

CP TD1

User Manual



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The product information, specifications, and technical data embodied in this manual represent the technical status at the time of writing and are subject to change without prior notice.

We have done our best to ensure that the information given in this manual is useful, accurate and entirely reliable. However, OMICRON does not assume responsibility for any inaccuracies which may be present.

The user is responsible for every application that makes use of an OMICRON product.

OMICRON translates this manual from the source language English into a number of other languages. Any translation of this manual is done for local requirements, and in the event of a dispute between the English and a non-English version, the English version of this manual shall govern.

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About this manual

This User Manual provides information on how to use the *CP TD1* test system safely, properly and efficiently. The *CP TD1* User Manual contains important safety rules for working with the *CP TD1* and gets you familiar with operating the *CP TD1*. Following the instructions in this User Manual will help you to prevent danger, repair costs, and avoid possible down time due to incorrect operation.

The *CP TD1* User Manual always has to be available on the site where the *CP TD1* is used. The users of the *CP TD1* must read this manual before operating the *CP TD1* and observe the safety, installation, and operation instructions therein.

Reading the *CP TD1* User Manual alone does not release you from the duty to comply with all national and international safety regulations relevant to working on high-voltage equipment.

Safety symbols used

In this manual, the following symbols indicate safety instructions for avoiding hazards.



DANGER

Death or severe injury will occur if the appropriate safety instructions are not observed.



WARNING

Death or severe injury can occur if the appropriate safety instructions are not observed.



CAUTION

Minor or moderate injury may occur if the appropriate safety instructions are not observed.

NOTICE

Equipment damage or loss of data possible

Related documents

The following documents complete the information covered in the CP TD1 User Manual:

Title	Description
CPC 100 User Manual	Contains information on how to use the <i>CPC 100</i> test system and relevant safety instructions.
CPC 100 Reference Manual	Contains detailed hardware and software information on the <i>CPC 100</i> including relevant safety instructions.
CPC 80 User Manual	Contains information on how to use the <i>CPC 80</i> test system and relevant safety instructions.
TESTRANO 600 User Manual	Contains information on how to use the <i>TESTRANO 600</i> test system and relevant safety instructions.
CPC 100 PTM User Manual	Contains information on how to use the <i>Primary Test Manager PTM</i> together with the <i>CPC 100</i> .
CP CR500 User Manual	Contains information on how to use the <i>CP CR500</i> compensating reactor and relevant safety instructions.
CP TC12 Reference Manual	Contains information on how to use the <i>CP TC12</i> oil test cell and relevant safety instructions.
CP CAL1 User Manual	Contains information on how to use the <i>CP CAL1</i> calibration system and relevant safety instructions.
TD1 C-Load User Manual	Contains information on how to use the <i>TD1 C-Load</i> accessory and relevant safety instructions.

1 Safety instructions

1.1 Operator qualifications

Working on high-voltage assets can be extremely dangerous. Testing with the *CP TD1* must be carried out only by qualified, skilled and authorized personnel. Before starting to work, clearly establish the responsibilities.

Personnel receiving training, instructions, directions, or education on the *CP TD1* must be under constant supervision of an experienced operator while working with the equipment. The operator is responsible for the safety requirements during the whole test.

1.2 Safety standards and rules

1.2.1 Safety standards

Testing with *CP TD1* must comply with the internal safety instructions and additional safety-relevant documents.

In addition, observe the following safety standards, if applicable:

- EN 50191 (VDE 0104) "Erection and Operation of Electrical Test Equipment"
- EN 50110-1 (VDE 0105 Part 100) "Operation of Electrical Installations"
- IEEE 510 "IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing"

Moreover, observe all applicable regulations for accident prevention in the country and at the site of operation.

Before operating the *CP TD1* and its accessories, read the safety instructions in this User Manual carefully.

Do not turn on the *CP TD1* and do not operate the *CP TD1* without understanding the safety information in this manual. If you do not understand some safety instructions, contact OMICRON before proceeding.

Maintenance and repair of the *CP TD1* and its accessories is only permitted by qualified experts at OMICRON Service Centers (see "Support" on page 68).

1.2.2 Safety rules

Always observe the five safety rules:

- ▶ Disconnect completely.
- ▶ Secure against re-connection.
- ▶ Verify that the installation is dead.
- ▶ Carry out grounding and short-circuiting.
- ▶ Provide protection against adjacent live parts.

1.3 Operating the measurement setup

The *CP TD1* works as an add-on device to the *CPC 100*, *CPC 80* or *TESTRANO 600* which controls the measurement. In this manual, those devices are collectively named *Control Device* if no specific device is referred to. Do not connect the *CP TD1* to any other device than the *CPC 100*, *CPC 80* or the *TESTRANO 600*.

Only personnel qualified in electrical engineering and trained by OMICRON are authorized to operate the *CP TD1*.

- ▶ Before starting the work, clearly establish the responsibilities.

Personnel receiving training, instructions, directions, or education on the *CP TD1* must be under constant supervision of an experienced operator while working with the equipment.

The operator is responsible for the safety requirements during the whole test.

- ▶ Do not enter the high-voltage area if the red warning light of the *Control Device* is on since all outputs can carry dangerous voltage or current!
- ▶ Always obey the five safety rules and follow the detailed safety instructions in the respective user manuals.

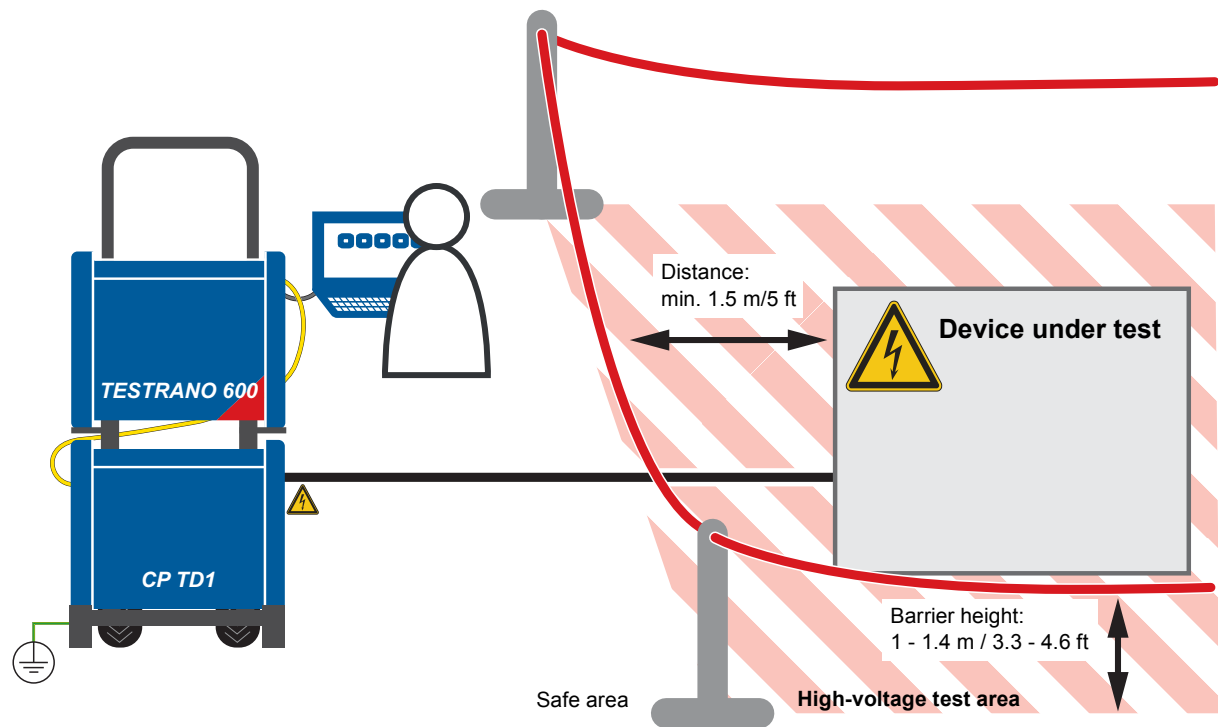


Figure 1-1: Example of the separation of safe and high-voltage area using the *CP TD1* with *TESTRANO 600*

Before performing tests using high voltage, observe the following instructions:

- ▶ Do not use the test equipment without a good connection to substation ground.
- ▶ Do not insert objects (for example screwdrivers, etc.) into any input/output socket.
- ▶ Do not operate the *CP TD1* under ambient conditions that exceed the temperature and humidity limits listed in 12.2 "Environmental Conditions" on page 109.
- ▶ Make sure to position the test equipment on dry, solid ground.
- ▶ Do not operate the *CP TD1* in the presence of explosives, gas or vapors.
- ▶ Opening the *CP TD1* invalidates all warranty claims.
- ▶ Do not use an extension cable on a cable reel to prevent an overheating of the cord; run out the extension cord.
- ▶ If the *CP TD1* does not seem to function properly, do not use it anymore. Please call the OMICRON technical support.

1.4 Handling cables

- ▶ Always turn off the *CP TD1* completely before you connect or disconnect any cable (disconnect the *CPC 100* from mains or press its Emergency Stop button).
- ▶ The high-voltage cable must always be well attached and tightly connected to both the *CP TD1* and the test object. A loose or even falling off connector at the test object carrying high-voltage is life-hazardous. Make sure the connectors are clean and dry before connecting.
At the *CP TD1*, press the high-voltage cable's plug to the connector tightly and turn the screw cap until you feel a mechanical stop. If you notice a rough-running of the screw-cap, clean the screw thread and use a lubricant (Vaseline recommended).
At the test object, insert the high-voltage cables' plugs carefully until you feel a "click" position. Now they are locked. Confirm this by trying to pull them out. This should not be possible now.
Note: Tighten the plugs manually. Do not use any tools for that because that can damage the plugs or connectors.
Insert the yellow banana plug (the high-voltage cable's grounding) into the respective plug socket.
- ▶ Do not connect any cable to the test object without a visible grounding of the test object.
- ▶ The high-voltage cable is double-shielded and therefore safe. However, the last 50cm (20 inch) of this cable have no shield. Therefore, during a test consider this cable a life wire and due to the high-voltage life-hazardous!
- ▶ When the *CPC 100* is switched on, consider this part of the cable has to be in the high-voltage area due to a hazard of electric shock!
- ▶ Never remove **any** cables from the *CP TD1* or the test object during a test.
- ▶ Keep clear from zones in which high voltages may occur. Set up a barrier or establish similar adequate means.
- ▶ Both low-voltage measuring cables must always be well attached and tightly connected to the *CP TD1*'s measuring inputs IN A and IN B.
Make sure to insert the red and blue marked cables into the corresponding measuring inputs: IN A = red, IN B = blue.
Tighten the plugs by turning them until you feel a stop.
Note: Tighten the plugs manually. Do not use any tools for that because that can damage the plugs or connectors.
- ▶ Do not use any other cables than the ones supplied by OMICRON.

1.5 Orderly measures

The CP TD1 User Manual or alternatively the e-book in PDF format has always to be available on site where the *CP TD1* is being used. It must be read and observed by all users of the *CP TD1*.

The *CP TD1* may be used only as described in this User Manual. Any other use is not in accordance with the regulations.

The manufacturer and/or distributor is not liable for damage resulting from improper usage. The user alone assumes all responsibility and risk.

Following the instructions provided in this User Manual is also considered part of being in accordance with the regulations.

Opening *CP TD1* or its accessories invalidates all warranty claims.

1.6 Static charges

Static charges on bushings or other apparatus such as transformer windings may be induced by test potentials. While the voltage may not be significant enough to do any damage to the equipment, it can be a source for serious accidents due to falls caused by reflex action.

High static charges may also be encountered at the bushing capacitance taps if the covers are removed.

► Use safety grounds before handling.

Always observe the five safety rules!

1.7 Disclaimer

If the equipment is used in a manner not specified by the manufacturer, the protection provided by the equipment may be impaired.

1.8 Compliance statement

Declaration of conformity (EU)

The equipment adheres to the guidelines of the council of the European Community for meeting the requirements of the member states regarding the electromagnetic compatibility (EMC) directive, the low voltage directive (LVD) and the RoHS directive.

FCC compliance (USA)

This equipment has been tested and found to comply with the limits for a Class A digital device, pursuant to part 15 of the FCC Rules. These limits are designed to provide reasonable protection against harmful interference when the equipment is operated in a commercial environment. This equipment generates, uses, and can radiate radio frequency energy and, if not installed and used in accordance with the instruction manual, may cause harmful interference to radio communications. Operation of this equipment in a residential area is likely to cause harmful interference in which case the user will be required to correct the interference at his own expense.

Changes or modifications not expressly approved by the party responsible for compliance could void the user's authority to operate the equipment.

Declaration of compliance (Canada)

This Class A digital apparatus complies with Canadian ICES-003.
Cet appareil numérique de la classe A est conforme à la norme NMB-003 du Canada.

1.9 Recycling



This test set (including all accessories) is not intended for household use. At the end of its service life, do not dispose of the test set with household waste!

For customers in EU countries (incl. European Economic Area)

OMICRON test sets are subject to the EU Waste Electrical and Electronic Equipment Directive 2012/19/EU (WEEE directive). As part of our legal obligations under this legislation, OMICRON offers to take back the test set and ensure that it is disposed of by authorized recycling agents.

For customers outside the European Economic Area

Please contact the authorities in charge for the relevant environmental regulations in your country and dispose the OMICRON test set only in accordance with your local legal requirements.

2 Introduction

2.1 Designated use

The *CP TD1* works as an add-on device to the *CPC 100*, *CPC 80* or *TESTRANO 600* which controls the measurement. In this manual, those devices are collectively named *Control Device* if no specific device is referred to. Do not connect the *CP TD1* to any other *Control Device* than the *CPC 100*, *CPC 80* or the *TESTRANO 600*.

The *CP TD1* is an optionally available high-precision test system for on-site insulation tests of high-voltage systems like power and measuring transformers, circuit breakers, capacitors and isolators. With the add-on device *CP TD1*, the *Control Device* increases its range of possible applications into high-voltage measurements.

The internal switched mode power amplifier enables measuring at different frequencies without interferences with the mains frequency. Automatic test procedures reduce the testing time to a minimum. Test reports are generated automatically.

When used with the *CPC 100* or *CPC 80*, the *CP TD1* comes with its own *CPC* test card named **TanDelta** (Tangent Delta), which provides highly accurate measurements of the capacitance C_x and the dissipation factor $\tan \delta$ (DF) or power factor $\cos \varphi$ (PF), respectively.

Additionally, the *CP TD1* measures the following quantities:

- Actual, apparent and reactive power
- Quality factor QF
- Inductance
- Impedance, phase angle
- Test voltage & current

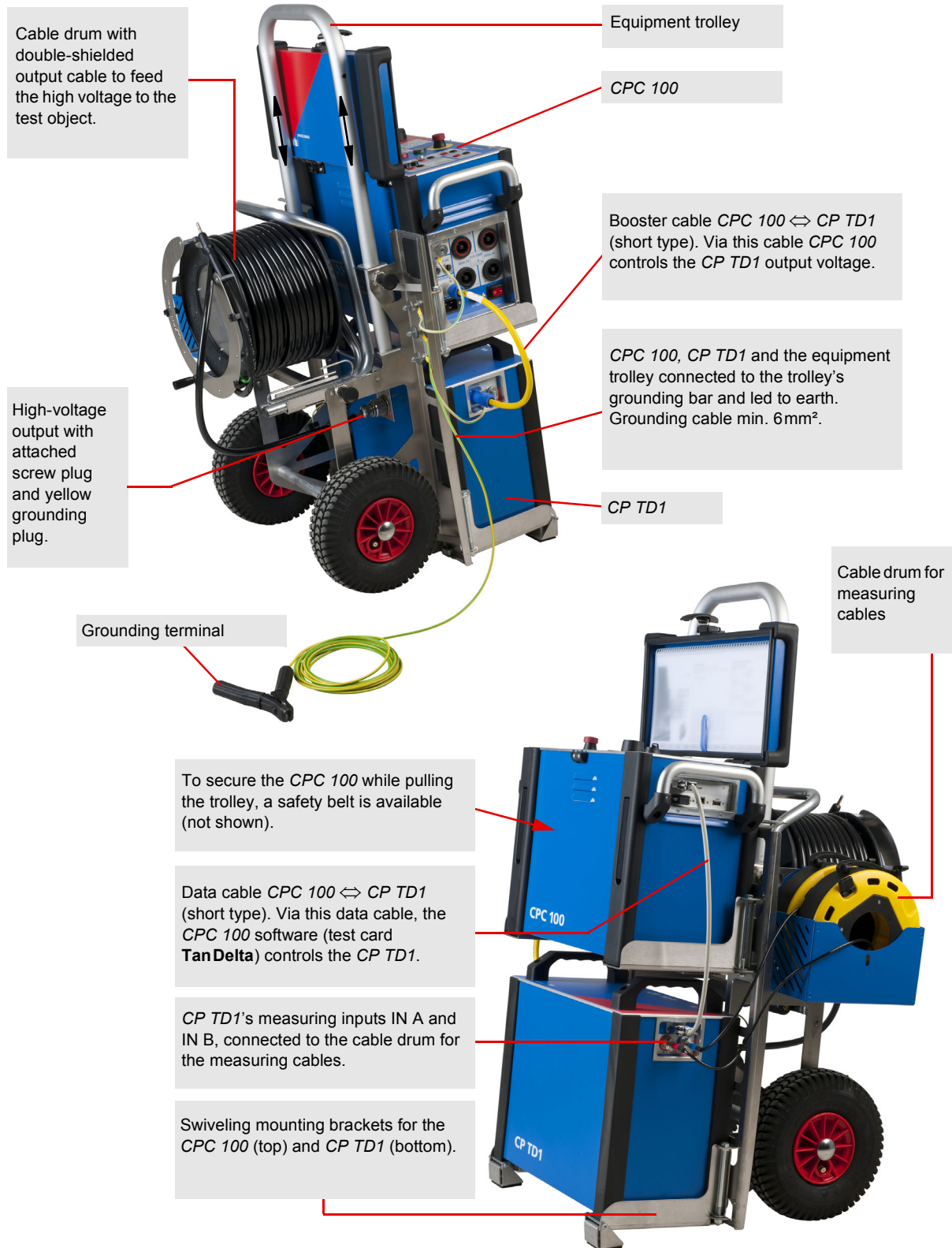
The *CP TD1* can also be used as high-voltage source.

Any other use of the *CP TD1* but the one mentioned above is considered improper use, and will not only invalidate all customer warranty claims but also exempt the manufacturer from its liability to recourse.

2.2 Functional components of the *Control Devices* and the *CP TD1*

On the following pages the functional components of the different *Control Devices* (*CPC 100*, *CPC 80* and *TESTRANO 600*) and the *CP TD1* as well as the trolley options for the different device combinations are described.

2.3 CPC 100 and CP TD1 equipment trolley



2.4 Functional components of the *CPC 100*

2.4.1 *CPC 100* Front panel

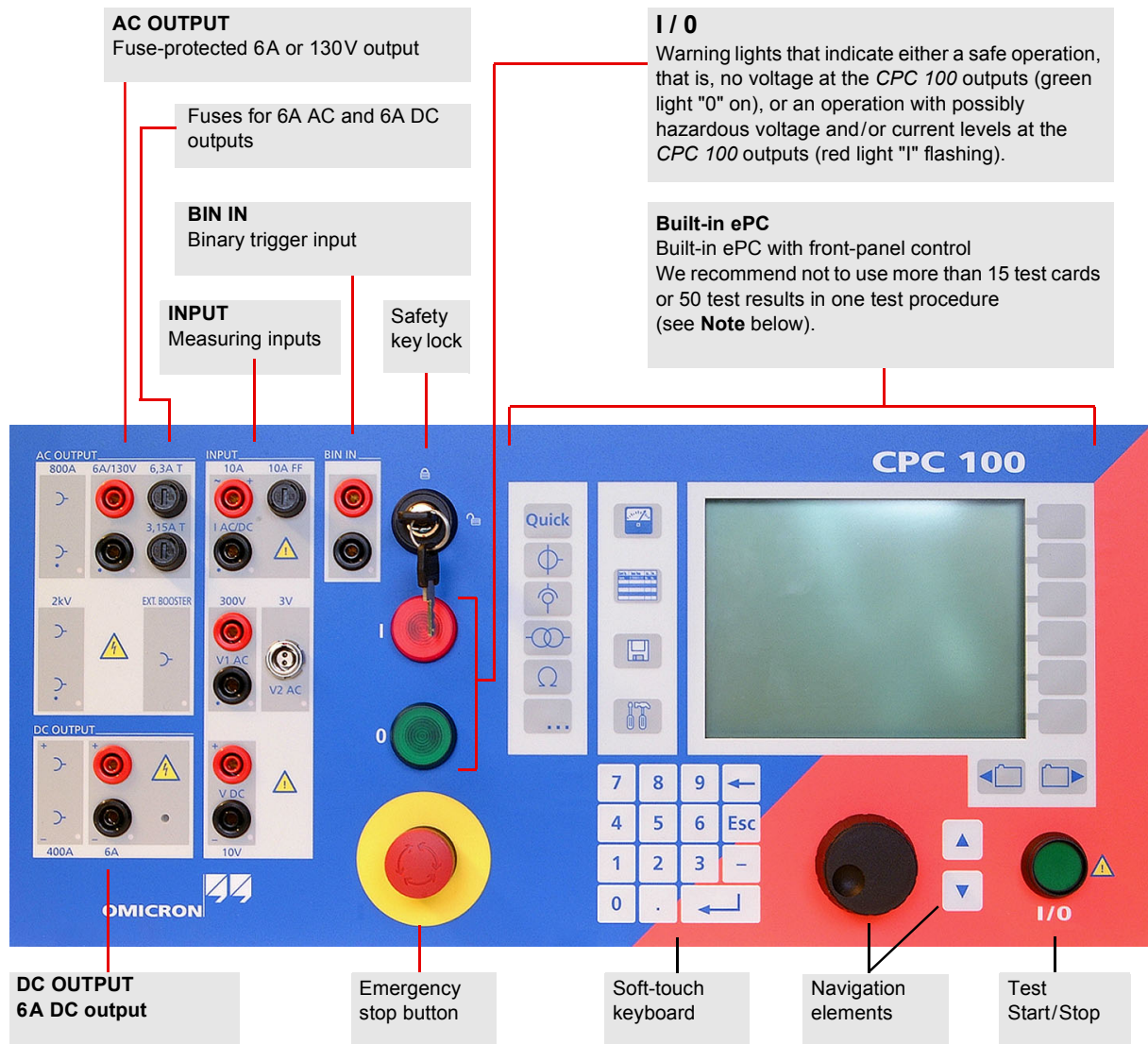


Figure 2-1: *CPC 100* Front panel

Note: With the *CPC 100* V0, the number of test cards in one test procedure should be limited to 15 to avoid memory problems. The *CPC 100* V1 allows using more test cards in one test procedure but we recommend not to use more than 15 test cards or more than 50 test results to keep the tests clearly structured.

