CP TD12/15

User Manual

Manual Version: ENU 1226 05 03

Contents

About this manual

This User Manual provides information on how to use the *CP TD12/15* test system safely, properly and efficiently. The CP TD12/15 User Manual contains important safety rules for working with the *CP TD12/15* and gets you familiar with operating the *CP TD12/15*. 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 TD12/15 User Manual must be always available on the site where the *CP TD12/15* is used. The users of the *CP TD12/15* must read this manual before operating the *CP TD12/15* and observe the safety, installation, and operation instructions therein.

Reading the CP TD12/15 User Manual alone does not release you from the duty to comply with all national and international safety regulations relevant to working with and around 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 TD12/15 User Manual:

Title	Description
CPC 100 User Manual	Contains information on how to use the *CPC 100* test system and relevant safety instructions.
CPC 100 Reference Manual	Contains detailed hardware and software information on the *CPC 100* including relevant safety instructions.
CPC 100 PTM User Manual	Contains information on how to use the *Primary Test Manager PTM* together with the *CPC 100*.
CPC 80 User Manual	Contains information on how to use the *CPC 80* test system and relevant safety instructions.
CPC Getting Started	Contains general safety instructions and information on the *CPC 100* and CPC 80.
TESTRANO 600 User Manual	Contains information on how to use the *TESTRANO 600* test system and relevant safety instructions.
CP CR600 User Manual	Contains information on how to use the *CP CR600* compensating reactor and relevant safety instructions.
CP TC12 Reference Manual	Contains information on how to use the *CP TC12* oil test cell and relevant safety instructions.
CP CAL1 User Manual	Contains information on how to use the *CP CAL1* calibration system and relevant safety instructions.

1 Safety instructions

1.1 Operator qualifications

Working with or around high-voltage assets can be extremely dangerous. Only authorized personnel who are qualified, skilled and regularly trained in electrical engineering are allowed to operate the *CP TD12/15* and its accessories. Before starting to work, clearly establish the responsibilities.

Personnel receiving training, instructions, directions, or education on the *CP TD12/15* must be under constant supervision of an experienced operator while working with the equipment. The supervising operator must be familiar with the equipment and the regulations on site. The operator is responsible for ensuring that safety requirements are fulfilled during the whole test.

1.2 Safety standards and rules

1.2.1 Safety standards

Testing with *CP TD12/15* 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 TD12/15* and its accessories, read the safety instructions in this User Manual carefully.

Do not turn on the *CP TD12/15* and do not operate the *CP TD12/15* 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 TD12/15* and its accessories is only permitted by qualified experts at OMICRON Service Centers (see "Support" on page 64).

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 General

- ► *CP TD12* and *CP TD15* are collectively named *CP TD12/15* if no specific device is referred to.
- ► Only use the *CP TD12/15* on dry, solid ground.
- ► Never connect or disconnect a test object while the outputs are active.
- ► When connecting cables to a control cabinet, be aware of uninsulated live components. Adhere to the safety instructions provided by the manufacturer.
- ► Make sure that the test object's terminals which are to be connected to the *CP TD12/15* do not carry any voltage potential. During a test, the only power source for a test object may be the *CP TD12/15*.
- ► Do not insert objects (for example, screwdrivers, etc.) into any input/output socket.

When measuring the ratio of voltage and power transformers make sure that the test voltage is connected to the corresponding primary winding, and that the voltage of the secondary winding is the one that is measured. Accidentally mixing up the windings can generate life-threatening voltages within the transformer.

Life-threatening voltages can be induced on open windings!

- ► Make sure that when testing a current transformer by feeding a test current into its primary winding, all secondary windings are shorted.
- ► Do not operate the *CP TD12/15* under ambient conditions that exceed the temperature, humidity and altitude limits listed in the technical data.
- ► Do not operate the *CP TD12/15* in the presence of explosives, gases or vapors.
- ► Opening the *CP TD12/15* or its accessories without authorization invalidates all warranty claims. Any kind of maintenance, calibration or repair on the device itself may only be carried out by persons authorized by OMICRON.
- ► Stop using the *CP TD12/15* or any add-on device or accessory if they seem not to function properly. Prevent the use of the devices and call the OMICRON hotline.

1.4 Operating the measurement setup

Note: The *CP TD12/15* 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 TD12/15* to any other device than the *CPC 100*, *CPC 80*, or the *TESTRANO 600*.

- ► If you have a cardiac pacemaker, do not use the *CP TD12/15*! If you have another type of electronic medical implant consult your doctor before operating the *CP TD12/15*. Make sure there is no person with an electronic medical implant such as a cardiac pacemaker in the immediate vicinity.
- ► Before handling the *CP TD12/15* in any way, connect its measurement ground terminal with the supplied measurement ground cable to the ground terminal of the asset under test.
- ► Make sure that the ground terminal of the asset under test is in good condition, clean and free of oxidation.
- ► Before disconnecting the asset under test from the *CP TD12/15*, ground all asset's connections.
- ► Do not open the *CP TD12/15* housing.
- ► Do not repair, modify, extend, or adapt the *CP TD12/15* or its accessories.
- ► Use only the *CP TD12/15* original accessories available from OMICRON.

- Use the *CP TD12/15* and its accessories only in a safe manner and only if they are in a technically sound condition, mindful of the dangers while paying attention to the User Manual.
- Make sure the use of the *CP TD12/15* is in accordance with the regulations on site and the designated use described in this document.
- Comply with the workflows described in this document. Avoid interruptions or distractions that could affect safety.
- Do not enter the high-voltage area if the red status 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.

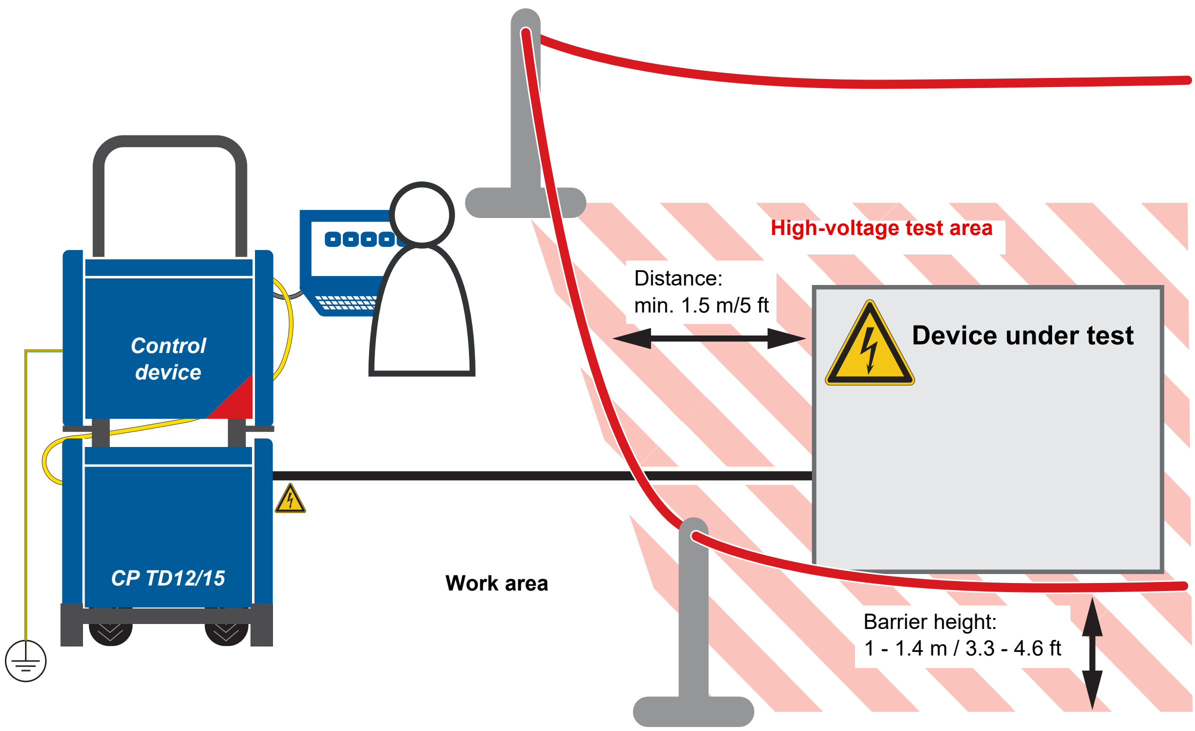


Figure 1-1: Example of the separation of work and high-voltage area

1.5 Handling cables

Before handling the cables:

1. If a test is running, end the test.
2. Verify that the test has ended by checking the status lights of the *Control device:*
   The green status light must be on and at the same time the red status light must off.

WARNING

Death or severe injury caused by high voltage or current possible

The green status light indicates that the outputs of the *Control device* are not activated.

► Even if you switched off the *Control device*, wait until the red status light is off. As long as this status light is on, there is still voltage potential on the output.

3. Lock the *Control device* to avoid any unauthorized execution of tests.

   Note: For more details, refer to the corresponding User Manual of the *Control device*.
4. Ground and short-circuit the test object's terminals using a suitable grounding set.
5. Disconnect the booster cable from the *Control device*.
6. Disconnect the booster cable from the *CP TD12/15*.

► The HV-cable must always be well attached and tightly connected to both the *CP TD12/15* and the test object. A loose connector or a connector falling off or into a test object carrying high-voltage is life-hazardous. Make sure the connectors are clean and dry before connecting.

► Plug the HV-plug into the *CP TD12/15* until the plug is securely fastened. Confirm this by trying to gently pull it out.

► At the test object, insert the HV-cable's plug carefully until you feel the plug "click" into place. Now it is locked. Confirm this by trying to pull it out. This should not be possible now.
Do not connect any cable to the test object without a visible grounding of the test object.

► The HV-cable is double-shielded. However, the last 50 cm (20 inches) of this cable has no shield. Therefore, consider this cable to be a live wire carrying life-hazardous high-voltage during testing!

► When the *Control device* is switched on this part of the cable has to be in the high-voltage area due to an electric shock hazard!

► Never remove ***any*** cables from the *CP TD12/15* or the test object during a test.

► Keep clear from zones in which high voltages may occur. Set up a safety barrier or establish similar adequate means.

► Both low-voltage measuring cables must always be well attached and tightly connected to the *CP TD12/15*'s measuring inputs IN A and IN B.
Make sure to insert the cables with the red and blue marker sleeves at the connector into the correspondingly colored measuring inputs: IN A = red, IN B = blue.

► Use only original cables supplied by OMICRON.

1.6 Orderly measures

The CP TD12/15 User Manual or alternatively the e-book must always be available at the operating site of the *CP TD12/15*.

The users of the *CP TD12/15* must read this manual before operating the *CP TD12/15* and observe the safety, installation, and operation instructions therein.

When setting the *CP TD12/15* into operation, follow the instructions in 3 "Application" on page 25. The *CP TD12/15* and its accessories may only be used in accordance with the user documentation (including but not limited to User Manuals, Reference Manuals, Getting Started manuals and manufacturer manuals). The manufacturer and the distributor are not liable for damage resulting from improper usage.

Opening the *CP TD12/15* or its accessories without authorization invalidates all warranty claims. Any kind of maintenance, calibration or repair on the device itself may only be carried out by persons authorized by OMICRON.

1.7 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, 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.

► Ground all test objects before handling.

1.8 Disclaimer

If the equipment is used in a manner not described in the user documentation, the protection provided by the equipment may be impaired.

1.9 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.

1.10 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 TD12/15* works as an add-on device to the *CPC 100*, *CPC 80*, or the *TESTRANO 600*, which are used to control the measurement. In this manual, these devices are collectively named *Control device* if no specific device is referred to. Do not connect the *CP TD12/15* to any other *Control device* than the *CPC 100*, *CPC 80*, or the *TESTRANO 600*.

The *CP TD12/15* is a high-precision test system for on-site insulation tests of high-voltage assets such as power transformers, bushings, capacitors and rotating machines.

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

When used with the *CPC 100*, *CPC 80*, or the *TESTRANO 600*, the *CP TD12/15* comes with its own *CPC* test card named **TanDelta**, which provides highly accurate measurements of the capacitance Cx and the dissipation factor tanδ (DF) or power factor cosφ (PF), respectively.

Additionally, the *CP TD12/15* can measure the following quantities:

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

The *CP TD12/15* can also be used as high-voltage source.

Any other use of the *CP TD12/15* not mentioned above is considered improper use and will invalidate all customer warranty claims and exempt the manufacturer from liability.

2.2 Functional components of the *CPC 100* and *CPC 80*

2.2.1 *CPC 100* front panel

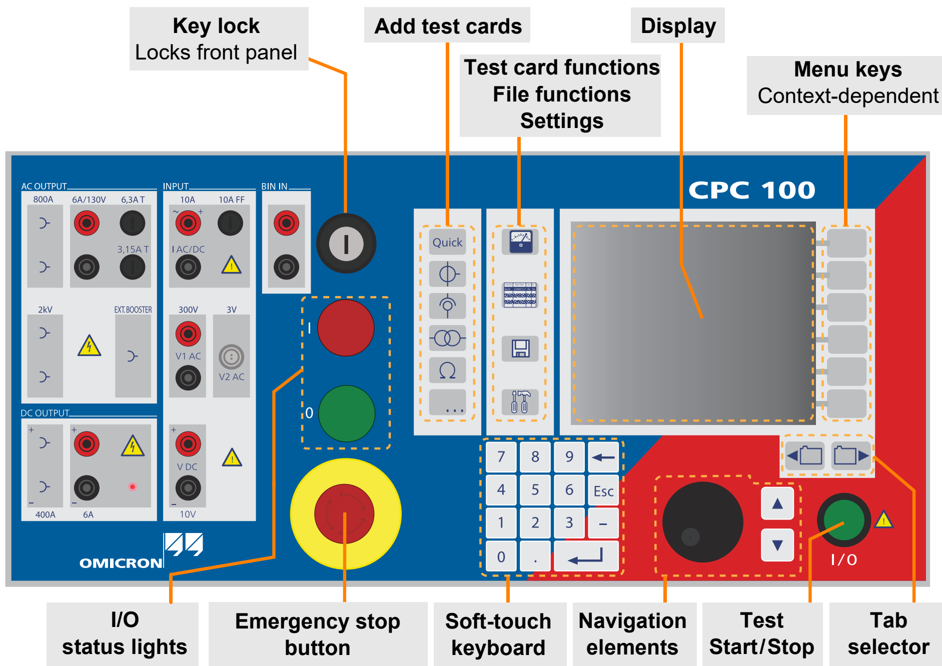


Figure 2-1: *CPC 100* front panel

2.2.2 *CPC 100* side panel

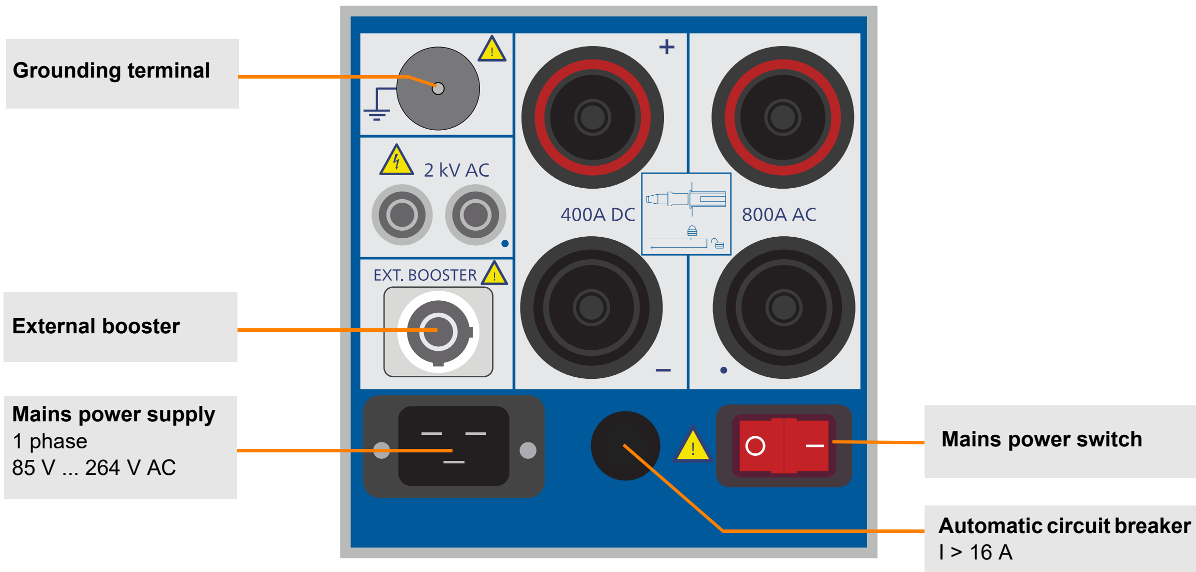


Figure 2-2: Left side view of the *CPC 100*

DANGER

Death or severe injury caused by high voltage or current

The **Ext. Booster** connector is **always** galvanically connected to mains.
This also applies when no external booster is selected, the green status light (0) is on, the outputs are turned off or the Emergency Stop button is pressed.

