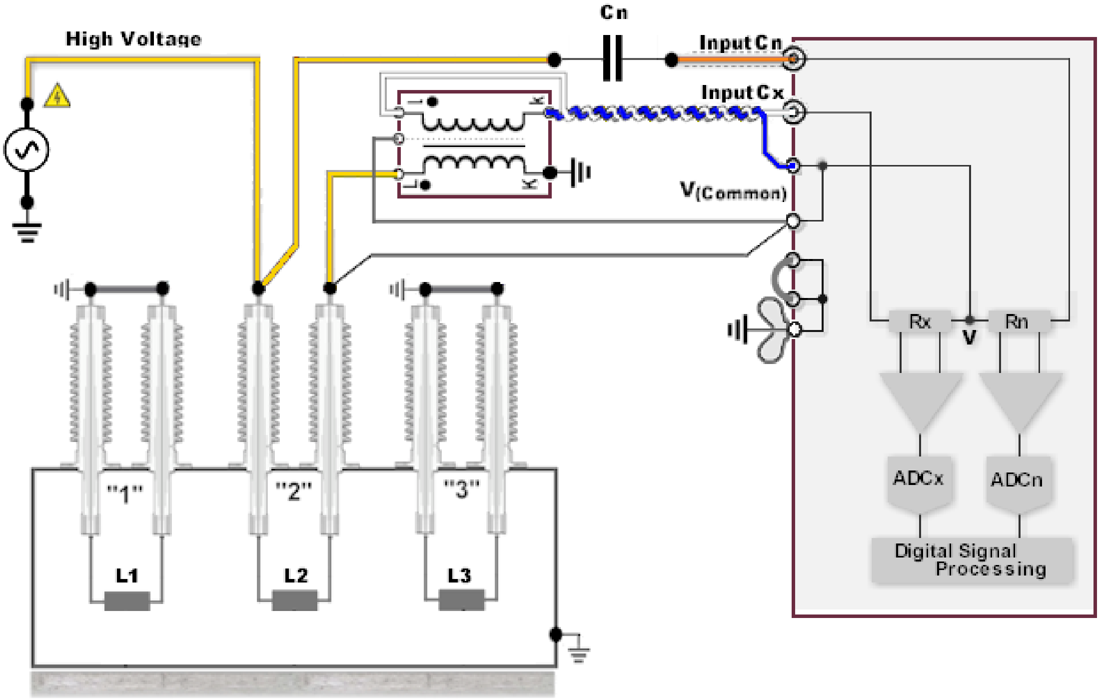
Oil-filled shunt reactors are used in HV systems to limit over-voltage surges associated with long transmission lines. The shunt reactor compensates the capacitive generation on power lines to avoid non-controlled voltage rise especially on lightly loaded lines.

Two configurations of shunt reactors are available: either each phase is contained in its own separate tank or all three phases are contained in a common tank.

If shunt reactors < 30kV shall be measured:
→ **Use a standard capacitor Cn of 1000pF**, with smaller types accuracy will decrease

16.3.1.1 Inductance measurement

To determine the inductance of shunt reactors normally a current higher than 15A is needed to measure. Therefore the connection diagram here is together with a current comparator.



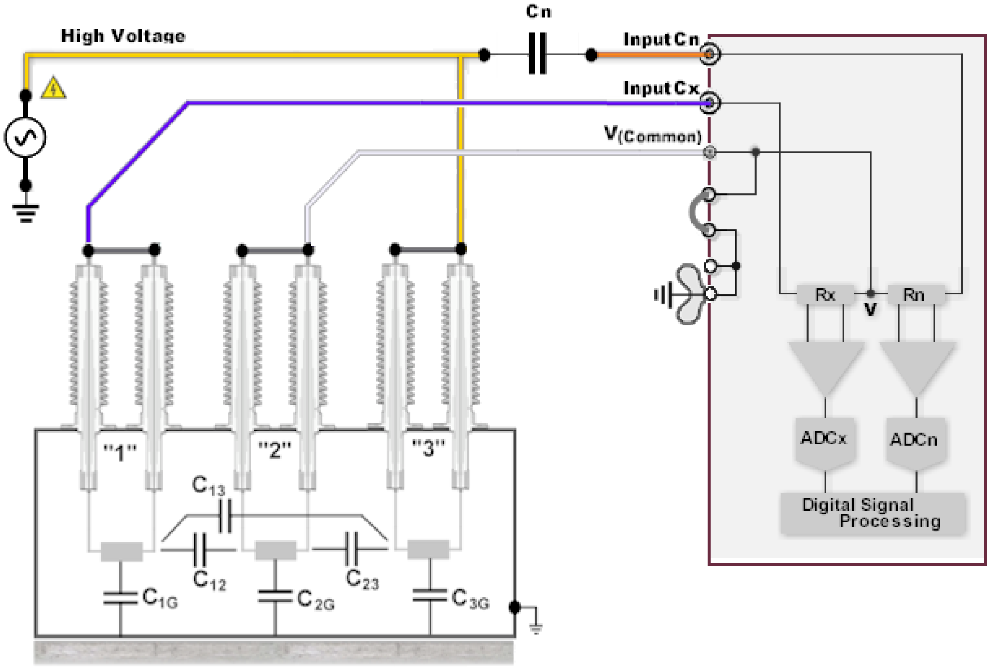
3 phase shunt reactor; measurement configuration "B" shown for measurement of inductance L2

Measure the two other inductances L1 and L3 in the same manner.

For further information about the different measuring configurations see chapter "Use of Current Comparator CC"

16.3.1.2 Insulation measurement

If the insulation of the shunt reactor shall be tested use the following connection:



3 phase shunt reactor; measurement connections for measurement of C_{13}

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	High Voltage to
C_{1G}	Tank, GND	2, 3	GST	1
C_{12}	2	3, Tank, GND	UST	1
C_{13}	3	2, Tank, GND	UST	1
C_{23}	3	1, Tank, GND	UST	2
C_{2G}	Tank, GND	1, 3	GST	2
C_{3G}	Tank, GND	1, 2	GST	3
$C_{1G} + C_{2G} + C_{3G}$	Tank, GND	-	GST	1 + 2 + 3

For the **GST** test mode the **HV supply must not be grounded** ! Connect the Low of the HV supply with $V_{(Common)}$ and **open the bridge** between Earth and $V_{(Common)}$ on the back panel.

Note: For a single-phase shunt reactor only the overall measurement is made, by short-circuiting the winding and making a GST measurement (above table, row #1)

The overall winding dissipation factors should be corrected for top oil temperature. The dissipation factors are analyzed in the same manner as power transformers.

The test results can be supplemented by tests on the bushings, on oil samples, and by excitation-current measurements on the individual phases.

16.4 Rotating Machines

Approximately 70% of breakdowns of big rotating machines are ascribed to problems of the winding insulation. These insulation problems are mainly caused by voids which allow localized ionization processes (partial discharge). As a consequence the temperature can increase locally (hot spots) until a breakdown occurs which results in a short-circuit.

The main purpose of capacitance and dissipation factor tests on rotating machines is to assess the extent of void formation within the winding insulation. The measurements will also reveal potential problems due to deterioration, contamination, or moisture penetration.

