



INSTRUCTION MANUAL

ENGLISH



mini-ATOS

mini Automatic Transformer
Observation System

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Preliminary

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1 Safety Precautions

The following safety precautions must be observed during all phases of operation, service and repair of this instrument. By purchasing this equipment, the purchaser assumes all liability for the operation and use of this equipment. The intended use of the instrument, its design and manufacture, is to be conducted within the precautions or other specific warnings located within this manual. Failure to comply with these precautions and other specific warnings violates the safety standards of design, manufacture, and intended use. Raytech assumes no liability for the operation and use of this equipment.

1.1 Operators Qualifications

Only qualified, knowledgeable persons should be permitted to or attempt to operate this test equipment. All testing personnel should fully familiarize themselves with the correct application and operation of this and all test equipment before operation.

The measurements should never be performed by only one operator without the presence of other personnel or supervisors. Someone else other than the main operator must be aware and easily accessible to help in case of an emergency.

1.2 High Voltage Apparatus Accessibility During the Tests

Persons directly and indirectly engaged in the operation of this test equipment should keep clear of all high-voltage apparatus while conducting tests and measurements. A barrier band must always be used so the test object under the test is not accessible to any person during the test.



WARNING!

Never connect the instrument to an energized transformer!

1.3 Ground the Instrument

The power cord supplied with the equipment must be connected to an electrical receptacle with an electrically grounded terminal (earthed ground). To minimize shock hazards, the ground terminal on the instrument must be properly connected to the earth point. In many cases, the quality of the safety ground terminal provided by the power cord does not fulfil the safety requirements.

**WARNING!**

Non-grounded instruments are dangerous and may cause damage to personnel and to the instrument.

1.4 Before Applying Power

Read this manual carefully before operating the system. The instrument is line-operated. The system is designed to be used with either 110VAC or 230VAC 50/60 Hz. The system performs a self-check each time it is powered on.

1.5 Keep Away from Live Circuits

Operating personnel must not remove instrument covers. Component replacement and internal repairs must be made by qualified service personnel. Do not replace components or service this instrument with the power cable connected. To avoid injuries, always discharge circuits, disconnect power and remove external voltage sources before touching components.

1.6 Do Not Operate in An Explosive Atmosphere

Do not operate the instrument in the presence of flammable gases or fumes.

1.7 Do Not Substitute Parts or Modify Instrument

Because of the danger of introducing additional hazards, do not install substitute parts or perform any unauthorized modification to the instrument. Return the instrument to a Raytech service department for service to ensure proper operation and that safety features are maintained.

Instruments, which appear damaged or defective, should be made inoperative and secured against unintended operation until they can be repaired by qualified service personnel.

1.8 Do Not Operate in A Condensing Humidity or Under Rain

Operating the instrument in condensing humidity or under the rain can introduce an electric shock hazard for the user and also can damage the instrument. This instrument is not supposed to be installed permanently outdoors.

1.9 Always Keep Distance from the Test Object During the Tests

During performing the tests, there may be a hazardous voltage at the terminals of the test object. Always keep a distance of a minimum of 1.5m from the test object. The unsafe area must be specified and restricted with barrier tapes or ropes like Figure 1. Enter the area only when not testing and when the instrument shows that there is no output voltage which is specified when the green light indicator on the front panel is on.

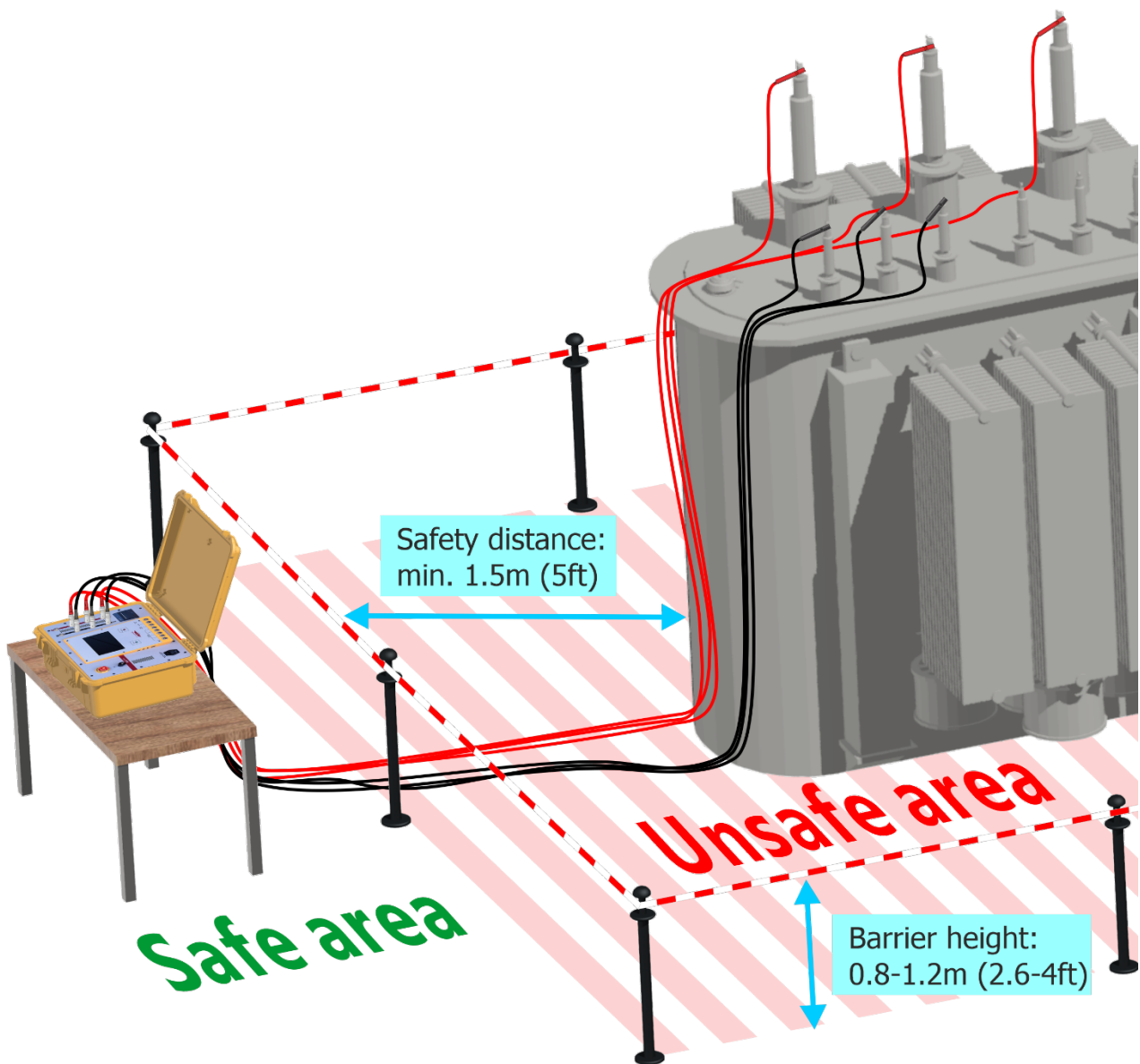


Figure 1: The unsafe area must be specified and restricted with barrier tapes or ropes



WARNING!

Always keep distance from the test object during the tests and the unsafe area must be specified and restricted with barrier tapes or ropes

2 Unpacking



The Instrument



Cable Bags



Measuring Cables H (H0-H3)



Measuring Cables X (X0-X3)



Safety Ground Cable



Power Cord



Spare Paper rolls & Fuses



USB Memory Stick



Instruction Manual (Pre.)

3 Introduction

The Raytech precision mini–Automatic Transformer Observation System (mini-ATOS) is a professional multifunctional power transformer and substation diagnosing test instrument developed by Raytech engineers. It is designed for a high degree of accuracy and ease of use.

This compact and intelligent instrument can perform many routines and advanced tests such as Winding Resistance (WR), Dynamic Resistance Measurement (DRM), Turns Ratio (TR), Frequency Response of Stray Losses (FRSL), Magnetic Balance, and other diagnostic parameters. With the built-in fully automatic multiplexer, only a one-time connection is required for nearly all functions which saves a considerable amount of time. The portable, rugged case is perfect for use anywhere on site or in a laboratory. It is specially designed for fast and easy measurements with the well-known high precision and quality of all Raytech instruments.



INFO:

The mini-ATOS field case is a waterproof design (IP67). A pressure regulator activates when the case is opened to compensate for atmospheric pressure changes.

4 Calculation and Measurement Methods

4.1 Turns Ratio Measurement

4.1.1 Principle

The transformer turns ratio test is used for measuring the ratio of turns of wires of the two sets of windings e.g., the primary side and the secondary side of a transformer. The turns ratio test does not tell exactly how many turns of wire are in each coil, but rather, it measures and displays the ratio of the number of turns of two coils.

This is a useful test to check for shorted turns and also to find probable incorrect settings of tap changers during manufacturing or repair.

The mini-ATOS performs the turns ratio by applying voltage on the high voltage side of each phase and measuring the applied voltage and transformed voltage. Figure 2 represents the very simple schematic of the measuring circuit.