- ▶ Handle the **Ext. Booster** connector with extreme caution.
- ▶ 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.

2.2.3 *CPC 80* front panel

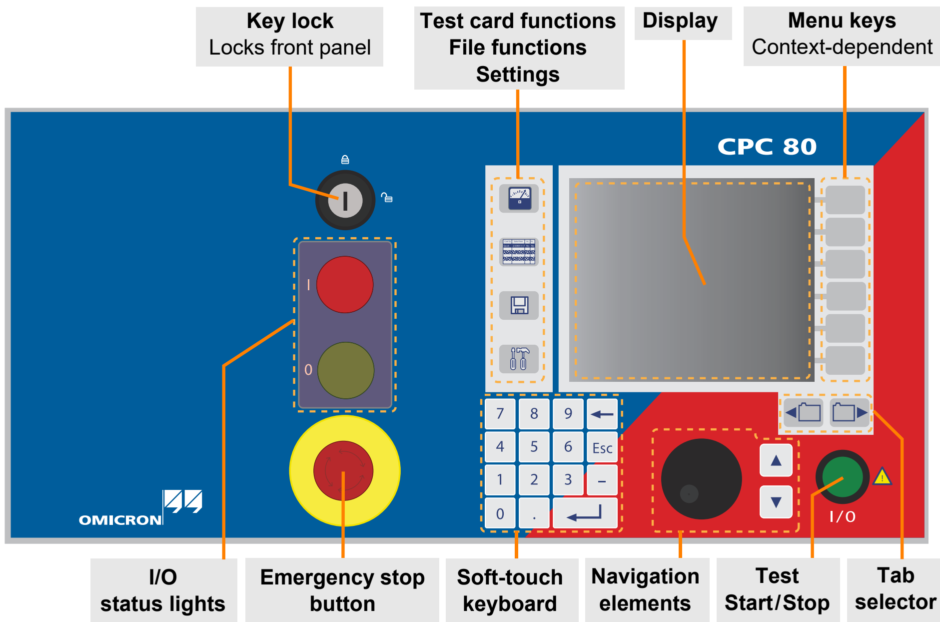


Figure 2-3: *CPC 80* front panel

2.2.4 *CPC 80* side panel

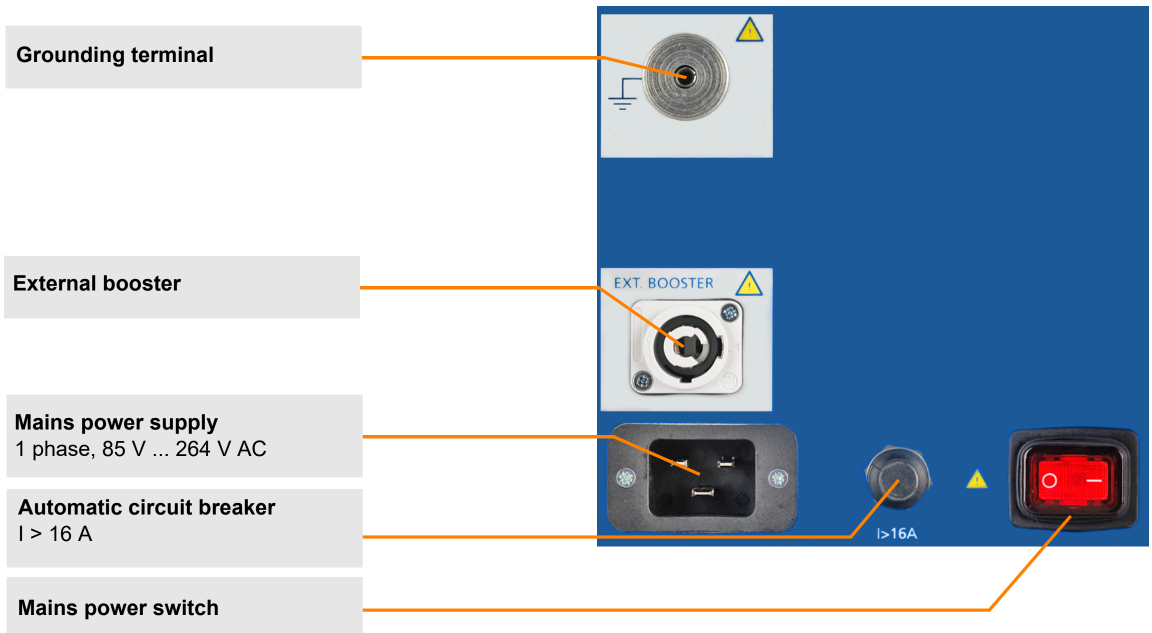


Figure 2-4: Left side view of the *CPC 80*

DANGER

Death or severe injury caused by high voltage or current

The **Ext. Booster** connector is **always** galvanically connected to mains.
This also applies when no external booster is selected, the green status light (0) is on, the outputs are turned off or the Emergency Stop button is pressed.

- ▶ Handle the **Ext. Booster** connector with extreme caution.
- ▶ 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.

2.2.5 Status lights

The status lights indicate the operational status of the *CPC 100* and *CPC 80* as a current/voltage source.

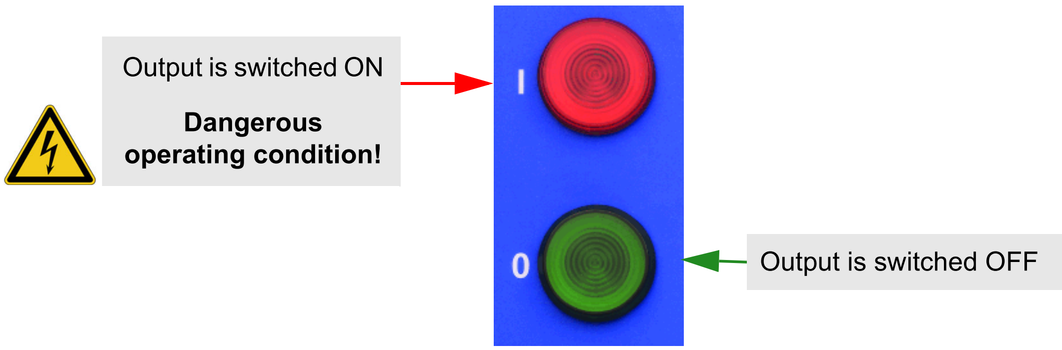
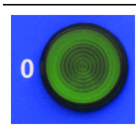
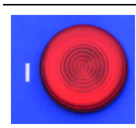


Figure 2-5: Status lights

	1. Output is switched OFF	Green status light (0) on	Current/voltage source is inactive/off	
	2. Output is switched ON and/or measurement process is active	Red status light (I) is flashing	**Dangerous** operating condition	
If the *CPC 100* or *CPC 80* is supplied by mains and switched on, and *no* or *both* status lights are on, the unit might be defective. ► Contact OMICRON support (see "Support" on page 64).			**Dangerous** operating condition	

2.2.6 Emergency Stop button

Pressing the Emergency Stop button *immediately* shuts off all current and voltage outputs except for the **Ext. Booster** output.

A running test is terminated, the software does not accept any more entries and/or commands.

Once the reason for the Emergency Stop is cleared and the Emergency Stop button released, the test can be re-started by pressing the I/O (test start/stop) push-button while in Test Card View.

Figure 2-6: Emergency Stop button

DANGER

Death or severe injury caused by high voltage or current

The **Ext. Booster** connector is **always** galvanically connected to mains.
This also applies when no external booster is selected, the green status light (0) is on, the outputs are turned off or the Emergency Stop button is pressed.

- ► Handle the **Ext. Booster** connector with extreme caution.
- ► 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.

WARNING

Death or severe injury caused by high voltage or current possible

Stopping a test does not shut off the *CPC* outputs instantaneously. First, the currently running test sequence finishes, then the test execution is stopped.
Most test cards finish the running test sequence with a predefined ramp function.

- ► Therefore, in a hazardous situation never press "Stop Test".
- ► Instead, use Emergency Stop.

2.2.7 ePC Interface

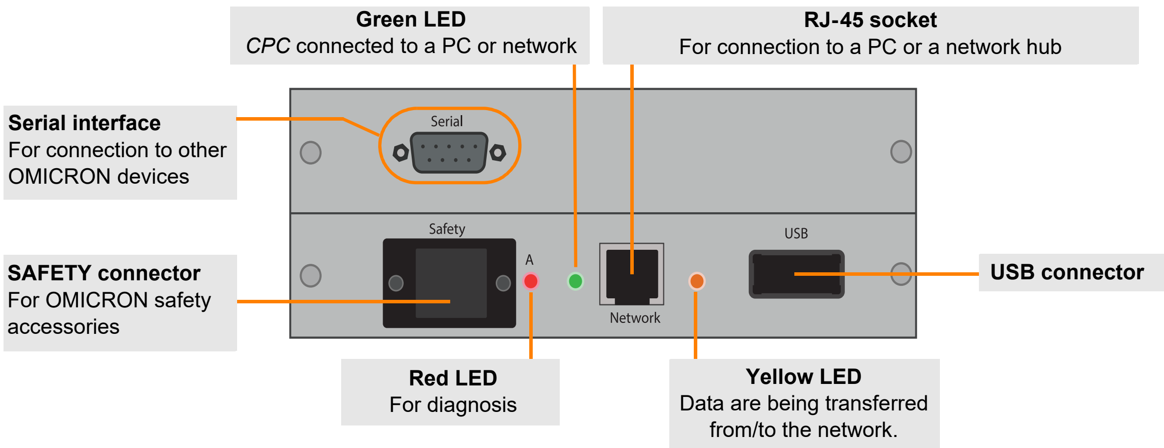


Figure 2-7: Connectors on the right side of the *CPC 100* and the *CPC 80*

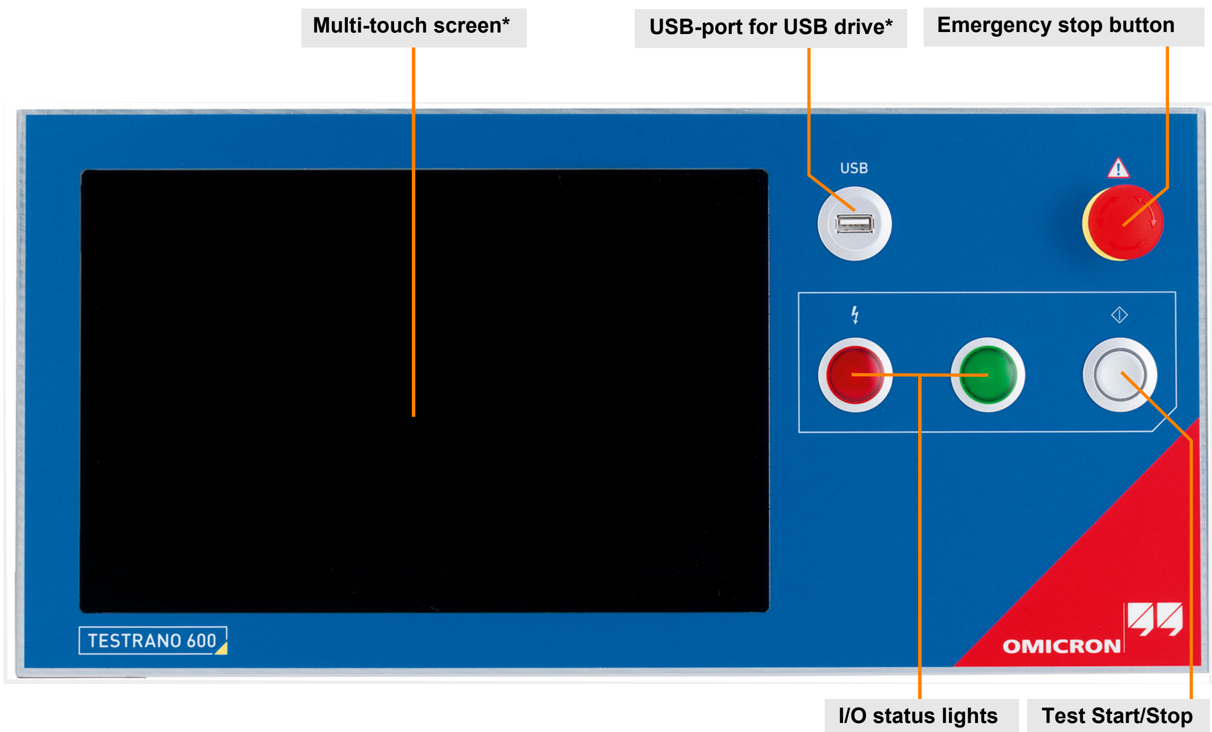
The following table describes the LEDs on the ePC interface:

Table 2-1: LEDs on the *CPC 100* and *CPC 80* ePC interface

LED	Description
Green	The *CPC 100* or *CPC 80* is properly connected to a PC or network.
Yellow	Data are being transferred from/to the network.
Red	For diagnosis purposes

