TRAX

Transformer and Substation Test System

User's Manual

Megger

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Contents

1 Introduction

1.1 Product description

TRAX™ is a unique testing instrument designed to accomplish routine and advances diagnostics on power, distribution and instrument transformers as well as on many other substation components.

A wide range of AC DC current and voltage sources together with high precision metering instrumentation allow TRAX to be used in a wide range of applications such as resistance, ratio, excitation, impedance and primary measurements of power system components.

TRAX is a unique test system for testing power transformers, CTs, VTs, and a variety of other power components. TRAX is capable of providing up to 800 A and 2200 V (up to 2000 A and 12000 V with optional accessories) with a frequency range of 5-505 Hz (1-505 for insulation testing) and can be controlled via integrated touch-screen or an external computer device with a web browser. The compact design weighs in at only 26 kg (TRAX220) and can be shipped in its transportation case within the limits of check-in luggage (< 32 kg).

1.2 Features and benefits

- Multi-function system for transformer/substation testing
- Flexible AC / DC current and voltage sources for a variety of tests.
- State of the art measurement methods for advanced diagnostic testing
- Variable output frequency for accurate measurements in high interference environments
- Compact and lightweight

User interface

TRAX user interface architecture is based on a number of individual test set-ups/"instruments", in this manual called "Apps", where only the necessary functionality is displayed by default. All Apps are "ready to go" in manual test mode without doing any specific settings. Just select the amplitude of the test signal and press start/play. If you prefer guidance from TRAX on how to perform the measurement, enter the configuration and TRAX will provide connection diagrams and a table with the order of measurements. And if a specific non-standardized measurement is needed, the "Manual control" instrument can be used to generate any voltage or current test signal and measure the necessary parameters.

All results can be stored and reported as a specific report containing test object information and all tests or as data to be imported in e.g. Excel. When testing a certain substation component, e.g. a power transformer, all measurements from different Apps can be collected in one report/file. It is also possible to use a former measurement as a template for a new test session.

Applications

A wide range of voltage and current levels can be achieved and measured with high precision which allows the test system to be used for a wide range of applications such as ratio, excitation current, winding and contact resistance, impedance, tan delta/power factor testing and various other measurements of power system components.

- Examples are:
- Power transformer
- Current transformer
- Voltage transformer
- Resistance testing
- Primary injection testing

1.3 Warranty

Products supplied by Megger are warranted against defects in material and workmanship for a period of one year following shipment.

Our liability is specifically limited to replacing or repairing, at our option, defective equipment.

This warranty does not include batteries, lamps or other expendable items, where the original manufacturer's warranty shall apply.

We make no other warranty. The warranty is void in the event of negligence and/or abuse (failure to follow recommended operating procedures) or failure by the customer to perform specific maintenance as indicated in this manual.

Receiving Instructions

- Check the equipment received against the packing list to ensure that all materials are present. Notify Megger of any shortage.
- Examine the instrument for damage occurred in transit. If damage is identified, file a claim with the carrier at once and notify Megger giving a detailed description of the damage.
- The instrument has been thoroughly tested, calibrated and inspected to meet rigid specifications before being shipped. It is ready for use when set up as indicated in this user manual.

Warranty repair

Equipment returned to the factory for repair must be shipped prepaid and insured.

Contact your Megger representative for instructions and a return authorization (RA) number.

Please indicate all pertinent information, including problem symptoms.

Also specify the serial number and the catalog number of the unit.

2 Safety

2.1 General

Important
Read and comply with the following instructions.
Always comply with local safety regulations.

Symbols

	Caution, refer to accompanying documents.
	Protective conductor terminal/test ground.
	Ground **For connecting an additional ground between the main unit and accessories or to ground external objects e.g. optional trolley.**
	Open ground = the ground Loop Detector will indicate that the separate "Test Ground" on the side panel is not connected to safety/chassis ground.
	WEEE, Waste Electrical and Electronic Equipment. Please utilize your local WEEE collection facilities in the disposition of this product and otherwise observe all applicable requirements. The unit can be returned to Megger at any time at no charge for the disposal.

Information duty regarding substances on REACH article 33, SVHC-list

This product contains a coin cell battery which contains 1,2- dimethoxyethane (CAS 110-71-4) above 0.1% by weight.

Warning and Caution Notices

Warning and caution notices are used throughout this manual where applicable and should be strictly observed. These notices appear in the format shown below and are defined as follows:

Warning
Warning, as used in this manual, is defined as a condition or practice which could result in personal injury or loss of life.

Caution
Caution, as used in this manual, is defined as a condition or practice which could result in damage to or destruction of the equipment or apparatus under test.

Open ground detection

1. The unit has an open ground detection circuit which gives alarm if the mains outlet ground is missing or different from the station/test specimen ground. The alarm can be configured by the user to give an alarm only or actually lock the unit and prohibit any test signal generation.
2. The mains outlet must have a PE, protective earth (ground) connected to station ground. Normally mains outlet PE is connected to station ground. If that is not the case there are two alternatives:
   - In compliance with local safety regulations and permits, use an isolation transformer where the secondary side Earth/Ground is to be connected to station ground using a separate ground cable (not via TRAX unit!)
   - In compliance with local safety regulations and permits, use a temporary grounding connection by connecting mains outlet ground with station ground.

Instrument safety

1. This instrument operates from a single-phase power source. It has two-pole terminal with ground connector and requires a two-pole, 16A, three-terminal, voltage and ground type connector. The voltage of the power source must be within the following rated operating voltage: 100-240 V ± 10 %, 47/63 Hz.

2.	Before making connection to the power source, determine that the instrument rating matches the voltage of the power source and has a suitable two-pole terminal with ground connector.
3.	The power input plug must be inserted only into a mating receptacle with a ground contact. Do not bypass the grounding connection. Any interruption of the grounding connection can create an electric shock hazard. Determine that the receptacle is properly wired before inserting the plug.

2.2 Safety instructions

1.	It is not possible to eliminate all potential hazards from, and in using, electrical test equipment. For this reason, every effort has been made to point out in this instruction manual the proper procedures and precautions to be followed by the user in operating this equipment and to mark the equipment itself with precautionary warnings where appropriate. It is not possible to foresee every hazard which may occur in the various applications of this equipment. It is therefore essential that the user, in addition to following the safety rules in this manual, also carefully consider all safety aspects of the test before proceeding.
2.	The test set and the specimen to which it is connected are a possible source of high-voltage electrical energy and all persons making or assisting in tests must use all safety practice precautions to prevent contact with energized parts of the test equipment and related circuits.
3.	Persons actually engaged in the test must stand clear of all parts of the complete high-voltage circuit, including all connections, unless the test set is de-energized and all parts of the test circuit are grounded. Persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades, or warnings.
4.	Treat all terminals of high-voltage power equipment as a potential electric shock hazard. There is always the potential of voltages being induced at these terminals because of proximity to energized high-voltage lines or equipment.
5.	Always ground connection points of the test specimen before connecting any leads from the test set. Whenever possible, always keep one side of the test specimen grounded at all times. Always use a safety ground stick to ground any high-voltage conductor.
6.	The ground connection on the test set must be the first made and the last removed. Any interruption of the grounding connection can create an electric shock hazard.
7.	Make sure that the instrument is properly grounded, both through its AC power cord and through the ground connector. The AC power cord is the disconnecting device.
8.	Always disconnect test leads from test specimen before attempting to disconnect them at the test set.

9.	High-voltage discharges and other sources of strong electric or magnetic fields may interfere with the proper functioning of heart pacemakers. Persons with heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.
10.	All persons making or assisting in tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. Also follow all local and company safety requirements. Persons actually engaged in the test must stand clear of all parts of the complete high- voltage circuit, including all connections, unless the test set is de-energized and all parts of the test circuit are grounded. Persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades, or warnings.
11.	Safety is the responsibility of the user.
12.	Misuse of this high-voltage equipment can be extremely dangerous.
13.	The purpose of this equipment is limited to use as described in this manual. Do not use the equipment or its accessories with any device other than specifically described.
14.	Before making any connections, make sure that the instrument is de-energized and that all parts of the test circuit are properly grounded.
15.	Never connect more than one output at the time. All outputs are energized by the same amplifier and therefore all outputs are energized simultaneously.
16.	Operation is prohibited in rain or snow.
17.	Do not use the test set in an explosive atmosphere.
18.	A qualified operator should be in attendance at all times while the test equipment is in operation.
19.	Observe all safety warnings marked on the equipment.
20.	Corrective maintenance must only be performed by qualified personnel who are familiar with the design and operation of the test set and the hazards involved.

Maintenance

1.	DISCONNECT the MAINS plug before any cleaning or maintenance.
2.	Maintenance should be performed only by qualified personnel familiar with the hazards involved with high-voltage test equipment.
3.	Read and understand Safety in the User Manual before performing any service.
4.	Routine maintenance is all that is required for these test sets. The cables and connector panel should be inspected frequently to be sure all connections are tight and all ground connections intact.
5.	The appearance of the test set can be maintained by occasional cleaning of the case, panel and cable assemblies. The outside of the carrying case can be cleaned with detergent and water. Dry with a clean, dry cloth. The control panel can be cleaned with a cloth dampened with detergent and water. Do not allow water to penetrate panel holes, because damage to components on the underside may occur. A household all-purpose spray cleaner can be used to clean the panel. Polish with a soft, dry cloth, taking care not to scratch the display screen cover. The cables and mating panel receptacles can be cleaned with isopropyl or denatured alcohol applied with a clean cloth.

3 Instrument description and Accessories

3.1 Side panel

1. **0-2200 V AC**
   1 A (max 1 minute). The output is additionally disconnected with a relay and the output is "live" only when this generator is selected.
2. **0-250 V AC / 0-10 A**
   10 A (max 1 min)
3. **0-16 A DC**
   0-1 or 0-16 A continuous
4. **0-300 V DC**
   Rectified AC, max 10 A for 1 minute
5. **0-100 A DC**
   100 A (max 2 minutes, continuous 70 A)
6. **0-200 A AC / 0-800 A AC**
   TRAX 220: 0-200 A (6 V), TRAX 280: 0-800 A (6 V)
7. **AUX CONTROL**
   Ethernet communication and power (48 V DC) to accessories.
8. **F1 F2**
   Main fuses 25 A
9. **AUX POWER**
   Output 0-235 V AC directly from power amplifier for powering accessories, TRAX TDX and TRAX TCX.
10. Protective conductor terminal
    To be connected to the test object ground before connecting any other cables to the unit.
11. **Mains >265 V AC**
    LED is lit if mains voltage exceeds 265 V. An electronic protection switches off the generation.
12. **MAINS INPUT** 100-240 V AC, 16 A, 50/60 Hz
    Single phase + Ground.
13. **Ground**
    For connecting an additional ground between the main unit and accessories or to ground external objects e.g. optional trolley.

WARNING

The outputs 1, 2, 4 and 6 are connected internally to the same output transformer and should be considered "live" when one of the outputs is activated.
Never connect more than one output at a time.

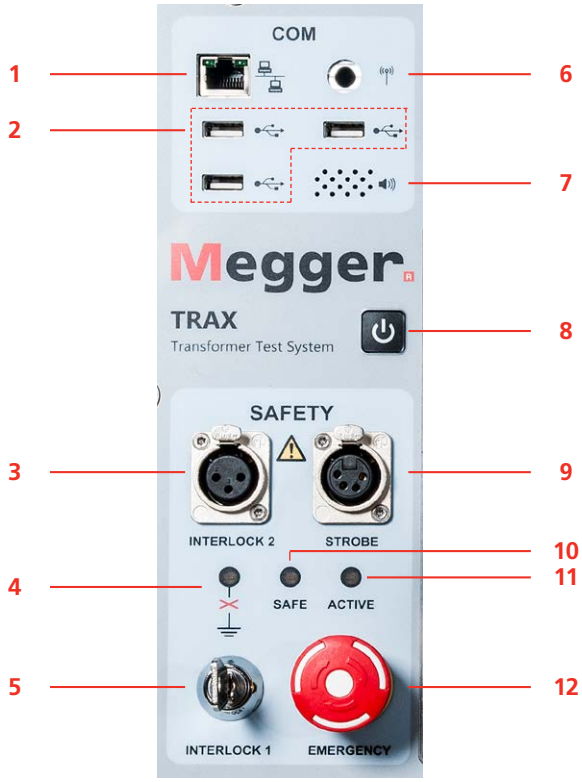
Test objects should be grounded at one end to minimize risk for high voltage interference entering the instrument.

3.2 Top panel

Screen and control knob

1.	Capacitive touch screen, TRAX 220 and 280.
2.	Control knob for controlling selected output generator. Press to change value for the incremental steps (e.g. 1 V, 2 V, 5 V, 10 V). Used as pairing device when connecting TRAX for external control via Ethernet or Wifi. Cursor up/down when reading reports.

Communication and safety



1. Ethernet port for running the instrument from an external PC or connect it to an external network.
2. Three USB ports for multipurpose use: USB memory stick, external mouse or keyboard.
3. **INTERLOCK 2**
   Manual interlock. If activated, the power amplifier shuts off when the interlock is open.

Note *Interlock 2 can not be deactivated for 2.2 kV output and when using the TDX120 accessory.*

4. The orange LED will indicate if the TRAX is not properly grounded.

WARNING
When the LED is flashing, one or more of the following criteria is not met:
Test ground is not connected to ground
Test ground cable is connected poorly
Test ground cable is faulty
The mains outlet is not grounded
The mains cable ground is faulty
Station ground and test object ground are not on the same potential

Important
Safety is always a priority.
Make sure that the TRAX system is properly grounded..

5. **INTERLOCK 1**
   Fixed interlock with key switch. If the key is in the OFF position, or is not in the unit, the power amplifier is OFF.
6. Connector for Wifi antenna, making it possible to run the instrument wireless from a PC or tablet (option).
7. Communication Speaker
   Beeper under the panel for sound indicator.
8. **ON / OFF**
   Press button for 1 second and the instrument will start.
   Press for 3 seconds and the instrument will shut off.
9. **STROBE**
   For connection of the optional TIB225, Trax Indicator Box, Indicating safe (green) or voltage/current generating (red).
   The optional TIB225 acts similar to the indicator lights on the panel (10 and 11).
10. **SAFE**
    Green LED indicates that the instrument is in a safe state for connecting and disconnecting of cables.
11. **ACTIVE** Indicator
    Red LED flashes – Instrument is generating a voltage or current or discharging an inductive circuit after a DC test (winding resistance measurements).
12. **EMERGENCY**
    Emergency shut down (ESD) button.

Warning
If any of the two indicators above, 10 and 11, does not work properly, the TRAX and any TRAX accessory, must be considered in generating (unsafe) mode.

How to set TRAX and any accessory in safe mode

There are two ways to set TRAX in a safe mode, which means that it can not generate any voltage / current.

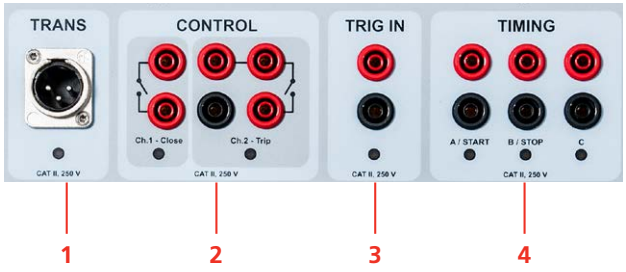
- **Put INTERLOCK 1 key into vertical position (locked).**

During normal operation when the TRAX shall be set in a safe mode.

- **Press the EMERGENCY button.**

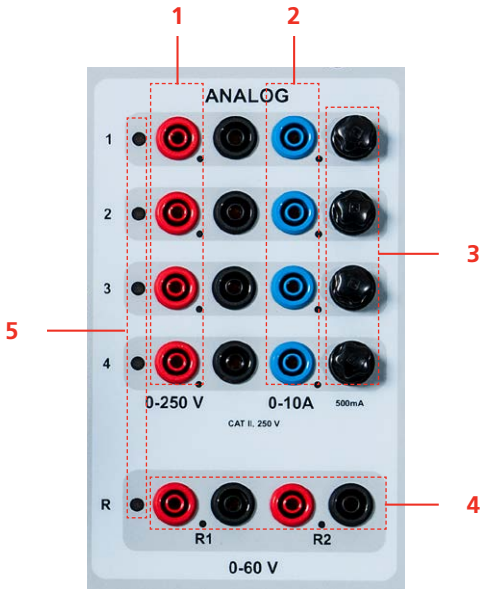
In emergencies when all generation from TRAX and its accessories shall be stopped immediately.

Transducer, binary outputs and timing



1. **TRANS**
   General input for analog transducers and low level analog signals e.g. motion transducers, Rogowski coils etc.
2. **CONTROL**
   close/open contacts for OLTC and circuit-breaker control (up-down, close-trip)
3. **TRIG IN**
   External trig input for starting measurements or recording based on external event.
4. **TIMING**
   Binary inputs for timing measurements in timer and relay testing applications when used as a timer. A and B inputs dedicated for Start and Stop.

Analog inputs



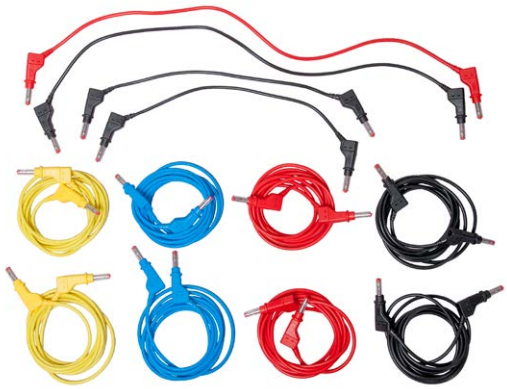
1. VOLTAGE INPUTS
   Four channels 0-250 V AC, 0-350 V DC
2. CURRENT INPUTS
   Four channels 0-10 A AC, 0-10 A DC

Note *Voltage and current cannot be measured on the same channel simultaneously.*

3. FUSES
   4 x 500 mA/25 V AC fast, can be changed from the outside, protects the low current gain shunt. Inside the top panel, there are 4 x 15 A/250 V AC fast fuses for the high current gain step
4. DC INPUTS
   These two channels (R1 & R2) are designed for measuring low DC voltage, <60 V DC, when measuring contact and winding resistance, using the 100 A or 1 to 16 A DC current outputs. If the channels are used for measuring AC, max input is 40 V RMS.
5. LED INDICATORS
   Red LED's indicate which channel to connect to depending on what App is used.

3.3 Included accessories

Ground cable, 6 mm², 10 m (33 ft)	GC-30080



Test cable set	GA-00032

Sense cable, 10 m (33 ft), black	KG-00530
Sense cable, 10 m (33 ft), red	KG-00532
OR	
Sense cable, 15 m (49 ft), black	KG-00540
Sense cable, 15 m (49 ft), red	KG-00542
OR	
Sense cable, 20 m (66 ft), black	KG-00570
Sense cable, 20 m (66 ft), red	KG-00572

Kelvin cable, 10 m (33 ft), black	GC-32310
Kelvin cable, 10 m (33 ft), red	GC-32312
OR	
Kelvin cable, 15 m (49 ft), black	GC-32315
Kelvin cable, 15 m (49 ft), red	GC-32317
OR	
Kelvin cable, 20 m (66 ft), black	GC-32320
Kelvin cable, 20 m (66 ft), red	GC-32322
Note: Only included in the Power transformer testing	

Current cable, 35 mm², 10 m (33 ft), black	GC-32010
Current cable, 35 mm², 10 m (33 ft), red	GC-32012
OR	
Current cable, 35 mm², 15 m (49 ft), black	GC-32015
Current cable, 35 mm², 15 m (49 ft), red	GC-32017
OR	
Current cable, 35 mm², 20 m (66 ft), black	GC-32020
Current cable, 35 mm², 20 m (66 ft), red	GC-32022

Note: For TRAX 219/220 with 15/20 m cables are also a pair of current cables, 35 mm², 6 m (20 ft) included.

Current cable, 800 A, 95 mm², 2 x 6 m (20 ft), (TRAX 279/280)	GC-32106

HV cable, 10 m (33 ft), black	04-35310
HV cable, 10 m (33 ft), red	04-35315

Alligator clip, black	40-08320
Alligator clip, red	40-08322

Large clamp for HV-cable, black	GC-80040
Large clamp for HV-cable, red	GC-80042

Jumper cable, 10 mm², 5 m (16 ft)	GC-32091

Ethernet cable, shielded	GA-00985

Saftey hand switch interlock, 3 m (10 ft)	GC-31103

Transport case, with wheels	GD-30200
Case for accessories, with wheels	GD-30220

3.4 Optional accessories

TDX 120, AJ-69090

High voltage unit (12 kV) for excitation current and, capacitance and DF/PF/Tan-delta measurements.

TCX 200, AJ-69290

High current accessory.

TSX 303, AJ-69490

3-phase/6-winding automated switchbox.
Note: Release is planned during 2018

TSX 300, AJ-69390 / AJ-69395

3-phase/6-winding manual switchbox with IEC or ANSI panel design.

Line impedance kit, AJ-69690

The Line Impedance Kit is an accessory for TRAX. It consists of TSA230 - surge arrester unit and TPB230 - protection box, plus cables, accessories and AJ-8050X software app for TRAX.

B10E, BG-29092

A variable DC voltage can be needed to test a circuit breaker. The B10E supplies 24-250 V AC or DC.

TIB225, AJ-90030

TIB225, Trax Indicator Box, Indicating safe (green) or voltage/ current generating (red)

Interlock foot switch, GC-31150

Saftey foot switch interlock, 3 m (10 ft)

Interlock hand switch, GC-31120

Saftey hand switch interlock, 18 m (60 ft)

Soft light case, GD-31050

Soft case for TRAX, except accessories, to minimize weight for flight purpose.

Trolley, AJ-90040

Trolley suited for TRAX and optional accessories, e.g. TDX 120

Connection kit, GA-90010

Connection kit for Control cables

3.5 Optional software

Advanced transformer	AJ-8020X
▪ Dynamic OLTC measurements (DRM) ▪ FRSL (frequency response of stray losses) ▪ Magnetic balance	
Instrument transformer	AJ-8030X
▪ CT ratio ▪ CT burden ▪ CT excitation curve (knee point) ▪ CT polarity ▪ CT winding resistance ▪ VT ratio ▪ VT burden ▪ VT polarity	
Substation	AJ-8040X
▪ Circuit-breaker analyzer ▪ Relay over current timing ▪ Timer ▪ Phase angle meter (manual) ▪ Ground/earth/impedance (manual)	
Line impedance/K-factor	AJ-8050X
Note: Hardware needed (TSA230 - surge arrester unit and TPB230 - protection box, cables and accessories).	
Recommended cables for SW AJ-8040X	
Test lead set:	GC-32600
4 Test lead, 0.5 m (1.6 ft) red/black/yellow/blue 6 Test lead, 2 m (6.5 ft) red/black/yellow/blue 4 Test lead, 5 m (16 ft) red/black/yellow/blue 4 Dolphin clamp (black/red)	
Timing test lead set:	GC-32610
6 Clamp with banana jack 6 Test cable, 10 m (33 ft) black/red	
Connection kit for Control cables:	GA-90010
5 Test clip 5 Adapter for terminal block 5 Cable lug adapter 1 Plastic box	

4 Basic operating

4.1 General

TRAX measurements are collected together in test sessions and tests. A test is often containing several individual measurements and a TRAX test session/file/report often contains several tests performed with different apps.

Manual and configured tests

Manual control

Manual tests can be done by using Manual control where you define what generator to use, type of test signal, how results are measured and how parameters are calculated. This gives unlimited possibilities to perform almost any AC or DC test on any electrical component within the limits of TRAX generating capabilities.

Results from Manual control measurements for a certain setup are collected in a result table. If the test setup is modified due to change of measurement channels and/or calculated parameters, the new results are collected in a new test/results table.

Manual test

It is also possible to use TRAX as a manual standard instrument. This operation mode is defined as "Manual Test/No configuration" and "is available in most of the Apps. Compared to Manual control, this operation mode is locked to a certain application. As an example, winding resistance measurements in Manual Test mode is limited to using any of the three DC current generators and one or two DC measurement inputs.

Results from Manual Test measurements for a certain setup are collected in a results table. If the test setup is changed by e.g. changing from single to dual channels (simultaneous winding magnetization) winding resistance, the new results are collected in a new test/result table.

Configured test

Configured tests are defined by entering information about the test object, as is the case of vector group and configuration of a power transformer, if there is a tap-changer or not and if so on what winding and how many taps. Using this information the TRAX app is mastering the test and you have to perform the test following the connections described by the unit to get the automatic assessment of the test.

Also in a configured test, you may use several test to fully test a transformer. As an example, if the test object is a three-winding transformer, TTR measurements need to be performed is several test, e.g. Primary windings to Seconday windings, Primary to Tertiary and Secondary to Tertiary. Each of these is done as a separate test with a separate test table, collected together in the same test session.

Test object information (nameplate)

Test object/nameplate information must be entered for any configured test and will be part of the test report. The mandatory information needed for a certain app is asked for and added to the report. The next app will have the same information automatically but may need some additional information to be added. After all tests you can go to the report and add any information that is still missing.

Create a test session in advance

If a test session needs to be defined before the test is actually performed, the workflow is the following:

1] Open the first app and define the test object, define parameters such as: transformer vector group.

2] Name and save (the empty) test.

3] Go to the report and fill in all necessary information for the test object and all planned tests.

4] Open the next app to create a test table

5] Save and go to the next app. Continue as above for all desired apps.

6] Finally check the report once again to see that all the needed data is entered and that all planned tests are there.

7] Confirm/save and close.

At the site

1] Load the report that was created for the test object.

2] Go from report to a certain app to perform the specific measurements as guided by TRAX.

3] Save and go to the next app. Continue as above for all desired apps.