Test Levels

For evaluating the extent of insulation deterioration caused by ionization a power factor (dissipation factor) tip-up test can be used. In this test, the dissipation factor is measured at two different voltages, the first low enough so that no ionization occurs (normally 25 percent of rated line-to-ground voltage), the second at rated line to ground voltage or slightly above it. The tip-up value is obtained by subtracting the value of the dissipation factor measured at the lower test voltage from that measured at the higher test voltage.

When the dissipation factor increases significantly above a certain voltage, it is evident that ionization is active and producing some loss.

Sometimes it might be helpful to perform the tip-up test at more than only two voltages. For example if the first measurements show an abnormal tip-up a second test sequence with 20% , 40%, 80%, 100% and 125% of the rated voltage can be executed. This can give the a deeper insight into the aging mechanism of the tested insulation.

16.4.1 Test Procedure

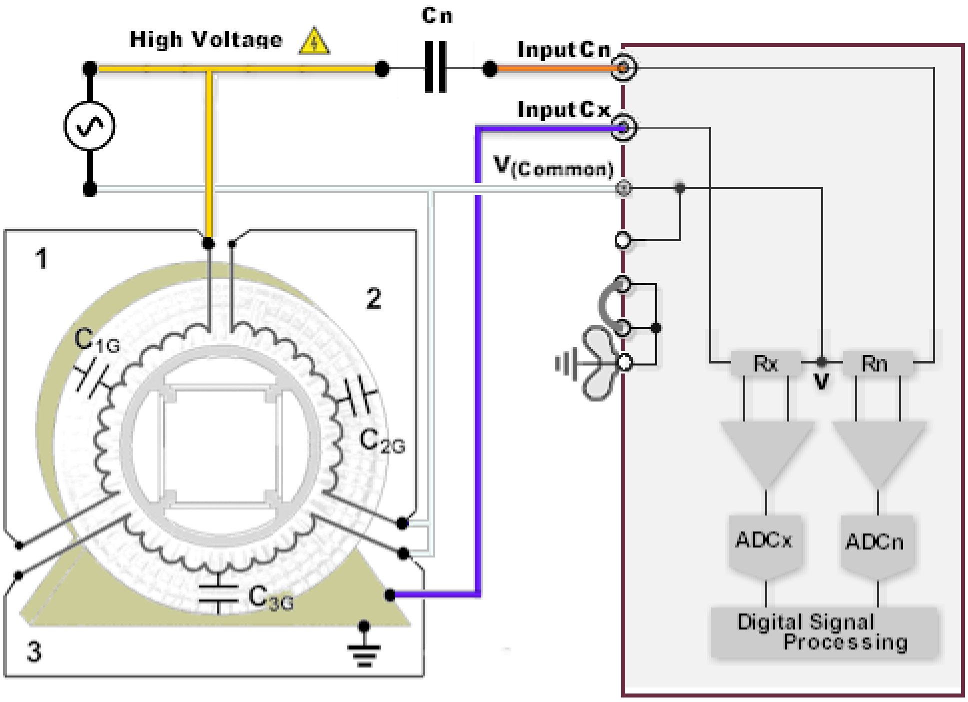
An overall measurement on a rotor or stator winding will proof the insulation condition between the winding and ground. If the connection between the winding phases and neutral can be conveniently opened the inter-winding or phase-to-phase insulation can also be measured.

When a tip-up test is made on a complete phase winding, the average dissipation value is measured. Therefore an isolated section having an abnormally high tip-up may be completely masked.

The temperature of the windings should be above and never below the ambient temperature to avoid the effects of moisture condensation on the exposed insulating surface. Temperature measurements when using temperature correction (if data available) should be based on that at the winding surface.

Prolonged exposure to high humidity conditions before testing should be avoided because such exposure may result in moisture absorption in the insulating materials. It is desirable to make tests on the winding insulation shortly after shutdown.

The figure below shows the specific connections between the test set and a typical generator. It is assumed that the connection between the winding phases and neutral can be opened.



Rotating Machine Stator Test connections to measure C_{1G} .

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	High Voltage to
C_{1G}	Casing GND	2 + 3	GST	1
C_{2G}	Casing GND	1 + 3	GST	2
C_{3G}	Casing GND	1 + 2	GST	3
C_{1G} + C_{2G} + C_{3G}	Casing GND	-	GST	1 + 2 + 3

16.4.2 Measuring Data Interpretation

An increase in dissipation factor above a certain voltage is a guide to the rate at which ionization is occurring and gives guidance how the ionization action may be expected to accelerate. If voids are short-circuited when ionization occurs, some increase of capacitance with voltage may also result.

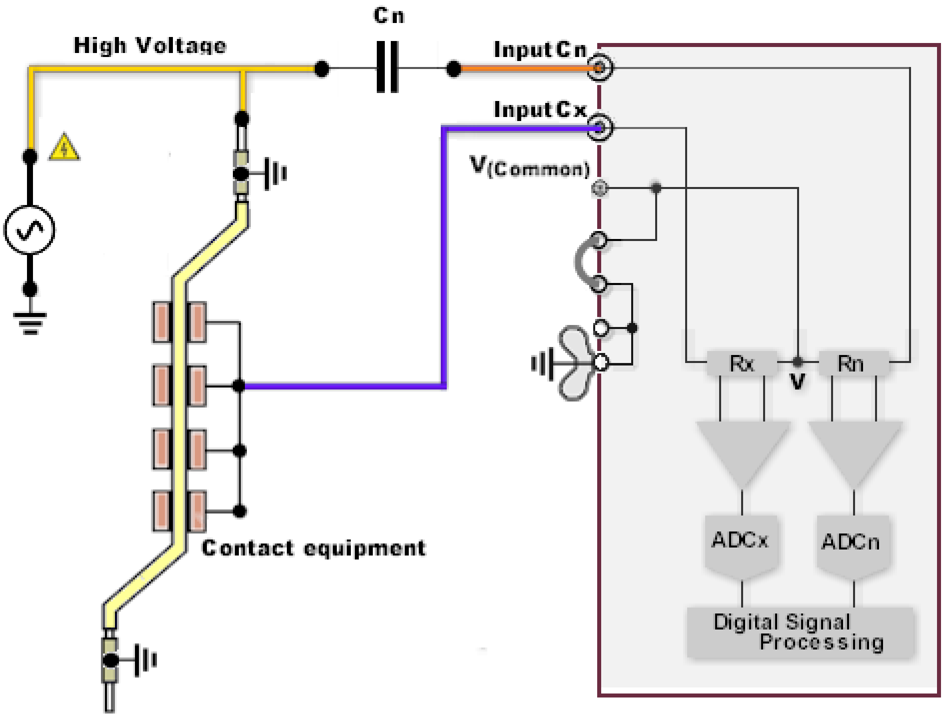
In general, the coils nearest to the line terminals operate at the highest voltage to ground and are therefore most affected by ionization. The remaining life in a winding can often be extended by obtaining dissipation factor versus voltage curves on all coils, replacement only the worst, and regrouping them so that the coils with the least increase of dissipation factor, and preferably lower value of dissipation factor, are nearest the line terminals. Considerable extension of winding life can also be realized in many cases by measuring dissipation factor versus voltage on groups of coils without removal and rearranging the line and neutral connections accordingly. This can be done several times in a lifetime so that the coils are evenly deteriorated.

A reduction in the phase-to-ground capacitance (charging current) of a new winding after an initial period of operation may be an indication of incomplete curing of the winding. This can lead to corona in the slot sections or to a loss of compactness.