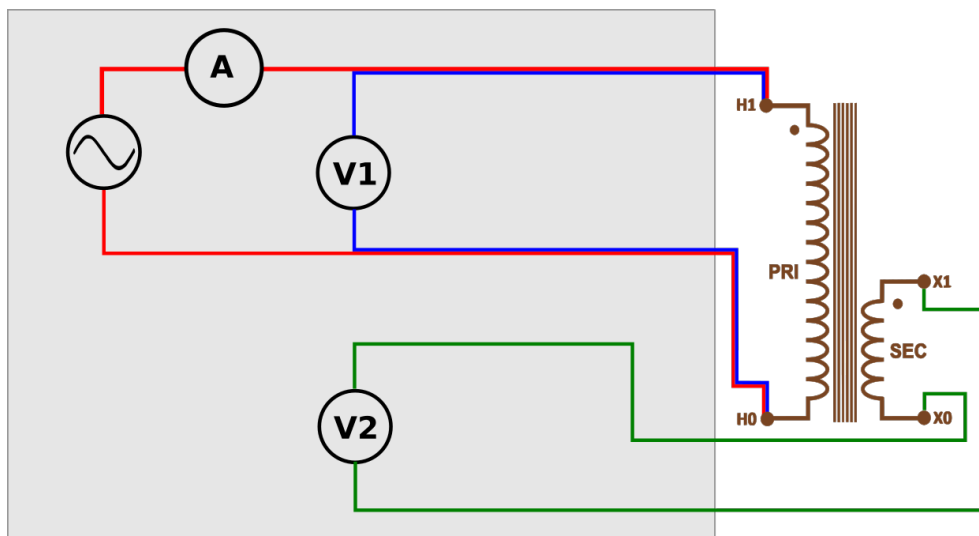


Figure 2: Very simple schematic of mini-ATOS turns ratio measuring circuit

The excitation current is also measured during the turns ratio test. The value of the excitation current has a direct relation to the test voltages. A higher test voltage leads to a higher excitation current. Additionally, the phase angle between the applied voltage and the transformed voltage is also measured and is included in the results.

4.1.2 Voltage Ratio and Turns Ratio

It is important to understand the differences between transformer voltage ratio and transformer turns ratio. The voltage ratio is the ratio of rated voltages of two windings but the turns ratio is exactly the ratio of the number of turns of two sets of windings. For a single-phase Transformer, the Turns Ratio is the same as the Voltage Ratio, however for a three-phase transformer they may be different.

As an example, consider a single-phase transformer schematic with a primary side and a secondary side. The primary side nominal voltage which is written on the nameplate is 6900V and from the manufacturing data, we know it consists of 15000 turns. And secondary side nominal

voltage written on the nameplate is 230V which consists of 500 turns from manufacturing data. The following equations are valid:

$$\text{Voltage Ratio} = \frac{\text{Rated Voltage Primary}}{\text{Rated Voltage Secondary}} = \frac{6900}{230} = 30$$

$$\text{Turns Ratio} = \frac{\text{Primary Number of Turns}}{\text{Secondary Number of turns}} = \frac{15000}{500} = 30$$

$$\text{Voltage Ratio} = \text{Turns Ratio} = 30$$

With three-phase transformers of different configurations, turns ratio and voltage ratio can be different.

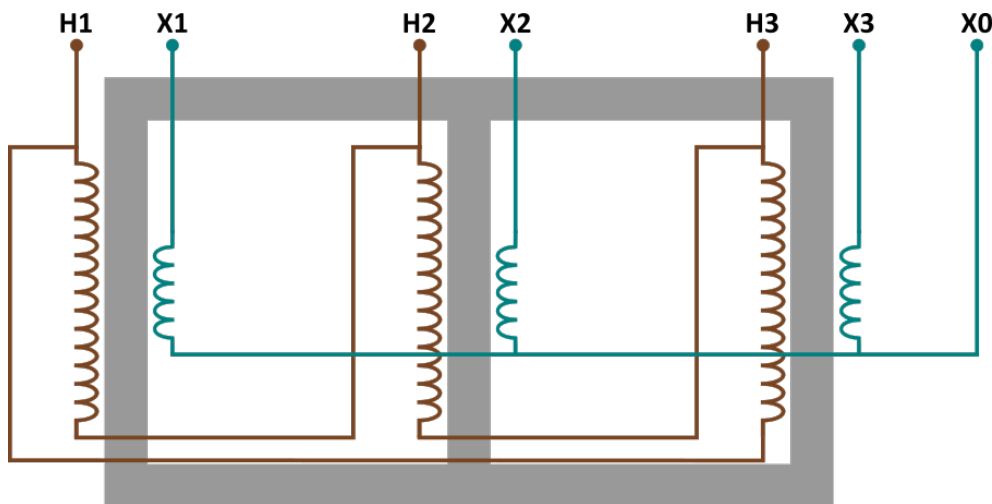


Figure 3: Three-phase transformer schematic with Dyn11 vector group

For example, Figure 3 shows a three-phase transformer schematic with a delta connection on the primary and a star connection on the secondary side. 120000V and 20000V are written as primary and secondary rated voltages respectively on the nameplate. The rated values are always line-line voltages and the voltage ratio can simply be calculated as follow:

$$\text{Voltage Ratio} = \frac{\text{Rated Voltage Primary}}{\text{Rated Voltage Secondary}} = \frac{120000}{20000} = 6$$

Here, turns ratio is different from the voltage ratio because the low voltage side connection is star and line-line rated voltage is different from the phase voltage. So, a factor of $\sqrt{3}$ is required as follow to calculated the nominal turns ratio:

$$\text{Turns Ratio} = \text{Voltage Ratio} \times \sqrt{3} = 6 \times \sqrt{3} = 10.3923$$

When we know the number of turns from the manufacturing data, the turns ratio can be calculated directly. Consider that for the current example the number of turns is 93531 and 9000 for each primary and secondary winding respectively. The following equations are valid:

$$\text{Turns Ratio} = \frac{\text{Primary Number of Turns}}{\text{Secondary Number of turns}} = \frac{93531}{9000} = 10.3923$$

$$\text{Voltage Ratio} = \frac{\text{Turns Ratio}}{\sqrt{3}} = \frac{10.3923}{\sqrt{3}} = 6$$

4.1.3 Relative Error

Turns ratio error can be calculated by comparison of the measured value and the reference rated value using the following formula:

$$\text{Err. [\%]} = \frac{|TR_{meas.} - TR_{rated}|}{TR_{rated}} \times 100\%$$

The calculated error can be compared with a limit value. Generally, there are limit values for the turns ratio relative error. A typical limit value according to IEEE C57.12.00-2010 is 0.5%. This limit value can be used to judge if the test is passed or failed.

4.2 DC Resistance Test

4.2.1 Principle

The winding DC resistance test is one of the most important tests. Many power transformer faults such as shorted turns, tap changer problems and loose connections can be detected.

Figure 4 represents the summarized winding resistance measurement circuit of the mini-ATOS. It utilizes the 4-wire measuring technique for each measurement. 2 wires to inject current and 2 wires to measure voltage. The test measuring cables and clamps are Kelvin type which means that the user does not have to hook up separately additional cables to the transformer for measuring.

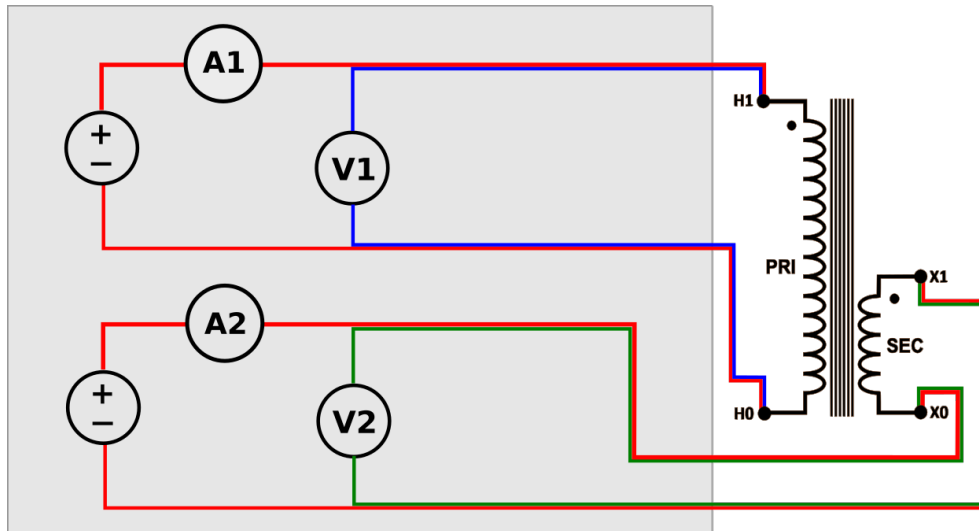


Figure 4: Summarized schematic of mini-ATOS winding resistance measuring circuit

The mini-ATOS has two power supplies with the same output power which can be used to measure both high and low voltage side winding simultaneously.

The maximum output voltage and current of each power supply are different to provide optimal output for each side. One power supply has more output voltage which is suitable for the high voltage side with a bigger resistance and the other one has more output current which is suitable for the low voltage side with a smaller resistance.

During the measurement, because of the high inductivity, the core and winding must be charged and only after charging, stable and accurate measuring is possible. The following equation represents the relation between the current injected into the winding, $I(t)$, and the voltage drop value, $U(t)$, across the winding. R is the winding resistance value that is aimed to be measured and L is the equivalent value of the inductivity.

$$U(t) = R \times I(t) + L \times \frac{dI(t)}{dt}$$

The voltage drop value consists of two parts; the first part is the voltage drop because of the resistance, and the second part is the voltage drop because of the inductivity. After charging, the second part tends to zero and then the Resistance value can be calculated:

$$\frac{dI(t)}{dt} \rightarrow 0 \Rightarrow U(t) = R \times I(t) \Rightarrow R = \frac{U}{I}$$

The mini-ATOS winding resistance circuit is also equipped with heavy-duty discharge circuits that are very unique in design to dissipate the stored energy in the transformer windings.