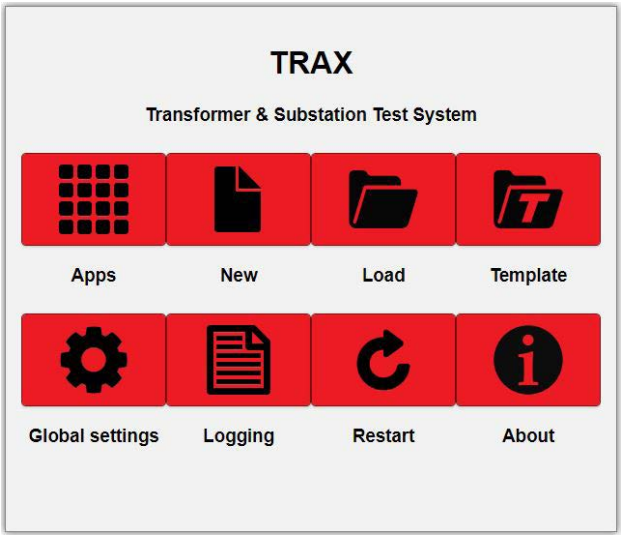
Use measurement as template

If a new test object is very similar to an already existing test object, the old test session can be used as template for the new test. By selecting "Load template" in the home view, the old test will open with a new date and no results. By copying the test under a new name it will be stored and can be used as template with any necessary changes.

5 General operating

5.1 Main menu

1] Press  for one second to turn on TRAX.



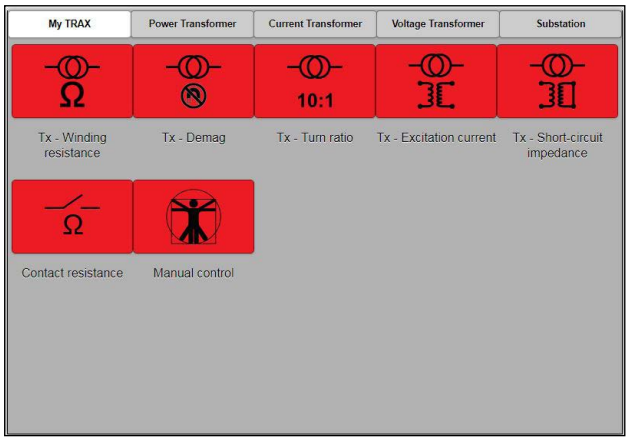
 **App**	Selecting app. If this is the first app selected after starting the unit, TRAX prepares itself for a new test session. If previous tests are performed, TRAX continues with the same session (see section "Data handling and reporting")
 **New**	New test file/session/report
 **Load**	Load a saved test session/report
 **Template**	Load a saved test as template for a new test session
 **Global settings**	Global settings for all apps
 **Logging**	Opens the dialog for reading and downloading TRAX log-files with single measurements (see section "Data handling and reporting")
 **Restart**	Restart the TRAX SW (but not the HW) **Note** *When TRAX is operated from a PC, shortcut key F5 can also be used for restart*
 **About**	Information; SW version, serial number, internal temperatures etc.

Turn off TRAX

1] Press  for 3 seconds to turn off TRAX.

5.2 Apps menu

1] Press  to access the different apps.



My TRAX	In "My TRAX"you can place your favourite apps for easy access by opening the "Tools" screen and activate a certain app.
Power Transformer	Apps suitable for testing power transformers.
Current Transformer	Apps suitable for testing current transformers.
Voltage transformer	Apps suitable for testing voltage transformers.
Substation	Apps suitable for general testing in substations.

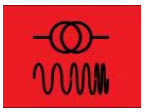
Short app descriptions

My TRAX

1] Click  and select the apps you want to be shown in "My TRAX".

Note *The selections are only possible to make for "My TRAX".*

Power Transformer

 **Winding resistance**	The winding resistance app is used for measuring DC resistance in transformer windings and other objects with high inductance.
 **Demag**	Demagnetization of transformer core, recommended before and after testing a transformer and in particular before excitation current and/or SFRA measurements.
 **Turn ratio**	Turn ratio measurements on transformer windings (TTR).
 **Excitation current**	Excitation current app is used for measuring current and impedance on one side of a transformer with the opposite windings open.
 **TDX Tan delta / Power Factor**	Tan delta app is used for testing high-voltage electrical insulating systems and measuring capacitance and tan delta/power factor at test voltages up to 12 kV.
 **Short circuit impedance**	Short-circuit Impedance/Leakage Reactance app is intended for impedance measurements on the HV side of the transformer with the LV side shorted.
 **FRSL**	FRSL (Frequency Response of Stray Losses) app is used for assessing transformer windings' condition by performing the short-circuit test in wide range of frequencies.
 **Magnetic balance**	The magnetic balance app is used for assessing the condition of magnetic core, winding and other associated parts of the magnetic circuit.
 **OLTC**	OLTC app is used to perform static/dynamic resistance measurements on resistor type on-load tap changers.
 **Excitation current (GOST)**	Load loss app is used to perform excitation current test on LV side of the transformer. (According to the Russian standard GOST)
 **Manual control**	Manual control is used to operate TRAX in manual mode.

Current Transformer

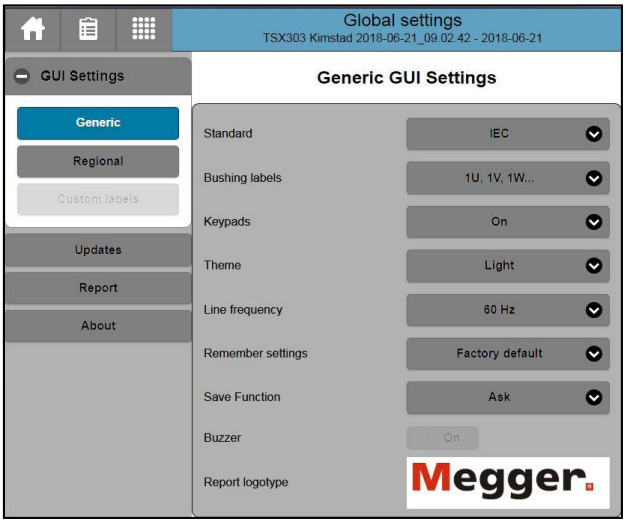
 **Winding Resistance**	The CT winding resistance app is used for measuring DC resistance in current transformer secondary windings.

Saturation & Demag	Saturation test is used to identify the rated knee point of the CT according to the standards.
Ratio U	CT ratio testing using voltage.
Ratio I	CT ratio testing using current.
Manual control	Manual control is used to operate TRAX in manual mode.
Voltage Transformer	
Ratio	VT ratio app determines the voltage transformer ratio as defined by international standards.
Manual control	Manual control is used to operate TRAX in manual mode.
Substation	
Circuit breaker	Circuit breaker app is used for testing the timing of circuit breaker.
Contact resistance	Contact resistance app is used for DC low resistance measurements on resistive loads.
Line impedance (k-factor)	The line impedance app is used to determine a transmission line impedance parameters to be used in distance protection relays settings. Note: Hardware accessories necessary.
Manual control	Manual control is used to operate TRAX in manual mode.

5.3 Global settings

1] Press for the global settings.

2] Press the button "+ GUI Settings"
A window with the following fields opens.



GUI Settings

Generic	
Standards	ANSI or IEC
Bushing labels	1U, 1V, 1W... Australian / GOST User defined
Keypads	Virtual keyboard can be turned on or off (e.g. when using external computer).
Theme	Change GUI color scheme
Line frequency	60, 50, 25 or 16 2/3 Hz
Remember settings	Remember last means that TRAX starts with settings and configuration as in the last performed individual measurements and configuration. As default TRAX starts with factory settings.
Save Function	■ Ask: Upon closing an app or a test session without manual saving, TRAX checks if anything has changed in the test or session and if so, will ask the user to save changes or not ■ Auto: TRAX will create a file directly when the first (new) app is opened and ask for name and location for saving. After this, every measurement and/or change will be automatically saved.
Buzzer	On/Off With buzzer on, there will be an alarming sound under discharges

Report logotype	Change to your desired logo by clicking the logo and select new logo file (jpg or png) from directory.

Regional

Language	Select language
Keyboard	Select language for on-screen keyboard
Decimal separator	Select point or comma
Time format	Hours:minutes:seconds in 24 or 12 hour format
Date format	Select date format

Custom labels

Define specific terminal naming

Updates TRAX stand-alone, direct connect

Release track	TRAX main SW version
Download	Get the available file
Install	Selected update is ready to be installed

Updates TRAX stand-alone via USB

Insert a USB stick with a valid TRAX update (from remote update)

Source	Select USB
Download	Get the available file from USB
Install	Selected update is ready to be installed

Updates (Remote)

Note *For details on TRAX updates see chapter "12 Update TRAX" on page 82*

Release track	TRAX main SW version
Download	Get the available file
Create	Copy the update file to USB (remote PC only)

Network

Settings for TRAX remote operation. Not available in offline mode.

Report

Test Object	Define naming for the first ID fields in the report.
Header Fields	Select fields to be used for identification in TRAX.

Safety

Interlock	Interlock 2 can be selected as mandatory for all TRAX generators/outputs. If turned off, interlock 2 is only mandatory for 2 kV and 12 kV* generator. *TDX120 optional accessory
Ground loop detector	Can be turned on/off for all generators except 2 kV and for TDX120

Note:
Settings are not available in offline mode

Hardware Configuration

TRAX model 800 A or 200 A

About

About	HW and SW version information
Temperature	Temperatures in TRAX internal parts
Legal Notices	Legal information

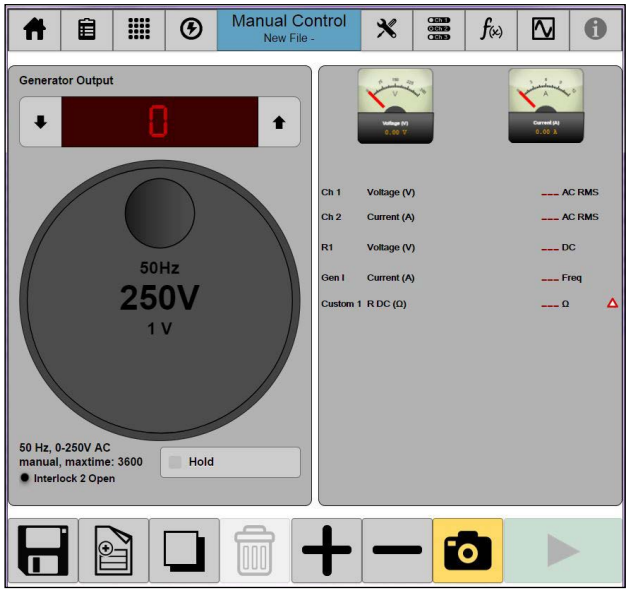
5.4 Manual control

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 

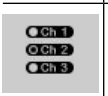
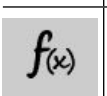
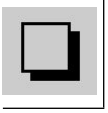
Output generators and input channels can be selected to perform a variety of measurements.

TIP
All generators and analog measurement channels except transducer input and timing channels can be accessed from Manual control.



Buttons in the apps

Buttons described below are common to most of the apps.

	Home
	Report
	Back
	Apps
	Generator settings
	App settings
	Measurement channel selection
	Calculated parameters
	Oscilloscope
	Information; SW version, internal temperatures etc. The icon changes color depending on the internal temperature: Green = OK Yellow = Attention Red = Warning
	Help on app screen wiring diagrams. **Note**: Not in Manual control.
	Saves the test results to report/file. If it is the first test TRAX will ask for filename and location.
	Save a copy **Note**: In the report window
	Starts a new test for the same test session. The new test will be reported as a new table if Manual control is used for various tests that you want to save and report as separate tests.
	Shows result as a diagram **Note**: Not in Manual control.
	Displays the individual measurements in the test in a table format. Click one more time to return to the control view.
	Delete
	Notes **Note**: Not in Manual control.
	Demagnetization **Note**: Not in Manual control.

Hold	Click the checkbox to hold / freeze values for reading without capture data to the test.
+ –	The + button operate the output contact Ch 1. The – button operate the output contact Ch 2. Activating + or – buttons closes the contact for about 500 ms. After one operation the contacts are blocked for about 2 seconds before the next operation is possible.
	When the button is pressed, TRAX records a measurement while the test signal continues.
	Start and stop the generator. Output signals and selected measurement signals are continuously displayed and updated on the analog meters and in the results. When the generator is stopped, measurement data and calculated parameters are automatically captured and displayed and added to the test. Note: In settings, the options ''Hold on Stop" and ''Store data on Stop" can be selected "ON" or "OFF".

Control knob

The on screen control knob is used in a similar way as the control knob on panel.

1] Press to change value for the incremental steps (0.1 V, 1 V, 2 V, 5 V).

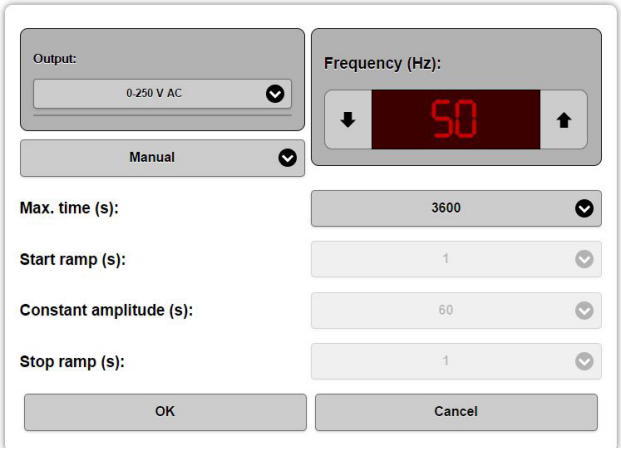
2] Press and drag according to the arrows to increase/decrease the value.

3] Sensitivity/scaling can be adjusted by pressing in the middle of the control knob

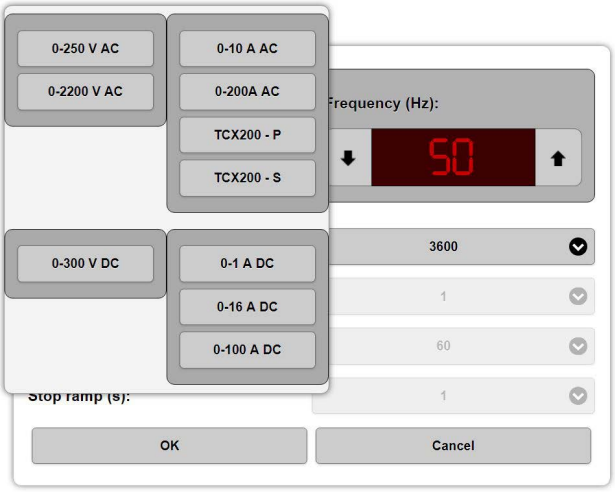
Generator settings

1] Press to make the generator settings.

2] Press the "Output" button to select generator output.



Output



The following outputs are connected internally to the same output transformer and should be considered "live" when one of the outputs is activated.

- 0-2200 V AC
- 0-250 V/10 A AC
- 0-300 V DC
- 0-200/800 A AC

The 2.2 kV output is additionally disconnected with a relay (interlock 2) and the output is "live" only when this generator is selected to be used and interlock 2 is open.

The 1, 16 and 100 A DC current outputs are intended for resistance measurements.

3] Make settings for "Frequency".

4] Select "Manual" or "Ramp".

In manual mode the generator is started instantly. A maximum generating time can be set.

In ramp mode, the output signal amplitude is increased continuously, hold at the set value and

decreased back to zero. Ramp and hold times are selectable.

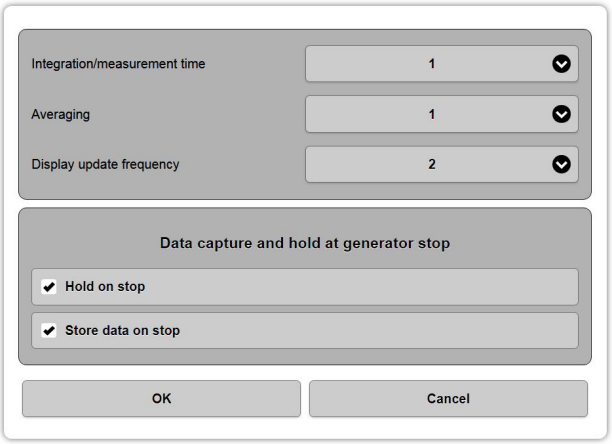
Warning
The Manual control is not designed for resistance measurements on inductive loads.

Note *If Manual control is used for resistance measurements on inductive loads, manual setting with small and slow adjustment of test current should be used. For measuring highly inductive loads, e.g. transformer windings, the winding resistance app should be used.*

5] When you are ready, press "OK" or "Cancel".

App settings

1] Press



Integration / measurement time	Integration time for the individual measurement record
Averaging	Number of averaged measurement records in the measured value
Display update frequency	Interval for updating displayed values (Time per measurement record)

Example: 1,1,1 means that a measurement is performed over 1 s, no additional averaging and the display is updated every second. 2, 3, 1 means that a measurement is performed over 2 seconds and 3 measurements are averaged. The display shows a running average every second (2/2).

Data capture and hold at generator stop

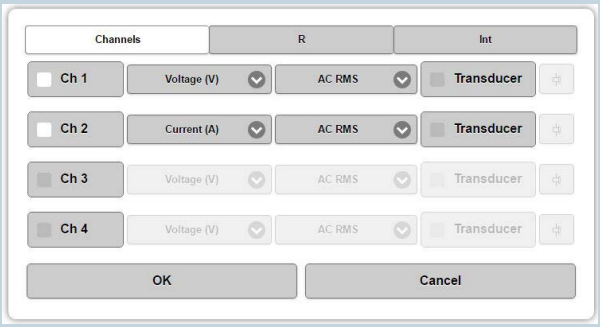
1] Make desired action at generator stop, "Hold on stop" and/or "Store on stop".

2] When you are ready, press "OK" or "Cancel".

App channel selection

1] Press to select measurement channels.

Channels



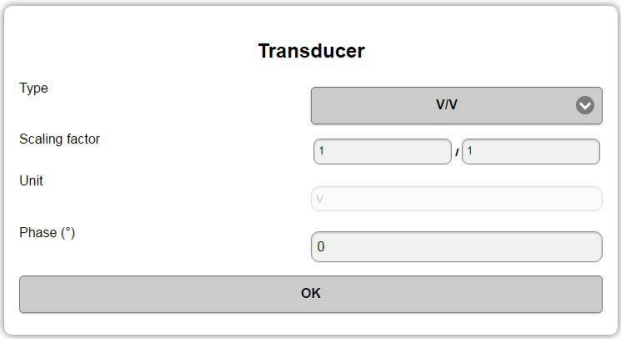
External multi-purpose AC/DC voltage or current measurement channels that are separately activated.

The measurement data can be selected to be displayed and used in calculations as:

AC RMS	RMS value of the AC component in the test signal
Freq	Narrow-band data for the selected frequency (factory default)
RMV	Rectified Mean Value of signal multiplied by 1.41 to equivalent RMS value
DC	DC value

Transducer

Transducers can be used to convert a measurement signal to an appropriate current or voltage signal to be measured by TRAX, e.g. active current clamps (current to voltage).

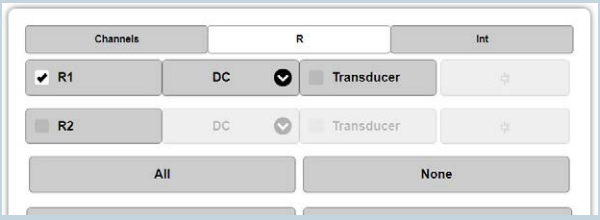


Voltage measurement channels	
Type	V/V V/A V/Custom
Current measurement channels	
Type	A/A A/V A/Custom
Scaling factor	Conversion data for the transducer is entered in two fields; Output entity and input entity (+ phase deviation if applicable, default = 0)

Example:
Active current clamp, labeled 10 mV/A

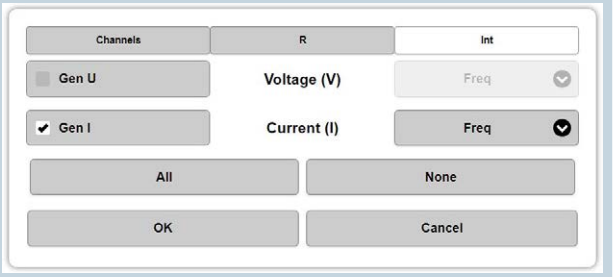
Selected type	V/A
Scaling factor	0.01/1
Unit	A (preset)
Phase	Phase deviation as stated in datasheet

R



Voltage measurement channels, R1 and R2 are intended for DC resistance measurements. But they can also be used for AC measurements and/or with transducers. If used for AC measurements (up to 60 Hz, can be used for higher frequencies at somewhat reduced accuracy), the voltage must not exceed 40 V RMS.

Int

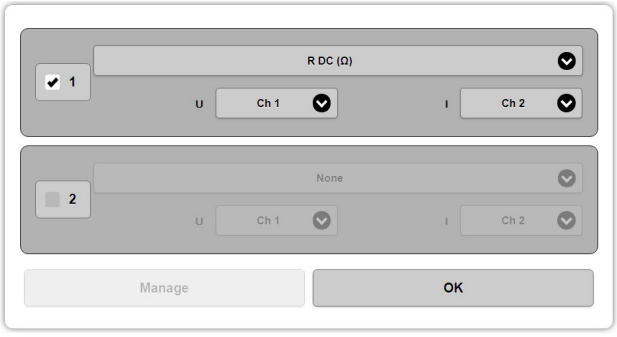


Internal measurement channels. Always active showing RMS values in the analog meters. Needs to be selected to be captured and hold and/or used for calculations.	
The measurement data can be selected to be displayed and used in calculations as:	
AC RMS	RMS value of the AC component in the test signal
Freq	Narrow-band data for the selected frequency (factory default)
RMV	Rectified Mean Value of signal multiplied by 1.11 to equivalent RMS value
DC	DC value

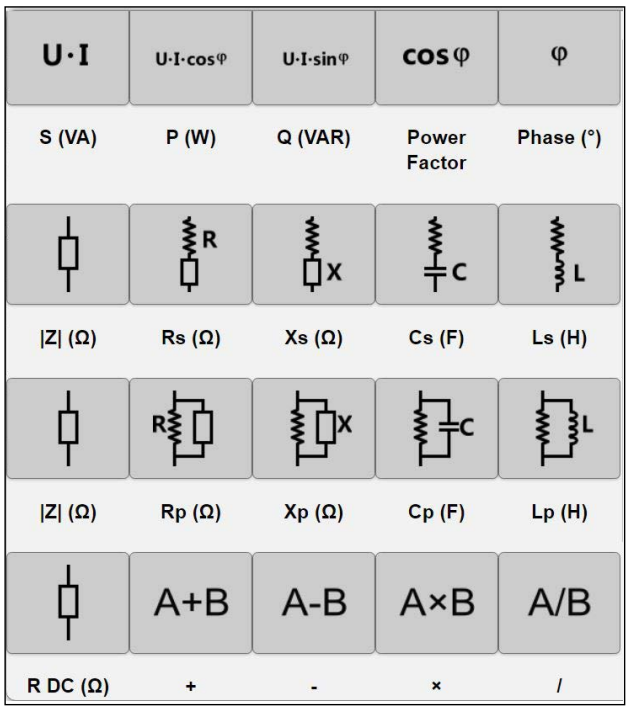
2] When you are ready, press “OK” or “Cancel”

Calculated parameters

1] Press $f(x)$



The dialog activates mathematical operations on test data. Measured data can be used to calculate one or two selected parameters out of the following list:



For phase measurements, the lowest channel number is reference (e.g. phase difference between Ch 1 and Ch 2 is calculated as Ch 2 lag).

For phase related measurements e.g. Z, X etc. the value is calculated with voltage reference.

2] When you are ready, press "OK".

Oscilloscope

1] Press 

The oscilloscope can be used to monitor measurement signals.

2] Press "Inputs" (red square) and select measurement channels for display.

3] Press "Freeze" to hold and show the oscilloscope picture.

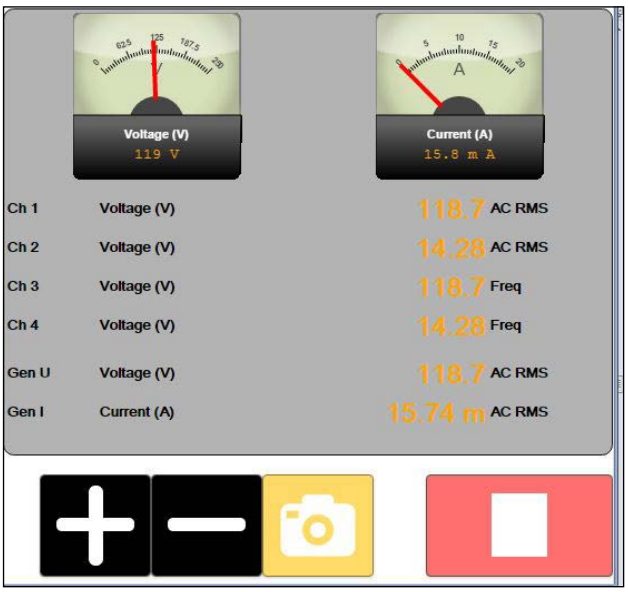
4] Press "Channel Control" to make oscilloscope settings.

5] To close the oscilloscope, press 

Start/Stop measurements

1] Press  to start the measurement.

Output signals and selected measurement signals are continuously displayed on the analog meters and in the results fields.



2] Press  to stop the generator.

Measurement data and calculated parameters are captured and held. Based on the app settings, the results are stored in the results table.