2.4.2 CPC 100 High-voltage and High-current outputs

When the *CPC 100* outputs high current, observe the allowed duty cycles that may apply to the selected AC output range. For more information please refer to "CPC 100 outputs" on page 15-273.

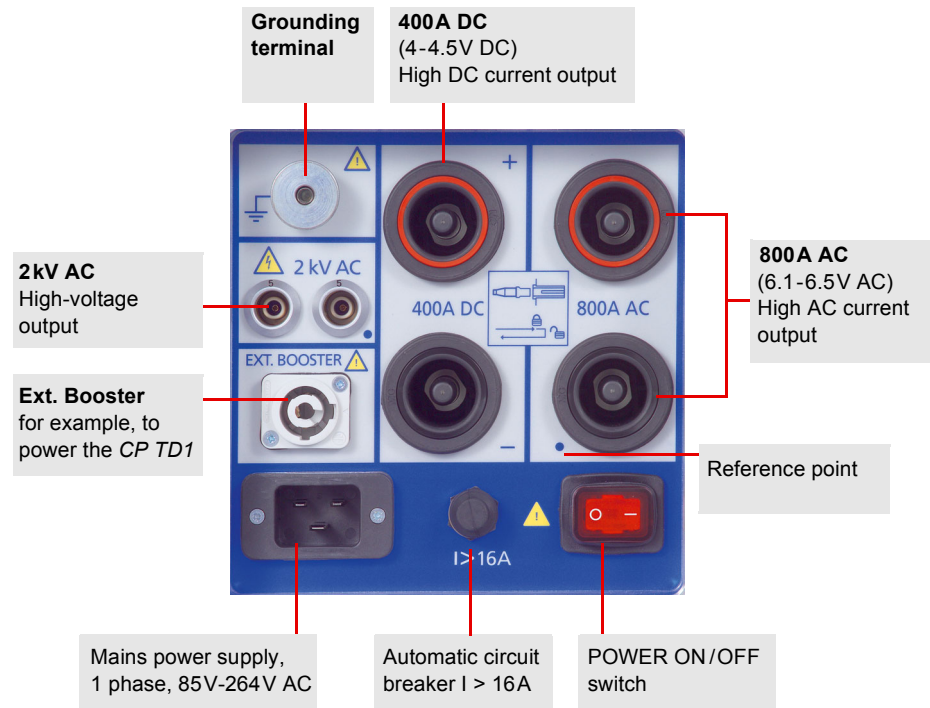


Figure 2-2: High-voltage and high-current outputs on left-hand side of the *CPC 100*

DANGER



Death or severe injury caused by high voltage or current

The connector "Ext. Booster" is always galvanically connected to mains, regardless whether or not an external booster is selected on the software tab **Options | Device Setup**, the green warning light (0) is on, the outputs are turned off or the Emergency Stop button is pressed.

- ▶ Do not use any other booster cables than the ones supplied by OMICRON.
- ▶ Do not use booster cables that are frayed or damaged in any way
- ▶ Handle with extreme caution.

2.4.3 CPC 100 ePC interfaces

The ePC interfaces are located on the right-hand side of the *CPC 100* housing. The PC and network interfaces differ depending on the *CPC 100* version as described below.

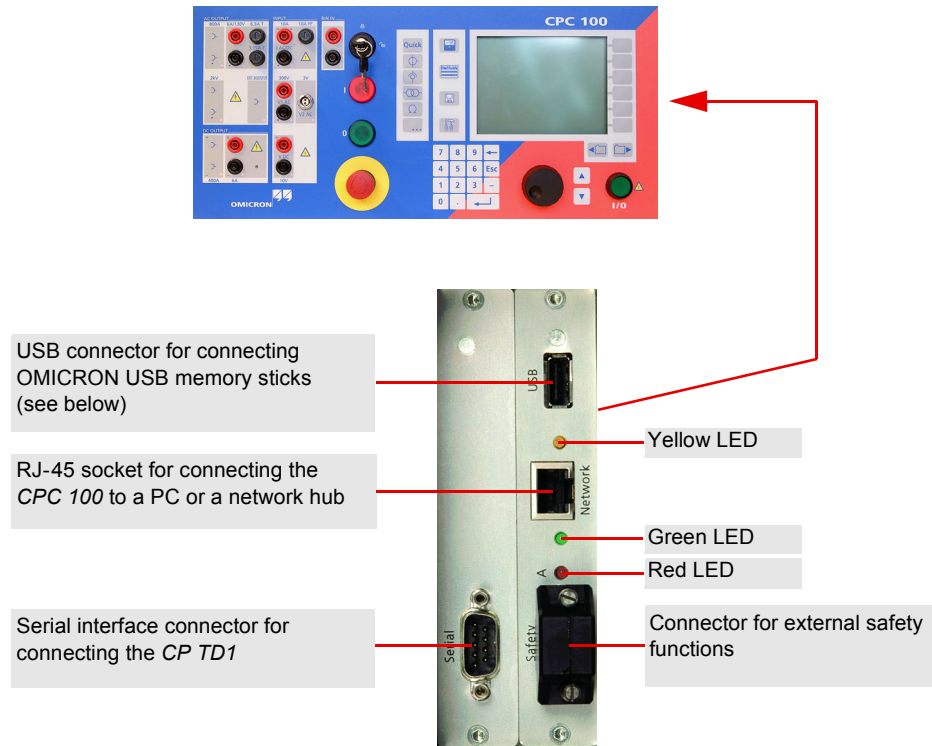


Figure 2-3: ePC interfaces of the *CPC 100 V1*

The *CPC 100 V1* supports the USB interface 1.1 and 2.0 for connecting the USB memory stick shipped with the *CPC 100*.

Note: The full functionality is guaranteed only for the stick delivered with the *CPC 100*.

The serial and safety interfaces are identical with the *CPC 100 V0* version (see above). The network interface is an auto-crossover Ethernet connector that can be connected to a network hub or directly to a PC or a notebook.

The *CPC 100 V1* provides the following LEDs on the ePC interface:

- Green LED lights if the *CPC 100* is properly connected to a PC or network.
- Yellow LED lights if data is transferred from or to the network.
- Red LED serves for diagnosis purposes.

2.5 Functional components of the *CPC 80*

2.5.1 *CPC 80* front panel

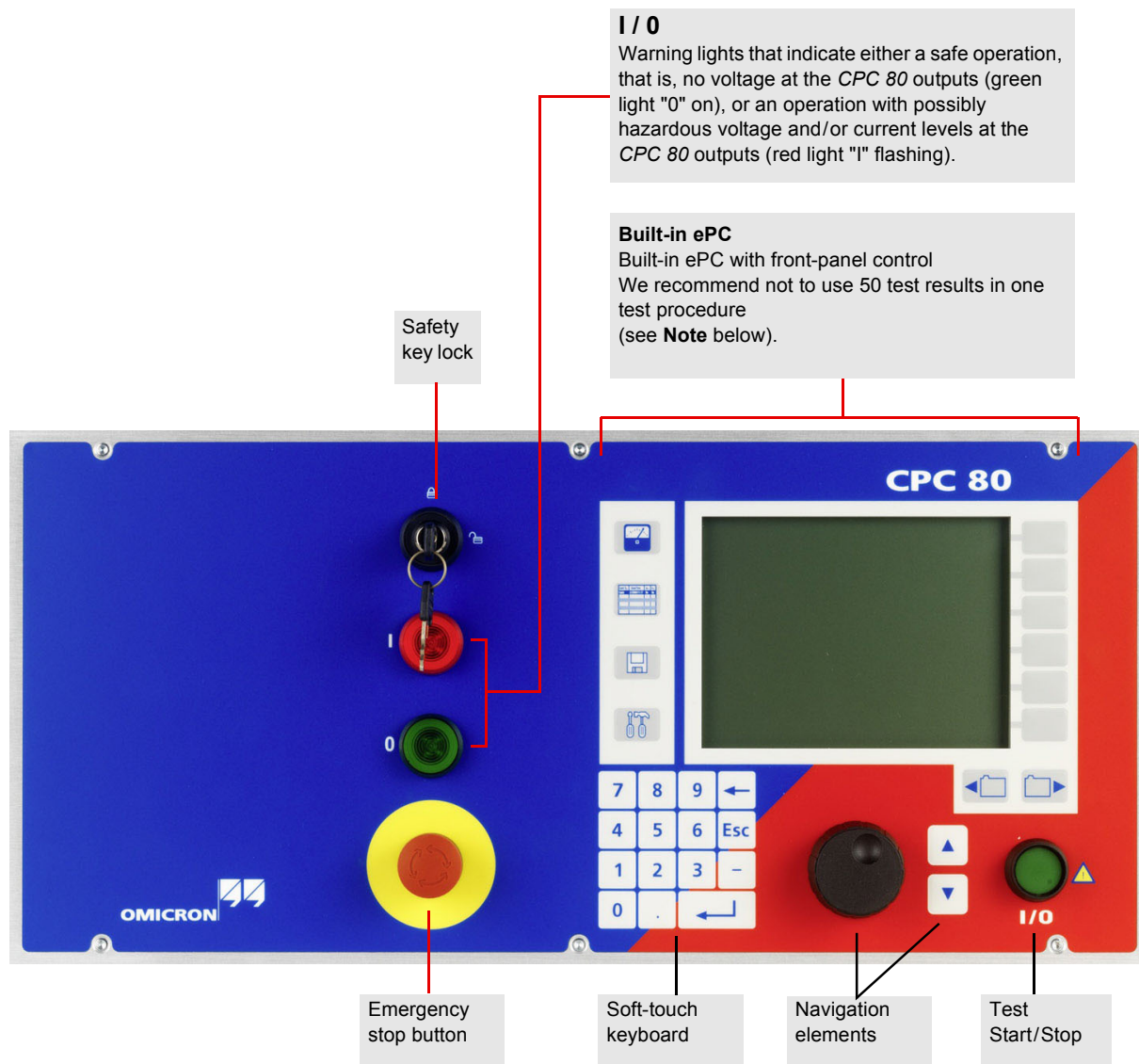


Figure 2-4: *CPC 80* front view

2.5.2 CPC 80 mains power supply and Booster output

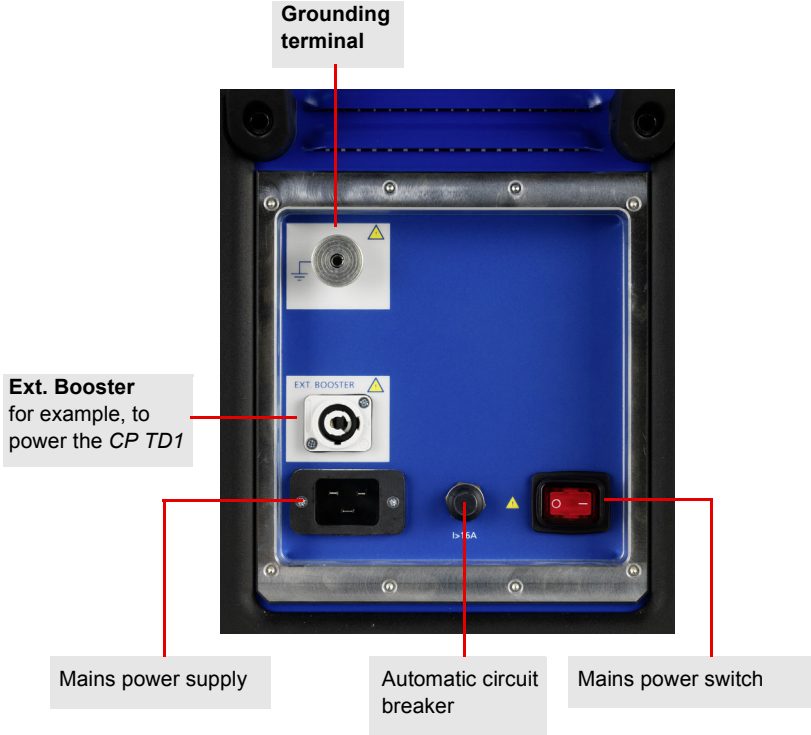


Figure 2-5: Mains power supply, booster output and grounding terminal

2.5.3 CPC 80 ePC Interfaces

The ePC interfaces are located on the right-hand side of the *CPC 80* housing.

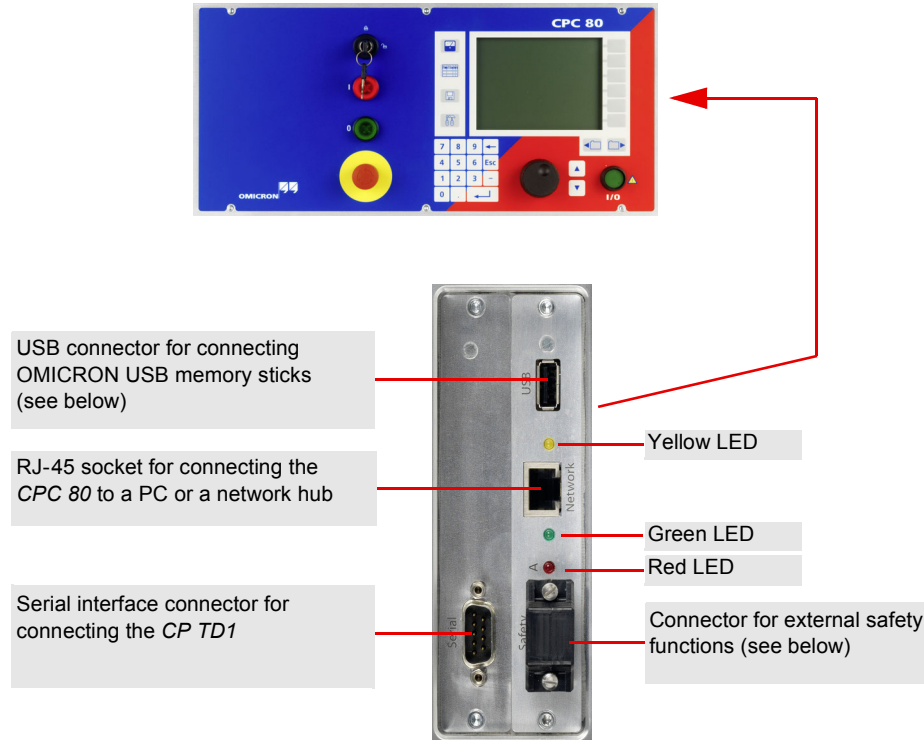


Figure 2-6: ePC interfaces of the *CPC 80*

The *CPC 80* supports the USB interface 1.1 and 2.0 for connecting the USB memory stick shipped with the *CPC 80*.

The full functionality is guaranteed only for the stick delivered with the *CPC 80*.

The network interface is an auto-cross-over Ethernet connector that can be connected to a network hub or directly to a PC or a notebook.

The *CPC 80* provides the following LEDs on the ePC interface:

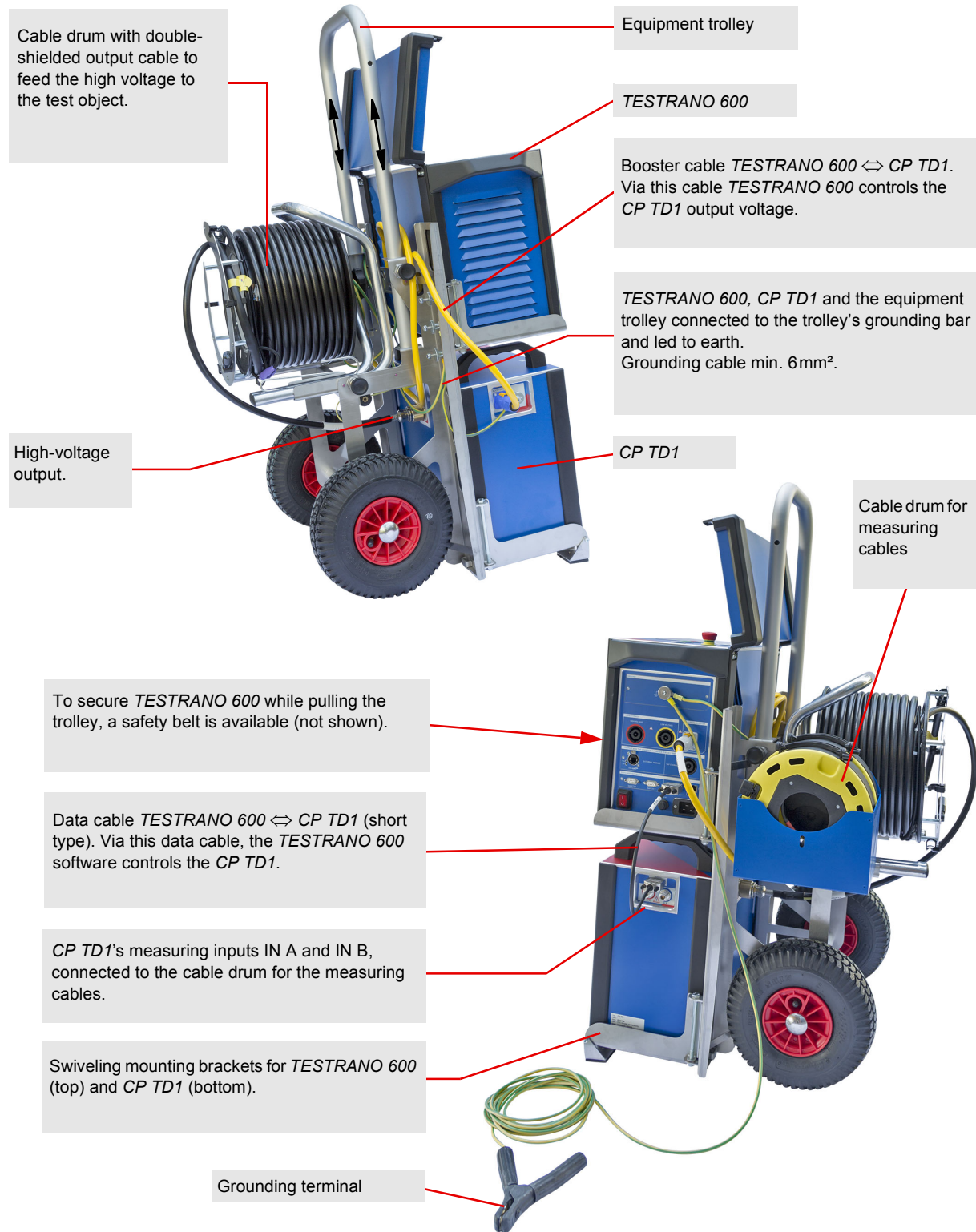
- Green LED lights if the *CPC 80* is properly connected to a PC or network.
- Yellow LED lights if data is transferred from or to the network.
- Red LED serves for diagnosis purposes.

The connector for external safety functions allows connecting:

- an external Emergency Stop or "dead man" button
- an external "test start / stop" push-button
- external I / O warning lights.

The attached plug contains a jumper for the emergency stop or "dead man" function, and as long as the plug is placed on the connector, these functions are bridged. If the plug is removed, emergency stop is active.

2.6 TESTRANO 600 and CP TD1 equipment trolley



2.7 Functional components of *TESTRANO 600*

2.7.1 *TESTRANO 600* front panel

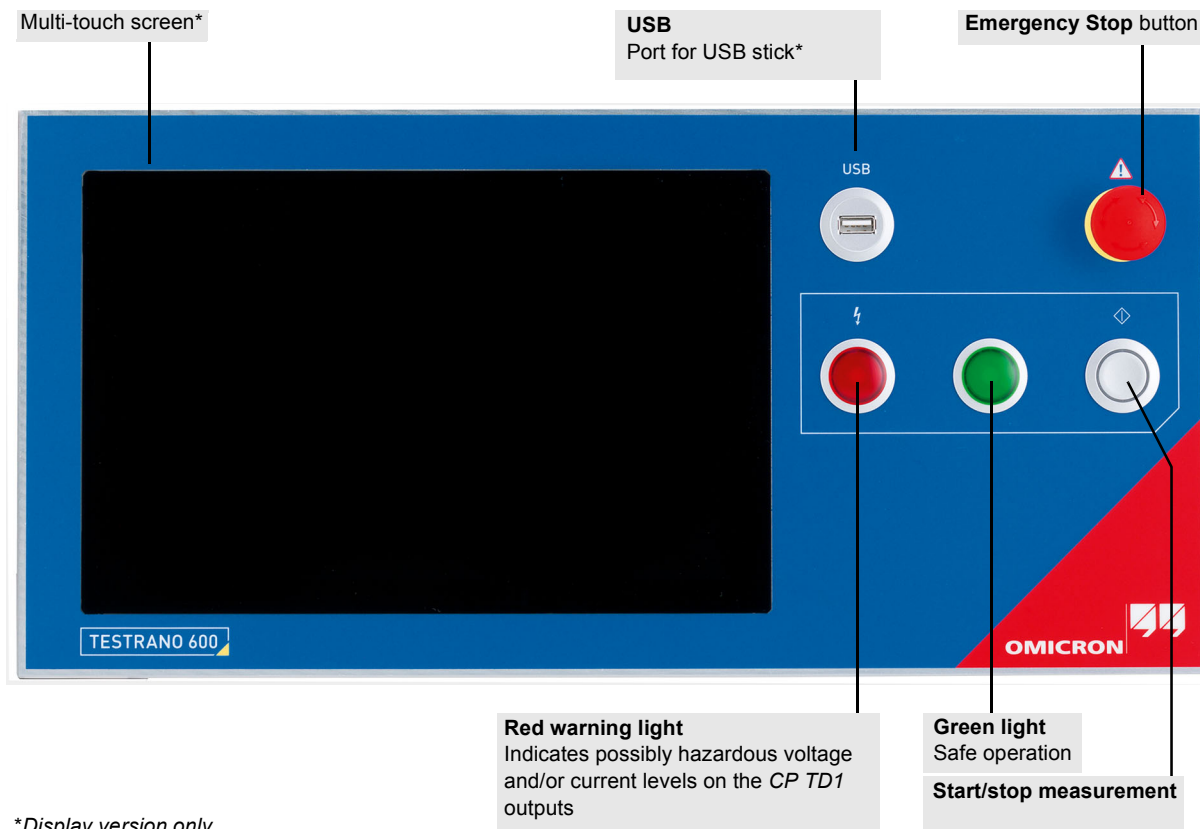


Figure 2-7: *TESTRANO 600* front panel with display

2.8 TESTRANO 600 side panel

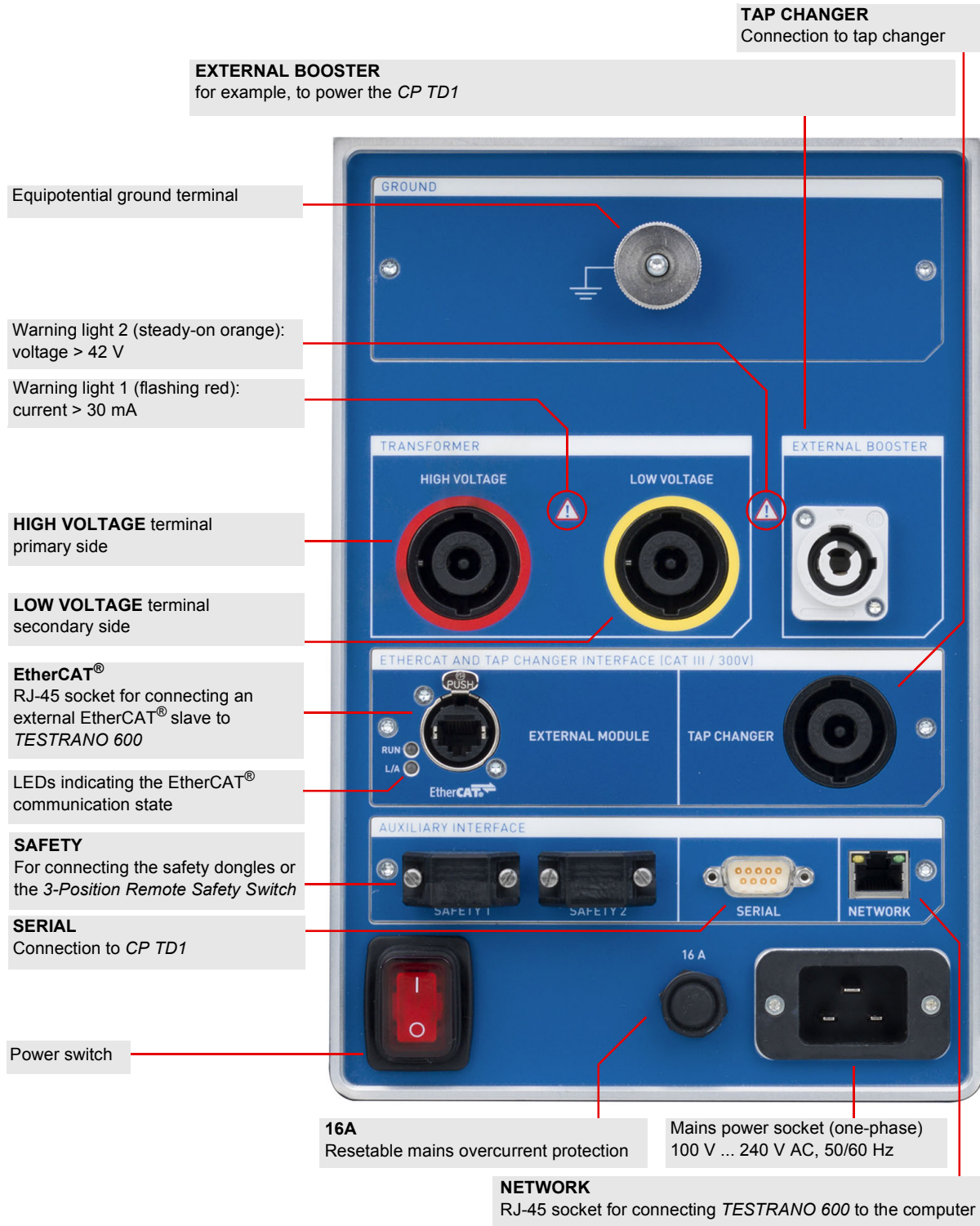


Figure 2-8: TESTRANO 600 side panel

2.9 Functional components of the *CP TD1*

2.9.1 *CP TD1* grounding terminal and Booster input



Figure 2-9: Grounding terminal and booster input of the *CP TD1* (left side of the device)