4.2.2 Temperature Correction

The measured resistance values can be corrected to desired reference values by employing the following equation based on IEEE C57.12.90:

$$R_s = R_m \frac{T_s + T_k}{T_m + T_k}$$

Where:

$R_s[\Omega]$ = Corrected resistance

$R_m[\Omega]$ = Measured resistance

$T_s[^\circ\text{C}]$ = Desired reference temperature

$T_m[^\circ\text{C}]$ = Actual temperature at the time of resistance measurement

$T_k[^\circ\text{C}]$ = Temperature constant of the material

Temperature constant values for copper and aluminum are:

Table 1: Cu and Alu temperature correction values

Material	$T_k[^\circ\text{C}]$
Copper	234.5
Aluminum	225
Alloyed aluminum	Can be up to 230

The other form of temperature correction formula is:

$$R_m = R_s(1 + \alpha(T_m - T_s))$$

Where:

α = Coefficient factor of resistivity at desired reference temperature

T_k and α have the following relationship:

$$T_k = \frac{1}{\alpha} - T_s = \frac{1}{\alpha(@20^\circ\text{C})} - 20$$

For example, by considering that the value of α for copper is 0.00393 at 20°C, T_k is:

$$T_k = \frac{1}{0.00393(@20^\circ\text{C})} - 20 \cong 234.5$$

4.2.3 Resistance Deviation

For a 3-phase test object, the DC resistance values of each phase are supposed to be almost the same. Hence, it is possible to measure a deviation value from the average value for each phase as follows:

$$R_{avg}[\Omega] = \frac{R_A + R_B + R_C}{3}$$
$$R_{dev,A}[\%] = \frac{R_A - R_{avg}}{R_{avg}} \times 100$$
$$R_{dev,B}[\%] = \frac{R_B - R_{avg}}{R_{avg}} \times 100$$
$$R_{dev,C}[\%] = \frac{R_C - R_{avg}}{R_{avg}} \times 100$$

The calculated deviations can be compared to a maximum deviation limit value to find out if the result is passed or failed. There is a limit in IEEE C57.12.152-2013, which is 2%. However other values are also possible with agreements.

Please note that if the temperature of phases is not the same during the resistance measurements, the deviation values may be higher. In this case, it is better to calculate the deviation values of the temperature-corrected resistances.

4.3 Demagnetization

After transformer shutdown or a measurement with a direct current, there is always residual magnetism or remanence in the transformer magnetic core. There are various reasons that this remanence should be removed. One reason is that energizing a transformer with remanence can cause a much higher inrush current and this may cause deformation of the winding. The other reason is that the remanence will affect the results of some tests such as SFRA, magnetic balance and excitation current, which may lead to a wrong diagnosis.

The mini-ATOS includes a very efficient, fast and modern demagnetization feature. During the demagnetization, all important parameters are measured, calculated and monitored continuously and each cycle of the demagnetizing is adjusted and performed according to the previous cycles.

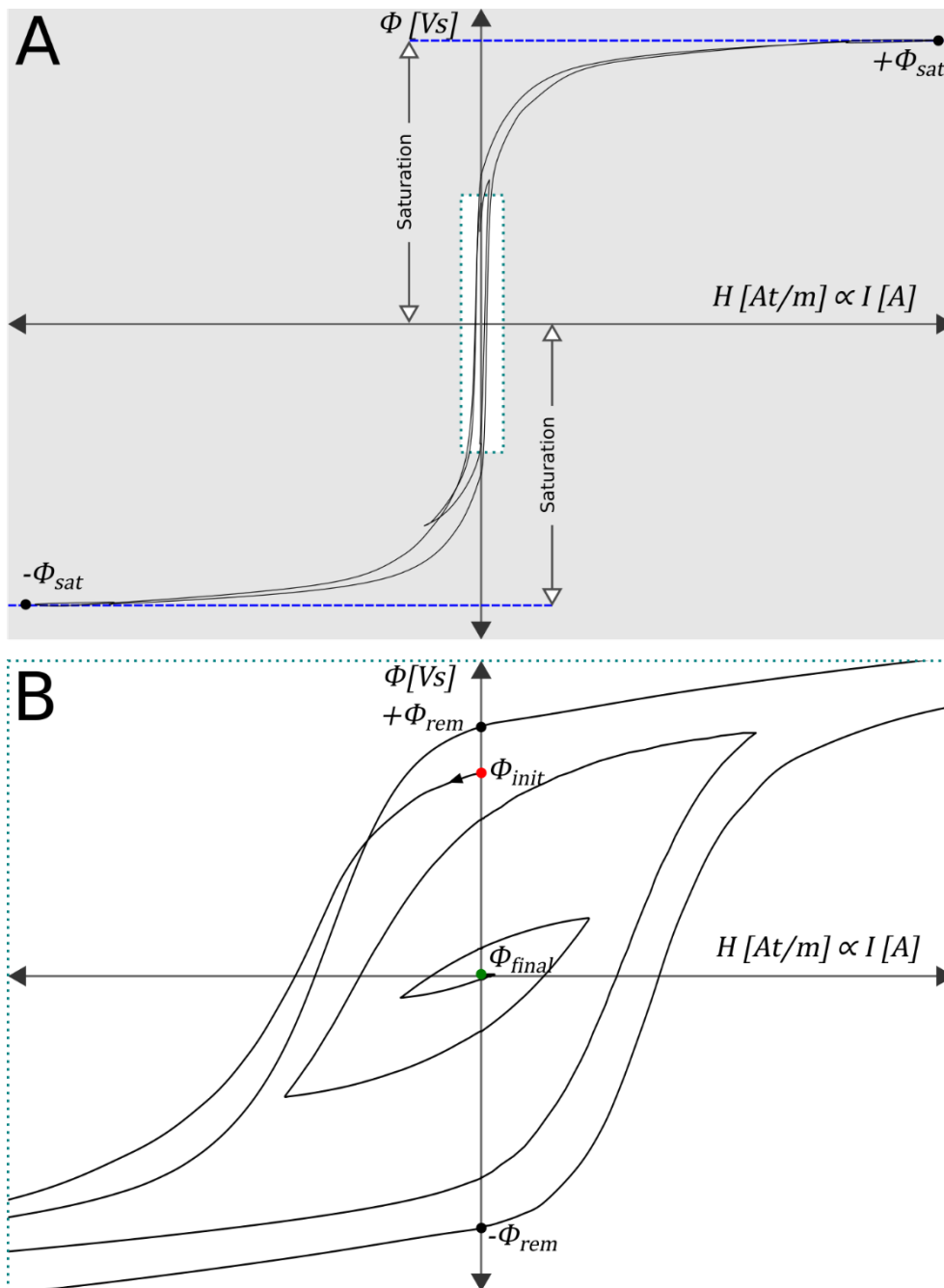


Figure 5: A) A real example of a demagnetization with mini-ATOS. B) Closer look at the same curve in A.

Figure 5-A shows an actual example of a hysteresis curve during demagnetization which is performed using the mini-ATOS. Figure 5-B is a closer look at the same curve. The depicted parameters are described below:

- $\Phi[V \cdot s]$: Magnetic flux with the unit of volt-seconds or weber. It will be measured as integral of the inductive part voltage over time. The value of the Vs is related directly to the magnetic flux density with the unit of tesla, by considering that the cross-section area of the transformer magnetic core is a constant value:

$$T = \frac{V \cdot s}{m^2} ; m^2 = \text{constant} \Rightarrow T \propto V \cdot s$$

- $H[At/m]$: Magnetic field strength with the unit of ampere-turn/meter. The number of turns and length of the magnetic path are usually unknown but since they are constant values, the magnetic field strength is in direct relation to the injected current to the winding which can be measured directly:

$$\frac{At}{m} ; t = \text{constant}, m = \text{constant} \Rightarrow \frac{At}{m} \propto A$$

- $\pm\Phi_{sat}$: Maximum positive or negative flux at saturation point
- Φ_{init} : The initial value of the residual magnetism flux or remanence flux before demagnetization
- Φ_{final} : The final value of the remanence flux after performing the demagnetization
- $\pm\Phi_{rem}$: Maximum positive or negative remanence flux remains in the magnetic core which is normally happened after saturation.

4.3.1 Raytech SPP Demagnetization Method

To achieve a very small residual magnetism, the mini-ATOS uses a special method to perform the final cycles of the demagnetization, called **SPP**, **Smart Pattern Predictor**, which is based on pattern recognition. This is very useful when special measurements like SFRA are desired to perform.

This method recognizes the properties and shape of the demagnetization of previous cycles to achieve a very small remanence, the shape and properties of the final cycles are predicted and then the final cycles will be performed in a way to achieve the best and the smallest possible residual magnetism state.

4.3.2 Three-Phase Transformer Demagnetization

For a core-type three-phase transformer with three limbs, the demagnetization is usually performed from the middle phase. Many times, it is enough to achieve a safe residual magnetism state to connect the transformer to the power grid without the risk of high inrush current. However, it is not always like this. Sometimes the demagnetization should be performed from all three phases. The following items can be a reason to consider a three-phase demagnetization:

- When the core consists of 4 limbs or 5 limbs
- When the transformer is a shell-type
- When the aim is to achieve a very small residual magnetism to perform special tests like SFRA

The mini-ATOS can use the advantage of the automatic multiplexer to perform demagnetization from each phase automatically and without changing the connection setup.

4.4 Magnetic Balance

Raytech mini-ATOS performs the magnetic balance test by applying AC voltage on each winding of the three-phase transformer from the high voltage side and measuring induced voltage into other windings on the same side. The applied voltage produces magnetic flux in the core which is distributed to other parts of the core and induces a voltage into other windings. Any problem or fault in the magnetic core may change the distribution of flux.

For a healthy core-type transformer with a demagnetized 3-limbs core, the magnetic balance test results should be in the form of Table 2:

Table 2: Typical magnetic balance pattern of a core-type transformer with 3 limbs

Phase	→ A	→ B	→ C
A	$V_{A \rightarrow A} = 100\%$	$V_{A \rightarrow B} \cong M\%$	$V_{A \rightarrow C} = N\%$
B	$V_{B \rightarrow A} \cong 50\%$	$V_{B \rightarrow B} = 100\%$	$V_{B \rightarrow C} \cong 50\%$
C	$V_{C \rightarrow A} \cong N\%$	$V_{C \rightarrow B} \cong M\%$	$V_{C \rightarrow C} = 100\%$

The sum of M and N should be almost 100% and it is supposed to M be greater than N :

$$M + N \cong 100, \quad M > N$$

The index TCI [%], Transformer Core Imbalance, introduced by Raytech for easy diagnosing of magnetic balance test results. It is calculated using the following formula:

$$\text{Core Imbalance [\%]} = 100 \times \left(\frac{|V_{A \rightarrow C} - V_{C \rightarrow A}|}{V_{A \rightarrow C} + V_{C \rightarrow A}} + \frac{|V_{B \rightarrow A} - V_{A \rightarrow B}|}{V_{B \rightarrow A} + V_{A \rightarrow B}} + \frac{|V_{C \rightarrow B} - V_{B \rightarrow C}|}{V_{C \rightarrow B} + V_{B \rightarrow C}} \right) \times \frac{1}{3}$$

Please note that when the core is not fully demagnetized, the TCI value may be high. For a correct magnetic balance test, it is highly recommended to always demagnetize the core beforehand. On the other hand, by performing the magnetic balance test, it is possible to find out if the transformer core is demagnetized or not.

miniATOS uses 10Hz as the test voltage frequency. The reason why is at low frequencies, the flux distribution is less affected from the stray capacitances and so it is better for magnetic circuit diagnosis.

