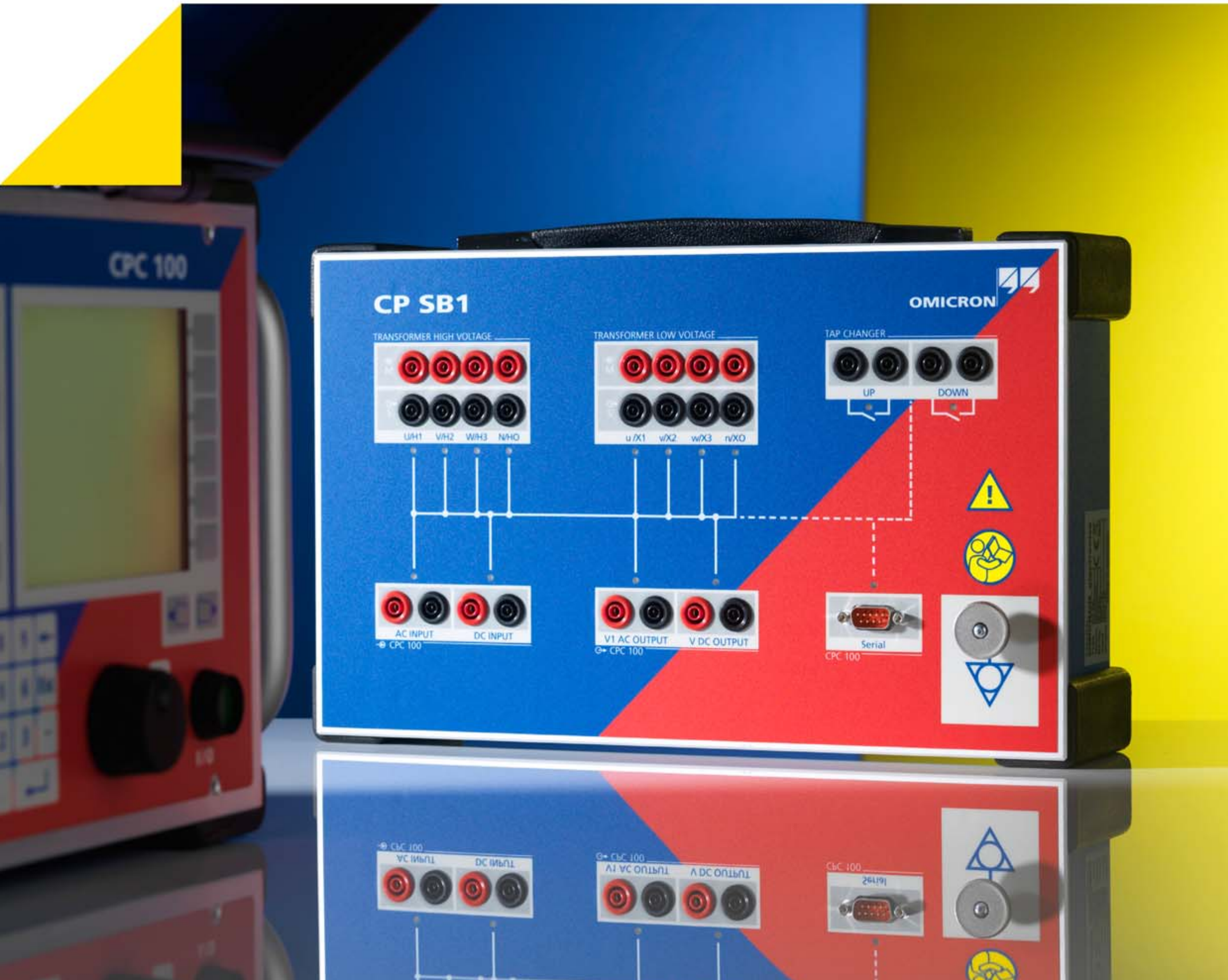
OMICRON

CP SB1

User Manual



Manual Version: CPSB1.AE.3

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 electronics 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 electronics 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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Using This Manual

This User Manual provides detailed information on how to use the *CP SB1* transformer switch box safely, properly and efficiently. The CP SB1 User Manual contains important safety instructions for working with the *CP SB1*, gets you familiar with operating the *CP SB1*, and provides typical application examples. Following the instructions in this User Manual will help you to prevent danger, repair costs and possible down time due to incorrect operation.

The CP SB1 User Manual always has to be available at the site where the *CP SB1* is used. It must be read and observed by all users of the *CP SB1*.

Reading the CP SB1 User Manual alone does not release you from the duty of complying with all national and international safety regulations relevant to working with the *CPC 100* and *CP SB1*. The regulation EN 50191 "The Erection and Operation of Electrical Test Equipment" as well as all the applicable regulations for accident prevention in the country and at the site of operation has to be fulfilled.

Operator Qualifications and Safety Standards

Working on overhead lines is extremely dangerous. Testing and measuring with the *CP SB1* 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 SB1* must be under constant supervision of an experienced operator while working with the equipment.

Testing and measuring with the *CP SB1* must comply with the relevant national and international safety standards listed below:

- EN 50191 (VDE 0104) "Erection and Operation of Electrical 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, additional relevant laws and internal safety standards have to be followed.

Conventions and Symbols Used

In this manual, the following symbols indicate paragraphs with special safety relevant meaning:

Symbol	Description
	Equipment damage or loss of data possible.
	Personal injury or severe damage to objects possible.

Related Documents

The following documents complete the information covered in the CP SB1 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.

Safety Rules

Before operating the *CP SB1* transformer switch box, read the following safety rules carefully. If you do not understand some safety rules, contact OMICRON electronics before proceeding. The *CP SB1* is designated for use with the *CPC 100* test system. Therefore, observe the safety rules both in this User Manual and in the *CPC 100* User/Reference Manual when working with the *CP SB1*.

Depending on the application and the device under test, specific safety instructions must be observed. Very often, the danger coming from the device under test is even higher than the danger from the *CP SB1* itself. For application-specific safety instructions, see 3.1 "Safety Instructions for Connecting the CP SB1 to Power Transformers" on page 21.

Maintenance and repair is only permitted by qualified experts either at the factory or certifeid external repair centers.

General

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

Operating the Measurement Setup

Only personnel qualified in electrical engineering and trained by OMICRON electronics are authorized to operate the *CP SB1*. Before starting the work, clearly establish the responsibilities.

Personnel receiving training, instructions, directions, or education on the *CPC 100* or *CP SB1* 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.

In principle, the safety instructions that apply to the *CPC 100* and its accessories (refer to "Safety Instructions for *CPC 100* and its Accessories" in the *CPC 100* Reference Manual) also apply to the *CP SB1*. Following, only safety instructions that exclusively apply to the *CP SB1* are listed. Before performing tests using high voltage, please read the following:

- Do not use the test equipment without a good connection to substation ground.
- Keep clear from zones in which high voltages may occur. Set up a barrier or establish similar adequate means.
- Make sure to position the *CP SB1* in a safe area.

- Pay attention to the national and the international standards for the safe operation of high-voltage test equipment (EN 50191, IEEE 510).
- Never touch any terminal without a visible ground connection!
- Before connecting or disconnecting test objects and/or cables, turn off the *CPC 100* by either the POWER ON/OFF switch or the Emergency Stop button. Never connect or disconnect a test object while the outputs are active.

  Note: Even if you switched off the *CPC 100*, wait until the red I/O warning light is fully extinguished. As long as this warning light is lit, there is still voltage and/or current potential on one or more of the outputs.

- Make sure that the test object's terminals that are to be connected to the *CP SB1* or *CPC 100* do not carry any voltage potential. During a test, the only power source for a test object may be the *CPC 100*.
- Do not insert objects (for example screwdrivers, etc.) into any input/output socket.
- When measuring the ratio of power transformers make sure that the test voltage is connected to the corresponding high-voltage winding, and the voltage of the low-voltage winding is the one that is measured. Accidentally mixing up the windings can generate life-threatening voltages within the transformer.

For example: feeding a voltage of 300 V to the low-voltage winding of a power transformer that has a ratio of 400000 V : 30000 V, induces a voltage of 4000 V in the transformer's primary winding.

- Do not operate the *CP SB1* under ambient conditions that exceed the temperature and humidity limits listed in 4 "Technical Data" on page 57.
- Make sure to position the test equipment on dry, solid ground.
- Do not operate the *CP SB1* in the presence of explosives, gas or vapors.
- Opening the *CP SB1* invalidates all warranty claims.
- If the *CP SB1* or any add-on device or accessory does not seem to function properly, do not use it anymore. Please call the OMICRON electronics hotline.
- Before handling the *CP SB1* or *CPC 100* in any way, connect them with a solid connection of at least 6 mm^2 cross-section to equipotential ground. Ground the *CP SB1* as close as possible to the *CPC 100*.

DC Output to Test Objects with a High Inductance

When using the DC Output to test power transformers with a high inductance, observe the following safety instructions:

- Use the **TRTapCheck** (tap changer winding resistance and on-load tap changer interruption check) test card only.
- As long as the *CPC 100* software shows the on-screen message "Switch off in progress", NEVER connect or disconnect test objects and/or cables.
- The message "Switch off in progress" notifies you that, while the *CPC 100* is deactivating, the connected external inductance (this means the test object) still "feeds" voltage potential back into the 6 A DC output.

  Note: The existence of this voltage potential at the 6 A DC output is also indicated by a lit LED - even if the *CPC 100* is switched off.
- If a test object with a high inductance was connected to the *CPC 100*, short-out the test object additionally before disconnecting any cables.

High-Voltage Outputs

All AC and DC output sockets of the *CP SB1* can carry life-hazardous voltage potential and provide life-hazardous currents. Therefore:

- While connecting cables to the *CP SB1* outputs or other conducting parts that are not protected against accidental contact, press the Emergency Stop button on the *CPC 100* front panel, and keep it pressed as long as an output signal is not absolutely necessary for the test.

- When connecting cables to the front panel input/output sockets, use wires with 4 mm safety "banana" connectors and plastic housing.
- For the connection between the *CPC 100* and *CP SB1* only use the specially manufactured cables supplied by OMICRON electronics (see 1.4 "CP SB1 Accessories" on page 17).

  Note: One end of the high-voltage cable has a coaxial safety plug that is certified for a voltage level of 2 kV AC. The other end is equipped with a safety banana plug that is insulated with a shrink tube.

- When the *CPC 100* is activated, consider this part of the cable to be a hazard of electric shock.
- Do not stand right next to or directly underneath a connection point because the clamps may fall off and touch you. This is a physical and an electrical hazard.
- The red warning light on the *CPC 100* front panel indicates hazardous voltage and/or current levels at the *CPC 100* outputs (red light "I" on or flashing). The green warning light indicates that the *CPC 100* outputs are not activated.

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

Static Charges

Static charges on transformer windings may be induced by test potentials. While the voltage may not be significant enough to cause any damage, it can be a source for serious accidents due to falls caused by reflex action.

Connect the windings to ground as described in the *CPC 100* Reference Manual.

Orderly Measures

The CP SB1 User Manual or alternatively the e-book in PDF format has always to be available on site where the *CP SB1* is being used. It must be read and observed by all users of the *CP SB1*.

The *CP SB1* may be used only as described in 3 "Application" on page 21. 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.

Disclaimer

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

1 Hardware Information

1.1 Designated Use

The *CP SB1* is a transformer switch box designated for automatically measuring the ratio and winding resistance, and testing the tap changer of three-phase power transformers. It is an accessory to the *CPC 100*. Automatic control of the On-Load Tap Changer (OLTC) is included. Testing of power transformers over all taps and all phases is fully automated. Therefore, no rewiring is required. The *CP SB1* is controlled from the *CPC 100* via its serial interface. The results are recorded in the *CPC 100* with the ratio and tap changer test cards, and can be analyzed with the computer tool set (*CPC 100 Excel File Loader*).

1.2 Circuit Diagram of the *CP SB1*

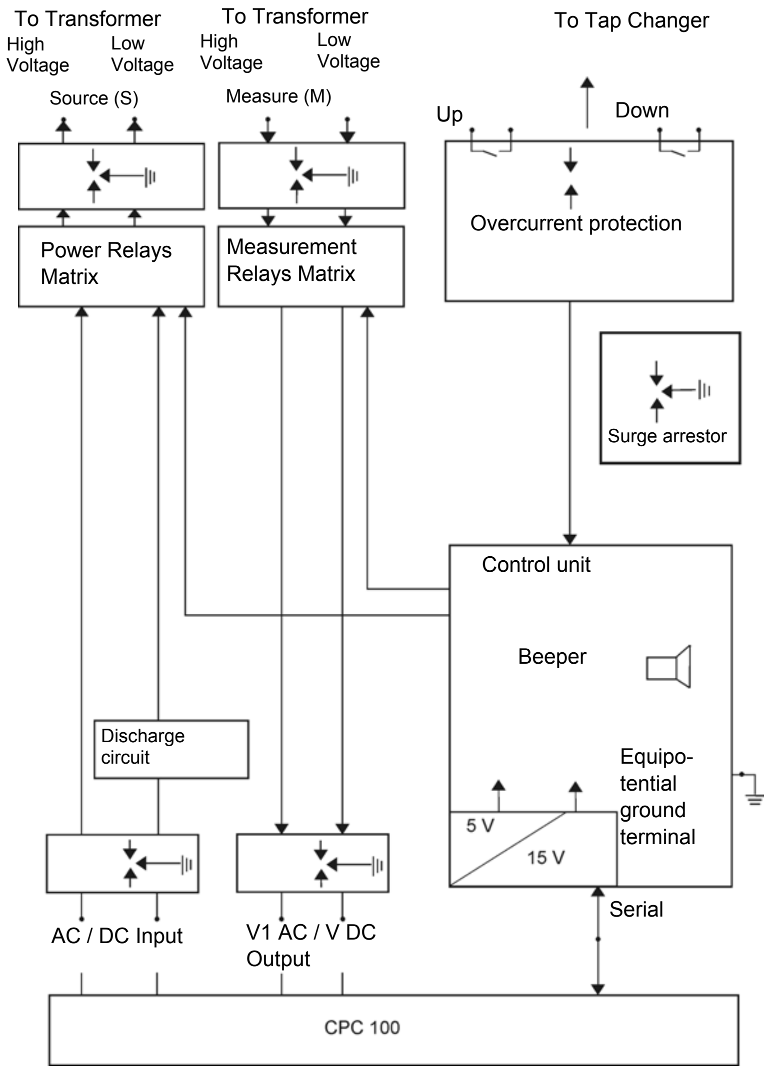


Figure 1-1 Circuit diagram of the *CP SB1*

1.3 Functional Components of the *CP SB1*

The front panel of the *CP SB1* provides the following functional components:

- Transformer High Voltage:
  - Outputs (**S**ource) for the input of current or voltage on the individual phases of the transformer
  - Inputs (**M**easure) for the voltage measurement

  Note: The inputs and outputs of the respective connections (U/H1, V/H2, W/H3, N/H0) are connected to the transformer using Kelvin clamps.
- Transformer Low Voltage:
  - Outputs (**S**ource) for the input of current or voltage on the individual phases of the transformer
  - Inputs (**M**easure) for the voltage measurement

  Note: The inputs and outputs of the respective connections (u/X1, v/x2, w/x3, n/X0) are connected to the transformer using Kelvin clamps.
- Tap Changer: Two potential-free contacts for switching the tap changer
- AC input for connection to the 2 KV AC output of the *CPC 100*
- DC input for connection to the 6 A DC output and I AC/DC input of the *CPC 100*
- AC output for connection to the V1 AC input of the *CPC 100*
- DC output for connection to the V DC input of the *CPC 100*
- Serial interface for the *CPC 100* (**TRRatio** and **TRTapCheck** test cards) to control the *CP SB1*
- Equipotential ground terminal for grounding the *CP SB1* close to the position of the operating staff

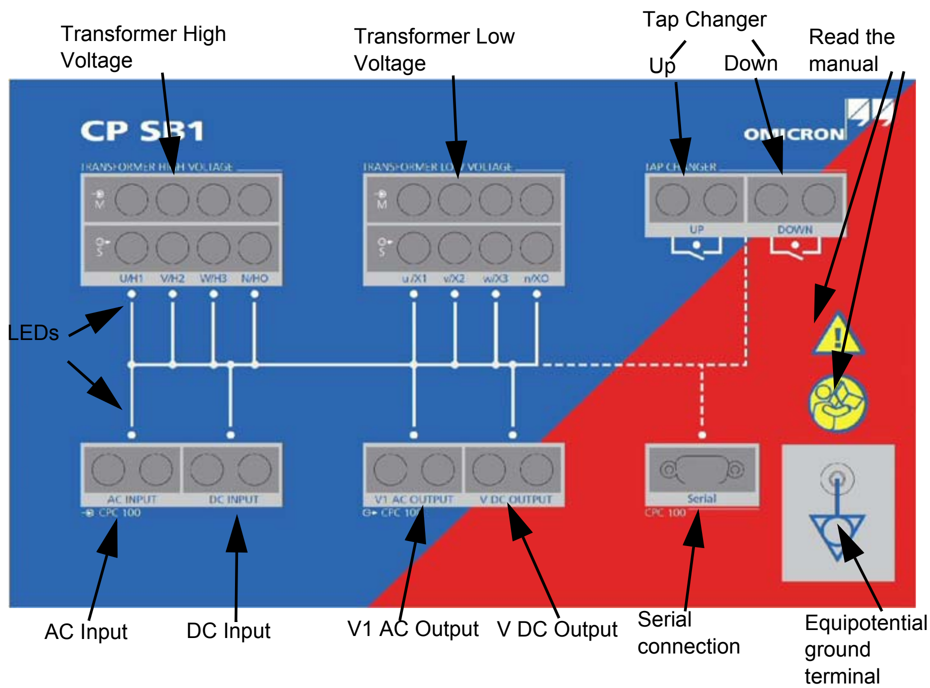


Figure 1-2 Front panel

1.4 *CP SB1* Accessories

The following accesories are delivered with the *CP SB1* tranformer switch box:

Table 1-1 *CP SB1* Accessories

Accessories		Description
1x Transport case		To transport the entire equipment
Coax. cables 15 m/2.5 mm^2 3x red, 3x blue, 2x green, 2x yellow supplied in cable drums		Connection from the *CP SB1* to the transformer via Kelvin clamps and the tap changer via flexible terminal adapter
1x Grounding cable		Connection from the *CP SB1*'s equipotential ground terminal to the substation ground
Banana cables 2 m 4x red and 4x black		Connection from the *CPC 100* to the *CP SB1*'s DC input, V1 AC output and V DC output

Table 1-1 *CP SB1* Accessories (continued)

Accessories		Description
8 Kelvin clamps black		Connection to bushings
6x Flexible terminal adapter		Connection to tap changer
1x Data cable 3 m grey		Connection from the *CP SB1* to the *CPC 100*
1x Backpack		To transport the cable drums and Kelvin clamps

2 Operation

2.1 Measurement Setup

The measurement setup consists of the *CPC 100* test system and the *CP SB1* transformer switch box. Figure 2-1 "Measurement setup" shows the functional setup.

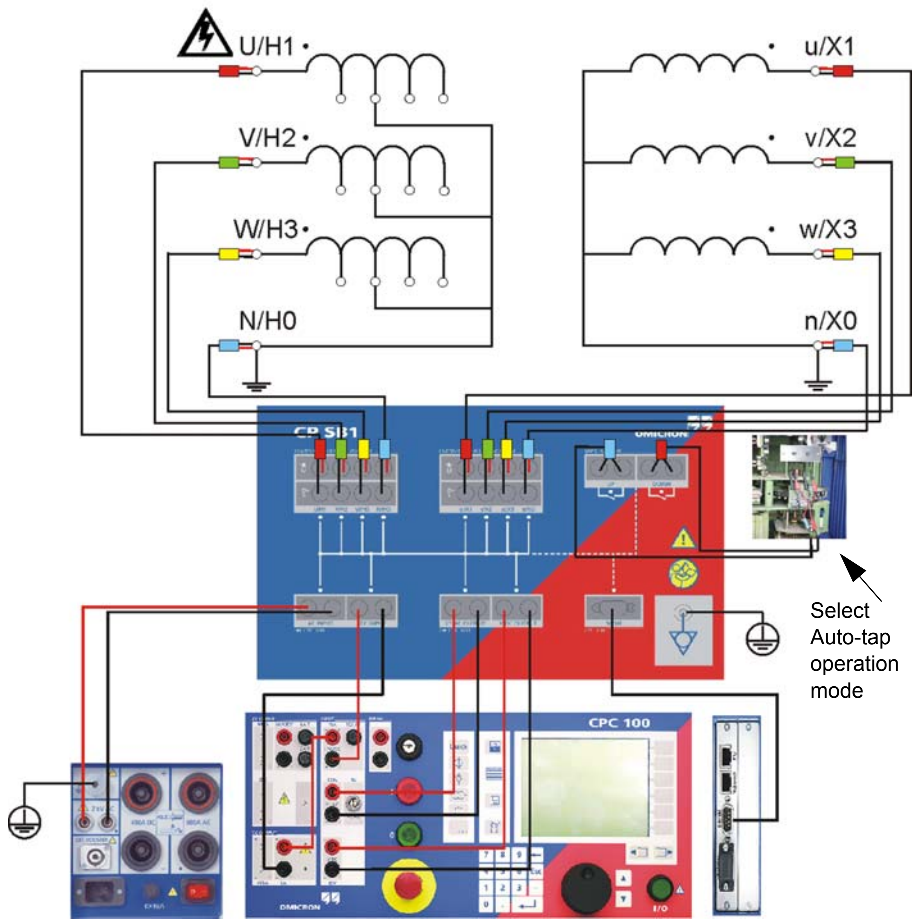


Figure 2-1 Measurement setup

2.2 Operating Principle

The *CP SB1* is a transformer switch box whose relays are controlled by the serial interface of the *CPC 100* test system. Potential-free relay contacts control the AC tap changer of the transformer under test. With the switch box, you can measure the winding resistance (current up to 6 A) and ratio on three-phase transformers (output voltage limited to 300 V/150 V). Automatic control of the OLTC is included. The *CP SB1* consists of a relay switching matrix with which you can conduct automatic testing.

An integrated logic which is controlled by the *CPC 100* controls the relays and the OLTC. The *CP SB1* has two outputs to operate the tap changer together with an optimized "Auto Keep Result" algorithm within the **TRTapCheck** test card. Both **TRRatio** and **TRTapCheck** test cards can record the results of all three phases with a single test card. The switch box automatically switches to the next phase after testing of a phase is completed.

You can conduct the transformer ratio test and the time-consuming tap changer resistance test over all taps and all three phases without rewiring. For special measurements and single-phase transformers, the operation mode can be set to manual. In this case, use banana cables between the connections to the transformer and the *CPC 100* of the *CP SB1*.

An acoustic signal (intermittent beep) indicates if the discharge is in progress. A double beep informs the user when a correct connection has been established. An intermittent beep with a longer interval sounds in case of firmware download.

For the ratio measurement, the voltage is always injected into the high-voltage side of the transformer. The winding resistance can be measured on the high- or low-voltage side. Manual mode is possible for both **TRTapCheck** and **TRRatio**.

Note: For detailed information about the ratio measurement, as well as winding resistance and tap changer test, refer to the *CPC 100* User Manual.

2.3 Test Cards

The *CP SB1* comprises two test cards: **TRRatio** to measure the ratio, and **TRTapCheck** to test the tap changer of power transformers and the winding resistance.

Note: The license is indicated on the nameplate with the option "advanced". If your *CP SB1* has a license, the tap check runs in automatic mode by default. Otherwise (without license), the tap changer has to be tested in manual mode.

Note: For detailed information about further test cards, test procedures and templates refer to the *CPC 100* User Manual.

3 Application

3.1 Safety Instructions for Connecting the *CP SB1* to Power Transformers

3.1.1 Before Starting

Caution: Before operating the *CP SB1*, always observe the five general safety rules as described in "General" on page 7.

3.1.2 Connecting the Measurement Setup to Power Transformers

1. Position the *CP SB1* in the safety area and do not enter this area during the entire measurement.
2. Connect the *CPC 100* and *CP SB1* using the delivered grounding cable.
3. Connect the grounding cable of the *CP SB1* at a safe grounding point at the transformer.

   Note: Do not operate the test equipment without safe connection to ground.
4. Make sure that all high-voltage connections of the transformer are removed.
5. Make sure that all terminals of the transformer are connected to ground.
6. Switch off the power supply of the tap changer.
7. Connect the Kelvin clamps to the bushings.

8. Connect the cables to the Kelvin clamps. Make sure that the cables show upwards and that each colour is connected to a different phase.

9. Connect the cables from the Kelvin clamps' voltage sense outputs to the *CP SB1*'s transformer inputs. Observe the color code.
10. Make sure to measure the voltage to ground at the terminals of the tap changer. If no voltage is measured, connect the flexible terminal adapters to the "up" and "down" terminals of the tap changer.
11. Connect the cables ("up", "down") to the *CP SB1*.
12. Connect the *CP SB1* to the *CPC 100* according to 1.3 "Functional Components of the CP SB1" on page 15.
13. Switch on the power supply of the tap changer.
14. Remove all grounding connections of the terminals except one per winding. Use Neutral (N) for the grounding connection if accessible.
15. Start the measurement according to 3.4.3 "Performing Measurements with TRRatio" on page 30 and 3.5.3 "Performing Winding Resistance Measurements" on page 52.

3.2 Template Usage

With the *CPC 100 Excel File Loader* you can load XML files generated with the *CPC 100* into Microsoft Excel templates for post-processing. The *CPC 100 Excel File Loader* is installed with the setup disk. After the installation, a shortcut to open the *CPC 100 Start Page* appears on your desktop, where you can start the *Excel CPC 100 File Loader*. Templates are pairs of XML documents and Microsoft Excel templates designed by OMICRON electronics or end users for designated applications. The XML templates are predefined test procedures, often with comments, that run on the *CPC 100* and guide the user through the test. Once completed, the XML file is saved on the *CPC 100*. The file is then loaded into the corresponding Microsoft Excel template. There the results are post-processed and a final test report is generated. The template pairs facilitate and speed testing with the *CPC 100* and the evaluation of results.

To run a test procedure according to a template:

1. Upload the XML template for the intended application from the computer to the *CPC 100*.
2. Open the template on the *CPC 100*.
3. Run the test procedure according to the template.
4. After completing the test procedure, save the test in a new file.
5. Open the corresponding Microsoft Excel template on the *CPC 100 Start Page.* A Microsoft Excel workbook appears.
6. Click the **Load XML-File** button and open the **.xml* file saved on your *CPC 100* that is available under the *OMICRON Devices* tree.
7. After all worksheets are filled with data, the test results are calculated.

3.3 Test Cards

To select a test card, press **Insert Card** in the Test Card View.

Use the context-dependent **Up/Down** menu keys to the right, or the handwheel, to browse through the structure. On Transformer, press **Enter**.

Alternatively, press the accelerator key to open the **Insert a new test card** dialog box.

For power transformers, the following test cards are available:

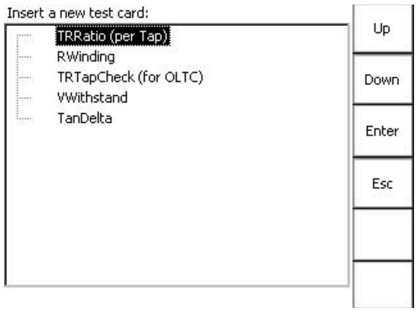


Figure 3-1 Inserting test cards

Highlight the test card of your choice either by navigating with the handwheel or by using the context-dependent **Up/Down** menu keys, and then press **Enter**.

Note: The test card **TRRatio** (per Tap) employs the frequency-selective measurement method, which is used to filter out interferences usually present in substations.

Note: To learn more about the frequency-selective measurement, refer to "The Frequency-Selective Measurement" in the *CPC 100* Reference Manual.

3.4 TRRatio Test Card

Use the **TRRatio** test card to measure the ratio of power transformers by injecting AC voltage from **AC OUTPUT** into the transformer's high-voltage side. The maximum voltage for Y and D transformers is limited to 300 V, and for YN transformers to 150 V.

The *CPC 100* measures both the voltage it applies to **AC OUTPUT** and the transformer's low-voltage side at **V1 AC**. From these values, it calculates the ratio and its deviation from the nominal ratio in percent.

In addition, the excitation current and its phase angle is measured. Moreover, the phase angle between the high-voltage and the low-voltage side is measured.

Furthermore, you can use the **TRRatio** test card to measure a power transformer's ratio for each single tap changer position.

3.4.2 "Test Settings for TRRatio" on page 26 shows the Vprim and Vsec settings on the **TRRatio** test card for different connections of the transformer under test.

