Operating

HAEFELY TEST AG

2293

Winding Analyser

Version 2.0

4842186

Revision History

V0.9	*06/2011*	*LWA*	*Initial release of the document*
V1.0	*07/2011*	*SG*	*Additional features added, manual completed*
V1.1	*03/2012*	*MM*	*Remote control chapter added*
V1.2	*06/2012*	*LWA*	*3rd LED added, CE with new address*
V1.3	*04/2013*	*SM, LWA, MM*	*Turns Ratio, graphical updates, connection hints*
V1.4	*06/2013*	*SM, LWA*	*Cooling curve & Temperature Rise added*
V1.5	*02/2014*	*SM*	*Magnetic Balance, dry type temperature rise added*
V1.6	*06/2014*	*SM, LWA, MM, SG*	*License screen updated, Additional Demag information*
V1.7	*07/2014*	*SM*	*Magnetic Balance updated*
V1.8	*09/2014*	*LW*	*Additional info to temperature probes*
V1.9	*11/2014*	*LW*	*Additional info to calibration and classic mode*
V2.0	*08.2015*	*SG*	*Tap changer and short circuit impedance added. Interlock connection explanation. CT connection description*

WARNING

Before operating the instrument, be sure to read and fully understand the operating instructions. This instrument produces hazardous voltages. It is the responsibility of the user to ensure that the system is operated in a safe manner.

⚠️ **This equipment contains exposed terminals carrying hazardous voltages. There are no user serviceable components in the unit. All repairs and upgrades that require the unit to be opened must be referred to HAEFELY TEST AG or one of their nominated agents.**

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

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

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

Unauthorized opening of the unit may damage the EMI protection of the system and will reduce its resistance to interference and transients. It may also cause the individual unit to be no longer compliant with the relevant EMC emission and susceptibility requirements. If the unit has been opened, the calibration will be rendered invalid.

Note

HAEFELY TEST AG has a policy of continuing improvement on all their products. The design of this instrument will be subject to review and modification over its life. There may be small discrepancies between the manual and the operation of the instrument, particularly where software has been upgraded in the field.

HAEFELY TEST AG retains the right to modify the functionality, specification or operation of the instrument without prior notice.

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Manual Conventions

In the manual, the following conventions are used:

Indicates a matter of note.

If it refers to a sequence of operations, failure to follow the instructions could result in errors in measurement.

Indicates hazards.

There is a risk of equipment damage or personal injury or death. Carefully read and follow the instructions. Be sure to follow any safety instructions given in addition to those for the site at which tests are being performed.

Foreword

Welcome as a new user of the "Winding Analyzer 2293". Thank you for placing your confidence in our product.

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

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

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

Abbreviations, definitions

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

LV	Low voltage or low voltage transformer winding
HV	High voltage or high voltage transformer winding
DUT	Device under test
LED	Light Emitting Diode

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1   Introduction

1.1   Receiving Instructions

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

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

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

1.2   General

The Tettex 2293 is the result of extensive research and years of experience testing transformers. It incorporates a fast and highly advanced procedure to measure winding resistance. A simple one-time-connection system together with the simultaneous winding magnetization method drastically reduces measuring time.

The simultaneous winding magnetization (SWM) method guarantees fast and reliable measurements even on large power transformers with delta windings on the low voltage side, where stable measurements can be seldom reached using traditional winding resistance measurement instruments.

In addition, the new demagnetization function eliminates the magnetic remanence in the core after the application of a DC voltage. This feature can be used before performing other tests such as frequency response analysis (FRA), transformer turns ratio measurement (TTR) or recovery voltage measurement (RVM) which are adversely affected by remanence effects.

The transformer is discharged by a state-of-the-art discharge circuit in a fraction of the time taken by other instruments. The discharging function and the "Caution" indicator continue to operate even when line power is lost.

1.3   Scope of Supply

1.3.1 Standard scope of supply

The following items are supplied with the standard instrument:

Qty	Description

1	2293 Winding Analyzer Instrument
1	High voltage side (H) measuring adaptor, 0.5m
1	Low voltage side (X) measuring adaptor, 0.5m
4	High voltage side (H) measuring cables, 4 units, (U, V, W, N) with clamp, 10m
4	Low voltage side (X) measuring cables, 4 units, (u, v, w, n) with clamp, 10m
1	Mains cable
1	Operating Instructions
1	carrying bag for cables and accessories
1	Spare kit (Printer paper roll, Fuses)

Once receipt of the unit check that all items have been delivered. Also check that the correct power cord for your location has been supplied. In the event of missing or damaged parts please contact you local sales representative stating the serial number and type of the instrument and the sales order number.

1.3.2 Options and accessories

For detailed information about accessories and options please refer to the chapter 21 "Accessories and spares"

1.4   Optional features

The 2293 is equipped with optional features. These optional features can be enabled using the license manager. . For getting licenses for new features contact our sales department (sales@haefely.com)

	2293/SKTTR	3-phase transformer turns ratio measurement add on application for 2293
	2293/SKAP	Arbitrary phase shift add on application for the 2293, (2293/SKTTR needed)
	2293/SKTR	Heat rise add on application for the 2293
	2293/SKMB	Magnetic balance add on application for the 2293
	2293/SKSI	Short circuit impedance add on for the 2293
	2293/SKTC	Tap changer add on for the 2293

Additional features will be added to the device regularly, for a complete list or for questions please check in our web page (www.haefely-hipotronics.com).

To activate the additional features (software keys) please read chapter 16- Optional Features activation, of this manual.

Tettex
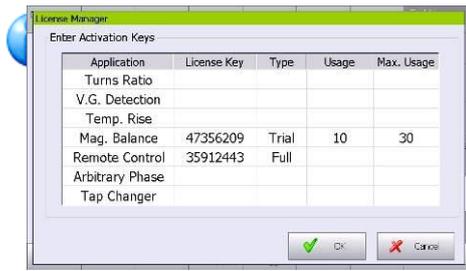
Trial licenses for a number of tests are available under request. Contact our sales department to get a trial code.

1.5   Technical Data

1.5.1   Standard Features

- 8 measuring channels (2 x 3 phases and 2 x 1 neutral)
- 6 temperature channels with automatic resistance correction
- High efficient DC supply with SWM (simultaneous winding magnetization)
- SWM mode and Classic mode (for traditional resistance measurement method)
- Turbo discharge circuit
- Automated demagnetizing function with flux indicator
- Automatic heat run function
- Tap changer control signal to automate test procedures on transformers with motorized tap changer
- Charges any inductive load and works with any resistive or inductive test object
- Heavy duty protection circuit
- Safety circuit ensures discharge even when line power is lost
- Caution indicator

1.5.2   Physical and Environmental Specifications

Mains	90 VAC … 264 VAC
Maximum Power	1 kW
Frequency	47 Hz … 63 Hz
Operating temperature	-10°C … +60°C
Storage temperature	-20°C ... +70°C
Humidity	5% … 90% r.h. non-condensing
Dimensions (W x D x H)	521 mm x 425 mm x 216 mm
Weight [2]	17.8 kg (Instrument only)

1.5.3   Resistance Measurement

Max. Meas. Current DC	32 A (user selectable)
Max. Charge Voltage DC	100 V
Range	0.1 µΩ … 320 kΩ
Resistance	Accuracy [1] → See graphic
0.1 µΩ ... 320 µΩ	0.1% ± 0.5 µΩ

Tettex

320 µΩ … 32 kΩ	0.1%	13
32 kΩ … 320 kΩ	1%	

(1) at temperature -10 …+60°C at highest available current
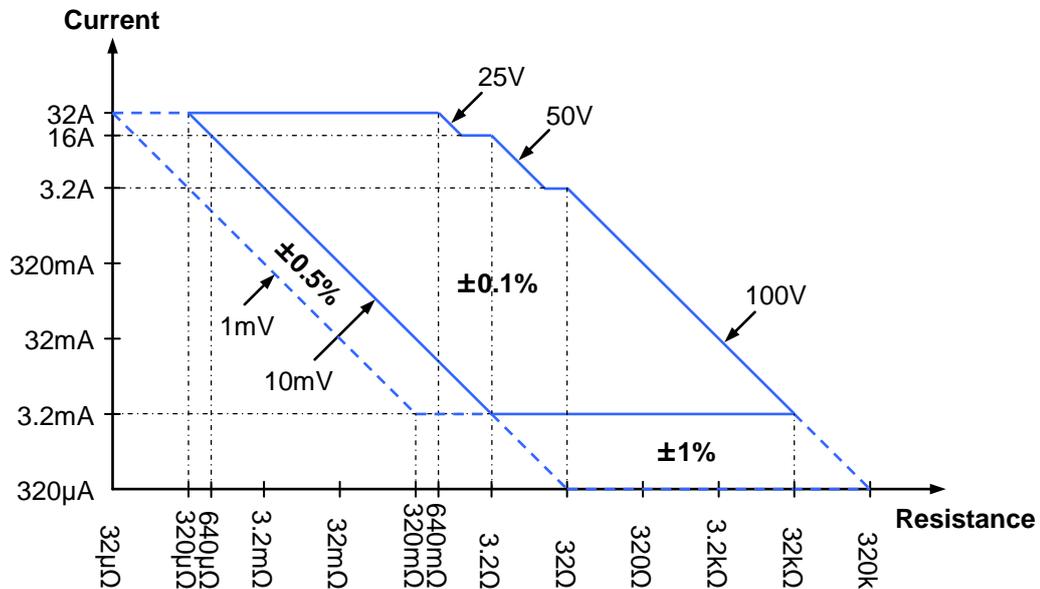
1.5.4   Ratio Measurement

General	
Max. Supply Current AC	1 A_{Peak} ≈ 700 mA_{RMS}
Max. Meas. Voltage AC	95 V_{Peak} ≈ 67 V_{RMS}
Range	1.0 … 10'000
Ratio	**Accuracy at highest measuring voltage**
1.0 … 100	0.05%
100 … 2'000	0.1%
2'000 … 20'000	1%
20'000 … 100'000	5%
Phase (AC Meas.)	**Typical Accuracy at highest measuring voltage**
1.0 … 500	±0.10°
500 … 10'000	±1.00°
Phase (Clock Number)	**Accuracy at highest measuring voltage**
1.0 … 500	±0.05°

1.5.5 Temperature Measurement

Built-in Channels	6
Max. Meas. Channels	30 (6 internal + 3x external 8CH box "2293T")
Sensor Probe	PT100 Class A
Temperature	Accuracy
-20°C … +150°C	± (0.41°C + 0.2% T_{Meas})

1.5.6 User Interface System

MMI	7" graphical touch screen interface
Memory:	>10'000 measurements
Communications:	USB 2.0 LAN connection Data can be saved on a memory stick or directly transferred to PC
Printer:	Thermal

1.5.7 Printer paper Specification

Paper Type:	Thermal Roll
Paper Width:	58mm
Paper Capacity:	32mm Diameter (10m length) Inner Diameter 12mm

1.5.8 Tap Changer Interface

Feedback (sense input)	
Function	Connect the feedback contactor of the tap changer
Ratings	3.3V, 1mA (input impedance 100kΩ)

Up/Down (set output)	
Function	Connect the Up/Down control contacts of the tap changer
Ratings	Max. 250V AC Max. 230V DC, 300mA Max. 30V DC, 2000mA

1.5.9 Interlock Interface (optional)

Function	Connect an external contactor of interlock circuit
Connector	Socket: LEMO2 (2P ERA 1S) Plug: LEMO2 (FFA 2S 302 CLAC62 2P)
Ratings	Max. 5V, 100mA

1.5.10 Covered Standards

CE mark	Compliant
Standards	IEC 61010, General IEC 61326-1, IEC 61000-4-X, 61000-3-X, EN 55011, ANSI/IEEE C37.90
Safety	VDE 0411/part 1a , IEC/EN 61010-1:2002

2   Safety

⚠ The unit should only be operated after carefully reading the user manual which is an integral part of the instrument.

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

2.1   General

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

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

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

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

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

⚠ Safety is the responsibility of the user. Always operate the equipment in accordance with the instructions, always paying full attention to local safety practices and procedures.

⚠ This equipment must be operated only by trained and competent personnel who are aware of the dangers and hazards involved in testing transformers.

⚠ Do not operate the 2293 from a variable power supply. The 2293 adjusts to the local line voltage at start-up. Changing the line voltage while the unit is in operation may cause damage to the unit and to the test object

2.2 Essential Safety Recommendations

Before connecting the instrument ensure that the transformer to be tested is completely de-energized and isolated from both line and load. Every terminal should be checked and verified before connection of the instrument. Ground connections may be left in place.

Never exchange connections to the HV and LV sides of the transformer. The red connections must always be connected to the High Voltage side of the transformer. The black connections must always be connected to the Low Voltage side of the transformer. Interchanging any or all of the connections may result in damage to the transformer or the instrument and represents a significant safety hazard for personnel.

Never operate the equipment in an explosive environment or where there are flammable gases or fumes

The instrument must always be connected to a grounded power outlet (i.e. a safety earth). It must never be operated in a non-grounded configuration as this may result in electrical shock to the user or damage to the instrument.

Please be aware that any inductive voltage (L_M) applied, is transformed to any other winding on the transformer according to the turns ratio. For high ratios, high voltages can appear on the DUT!

Never open the current path of the measuring circuit while the current flowing is higher than 5mA → warning LED is on! The current flowing in the magnetizing inductance (L_M >> 1H) of the transformer can generate high voltages and electrical flashes. → High risk of electrical shock!

The three led between the cable connections are the main device status indication. They light even if the Emergency button is pressed or main voltage is lost.

The upper two red Caution LEDs (14) indicate current flow and overvoltage. While any of the red led are lighting there is still energy stored in the transformer and therefore it is being discharged!

Never disconnect the cables or touch the clamps while the red LEDs are lit!

In a safe state the third green LED on the bottom turns on.

2.3 Interlock connection

The aim of the interlock is to avoid starting a test while the fences/doors are not closed, or there is somebody in the test area/laboratory. In addition it should stop the test and return to safe situation if the safe status in the laboratory is broken (for example a door is opened).

The interlock is an additional (optional) input in the 2293 front panel to be connected to the factory/fences safety circuit that encloses the high-voltage zone. It sends an electrical signal and read the return, if the return is not there, an alarm message arise in the screen and test cannot be started or are interrupted if running.

To avoid damaging the device due to induced overvoltage's or wrong connections, the Interlock input of the 2293 has to be connected to the safety circuit only by using a relay contact trough short screened cables.

⚠️ Opening the Interlock doesn't mean a safe situation by itself, as the test object (transformer) has been charged while measuring and stored energy has to be removed. Once Interlock is opened the instrument will start the discharging of the test and special caution has to be taken not to go into the test area until the red LEDS (14) are off.
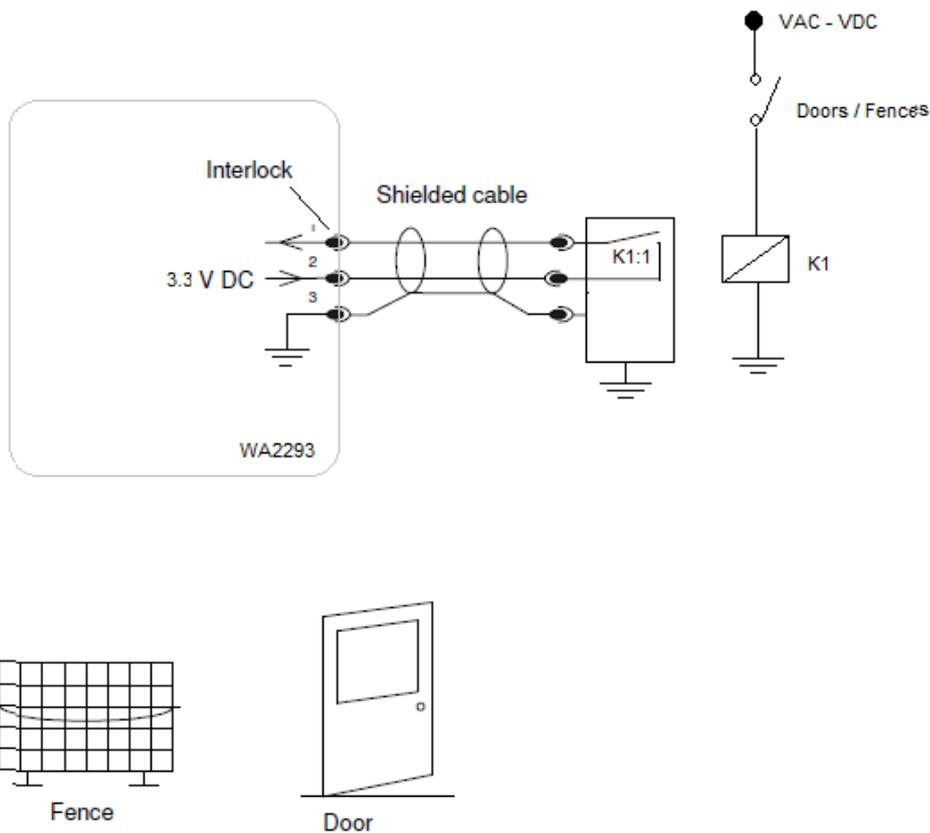
1.   Interlock connection example

2.4   Summary

Note: Many accidents that happen around high voltage equipment involve personnel who are familiar, and perhaps too familiar, with high voltage equipment. Staying alert and ever watchful requires constant training and awareness of the inherent hazards. The greatest hazard is the

possibility of getting on a live circuit. To avoid this requires constant vigilance - for oneself and for one's fellow workers.

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

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

Remember: Safety, FIRST, LAST, ALWAYS !

3 *Theory*

3.1 *General Resistance Measuring Principle*

Basically the instrument consists of 3 programmable power supplies, which can operate in constant current or constant voltage mode. Further, these power supplies operate in two quadrants. This means that a power supply can act as an active load, which is used to quickly discharge the current from high inductive DUT.

To determine the resistance of the DUT, the device uses 2 voltage and 2 current measuring units. This way the unit can measure 2 different resistances with individual currents at the same time.

The resistance is calculated according to the principle described in the figure below:
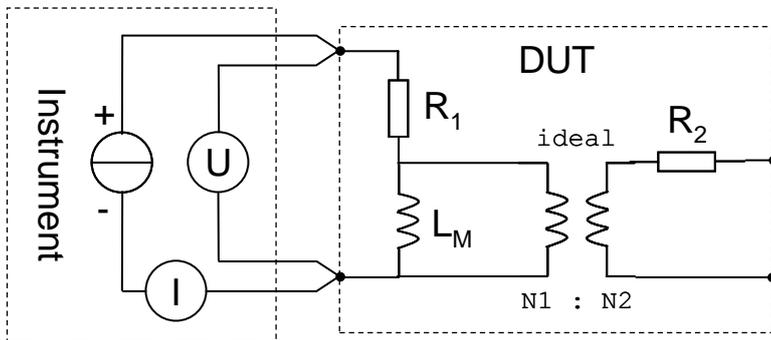
The resistance displayed on the device is calculated as follows:

$$R = \frac{U}{I} = \frac{U_R + U_{LM}}{I} = \frac{U_R}{I} + L_M \cdot \frac{dI}{dt}$$

The reading is correct only after the current has stabilized (dI/dt = 0).

3.2 Power Supply Modes

The 3 programmable power supplies in the 2293 can operate in different configurations. These configurations will be explained in this chapter.

3.2.1 Parallel Mode on HV-side 16A ¦ 100V (A1) or 32A ¦ 50V (A2)

This supply mode is selected, when a phase on the **high voltage side** of the transformer has to be measured without the corresponding phase on the low voltage side. The three supplies are connected in parallel and the range is selected according to the desired measuring current as follows:

I ≤ 16.0A → 16A ¦ 100V

I > 16.0A → 32A ¦ 50V

The measuring circuit for phase **A** of an YNyn0 transformer is illustrated below:
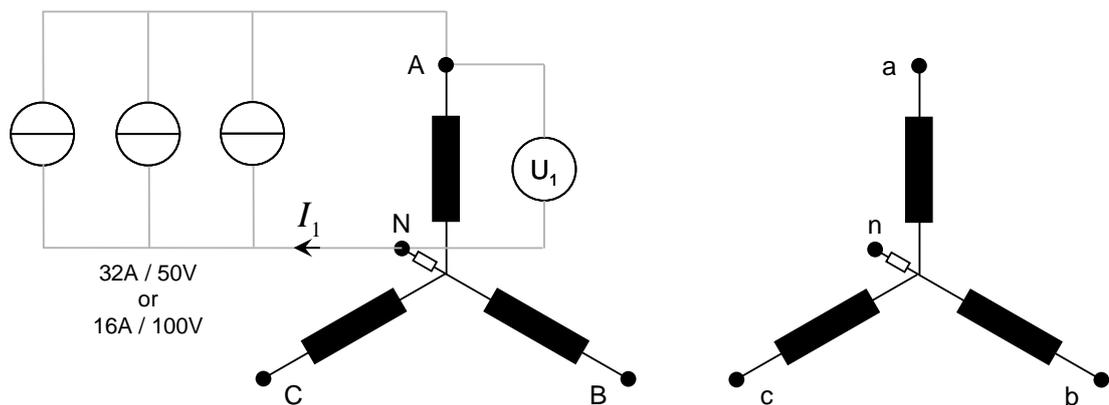
The measured resistance is calculated as follows:

$$R_{AN} = R_A + R_N = \frac{U_1}{I_1}$$

The following diagram shows the operating area for the power supply in mode A1 and B1 - **16A ¦ 100V**:

Current

32A

Active Load
Region
(Discharging)

Supply
Region
(Charging)

24A

800W

16A

400W

8A
4A

-100V -75V -50V -25V 0V +25V +50V +75V +100V Voltage
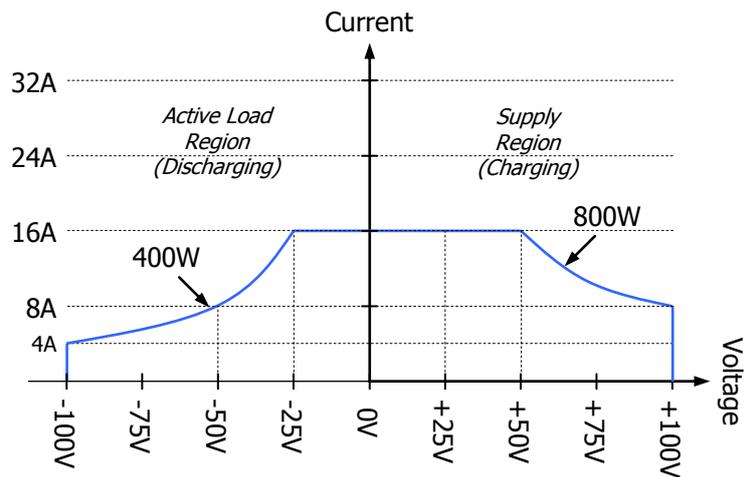
The following diagram shows the operating area for power supply in mode A2 and B2 - **32A ⁞ 50V**:

Current

32A

Active Load
Region
(Discharging)

800W

24A

16A

Supply
Region
(Charging)

400W

8A
4A

-100V -75V -50V -25V -12.5V 0V +25V +50V +75V +100V Voltage
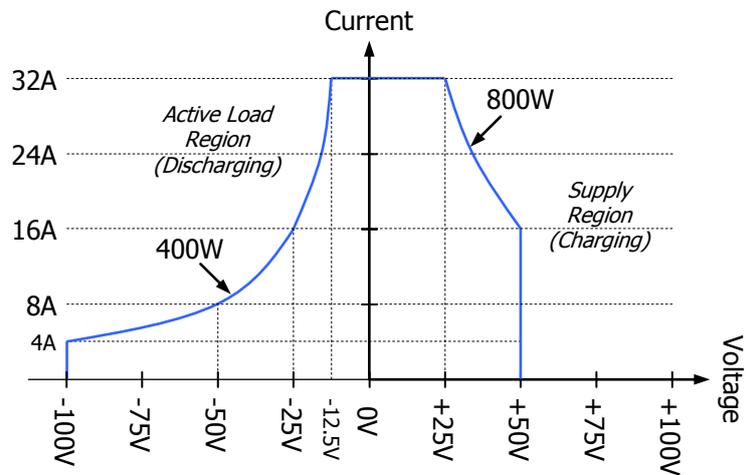
3.2.2 Parallel Mode on LV-side 16A ⁞ 100V (B1) or 32A ⁞ 50V (B2)

This supply mode is selected, when a phase on the low voltage side of the transformer has to be measured without the corresponding phase on the high voltage side. The three supplies are connected in parallel and the range is selected according to the desired measuring current as follows:

I ≤ 16.0A   →   16A ⁞ 100V

I > 16.0A   →   32A ⁞ 50V

The measuring circuit for phase a of an YNyn0 transformer is illustrated below:

Theory
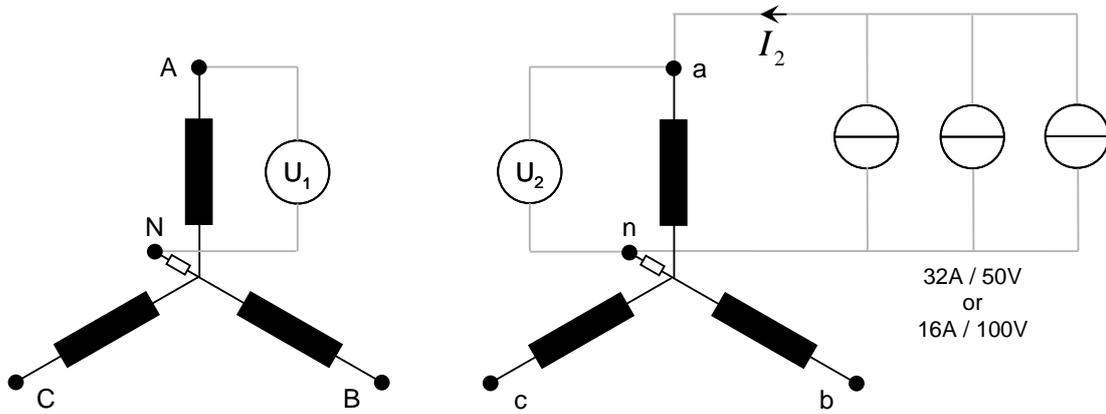
The measured resistance is calculated as follows:

$$R_{an} = R_a + R_n = \frac{U_2}{I_2}$$

The transformer transforms any inductive voltage applied to the low side to a higher voltage on the high voltage side (the resistive voltage drop is not transformed!). For this reason, the device senses the voltage on the high voltage side and limits it by controlling the supplies on the low voltage side accordingly.

It is possible that the overvoltage protection of the device triggers on transformers with a high turns ratio. In this case the user must disconnect the cables from the high voltage terminals of the DUT to perform a measurement in this mode (B1 or B2).

3.2.3 Individual Mode 2x 16A ⫶ 50V (C)

This supply mode is selected, when two the corresponding phases of the high and low voltage side of the transformer have to be measured. The three power supplies are split to the HV and LV side. The measuring current must be selected as follows:

I1 ≤ 16.0A

I2 ≤ 16.0A

The measuring circuit for a simultaneous measurement of HV and LV on phase A of an YNd1 transformer is illustrated below. YNd measuring mode must be set to "with Rn (Ph-N)":
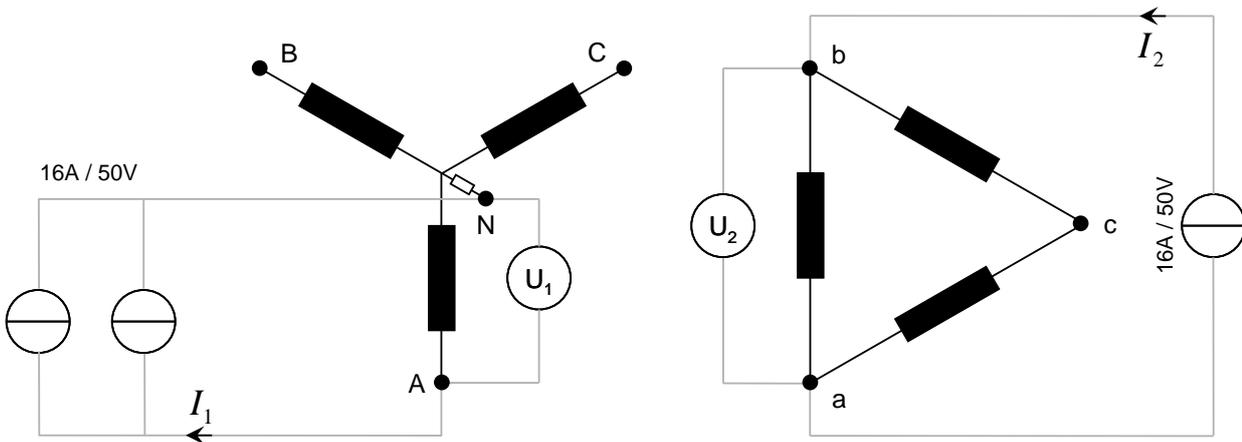
The measured resistances are calculated as follows:

$$R_{AN} = R_A + R_N = \frac{U_1}{I_1} \quad \text{(with Rn)}$$

$$R_{ab} = R_a \parallel (R_b + R_c) = \frac{U_2}{I_2}$$

The following diagram shows the operating area for each power supply in mode C – 2x 16A ⫶ 50V:
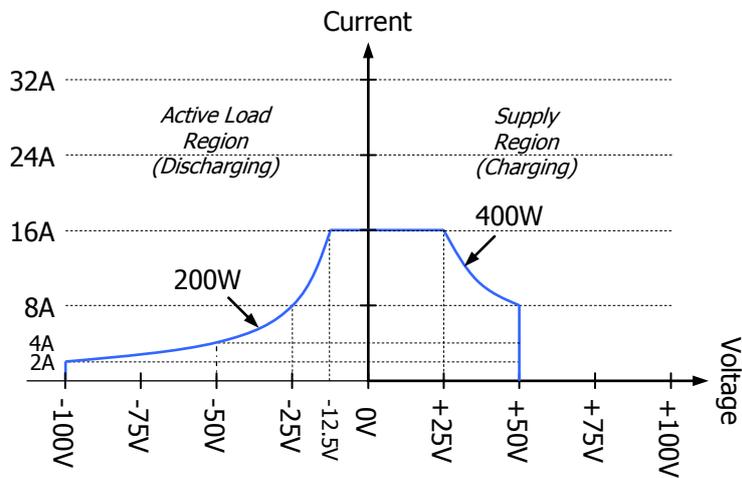
3.2.4 YNdx Mode 2x 16A ⦙ 50V (D)

This supply mode is selected, when two the corresponding phases of the high and low voltage side of an YNdx (x = 1, 3, 5, 7, 9, 11) transformer have to be measured. This mode is on applicable to YNd transformers. It is intended to ideally magnetize and saturate the core, to achieve a faster current balancing in the delta winding. The three power supplies are split to the HV and LV side. The measuring current must be selected as follows:

I1 ≤ 16.0A

I2 ≤ 16.0A

The measuring circuit for a simultaneous measurement of HV and LV on phase A of an YNd1 transformer is illustrated below. YNd measuring mode must be set to "without Rn (Ph-Ph)":
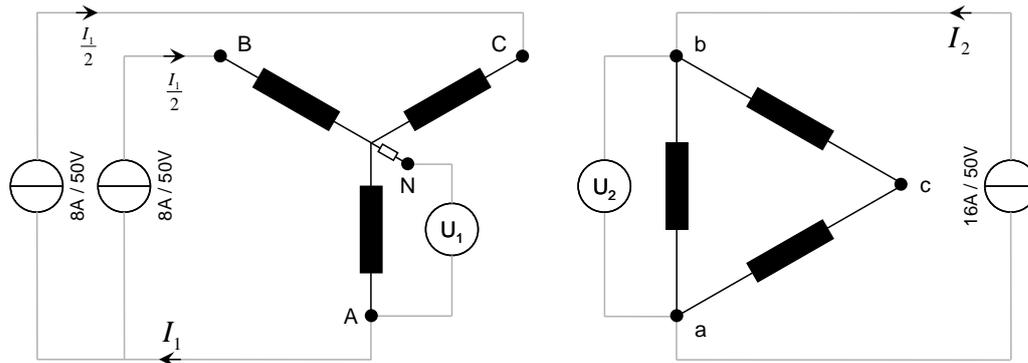
The measured resistances are calculated as follows:

$$R_{AN} = R_A = \frac{U_1}{I_1} \quad \text{(without Rn)}$$

$$R_{ab} = R_a \parallel (R_b + R_c) = \frac{U_2}{I_2}$$

The operating area for the power supplies is the same as in mode C.

3.3 Measuring sequences

This section describes how the device selects the measuring mode depending on the user settings done in the user software. The coloring of the drawings is equivalent to the user software:

- **Violet**   Phase to be measured

- **Red**   Phase currently measuring

- **Blue**   Phase already measured

- **Grey**   Nothing measured nor to be measured

General Rules

1.   If the measuring current selected on any winding is greater than 16.0A, a single winding measurement will be performed for each winding and phase → Mode A2, B2.

2.   Mode C is used only when the two corresponding phases on HV and LV are selected to be measured and the current is less or equal 16.0A.

3.   Mode D is used only when the two corresponding phases on HV and LV are selected to be measured, the DUT is an YNd transformer and the current is less or equal 16.0A. YNd measuring mode must be set to "without Rn (Ph-Ph)":

The following examples show the measuring sequence generated by the 2293 depending on the measurement settings. For simplicity an YNyn0 transformer was chosen as DUT in most examples.

3.3.1 Example 1

Settings:
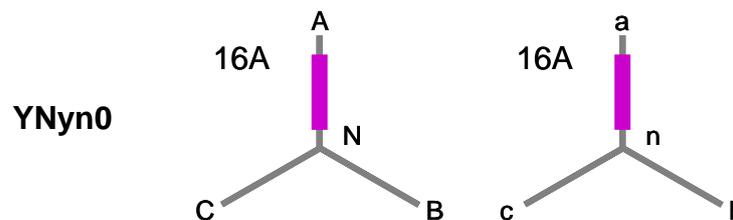
Sequence:
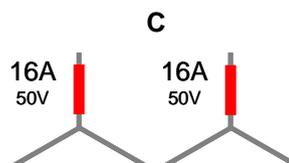
3.3.2 Example 2

Settings:
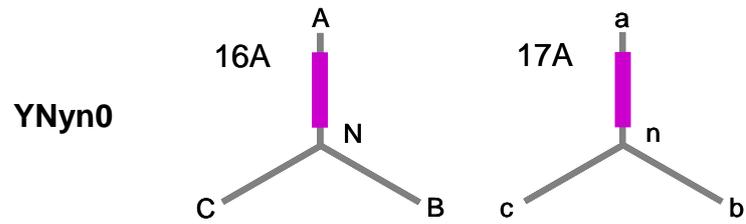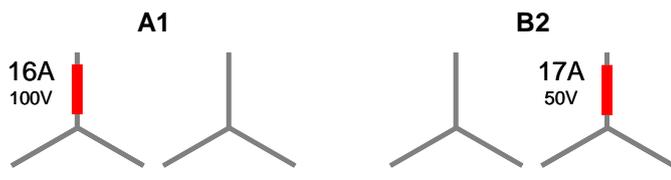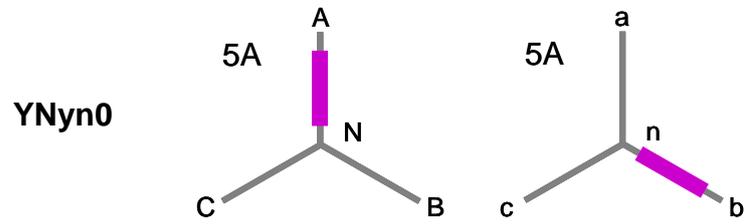
YNyn0

16A   17A

Sequence:

A1   **B2**

16A
100V

17A
50V

Example 3

Settings:

YNyn0

5A   5A

Sequence:

A1   **B1**

5A
100V

5A
100V

3.3.3 Example 4

Settings:

YNyn0

16A   16A

Theory

Tettex

Sequence:

C

| 16A | 16A | 16A | 16A | 16A | 16A |
| 50V | 50V | 50V | 50V | 50V | 50V |

3.3.4 Example 5

Settings:

16A

YNd11

16A

Sequence:

D or C		A1		B1	
16A	16A	16A			16A
50V	50V	100V			100V
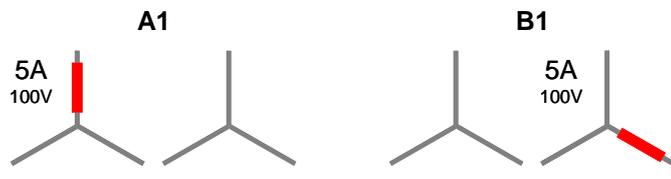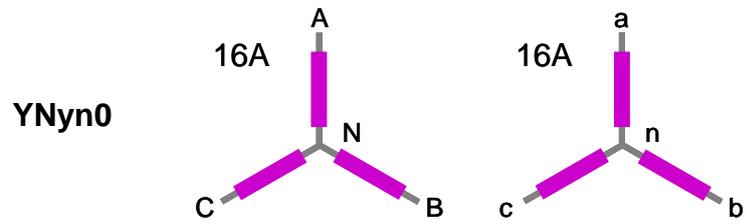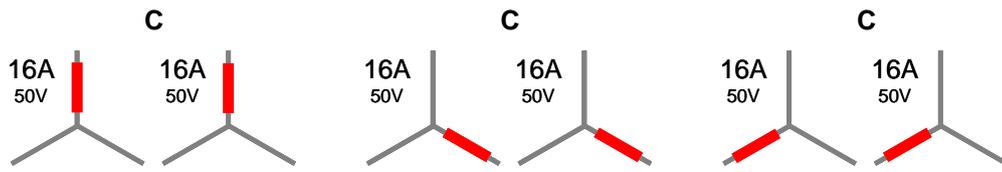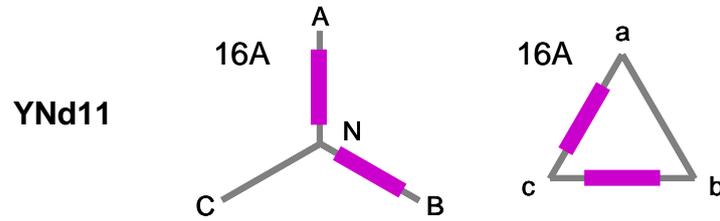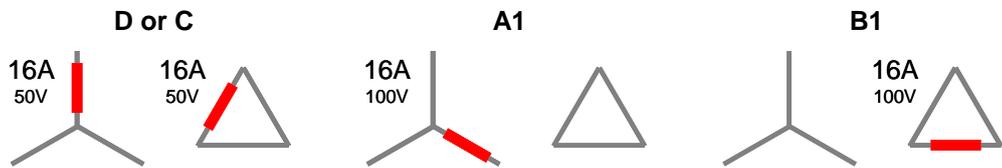
4   Front Panel

The lockable mains plug for connecting the mains cable is located in the front panel (6). According to the ordering data the proper mains cable is delivered with the instrument.

1	Connector for LV cable "X" connection, Black (to Low voltage side of DUT)
2	Connector for HV cable "H" connection, Red (to High voltage side of DUT)
3	I/O connector (for cascading of additional temperature interfaces)
4	Tap Changer connector (for optional Tap Changer Remote interface TAP/2293)
5	6 Temperature probes connectors
6	Power inlet with integrated mains switch and fuse holder
7	Printer
8	Touch screen display
9	USB (Host)
10	USB (Device)
11	Ethernet (LAN)
12	Emergency Stop button with (optional) interlock connector
13	Cooling air outlet / inlet
14	Caution indication. The two red LEDs on top are lit to indicate a current is flowing.

| | The third green LED on the bottom indicates a safe state. | 31 |
| 15 | Additional PE (Protective Earth) connector.   (Parallel to the PE pin of the power inlet connector) → Can be used when power inlet cable is not connected to Earth. | |

5   Connection and Setup

5.1   Connection Cables

The equipment is delivered with 8 measuring cables and two adaptors as standard scope of supply.

Cable set for the Low Voltage side X (black clamps)".
Cables are equipped with special Kelvin clamps.

Cable set for the High Voltage side H (red clamps)".
Cables are equipped with special Kelvin clamps.

Connecting Cables end colors code:

Connector phase U/R (brown)

Connector phase V/S (black)

Connector phase W/T (grey)

Neutral N (blue)

Adaptors:

Adaptor for the low volt side
(black ring in the connector)

Adaptor for the high volt side
(red ring in the connector)

Colour code has been defined in the cables and must be followed to guarantee the proper device connection. Red is used for the connections to the DUT's High Voltage side "H", Black is used for the connections to the DUT's Low voltage side "L".

During a 32A test the cables are operating at their maximum specification and it's normal operation that they get warm.

5.1.1 Cable extensions (optional)

As option, extension cables of 10 m are available.

Extension cables, same colour code is used.

5.2 Connecting the Instrument

Before attempting to connect to the test object make sure that it is fully disconnected and de-energized.
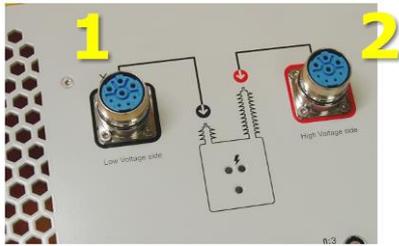
Red connector has to be connected to the right side (2) defined by a red dot. (H)

Black connector has to be connected to the left side (1) defined by a black dot. (X)

5.2.1   Connection without extenders
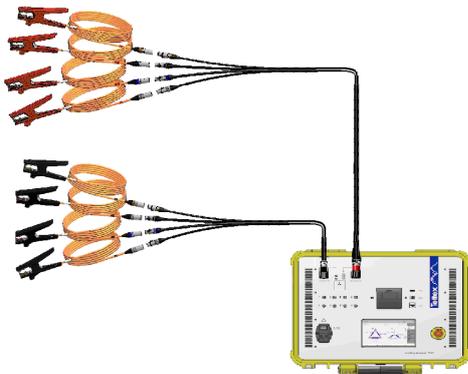
Connect the adaptors to the device connectors. The easiest way to screw the connector is to hold them straight with one hand and screw with the other one. . Ensure that the connectors are locked.

Now connect the single phase connection cables (labelled at the clamp) to the test object using the Kelvin clamps.

Connect the single phase connection cables (orange cable, colored connector) to the matching color of the spider connectors.

5.2.2   Connection with extenders

Connect the extenders to the device respecting the colour code (red with red, black with black). The easiest way to screw the connector is to hold them straight with one hand and screw with the other one. Ensure that the connectors are locked.

Connect the extenders to the adaptors.

Now connect the single phase connection cables (labelled at the clamp) to the test object using the Kelvin clamps.

Connect the single phase connection cables (orange cable, colored connector) to the matching color of the spider connectors

Make sure that you don't shortcut the specially designed 4-wire measurement Kelvin clamp. Only use the designated teeth in the front of the clamp.

If a DUT type is entered in the top bar of the display, the unit shows an icon of the DUT type and on each connection the label of the correct cable to be connected is displayed.

5.2.3 Connection in Automated mode to a 3 phase transformer

For a normal transformer, connection is done following the labels in the cable; means connecting transformer phases with corresponding labeled cables as shown in the bellow diagram.
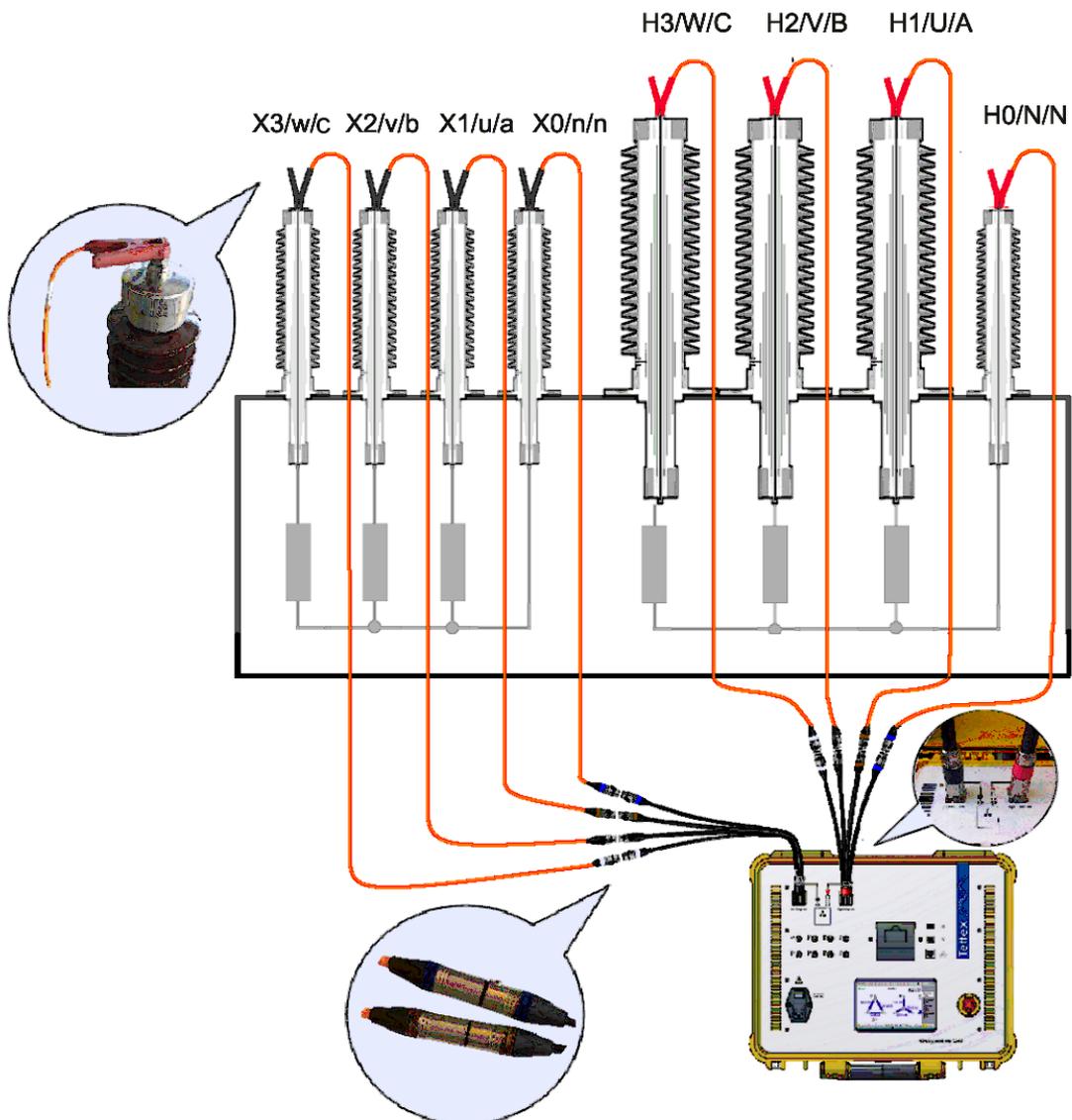
If only one side of a transformer has to be measured it's possible to connect only that side.