2.3 Functional components of *TESTRANO 600*

2.3.1 *TESTRANO 600* front panel



**Display version only*

Figure 2-8: *TESTRANO 600* front panel with display

2.3.2 *TESTRANO 600* side panel

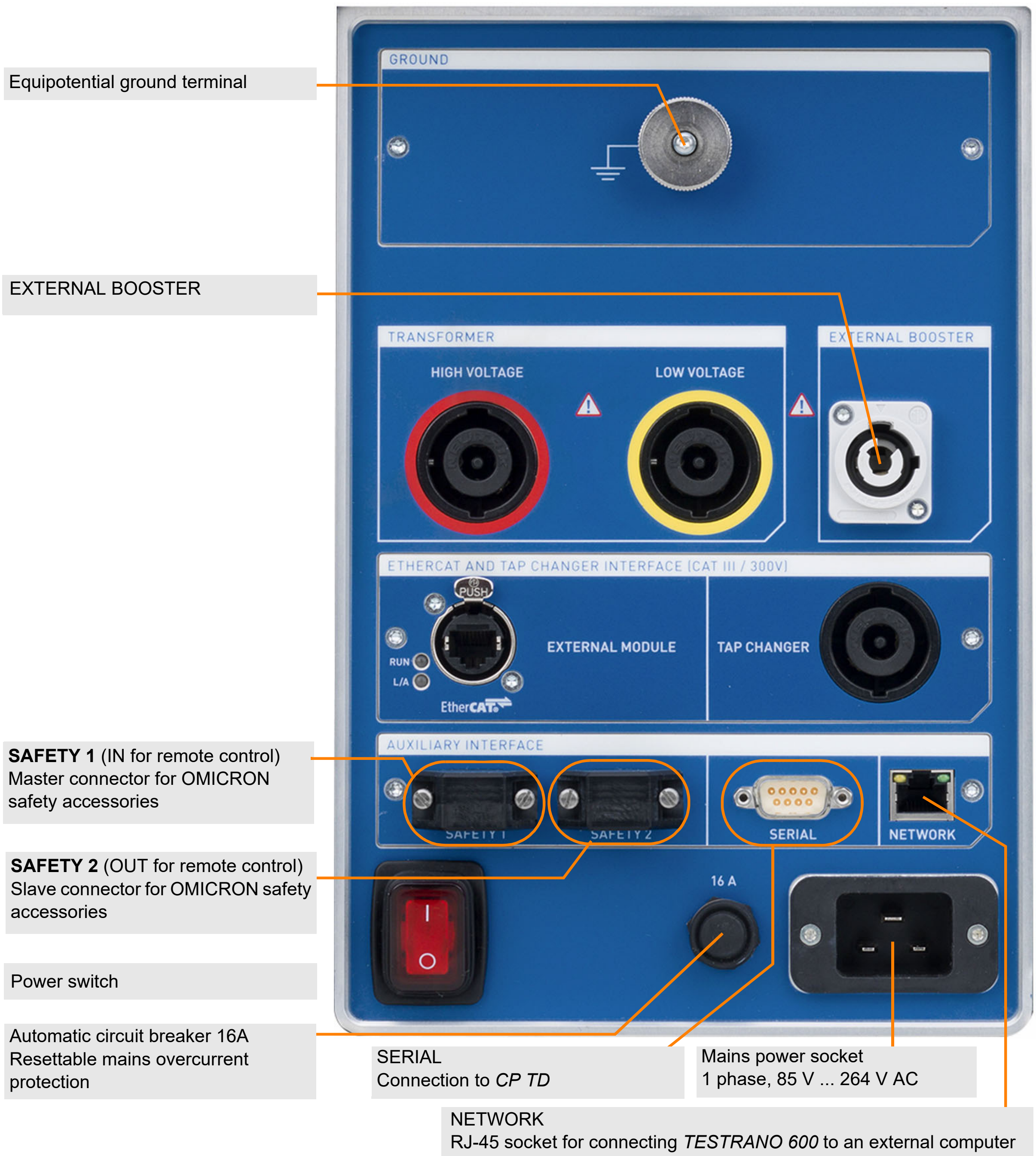
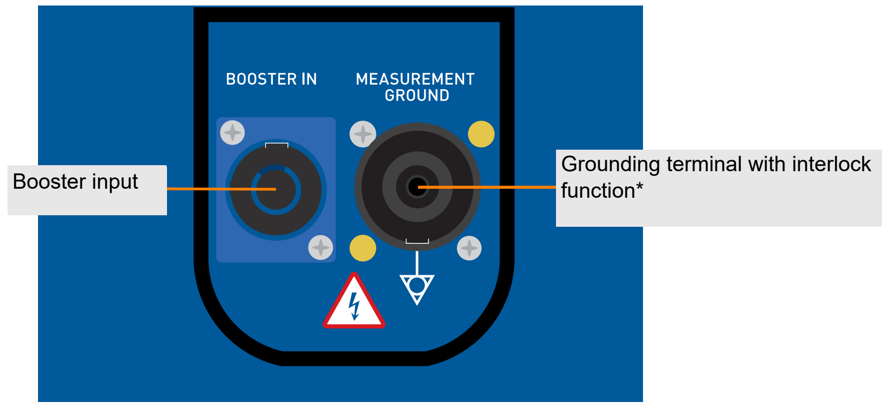


Figure 2-9: *TESTRANO 600* side panel

2.4 Functional components of the *CP TD12/15*

2.4.1 *CP TD12/15* grounding terminal and Booster input



* For more details on the interlock function, refer to 2.4.4 "Safety and interlock functions" on page 24.

Figure 2-10: Grounding terminal and booster input of the *CP TD12/15* (left side of the device)

2.4.2 *CP TD12/15* serial interface connector and measuring inputs

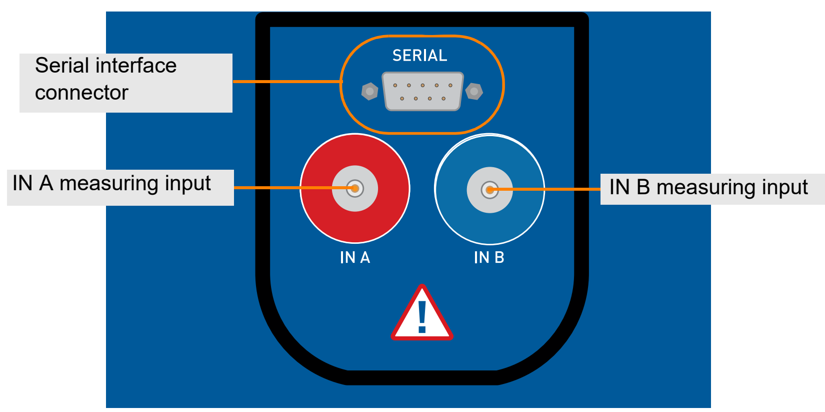
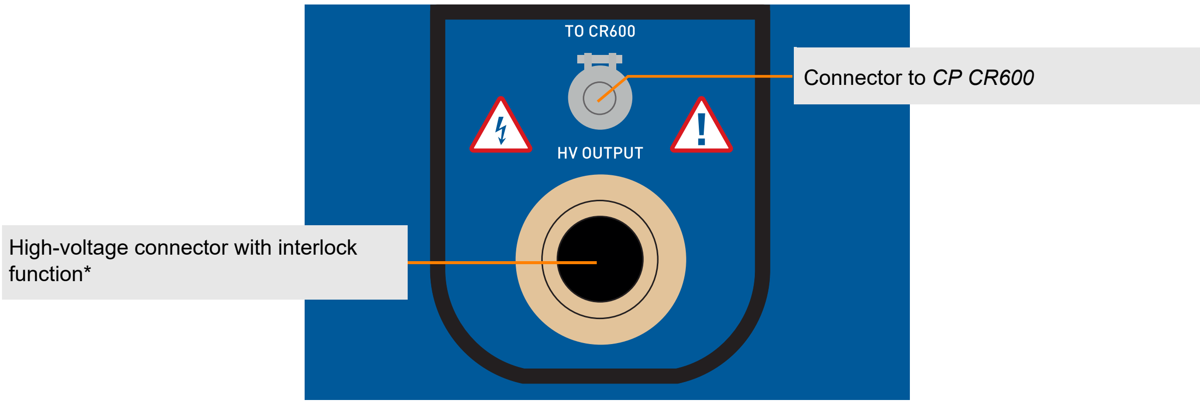


Figure 2-11: Serial interface and measuring inputs of the *CP TD12/15* (right side of the device)

2.4.3 *CP TD12/15* high-voltage connector



* For more details on the interlock function, refer to 2.4.4 "Safety and interlock functions" on page 24.

Figure 2-12: High-voltage connector of the *CP TD12/15* (rear of the device)

2.4.4 Safety and interlock functions

The *CP TD12/15* has several internal and external safety functions to prevent dangerous situations. The *CP TD12/15* will not work if a safety function detects a problem, such as:

- defect of the protective earth connection to the *Control device*
- missing measurement ground connection (cable not connected to device)
- bad measurement ground connection (measurement ground has no contact to protective ground)
- HV-cable is not connected to the *CP TD12/15*

Additionally, the interlock function is active when an external *CP CR600* is connected. The *CP TD12/15* will not work if the interlock function detects one of the following problems:

- missing safety connection to the *CP CR600*
- HV-cable is not connected to the *CP CR600*
- overtemperature of the *CP CR600*

Note: If the interlock function prevents the *CP TD12/15* from working, check all connections and options mentioned above.

2.5 Cleaning

WARNING

Death or severe injury caused by high voltage or current possible

► Prior to cleaning disconnect the device.

To clean one of the devices described in this document, use a cloth dampened with isopropanol alcohol or water.

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 TD12/15*, the following steps need to be carried out by an authorized and qualified 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.
- ► Ground and short-circuit 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 TD12/15* and the area of danger (that is, the test object), a second person with an additional "Emergency Stop" button is required.

DANGER

Death or severe injury caused by high voltage or current

- ► If you have a cardiac pacemaker, do not use the *CP TD12/15*! If you have another type of electronic medical implant consult your doctor before operating the *CP TD12/15*.
- ► Before operating the *CP TD12/15*, make sure there is no person with an electronic medical implant in the immediate vicinity.

3.2 Connecting the *CP TD12/15* to the *Control device*

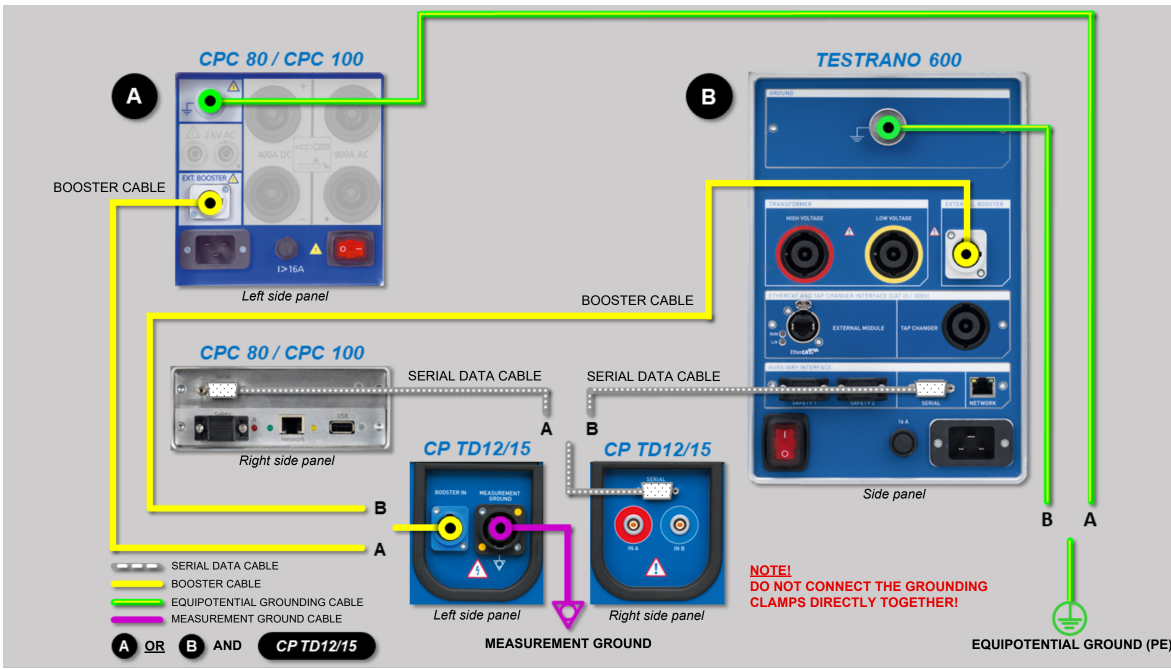


Figure 3-1: Connecting the *CP TD12/15* to the *CPC 100*, *CPC 80* or *TESTRANO 600*

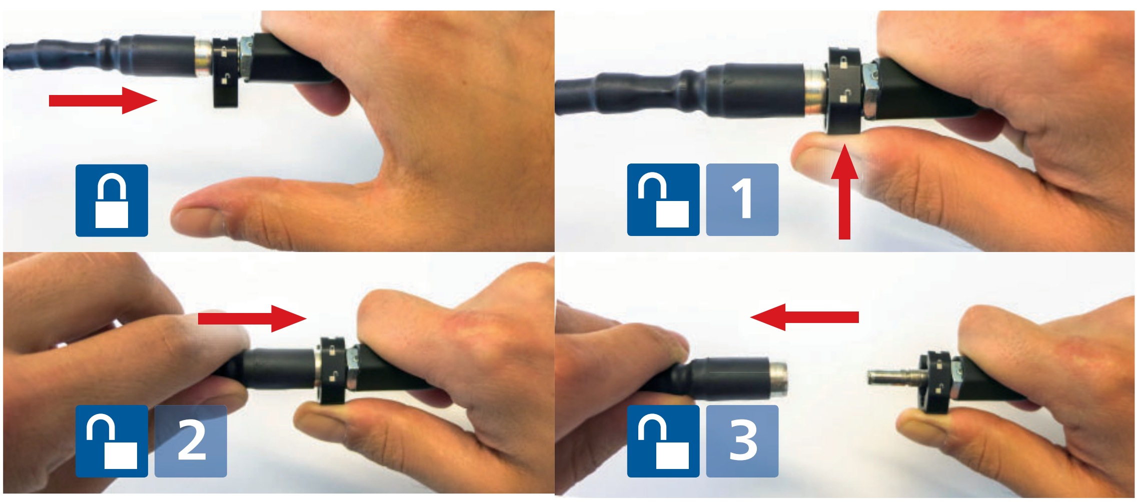
DANGER

Death or severe injury caused by high voltage or current

► Never use the *CP TD12/15* without connecting measurement ground with the supplied cable.

1. Ensure that the *Control device* is switched off at the mains power switch.
2. Properly connect the *Control device* grounding terminal to substation ground.
3. Properly connect the *CP TD12/15* measurement ground to ground of the asset to be measured.
4. Make sure that all cable connectors are clean and dry before connecting them tightly.
5. Connect the *CP TD12/15*'s "BOOSTER IN" to the *Control device*'s "EXT. BOOSTER" with the booster cable.
6. Connect the *CP TD12/15*'s "SERIAL" to the *Control device*'s "SERIAL" with the serial cable.
7. Pull out the measuring cables from the cable drum and connect the test object to the *CP TD12/15*'s measuring inputs IN A and IN B.
8. Connect the HV-cable from the test object to the *CP TD12/15*'s HV-output.
   - ► Plug the HV-plug into the *CP TD12/15* until the plug is securely fastened. Confirm this by trying to gently pull it out.
   - ► At the test object, insert the HV-cable's plug carefully until you feel the plug "click" into place. 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 HV-cable.



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

DANGER

Death or severe injury caused by high voltage or current

The HV-cable is double-shielded and therefore safe. However, the last 50 cm (20 inches) of this cable has no shield.

- ► Avoid any direct contact of this part of the cable to ground potential or to any objects.
- ► Due to the life-hazardous high-voltage consider this part of the cable as live during testing.

9. 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 safety barrier to isolate the high-voltage area.

10. Turn on the *Control device* at its mains power switch.

11. The green status light lights up, showing that the *Control device*'s output does not carry a dangerous voltage or current yet.

WARNING

Death or severe injury caused by high voltage or current possible

► If none or both status lights are on, the unit is defective and must not be used anymore.

12. Verify that the PE connection of the *Control device* is properly made.

3.3 Measurement

The *CP TD12/15* 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 Disconnecting the *CP TD12/15*

1. End the test.
2. Verify that the test has ended by checking the status lights of the *Control device:*
   The green status light must be on and at the same time the red status light must be fully off.

WARNING

Death or severe injury caused by high voltage or current possible

The green status light indicates that the outputs of the *Control device* are not activated.

► Even if you switched off the *Control device*, wait until the red status light is off. As long as this status light is on, there is still voltage potential on the output.

3. Lock the *Control device* to avoid any unauthorized execution of tests.

   Note: For more details, refer to the corresponding User Manual of the *Control device*.
4. Ground and short-circuit the test object's terminals using a suitable grounding set.
5. Disconnect the booster cable from the *Control device*.
6. Disconnect the booster cable from the *CP TD12/15*.
7. Disconnect the serial cable from the *CP TD12/15*.
8. Disconnect the HV- and LV-cables from the *CP TD12/15* and the test object.
9. Disconnect the measurement ground from the test object and the *CP TD12/15*.

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 $\delta = 90° - \varphi$ 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.