Note *Selected measurement channels in Manual control are "always on" (multimeter mode) to be able to be used with or without TRAX generators. This means that values are displayed also before the TRAX generator is started.*

5.5 Manual control application examples

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

Note *The circuitry for safe discharge of inductive loads is activated in Manual control as well as in the winding resistance app. Discharge is performed via the current output and the R1/ R2 voltage measurement inputs.*

Resistance measurements

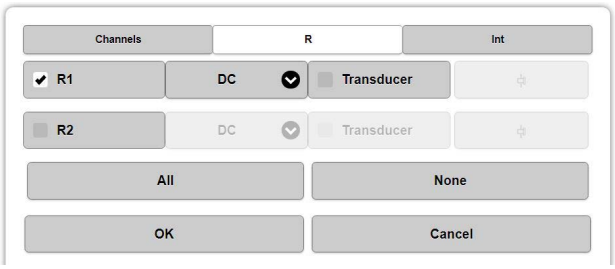
1] Press

2] Select a DC current generator 1, 16 or 100 A output.
Based on the resistance of the test object.
Max measurable resistance resistance is about 10 kΩ when generating 5 mA from the 1 A generator.

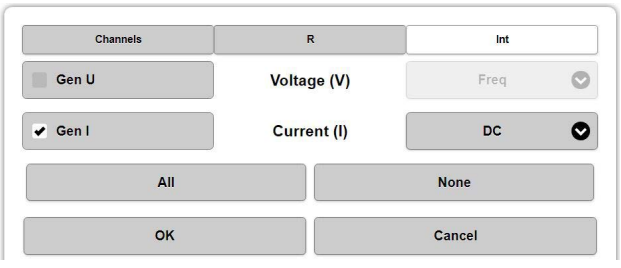
Recommended test current ranges		
1 A generator	5 mA – 1 A	Resistance range 1 mΩ – 10 kΩ
16 A generator	1 A – 16 A	Resistance range 160 µΩ – 50 Ω
100 A generator	10 A – 100 A	Resistance range 10 µΩ – 5 Ω

3] Press

4] Select “R” > “R1” > “DC”



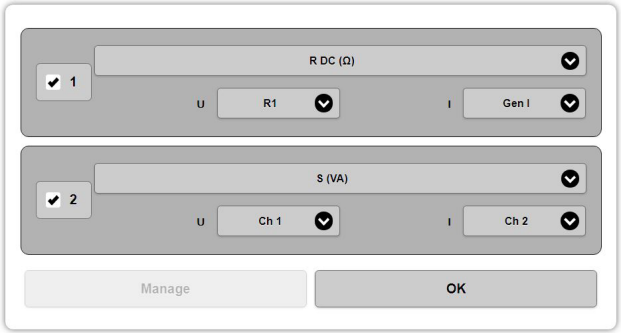
5] Select “Int” > “Gen I” > “DC”.



6] Press “OK”.

7] Press $f_{(x)}$

8] Select resistance calculation “R DC (Ω)” using “R1” and “Gen I”.



9] Connect current and voltage sense leads to the test object.

Note *This is a 4-wire method. Connect voltage sense leads “inside” the current leads connectors. The connectors must NOT touch each other.*

10] Select an appropriate test current suitable for the test object.
Always use highest recommended current by standard but avoid unintentional heating of the test object.

11] Press

12] Wait for results to stabilize.

13] Press and read the results.

Note *Manual control is not designed for resistance measurements on inductive loads e.g. transformer windings. If Manual control is used for this, manual setting with small and slow adjustment of test current should be used. For measuring highly inductive loads, e.g. transformer windings, the winding resistance app should be used.*

Note *For measuring high resistances it is possible to use a simplified 2-wire technique. Connect the 1A DC outputs directly to the R1 inputs and connect from R1 inputs to the resistor. Please observe that maximum compliance voltage is about 50 V so select a very low current when measuring in the kΩ range.*

Excitation current (impedance) measurements

1] Select 0-250 V or 0-2200 V generator pending the expected saturation voltage of the test object.

2] Select “Gen I” and “Gen U” measurement channel set to frequency to measure the excitation voltage and current and use the data for calculations.

3] Press $f(x)$ and select e.g. “Inductance”, “Impedance”, “Power factor” or other parameters to get additional information of the test

4] Connect the generator leads to the test object.

5] Select an appropriate test voltage for the test object or manually control the voltage (after pressing ▶) and observe the excitation current for e.g. determine saturation/knee-point.

6] Press ▶ to start the generator.

7] Wait for results to stabilize or manually control the voltage and observe the excitation current for e.g. determine saturation/knee-point.

8] Press ■ and read the results.

Note *The description above is using an internal current measurement channel and measures the total current generated into the test object. (GST-GND)*
If the test object has two parallel parts e.g. a winding in a delta configuration, the measured value is the current going through one winding in parallel with two series windings. For measuring excitation current on a single winding in a delta configuration, an external current measurement can be used and by grounding correctly a UST measurement can be performed.

Warning
When using 2.2 kV output and external ammeter, its is ABSOLUTELY MANDATORY to ground black terminal and connect the external current measurement channel to the grounded side of the generator/ winding.

Short-circuit/leakage reactance measurements

1] Select 0-10 A AC generator.

2] Select Gen I measurement channel, set to freq, to measure the excitation current and use the data for calculations.

3] Select Ch 1, set to freq, for voltage measurement. (Gen U can be used for the measurement but for higher accuracy a separate voltage measurement using Ch 1 is recommended).

4] Press $f(x)$ and select e.g. Inductance, Impedance, Reactance or other parameters to get appropriate data for the test.

5] Connect current leads and voltage sense leads to 0-10 A output and channel 1 voltage input respectively. At sample, place voltage sense leads “inside” current connectors.

6] Short appropriate low voltage winding (e.g. first measurement of a YNyn0, measure 1U-1N, short 2U-2N).

7] Select an appropriate test current for the test object. For power transformer windings, typical test current are 1 to 5 A for short-circuit impedance/leakage reactance measurements.

Note *Max compliance voltage is 250 V. When measuring small transformers with high winding resistance you need to select a lower current, (typically 100 mA or lower) to not trip the generator.*

8] Press ▶

9] Wait for results to stabilize.

10] Press ■ and read results.

11] Move to next phase and continue the test.

Note *This measurement can also be performed by using the 250V generator and adjust the voltage until the preferred test current is achieved.*

Zero-sequence impedance measurements

1] Select 0-250V AC generator and 55 Hz.

2] Select Gen I measurement channel, set to freq, to capture an hold the excitation current and use the data for calculations.

3] Select Ch 1, set to freq, for voltage measurement.
(Gen U can be also used for the measurement

but for higher accuracy on low inductances a separate voltage measurement using Ch 1 is recommended).

4] Press $f(x)$ and select e.g. Inductance, Impedance, Power factor or other parameters to get appropriate data from the test.

5] Connect generator leads and voltage sense leads to 0-250V A output and Ch1 voltage input to one winding of the transformer.

6] Connect the other two windings of the transformer in parallel with the first winding (e.g. for a YNyn transformer A-B-C should be connected in parallel).

7] Press ▶ to start the generator and adjust the voltage to get an appropriate current, typically a few amps.

8] Wait for results to stabilize.

9] Press ■ and read results.

Power transformer turns-ratio measurements

1] Select 0-250 V AC generator.

2] Select Ch 1 and Ch 2 for AC voltage measurements set to freq. If excitation current needs to be recorded select Gen I measurement channel set to Freq.

3] Press $f(x)$ and select ratio calculation "/ " (division) between Ch 1 and Ch 2. If phase deviation is to be recorded select "Phase" between Ch 1 and Ch 2.

4] Connect the generator cable to the HV winding.

5] Connect the Ch 1 voltage measurement to the HV winding and the Ch 2 voltage measurement to the LV.

Note This is a 4-wire method and the Ch 1 voltage measurement lead must NOT be connected "outside" or in contact with the voltage generator lead.

6] Select an appropriate test voltage for the test object. For power transformer windings, use 250 V for highest accuracy.

7] Wait for results to stabilize.

8] Press ■ and read the results.

CT excitation current

1] Select 0-250 V or 0-2200 V generator pending the expected saturation voltage of the CT.

2] Select frequency, typically 50 or 60 Hz.

3] Activate Int "Gen U", configure it to RMV*.

4] Activate Int "Gen I" configure it to AC RMS*.

* As stated in IEC 61869-2: 2012 and IEEE C57.13

5] Connect CT terminal S2/X2 to ground. Connect black generator terminal to S2/X2 and green (250V)/red (2200V) generator terminal to CT terminal S1/X1.

6] Make sure that one side of primary winding P1/H1 or P2/H2 is floating (other side may be connected to ground).

7] Set a start voltage level at about 1% of max generator voltage, 2.5V and 22V for respective generator.

Note *For very small CTs, start at minimum voltage 1 V.*

8] Press ▶ to start the generating.

9] Slowly increase voltage until knee point is reached, or until a certain current level is achieved e.g. 500 mA.
Press data capture button to save a data point.
Slowly decrease voltage in steps and after let current stabilize, capture data points.

10] Press ■

CT ratio with voltage

Caution
Make sure that one side of primary side winding is connected to ground at all times. Otherwise, the measurement results will be affected and the instrument may be damaged.

1] Select 0-250 V or 0-2200 V generator pending the expected saturation voltage of the CT. Select frequency, for highest accuracy 55Hz test frequency is recommended.

2] Activate Int Gen U, configure it to Freq.
If excitation current is of interest, also activate Int Gen I and configure it to AC RMS.

3] Activate Channel Ch 1, configure it to Voltage (V) and Freq.

4] Press $f(x)$.
For calculation 1, select ratio "/" (division) between Gen U and Ch 1.
If phase deviation is to be recorded, for calculation 2, select "Phase" between Gen U and Ch 1.

5] Connect CT terminal S2/X2 to ground.

6] Connect black generator terminal to S2/X2 and green (250V)/red (2200V) generator terminal to CT terminal S1/X1.

7] **IMPORTANT**
Connect P1/H1 (or P2/H2) to ground.
Connect Ch1 terminals to primary winding, black terminal to P2/H2 and red terminal to P1/H1.

8] Select an appropriate test voltage, best accuracy is achieved at about 75% of saturation voltage.

9] Press ▶ to start the generating.

10] Wait for results to stabilize

11] Press ■ and read results.

TIP
If saturation voltage is unknown: start energizing with a low voltage, approximately 1% of generator max voltage. Increase the voltage slowly until excitation current starts increasing considerably (e.g. to 100 mA) and the lower voltage to about 75% of its value result in high current. Now a high accuracy measurement of "ratio with voltage" is achieved.

CT ratio with current

Caution
Make sure that one side of primary side winding is connected to ground at all times. Otherwise, the measurement results will be affected and the instrument may be damaged.

1] Select 0-200 A (or 0-800 A if TRAX 280) generator.
Select frequency, typically 50 or 60 Hz.

2] Activate Int Gen I, configure it to Freq.

3] Activate channel Ch 1, configure it to Current (A) and Freq.

4] Press $f(x)$
For calculation 1, select ratio "/" (division) between Gen I and Ch 1.
If phase deviation is to be recorded, for calculation 2, select "Phase" between Gen I and Ch 1.

5] Connect CT terminal S2/X2 to ground.
Connect black Ch 1 terminal to terminal S2/X2 and blue Ch 1 to terminal S1/X1.

6] **IMPORTANT**
Connect P1/H1 (or P2/H2) to ground.
Connect 200A/800A current output terminals to primary winding, black terminal to P2/H2 and red terminal to P1/H1.

7] Select an appropriate test current, usually rated primary current or a fraction of rated primary current.
Make sure expected resulted secondary current is lower than 1 A (IEC) or 5 A (IEEE).

8] Press ▶ to start the generator.

9] Wait for results to stabilize

10] Press ■ and read results.

CT / VT Voltage withstand measurements

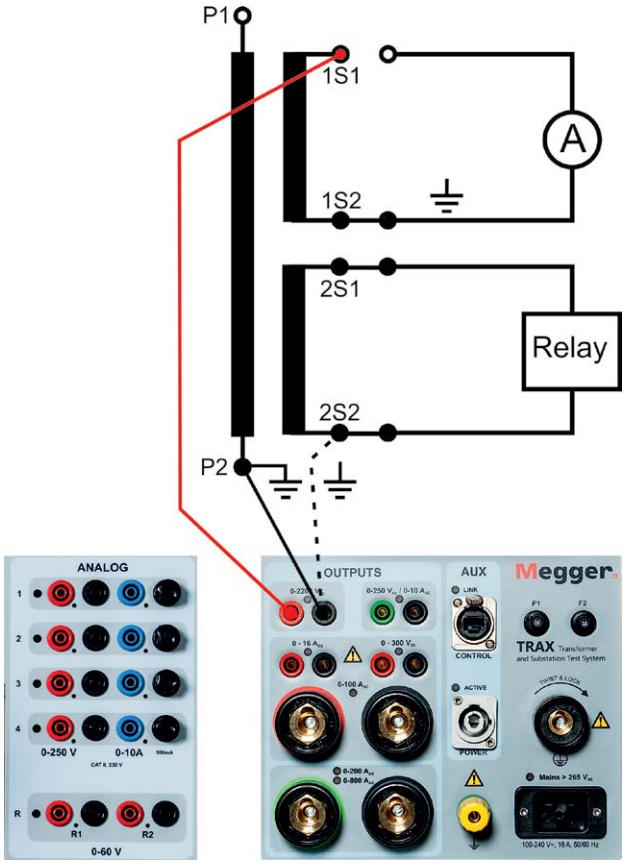
1] Select 2.2 kV generator and 55 Hz.

2] Select Gen I and GenU measurement channels set to Freq.

3] If insulation properties are to be measured, press $f(x)$ and select e.g. Cp and PF.

4] Connect red terminal to the actual test object and black terminal to ground.

IMPORTANT
Make sure that one side of primary and secondary windings are connected to ground at all times. Otherwise, the measurement results will be affected and the instrument may be damaged.



5] Make sure the test object is connected to ground at one end (generator black)!

6] Set the test voltage as high as possible with respect to the test object. In most cases 2.2 kV is used.

7] Press ▶ to start the generator

8] Wait for results to stabilize.

9] Press ■ and read results.

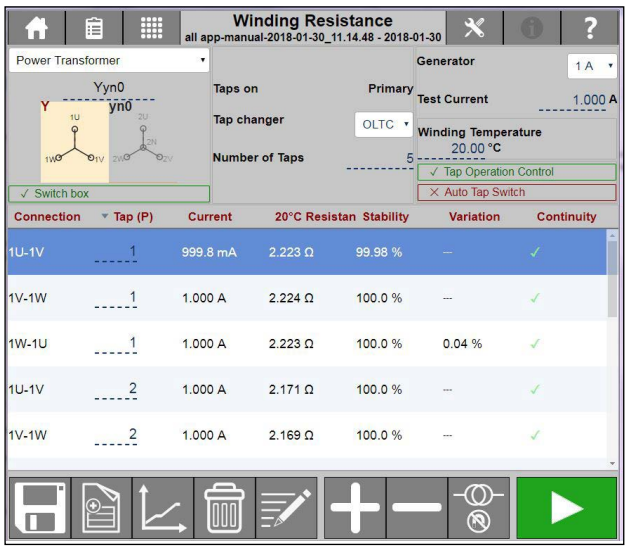
Note *The test mode is GST-GND which means that the total current to ground will be measured. The test result will be affected by all stray capacitors including e.g. cables and surface current. To estimate the effect of cables (typically 50-100 pF), measure the cables without connecting to the specimen.*

6 Standard transformer apps

6.1 Winding resistance

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



The winding resistance app is used for measuring DC resistance in transformer windings and other objects with high inductance. The app supports single channel and dual channel (Simultaneous Winding Magnetization, SWM).

Recommended test current ranges

1 A	5 mA – 1 A	Resistance range 1 mΩ – 10 kΩ
16 A	1 A – 16 A	Resistance range 160 µΩ – 50 Ω
100 A	10 A – 100 A	Resistance range 10 µΩ – 5 Ω

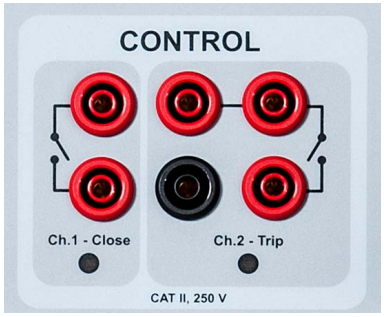
Note *When testing transformer windings, the test current should be sufficient to saturate the core and thus minimizing inductance. This happens typically at about 1% of the rated winding current. Avoid testing at >15% of rated current since this may cause heating which will affect the accuracy. Typical test currents are 1-15% and using 5-15% will give fast and stable readings.*
*As the max voltage for measurement channels are 50 V, with higher resistances the measured current will get smaller, U=R meas*I test*

Controls for tap changer operation

These will be activated if you select an OLTC and ‘Tap operation control’ in the TRAX software, having a DETC it will not be possible to use automatic switching.

Auto tap switch will make the sw to switch between the taps automatically if the Trax sw can control the tap changer.

If you also use the TSX accessory you will have the option to connect to all bushings at the same time. Testing through all taps without any user interaction.



+ / raise controls the left ch 1 contact.

- / lower controls the right ch 2 contact.

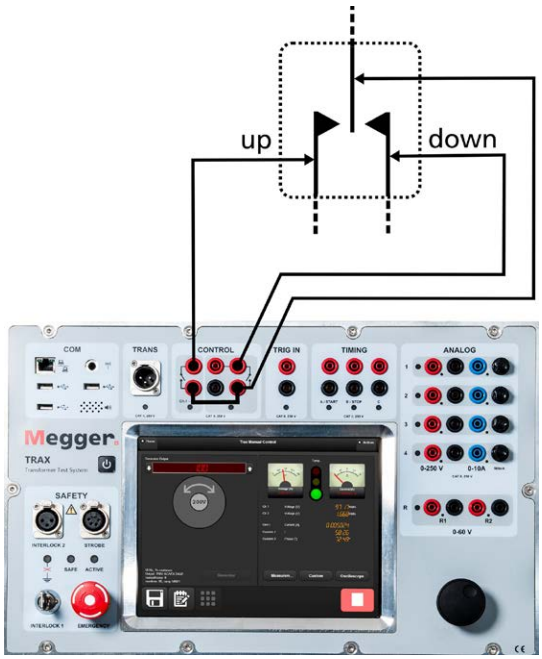
Buttons to use during operation

+	+ / raise
–	- / lower

capture/measure data without stopping the generator (for OLTC measurements).

Activating + or - buttons closes the contact for about 500 ms. After one operation the contacts are blocked for about 2 seconds before the next operation is possible.

Run two wires from each output contact and connect them in parallel with the manual operating contacts for raise/lower tap (at the tap-changer control cabinet). Max carrying current (short-term) is 35 A.



Note *The tap-changer must be powered separately, typically with 3-phase AC for the motor and a DC control voltage.*

Measurements can be performed on defined/configured transformers or in "no configuration/manual test." Discharge is automatic when the generator is stopped and performed via the current cables (primary) and also (secondary) via the voltage measurement cables. Discharge is also performed if the input power to TRAX is accidentally lost.

CAUTION

The no power emergency discharge may take significantly longer time due to lower discharge voltage. Make sure to wait for a sufficient time (>2 minutes for a large transformer) before removing any cables.

Note *The no power emergency discharge works when the TRAX gets disconnected from power. Two discharge circuits, active and passive work in case of no power situation.*

Transformer configuration (Vector diagram)

Transformer configuration and vector group is selected by entering configuration via. keyboard or selecting in the matrix.

If no configuration is entered the test will automatically be defined as a manual test

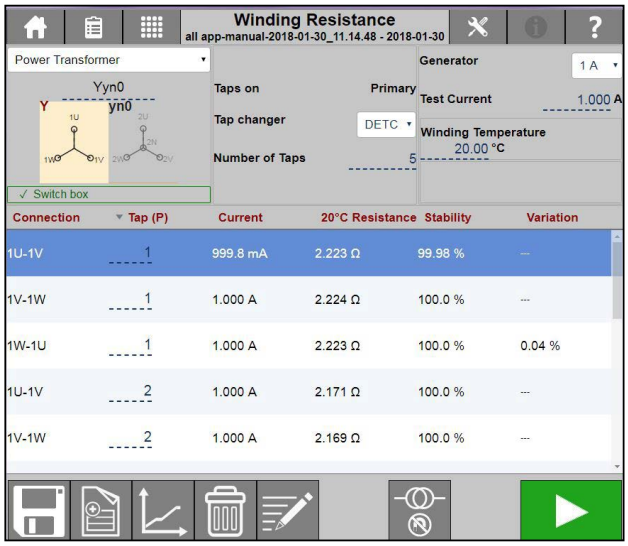
Note *It is possible to mix configured and manual tests in the same session but NOT two tests with different configurations.*

When configuration is defined, select which measurement to define and/or perform by activating the actual winding(-s). Windings can be turned on or off and if two windings are active, TRAX assumes that it should do a dual-channel (simultaneous winding magnetization) test (recommended for LV delta configurations). If the activated winding(-s) have tap-changers, define type, location, number of taps and which taps that should be measured in the actual test.

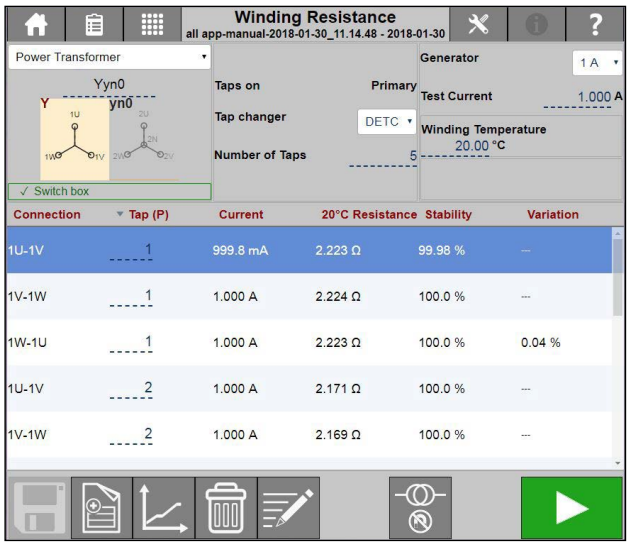
Example:

2-w transformer with DETC (5 taps) on HV and OLTC (19 taps) on LV.

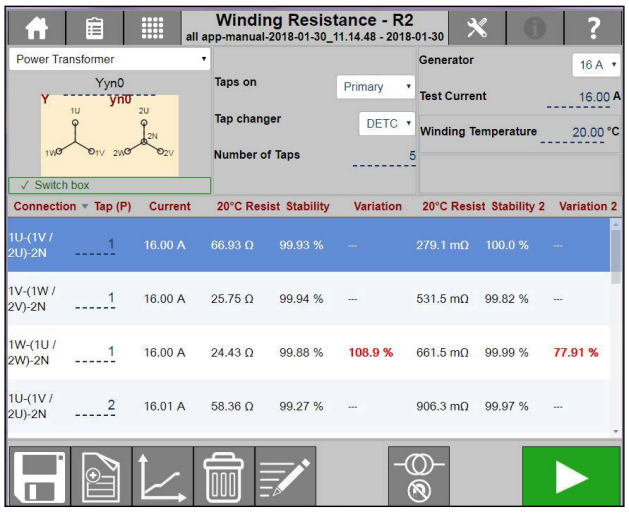
HV measurements



LV measurements

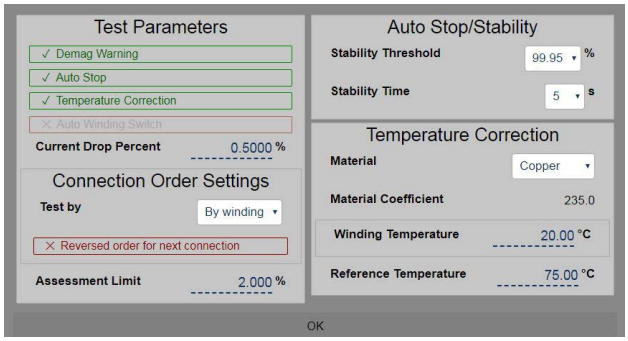


Dual – taps on HV



Settings

1] Press 



2] Select test parameters and make settings.

Test Parameters

Demag Warning	When activated, TRAX suggest to do demagnetization when leaving the WRM app.
Auto Stop	Enable auto stop
Temperature Correction	Enable temperature correction.
Auto winding switch	When the TSX303 accessory is used the TRAX SW will automatically switch between different windings.
Current Drop Percent	Current drop percent is the smallest current drop to be detected at a tap change. If it is set too high, the automatic tap change does not work. If it is set too low, the current drops will be incorrectly detected and this might lead to strange measurement results. Default 0.5% is a good value in the vast majority of cases.

Connection Order Settings

Test by	Transformer test tables are organized by tap or winding. Note: Changes will take place after you have selected the relevant app from the App menu.
Reversed order for next tap	Transformer test tables are organized with mid-phase in reversed tap order. Note: It is also possible to change tap order in a specific test by clicking on “Tap” in the test table
Assessment Limit	Limit for winding resistance variation between windings Default 2%

Auto Stop/Stability

Stability Threshold	Select minimum values for stability
Stability Time	Minimum time for stability before initiating measure/stop. When the measurement reaches to the stability the +/- buttons get activated for changing to the next tap.

Temperature Correction

Material	Copper, Aluminum or Custom
Material Coefficient	For copper, aluminum or as customer defined

Winding Temperature	Enter the winding temperature (°C)
Reference Temperature	Enter the reference temperature for the correction (°C)

Step-by-step instructions

No configuration measurements

1] Connect current and voltage leads to the test object.

Note *This is a 4-wire method. Connect voltage sense leads "inside" the current leads connectors. The connectors must NOT touch each* other.

2] Select test current and start measurement.

3] When reading is stable (manual mode), stop measurement and the result is displayed.
In autostop, measurement will be automatically stopped.

4] Perform next measurement.

5] Discharge is automatic.

WARNING
Do not remove any cables until discharge is finalized.