5.2.4 Connection in Automated mode to a 1 phase transformer

For a normal transformer, connection is done following the labels in the cable; means connecting transformer phases with corresponding labeled cables as shown in the bellow diagram.
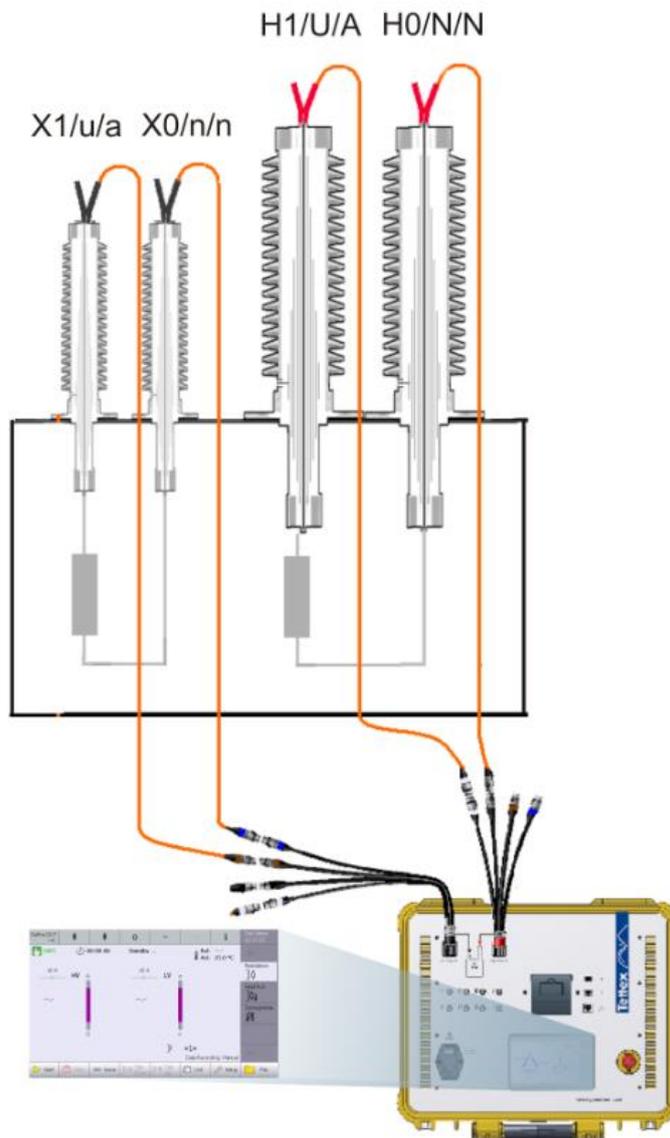
5.2.5 Connection in Classic mode

To connect the device to a test object different from a transformer, connections must be done as following.
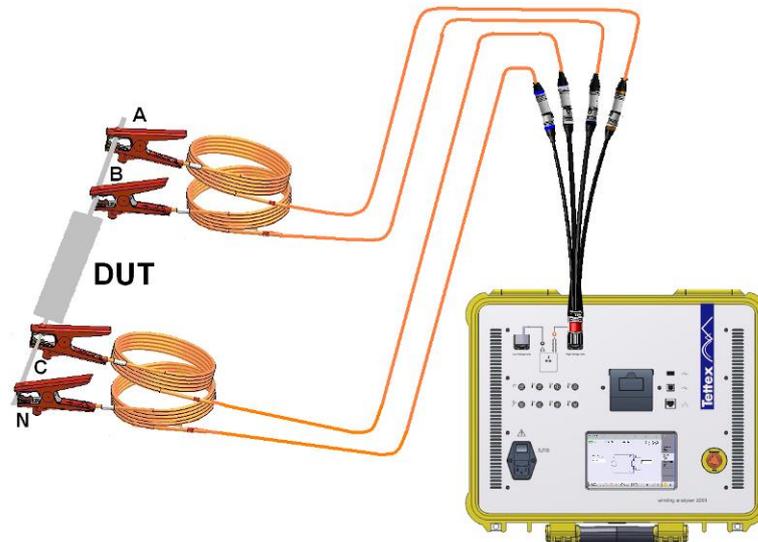
1 Resistance	
Terminal A →	positive of the high current power supply
Terminal N →	negative of the high current power supply
Terminal B →	positive of the voltage measurement
Terminal C →	negative of the voltage measurement

Instrument is equipped with two voltage measuring channels, therefore two resistances can be measured simultaneously, connect the equipment according bellow table to measure both resistances.

2 Resistances	
Terminal A →	positive of the high current power supply
Terminal N →	negative of the high current power supply

Terminal B →	positive of first voltage measurement
Terminal C →	negative of first voltage measurement
Terminal b →	positive of the second voltage measurement
Terminal c →	negative of the second voltage measurement

5.3   USB Type A Host Port

The USB Type A Host Port support various devices:

- USB Flash Memory Stick (for Data Export)

- Keyboard

- Mouse

- Hub

Please note that the USB Type A Standard specifies a maximum of 1500 mating cycles. 10 mating cycles per day would easily lead to connector degradation within 1 Year.

In case of frequent usage of the USB A port (typically for Data Export to a USB Flash Memory Stick), we strongly recommend using a **short extension cable** to protect the front panel connector of the device. See the following picture as an example:

6 User Interface

6.1 Startup

To start the device, turn on the main switch and wait until the warning screen arises. Booting can take some seconds.

Read carefully the warning messages and click OK when understood. Read also carefully the safety warnings at the beginning of this manual before operating the instrument.

6.2   Structure

The device is equipped with an intuitive interface, and all parameters are selected through its touch screen.

⚠️ Use the finger or a non sharp object to operate the touch screen.
Using sharp or metallic pointers can damage the screen!

The interface of the application software consists of four designated areas:
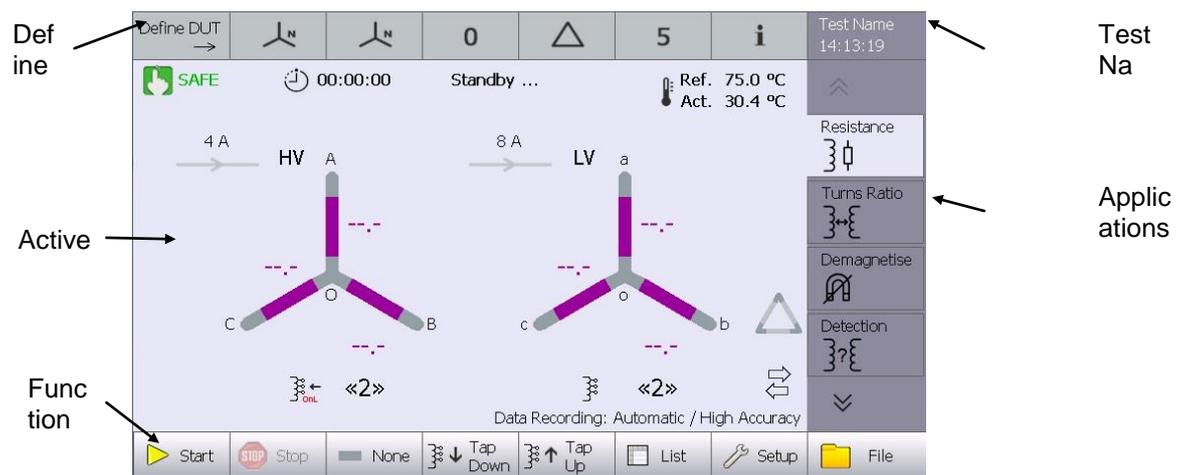
6.3   Define DUT (Top Bar)

The upper bar shows information about the actual test object and allows the definition of its main parameters.

DUT Definition:

HV winding configuration

LV winding configuration

Phase displacement HV / LV

TV winding configuration
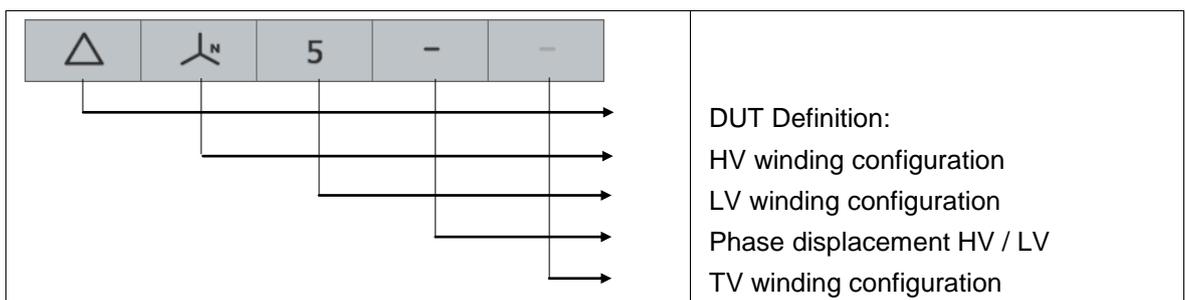
6.3.1 Selection of DUT Type

Transformer main parameters selection is done in the upper part of the main screen. The HV winding configuration, the LV winding configuration and the phase shift can easily be selected in the pop up menu.
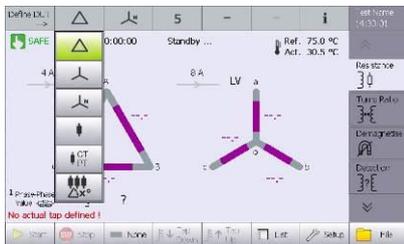
Selection of the HV winding   Selection of the LV winding   Selection of the phase shift
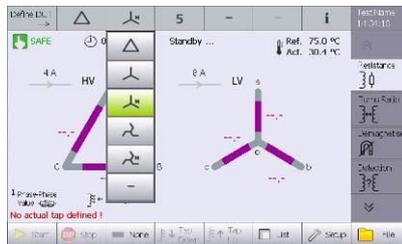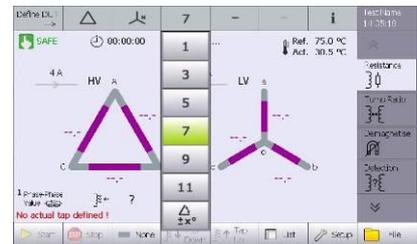
The tertiary winding, when existing, can also be configured by touching the corresponding icon
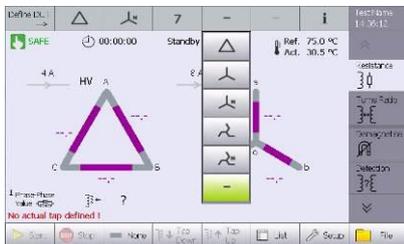
Selection of the Tertiary winding (if available)   Selection of the tertiary winding phase shift
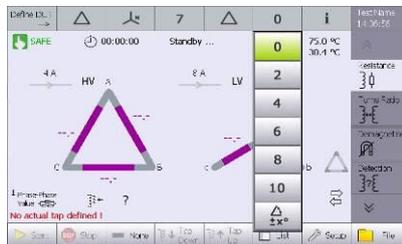
Winding settings

△	A delta winding of a 3 phase transformer
⅄	A wye winding of a 3 phase transformer
⅄ⁿ	A wye winding with neutral of a 3 phase transformer
⋏	A zig-zag winding of a 3 phase transformer
⋏ⁿ	A zig-zag winding with neutral of a 3 phase transformer
⸉	A one-phase winding
CT PT	A current transformer or potential transformer
△x°	An unconventional transformer

Examples

Example for a setup of a 3 winding 3 phase transformer Dyn7d0

△	⅄ⁿ	7	△	0

The selected transformer is then shown on a graphical mode in the main screen. In case tertiary winding has been selected two arrows in the right side will indicate that a tertiary winding has been configured. By clicking in the arrows either the low voltage winding or the tertiary winding actual configuration appears in the screen. The other winding appears as a small grey icon in the button right of the screen.

6.3.2 DUT data definition

i	DUT additional settings and technical data
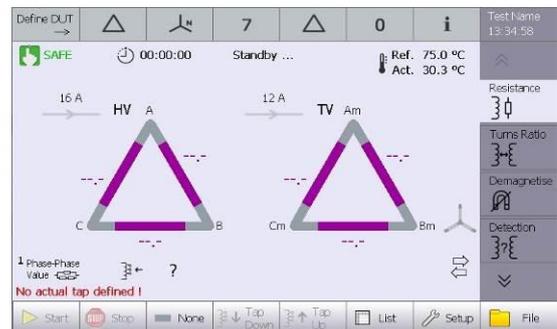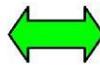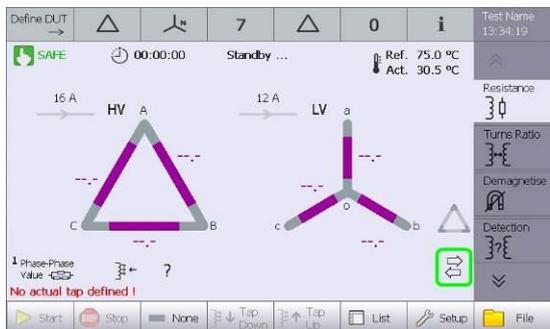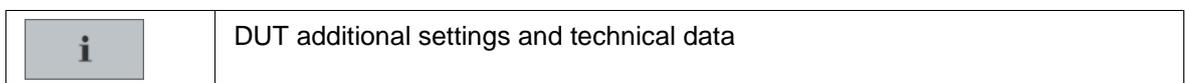
General information is necessary to identify the test and a proper reporting generation. Following fields are available in the device software.

Type

Enter here the Serial number and Type of the device under Test (DUT) and – if existing – also the Tap Changer information.

This info is then also used to name the test files and later on to easy classify measuring data.
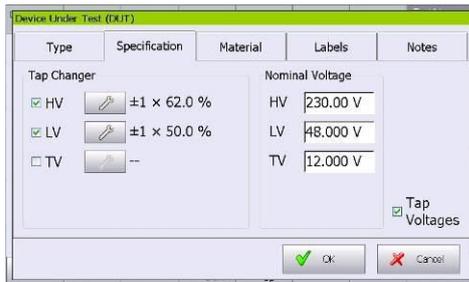
Specification

Here the definition about Nominal Voltages of windings have to be entered (used for desired value of ratios and as limits)

If a winding is equipped with a Tap Changer (on load or off load) it has to be configured by clicking the selection box in the left of the corresponding winding (HV for High voltage, LV for low voltage and TV for tertiary winding).

See next chapter for detailed description.
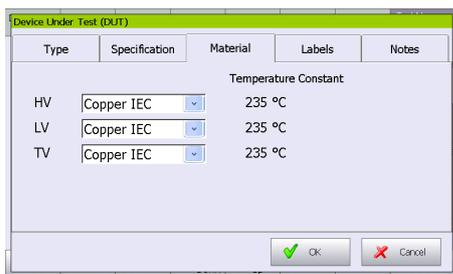
Materials

The material of the different windings has to be defined (used for temperature correction)

Following possibilities with its temperature constants are available; Copper IEC, Copper ANSI and Aluminium. Different materials can be selected for each winding.
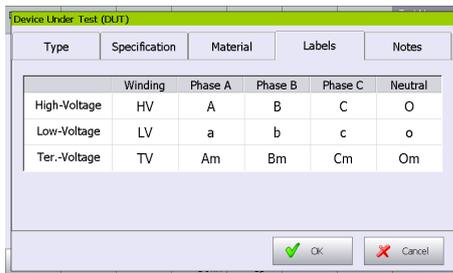
Labels

Here the user can define the Terminals labelling according to his country or standards.

These Labels then will be used in all displaying and recording of measuring data.
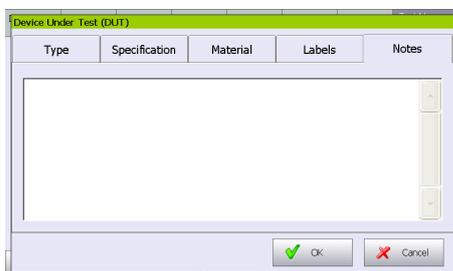
Notes

Long text field where any information regarding the DUT, test conditions, remarks, etc. can be added.

Above information is included in the measurement results file as well as in the printed report.

6.3.3 Tap Changer configuration

In case the transformer is equipped with a tap changer, it can be easily configured in the device to allow automation of the measuring procedure and complete test reports generation. The tap changer configuration screen is accessed selecting the DUT configuration **i** button in the upper DUT Top Bar, and selecting the specific folder.

```
┌─────────────────────────┐
│     Number of taps      │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   Number of nominal     │
│         taps            │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│     Nominal tap         │
│       position          │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│     Minimum tap         │
│       number            │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│   1 or 3 nominal taps   │
│       selection         │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│    On load or off load  │
│      tap changer        │
└─────────────────────────┘
```
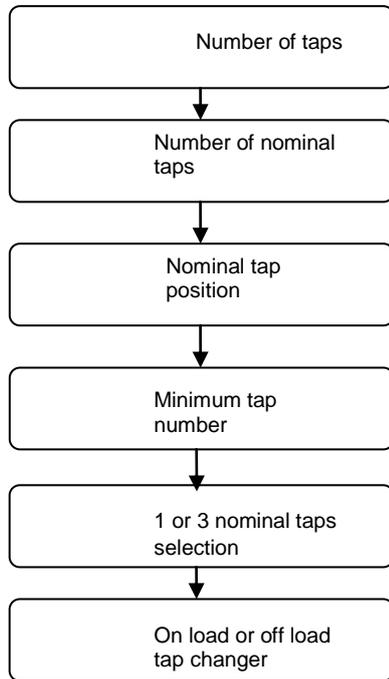
Tap changer configuration consist of the follow steps:

Tap changer configuration is described trough following examples which shows the procedure step by step.

Once the tap changer configuration has been finalized, just click the OK button to save the actual configuration.

6.3.3.1 Nominal tap and tap voltage setup
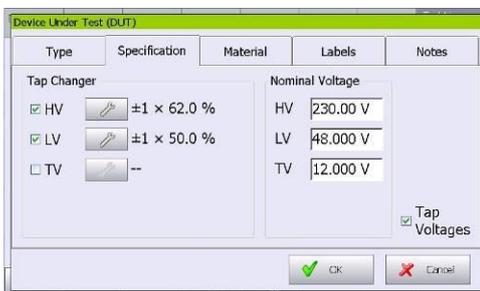
Select the tap voltages option and enter the nominal voltages of the transformer.

This step is all that is required for an untapped transformer.

For tapped transformers it is necessary to define each tap voltage. The button [wrench icon] has to be clicked and the following dialog will appear:

Actual tap chan

No

Number of nominal

Total number of tap changer

First position number

Select if if when more than 1 nominal position, the

Select if the intermediate taps are reachable and

Enter each theoretical tap voltage in the voltage column.

Alternatively change to the voltage folder for a quick way to enter multiple tap voltages.

The nominal & step option will automatically populate the voltage values when the apply button is pressed. In this example the nominal voltage is 20kV and each tap steps up 1kV.

The bottom & top option will automatically populate the voltage values when apply is pressed. In this example, the bottom tap is 11kV and the top tap is 18kV. The apply button calculates each tap voltage in proportion to the number of taps.
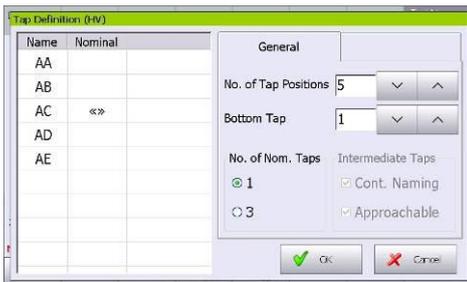
Nominal Tap

Nominal tap is indicated by the symbol "<<>>" beside the number, in case 3 nominal taps are selected, the other 2 nominal taps are marked with the symbol "<>". Selection of the nominal tap is done by clicking beside the number.

Tap Naming

In case the tap changer positions are not consecutive, or are not numbers, the new character/characters to define each position can be introduced manually by clicking in the "Name" cell of the row that will be modified. The following example shows a tap changer defined by letters instead numbers.
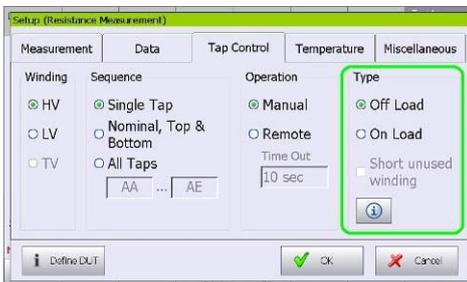
Type (On load / Off load)

The tap changer type can be selected from the Setup screen "tap control" folder.

6.3.3.2 Tap changer configuration examples
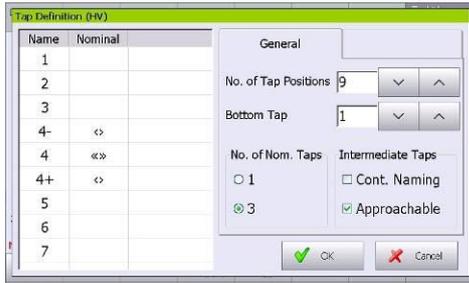
Example 1

9 taps transformer, with 3 reachable intermediate taps with no continuous naming, button position number 1 and nominal tap 4
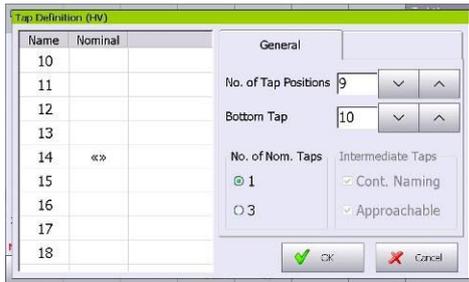
Example 2

9 taps transformer, with button position number 10, 1 nominal tap in position 14.

6.3.4 Test Name

The first line shows the name of actual test. Yellow colour means no file name has been defined yet.

The second line shows the actual time.

6.4 Applications (Side Bar)

The application bar (right side bar) allows the selection of the actual measurement application (e.g. Resistance or Demagnetization).

The DUT settings in the top bar are valid for all applications. The bottom function key changes depending on the selected application.

6.5   Active Window

In the centre of the display graphical information and measuring status of the current application is shown. The screen change depending of the operating mode or the application selected.
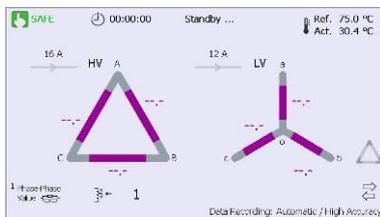
Automated mode main screen   Classic mode main screen   Demagnetization screen
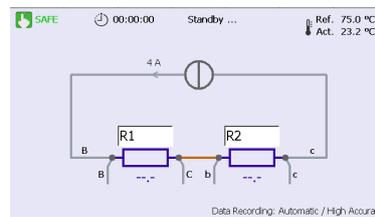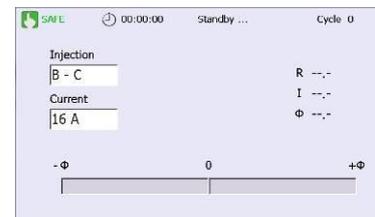
6.6   Function Keys (Bottom Bar)

At the bottom of the window a key bar is located which includes all buttons necessary to perform measurements, prepare setups or analyze test results. The buttons are case sensitive, i.e. they change according to the actual status.

The common keys, which are used in most applications, are described as bellow:

Tap Down	Move tap changer, that marked with ←, one step down
Tap Up	Move tap changer, that marked with ←, one step up
List	Change display to list mode
Gra-phic	Change display to graphic mode
Setup	Open setup menu of the selected application
File	Open data handling functions See next chapter for details

Specialised keys for the single applications see single application chapters

6.7   Device Information

The device information is accessible over Setup button in the bottom bar of each application.

Select the "Miscellaneous" folder. Here you will find the system info.

The device information is accessible over Setup button in the bottom bar of each application.

Select the "Miscellaneous" folder. Here you will find the system info.

6.8   Data Handling

6.8.1   File management.

The device can print in the included printer, store in the internal memory and export measurement results. All these operation are done in the file management popup menu
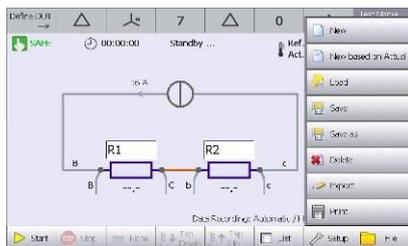
Access the File management menu popup by clicking the file button in the function key bar.

New	Open a new test

New based on Actual	Open a new test based in the actual data
Load	Load a recorded test
Save	Save actual test under the actual name
Save as	Save actual test under a new name
Delete	Delete actual test
Export	Export data to a memory stick
Print	Print the actual test in the included printer
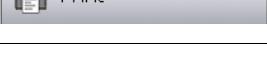
6.8.2 Printing results.

Results can be printed in the internal device printer by clicking the print button in the file popup menu.

6.8.3 Exporting measurement results.

Measurement data, as well as the header and test object information can be exported to a memory stick or the internal storage in a comma separated values file format. This data can be later read by any commercial software, as for example MS excel.
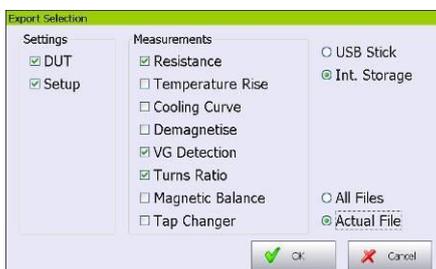
When export option is selected. A popup screen will ask which data wants to be exported; data will be saved in the root directory of the memory stick.

It is possible to export All test saved in the device memory, or only the actual test. In addition following options are available:

All Files / Actual File	Select "All Files" if all tests stored in the device memory want to be exported
	Select "Actual File" if only the actual test wants to be exported.

Settings ☐ DUT ☑ Setup	Select if the device under test data (DUT) and the setup data want to be exported to the memory stick
Measurements ☑ Resistance ☐ Temperature Rise ☑ Cooling Curve ☑ Demagnetise ☐ VG Detection ☐ Turns Ratio ☐ Magnetic Balance	Select the measurements that wants to be exported, resistance, cooling curve and demagnetization.
○ USB Stick ◉ Int. Storage	Select the CSV output file destination: USB Stick - Writes the report to the attached USB Memory Stick Int. Storage – Writes the report to the internal Webserver storage.
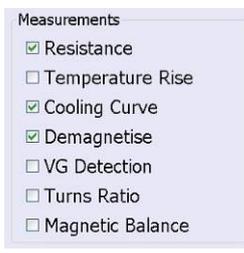
Infomation ⓘ 2 file(s) exported ! ✔ OK	If exporting was successful, a popup message will arise informing about number of exported files. Once this message arises, the files can be found on the specified destination.

6.8.4 Webserver access / Ethernet interface

To access the files that have been written to the internal webserver storage, a network connection between the device and your office computer must be established. Please refer to the "Remote Control" section of this manual for further help.

You can find the IP address configuration of your device in the "Setup" – "Miscellaneous" dialog:
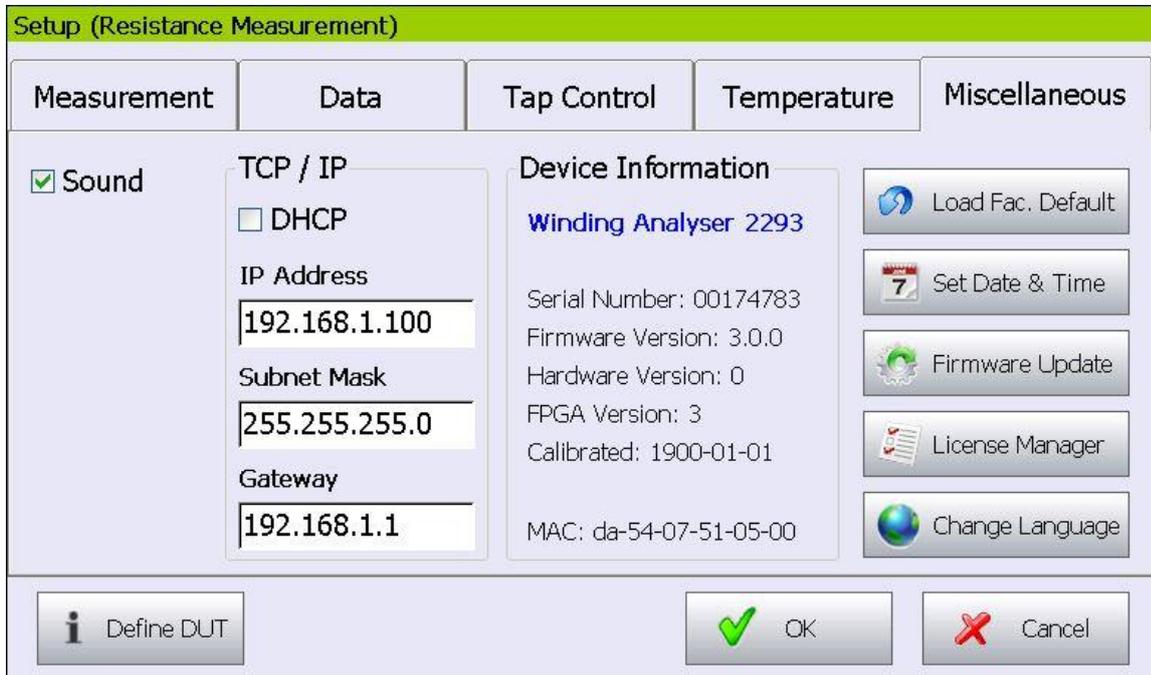
Please make sure that these settings are compatible with the settings on your office computer. As an example in this case, the IP address of your office computer could be configured to 192.168.1.50. Then you can access the WebServer on the WA2293 using your Internet Browser (e.g. "Internet Explorer" or "Mozilla" or "Chrome"). Simply type the IP address of the WA2293 into the address line:
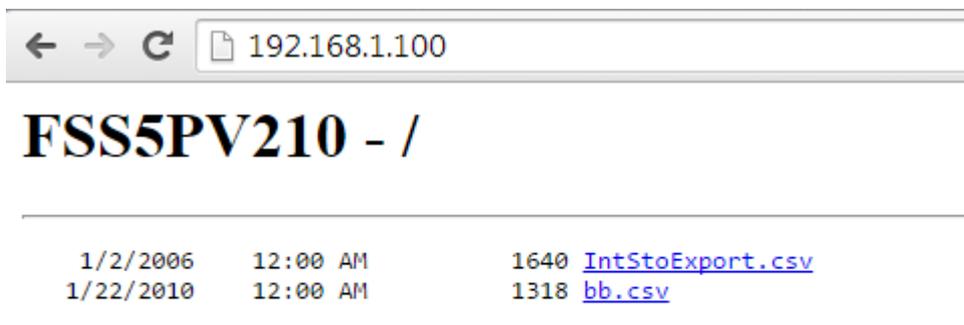
You can download your saved report files by clicking on the file in the browser.

7　Resistance Measurement

7.1　Operating modes

The unit can perform resistance on all types of objects, but has been specially designed to measure resistance on highly inductive objects (as for example transformer's windings, generators windings, etc).

During resistance measurement the device can be used in two operating modes: the "classic mode" and the "automated mode".

Automated mode is used for measuring resistance on power transformer, as the unit is equipped with an internal relay matrix that perform the test in all phases of a three phase transformer without any reconnection.

Classic mode is used for measuring resistances or any test object different from a transformer.
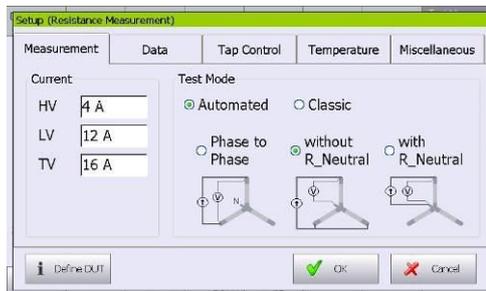
Selection on the measuring mode is done in the Setup screen, accessible over:

Select the Test Mode "Automated" or "Classic"

7.2　Automated mode

7.2.1　General

On automated mode, the unit will perform all necessary steps to measure all resistances on a transformer automatically.
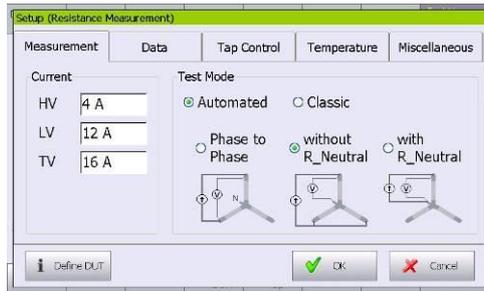
Automatic mode selection is selected in the measurement folder, clicking in the function key bar.
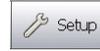
When selected, additional options like YnD measurement and tap sequence are available

7.2.2 Function keys during resistance in automated mode

While in automated resistance measurement mode, following actions are available in the button key. The buttons are case sensitive, i.e. they change according to the actual status.

▷ Start	Start the measurement
⟳ Record	Record a result while manual recording mode is used
🛑 Stop	Stop the measurement
▬ None	Deselect all windings
▬ All	Select all windings
🔢 Wind. Calc.	Calculate the winding resistance based on the results of the combined measured resistance when a delta type transformers is measured.
⭍↓ Tap Down	Move tap changer one step down
⭍↑ Tap Up	Move tap changer one step up
▦ List	Change display to list mode
△⅄ Gra-phic	Change display to graphic mode
🔧 Setup	Open setup menu for the selected measuring application

7.2.3 Active Window

The automated resistance measurement screen is bellow described:
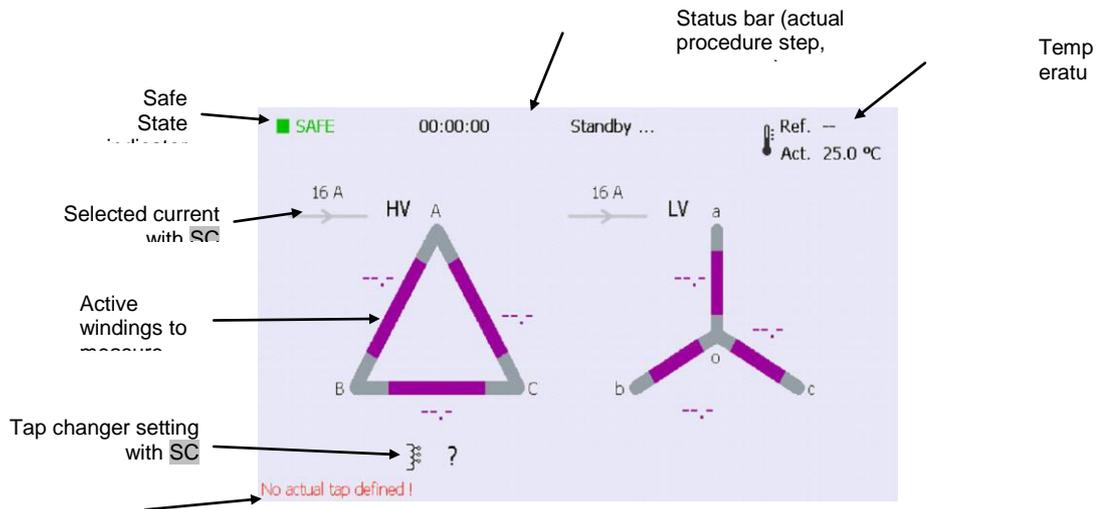
Tettex

Status bar (actual procedure step,

Temperatu

Safe State indicator

Selected current with SC

Active windings to measure

Tap changer setting with SC

No actual tap defined !

* SC = Shortcut; direct action or access to setup over touching

Tap Changer Visualization:

	Tap changer graphical representation
	"Remote Controlled" is active in dialog "Setup"
	this winding is selected at "Tap Control" / "Winding" in dialog "Setup"
OnL	tap-changer is defined as "On Load" in "DUT" dialog
1	Actual tap position

7.3 Performing a test using Automated mode

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

7.3.1 Measurement steps

Performing a resistance measurement on a power transformer consist of following steps

```
┌─────────────────────────┐                    ┌─────────────────────────┐
│    DUT general data     │                    │   Configuration of the  │
│                         │                    │   automatic             │
└───────────┬─────────────┘                    │   temperature           │
            │                                   └───────────┬─────────────┘
            ▼                                               │
┌─────────────────────────┐                                ▼
│    Selection of the     │                    ┌─────────────────────────┐
│    corresponding DUT    │                    │    Selection of the     │
│    main parameters      │                    │    desired test current │
└───────────┬─────────────┘                    └───────────┬─────────────┘
            │                                               │
            ▼                                               ▼
┌─────────────────────────┐                    ┌─────────────────────────┐
│   Configuration of the  │                    │    Auto recording       │
│   tap changer (when     │                    │    selection            │
│   existing)             │                    └───────────┬─────────────┘
└───────────┬─────────────┘                                │
            │                                               ▼
            ▼                                   ┌─────────────────────────┐
┌─────────────────────────┐                    │        Measuring        │
│   Winding material      │                    └───────────┬─────────────┘
│   selection             │                                │
└─────────────────────────┘                                ▼
                                                ┌─────────────────────────┐
                                                │   Exporting and         │
                                                │   printing results      │
                                                └─────────────────────────┘
```
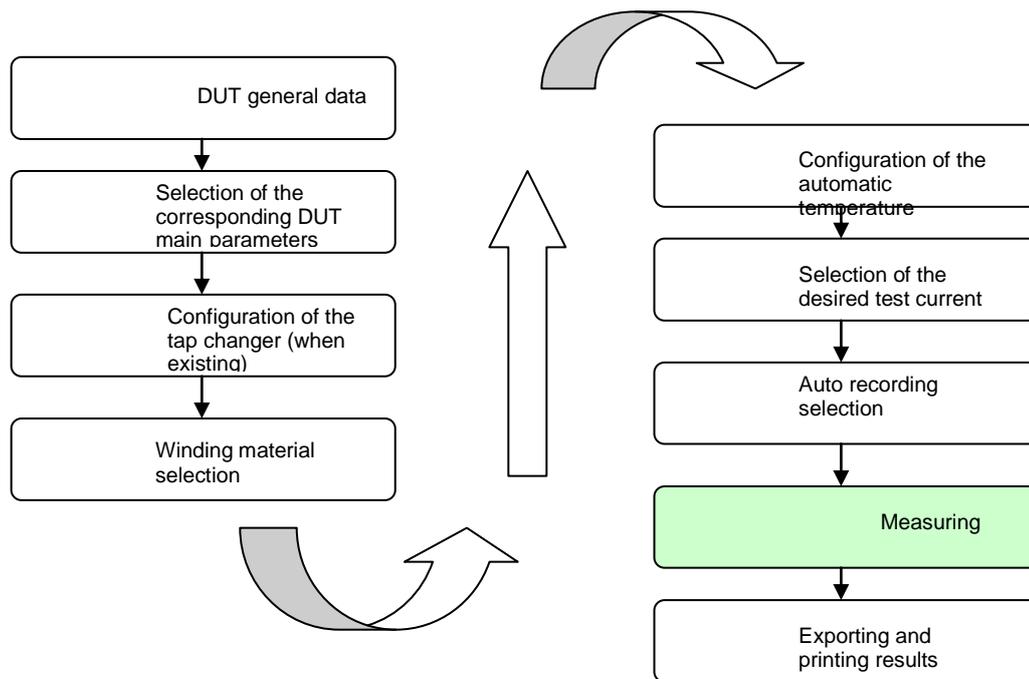
7.3.2   Set up DUT data

To set up the steps with DUT related data:

→ see related chapters in the "User Interface" part.

7.3.3   Test current selection

According international standards, the maximum test current should not be higher than 10% (IEC) or 15% (ANSI) of the nominal winding current to avoid heating up of the winding and therefore non stable readings.

⚠️ Selection of measuring currents above the transformer nominal current can end in the transformer break down.
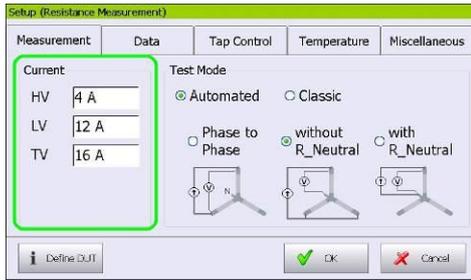
The measuring current must be introduce independent for each winding and is done in the "measurement" folder clicking over the Setup button in the function key bar.

A shortcut for current selection is available in the main screen; clicking in the current by winding drawing

7.3.4 Test current recommendations

Normally 32 Amps are not necessary, except when really low resistances (<0.5mOhm) have to be measured it can help to improve accuracy.

It is recommend to use 16A maximum. This way two windings of the transformer can be measured simultaneously, which speeds up the measurement process a lot!

Current settings guideline

DUT type	Current
Distribution	HV = 1A .. 8A LV = 10A .. 16A
Power < 20MVA	HV = 4A .. 8A LV = 8A .. 16A
Power <200MVA	HV = 8A .. 16A LV = 12A .. 16A
Power >200MVA	HV = 16A LV = 16A
GSU (Generator Step Up):	HV = 16A LV = 16A (with option "without R_Neutral")

Generally the resistance of the transformer winding to be measured is a good indicator for the required measurement current:

< 10mΩ	16A
< 100mΩ	4A .. 12A
< 1Ω	2A .. 4A
< 10Ω	<1A

7.3.5 Tap sequence

If the transformer is equipped with tap changer and it has been configured in the device, the tap changer measuring sequence should be defined. Different options are available in the Tap Control folder, selecting the setup in the main menu.
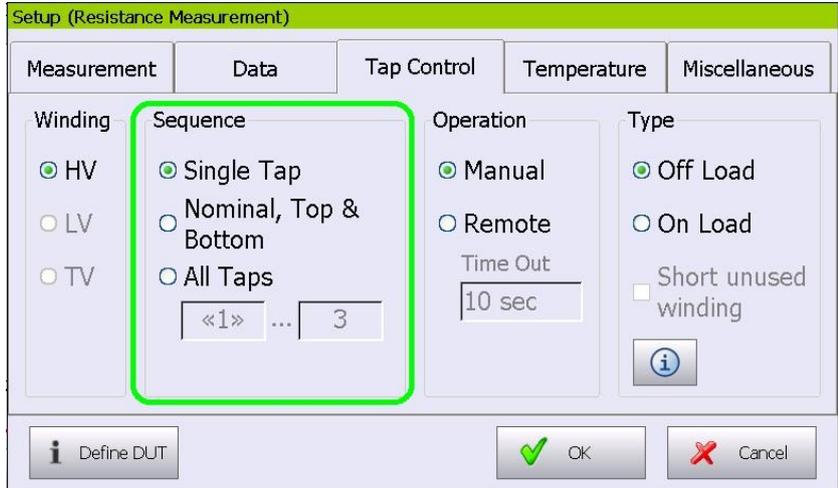
Single Tap		Measurement will be done tap by tap (no sequence to be followed), the tap to be measured can be manually selected in the main screen.
Nominal, Top & Bottom		Only the nominal, upper and bottom taps will be measured
All Taps 1 ... 5		Several or all taps will be measured following a sequence

7.3.6 Auto recording configuration

Measurement can be done in auto stop mode (value is automatically recorded when stable) or in manual mode (unit stays measuring until the operator click the stop button), selection between both operations modes is done in the setup screen, Data folder.

To record a value while measuring on this mode, click the record button in the function key bar.

If Automatic mode is selected, two pre-programmed stabilization parameters are available, in addition the user can introduce any value manually.