2.9.2 *CP TD1* serial interface connector and measuring inputs

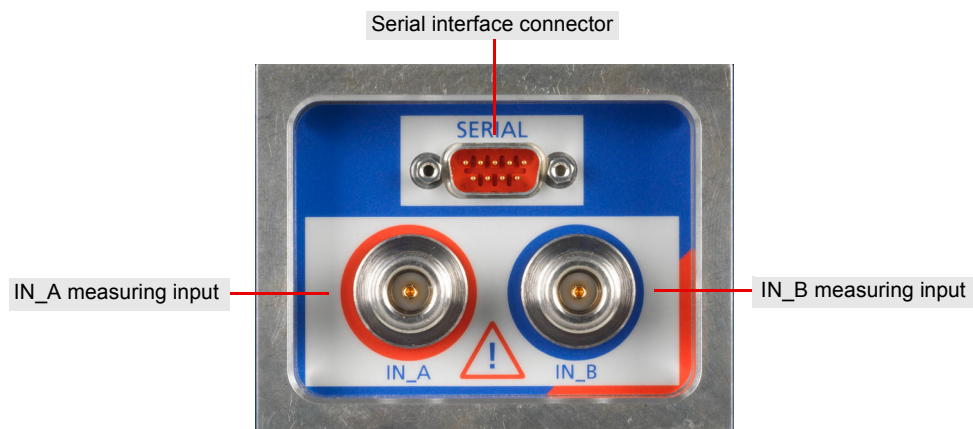


Figure 2-10: Serial interface and measuring inputs of the *CP TD1* (right side of the device)

2.9.3 *CP TD1* high-voltage connector

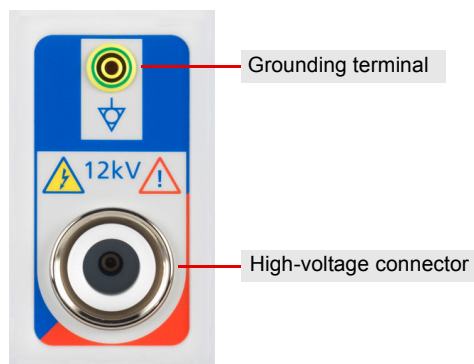


Figure 2-11: High-voltage connector of the *CP TD1* (rear of the device)

3 Application

3.1 Preparations on site



DANGER

Death or severe injury caused by high voltage or current

Prior to connecting a test object to the *CP TD1*, the following steps need to be carried out by an authorized employee of the utility:

- ▶ Turn off and disconnect the high voltage from the test object.
- ▶ Protect yourself and your working environment against an accidental re-connection of high voltage by other persons and circumstances.
- ▶ Verify a safe isolation of the test object.
- ▶ Earth-connect and shorten out the test object's terminals using a grounding set.
- ▶ Protect yourself and your working environment with a suitable protection against other (possibly live) circuits.
- ▶ Protect others from accessing the dangerous area and accidentally touching live parts by setting up a suitable barrier and, if applicable, warning lights.
- ▶ If there is a longer distance between the location of the *CP TD1* and the area of danger (that is, the test object), a second person with an additional "Emergency Stop" button is required.

3.2 Connecting the *CP TD1* to the *Control Device*

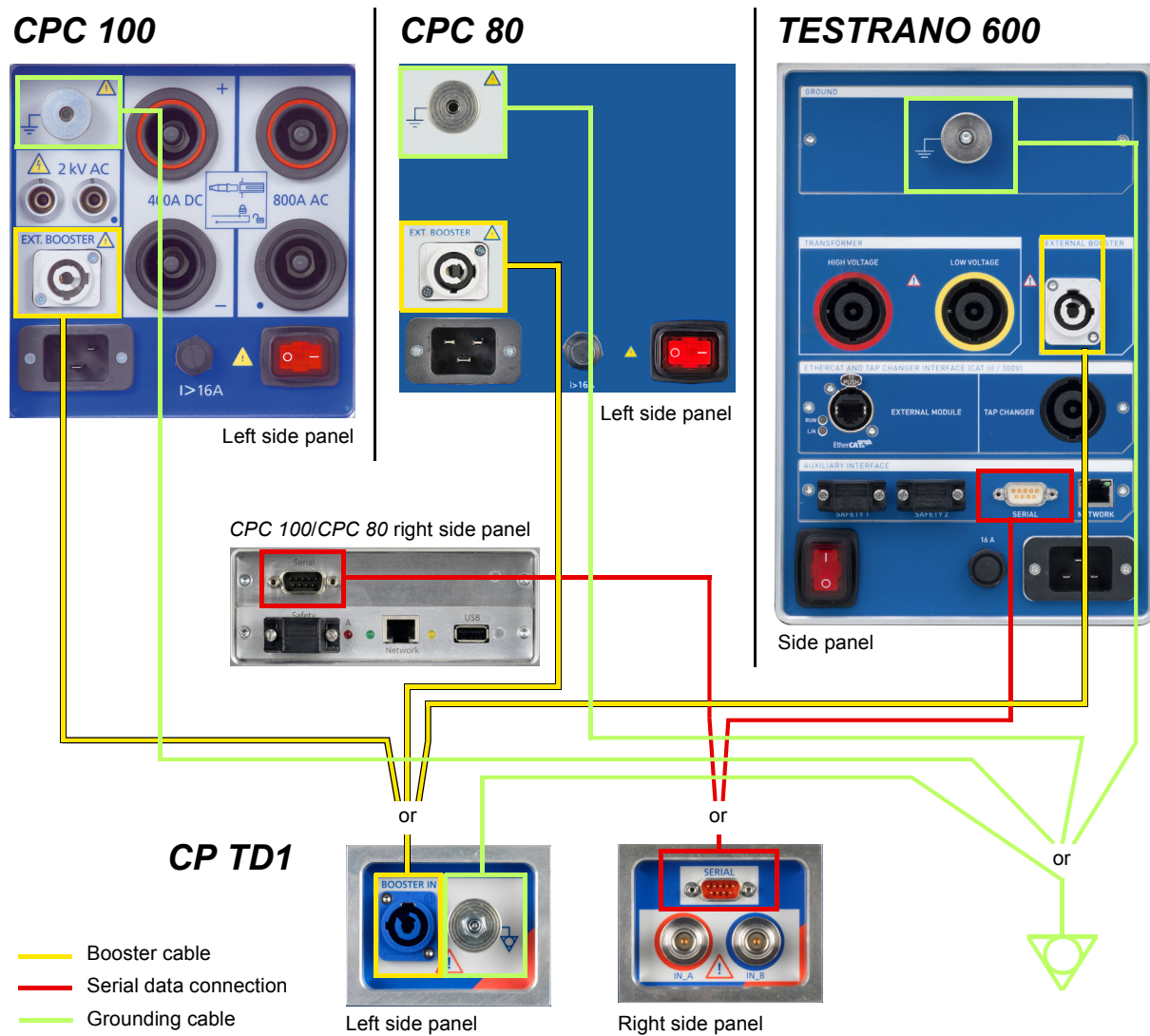


Figure 3-1: Connecting the *CP TD1* to the *CPC 100*, *CPC 80* or *TESTRANO 600*

DANGER

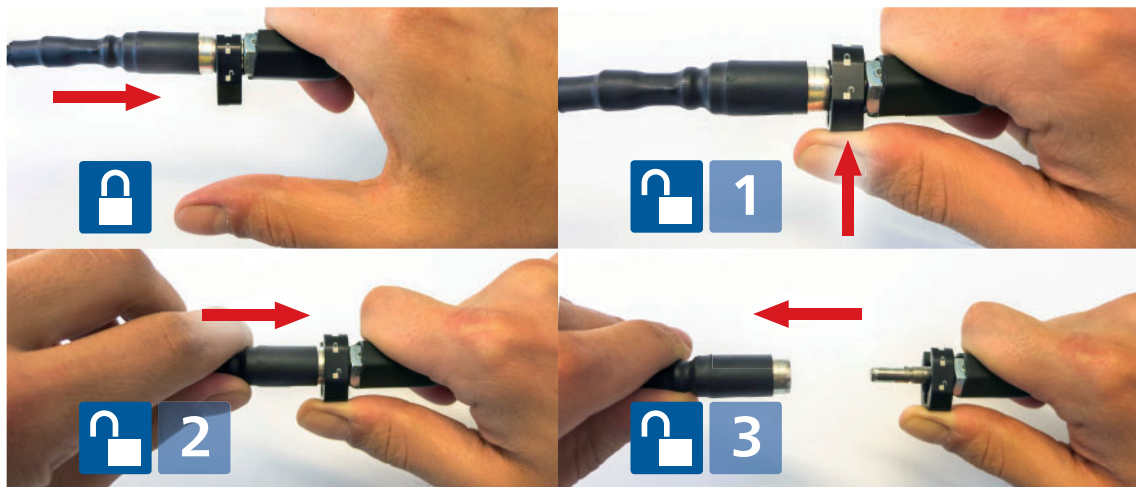


Death or severe injury caused by high voltage or current

- ▶ Never use the *CP TD1* without a solid connection to ground with at least 6 mm².
- ▶ Use a ground point as close as possible to the test object.
- ▶ Make sure to position the test object or *CP CAL* in the high-voltage area.

1. Ensure that the *Control Device* is switched off at the mains power switch.
2. **Without trolley:**
 - ▶ Properly connect the *Control Device* and *CP TD1* grounding terminals to substation ground.**With trolley (optional):**
 - ▶ Connect the trolley's ground bar to earth.
 - ▶ Properly connect the *CPC 100* or *TESTRANO 600* and *CP TD1* grounding terminals to the trolley's ground bar.
3. Make sure that all cable connectors are clean and dry before being tightly connected.
4. Connect the *CP TD1*'s "BOOSTER IN" to the *Control Device*'s "EXT. BOOSTER" with the booster cable.
5. Connect the *CP TD1*'s "SERIAL" to the *Control Device*'s "SERIAL" with the data cable. This cable also provides the power supply for the *CP TD1*.
6. Pull out the measuring cables from the cable drum and connect the test object to the *CP TD1*'s measuring inputs IN A and IN B.
7. Connect the high-voltage cable from the test object to the *CP TD1*'s high-voltage output.
 - ▶ At the *CP TD1*, press the high-voltage cable's plug to the connector tightly and turn the screw cap manually without using any tools until you feel a mechanical stop. If you notice a rough-running of the screw-cap, clean the screw thread and use a lubricant (Vaseline recommended).
 - ▶ Insert the yellow banana plug (the high-voltage cable's grounding) into the respective plug socket.
 - ▶ At the test object, insert the high-voltage cable's plug carefully until you feel a "click" position. Now they are locked. Confirm this by trying to pull them out. This should not be possible now.

The images below show how to unlock the cable connection again. This is also shown on a label fixed to the high-voltage cable.



- ▶ After the HV cable connection is established, use the strain relieve delivered with the HV cable to fasten it to the test object.

DANGER**Death or severe injury caused by high voltage or current**

The high-voltage cable is double-shielded and therefore safe. However, the last 50 cm (20 inch) of this cable have no shield.

- ▶ During a test, consider this cable a live wire and, due to the high-voltage, life-hazardous.

8. Connect the *Control Device* to the mains power supply using the provided cable..

WARNING**Death or severe injury caused by high voltage or current possible**

- ▶ Establish a barrier to the high-voltage area.

9. Turn on the *Control Device* at its mains power switch.

10. The green warning light lights up, showing that the *Control Device*'s output does not carry a dangerous voltage or current yet (on the *TESTRANO 600* the blue ring of the Start/Stop button is additionally lit).

WARNING**Death or severe injury caused by high voltage or current possible**

- ▶ If none or both warning lights are on, the unit is defective and must not be used anymore.

11. An error message appears either if the PE connection is defective or if the power supply has no galvanic connection to ground. The latter is the case on very special power supplies like with generators or when insulation transformers are used.

WARNING**Death or severe injury caused by high voltage or current possible**

This is a safety-relevant message. If the reason for this message is that neither PE nor grounding terminal is connected, it can cause injury or possibly death of the operating staff. The operator is fully responsible for any hazard that might occur due to improper grounding.

- ▶ For safe operation always make sure that both PE and grounding terminal are connected.

If the CPC 100 or CPC 80 is the Control Device:

12. If the PE connection and the galvanic ground connection of the power supply are both intact and the error message still appears, you can deactivate the Ground check and continue testing.

WARNING



Death or severe injury caused by high voltage or current possible

If the Ground check is disabled, the operator is fully responsible for any hazard that might occur due to improper grounding.

- ▶ Only deactivate the Ground check if you are completely sure that the measurement equipment is properly grounded via PE and grounding terminal connections.
- ▶ Make sure that the grounding terminal connections stay intact during the whole measurement procedure. If necessary, block the area to prevent unaware people from stumbling over the grounding cables, possibly disconnecting them inadvertently.

Note: After the CPC 100 or CPC 80 has been rebooted, the "Disable ground check" check box is cleared for safety reasons.

3.3 Measurement

The CP TD1 can be either controlled via one of the *Control Devices* directly or via *Primary Test Manager (PTM)* in combination with a *Control Device*.

For a detailed description of the user interface of the respective *Control Device* or *Primary Test Manager* and how to start measurements using the respective option please refer to the following documents:

Option	Document
CPC 100	CPC 100 User Manual CPC 100 Reference Manual
CPC 100 + PTM	CPC 100 PTM User Manual
CPC 80	CPC 80 User Manual
TESTRANO 600	TESTRANO 600 User Manual
TESTRANO 600 + PTM	TESTRANO 600 User Manual

3.4 Disconnection

1. Switch off the high voltage with start/stop push-button.

WARNING



Death or severe injury caused by high voltage or current possible

The green warning light indicates that the outputs of the *Control Device* are not activated.

- ▶ Even if you switched off the *Control Device*, wait until the red warning light is fully extinguished. As long as this warning light is lit, there is still voltage potential on the output.

2. Press the **Emergency Stop** button on the *Control Device*'s front panel.

3. **If you are using the CPC 100 or CPC 80:** Turn the safety key to "lock" (vertical) and remove the key to avoid anybody accidentally turning on the high voltage.
4. Earth-connect and shorten out the test object's terminals using a grounding set.
5. Plug off the high-voltage cable from the high-voltage output of the *CP TD1*.
6. Disconnect the cables from the *CP TD1*.

4 Introduction to capacitance and dissipation factor measurement

Capacitance (C) and Dissipation Factor (DF) measurement is an established and important insulation diagnosis method. It can detect:

- Insulation failures
- Aging of insulation
- Contamination of insulation liquids with particles
- Water in solid and liquid insulation
- Partial discharges

4.1 Theory

In an ideal capacitor without any dielectric losses, the insulation current is exactly 90° leading according to the applied voltage. For a real insulation with dielectric losses this angle is less than 90° . The angle $\delta = 90^\circ - \varphi$ is called loss angle. In a simplified diagram of the insulation, C_p represents the loss-free capacitance and R_p the losses (see Figure 4-1). Losses can also be represented by serial equivalent circuit diagram with C_s and R_s . The definition of the dissipation factor and the vector diagram are shown in Figure 4-2 on the following page.

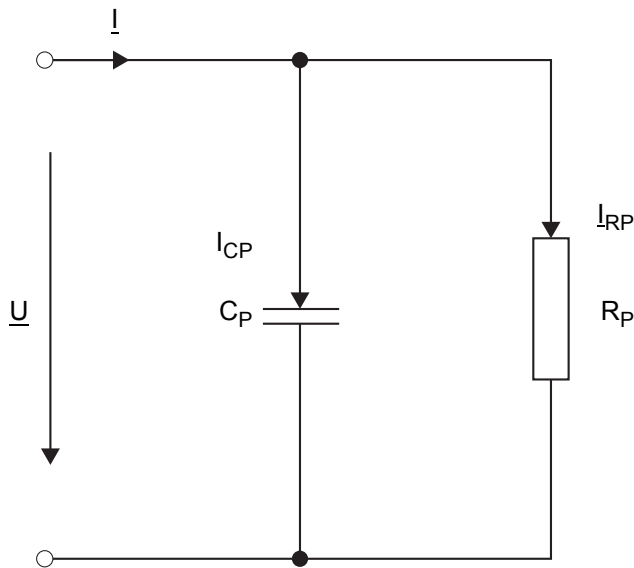


Figure 4-1: Simplified circuit diagram of a capacitor

Introduction to capacitance and dissipation factor measurement

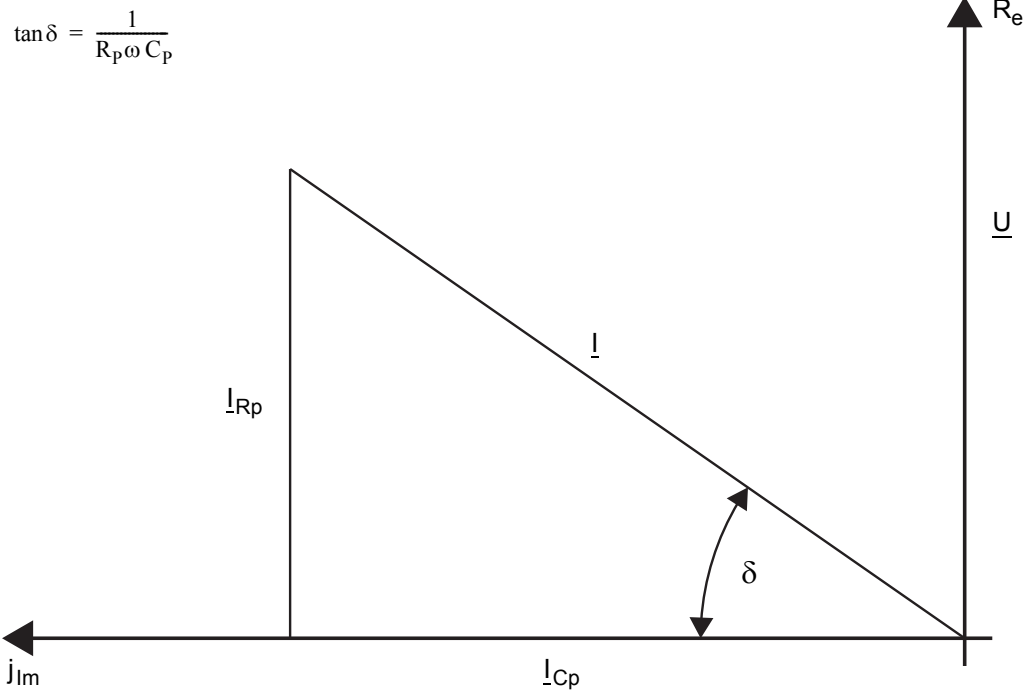


Figure 4-2: Definition of dissipation factor ($\tan \delta$) and the vector diagram

The correlation between the Dissipation Factor and Power Factor ($PF = \cos \varphi$) and the vector diagram are shown in Figure 4-3.