The ungrounded specimen tests between phases with a voltage below corona-starting voltage can give some indications about general deterioration, moisture or dirt. Because the stator iron shields the slot sections of the phases from one another, the inter-phase test becomes essentially a test of the exposed end-turn insulation which is affected most by atmospheric contamination.

All measurement results should be compared between phases, with previous test results (if any), with data recorded for similar units on the system, and against factory data (if any). The results should compare closely between phases.

16.5 Testing of Individual Stator Coils and Generator Bars



Measurement of Generator bars

A very important application of dissipation-factor tip-up test is in the measuring of individual stator coils to determine whether they conform to a purchase specification or are within a range deemed to be acceptable.

The tip-up technique is also useful in determining the condition of individual coils for possible reuse in the rewinding of a machine.

Standards of this test can be found in:

- IEC60034-1 (1999) “Rotating Electrical Machines – Rating and Performance”
- IEEE Std 286-2000 “Recommended Practice for Measurement of Power Factor Tip-Up of Electric Machinery Stator Coil Insulation”
- VDE 0530 “Drehende Elektrische Maschinen”

Typical values and limits for stator coils and generator bars according to IEC60034-1 and VDE0530:

Dissipation factor @ 20% rated voltage	max. 0.04	typical < 0.03
Max. Dissipation factor	0.05	
Tip-Up Dissipation factor / kV	0.0025	

Typical phase windings values (measured @ rated voltage 21kV) of a 500MVA generator:

Capacitance	0.27uF
Dissipation factor	0.014

16.6 Liquid Insulation

To test liquid insulation a special oil test cell has been constructed. The oil test cell is basically a capacitor with a liquid insulation as a dielectric constant. The test cell is supplied in an insulated case for simple transportation and for use as insulation of the cell from ground during the test. After each test the cell should be cleaned. If the same type of liquid will be tested, it is sufficient to flush the cell by a portion of the new oil sample, or other oil of the same type. If the cell will be used to test a different type of liquid insulation or is dirty, it should be cleaned with a suitable solvent properly. After cleaning with solvent the cell should be dried. The cell shouldn’t be wiped out with rags to avoid cotton fibers, etc., to be left in the cell and affect the test results of the sample.

To test a representative sample of liquid insulation any dirt or water in the sample should be avoided.

The volume of the test cell is approximately one liter. It should be filled until there is about 2cm of liquid above the top of the cylinder inside the cell; when the cover is replaced, the cylinder of the inner cell should be covered with liquid. If there is an insufficient amount of liquid in the cell, sparking may take place above the liquid level.

The test cell should be placed either at the bottom of the plastic case, or on a suitable insulating material. The reason for undesirable breakdown could be caused by air bubbles, water, and other foreign material in the cell. To prevent such breakdowns the sample should be allowed to settle down before testing. Air bubbles could evaporate and any foreign particles can settle to the bottom.
By rotating slowly the seated inner cell, air bubbles can be released through holes in the inner cylinder.

The test cell is built on the “Outer Cell Electrode” and the removable “Inner Cell Electrode with Cover”

Onsite dissipation factor test cell for liquid insulation including transportation case

16.6.1 Test Procedures

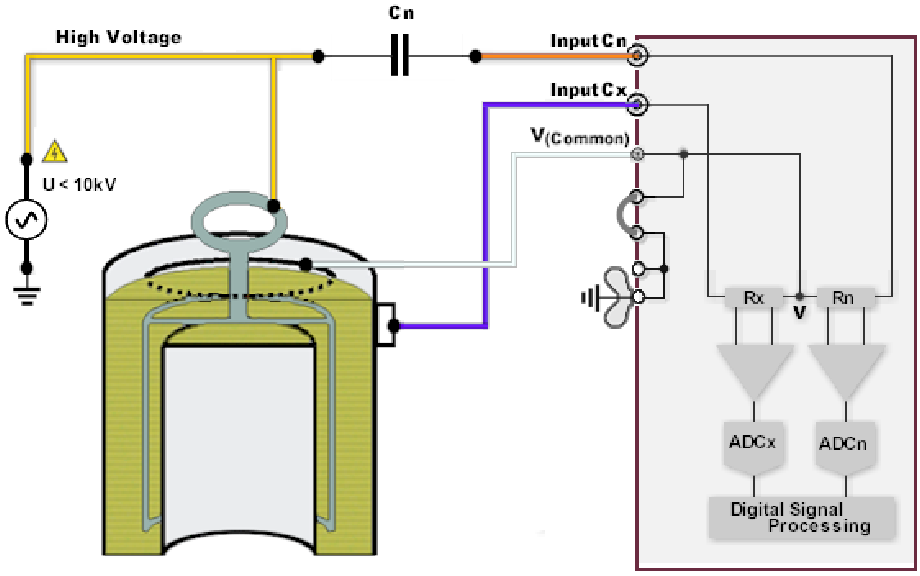
Onsite test cell 6835 connection

The high-voltage should be connected to the handle on the inner cell by using the high voltage cable. The V-potential should be connected to the metallic ring on the inner cell cover, using delivered V connection. The outer cylinder should be insulated from ground and connected either to channel A or B of the measuring bridge by using special connection cables. A clearance of several centimeters should be maintained between the HV connection and the ring which is connected to V-potential, so that flashover will not occur between these parts.

The test voltage should be raised to 10 kV. The radial electrode spacing of the cell is about 6.7 mm, the sample should not break down at this voltage unless it is in very poor condition. If a breakdown occurs before 10 kV is reached, then attempt a measurement at some lower voltage (e.g. 2 kV).

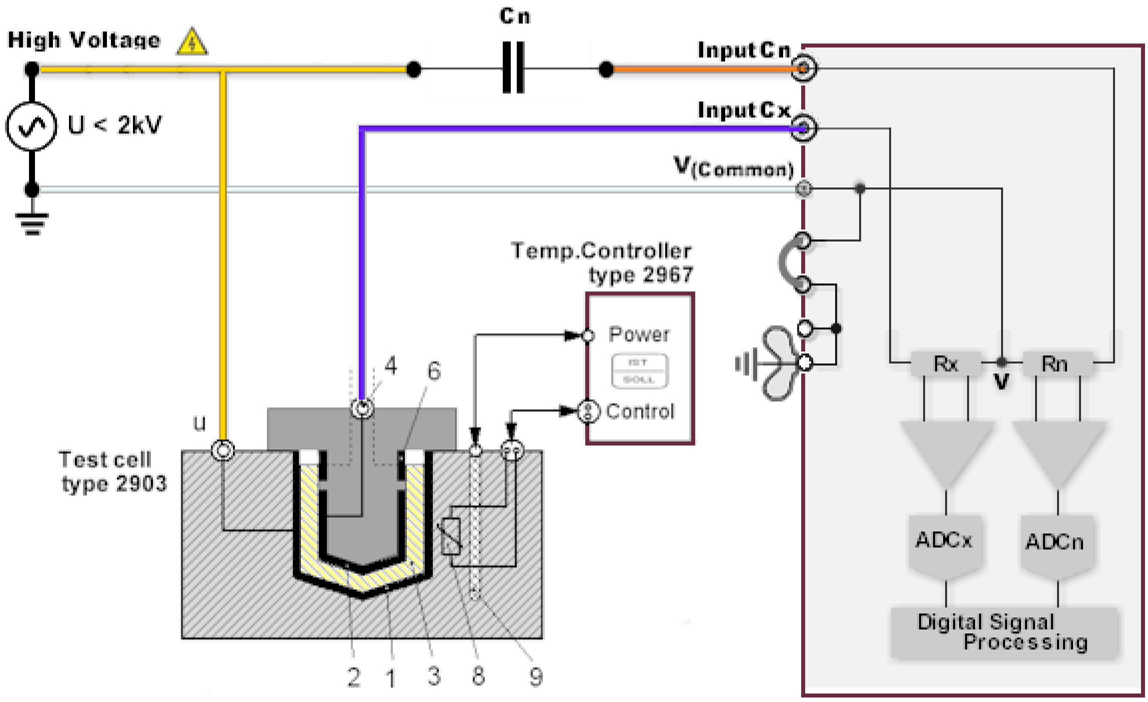
Before the sample is tested, its temperature should be taken. The actual temperature of the sample should be set in Setup – Condition – Temperature and a Temperature Correction Factor should be selected. By choosing the normalized dissipation factor (to 20°C) as a measuring value the automatically calculated value will be recorded.