4.5 Short Circuit Impedance

4.5.1 Principle

The short-circuit impedance/leakage reactance test is helpful in detecting mechanical deformations in the windings. It is performed by applying AC voltage to each phase on the primary side while shorting the circuit on the other side. The performed voltage, injected current, and phase difference will be measured. From the measured values, the short-circuit impedance, leakage reactance, and AC resistance will be calculated:

$$Z_m [\Omega] = \frac{U}{I} = (R_m + iX_m) [\Omega]$$

Where:

U = Applied test voltages for each phase

I = Test currents for each phase

Z_m = Measured short circuit impedance of each phase

R_m = The AC resistance part for each phase

X_m = The leakage reactance part for each phase

The equivalent three phases short circuit impedance, AC resistance and leakage reactance will be calculated as follows:

$$Z_{sc} [\Omega] = \frac{1}{3} (Z_{m_A} + Z_{m_B} + Z_{m_C})$$

$$Z_{sc} = (R_{sc} + iX_{sc}) [\Omega]$$

With the Nominal voltage and base power, it is also possible to calculate the values in percents:

$$Z_{base} = \frac{U_n^2}{S_{base}}$$

$$Z_{sc} [\%] = \frac{Z_{sc} [\Omega]}{Z_{base}} \times 100\%$$

$$R_{sc} [\%] = \frac{R_{sc} [\Omega]}{Z_{base}} \times 100\%$$

$$X_{sc} [\%] = \frac{X_{sc} [\Omega]}{Z_{base}} \times 100\%$$

4.5.2 Short Circuit Jumpers

The mini-ATOS automatically short-circuits the windings on the other side, but it is strongly recommended to manually short the 3 low voltage side phase terminals (without Neutral) using low resistance jumpers. The reason for this is that the resistance of the mini-ATOS test cable is much higher compared to the resistance of the windings, which can affect the measurement.

The cross-section area of the cable should be better than the low voltage winding cross-section area or at least 1 AWG¹ (42.4 mm²). You can use also a low-resistance metal bar like the copper bar instead of cable. It is however very important to connect it very good to the clean terminals to avoid high resistance connection.

The length of the cable should be also as short as possible. Special jumper cables designed for this purpose can be ordered as optional accessories from Raytech.

4.5.3 Temperature Correction

The winding temperature has effect on the ac resistance value and so it can be corrected to a reference temperature. The method is exactly like the DC resistance temperature correction. For more information, please refer to chapter 4.2.2.

The winding temperature does not affect the leakage reactance, however, it affects the short circuit impedance, because the AC resistance is the real part of the short circuit impedance.

4.5.4 Short circuit impedance deviation

For a 3-phase test object, the short circuit impedance values of each phase are supposed to be almost the same. Hence, it is possible to measure a deviation value from the average value for each phase as follows:

$$Z_{avg}[\Omega] = \frac{Z_{m_A} + Z_{m_B} + Z_{m_C}}{3}$$

$$Z_{dev,A}[\%] = \frac{Z_{m_A} - Z_{avg}}{Z_{avg}} \times 100\%$$

$$Z_{dev,B}[\%] = \frac{Z_{m_B} - Z_{avg}}{Z_{avg}} \times 100\%$$

$$Z_{dev,C}[\%] = \frac{Z_{m_C} - Z_{avg}}{Z_{avg}} \times 100\%$$

The calculated deviations can be compared to a maximum deviation limit value to find out if the result is passed or failed.

Please note that if the temperature of phases is not the same during the short circuit impedance measurements, the deviation values may be higher. In this case, it is better to calculate the deviation values of the temperature-corrected values.

¹ This size is coming from the IEEE C57.152-2013 standard (Chapter 7.2.12.2, page 41).

4.6 Dynamic Resistance Measurement (DRM)

The Onload Tap Changer plays a critical role in numerous power transformers, as it is responsible for regulating the output voltage by selecting different winding taps while the transformer is operating under load. Due to the presence of moving components, tap changer failures often contribute to the malfunction of power transformers.

To address this issue, the mini-ATOS offers a comprehensive solution by effectively testing the dynamic resistance of the tap changer with a remarkable level of accuracy. With a fast sampling rate of 10ksps, the mini-ATOS ensures precise measurements. Additionally, as a valuable diagnostic tool for OLTC, it allows for the measurement of the tap changer's motor drive current (Please see 4.7) when used in conjunction with an optional current clamp.

In order to analyse the switching process of the onload tap changer, the mini-ATOS injects a desired DC current and record it during each transition. The mini-ATOS can perform DRM on resistive-type OLTCs. Transition resistors are used in an onload tap changer to limit the circulating current in transformer winding during tap transitions. Because of these transition resistors, there is a current drop during the switching process which can be investigated by DRM test.

A typical DRM curve of a resistive type OLTC can be seen in Figure 6. The mini-ATOS calculates the parameters listed in Table 3 for each DRM curve.

Table 3: DRM parameters for each transition

Parameter	Unit	Description
Tdrm	[ms]	Time when transition resistors are carrying current
Idrop	[%]	Maximum current drop during transition
Slope	[A/s] or [%/ms]	The rate of the current drop in A/sec or %/ms at the moment of breaking the first tap

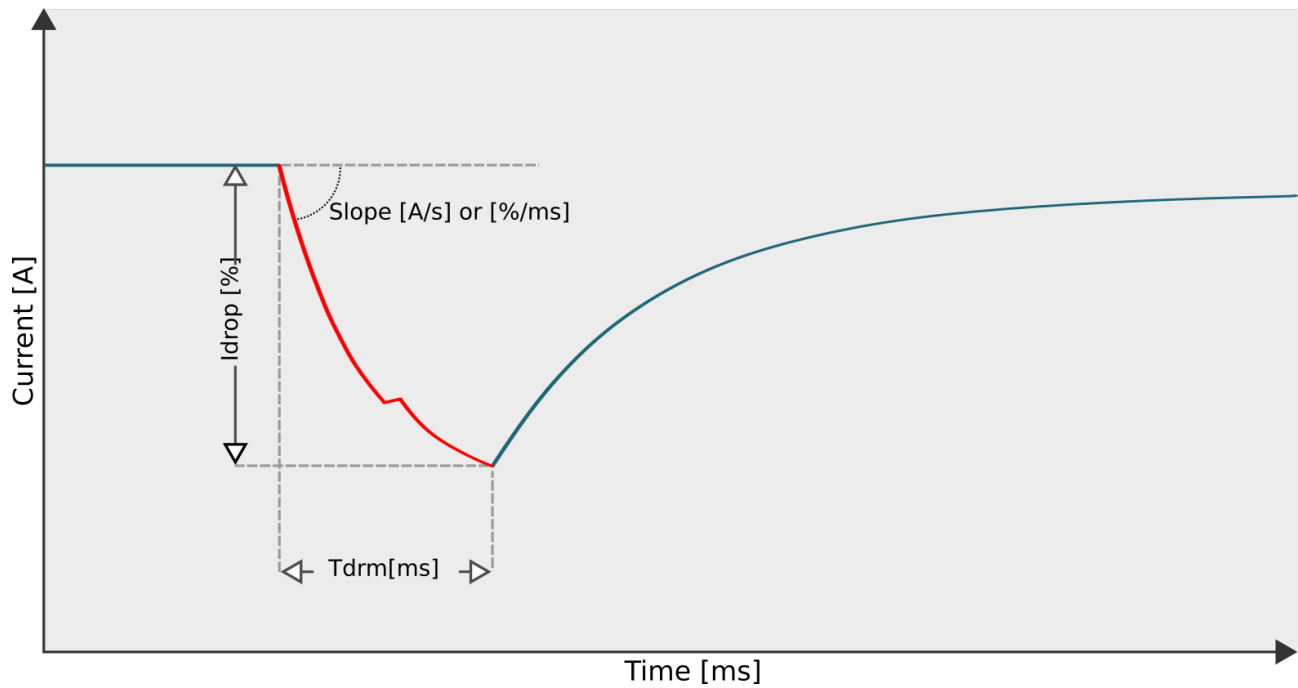


Figure 6: Typical DRM curve of a resistive type OLTC

During the dynamic resistance measurement, it is possible to short circuit the other transformer sides. In this way, the current drop is much bigger.

4.7 OLTC Motor Drive Current

Many mechanical and control problems of OLTC can be detected by the drive motor current. The mini-ATOS can measure this current by utilizing a current clamp. This test can be performed simultaneously with DRM. The measured current then would be shown as a graph like Figure 7 for comparison and the parameters according to Table 4 will be calculated.