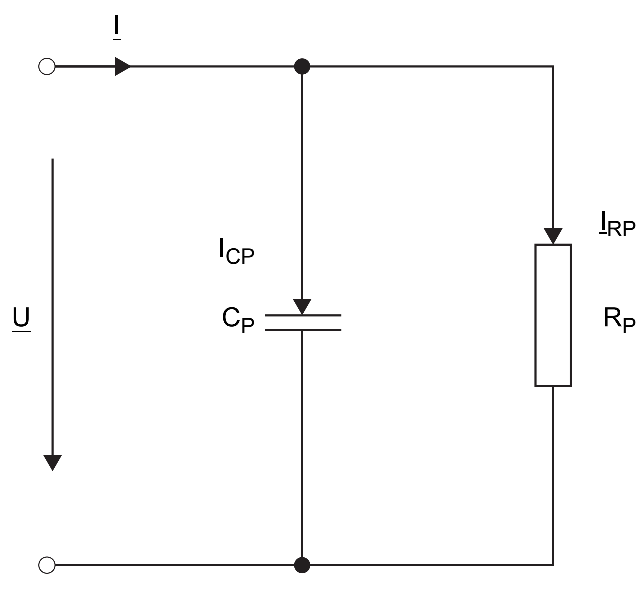


Figure 4-1: Simplified circuit diagram of a capacitor

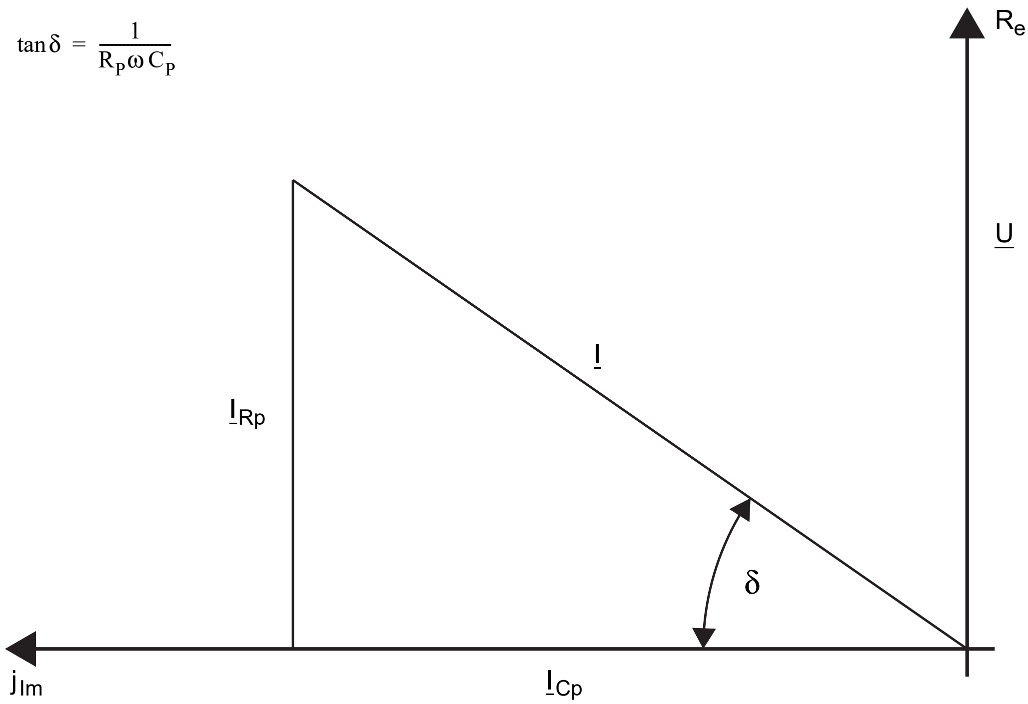


Figure 4-2: Definition of dissipation factor (tan δ) and the vector diagram

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

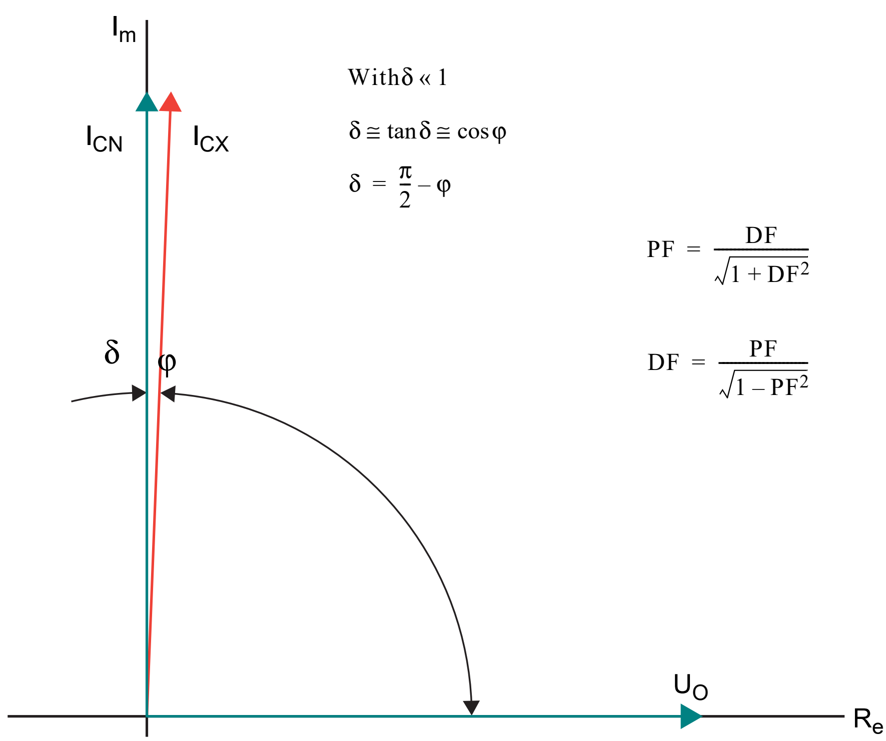


Figure 4-3: Correlation between DF and PF

The dielectric losses in the insulation are caused by polarization and conduction phenomena. The different polarization mechanisms are caused by various physical processes. Details can be found in [1] and [2].

4.2 Measurement of Capacitance and Dissipation Factor / Power Factor

Capacitance (C) and Dissipation Factor (DF) measurement was first published by Schering in 1919 [3] 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.

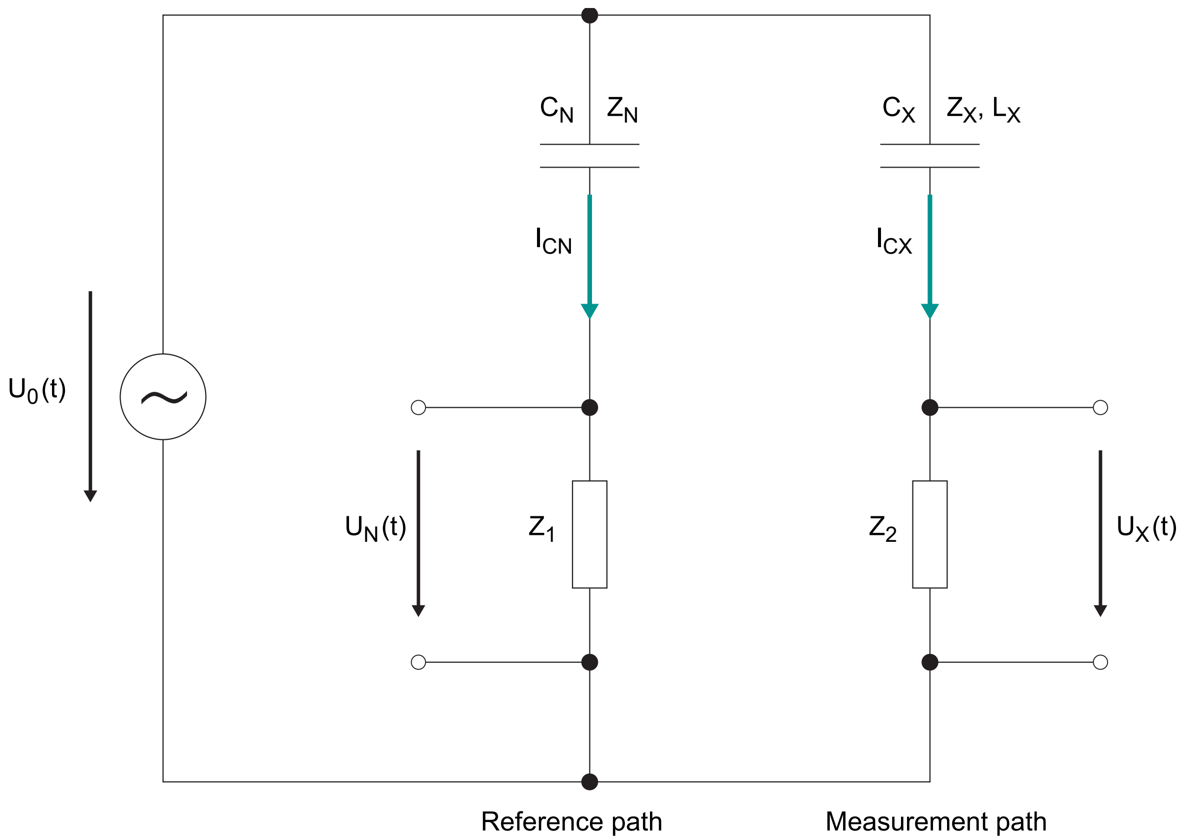


Figure 4-4: *CP TD12/15* measuring principle

The *CP TD12/15* test system utilizes a method similar to that of the Schering bridge. The main difference is that the *CP TD12/15* measuring principle does not require tuning for measuring C and DF. C_n is a low loss reference capacitor.

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. Krüger, M.: "Prüfung der dielektrischen Eigenschaften von Isolierflüssigkeiten", ÖZE, No. 5, Vienna, May 1986
3. Schering, H.: "Brücke für Verlustmessungen", Tätigkeitsbericht der Physikalisch-Technischen Reichsanstalt, Braunschweig 1919

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

The *CP TD12/15* 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 evolved historically. “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).

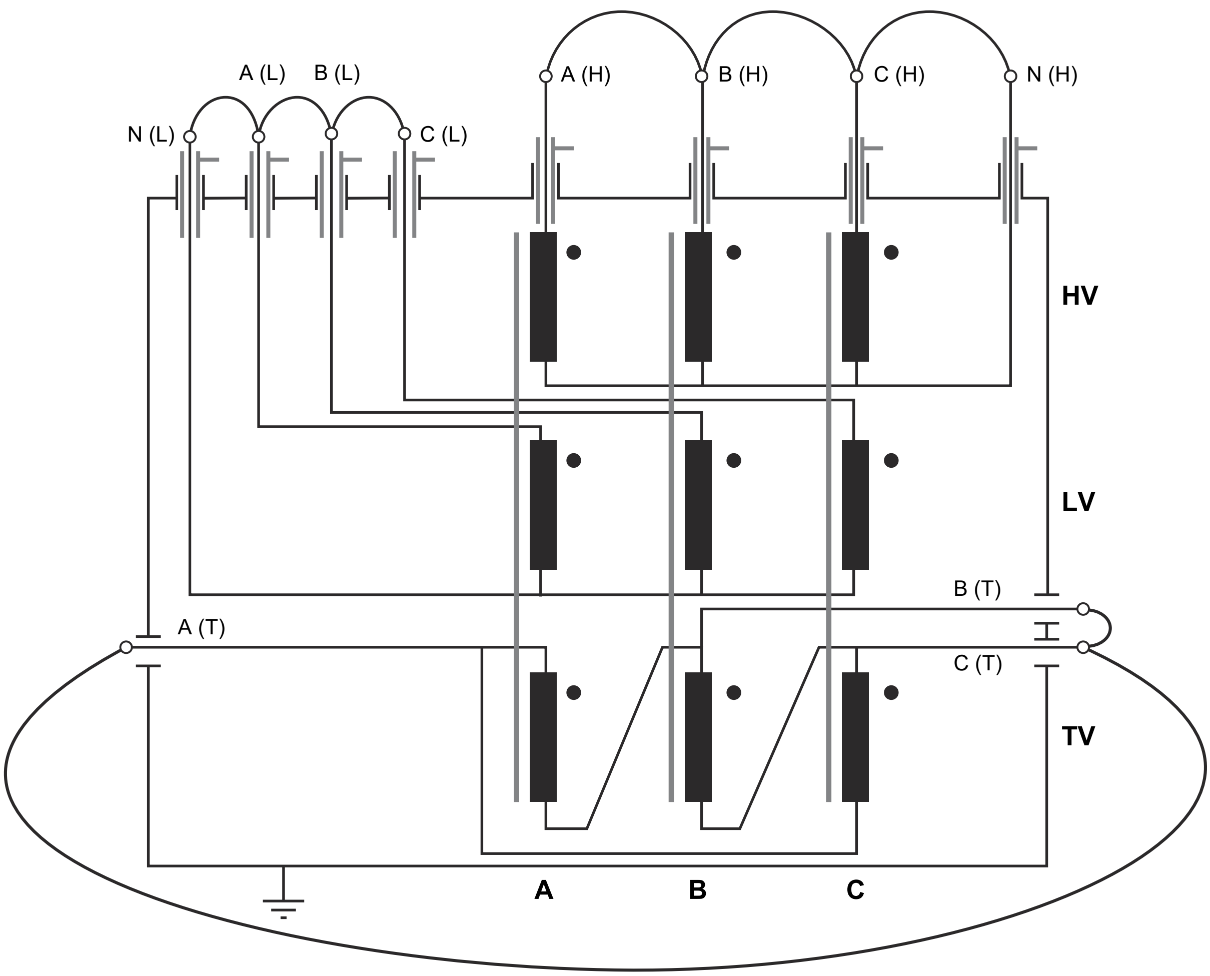


Figure 5-1: Three-winding transformer with connected windings

- 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 TD12/15* 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 faults with high currents. Changes in capacitance serve as an excellent indicator of winding movement and structural problems (displaced wedging, buckling etc.). If 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.

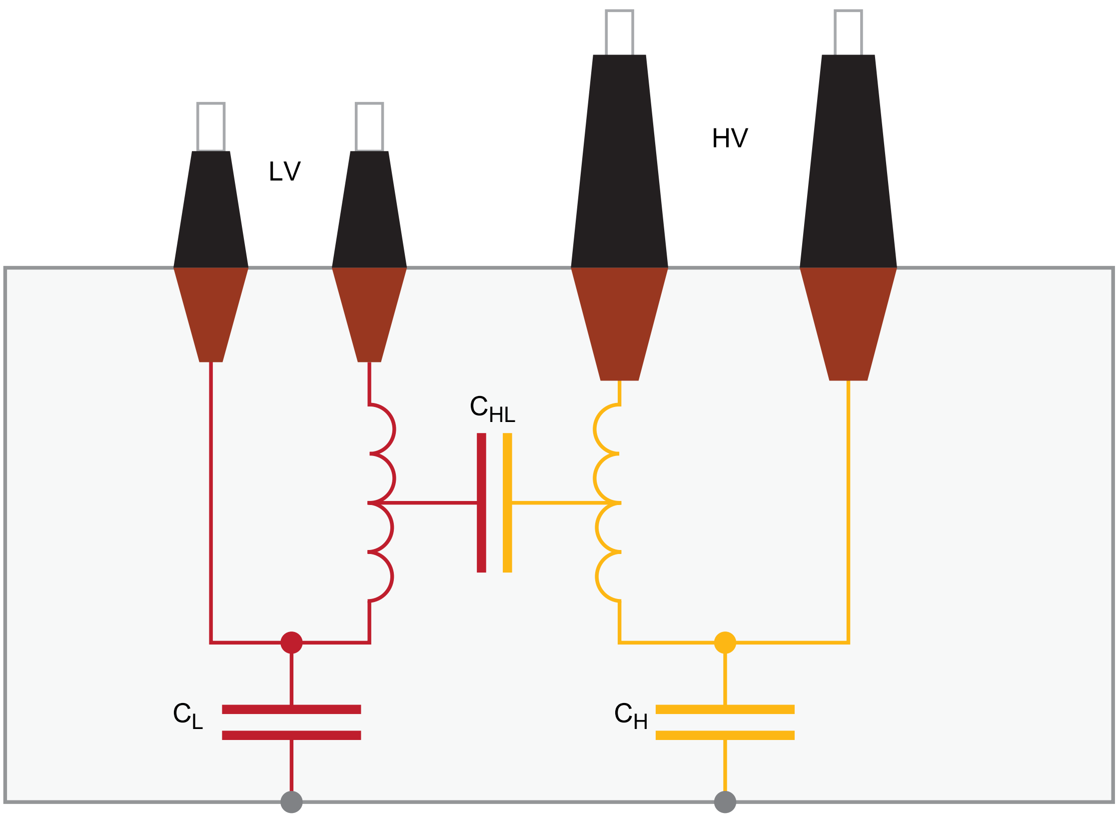


Figure 5-2: Insulations of a two-winding transformer

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 TD12/15* is connected to the HV-side and IN A to the LV-side (see Figure 5-3 on page 37). To prevent induced currents, all bushings of the HV-side are shortened, the same applies to the LV-side. The ground of the transformer and the ground of the *CP TD12/15* are connected.