3.4.1 Measurement Setup for TRRatio

The measurement setup in connection with the **TRRatio** test card is shown below.

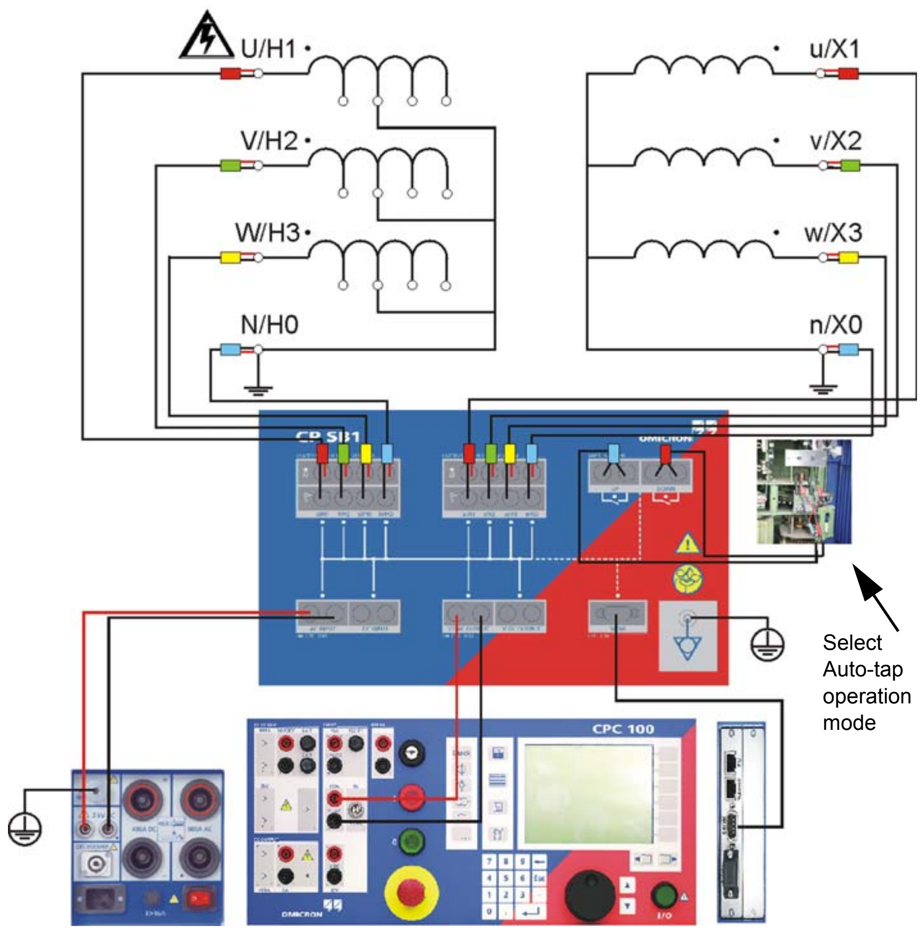


Figure 3-2 Measurement setup for **TRRatio**

Note: You can also use the measurement setup as shown in Figure 2-1 on page 19.

3.4.2 Test Settings for TRRatio

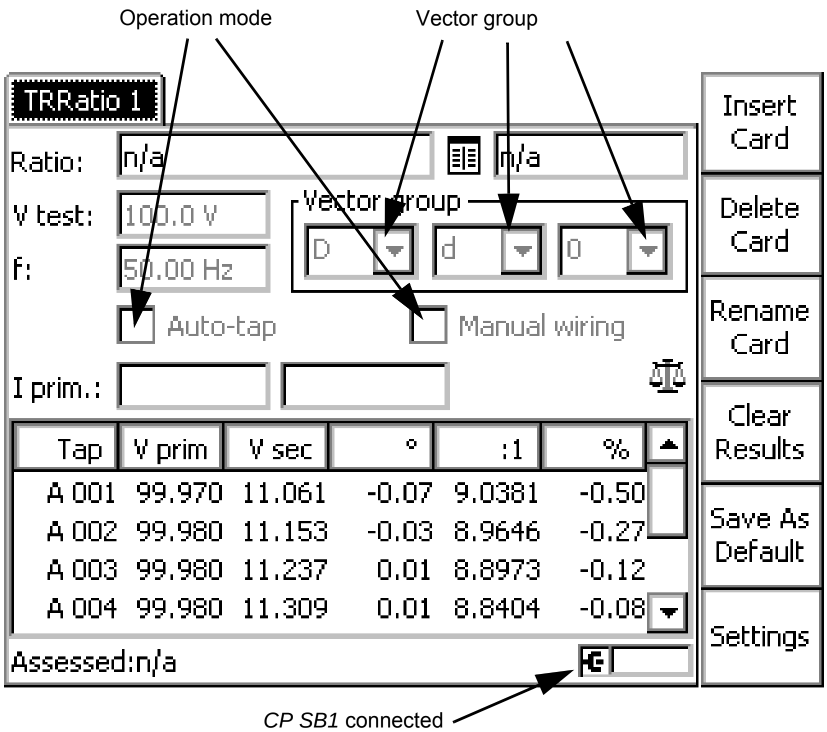


Figure 3-3 **TRRatio** test card

Navigate to the parameter fields and enter the values according to your test requirements:

Ratio table:	Nominal ratios of all taps, calculated from Vprim nom / Vsec nom
Vtest:	Nominal primary injection voltage
f:	Output frequency
Operation mode:	The wiring information can be displayed via the **Wiring Info** soft key.
Vector group:	Selection depending on the settings

Pressing the **Settings** menu key opens the **Settings** page. The **Settings** page of the **TRRatio** test card has another functionality as on other test cards.

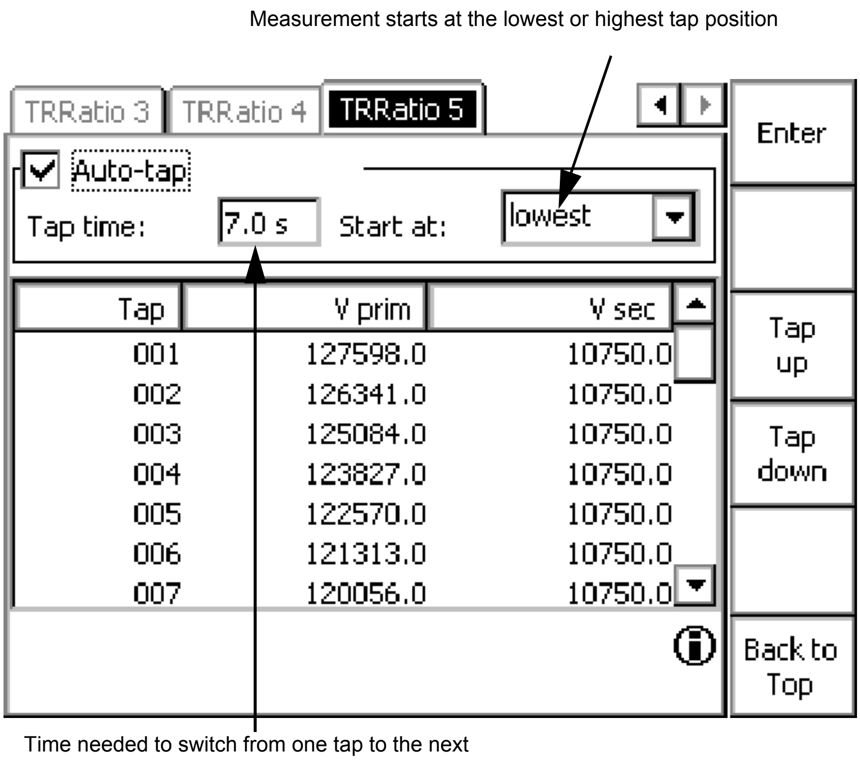


Figure 3-4 Settings page of the **TRRatio** test card

Note: The **Settings** page opens automatically if the **Auto-tap** operation mode is activated.

For proper **Auto-tap** operation, the **Tap time** and **Start at** settings need to be adjusted. The **Tap time** is the time needed to switch from one tap to the next. **Start at** defines the initial position of the tap. With the **Tap up** / **Tap down** softkeys you can move the tap changer manually. Move the tap changer to the highest or lowest tap, depending on your setting before measurement.

The **Settings** page allows adding the transformer's ratio per tap as follows. After pressing the **Add Tap** menu key first enter the Tap Number, Vprim and Vsec. Add the next tap by pressing the **Add Tap** menu key and enter the corresponding Vprim and Vsec values. After then, pressing the **Add Tap** menu key repeatedly adds more taps with a step calculated from the values of the preceeding taps. The tap entries apply equally to all phases. After adding all taps, press the **Main Page** menu key to transfer the data to the main page.

Note: After the transformer's ratio was specified on the **Settings** page, you can save the data by pressing the **Save As Default** menu key. Then, for each new test card these tap values will be retained.

To set up the different measurements, use the **A**, **B**, and **C** keys to the right:

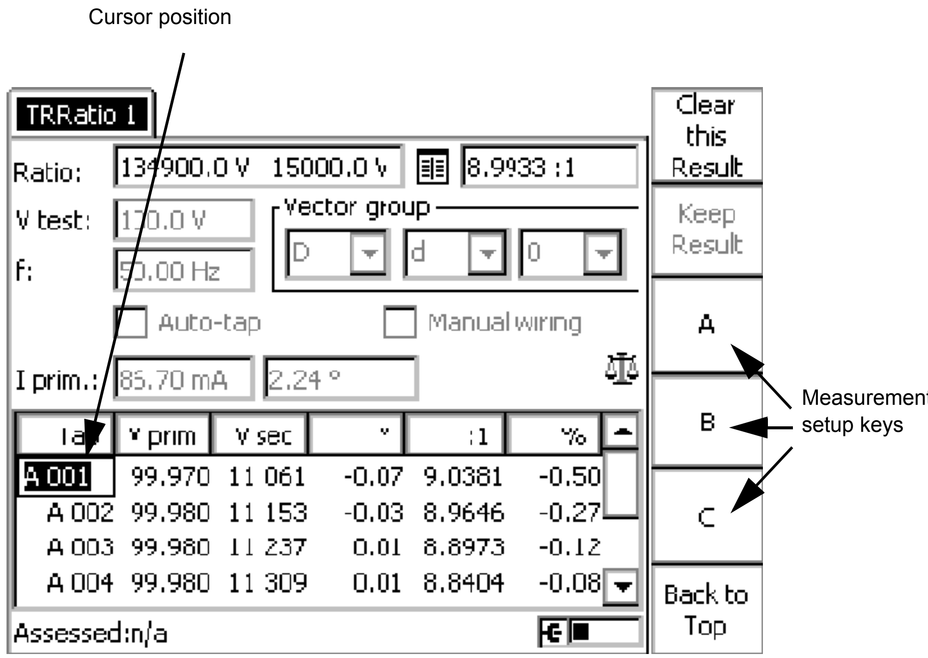


Figure 3-5 Setting up the different measurements

Note: The context-dependent keys to the right will only appear if the cursor is positioned in the result line.

The **TRRatio** test card displays the measurement results in two display fields and a table:

Iprim:	Primary current from **2 kV AC** output**,** measured by the *CPC 100* internally If the focus is on the table, scrolling through the lines will change this display accordingly, depending on the selected line. The ° shows the phase angle of the primary current relative to Vprim nominal.
Tap (in table):	Displays the transformer tap identifier and tap number for the measurements in the respective line of the table.
Vprim:	Actual voltage injected from **AC OUTPUT** into the transformer's high-voltage side
Vsec:	Actual voltage measured at **V1 AC** from the transformer's low-voltage side. The ° shows the phase angle of the primary current relative to Vprim nominal. **Note:** Even on transformers such as Yd5, only phase angles like 0° or 180° can be found using a single phase test set because a transformer can change the phase angle only by "mixing" different phases.
Ratio :1	Calculated ratio value from the measured values Vprim / Vsec
%:	The % shows the deviation of the actual ratio from the nominal ratio in %.

3.4.3 Performing Measurements with TRRatio

The *CP SB1* can be operated in four different modes, depending on the way you like to test and operate the tap changer. These modes also apply to the **TRTapCheck** test card.

Auto-tap	Manual wiring	Mode	Description
☑	☐	Fully automatic mode	The tap changer, phase switches and the measurement procedure are controlled by the *CPC 100*. The test runs fully automatically through all the taps and phases, and is completed automatically. There is no need to save the individual measurement results manually.
☐	☐	Half-automatic mode	If the tap changer is not connected, the *CP SB1* performs a half-automatic test. The procedure is the same as for the manual mode. The only difference is that the phases can be switched without deactivating the *CPC 100*.
☑	☑	Extended manual mode	The tap changer is controlled by the *CPC 100*, and measurements are performed automatically. However, you are able to manually wire the connections. Therefore, the phases cannot be switched automatically.
☐	☑	Manual mode	Manual wiring is required, and the taps have to be switched manually.

Fully Automatic Test

To perform a fully automatic test:

1. Select **Auto-tap** operation, deselect **Manual wiring** (default).
2. On the **Settings** page, define **Tap time**, **Start at** and the tap table. In case the nominal ratios are not known, select **n/a**.
3. Select **Vector group**, **Vtest** and **frequency**.

4. Press the **I/O** (test start/stop) push button to start the test.
5. The test voltage increases in a ramp characteristic from 0 V to **Vtest** within 1 second. Then, the first set of measurements is taken.
6. The *CPC 100* deactivates when the test is completed.

Note: In fully automatic mode, an interrupted test will be resumed at the current tap position.

Manual or Half-Automatic Test

To perform a manual or half-automatic test:

1. Define the parameters first on the **Settings** page, then on the main page and press the **I/O** (test start/stop) push button to start the test.
2. The test voltage increases in a ramp characteristic from 0V to Vtest within 1 second.

3. Save the test results of the first tap by pressing **Keep Result**. This adds the measured values to the first line of the table.
4. While passing through the power transformer's tap changer positions, press **Keep Result** for each single position. This adds new lines to the table holding the measured values.
5. When all test points are measured, press the **I/O** (test start/stop) push button to stop the test. Vtest decreases in a ramp characteristic within 1 second, and the last unsaved line, that is, the line that was not saved by pressing **Keep Result**, will be discarded.

Caution: The maximum voltage between the connectors is 300 Veff AC. Depending on the configuration of your transformer, the voltage between the connectors might be higher than the injected voltage.