Table 4: OLTC drive motor current parameters

Parameter	Unit	Description
Inrush	[A]	Initial inrush current peak for each tap transition
Tmotor	[s]	Duration of each tap transition
MCI	[Acyc] or [Asec]	Motor Current Index (IEEE C57.143-2012): The area under the motor current curve during whole tap transition

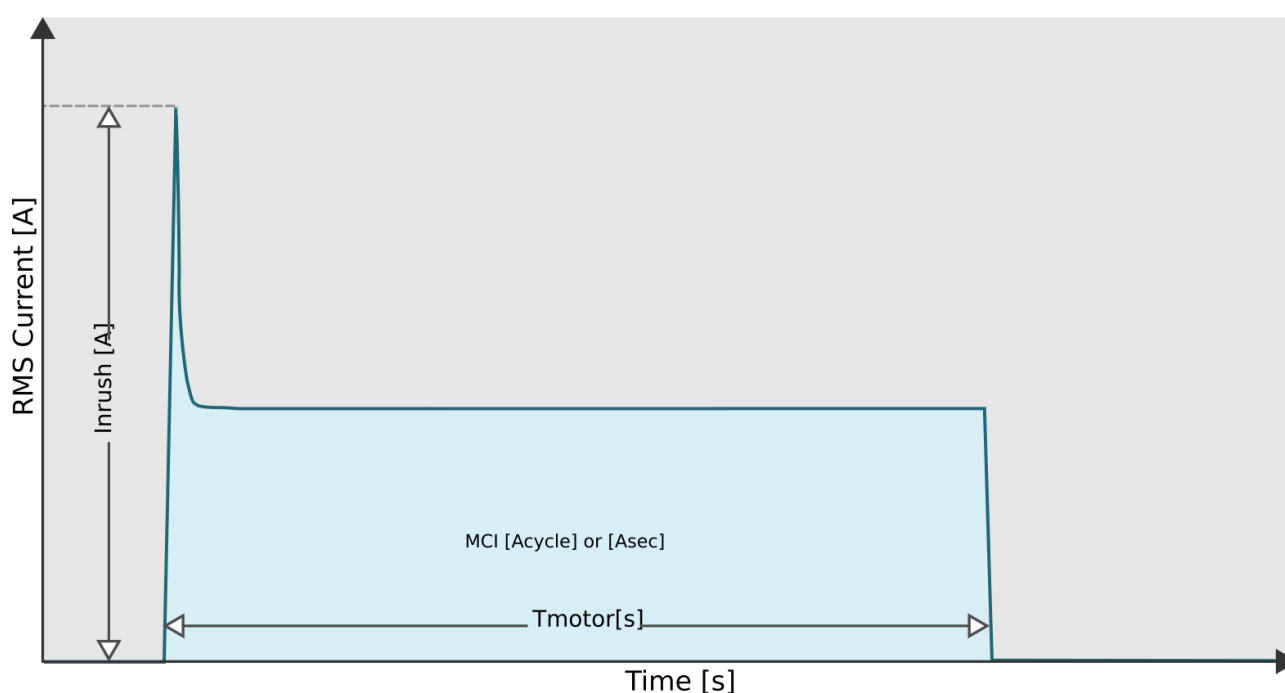


Figure 7: Typical motor current curve of a OLTC motor

4.8 Frequency Response of Stray Losses (FRSL)

4.8.1 Principle

With the FRSL test, it is possible to find windings mechanical problems like the shorted turns between the parallel strands of a winding. FRSL is somehow the advanced version of short circuit impedance. mini-ATOS performs FRSL by measuring the short circuit impedance, in various frequencies up to 400Hz:

$$Z_m(f)[\Omega] = \frac{U(f)}{I(f)} = R_m(f) + i2\pi f L_m(f)$$

Where:

$U(f)$ = Applied test voltages for each phase at various frequencies

$I(f)$ = Test currents for each phase at various frequencies

$Z_m(f)$ = Short circuit impedance for each phase at various frequencies

$R_m(f)$ = The resistance part for each phase at various frequencies

$L_m(f)$ = The inductance for each phase at various frequencies

The resistive part of the measured impedances at various frequencies ($R_m(f)$) are then plotted to form the FRSL graph (Figure 8). Additionally, the inductance values at various frequencies $L_m(f)$ are also plotted (Figure 9).

As can be seen from the typical FRSL graph (Figure 8), the measured resistance will increase in higher frequencies. The reason for this is that the skin effect is more at higher frequencies. Skin effect means that when AC current flows through a conductor, most of the current tends to the surface which then decrease the effective cross-section and increase the resistance.

The measured graphs can be compared with reference graphs. It is supposed then to look not different from the reference otherwise it may be signs of short circuits between parallel strands or other problems.

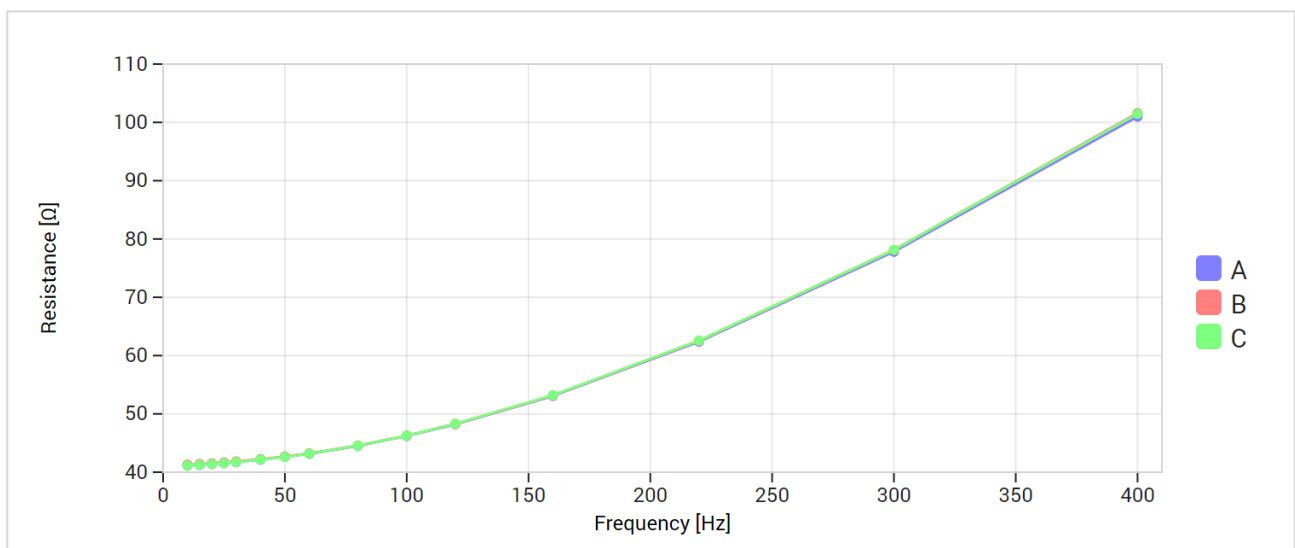


Figure 8: Typical FRSL curve

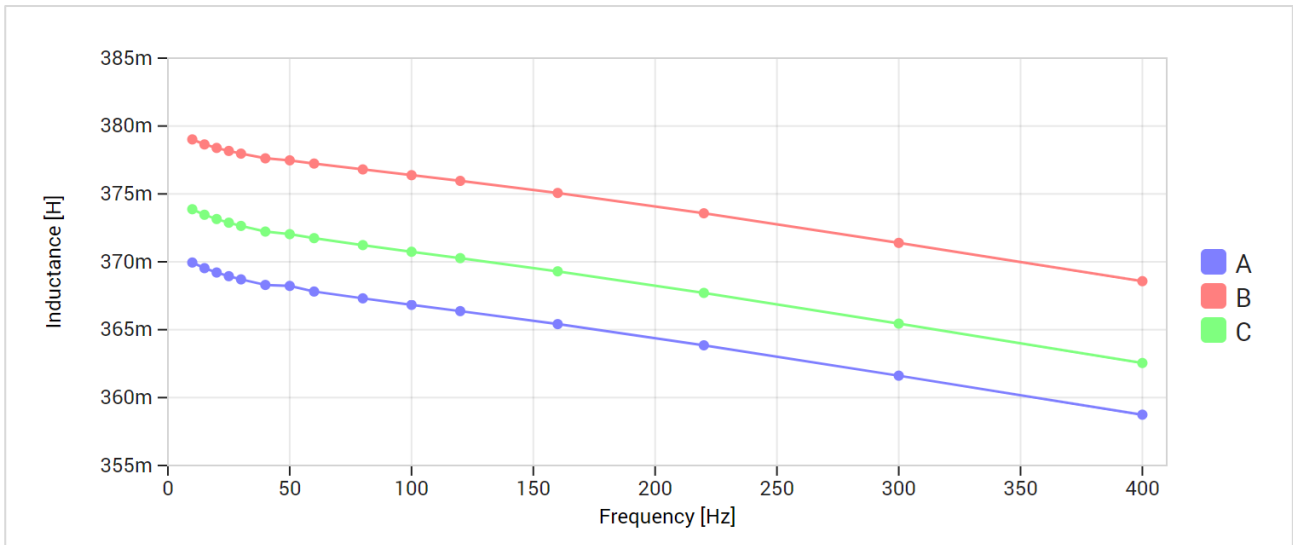


Figure 9: Typical FRSL inductance curve

When because of a failure 2 or more parallel strands shorted together, the equivalent surface length will be decreased and so the effective resistance will be increased. This change of resistance is easier to detect when measuring with higher frequencies. When diagnosing, one can compare the new measured FRSL graph with a reference graph. If the resistance of the new measurements is higher at high frequencies, this may be a sign of failure and shorted strands.

4.8.2 Short Circuit Jumpers

Like the short circuit impedance measurement, the low voltage side phase terminal (without Neutral) must be shorted. Please see 4.5.2 for more information.

4.8.3 Temperature Correction

The winding temperature has effect on the resistance values and so it can be corrected to a reference temperature. The method is exactly like the DC resistance temperature correction. For more information, please refer to chapter 4.2.2.

4.9 Temperature Rise Measurement (HRT)

Temperature rise measurement or Heat Run Test (HRT) is a measurement which is used for the evaluation of transformer design and its cooling system effectiveness. There are temperature rise limit values which are usually defined by power transformer manufacturers based on design and insulation material. Some limit values are also determined by international standards such as IEC60076-2.

When the winding temperature rise is known, then the actual temperature during the operation of a power transformer can be calculated depending on the ambient temperature. Maximum actual winding temperature can also be defined by adding the transformer's maximum operating ambient temperature and maximum winding temperature rise.

Temperature rise measurement is performed actually by the winding resistance measurement. From the winding resistance measurement, the average winding temperature can be calculated.