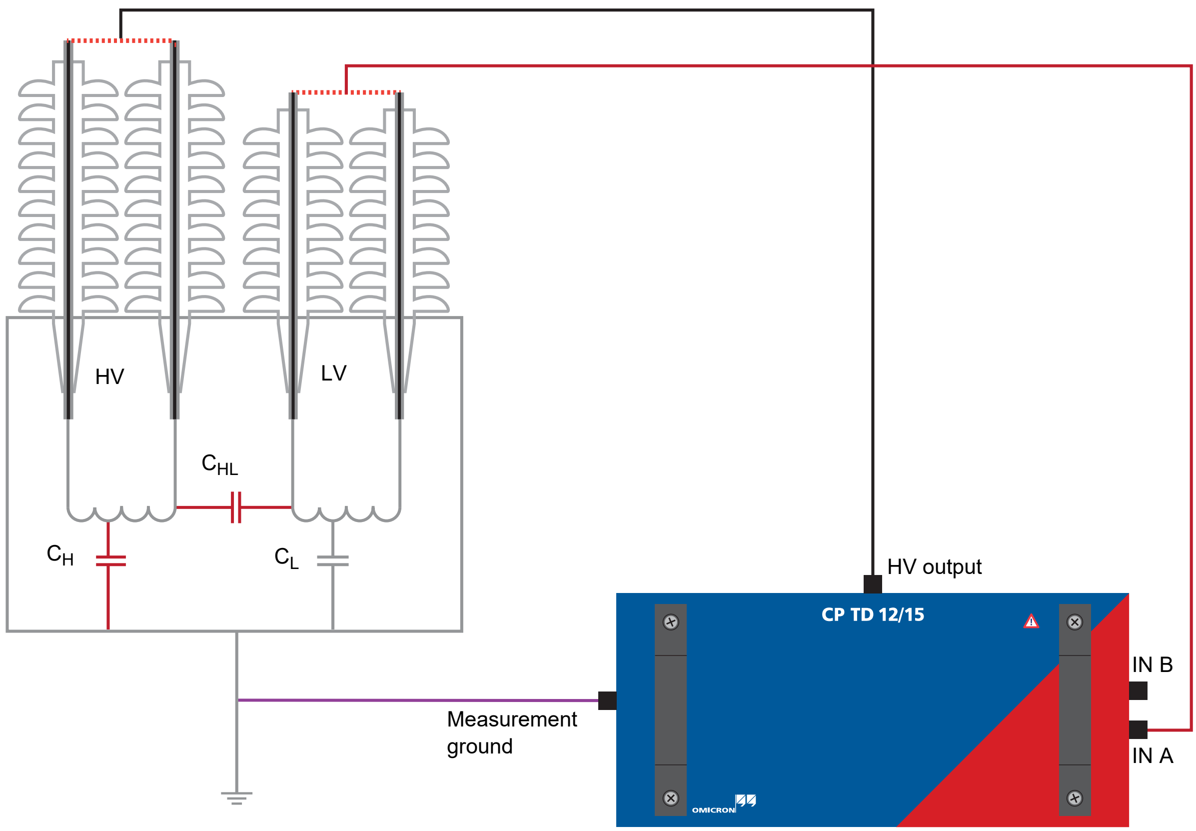


Figure 5-3: *CP TD12/15* connected to a two-winding transformer for the measurement of C_{HL} and C_H

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).

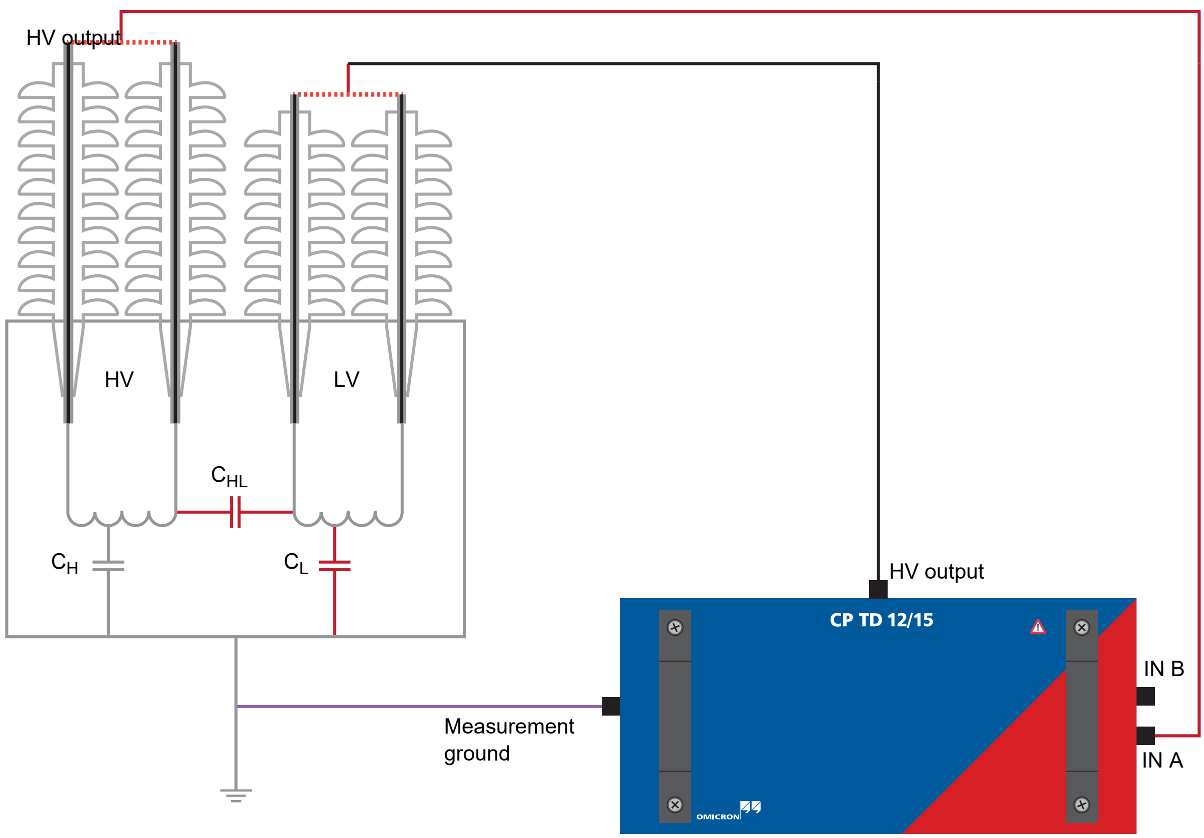


Figure 5-4: *CP TD12/15* connected to a two-winding transformer for the measurement of C_{HL} and C_L

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].

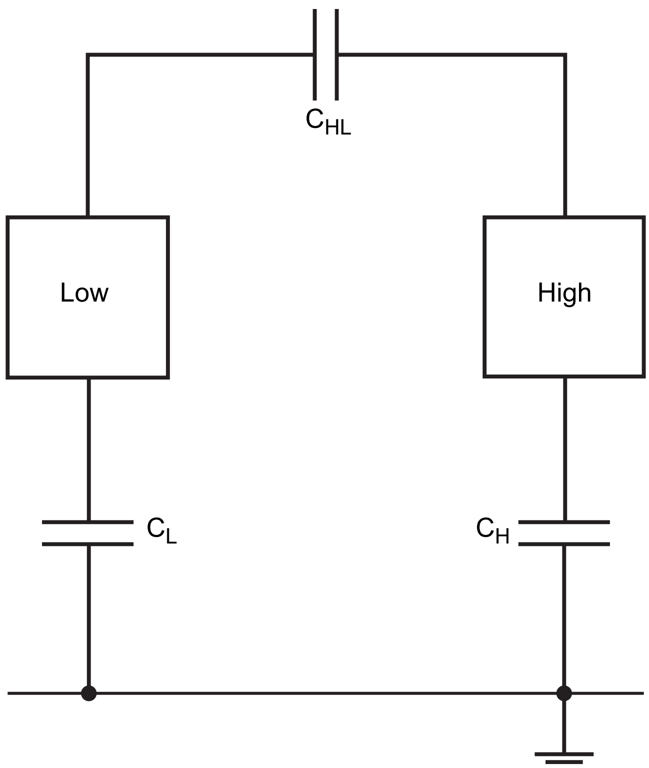


Figure 5-5: Two-winding transformer test according to IEEE 62-1995

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.

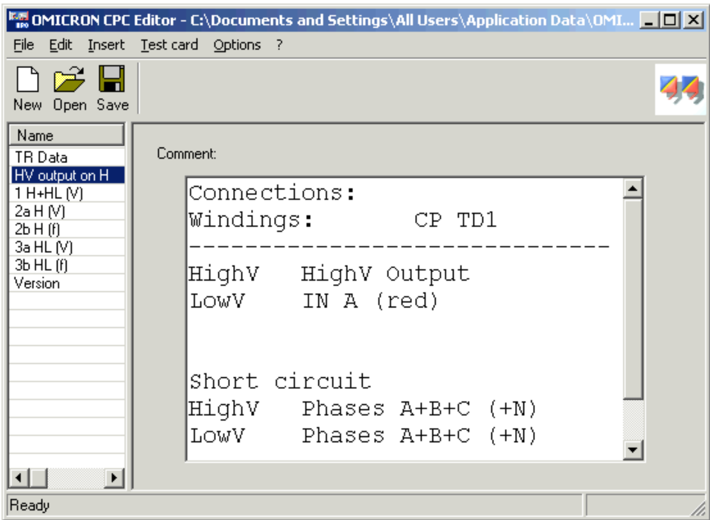
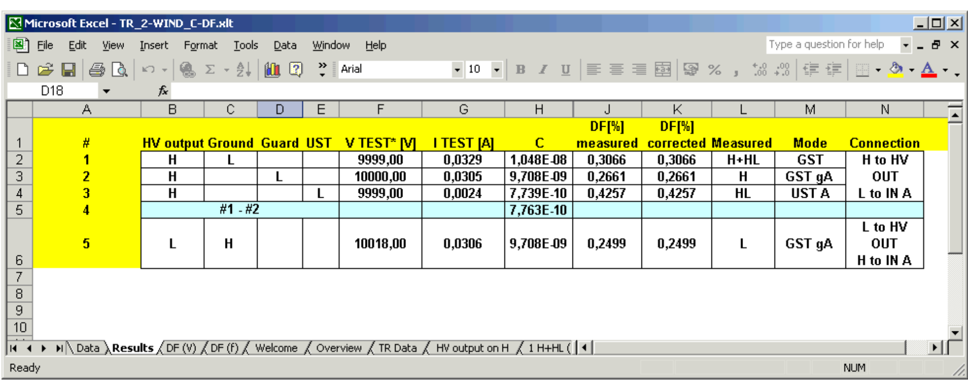


Figure 5-6: Two-winding transformer test preparation with *CPC Editor*



#	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 OUT L to IN A
2	H		L		10000,00	0,0305	9,708E-09	0,2661	0,2661	H	GST gA	
3	H			L	9999,00	0,0024	7,739E-10	0,4257	0,4257	HL	UST 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 the *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.

In addition to insulation C_H, which is similar to C_H in a two-winding transformer, there are the following: 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.

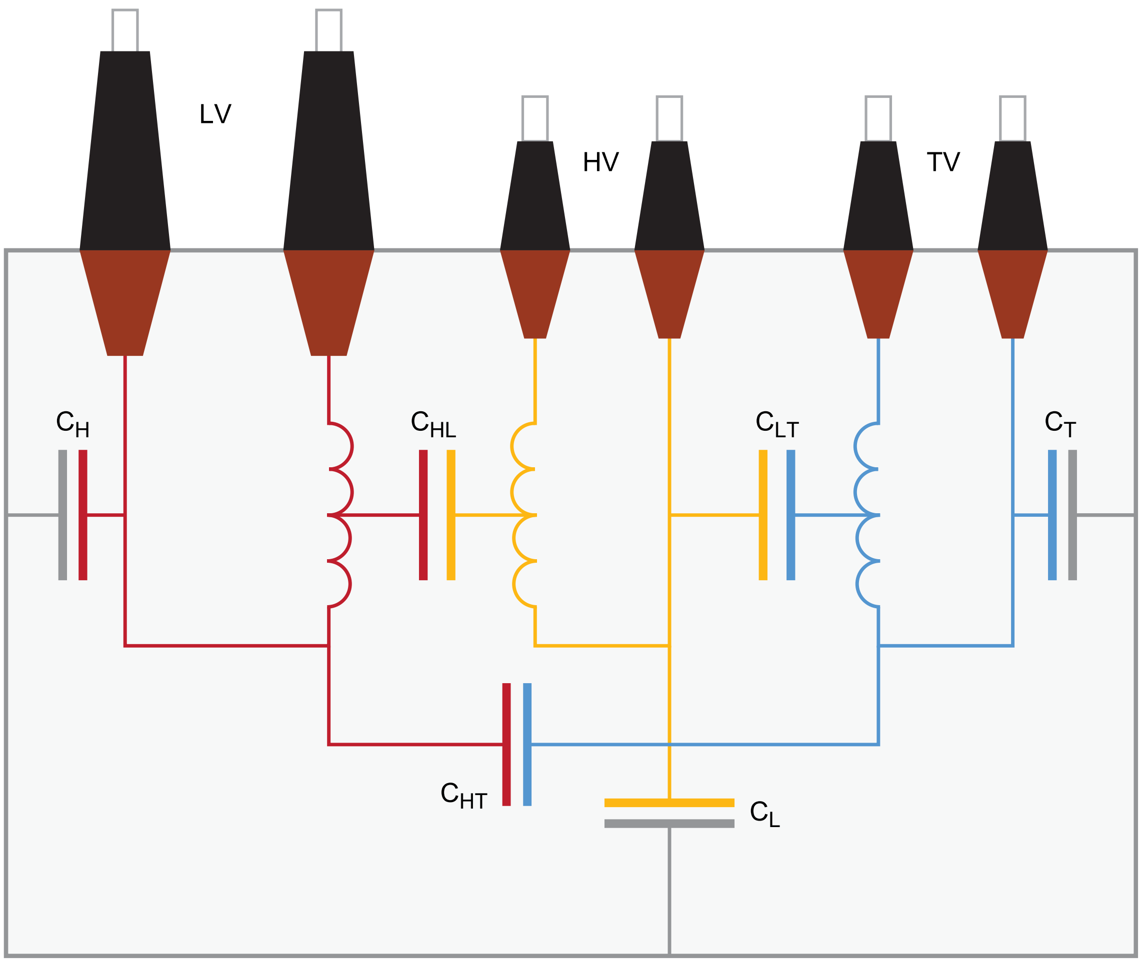


Figure 5-8: Insulations of a three-winding transformer

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.