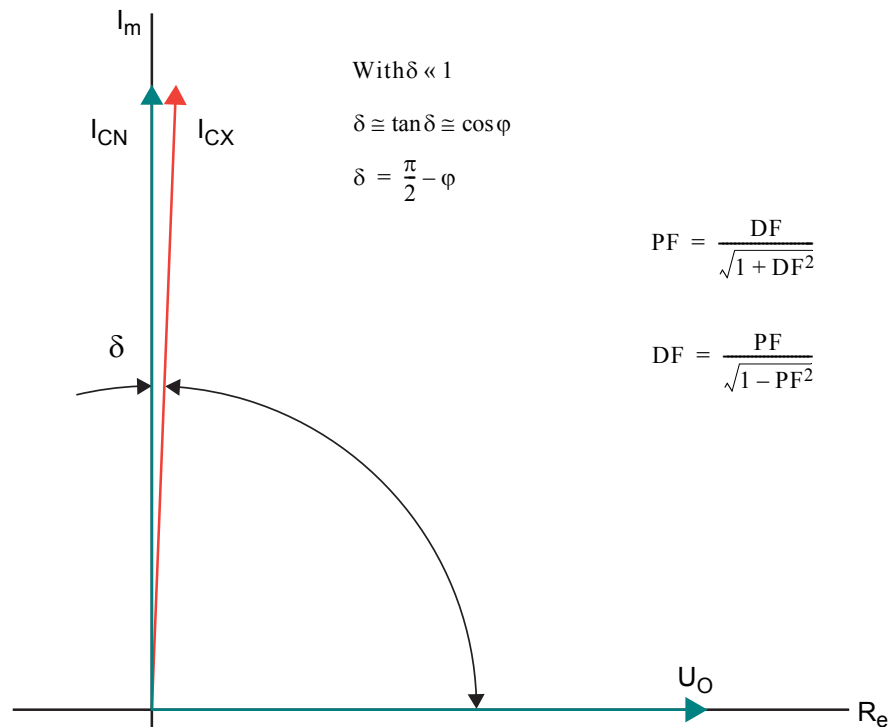


Figure 4-3: Correlation between DF and PF

The dielectric losses in the insulation are caused by polarization and conduction phenomena. The different polarization mechanisms are caused by various physical processes: [1]

- Electronic polarization: Shifting of the (negative) atomic shell charge concentration towards the (positive) nucleus charge concentration.
- Ionic Polarization: Shifting of positive and negative ions relative to each other.
- Orientation polarization: Alignment of permanent dipoles due to the applied electrical field.
- „Hopping“ polarization: „Hopping“ polarization is caused by movement of so called „hopping charge carriers“. These charge carriers are stationary most of the time but at times change their position through tunneling or thermal activation. [2]
- Space Charge Polarization: If different dielectrics with different permittivities and conductivities are present in a material, this can lead to accumulations of charge carriers at the boundary surfaces of these dielectrics.

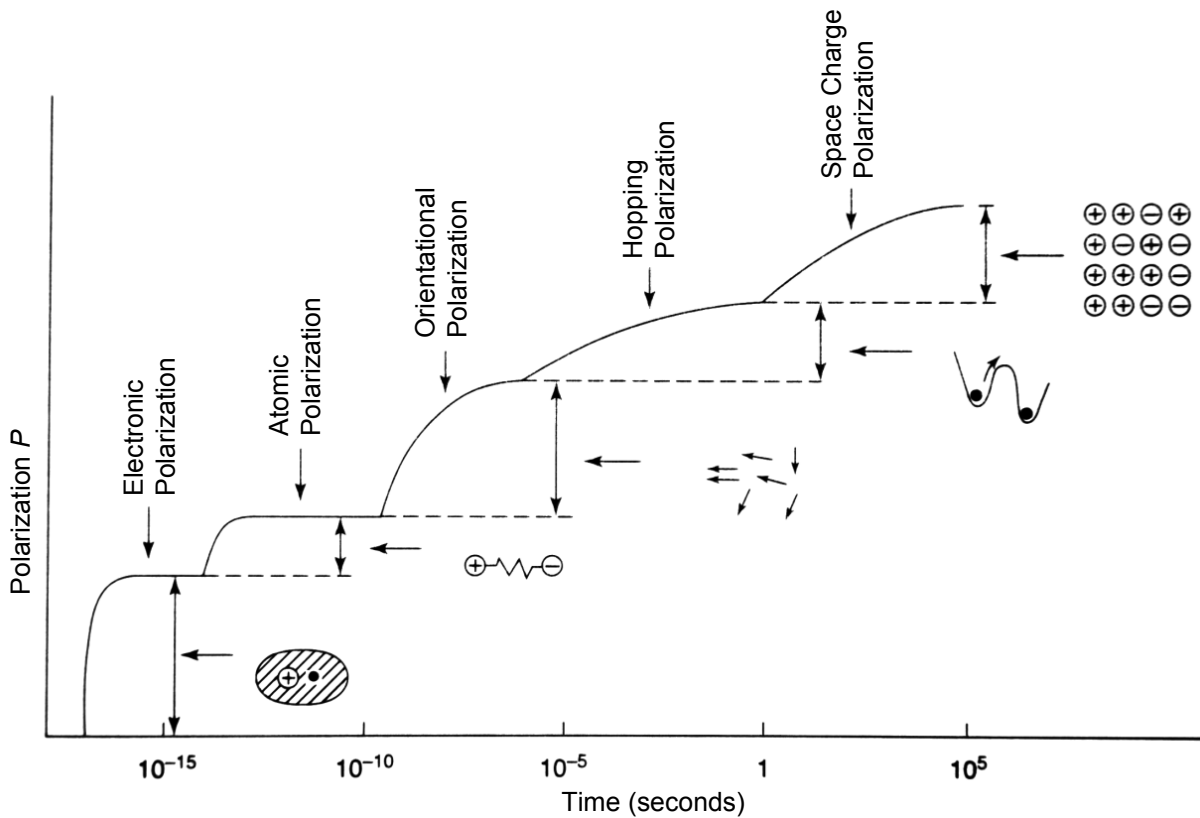


Figure 4-4: Polarization mechanisms and their respective time constants [3]

1. Zaengl, W.: Dielectric Spectroscopy in Time and Frequency Domain for HV Power Equipment, Part I: Theoretical Considerations. IEEE Electrical Insulation Magazine, Vol. 19, No. 5, 2003, pp. 5-19
 2. Jonscher, A.K.: Dielectric Relaxation in Solids. Chelsea Dielectric Press, 1983, ISBN: 0950871109
 3. Kao, K.-C.: Dielectric Phenomena in Solids. Academic Press; 1st edition, 2004, ISBN 0123965616

Influence of different parameters as water content, temperature and aging on DF

Figure 4-5 shows the breakdown voltage and the DF in oil, dependent on the water content [1]. With low water content, the breakdown voltage is very sensitive; with higher water content, the DF is a good indicator.

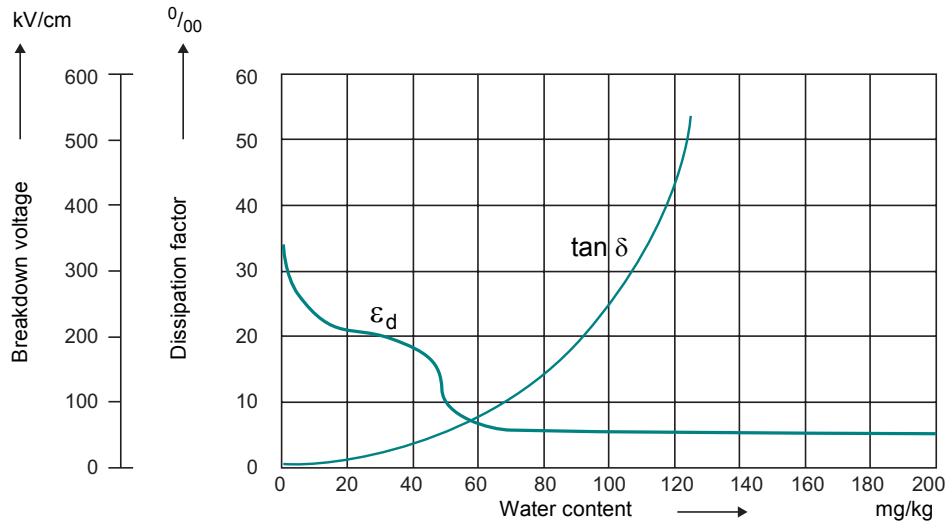


Figure 4-5: Breakdown voltage and DF in oil, dependent on the water content

Figure 4-6 shows the DF of new and used oil, dependent on the temperature. With higher temperatures, the viscosity of the oil decreases so the particles, ions and electrons can move easier and faster. Thus the DF increases with temperature.

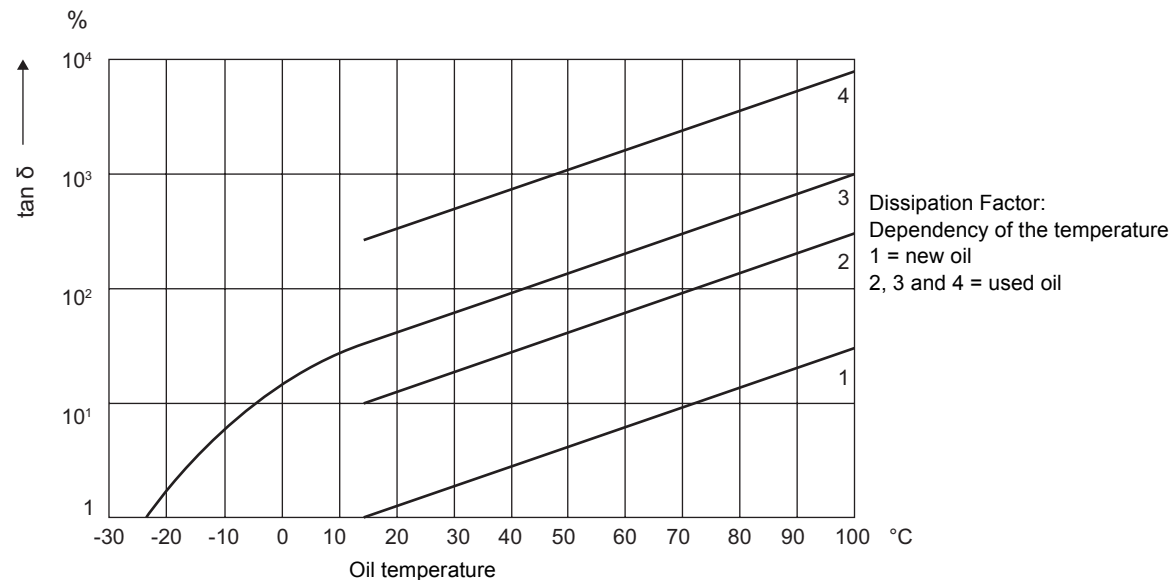


Figure 4-6: DF of new and aged oil, dependent on temperature

1. Krüger, M.: "Prüfung der dielektrischen Eigenschaften von Isolierflüssigkeiten", ÖZE, No. 5, Vienna, May 1986

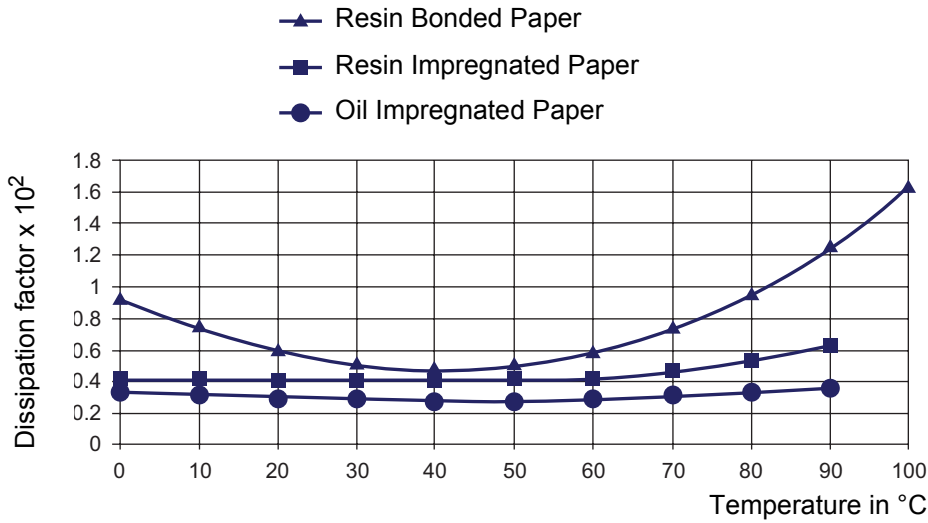


Figure 4-7: Example for the temperature behavior of RBP, RIP and OIP bushings ¹

The dissipation factor is dependent on the frequency. With modern test devices like the *CPC 100 + CP TD1*, it is possible to cover a wide frequency range for capacitance and DF measurements. Conventional fingerprint measurements for comparison are normally available only at line frequency. The following figures show the frequency dependency for transformer windings (oil-paper insulation) and an OIP bushing. See Figures 4-8 and 4-9.

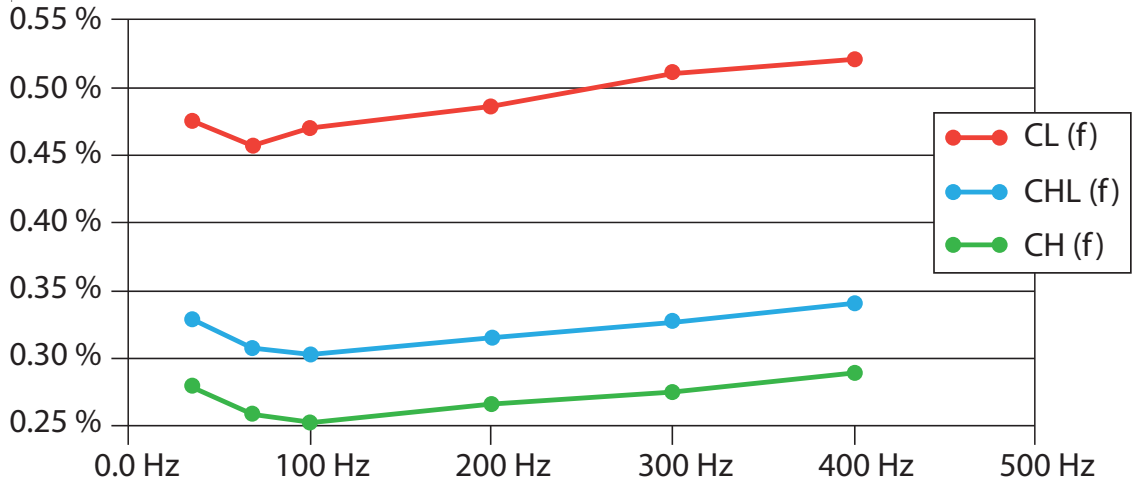


Figure 4-8: Frequency dependent dissipation factor of a power transformer

1. Seitz, V.: "Vorbeugende Instandhaltung an Leistungstransformatoren – Betriebsbegleitende Messungen an Stufenschaltern und Durchführungen, OMICRON Anwendertagung 2003, Friedrichshafen

Introduction to capacitance and dissipation factor measurement

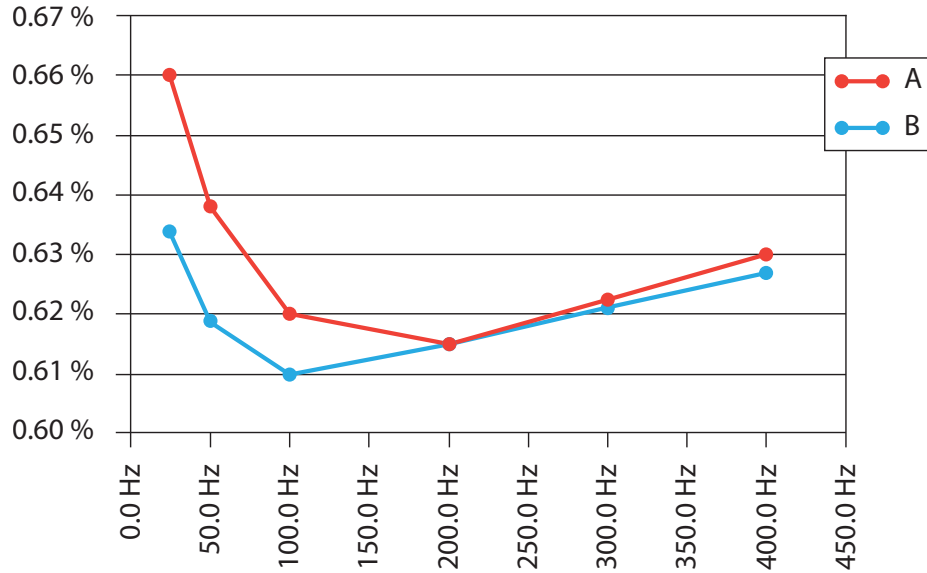


Figure 4-9: Frequency dependent dissipation factor of two OIP bushings (phase A and phase B)

If the dissipation factor is also dependent on the voltage, this is an indication for partial discharges or contact problems. Figure 4-10 shows a measurement of a 6kV motor. Above 4kV, partial discharges occur which increase the dissipation factor.

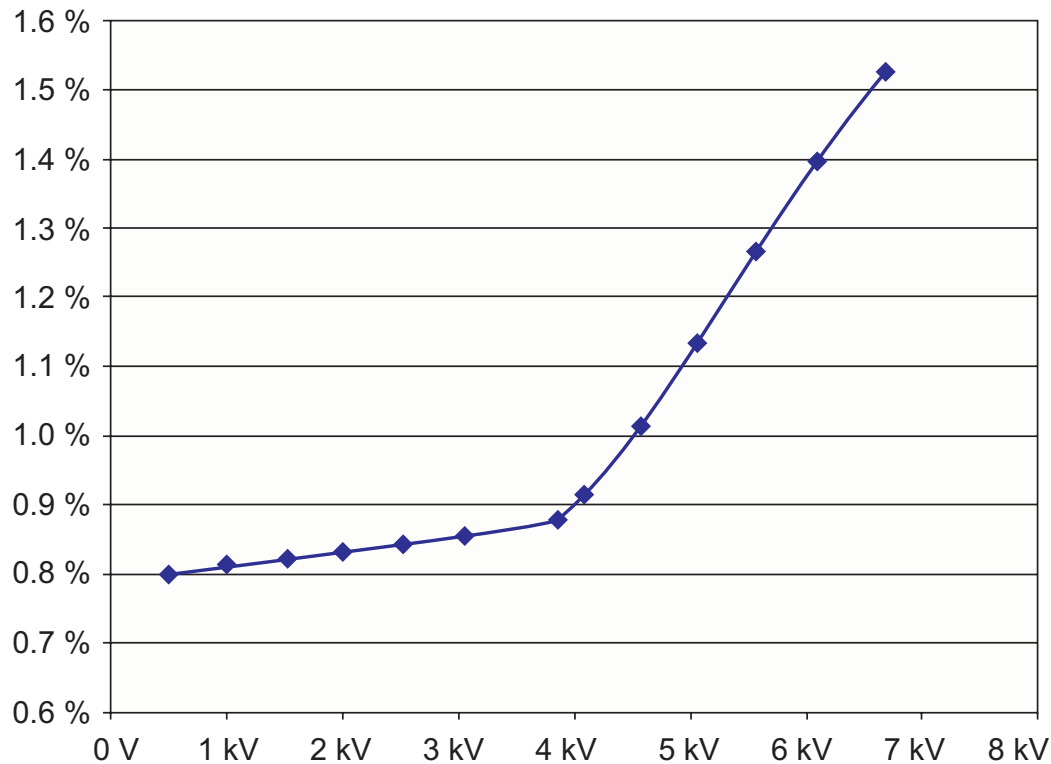


Figure 4-10: Voltage dependent dissipation factor of a 6 kV motor

4.2 Measurement of Capacitance and Dissipation Factor / Power Factor

Capacitance (C) and Dissipation Factor (DF) measurement was first published by Schering in 1919 ¹ and utilized for this purpose in 1924. The serial connected C_1 and R_1 represent the test object with losses, C_2 the loss-free reference capacitor.

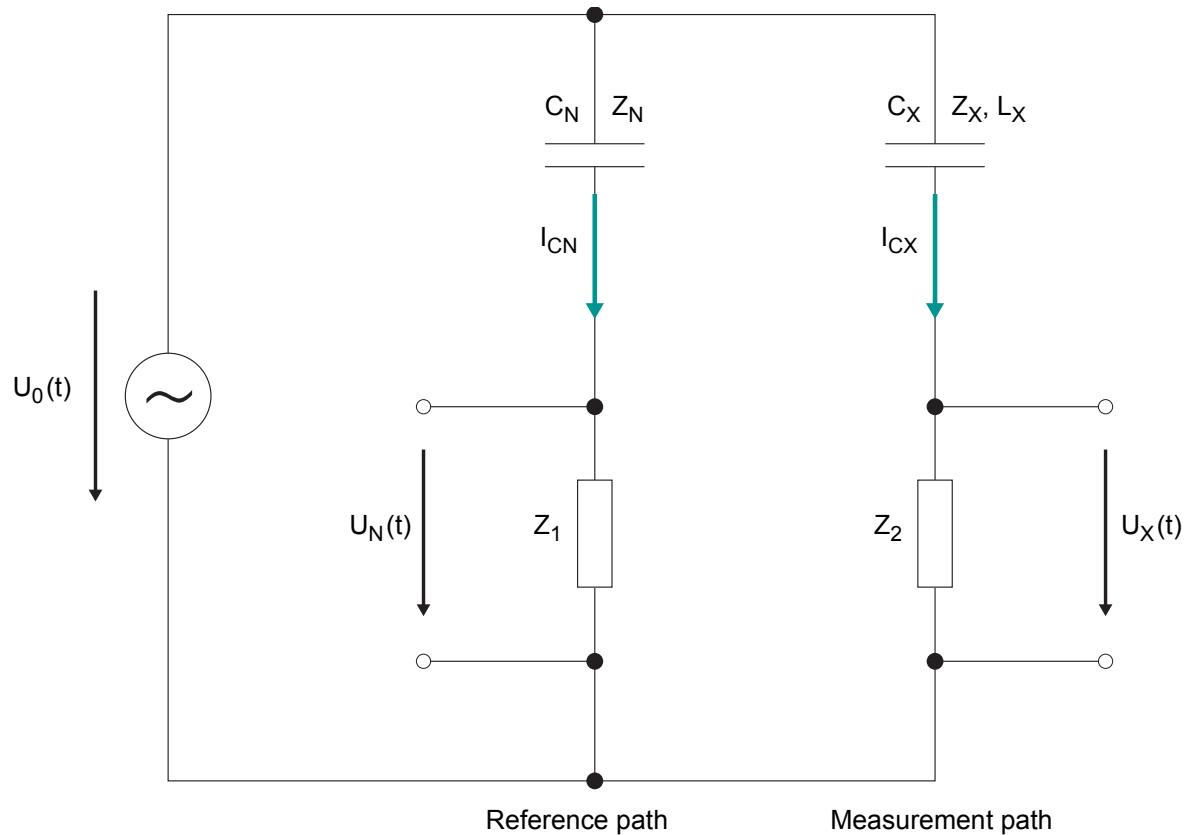


Figure 4-11: CP TD1 measuring principle

The CP TD1 test system utilizes a method similar to that of the Schering bridge. The main difference is that the CP TD1 measuring principle does not require tuning for measuring C and DF. C_n is a low loss reference capacitor.

1. Schering, H.: "Brücke für Verlustmessungen", Tätigkeitsbericht der Physikalisch-Technischen Reichsanstalt, Braunschweig 1919

4.3 "UST" and "GST" Measurements Using the Guard Technology

The *CP TD1* has three external measuring inputs, IN A, IN B and ground. Those three inputs can be individually switched to guard or to the measuring unit. If an input is switched to the measuring path, the connected capacitance is part of the measurement. If it is switched to guard, the current bypasses the measurement path and is not included in the measurement. The advantage of using a switch matrix to configure the measurement is that multiple measurements can be made without changing the measurement setup or wiring.