Table 3-1 Different Vector Groups

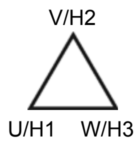
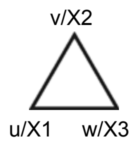
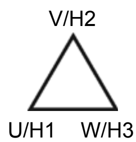
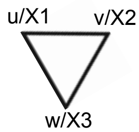
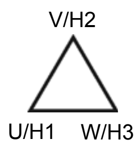
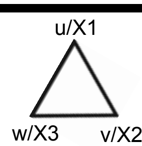
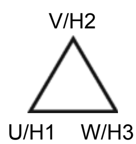
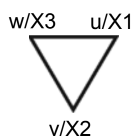
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Dd0			A	U-V / H1-H2	u-v / X1-X2	1
			B	V-W / H2-H3	v-w / X2-X3	
			C	W-U / H3-H1	w-u / X3-X1	
Dd2			A	U-V / H1-H2	w-v / X3-X2	1
			B	V-W / H2-H3	u-w / X1-X3	
			C	W-U / H3-H1	v-u / X2-X1	
Dd4			A	U-V / H1-H2	w-u / X3-X1	1
			B	V-W / H2-H3	u-v / X1-X2	
			C	W-U / H3-H1	v-w / X2-X3	
Dd6			A	U-V / H1-H2	v-u / X2-X1	1
			B	V-W / H2-H3	w-v / X3-X2	
			C	W-U / H3-H1	u-w / X1-X3	

Table 3-1 Different Vector Groups (Continued)

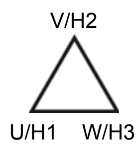
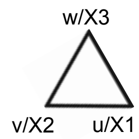
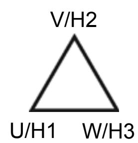
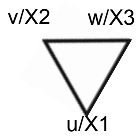
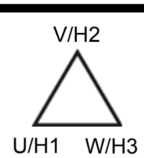
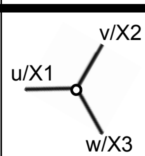
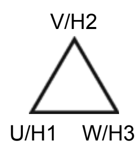
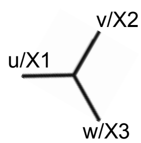
IEC 60076 vector group	Winding connection		Measure-ment	Trans-former high-voltage side	Trans-former low-voltage side	Mea-sured turn ratio
	HV / H	**LV /X**				
Dd8			A	U-V / H1-H2	v-w / X2-X3	1
			B	V-W / H2-H3	w-u / X3-X1	
			C	W-U / H3-H1	u-v / X1-X2	
Dd10			A	U-V / H1-H2	u-w / X1-X3	1
			B	V-W / H2-H3	v-u / X2-X1	
			C	W-U / H3-H1	w-v / X3-X2	
Dyn1			A	U-V / H1-H2	n-v / X0-X2	1*√3
			B	V-W / H2-H3	n-w / X0-X3	
			C	W-U / H3-H1	n-u / X0-X1	
Dy1			A	U-(V+W) / H1-(H2+H3)	u-v / X1-X2	√3/2
			B	V-(U+W) / H2-(H1+H3)	v-w / X2-X3	
			C	W-(U+V) / H3-(H1+H2)	w-u / X3-X1	

Table 3-1 Different Vector Groups (Continued)

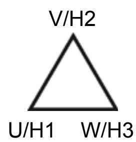
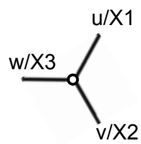
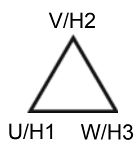
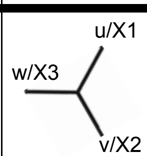
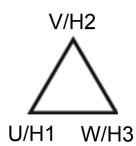
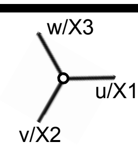
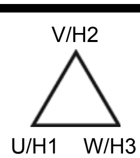
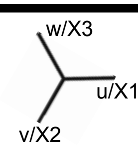
IEC 60076 vec- tor group	Winding connection		Mea- sure- ment	Trans- former high- voltage side	Trans- former low-voltage side	Mea- sured turn ratio
	HV / H	**LV /X**				
Dyn5			A	U-V / H1-H2	n-u / X0-X1	1*√3
			B	V-W / H2-H3	n-v / X0-X2	
			C	W-U / H3-H1	n-w / X0-X3	
Dy5			A	U-(V+W) / H1-(H2+H3)	w-u / X3-X1	√3/2
			B	V-(U+W) / H2-(H1+H3)	u-v / X1-X2	
			C	W-(U+V) / H3-(H1+H2)	v-w / X2-X3	
Dyn7			A	U-V / H1-H2	v-n/ X2-X0	√3
			B	V-W / H2-H3	w-n / X3-X0	
			C	W-U / H3-H1	u-n / X1-X0	
Dy7			A	U-(V+W) / H1-(H2+H3)	v-u / X2-X1	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	w-v / X3-X2	
			C	W-(U+V) / H3-(H1+H2)	u-w / X1-X3	

Table 3-1 Different Vector Groups (Continued)

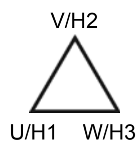
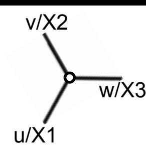
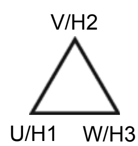
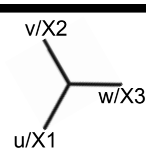
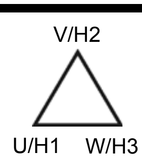
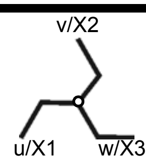
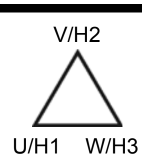
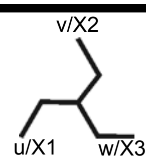
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Dyn11			A	U-V / H1-H2	u-n / X1-X0	√3
			B	V-W / H2-H3	v-n / X2-X0	
			C	W-U / H3-H1	w-n / X3-X0	
Dy11			A	U-(V+W) / H1-(H2+H3)	u-w / X1-X3	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	v-u / X2-X1	
			C	W-(U+V) / H3-(H1+H2)	w-v / X3-X2	
Dzn0			A	U-(V+W) / H1-(H2+H3)	u-n / X1-X0	1.5
			B	V-(U+W) / H2-(H1+H3)	v-n / X2-X0	
			C	W-(U+V) / H3-(H1+H2)	w-n / X3-X0	
Dz0			A	U-V / H1-H2	u-v / X1-X2	1
			B	V-W / H2-H3	v-w / X2-X3	
			C	W-U / H3-H1	w-u / X3-X1	

Table 3-1 Different Vector Groups (Continued)

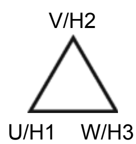
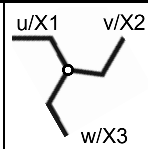
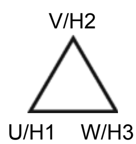
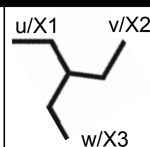
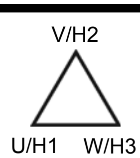
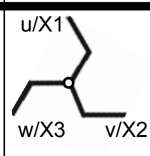
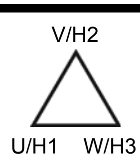
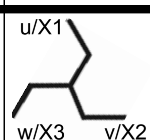
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Dzn2			A	U-(V+W) / H1-(H2+H3)	n-v / X0-X2	1.5
			B	V-(U+W) / H2-(H1+H3)	n-w / X0-X3	
			C	W-(U+V) / H3-(H1+H2)	n-u / X0-X1	
Dz2			A	U-V / H1-H2	w-v / X3-X2	1
			B	V-W / H2-H3	u-w / X1-X3	
			C	W-U / H3-H1	v-u / X2-X1	
Dzn4			A	U-(V+W) / H1-(H2+H3)	w-n / X3-X0	1.5
			B	V-(U+W) / H2-(H1+H3)	u-n / X1-X0	
			C	W-(U+V) / H3-(H1+H2)	v-n / X2-X0	
Dz4			A	U-V / H1-H2	w-u / X3-X1	1
			B	V-W / H2-H3	u-v / X1-X2	
			C	W-U / H3-H1	v-w / X2-X3	

Table 3-1 Different Vector Groups (Continued)

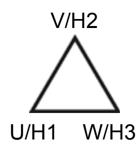
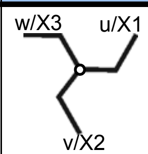
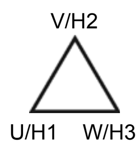
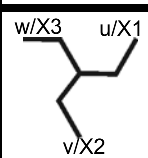
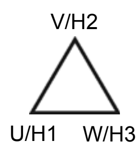
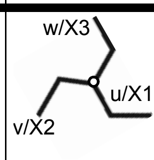
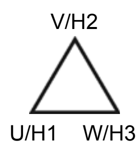
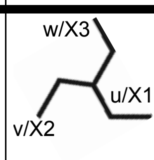
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Dzn6			A	U-(V+W) / H1-(H2+H3)	n-u / X0-X1	1.5
			B	V-(U+W) / H2-(H1+H3)	n-v / X0-X2	
			C	W-(U+V) / H3-(H1+H3)	n-w/ X0-X3	
Dz6			A	U-V / H1-H2	v-u / X2-X1	1
			B	V-W / H2-H3	w-v / X3-X2	
			C	W-U / H3-H1	u-w / X1-X3	
Dzn8			A	U-(V+W) / H1-(H2+H3)	v-n / X2-X0	1.5
			B	V-(U+W) / H2-(H1+H3)	w-n / X3-X0	
			C	W-(U+V) / H3-(H1+H2)	u-n / X1-X0	
Dz8			A	U-V / H1-H2	v-w / X2-X3	1
			B	V-W / H2-H3	w-u / X3-X1	
			C	W-U / H3-H1	u-v / X1-X2	

Table 3-1 Different Vector Groups (Continued)

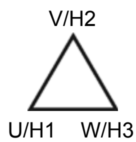
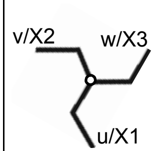
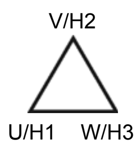
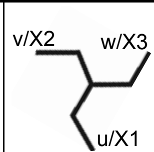
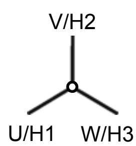
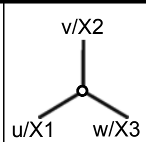
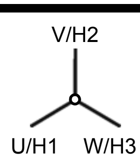
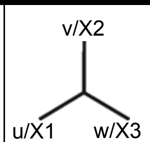
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Dzn10			A	U-(V+W) / H1-(H2+H3)	n-w / X0-X3	1.5
			B	V-(U+W) / H2-(H1+H3)	n-u / X0-X1	
			C	W-(U+V) / H3-(H1+H2)	n-v / X0-X2	
Dz10			A	U-V / H1-H2	u-w / X1-X3	1
			B	V-W / H2-H3	v-u / X2-X1	
			C	W-U / H3-H1	w-v / X3-X2	
YNyn0			A	U-N / H1-H0	u-n / X1-X0	1
			B	V-N / H2-H0	v-n / X2-X0	
			C	W-N / H3-H0	w-n / X3-X0	
YNy0			A	U-V / H1-H2	u-v / X1-X2	1
			B	V-W / H2-H3	v-w / X2-X3	
			C	W-U / H3-H1	w-u / X3-X1	

Table 3-1 Different Vector Groups (Continued)

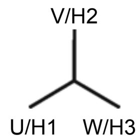
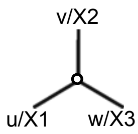
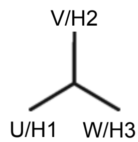
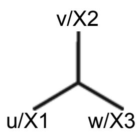
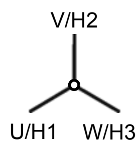
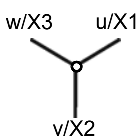
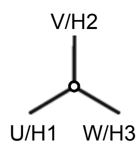
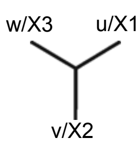
IEC 60076 vector group	**Winding connection**		**Measurement**	**Transformer high-voltage side**	**Transformer low-voltage side**	**Measured turn ratio**
	HV / H	**LV /X**				
Yyn0			A	U-V / H1-H2	u-v / X1-X2	1
			B	V-W / H2-H3	v-w / X2-X3	
			C	W-U / H3-H1	w-u / X3-X1	
Yy0			A	U-V / H1-H2	u-v / X1-X2	1
			B	V-W / H2-H3	v-w / X2-X3	
			C	W-U / H3-H1	w-u / X3-X1	
YNyn6			A	U-N / H1-H0	n-u / X0-X1	1
			B	V-N / H2-H0	n-v / X0-X2	
			C	W-N / H3-H0	n-w / X0-X3	
YNy6			A	U-V / H1-H2	v-u / X2-X1	1
			B	V-W / H2-H3	w-v / X3-X2	
			C	W-U / H3-H1	u-w / X1-X3	

Table 3-1 Different Vector Groups (Continued)

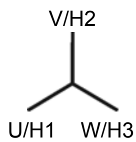
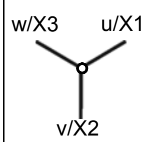
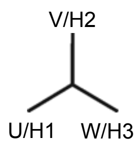
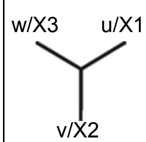
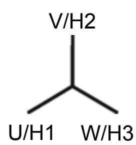
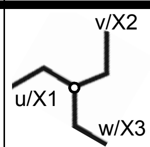
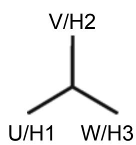
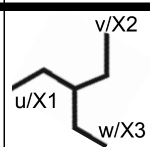
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	LV /X				
Yyn6			A	U-V / H1-H2	v-u / X2-X1	1
			B	V-W / H2-H3	w-v / X3-X2	
			C	W-U / H3-H1	u-w / X1-X3	
Yy6			A	U-V / H1-H2	v-u / X2-X1	1
			B	V-W / H2-H3	w-v / X3-X2	
			C	W-U / H3-H1	u-w / X1-X3	
Yzn1			A	U-V / H1-H2	n-v / X0-X2	1*√3
			B	V-W / H2-H3	n-w / X0-X3	
			C	W-U / H3-H1	n-u / X0-X1	
Yz1			A	U-(V+W) / H1-(H2+H3)	u-v / X1-X2	√3/2
			B	V-(U+W) / H2-(H1+H3)	v-w / X2-X3	
			C	W-(U+V) / H3-(H1+H2)	w-u / X3-X1	

Table 3-1 Different Vector Groups (Continued)