When the *CP TD12/15*'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).

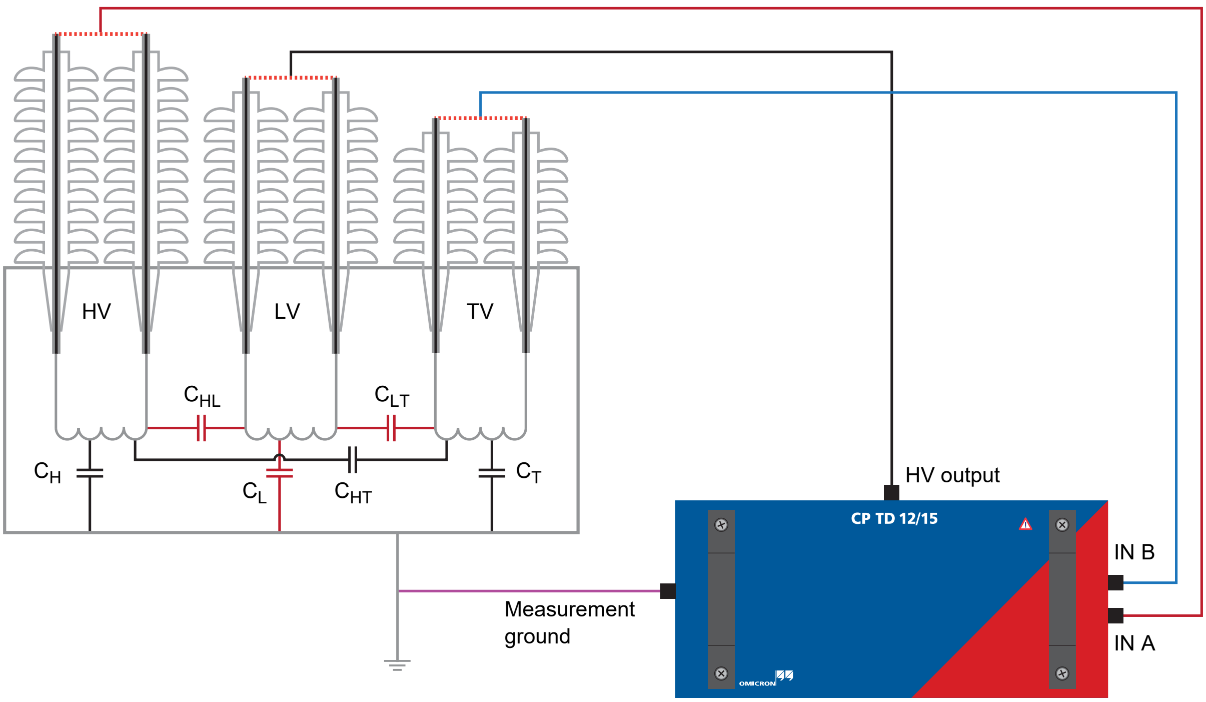


Figure 5-9: *CP TD12/15* connected to a three-winding transformer for the measurement of C_{HL}, C_{LT} and C_L

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).

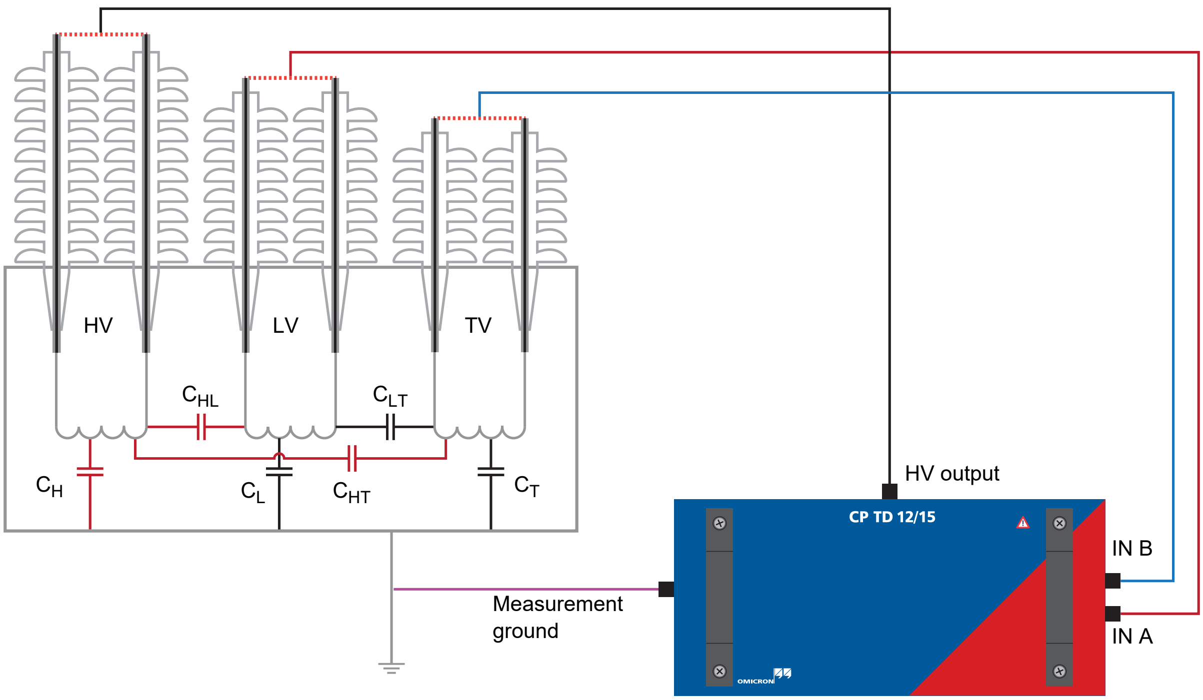


Figure 5-10: *CP TD12/15* connected to a three-winding transformer for the measurement of C_H

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}

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).

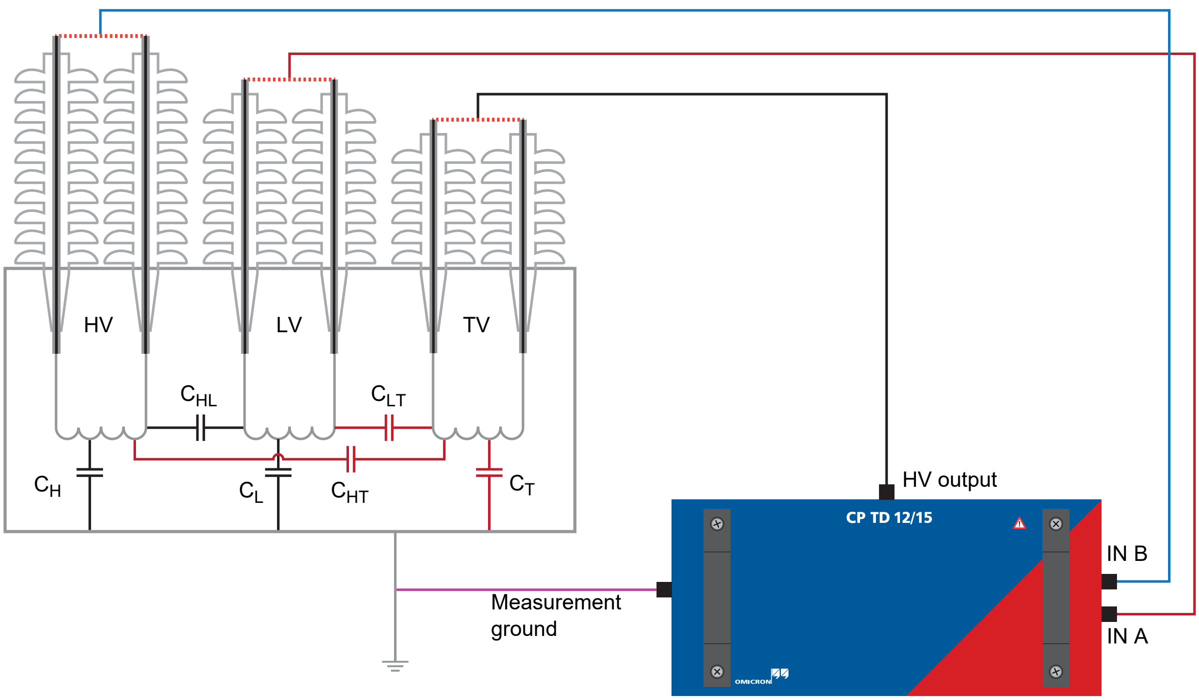


Figure 5-11: *CP TD12/15* connected to a three-winding transformer for the measurement of C_T

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.

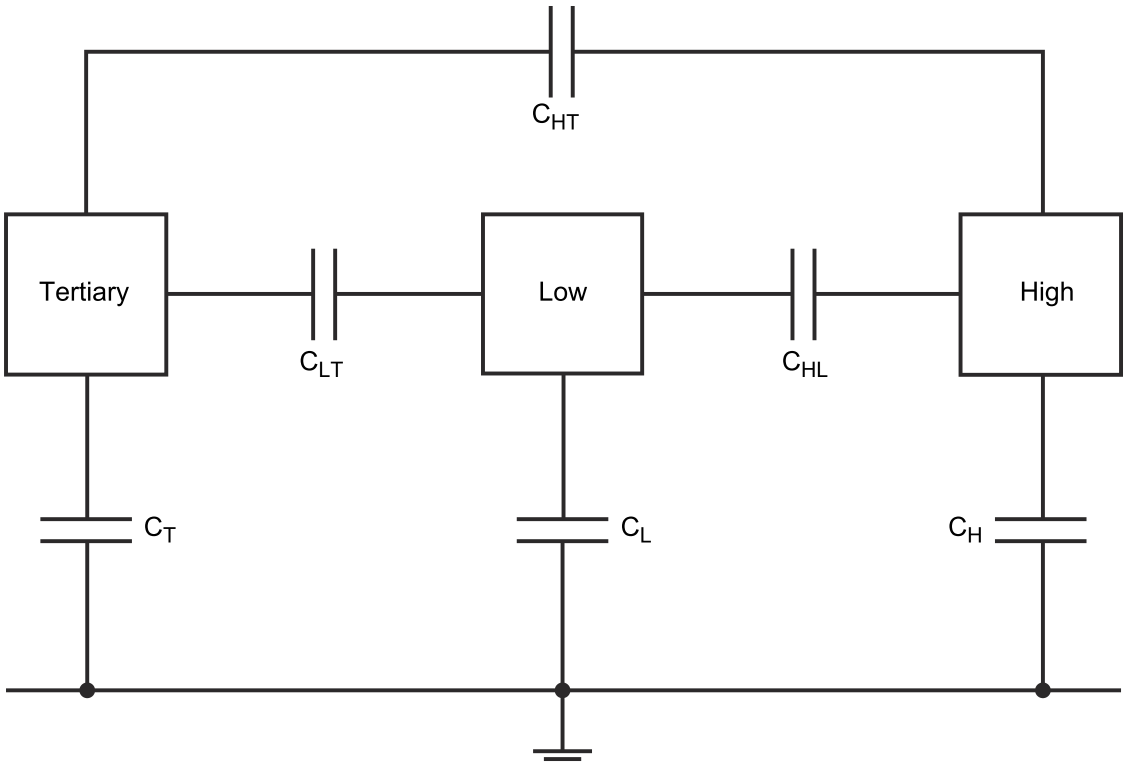


Figure 5-12: Three-winding transformer test according to IEEE 62-1995

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 HV-winding connected to the HV-output of the *CP TD12/15*.

First file

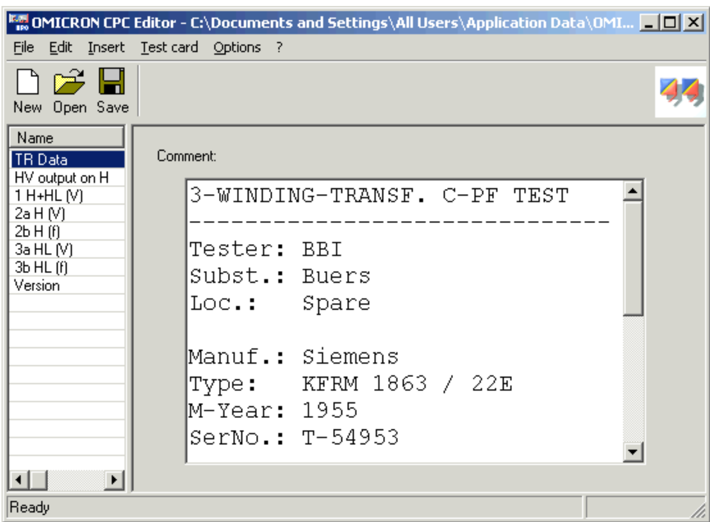


Figure 5-13: Input of transformer data

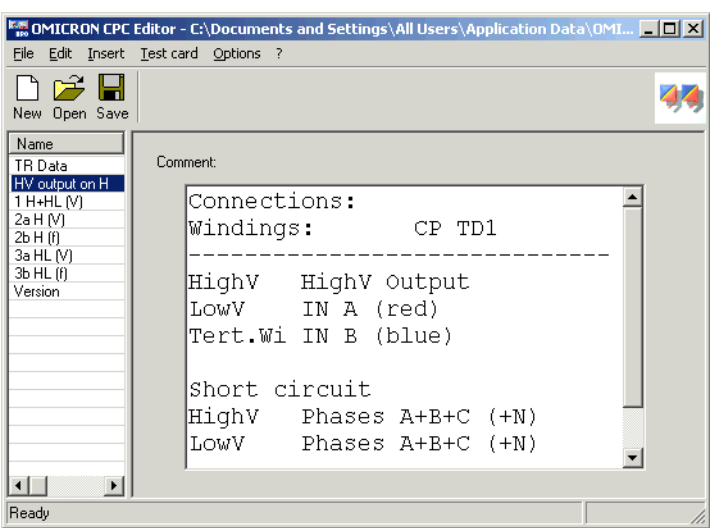


Figure 5-14: Instruction about test lead connections

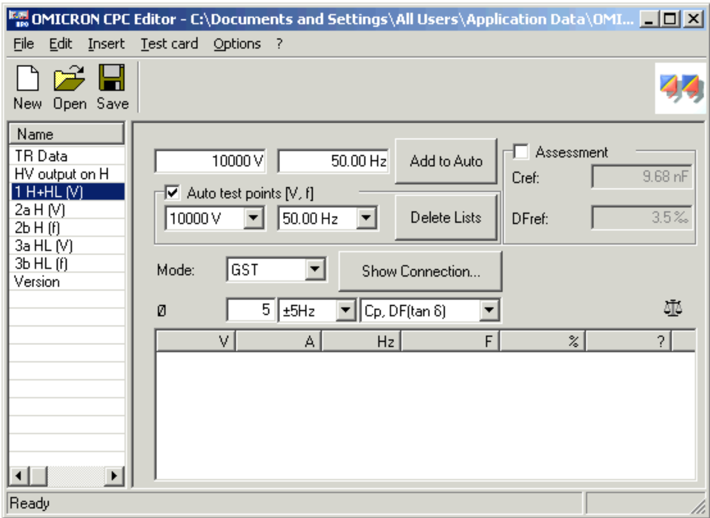


Figure 5-15: Measurement of C_H and C_{HL} in GST g-B mode

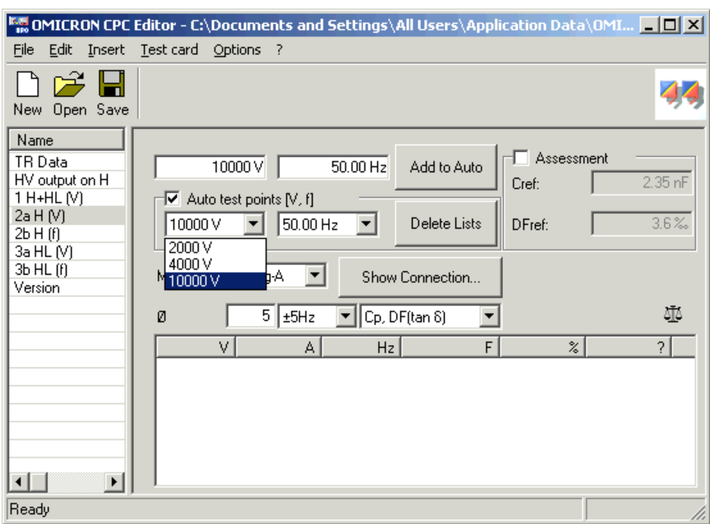


Figure 5-16: Voltage-scan of HV-windings to tank and core (GST gA+B)

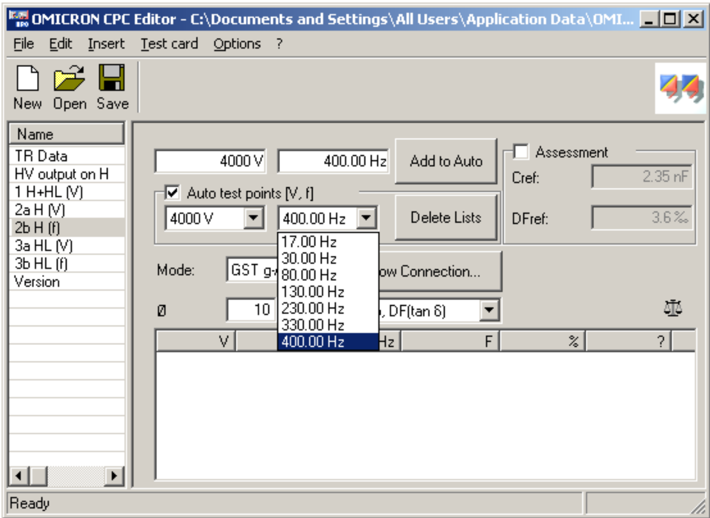


Figure 5-17: Frequency-scan of high-voltage windings to tank and core (GST gA+B)

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

Second file

A second test file contains the tests with the LV-winding connected to the HV-output of the *CP TD12/15*. Figure 5-18 shows the first screen with the connection instructions.