Winding resistance with transformer configuration

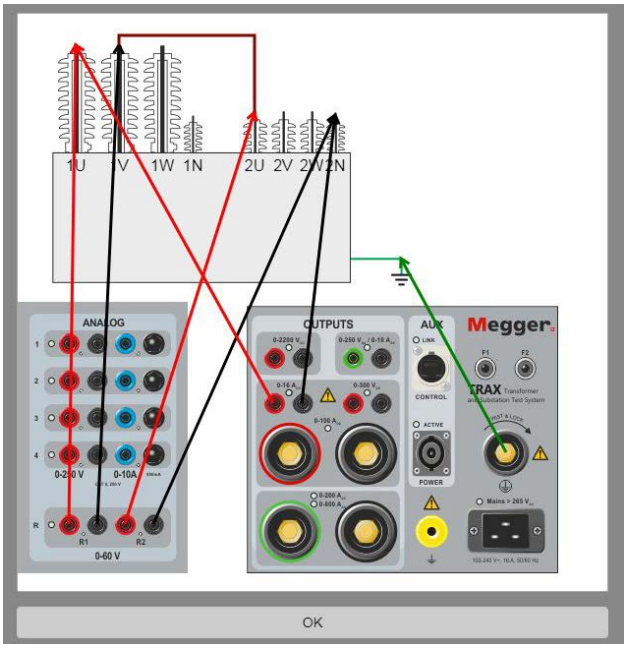
1] Enter the transformer configuration and select winding(-s) for test.

2] Select either of the windings or both of them.
For simultaneously winding measurement, press on the winding figure with vector group.

3] Connect the cables as described, e.g. current H1-N with jumper N-X1, x1-x3.

4] Connect current and voltage leads to the test object.
Pressing **?** will show the connection.

Note *This is a 4-wire method. Connect voltage sense leads "inside" the current leads connectors. The connectors must NOT touch each other.*



5] Select test current and start measurement.

Without tap changer

1] When reading is stable, stop measurement and the result is displayed.

2] Reconnect cables and perform test on next phase.

Resistance variation between windings will be displayed when all phases are measured.

How the resistance is calculated:
(Max measured resistance - min measured resistance/ Avg measured resistance)*100 for values between three phases.

With taps on DETC

Note *In field tests, the transformer is often tested with the DETC position "as found" and it may not be recommended to change the DETC selector switch. Make sure to confirm with the transformer owner before making any changes.*
DETC and OLTC measurements are recommended to be tested by winding (see global settings).

1] When reading is stable, stop measurement and the result is displayed

2] Stop generator.

3] Operate tap changer.

4] Start generating, when reading is stable, stop measurement and the result is displayed

5] Repeat from step 2 until last tap.

6] Reconnect cables and perform test on next phase.

Winding variation will be displayed when all phases are measured.

With taps on OLTC

Important
Do not use autostop when testing OLTC. OLTC measurements must be performed by winding (see global settings).

1] When reading is stable, press
The measurement and the result is captured and displayed for the actual row/tap.
Measurement will continue on the next table row (next tap position).

Note *Do not stop generating until last tap is tested.*

2] Operate tap changer.

A] If a discontinuity occurs (brake before make), TRAX will automatically stop the test, discharge the winding and report fail in the continuity column.
The discontinuity is reported on the row/tap that the switch transition is going TO, i.e a transition discontinuity when going from tap 5 to 6 will be reported on the row for tap 6.

B] If continuity is OK, TRAX will start measure resistance for the actual tap on the active row.
Wait for stable reading and press
TRAX will continue to measure next position.

3] Repeat from step 2.
Continue until last tap.

4] Stop measurement (generator) and capture data when the reading is stable.

5] Reconnect cables and perform test on next phase.

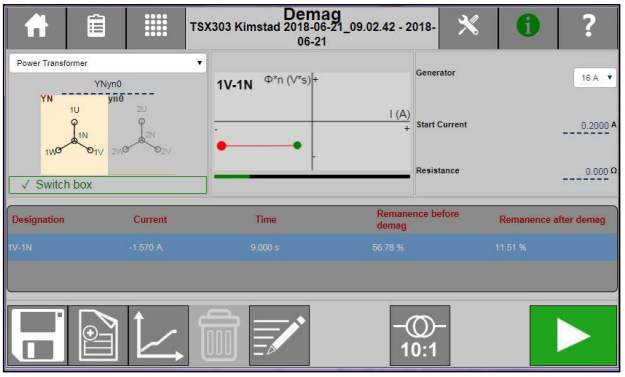
Winding variation will be displayed when all phases are measured.

Important
Transformer must get demagnetized after WRM test. Leaving the WRM app suggests you to go directly to the Demag app, see “6.2 Demagnetization” on page 40.

6.2 Demagnetization

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press



Demagnetization is recommended before performing any tests on the transformer and in particular before excitation current and/or SFRA.

Demagnetization with TRAX is performed by injecting an alternating and decreasing DC voltage/current to magnetize the core in two directions. Starting current is normally selected as about the same as the last performed winding resistance test and should be above the DC saturation level of the actual winding (typically 1 % of rated winding current). Demagnetization is normally done on the HV side of the transformer and on the connection with the lowest excitation current (the mid-leg for a YN configuration). For configurations with no neutral, demagnetization connection is terminal-terminal.

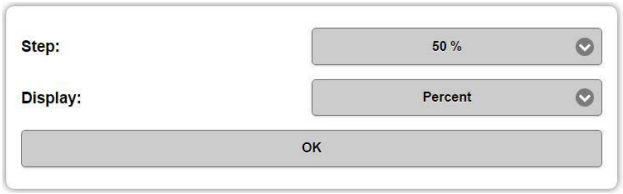
The adaptive algorithm for the demagnetization process is based on measuring and reducing Vs (voltage * time). This implies that the voltage measurement channel R1 MUST be connected during demagnetization.

For demagnetization with current less than 1 A, the 1 A generator must be used.

“Resistance” must be filled with the corresponding winding resistance value. This is specially important to be done for transformer with high resistance value.

Settings

1] Press 



Step	Vs reduction per demag cycle (default 50%)
Display	% remanence or absolute values in Vs (default %)

Step-by-step instructions

1] Connect generator cable and R1 measurement cable to the transformer HV terminals. If YN, connect to H2/V to neutral, if Y or D connect H1/U to H2/V.

Note *Using the TSX accessory in configured mode you will get the recomended winding automatically.*

2] Select generator.

3] Select demagnetization current, normally the same as the test current, about 1% of rated winding current.

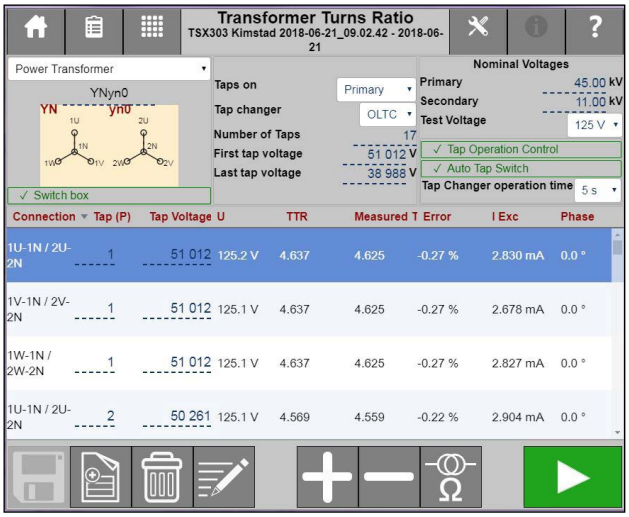
4] Press  to start test

5] Demagnetization starts and stops automatically when finished.

6.3 Turn ratio

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



TRAX turn ratio app determines the transformer turns-ratio as defined by international standards. The app provides an excitation test voltage to the primary windings of the transformer and measures simultaneously the voltage at the corresponding secondary winding. The voltage ratio is displayed and compared with the expected nameplate ratio.

TRAX measures ratio, phase deviation and excitation current at the same time. Testing can be done at power frequency, or preferably at a frequency different from the power frequency to avoid interference. Default test frequency is 55 Hz.

Transformer configuration

Transformer configuration and vector group is selected by entering configuration via. keyboard or selecting in the matrix.

If no configuration is entered the test will automatically be defined as a manual TTR test on a 2-winding transformer.

Note *It is possible to mix configured and manual tests in the same session but NOT two tests with different configurations.*

Choose the intended winding pair for the test if the configuration is a three winding transformer (nameplate voltages). If the configuration is a three-winding

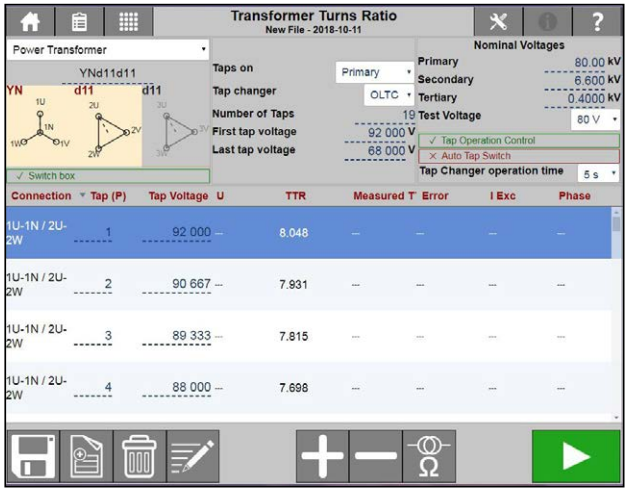
transformer, select which winding pair to define and/ or test.

If the activated winding pair has tap-changers, define type, location, number of taps, tap voltages and which taps that should be measured in the actual test.

Example:

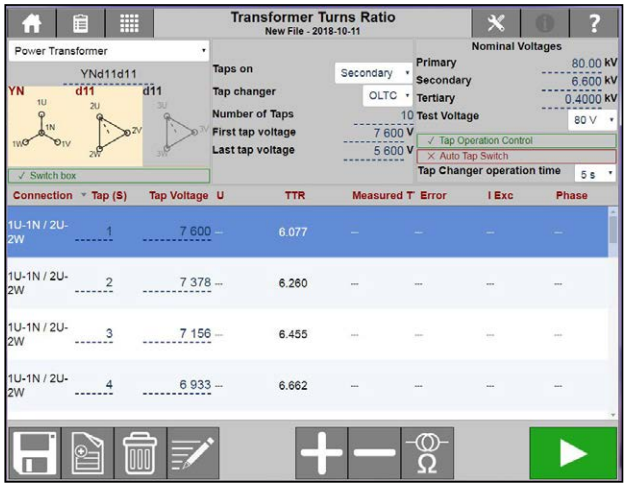
3-w transformer with DETC (5 taps) on HV, OLTC (19 taps) on LV, no taps on tertiary

HV-LV, taps on primary

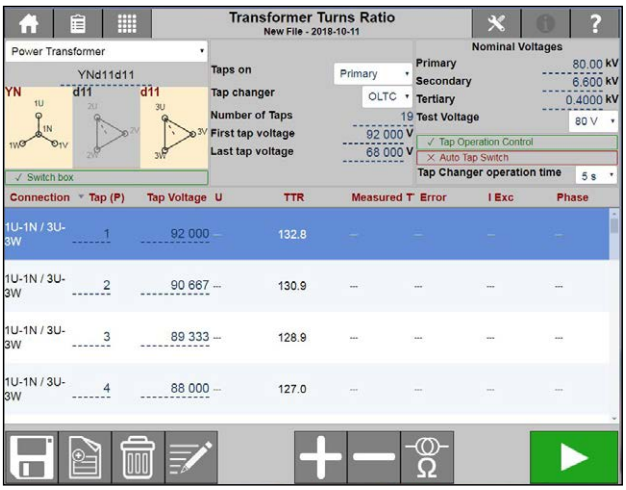


Note *If the transformer has dual tap changers, the not tested tap is default assumed to be nominal. If not, the actual (as found) tap can be changed manually*

HV-LV, taps on secondary

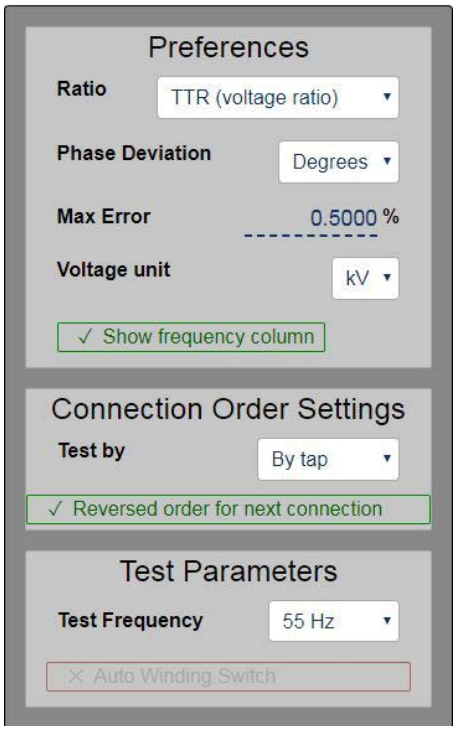


HV-Tertiary



Settings

1] Press 



Preferences	
Ratio	Ratio can be displayed as TTR/ voltage ratio or nameplate ratio. TTR/voltage ratio is calculated with respect to the actual configuration using common recalculation factors for various configurations. When selecting nameplate ratio, results are calculated to reflect the ratio between the transformers line-to-line (nameplate) voltages. Example: For a Dyn11 100 to 10 kV transformer, the TTR/voltage ratio is 10 x sqrt3, 100 kV to 10 kV x sqrt3 while the nameplate voltage is 10, 100 kV to 10 kV.
Phase Deviation	Degrees or minutes
Max Error	Setting defines the limit where measured values should be highlighted.
Voltage unit	V or kV
Show frequency column	Displays the frequency used for testing (default 55Hz) in the report.

Connection Order Settings

Test by	Transformer test tables are organized by tap or winding. Note: Changes will take place after you have selected the relevant app from the App menu.
Reversed order for next connection	Transformer test tables are organized with mid-phase in reversed tap order. **Note**: It is also possible to change tap order in a specific test by clicking on "Tap" in the test table

Test Parameters

Test Frequency	Test frequency selection; 16 2/3, 25, 50, 55 (default) or 60 Hz
Auto winding switch	If the TSX303 accessory is used you can use this function to automatically switch between phases. This will complete all tests without any user interaction with the Trax software

Step-by-step instructions

No configuration

1] Connect cables.

2] Select test voltage.

3] Press ▶ to start test.

4] Perform next measurement.

5] Save results.

With configuration

1] Select transformer "Configuration" and enter the first and last tap voltage values.

Note *First tap voltage must be higher than nominal voltage for the winding with taps and last tap voltage lower.*
In case the calculated tap voltage differs from the nameplate it is possible to manually enter the values in the table.

2] Connect cables.
Press **?** to display a connecting diagram.

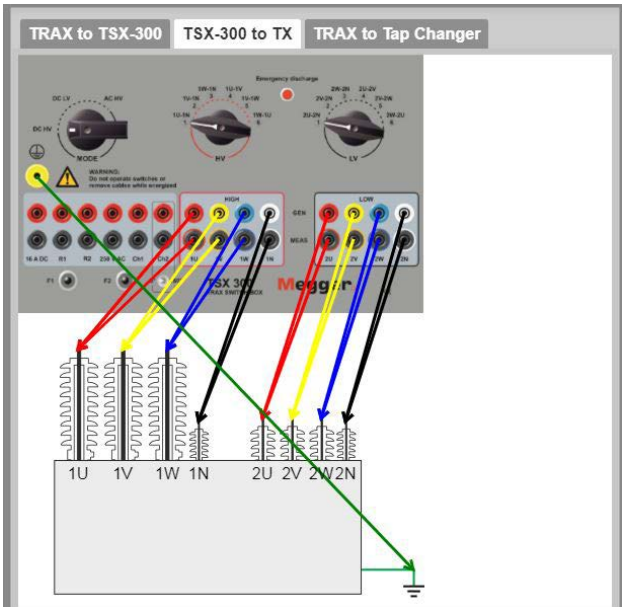
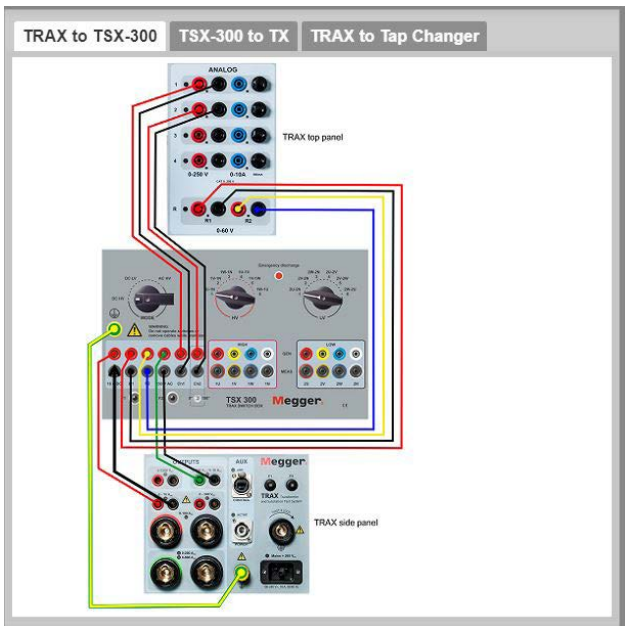
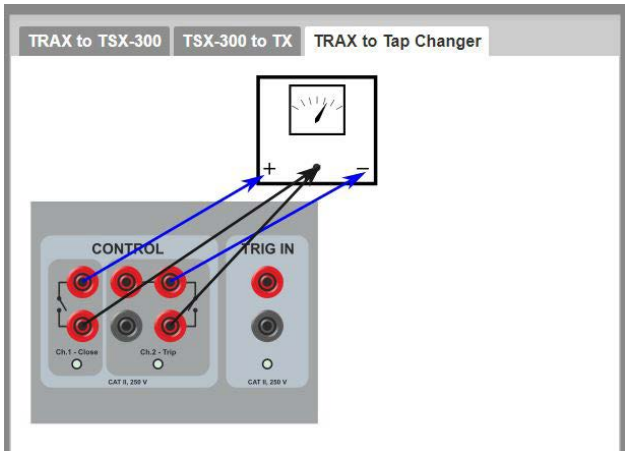


Illustration shows the connection to HV and LV.



Above is an example of how to connect when the TSX 300 accessory is connected.



Picture shows how to connect CONTROL to the Tap Changer.

3] Select test voltage.

4] Press ▶ to start test.
The test automatically stops when finished.

5] Select next tap, operate tap changer and continue until all taps are measured.

6] Reconnect cables to next phase. Press ? to see connecting diagram.

7] Measure all taps.

8] Continue with next phase.

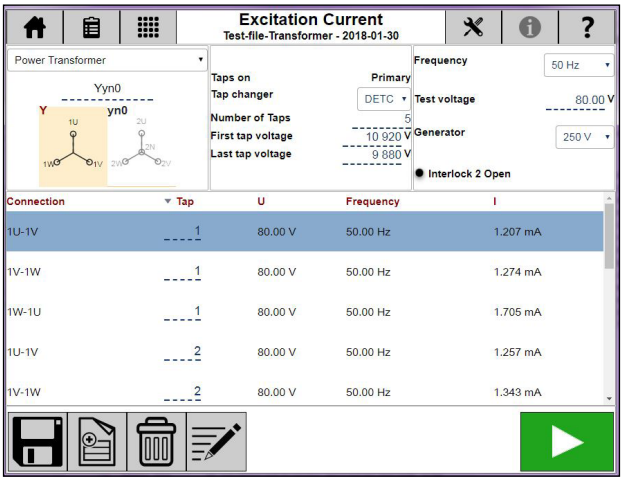
9] Save results.

Note *If connecting the tap changer control to the top panel of the TRAX you can automatically test all taps and winding if you have a TSX303 accessory*

6.4 Excitation current

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press

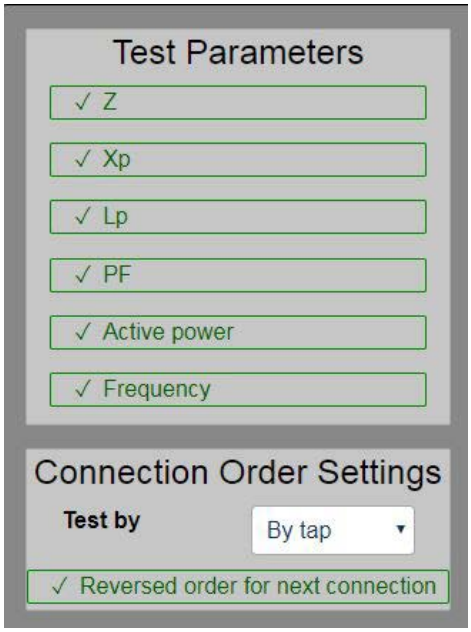


TRAX Excitation current app is intended for measuring current and impedance on one side of a transformer with the opposite windings open.

WARNING
The common practice is to measure excitation current on HV windings. If excitation current is to be measured on LV side on a transformer please note that the HV side will be energized at a higher voltage that can be very dangerous.

Settings

1] Press 



Select the calculated parameters to be displayed in results table. For description of the parameters see "Calculated parameters" on page 29.
Frequency displays the test frequency in the report, default test frequency is taken from general settings.

Step-by-step instructions

No configuration

1] Select what generator to use, 250 V AC or 2200 V AC.

2] Connect the generator leads to the HV winding.

3] Press  to start the first test.

4] Readings will be displayed automatically when stable and generator will stop.

5] Continue with next test. New tests will be added to the table. It is possible to re-measure a line in the table by activating the actual row and start a new measurement.

6] When the test is finished the results can be saved to a file/report.

With transformer configuration

1] Select transformer configuration and number of taps.

2] Select what generator to use, 250 V AC or 2200 V AC.

3] Connect cables to the test object as described in the table and connection picture.

4] Press  to start the first test.

5] Readings will be displayed automatically when stable and generator will stop.

6] Continue with next test. New tests will be added to the table. It is possible to re-measure a line in the table by activating the actual row and start a new measurement.

7] When the test is finished the results can be saved to a file/report.

Note *The app is using an internal current measurement channel and measures the total current generated into the test object. If the test object has two parallel parts e.g. a winding in a delta configuration, the measured value is the current going through one winding in parallel with two series windings.*

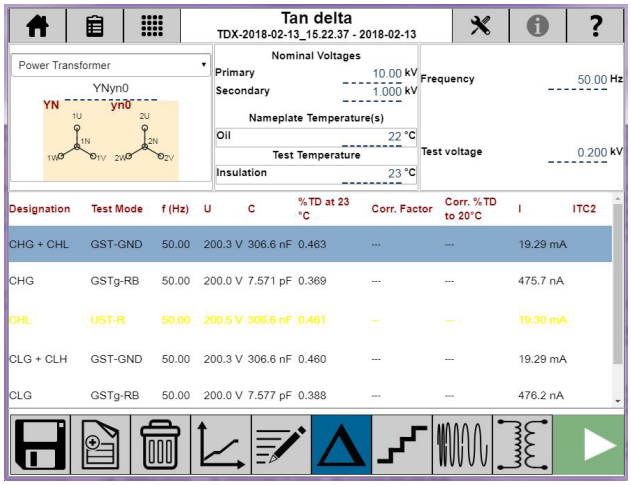
For measuring excitation current on a single winding in a delta configuration, Manual control with external current measurement can be used and by doing correct grounding, measurements can be performed on single windings.

6.5 TDX TanDelta/Power Factor

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

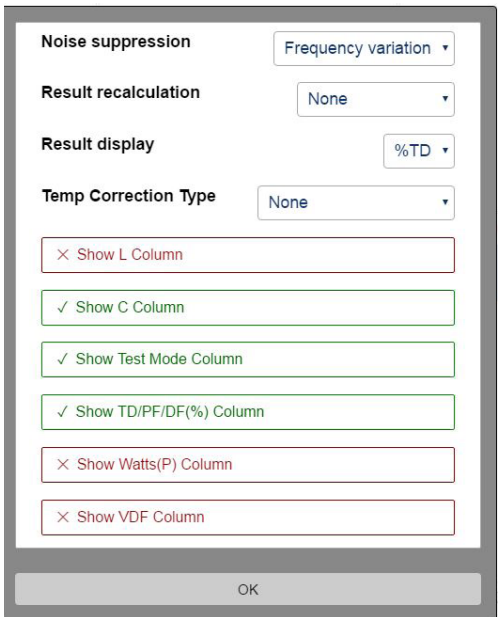
Note *This app only works together with optional accessoryTDX120.*
For full information for using TDX120, see the TDX120 User manual.

1] Press 



Settings

1] Press 



Noise supression	None Frequency variation
Result calculation	None 10 kV equivalent
Result display	%TD, Tan D in percent %PF, Power factor in percent %DF, Dissipation Factor in percent
Temp correction type	None >500 T11 <500 T19 ITC1(Single Material) for bushings ITC2(Two Materials) for oil/paper transformer Frequency Corrected

2] Select the calculated parameters to be displayed in results table.
For description of the parameters see the separate TDX user manual.

Step-by-step instructions

Note *For the complete instructions, see the User’s manual for the “TDX120”.*
Art. No. ZP-AJ02E

Manual test

1] From the bottom keys choose between PF, Tip-up, Frequency or Excitation.

2] Choose insulation temperature.

3] Choose the test voltage and frequency.

- For Tip-up number of steps must be selected.
- For Frequency sweep, DFR test voltage must be chosen.

4] Choose the Test Mode.

5] Connect cables.

6] Press  to start the test.

7] Perform next measurement.

Test with Configuration

1] Select power transformer, Bushings C1, Bushings C2 or Bushings Hot collar.

For each component, the test mode and number of tests are shown in the table.

In power transformer, temperature correction (ITC 2) is active for CHL measurement.

In Bushing C1, temperature correction (ITC 1) is active for measurement of all phases.