The Liquid Insulation Test is made by normal UST mode.



The 6835 test cell can be set in the bottom part of the transportation case for this measurement.

Lab test cell 2903 connection



Lab test cell 2903 connection

1 High Voltage electrode
2 Measuring electrode
3 Oil to be measured (Cx)
4 Connection plug of measuring electrode
6 Guard electrode (connected to $V_{(Common)}$ over shield of Cx cable)
8 PT100 temperature sensor
9 Heating element

16.6.2 Measuring Data Interpretation

It is suggested that the following guides serve for grading liquid insulation by dissipation factor tests:

Classification	Dissipation factor @ 20 °C		
	Mineral Oil	Synthetic	Others
Good (new)	< 0.05 %	< 0.05 %	< 0.05 %
Used - usually considered satisfactory for continued service	< 0.3 %	< 0.5 %	< 0.3 %
Used - should be considered in doubtful condition, and at least some type of investigation (dielectric breakdown tests) should be made.	> 0.5 %	> 0.5 %	> 0.5 %
Used - should be investigated, and either reconditioned or replaced. Should be investigated to determine the cause of the high power factor.	> 1.0 %	> 2.0 %	> 1.0 %

Note: High dissipation factors indicates deterioration and/or contamination with moisture, carbon, varnish, glyptal, sodium, asphalt compounds, deterioration products, gasket materials or other foreign products.

Mineral Oil

Carbon or asphalt in oil can cause discoloration. Carbon in oil will not necessarily increase the power factor of the oil unless moisture is also present.

Synthetic Insulation Liquid (e.g. Askarel®)

If the high dissipation factor is caused by water or other conducting matter, free chlorides or a high neutralization number, the synthetic oil is probably an operating hazard. If the high dissipation factor is not due to these causes, it is probably not an operating hazard, except that when the dissipation factor is quite high it may result in excessive heating of the device in which it is used. Care should also be taken that the high dissipation factor is not due to dissolved materials from gaskets or insulation necessary for safe operation of the askarel filled device. High dissipation factor due to askarel contamination may mask other defects in askarel-filled units.

The question of what decision to make regarding the condition of the oil depends upon what is causing the high dissipation factor. Dielectric breakdown or water content tests should be made to determine the presence of moisture. The necessity for further tests will depend to a large extent upon the magnitude of the dissipation factor, the importance of the apparatus in which the insulation liquid was used, its rating, and the quantity of insulation liquid involved.

16.7 Cables

Dissipation-factor tests on cables are useful to indicate general deterioration and/or contamination. An increase in dissipation-factor with test voltage may be an indication of a serious general condition of corona in the insulation.

The measured dissipation-factor is an average of the dissipation-factor of each elementary length of insulation. Therefore, if a long cable is measured, an isolated section of the cable having an abnormally high dissipation factor may be completely masked and have no significant effect on the average value.

Effective dissipation-factor tests can be performed on relatively short lengths of cable (especially on shielded cables and unshielded cables enclosed in a metallic sheath). Tests on cables should be performed from both ends.

Testing of cables generally requires additional precautions because the entire device under test is not always visible. Both ends of the cable under test should be clearly identified and isolated.

Avoid prolonged exposure to high humidity conditions before testing because such exposure may result in moisture absorption in the insulating materials. It is desirable to make tests on the winding insulation shortly after shutdown.

Test Levels

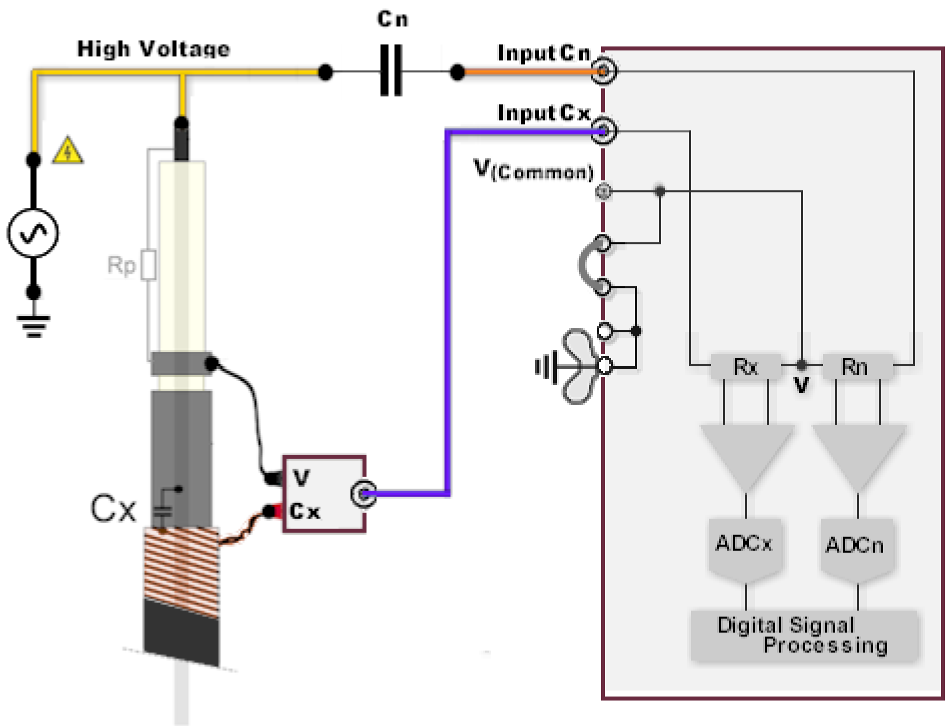
Cables rated up to 15 k V should be tested at several voltages up to the operating line-to-ground voltage. For example, a 15 kV insulation class cable on a 13.8 kV systems normally operated at 8 kV should be tested at several voltages up to 8 kV. Additional a test with 10% to 25% above the operating line-to-ground voltage can be performed to accentuate corona and other high-loss conditions.

Cables rated above 15 kV insulation class should be tested at the highest test voltage possible or at the rated voltage of the DUT.

16.7.1 Test procedures on different cables

Single-Conductor Shielded or Sheathed Cable

The cable should be removed from service and all associated electrical equipment disconnected. The test procedure consists of applying the test voltage to the cable conductor with the cable shield or sheath effectively grounded. The test is made in the UST mode (HV to conductor, Input Cx to shield).