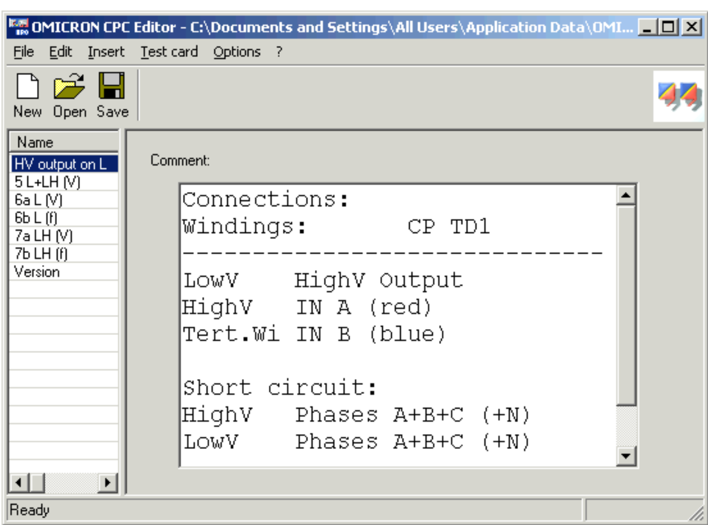


Figure 5-18: Connection instructions for the tests with energized LV-winding

Third file

A third test file is used for the tests with the tertiary winding connected to the HV-output of the *CP TD12/15*. Figure 5-19 shows the connection instructions for the tests with energized tertiary winding.

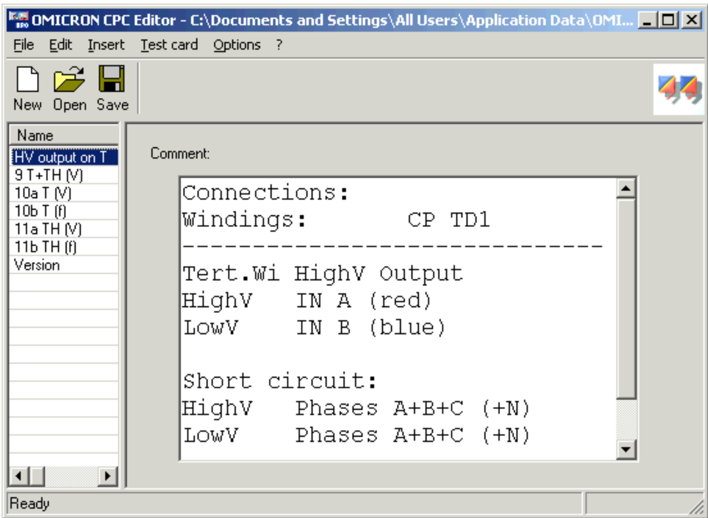
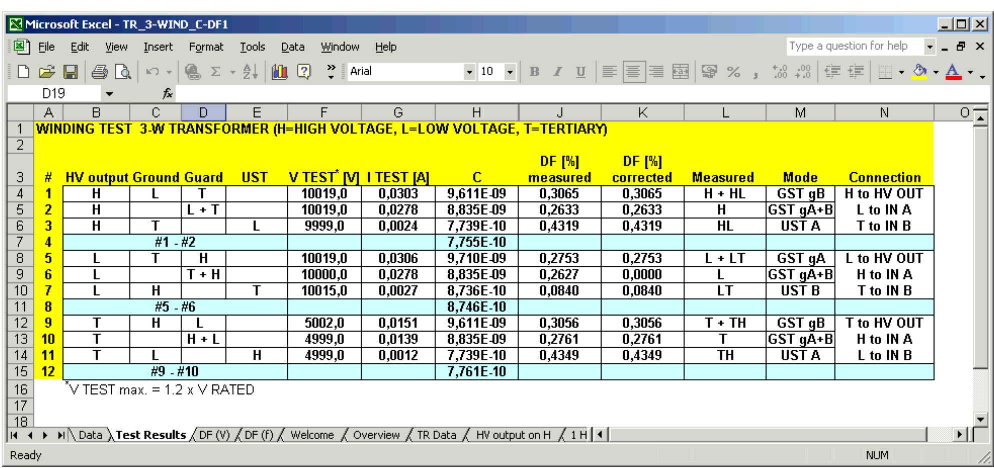


Figure 5-19: Connection instructions for the tests with energized tertiary winding

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).



WINDING TEST 3-W TRANSFORMER (H=HIGH VOLTAGE, L=LOW VOLTAGE, T=TERTIARY)

#	HV output	Ground	Guard	UST	V TEST* [V]	I TEST [A]	C	DF [%] measured	DF [%] corrected	Measured	Mode	Connection
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
4	#1 - #2						7,755E-10					
5	L	T	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
8	#5 - #6						8,746E-10					
9	T	H	L		5002,0	0,0151	9,611E-09	0,3056	0,3056	T + TH	GST gB	T to HV OUT
10	T		H + L		4999,0	0,0139	8,835E-09	0,2761	0,2761	T	GST gA+B	H to IN A
11	T	L		H	4999,0	0,0012	7,739E-10	0,4349	0,4349	TH	UST A	L to IN B
12	#9 - #10						7,761E-10					

*V TEST max. = 1.2 x V RATED

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

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.

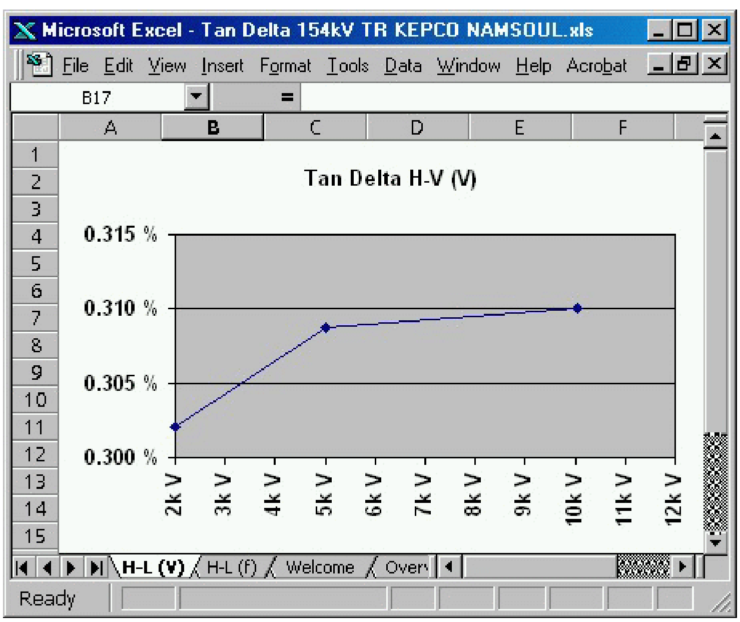


Figure 5-21: Voltage-scan for H-L (V) (50 Hz)

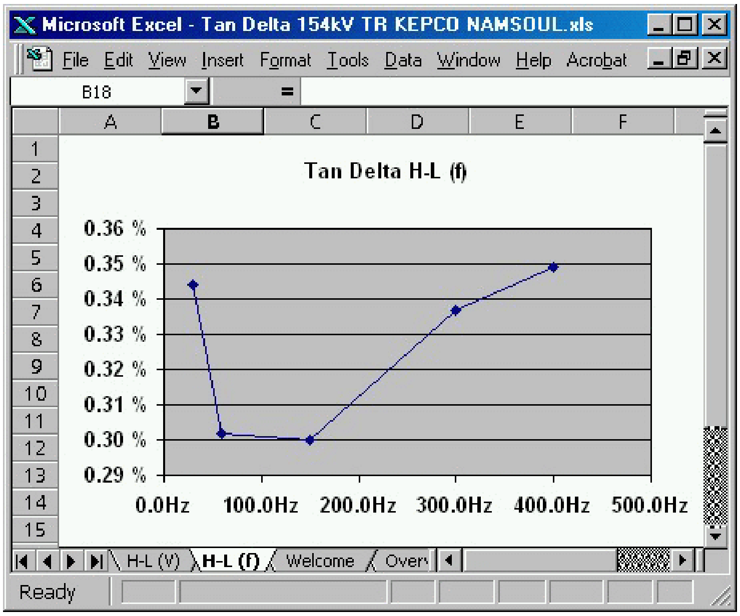


Figure 5-22: Frequency scan for H-L (f) (5 kV)

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 LV-output. Only one measurement is made of the winding to tank and core. All HV-terminals and LV-terminals are connected together to form a single HV-electrode.

5.8 Reactors

Similar to the auto-transformers, reactors also normally have only one winding. Often the LV-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

High-voltage bushings are essential parts of power transformers, circuit breakers and of other power apparatus. More than 37 % of all fire and explosion failures of high-voltage power transformer failures are caused by defective bushings [1]. Although the price for a bushing is low compared to the cost of a complete transformer, a bushing failure can damage a transformer completely. Regular capacitance and DF measurements are highly recommended.

Testing and maintaining HV-bushings are essential for continued successful operation of transformers and circuit breakers. Power outages may occur as the result of a bushing failure. The most frequently used type of HV-bushings is the condenser and therefore, it is the only one which will be described in this manual. 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 Figure 6-1).

Note:
- Equal capacitances, C_A through C_J, procedure equal distribution of voltage from the energized center 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.

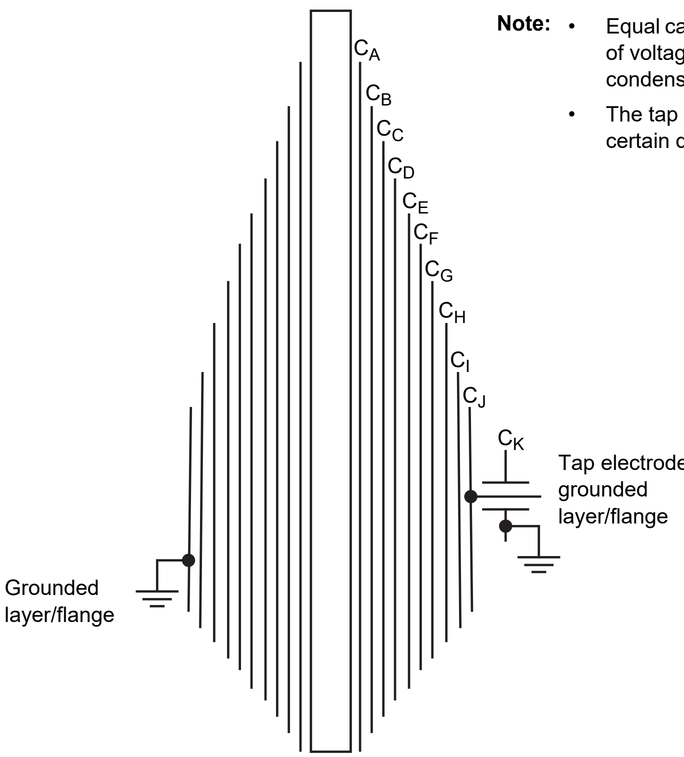


Figure 6-1: Condenser bushing design

Condenser bushings may have:

- "Resin-Bonded Paper (RBP) insulation
- "Resin-Impregnated Paper (RIP) insulation
- "Oil-Impregnated Paper (OIP) insulation
- Resin-Impregnated Fibre (RIF) or Resin Impregnated Synthetics (RIS) insulation

1. CIGRE, "TB 642 - Transformer Reliability Survey," 2015

6.1 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:

6.2 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.

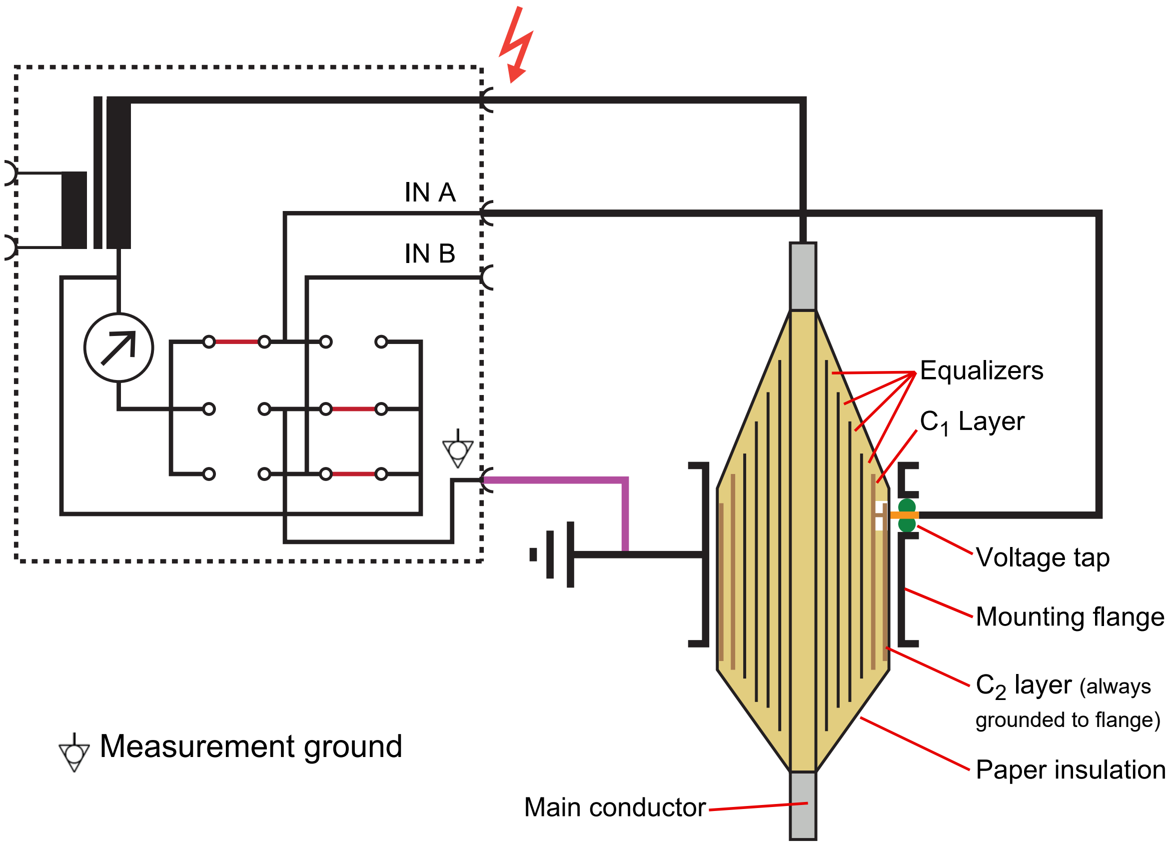


Figure 6-2: UST-A bushing test (C_1)

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.