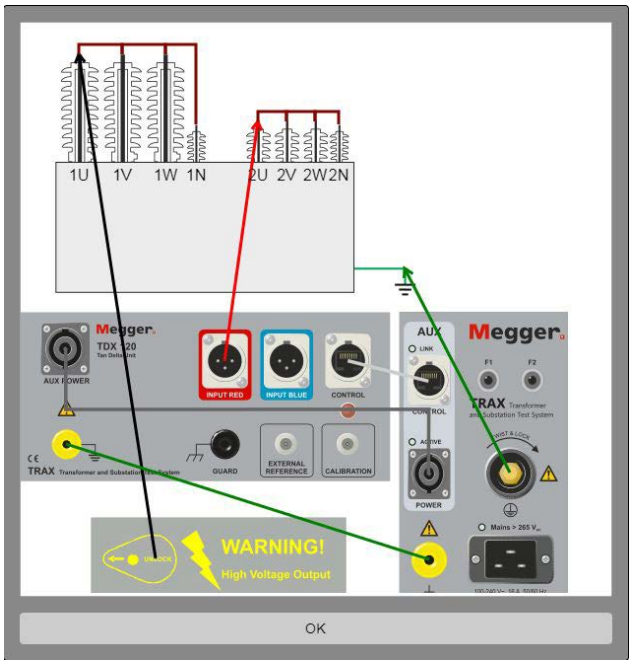
2] From the bottom keys choose between PF, Tip-up, Frequency or Excitation (for power transformer).

3] Choose insulation temperature.
Insulation temperature is the temperature that is shown from the winding temperature meter. In case of lack of this meter, oil temperature can be used as insulation temperature as well.

4] Choose the test voltage and frequency.

- For Tip-up number of steps must be selected.
- For Frequency sweep, DFR test voltage must be chosen.

5] Press **?** to show the connection



6] Press ▶ to start the test.
When measurement is done, the result is displayed.

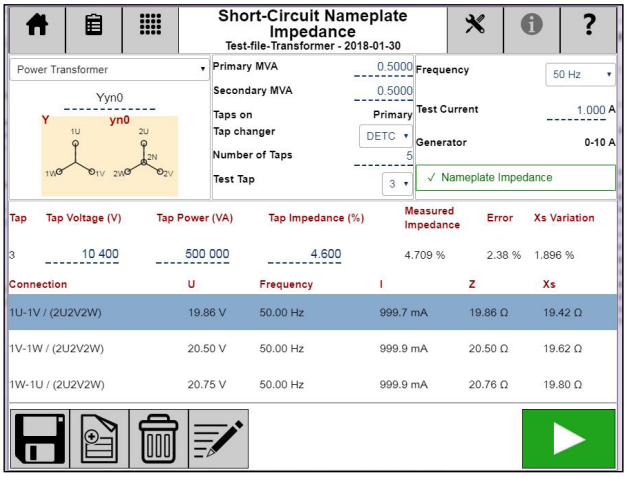
7] Perform next measurement.

8] Save the results.

6.6 Short-circuit impedance / Leakage reactance

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



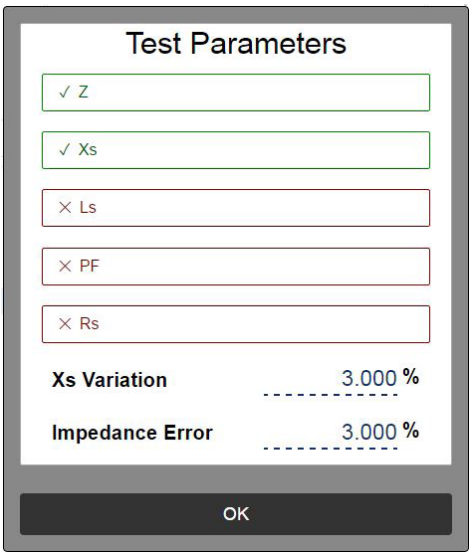
TRAX Short-circuit Impedance/Leakage Reactance app is intended for impedance measurements on the HV side of the transformer with the LV side shorted.

Without configuration you need to decide how to connect and what to measure. With configuration, the app supports short-circuit impedance/leakage reactance measurement per phase or by using three-phase equivalent model.

Note *Not all transformer configurations are supported in this app. Three phase equivalent impedance analysis is not supported for zig-zag configurations. Per phase measurements are not supported for configurations without HV neutral (Dx, Yx and Zx). For measuring these configurations on an individual basis with custom connections and shorts, please use Manual control.*

Settings

1] Press 



Select the calculated parameters to be displayed in results table. For description of the parameters see "Calculated parameters" on page 29.

Xs Variation	Variation between windings Default 3%
Impedance Error	Deviation from nameplate impedance Default 3%

Transformer configuration

1] Configuration is selected by entering the corresponding transformer vector diagram via keyboard or selecting in the matrix (see winding resistance app).
If no configuration is entered the test will automatically be defined as a manual test on a 2-winding transformer.

Note *It is possible to mix configured and manual tests in the same session but NOT two tests with different configurations.*

2] Define the winding pair to test.
If impedance is to be calculated (3-phase equivalent), enter MVA , voltage and impedance for actual tap to test). If the configuration is a three-winding transformer, select which winding pair to define and/or test.

A] If "Nameplate impedance" is not selected, the test will be "per phase". Please note that the connections and shorts are different between "per phase" and "3-phase equivalent".

B] If the activated winding pair has tap-changers, define type, location, number of taps, tap voltages and which taps that should be measured in the actual test.

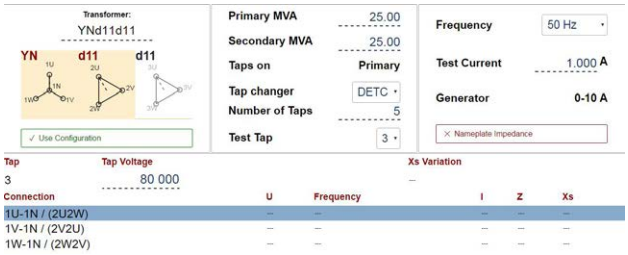
C] If the configuration is not supported at all for leakage reactance tests it is still possible to run manual and connect and short based on previous experiences with the actual transformer and/or configuration.

Example:

3-w transformer with DETC (5 taps) on HV, OLTC (19 taps) on LV, no taps on tertiary

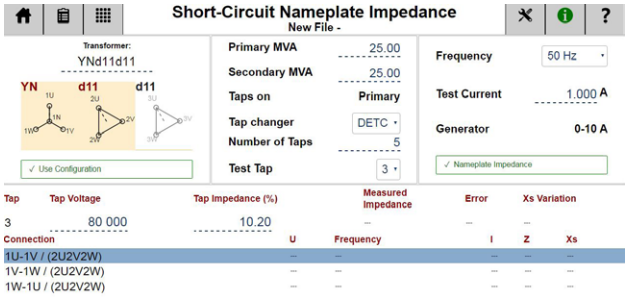
HV-LV Impedance

Per-phase measurements



When configuration is selected, TRAX suggest measurements per-phase and the variation in leakage reactance, Xs, is calculated and displayed.

Three-phase equivalent



By choosing Nameplate impedance, the app automatically selects three-phase equivalent model and the results can be compared with the transformer nameplate.

Three-phase equivalent works for Y and delta configurations with the three LV terminals (but NOT the neutral) shorted.

Important
Make sure the shorts are good with low resistance, large conductor area and tight connections, since LV current will be test current multiplied with transformer ratio.

Three-phase equivalent model does not work for Zigzag configurations and the resulting impedance cannot be compared with nameplate.

Step-by-step instructions

1] Select transformer configuration (and number of taps, however this test is normally done on nominal tap only).

2] Enter transformer nameplate information including: “Impedance”, Nominal HV voltage (kV), Power (MVA) and Impedance (%).

3] Confirm cable connections/hook-up.

4] Select test frequency:
Default and recommended frequency for short-circuit measurements is line frequency and winding variation is calculated for Xs (leakage reactance). For higher frequency comparisons of Rs and Ls, select 500 Hz. Please note that winding variation is still calculated for Xs.

5] Select test current (default 1 A). Short-circuit impedance is not pending test current. Typical test current are 1-5 A. Note that maximum output voltage is 250 V which may be limiting the maximum test current for small transformers with high HV winding resistance.

6] Press  to start the generator and measure.

7] Reconnect cables to next phase.

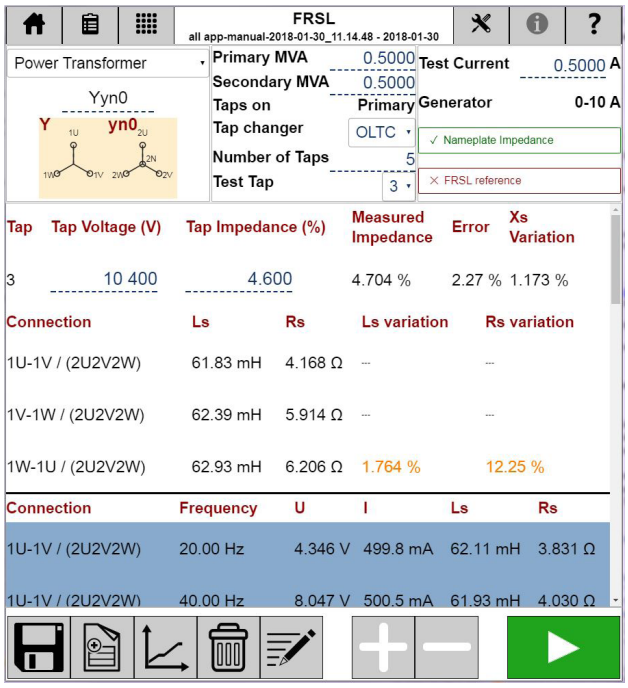
8] Save results.

7 Advanced transformer apps (optional software)

7.1 Frequency response measurement of stray losses - FRSL

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

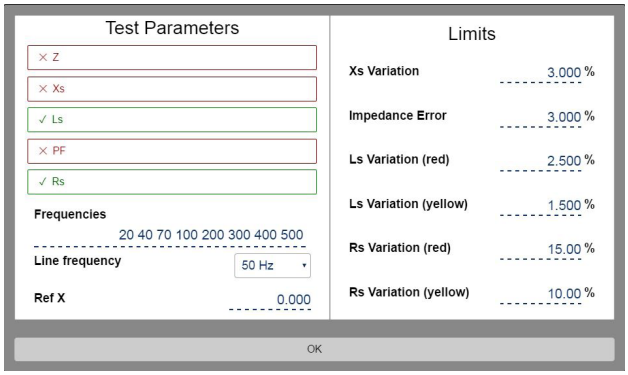
1] Press 



FRSL (Frequency Response of Stray Losses) is a technique for assessing transformer windings’ condition by performing the short-circuit test in wide range of frequencies. Diagnostics based on FRSL is done through comparison of the results with earlier measurements, identical transformer or between phases. The measurements are done on the HV side, while the LV side is short circuited.

Settings

1] Press 



Select the calculated parameters to be displayed in results table.
For description of the parameters see “Calculated parameters” on page 29.

Test Parameters

Frequencies	Frequencies that the measurement are done can be defined The max frequency is 500 and min frequency is 20 Hz
Line frequency	16⅔, 25, 50, 55, 60, 500 Hz
Ref X	Reference reactance
Xs Variation	Reactance variation between windings, Default 3%
Impedance Error	Impedance deviation from the nameplate impedance, Default 3%
Ls Variation (red)	Inductance variation between windings, Default 2.5%, warning
Ls Variation (yellow)	Inductance variation between windings, Default 1.5%, warning
Rs Variation (red)	Resistance variation between windings, Default 15 %, warning
Rs Variation (yellow)	Resistance variation between windings Default 10%, warning

Transformer configuration

1] Configuration is selected by entering the corresponding transformer vector diagram via keyboard or selecting in the matrix (see winding resistance app). If no configuration is entered the test will automatically be defined as a manual test on a 2-winding transformer.

2] If the configuration is not supported at all for FRSL tests it is still possible to run "Manual Test" and connect and short the transformer based on previous experiences with the actual transformer and/or configuration.

HV-LV Impedance

Three-phase equivalent

The nameplate value of the impedance can be used as an additional reference for FRSL (impedance at rated frequency).

- By choosing the "Nameplate Impedance", Tap Impedance can be defined and Measured Impedance and the Error will be shown after the measurement.
- By providing a value for as per nameplate "Impedance", the app automatically selects three phase equivalent model and the results can be compared with the transformer nameplate. Three-phase equivalent works for Y and delta configurations with the three LV terminals (but NOT the neutral) shorted. Make sure the shorts are good with low resistance since LV current will be test current multiplied with transformer ratio. Three-phase equivalent model does not work for Zigzag configurations and the resulting impedance cannot be compared with nameplate.
- By choosing "FRSL reference", reference values of each phase's inductance and resistance can be defined and measured values, Ls and Rs, and their corresponding Error will be shown after the measurement.

Per-phase measurements

- If the "Nameplate Impedance" is not selected, TRAX suggest measurements per-phase and the variation in leakage reactance, Xs, is calculated and displayed. Rs and Ls values of each phase are calculated and their variations will be shown after the measurement.

Step-by-step instructions

1] Select transformer configuration (and number of taps; however this test is normally done on nominal tap only).

2] Enter transformer nameplate information including: "Impedance", Nominal Power (MVA) and Impedance (%) if "Nameplate Impedance" is selected.

3] Chose the type of tap changer, Number of Taps and the Test Tap number

4] Confirm cable connections/hook-up.

5] Select test current (default 1 A). Short-circuit impedance is not pending test current. Typical test current is 1-5 A.

Note *The maximum output voltage is 250 V which may be limiting the maximum test current for small transformers with high HV winding resistance and test voltage will increase when frequency increases.*

6] Press  to start the generator and measure.

7] The voltage U, current I, impedance Z and reactance Xs will be displayed for each frequency.

8] Reconnect cables to next phase.

9] Save results.

Interpretation of the results

The recommended ranges for Ls and Rs variations[1)] for comparison with reference results or comparison between phases are as shown in the table below.

Comparison with Ref	Green	Yellow	Red
Ls variation (%)	0-0.5	0.5-1.0	> 1.0
	and	or	or
Rs variation (%)	0-5	5-10	> 10

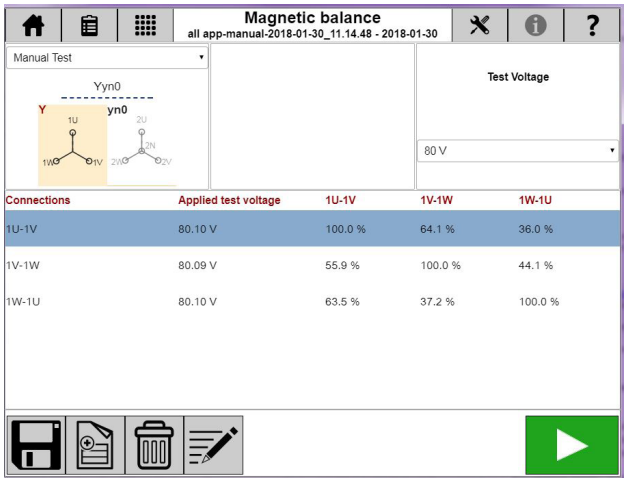
Comparison between phases	Green	Yellow	Red
Ls variation (%)	0-1.5	1.5-2.5	> 2.5
	and	or	or
Rs variation (%)	0-10	10-15	> 15

1) P. Picher and C. Rajotte, "Comparison of FRA and FRSL Measurements for the Detection of Transformer Winding Displacement," CIGRE 2003 Transformers Colloquium Paper, Merida, Mexico, 2-4 June 2003.

7.2 Magnetic balance

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



The magnetic balance app is used for assessing the condition of magnetic core, winding and other associated parts of the magnetic circuit. The magnetic balance test is performed on three phase transformer to check whether the transformer core has been properly demagnetized or to find out the magnetization status of the core.

Settings

1] Press 
In “Display type” the voltages can be chosen to be in percent or in measured voltage values.
“Test Frequency” can be chosen for 50/60 Hz

Step-by-step instructions

No configuration measurements

1] Choose “Manual test”

2] Connect current and voltage leads to the test object.

3] Connect the cables to the TRAX channels

For example if you have applied voltage between phase H3 (red) and H1 (black), the cable connections must be:

Ch1	Ch2	Ch3
H3-H1	H1-H2	H2-H3

Ch1 (red) is the phase that we apply voltage to and Ch2 (red) the phase we return the voltage from, and Ch3 (red) the other phase.

4] Select test voltage, 1.5 / 8 / 40 / 80 / 125 / 250 V
It is recommended to use enough voltage (depending on the transformer) to magnetize the core to get the correct result for assessment.

5] Press  to start test.

6] Perform next measurement on another windings set.

7] Save results.

Magnetic balance with transformer configuration

1] Choose Power Transformer

2] Enter the transformer configuration and select winding(-s) for test.

3] Choose the type of tap changer, Number of Taps, HV and LV nominal voltage

4] Connect the cables as described, e.g. apply voltage over H1- H3 and measure voltage between each two phases

5] Connect current and voltage leads to the test object.
Pressing  will show the connection.

6] Select test voltage, 1.5 / 8 / 40 / 80 / 125 / 250 V
It is recommended to use enough voltage (depending on the transformer) to magnetize the core to get the correct result for assessment.

7] Press  to start test.

8] Perform next measurement.

9] Save results.

Interpretation of the results

The sum of induced voltages should add up to the applied voltage. With the mid-limb excited, the extreme limbs will have 40 to 60% induced voltage. With the extreme limbs excited, the middle limb will have 60 to 90% induced voltage and the other extreme limb will have 10 to 40% induced voltage. Therefore, the results must be in the ranges shown in the table[1)].

	H1-N	H2-N	H3-N
H1-N	100 %	60% - 90%	10% - 40%
H2-N	40 to 60%	100 %	40 to 60%
H3-N	10% - 40%	60% - 90%	100 %

When there is no grounded winding available on the primary, we can apply voltage and measure voltage between the phases. In this case the voltage we applied between two phases must be equal to the summation of the voltages between two other phases, e.g: Voltage (H1-H2) = Voltage (H2-H3) + Voltage (H3-H1).

Note *These results are valid for 3 legs transformer and may not be valid for 5 legs transformer.*

1) "Core balance test of transformers and to evolve minimum acceptable value for various voltages range of power transformers", technical report no. 125, central board of irrigation and power, New Delhi, June 2000.

7.3 On load tap changer - OLTC

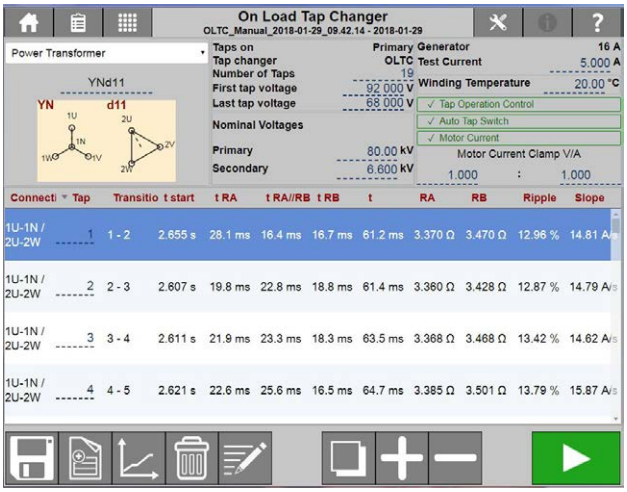
Important
Read and comply with the safety instructions "2 Safety" on page 8.
Always comply with local safety regulations.

1] Press 

OLTC is used to perform static/dynamic resistance measurements on resistor type on-load tap changers.

With this app, the instrument is continuously injecting test current to the transformer and the resistances for each tap setting are measured sequentially as the tap changer is stepped through its positions. Results are typically presented as a graph or table with resistance values for each tap. Resistance changes between taps should be consistent with only small deviations between different tap positions.

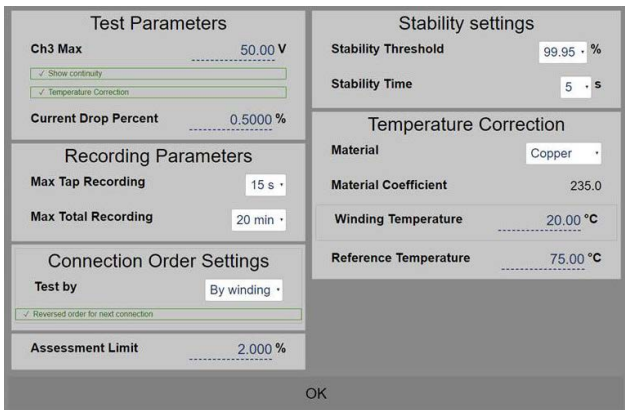
OLTC can be used for continuity verification through dynamic resistance measurements (timing and resistance). LTC control can also be done through OLTC app.



Generator current source available for LTC test has the max value of 16 A.

Settings

1] Press 



Test Parameters

Ch3 Max	Max 50 V voltage for measurement channels, lowering this value can increase the measurement resolution
Show continuity	Select Show continuity in the Test Parameters to be displayed in the results table.
Temerature Correction	Enable temperature correction.
Current Drop Percent	Current drop percent is the smallest current drop to be detected at a tap change. If it is set too high, the automatic tap change does not work. If it is set too low, the current drops will be incorrectly detected and this might lead to strange measurement results. Default 0.5% is a good value in the vast majority of cases.

Recording Parameters

Max Tap Recording	Max recording time for each tap
Max Total Recording	Max recording time for all taps

Connection Order Settings

Test by	Transformer test tables are organized by tap or winding. Note: Changes will take place after you have selected the relevant app from the App menu.
Reversed order for next connection	Transformer test tables are organized with mid-phase in reversed tap order. Note: It is also possible to change tap order in a specific test by clicking on “Tap” in the test table
Assessment Limit	Limit for winding resistance variation between windings Default 2%

Stability Settings

Stability Threshold	Select minimum values for stability
Stability time	Minimum time for stability before initiating measure/stop. When the measurement reaches to the stability the +/- buttons get activated for changing to the next tap.

Temperature correction

Material	Copper, Aluminium or Custom
Material Coefficient	For copper, aluminium or as customer defined
Object Temperature	Enter the winding temperature (°C)
Reference Temperature	Reference temperature for the correction (°C)

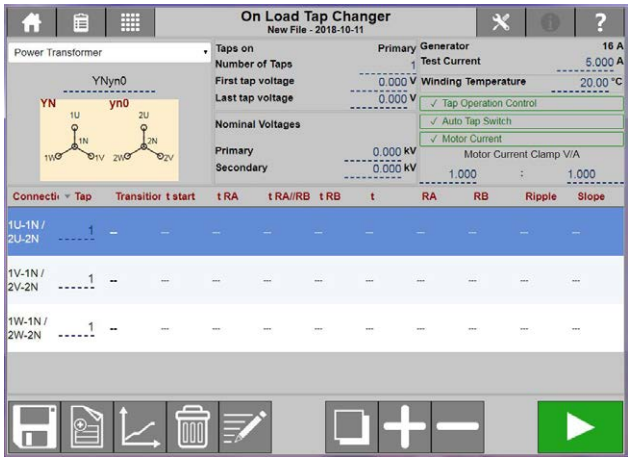
Transformer configuration (Vector diagram)

1] Transformer configuration and vector group is selected by entering configuration via key-board or selecting in the matrix.

2] Discharge is automatic when the generator is stopped and performed via the current ca-bles (primary). Discharge is also performed if the input power to TRAX is accidentally lost.

3] Demagnetization is recommended after OLTC measurement, which can be done using the Demagnetization app 

Controls for tap changer operation



Tap Operation Control

By choosing the ‘’Tap Operation Control” option, you need to connect the tap changer to the control panel of the TRAX.

Auto Tap Switch

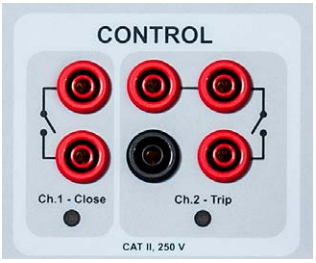
Automatically steps through, and records, the taps without any user interaction with the TRAX software.

Motor Current

Option for also recording the motor current of the tap changer.
Connect a current clamp to the motor and give the settings to the Trax software for the current clamp.
How many volts/ampere is the clamp.

Controls for tap changer operation

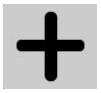
The CONTROL contacts are used to remotely operate the tap-changer.



+ / raise controls the left ch 1 contact.

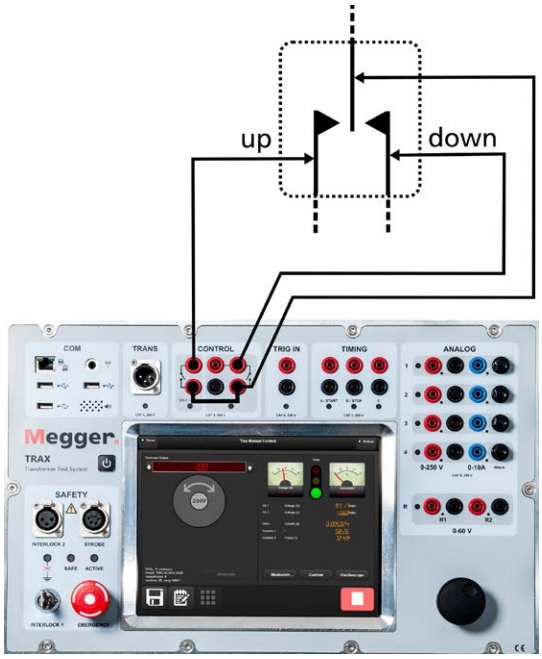
- / lower controls the right ch 2 contact.

Buttons to use during operation

	+ / raise
	- / lower
	capture/measure data without stopping the generator (for manual tap changing).

Activating + or - buttons closes the contact for about 500 ms. After one operation the contacts are blocked for about 2 seconds before the next operation is possible.

Run two wires from each output contact and connect them in parallel with the manual operating contacts for raise/lower tap (at the tap-changer control cabinet). Max carrying current (short-term) is 35 A.



Step-by-step instructions

1] Choose Power Transformer

2] Enter the transformer configuration and select winding(-s) for test.

3] Enter the ''Number of taps" and the voltage rate for the ''High" and ''Low" taps. ''Tap Voltage" is calculated based on the defined High and Low voltages and the number of taps.