Single-Conductor Unshielded and Unsheathed Cables

Measurements on unshielded single-conductor cables are performed using the UST test mode (HV to conductor, Input Cx to earth). The test results may be affected by material which surrounds the cable (e.g., fibre ducts), or any material that forms the ground return path of the leakage current. This can result in unpredictably high dissipation factors.

3 Phase Individually Shielded Cables

The same procedure as for single conductor shielded cable can be applied for this type of cable. Cable conductors not under test must be grounded. (See the Test Procedure Example and note below.)

3 Phase Unshielded or Unsheathed Cables

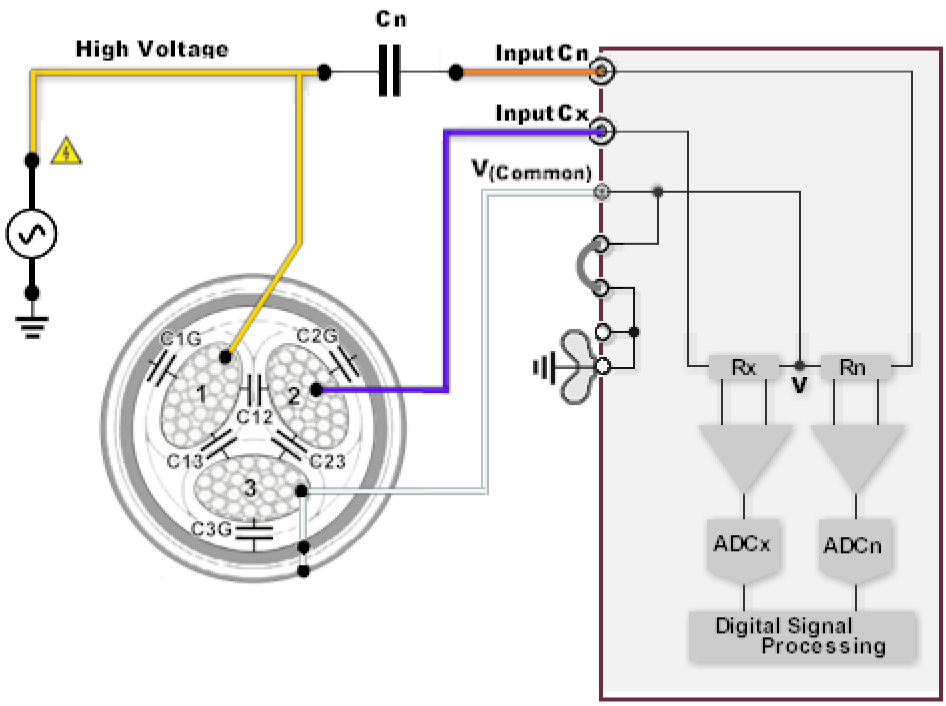
In the case of a three phase unshielded cable a test procedure as outlined for a single-conductor unshielded cable can be performed. Supplementary it is possible, by an UST mode, to perform dissipation-factor measurements between two conductors, which are practically confined to the insulation between the two conductors.

3 Phase Unshielded Cables Enclosed in a Common Metallic Sheath

Each conductor of an unshielded three phase cable should be tested individually with the other conductors and the common sheath grounded. An overall test can be made with all conductors connected together and energized with the sheath grounded. See the Test Procedure Example below.

16.7.2 Test Procedure Example

The figure and table below shows the specific connections with the corresponding test modes of a typical belted three-phase cable. It is assumed that no phase is left floating.



3 Phase Unshielded Cables Enclosed in a Common Metallic Sheath: Test connections to measure C_{12}

Test Connections

DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	High Voltage to
C_{1G}	GND shield	2, 3	GST	1
C_{12}	2	3, GND shield	UST	1
C_{13}	3	2, GND shield	UST	1
C_{23}	3	1, GND shield	UST	2
C_{2G}	GND shield	1, 3	GST	2
C_{3G}	GND shield	1, 2	GST	3
$C_{1G} + C_{2G} + C_{3G}$	GND shield	-	GST	1 + 2 + 3

Note: On 3 Phase Individually Shielded Cables only the capacitances C1G, C2G and C3G are measured in the same manner as described in the table above.

16.7.3 Measuring Data Interpretation

Temperature correction of the dissipation factors for cables is normally not made, since it requires a fairly close approximation of cable temperature, knowledge of the type of insulation and the date of its manufacture. Especially the temperature characteristics of the cable are normally not available and can therefore not be considered.

Evaluation of cable tests should be based on one or more of the following:

- Comparison of power factors obtained for similar insulated cables obtained at time of test and under the same conditions.
- Comparison with previous test results.
- Comparison of results obtained from both ends.
- Comparison with available manufacturer data.

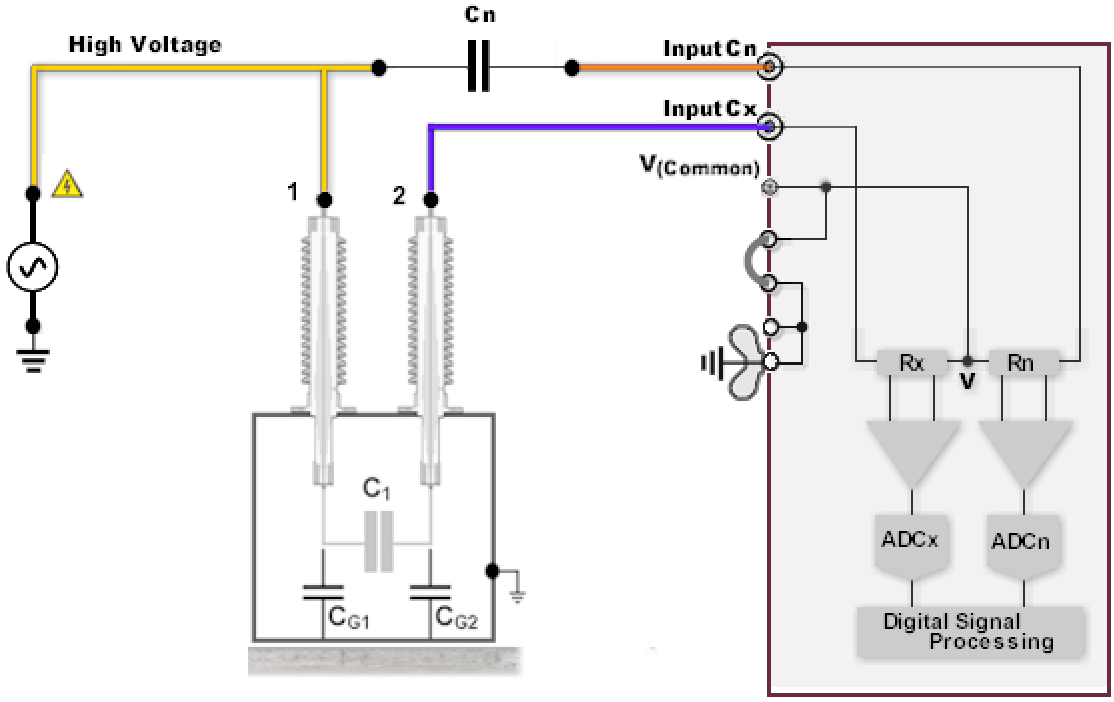
16.8 Capacitors

Capacitor test do check the insulation quality of the device. Normally the dissipation factor should be low and should stay stable as well as the capacitance. Units to be tested are power-factor correction capacitors (cap banks, used to improve the power factor of a high voltage grid), surge capacitors, energy storage capacitors, etc.