The terms "UST" for "ungrounded specimen test" and "GST" for "grounded specimen test" have historically evolved. "UST" describes a measurement setup, where ground is not connected to the measurement path, whereas "GST" describes a measurement setup, where ground is part of the measurement path. In the "UST" configuration, 3 configurations are possible. Depending on configuration, the currents via IN A and IN B are measured or not (see Table 4-1 below). The measurement result is the sum of all measured channels.

Table 4-1: UST measurement modes

Mode	IN A	IN B	Ground
UST-A	Measured	Guarded	Guarded
UST-B	Guarded	Measured	Guarded
UST-(A+B)	Measured	Measured	Guarded

In the "GST" configuration, 4 configurations are possible (see Table 4-2). The naming is a bit different compared to the "UST" modes as it indicates the channels which are guarded, not the channels which are measured. The measurement result is also the sum of all measured channels.

Table 4-2: GST measurement modes

Mode	IN A	IN B	Ground
GST	Measured	Measured	Measured
GSTg-A	Guarded	Measured	Measured
GSTg-B	Measured	Guarded	Measured
GSTg-(A+B)	Guarded	Guarded	Measured

In general, the UST measurement is less influenced by external noise or stray capacitances than the GST measurement and should be preferred if both modes are possible.

The different configurations allow multiple measurements with only a few re-connections at the device under test. On the following pages examples are shown for the common cases of a two-winding and a three-winding transformer.

5 Power transformers

General

- The transformer must be taken out of service and completely isolated from the power system.
- The proper grounding of the transformer tank has to be checked.
- All bushing high-voltage terminals must be isolated from the connection lines.
- All bushing terminals of one winding group, which means A, B, C (and Neutral) of high-voltage winding, A, B, C (and Neutral) of low-voltage winding and A, B, C (and Neutral) of tertiary winding have to be connected by a copper wire (see Figure 5-1).

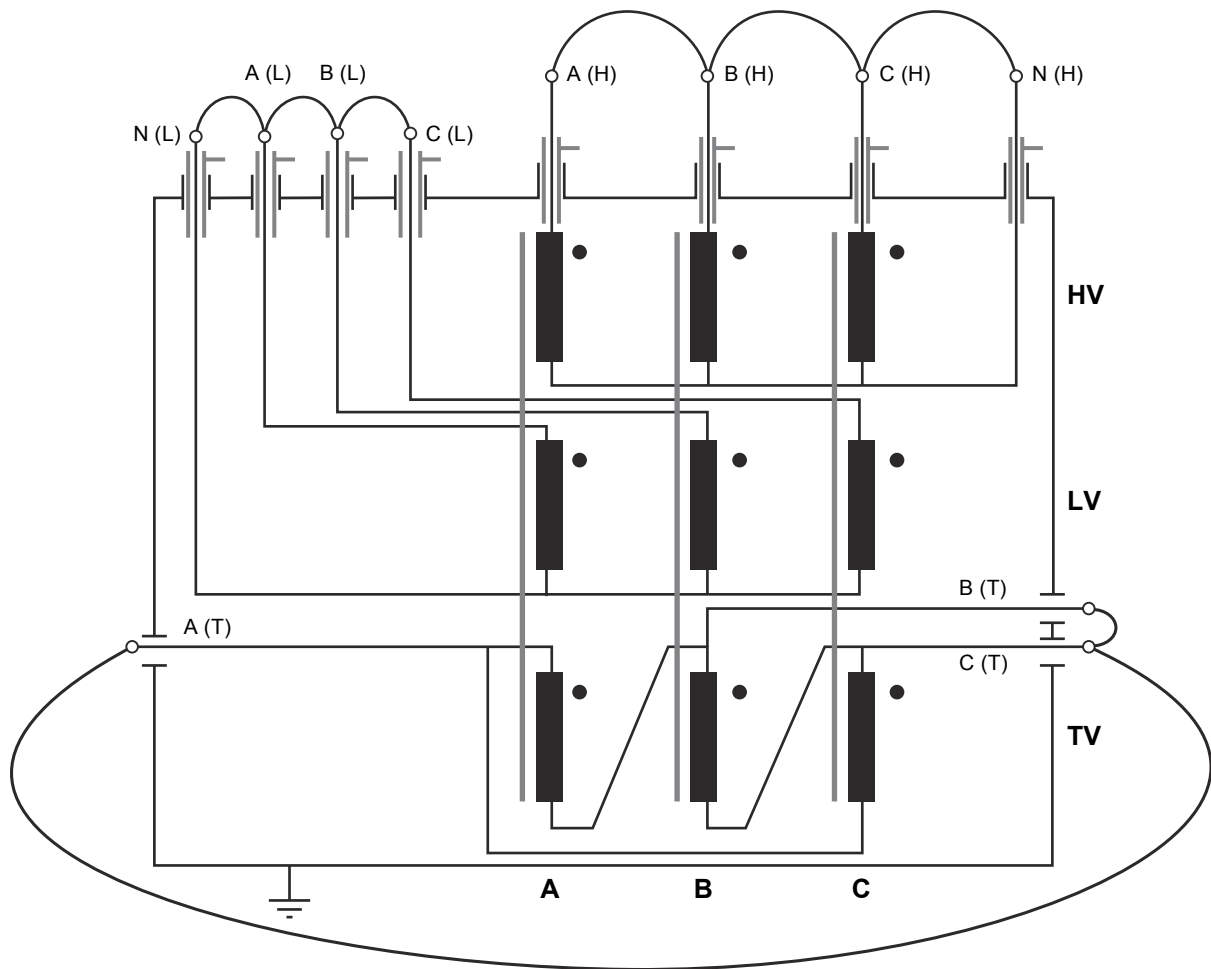


Figure 5-1: Three-winding transformer with connected windings

- The neutral terminals of all Y-connected windings with outside-connected Neutral have to be disconnected from ground (tank).
- If the transformer has a tap changer then it should be set to the neutral position (0 or middle tap).
- Connect the *Control Device* + *CP TD1* ground terminal to the transformer's (substation) ground.

- Short-circuit all bushing CTs.
- Do not perform high-voltage tests on transformers under vacuum.
- The test voltage should be chosen with respect to the rated voltage of the winding.
- All tests should be made with oil temperatures near 20 °C. Temperature corrections can be calculated by using correction curves, but they depend a great deal on the insulation material, the water content and many other parameters. This way the correction has limited accuracy.

5.1 Dissipation Factor Measurement

Environmental Conditions

Environmental factors can influence DF measurements greatly. Therefore it is important to record the ambient conditions at the time of testing when comparing test results. The tests should be made with oil temperatures near 20°C. Temperature corrections can be calculated, utilizing correction curves, but they depend very much on the insulation material, the water content and a lot of other parameters. This way the correction has limited accuracy. Testing at very low temperatures provides less accurate results and should be avoided if possible.

Other factors like relative humidity and the general weather conditions should be recorded in the test report for future reference.

It is always better to measure the values regularly and save them for comparison to tests in the past and in the future. In this way, trends can be observed and the evaluation of results is of much higher quality.

5.2 Capacitance Measurement

The capacitance of the insulation gaps between the windings to each other and to ground depends mainly on the geometry of the winding. Windings may be deformed after transport of the transformer or nearby through faults with high currents. Changes in capacitance serve as an excellent indicator of winding movement and structural problems (displaced wedging, buckling etc.). If a winding damage is suspected then the capacitance measurement should be supplemented by a leakage reactance measurement. A separate test can be done for each phase with this measurement technique. Therefore this method is more sensitive to small changes in one phase.

5.3 Two-winding transformer

The two-winding transformer is a very good example to show the different parts of insulation which can be measured in a transformer.

A two-winding transformer with high and low voltage windings provides three different insulations which can be measured (see Figure 5-2 below): Insulation C_{HL} between the high- and the low-voltage windings, insulation C_H between the high-voltage winding and ground and the insulation C_L between the low-voltage winding and ground.

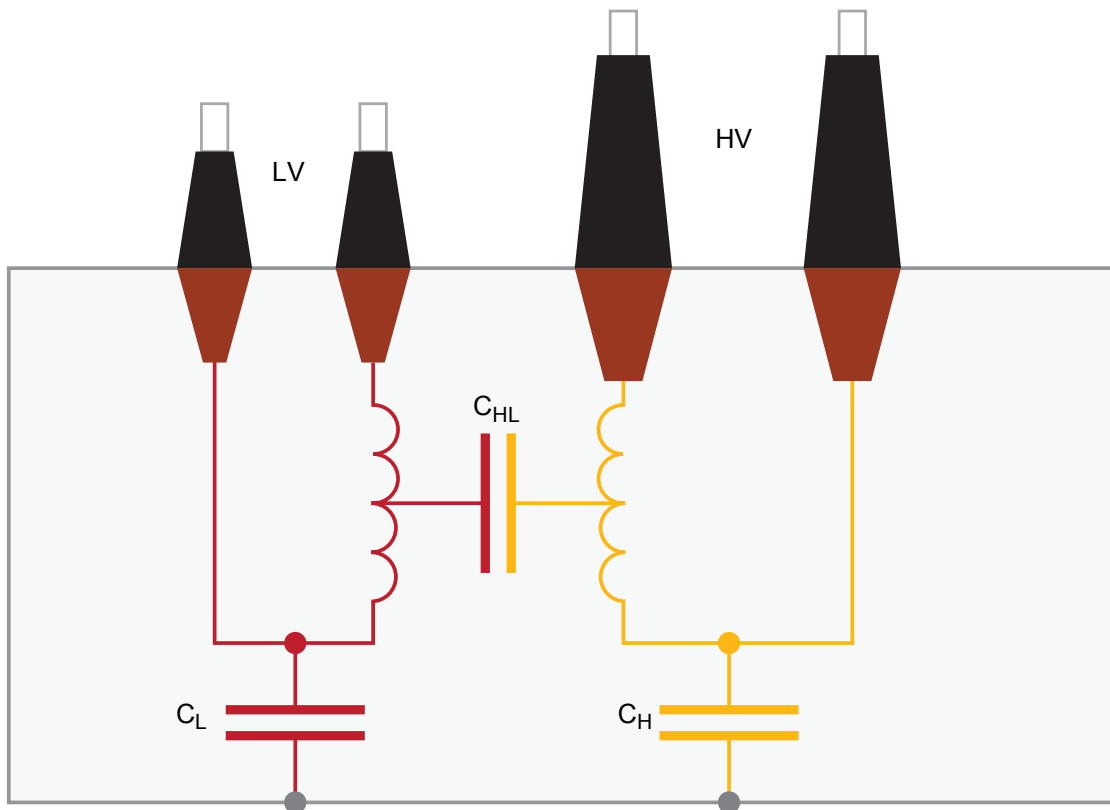


Figure 5-2: Insulations of a two-winding transformer

In case of core type transformers, insulation C_{HL} is made of barriers and spacers which give it mechanical stability and enable oil flow to cool the windings. Compared to the other insulation parts, insulation C_{HL} contains the highest amount of paper.

Insulation C_H , insulating the high-voltage windings from the tank, mainly consists of oil. The paper influence usually mainly comes from parts of the clamping construction.

Insulation C_L , insulating the low-voltage windings from the core, also consists of oil and paper but there usually is much less paper present than in the C_{HL} insulation.

Dielectric measurements on a two-winding power transformer usually include all 3 insulations C_{HL} , C_H and C_L . To measure C_{HL} and C_H , the HV output of the *CP TD1* is connected to the HV side and IN A to the LV side (see Figure 5-3 on page 41). To prevent induced currents, all bushings of the HV side are shorted, the same applies to the LV side. The ground of the transformer and the ground of the *CP TD1* are connected.

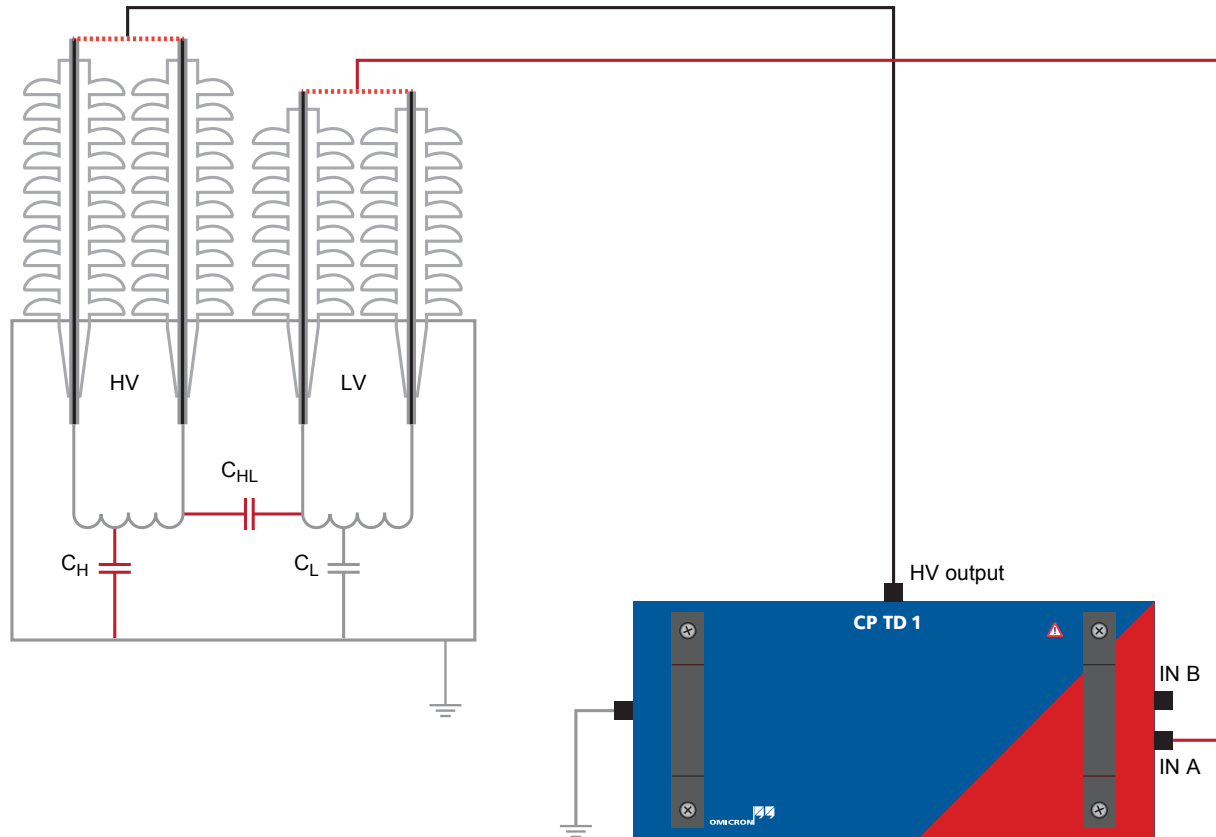


Figure 5-3: *CP TD1* connected to a two-winding transformer for the measurement of C_{HL} and C_H

With this setup 3 configurations are available (see Table 5-1 below). C_{HL} and C_H can be measured without reconnecting.

IN B is not connected, so the modes GSTg-A and GSTg-(A+B) give the same result as it makes no difference whether the current over IN B is guarded or measured.

Table 5-1: Modes available with a measurement setup as seen in Figure 5-3

Mode	IN A	Ground	Result
UST-A	Measured	Guarded	C_{HL}
GSTg-A or GSTg-(A+B)	Guarded	Measured	C_H
GSTg-B	Measured	Measured	$C_{HL} + C_H$

For the measurement of C_L the setup has to be changed. The HV output has to be connected to the LV side and IN A to the HV side (see Figure 5-4 blow).

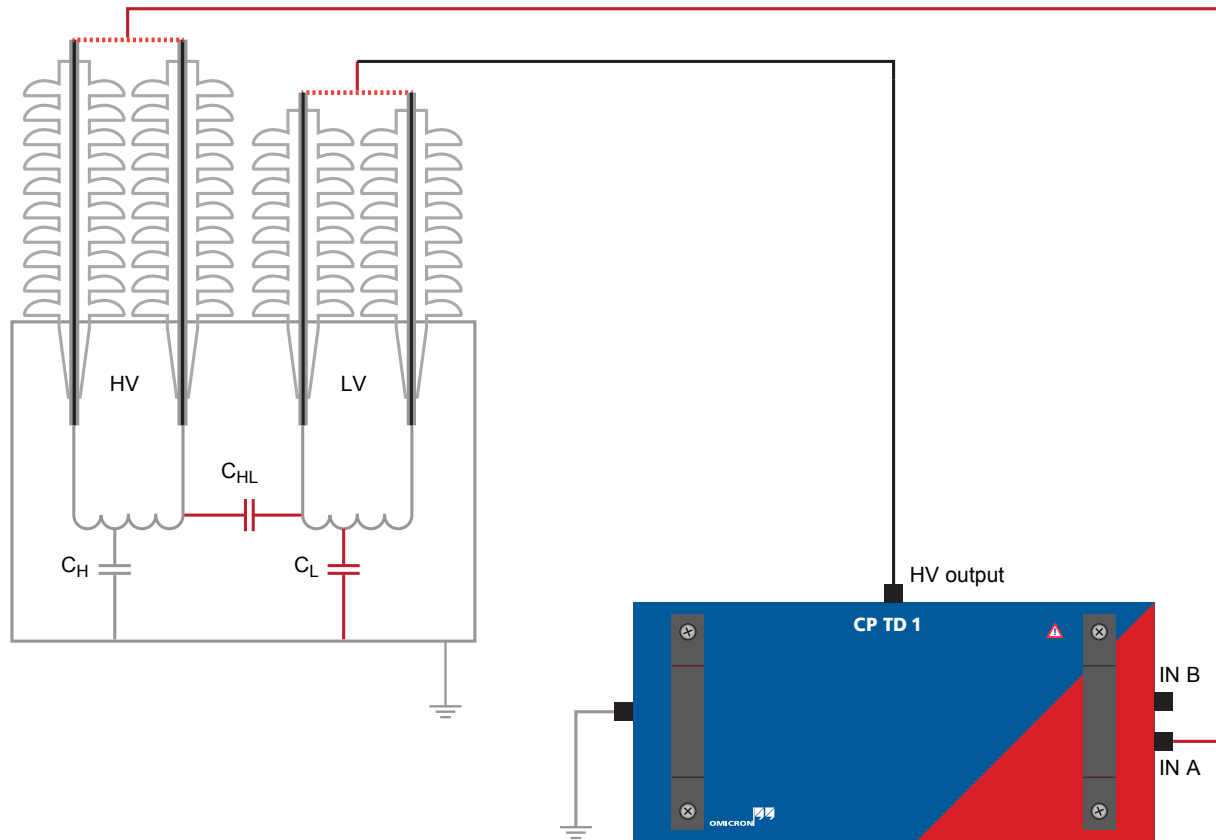


Figure 5-4: CP TD1 connected to a two-winding transformer for the measurement of C_{HL} and C_L

With this setup 3 configurations are available as well (see Table 5-2 below). As C_{HL} has been measured before, usually only C_L is measured in this second measurement.

Table 5-2: Modes available with a measurement setup as seen in Figure 5-4

Mode	IN A	Ground	Result
UST-A	Measured	Guarded	C_{HL}
GSTg-A or GSTg-(A+B)	Guarded	Measured	C_L
GSTg-B	Measured	Measured	$C_{HL} + C_L$

5.4 Measurements on two-winding transformers

Figure 5-5 shows the measurements necessary for a two-winding transformer, according to IEEE 62 1995 [1].

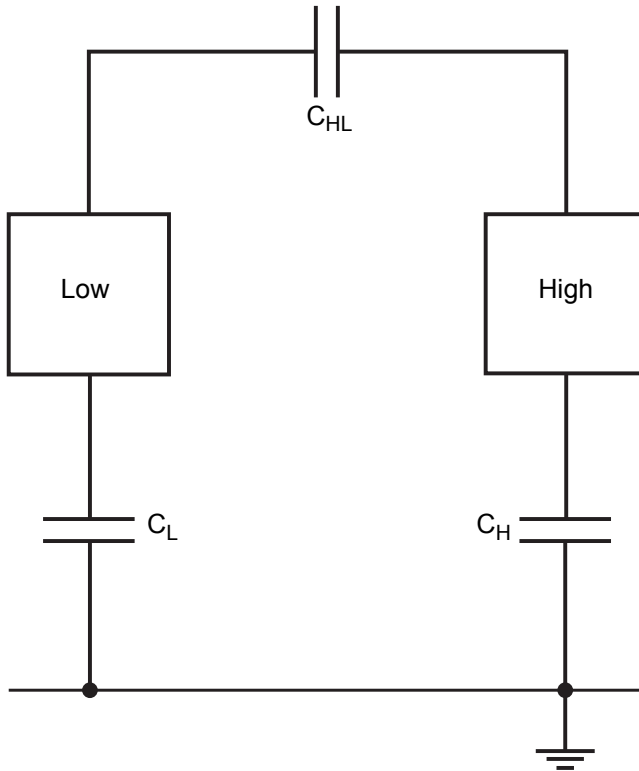


Figure 5-5: Two-winding transformer test according to IEEE 62-1995

Table 5-3: The necessary measurements

Test mode	Energize	Ground	Guard	UST	Measure
GST	High (HV)	-	Low	-	C_H
GST	Low (LV)	-	High	-	C_L
Alternative test for C_{HL}					
UST	High (HV)	-	-	Low (LV)	C_{HL}
UST	Low (LV)	-	-	High (HV)	C_{HL}

1. ANSI Standard 62-1995: "IEEE Guide for Diagnostic Field testing of Electric Power Apparatus - Part 1: Oil Filled Power Transformers, Regulators, and Reactors", IEEE New York, 1995

5.4.1 Measurements on a two-winding transformer with the CPC 100 and CPC 80

Figures 5-6 and 5-7 show the preparation with the *CPC Editor* and the test results in MS Excel format.

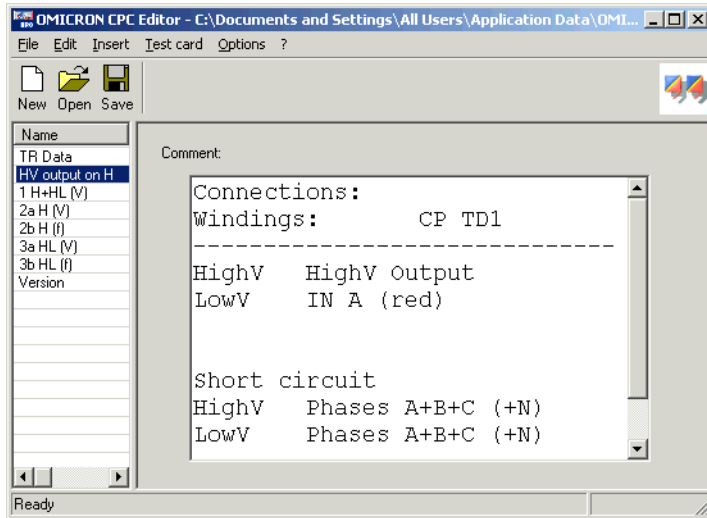


Figure 5-6: Two-winding transformer test preparation with *CPC Editor*

#	HV output	Ground	Guard	UST	V TEST [V]	I TEST [A]	C	DF[%] measured	DF[%] corrected	Measured	Mode	Connection
1	H	L			9999,00	0,0329	1,048E-08	0,3066	0,3066	H+HL	GST	H to HV
2	H		L		10000,00	0,0305	9,708E-09	0,2661	0,2661	H	GST gA	OUT
3	H			L	9999,00	0,0024	7,739E-10	0,4257	0,4257	HL	UST A	L to IN A
4		#1 -#2					7,763E-10					
5	L	H			10018,00	0,0306	9,708E-09	0,2499	0,2499	L	GST gA	L to HV OUT H to IN A

Figure 5-7: 10 kV results for a two-winding transformer (50 Hz)

5.4.2 Measurements on a two-winding transformer with TESTRANO 600

For a detailed description of the Tan Delta measurement with *TESTRANO 600* refer to the *TESTRANO 600* User Manual under section "TouchControl tests" and its sub-section "Tan Delta".