4] Enter the Nominal Voltages for ''Primary" and ''Secondary"

5] Choose the test current

6] **If** Tap Operation Control is chosen, connections must be done according to the Controls for tap changer operation.
If ''Auto Tap Changer" is not selected, there will be a button  for recording each tap manually. In this case you need to press the recording button first and then immediately (in less than15 seconds) change the tap manually.

7] Press  to start test

8] When reading is stable, the measurement and the result is captured and displayed for the actual row/tap.
When the measurement reaches to the stability the +/- buttons will be activated for changing to the next tap. Measurement will continue on the next table row (next tap position).

Note *If you have selected Auto tap change the tap changer will automatically switch.*
Do not stop generating until last tap is tested.

9] Operate tap changer with 
Continue until last tap.

10] Reconnect cables and perform test on next phase.
Winding variation will be displayed when all phases are measured.

Result table

OLTC app measures **RA** and **RB** transition resistance values per tap, RA switching time (**tRA**), RB switching time (**tRB**) and switching time that both R1 and R2 are in parallel (**t RA/RB**). The total time of switching / transition is shown as **t**.

Ripple and **Slope** shows the dynamic current parameters. How much does the current drop, in percent,

when the tap change occurs. How fast, in A/s, does it drop. Both are displayed for each tap.

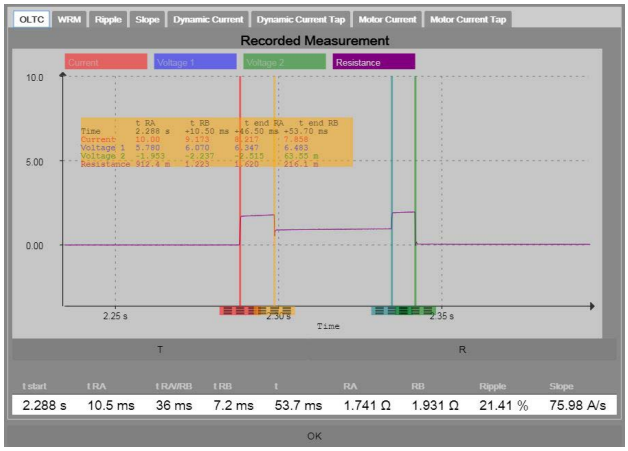
''Current"	shows the measured test current
''Measured resistance"	shows the resistance measured at each moment and finally in the stable phase of the measurement
''Stability"	shows the stability level for the resistance measurement
''Variation"	shows the variation between the measured resistance of each tap for different phases
''Transition"	shows the action is made from each tap to the next one in a descending or ascending condition.

To view the graphs

1] Clic the row for the desired tap in the result table.

2] Click the graph button 
The dynamic resistance curve will be shown.

3] To activate other relevant graphs, click and hold their name tag in the left column.



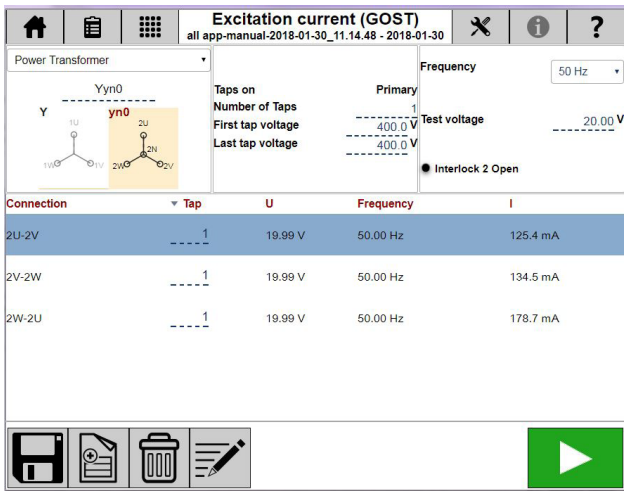
WRM	Displays the winding resistance graph recorded at the same time as the OLTC parameters are taken
Ripple	Graph of the ripple per tap. Shows all windings and in which direction the measurement was taken e.g. from tap 1-19 or 19-1.
Slope	Same as ripple but displayes the slope of the test current per tap.
Dynamic current	Shows the recorded test current throughout all taps.
Dynamic current tap	Shows the selected tap
Motor current	Shows the recorded motor current throughout all taps.
Motor current tap	Shows the motoer current for the selected tap.

7.4 Exitation current (GOST)

TRAX Excitation current (GOST) app is intended for measuring current and impedance on LV side of a transformer according to the Russian standard ''GOST", with the HV windings open.

Important
Read and comply with the safety instructions "2 Safety" on page 8.
Always comply with local safety regulations.

1] Press 



Warning
When excitation current is to be measured on LV side on a transformer please note that the HV side will be energized at a higher voltage that can be very dangerous.

Settings

1] Press 

2] Select the calculated parameters to be displayed in results table.

Step-by-step instructions

No configuration

1] Select the test voltage. For this test 250 V generator is used. Select also the frequency (Default value is the line frequency)

2] Connect the generator leads to the HV winding.

3] Press  to start the first test.

4] Readings will be displayed automatically when stable and generator will stop.

5] Continue with next test. New tests will be added to the table. It is possible to re-measure a line in the table by activating the actual row and start a new measurement.

6] When the test is finished the results can be saved to a file/report.

With transformer configuration

1] Select transformer configuration,

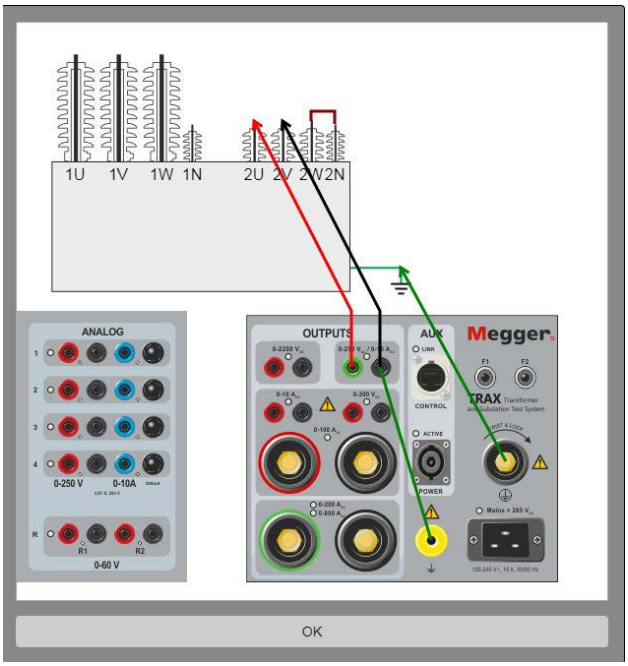
2] Enter number of taps and voltages for first tap and last tap.

3] Choose the winding that has taps on.

4] Select the test voltage.

5] Select the frequency (Default value is the line frequency)

6] Connect cables to the test object as described in the table and connection picture.



7] Press  to start the first test.
Readings will be displayed automatically when stable and generator will stop.

8] Continue with next test.
It is possible to re-measure a line in the table by activating the actual row and start a new measurement.

9] When the test is finished the results can be saved to a file/report.

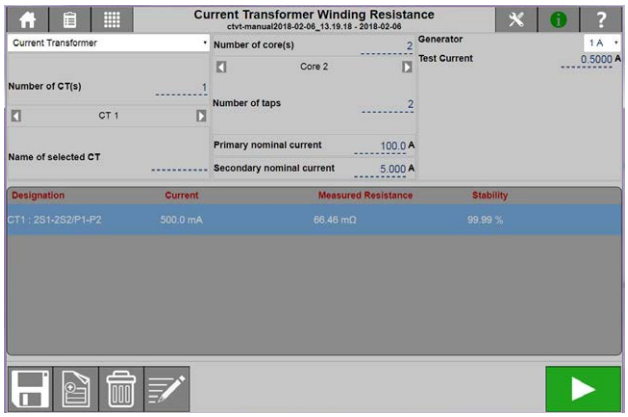
8 Instrument transformer apps (optional software)

8.1 Current transformer winding resistance

The CT winding resistance app is used for measuring DC resistance in current transformer secondary windings.

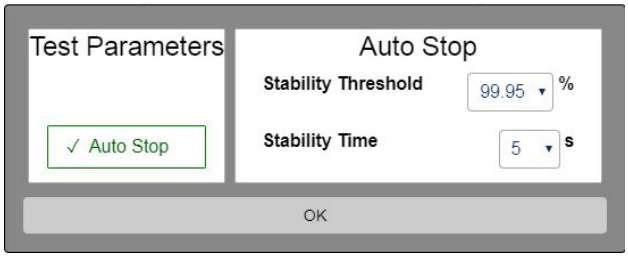
Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



Settings

1] Press 



2] Select test parameters and make settings.

Test Parameters	
Auto Stop	**Enable Auto Stop**

Auto Stop	
Stability Threshold	Select minimum values for stability
Stability Time	Minimum time for stability before initiating measure/stop. E.g when stability is > 99.95% for > 3 s the measurement is automatically stopped.

Step-by-step instructions

Manual test

1] Choose “Manual test”

2] Connect current and voltage cables to the test object.

3] Connect the cables to the TRAX channels.

4] Choose a generator.

5] Select test current and Press  to start the test.

6] In manual mode, when reading is stable stop the measurement and the result is displayed. In autostop, measurement will be automatically stopped when stability criteria is reached.

7] Perform next measurement.

8] Discharge is done automatically when the measurement is stopped.

WARNING
Do not remove any cables until discharge is finalized. Wait until the **ACTIVE** indicator lamp on the TRAX panel goes out. There is also a discharge pop-up on screen and sound (if buzzer is on).

Test with transformer configuration

1] Select current transformer.

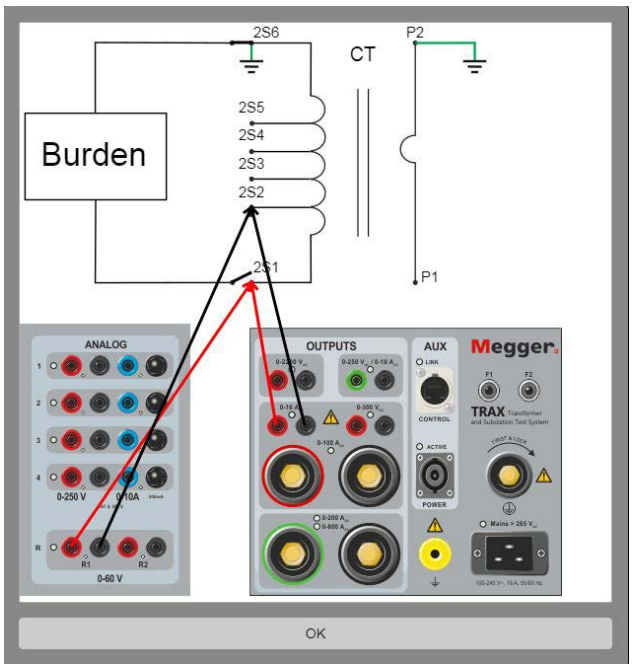
2] Select number of CTs and enter each one’s name.

3] Select number of cores.

4] Select number of taps for each core.

5] Enter the insulation temperature

6] Connect the cables.
Pressing  will show the connection.



7] Select generator and set the test current.

8] Press ▶ to start the test.
The current will be injected and the winding resistance measured.

Note *Normally the winding resistance is measured only at the tap that is used. However, it is possible to measure winding resistance for all taps.*

9] In manual mode, when reading is stable stop the measurement and the result is displayed. In autostop, measurement will be automatically stopped when stability criteria is reached.

10] Repeat the test for all the taps and cores.

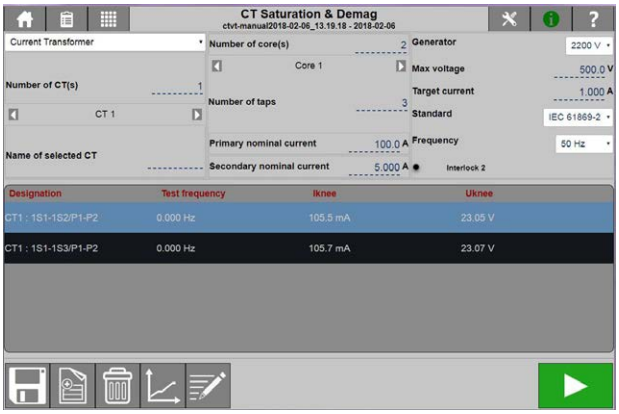
11] Save results.

Note *It is recommended to demagnetize the current transformer cores after a DC-test. It can be done by CT excitation and Demag app.*

8.2 Current transformer saturation & Demag

Saturation test is used to identify the rated knee point of the CT according to the standards. The CT is excited by applying voltage to the secondary side and the voltage is increased gradually until the CT is in saturation. The knee point can be defined as a point at which by increasing a small amount of voltage, current increases significantly. Then the test voltage is decreased gradually to zero to demagnetize the CT.

1] Press



Settings

1] Press

Test parameters

- In '' Frequency", power frequency (50/60 Hz) or 16 2/3, 25 and 55 can be chosen. Default is the frequency chosen in general settings.

Step-by-step instructions

Manual test

1] Choose "Manual test"

2] Connect current and voltage cables to the test object.

3] Connect the cables to the TRAX channels.

4] Choose a generator.

5] Select Max test voltage and current

Note *The test voltage is recommended to set to approximately 75% of the knee-point voltage. See knee-point calculation below if it is unknown.*

6] Press ▶ to start the test.
The voltage will be injected and the ratio measured.

The test will stop automatically when a result is acquired.

7] Perform next measurement.

8] Save the results.

With configuration

1] Select Current Transformer.

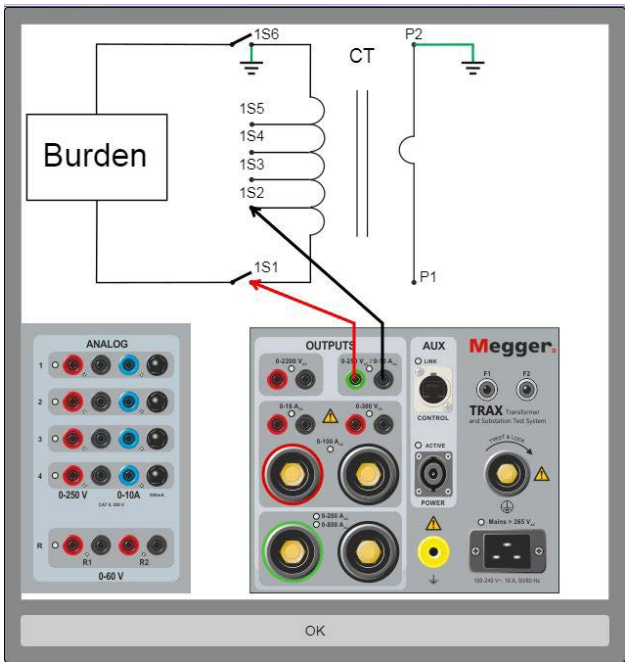
2] Select number of CTs and enter each one's name.

3] Select number of cores.

4] Select number of taps for each core.

5] Connect cables.

6] Pressing **?** will show the connection.



7] Select test voltage.

8] Press ▶ to start the test.
The voltage will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

9] Repeat the test for all the taps and cores

10] Save the results.

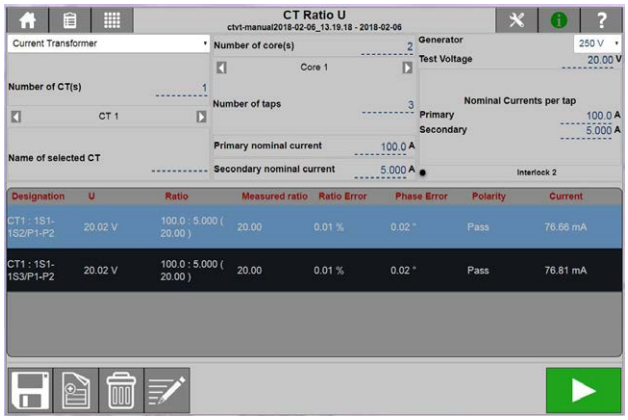
8.3 Current transformer ratio U

TRAX CT ratio app determines the current transformer ratio as defined by international standards. The app provides an excitation test voltage to the secondary winding of the current transformer and measures simultaneously the voltage at the primary winding. The voltage ratio is measured and equivalent nameplate ratio is displayed and compared with the expected nameplate ratio.

TRAX measures ratio, phase deviation and polarity at the same time. Testing can be done at power frequency, or preferably at a frequency different from the power frequency to avoid interference.

Important
Read and comply with the safety instructions "2 Safety" on page 8.
Always comply with local safety regulations.

1] Press 10:1 V



Settings

1] Press

Max Error (%)	Setting defines the limit where measured values should be highlighted.
Test Frequency	Test frequency selection; 16 2/3, 25, 50, 55 or 60 Hz

Step-by-step instructions

Manual test

1] Choose "Manual test"

2] Connect current and voltage leads to the test object.

3] Connect the cables to the TRAX channels

4] Choose a generator

5] Select test voltage

Note *The test voltage is recommended to set to approximately 75% of the knee-point voltage. See knee-point calculation below if it is unknown.*

6] Press ▶ to start the test.
The voltage will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

7] Perform next measurement.

8] Save the results.

With configuration

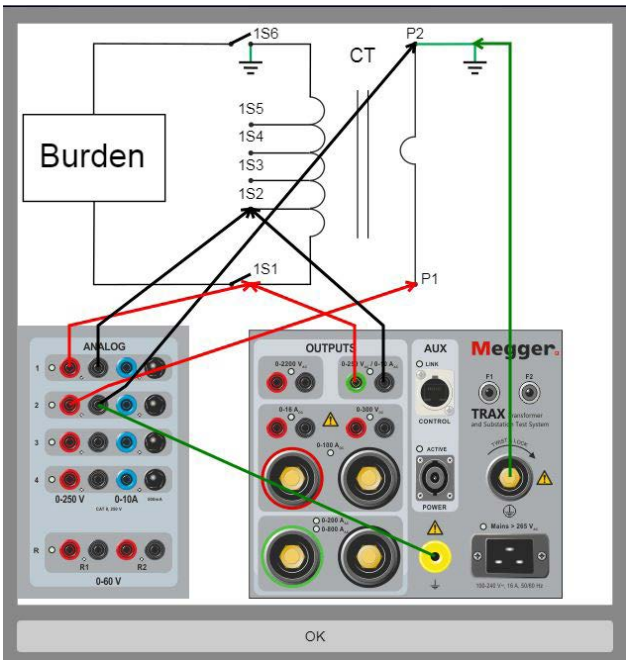
1] Select current transformer.

2] Select number of CTs and enter each one's name

3] Select number of cores.

4] Select number of taps for each core.

5] Connect the cables
Pressing **?** will show the connection.



6] Select test voltage

7] Press ▶ to start the test.
The voltage will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

8] Repeat the test for all the taps and cores

9] Save the results.

TIP

The approximate knee-point voltage can be calculated with the formulas:
Polarity:Pass, phase close to 0 degrees.
Fail, phase close to 180 degrees.

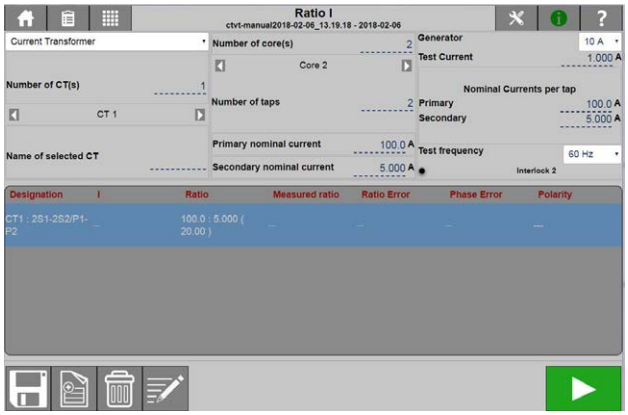
Protection core	Vslv=Is*ALF (Rct + (VA/Is2))
Measuring core	Vslv=Is*FS (Rct + (VA/Is2))
Where:	
Is	Rated secondary current
Rct	CT secondary resistance
VA	Rated CT burden
ALF	Accuracy Limit Factor
Fs	Safety factor

The formulas only allow a rough estimation. The theory behind the formulas is just source voltage, source impedance and load. It is not based on any magnetic core behavior.

8.4 Current transformer ratio I

In CT ratio I, the current is injected on the primary side of CT and the secondary current and voltage is measured and recorded. Burden can also be measured in this app. It measures amplitude and phase angle of the current and voltage on the CT secondary, and with measured primary current calculates the actual ratio and the deviation from the nominal ratio.

1] Press 



2] Select "Current Transformer"

Settings

1] Press 

2] Set the Max error and select Frequency.

Max Error (%)	Setting defines the limit where measured values should be highlighted.
Frequency	Test frequency selection; 16 2/3, 25, 50, 55 or 60 Hz

Step-by-step instructions

Manual test

Important

Make sure that one side of primary and secondary windings are connected to ground at all times. Otherwise, the measurement results will be affected and the instrument may be damaged.

1] Choose Manual test.

2] Connect current and voltage leads to the test object.

3] Connect the cables to the TRAX channels.

4] Short circuit all secondary cores that are not measured.

5] Define the nominal currents for Primary/Secondary.

6] Choose a generator 10/200/800A, pending type of TRAX unit.

7] Select test current.

Note *Select an appropriate test current best accuracy is achieved at about 75% of nominal current but any value between 10% - 100% of nominal is considered to be ok.*

8] Press  to start the test.
The current will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

9] Perform next measurement.

10] Repeat the test for all phases and cores.

11] Save results.

With configuration

1] Select current transformer.

2] Select number of CTs and enter each one's name.

3] Select number of cores.

4] Select number of taps for each core.

5] Short circuit all secondary cores that are not measured.

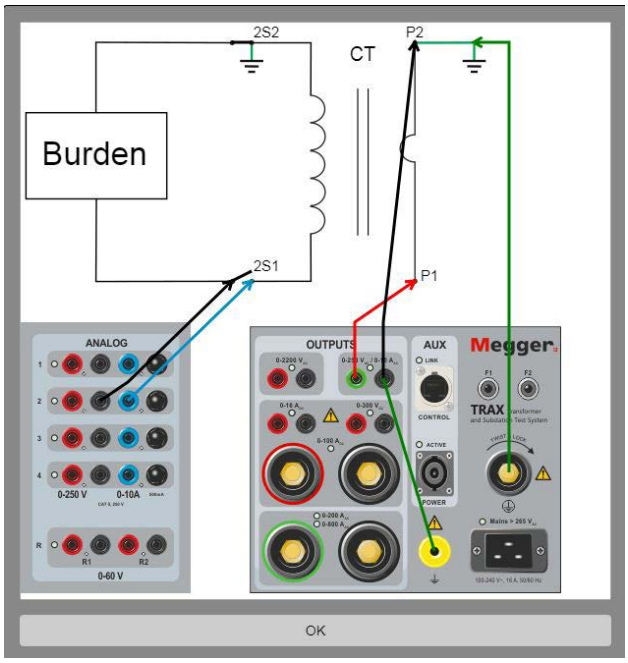
6] Define the nominal currents for Primary/Secondary.

7] Choose a generator 10/200/800 A.

8] Select test current.

Note *Select an appropriate test current, best accuracy is achieved at about 75% of nominal current but any value between 10% – 100% of nominal is considered to be ok.*

9] Connect cables as shows in the picture.
Pressing  will show the connection.



10] Press ▶ to start the test.
The current will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

11] Repeat the test for all the taps and cores

12] 12] Save results.

The obtained turn's ratio should match with rated nameplate ratio and polarity should show pass.

Results table

I	measured primary current
Phase Error	phase angel between primary and secondary current
Ratio	value from nameplate
Measured ratio	ratio calculated from the measured currents
Ratio Error	difference between the nameplate and measured ratio
Polarity	Pass, phase close to 0 degrees. Fail, phase close to 180 degrees.

8.5 Voltage transformer ratio

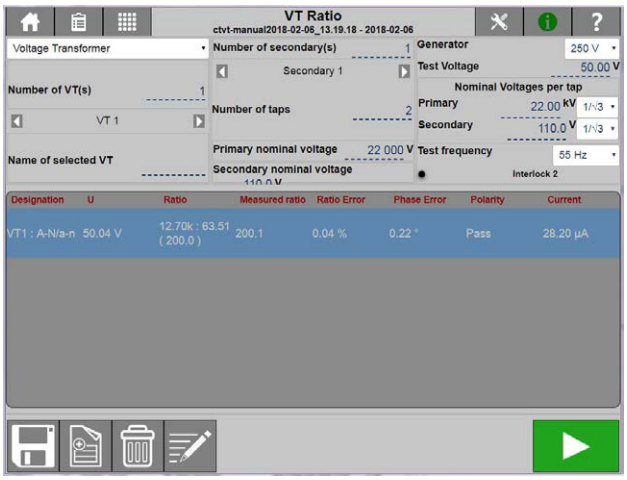
TRAX VT ratio app determines the voltage transformer ratio as defined by international standards. The app provides an excitation test voltage to the primary winding of the voltage transformer and measures simultaneously the voltage at the secondary winding. The voltage ratio is displayed and compared with the expected nameplate ratio.

TRAX measures ratio, phase deviation and polarity at the same time. Testing can be done at power frequency, or preferably at a frequency different from the power frequency to avoid interference.

Important
Read and comply with the safety instructions "2 Safety" on page 8.
Always comply with local safety regulations.

Caution
Never generate voltage on the secondary side of the VT.

1] Press 10:1



Settings

1] Press ✕

Max Error (%)	Setting defines the limit where measured values should be highlighted.
Frequency	Test frequency selection; 16 2/3, 25, 50, 55 or 60 Hz

Step-by-step instructions

Manual test

1] Choose Manual test

2] Connect current and voltage cables to the test object.

3] Connect the cables to the TRAX channels

4] Choose a generator

5] Select test voltage

6] Press ▶ to start the test.
The voltage will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

7] Perform next measurement.

8] Save the results.

With configuration

1] Select voltage transformer.