Capacitors can be built based on series of single cap modules (e.g. paper-oil coupling capacitor) If one modules shows a problem the result is always the average of all connected modules. So a small change in the measured total value could show a bigger problem in a single module.

Before any measurements are done it must be verified that the capacitor is completely discharged. Bushings and housing must be earthed.

Measurement Procedure



Measurement on an ungrounded two-bushing energy storage capacitor, connection for determination of C1

C_1: main capacitor

C_{G1}, C_{G2}: earth insulation capacitance

Test Connections

DUT	High Voltage to	INPUT Cx to	$V_{(common)}$ to	Test Mode
C_1	1	2	GND	UST
C_{G1}	1	Tank GND	2	GST
C_{G2}	2	Tank GND	1	GST
C_{G1} + C_{G2}	1 + 2	Tank GND	-	GST

Measuring Data Interpretation

When available the measurement results should be compared with the nameplate values or with results obtained in previous measurements.

The power factor of the earth insulation is expected to be in the order of 0.5% or less. The main capacitor should have a much lower power factor.

An increase in capacitance of several percent is an indication of short-circuited layers of the insulation or the dielectric.

⚠ **Measurements with power capacitors and current comparator**
(DF range switching error < 0.5E-5):

Cx < 10uF use Current Comparator ratio 10:1 or higher, Ix (10uF) = 3.1A @ 1KV

Cx = 10 ..20uF, use Current Comparator ratio 20:1 or higher, Ix (20uF) = 6.2A @ 1kV

Cx = 20 .. 50uF, use Current Comparator ratio 50:1 or higher, Ix (50uF) = 15.5A @ 1kV

Cx = 50 ... 200uF, use Current Comparator ratio 100:1 or higher, Ix (200uF) = 62A @ 1kV

Cx = >200uF, use Current Comparator ratio 200:1 or higher (untested)

16.9 Circuit Breakers

For insulation measuring purposes high voltage circuit breakers can be classified into two groups. Live tank breakers whose interrupting chamber is on HV potential and dead tank breakers whose interrupter chamber is accommodated in an earthed metal housing.

The applied test voltage for breakers should not exceed 10% to 25% above their rated operating line-to-ground voltage. That means in formula:

U_{test} = [110% .. 125%] x $U_{rated}/\sqrt{3}$

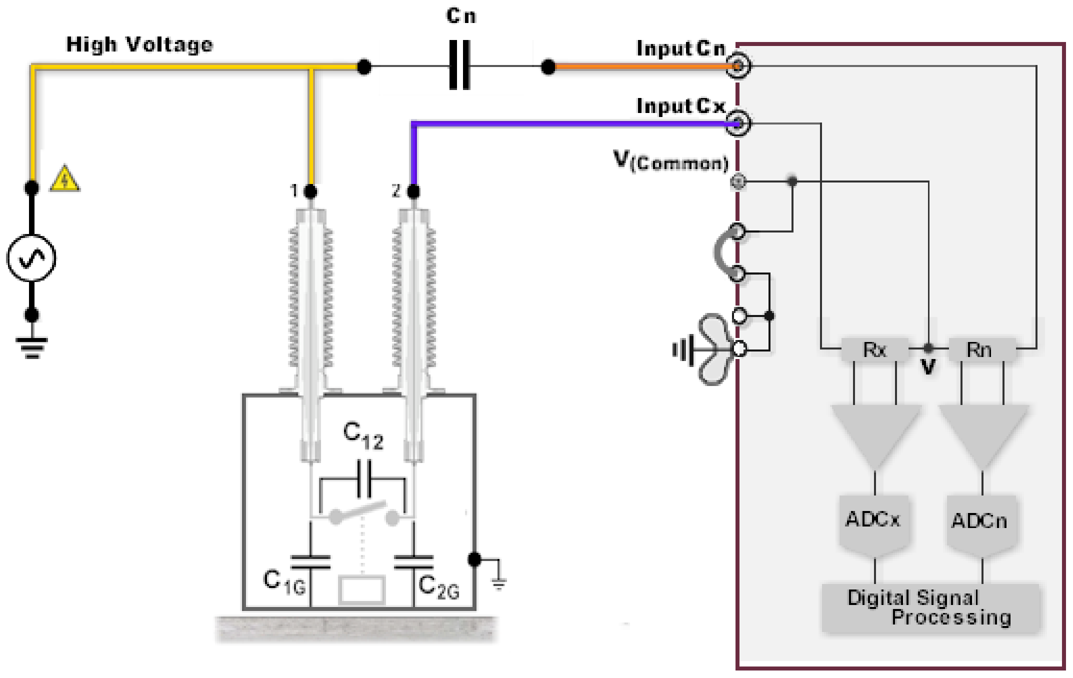
Depending on the nominal line voltage, operating mechanism (spring, hydraulic) and arc-quenching medium (air, oil, sulphur hexafluoride) circuit breakers are sometimes designed with two or more series connected interrupting chambers. For uniformly distributed voltage above the interrupting sections these breakers need grading capacitors across the interrupting chambers.

The following sections will give two examples of a procedure for testing circuit breakers. First a dead tank design is discussed and after the principle of testing a live tank CB with two interrupting chambers is shown.

For simpleness the examples below illustrate the testing procedure of one phase of switchgear. Although some designs have all three phases housed in a single tank, the test procedure and the analysis of the test results can be done on a per-phase basis.

16.9.1 Dead Tank Breaker

The test connections for a Dead Tank Breaker (e.g. ABB PASS type) is outlined below:



Dead Tank Breaker measurement connections for measurement of C_{12}

C_{12}: contact insulation capacitance

C_{1G}, C_{2G}: earth insulation capacitance

Test Connections

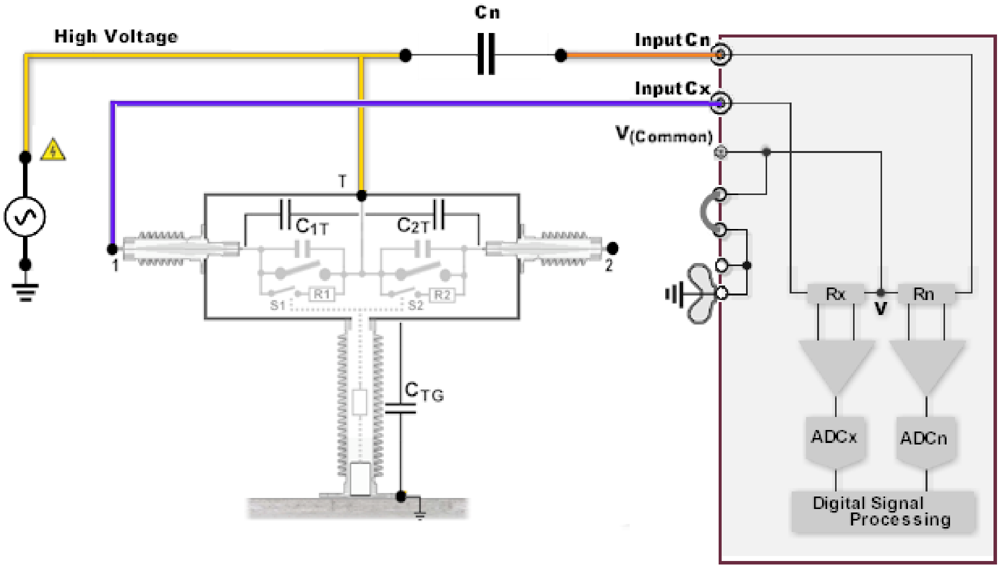
DUT	INPUT Cx to	$V_{(Common)}$ to	Test Mode	High Voltage to	Breaker Status
C_{1G}	Tank GND	2	GST	1	open
C_{2G}	Tank GND	1	GST	2	open
C_{12}	1	Tank GND	UST	2	open
C_{1G} + C_{2G}	Tank GND	-	GST	1 + 2	closed

Note: Test line #4 can be used to inter-check the measurement results. (#4 = #1 + #2). Additional measurements in other test modes can be executed to inter-check the measurements results.