○ High Accuracy	Value is stable and therefore recorded when a change of 0.0003% per second, or 0.003% per 10 seconds or 0.03% per 100 seconds is achieved.
⊙ Fast	Value is stable and therefore recorded when a change of 0.003% per second, or 0.03% per 10 seconds or 0.3% per 100 seconds is achieved.
⊙ 0.003 %/sec.	User can manually introduce any stabilization parameter, the value introduced is the slope of the change, and is defined as value (in percentage) per second

7.3.7 Tap Control

Here the user defines how the tap changer is used in the resistance measurement.
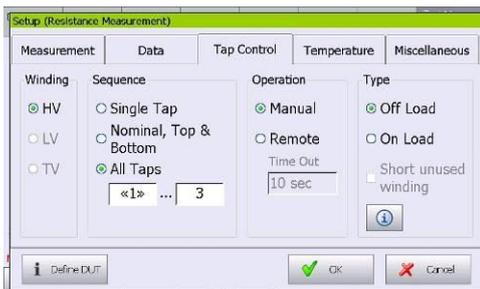
Winding:

Define which available tap changer is used (taped trough) in the actual measurement.

Sequence:

Select which taps have to be measured (single extremes, all)

Operation:

Define if the tap changer is operated manually (the unit gives a message to change and waits for confirmation) or automated together with the "Remote Tap Switch" cable.

Set as timeout the time which is maximum needed to change the tap (used if no feedback signal is available from the tap changer)

Type:

Off Load → the unit will be discharged before changing a tap

On Load → The unit stays charged while tap changing.

Short unused windings → Normally checked. Avoids overvoltage protection problems.

Example: When "All Taps" and "On Load" is selected the sequence is as follows:

First phase – test all taps – next phase etc., tap changing in charged state and the measurements on multiple windings are performed sequential.

See also chapter "Tap Changer Interface" for more details and connection advice.

7.3.8 Temperature correction

The instrument can perform temperature correction for the values measured, as related in the IEC or other national or international standard.

```
          ┌─────────────────────────────┐
          │ Select the winding material │
          └─────────────────────────────┘
                          │
                          ▼
          ┌─────────────────────────────┐
          │ Reference temperature       │
          │ selection                   │
          └─────────────────────────────┘
                          │
                          ▼
          ┌─────────────────────────────┐
          │ Test object actual          │
          │ temperature                 │
          └─────────────────────────────┘
```
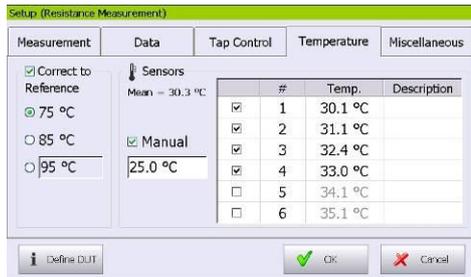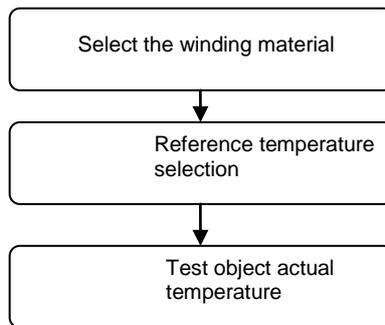

If automatic temperature correction is desired, the DUT actual temperature and the reference temperature have to be introduced by selecting the temperature folder after clicking the setup button in the function key bar.

Read the chapter "Temperature correction" for the proper data introduction.

7.3.9 Measurement

Performing a measurement on a transformer is quite simple. Once all transformer and options have been introduced; just click the start button. The instrument will perform all operations automatically.

During the measuring and while in graphical mode the parts of the circuit being measured will become red and the actual measured value will be shown bellow the label.

Before starting the test, a screen showing the tap position that will be measured arises. Tap changer must be positioned in this position. Measurement sequence depends on the tap changer configuration menu.

Tap changer position selection (automatic with optional tap changer remote control)

↓

Charging the transformer

↓

Resistance measurement (all phases)

↓

Discharging the transformer

↓

Measurement results
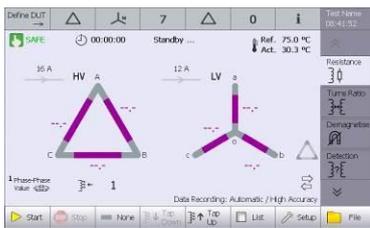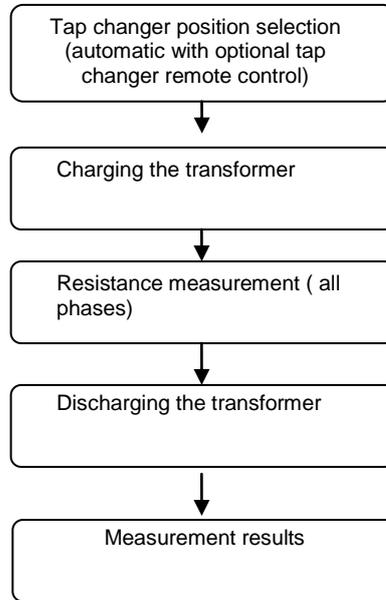
Click start button to initiate the test
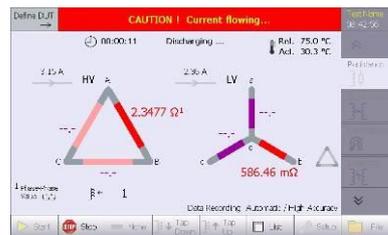
Automatic measurement running
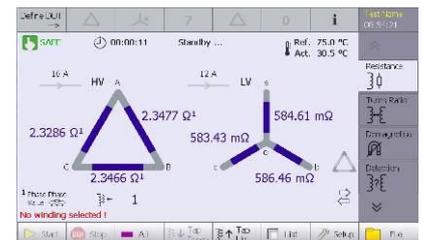
Measurement results

If auto recording is active, instrument will record the value and stop the measurement when the stabilization condition has been reached.

Windings to be measured are selected by clicking on them. Purple color means that this winding will be measured; blue color means that this winding will not be measured. If a previous measurement on this winding and tap position has been done, results are shown in blue, but measurements can be repeated.

	Selecting or de-selecting all windings can be easily done using the corresponding buttons in the function key bar.
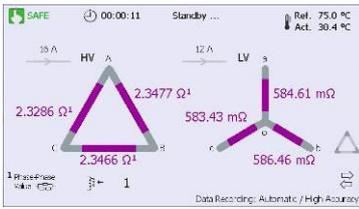
All phases will be measured
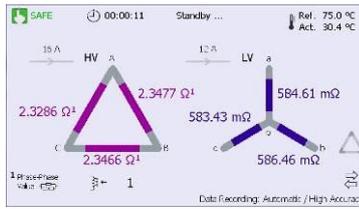
Only HV side will be measured
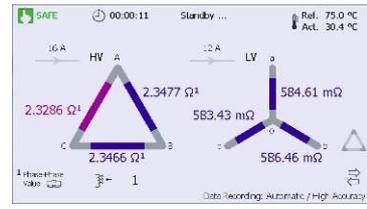
Only phase AC in the HV winding will be measured

Measurements will be automatically saved after each test. Data storage options can be selected in the Data folder, clicking in the setup button of the function key bar.

Overwrite → when a measurement is repeated, results overwrite the actual measured values

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

Results can also be shown as a table list, selecting the list button in the function key bar.

Tettex

7.4   Classic mode

7.4.1   Generalities

On classic mode, the unit work as a standard low resistance measuring bridge using the Kelvin method. The unit includes one current power supply and 2 voltage measuring channels (for measuring up to 2 resistances simultaneously), This mode can be used for measuring test objects different from transformers, as well as for calibration purposes.
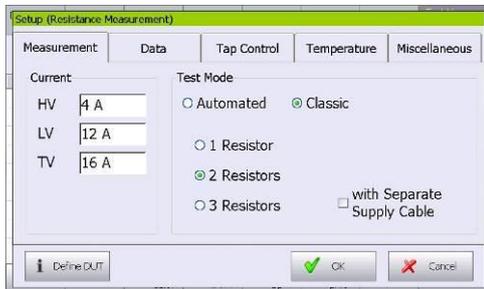
Classic mode is available by selecting this mode in the measurement folder, clicking setup in the function key bar.

When selected, 1, 2 or 3 resistances measurement mode is available and can be selected.

If Separate Supply Cable is selected, the system supports a separate cable for supply and for sense is used. (see also graphic in main screen)

Selection between 1, 2 or 3 resistances can also be done in the main screen by clicking on the drawing.

7.4.2   User Interface structure

Define →

Active →

Function →

Test Na

Applications
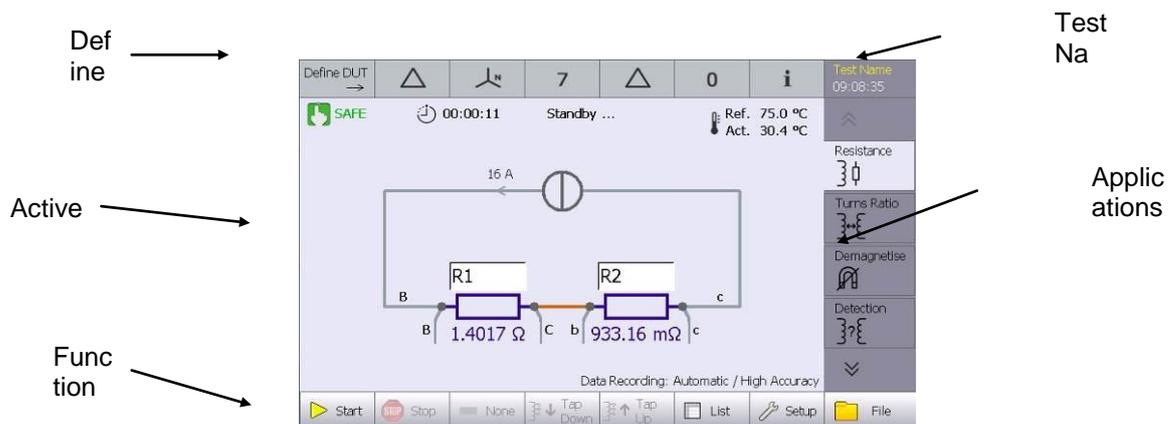
The function key bar is adapted to this measurement method. The buttons are case sensitive, i.e. they change according to the actual status.

▷ Start	Record	Start the measurement or Record the actual value (only available during measurement)
Stop		Stop the measurement
List	△人 Gra-phic	Change display to list mode or graphic mode
Setup		Open setup menu for the selected measuring application

📁 File	Open data handling functions

7.4.3 Active window
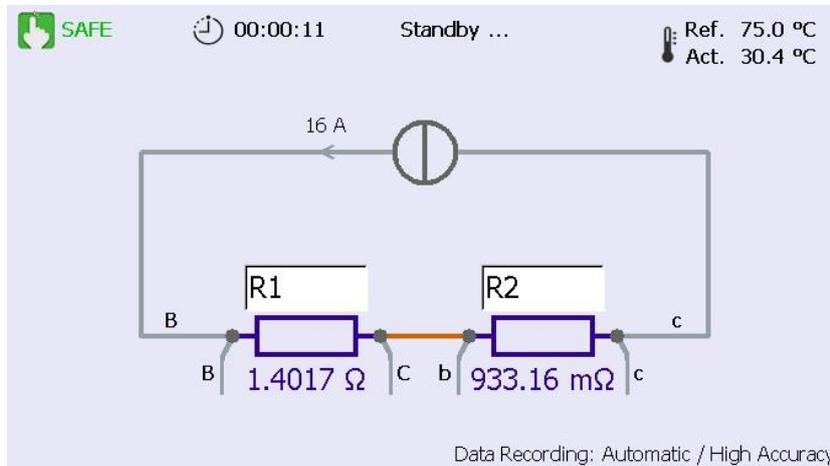
🌡 Ref. -- Act. 25.0 ºC	Temperature correction, when active the reference temperature is shown.
(circuit schematic)	Measuring circuit schematic, letters indicate the cable labels to be used
R1 1.4017 Ω	Label and value of the resistance
16 A	Test current selected
👆 SAFE	Test object status. Be advised that the external red lamp is the safety master (14 in the front panel description). The test object can not be touched or disconnected only when this lamp is still on.
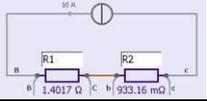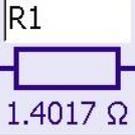
ℹ️ For the correct cable connection in classic mode see also in chapter
"5.2.5 Connection in Classic Mode"

7.5   *Performing a test using Classic mode*

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

Performing a resistance measurement using classic mode consist of following steps

```
┌─────────────────────────┐              ┌─────────────────────────┐
│    DUT general data     │              │    Selection of the     │
└───────────┬─────────────┘              │   desired test current  │
            │                            └───────────┬─────────────┘
┌───────────▼─────────────┐              ┌───────────▼─────────────┐
│    Selection of the     │              │     Auto recording      │
│    corresponding DUT    │              │       selection         │
│     main parameters     │              └───────────┬─────────────┘
└───────────┬─────────────┘              ┌───────────▼─────────────┐
┌───────────▼─────────────┐              │       Measuring         │
│   Material selection    │              └───────────┬─────────────┘
└───────────┬─────────────┘              ┌───────────▼─────────────┐
┌───────────▼─────────────┐              │     Exporting and       │
│   Configuration of the  │              │   printing results      │
│       automatic         │              └─────────────────────────┘
│      temperature        │
└─────────────────────────┘
```
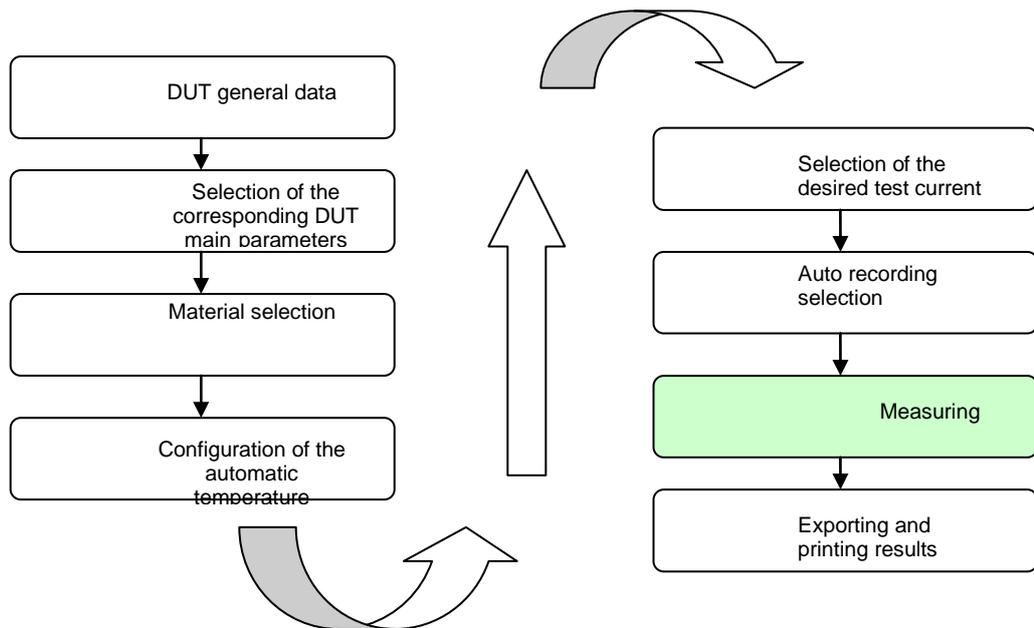
7.5.1   Test object connection on classic mode

Follow the instructions in the "connection and setup" chapter in this manual.

7.5.2   Set up DUT data

ℹ️ To set up the steps with DUT related data:
→ see related chapters in the "User Interface" part.

7.5.3   Temperature correction

The bridge can perform temperature correction for the values measured, as related in the IEC or other national or international standard.

```
┌─────────────────────────────┐
│  Select the winding material │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│   Reference temperature      │
│   selection                  │
└─────────────────────────────┘
                │
                ▼
┌─────────────────────────────┐
│   Test object actual         │
│   temperature                │
└─────────────────────────────┘
```
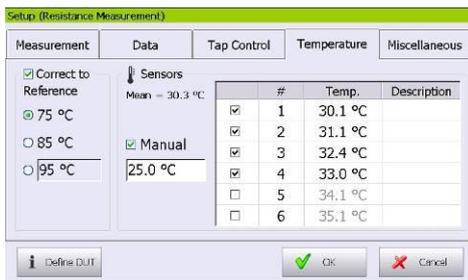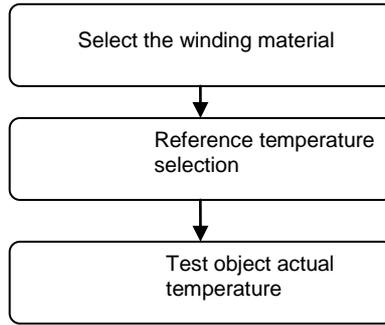
If automatic temperature correction is desired, the DUT actual temperature and the reference temperature have to be introduced by selecting the temperature folder after clicking the setup button in the function key bar.

Read the chapter "Temperature correction" for the proper data introduction.

If temperature correction is active, then the main screen will show the actual temperature and the reference temperature.

7.5.4 Test current selection

Selection of the measuring current is done by clicking on the test current field in the main screen, any value between 0 and 32A can be introduced, some values are directly selectable.

0.1 A	1 A	8 A	User Defined
0.25 A	2 A	16 A	5 A
0.5 A	4 A	32 A	

7.5.5 Auto recoding configuration

Measurement can be done in auto stop mode (value is automatically recorded when stable) or in manual mode (unit stays measuring until the operator click the stop button), selection between both operations modes is done in the setup screen, Data folder.

To record a value while measuring on this mode, click the record button in the function key bar.

If Automatic mode is selected, two pre-programmed stabilization parameters are available. In addition the user can introduce any value manually.

○ High Accuracy	Value is stable and therefore recorded when a change of 0.0003% per second, or 0.003% per 10 seconds or 0.03% per 100 seconds is achieved.
⊙ Fast	Value is stable and therefore recorded when a change of 0.003% per second, or 0.03% per 10 seconds or 0.3% per 100 seconds is achieved.
⊙ 0.003 %/sec.	User can manually introduce any stabilization parameter, the value introduced is the slope of the change, and is defined as value (in percentage) per second

7.5.6 Measurement

Measurement starts just after clicking the start button in the main screen. During the measuring and while in graphical mode the measured value will become red and the actual measured value will be shown bellow the label
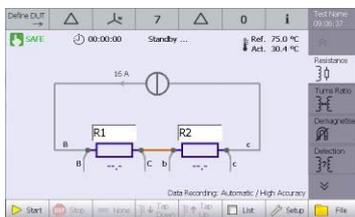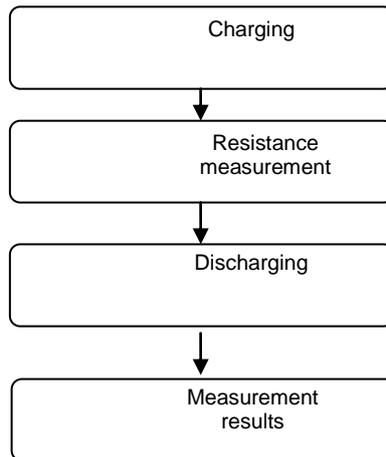
Click start button to initiate the test
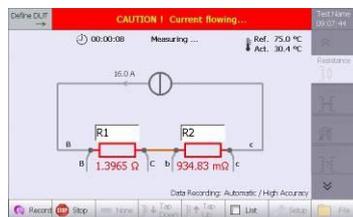
measurement running
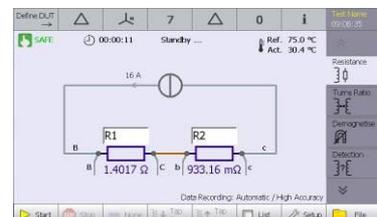
Measurement results

If auto recording is active, instrument will record the value and stop the measurement when the stabilization condition has been reached. Otherwise the stop button has to be pushed to stop the test. Values can be recorded manually using the record button.

Measurements will be automatically saved after each test. Data storage options can be selected in the Data folder, clicking in the setup button of the function key bar.
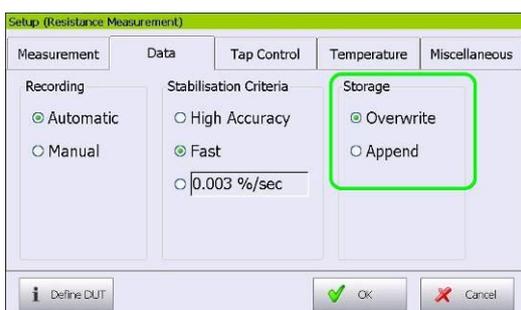
Overwrite → when a measurement is repeated, results overwrite the actual measured values

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

If measurement has to be repeated, just click the start button again.

Results can also be shown as a table list, selecting the list button in the function key bar.

7.6 Temperature Measurement
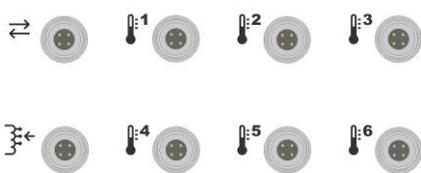
Temperature sensors can be connected to the corresponding connectors in the front panel. If more than 6 temperature sensors are requested, optional extender can be purchased. PT100 sensors are used for temperature measurement.
Sensors for liquids or magnetic sensors are available, consult the accessories chapter for additional information.

The temperature measuring screen is accessed clicking the Setup button, under the temperature folder in the function key bar.

	Measured resistance can be automatically corrected to a referenced temperature. This temperature can be 75 degrees, 85 degrees or any temperature between -50 and 100 degrees. The selection is done by clicking into the white button field	
	When no temperature sensor is connected, the DUT actual temperature can be introduced manually by clicking in the white field bellow the manual selection. Manual selection must be activated	
	Actual temperature of the sensors. If more than one sensor is selected, then the temperature shown is the medium of all actives ones	
	If temperature correction is active, then the main screen will show the actual temperature and the reference temperature.	

	#	Temp.	Description
☑	1	30.4 °C	
☑	2	31.4 °C	
☑	3	32.4 °C	
☑	4	33.1 °C	
☑	5	34.5 °C	
☑	6	35.5 °C	

Actual reading of the six temperature channels. To be added to the medium temperature they should be selected. A description (text) can be added to every temperature channel.

By clicking on a sensor line in this list you enter the temperature probe definition dialog:

Select the position where the sensor is mounted on the DUT by clicking. On the "Temp:" column of the specific probe.

In resistance measurement only the simple average temperature of the activated sensors is taken. In the heat run measurements, the standard based calculations are implemented with respect to specific probe positions. (see related heat run chapters)

Description

Here an additional text for the sensor can be added (e.g. when an external sensor is used on a cooler fan)

The Text input field can also be accessed directly by clicking in the specific "Description" column in the parent dialogue.

‹	›

With these arrows you can toggle trough the single probes definitions

8 Demagnetization

8.1 Theory

After disconnecting a transformer from the grid or performing a winding resistance measurement with direct current, the transformer core will be magnetized. The following figure shows a transformer core hysteresis curve with a possible magnetization M_0. M_0 can be anywhere on the y-axis within the hysteresis loop.
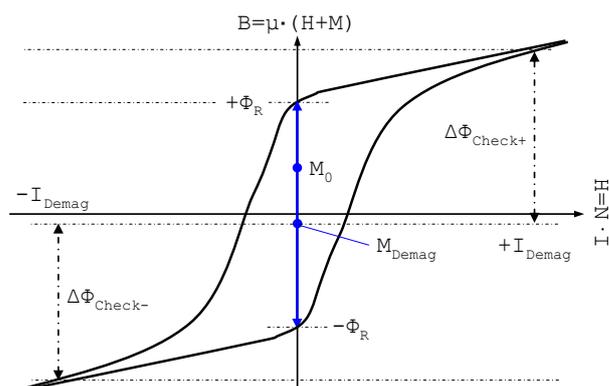
The magnetization M_0 can influence various measurements like turns ratio or frequency response. For these measurements the magnetization should be $M_0 \approx 0$ Am^{-1}, otherwise the results can be wrong or not comparable. Further, connecting a magnetized transformer to the grid can cause high inrush currents.

The common method to demagnetize a transformer core is to apply nominal AC voltage to the transformer and slowly decrease its amplitude to zero. But this method requires a very large and not portable controllable AC voltage source.

With the 2293 demagnetization function, the hysteresis loop of the transformer is calculated using a special algorithm, later using an iterative procedure running in several cycles the demagnetization status is reached

8.2 User interface

The demagnetization procedure is done automatically. Few parameters have to be selected before proceeding to demagnetize the transformer. Parameters selection and function are accessible in the demagnetization function.
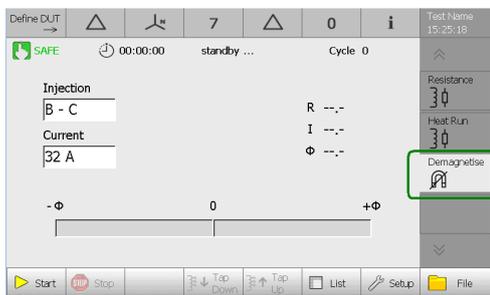
To access to this application, select demagnetize function in the applications bar (side bar)

8.2.1 Active Window

The demagnetization function main screen components are described below.

While in demagnetization application, following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

Start	Start the measurement
Stop	Stop the measurement
Tap Down	Move tap changer, that marked with ←, one step down
Tap Up	Move tap changer, that marked with ←, one step up
List	Change display to list mode

△⅄ Gra-phic	Change display to graphic mode
⚒ Setup	Open setup menu for the selected measuring application

8.3 Performing a demagnetization

8.3.1 Measurement steps

Performing demagnetization with the 2293, consist of following steps
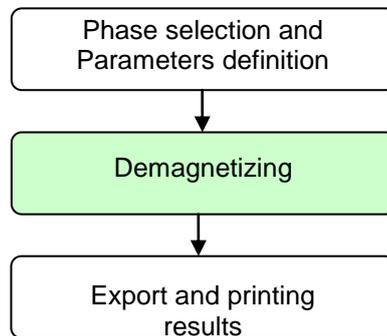
```
┌─────────────────────────┐
│   Phase selection and    │
│  Parameters definition   │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│      Demagnetizing       │
└─────────────────────────┘
            │
            ▼
┌─────────────────────────┐
│    Export and printing   │
│         results          │
└─────────────────────────┘
```

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

8.3.2 Parameters definition

To define the application parameters, push the setup button in the function key bar while in demagnetization application.

Injection ◉ HV ○ A - B ○ LV ◉ B - C ○ TV ○ C - A	Injection Phase and Winding Selection of winding and phases to be used for the demagnetization. It is recommended to use the high voltage side and the center limb of the transformer.
Current HV 32 A LV 16 A TV 16 A	**Current** used during the demagnetization. It is recommended to use at least 2 times the no load losses current of the transformer of the winding used
Completion Condition Cycles 20 Rel. Res. Flux 5 % Abs. Res. Flux 20 mWb	Stop criteria to determine when a demagnetisation run will be completed: Cycles Maximum number of cycles the instrument will perform. Set this parameter high enough (>50) to prevent abnormal termination Relative Residual Flux Percentage of the initial maximum magnetic flux that will declare the transformer as demagnetized. Select low values for good demagnetisation results. Absolute Residual Flux Maximum flux value in Weber (1Wb = 1Vs) that will declare the transformer as demagnetized Select low values for good demagnetisation results. 20mWb represents the lower technical limit of the device. The demagnetization iterations will be completed, if any of the above conditions is fulfilled.

If the Rel.Res.Flux is set to 5% (e.g. 30Wb x 5% = 1500mWb), the unit does usually stops based on that higher value. Instead at its technical limit (Abs.Res.Flux) of 20mWb.

8.3.3 Demagnetizing

Click the start button and the instrument will perform the demagnetization.
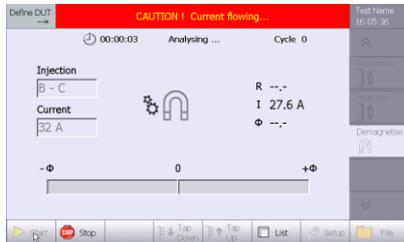
Current injection and resistance measurement
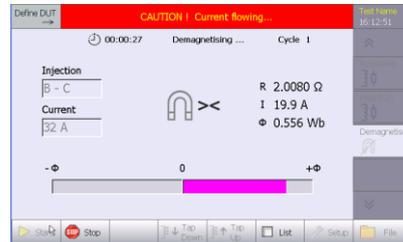
Transformer is being demagnetized. The bar indicates the actual core flux.
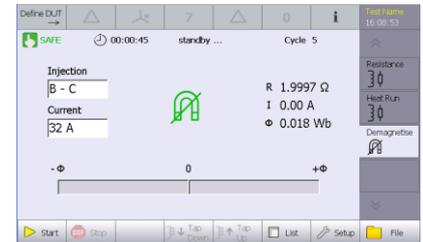
Transformer demagnetized

8.4 Application hints

Repeating the demagnetization function more than once does theoretically not result in a much better demagnetization of the transformer because the procedure starts with a maximal magnetisation to get a defined initial condition of the core.

Please verify that the measured "Winding Resistance" "R" matches the real winding resistance with good accuracy (e.g. 1%-2%). Otherwise the demagnetization will eventually not be performed reliable.

Power transformers with closed delta windings (>100MVA, YNd or YNynd)
Transformers with low voltage delta windings create a circulating current which can influence the demagnetisation. This is because of the fact that the magnetic flux is not distributed equally on all limbs within reasonable time.
Wherever possible, we recommend to open a Delta Winding, to improve Demagnetization performance.

It could also be helpful to repeat the demagnetisation on all three phases.
However – at power transformers with closed delta windings, a demagnetisation without a real 3 phase high-voltage power source is difficult and mobile devices reach their limits.

Demagnetization

Tettex

9 Heat Run – Cooling Curve

9.1 Theory

The purpose of this test is to establish the top oil temperature rise in steady-state condition with dissipation of total losses and to establish the average winding temperature rise at rated current and with the top oil temperature rise specified before.

This target is achieved in two main steps:
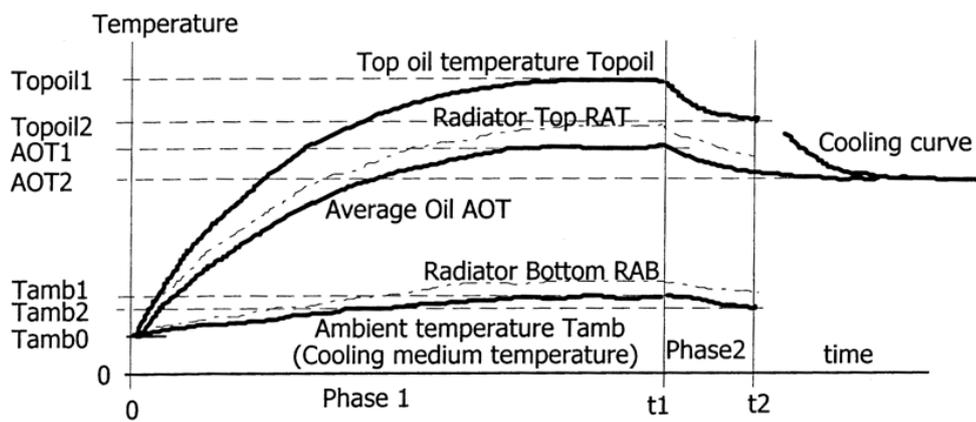
First the top oil and average oil temperature rises are established when the transformer is subjected to a test voltage such that the measured active power is equal to the total losses of the transformer. The oil temperature and the cooling medium temperature are monitored, and the test is continued until a steady-state oil temperature is reached. When the top oil temperature has been established, the test shall immediately continue with the test current reduced to the rated current for the connected winding. This condition is maintained for a certain time (normally 1h).

Following the first part of the procedure (heating), resistance has to be measured after a quick disconnection of the power supply. The values of average temperature of the two windings are determined from the resistances change along the time, known as cooling curve.
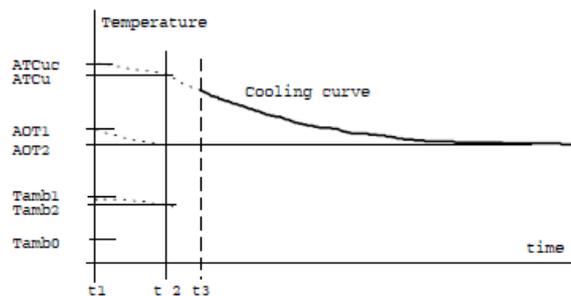
9.2   User interface

The 2293 is equipped with a heat run function which allows the measurement of the resistance values for the cooling curve calculation during heat run test.
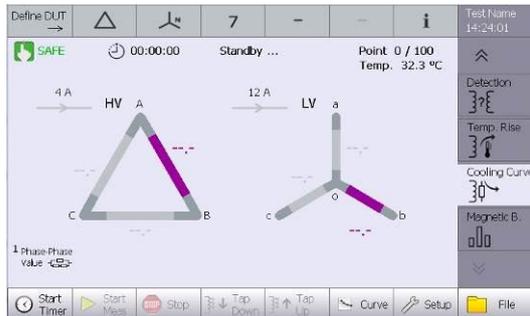
To access to this feature, select cooling curve function in the applications bar (side bar).

9.2.1   Active Window

The cooling curve function main screen components are described bellow.
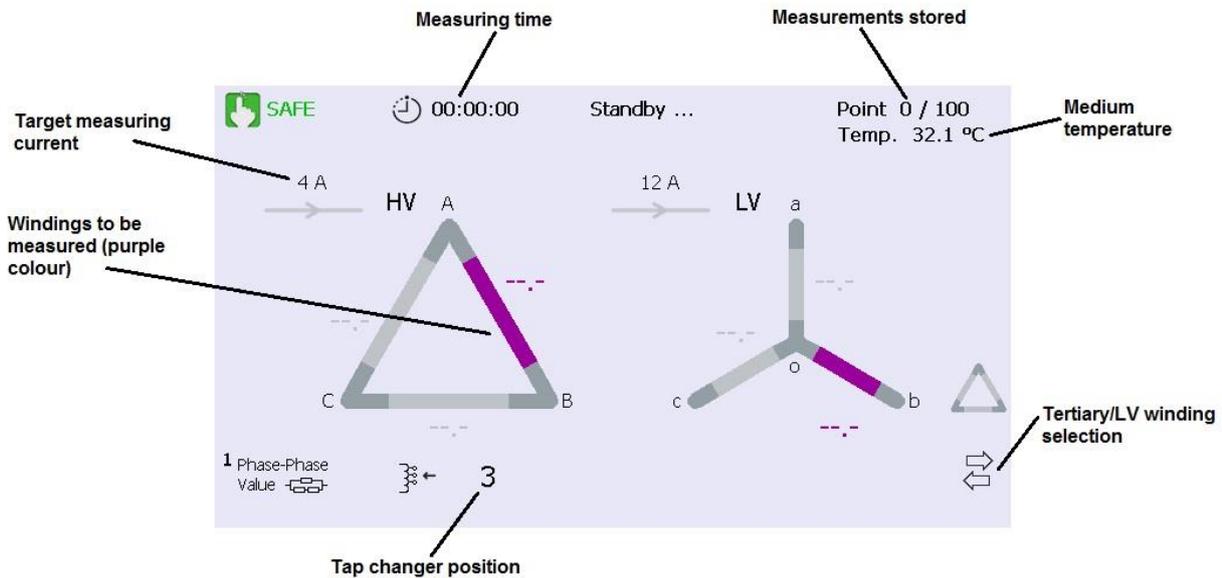
While in heat run application, following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

Start Timer	Start the timer after disconnecting the power supply (zero time). Has to be started when the Rated current Supply is switched OFF
Start Meas	Start the resistance measurement when the connection cables are mounted. When started this button becomes the "Break" function

Break Meas	Stops the resistance measurement but NOT the timer (with "Start Meas" the measurement can be reactivated) In case the test is stopped by this button during first stage (t2-t4) of 3 phase sequential measurement, the whole sequence will be redo after reactivated.
Stop	Stop and resets the application (resistance measurement and timer)
Tap Down	Move tap changer, that marked with ←, one step down
Tap Up	Move tap changer, that marked with ←, one step up
Curve	Change display to curve mode
List	Change display to list mode
Graphic	Change display to graphic mode
Setup	Open setup menu for the selected measuring application
File	Open data handling functions

9.3 Performing a resistance measurement (cooling curve)

Measurement steps

Performing resistance measurement on cooling curve test with the 2293, consist of following steps
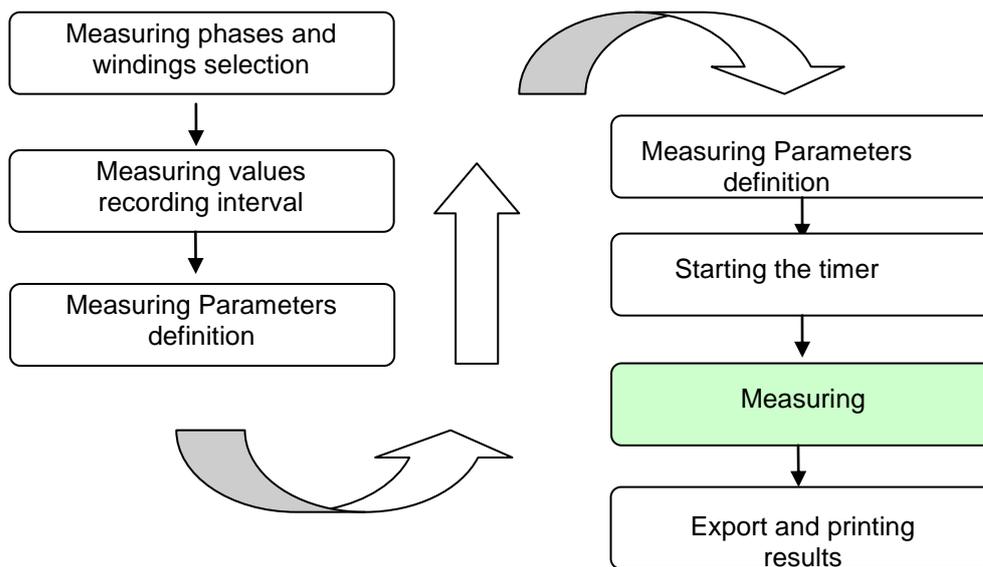
```
┌─────────────────────┐          ┌─────────────────────┐
│ Measuring phases and│          │ Measuring Parameters│
│  windings selection │          │     definition      │
└─────────────────────┘          └─────────────────────┘
          │                                 │
          ▼                                 ▼
┌─────────────────────┐          ┌─────────────────────┐
│  Measuring values   │          │  Starting the timer │
│  recording interval │          │                     │
└─────────────────────┘          └─────────────────────┘
          │                                 │
          ▼                                 ▼
┌─────────────────────┐          ┌─────────────────────┐
│ Measuring Parameters│          │      Measuring      │
│     definition      │          │                     │
└─────────────────────┘          └─────────────────────┘
                                            │
                                            ▼
                                 ┌─────────────────────┐
                                 │ Export and printing │
                                 │      results        │
                                 └─────────────────────┘
```

> ⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

9.3.1 Phases and winding selection

One resistance per winding can be selected for heat run test resistance measurement. Selection is done by clicking in the corresponding part of the drawing in the heat run test main screen. Purple color indicates the windings to be measured.

9.3.2 Resistance measurements recording interval

During a cooling curve test, a resistance value has to be recorded on regular intervals; this interval is user defined.
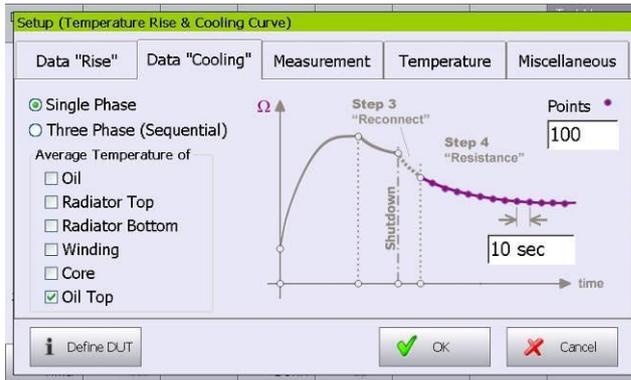
The recording option is available after selecting the Setup button in the function key bar while cooling curve is selected in the applications bar.

When Single Phase is selected, the measurement will be performed on one phase of each selected winding.

The interval (time between readings) and the number of readings can be here selected by clicking in the corresponding field
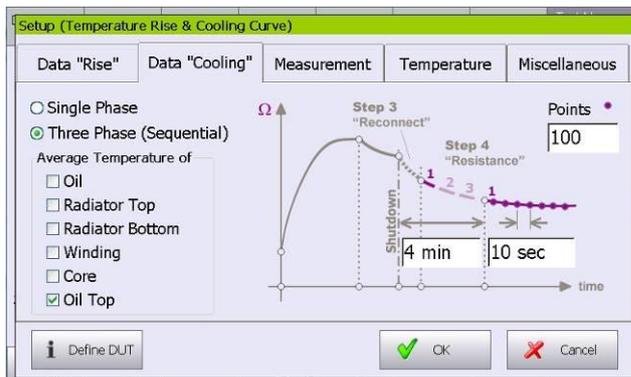
When Three Phase (Sequential) is selected, the measurement will be performed sequentially on all three phases of each selected winding up to the time interval (t2-t4).

After this time interval the measurements will be performed on the selected phase until the number of readings is reached.

The exact number of 3 phase measurements achieved is dependent on the time taken before reconnection and the charging time.

9.3.3 Test current selection

According international standards, the maximum test current should not be higher than 10% (IEC) or 15% (ANSI) of the nominal winding current to avoid heating up of the winding and therefore non stable readings.

⚠ Selection of measuring currents above the transformer nominal current can end in the transformer break down.
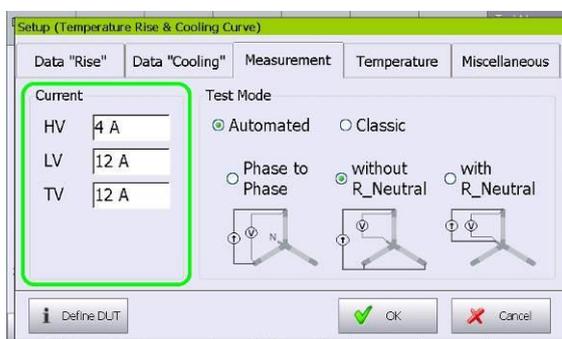
The measuring current must be introduce independent for each winding and is done in the "measurement" folder selecting the Setup menu in the function key bar.

Independent current per winding must be selected. Read carefully the chapter "Power supply modes" to understand the operating mode of the unit and let the unit select the faster measurement procedure.
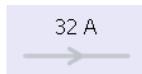
ℹ 32 A → A shortcut for current selection is available in the main screen; clicking in the current by winding drawing.

9.3.4 Temperature settings
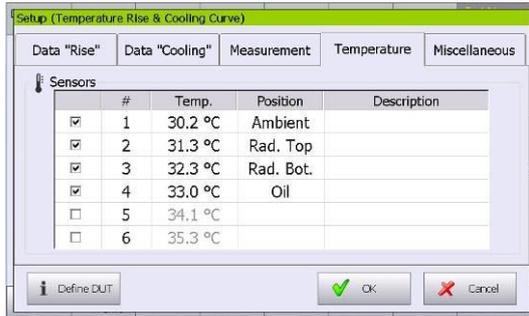
The temperature measuring screen is accessed clicking the Setup button, under the temperature folder in the function key bar.
Activate the used probes by clicking the left sided check box.
Click on the single probes line to enter the configuration dialog of the single probes (position & description)

Actual reading of the six temperature channels. To be added to the medium temperature they should be selected. A description (text) can be added to every temperature channel.
By clicking on a sensor line in this list you enter the temperature probe definition dialog:
Select the position where the sensor is mounted on the DUT by clicking on the transformer icon.
In the heat run measurements, the standard based calculations are implemented with respect to specific probe positions. (see related heat run chapters)
In resistance measurement only the simple mean temperature of the activated sensors is taken.

Here an additional text for the sensor can be added (e.g. when an external sensor is used on a cooler fan)

With these arrows you can toggle trough the single probes definitions without closing this dialog window.

 The temperature settings are common for the Temperature Rise and Cooling Curve functions

Liquid cooled transformers will use the ambient, oil, rad. top and rad. Bottom positions.
Dry type transformers are likely to use the ambient, winding and core positions.

9.3.5 Tap changer position selection

The tap position for the cooling curve test can be selected using the tap up/tap down button in the function key bar. The actual tap changer position is shown in the main screen.

  A shortcut for tap changer position selection is available in the main screen; clicking in the tap changer drawing, a popup screen will then arise allowing the selection of any tap position

9.3.6 Measurement Single Phase

Measurement consist on two steps, initiate the timer when the power supply is disconnected, and then, after connecting the instrument by clicking the start button.
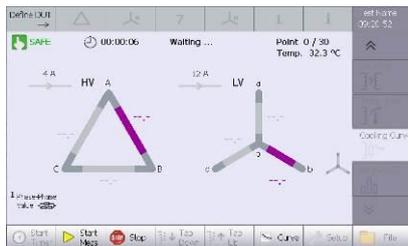
Start the timer when power supply is disconnected by clicking Start Timer, timer starts to count.
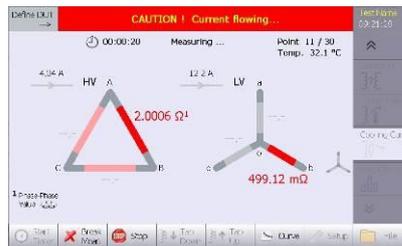
When instrument connected, click Start Meas, a reading is stored every defined time interval.
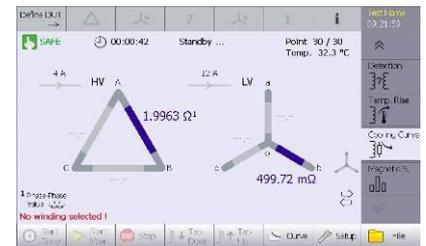
All measurement points recorded, measurement finalized, last measurement value is shown.