2] Enter nominal primary and secondary voltages.

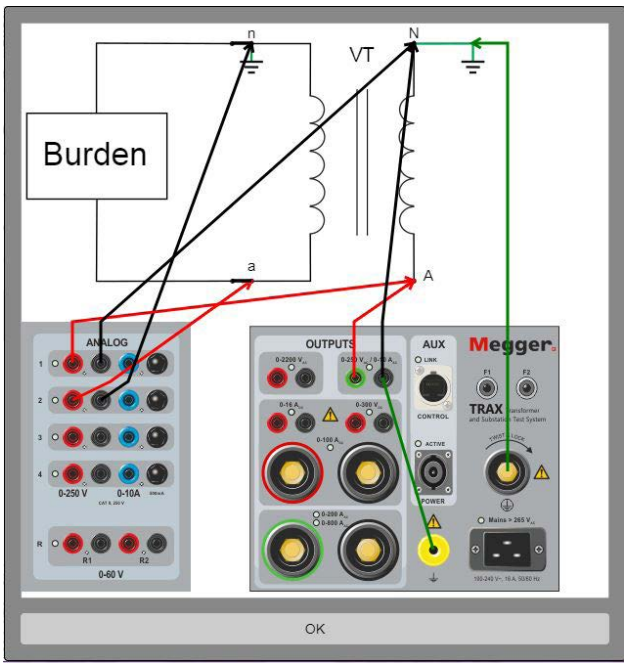
Note *The primary and secondary nameplate voltages are many times displayed as phase-phase voltage divided by √3 on the nameplate. For convenience it can be set if the primary and secondary values are set to Phase-Phase or Phase-Neutral, see settings (Not released yet).*

3] Select number of VTs and enter each one's name.

4] Select number of cores.

5] Select number of taps for each core.

6] Connect the cables.
Pressing **?** will show the connection.



7] Select test voltage.

8] Press ▶ to start the test.
The voltage will be injected and the ratio measured.
The test will stop automatically when a result is acquired.

9] Perform next measurement.

10] Save the results.

Polarity: Pass, phase close to 0 degrees.
Fail, phase close to 180 degrees.

9 Substation apps (optional software)

9.1 Contact resistance

Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

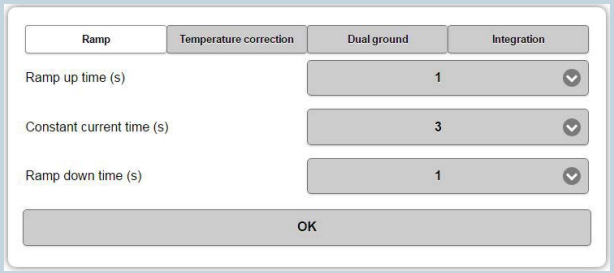
1] Press 

Settings

1] Press 

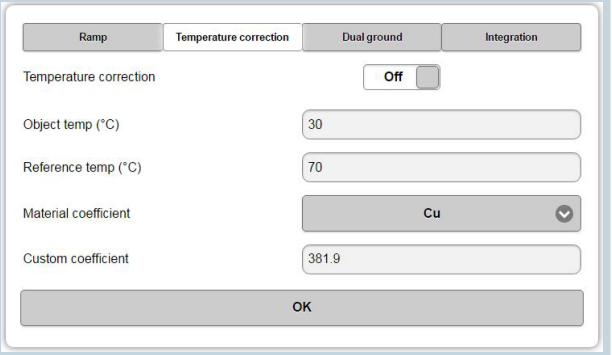
Make desired settings for the following subjects, Ramp, Temperature correction DualGround and Integration.

Ramp



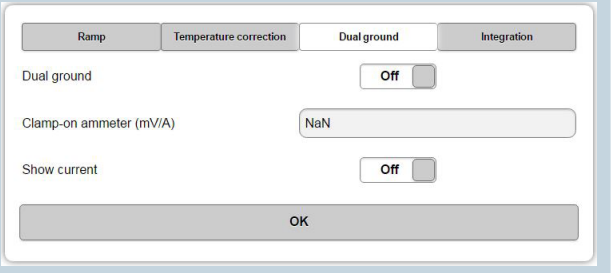
Ramp up time (s)	1, 2, 3, 5, 10 or 20
Constant current time (s)	3, 5, 10, 20, 60 or 3600
Ramp down time (s)	0.3, 1, 2, 3, 5, 10 or 20

Temperature correction



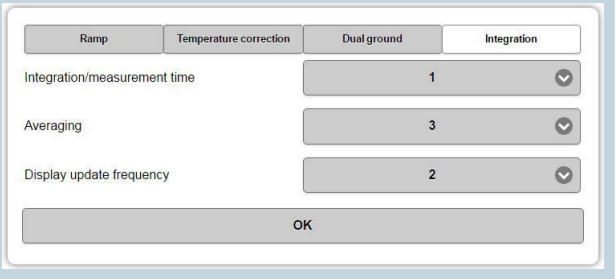
Temperature correction	On/Off Measured values will be automatically corrected to the reference temperature.
Object temp (°C)	Enter test object temperature.
Reference temp (°C)	Reference temperature to where the resistance will be adjusted to.
Material coefficient	For copper, aluminum or as customer defined.
Custom coefficient	Only applicable when Material coefficient is set to customer defined.

DualGround



DualGround	On/Off
Clamp-on ammeter (mV/A) (optional accessory, connected to R2 input)	Set the ratio for the clamp-on ammeter (mV/A)
Show current	On/Off

Integration (Only for continuous mode operation)



Integration/measure-ment time	0.1, 0.2, 0.5, 1, 2, or 4
Averaging	1, 2, 3, 4 or 5
Display update frequency	1, 2, 3 or 4

Connection for measurement

1] Connect to the test object and ground one side.

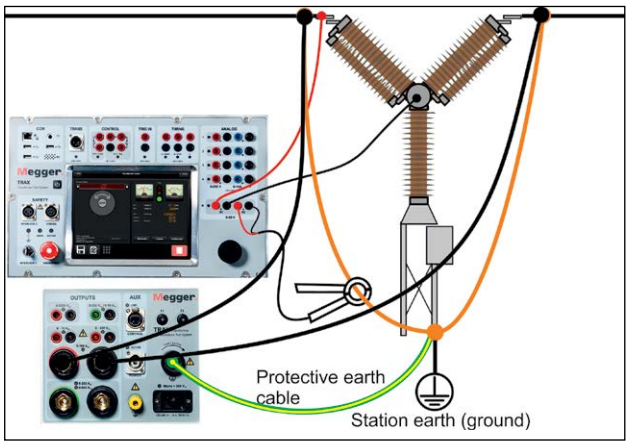
2] Select desired "Generator" and then "Test current".
After selection the test current can be adjusted within the actual current range.

3] Select "Continuous" if desired.
Single test is default.

4] Press ▶ to start injecting current.
A) In single test, the measurement will be performed automatically and the result is displayed.
B) In continuous mode, press 📷 to record each test and press ■ to stop the generator.

Dual ground measurements

The DualGround feature is used in situations where the current through the test object is not the same as the generated current. A typical example is measuring circuit breaker contacts while the circuit breaker is grounded on both sides.



The parallel current is measured with an external clamp-on CT connected to channel R2 and a value for the clamp-on ammeter in mV/A is needed (settings page). This is used to calculate the current flowing in the parallel path.

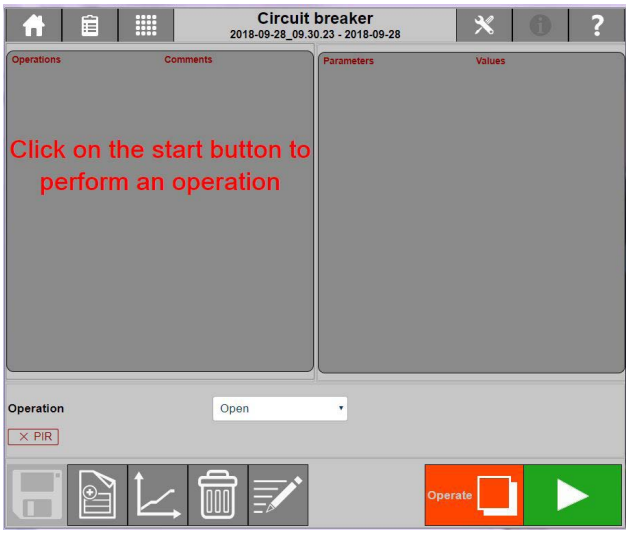
Measurements are performed as above and the measured value is automatically adjusted for the parallel current.

9.2 Circuit breaker

The circuit breaker app is used for timing and coil current measurement of circuit breakers with operating coils, normally 1 kV circuit breakers, or higher voltages. The app is suited for measuring a three phase circuit breaker with one break point per phase, i.e. a common circuit breaker in a distribution network.

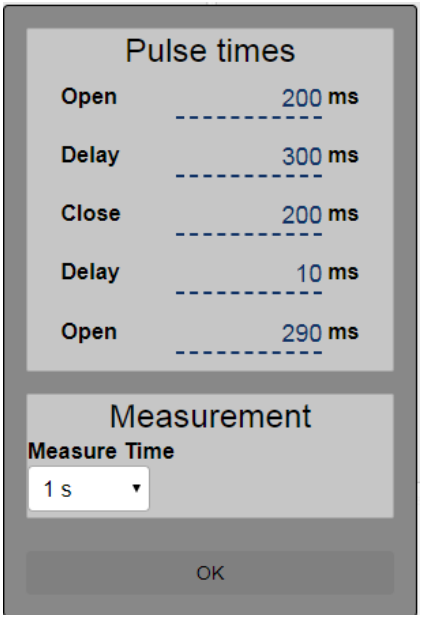
Important
Read and comply with the safety instructions “2 Safety” on page 8.
Always comply with local safety regulations.

1] Press 



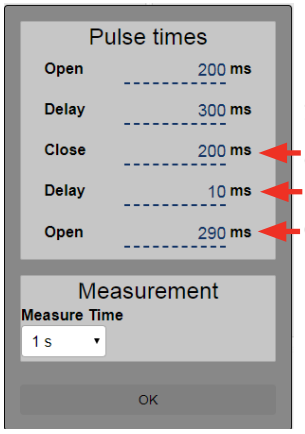
Settings

1] Press 



Pulse times	
Open	Pulse lenghts and delay times can be set for the circuit breaker operating sequence.
Delay	
Close	An open or close pulse starts at 0 ms and ends at the set time.
Delay	
Open	The delay time is the time between open/close pulses.
Measurement	
Measure Time	Select the total time for the measurement

Example for close-open operation



Set times for:
Close
Delay
Open

Step by step instruction

Operating buttons

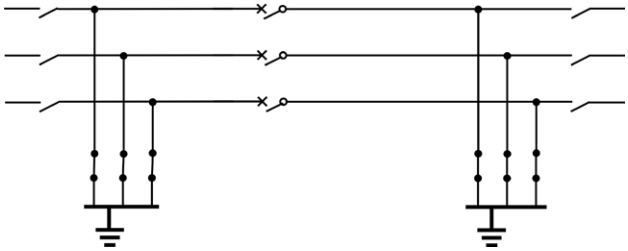
Operate if you only want to change position of circuit breaker and not measure the operation.


Run and measure if you want to make a measurement of the circuit breaker operation.

The normal test procedure is to make a series of single operations. Start with one open, then one close and repeat this 3 times for each type. After that you continue with a couple of multiple operations.

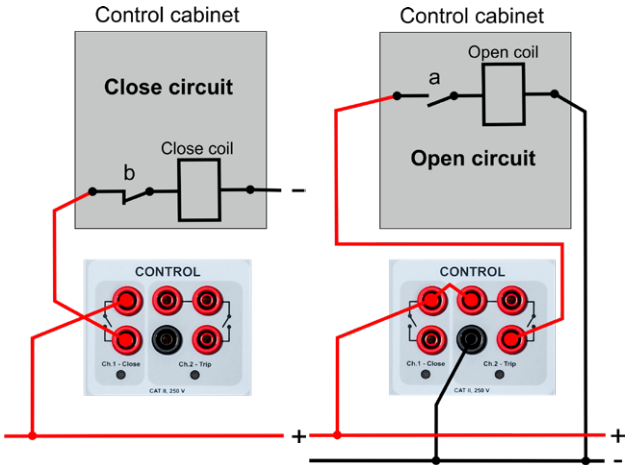
1] Open the circuit breaker.

2] Disconnect and ground on both sides of the circuit breaker before making any connections.

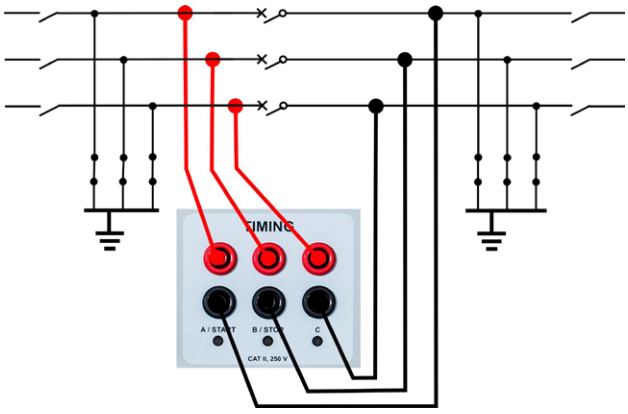


3] Connect the CONTROL outputs to close and open circuits in the control cabinet for the circuit breaker.
The CONTROL contacts on TRAX are used to remotely operate the circuit breaker. CONTROL also measure the current and voltage supplied for the operation. Control voltage can be supplied from the station battery or from a power supply unit, i.e. a Megger B10E. The open voltage is recorded.

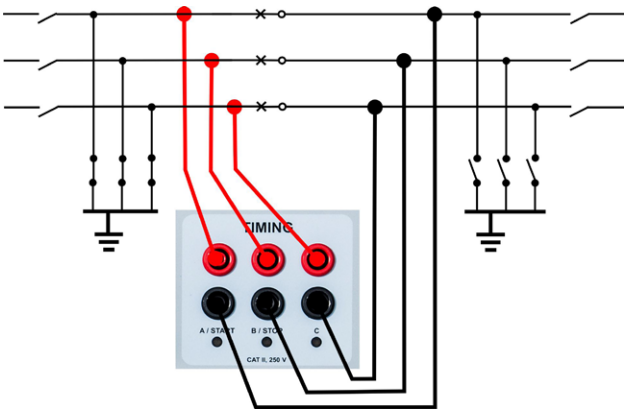
Note *If the DC minus is not accessible, measurements can still be performed but parameter "Open Control V" cannot be measured.*



4] Connect the TIMING inputs to respective phases over the break point of the circuit breaker.



WARNING
Close the circuit breaker before removing ground connections at one side of the circuit breaker.
Before testing, ground on one side must be removed.



5] Set "Measure Time" and "Pulse times". Recomended values for an Open operation is: 1 s for measure time and 200 ms for pulse time.

6] Select "Operation" in the drop down list.

7] Connect the remote interlock device to TRAX "Interlock 2".

8] Press and hold Interlock button and press to operate the circuit breaker.

9] Read the results.

10] Select next operation and operate the circuit breaker again.

Note *For cassette or plug in circuit breakers you disconnect the circuit breaker from the switchgear and connect the timing cables at phase flags with no grounding connections.*

Multiple operations

Pulse times (ms)

Recommended pulse length for an operation (close or open) is 200 ms. Delay 300 ms before close operation during multiple operations.

Close- open operation (Trip Free)

An operation to simulate connection to a fault and the circuit breaker should trip (open) directly. Normally no delay or 10 ms is used at this operation.

Open-close operation (Auto reclose)

Simulation of a reclose operation on feeder circuit.

To simulate a line circuit breaker which get the order from auto-reclose after a fault. According to IEC the close operation should always be delayed with 300 ms at a multiple operation.

Open- close – open

Simulation of a reclose operation during which the fault has not cleared.

According to IEC the close operation should always be delayed with 300 ms at a multiple operation.

Test result parameters

Timing

Open time A/B/C

Time elapse from system time zero (when open pulse is sent to circuit breaker) to final contact separation at opening operation for that phase.

Open time RA/RB/RC

Time elapse from system time zero (when open pulse is sent to circuit breaker) to final contact separation for PIR (preinsertion resistor contact)of slowest phase.

Open time

Time elapse from system time zero (when open pulse is sent to circuit breaker) to final contact separation of slowest phase.

Pk current

Peak current at open operation. Max current through coil during operation.

O contr. V (Open control V)

Voltage supply open [V] the minimum voltage available during open operation. Measured automatically inside instrument.

Close time A/B/C

Time elapse from system time zero (when close pulse is sent to circuit breaker) to first contact touch at closing operation for that phase.

Close time RA/RB/RC

Time elapse from system time zero (when close pulse is sent to circuit breaker) to first contact touch for PIR (preinsertion resistor contact) to first contact touch at closing in slowest phase.

Close time

Time elapse from system time zero (when close pulse is sent to circuit breaker) to first contact touch at closing in slowest phase.

Pk current

Peak current at closing.
Should follow circuit breaker manual values of max coil current during operation.

Cls df ABC (Timing circuit breaker close)

Syncronization of phases in timing in close operation. Time difference (df) between slovest phase and fastest phase in close operation.

Opn df ABC (Timing circuit breaker open)

Syncronization of phases in timing in a open operation. Time difference (df) between slowest phase and fastest phase in a open operation phases in timing.

Cls df M-R RA/RB/RC

Difference between main and resistor contact at at closing. Time difference (df) between the first touch of the resistor contact and the first touch of the main contact at closing operation.

Opn df M-R RA/RB/RC

Difference between main and resistor contact at opening. Time difference (df) between the last separation of the main contact and last separation for the resistor contact at an opening operation.

Diff A-B-C

Difference between phases Diffference in time between the slowest and the fastest phase in an operation.

CO time A / B / C

Time elapse from the first contact touch to the final separation for a single contact at a CO (Close Open) operation.

CO time RA / RB / RC

Time elapse from the first contact touch of resistor contact to the final separation for a single resistor contact at a CO operation.

OC time A / B / C

Time elapse from the final contact separation to the first contact touch for a single contact at an OC (Open Close) operation.

OC time RA / RB / RC

Time elapse from the final resistor contact separation to the first resistor contact touch for a single resistor contact at an OC operation.

Open time 2

Time elapse from system time zero to the final contact separation for a single contact at an OCO operation.

Interpretations of results

Values are available in the circuit breaker manual or a protocol from manufacturer of circuit breaker.

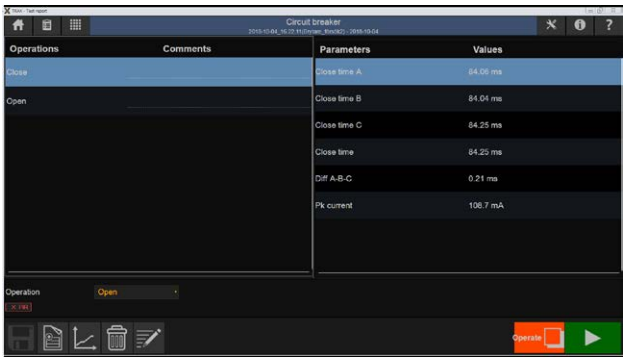
Note *It is common that the data for a circuit breaker are not available. You can compare new and old measurements and also between circuit breakers of the same type.*

Timing

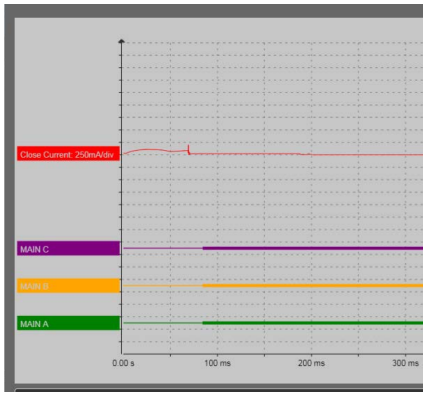
Breaker synchronization (phase vs. phase) Diff A-B-C

- <1/4 cycle at close operation (IEC62271-100) (5 ms)
- <1/6 cycle at open operation (IEC62271-100) (3.33 ms)

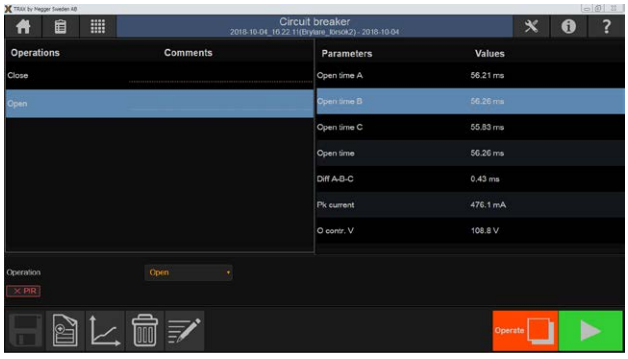
Result examples



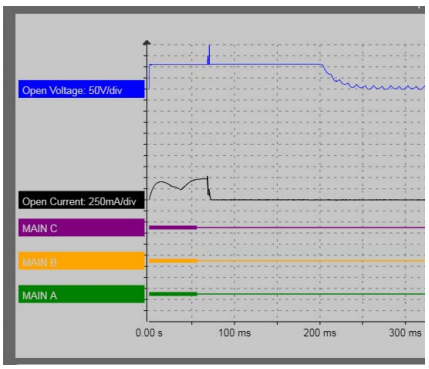
Example: Close recording, parameter list.



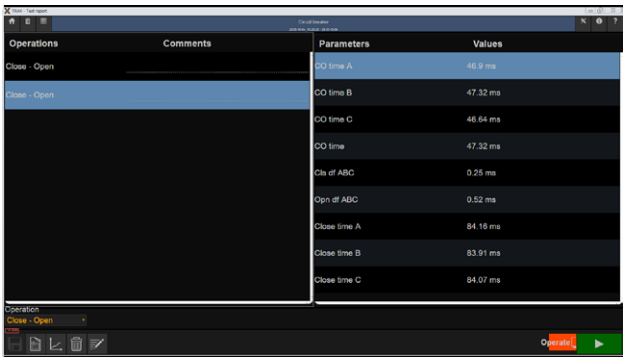
Example: Close graph.



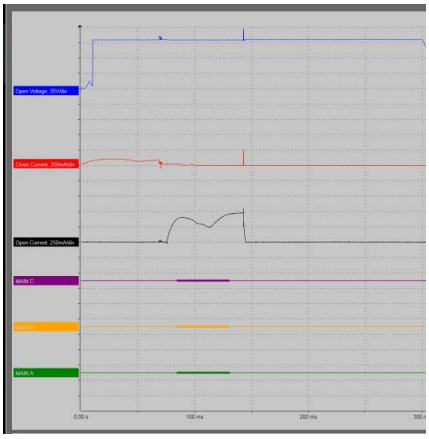
Example: Open recording, parameter list.



Example: Open graph showing supply voltage (blue), coil current (black) and timing; C (purple), B (yellow), A (green).



Example: Close-open recording, parameter list.



Example: Close-open graph.

9.3 Line impedance (k-factor)

Line impedance app can be found under the Substation section.

1] Press 

The purpose of the line impedance measurement is to determine the line model's parameters. In line model using symmetrical components these parameters are defined by zero sequence impedances Z1 and Z0, and they are used for calculation of the k-Factors.

Seven different test set-ups have to be measured. At each set-up, test is done at two frequencies other than power frequency as measurement at line frequency is not possible due to high interference. The results will be shown at power frequency by interpolation of the measured points.

Note *For the complete instructions, see the User's manual for the "Line impedance kit". Art. No. ZP-AJ06E*

10 Data handling and reporting

10.1 General

- The data architecture in TRAX is based on tests performed with a specific app where each test can contain one or several measurements.
- Tests can be collected together in a test session containing several tests on e.g. a power transformer.
- Tests can be stored in files as separate tests or as a file containing a complete session with several tests.
- A test session can only contain measurements for one configuration and additional manual tests. If a session is started with configuration of e.g. a two-winding Delta-Wye transformer with 17 taps, the consecutive tests will automatically have the same configuration.
- A test session is started when TRAX is started and finished when TRAX is closed or when the user select "new" in the home view.
- Any test session can be saved in the report file during the session, after the session or when closing the session. This is defined as "active save" i.e. data is saved with an action e.g. with the "save" button from one app to another.
- If autosave mode is selected, TRAX will create a file when the first (new) app is opened and contain one first measurement, and ask for name and location. After this, every measurement and/or change in the apps will be automatically saved.
- In manual ("never"/"multimeter")mode, TRAX will not send save reminders but the user can still manually save results if needed.
- Besides saving results from measurements and tests, TRAX is automatically saving each individual measurement in logfiles for each app. This is to be considered as a back-up and not intended for general reporting

10.2 Test object configuration

No configuration – Manual test

Several TRAX apps are as factory default opened without any test object configuration. This is a manual test mode that allows direct measurement without entering any specific information. You specify (and can enter in the notes field) the connections and the app displays the test results in the table. Any number of measurements can be performed and if/when the test is saved, the file will not contain any test object information other than those entered directly in the report file.

Test configuration

In many situations it is advisable and sometimes mandatory to enter the test object configuration, e.g. when measuring transformer turn ratio and comparing with nameplate.

When "Use configuration" is selected, TRAX will ask for information: vector group, HV and LV voltage etc. This information will be used in the consecutive tests and stored in the report file.

10.3 Save and report

A measurement or a test session can be saved to the file/report during the session or after the session is finalized. The report files can be viewed anytime by .by pressing the report icon

Menu buttons in report and save views

	Home
	Back
	Apps
	Load test
	Save
	Save a copy to a selectable destination e.g. USB stick
	Return to previous report/file
	Print Printer function only works using TRAX Control on computer.
	Export as xml Result data can be exported as an XML file, which can be used by other programs.
	Export as text Result data can be exported as an text file, which can be used by other programs
	Activates/deactivates the edit function in the Test report table
	Deleting file. Can only be used if the file folder is unlocked
	Create new folder
	Safe eject USB for USB sticks connected to TRAX
	Toggle to show PC or TRAX folders and files
	Refresh folder content
	Lock/unlock folder for deleting files

Action buttons

The report may contain several tests on multiple pages. The action buttons, described below, are activated with the button upper right in the "Test report" window.