Higher dissipation or power factor could be the result of excessive moisture or by-products of arced SF6 or oil, which have condensed or deposited on internal insulating members. In this case several make-break operations should be performed to verify that the result is reproducible.

16.9.2 *Live Tank Breaker*

The test procedure for a Live Tank Breaker (e.g. SIEMENS 3AP1 type) is shown below:



Live Tank Breaker measurement connections

$C_{1T} = C_{1B} + C_{G1} + (PS_1 + R_1)$

$C_{2T} = C_{2B} + C_{G2} + (PS_2 + R_2)$

C_{1B}, C_{2B}: bushing stray capacitances (undrawn)
C_{G1}, C_{G2}: grading capacitors
C_{TG}: insulation column capacitance
S_1, S_2: breaker switches
PS_1, PS_2: pre insertion switches
R_1, R_2: pre insertion resistors

Test Connections

DUT	INPUT A to	$V_{(Common)}$ to	Test Mode	High Voltage to	Breaker Status
C_{1T}	1	Floor GND, 2	UST	Tank (T)	open
C_{2T}	2	Floor GND, 1	UST	Tank (T)	open
C_{TG}	Floor GND	1, 2	GST	Tank (T)	open
$C_{1T} + C_{2T}$	1, 2	Floor GND	UST	Tank (T)	open

Note: Test line #4 can be used to inter-check the measurement results. (#4 = #1 + #2). Additional measurements in other test modes can be executed to inter-check the measurements results.

Although pre insertion resistors and their switches are included in the sum capacitances of the interrupting chambers (C_{1T}, C_{2T}), the resistors R_1 and R_2 are normally very low resistive and the switches S_1 and S_2 have very low capacitance compared to the bushing and grading capacitors. Therefore the influences of these elements can be neglected.

Higher dissipation or power factor for the bushing/grading capacitor assemblies generally indicate a degradation or contamination of the grading capacitors. The measurement could also be influenced by surface leakage on the bushings. Abnormal capacitance values may be a sign of short-circuited sections of the grading capacitor assembly.

High losses along the insulation column may be caused by surface leakage or moisture, which may have condensed on internal tubes and rods.

16.9.3 Measuring Data Interpretation

The specific term “Tank-Loss Index (TLI)“ was introduced to assist in evaluating the results of the open and closed circuit breaker tests. The TLI index is defined as the real power difference of the measured open circuit and closed circuit for each phase. The open circuit real power value consists of the individual values measured on the two bushings of each phase. The index is calculated as follows:

TLI = (closed-breaker real power value) – (sum of two open-breaker real power values)

A TLI above 0.1W or below –0.2W may indicate a problem in the tank insulation medium, the drive rod or in other auxiliary insulations. In this case further investigations including SF_6/oil sample analysis or partial discharge measurements should be performed immediately

It is important to be aware, that circuit breakers can show complete different characteristics when they are not operated during a long period. Therefore if measurement results are in an unacceptable range, the breaker should be operated several times and the measurement should be performed once again.

If abnormal results are obtained, it is useful to investigate these values further by making a series of tests at several voltages. This can be used to determine if the condition causing the abnormal results is nonlinear or voltage sensitive.

Bushings with potential or dissipation factor taps may be tested separately. See also section “Applications Guide - Bushings”.

16.10 Surge (Lightning) Arresters

Surge arresters protect the electrical system by neutralizing discharge transient currents which are the result of lightning and switching.

The function of a surge arrester is similar to that of a circuit breaker. If a discharge transient current occurs it should close to eliminate the disturbance. After that it must reopen to prevent the flow of system power which would be destructive to itself.

A complete test on a surge arrester involves impulse and over-voltage testing as well as a test for power loss at a specified test voltage using normal 50/60 Hz operating frequency. Impulse and over-voltage testing is generally not performed in the field since it involves a large amount of test equipment that is not easily transportable. Experience has demonstrated that the measurement of power loss is an effective method of evaluating the integrity of an arrester.

On the unit power losses are automatically calculated and can be displayed by selecting the corresponding value “Real Power P” (see chapter “Software – Display of Measurement Values”.

The surge arrester power loss test can reveal the presence of moisture, salt deposits, corrosion, cracked porcelain, open shunt resistors, defective pre-ionising elements and defective gaps.

Exercise extreme care when handling arresters suspected of being damaged, since dangerously high gas pressures can build up within a sealed unit. Everyone is instructed to stand clear during the testing of surge arrestors because of the possibility of their violent failure.

16.10.1 Test Levels

Surge arresters are built on a semiconductor or a metal oxide which have a non-linear volt-ampere characteristic. In order to permit meaningful comparisons between different units or older measurement results the test on surge arresters should always be performed at the same test voltage.

The following table gives an overview of recommended Test Levels for several surge arresters.

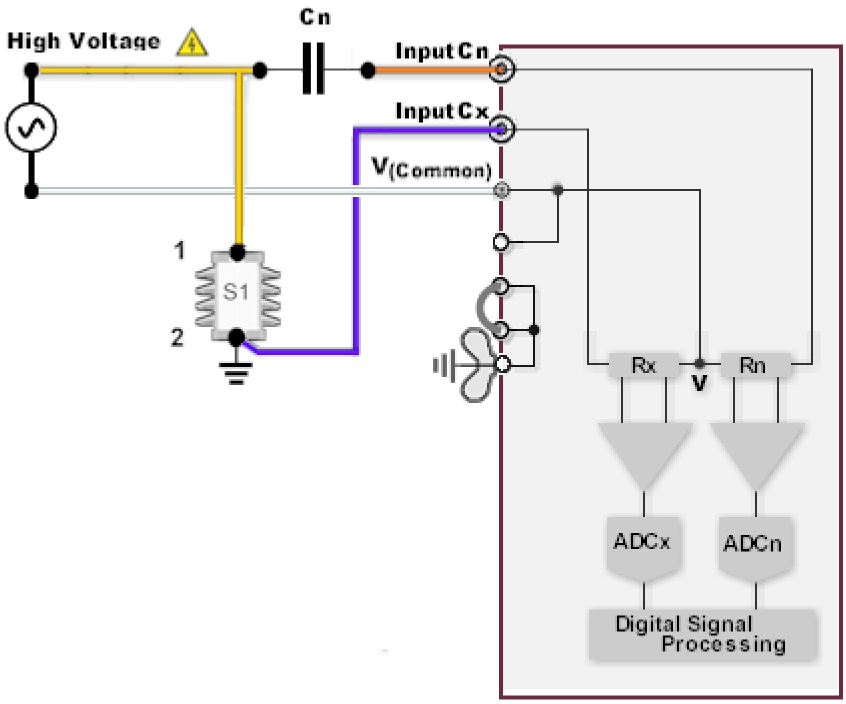
Arrester Type	Arrester Unit Rating [kV]	Test Voltage [kV]
Silicon Carbide	3.0	2.5
	4.5	4.0
	6.0	5.0
	7.5	7.0
	9.0 / 10.0	7.5
	12.0 and above	10
Metal Oxide	2.7 to 3.0	2.0
	4.5 to 12.0	2.5
	15.0 and higher	10.0

16.10.2 Test Procedures

Surge arresters can be equipped with leakage-current detectors or discharge counters. When testing such units the detector or counter should be short-circuited by applying a ground directly to the base of the arrester. The short-circuit must be removed before the arrester is returned to service.