  Stops the resistance measurement but NOT the timer (with "Start Meas" the measurement can be reactivated)

9.3.7 Measurement 3 Phase Sequential

Measurement consist on two steps, initiate the timer when the power supply is disconnected, and then, after connecting the instrument by clicking the start button.
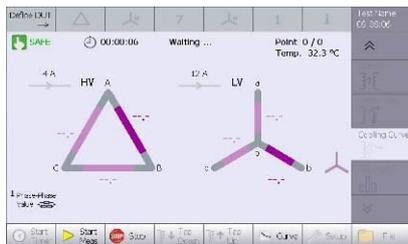
Start the timer when power supply is disconnected by clicking Start Timer, timer starts to count.
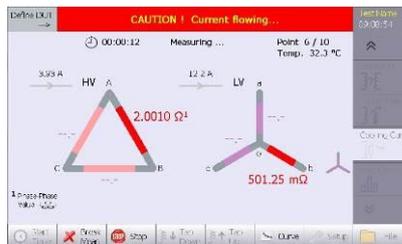
When instrument is connected, click Start Meas. Auxiliary measurements of the selected phase are recorded every second.
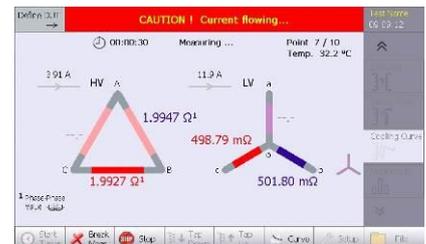
Auxiliary measurements of the selected second phase are recorded every second.
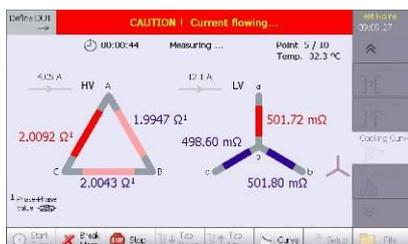
Auxiliary measurements of the selected third phase are recorded every second.
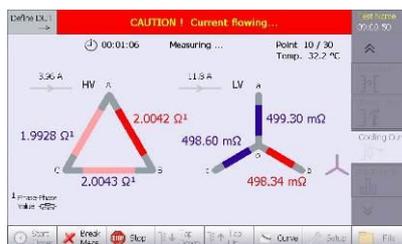
The main measurement. A reading is stored every defined time interval.
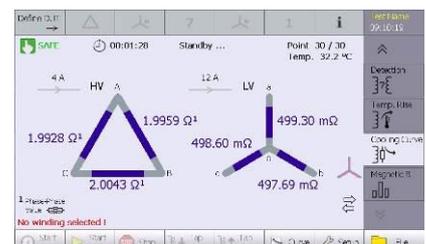
All measurement points recorded, measurement finalized, last measurement value is shown.

9.3.8 View Results

To see the measured results in graph format, select the Curve in the function key bar.
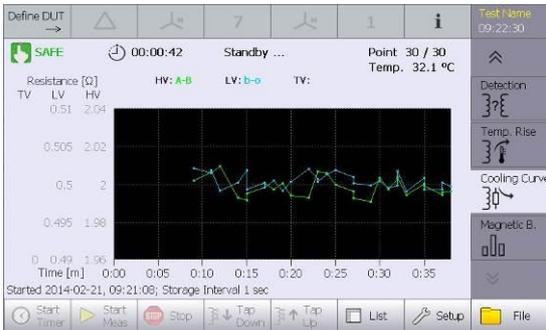
Measured results are shown in graph mode by selecting the curve button.

If additional tests of other phases, windings or taps are performed, the graph shows the results for the last 9 windings measured.

Time is shown from the point of disconnection.
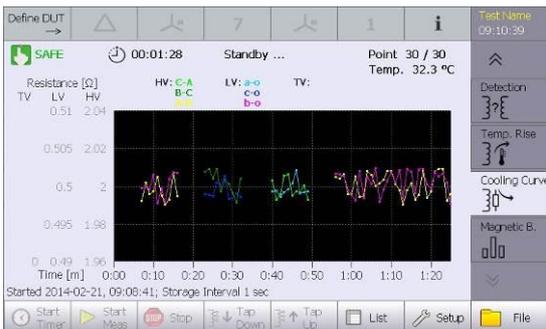
Measured results for a three phase (sequential) test display the readings during the (t2-t4) interval and the single phase measurements after time t4.

Time is shown from the point of disconnection. There are no readings during the charging/discharging time for each phase.

To see the measured results, select the List in the function key bar.

Measured results are shown in a table mode by selecting the list button.

The function keys in the bottom bar cycle through the sequence curve → list→ graphic → curve

9.3.9   Export results

See chapter "Data Handling" for information about exporting and printing results.

10 Heat Run - Temperature Rise

10.1 Overview

The 2293 is equipped with an optional temperature rise function. This optional feature is enabled using the license manager. This process only needs to be completed the first time temperature rise is used.

See chapter "Heat Run Cooling Curve" for a description of the theory of this test. Temperature rise performs the total loss injection and rated current injection phase of the heat run test before switching to the cooling curve function to perform the final phase of the heat run test.

10.2 User Interface
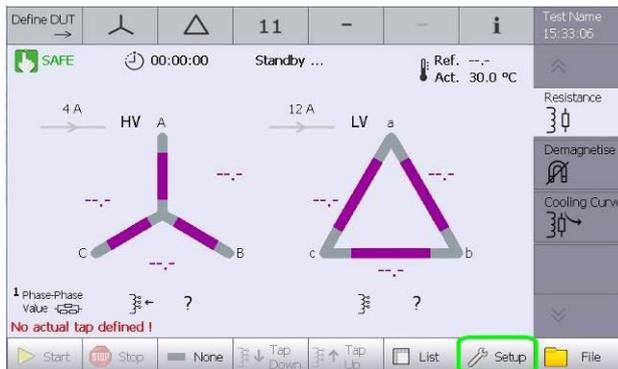
To access to the license manager, select setup function key in the bottom bar of any application

Select the Miscellaneous folder and then press the License Manager button.
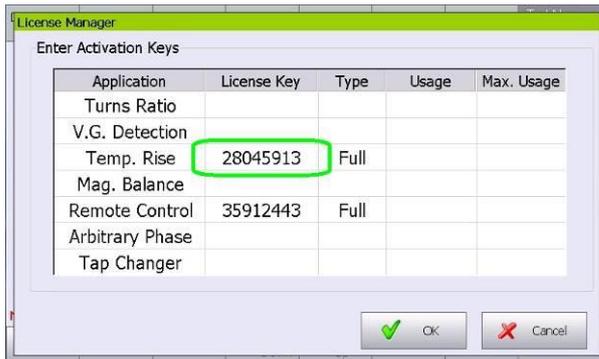
Enter the license key in the Temp. Rise box and press OK.

If the temperature rise function was previously used with a trial license key, clear this number and replace it with the full license key.
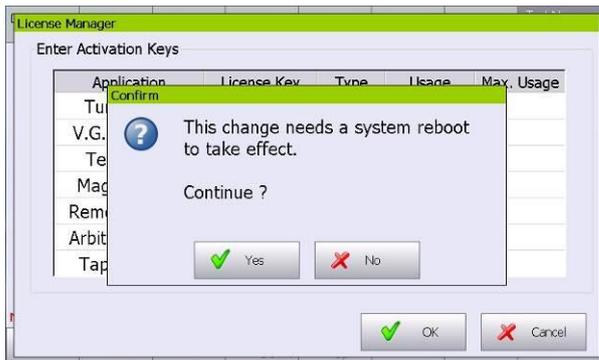
Press Yes to reboot the unit and install the detection function.
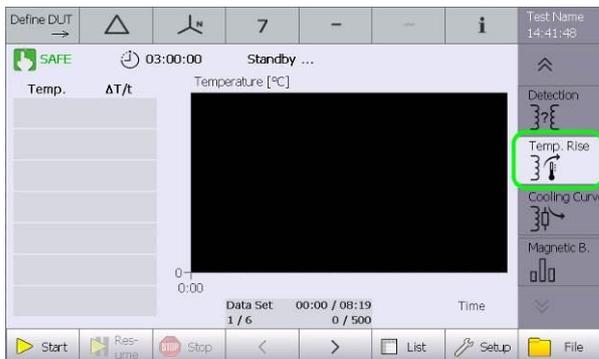
To access the detection feature, select temp. rise function in the applications bar (side bar).

You may need to press the up/down arrow buttons to view the temperature rise button depending on which other functions are enabled.
Trial licenses for temperature rise are available which permit a limited number of tests to be performed. The remaining number of tests is displayed on the license screen.
Removing the trial license key will remove the temperature rise function from the application bar.
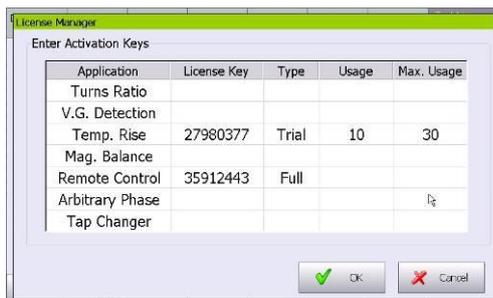
10.2.1 Active Window

The temperature rise function main screen components are described below.
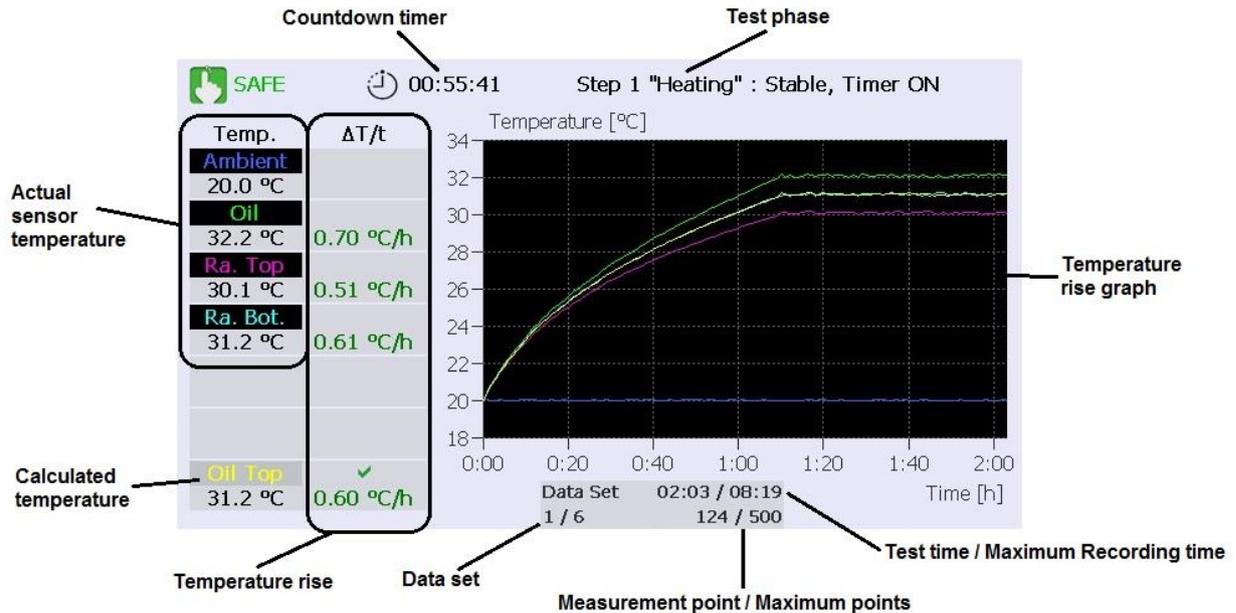
10.2.2 Function keys

While in temperature rise application, following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

Start	Start the temperature rise
Res-ume	Resume the temperature rise
Stop	Stop the temperature rise
Next	Jump to next step of the test
Cont-inue	Continue from step 1 "Heating" to step 2 "Rated current", or to Cooling curve
<	Move to previous data set
>	Move to next data set
List	Change display to list mode
Gra-phic	Change display to graphic mode
Setup	Open setup menu for the selected measuring application

10.3 Performing a Temperature Rise Test

10.3.1 Measurement Steps

Performing temperature rise test with the 2293, consist of following steps

```
Measuring parameters
definition
        │
        ▼
Temperature probe
setup
        │
        ▼
Apply total loss injection
        │
        ▼
Start test
        │
        ▼
Measuring

                        Liquid cooled or dry type
                        transformer?
                                │
                        Liquid  │
                                ▼
                        Apply rated current
                        injection
                                │
                                ▼
                        Continue test
                                │
                                ▼
                        Measuring
                                │
                                ▼
                        Change to cooling curve
                        function
                                │
                                ▼
                        Export and print results
```
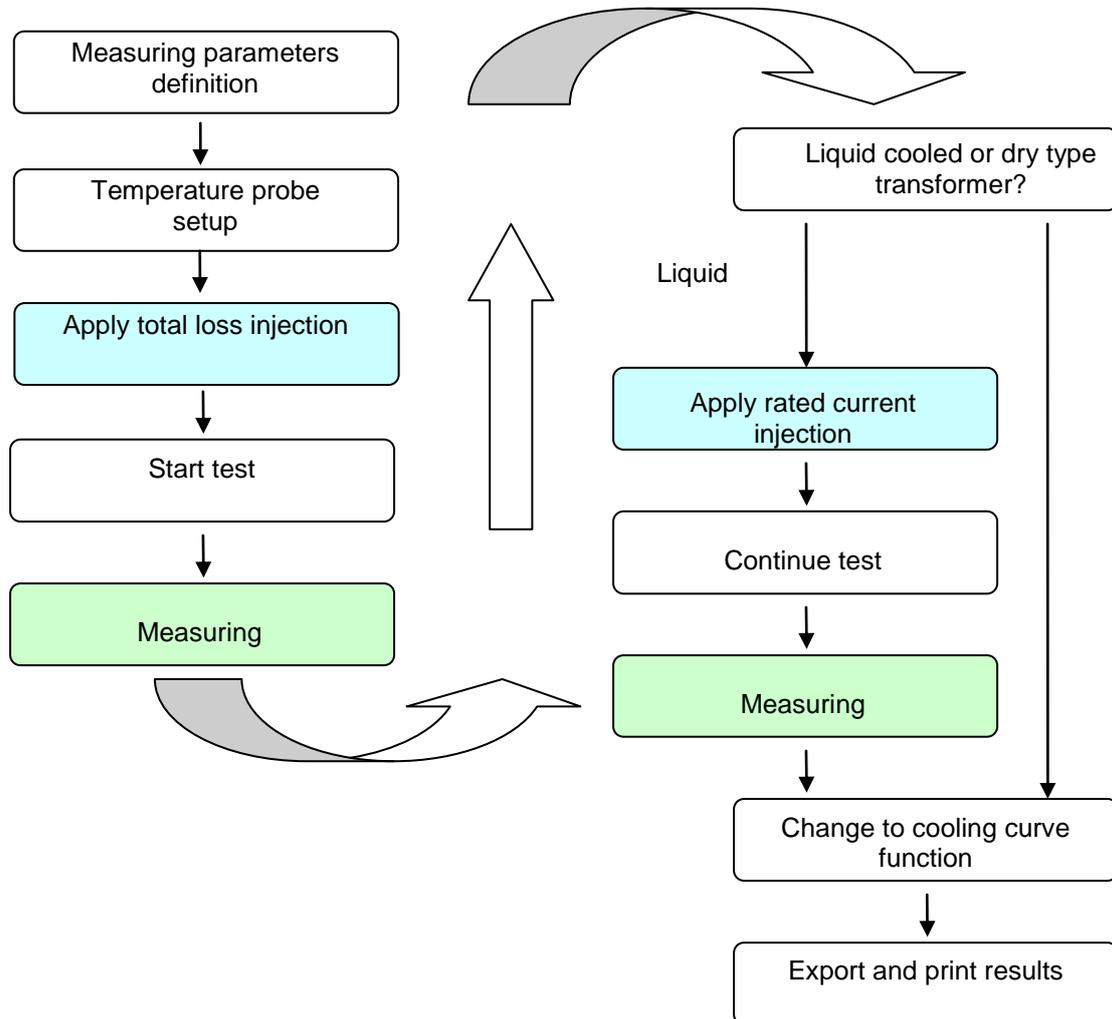
10.3.2 Recording Settings
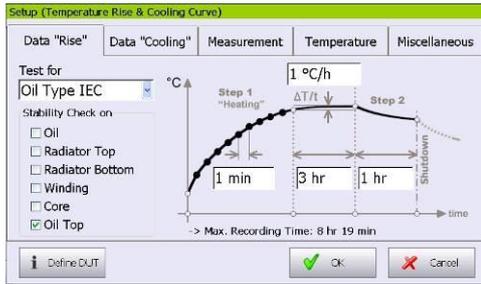
The temperature rise settings screen is accessed by clicking the Setup button in the function key bar when temperature rise is selected in the application bar.
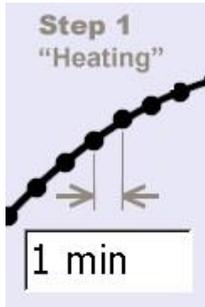
The interval (time between readings) can be selected by clicking in this field. Consider the predicted duration of the test when choosing a value because the test is limited to a maximum of 500 readings per data set.
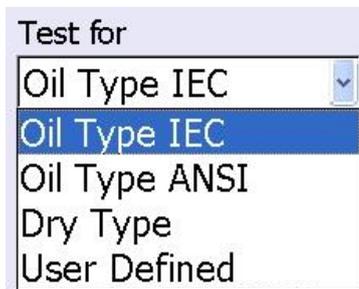
Click here to automatically configure the rate of change of oil temperature rise, the duration this must be stable and the duration of the rated current injection according to standard parameters.
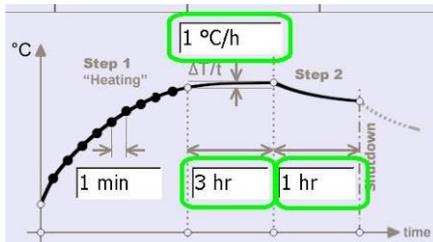
The User Defined option allows the rate of change of oil temperature rise, the duration this must be stable and the duration of the rated current injection to be manually configured. Clicking in the highlighted areas allows manual setup of these values.
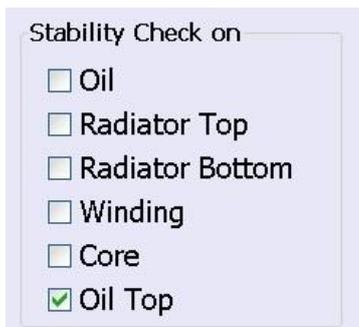
Stability check selects which temperature sensors are monitored during the heating and rated current steps of the test. If stability is not maintained the stable timer is reset.
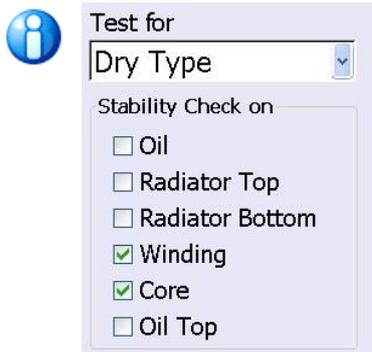
Liquid cooled transformers default to stability check on Oil Top. Dry type transformers default to stability check on winding and core.
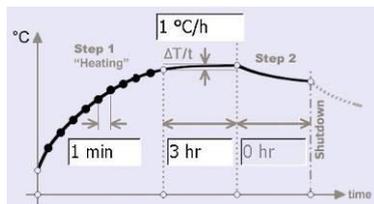
Dry type transformer setup is only for the heating part of the test. There is no step 2, rated current injection. It is only necessary to specify the temperature rise, stable temperature duration and recording interval.

10.3.3 Temperature Settings
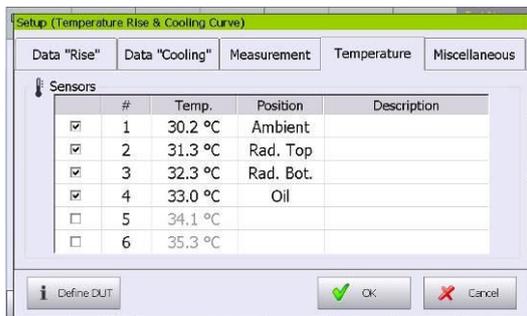
The temperature measuring screen is accessed by clicking the Setup button, under the temperature folder in the function key bar.
Activate the used probes by clicking the left side check box.
Click on the single probes line to enter the configuration dialog of the single probes (position & description)

Actual reading of the six temperature channels. To be added to the medium temperature they should be selected. A description (text) can be added to every temperature channel.
By clicking on a sensor line in this list you enter the temperature probe definition dialog:
Select the position where the sensor is mounted on the DUT by clicking on the transformer icon.
In the heat run measurements, the standard based calculations are implemented with respect to specific probe positions. (see related heat run chapters)
In resistance measurement only the simple mean temperature of the activated sensors is taken.

Here an additional text for the sensor can be added (e.g. when an external sensor is used on a cooler fan)

With these arrows you can toggle trough the single probes definitions without closing this dialog window.

The temperature settings are common for the Temperature Rise and Cooling Curve functions

Liquid cooled transformers will use the ambient, oil, rad. top and rad. Bottom positions.

Dry type transformers are likely to use the ambient, winding and core positions.

10.3.4 Liquid Cooled Transformer Measurement

Measurement consist of three steps, start the test when total loss injection is applied to the transformer and then press continue after the total loss phase is completed and the HV supply is reduced to rated current injection. Finally continue to the cooling curve application before the HV supply is switched off.
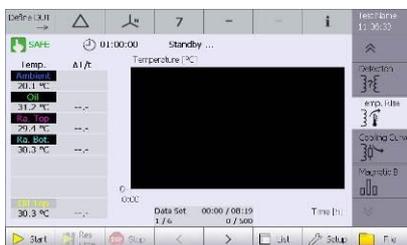
Click Start for temperature recording to begin when total loss injection is applied.
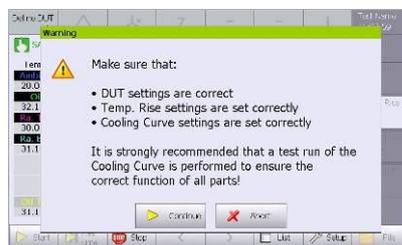
A warning message is displayed as a reminder that temperature rise and cooling curve must be setup before clicking Continue
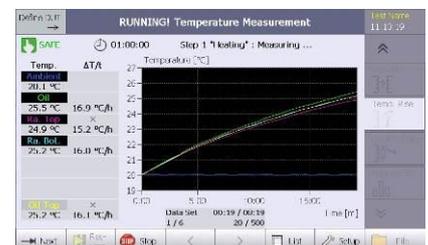
The latest readings are shown on the screen and the graph shows all the measurements from when the test was started.
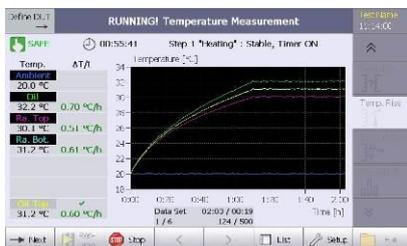
When the temperature rise reaches the setup value the status changes to green and the phase 1 timer starts to countdown. If the setup value is exceeded, the countdown will reset
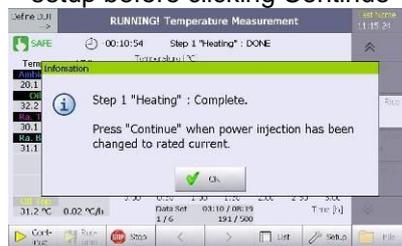
When the temperature rise has been maintained for the required time, the total loss injection is complete. Click OK to start the next phase of the test.

Apply the rated current injection and then click Continue to start phase 2 of the test.
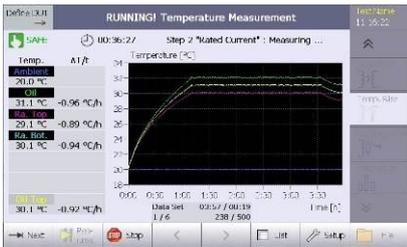
Temperature measurements continue while the phase 2 timer counts down.
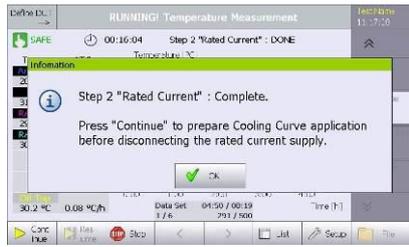
When the countdown is complete, click OK
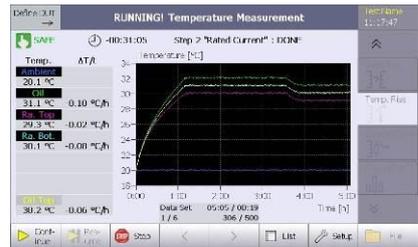
Click Continue to switch automatic from Temperature Rise to Cooling Curve application.
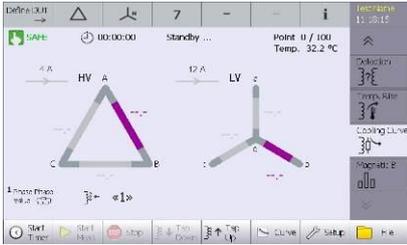
When the rated current injection is switched off, press Start Timer. Then connect immediately the measurement clamps to the transformer and press Start Meas

Temperature rise tests cannot be run unless one temperature position is defined in setup.

10.3.5 Dry Type Transformer Measurement

Measurement consists of only two steps. Firstly start the test when HV is applied to the transformer. Second continue to the cooling curve application before the HV supply is switched off.
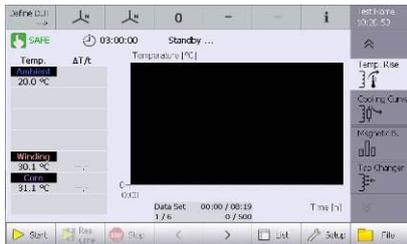
Click Start for temperature recording to begin when HV injection is applied.
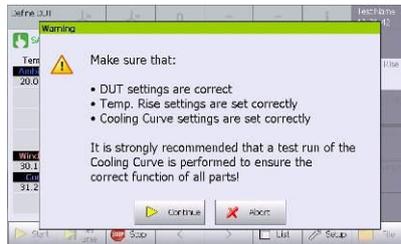
A warning message is displayed as a reminder that temperature rise and cooling curve must be setup before clicking Continue
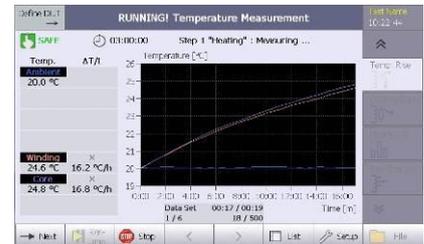
The latest readings are shown on the screen and the graph shows all the measurements from when the test was started.
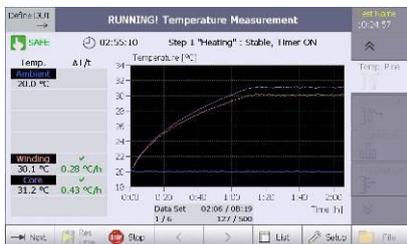
When the winding/core temperature rise reaches the setup value the status changes to green and the step 1 timer starts to countdown. If the setup value is exceeded, the countdown will reset
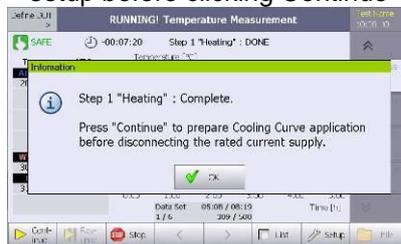
When the temperature rise has been maintained for the required time, the test is complete. Click OK
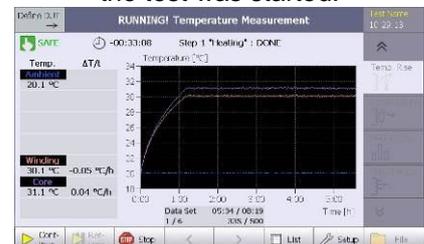
Click Continue to switch automatically from Temperature Rise to Cooling Curve application.
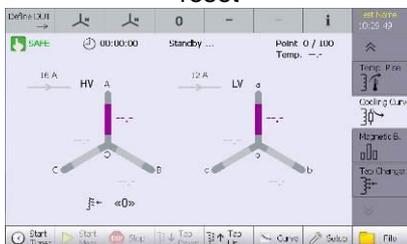
When the HV injection is switched off, press Start Timer.
Then connect immediately the measurement clamps to the transformer and press Start Meas

10.3.6 View Results

To see the measured results, select the List in the function key bar.

Measured results are shown in a table mode by selecting the list button.

The results shown are dependent on whether the transformer is liquid cooled or dry type and the sensor positions used during the test.

10.4 Export Results

See chapter "Data Handling" for information about exporting and printing results.

11 Transformer configuration Detection

11.1 Overview

The unit can perform automatic detection of the transformer winding configuration and the phase displacement. Typically this is used to check the winding connections of a known transformer type or to find out the configuration of an unknown type.

To access to this feature, **the equipment must be equipped with the Turns ratio option**, see chapter 12Turns Ratio Measurement

The function energises and measures the transformer using various different connections and shorting to determine the phase displacement. Further energisation and measurements are performed to determine whether there is a neutral connection on either the primary or secondary winding. Finally the likely transformer configurations are presented in the results grid. Less likely zig-zag configurations are also shown in a different color.

he function includes a user selectable threshold to control how close the reported phase angle must be to a perfect clock number phase shift. This allows differentiation of arbitrary phase shift transformers from standard phase shifts.

11.2 User Interface

The 2293 is equipped with an optional detection function. This optional feature is enabled using the license manager. This process only needs to be completed the first time detection is used.
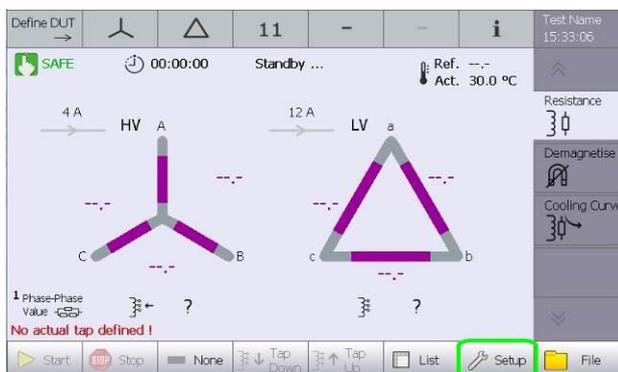
To access to the license manager, select setup function key in the bottom bar of any application
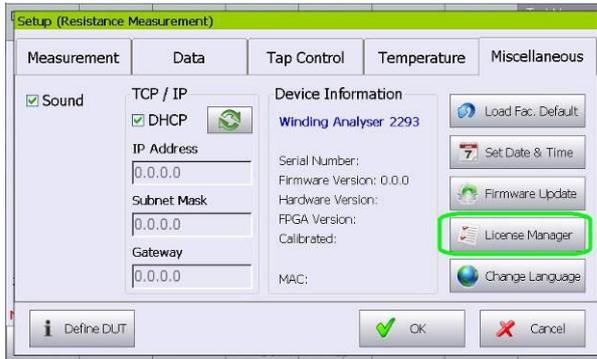
Select the Miscellaneous folder and then press the License Manager button.
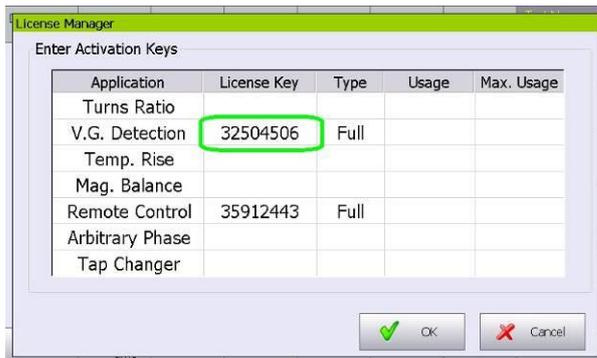
Enter the license key in the V. G. Detection box and press OK.

If the detection function was previously used with a trial license key, clear this number and replace it with the full license key.
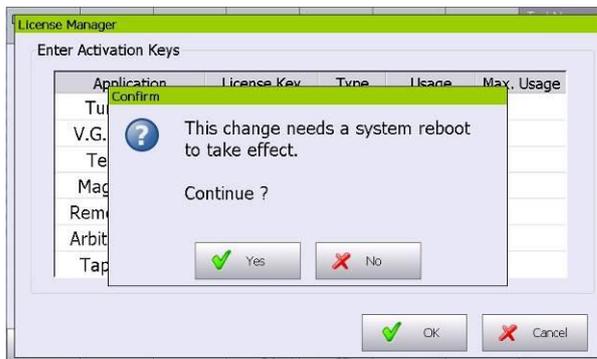
Press Yes to reboot the unit and install the detection function.
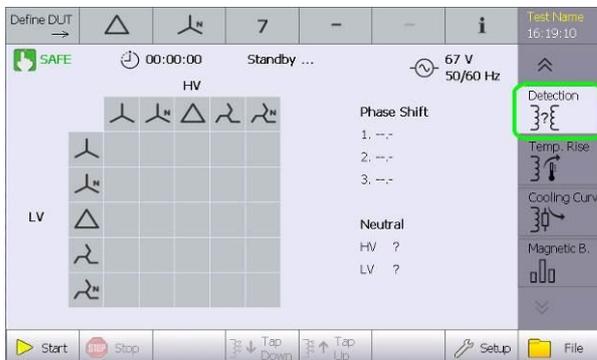
To access the detection feature, select detection function in the applications bar (side bar).

Transformer configuration
Detection

Tettex

You may need to press the up/down arrow buttons to view the detection button depending on which other functions are enabled.

Trial licenses for detection are available which permit a limited number of tests to be performed. The remaining number of tests is displayed on the license screen.

Removing the trial license key will remove the detection function from the application bar.

License Manager

Enter Activation Keys

Application	License Key	Type	Usage	Max. Usage
Turns Ratio				
V.G. Detection	32307898	Trial	5	30
Temp. Rise				
Mag. Balance				
Remote Control	35912443	Full		
Arbitrary Phase				
Tap Changer				

✓ OK   ✗ Cancel

11.2.1 Active Window

The detection function main screen components are described below.
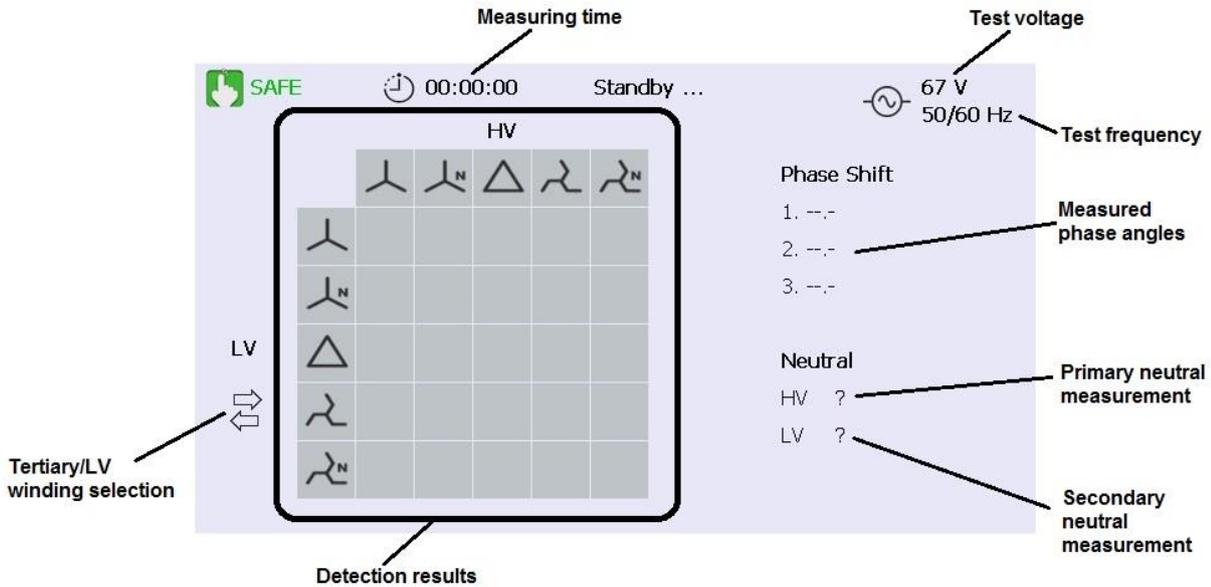
11.2.2 Function keys

While in detection application, following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

Start	Start the detection
Stop	Stop the detection
Tap Down	Move tap changer, that marked with ←, one step down
Tap Up	Move tap changer, that marked with ←, one step up
Setup	Open setup menu for the selected measuring application

11.3 Performing a Detection

11.3.1 Measurement steps

Performing vector group detection with the 2293, consist of following steps
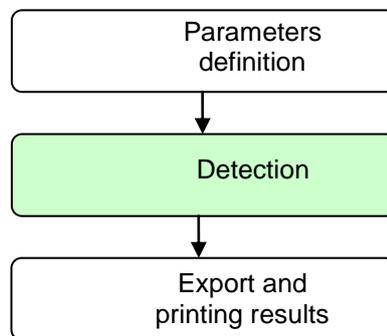
```
┌─────────────────────┐
│   Parameters        │
│   definition        │
└─────────────────────┘
          │
          ▼
┌─────────────────────┐
│   Detection         │
└─────────────────────┘
          │
          ▼
┌─────────────────────┐
│   Export and        │
│   printing results  │
└─────────────────────┘
```

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

11.3.2 Parameters definition

To define the application parameters, push the Setup button in the function key bar while in detection application.
Test Voltage:
Voltage used during the vector group detection. It is recommended to use as high a value as possible particularly with larger transformers or high ratio transformers.
Frequency:
Frequency of the test voltage applied during the test. This can be different than the DUT specification.
Threshold:
Limit used for phase angle detection
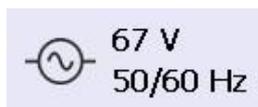
ℹ️ A shortcut for voltage selection is available in the main screen; clicking on the voltage text or symbol.

11.3.3 Detection

Click the start button and instrument will perform the vector group detection.
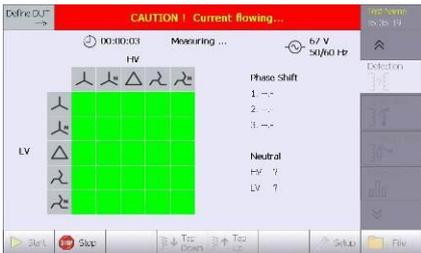
Voltage applied and detection measurements are running. The grid shows all transformer configurations are possible.
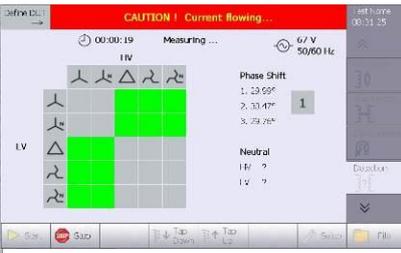
Phase angle measurements are completed. The grid shows a reduced set of possible transformer configurations and phase displacement of 1.
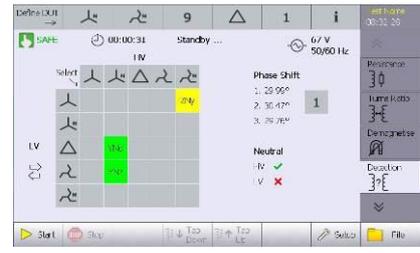
Neutral measurements are completed. The grid shows the likely transformer configuration in green and less likely configurations in yellow.
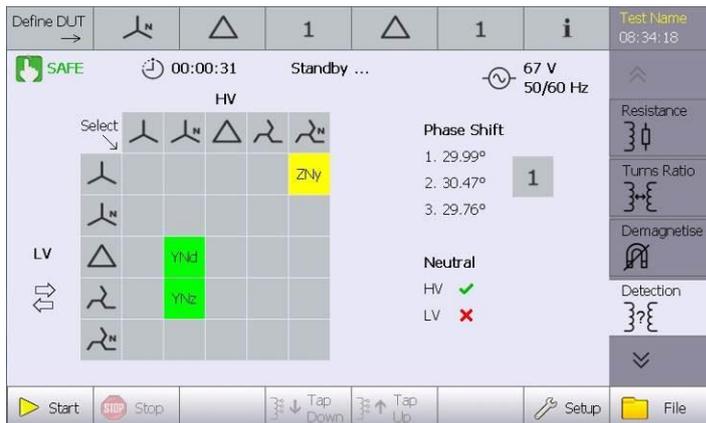
Press on the appropriate green or yellow square to preset "Define DUT" line (top bar) with the selected vector group, phase shift and neutral connection.

Note: It is not possible to change the transformer configuration shown in the Define DUT (top bar) if other functions have already stored results for the DUT.
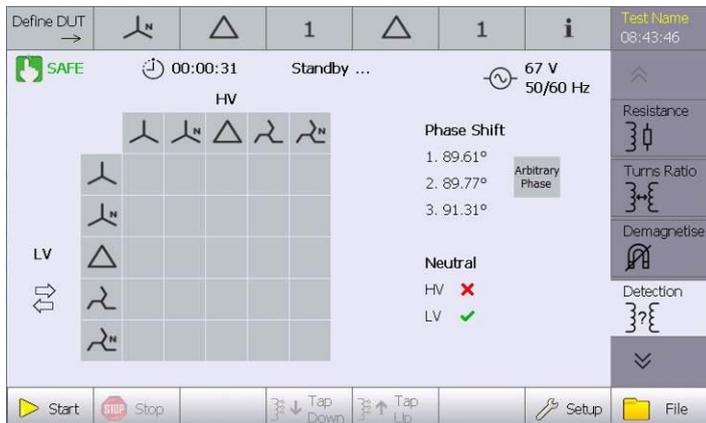
If the phase angle measurements are outside the phase threshold limit then Arbitrary Phase will be shown and no possible grid squares will be highlighted.

A shortcut for LV/tertiary winding selection is available on the main screen. Detection measurements are possible for HV/LV or HV/TV windings.

Transformer configuration
Detection

Tettex

After detecting HV/TV, pressing the <mark style="background-color:#00ff00">green</mark> or <mark style="background-color:#ffff00">yellow</mark> squares will set the HV/TV configuration in the DUT details (top bar).

11.3.4 Export results

See chapter "Data Handling" for information about exporting and printing results.

12 Turns Ratio Measurement

12.1 Overview

The unit can perform ratio measurements on all types of objects, but has been specially designed to measure ratios on highly inductive objects (as for example transformer's windings, generators windings, etc).

This **optional feature is enabled using the license manager**. This process only needs to be completed the first time magnetic balance is used. For instruction how to enable a feature please read Chapter 16 Optional Features activation.

12.2 Theory

12.2.1 Definitions

The term "Turns Ratio" (TR) is defined as the theoretical voltage ratio, the term "Voltage Ratio" (VR) as the ratio of the rated voltages ("boilerplate voltages").

$$TR = \frac{\text{Windings High Voltage side}}{\text{Windings Low Voltage side (LV turns)}}$$
TR   Turns Ratio

$$VR = \frac{\text{Phase to Phase Voltage}}{\text{Phase to Phase Voltage (Low Voltage side)}}$$
VR   Voltage Ratio

As a rule, the voltage ratio of three-phase transformers can be measured using a single-phase supply, as long as the distribution of magnetic flux in the core is taken into consideration. Only windings, winding segments and winding combinations which have the same magnetic flux applied, can be compared with one another. The measuring circuit can be derived from the phasor diagram of the test transformer's vector group. The two voltages which are to be compared must be in phase and have the same orientation.

But –depending on the winding configuration and phase rotation of the transformer - it's not possible to have always phase voltages which are being compared. The WA22293 therefore internally corrects the measurement with the "TR/(V_A/V_a)" factor and displays automatically the correct ratio value.

The TR/(V_A/V_a) factor determines how the turns ratio is calculated from the ratio of the energizing voltage to the output voltage of the winding. The ratio of the measured voltages are multiplied by this factor to give the turns ratio for that winding/tap.

Due to similar reasons the voltage ratio VR and the turns ratio TR is –depending on the winding configuration and phase rotation of the transformer – not always equal. The WA2293 therefore internally corrects the entered rated voltages (VR) with the "VR/TR" factor and displays automatically the correct ratio deviation which is calculated out of the rated voltages (boilerplate voltages) as reference and the actually measured (and corrected) ratio value.

The VR/TR factor determines the multiplier applied to the measured voltage ratio (VR) to get the turns ratio (TR) of the transformer. When the boilerplate voltages for the transformer are set up, the calculated voltage ratio is divided by this factor to give the nominal turns ratio for that winding/tap.