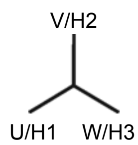
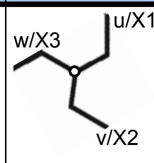
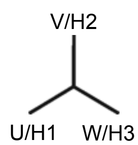
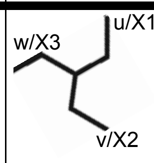
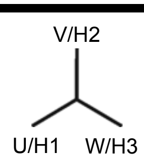
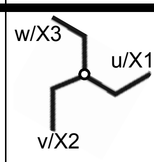
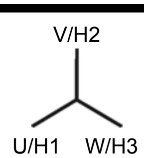
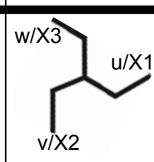
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
Yzn5			A	U-V / H1-H2	n-u / X0-X1	1*√3
			B	V-W / H2-H3	n-v / X0-X2	
			C	W-U / H3-H1	n-w / X0-X3	
Yz5			A	U-(V+W) / H1-(H2+H3)	w-u / X3-X1	√3/2
			B	V-(U+W) / H2-(H1+H3)	u-v / X1-X2	
			C	W-(U+V) / H3-(H1+H2)	v-w / X2-X3	
Yzn7			A	U-V / H1-H2	v-n / X2-X0	√3
			B	V-W / H2-H3	w-n / X3-X0	
			C	W-U / H3-H1	u-n / X1-X0	
Yz7			A	U-(V+W) / H1-(H2+H3)	v-u / X2-X1	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	w-v / X3-X2	
			C	W-(U+V) / H3-(H1+H2)	u-w / X1-X3	

Table 3-1 Different Vector Groups (Continued)

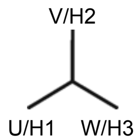
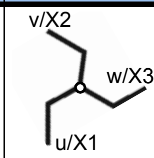
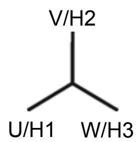
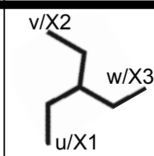
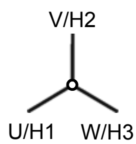
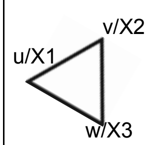
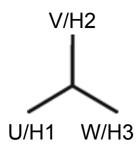
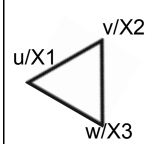
IEC 60076 vector group	**Winding connection**		**Measurement**	**Transformer high-voltage side**	**Transformer low-voltage side**	**Measured turn ratio**
	HV / H	**LV /X**				
Yzn11			A	U-V / H1-H2	u-n / X1-X0	√3
			B	V-W / H2-H3	v-n / X2-X0	
			C	W-U / H3-H1	w-n / X3-X0	
Yz11			A	U-(V+W) / H1-(H2+H3)	u-w / X1-X3	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	v-u / X2-X1	
			C	W-(U+V) / H3-(H1+H2)	w-v / X3-X2	
YNd1			A	U-N / H1-H0	u-v / X1-X2	1/√3
			B	V-N / H2-H0	v-w / X2-X3	
			C	W-N / H3-H0	w-u / X3-X1	
Yd1			A	U-(V+W) / H1-(H2+H3)	u-v / X1-X2	√3/2
			B	V-(U+W) / H2-(H1+H3)	v-w / X2-X3	
			C	W-(U+V) / H3-(H1+H2)	w-u / X3-X1	

Table 3-1 Different Vector Groups (Continued)

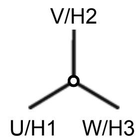
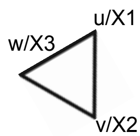
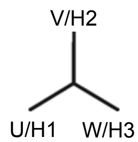
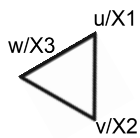
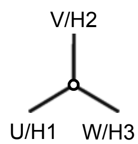
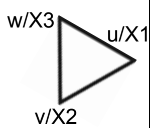
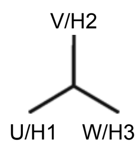
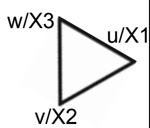
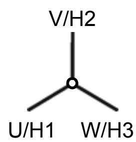
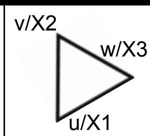
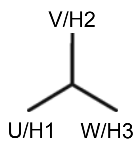
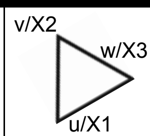
IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	LV /X				
YNd5			A	U-N / H1-H0	w-u / X3-X1	1/√3
			B	V-N / H2-H0	u-v / X1-X2	
			C	W-N / H3-H0	v-w / X2-X3	
Yd5			A	U-(V+W) / H1-(H2+H3)	w-u / X3-X1	√3/2
			B	V-(U+W) / H2-(H1+H3)	u-v / X1-X2	
			C	W-(U+V) / H3-(H1+H2)	v-w / X2-X3	
YNd7			A	U-N / H1-H0	v-u / X2-X1	1/√3
			B	V-N / H2-H0	w-v / X3-X2	
			C	W-N / H3-H0	u-w / X1-X3	
Yd7			A	U-(V+W) / H1-(H2+H3)	v-u / X2-X1	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	w-v / X3-X2	
			C	W-(U+V) / H3-(H1+H2)	u-w / X1-X3	

Table 3-1 Different Vector Groups (Continued)

IEC 60076 vector group	Winding connection		Measurement	Transformer high-voltage side	Transformer low-voltage side	Measured turn ratio
	HV / H	**LV /X**				
YNd11			A	U-N / H1-H0	u-w / X1-X3	1/√3
			B	V-N / H2-H0	v-u / X2-X1	
			C	W-N / H3-H0	w-v / X3-X2	
Yd11			A	U-(V+W) / H1-(H2+H3)	u-w / X1-X3	1*√3/2
			B	V-(U+W) / H2-(H1+H3)	v-u / X2-X1	
			C	W-(U+V) / H3-(H1+H2)	w-v / X3-X2	

In the Transformer high-voltage side column, + means that the terminals in the *CP SB1* are short circuited.

In the graphics, the ∘ symbol means N / H0.

3.4.4 Trouble-Shooting

If you encounter any problems in the operation of the *CP SB1*, you can check the performance of the switch box in connection with the **TRRatio** test card by conducting a simple test.

- Connect the *CP SB1* with the *CPC 100* as shown in Figure 3-6:

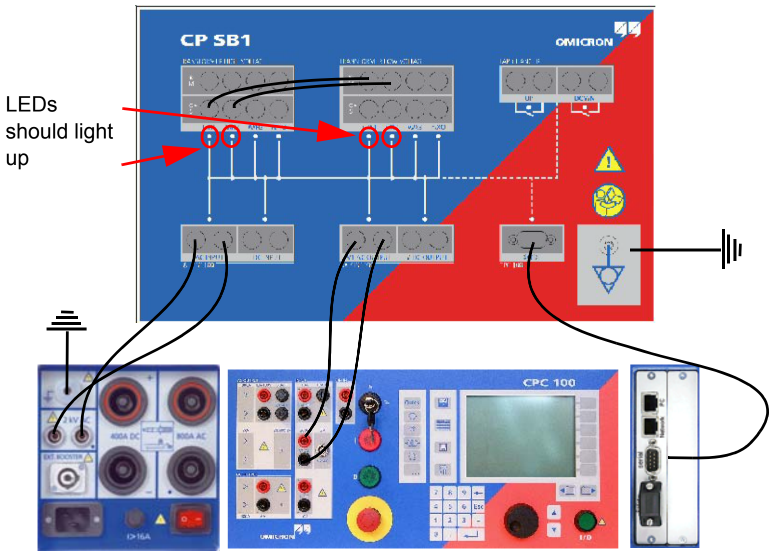


Figure 3-6 Measurement setup for the trouble-shooting test

- Select the following vector group on the **Settings** page and enter a value of 30 V for Vprim:

Dd0	V/H2 U/H1 W/H3	v/X2 u/X1 w/X3	A	U-V / H1-H2	u-v / X1-X2	1

- Press the **I/O** (test start/stop) push button to start the test.
- The respective LEDs of the *CP SB1* should light up in red if the switch box performs correctly. The measured value for Vsec should be 30 V.

Note: You can conduct the test in the same manner with the *CPC 100* to check its performance.

3.5 TRTapCheck Test Card

Use the **TRTapCheck** test card to measure the winding resistance of the individual taps of a power transformer's tap changer, and to check whether the on-load tap changer (OLTC) switches without interruption.

The *CPC 100* injects a constant current from the **6 A DC output** into the power transformer and the current is led via the **IAC/DC** input for measurement. From this current value and the voltage measured by the **V DC input**, the winding resistance is calculated.

The moment the tap is changed, the **IAC/DC** measuring input detects the sudden, very short drop of the current flow. A properly working tap change differs from a malfunctioning one, for example, an interruption during the change, by the magnitude of the ripple and slope values. An interruption will result in much higher ripple and slope values than a properly functioning tap change.

3.5.1 Measurement Setup for TRTapCheck

The measurement setup on the high-voltage side in connection with the **TRTapCheck** test card is shown below.

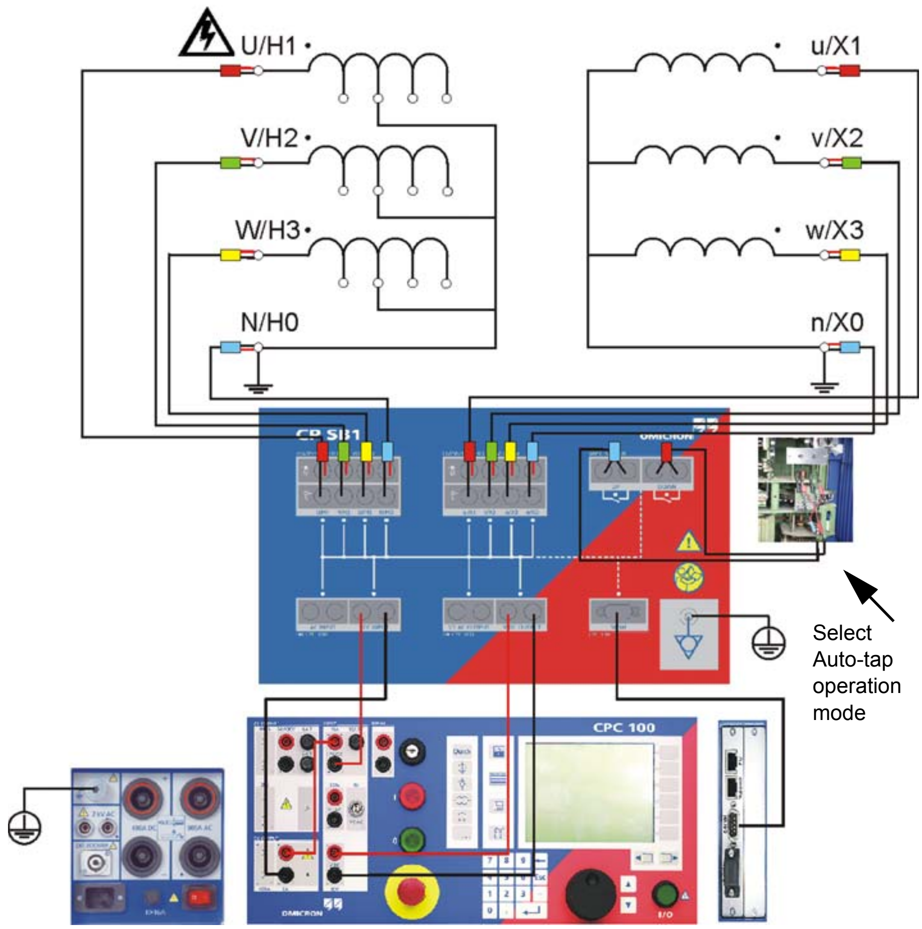


Figure 3-7 Measurement setup for **TRTapCheck** on the high-voltage side

Note: It is not necessary to connect the low-voltage side. You can also use the measurement setup as shown in Figure 2-1 on page 19.

The measurement setup on the low-voltage side in connection with the **TRTapCheck** test card is shown below.

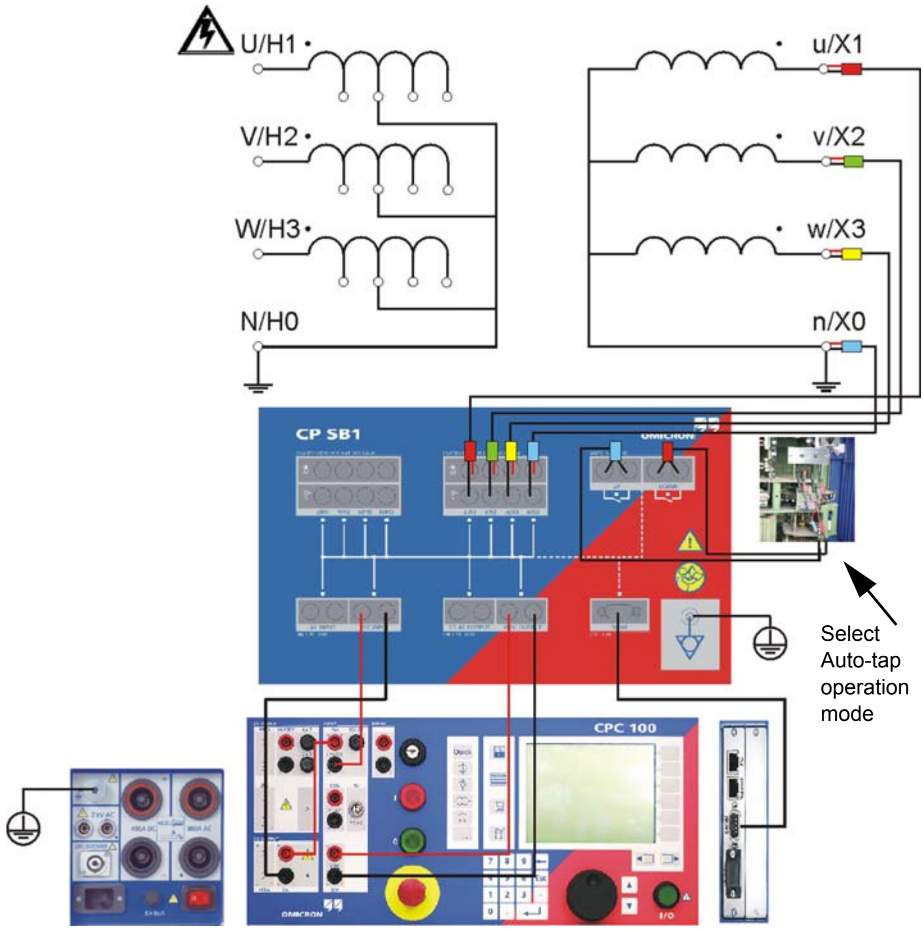


Figure 3-8 Measurement setup for **TRTapCheck** on the low-voltage side

Note: You can also use the measurement setup as shown in Figure 2-1 on page 19.