5.5 Three-winding transformer

In a three-winding transformer there are two parts of insulation which are formed by barriers and spacers, C_{HL} and C_{LT} between the low- and tertiary-voltage windings (see Figure 5-8 below). Both insulation parts are similar in construction to C_{HL} in a two-winding transformer.

Additionally to insulation C_H which is similar to C_H in a two-winding transformer, there are insulation C_L between the low-voltage winding and the tank, insulation C_T between the tertiary winding and the tank and insulation C_{HT} between the high-voltage winding and the tertiary windings. C_T is similar to C_L in a two-winding transformer, whereas C_L in a three-winding transformer is mainly formed by the insulation between the low-voltage winding and the tank and not the core limb. C_{HT} is very small and usually not of any specific importance as it is mainly formed by the stray capacitance from the HV side to the TV side via the press construction above and below the windings.

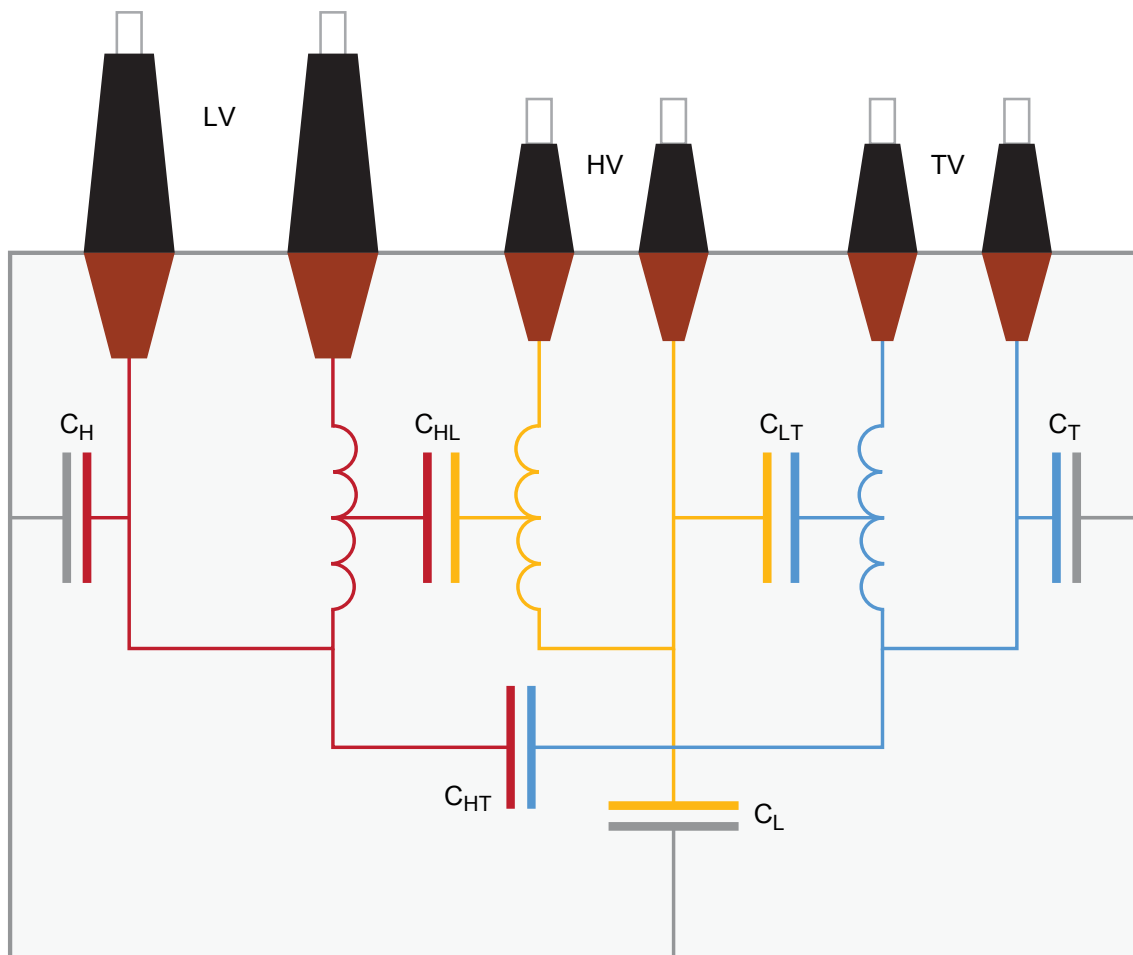


Figure 5-8: Insulations of a three-winding transformer

All phases and the neutral terminal of one winding (H, L and T) have to be short-circuited. Due to the inductance of the windings, resonant effects may occur and influence the measurement.

CP TD1 User Manual

When the *CP TD1*'s HV output is connected to the LV winding and IN A and IN B to HV and tertiary, the capacitances C_{HL} , C_{HT} and C_L can be measured without reconnection (see Figure 5-9 and Tables 5-4 and 5-5 below).

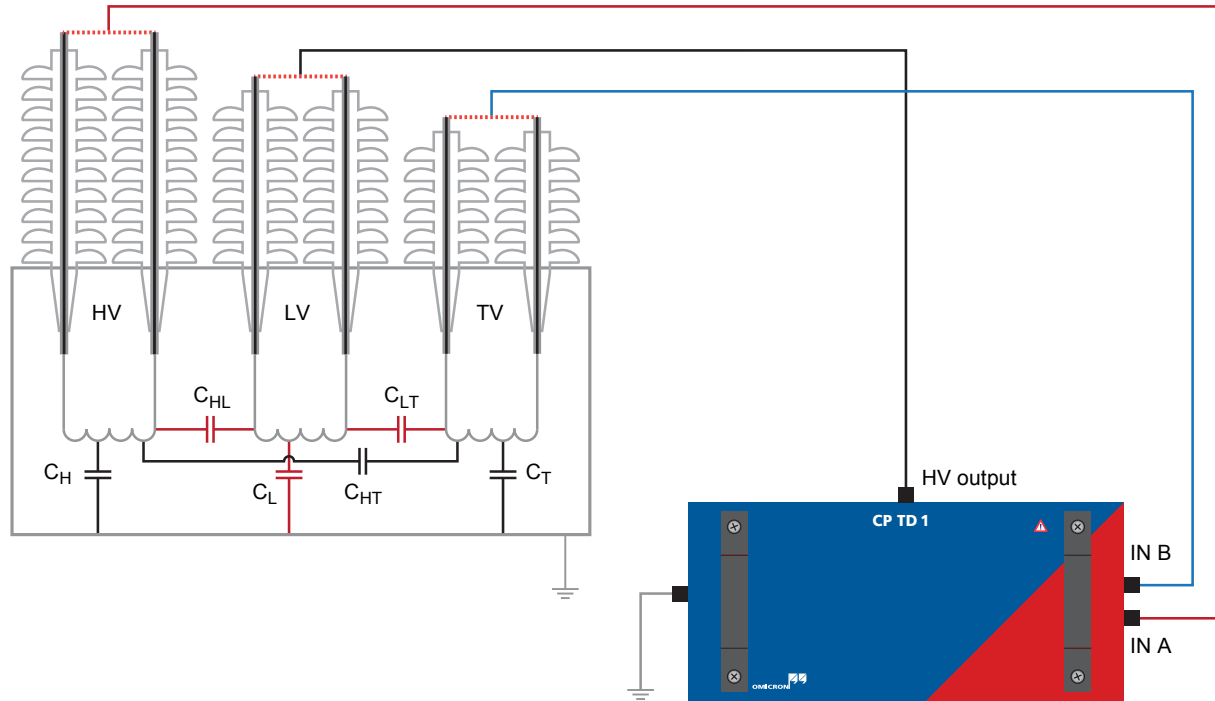


Figure 5-9: *CP TD1* connected to a three-winding transformer for the measurement of C_{HL} , C_{LT} and C_L

With this setup the following 3 configurations are available:

Table 5-4: Modes available with a measurement setup as seen in Figure 5-9

Mode	IN A	IN B	Ground	Result
UST-A	Measured	Guarded	Guarded	C_{HL}
UST-B	Guarded	Measured	Guarded	C_{LT}
GSTg-(A+B)	Guarded	Guarded	Measured	C_L

Additionally, combinations of the different inputs are possible but as it is usually preferred to assess each part of the insulation individually, they are less commonly used:

Table 5-5: Additional configurations available with a measurement setup as seen in Figure 5-9 if the inputs are combined differently

Mode	IN A	IN B	Ground	Result
GSTg-(B)	Measured	Guarded	Measured	$C_L + C_{HL}$
GSTg-(A)	Guarded	Measured	Measured	$C_L + C_{LT}$
GST	Measured	Measured	Measured	$C_L + C_{LT} + C_{HL}$
UST-(A+B)	Measured	Measured	Guarded	$C_{HL} + C_{LT}$

For the measurement of C_H the HV output has to be attached to the HV winding. The other windings are connected to IN A and IN B. This way, also C_{HL} and C_{HT} could be measured (see Figure 5-10 and Table 5-6 below).

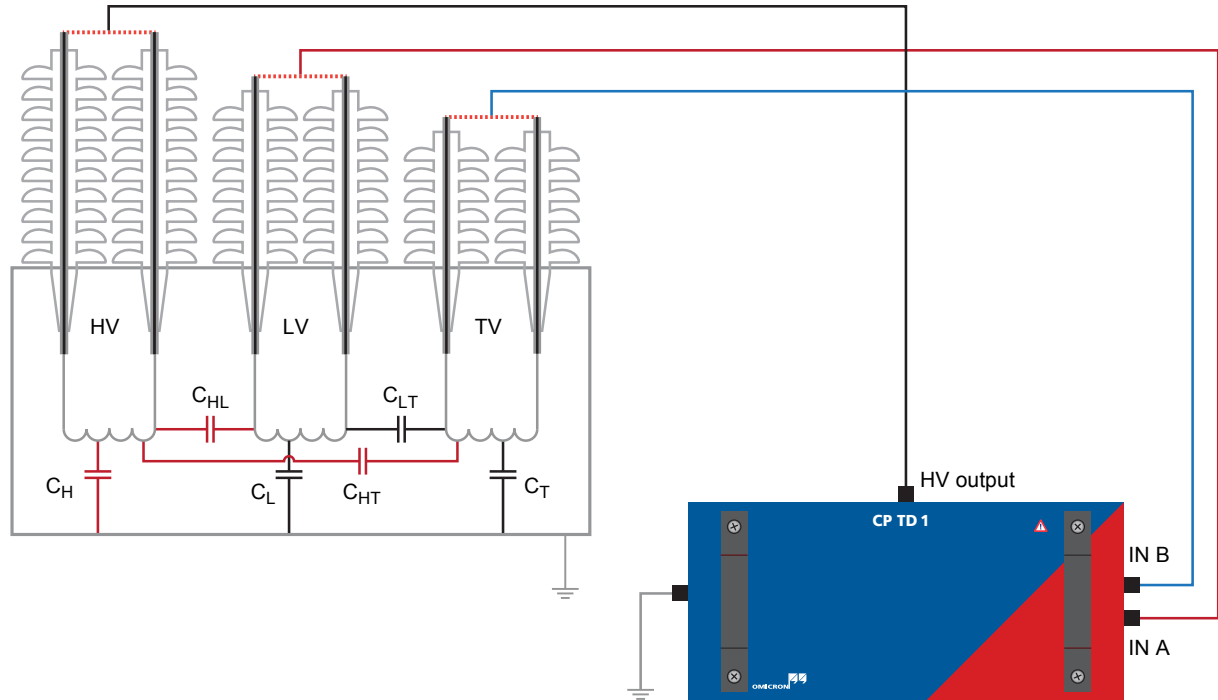


Figure 5-10: CP TD1 connected to a three-winding transformer for the measurement of C_H

With this setup the following 3 configurations are available:

Table 5-6: Modes available with a measurement setup as seen in Figure 5-10

Mode	IN A	IN B	Ground	Result
GSTg-(A+B)	Guarded	Guarded	Measured	C_H
UST-A	Measured	Guarded	Guarded	C_{HL}
UST-B	Guarded	Measured	Guarded	C_{HT}

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For the measurement of C_T the HV output has to be attached to the TV winding. The other windings are connected to **IN A** and **IN B**. This way, also C_{LT} and C_{HT} could be measured (see Figure 5-10 and Table 5-6 below).

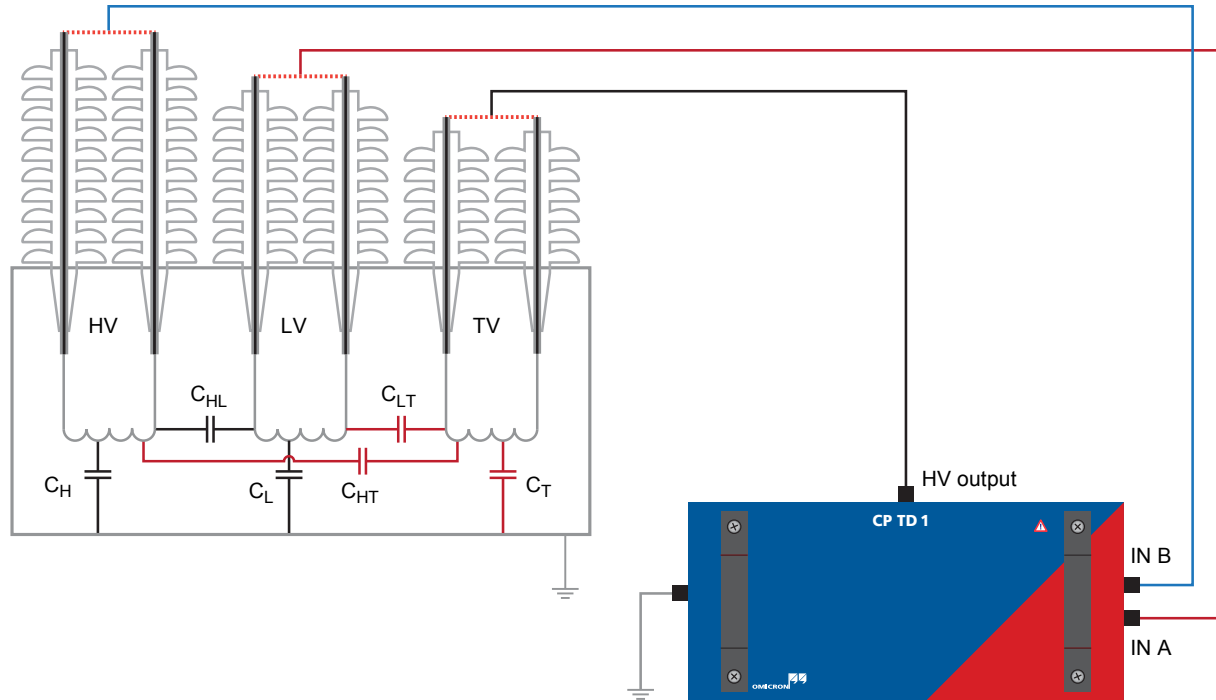


Figure 5-11: *CP TD1* connected to a three-winding transformer for the measurement of C_T

With this setup the following 3 configurations are available:

Table 5-7: Modes available with a measurement setup as seen in Figure 5-11

Mode	IN A	IN B	Ground	Result
GSTg-(A+B)	Guarded	Guarded	Measured	C_T
UST-A	Measured	Guarded	Guarded	C_{LT}
UST-B	Guarded	Measured	Guarded	C_{HT}

5.6 Measurements on three-winding transformers

In IEEE Std. 62-1995 [1] the test procedure is described for transformers with two and three windings. Figure 5-12 shows the six measurements necessary for a three-winding transformer.

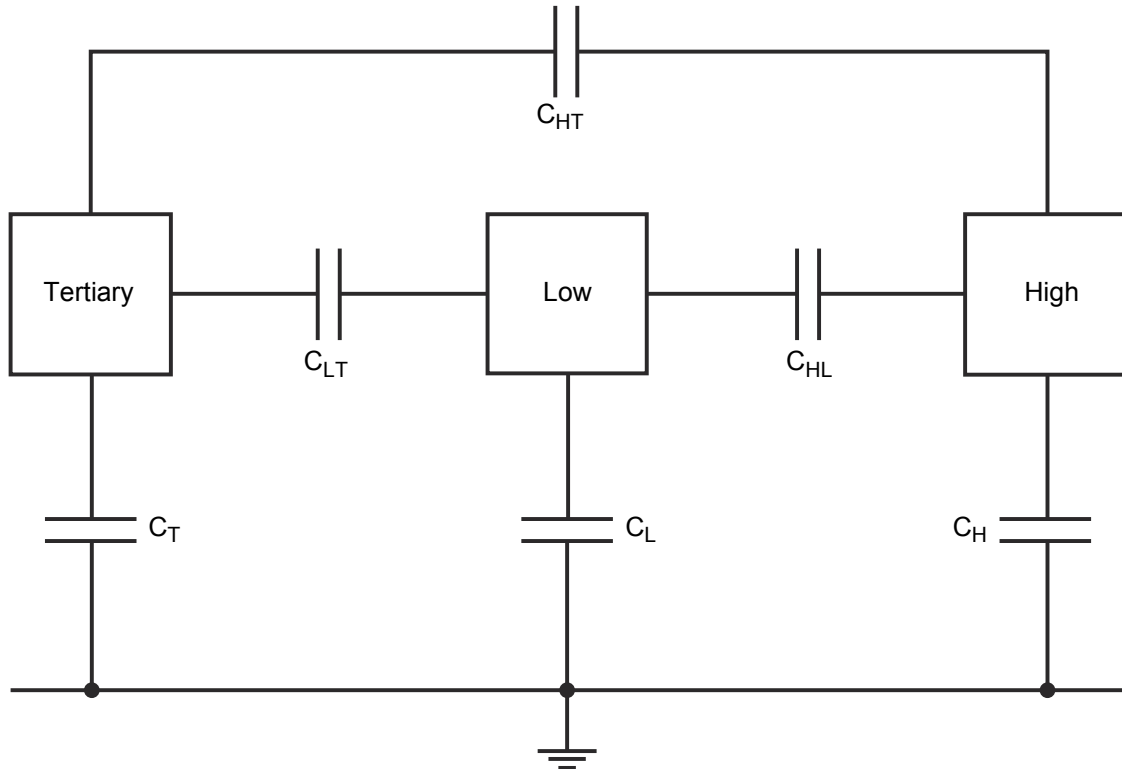


Figure 5-12: Three-winding transformer test according to IEEE 62-1995

Table 5-8: The six necessary measurements

Test mode	Energize	Ground	Guard	UST	Measure
GST	High (HV)	-	Low, Tertiary	-	C_H
GST	Low (LV)	-	Tertiary, High	-	C_L
GST	Tertiary (TV)	-	High, Low	-	C_T
Supplementary Test for inter-winding insulations					
UST	High (HV)	Tertiary (TV)	-	Low (LV)	C_{HL}
UST	Low (LV)	High (HV)	-	Tertiary (TV)	C_{LT}
UST	Tertiary (TV)	Low (LV)	-	High (HV)	C_{HT}

A more detailed test procedure for 2- and three-winding transformers can be found in IEEE C57.12.90 [2]

1. ANSI Standard 62-1995: "IEEE Guide for Diagnostic Field testing of Electric Power Apparatus - Part 1: Oil Filled Power Transformers, Regulators, and Reactors", IEEE New York, 1995
2. IEEE Standard C57.12.90: "IEEE Standard Test Code for Liquid-Immersed Distribution, Power, and Regulating Transformers", IEEE New York, 1995

5.6.1 Measurements on a three-winding transformer with the CPC 100 and CPC 80

This example shows the preparation of a three-winding transformer measurement with the CPC Editor. Due to the high amount of measuring data, the test is split into three single test files. The first file contains the tests with the high-voltage winding connected to the high-voltage output of the *CP TD1*.