Note for the transformer configuration look up tables:

The "HV Connect" and "LV Connect" give the basic configuration for measuring the transformer to determine the turns ratio (TR). The actual applied configuration depends on the phase rotation of the transformer (see the "Phase Displacement" Info line)

Example: Dyn11 Transformer, HV-LV: 150kV-50kV, N_{HV}: 520 turns, N_{LV}: 100 turns	TR Turns Ratio VR Voltage Ratio NHV Number of HV-windings NLV Number of LV-windings

$TR = N_{HV} / N_{LV} = 520 / 100 = 5.2$
$(=>VR*\sqrt{3}=3*\sqrt{3}=5.2)$.

$VR = 150/50 = 3$.

12.2.2 Measurement Example

This section shows two different measurement examples to clarify the calculation and use of the results.

In the first example the DUT (YNd11 with turn fault on phase C) is measured as **YNd11**. Because the neutral is available, the 2293 can directly measure each individual phase. The system steps through the following procedure:

2. Connect to the DUT according the "Connection" column

3. Apply AC test voltage (in this case $25V_{RMS}$ / 55Hz)

4. Measure the "Ratio Raw" as U_{HV} / U_{LV}

5. Calculate the "Ratio Voltage" as "Ratio Raw" • "VR:RR" ($\sqrt{3}$ in this case)

6. Repeat 1-4 for the other two phases

7. Calculate "Ratio Turn" as "Ratio Voltage" • "TR:VR" (**1/√3** in this case)
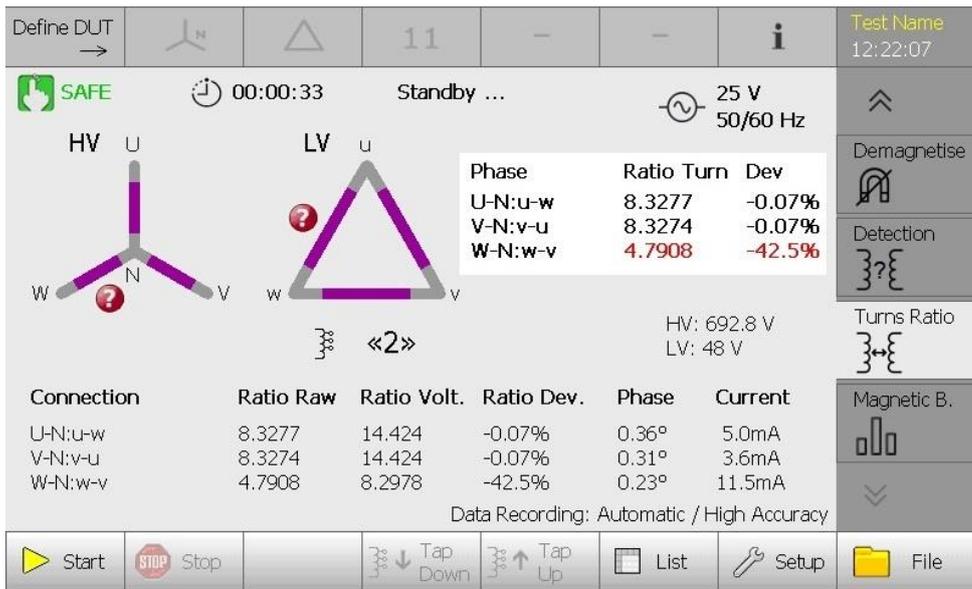
In the second example same the DUT as in the first example (YNd11 with turn fault on phase C) is measured as **Yd11**. Because the neutral is not available, the 2293 can not measure each phase individually. The measurement returns a combination of ratios of all three phases. The system steps through the following procedure:

1. Connect to the DUT according the "Connection" column

2. Apply AC test voltage (in this case $25V_{RMS}$ / 55Hz)

3. Measure the "Ratio Raw" as U_{HV} / U_{LV}

4. Calculate the "Ratio Voltage" as "Ratio Raw" • "VR:RR" (**2/√3** in this case)

5. Repeat 1-4 for the other two phases

6. Solve a system of equations generated by these three measurements to obtain the **true** "Ratio Turn"

When looking at the measurement sections ("Ratio Raw" and "Ratio Turns") of these two examples, we can clearly see a difference. If measuring without neutral (e.g. Y or Z) a deviation in only one Phase inflicts all three measurements. The deviations are -8.94%, -8.99% and -28.3% although there is a turn fault in only one phase. To locate the fault conclusively it is necessary to solve a system of equations, which can be solved only after all three individual measurements have been done. But it clearly reveals the fault location.

12.2.3 Tables

This table describes the method used to measure a certain transformer configuration. ZN is always handled the same way as Z. For simplicity the connection table is valid for a 0 or 1 clock number. For other clock numbers the connections are rotated/inversed accordingly.

VR:TR	Factor applied from Ratio Raw to Ratio Voltage
TR:VR	Factor applied from Ratio Voltage to Ratio Turns
TR Method	Method used to calculate the Ratio Turns
True TR	simply apply the TR:VR factor.
Con HV	HV Terminals used to perform a certain measurement
Con LV	LV Terminals used to perform a certain measurement

HV	LV	VR:RR	TR:VR	TR Method	True TR	Con HV	Con LV
		1 1.00000	1 1.00000	System of Equations	Yes	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
	N	1 1.00000	1 1.00000	System of Equations	Yes	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
		$2/\sqrt{3}$ 1.15470	$1/\sqrt{3}$ 0.57735	System of Equations	Yes	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
		$2/\sqrt{3}$ 1.15470	$\sqrt{3}/2$ 0.86603	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
N		1 1.00000	1 1.00000	System of Equations	Yes	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
N	N	1 1.00000	1 1.00000	Directly measured	Yes	H1-H0 H2-H0 H3-H0	X1-X0 X2-X0 X3-X0
N		$\sqrt{3}$ 1.73205	$1/\sqrt{3}$ 0.57735	Directly measured	Yes	H1-H0 H2-H0 H3-H0	X1-X2 X2-X3 X3-X1
N		$2/\sqrt{3}$ 1.15470	$\sqrt{3}/2$ 0.86603	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
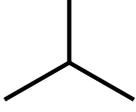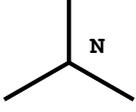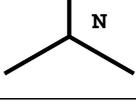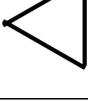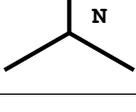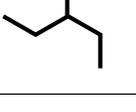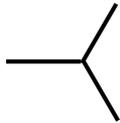
HV	LV	VR:RR	TR:VR	TR Method	True TR	Con HV	Con LV
		2/√3 1.15470	1/√3 0.57735	System of Equations	Yes	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
	N	1/√3 0.57735	√3 1.73205	Directly measured	Yes	H1-H2 H2-H3 H3-H1	X0-X2 X0-X3 X0-X1
		1 1.00000	1 1.00000	Directly measured	Yes	H1-H2 H2-H3 H3-H1	X1-X2 X2-X3 X3-X1
		1 1.00000	3/2 1.50000	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
		2/√3 1.15470	2/√3 1.15470	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
	N	2/√3 1.15470	2/√3 1.15470	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
		1 1.00000	2/3 0.66666	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
		1 1.00000	1 1.00000	VR • TR:VR	No	H1-H2H3 H2-H3H1 H3-H1H2	X1-X2 X2-X3 X3-X1
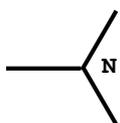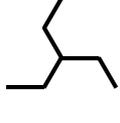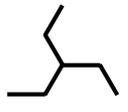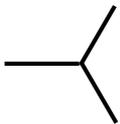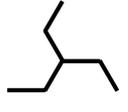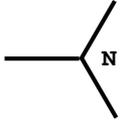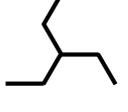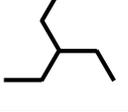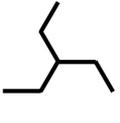
12.3 User Interface
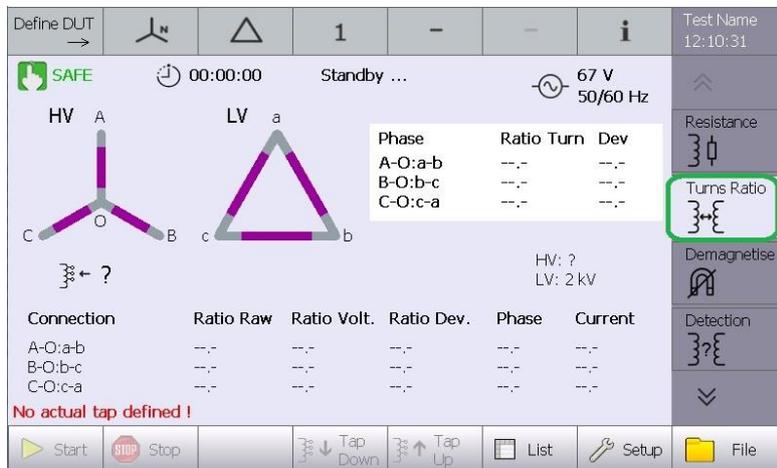
To access the turns ratio feature, select turns ratio function in the applications bar (side bar).

You may need to press the up/down arrow buttons to view the turns ratio button depending on which other functions are enabled.

12.3.1 Function keys

While in turns ratio application, following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

▷ Start		Start the measurement
↻ Record		Record a result while manual recording mode is used
🛑 Stop		Stop the measurement
↓ Tap Down		Move tap changer one step down
↑ Tap Up		Move tap changer one step up
▦ List		Change display to list mode
△人 Gra-phic		Change display to graphic mode
🔧 Setup		Open setup menu for the selected measuring application

12.3.2 Active Window

The turns ratio measurement screen is below described:
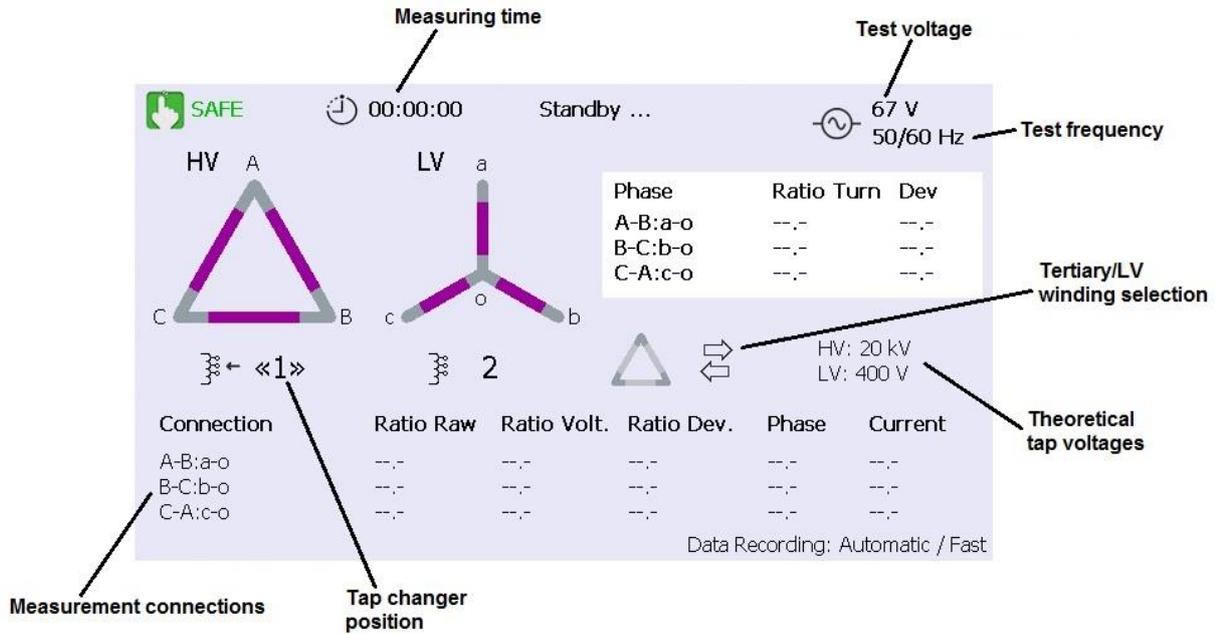
* SC = Shortcut; direct action or access to setup over touching

Tap Changer Visualization:

	Tap changer graphical representation
	"Remote Controlled" is active in dialog "Setup"
←	this winding is selected at "Tap Control" / "Winding" in dialog "Setup"
OnL	tap-changer is defined as "On Load" in "DUT" dialog
1	Actual tap position

12.4 Performing a Ratio Measurement

12.4.1 Measurement steps

Performing a turns ratio measurement on a transformer consist of following steps
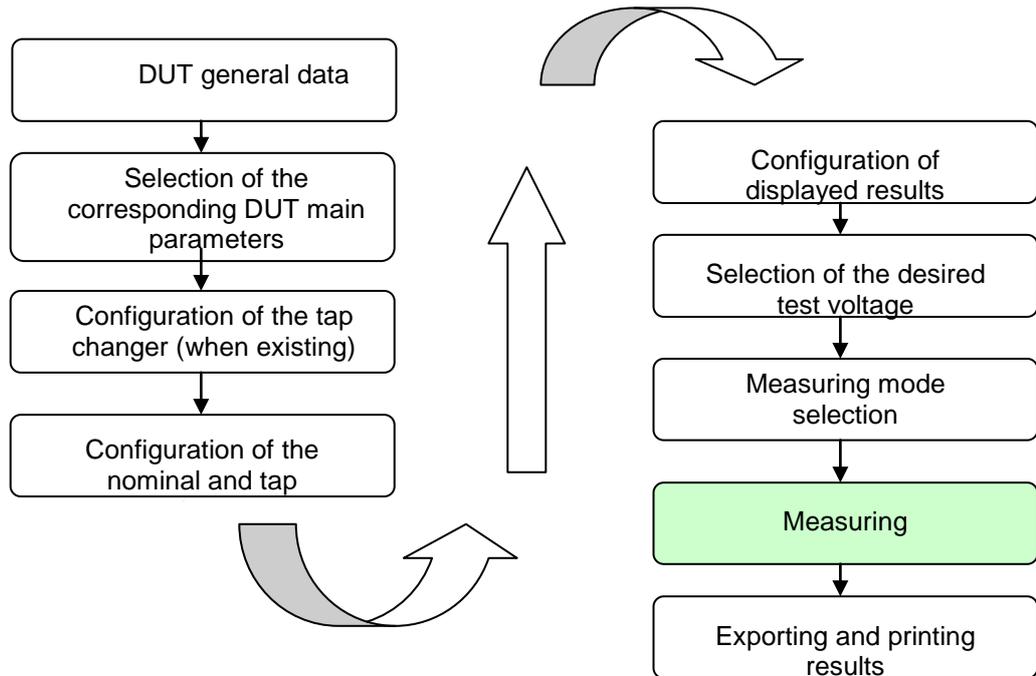
DUT general data

↓

Selection of the corresponding DUT main parameters

↓

Configuration of the tap changer (when existing)

↓

Configuration of the nominal and tap

Configuration of displayed results

↓

Selection of the desired test voltage

↓

Measuring mode selection

↓

Measuring

↓

Exporting and printing results

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

12.4.2 Set up DUT data

ℹ️ To set up the steps with DUT related data:
→ see related chapters in the "User Interface" part.
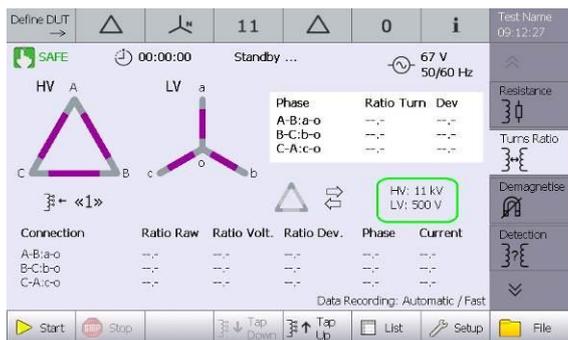
When tap voltages are defined, they are shown on the main screen as highlighted.

The turns ratio function can calculate the ratio deviation between the theoretical transformer ratios and the measured ratios. This data is optional, but if not entered the calculated ratio deviation will be blank (--,-).

12.4.3 Turns ratio measurement on Current instrument transformers

⚠️ Care has to be taken to ensure that the current transformer is connected correctly otherwise there is a risk of damage to the CT and Instrument. There is also the risk of injury.

ℹ️ When testing CT's, care has to be taken to ensure that the energization voltage does not cause saturation of the transformer core. It is recommended that the test voltage is limited to 5 VAC unless it is certain that the CT can tolerate a higher voltage.

ℹ️ If the CT saturates at 5VAC try using lower voltages. This is a problem that is more likely to be encountered with smaller transformers with a ratio of 20:1 or less, or with small cores such as "wedding ring" CTs..

CTs are measured by energizing the secondary and measuring on the primary. connect the system as follows:
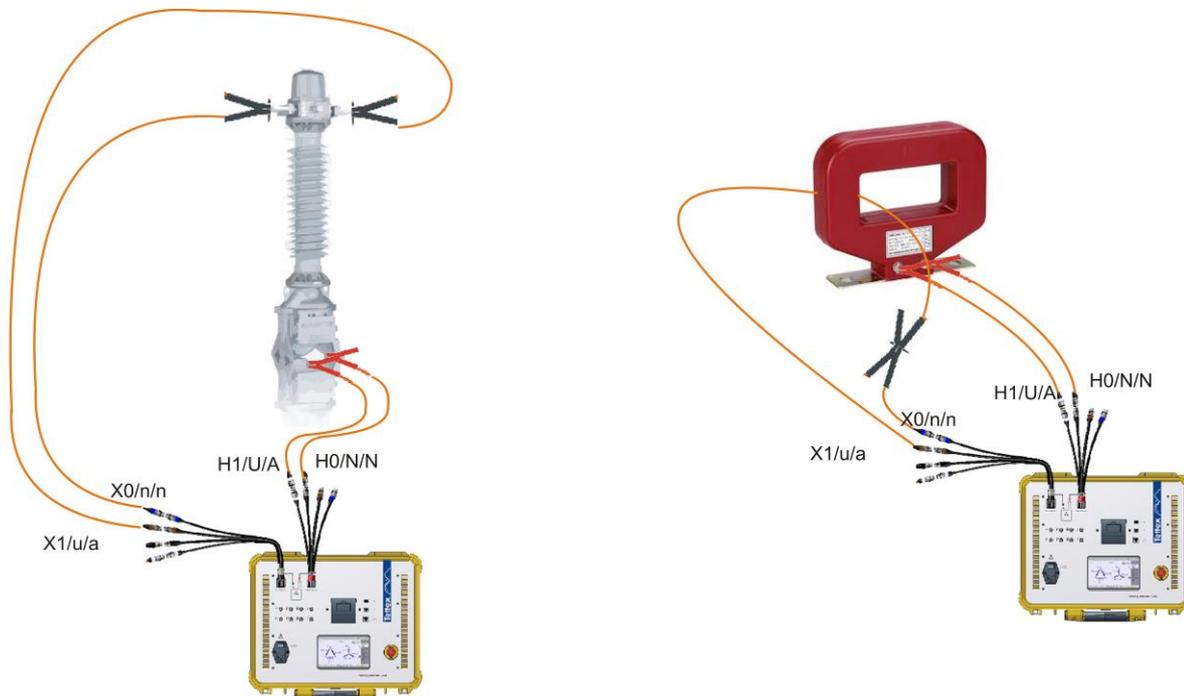
8.   *Connecting to a CT*

For core type current transformers, the "H" connections should be made to the secondary (Low current side) and the "X" connections made to the primary (High current side). The transformer can then be tested using single phase.

If the CT has multiple taps, these must be tested individually. Each tap on the secondary is tested in turn, by connecting the "H" connections to each tap in turn. How this is handled depends on whether the current transformer provides a single winding with multiple taps, or separate secondary windings.
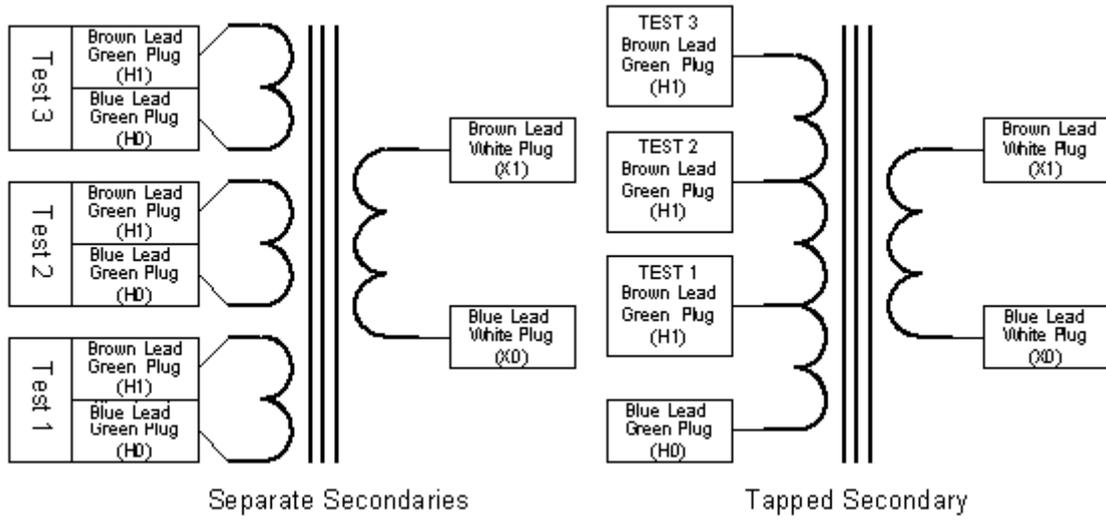
9. *Connecting to Tapped Current Transformers*

If the transformer is equipped with a tapped secondary, it is also possible to test the secondary by connecting it as an autotransformer to evaluate the relationship between the individual taps.

12.4.4 Data handling definitions

Storage:

Overwrite → when a measurement is repeated, results overwrite the actual measured values for the tap

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

Printout:

The printout option controls whether the default paper printout shows turns ratios or voltage ratios. This is limited by the width of the printer paper. Exported result data contains both values.

Zig-Zag Turns Ratio:

1 leg of Z → The turns on one limb of the zig-zag are included in the turns ratio.

Complete Z → The windings on both limbs of the zig-zag are included in the turns ratio.

Phase Display:

The phase display controls whether an arbitrary phase shift is shown in the range 0° to 360° or -180° to +180°.

12.4.5 Test Voltage Selection
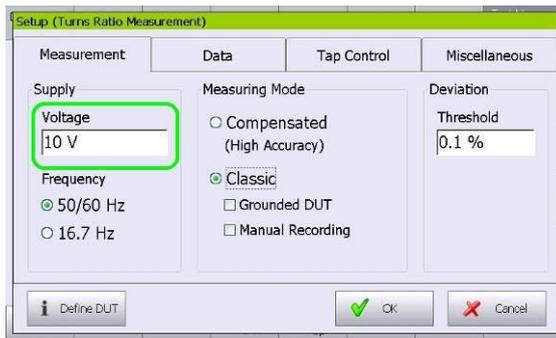
Selection of the measuring voltage is done by clicking on the test voltage field in the main screen, any value between 0 and 67V can be introduced, some values are directly selectable.

12.4.6 Test frequency selection
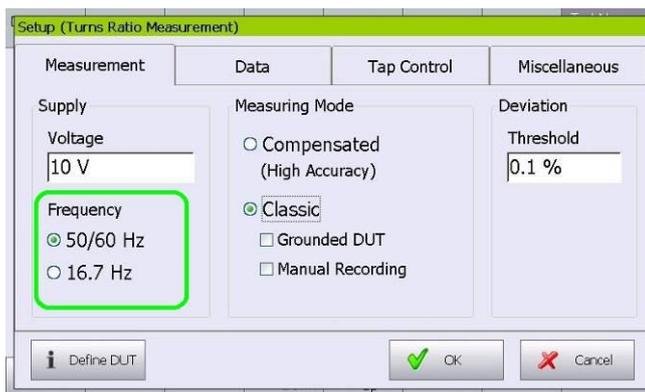
Selection of the measuring frequency is done automatically by the unit. Just select if your DUT is a 50/60Hz type or a 16.7Hz traction transformer type.

12.4.7 Ratio deviation selection
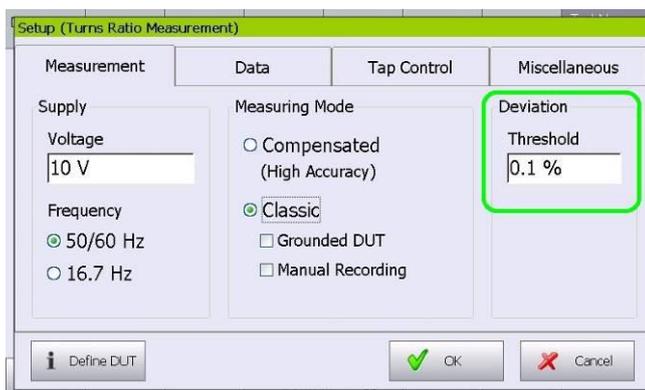
Threshold:

The ratio deviation threshold is the allowed percentage difference between the theoretical turns/voltage ratios and those measured during the test.
The test results will be highlighted in red if this threshold is exceeded.

Shortcut buttons show typical ratio deviation values. Alternatively the user defined field allows values between 0.001% and 100%

12.4.8 Measuring mode selection

The turns ratio function has two measuring modes:

Classic mode (Fast): This is the standard method for determining the Transformer Turns Ratio. It performs a single measurement per Phase by applying sinusoidal AC Voltage (up to 67V RMS) to the High Voltage side of the transformer. The voltages are measured simultaneously on the corresponding High and Low Voltage Phases and thereof the Ratio is calculated.

Compensated mode (High accuracy): This is an advanced method for determining the Transformer Turns Ratio. It increases the accuracy of Turns Ratio measurements of Power and Distribution Transformers where the actual Turns Ratio matches the No-Load Voltage Ratio. This method performs multiple Classic Ratio Measurements per Phase. Using the results of these measurements the components of a transformer equivalent circuit can be calculated. The purpose of this equivalent circuit is to compensate non-linear effects affecting Ratio Measurement accuracy at lower test voltages. In the manner described the turns ratio (N1:N2) can be calculated more accurate compared to the classic method, because the voltage ratio is physically a slight non-linear function of the excitation voltage.

(This is not an appropriate method for measuring PTs, because they have a Turns Ratio which differs from their No-Load Voltage Ratio to compensate for their losses).
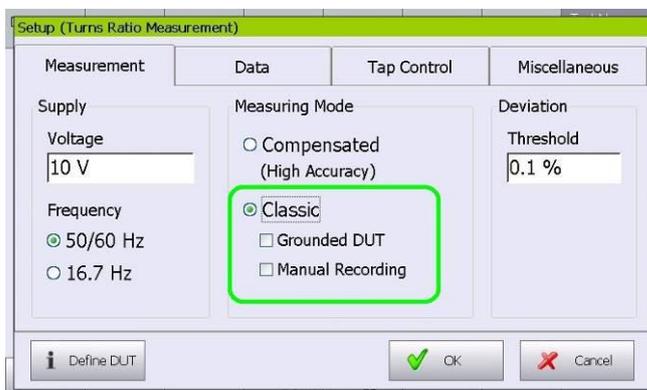
Classic Mode:

Grounded DUT → If the test transformer is grounded, select this option and select Classic Mode

Manual recording → Only accessible in Classic Mode. Each phase will be repeatedly measured until you press continue.

Compensated mode is not available when CT/PT is tested or for grounded transformers.
If the ratio is too high for compensated mode, the measurement will automatically use classic mode.
Shortcut to DUT setup. Similar to pressing

i on main screen

12.4.9 Measuring

Performing a measurement on a transformer is quite simple. Once all transformer and options have been introduced; just click the start button. The instrument will perform all operations automatically.

Before starting the test, a screen showing the tap position that will be measured arises. Tap changer must be positioned in this position. Measurement sequence depends on the tap changer configuration menu.

Click start button to initiate the test

Automatic measurement running

Measurement results

If auto recording is active, instrument will record the value and stop the measurement when the stabilization condition has been reached.

If manual recording is active, the instrument will repeatedly measure a phase.
Pressing the record button stores the latest result and moves to the next phase.

Connection shows the energisation, measurement and shorting connections used in the test

Ratio raw shows the measured voltage ratio using the connections

Ratio volt shows the actual voltage ratio of the transformer taking into account the measurement connections and the configuration of the transformer.

Ratio dev is the percentage voltage ratio error between the measured and theoretical values. This will appear as --.- if nominal/tap voltage data has not been entered.

Phase shows the phase shift between the energisation and measurement connections.

Current shows the primary excitation current during the measurement.

The white box shows the measured turns ratio and the turns ratio deviation between the measured result and the theoretical value.
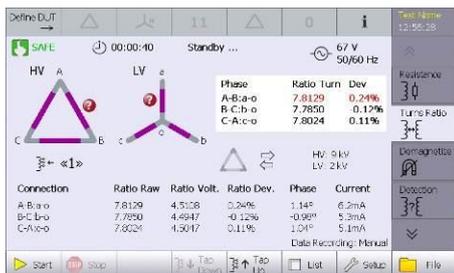
Ratio results which exceed the ratio threshold value are highlighted in red. The corresponding windings display the symbol.
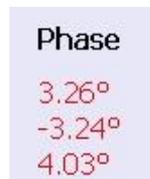
Phase shifts greater than 3° are highlighted in red.

Measurements will be automatically saved after each test. Data storage options can be selected in the Data folder, clicking in the setup button of the function key bar.

Overwrite → when a measurement is repeated, results overwrite the actual measured values

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

Results can also be shown as a table list, selecting the list button in the function key bar.
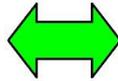
Clicking the voltage column changes the report to show ratio deviation.
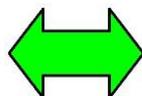
Clicking the ratio turn column changes the report to show ratio volt.

Clicking the phase column changes the report to show decimal or degrees/minutes

Phase
1.03°
-1.26°
1.06°
1.29°
-1.02°
1.35°

Phase
1°2'
-1°16'
1°4'
1°17'
-1°1'
1°21'

12.4.10   Exporting and printing results

See the chapter "Data Handling" for information about exporting and printing results.

12.5 Arbitrary Phase

Arbitrary phase displacement (those that don't follow the 30° clock steps) between the primary and secondary winding are an usual feature in multi-winding transformers like rectifier transformers, to reduce harmonics injected into the system (increasing the number of rectifier phases to increase the number of pulses in the rectified dc signal).

In the 2293 arbitrary phase shift measurement is achieved by using a single-phase supply with no extra hardware. The necessary three phase equivalent voltages at different transformer terminals are simulated by energizing a pair of the transformer terminals and interconnecting certain other terminals. The resulting voltages at different terminals is used to determine the arbitrary phase shift.

12.6 Activate the Arbitrary Phase option

The 2293 is equipped with an optional turns ratio function. This optional feature is enabled using the license manager. This process only needs to be completed the first time turns ratio is used.
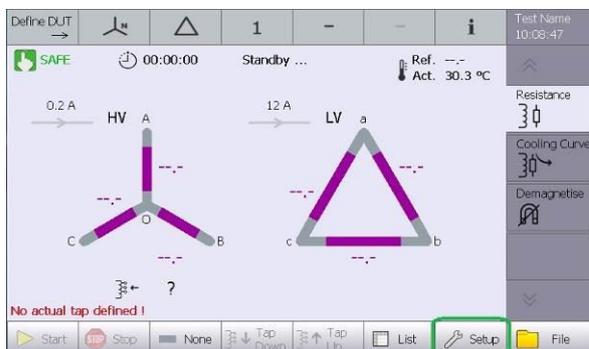
To access to the license manager, select setup function key in the bottom bar of any application

Select the Miscellaneous folder and then press the License Manager button.
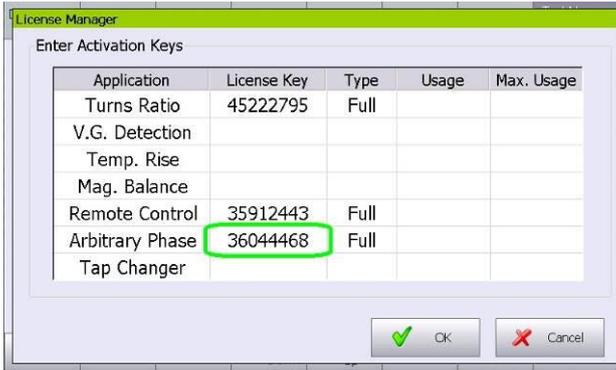
Enter the license key in the "Arbitrary Phase" box and press OK.

If the arbitrary phase function was previously used with a trial license key, clear this number and replace it with the full license key.
A turns ratio license must be present for the arbitrary function to be active.
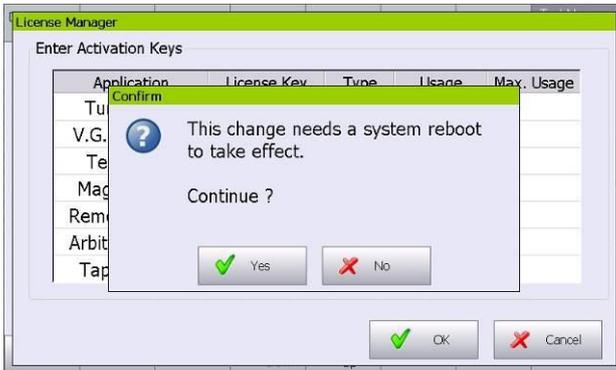
Press Yes to reboot the unit and install the arbitrary phase function.
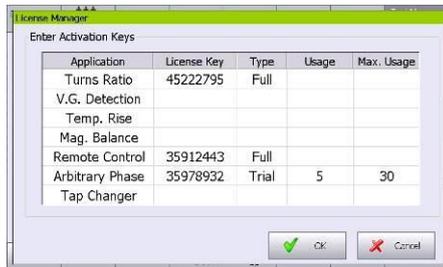
Trial licenses for arbitrary phase are available which permit a limited number of tests to be performed. The remaining number of tests is displayed on the license screen.
Removing the trial license key will remove the arbitrary phase function.

12.7 User Interface

12.7.1 Setup
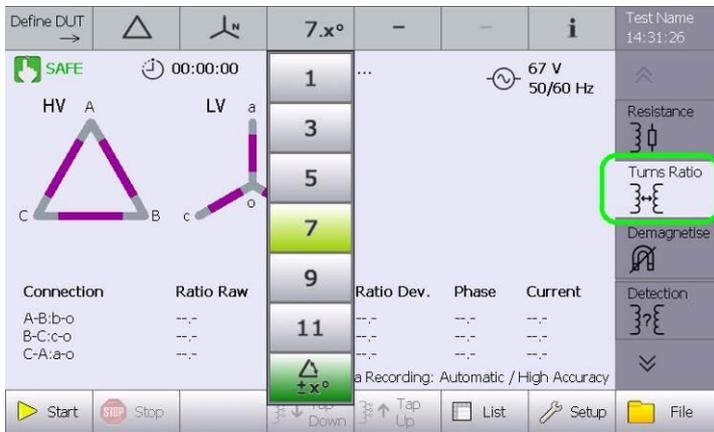
To access the arbitrary phase feature, select turns ratio function in the applications bar (side bar).

Set the DUT winding types. Select in the phase displacement drop down list the closest clock number and also activate there the "Arbitrary" button in the lowest position.

The arbitrary measuring mode is activated now. This is stated in the DUT phase displacement info as clock number.x°   (e.g. 7.x°)

If Define DUT has the "3phase unconventional transformer" setting selected, the arbitrary mode in the turns ratio application is preset automatically.

12.7.2 Function Keys and Setup

See the chapter Turns Ratio Measurement User Interface for information about the function keys.

DUT and test setup is similar to making a turns ratio measurement and so the chapters Turns Ratio Measurement Setup DUT Data and Data Handling Definitions give details of this.

12.7.3 Active Window
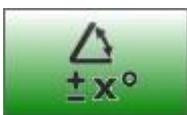
When the arbitrary phase shift is selected the measurement screen displayed is described below. An example use would be a transformer with a zig-zag winding where each leg of the zig-zag has a different number of turns.

Measuring time — Test voltage

SAFE 00:00:00 Standby … 67 V 50/60 Hz — Test frequency

HV A   LV a
c   B   c   o   b

⅀← «1»   ⅀ 2   Tertiary/LV winding selection

HV: 132 kV
LV: 11.5 kV — Theoretical tap voltages

Connection	Ratio Raw	Ratio Volt.	Ratio Dev.	Phase	Current
A-B:a-o	--.-	--.-	--.-	--.-	--.-
B-C:b-o	--.-	--.-	--.-	--.-	--.-
C-A:c-o	--.-	--.-	--.-	--.-	--.-

Data Recording: Automatic / High Accuracy

Measurement connections   Tap changer position
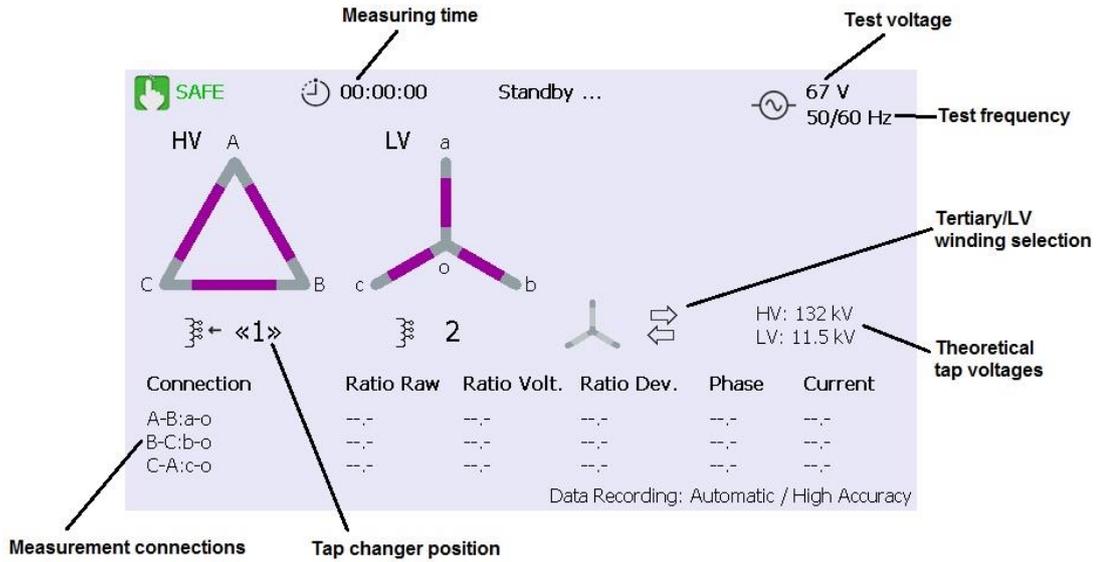
When the unconventional transformer is selected the measurement screen displayed is described below. No transformer windings are shown due to the unconventional nature of the device. An example usage would be a quad-booster transformer.

Measuring time — Test voltage

SAFE 00:00:00 Standby … 67 V 50/60 Hz — Test frequency

△ˣ° arbitrary phase

Tertiary/LV winding selection

HV: 132 kV
LV: 11.5 kV — Theoretical tap voltages

⅀← «1»   ⅀ 2

Connection	Ratio Raw	Ratio Volt.	Ratio Dev.	Phase	Current
A-BC:a-b	--.-	--.-	--.-	--.-	--.-
B-CA:b-c	--.-	--.-	--.-	--.-	--.-
C-AB:c-a	--.-	--.-	--.-	--.-	--.-

Data Recording: Automatic / High Accuracy

Measurement connections   Tap changer position
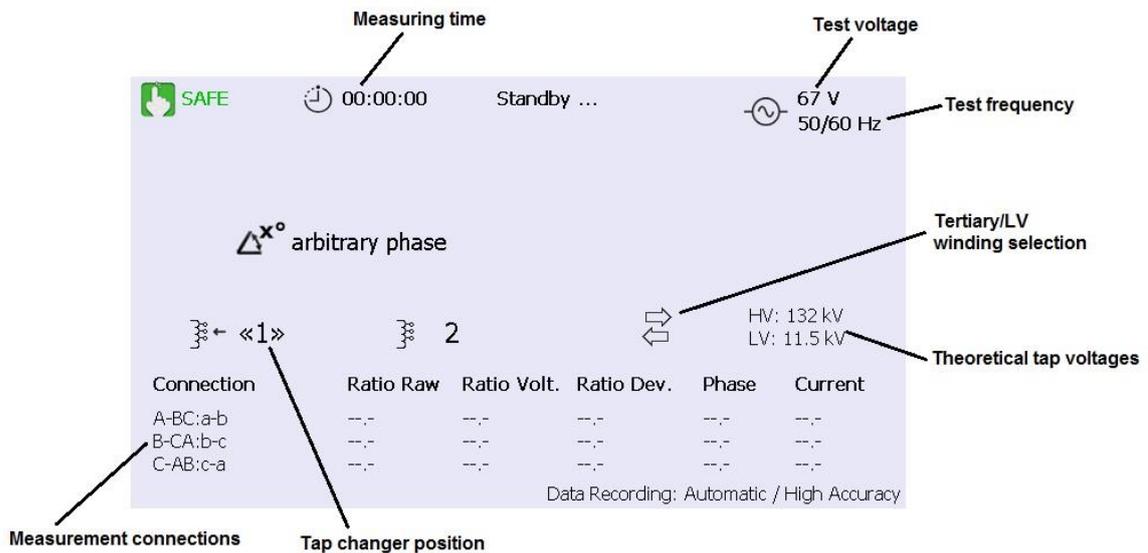
12.7.4 Measuring

Performing an arbitrary phase measurement on a transformer is similar to a turns ratio measurement. Once all the transformer settings and options have been entered, just click the start button. The instrument will perform all operations automatically.
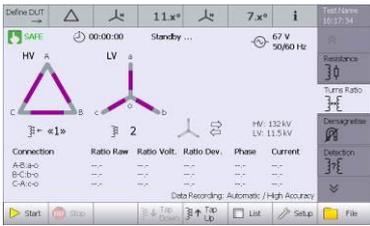
Click start button to initiate the test
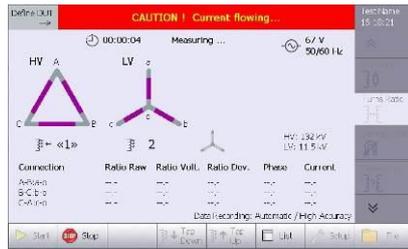
Automatic measurement running
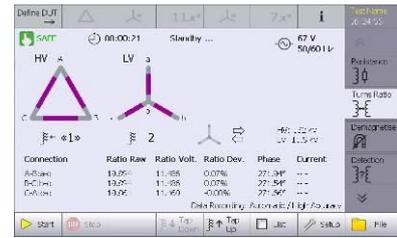
Measurement results

Connection shows the energisation, measurement and shorting connections used in the test

Ratio raw shows the measured voltage ratio using the connections

Ratio volt shows the actual voltage ratio of the transformer taking into account the measurement connections and the configuration of the transformer.

Ratio dev is the percentage voltage ratio error between the measured and theoretical values. This will appear as --.- if nominal/tap voltage data has not been entered.

Phase shows the phase shift between the energisation and measurement connections.
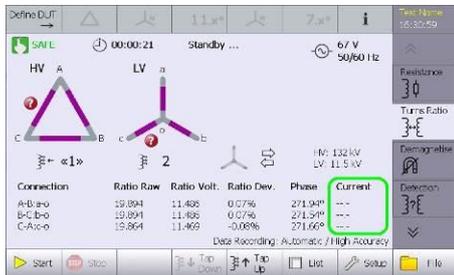
Current shows -,--. The primary excitation current during the measurement is not shown because several different single phase measurements are taken for each connection and used to calculate the voltage ratio and phase angle.
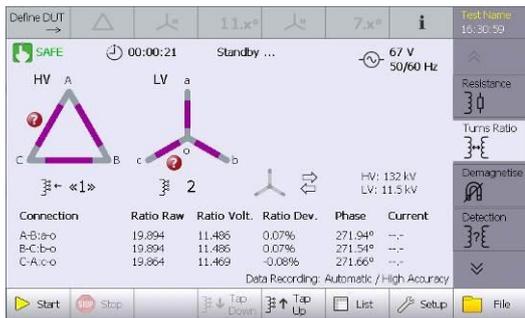
Ratio results which exceed the ratio threshold value are highlighted in red. The corresponding windings display the ![symbol] symbol.
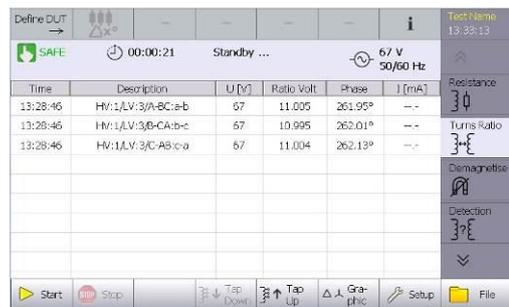
Results can also be shown as a table list, selecting the list button in the function key bar.

Current I [mA] will always show -,-- as in the graphic view.

The phase display setup option controls whether an arbitrary phase shift is shown in the range 0° to 360° or -180° to +180°.

Note that the phase angle shown is the complete angle between HV and LV or HV and TV and does not include the clock number/phase displacement.