Caution: When performing a winding resistance measurement on the low-voltage side, dismount the high-voltage cables first. Otherwise, the *CP SB1* might be damaged.

3.5.2 Test Settings for TRTapCheck

The ripple and slope values are indicated at the **TRTapCheck** test card's measurement table (see Figure 3-11 "Measurement table with relevant columns for winding resistance measurement").

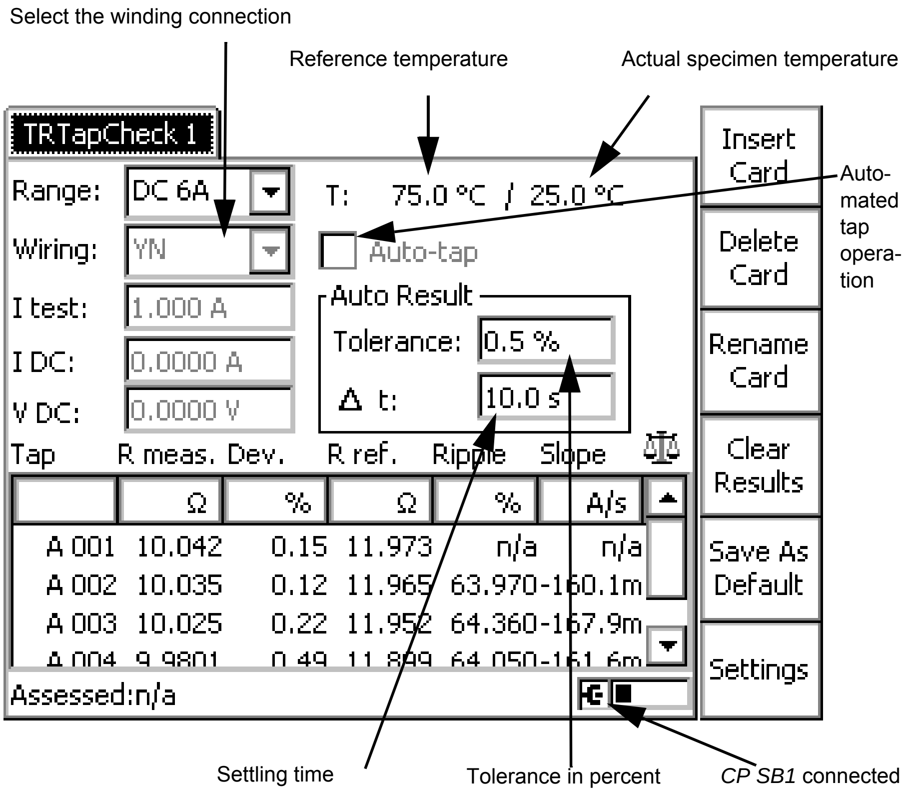


Figure 3-9 **TRTapCheck** test card

Pressing the **Settings** menu key or activating the **Auto-tap** operation mode will open the second page of the **TRTapCheck** test card.

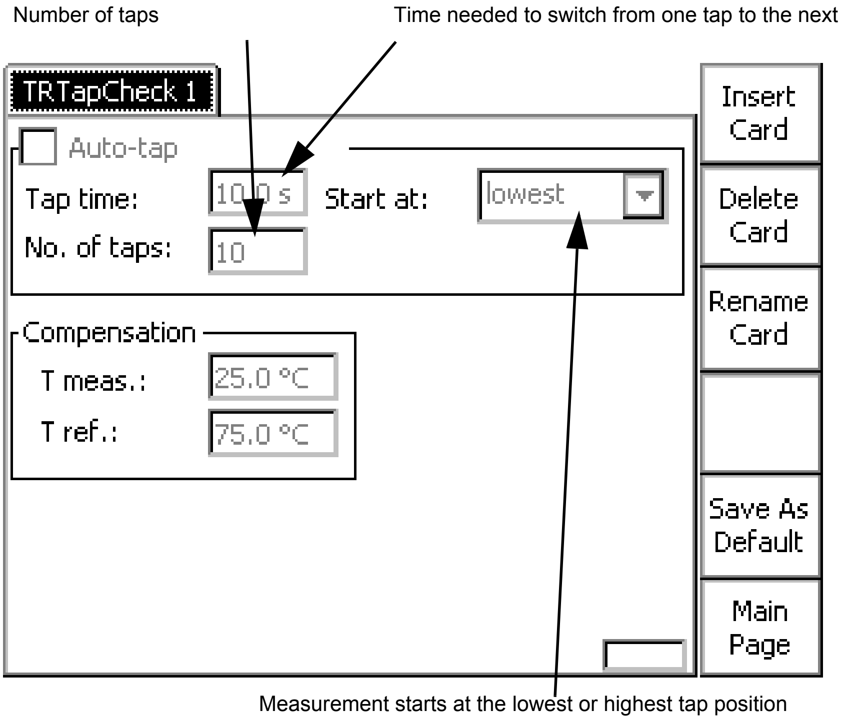


Figure 3-10 Settings page of the **TRTapCheck** test card

Navigate to the parameter fields, and enter the values according to your test requirements:

Range:	Output range
Itest:	Nominal test current
Wiring:	• **D**, **Y**, **YN:** for measurements on the high-voltage side • **d**, **y**, **yn**, **z**, **zn:** for measurements on the low-voltage side The measurement is performed where the tap changer is mounted. • **manual:** manual wiring to the *CP SB1* for special measurements The wiring information can be displayed via the **Wiring Info** soft key. **Note:** If the winding connections YN, yn, zn are selected, the measured resistance is always from phase to neutral. Otherwise, the measurement is between the phases.
Tmeas:	Actual specimen temperature
Tref:	This is the reference temperature at which the manufacturer measured the taps' winding resistance values. Generally, this value should be specified in the transformer's data sheet. The winding resistance value at this temperature always represents the nominal resistance value. The resistance correction is only valid for copper as winding material.
Auto-tap:	Automated tap operation mode for performing automatic tap switches
Tap time:	Time needed to switch from one tap to the next
Start at:	Starts the measurement at the lowest or highest position of the tap

No. of taps:	Indicates the number of taps of the transformer
Tolerance:	Tolerance of the deviation in percent
Δt:	Settling time

The **TRTapCheck** test card displays the measurement results in two display fields and a table:

IDC:	Actual test current from 6 A **DC output** measured at **IAC/DC input**
VDC:	Voltage measured at the 10 V **DC input**
Tap (in table):	Displays the transformer tap identifier and tap number for the measurements in the respective line of the table.
Rmeas:	Actual resistance, calculated from VDC / IDC
Dev. in %:	Deviation in % between the maximum and the minimum measured values evaluated within the settling time (Δt).
Rref:	Temperature-corrected resistance value, that is, the resistance value at an actual specimen temperature of Tref.
Ripple:	Samples and holds the biggest measured current ripple that occurred in the measuring cycle. It is indicated in % with reference to IDC.
Slope:	Samples and holds the biggest measured steepness of the falling edge of the actual test current that occurred in the measuring cycle.

3.5.3 Performing Winding Resistance Measurements

For the available modes see 3.4.3 "Performing Measurements with TRRatio" on page 30. The only difference in the fully automatic mode is that the *CPC 100* automatically performs the **Auto Keep Result** algorithm.

Press the context-dependent **Keep Result** or **Auto Keep Result** menu keys to save the actual result in the measurement table (only required for manual mode). This adds a new line to the measurement table and the next measurement can be started.

After pressing the **Auto Keep Result** menu key, the *CPC 100* waits until stable results with a deviation less than the defined tolerance (in %) within the defined settling time (Δ t) are achieved. After then, a new result line is added and the next measurement starts.

Note: If the *CPC 100* is in **Auto Keep Result** status, the user can end the process by either pressing **Keep Result** or by changing to the **Tolerance** setting and changing the value. The soft key **Set current deviation** resumes the value of the current deviation in the **Tolerance** field.

Note: The manual mode also applies, if you have not purchased a license.

Fully Automatic Test

To perform a fully automatic test:

1. Select **Auto-tap** operation.
2. Select **Wiring** (vector group), **Itest**, **Tolerance** and Δ t.

3. On the **Settings** page, define **Tap time**, **Start at** and **No. of taps**.
4. Press the **I/O** (test start/stop) push button to start the test.
5. The *CPC 100* deactivates when the test is completed.

Note: In fully automatic mode, an interrupted test will be resumed at the current tap position.

Manual or Half-Automatic Test

To perform a manual or half-automatic test:

1. For a manual test, choose **manual** under **Wiring**. For a half-automatic test, choose the wiring as required.
2. Press the **I/O** (test start/stop) push button to start the test.

3. Press **Keep Result** to save the resistance value of this tap or press **Auto Keep Result**. In this case, the *CPC 100* waits until stable results within the set **Tolerance** and Δ t are achieved. After then, a new result line is added showing the number of the next measured tap.
4. At the transformer, set the tap displayed in the current result line.

5. Repeat steps 3 and 4 for all taps you want to measure.
6. Press the **I/O** (test start/stop) push button to stop the test and wait until the transformer windings are discharged.

Caution: Before disconnecting the transformer under test, ground all transformer connections.

For the winding resistance, the first 4 columns (Tap, Rmeas in Ω, Dev. in % and Rref in Ω) of the measurement table are relevant.

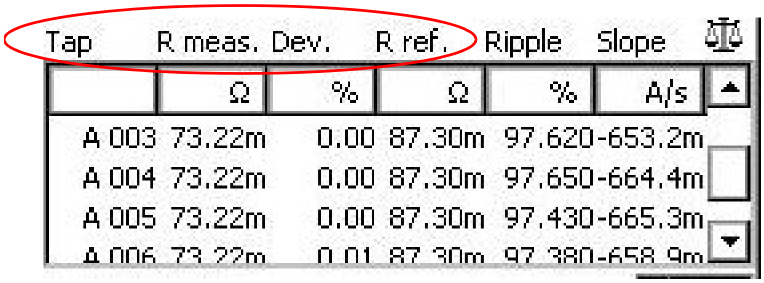


Figure 3-11 Measurement table with relevant columns for winding resistance measurement

Editing the Tap Number

It is possible to edit the tap number during or after a test.

You can publish the results in a report. To do so, change to File Operations.

After the test has been finished, you can delete a result line by selecting the result line you want to delete and pressing the **Clear Results** menu key.

Tap Changer Test and Measuring the Winding Resistance

When testing a tap changer, we recommend:

- To inject the same current value for each phase.
- To perform tests of each phase, start with the lowest tap through to the highest and continue backwards down to the lowest tap again. Measurements may show quite different results depending on the direction of the tap movement and defects can behave differently. An interruption caused by a defective tap changer results in comparatively high measured values for ripple and slope.

For the tap changer test, the last 2 columns of the table are relevant.

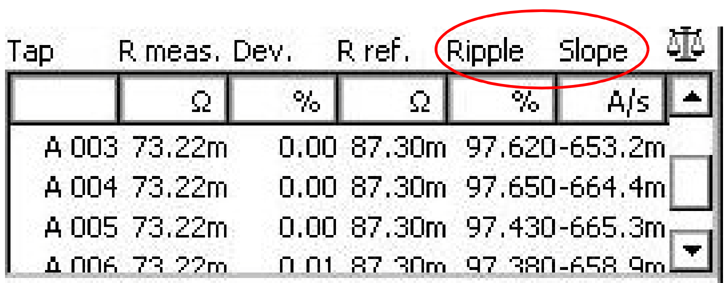


Figure 3-12 Measurement table with results of tap changer and winding resistance test

Note: During switching between the phases, the transformer is always automatically discharged.

Automated Winding Resistance Measurement without Tap Changer

A special test is available for the opposite side of where the tap changer is mounted (either high- or low-voltage side). To perform the automated winding resistance measurement without tap changer on all phases, or on a transformer voltage level, where no tap changer is mounted, select the respective winding connection in the **Wiring** dialog box and check **Auto-tap** operation. Set the **No. of taps** to 1 and start the test.

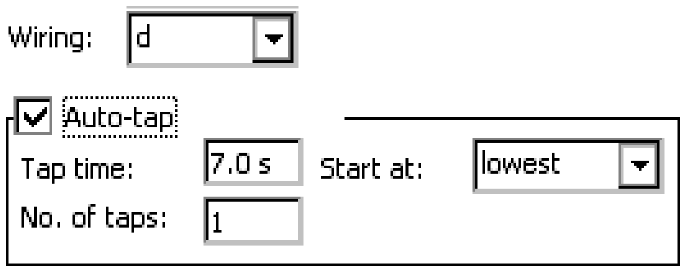


Figure 3-13 Settings for the automated winding resistance test without tap changer

3.5.4 Trouble-Shooting

If you encounter any problems in the operation of the *CP SB1*, you can check the performance of the switch box in connection with the **TRTapCheck** test card by conducting a simple test.

- Connect the *CP SB1* with the *CPC 100* as shown in Figure 3-14:

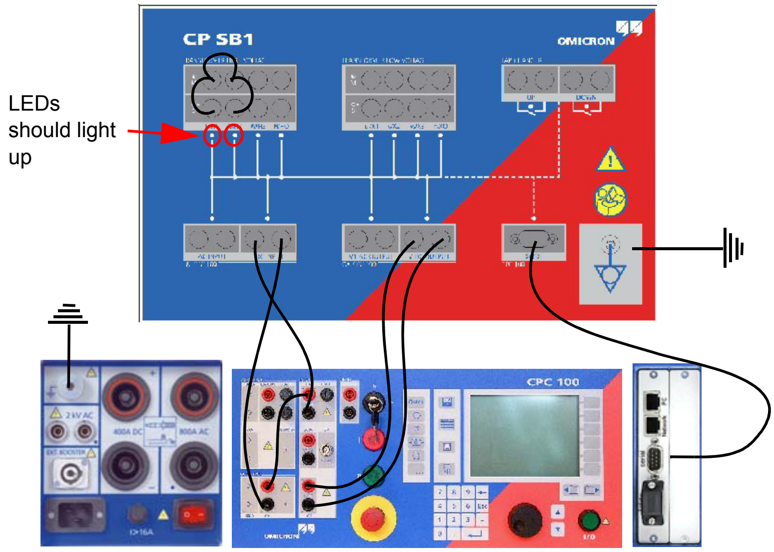


Figure 3-14 Measurement setup for the trouble-shooting test

- Select D as winding connection, A for measurement, and enter a value of 1 A for Itest on the **Settings** page.
- Press the **I/O** (test start/stop) push button to start the test.
- The respective LEDs of the *CP SB1* should light up in red if the switch box performs correctly. The measurement should produce a value in the respective value range for the cable used.