For average winding temperature, a reference resistance value (also called cold resistance) at a defined temperature is required. From the following equation the average winding temperature can be calculated:

$$\theta_2 = \frac{R_2}{R_1} (T_k + \theta_1) - T_k$$

θ_1, R_1 : Reference measurement

T_k : Temperature coefficient (≈ 234.5 for copper)

R_2 : Measured resistance

θ_2 : Calculated average winding temperature

During winding resistance measurement, the transformer must be de-energized and must be disconnected from the grid. As a result, during the heating-up process, it is not possible to measure resistance. The solution is to shut down the transformer, and then measure the resistance as fast as possible after shutdown.

Figure 10-A shows a typical winding temperature curve during temperature rise measurement. There are two main parts: The heating-up period and the cooling-down period. The temperature value at the instant of the shutdown is aimed to be found.

Figure 10-B shows the temperature curve zoomed around and after the instant of the shutdown. There is always a time delay between the instant of the shutdown and the first valid resistance measurement.

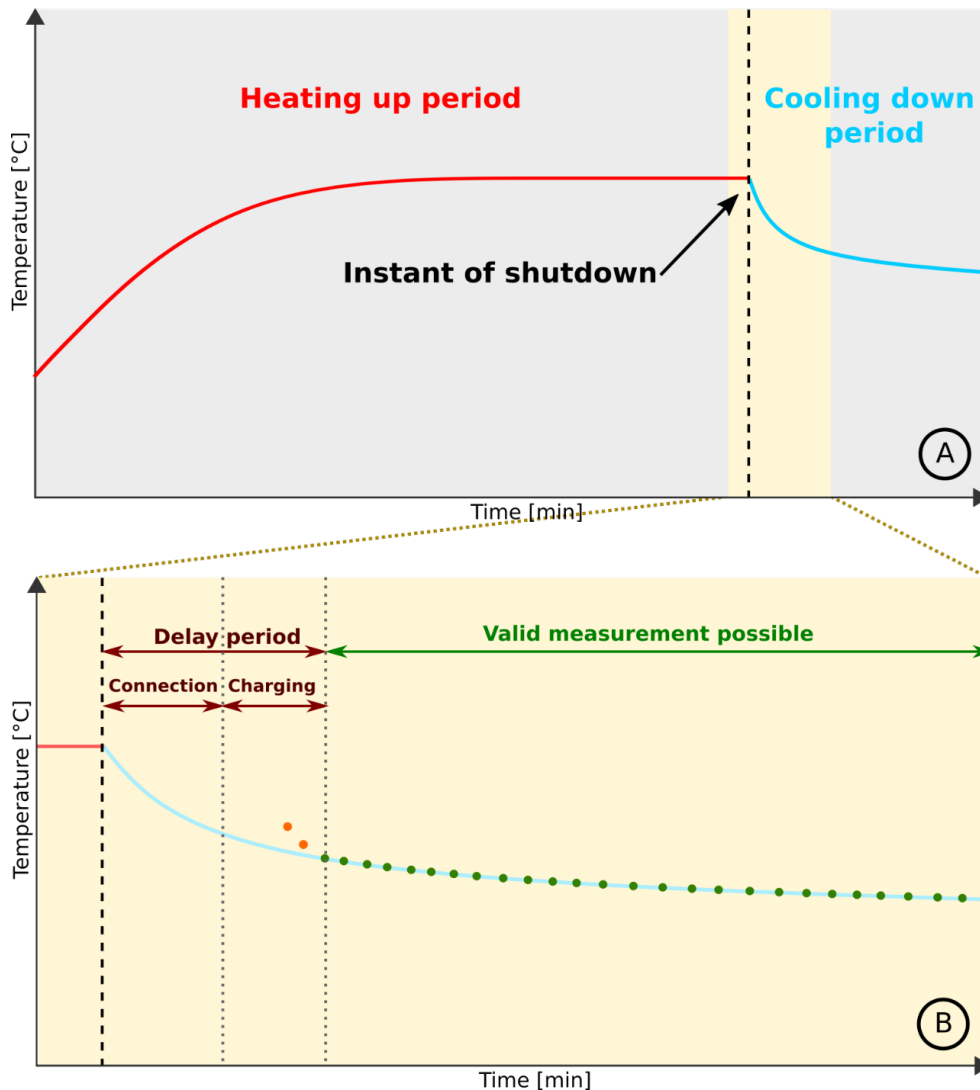


Figure 10: Typical shape of winding temperature curve during a temperature rise test

The time delay consists of:

1. The time required for disconnecting the transformer from the grid and connecting the winding resistance meter test cables to transformer terminals
2. The time required to start the measurement, charge the transformer and read the first stable and valid resistance value. Usually, some points at the beginning of measurement are not valid and later they must be skipped.

Because of this time delay, it is not possible to measure the resistance (and hence winding temperature) directly at the instance of the shutdown. The solution for this problem that there are mathematical techniques such as curve fitting methods which can help to estimate and calculate the temperature at this point.

Since the winding is in the transformer tank full of oil or insulating liquid, the winding temperature rise can be divided into two parts: Winding and oil temperature gradient, plus oil temperature rise. After the instant of the shutdown, the winding temperature cools down to the oil temperature in exponential form. Simultaneously oil temperature decreases but gently and with longer thermal time-constant to external cooling medium temperature (e.g., ambient temperature). The cooling curve thus can be formulated as follows which is derived from IEC 60076-2:2011.

$$\theta_w(t) = \theta_{om}(t) + B e^{-t/T_w}$$

t : Time started from the instant of the shutdown

$\theta_w(t)$: Average winding temperature estimation

$\theta_{om}(t)$: Average oil temperature estimation/measurement

B : Winding and oil temperature gradient at the instant of the shutdown

T_w : Thermal time constant of winding and oil temperature gradient

B and T_w are unknown and curve-fitting aims to find them.

The oil temperature term is also originally in exponential form and can be expressed as:

$$\theta_{om}(t) = A_0 e^{-t/T_0} \text{ (exponential form)}$$

A_0 : Average oil temperature at the instant of the shutdown

T_0 : Thermal time constant of the oil

However, since the thermal time constant of the oil is usually far bigger than the thermal time constant of winding temperature, the oil temperature term can be simplified to linear form or can be considered as a constant value.

$$\theta_{om}(t) = A_0 - kt \text{ (linear form)}$$

$$\theta_{om}(t) = A_0 \text{ (constant form)}$$

Alternatively, oil temperature can also be measured directly and continuously during the test using temperature sensors.

Finally, when the cooling down curve equation is calculated using curve fitting methods, winding temperature at the instant of shutdown can be determined as follows.

$$\theta_w(t = 0) = \theta_{om}(0) + B e^{-0/T_w} = A_0 + B$$

Winding temperature rise at the instant of shutdown can then be calculated easily by subtracting external cooling medium temperature (or ambient temperature in case of air) from the above value.

5 Measurement Setup

5.1 Connecting Test Cables to Transformer Terminals

This chapter explains the measurement setup of power transformers and autotransformers.

Connect the mini-ATOS to the test object terminals with the labelled test leads by using the connection guides according to Table 3 or Table 4.

When you want to perform a measurement in which tertiary winding is involved (e.g., Turns ratio between primary and tertiary), you have to connect the mini-ATOS X Cables to the tertiary side.

Because of safety, it is not recommended to perform tests between secondary and tertiary. The voltage may transform to a very dangerous level at the primary side during the measurements.

Check the nameplate information of the transformer. If the nameplate is missing it is still possible to test the transformer by a trial-and-error method. The mini-ATOS test set is designed to detect errors in transformer hook-ups. Contact the Raytech Service & Support department if you need assistance.



WARNING!

It is not recommended to test between secondary and tertiary sides! The voltage may transform to a very dangerous level at the primary side during the measurements.

Table 5: Test cables connection guide for a single-phase power transformer and autotransformer

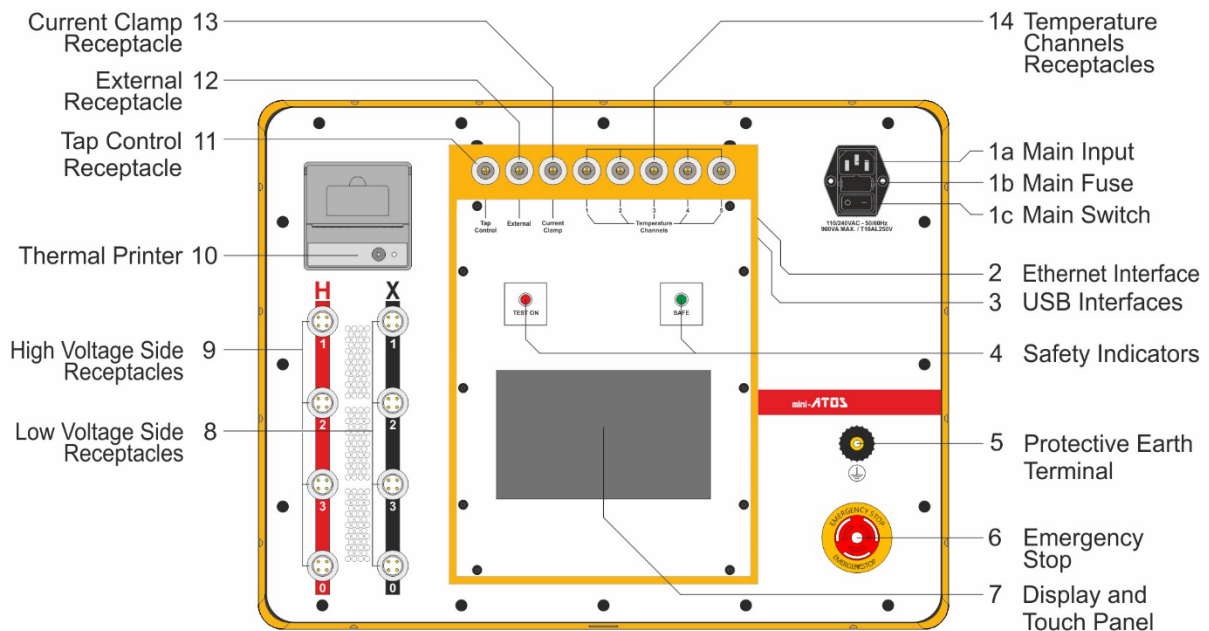
Voltage Level	mini-ATOS Test Cable Label	Transformer Naming Scheme			
		IEEE		IEC	ABCN
Primary	H1	H1	1.1 ²	U1	A1
	H2	H2	1.2	U2	A2
Secondary	X1	X1	2.1	u1	a1
	X2	X2	2.2	u2	a2
Tertiary	X1	Y1	3.1	3U1	3A1
	X2	Y2	3.2	3U2	3A2

² Dot can be a letter. For example: 1U1

Table 6: Test cables connection guide for a three-phase power transformer and autotransformer

Voltage Level	mini-ATOS Test Cable Label	Transformer Naming Scheme			
		IEEE	IEC	ABCN	
Primary	H1	H1	1U	U	A
	H2	H2	1V	V	B
	H3	H3	1W	W	C
	H0	H0	1N	N	N
Secondary	X1	X1	2U	u	a
	X2	X2	2V	v	b
	X3	X3	2W	w	c
	X0	X0	2N	n	n
Tertiary	X1	Y1	3U	3U	3A
	X2	Y2	3V	3V	3B
	X3	Y3	3W	3W	3C
	X0	Y0	3N	3N	3N

6 Operation Elements



6.1 Mains Input, Fuse and Mains Switch

- a- Connect the power cable to the Mains Input. Use only a standard C13 type connector. The cable must be rated at least 10A.
- b- Two 5mm x 20mm T10A slow blow fuses protects the device. Use only the same type for replacement.
- c- Press the Mains Switch to turn the mini-ATOS ON/OFF.