First file

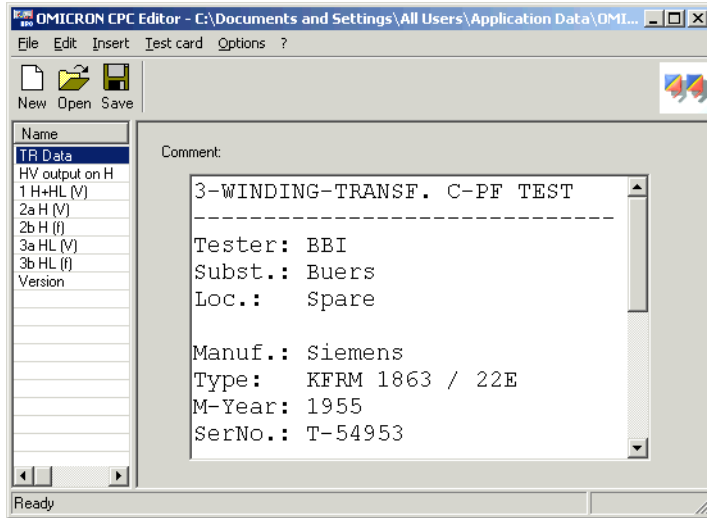


Figure 5-13: Input of transformer data

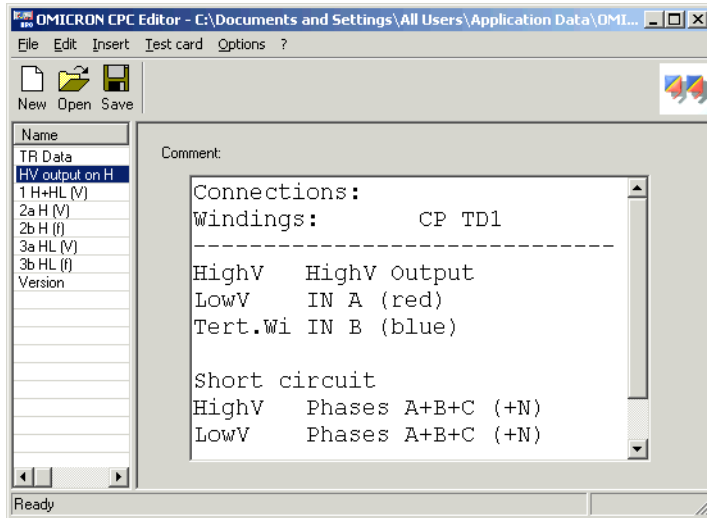


Figure 5-14: Instruction about test lead connections

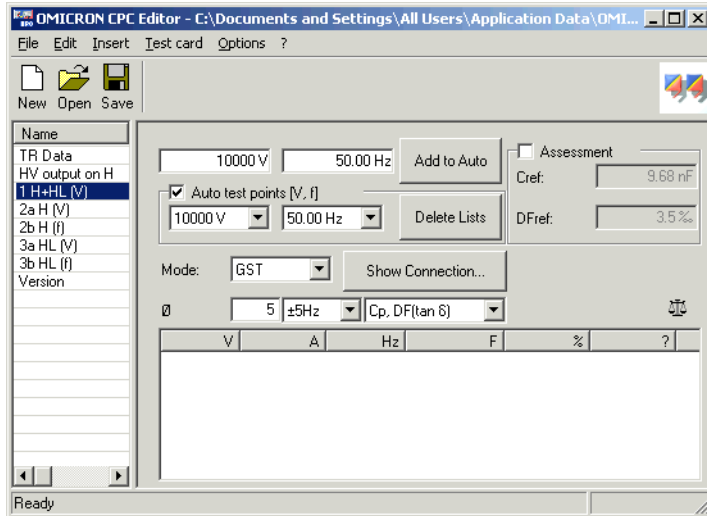


Figure 5-15: Measurement of C_H and C_{HL} in GST g-B mode

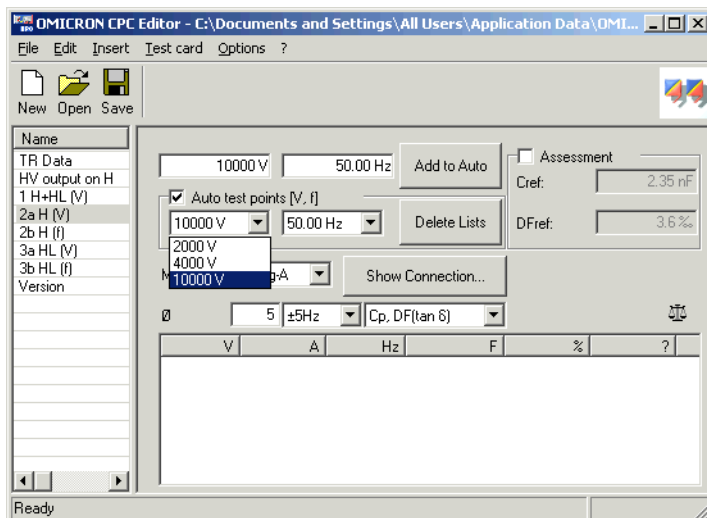


Figure 5-16: Voltage-scan of high-voltage windings to tank and core (GST gA+B)

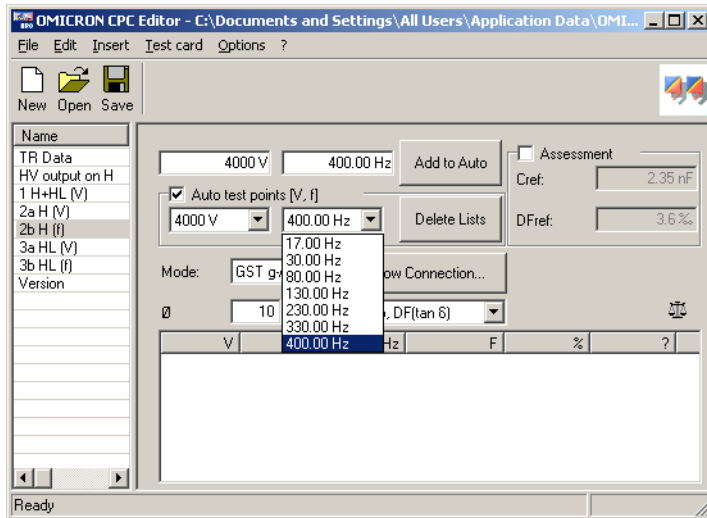


Figure 5-17: Frequency-scan of high-voltage windings to tank and core (GST gA+B)

The other tests for H_L are prepared analog to the examples.

Second file

A second test file contains the tests with the low-voltage winding connected to the high-voltage output of the *CP TD1*. Figure 5-18 shows the first screen with the connection instructions.

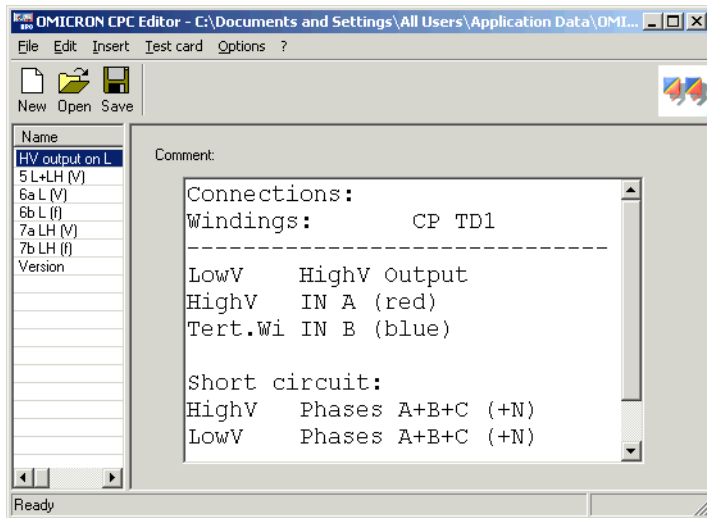


Figure 5-18: Connection instructions for the tests with energized low-voltage winding

Third file

A third test file is used for the tests with the tertiary winding connected to the high-voltage output of the CP TD1. Figure 5-19 shows the connection instructions for the tests with energized tertiary winding.

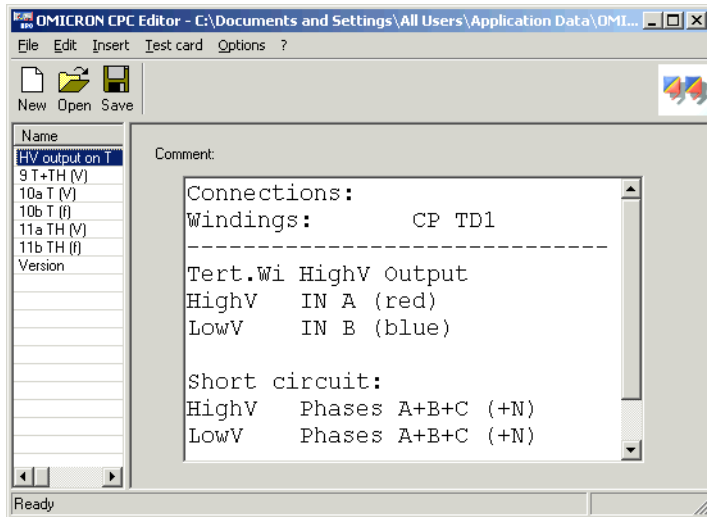


Figure 5-19: Connection instructions for the tests with energized tertiary winding

The prepared tests are to be uploaded to the CPC 100 as xml files without results. After the test is done, this xml file with the results is downloaded to the computer and loaded into Microsoft Excel with the OMICRON CPC 100 File Loader (the complete test files are included on the CD-ROM).

#	HV output	Ground	Guard	UST	V TEST [V]	I TEST [A]	C	DF [%] measured	DF [%] corrected	Measured	Mode	Connection
WINDING TEST 3-W TRANSFORMER (H-HIGH VOLTAGE, L-LOW VOLTAGE, T-TERTIARY)												
1	H	L	T		10019,0	0,0303	9,611E-09	0,3065	0,3065	H + HL	GST gB	H to HV OUT
2	H		L + T		10019,0	0,0278	8,835E-09	0,2633	0,2633	H	GST gA+B	L to IN A
3	H	T		L	9999,0	0,0024	7,739E-10	0,4319	0,4319	HL	UST A	T to IN B
#1 - #2												
4	L	T					7,755E-10					
5	L		H		10019,0	0,0306	9,710E-09	0,2753	0,2753	L + LT	GST gA	L to HV OUT
6	L		T + H		10000,0	0,0278	8,835E-09	0,2627	0,0000	L	GST gA+B	H to IN A
7	L	H		T	10015,0	0,0027	8,736E-10	0,0840	0,0840	LT	UST B	T to IN B
#5 - #6												
8	T	H		L	5002,0	0,0151	9,611E-09	0,3056	0,3056	T + TH	GST gB	T to HV OUT
9	T		H + L		4999,0	0,0139	8,835E-09	0,2761	0,2761	T	GST gA+B	H to IN A
10	T	L		H	4999,0	0,0012	7,739E-10	0,4349	0,4349	TH	UST A	L to IN B
#9 - #10												
11							7,761E-10					
V TEST max. = 1.2 x V RATED												

Figure 5-20: 10 kV results for a three-winding transformer (50 Hz)

CP TD1 User Manual

Figure 5-20 shows the results for 10 kV:

1	H+HL
2	H
3	HL
5	L+LT
6	L
7	LT
9	T+TH
10	T
11	TH

In line 4, the difference of the capacity values of test 1 - test 2 is calculated so it can be compared to test 3. In lines 8 and 12, the differences of lines 5-6 and 9-10 are calculated to also enable a comparison to tests 7 and 11. This way the reliability of the measured values can be checked. For the tertiary winding, the test voltage was reduced to 5 kV due to the lower rated voltage of this winding.

A voltage scan measurement is shown in Figure 5-21, a frequency scan in Figure 5-22.

Voltage and frequency scans enable additional information about the insulation quality. They should be saved as "fingerprint" for future measurements. For all the described measurements only three different connections of the test leads are necessary. Preparing the test in the office by utilizing the *CPC Editor*, the testing time on-site can be reduced to a minimum.

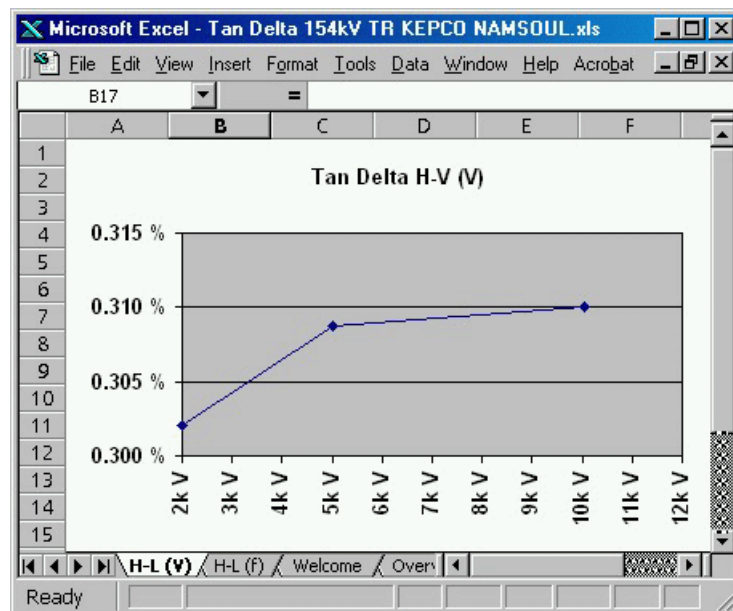


Figure 5-21: Voltage-scan for H-L (V) (50 Hz)

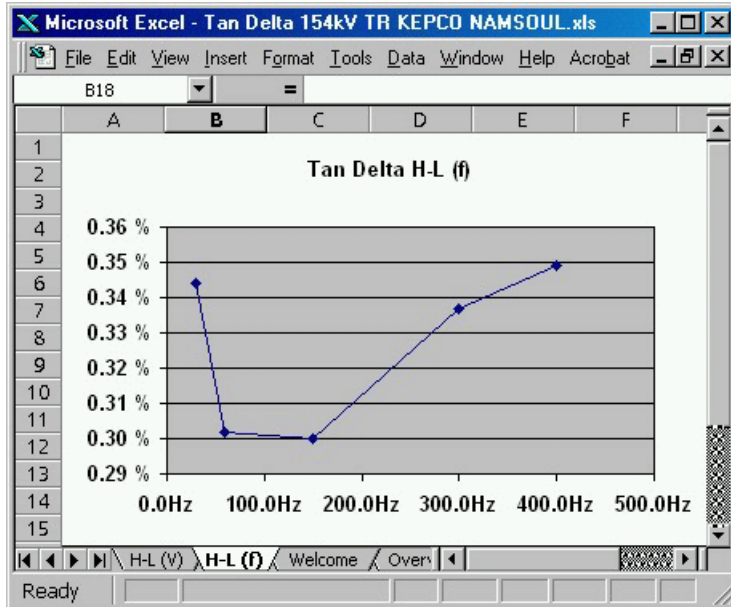


Figure 5-22: Frequency scan for H-L (f) (5 kV)

5.6.2 Measurements on a three-winding transformer with *TESTRANO 600*

For a detailed description of the Tan Delta measurement with *TESTRANO 600* refer to the *TESTRANO 600* User Manual under section "TouchControl tests" and its sub-section "Tan Delta".

5.7 Auto-Transformer

The auto-transformer has only one winding with a tap for the low-voltage output. Only one measurement is made of the winding to tank and core. All high-voltage and low-voltage terminals are connected together as they are building the high-voltage electrode of the capacity.

5.8 Reactors

Similar to the auto-transformers, reactors also normally have only one winding. Often the low-voltage ends of the three phases are connected outside the tank to the Neutral. In this case there are 2 bushings per phase, which have to be connected for the DF test. All combinations can be measured: Phase to phase and phase to tank (ground).

6 High-voltage bushings

6.1 Introduction

High-voltage bushings are essential parts of power transformers, circuit breakers and of other power apparatus. More than 10% of all transformer failures are caused by defective bushings. Although the price for a bushing is low compared to the costs of a complete transformer, a bushing failure can damage a transformer completely. A regular capacitance and DF measurement is highly recommended.

6.2 Types of bushings

Testing and maintaining high-voltage bushings are essential for continued successful operation of transformers and circuit breakers. Power outages may occur as the result of a bushing failure. High-voltage bushings used on transformers and breakers exist in many forms, including:

6.2.1 Condenser

This type is most frequently used for high-voltage bushings and it is therefore the main one focused in this guide. Cylindrical conducting layers are arranged coaxially with the conductor within the insulating material. The length and diameter of the cylinders are designed to control the distribution of the electric field in and over the outer surface of the bushing. The partial capacities are switched in series and the voltage drops across the capacities is nearly equal to each other (see Figures 6-1 and 6-2).

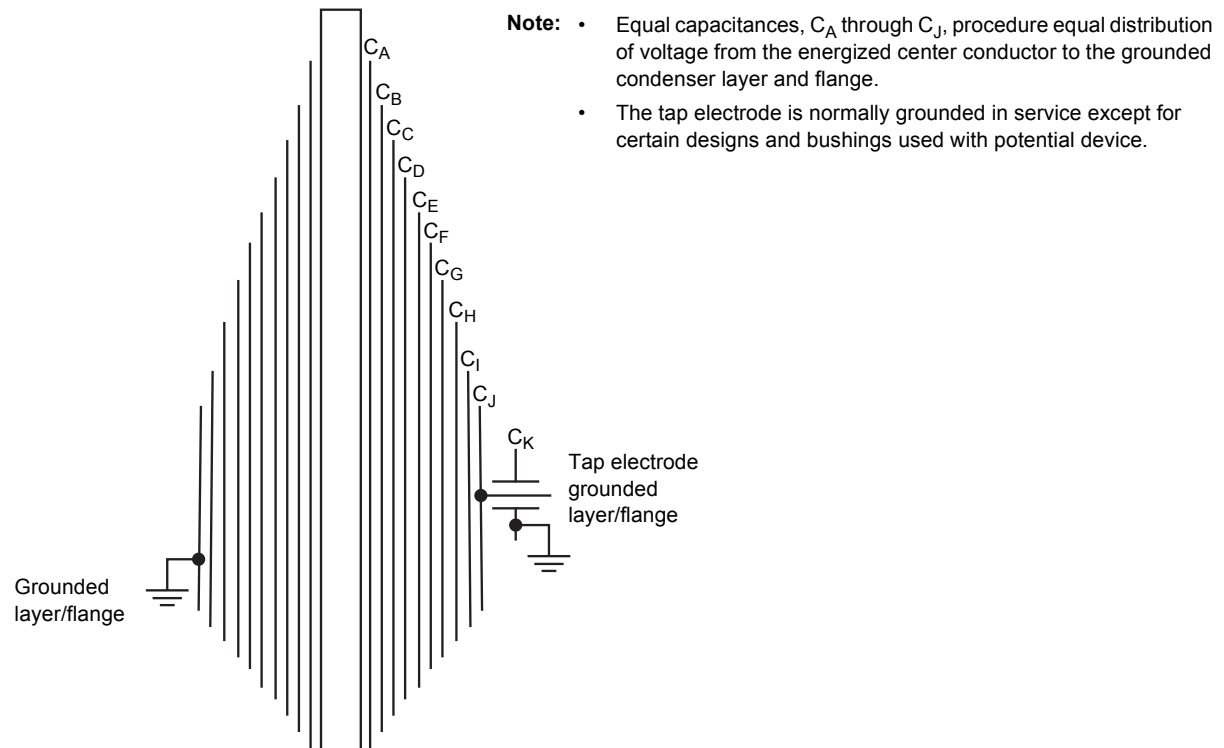
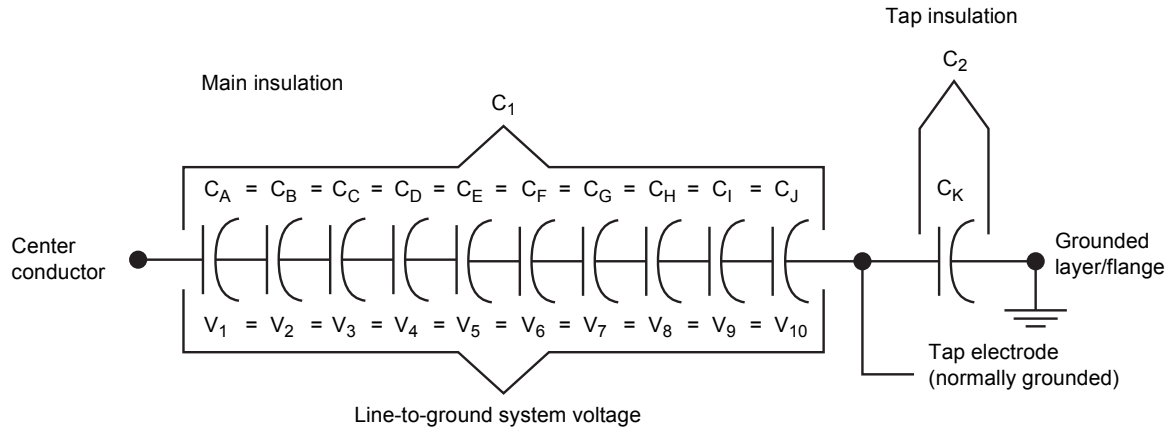


Figure 6-1: Condenser bushing design



Note: For bushings with potential taps, the C_2 capacitance is much greater than C_1 . For bushings with power-factor tap, C_1 and C_2 capacitances may be same order of magnitude.

Figure 6-2: Condenser bushing circuit diagram

Condenser bushings may have:

- "Resin-Bonded Paper insulation (RBP)
- "Resin-Impregnated Paper insulation (RIP)
- "Oil-Impregnated Paper insulation (OIP)

6.2.2 Composite

A bushing where the insulation consists of two or more coaxial layers consisting of different insulating materials.

6.2.3 Compound-filled

A bushing where the space between the major insulation or conductor, if no major insulation is used, and the inside surface of a protective weather casing (usually porcelain) is filled with a compound that contains insulating properties.

6.2.4 Dry or unfilled

A bushing consisting of a porcelain tube with no filler in the space between the shell and the conductor. These are usually rated 25 kilovolts and below.

6.2.5 Oil-filled

A bushing where the space between the major insulation or the conductor, and the inside surface of a protective weather casing is filled with insulating oil.

6.2.6 Oil-immersed

A bushing composed of major insulators that are totally immersed in a bath of insulating oil.

6.2.7 Oil-impregnated paper-insulated

A bushing where the internal structure is made of cellulose material impregnated with oil.

6.2.8 Resin-bonded paper-insulated

A bushing where cellulose material bonded with resin provides the major insulation.

6.2.9 Solid, ceramic

A bushing where a ceramic or other similar material provides the major insulation.

6.2.10 Gas insulated

A bushing that contains compressed gas like SF₆ or mixtures of SF₆ with other gasses i.e. N₂. This type is frequently used for circuit breaker bushings.

6.3 Capacitance and DF measurement on high-voltage bushings

The dissipation factor test is the most effective known field test procedure for the early detection of bushing contamination and deterioration. It also measures alternating (AC) test current, which is directly proportional to bushing capacitance.

Bushing dissipation factor and capacitance should be measured when a bushing is first installed and also one year after installation. After these initial measurements, bushing power or dissipation factor and capacitance should be measured at regular intervals (3 to 5 years typically). The measured values should be compared with previous tests and nameplate values.

Note: Large variations in temperature significantly affect dissipation factor readings on certain types of bushings. For comparative purposes, readings should be taken at the same temperature. Corrections should be applied before comparing readings taken at different temperatures.

Bushings may be tested by one or more of four different methods, depending upon the type of bushing and the dissipation factor test set available. For more detailed instructions on this test procedure, see the dissipation factor test set instruction book from the appropriate manufacturer. The four test methods are described as follows:

6.4 Ungrounded Specimen Test (UST)

This test measures the insulation between the center conductor and the capacitance tap, the dissipation factor tap, and/or ungrounded flange of a bushing. This test may be applied to any bushing in or out of the apparatus that is either equipped with capacitance or dissipation factor taps, or with the flange that can be isolated from the grounded tank in which the bushing is installed. The insulation resistance between the taps or insulated flanges and ground should be 0.5 M or greater. While in this case anything that is attached to the bushing would also be energized, only the insulation of the bushing between the center conductor and the ungrounded tap or flange would be measured. In the case of bushings equipped with capacitance taps, a supplementary test should always be made on the insulation between the tap and the flange.

Most manufacturers list the UST dissipation factor and capacitance values on the bushing nameplate.