Note: You can conduct the test in the same manner with the *CPC 100* to check its performance.

4 Technical Data

4.1 Specifications

Table 4-1 Specifications

Characteristic	Rating
AC Input / V1 AC Output	max. 300 Veff
DC Input	max. 6 A DC
Transformer High and Low Voltage connections	max. 300 Veff between all connectors and ground
Tap Changer	Two potential-free contacts, short circuit-protected; 0-240 V AC (only AC permitted); Overvoltage Category II; Resistance per contact = max. 4 Ω I continuous = 0.9 A rms
Supply	Via serial interface from *CPC 100* (+15 V)
Overvoltage protection to case with surge arrestors	All connections to Tranformer High and Low voltage side; AC/DC Input; V1 AC / V DC Output

Two different *CPC 100* versions exist, V0 and V1. An upgrade from the version V0 to V1 is possible. For *CPC 100* V1 units you will find the text "V1" in the "Options" field of the nameplate on the right-hand side of your *CPC 100*. Depending on the version, the *CPC 100* is delivered with different processor options and only V1 supports the *CP SB1*. For further information, please refer to the CPC 100 Reference Manual.

4.2 Environmental Conditions

4.2.1 Climate

Table 4-2 Climate

Climate	
Operating temperature	–10 … +55 °C (+14 … 131 °F)
Storage and transportation	–20 … +70 °C (–4 … 158 °F)
Max. altitude	2000 m
Humidity	5 … 95% relative humidity; no condensation Tested according to IEC 68-2-78

4.2.2 Shock and Vibration

Table 4-3 Shock and Vibration

Dynamics	
Vibration	Tested according to IEC 60068-2-6; frequency range 10 … 150 Hz; acceleration 2 g continuous (20 m/s^2); 20 cycles per axis
Shock	Tested according to IEC 60068-2-27 (operating mode); 15 g / 11 ms, half-sinusoid, 3 shocks in each axis

4.2.3 Mechanical Data

Table 4-4 Mechanical Data

Weight, Dimensions and Protection	
Weight *CP SB1* Weight filled transport case	3.5 kg (7.7 lbs) 28.5 kg (62.7 lb)
Dimensions W x H x D *CP SB1* Dimensions transport case	357 x 235 x 111 mm (14.1 x 9.2 x 4.4") 700 x 450 x 500 mm (27.6 x 17.7 x 19.7")
Housing and transport case	IP20 according to EN 60529

4.2.4 Cleaning

To clean the *CP SB1*, use a cloth dampened with isopropanol alcohol or water. Prior to cleaning, always disconnect the *CP SB1*.

4.2.5 Safety Standards, Electromagnetic Compatibility (EMC)

Table 4-5 CE Conformity, Safety Standards, EMC

CE Conformity, Requirements	
The product adheres to the specifications of the guidelines of the Council of the European Community for meeting the requirements of the member states regarding the electromagnetic compatibility (EMC) Directive 2004/108/EC and the low-voltage Directive 2006/95/EC.	
EMC	
Emission Europe International USA	 EN 61326-1 Class A IEC 61326-1 Class A FCC Subpart B of Part 15 Class A

Table 4-5 CE Conformity, Safety Standards, EMC (Continued)

CE Conformity, Requirements	
Immunity Europe International	 EN 61326-1 IEC 61326-1
Certified Safety Standards	
Europe International USA	EN 61010-1 IEC 61010-1 UL 61010-1
Suitable for usage according to	IEEE 510, EN 50191 (VDE 0104), EN 50110-1 (VDE 0105 Part 100)

5 Appendix

5.1 Transformer Diagnosis

This section describes practical experience using simple methods like winding resistance measurement, dynamic tap changer testing, and ratio measurement.

5.1.1 Introduction

Due to ever-increasing pressure to reduce costs, the power industry is forced to keep old power facilities in operation for as long as possible. In most European countries, about one third of the transformers are older than 30 years. Transformers, which are older than 50 years can still be found in service [1].

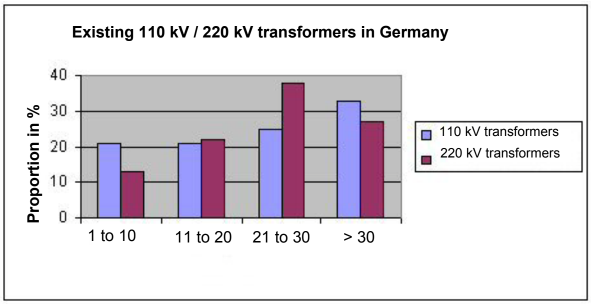


Figure 5-1 110/220 kV transformers in Germany

With the advancing age of transformers, a regular check of the operating conditions becomes more and more important. The Dissolved Gas Analysis is a proven and meaningful method such that if increased proportions of hydrocarbon gases are found in the oil, the fault must be located as soon as possible. This way, important preventative maintenance can be performed in time to avoid an unexpected total failure (see Figure 5-2 "Transformer fault due to a defective bushing") [2].

Figure 5-2 Transformer fault due to a defective bushing

The most frequent sources of failure are the tap changers, bushings, the paper-oil insulation and the accessory equipment (see Figure 5-3 "Sources of transformer faults").

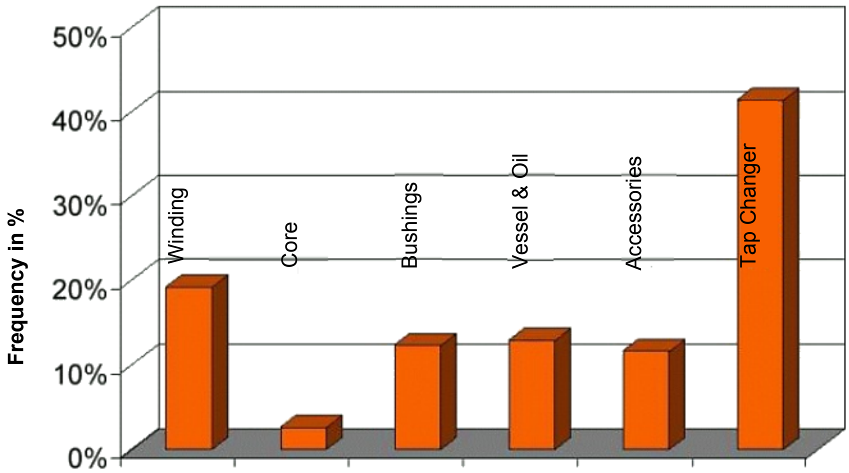


Figure 5-3 Sources of transformer faults

5.1.2 Fault Localization

In order to find out the reason for high gas values, further tests have to be performed for the transformer. Common test methods are:

- Winding resistance measurement
- On-Load Tap Changer (OLTC) test
- Turns ratio measurement
- Excitation current measurement
- Measurement of leakage reactance
- Capacitance and Dissipation factor measurement

5.1.3 Winding Resistance Measurement and On-Load Tap Changer Test

Winding resistances are tested in the field to check for loose connections, broken strands and high contact resistance in tap changers. Additionally, the dynamic resistance measurement enables an analysis of the transient switching operation of the diverter switch.

For a better understanding of the resistance measurements, it is necessary to understand the method of operation of the tap changer (see Figure 5-4 "Equivalent circuit diagram of On-Load Tap Changer (OLTC)").

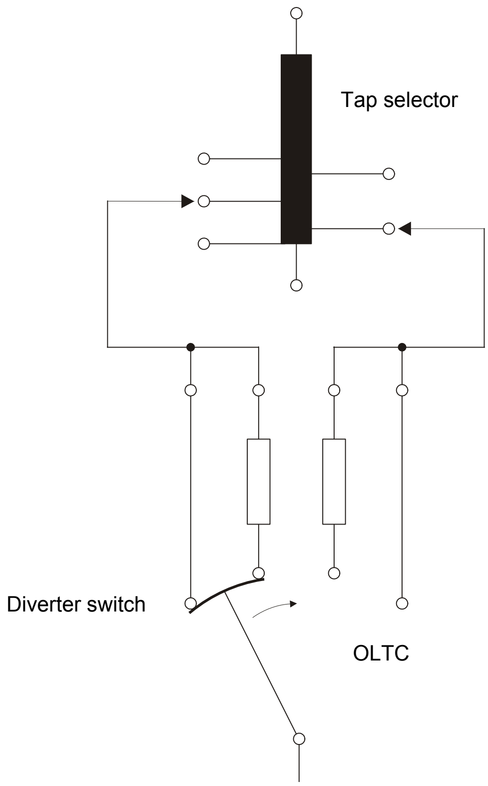


Figure 5-4 Equivalent circuit diagram of On-Load Tap Changer (OLTC)

In most cases, the tap changer consists of two units. The first unit is the tap selector, which is directly located inside the transformer tank and which switches to the next higher or lower tap without carrying current. The second unit is the diverter switch, which switches without any interruption from one tap to the next while carrying load current. The commutation resistances R limit the short circuit current between the taps which could otherwise become very high due to the interruption-free switching of the contacts. The switching process between two taps takes approximately 40 - 80 ms.

Figure 5-5 Tap changer

Figure 5-5 shows a tap changer with the tap selector (lower part) and the diverter switch (upper part).

In Figure 5-6, a transformer with an attached tap changer is shown. In both pictures the separate oil tank of the diverter switch is clearly visible.

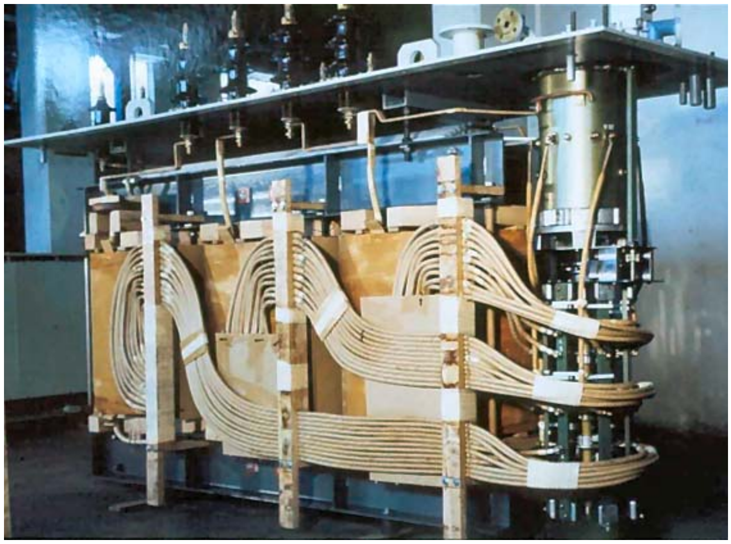


Figure 5-6 Transformer with tap changer

Figure 5-7 shows a diverter switch of a 40 MVA transformer for 110 kV. The switches shown are positioned near the star-point of the transformer's high voltage windings.

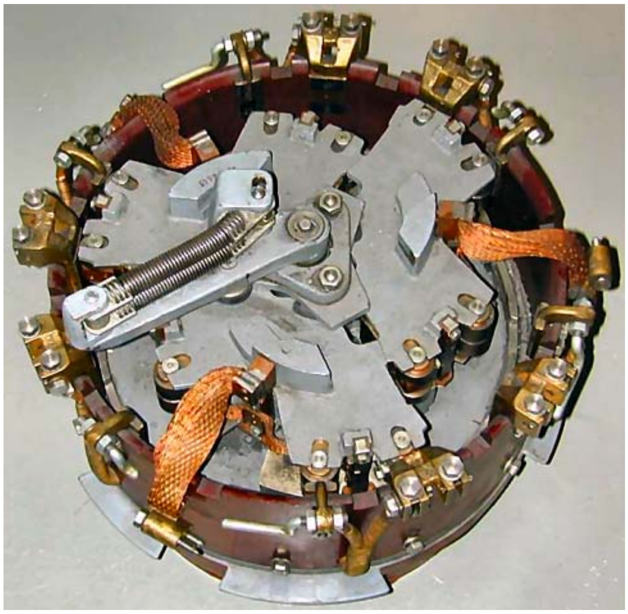


Figure 5-7 Diverter switch for 110 kV / 40 MVA

5.1.4 Four-Wire Connection for Transformer Winding Resistance Measurement

Since the winding resistances are very small, the test set is connected in a four-wire configuration. It has to be observed that the contact resistances of the connection clamps do not falsify the measuring result.

A constant current source is used to feed a direct current into the winding. The test current should be at least 1% of the rated current to bring the core into saturation. On the other hand, it should not exceed 15% of the rated current to avoid temperature rise during measurement. A relatively high no-load voltage enables a quick saturation of the core and a final value with only minor fluctuations is reached. Therefore, in most cases the charging time per tap is distinctly less than 30 seconds.

5.1.5 Safety Aspects

Feeding currents of several amps through a coil rated at hundreds of Henries causes a high magnetic energy to be stored in the coil inductance. If the measuring circuit was interrupted without discharging this energy, very high voltages would be induced which would be very dangerous for the operator and the test system. An automatic discharge of the coil inductance after measurement is automatically carried out as it is essential for safe operation, though while switching from one tap to another, a discharge cycle is not necessary and this saves a lot of time.

5.1.6 Delta-Connected Windings

For delta-connected windings, R12, R23 and R31 cannot be measured directly but are calculated from the measured Ra, Rb and Rc values.