For example a standard Dy11 transformer measured using the Dy11.x° or unconventional transformer DUT setup would show 330° if measured using the 0..360° option or -30° if measured using the +/-180° option.
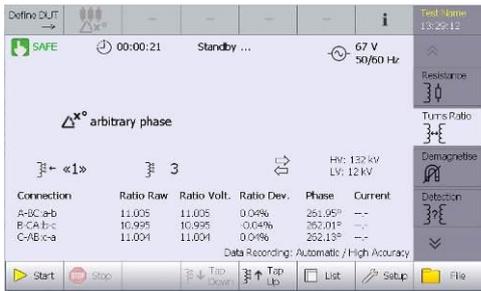
The test procedure for an unconventional transformer is similar but the red highlights are not shown because the winding arrangement is unknown.

13 Magnetic Balance

13.1 Overview

The unit can perform magnetic balance measurements on transformers. This particularly useful for checking the balance after a DC test current has been applied to the transformer during a resistance measurement which may have caused the core to become magnetized.

This **optional feature is enabled using the license manager**. This process only needs to be completed the first time magnetic balance is used. For instruction how to enable a feature please read Chapter 16 Optional Features activation.

13.2 Theory

The Magnetic Balance test is conducted on Transformers to identify inter-turn faults, magnetic imbalance or the flux distribution.

It can be conducted either in HV side or LV side of the transformer.

On the HV side, a voltage is applied across 2 phases (say 1U and 1V) and the voltage across the other phases is measured (between U-W and V-W). The test is repeated for each of the three phases.

Result: The sum of the two measured voltages will be equal to the applied voltage.

1U1V = 1U1W + 1V1W

The voltages obtained in the secondary will also be proportional to the voltages above.

This indicates that the transformer is magnetically balanced. If there is any inter-turn short circuit that may result in the sum of the two voltages not being equal to the applied voltage.

13.3 Activate the Magnetic Balance option

The 2293 is equipped with an optional magnetic balance function. This optional feature is enabled using the license manager. This process only needs to be completed the first time magnetic balance is used.
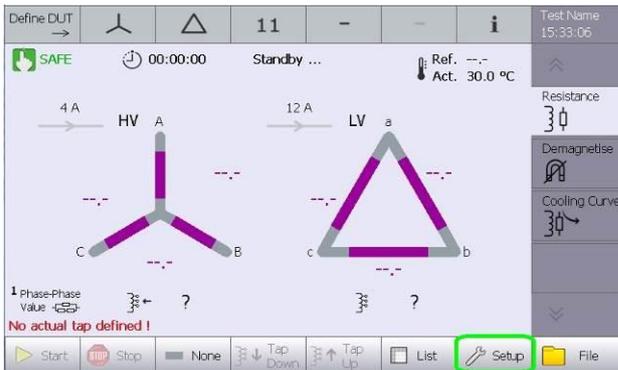
To access to the license manager, select setup function key in the bottom bar of any application
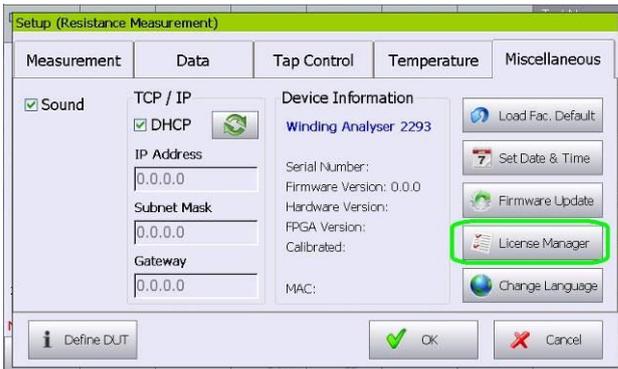
Select the Miscellaneous folder and then press the License Manager button.
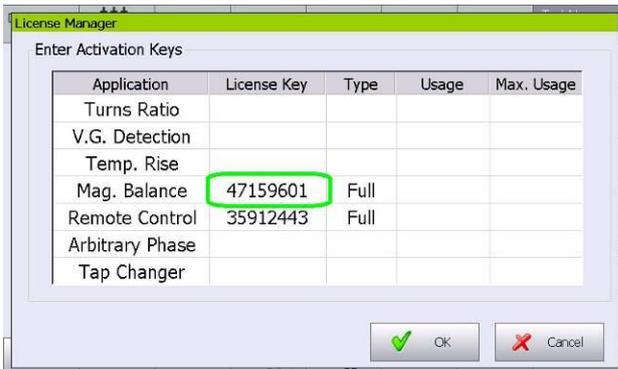
Enter the license key in the Mag. Balance box and press OK.

If the magnetic balance function was previously used with a trial license key, clear this number and replace it with the full license key.

Press Yes to reboot the unit and install the magnetic balance function.
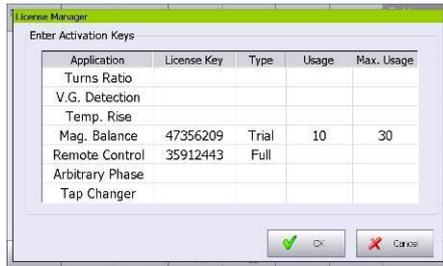
Trial licenses for magnetic balance are available which permit a limited number of tests to be performed. The remaining number of tests is displayed on the license screen.

Removing the trial license key will remove the magnetic balance function from the application bar.

13.4 User Interface
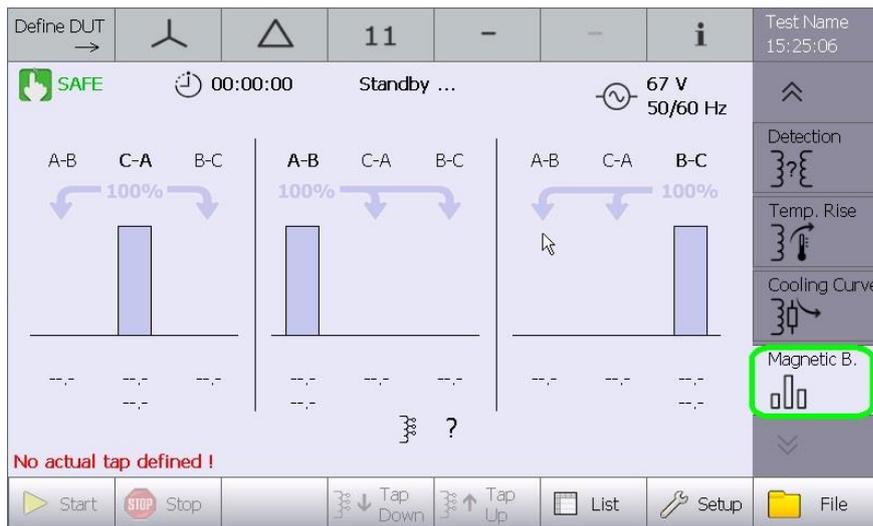
To access the magnetic balance feature, select Magnetic B. function in the applications bar (side bar).

You may need to press the up/down arrow buttons to view the magnetic balance button depending on which other functions are enabled.

13.4.1 Function keys

While in magnetic balance application, the following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

▷ Start	Start the measurement
Record	Record a result while manual recording mode is used
STOP Stop	Stop the measurement
Tap Down	Move tap changer one step down
Tap Up	Move tap changer one step up
List	Change display to list mode

△ 人 Gra-phic	Change display to graphic mode
🔧 Setup	Open setup menu for the selected measuring application

13.4.2 Active Window

The magnetic balance measurement screen is described below:

* SC = Shortcut; direct action or access to setup over touching

Tap Changer Visualization:

🔧 ⌇ ← 1 OnL	Tap changer graphical representation
🔧	"Remote Controlled" is active in dialog "Setup"
←	this winding is selected at "Tap Control" / "Winding" in dialog "Setup"
OnL	tap-changer is defined as "On Load" in "DUT" dialog
1	Actual tap position

13.5 Measurement

13.5.1 Measurement steps

Performing a magnetic balance measurement on a transformer consist of following steps
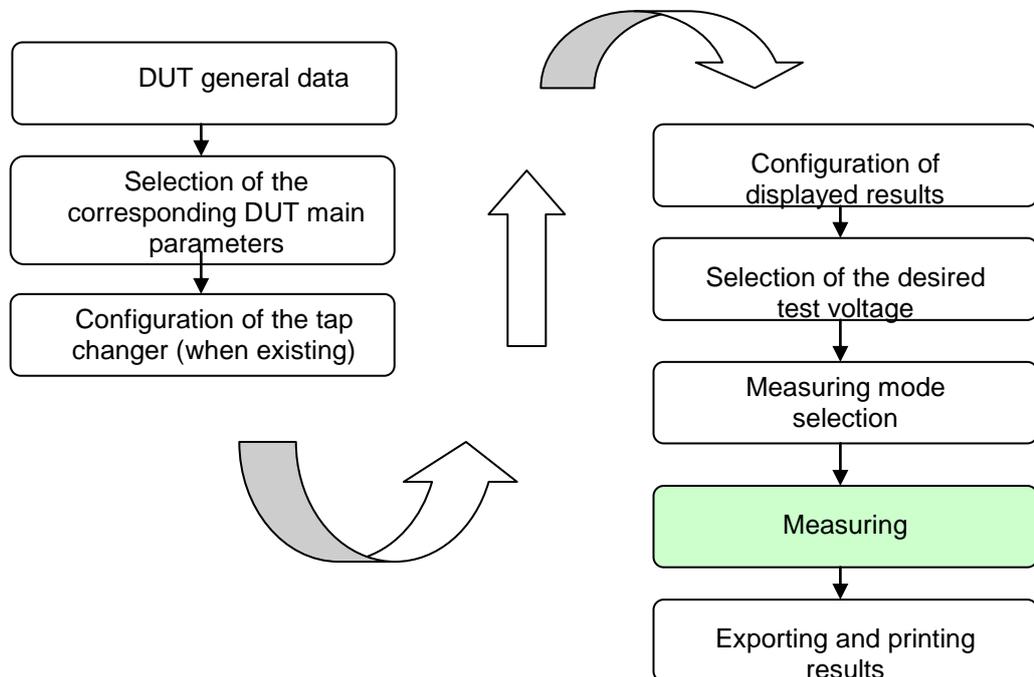
```
┌─────────────────────────┐          ┌─────────────────────────┐
│    DUT general data     │          │  Configuration of       │
└───────────┬─────────────┘          │  displayed results      │
            │                        └───────────┬─────────────┘
┌───────────▼─────────────┐          ┌───────────▼─────────────┐
│   Selection of the      │          │  Selection of the desired│
│  corresponding DUT main │          │     test voltage        │
│      parameters         │          └───────────┬─────────────┘
└───────────┬─────────────┘          ┌───────────▼─────────────┐
┌───────────▼─────────────┐          │   Measuring mode        │
│  Configuration of the tap│          │     selection           │
│  changer (when existing) │          └───────────┬─────────────┘
└─────────────────────────┘          ┌───────────▼─────────────┐
                                      │      Measuring          │
                                      └───────────┬─────────────┘
                                      ┌───────────▼─────────────┐
                                      │  Exporting and printing │
                                      │        results          │
                                      └─────────────────────────┘
```

> ⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

13.5.2 Set up DUT data

To set up the steps with DUT related data:→ see related chapters in the "User Interface" part.

> ℹ️ The Magnetic Balance function is mostly applicable to start with Neutral Windings. On these configurations unbalance results can be a result of a transformer fault or residual magnetism,

13.5.3 Data handling definitions


Storage:

Overwrite → when a measurement is repeated, results overwrite the actual measured values for the tap

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

Recording:

Measurement can be done in auto stop mode (value is automatically recorded when stable) or in manual mode (unit stays measuring until the operator click the stop button), selection between both operations modes is done in the setup screen, Data folder.

To record a value while measuring on this mode, click the record button in the function key bar.

13.5.4 Test Voltage Selection
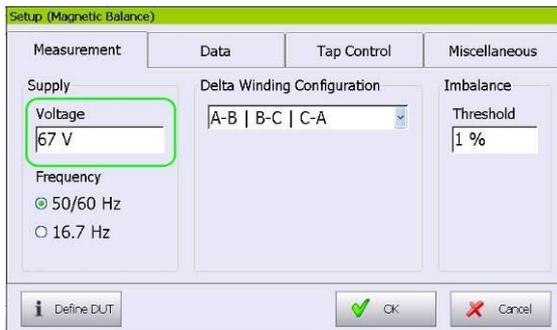
Selection of the measuring voltage is done by clicking on the test voltage field in the main screen, any value between 0 and 67V can be introduced, some values are directly selectable.

13.5.5 Test frequency selection
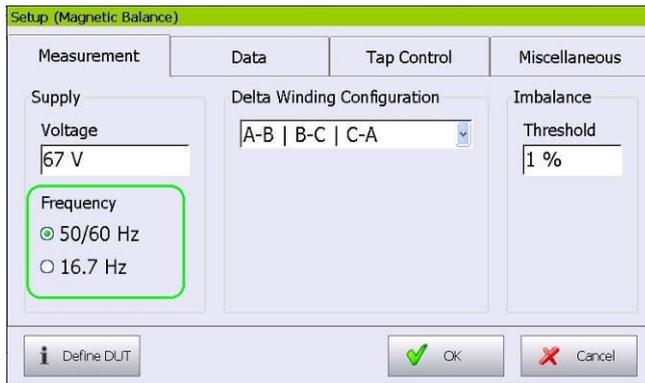
Selection of the measuring frequency is done automatically by the unit. Just select if your DUT is a 50/60Hz type or a 16.7Hz traction transformer type.

13.5.6 Magnetic Imbalance selection
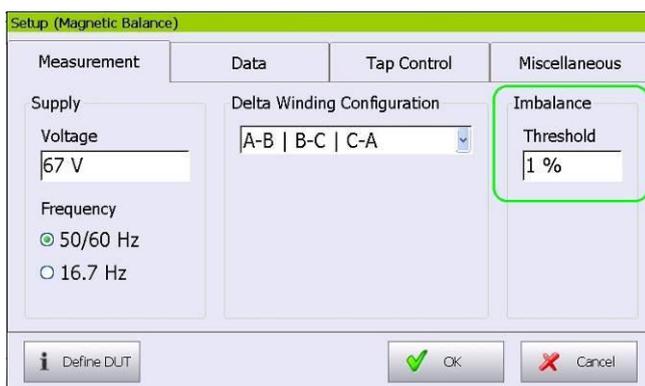
Imbalance:

The imbalance threshold is the allowed percentage difference between the voltages measured on transformer limbs which should balance.

The test results will be highlighted in red if this threshold is exceeded.

Shortcut buttons show typical magnetic imbalance threshold values. Alternatively the user defined field allows values between 0.001% and 100%

13.5.7 Delta Winding Configuration selection
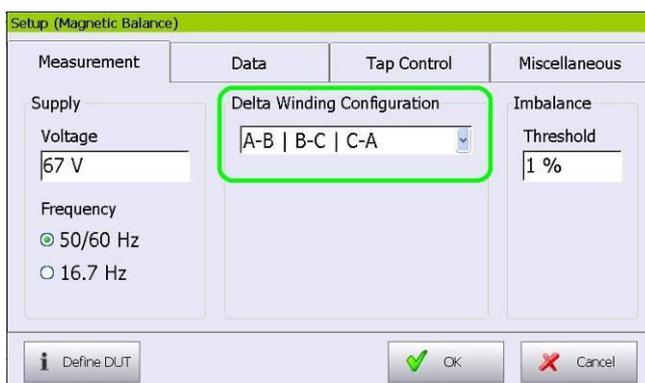
Delta Winding Configuration:

Use this setting to configure which winding is on the central limb of the transformer and which windings are on the outer limbs of the transformer.

| | | Shortcut to DUT setup. Similar to pressing on main screen |

13.5.8 Measuring

Performing a measurement on a transformer is quite simple. Once all transformer and options have been introduced; just click the start button. The instrument will perform all operations automatically.

 It is recommended to perform transformer demagnetization before measuring the magnetic balance, as residual magnetism can influence the test results.
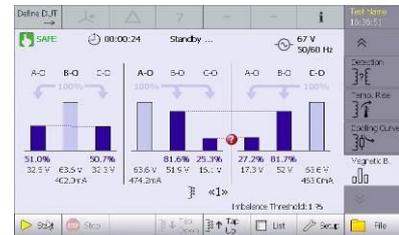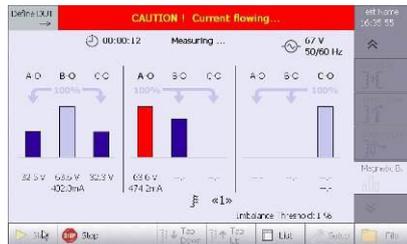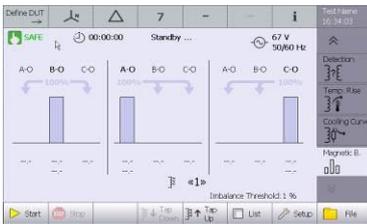
Click start button to initiate the test

Automatic measurement running

Measurement results

If auto recording is active, instrument will record the value and stop the measurement when the stabilization condition has been reached.
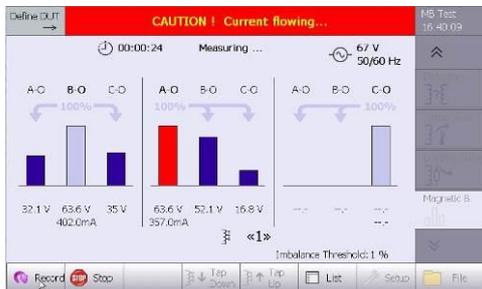
 If manual recording is active, the instrument will repeatedly measure a phase.
Pressing the record button stores the latest result and moves to the next phase.
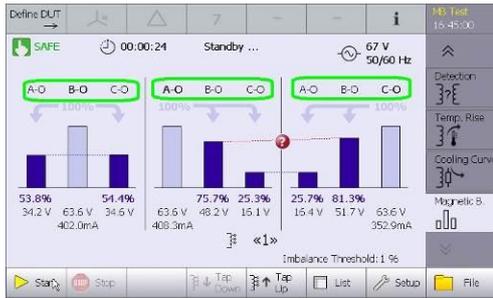
Connection shows the energisation and measurement connections used in the test.

Each limb of the transformer is sequentially energised and then the other limb voltages are measured.
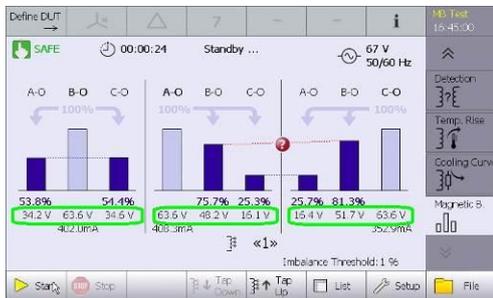
Highlighted area shows the voltage of the energized limb and the voltage measured on the other limbs.
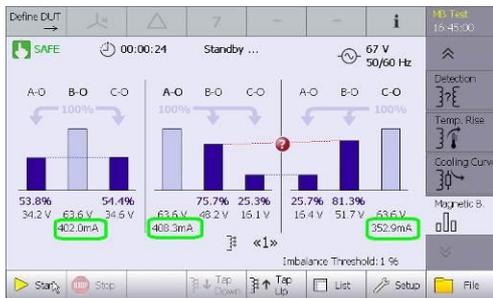
The energisation current for each limb of the transformer is shown.
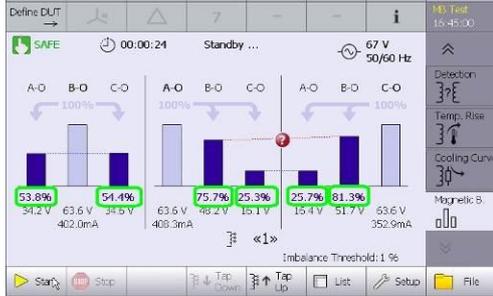
The percentage of the energisation voltage measured in each of the other two limbs.
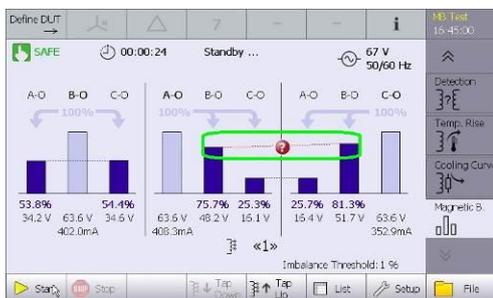
Voltage results which exceed the imbalance threshold value are highlighted in red. The corresponding measurements display the symbol.

Measurements will be automatically saved after each test. Data storage options can be selected in the Data folder, clicking in the setup button of the function key bar.
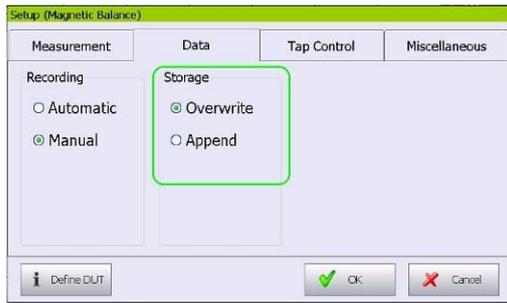
Overwrite → when a measurement is repeated, results overwrite the actual measured values

Append → When a measurement is repeated, results are added in the list but previous results are also kept.
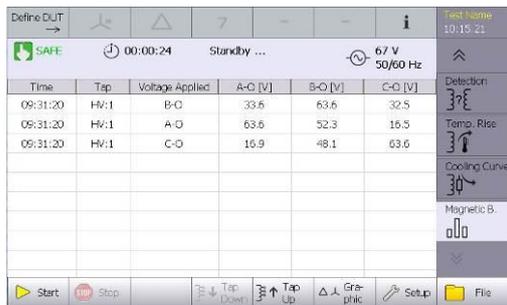
Results can also be shown as a table list, selecting the list button in the function key bar.

Clicking any of the voltage columns changes the report to show voltage percentages.

Clicking the voltage applied column changes the report to show energisation current.

13.5.9 Exporting and printing results

See the chapter "Data Handling" for information about exporting and printing results.

13.6 Application hints

13.6.1 Core Magnetization

Magnetic Balance results are sensitive to Transformer Core Magnetization. To get reproducible results, make sure to properly demagnetize the transformer core (directly) before performing a magnetic balance test:

In a lot of cases, the built-in demagnetization function of the WA2293 will deliver good result.

In some cases, especially for larger power transformer (>50MVA), it can be necessary to use a High Voltage AC power supply to properly demagnetize the transformer. Usually 110% of the nominal winding voltage is necessary.

The following example shows an YNyn0 DryType Transformer in two cases:

The upper results show a proper measurement (green box) → Balance is nearly 50%/50% on the middle phase.

The lower results show a measurement with a magnetized transformer core (red box) → Balance is bad on the middle leg (26.3%/72.8%).

13.6.2 Winding short-circuits

A single turn fault can cause high magnetic imbalance. Also the excitation current can be greatly influenced. The following example shows an YNyn0 DryType Transformer in two cases:

The upper results show a proper measurement (green box) → Balance is nearly 50%/50% on the middle phase.

The lower results show a measurement with a single turn short-circuit on phase A of the high voltage winding (red box) → Balance is very bad on the middle leg (8.66%/94.0%).

| Define DUT → | ⅄ᴺ | ⅄ᴺ | 0 | – | – | i | Dry Type Test 10:57:40 |

Time	Tap	I [mA]	A-O [%]	B-O [%]	C-O [%]
13:14:20	HV	7.4	49.4	100	50.1
13:14:20	HV	8.9	100	62.4	36.8
13:14:20	HV	8.8	36.5	62.7	100
13:17:06	HV	9.9	8.66	100	94.0
13:17:06	HV	70.1	100	62.2	36.8
13:17:06	HV	10.0	5.39	95.9	100
13:20:21	HV	7.4	49.3	100	50.2
13:20:21	HV	8.9	100	62.4	36.8
13:20:21	HV	8.8	36.4	62.8	100

SAFE 00:00:00 Standby … 50 V 50/60 Hz

Detection
Temp. Rise
Cooling Curve
Magnetic B.

▷ Start | ⬛ Stop | ⬇ Tap Down | ⬆ Tap Up | △⅄ Gra-phic | Setup | 📁 File

Tettex

14 Short circuit impedance

14.1 Overview

The unit can perform the short circuit impedance test of a transformer at reduced voltages, the short circuit impedance in a transformer is quite linear with the voltage and therefore an extrapolation to the nominal voltage can be perform for comparison.

This **optional feature is enabled using the license manager**. This process only needs to be completed the first time magnetic balance is used. For instruction how to enable a feature please read Chapter 16 Optional Features activation.

14.2 Theory

14.2.1 Definitions

The short-circuit impedance ($Z_{short-circuit}$) is defined as the impedance corresponding to the voltage (U_{cc}) that must be connected to one pair of terminals of a transformer, with terminals of other side shorted, which causes rated current (I_{rated}) to flow on the two sides of the transformer.
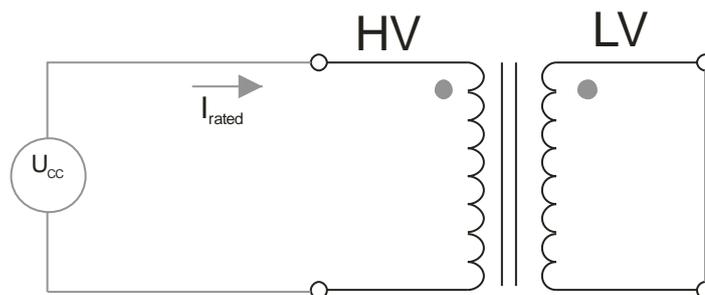
$$Z_{CC} = \frac{U_{cc}}{I_{rated}}$$

For single phase transformers, the sort circuit impedance in % (ε_{cc}) can be easily calculated after the Z_{cc} has been measured according the formula

$$\varepsilon_{cc} = Z_m \cdot \frac{S}{U^2} \cdot 100$$

Where:

ε_{cc} Short circuit impedance in %

U_{cc} Short circuit voltage in V

S   apparent power in VA from nameplate

U   line to line voltage in V from nameplate

or three phases transformers, test can be done by measuring each phase separately (phase to phase) and then calculating the transformer impedance according below formula

$$\varepsilon_{cc} = \frac{1}{6}(Z_{m12} + Z_{m13} + Z_{m23}) \cdot \frac{S}{U^2} \cdot 100$$

Where:

Z_{m12} = Short circuit impedance phase a to b

Z_{m13} = Short circuit impedance phase a to c

Z_{m23} = Short circuit impedance phase b to c

14.3   User interface
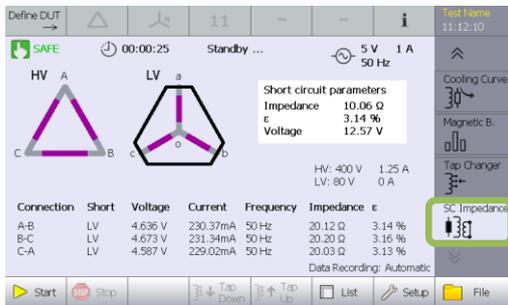
To access to the short circuit feature, select SC Impedance function in the applications bar (side bar).

You may need to press the up/down arrow buttons to view the magnetic balance button depending on which other functions are enabled.

14.3.1 Function keys

While in magnetic balance application, the following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

Start	Start the measurement
Record	Record a result while manual recording mode is used
Stop	Stop the measurement

↓ Tap Down		Move tap changer one step down
↑ Tap Up		Move tap changer one step up
List		Change display to list mode
△人 Gra-phic		Change display to graphic mode
Setup		Open setup menu for the selected measuring application

14.3.2 Active window

Measuring Time

Test Voltage & Frequency*

SAFE 00:00:25 Standby ... 2.5 V 1 A
50 Hz

HV A   LV a

Short circuit parameters
Impedance   30.09 Ω   Test
ε   9.40 %   Results
Voltage   37.61 V

C   B c   b

HV: 400 V   1.25 A
LV: 80 V   6.25 A

≪3≫

Connection	Short	Voltage	Current	Frequency	Impedance	ε
A-B	LV	2.342 V	38.99mA	50 Hz	60.06 Ω	9.38 %
B-C	LV	2.345 V	38.79mA	50 Hz	60.46 Ω	9.45 %
C-A	LV	2.330 V	38.81mA	50 Hz	60.03 Ω	9.38 %

Measurement Results

Data Recording: Automatic

Measurement connections   Tap changer position*   Data Recording Mode

* Shortcut; direct action or access to setup over touching:

14.4 Measurement

14.4.1 Measurement procedure

Performing a turns ratio measurement on a transformer consist of following steps
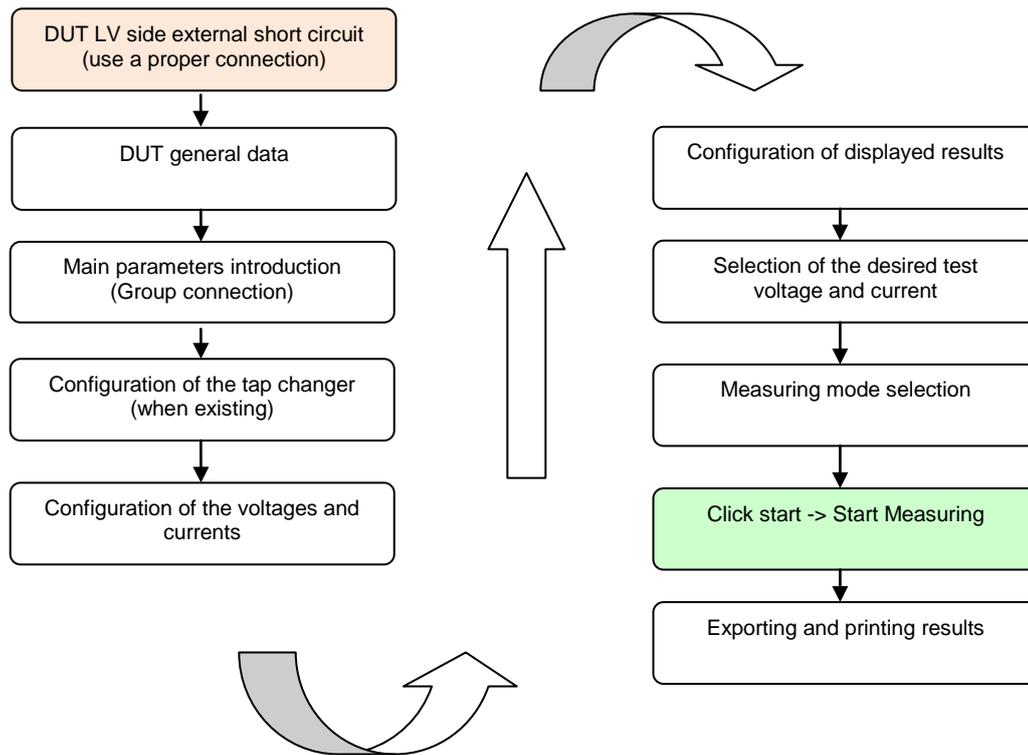
DUT LV side external short circuit (use a proper connection)		Configuration of displayed results
DUT general data		Selection of the desired test voltage and current
Main parameters introduction (Group connection)		Measuring mode selection
Configuration of the tap changer (when existing)		Click start -> Start Measuring
Configuration of the voltages and currents		Exporting and printing results

⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

14.4.2 Transformer connection

To perform a short circuit impedance measurement, the other transformer side (normally the low voltage side) must be short circuited with short and high current (low inductance) connections.

ℹ️ As the resistance is multiplied with the square of the ratio while measuring from the other transformer side, it is critical to keep the short circuit connection resistance as low as possible to avoid adding unnecessary error to the measuring circuit.
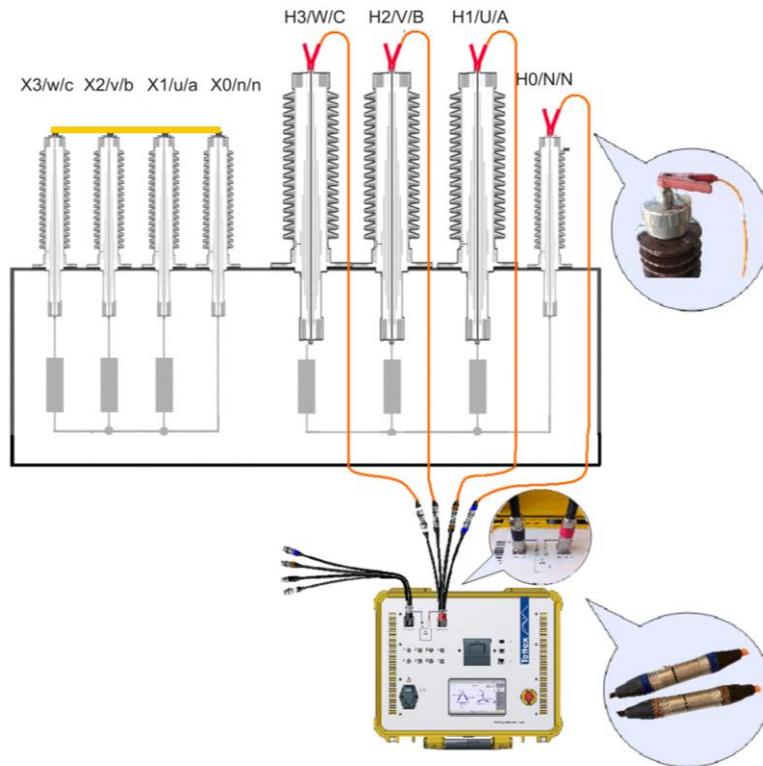
14.4.3 Set up DUT data

To set up the steps with DUT related data:→ see related chapters in the "User Interface" part.

The Magnetic Balance function is mostly applicable to start with Neutral Windings. On these configurations unbalance results can be a result of a transformer fault or residual magnetism,

14.4.4 Measurement Settings

To access the measuring parameters, click setup button in the bottom of the screen, and then select "Measurement" folder.

As the transformer impedance is fixed, instrument can only supply a defined current or voltage between the maximum voltages and currents of the devices.

The instrument will supply the target voltage or current first reached. In order to guarantee that a test is done at a particular voltage or current, fix the other parameter to the maximum possible.
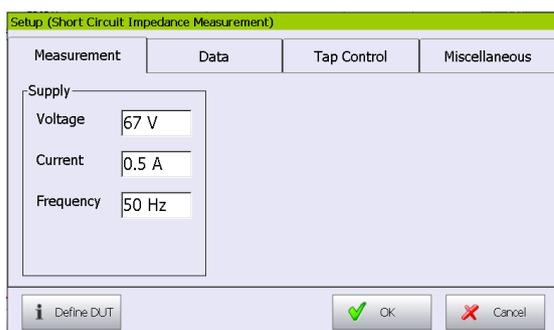
The test Voltage, maximum current and frequency can be selected
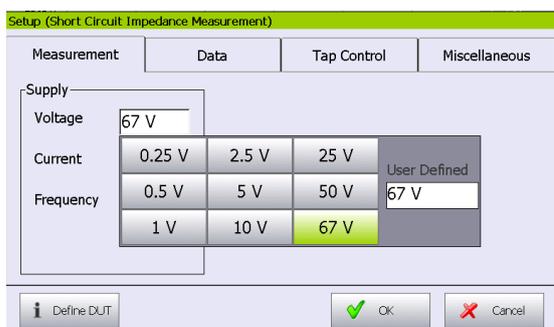
By clicking in the Voltage text Box, a window pop up proposing several voltages. To select one just click with the mouse over the desired value
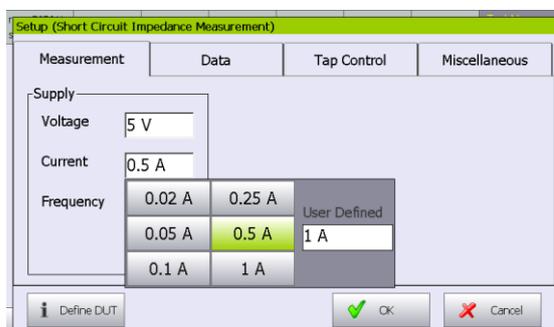
By clicking the current Box, a window will pop up proposing several maximum currents, an error message will arise during the test if the selected maximum current is exceeded during the test.
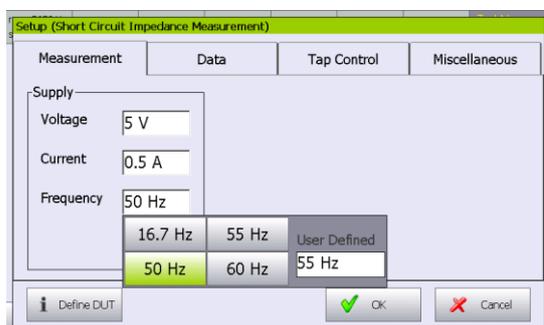
By clicking the Frequency Box, a window will pop up proposing several measuring frequencies. To select one just click with the mouse over the desired value
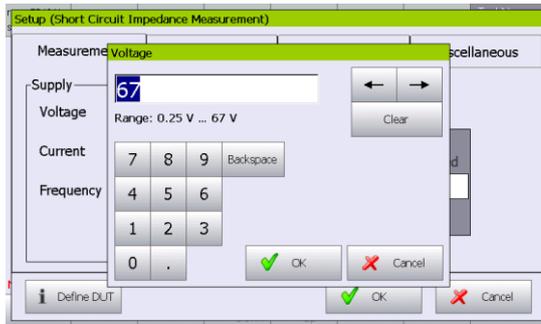
User can also introduce manually any desired value between the limits by clicking the "User Defined" Text Box. A Window to introduce the desired voltage manually will pop up, just introduce the value and click "OK" button.

14.4.5 Data Handling

To access the data parameters, click setup button in the bottom of the screen, and then select "Data" folder.
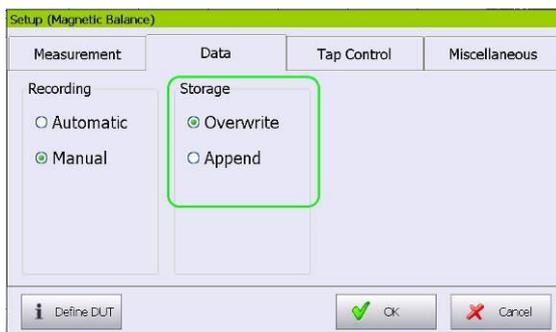
Storage:

Overwrite → when a measurement is repeated, results overwrite the actual measured values for the tap

Append → When a measurement is repeated, results are added in the list but previous results are also kept.

Recording:

Measurement can be done in auto stop mode (value is automatically recorded when stable) or in manual mode (unit stays measuring until the operator click the stop button), selection between both operations modes is done in the setup screen, Data folder.

To record a value while measuring on this mode, click the record button in the function key bar.

14.4.6 Tap Control

For information about the tap control window, refers to Chapter 7.3.7 Tap Control

14.4.7 Miscellaneous

For information about the tap control window, refers to Chapter 6.7 Device Information

14.4.8 Measuring

Performing a measurement on a transformer is quite simple. Once all transformer and options have been introduced; just click the start button. The instrument will perform all operations automatically.

Before a test can be done, the tap position has to be selected.
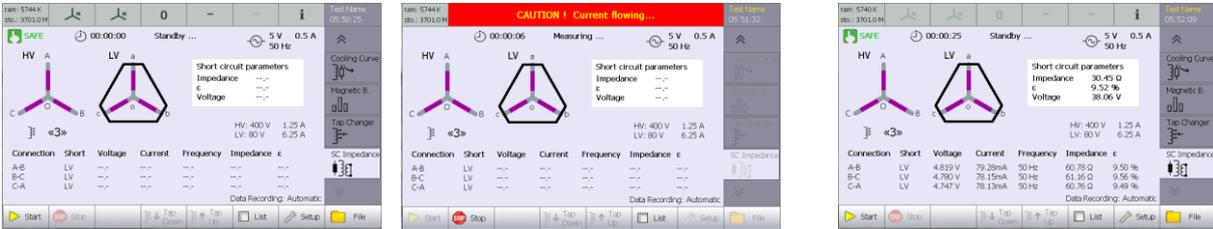
Click start button to initiate the test | Automatic measurement running | Measurement results

If auto recording is set to Auto, once a phase is being measured, instrument will automatically measure the other phases and shot the results.
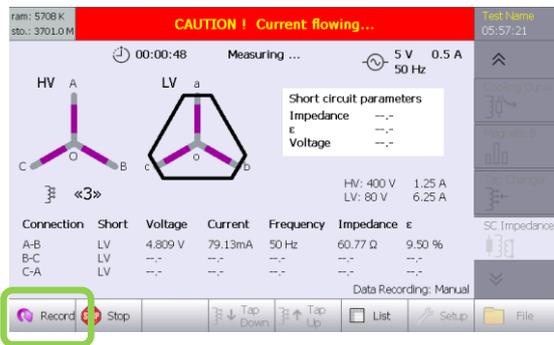
If manual recording is active, the instrument will repeatedly measure a phase.
Pressing the record button stores the latest result and moves to the next phase.
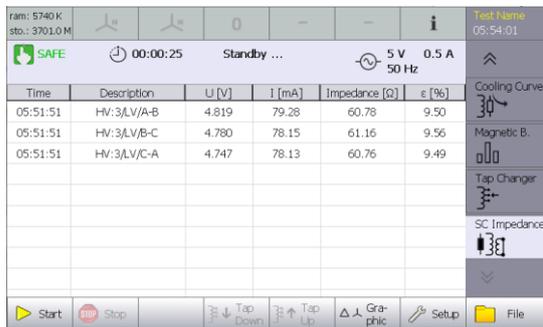
Results can also be shown as a table list, selecting the list button in the function key bar.

14.4.9 Measurement results

The instrument shows the results of the test by phase in the screen button and calculates the transformer values based in the single phase measurements. Measuring values description below

Connection	Short	Voltage	Current	Frequency	Impedance	ε
A-B	LV	2.342 V	38.99mA	50 Hz	60.06 Ω	9.38 %
B-C	LV	2.345 V	38.79mA	50 Hz	60.46 Ω	9.45 %
C-A	LV	2.330 V	38.81mA	50 Hz	60.03 Ω	9.38 %

Data Recording: Automa

Connection	Clamps used during the test
Short	Short circuited winding
Voltage	Voltage applied during the measurement
Current	Current applied during the measurement
Frequency	Frequency applied during the measurement
Impedance	Single phase impedance measured (Phase Voltage/ Phase Current)
Short circuit Imp (ε)	Single phase short circuit impedance calculation

After all phases are completed, then a calculation of the transformer overall values is done based in the single phase measurements

Short circuit parameters
Impedance	30.09 Ω
ε	9.40 %
Voltage	37.61 V

Impedance	Calculated three phases Impedance
Short circuit Imp (ε)	Calculated three phases short circuit impedance
Voltage	Calculated three phases Voltage

14.4.10 Exporting and printing results

See the chapter "Data Handling" for information about exporting and printing results.

15 Dynamic resistance on tap changer

15.1 Overview

The unit can perform optionally the Dynamic resistance measurement a transformer.

This **optional feature is enabled using the license manager**. This process only needs to be completed the first time Dynamic Resistance (Tap changer) feature is used. For instruction how to enable a feature please read Chapter 16 Optional Features activation.

15.2 Theory

15.2.1 Tap changer generalities

A tap changer is a connection point selection mechanism along a power transformer winding that allows a variable number of turns to be selected in discrete steps. A transformer with a variable turns ratio is produced, enabling stepped voltage regulation of the output. The tap selection may be made via an automatic or manual tap changer mechanism.

If tap switching can be done while current is circulating (transformer connected to the grid) the tap changer is called On Load Tap Changer (OLTC).

Simple changing of taps (switching) during energized condition is unacceptable due to momentary loss of power during the switching operation. Therefore the "make before break contact concept", is the basic design for all OLTCs.

This concept, which means the next tap is selected before disconnecting the previous one, would generate a large short circuit current between turns due to the large number of Ampere-Turns in a few turns. To limit this short circuit current an impedance (resistive or inductive) must be inserted between the two taps to be switched.

The figure below shows the basic operation procedure of a tap changer. The tap selector one is in the actual Tap position, while the tap selector 2 is located in the position to be switched to.
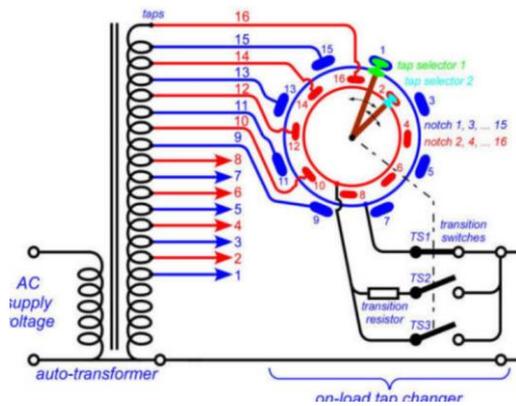
The tap change operation consist of 3 steps

The next tap is preselected by the tap selector at no load (no current circulation).

The arcing switch (on load tap changer) transfer the load current from the tap in operation to the preselected tap trough following operations

Switch TS2 close, current from tap selector 1 circulates trough TS1. TS2 connect the tap selector 2 to the output trough transition resistor.

Switch TS1 open, current from tap selector 2 circulates trough TS2 by the transition resistor

Switch TS3 close, the current from tap selector 2 goes to the put without the transition resistor.

Switch TS2 open, The transition resistor is eliminated from the circuit.

The tap selector 1 is release to move to the next tap.

The Total duration of a transition is of some tens of milliseconds.