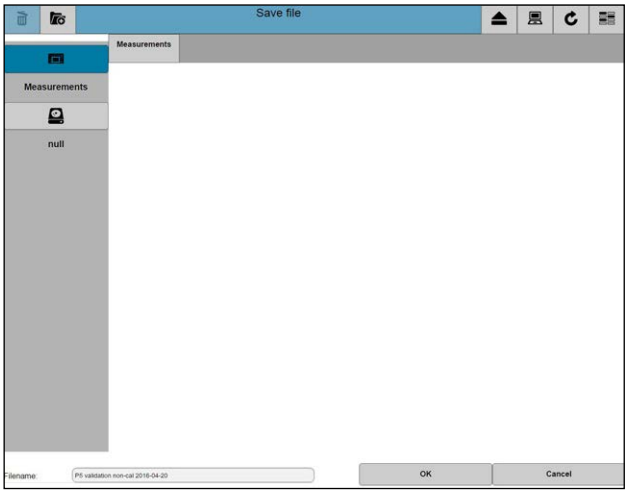
	Moves the test back to the actual app for e.g. remaking or adding measurements.
	Creates a new test within the same test session.
	Deleting a test from the session/report.
	Copy the result table in CSV/text format to a selected destination e.g. a USB stick.

Save a test in a report file

1] Press to save.

If autosave is selected, TRAX automatically ask for saving when the first app in the test session is opened.

You can save on PC, TRAX or USB stick.
To toggle location for saving (TRAX / PC), press



2] Change/edit file name and press "OK"

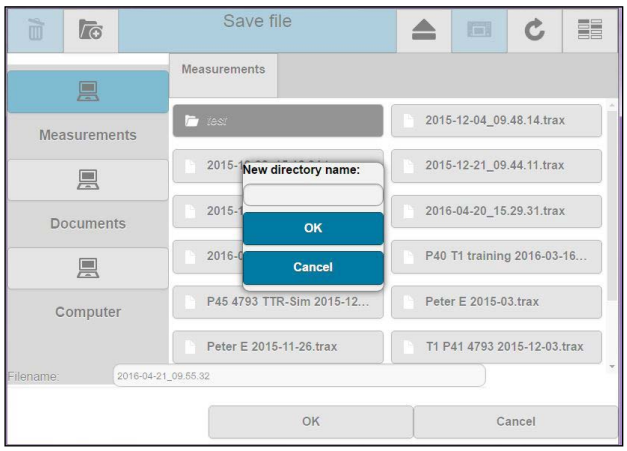
3] Press the report button

4] Press to save.

5] To save a copy in a new folder press

6] Select location for the copy.

7] Press to make a new folder.



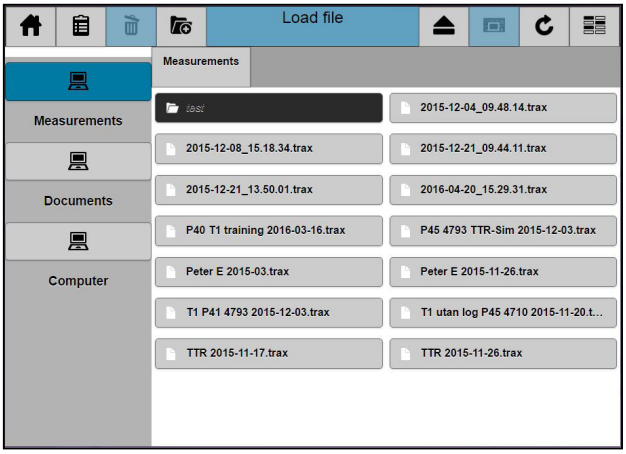
8] Enter new directory name and press OK.

9] Press “Filename” to enter the name.

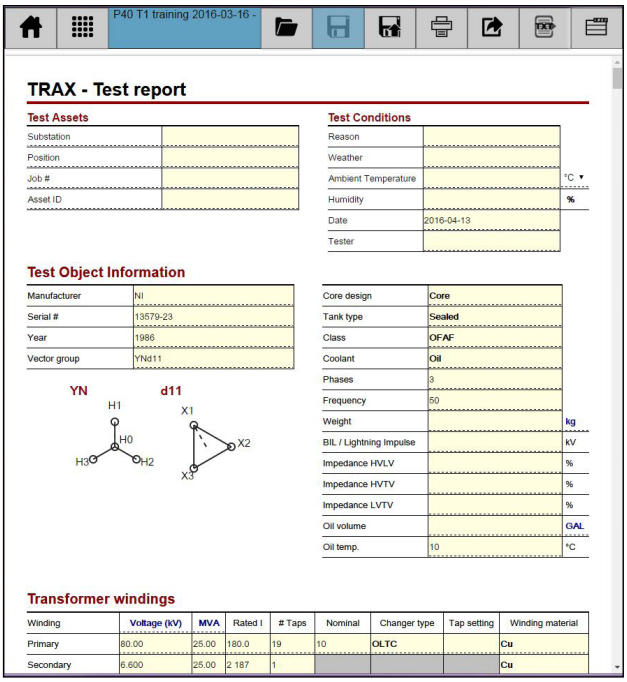
10] Press “OK” button to save the file.

10.4 Load file

1] Press 
The “Load file” window will be shown.

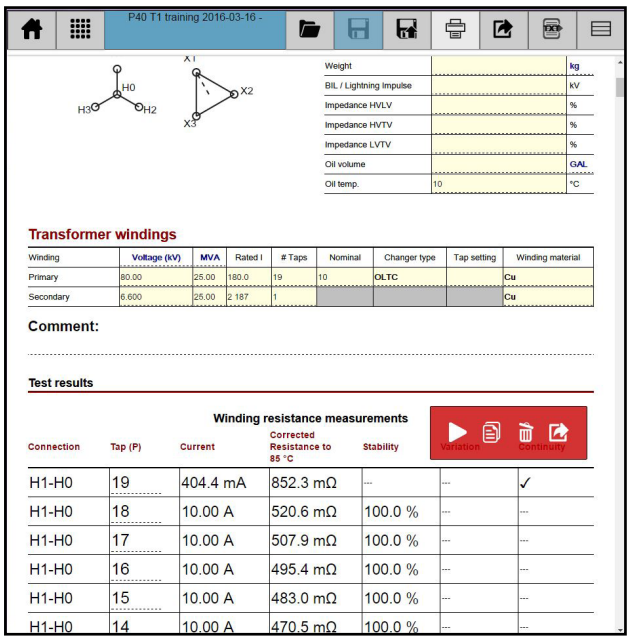


2] Select test report to open.



3] To select another report, press  to select report/file.

4] Press  to enable the action buttons, see “Action buttons” on page 75.



5] Scroll down to find desired measurements.

By using the action buttons you can:

- Move the test back to the actual app for e.g. remaking or adding tests.
- Start a new test within the same test session.
- Delete a test from the session/report.
- Copy the table in CSV/text file (tab separator and decimal point) format to a selected destination e.g. a USB stick.

Note *Deleting data in the file is not done until question "Save changes?" is answered. If deleting by mistake; Close/leave report view, answer "No" on question to save changes. The original report without any changes is stored. Reload the report.*

Delete files

In the "Load file" window you can also select files to delete.

1] Press  to enable deleting.

2] Select on ore more files to delete.

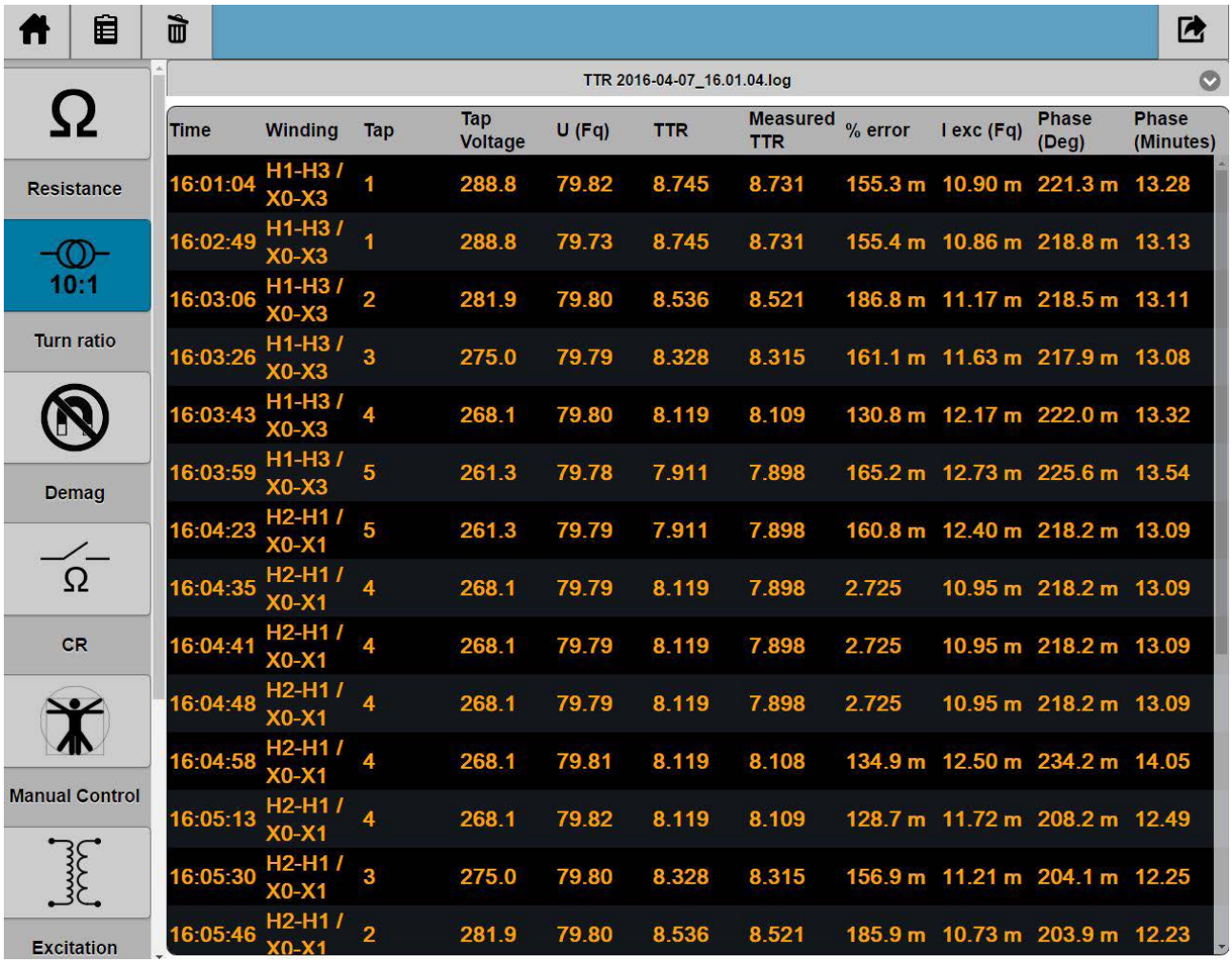
3] Press 

10.5 Load template

1] Press  to load an existing report as template for a new test session, e.g. when a similar transformer shall be measured. The TRAX file/report will be opened as-is with transformer data and test tables but without any measurements.

10.6 TRAX logfile

The logfiles are accessed via "Logging" in the home menu. The files are organized by apps.



Time	Winding	Tap	Tap Voltage	U (Fq)	TTR	Measured TTR	% error	I exc (Fq)	Phase (Deg)	Phase (Minutes)
16:01:04	H1-H3 / X0-X3	1	288.8	79.82	8.745	8.731	155.3 m	10.90 m	221.3 m	13.28
16:02:49	H1-H3 / X0-X3	1	288.8	79.73	8.745	8.731	155.4 m	10.86 m	218.8 m	13.13
16:03:06	H1-H3 / X0-X3	2	281.9	79.80	8.536	8.521	186.8 m	11.17 m	218.5 m	13.11
16:03:26	H1-H3 / X0-X3	3	275.0	79.79	8.328	8.315	161.1 m	11.63 m	217.9 m	13.08
16:03:43	H1-H3 / X0-X3	4	268.1	79.80	8.119	8.109	130.8 m	12.17 m	222.0 m	13.32
16:03:59	H1-H3 / X0-X3	5	261.3	79.78	7.911	7.898	165.2 m	12.73 m	225.6 m	13.54
16:04:23	H2-H1 / X0-X1	5	261.3	79.79	7.911	7.898	160.8 m	12.40 m	218.2 m	13.09
16:04:35	H2-H1 / X0-X1	4	268.1	79.79	8.119	7.898	2.725	10.95 m	218.2 m	13.09
16:04:41	H2-H1 / X0-X1	4	268.1	79.79	8.119	7.898	2.725	10.95 m	218.2 m	13.09
16:04:48	H2-H1 / X0-X1	4	268.1	79.79	8.119	7.898	2.725	10.95 m	218.2 m	13.09
16:04:58	H2-H1 / X0-X1	4	268.1	79.81	8.119	8.108	134.9 m	12.50 m	234.2 m	14.05
16:05:13	H2-H1 / X0-X1	4	268.1	79.82	8.119	8.109	128.7 m	11.72 m	208.2 m	12.49
16:05:30	H2-H1 / X0-X1	3	275.0	79.80	8.328	8.315	156.9 m	11.21 m	204.1 m	12.25
16:05:46	H2-H1 / X0-X1	2	281.9	79.80	8.536	8.521	185.9 m	10.73 m	203.9 m	12.23

Logfiles can be downloaded to USB or PC with the upper right button. Filename is *.log. Format is tab delimited text and the files can be directly imported as data from text in Excel. See example below.

Time	Winding	Tap	Tap Voltage	U (Fq)	TTR	Measured TTR	% error	I exc (Fq)	Phase (Deg)	Phase (Minutes)
16:01:04	H1-H3 / X0-X3	1	288,8	79,82298404	8,745039742	8,731460191	0,155282892	0,010902529	0,221320916	13,27925495
16:02:49	H1-H3 / X0-X3	1	288,8	79,73316426	8,745039742	8,731449598	0,155404028	0,010857631	0,218763181	13,12579086
16:03:06	H1-H3 / X0-X3	2	281,9125	79,79627549	8,536482051	8,520539455	0,186758382	0,011168756	0,218539378	13,11236269
16:03:26	H1-H3 / X0-X3	3	275,025	79,79326395	8,327924359	8,314507258	0,161109794	0,011634864	0,217935571	13,07613426
16:03:43	H1-H3 / X0-X3	4	268,1375	79,79542276	8,119366668	8,108744178	0,130829053	0,012166128	0,221951353	13,31708117
16:03:59	H1-H3 / X0-X3	5	261,25	79,77780771	7,910808977	7,897740809	0,165193822	0,012727199	0,225619454	13,53716726
16:04:23	H2-H1 / X0-X1	5	261,25	79,78636983	7,910808977	7,89808453	0,160848871	0,012395819	0,218229426	13,09376555
16:04:35	H2-H1 / X0-X1	4	268,1375	79,78636983	8,119366668	7,89808453	2,725362054	0,010952381	0,218229426	13,09376555
16:04:41	H2-H1 / X0-X1	4	268,1375	79,78636983	8,119366668	7,89808453	2,725362054	0,010952381	0,218229426	13,09376555
16:04:48	H2-H1 / X0-X1	4	268,1375	79,78636983	8,119366668	7,89808453	2,725362054	0,010952381	0,218229426	13,09376555
16:04:58	H2-H1 / X0-X1	4	268,1375	79,81087537	8,119366668	8,108414203	0,134893092	0,012499431	0,234196821	14,05180929
16:05:13	H2-H1 / X0-X1	4	268,1375	79,82208271	8,119366668	8,108918592	0,128680924	0,011717519	0,208185549	12,49113297
16:05:30	H2-H1 / X0-X1	3	275,025	79,79962282	8,327924359	8,314860947	0,156862758	0,011205049	0,204101436	12,24608618
16:05:46	H2-H1 / X0-X1	2	281,9125	79,80317883	8,536482051	8,520615935	0,185862464	0,010733944	0,203901405	12,2340843
16:06:03	H2-H1 / X0-X1	1	288,8	79,77118962	8,745039742	8,731616601	0,153494341	0,010298725	0,19919886	11,95193158
16:06:30	H3-H2 / X0-X2	1	288,8	79,81990417	8,745039742	8,723758047	0,243357324	0,007902342	0,154869073	9,292144371
16:06:38	H3-H2 / X0-X2	2	281,9125	79,81990417	8,536482051	8,723758047	2,193831082	0,007902342	0,154869073	9,292144371
16:07:01	H3-H2 / X0-X2	2	281,9125	79,83213248	8,536482051	8,513217914	0,272526038	0,008275373	0,161657851	9,699471065
16:07:18	H3-H2 / X0-X2	3	275,025	79,8004086	8,327924359	8,513275052	2,225652933	0,008245765	0,159178623	9,550717375
16:07:41	H3-H2 / X0-X2	3	275,025	79,7937044	8,327924359	8,307139828	0,249576371	0,008573294	0,157461986	9,447719172
16:08:06	H3-H2 / X0-X2	4	268,1375	79,81373307	8,119366668	8,101472628	0,220387141	0,008930984	0,159015948	9,540956886
16:08:31	H3-H2 / X0-X2	5	261,25	79,80348985	7,910808977	7,890445678	0,257411077	0,009323349	0,160623372	9,637402331

Note *The logfiles are intended for emergency/backup use and are normally not used for reporting.*

11 Remote control and communication ports

11.1 Communication ports

TRAX has the following data communication ports:

- Ethernet port for running the instrument from an external PC or connect it to an external network.
- WiFi (optional) for running the instrument from an external PC or other device.
- Three USB ports for multi-purpose use: Transfer data and reports to PC, use an external mouse or keyboard, upgrading the unit from a USB memory stick etc.

11.2 Remote control

TRAX220 and 280 can be used stand-alone or remote control via an external device with identical functionality.

TRAX219 is only used with remote control.

Note *For remote control, "TRAX Control" must be installed on the remote device.*

The external device must have a Windows operating system version 7 or higher and must have latest version Chrome web browser installed.

If you try to connect the TRAX from "TRAX Control" and every time a message pops up: "TRAX Control has been updated and will now restart". The problem can be fixed by restarting the PC.

Connecting a device to TRAX

When connecting the device the first time, "TRAX Control" SW must be installed on the device. Find the SW on the USB stick delivered with the unit and run/install on your device.

Connecting to TRAX:

1] Connect the Ethernet cable to TRAX or to a network where TRAX is connected.

2] Wait until your device has discovered an unknown unit (normally by displaying a "?" in your network symbol)

3] Start "TRAX Control".

4] After a while, the screen will display all TRAX units found on the network.

5] Select the unit you want to connect to.

6] A dialog is started where you are asked to confirm remote control by pressing and holding the control knob on TRAX to allow remote control.

Note *If TRAX has a different SW version than the remote device, TRAX will automatically change the external SW version to its own version*

7] Stop remote control by closing the program and unlocking TRAX for stand-alone use.

Note *The pairing procedure has to be repeated every time you make an attempt to connect. This is a safety feature especially in situations where one or more TRAX units are connected to a network and possible to operate from several computers.*

Off-line (simulation) mode

1] Start "TRAX Control".

2] Select "Work offline" to access the TRAX SW for demonstration/training purposes and for working with TRAX reports.

3] For some of the apps it is possible to "measure" and get simulated data.

Note *TRAX has no autostop functions in simulation mode.*

12 Update TRAX

12.1 Upgrading

TRAX SW can be upgraded via Internet or with a USB stick.

Upgrading via Internet

1] Connect TRAX to an open Internet port with unlimited access.

2] From the home page select “Settings” and “Update”.

3] TRAX will start searching for available updates and if/when an update is found, display “Update available”.

4] Download the update.

5] Start the updating process.

Important

Do NOT interrupt the updating process.

Upgrading via USB

1] Insert the USB stick to one of the USB ports.

2] Select “Updates” and “USB”.

3] Download the update.

4] Start the updating process.

Important

Do NOT interrupt the updating process.

Getting a TRAX (USB) upgrade via PC

1] Connect the PC to an open Internet port with unlimited access.

Important

The PC used to download the TRAX update must have been connected to the physical TRAX unit that is to be updated. This connection must be the last connected TRAX. The procedure is mandatory for identifying the correct update.

2] From the home page select “Settings” and “Update”.

3] The PC will start searching for available updates and if/when an update is found, display “Update available”.

4] Download the update and save on a USB

5] Bring the USB to the TRAX and continue as described in section “Upgrading via USB” on page 82.

Note *It is highly recommended to restart TRAX after upgrading.*

13 Specifications

SPECIFICATIONS TRAX

Specifications are valid at nominal input voltage and an ambient temperature of +23°C ±5°, (73°F). Specifications are subject to change without notice.

Evironment

Application field	For use in high-voltage substations and industrial environments
Temperature	
Operating	-20°C to +55°C (-4°F to +131°F)
Storage	-20°C to +70°C (-4°F to +158°F)
Humidity	< 90%RH, non-condensing

CE- marking

EMC	2004/108/EC
LVD	2006/95/EC

General

Mains input	100-240 V, 50/60 Hz (± 10%)
Input current	≤ 16 A continuous Short-term up to 30 A < 60 s
Main fuses	F1 and F2, 25 A
	TEST GROUND To be connected to the test object ground before connecting any other cables to the unit.
	GROUND For connecting an additional ground between the main unit and accessories or to ground external objects e.g. optional trolley
Dimensions	475 x 315 x 330 mm (excl. handles) (18.7" x 12.4" x 13")
Weight	
TRAX 219	25 kg (55 lbs)
TRAX 220	26 kg (57 lbs)
TRAX 279	29 kg (64 lbs)
TRAX 280	30 kg (66 lbs)
Display[1)]	
Size	10.4"
Resolution	1024x768 XGA
Type	TFT touch
Contrast ratio	1000:1
Brightness	1000 cd/m^2

1) TRAX 219 and 279 has no display

Outputs

Name	Specification	Comment
0-2200 V_{AC}	1 A, 1 min 0.2 A, >2 h 2500 VA (max) Frequency range: 5-70 Hz	The output is disconnected with a relay and the output is "live" only when this generator is selected
0-250 V_{AC} / 0-10 A_{AC}	10 A, 1 min 20 A, max 10 s 2.5 A, >2 h Frequency range: 5-505 Hz	
0-200 A_{AC}	200 A/6 V, 1 min 80 A, >2 h Frequency range: 45-70 Hz	TRAX 219/220
0-800 A_{AC}	0-800 A/6 V, 1 min 0-200 A/10 V, >2 h Frequency range: 45-70 Hz	TRAX 279/280
0-16 A_{DC}	16 A, continuous	
	1 A continuous	
0-300 V_{DC}	10 A,1 minute 2.5 A, >2 h	Rectified DC. Intended to be used as e.g. auxiliary DC supply
0-100 A_{DC}	100 A, 2 minutes 70 A, continuous	
DC output power	Max 1000 VA , continuous Max 50 V compliance voltage	
Binary output	250 V/35 A (max) 2 x 0-10000 s	Output contacts for OLTC and circuit breaker operation with internal voltage and current measurements
AUX		
CONTROL	54 V DC	Ethernet communication and power to accessories.
POWER	0-235 V AC	Directly from power amplifier for powering accessories (TDX/TCX)
With TRAX TDX	12 kV AC 0-12 kV/500 mA, 1 min 0-12 kV/300 mA, 4 min 0-12 kV/100 mA, continuous	See TDX datasheet
With TRAX TCX	2000 A AC 0-2000 A/2.4 V, 1 min 0-1000 A/4.8 V, 1 min	

Inputs

Name	Specification	Comment
ANALOG 1 2 3 4		
Current	4 x 0-10 A AC/DC	
Voltage	4 x 250/350 V AC/DC	
R1 R2	2 x 0-50 V DC	Intended for resistance measurements but can be used for AC voltage measurement up to 40 V_{RMS}
TRANS		Input for analog transducers and low level analog signals
TRIG IN		Contact or voltage sense
TIMING	3 x 0-10000 s	Binary inputs for timing measurements in timer and relay testing applications. A and B inputs dedicated for Start and Stop.

Calculated / displayed parameters

Arithmetic +, -, *, /

Power P, VA, Q, S

Impedance R (DC), Z, Xp, Xs, Rs, Rp, Ls, Lp, Cs, Cp, phase

Derating at lower mains voltage
TRAX specification is valid at 230-240 V mains voltage. Output power is decreased at lower mains voltages.

Derating at high ambient temperature
TRAX specification is valid at 23 ±5°C. Max output current times will be reduced when using TRAX in high ambient temperature.

Derating at lower frequencies
TRAX voltage output specification is at 50 Hz. Maximum voltage output at lower frequencies is limited by the transformer. Derating is linear with frequency and max voltage output at 5 Hz is 10% of rated output.

Measurement accuracy

External AC/DC voltage and current	0.05% of reading + 0.05% FS ($I \leq 5$ A DC/RMS) 0.2% of reading + 0.2% FS ($5 < I \leq 10$ A DC/RMS)
Internal DC current	0.1% of reading + 0.1% FS
Internal AC current	0.2% of reading + 0.2% FS
Internal AC voltage	0.2% of reading + 0.2% FS
Phase (0-360°)	0.1°

Measurement accuracy derived parameters (typical)

	Range	Accuracy	Resolution
WRM	1 A generator: 10 mΩ – 10 kΩ 16 A generator: 0.63 mΩ – 33.3 Ω 100 A generator: 0.1 mΩ – 2.5 Ω	0.15 % RD + 0.15 % FS	Up to 4 digits
TTR	2500:1 – 1:25 000	0.07 %	Up to 4 digits

COM

Ethernet port	For running the instrument from an external PC or connect it to an external network.
Connector for Wifi antenna	For running the instrument wireless from a PC or tablet. (Option)
USB	3 USB ports for multipurpose use

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