6.3 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.

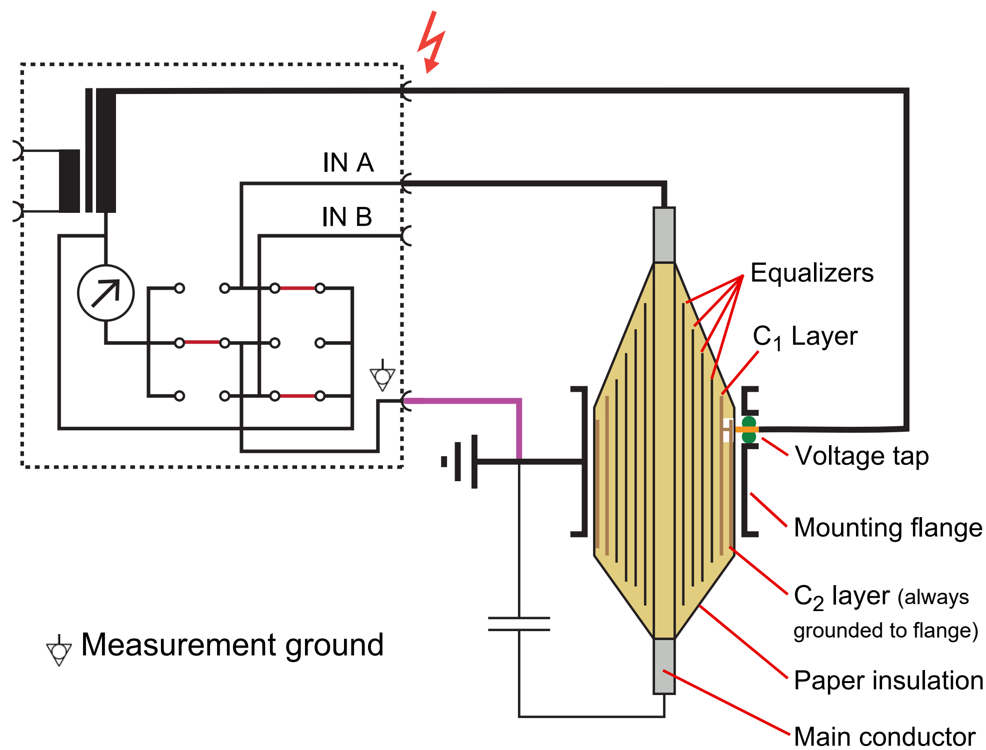


Figure 6-3: GST-A bushing test (C_2)

6.4 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.

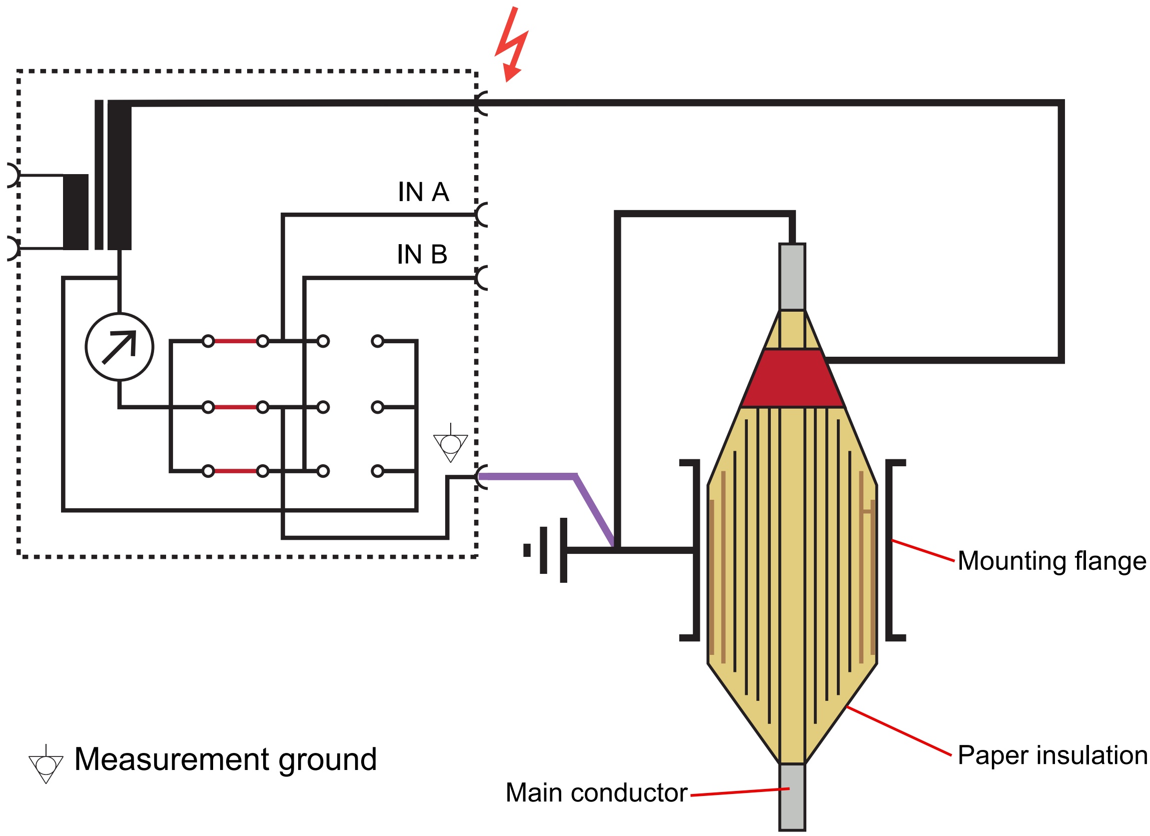


Figure 6-4: "Hot collar" test

6.5 Assessment of measurements

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 a reason to investigate the suitability of the bushing for continued service. The manufacturer should be consulted for guidance on specific bushings.

When 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 6-5).

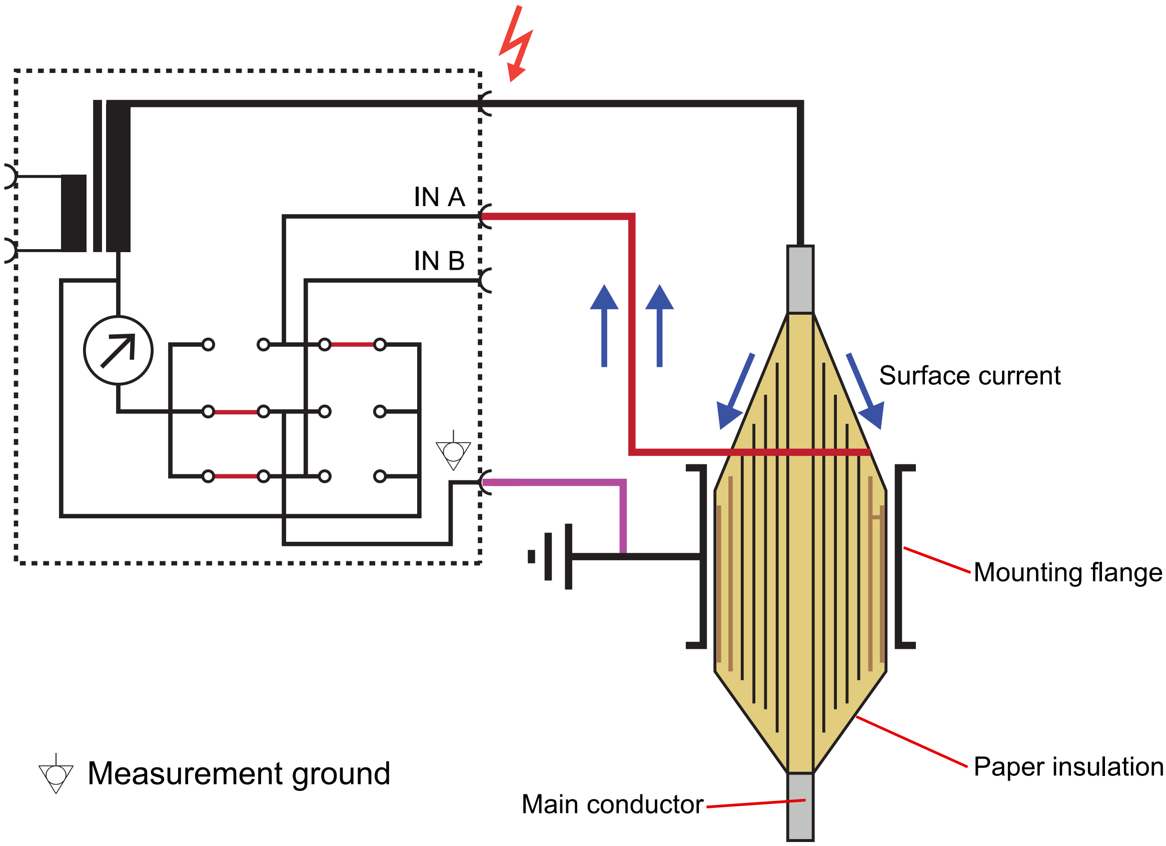


Figure 6-5: Use of the guard method for bypassing the surface current

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 TD12/15* 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: *CP TD12* – High-voltage output

Terminal	U	THD	I_{max}	S_{max}	t_{max}
High-voltage output	0...12 kV AC	< 2 %	300 mA	3600 VA	> 2 min
			100 mA	1200 VA	> 60 min

Table 7-2: *CP TD15* – High-voltage output

Terminal	U	THD	I_{max}	S_{max}	t_{max}
High-voltage output	0...15 kV AC	< 2 %	300 mA[1]	4500 VA[1]	> 2 min
			100 mA	1500 VA	> 60 min

1. Depending on Control device and power supply

7.1.2 Measurements

Test frequencies

Table 7-3: Test frequencies

Range	Typical accuracy[1]
15...400 Hz	error < 0.005 % of reading

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

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 7-4: Filter for selective measurements

Filter Bandwidth	Measurement time	Stop band specification (attenuation)
f_0 ± 5 Hz	2.2 s	> 110 dB at $f_x = f_0$ ± (5 Hz or more)
f_0 ± 10 Hz	1.2 s	> 110 dB at $f_x = f_0$ ± (10 Hz or more)
f_0 ± 20 Hz	0.9 s	> 110 dB at $f_x = f_0$ ± (20 Hz or more)

Test current (RMS, selective)

Table 7-5: Test current

Terminal	Range	Typical accuracy[1]	Conditions
IN A or IN B[2]	0...5 A AC	error < 0.3 % of reading + 100 nA	Ix < 8 mA
		error < 0.5 % of reading	Ix > 8 mA

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.
2. IN A (red) or IN B (blue), depending on the mode.

Test voltage (RMS, selective)

Table 7-6: *CP TD12* – Test voltage

Condition: U > 2 kV

Range	Typical accuracy[1]
2 kV...12 kV AC	error < 0.3 % of reading + 1 V

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Table 7-7: *CP TD15* – Test voltage

Condition: U > 2 kV

Range	Typical accuracy[1]
2 kV...15 kV AC	error < 0.3 % of reading + 1 V

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Capacitance Cp (equivalent parallel circuit)

Table 7-8: Capacitance Cp

Range	Typical accuracy[1]	Conditions
1 pF...3 µF	error < 0.05 % of reading + 0.1 pF	Ix < 8 mA, Utest = 2 kV...10 kV
	error < 0.2 % of reading	Ix > 8 mA, Utest = 2 kV...10 kV

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Dissipation factor DF (tan δ)

Table 7-9: Dissipation factor DF

Range	Typical accuracy[1]	Conditions
0...10 % (capacitive)	error < 0.1 % of reading + 0.005 % [2]	f = 45...70 Hz, I < 8 mA, Utest = 2 kV...10 kV
0...10000 %	error < 0.5 % of reading + 0.02 %	Utest = 2 kV...10 kV

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.
2. 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 7-10: Power factor Pf

Range	Typical accuracy[1]	Conditions
0...10 % (capacitive)	error < 0.1 % of reading + 0.005 % [2]	f = 45...70 Hz, I < 8 mA, Utest = 2 kV...10 kV
0...100 %	error < 0.5 % of reading + 0.02 %	Utest = 2 kV...10 kV

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.
2. 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 7-11: Phase angle φ

Range	Typical accuracy[1]	Conditions
-90 °...+90 °	error < 0.01 °	Utest = 2 kV...10 kV

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Impedance Z

Table 7-12: Impedance Z

Range	Typical accuracy[1]	Conditions
1 kΩ...1200 MΩ	error < 0.5 % of reading	Utest = 2 kV...10 kV

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Inductance Lx (equivalent serial circuit)

Table 7-13: Inductance Lx

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

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Quality factor QF

Table 7-14: Quality factor QF

Range	Typical accuracy[1]
0...1000	error < 0.5 % of reading + 0.2 %
> 1000	error < 5 % of reading

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Power P, Q, S (selective)

Table 7-15: *CP TD12* – Power P, Q, S

Range	Typical accuracy[1]
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

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.

Table 7-16: *CP TD15* – Power P, Q, S

Range	Typical accuracy[1]
0...4.5 kW[2]	error < 0.5 % of reading + 1 mW
0...4.5 kVAR[2]	error < 0.5 % of reading + 1 mVAR
0...4.5 kVA[2]	error < 0.5 % of reading + 1 mVA

1. "Typical accuracy" means at temperatures of 23 °C ± 5 K, after a warm-up time of more than 25 min, and in a frequency range of 45 Hz to 65 Hz, 98 % of all units have an accuracy which is better than specified.
2. Depending on Control device and power supply

7.2 Mechanical data

Table 7-17: Mechanical data

Characteristic		Rating
Dimensions (W × H × D)	*CP TD12*/15	460 × 317 × 223 mm 18.1 × 12.5 × 8.8 inches
Weight	*CP TD12*	23 kg / 51 lb
	CP TD15	24 kg / 53 lb

7.3 Environmental Conditions

Table 7-18: 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 7-19: 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 7-20: Standards conformity

Safety		
Safety	IEC / EN / UL 61010-1	CE
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!

24/7 Technical support – get support

www.omicronenergy.com/support

At our technical support hotline, you can reach well-educated technicians for all of your questions. Around the clock – competent and free of charge.

Make use of our 24/7 technical support hotlines:

Americas: +1 713 830-4660 or +1 800-OMICRON

Asia-Pacific: +852 3767 5500

Europe / Middle East / Africa: +43 59495 4444

Additionally, you can find our Service Center or Sales Partner closest to you at www.omicronenergy.com.

Customer Portal – stay informed

www.omicronenergy.com/customer

The Customer Portal on our website is an international knowledge exchange platform. Download the latest software updates for all products and share your own experiences in our user forum.

Browse through the knowledge library and find application notes, conference papers, articles about daily working experiences, user manuals and much more.

OMICRON Academy – learn more

www.omicronenergy.com/academy

Learn more about your product in one of the training courses offered by the OMICRON Academy.

OMICRON electronics GmbH, Oberes Ried 1, 6833 Klaus, Austria, +43 59495