15.2.2 Dynamic resistance test

Dynamic resistance test consist in recording currents and voltages during the tap position transition.

A standard current curve while measuring dynamic resistance would show following shape.
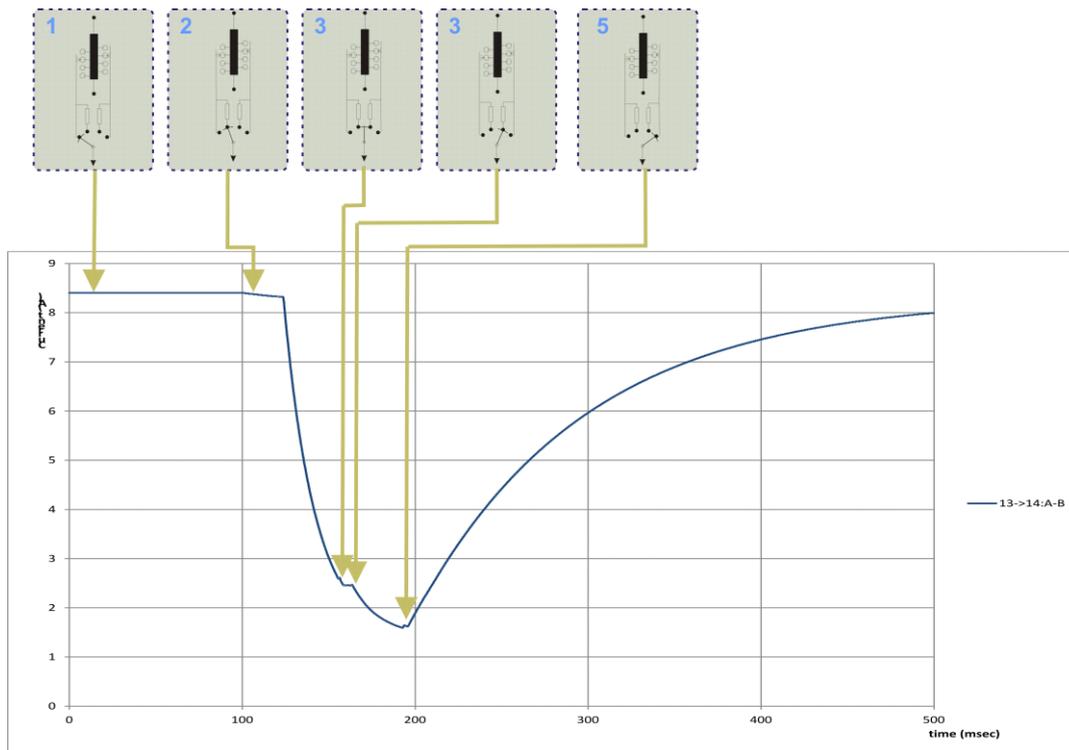
Following parameters are calculated and recorded by the device for each tap change.
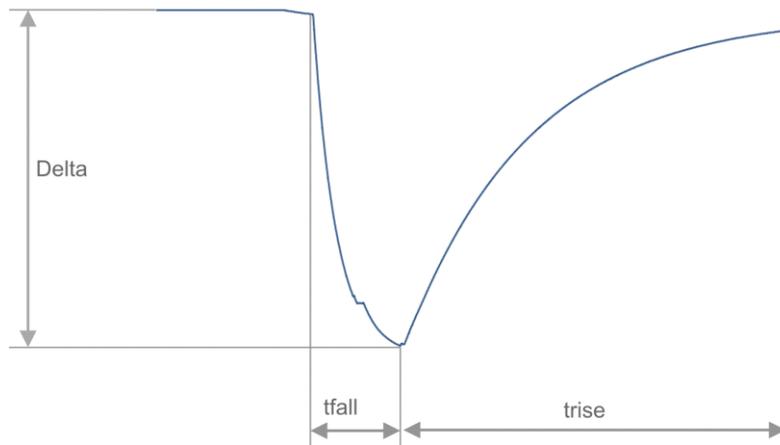
tFall [mS]:	Time from the staring of the tap changer movement (drop in current) until the minimum current is reached
tRise [mS]:	Time from minimum current reached until current becomes stable
Delta:	Current drop from stabilization to the minimum while changing tap

Dynamic resistance on tap changer

Tettex

15.3 User Interface
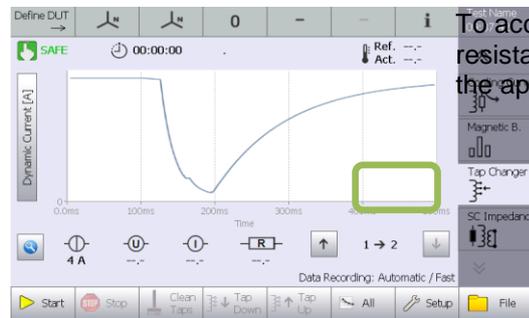
To access to the Tap changer (dynamic resistance) feature, select Tap changer function in the applications bar (side bar).

You may need to press the up/down arrow buttons to view the magnetic balance button depending on which other functions are enabled.

15.3.1 Function Keys

While in Tap changer (dynamic resistance) application, the following actions are available in the button key bar. The buttons are case sensitive, i.e. they change according to the actual status.

	Start the measurement
Record	Record a result while manual recording mode is used
Stop / Resume	Stop the measurement or Continue with the actual measurement
Clean Taps	Proceed with ta tap changer clean cycle
Tap Down	Move tap changer one step down
Tap Up	Move tap changer one step up
List / Single / All	Change display to: 1. List mode 2. Single Test 3. All tests

Setup	Open setup menu for the selected measuring application

15.3.2 Active window

Active Window can be changed between Single test, All test and List by clicking the respective button in the bottom bar..
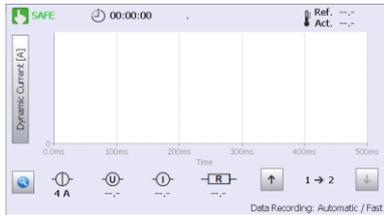
Click "All " button to change   Click "List" to change   Click "Single" Button to change
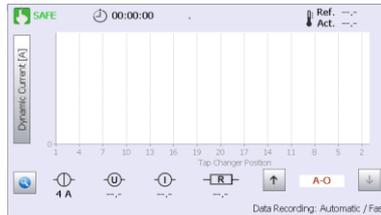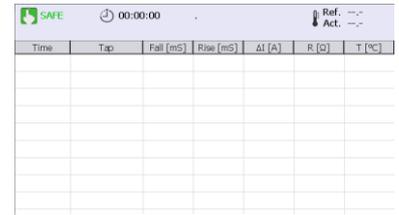
Active Window Single measurement
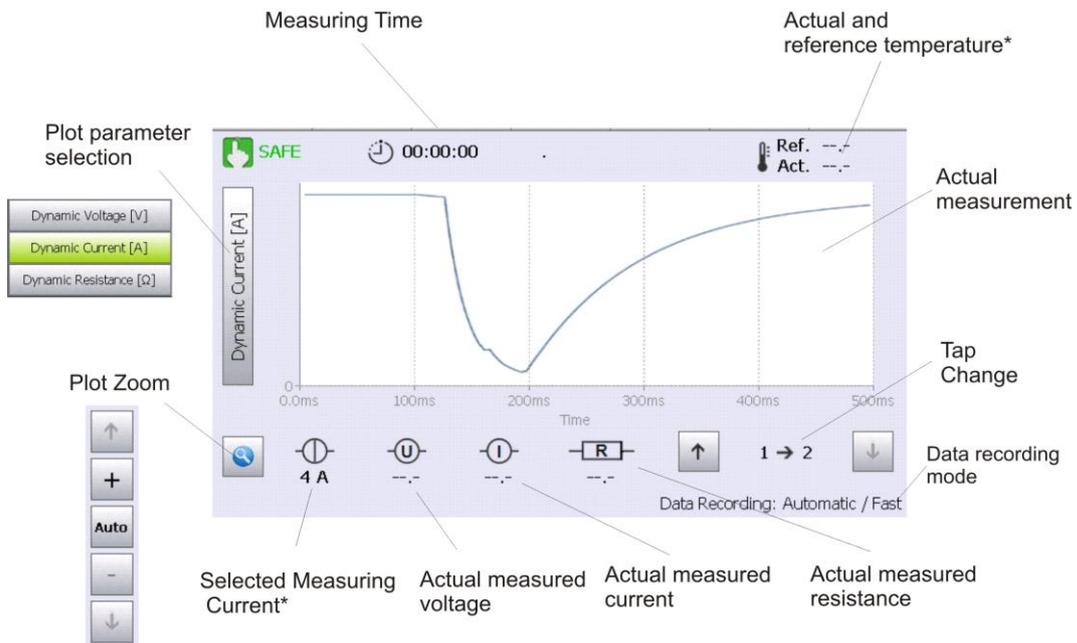
* Shortcut; direct action or access to setup over touching:

Active Window "ALL" measurements

Active Window List

15.4 Measurement

15.4.1 Measurement procedure

A tap changer test consist of following steps.

Dynamic resistance on tap
changer

Tettex

```
┌─────────────────────────┐                      ┌─────────────────────────────┐
│    DUT general data     │          ╭───╮        │     Tap changer test        │
└─────────────────────────┘         ╱     ╲       │  Select phases to be measured│
             │                                     └─────────────────────────────┘
             ▼                                                   │
┌─────────────────────────┐                                     ▼
│ Main parameters introduction│                     ┌─────────────────────────────┐
│   (Group connection)    │                          │     Tap changer test        │
└─────────────────────────┘                          │   Select Taps to be measured│
             │                                        └─────────────────────────────┘
             ▼                                                   │
┌─────────────────────────┐                                     ▼
│On load Tap changer configuration│                 ┌─────────────────────────────┐
└─────────────────────────┘                          │ Select the number of cleaning│
             │                                        │    cycles (if necessary)    │
             ▼                                        └─────────────────────────────┘
┌─────────────────────────┐                                     │
│ Tap changer Test current selection│                           ▼
└─────────────────────────┘                          ┌─────────────────────────────┐
             │                                        │     Tap changer test        │
             ▼                                        │  Select tap changer operation│
         ╱╲                                           └─────────────────────────────┘
        ╱  ╲                                                     │
       ╱     ╲                                                   ▼
      ╱ Static ╲                                     ┌─────────────────────────────┐
      ╲Resistance╱                                   │  Click start -> Start Measuring│
       ╲       ╱                                     └─────────────────────────────┘
        ╲    ╱                                                   │
         ╲ ╱                                                     ▼
          │                                          ┌─────────────────────────────┐
          ▼                                          │   Tap Changer -> Manual     │
┌─────────────────────────┐                          │ Set tap position to required Tap│
│ Static resistance parameters│                      └─────────────────────────────┘
│      introduction       │                                     │
└─────────────────────────┘                                     ▼
                                                     ┌─────────────────────────────┐
                                                     │   Tap Changer -> Manual     │
                                                     │ Wait for message to change tap│
                                                     └─────────────────────────────┘
                                                                │
                                                                ▼
                                                     ┌─────────────────────────────┐
                                                     │   Tap Changer -> Manual     │
                                                     │  Change tap, Wait For message│
                                                     └─────────────────────────────┘
                                                                │
                                                                ▼
                                                            ╱╲
                                                           ╱  ╲
                                                          ╱     ╲
                                                         ╱Last tap of last╲
                                                         ╲phase measured ╱
                                                          ╲     ╱
                                                           ╲ ╱
                                                            │
                                                            ▼
                                                     ┌─────────────────────────────┐
                                                     │  See results on the screen  │
                                                     │   Export or save results    │
                                                     └─────────────────────────────┘
```

> ⚠️ **Before operating the instrument, make sure that the safety rules have been fully read and understood. It is the responsibility of the end user to ensure that the system is operated in a safe manner.**

15.4.2 Transformer Connection

2 transformer connection are possible by selecting the short circuit in the transformer side without on load tap changer.

Short circuit done by the device (recommended and selected by default). The device will short circuit the secondary side of the transformer. This feature will allow a faster magnetization of the transformer for the first resistance reading
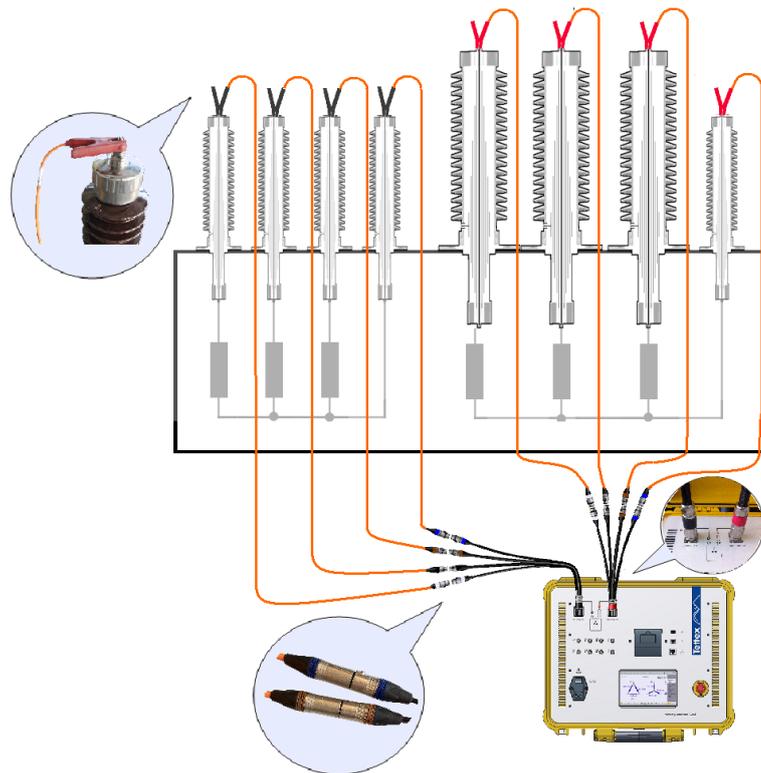
Short circuit done externally (not recommended). In case last test done was Short circuit impedance and short circuit is already available. It would avoid reconnecting the instrument.

Dynamic resistance on tap changer
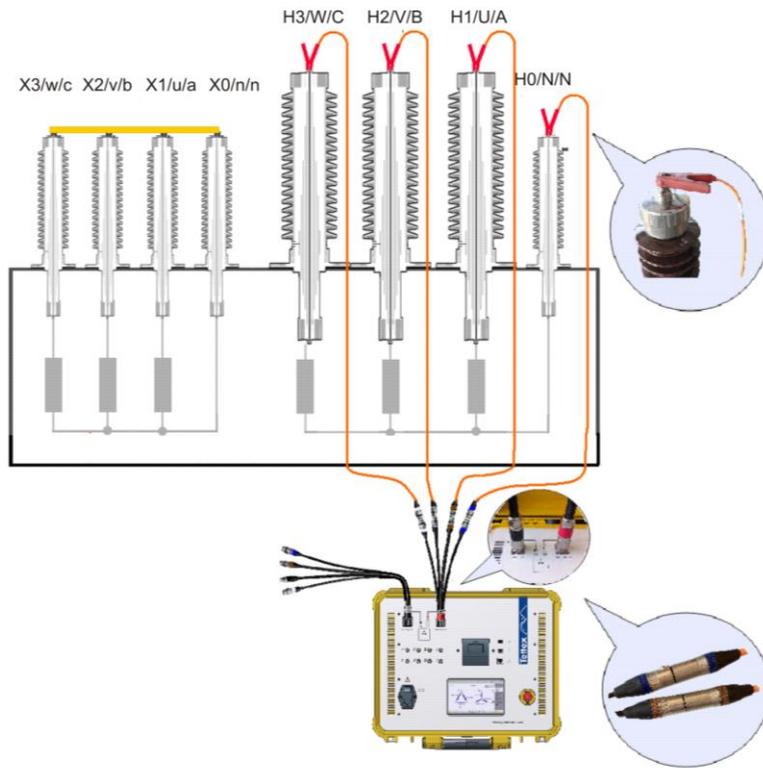
15.4.3 Set up DUT data

To set up the steps with DUT related data:→ see related chapters in the "User Interface" part.

15.4.4 Measurement Settings

To access the measuring parameters, click setup button in the bottom of the screen, and then select "Measurement" folder.
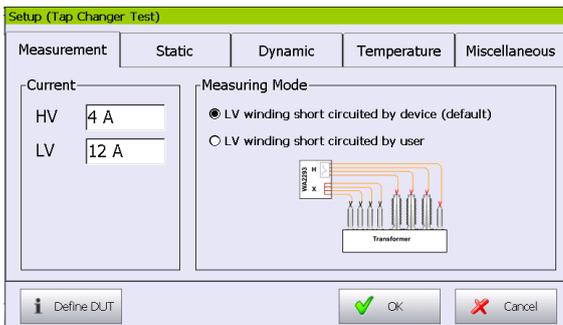
The test current and transformer connection can be selected
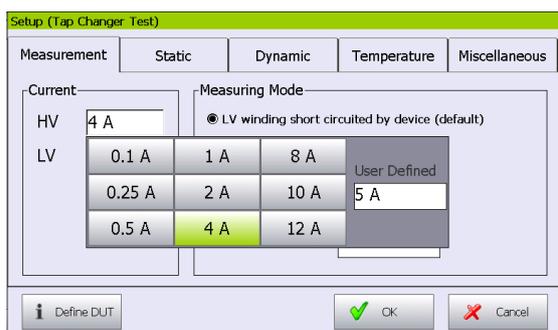
By clicking the current Box, a window will pop up proposing several maximum currents. The maximum selectable current for this test is 12A.

Any value can also be introduced by clicking over the "user defined values" textbox.
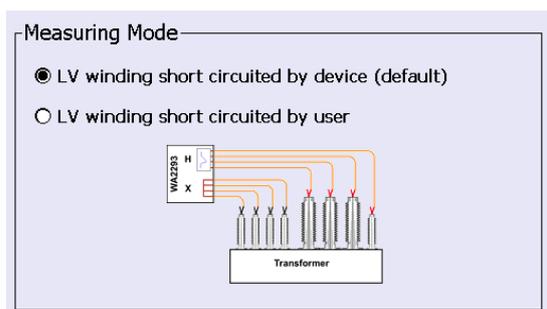
Two connections modes can be selected by how the sort circuit is done in the not measured transformer winding.

- LV winding short circuited by the device (recommended)

- LV winding short circuited externally, the operator is then responsible of removing the non tested winding measuring cables and performing the short circuit

15.4.5 Static resistance settings

To access the measuring parameters, click setup button in the bottom of the screen, and then select "Static" folder.

Record static resistance can be activated and deactivated by clicking the checkbox before "Record static resistance values simultaneous". If activated, after each tap change the instrument will stabilize and record the resistance value. This will slow down the overall procedure but will collect valuable information.
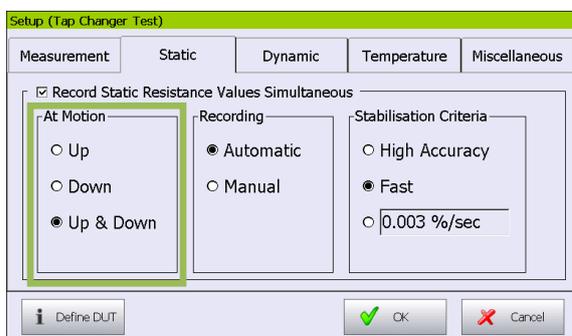
The static resistance can be measured while tap changer is increasing tap position (up), while is lowering tap position (Down) or bot cases (Up & Down).
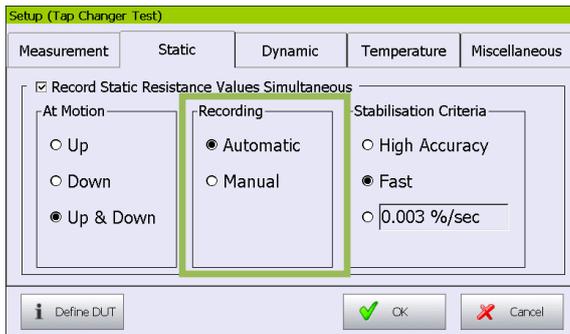
The resistance can be recorded automatically (when the stabilization criteria beside is fulfilled) or manually by operator by clicking the record button when required.
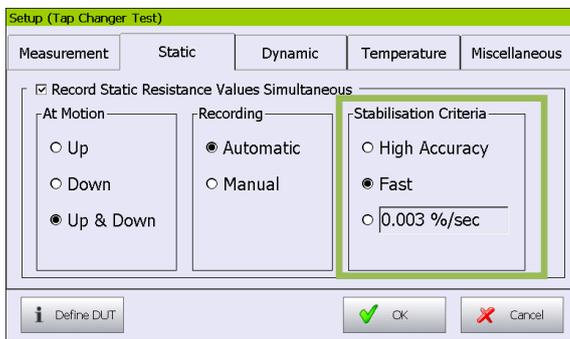
Stabilization criteria can be defined, high accurate , Fast or user defined.

15.4.6 Dynamic resistance settings

To access the Dynamic resistance settings, click setup button in the bottom of the screen, and then select "Dynamic" folder.
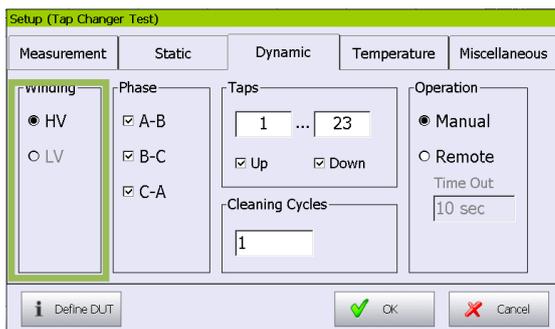
Winding where the measurement is going to take place, only windings configures as having a tap changer can be selected.
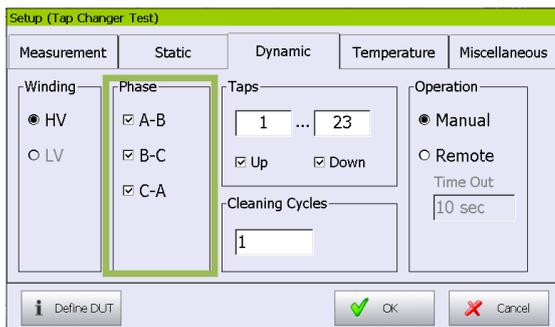
Phases to be measured, one, two or all three phases can be selected. If more than on phase is selected then instrument will switch to next phase once one phase is finalized
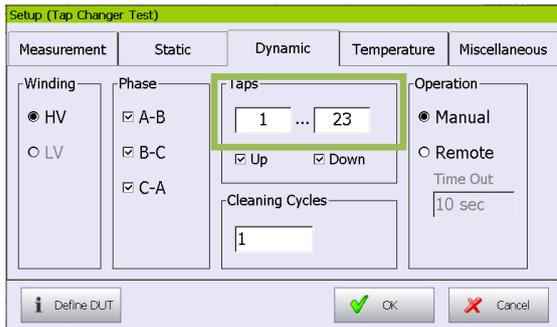
Taps to be measured, by clicking the textbox with the tap number the tap position can be selected
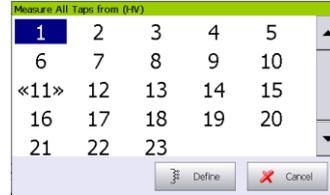
Testing order direction. Recording will be done when:

Up -> Only when increasing the tap

Down -> only when decreasing the tap

Both -> one increasing and decreasing tap.

Normal procedure is to select both and collect data one increasing and when decreasing the tap number
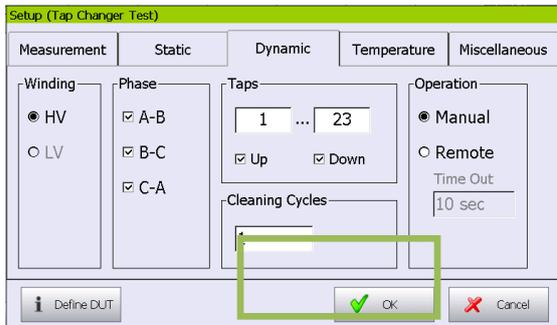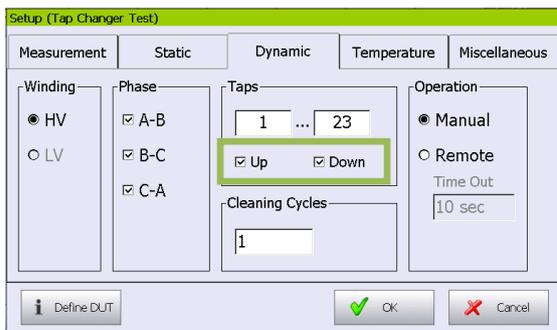
A cleaning cycle is defined as a movement of the complete tap changer from button to upper tap position and reverse. This is useful as some taps have not been used since long and rest of oil can show bad results due to poor contact. A claiming cycle will remove this thin oil layer.

The number of cleaning taps to be done is introduced in the corresponding text box.
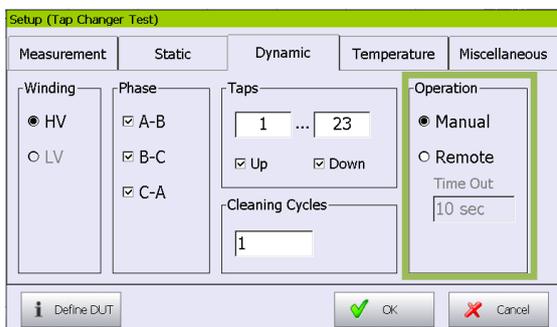
If tap changer accessory is available and connected, the operation mode can be switched to remote and the instrument will then send the order to the tap changer to change position once measurement has been finalized.

For information about connection of the remote tap changer accessory please refer to chapter 17 Tap Changer Interface.

15.4.7 Temperature settings

For temperature settings, refer to chapter 7.6 Temperature Measurement

15.4.8 Miscellaneous

For information about the tap control window, refers to Chapter 6.7 Device Information

15.4.9 Measuring

The measurement procedure will slightly differ if the remote tap changer accessory is available and connected to the transformer or not.

As the tap changer test includes lot of tap changer operations, it is recommended to acquire and connect this accessory

Performing a measurement on a transformer is quite simple. Once all transformer and options have been introduced; just click the start button. The instrument will perform all operations and indicate the operator the next step.

Standby …
Nothing being measured

Charging …
Instrument is charging the transformer, wait until measurement is performed

Measuring (stable) …
The resistance get stable, it will be recorded (if static resistance is selected)

Waiting for tap change…
Instrument is waiting for the tap changer to change. Operator have to to change tap

The direction of the tap change movement (move up or move down) is defined by the arrow in the button right of the screen as following.

8 → 9
Tap changer increasing, change will be from position 8 to position 9

8 ← 9
Tap changer decreasing, change will be from position 9 to position 8

The triggering of the measurement is automatically done by the instrument, no configuration or particular settings are needed for this purpose.

The following steps are performed while measuring the tap changer. Steps 3 to 5 will be repeated for all taps selected in the settings. Step 6 is only necessary if the tap changer accessory is not available.
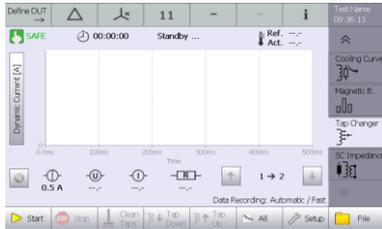
Click start button to initiate the test

Instrument will then require the operator to drive the tap changer to a starting position, normally position one

Instrument will charge and stabilize

If static resistance is selected, then it will be measured

The instrument will be waiting for a tap changer, operator have to change the transformer tap position

Only if tap changer accessory is not connected !

Operator change the tap position, instrument record the curve.
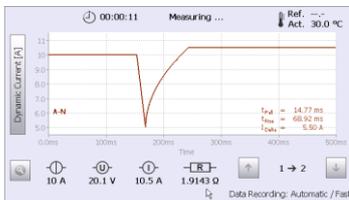
Instrument record the curve, and start the cycle for the next tap position

15.4.10 Measurement results

The instrument records the curve data, as well as some curve parameters:

tFall [mS]: Time from the staring of the tap changer movement (drop in current) until the minimum current is reached

tRise [mS]:   Time from minimum current reached until current becomes stable

Delta: Current drop from stabilization to the minimum while changing tap

For explanation about these parameters, see 15.2.2 Dynamic resistance test

The above parameters should be similar for all taps, deviations between one tap and the others are an indication of tap changer problem.

15.4.11   Exporting and printing

The test results are recorded in 2 separated files

- CSV -> Test results, including the parameters of the tap changer curve per tap.
- BIN -> row data of each curve.

See the chapter 6.8 Data Handling for information about exporting and printing results.

16 Optional Features activation

16.1 Software key Activation

Optional features are enabled using the license manager. This process only needs to be completed the first time the feature is used.
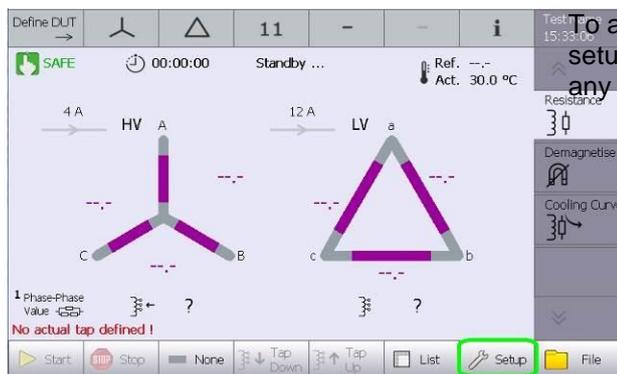
To access to the license manager, select setup function key in the bottom bar of any application
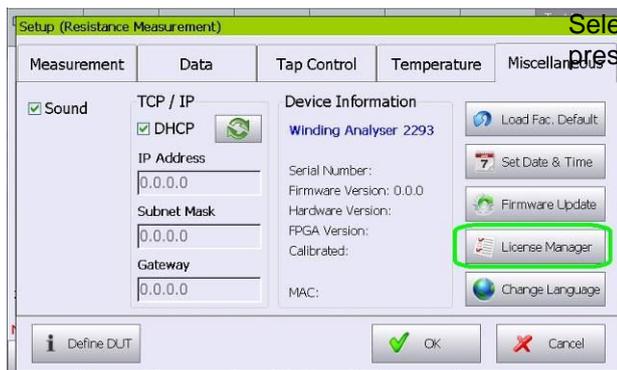
Select the Miscellaneous folder and then press the License Manager button.
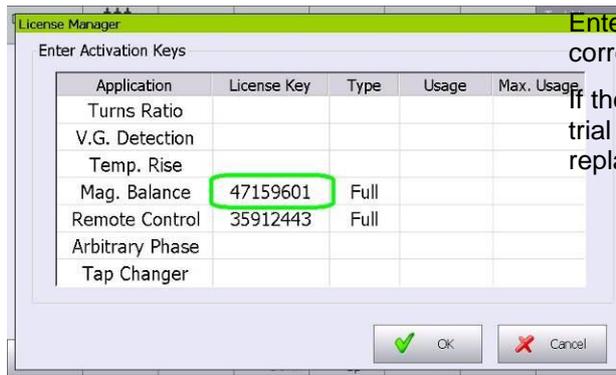
Enter the license key in the corresponding row

If the feature was previously used with a trial license key, clear this number and replace it with the full license key.
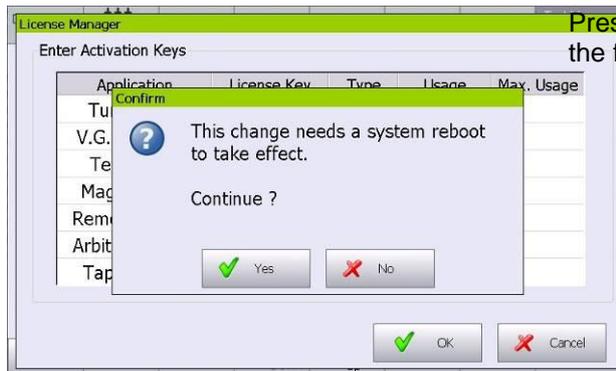
Press Yes to reboot the unit and install the function.

The Magnetic Balance function is mostly applicable to start with Neutral Windings. On these configurations unbalance results can be a result of a transformer fault or residual magnetism,

17 Tap Changer Interface

17.1 General

Tap changer interface allows the remote control of a motorized tap changer, as well as the remote control of the 2293 when operator is placed in front of the tap changer and far away from the device.

The tap changer remote controller consist of an electronic circuit, and three connecting cables

Connecting cable to the 2293

Connecting cable for tap changer remote operation

Return signal from tap changer when tap position change is completed.

Manual switch is also available for remotely trigger the next measurement in the 2293

17.1.1 Tap changer remote operation signal

The 2293 can operate the tap changer trough two free voltage contact switches. One for increasing the tap changer position, another for decreasing the tap changer position.
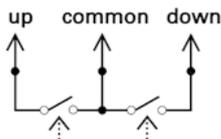
Up/Down (set output)	
Function	Connect the Up/Common/Down control contacts of the tap changer
Ratings	Max. 250V AC, 30V DC, 500mA
Up	White
Common	Brown
down	Green

The contacts have to be connected to the corresponding input signals located in the transformer control box. No output voltage is supplied by the device, therefore the necessary power to move the tap changer motor has be connected separately.

17.1.2 Tap changer feedback signal

The feedback signal can be connected when the transformer is equipped with this possibility. A free contact switch which closes when tap changer movement finalized must be available in the tap changer control box or transformer control box.

2293 supplies a 3.3V signal, and wait for the returning signal as confirmation that operation is finished.
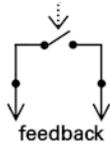
Feedback (sense input)	
Function	Connect the feedback contactor of the tap changer with the "switched" information
Ratings	3.3V, 1mA (input impedance 100kΩ)
Feedback 1	Brown
Feedback 2	White

17.2 Tap changer Remote operation

For remote operation of the tap changer, following parameters must be selected.
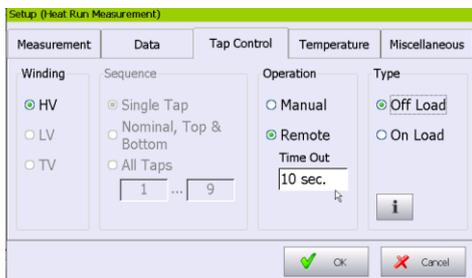
In the setup button in the function key bar, select the tap control folder. Then remote operation and off load tap changer.

Expected time for the tap changer to change position has also to be introduced (time out)

Once remote operation is selected, the instrument will try to change the position by closing the contacts up and down, and will wait for the feedback signal to start the new measurement. Procedure is as following

Unit will measure one position and discharge the transformer

The corresponding signal up/down to increase/decrease a position will be sent to the tap changer trough the tap changer adaptor.

The instrument will wait until the feedback signal come back or the time out expires (whichever happen first), in addition the tap changer remote control is also equipped with a small switch that will send the feedback signal to the device manually when pushed.

Steps one to three will be repeated for all positions to be measured.

In case the transformer is equipped with an on-load tap changer, a special operation mode is also available by selecting the on load tap changer option. During this mode the unit will not discharge the transformer after the measurement and will continue supplying current while the signal to change position to the tap changer is sent.

⚠ If on load tap changer is selected, and the measuring circuit is interrupted by any reason, overvoltage will appear in the tap changer contacts that can end in damaging this component. The on-load operation mode has to be used carefully.

18 Temperature Interfaces

18.1 General Notes

The 2293 unit supports 6 internal and max. 24 external PT100 Class A sensors.

Sensors for magnetic surface (a) or for liquids (b) are available. See also chapter "Accessories".

(a)

(b)

⚠ By a wrong probe handling or a not proper probe setup or connection, large temperature errors can be the result!

⚠ Surface temperature measurement is a delicate task. One has to consider the following main points:

■ Ensure best thermal conductivity between surface and temperature sensor. Use thermal compound or grease to maximize heat transfer.

■ Apply pressure to the probe in order to properly contact the surface (spring is loaded only on magnetic surfaces!

■ Isolate the temperature sensor from the ambient air in order to avoid unwanted cooling or heating of the sensor. This is especially important if the temperature difference between surface and ambient air is high (e.g. >10°C)

ⓘ See also Appendix "Temperature Measurement" for more details.

18.2 Additional Interfaces

Tettex

A temperature extension box 2293T adds 8 additional temperature input channels to the 2293. It is connected over the delivered 10m extension cable to the front panel of the 2293.

In total 3 external boxes can be connected (in daisy chain) to the 2293 which results in a total of 30 temperature measuring channels (6 + 3x8).

1	Connector to connect to the 2293 (Master)
2	Connector to connect other extension boxes (Slaves)
3	8 Temperature probe connectors

18.3 Operation
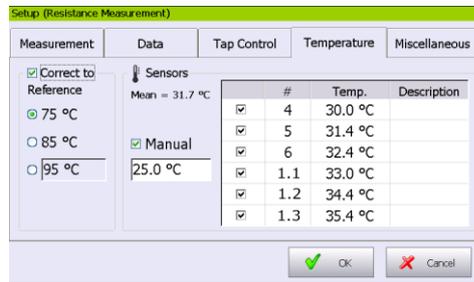
The temperature measuring screen is accessed clicking the Setup button, under the temperature folder in the function key bar.

The connected boxes and probes are automatically shown in the list # column as:

1 - 6   standard inputs on the 2293 front panel
1.1 – 1.8   8 inputs of the first box
2.1 – 2.8   8 inputs of the second box
3.1 – 3.8   8 inputs of the third box

The additional connected probes in the list can now be set up as the standard ones connected on the front panel. See related chapter.

19 Troubleshooting

19.1 Warning and Error Messages

19.1.1 Polarity reverse or HV and LV reverse

Before the devices starts the resistance measurement in mode C or D, the 2293 does a ratio check to verify that the transformer is connected correctly and the vector group and phase displacement are correct.

Polarity reverse → the measured ratio is negative (Ratio < 0).
HV and LV reverse → the measured ratio is positive smaller than 0.9 (0 < ratio < 0.9).

In any case, please check the connections from the 2293 to the DUT and the transformer vector group and phase displacement configuration (e.g. YNyn6).

19.1.2 Current to small

During charging the device checks if the applied current reaches the set current. If the applied current is much smaller than the set current or even zero, this error message pops up. To solve the problem, check the connections to the DUT or reduce the measuring current when trying to measure high resistances.

19.1.3 OVP - Overvoltage Protection

This message appears when the voltage between any pair of measuring leads to the DUT exceeded 250V and thus the OVP was triggered.

If you are performing a resistance measurement on the LV side of a transformer with a high ratio (e.g. distribution transformer) and this error arises during charging, you should try to disconnect the HV measuring leads. Because applying any voltage to the LV side results in a much higher voltage at the HV side.

19.1.4 OCP - Over current Protection

The device automatically shuts down the supplies if the current during measurement exceeds certain limits. It is possible that there is a hardware failure if this happens regularly.

19.1.5 OTP - Over temperature Protection

The temperature of the cooler of the power supplies is monitored permanently. If this temperature exceeds a certain safety limit, the supply will automatically shut down. This can be caused by very high ambient temperatures (>60°C) or direct exposure to the sun. If this is not the case, the reason is probably a hardware malfunction.

19.1.6 Hardware Error

If the device detects a hardware problem, it will pop up this message. If this message persists, the device should be completely rebooted. If this did not help, there is probably a hardware failure.

19.2 Firmware Update

The newest firmware can be downloaded from our update webpage http://update.haefely.com/2293

Steps:

Copy the file downloaded (WA2293.exe) to a USB stick

Insert into the USB socket of the front panel

Click Setup to open "Setup" dialog, on folder "Miscellaneous" click Firmware Update
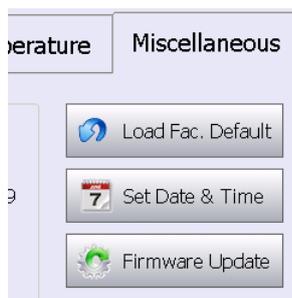
In case a newer version found on the USB stick, following dialog will be opened for confirmation

(xx.xx.xx: actual version number, yy.yy.yy: new version number found on the USB stick)
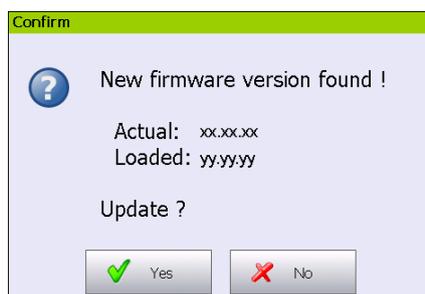
By clicking Yes, the updating will be started until all processes finished automatically.

19.3 Unit locks up and/or does not discharge completely

⚠️ The device features an emergency button to safely discharge the transformer in case of any problem. This works independent of the software!

⚠️ The user MUST always observe the red LEDs on the front panel (they work even if there is no mains supply!)

⚠️ The user MUST only disconnect the clamps, if there is NO red LED illuminated!

⚠️ A charged system is always very dangerous condition!
The User MUST NEVER disconnect any clamp from the Transformer as long as there is a current flowing in the Transformer!

Follow this safe discharge procedure in case of lock up:

1. Press emergency button

2. Wait for the red LED to turn OFF. This can take up to several minutes.

3. If the red LED did not turn off after 10 minutes, the user MUST switch off the device and disconnect the mains supply.

4. The user MUST continue to wait for the red LED to turn OFF. Even if it takes hours (normally it can only take up to some minutes).

5. Device could be rebooted now (not necessarily).

6. The user MUST only disconnect the Clamps from the transformer if the red LED is OFF!

20 Printer Operation

20.1 Buttons and Status

Status LED   Paper Feed Button   Mode Button
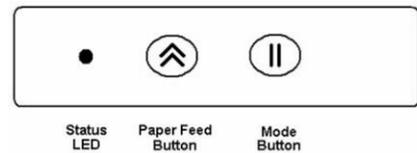
20.1.1 Status LED

LED indication	Condition	Solution
ON	Printer On	-
Off	Printer Off	-
✳ ✳ ✳	Paper Out	Fit new paper
✳✳ ✳✳ ✳✳	Thermal heat too hot	Allow to cool down

The printer automatically detects when the paper has run out and reports by blinking status LED.

20.1.2 Replacing Paper Roll

If the paper is out, open the paper cup lid and remove the remaining paper. Reel off a few centimeters from a new roll of paper. Hold approx. 5 cm of paper outside the device as you place the new roll into the reservoir. Now close the lid by applying equal amounts of pressure on each side ensuring the lid is in the locked position. Now tear the spare paper away.

21 Accessories & Spares

21.1 Temperature probe for liquids

This temperature probe is used for temperature measurements of liquids, e.g. oil bag on top of power transformer

21.2 Magnetic temperature probe

This magnetic temperature probe is used for temperature measurements on DUT tanks e.g. cooling radiator on power transformers

21.3 Temperature extension box 2293T

Up to three of these temperature extension boxes can be connected to the unit to extend the number of measured temperature probes to max. 30. (with 3 boxes)

Tettex

21.4 Tap changer connection cable

This remote control tap changer operation cable can be used to connect automated tap changers to support the fully automated measurement mode.

21.5 Extension cables

This cable is used to enlarge the connection cables by 10m for very large DUTs or longer distances between the 2293 instrument and DUT.

There are two versions:

Connectors **bolted** (Serial No. Lower than 179584)

Connectors **twist lock** (Used with devices Serial No. higher than 179585)

21.6 TTR-229x Adaptor
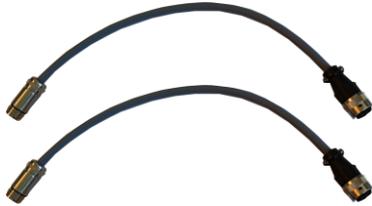
This adaptor allows the use of the 2293 cable set together with a Tettex TTR type 2795 or 2796.

21.7 HV cable set

Cable set for the High Voltage side (red clamps)". Cables are equipped with special Kelvin clamps.

21.8 LV cable set

Cable set for the Low Voltage side (black clamps)". Cables are equipped with special Kelvin clamps.

21.9 Adaptor set LV & HV, bolted

Adaptors Measuring device – Cable sets

(Red ring HV, black ring LV)

Fit on 2293 units with bolted connectors
(Serial No. Lower than 179584)

21.10 Adaptor set LV & HV, twist lock

Adaptors Measuring device – Cable sets

(Red ring HV, black ring LV)

Fit on 2293 units with twist lock connectors
they do **not** fit on bolted connectors!

(Used with devices Serial No. higher than 179585)

22 Remote Control

22.1 Ethernet Connection

The device can be remote controlled using an 10/100MBit Ethernet Connection. The advantage of Ethernet is that it is completely platform independent and no device specific drivers are necessary. This makes Ethernet Remote Control very flexible.