Ra = R1 + R2
Rb = R2 + R3
Rc = R3 + R1

Y connection without Neutral:

Rc - Rb + Ra = 2 R1 => R1 = (Rc + Ra - Rb) / 2
Ra - Rc + Rb = 2 R2 => R2 = (Ra + Rb - Rc) / 2
Rb - Ra + Rc = 2 R3 => R3 = (Rb + Rc - Ra) / 2

Closed delta winding

R12 = R1 + R2 + (R1 x R2) / R3
R23 = R2 + R3 + (R2 x R3) / R1
R31 = R3 + R1 + (R3 x R1) / R2

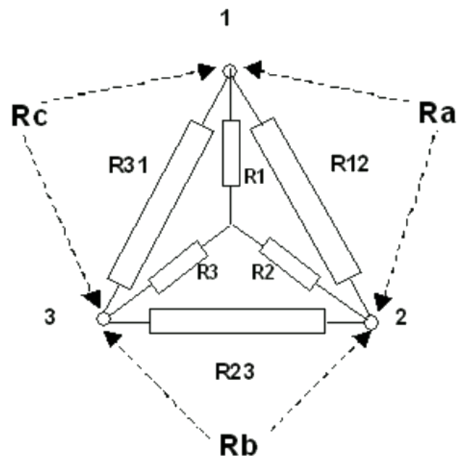


Figure 5-8 Delta-connected windings

5.1.7 Winding Resistance Measurement of a 100 MVA Transformer

The 220 kV/110 kV – 100 MVA transformer under test manufactured in 1995 was found to have conspicuously high quantities of gas in the oil, from which the conclusion was drawn of inner overheating. The measurement results taken with the test system (see Figure 5-9 "Winding resistance measurement H1-H0") show a very good match with the values measured by the manufacturer for the mid-position (denoted as tap 10) of the tap selector in all phases, where direct connection to the main winding occurs.

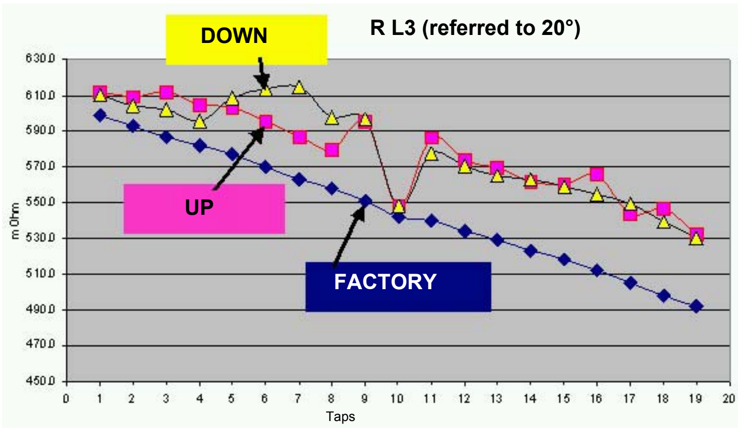


Figure 5-9 Winding resistance measurement H1-H0

In the measurements taken with the test system, the different winding temperatures were considered and all other taps showed a significant increase compared to the original measured values. The differences are more than 10% or, in absolute values, up to 70 mΩ. The deviations between switching upwards and switching downwards are likewise clearly significant. This shows that the high contact resistances are actually caused by the switching contacts of the tap selector. No silver-plated contacts were originally used and the copper contact surface was now coated with oil carbon (see Figure 5-10 "Bad tap selector") [2].

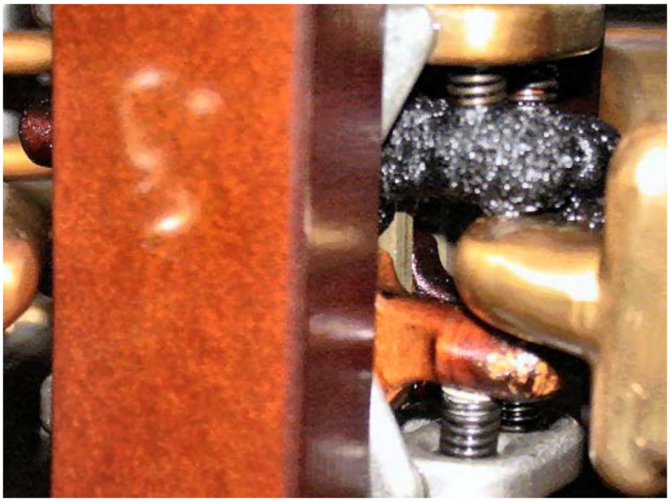


Figure 5-10 Bad tap selector

After a full maintenance of the tap selector, no significant difference to the values measured at the factory in 1954 could be observed (see Figure 5-11 "Resistance after maintenance").

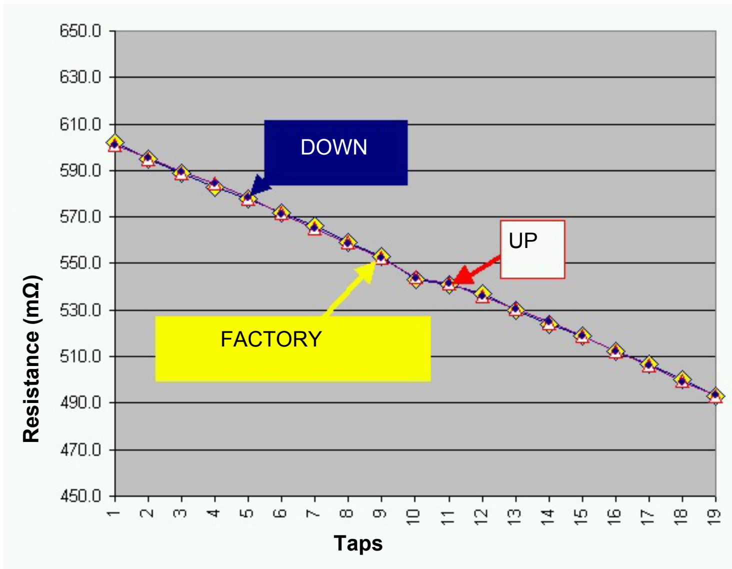


Figure 5-11 Resistance after maintenance

To examine the results in more detail, it is recommended to graph the difference between "UP" and "DOWN" values (see Figure 5-12 "Difference "UP" - "DOWN""). The difference before contact maintenance was up to 30 mΩ = 5% and after maintenance it was below 1 mΩ = 0.18%. Current maintenance practices require values to be measured only for the middle and two extreme taps, yet this test system has shown that this is incomplete, with potentially serious consequences. To undertake a complete test to record the values for all taps with the described test equipment is not a significant effort.

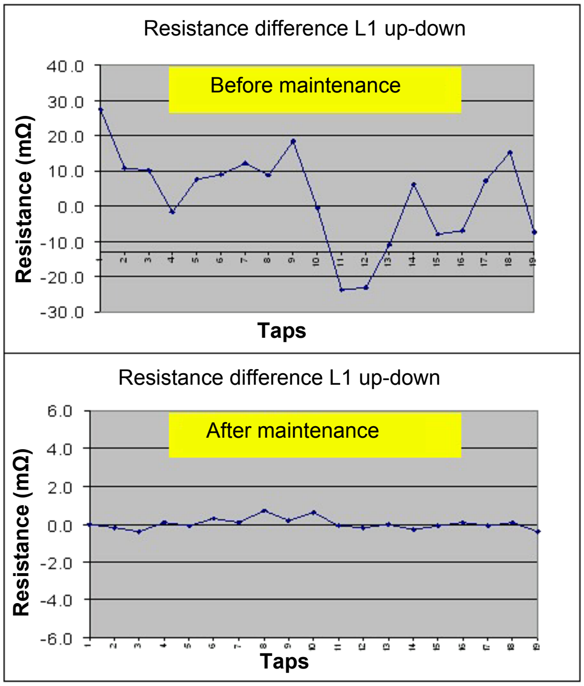


Figure 5-12 Difference "UP" - "DOWN"

5.1.8 Dynamic Behavior of the Diverter Switch

To date, only the static behavior of the contact resistances has been taken into account in maintenance testing. With a dynamic resistance measurement, the dynamic behavior of the diverter switch can be analyzed.

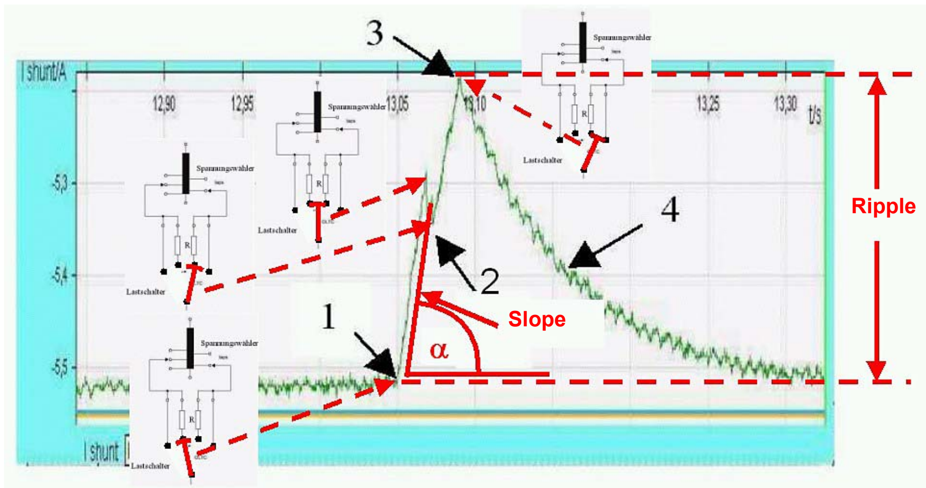


Figure 5-13 Dynamic resistance measurement for analysis of the diverter switch

1 = Diverter switch commutes from the first tap to the first commutation resistor

2 = The second commutation resistor is switched in parallel

3 = Commutation to the second tap (direct contact)

4 = Charging the additional windings

For the dynamic resistance measurement, the test current should be as low as possible. Otherwise, short interruptions or bouncing of the diverter switch contacts cannot be detected. In this case, the initiated arc has the effect of shortening the open contacts internally. Comparison to "fingerprint" results, which were taken when the item was in a known (good) condition, allows for an efficient analysis.

A glitch detector measures the peak of the ripple and the slope of the measuring current, as these are important criteria for correct switching (without bouncing or other short interruptions). If the switching process is interrupted, even if only for a short-time, the ripple (= I_{max} - I_{min}) and the slope of the current change (di/dt) increase. The values for all taps and particularly the values for the three phases are compared. Major deviations from the mean values indicate faulty switching. For a more detailed analysis, a transient recorder can be used to record the current curve in real time. For this measurement, the transient recording functionality of the OMICRON CMC 256 was used (see Figure 5-13 "Dynamic resistance measurement for analysis of the diverter switch").

5.1.9 Turns Ratio

This test is normally only performed if a problem is suspected from the DGA, dissipation factor test or relay operation. The turns-ratio test detects shorted turns, which indicate insulation failure. Shorted turns may result from short circuits with high currents or insulation failures. The voltage ratio obtained by the test is compared to the boilerplate voltage ratio. The ratio obtained from the field test should agree with the factory value to within 0.5%. New transformers normally compare to the boilerplate within 0.1%. With the described test system, it is additionally possible to measure the ratio with magnitude and phase angle over a wide frequency range.

In the Figures 5-14 and 5-15, an analysis of a transformer with shorted turns in the low-voltage winding (phase A) is shown.

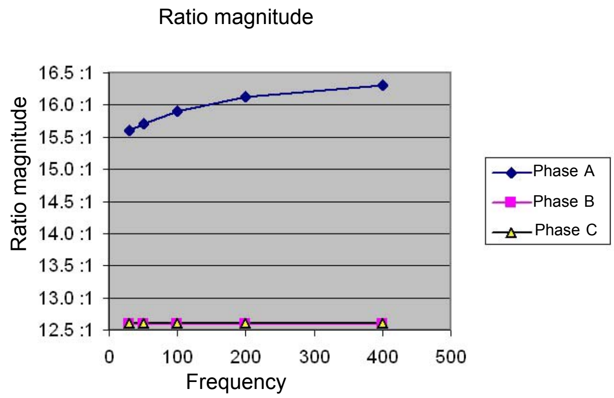


Figure 5-14 Ratio magnitude = f(f)

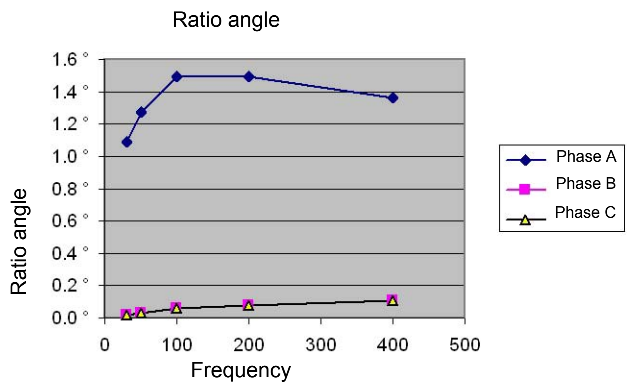


Figure 5-15 Ratio phase angle = f(f)

The large difference of approximately 20% indicates a failure with 20% of the turns. Due to the non-linear behavior, it can be assumed that the current, which is flowing through the low-voltage winding is partly flowing through the magnetic core. This can happen when the forces have significantly deformed the inner turns (see Figure 5-16 "Leakage flux and forces during a fault").

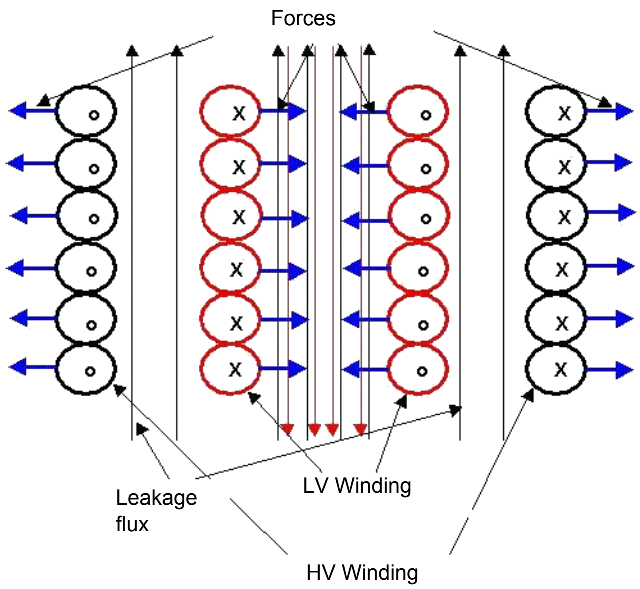


Figure 5-16 Leakage flux and forces during a fault

The winding is probably interrupted and parts of the winding are contacting the core which can be proven by measuring a resistance of 10 mΩ between LV winding and core. For intact windings, this ratio is nearly totally independent from the frequency in the discussed frequency range.

The ratio was measured with a test voltage of 200 V on the HV side. The excitation current of the defective phase was approximately 340 mA, whereas the excitation current of the intact phases was approximately 10 mA.

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