6.2 Ethernet Interface

This port can be used for remote access. Please see chapter 10.7 for more information about the remote connection.

6.3 USB Interfaces (1x Host, 2x Device)

1x USB Host which can be used for remote access

2x USB Device which can be used to connect a USB Stick, or to connect a mouse and keyboard

6.4 Safety Indicators

Green Light ON: The system is in safe mode. Ready for handling test leads and connections.

Red Light ON: Unsafe mode! Don't remove any cables, the current is flowing and there is a hazardous voltage on the test leads!



WARNING!

When the red light indicator is ON, the transformer is not discharged!

6.5 Protective Earth Terminal

Use this terminal to connect a protective earth line.

6.6 Emergency Stop

Press to stop. The measurement will cease and halt Voltage to the test leads immediately. Turn clockwise to release. The device will remain in a safe state.

6.7 Display and Touch Panel

The mini-ATOS can be easily controlled by this touch screen panel. Since it is a capacitive touch screen, use your finger to control it as you work with a smartphone.

If preferred, an external mouse and keyboard can be connected to the USB Port.

6.8 Low Voltage Side Receptacles

To connect the instrument to the low voltage side terminals of a test object.

6.9 High Voltage Side Receptacles

To connect the instrument to the high voltage side terminals of a test object.

6.10 Thermal Printer

Allows you to quickly get your results on paper by using the built-in thermal printer.

6.11 Tap Control

This port is used for an external connection to a tap changer dry contact. With this connection, the tap position can be changed from the mini-ATOS.

6.12 External

This port is multi-functional and consists of the following functions:

- connecting an external warning device like a warning lamp.
- connecting a tap-changing hand switch.
- connecting an external safety interlock like a safety door or a safety hand switch (Only the 6pin version).

6.13 Current Clamp Receptacle

This port can be used for connecting an optional current clamp. This current clamp is used for additional measuring features such as DRM motor current.

6.14 Temperature Channels Receptacles

These 5 receptacles are for connecting the external temperature probes.

7 User Interface

7.1 Home Screen

On the home screen, easy access to the main parts of the operation menu is provided. Figure 11 represents the mini-ATOS home screen.

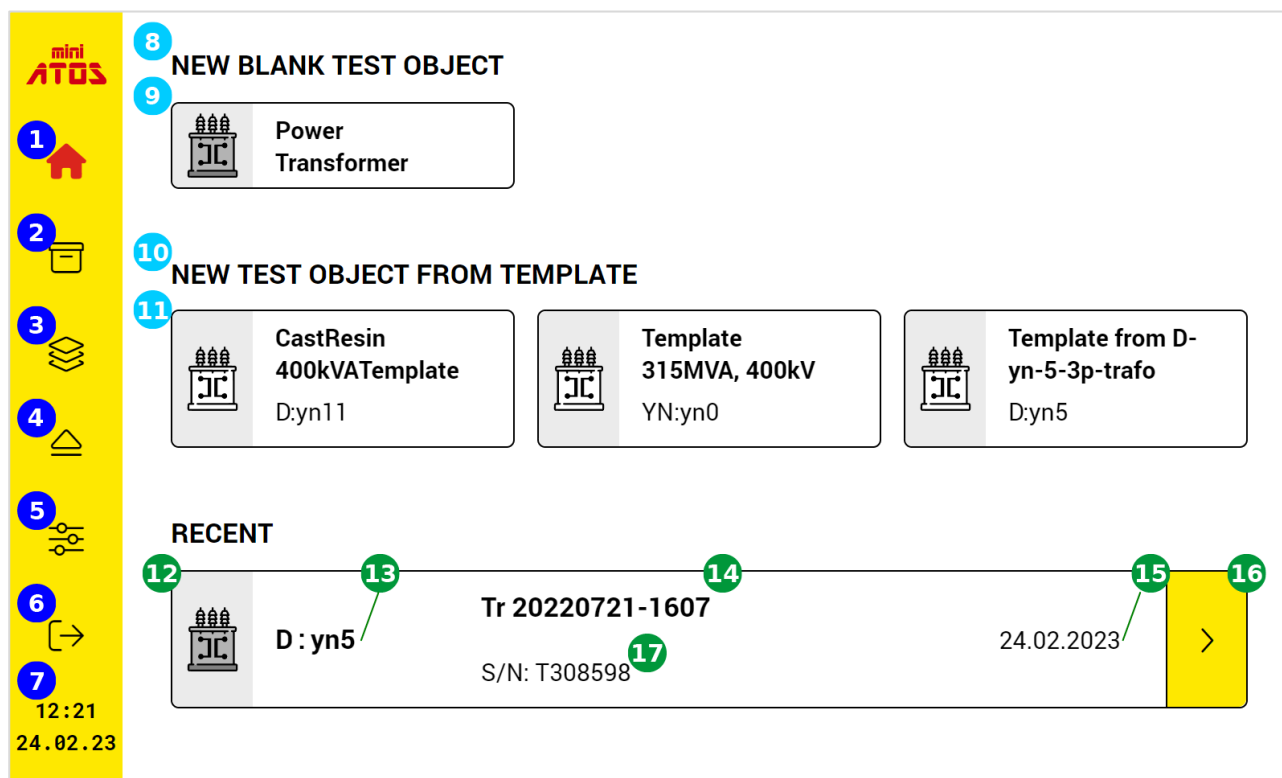


Figure 11: The mini-ATOS home screen

- 1 By tapping the Home icon from any page, you will jump to the Home Screen
- 2 Archive button, which is used to access all previously defined test objects. Please see chapter 7.2 for more details
- 3 Access all test object templates and manage them. Please see chapter 7.3 for more details
- 4 To remove safely the USB stick
- 5 Settings button to access the device settings. Please see chapter 7.4 for more details
- 6 By tapping this button, you will log out and it is possible to activate the remote connection. For more details about the remote connection, see chapter 10.7
- 7 Date and time
- 8 List of test object types to define a new blank one. Please see chapter 8 for more details
- 9 To define a new power transformer test object
- 10 List of favorite templates, to define a test object from a template. See chapter 7.3 to find out how to define a template
- 11 A test object template item
- 12 The most recent active profile

- 13 Connection and vector group
- 14 Test object name
- 15 Last measuring date
- 16 Jump to the last active measurement window
- 17 Test object serial number

7.2 Archive

In Archive, a list of already defined test objects is shown (Figure 12).