22.1.1 RJ45 Socket

Connect the device to the network using a RJ45 patch cable:
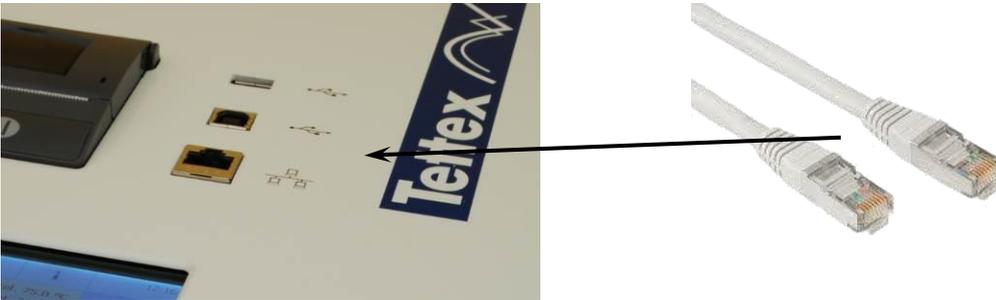
22.1.2 Direct connection

The device can be directly connected to a 10/100MBit Ethernet network interface of your computer. Typically addresses from the private network address space are used in such an environment.
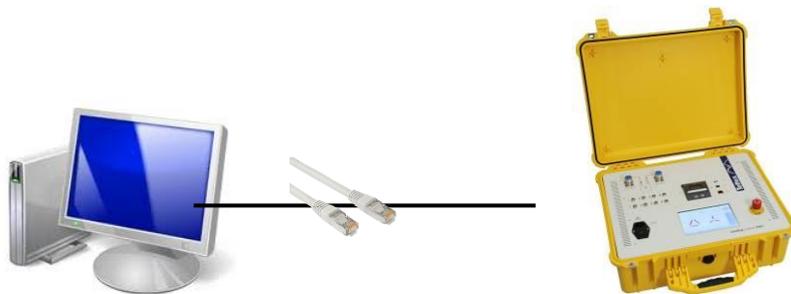
| Address: | 10.0.0.100 |
| Subnet: | 255.255.255.0 |

| Address: | 10.0.0.105 |
| Subnet: | 255.255.255.0 |

22.1.3 Switched Network

The device can also be operated in a non-routed private network environment. Typically addresses from the private network address space are used in such an environment. The setup would look like this:
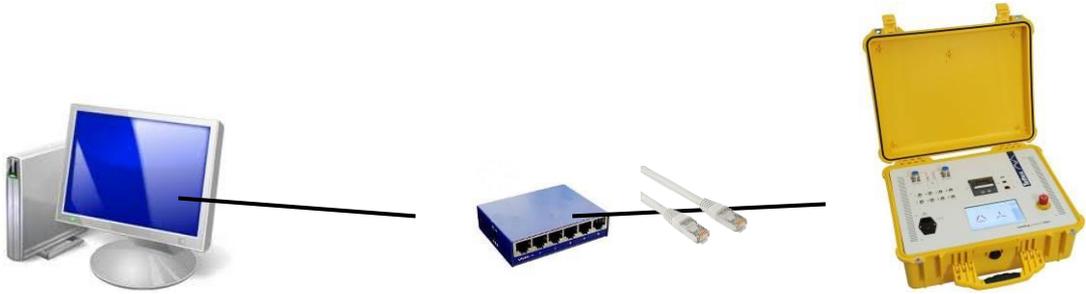
Address:
10.0.0.105

Subnet:
255.255.255.0

50000

10.0.0.100 Address:

255.255.255.0   Subnet:

TCP-Port:

22.1.4 Routed Network / Internet

The device can even be operated in a routed network environment or over the Internet. But therefore the device needs a globally (non-private) routed internet address. The setup would look like this:

Routed
Network

or
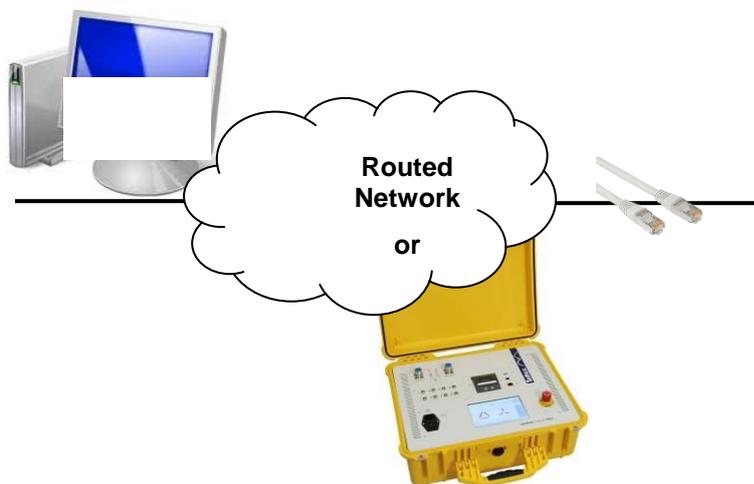
Address:
212.156.24.16

Subnet:
255.255.255.0

Gateway:
212.156.24.1

10.0.0.100 Address:

255.255.255.0   Subnet:

10.0.0.1   Gateway:

50000

or

Address:	132.20.196.55
Subnet:	255.255.0.0
Gateway:	132.20.0.1

22.2 *Protocol*

The device accepts exactly 1 incoming TCP connection on port 50000 for remote controlling. When a connection to a client has been established, the device will accept further connections, but it will immediately close these connections. Commands must be sent as TCP data. The protocol stack looks as follows:

Ethernet	IP	TCP	[Command][?] [Parameter1],[Parameter2],…<CR><LF>

22.2.1 Instructions

The device accepts the following format as remote control input:

```
                    [Instruction Sequence] <CR><LF>


    |    [Instruction1] <;> [Instruction2] <;> [Instruction3] …


    |    [Command] [?] <SP> [Parameter1] <,> [Parameter2] <,> [Parameter3] …
```

All characters (letters and symbols) must be sent as 1 Byte wide (8 Bit) ASCII characters. All instructions are case insensitive, but the syntax of instructions and commands must strongly be met. Extra white spaces (<SP>) must be avoided. Otherwise the instruction will be discarded upon reception of the next termination sequence (<CR><LF>). The following control characters are used:

Syntax	Description	String	Hex Code	Decimal Code
<?>	Question Mark	"?"	0x3F	63
<SP>	White Space	" "	0x20	32
<,>	Comma	","	0x2C	44
<;>	Semicolon	";"	0x3B	59
<CR>	Carriage Return	"\r"	0x0D	13
<LF>	Line Feed	"\n"	0x0A	10

22.3 Command Reference

- ***IDN**

    Returns a device identification string.

    - **Query:**   `*IDN?`

- **GTL**

    Sets the device to local controlled mode. This function will unlock the local touch panel.

- **REN**

    Sets the device to remote controlled mode. This function will lock the local touch panel. The device

    will only accept remote commands, if a REN command has been issued.

- **Mode**

    Returns the control mode of the device (remote or local).

    - **Query:**   `Mode?`

        → `Local ¦ Remote`

- **RemoteToLocal**

    Transfers the remote device configuration to the local device configuration. This command must

    always be issued for any remote settings to become effective.

- **Meas:App**

    Sets or returns the active measurement application.

    - **Set:** `Meas:App [App]`

        `[App] = Res ¦ HR ¦ Dem`

    - **Query:**   `Meas:App?`

        → `[App]`

- **Meas:Start**

    Starts the measurement for the current application (Resistance, HeatRun, Demagnetization …).

- **Meas:Stop**

Stops any ongoing measurement

• Meas:Continue

Continues any ongoing measurement which is waiting for user interaction in certain states (e.g. manual

recording resistance measurement).

• Meas:State

Returns the state of a measurement.

- Query: `Meas:State?`

→ `Standby ¦ Initializing ¦ Charging ¦ Measuring ¦ Discharging`

`¦ Reset ¦ Interlock ¦ OffsetNulling ¦ DemagAnalyzing ¦`

`DemagCycleInit`

• Meas:Error

Returns any errors that have occurred during measuring. Errors are reset by the Meas:Start

command.

- Query: `Meas:Error?`

    → `PolarityReverse ¦ HVLVReverse ¦ OverVoltageProtection`
¦

        `HardwareFail ¦ Interlock ¦ OverTemperature ¦`

        `RemanenceTooSmall ¦ CurrentTooSmall ¦ CurrentTooHigh ¦`

        `ACSupplyOffset ¦ UnknownError`

• DUT:Set:Vectorgroup

Sets and returns the winding configuration and phase shift of the DUT.

- Set: `DUT:Set:Vectorgroup`
`[WindHV],[WindLV],[ClockLV],[WindTV],[ClockTV]`

        `[Winding] = D ¦ Y ¦ YN ¦ Z ¦ ZN ¦ I ¦ -`

      `[Clock] = 0 ¦ 1 ¦ 2 ¦ 3 ¦ 4 ¦ 5 ¦ 6 ¦ 7 ¦ 8 ¦ 9 ¦ 10 ¦ 11`

- Query: `DUT:Set:Vectorgroup?`

    → `[WindHV],[WindLV],[ClockLV],[WindTV],[ClockTV]`

• DUT:Set:TempCoeff

Sets and returns the temperature coefficient for the three windings (HV, LV and TV). The coefficient is

used for temperature correction of the winding resistance value.

- Set: `DUT:Set:TempCoeff [CoeffHV],[CoeffLV],[CoeffTV]`

      `[Coeff] = CopperIEC ¦ CopperANSI ¦ Aluminium`

- Query: `DUT:Set:TempCoeff?`

    → `[Coeff]`

• TC:Move

Sends and up or down impulse to the remote controlled tap changer which is connected to the 2293

tap changer interface.

- Set: `TC:Move [Direction]`

      `[Direction] = Up ¦ Down`

• TC:Feedback

Resets or returns the state of the tap changer feedback signal. This signal indicates wheter the

button on the tap changer interface handheld has been pressed or the connected tap changer signaled

ready.

- Reset: `TC:Feedback Reset`

- Query: `TC:Feedback?`

        → `[FB] = 0 ¦ 1`

• TC:ButtonLED

Controls the state of the LED of the Button on the tap changer interface handheld.

- Set: `TC:ButtonLED [OnOff]`

        `[OnOff] = On ¦ Off`

Tettex

• Temp:Values

Returns the current temperature value measured by the temperature measuring channels in xxx.xx°C.

-100.00 indicates that no sensor is connected.

- **Query:**   `Temp:Values?`

       → `[Temp1],[Temp2],[Temp3],[Temp4],[Temp5],[Temp6]`

     `Temp:Values? [Channel]`

            → `[Temp[Channel]]`

• Res:Set:Mode

Sets and returns the measuring mode for winding resistance.

- **Set:** `Res:Set:Mode [Mode]`

        `[Mode] = Auto ¦ Classic1R ¦ Classic2R ¦ Classic3R`

- **Query:**   `Res:Set:Mode?`

       → `[Mode]`

• Res:Set:YNMode

Sets and returns the method used for measuring YN connected windings (Phase-to-Phase or

Phase-to-Neutral Supply).

- **Set:** `Res:Set:YNMode [YNMode]`

        `[YNMode] = PhPh ¦ PhNe`

- **Query:**   `Res:Set:YNMode?`

       → `[YNMode]`

• Res:Set:ConnClassic

Sets and returns the connection method used in Classic Resistance Measurement mode (separate or

combined supply clamps/cables).

- **Set:** `Res:Set:ConnClassic [ConnClassic]`

        `[ConnClassic] = Sep ¦ Comb`

-**Query:**`Res:Set:ConnClassic?`

        `[ConnClassic]`

• Res:Set:Data:Recording

Sets and returns whether automatic or manual resistance value recording is performed. Automatic

mode uses the stability criterion value to determine when to record a resistance value.

- Set: `Res:Set:Data:Recording [Recording]`

   `[Recording] = Auto ¦ Manual`

- Query: `Res:Set:Data:Recording?`

   → `[Recording]`

• Res:Set:Data:Stability

Sets and returns the value in %/s (percent change of resistance value per second) used to determine if

a resistance value is considered stable or not.

- Set: `Res:Set:Data:Stability [Stability]`

   `[Stability] = 0.0001 … 0.1000`

- Query: `Res:Set:Data:Stability?`

   → `[Stability]`

• Res:Set:Temp:Ref

Sets and returns the reference temperature in °C used for temperature dependent resistance

correction.

- **- Set:** `Res:Set:Temp:Ref [TempRef]`

    `[TempRef] = -100.00 … +200.00`

- **- Query:** `Res:Set:Mode?`

    → `[Mode]`

• Res:Set:Temp:Man

Sets and returns the manual value for the temperature of the DUT used for temperature correction.

- **- Set:** `Res:Set:Temp:Man [Temp]`

    `[Temp] = -100.00 … +200.00`

- **- Query:** `Res:Set:Temp:Man?`

    → `[Temp]`

• Res:Set:Temp:Use

Sets and returns which temperature channels are used to calculate the average temperature of the

DUT for temperature correction.

- **- Set:** `Res:Set:Temp:Use [Ch1],[Ch2],[Ch2],[Ch4],[Ch5],[Ch6],[ChManual]`

    `[Ch] = 0 ¦ 1`

- **- Query:** `Res:Set:Temp:Use?`

    → `[Ch1],[Ch2],[Ch2],[Ch4],[Ch5],[Ch6],[ChManual]`

• Res:Set:Temp:Enable

Sets and returns whether the temperature correction of the resistance is enabled or not.

- **- Set:** `Res:Set:Temp:Enable [TempEnable]`

    `[Temp] = 0 ¦ 1`

- **- Query:** `Res:Set:Temp:Enable?`

    → `[TempEnable]`

• Res:Set:Winding:Select

Sets and returns the selection of the winding pair to be measured.

- Set: `Res:Set:Winding:Select [WindingPair]`

   `[WindingPar] = HV-LV ¦ HV-TV`

- Query: `Res:Set:Winding:Select?`

→ `[WindingPair]`

• **Res:Set:Phase:Select**

Sets and returns the selection of the phases to be measured for all three windings. The 4 argument style command lets the user explicitly choose which phases on which windings have to be measured. Using the 1 argument style command, the software automatically selects the corresponding phases on

HV, LV and TV (one phase per winding). Phase assignment:

Phase 1A-B   A-N

Phase 2B-C   B-N

Phase 3C-A   C-A

- Set: `Res:Set:Phase:Select [Winding],[Phase1],[Phase2],[Phase3]`

            `[Winding] = HV ¦ LV ¦ TV`

            `[PhaseX] = 0 ¦ 1`

        `Res:Set:Phase:Select [Phase]`

              `[Phase] = 1 ¦ 2 ¦ 3`

- Query: `Res:Set:Phase:Select?`

      →

`HV,[Ph1],[Ph2],[Ph3];LV,[Ph1],[Ph2],[Ph3];TV,[Ph1],[Ph2],[Ph3]`

• Res:Set:Current

Sets and returns the measuring current in Ampere for the three different windings (HV, LV and TV).

- Set: `Res:Set:Current [Winding],[Current]`

            `[Winding] = HV ¦ LV ¦ TV`

            `[Current] = 0.0 … 32.0`

- Query: `Res:Set:Current?`

    → `HV,[Current];LV,[Current];TV,[Current]`

    `Res:Set:Current? [Winding]`

    → `[Current]`

• Res:Data:R ¦ Res:Data:U ¦ Res:Data:I ¦ Res:Data:T

Returns the recorded value for all or certain windings and phases as 1.23456e-3 Resistance (R), Voltage (U), Current (I) or Temperature (T)

- Query: `Res:Data:R?`

    → `[ResHV1],[ResHV2],[ResHV3],[ResLV1],[ResLV2],[ResLV3],`

        `[ResTV1],[ResTV2],[ResTV3]`

    `Res:Data:R? LV`

    → `[ResLV1],[ResLV2],[ResLV3]`

    `Res:Data:R? TV,2`

    → `[ResTV2]`

• Res:Meas:R ¦ Res:Meas:U

Returns the currently measured resistance values as 1.23456e-3. In automatic mode R1 and R2 are

the values of HV and LV, respectively the values of HV and TV, depending on which windings are

selected. In classic mode R1, R2 and R3 can be obtained. The same holds for the measured voltages.

- **Query:**   `Res:Meas:R?`

    → `[R1],[R2],[R3],[R4]`

  `Res:Meas:R? 2`
    → `[R2]`

• **Res:Meas:I**

Returns the currently measured current values as 1.23456e-3. In automatic mode I1 and I2 are the

values of HV and LV, respectively the values of HV and TV, depending on which windings are

selected. In classic mode I1 is the measuring current for all resistors.

- **Query:**   `Res:Meas:I?`

    → `[I1],[I2]`

  `Res:Meas:I? 1`
    → `[I1]`

• Res:Meas:T

Returns the currently measured average temperature value as 1.23456e-3. This value depends on

which temperature channels are marked for average calculation.

- Query: Res:Meas:T?

→ [TAverage]

• Res:Meas:Sequence

Returns the current measuring sequence for the started resistance measurement. The parameter

winding describes whether no (-) or only primary (1) or only secondary (2) or both (D) windings will be

measured. Mode defines which supply mode will be used. In case that no measurement will be

performed for a sequence step, mode will be set to "Nop". And phase describes between which

terminals the resistance will be measured for primary and secondary winding.

- Query: Res:Meas:Sequence?

→   [Winding],[Mode],[PhasePri],[PhaseSec];

[Winding],[Mode],[PhasePri],[PhaseSec];

[Winding],[Mode],[PhasePri],[PhaseSec];

[Winding],[Mode],[PhasePri],[PhaseSec];

[Winding],[Mode],[PhasePri],[PhaseSec];

[Winding],[Mode],[PhasePri],[PhaseSec];

[Winding1] = - ¦ 1 ¦ 2 ¦ D

[Mode] = Nop ¦ 32A/50V ¦ 16A/100V ¦ 16A/50V ¦ YdnMode ¦

Classic2R ¦ UnknownOperation

[Phase] = A-N ¦ B-N ¦ C-N ¦ N-A ¦ N-B ¦ N-C ¦

A-B ¦ B-C ¦ C-A ¦ B-A ¦ C-B ¦ A-C

• Res:Meas:State

Returns the current resistance measurement state. SeqNo indicates which measurement out of the

sequence described above is currently performed. An RxStable is set to 1 if the measured resistance

value is stable according to the Res:Set:Data:Stability criterion.

- Query: Res:Meas:State?

→ [SeqNo],[R1Stable],[R2Stable],[R3Stable]

```
            [SeqNo] = 0¦1¦2¦3¦4¦5¦6
        [RxStable] = 0¦1
```

• HR:Set:Interval

Sets and returns the interval time in seconds between two resistance values.

- Set: `HR:Set:Interval [Time]`
            `[Time] = 1 … 600`

- Query: `HR:Set:Interval?`
            → `[Time]`

• HR:Set:NumPoints

Sets and returns the number of points to be recorded for the heat run cooling curve.

- Set: `HR:Set:NumPoints [NPoints]`
            `[Time] = 10 … 1000`

- Query: `HR:Set:NumPoints?`
            → `[NPoints]`

• HR:Set:Phase:Select

Sets and returns the phase selection for the heat run test. Issuing the set command with only a phase

argument selects the corresponding two phases of the currently selected windings. By adding a

winding argument, the selection can be reduced to only one phase on only one winding.

- **Set:** `HR:Set:Phase:Select [Phase],[Winding]`

        `[Phase] = 1 ¦ 2 ¦ 3`

        `[Winding] = HV ¦ LV ¦ TV`

    `HR:Set:Phase:Select [Phase]`

        `[Phase] = 1 ¦ 2 ¦ 3`

- **Query:**   `HR:Set:Phase:Select?`

        →
`HV,[Ph1],[Ph2],[Ph3];LV,[Ph1],[Ph2],[Ph3];TV,[Ph1],[Ph2],[Ph3]`

        `[Ph] = 0 ¦ 1`

• HR:Data

Returns a measurement set (Time [t] in seconds, Resistance [R], Voltage [U], Current [I], Temperature

[T]) for a given winding, phase and index. The index is used to access various points recorded. Each

successful query returns [IndexCurrent] which shows the amount of points recorded so far. When

[IndexCurrent] has reached [NPoints] the heat run recording is finished and the device will discharge

the DUT.

- **Query:**   `HR:Data? [Winding],[Phase],[Index]`

        `[Winding] = HV ¦ LV ¦ TV`

        `[Phase] = 1 ¦ 2 ¦ 3`

        `[Index] = 1 … 1000`

        →
`[IndexCurrent],[t],[R],[U],[I],[T1],[T2],[T3],[T4],[T5],[T6]`

        → `[IndexCurrent],-  (No data for this index available)`

        → `-  (No data for this winding and phase available)`

• Dem:Set:Phase

Sets and returns the phase on which the demagnetizazion shall be performed.

- **Set:** `Dem:Set:Phase [Winding],[Phase]`

```
[Winding] = HV ¦ LV ¦ TV
[Phase] = 1 ¦ 2 ¦ 3
```

- Query: `Dem:Set:Phase?`

→ `[Winding],[Phase]`

• Dem:Set:Tolerance:Abs

Sets and returns the absolute stop criterion for demagnetization in V·s respectively Wb.

- Set: `Dem:Set:Tolerance:Abs [TolAbs]`

`[TolAbs] = 0.001 … 0.5`

- Query: `Dem:Set:Tolerance:Abs?`

→ `[TolAbs]`

• Dem:Set:Tolerance:Rel

Sets and returns the relative stop criterion for demagnetization in % of maximum remanence.

- Set: `Dem:Set:Tolerance:Rel [TolRel]`

`[TolRel] = 1 … 50`

- Query: `Dem:Set:Tolerance:Rel?`

→ `[TolRel]`

• Dem:Set:Cycles

Sets and returns the maximum number of cycles to be performed when demagnetizing.

- Set: `Dem:Set:Cycles [NCycles]`

`[NCycles] = 3 … 50`

- Query: `Dem:Set:Cycles?`

→ `[NCycles]`

• Dem:Meas

Returns the current set of measurements used in the demagnetization process. The current

demagnetization cycle [CycleAct], the remanence flux determined during analysis [FluxRemanence],

the current magnetic flux [FluxAct], the induced voltage [UInduced], the current [I] and the winding

resistance [R].

- Query: `Dem:Meas?`

→ `[CycleAct],[FluxRemanence],[FluxAct],[UInduced],[I],[R]`

22.4 *Programming examples*

22.4.1 Resistance Measurement

First, start with REN. This will enable remote controlling and it will transfer the current local set of settings to the remote set of settings. Then send all settings to the device and at the end call `RemoteToLocal` to transfer the remote settings to the local settings.

```
REN

Meas:Set:App RES

Res:Set:Mode Auto

Res:Set:YNMode PhPh

DUT:Set:Vectorgroup YN,YN,0,D,5

DUT:Set:TempCoeff CopperANSI,CopperIEC,Aluminium

Res:Set:Temp:Man 18.9

Res:Set:Temp:Ref 75.0

Res:Set:Temp:Use 0,1,0,0,0,0,1

Res:Set:Temp:Enable 1

Res:Set:Current HV,2.2
```

```
Res:Set:Current LV,8.9
Res:Set:Current TV,13.2
Res:Set:Phase:Select HV,1,1,0
Res:Set:Phase:Select LV,1,0,1
Res:Set:Phase:Select TV,1,1,1
Res:Set:Winding:Select HV-LV
Res:Set:Data:Stability 0.0003
Res:Set:Data:Recording Auto

RemoteToLocal
```

After sending all the settings, a

```
Meas:Start
```

will start the resistance measuring sequence. After the measurement has started, the measuring sequence and mode can be obtained using

```
Res:Meas:Sequence?
```

The result of this query helps to find out which winding and phase the device is currently measuring. Further

```
Res:Meas:State
```

Shows which sequence step is currently performed and if a stable resistance reading is reached.

```
Meas:State
```

Has to be used to find out in which state within a sequence step the device currently is. For resistance measurement the state flow will typically look like

```
Standby → Initializing → Charging → Measuring → Discharging →
Reset →
Standby
```

When "Data Recording" is set to auto, the device will automatically continue from `Measuring` to `Discharging`. When "Data Recording" to manual, the device stays in the `Measuring` state until

```
Meas:Continue
```

is issued. The sequence can be stopped anytime by sending

```
Meas:Stop
```

One can observe the current measured values during the whole process using

```
Res:Meas:R?
Res:Meas:U?
Res:Meas:I?
Res:Meas:T?
Temp:Values?
```

Recorded values (auto or manual) can be obtained using

```
Res:Data:R?
Res:Data:U?
Res:Data:I?
Res:Data T?
```

If a measuring process aborts unexpectedly or the system state is `Reset` or `Interlock`, one can get an error message using

```
Meas:Error
```

22.4.2 Tap Changer Control

A remote controlled tap changer can be operated using

```
TC:Move Up ¦ Down
```

This operation is only valid if the system state is either `Measuring` or `Standby`. Further only an On-Load Tap Changer could be operated during `Measuring`. NEVER operate an Off-Load Tap Changer during `Measuring`. An Off-Load Tap Changer must be operated ALWAYS during `Standby`. After issuing a `TC:Move` command the Tap Changer Feedback will be set to 0. When the Tap Changer movement completed, the feedback will be set to 1. This status can be obtained using

```
TC:Feedback?
```

22.4.3 Heat Run

```
REN

Meas:Set:App HR

Res:Set:YNMode PhPh

DUT:Set:Vectorgroup YN,YN,0,D,5

Res:Set:Current HV,2.2

Res:Set:Current LV,8.9

Res:Set:Current TV,13.2

HR:Set:Phase:Select 2

Res:Set:Winding:Select HV-LV

HR:Set:Interval 5

HR:Set:NumPoints 100

RemoteToLocal
```

After sending all the settings, a

```
Meas:Start
```

will start the Heat Run sequence. The start command will only start the timer when switching the transformer heating supply off. When the 2293 is connected to transformer and everything is ready for cooling curve acquisition, the command

```
Meas:Continue
```

will start the actual resistance measuring process. After the measurement has started, the measuring sequence and mode can be obtained using

```
Res:Meas:Sequence?
```

The result of this query helps to find out which winding and phase the device is currently measuring.

```
Meas:State
```

Has to be used to find out in which state within a sequence step the device currently is. For cooling curve measurement the state flow will typically look like

```
        Standby → Initializing → Charging → Measuring → Discharging →
Reset →

        Standby
```

When the device has reached the `Measuring` state, it will immediately start to record data sets. The sequence can be stopped anytime by sending

```
        Meas:Stop
```

One can observe the current measured values during the whole process using

```
        Res:Meas:R?
        Res:Meas:U?
        Res:Meas:I?
        Res:Meas:T?
        Temp:Values?
```

Recorded values can be obtained using

```
        HR:Data? HV,2,1
        HR:Data? LV,2,1
        HR:Data? HV,2,2
        HR:Data? LV,2,2
        HR:Data? HV,2,3
        HR:Data? LV,2,3
        …
```

If a measuring process aborts unexpectedly or the system state is `Reset` or `Interlock`, one can get an error message using

```
        Meas:Error
```

22.4.4 Demagnetization

First, start with REN. This will enable remote controlling and it will transfer the current local set of settings to the remote set of settings. Then send all settings to the device and at the end call `RemoteToLocal` to transfer the remote settings to the local settings.

```
        REN

        Meas:Set:App DEM

        DUT:Set:Vectorgroup YN,YN,0,D,5
```

```
Res:Set:Current HV,2.2
Res:Set:Current LV,8.9
Dem:Set:Phase HV,2

RemoteToLocal
```

After sending all the settings, a

```
Meas:Start
```

will start the demagnetization process. Further

```
Meas:State
```

Has to be used to find out in which state the device currently is. For the demagnetization process the state flow will typically look like

```
Standby → Initializing → Charging → Measuring → Discharging →
DemagAnalyzing → Initializing → Charging → Discharging →
DemagAnalyze →
DemagCycleInit
```

In the state DemagCycleInit the system decides whether the transformer is still magnetized (next cycle) or already demagnetized (no more cycles).

```
(Not Demag.)→ Initializing → Charging → Discharging →
DemagCycleInit
```

```
(Demag.)→ Reset → Standby
```

One can observe the current measured values during the whole process using

```
Dem:Meas?
```

If a measuring process aborts unexpectedly or the system state is `Reset` or `Interlock`, one can get an error message using

```
Meas:Error
```

At the end of successful demagnetization, this command should return

```
NoError
```

22.5 File & Data Transfer

File and data transfer is not covered in the 2293 remote control feature.

For file/data transfer we recommend the following methods:

USB Memory Stick

USB connection from a host computer to the device:

Windows XP and earlier:	Microsoft Active Sync.
Windows Vista or later:	Windows Mobile Device Center

Windows Remote API --- RAPI --- rapi.dll

The measurement data can be found in the directory

\Storage Card\Test

23 Miscellaneous

23.1 Care and Maintenance

The 2293 instrument is basically service free, as long as the specified environmental conditions are adhered to. As a result, service and maintenance is restricted to cleaning of the equipment and calibration at intervals stipulated by the application for which the instrument is used.

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

23.1.1 Cleaning the Instrument

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

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

23.1.2 Instrument Calibration

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

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

23.1.3 Changing Fuses

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

23.2 Instrument Storage

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

23.3 Packing and Transport
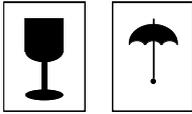
The packing of the 2293 instrument provides satisfactory protection for normal transport conditions. Nevertheless, care should be taken when transporting the instrument. If return of the instrument is necessary, and the original packing crate is no longer available, then packing of an equivalent standard or better should be used.

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

23.4 Recycling

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

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

24 Customer Support

All error messages appear on the display of the 2293 measuring instrument. If persistent problems or faulty operation should occur then please contact the Customer Support Department of HAEFELY TEST AG or your local agent.

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

HAEFELY TEST AG

Customer Service - Tettex

Birsstrasse 300

CH-4052 Basel

Switzerland

Tel: +41 61 373 4422

Fax: +41 61 373 4914

E-mail: support@tettex.com

We prefer contact via email. Then the case is documented and traceable. Also the time zone problems and occupied telephones do not occur.

Complete information describing the problem clearly helps us to help you:

Failure description

Used settings

DUT type

Firmware Version

Serial Number

MAC address

Printouts, Pictures

Firmware Version & Serial No. can be found in "Setup - Miscellaneous"

25 Appendix

25.1 Declaration of Conformity

HAEFELY
HIPOTRONICS

Declaration of Conformity

Haefely Test AG
Birsstrasse 300
4052 Basel
Switzerland

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

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

Product: **Winding Analyser 2293**

Description: The Winding Analyser 2293 is used to measure and evaluate transformer winding resistances and turns ratios.

Standards: EN 61010-1: 2010
                 EN 61326-1: 2013

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

Basel, February 13, 2014
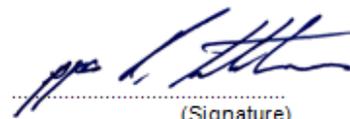
....
                (Signature)

Haefely Test AG, Birsstrasse 300, CH-4052 Basel / Switzerland
www.haefely.com

25.2 Application Note "Temperature Measurement"

25.2.1 1. Flat Surface

▪ Setup

To check the performance of different types of surface temperature measurement probes for flat surfaces, the setup depicted in figure 1 was constructed:

Figure 1: Flat surface test setup

The surface to be measured is a flat and 4.5mm thick steel plate, which was heated by 2 power resistors located at the bottom side of the plate. For reference temperature measurement 2 Thermocouples Type were used. Ech of them were sticked in a hole (d = 1.5mm, h = 2mm) filled with thermal compound for optimal thermal conduction. The thermocouples are the two black cables in figure 1. The probes under test were located near to the thermocouple probes.

The thermal contact is quite good in this setup for both types of probes.

▪ Probes under Test

1. Tettex magnetically Surface Temperature Measurement Probe Box (PT100)

$\rightarrow$ See figure 2, the probe with the black plastic handle.

2 Fühlersysteme OF/E-14/10-4 (PT100)

$\rightarrow$ See figure 1, the probe with the red horseshoe magnet and the spring loaded sensor tip.

▪ **Measurements**

1. Steady state at ambient
    Without thermal compound

OF/E-14	24.7°C	TC 1	24.4°C
Tettex	24.7°C	TC 2	24.4°C

2. Heating power: 17.6W
    Steady state (~0.1°C per minute)
    Without thermal compound

OF/E-14	67.9°C	TC 1	69.5°C	→ ΔT = -1.6°C
Tettex	68.1°C	TC 2	69.6°C	→ ΔT = -1.5°C

3. Heating power: 17.6W
    Steady state (~0.1°C per minute)
    With thermal compound

OF/E-14	69.4°C	TC 1	70.0°C	→ ΔT = -0.6°C
Tettex	70.2°C	TC 2	70.3°C	→ ΔT = -0.1°C

→ **Thermal compound increases measurement accuracy!** OF/E-14 (ΔT = -0.6°C) shows slightly worse measurement results than the Tettex probe (ΔT = -0.1°C). But it is easier to handle: Compare thermal compound usage in picture 1 (small dot compared to large area).

Tettex

25.2.2 2. Round Surface (Tube)

▪ **Setup**

During the HeatRun, the Radiator top and bottom (outlet and inlet) temperatures must be measured. Usually there are tubes, which are not very easy to measure. To check the performance of different types of surface temperature measurement probes for round surfaces, the setup depicted in figure 2 was constructed.
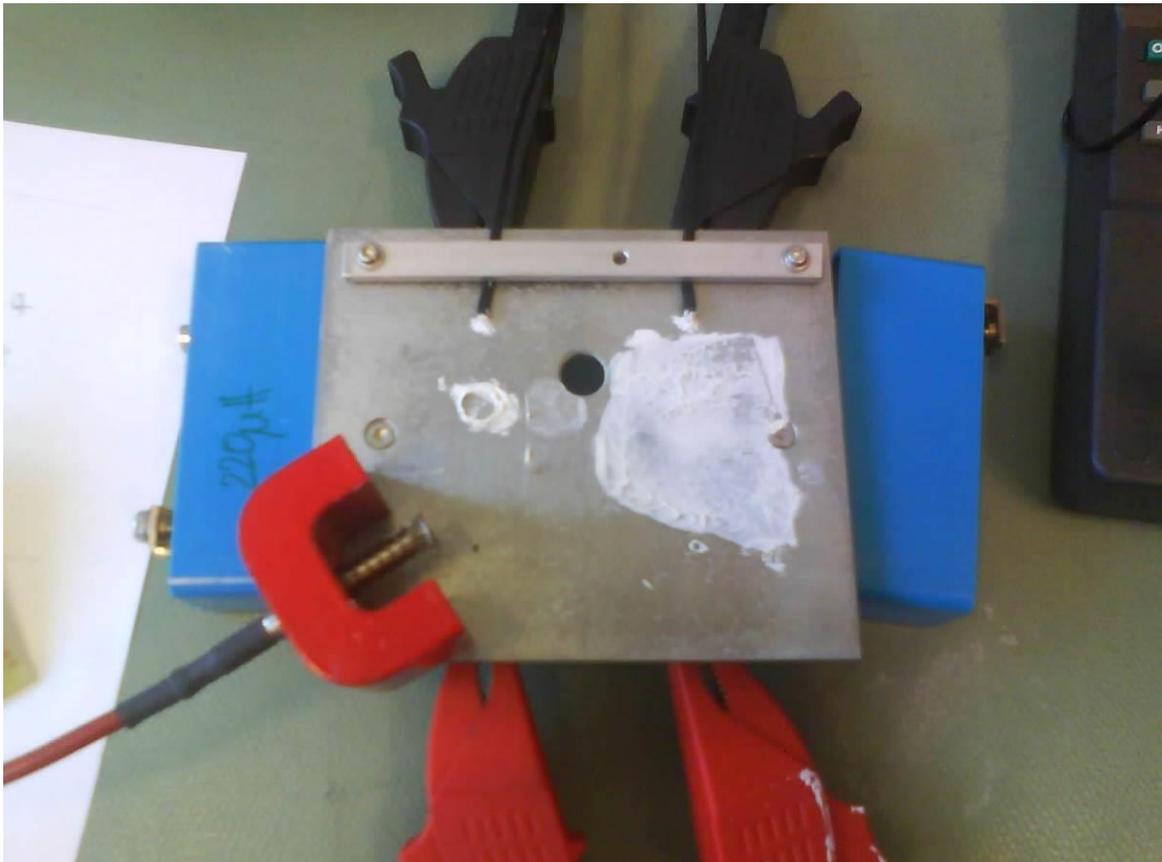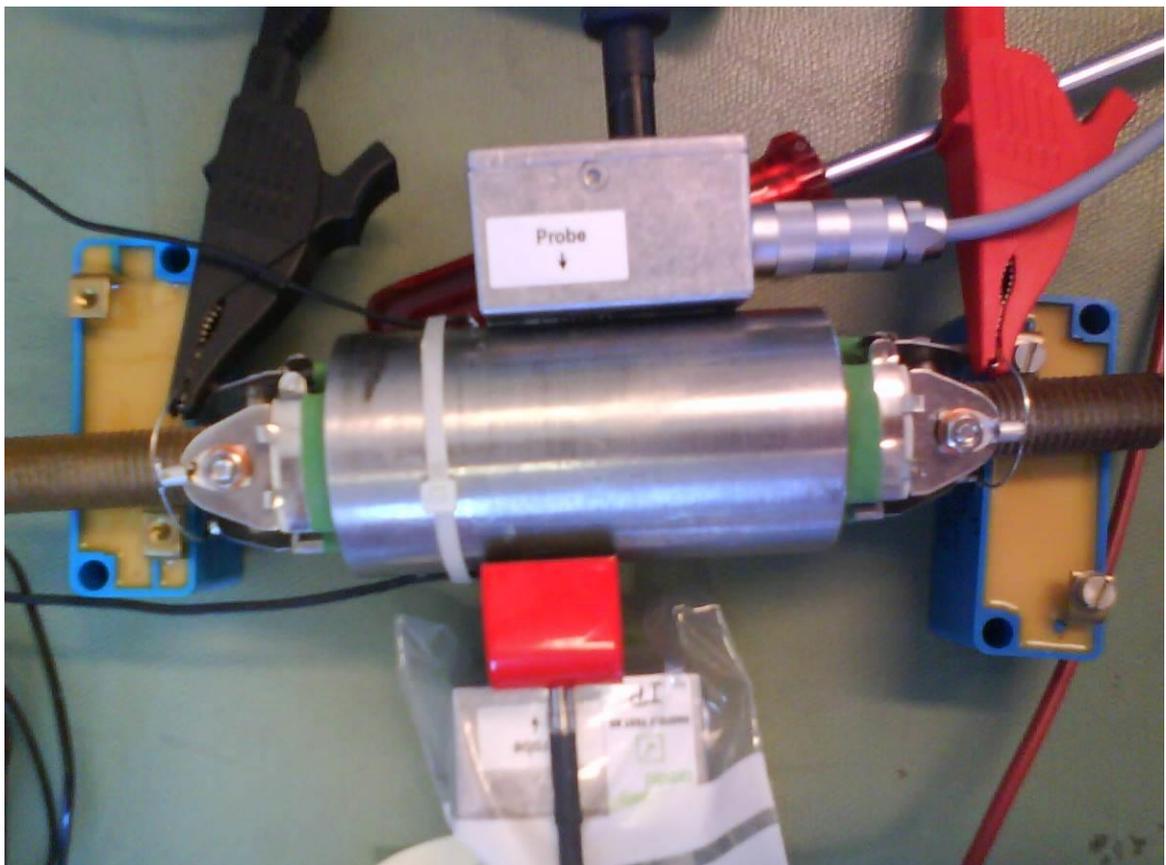

Figure 2: Round surface test setup

The steel tube to be measured has a diameter of 50mm and a thickness of 5mm. The tube was heated using 3 power resistors circularly arranged inside the tube . For reference temperature measurement 2 Thermocouples Type J were used. Each of them were sticked in a hole (d = 1.5mm, h = 2mm) filled with thermal compound for optimal thermal conduction. The thermocouples are the two black cables in figure 2. The probes under test were located near to the thermocouple probes.

The thermal contact is not very good for the OF/E-14 and even worse for the Tettex probe.

▪ **Probes under Test**

1. Tettex magnetically Surface Temperature Measurement Probe Box (PT100)

→ See figure 2, the probe with the black plastic handle.

2 Fühlersysteme OF/E-14/10-4 (PT100)

→ See figure 1, the probe with the red horseshoe magnet and the spring loaded sensor tip.

▪ Measurements

1.   Steady state at ambient
        Without thermal compound

OF/E-14	24.5°C	TC 1	24.1°C
Tettex	24.4°C	TC 2	24.1°C

2.   Heating power: 15.3W
        Steady state (~0.1°C per minute)
        Without thermal compound

OF/E-14	68.3°C	TC 1	75.1°C	→ ΔT = -6.8°C
Tettex	57.7°C	TC 2	74.6°C	→ ΔT = -16.9°C

3.   Heating power: 17.5W
        Steady state (~0.1°C per minute)
        With thermal compound

OF/E-14	67.4°C	TC 1	68.5°C	→ ΔT = -1.1°C
Tettex	65.9°C	TC 2	67.4°C	→ ΔT = -1.5°C

→ Thermal compound is absolutely necessary for measurements on round surfaces! Using thermal compound, OF/E-14 shows slightly better measurement results than the Tettex probe. But the OF/E-14 is much easier to handle: The Tettex probe must be positioned exactly according to its internal PT100 probe position. And it must be fixed in this position, since it is very likely to slip or turn (the screwdriver in figure 2 serves for this purpose). Otherwise the measurement performance decreases significantly. The OF/E-14 probe keeps the correct position by itself. See figure 3.
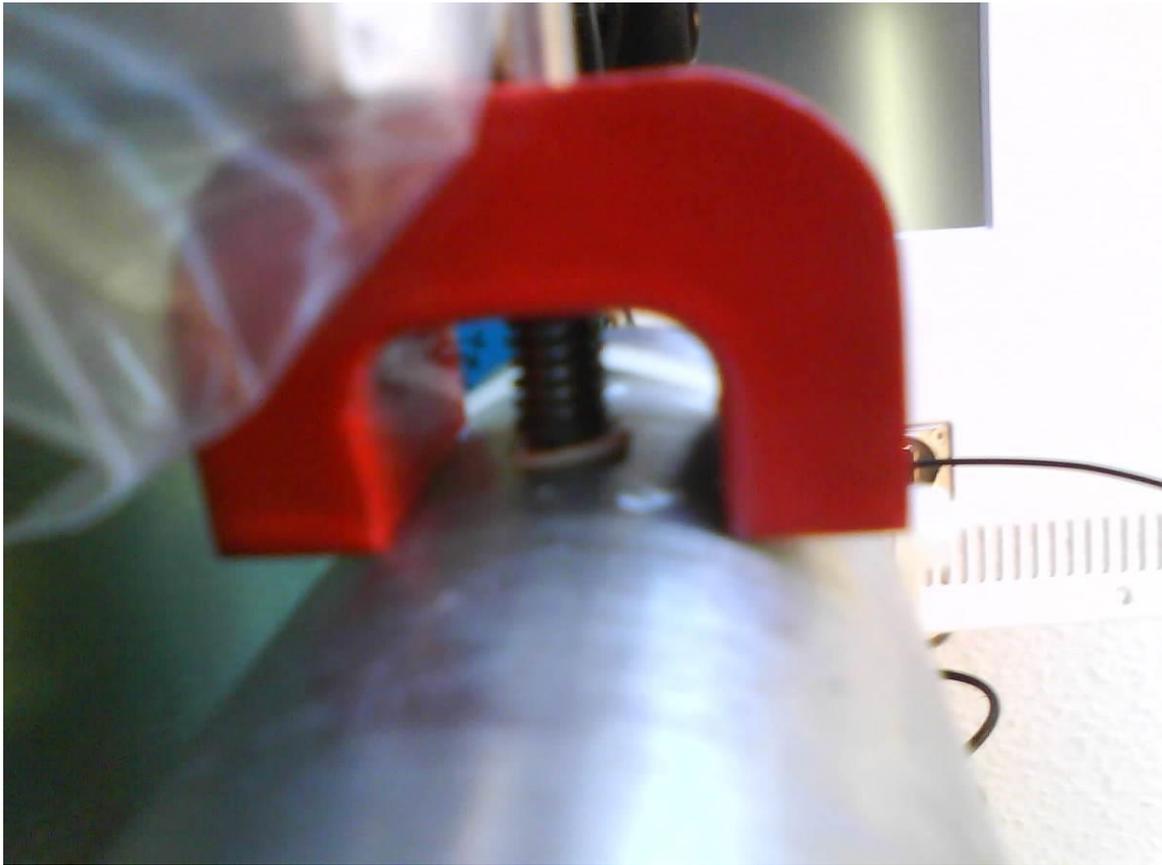
Figure 3: OF/E-14 placement on tube

3. Further Accuracy Improvement

The main Application issue, when measuring the temperature of a surface, is heat transfer from the surface to the probe. The surface will heat or cool the probe tip and the ambient air will do the opposite (cool or heat). Unless ambient air and surface temperature are equal, there will always be thermal flow at the probe. In order to reduce the thermal effect of the ambient air, it is strongly recommend isolating the temperature probe from the ambient. This can easily be achieved using an EPS foam box or similar.

See figure 4 as a reference design:

Figure 4: Thermal isolation using a piece of EPS foam

25.3 Application Note "Unit calibration"

Resistance measurement accuracy verification

To verify the resistance measurement accuracy of the instrument usually a certified standard resistor is used. These resistors normally have a current connection and a sense connection.

The 2293 measuring clamp is a Kelvin type. Means on one jaw is the current input on the other jaw is the voltage (sense) measurement.

> If calibration with a common standard resistor is performed, one has to isolate the voltage (sense) line from the current jaw to avoid failures by additionally measure the internal connection lead to the standard resistor part itself.