Test Procedure on a Single-Unit Arrester

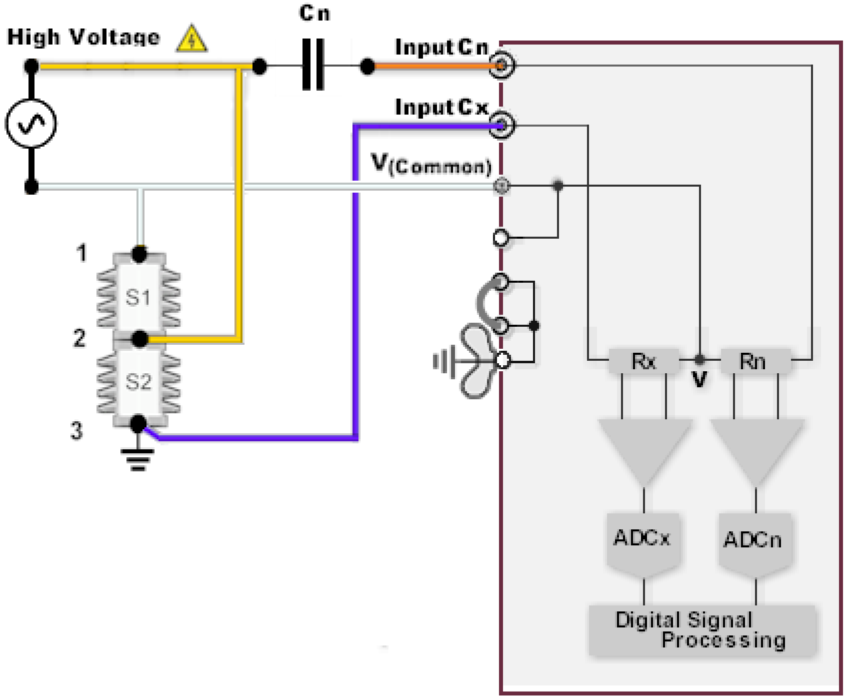
Arrester assemblies consisting of single units per phase can be tested by the grounded-specimen test method (GST). The line connected to the arrester is first de-energized and grounded, then disconnected from the arresters.



Single-unit arrester measurement in GST

Test Procedure on a Double-Unit Arrester Stack

Assemblies consisting of two units per phase are tested in the manner outlined below. Again, the line is de-energized and grounded then disconnected from the arrester stack.

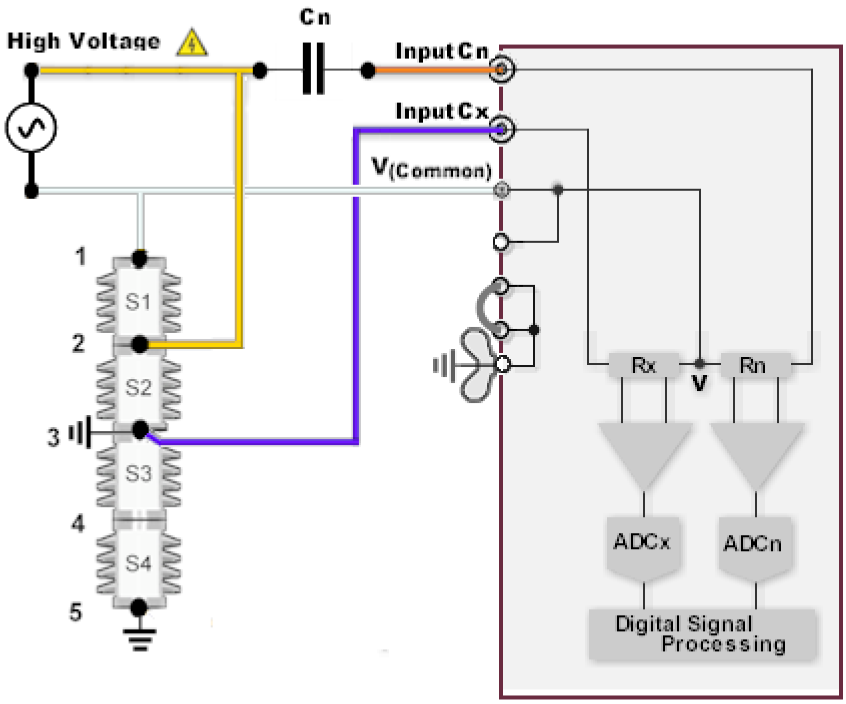


Double unit arrester stack measurement, connection for measurement of S2.

DUT	Test Mode	High Voltage to	INPUT Cx to	$V_{(Common)}$ to	GND
S1	UST	2	1	3	3
S2	GST	2	3	1	3

Test Procedure on a Multi-Unit Arrester Stack

Assemblies consisting of three units or more per phase are tested in the manner outlined in figure 53 on the next page. Again, the line is de-energized and grounded then disconnected from the arrester stack.



Multi unit arrester stack measurement, connection for measurement of S2

DUT	Test Mode	High Voltage to	INPUT Cx to	$V_{(Common)}$ to	GND
S1	UST A	2	1	3 (or 5)	5 + 3
S2	GST	2	3	1	5 + 3
S3	GST	3	4	1	5 + 4
S4	GST	4	5	1	5

16.10.3 Measuring Data Interpretation

Normally it is unnecessary to normalize the measurement result to a standard temperature since most types of surge arresters show only very little temperature dependence. Nevertheless if there is a substantial temperature influence it is useful to establish a temperature correction curve for each arrester design.

Surface leakage must be taken into account when power losses are measured. It can usually be minimized by wiping the porcelain with a plain, dry cloth. In some circumstances it might be necessary to use cleaning agents and waxes or to heat the porcelain surface.

Power loss values should be compared to older measurements or to similar units located under same conditions. If manufacturer data are available, they should be considered first.

Once a range of losses has been established, any deviation, either higher or lower, should be investigated. The following table points out the most important causes if abnormal losses are obtained and the surface leakage can be neglected.

Higher than Normal Losses

- Contamination by moisture and/or dirt or dust deposits on the inside surfaces of the porcelain housing, or on the outside surfaces of sealed-gap housings.
- Corroded gaps.
- Deposits of aluminum salts apparently caused by the interaction between moisture and products resulting from corona.
- Cracked porcelain.

Lower than Normal Losses

- Broken shunting resistors.
- Broken pre-ionising elements.
- Mistake in assembly.
- Poor contact and open circuits between elements.

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