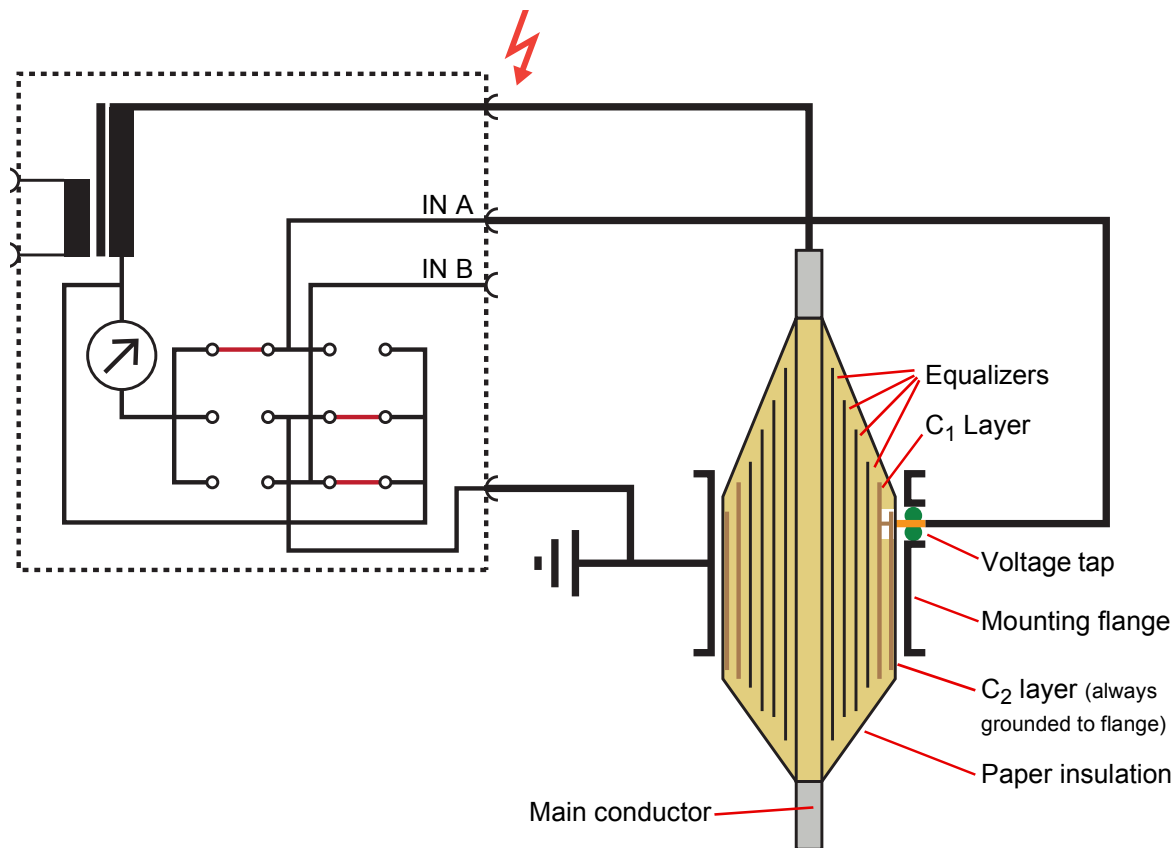


Figure 6-3: UST-A bushing test (C_1)

When bushings with capacitance or potential taps rated at 110 kV and above are tested by the ungrounded test specimen method, a separate dissipation factor test on the tap insulation should be performed as well.

For capacitance or potential taps, tests are performed at a voltage between 500 and 1,000 volts. The tap is energized with the bushing center conductor and flange grounded. The dissipation factor of a capacitance or potential tap will generally be of the order of 1.0 percent or less. Routine tap insulation tests are not normally recommended for bushings that are rated 69 kilovolts and below with dissipation factor taps. However, a dissipation factor test of the tap insulation should be performed when UST results are questionable or visual examination indicates the dissipation factor tap's condition is questionable. This test procedure is similar to that used earlier for capacitance taps. In such cases, the maximum permissible test potentials should be limited to those given in the appendix or as recommended by the bushing manufacturer. The dissipation factor value of the dissipation factor tap insulation for most of the bushings discussed earlier is generally in the order of 1.0 percent or less.

6.5 Grounded Specimen Test (GST)

This test measures the quality of the insulation between the current carrying or center conductor and the mounting flange of a bushing. This test is conducted on bushings that have been removed from equipment, bushings connected to de-energized equipment, spare bushings, or bushings that have been isolated from connected windings and interrupters. The test is performed by energizing the bushing conductor and grounding the flange.

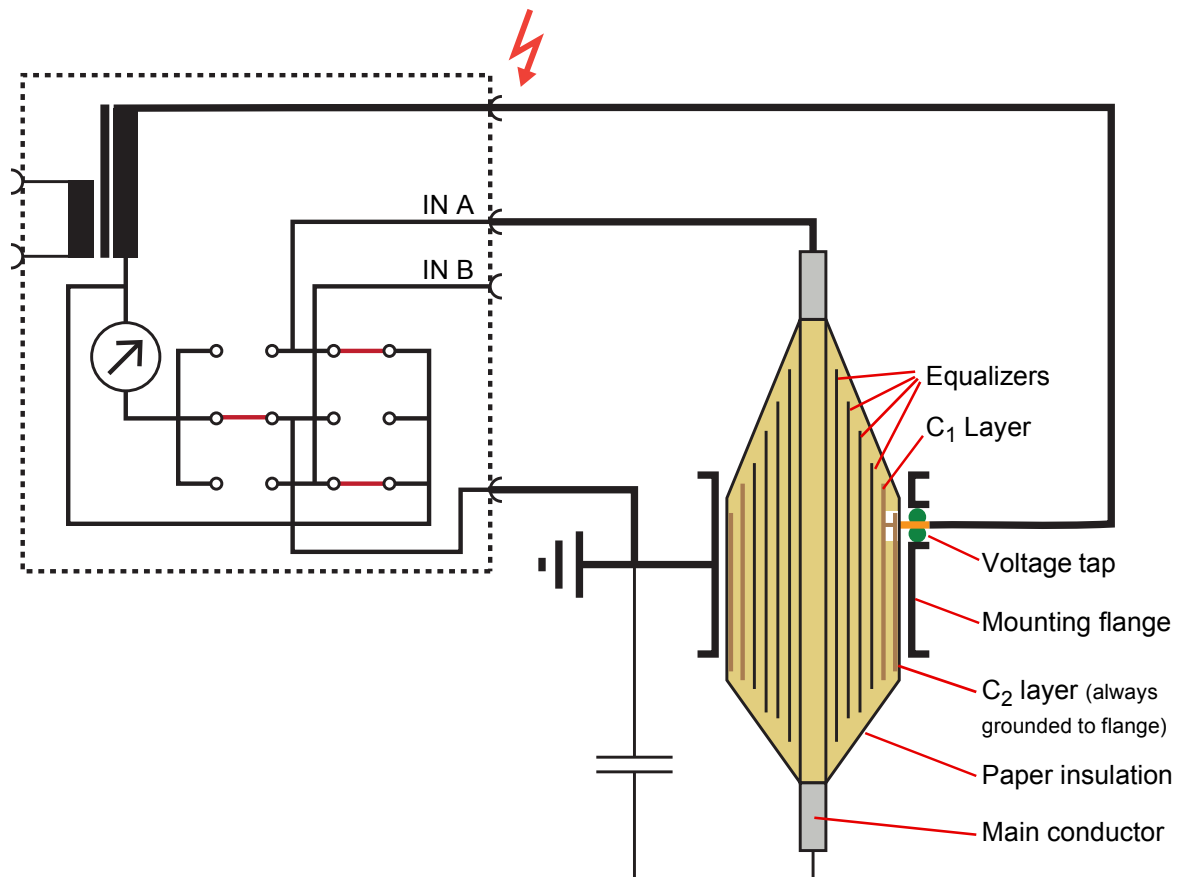


Figure 6-4: GST bushing test (C₂)

6.6 Hot collar test

This test measures the condition of a specific small section of bushing insulation between an area of the upper porcelain rain shed and the current carrying or center conductor. The test is performed by energizing one or more electrodes placed around the bushing porcelain with the bushing center conductor grounded. This test is used to supplement the three previous tests. It is also used to test bushings in apparatus when the three tests are either inapplicable or impractical, such as, with SF₆ bushings. Perform a hot-collar test at every third skirt on SF₆ bushings.

Hot-collar tests are effective in locating cracks in porcelain, deterioration, or contamination of insulation in the upper section of a bushing, low compound or liquid level, or voids in compound often before such defects are noticeable with the previous tests.

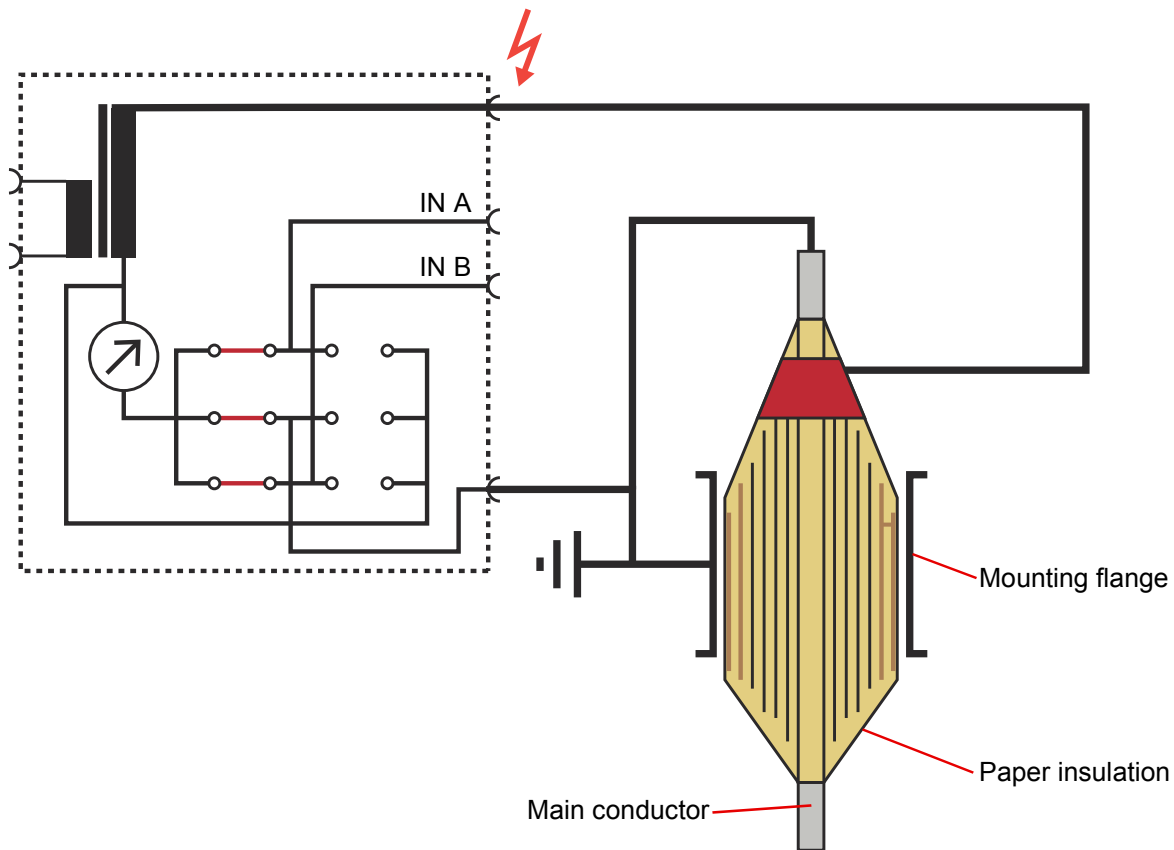


Figure 6-5: "Hot collar" test

Measured dissipation factor values should be temperature corrected to 20°C before being compared with reference values which are measured at 20°C.

Temperature correction factors are average values at best, and therefore, subject to some error. The magnitude of error is minimized if tests are performed at temperatures near the reference temperature of 20°C. If questionable dissipation factors are recorded at relatively high temperatures then the bushings should not be condemned until it has been allowed to cool down to near 20°C and repeat tests have been performed. This also applies to bushings tested near freezing where a large (greater than 1.00) correction may cause the result to be unacceptably high; in this case the equipment should be retested at a higher temperature. Bushings should not be tested when their temperatures are much below freezing because moisture may have changed to ice, which has a significantly higher volumetric resistivity and therefore may be undetected. In the case of bushings mounted in transformers, taking the average between the ambient and transformer top-oil temperatures approximates the bushing temperature.

Bushing capacitance should be measured with each power or dissipation factor test and compared carefully with both nameplate and previous tests in assessing bushing condition. This is especially important for capacitance-graded bushings where an increase in capacitance of 5 % more over the initial/nameplate value is cause to investigate the suitability of the bushing for continued service. The manufacturer should be consulted for guidance on specific bushings.

When the relative humidity is high, measurements are often influenced by the current, which is flowing on the surface of the insulator. Sometimes these currents are in the same order as the current, which is flowing through the insulation or even higher. If a good cleaning and drying of the insulator surface is not sufficient, the guard technique should be used to bypass this current (see Figure 6-6).

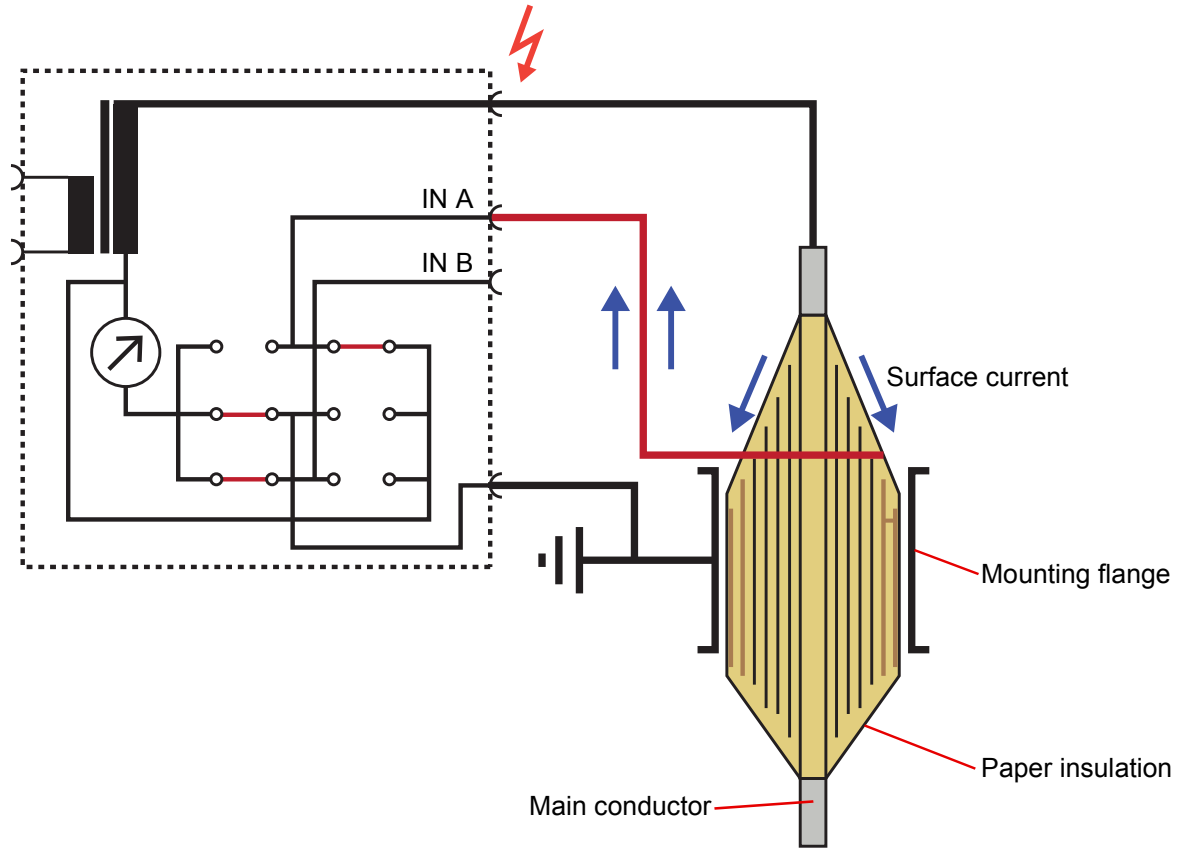


Figure 6-6: Use of the guard method for bypassing the surface current

This connection technique is also very useful when the insulation of cables is measured.

When transformer bushings are tested, IN A and IN B can be used to measure two bushings at a time without rewiring:

Table 6-1: Measurements

Measurement	UST A (IN A)	UST B (IN B)
1	Phase A	Phase B
2	Phase C	Neutral

Frequency scans of bushing insulation are helpful for a better diagnosis as some problems cause a larger deviation at power frequencies which is better visible when comparing good and bad bushings. This additional information should be used as benchmark of the bushing for future comparison.

7 Technical data

7.1 Technical data of the *CP TD1* in combination with the *Control Device*

7.1.1 High-voltage output

Conditions: Signals below 45 Hz with reduced values possible. Capacitive linear loads.

Table 7-1: High-voltage output

Terminal	U / f	THD	I	S	t _{max}
High-voltage output	0...12 kV AC	< 2 %	300 mA	3600 VA	> 2 min
	15...400 Hz		100 mA	1200 VA	> 60 min

7.1.2 Measurements

Test frequencies

Table 7-2: Test frequencies

Range	Typical accuracy
15...400 Hz	error < 0.005 % of reading

Only *CPC 100* and *CPC 80*: TanDelta test card: Column "Hz" of the results table

Special displays in the frequency column "Hz" and their meanings:

*50 Hz (*60 Hz)	Measurement mode suppressing the mains frequency interferences; doubles the measurement time.
!30 Hz	The selected test voltage is not available in Automatic measurement (applies to frequencies below 45 Hz only).
?xx Hz	Results with reduced accuracy, e.g., in case of a low testing voltage, influences of partial discharge etc.

Filter for selective measurements

Conditions: f = 15 ... 400 Hz

Table 7-3: Filter for selective measurements

Filter Bandwidth	Measurement time	Stop band specification (attenuation)
f0 ± 5 Hz	2.2 s	> 110 dB at fx = f0 ± (5 Hz or more)
f0 ± 10 Hz	1.2 s	> 110 dB at fx = f0 ± (10 Hz or more)
f0 ± 20 Hz	0.9 s	> 110 dB at fx = f0 ± (20 Hz or more)

Test current (RMS, selective)

Table 7-4: Test current

Terminal	Range	Typical accuracy	Conditions
IN A or IN B ¹	0...5 A AC	error < 0.3 % of reading + 100 nA	I _x < 8 mA
		error < 0.5 % of reading	I _x > 8 mA

1. IN A (red) or IN B (blue), depending on the mode.

Test voltage (RMS, selective)

Table 7-5: Test voltage

Condition: U > 2 kV

Range	Typical accuracy
0...12000 V AC	error < 0.3 % of reading + 1 V

Capacitance Cp (equivalent parallel circuit)

Table 7-6: Capacitance Cp

Range	Typical accuracy	Conditions
1 pF...3 μF	error < 0.05 % of reading + 0.1 pF	I _x < 8 mA, U _{test} = 300 V...10 kV
	error < 0.2 % of reading	I _x > 8 mA, U _{test} = 300 V...10 kV

Dissipation factor DF (tan δ)

Table 7-7: Dissipation factor DF

Range	Typical accuracy	Conditions
0...10 % (capacitive)	error < 0.1 % of reading + 0.005 % ¹	f = 45...70 Hz, I < 8 mA, U _{test} = 300 V...10 kV
0...100 (0...10000 %)	error < 0.5 % of reading + 0.02 %	U _{test} = 300 V...10 kV

1. Reduced accuracy of DF at mains frequency or its harmonics. Mains frequency suppression available by precisely selecting a mains frequency of *50Hz or *60Hz in the "Hz" column.

Power factor PF (cos φ)

Table 7-8: Power factor Pf

Range	Typical accuracy	Conditions
0...10 % (capacitive)	error < 0.1 % of reading + 0.005 % ¹	f = 45...70 Hz, I < 8 mA, U _{test} = 300 V...10 kV
0...100 %	error < 0.5 % of reading + 0.02 %	U _{test} = 300 V...10 kV

1. Reduced accuracy of PF at mains frequency or its harmonics. Mains frequency suppression available by precisely selecting a mains frequency of *50Hz or *60Hz in the "Hz" column.

Phase angle φ

Table 7-9: Phase angle φ

Range	Typical accuracy	Conditions
-90 °...+90 °	error < 0.01 °	Vtest = 300 V...10 kV

Impedance Z

Table 7-10: Impedance Z

Range	Typical accuracy	Conditions
1 k Ω ...1200 M Ω	error < 0.5 % of reading	Vtest = 300 V...10 kV

Inductance Lx (equivalent serial circuit)

Table 7-11: Inductance Lx

Range	Typical accuracy
1 H...1000 kH	error < 0.3 % of reading

Quality factor QF

Table 7-12: Quality factor QF

Range	Typical accuracy
0...1000	error < 0.5 % of reading + 0.2 %
> 1000	error < 5 % of reading

Power P, Q, S (selective)

Table 7-13: Power P, Q, S

Range	Typical accuracy
0...3.6 kW	error < 0.5 % of reading + 1 mW
0...3.6 kVAR	error < 0.5 % of reading + 1 mVAR
0...3.6 kVA	error < 0.5 % of reading + 1 mVA

7.2 Mechanical data

Table 7-14: Mechanical data

Device(s) / accessories		Weight	Dimensions (W x H x D)
CP TD1	Test set	25 kg / 55.2 lb	450 x 330 x 220 mm 17.7 x 13 x 8.7 inches without handles
	Test set & case ¹	38.1 kg / 84 lb	700 x 500 x 420 mm 27.5 x 19.7 x 16.5 inches
Cables and accessories	Equipment	16.6 kg / 36.6 lb	
	Equipment & case ¹	26.6 kg / 58.7 lb	680 x 450 x 420 mm 26.8 x 17.7 x 16.5 inches
Equipment trolley	Equipment	14.5 kg / 32 lb	
	Equipment & carton	18.9 kg / 41.7 lb	590 x 750 x 370 mm 23.2 x 29.2 x 14.6 inches
CP TD1, CPC 100, equipment & trolley	Equipment	85 kg / 187.5 lb	750 x 1050 x 600 mm 29.5 x 41.3 x 23.6 inches
	Equipment & packing	125 kg / 275.8 lb	
CP TD1, TESTRANO 600, equipment & trolley	Equipment	85 kg / 187.5 lb	750 x 1050 x 600 mm 29.5 x 41.3 x 23.6 inches
	Equipment & packing	125 kg / 275.8 lb	

1. Case = robust case, IP22

7.3 Environmental Conditions

Table 7-15: Climate


Characteristic		Rating
Temperature	Operating	-10...+55 °C / +14...+131 °F
	Storage and transportation	-20...+70 °C / -4...+158 °F
Max. altitude		2000 m
Relative humidity		5...95 %; no condensation, tested according to IEC 60068-2-78

Table 7-16: Noise Immunity

Characteristic	Rating
Noise Immunity	Electrostatic: 15 mA induced noise into any test lead without losing measurement accuracy at maximum interference to specimen current of 20:1
	Electromagnetic: 500 µT, at 60 Hz in any direction

7.4 Standards

Table 7-17: Standards conformity

Safety		
Safety	IEC / EN / UL 61010-1	
EMC		
EMC	IEC/EN 61326-1 (industrial electromagnetic environment) FCC subpart B of part 15, class A	
Other		
Shock	IEC 60068-2-27 (operating), 15 g/11 ms, half-sinusoid	
Vibration	IEC 60068-2-6 (operating), 10...150 Hz, acceleration 2 g continuous (20 m/s ²); 10 cycles per axis	
Humidity	IEC/EN 60068-2-78 (5...95 % relative humidity, no condensation)	

Support

When you are working with our products we want to provide you with the greatest possible benefits. If you need any support, we are here to assist you!



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