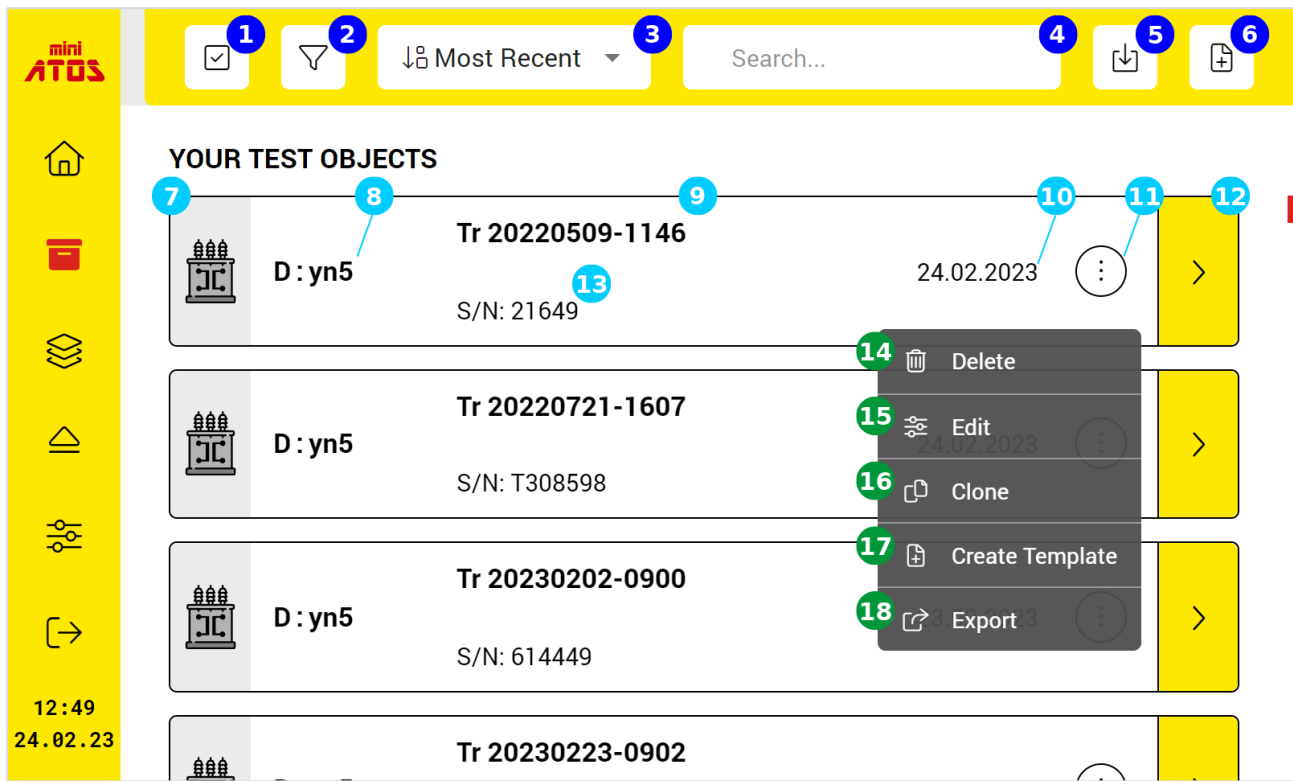


Figure 12: The mini-ATOS test objects Archive

- 1 To activate the multi-select to export or delete test objects
- 2 Filter the test object records
- 3 Arrange the test object records by sorting them according to different fields
- 4 Search tool to find a test object from the list. The search word can be the name, serial number or winding connection type
- 5 To import a test object from the connected USB stick
- 6 To create a new test object
- 7 Test object record
- 8 The test object winding configuration
- 9 Test object name
- 10 Last activity date
- 11 To open the option menu
- 12 Open the test object
- 13 Test object serial number
- 14 To delete the test object
- 15 To edit the test object
- 16 To clone the test object

- 17 To create a template from the test object (See chapter 7.3 for more information)
- 18 To export the test object to a USB stick

By opening each test object, the history of the inspections and test plan measurements will be displayed as in Figure 13.

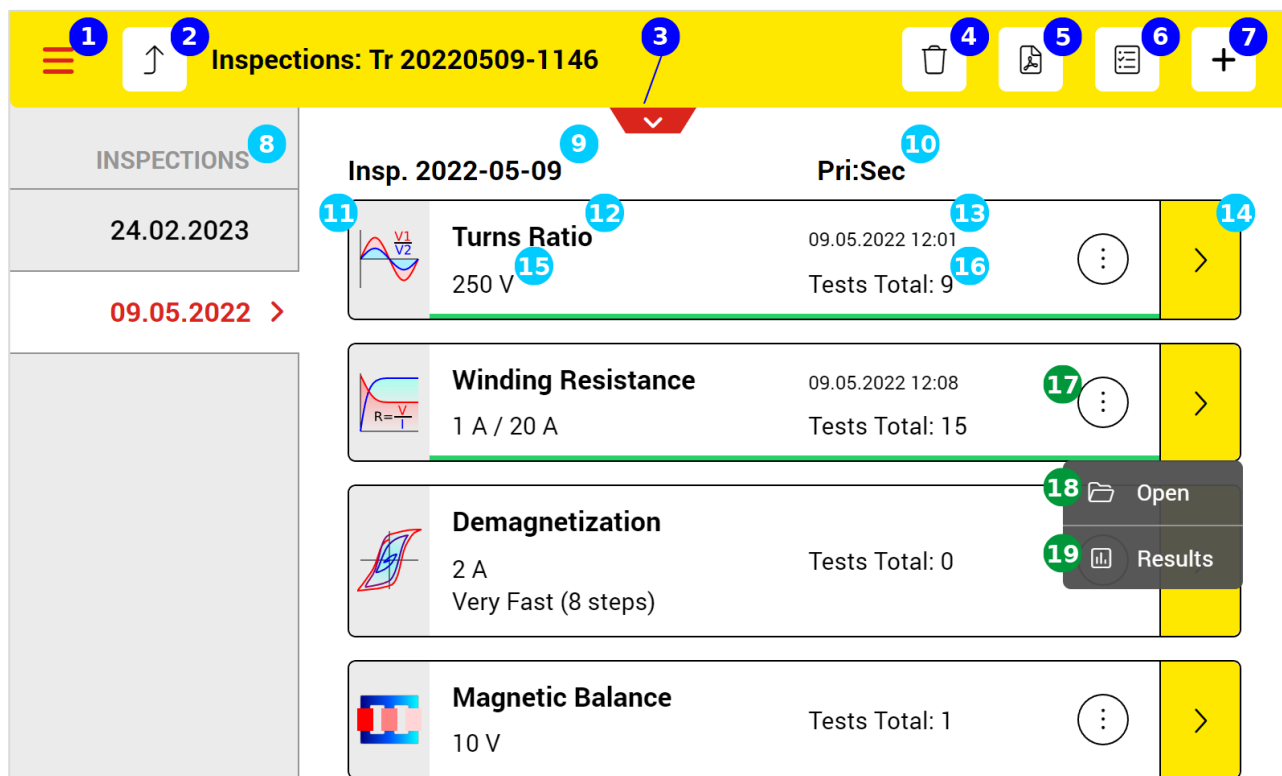



Figure 13: List of measurements for each test object in Archive

- 1 To open the main menu
- 2 To go back to the Archive
- 3 Open test object quick access
- 4 To delete the selected inspection
- 5 To generate and export the PDF report
- 6 To jump to the test plan page and perform the measurements
- 7 To add a new inspection
- 8 The list of inspections sorted by date
- 9 The selected inspection title
- 10 The selected test plan measurement sides
- 11 The test plan measurement item
- 12 The measurement type
- 13 The last measuring date and time
- 14 To open the result view in a graph and table

- 15 The measurement setting
- 16 The total tests possible for the measurement
- 17 To open the option menu
- 18 To open the measurement view
- 19 To open the result view in a graph and table

7.3 Templates

When there are some test objects with the same specifications, it is good to make a template for all of them. Later it is possible to use the template to define each test object easier and faster by avoiding entering the same information each time.

Figure 14 shows the template list. To create a new template, just tap the add button  and input the template data the same as to create a new test object (See chapter 8). You can then save it and jump to the test plan page. The test plan is also a part of the template. It is possible to adjust the test plan including the measurement settings.

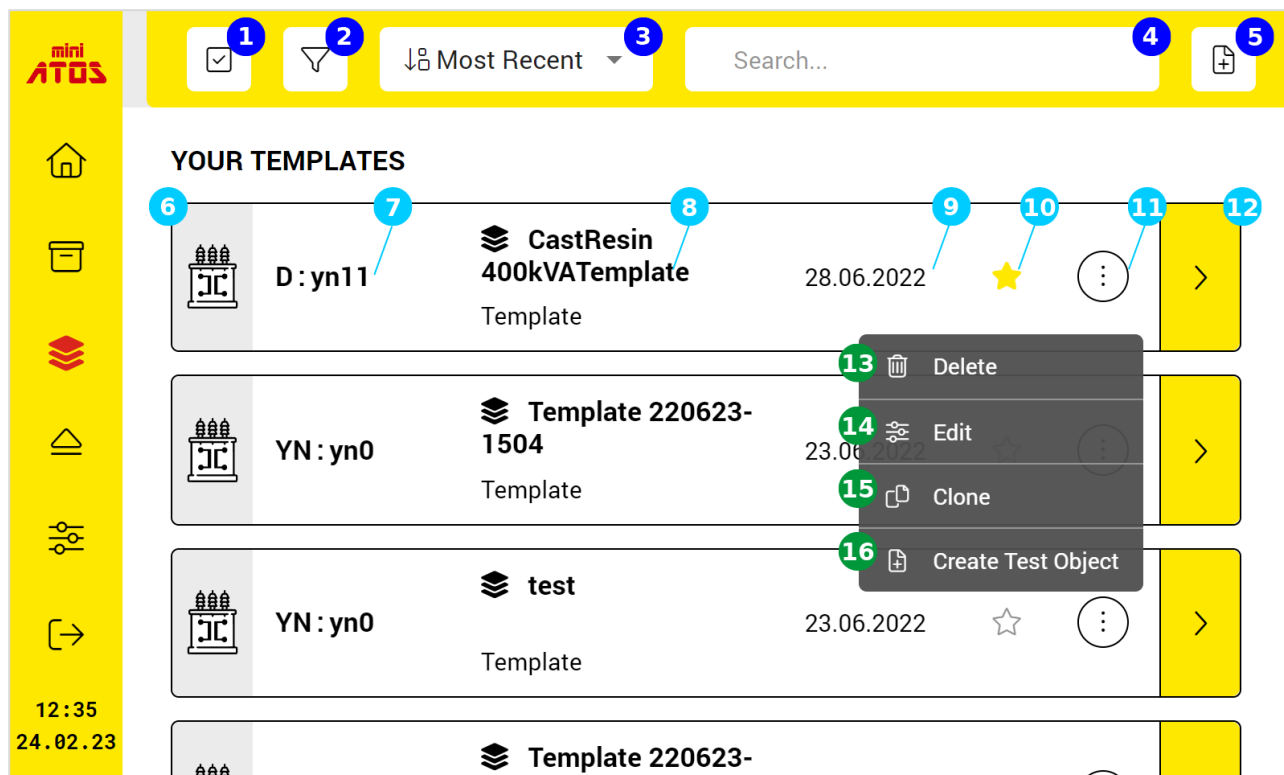


Figure 14: Test object templates

- 1 To activate the multi-select feature for deleting multiple templates simultaneously
- 2 Filter the test object records
- 3 Sort the template items based on various fields
- 4 Search tool to find a template from the list. The search word can be the name or the winding connection type
- 5 To create a new template
- 6 Template item
- 7 The template winding configuration
- 8 Template name
- 9 Date created
- 10 When it is marked, it will be shown on the home screen
- 11 To open the option menu
- 12 To activate the multi-select feature for deleting multiple templates simultaneously
- 13 Delete
- 14 Edit
- 15 Clone
- 16 Create Test Object

- 12 To open the template and edit the template test plan
- 13 To delete the template
- 14 To edit the template
- 15 To clone or make a copy from the template
- 16 To create a test object from the template

7.4 Settings

7.4.1 Date and Time

In this tab, Date and Time and related settings like Country and Time zone can be adjusted. Simply you can tap each field and change its values.

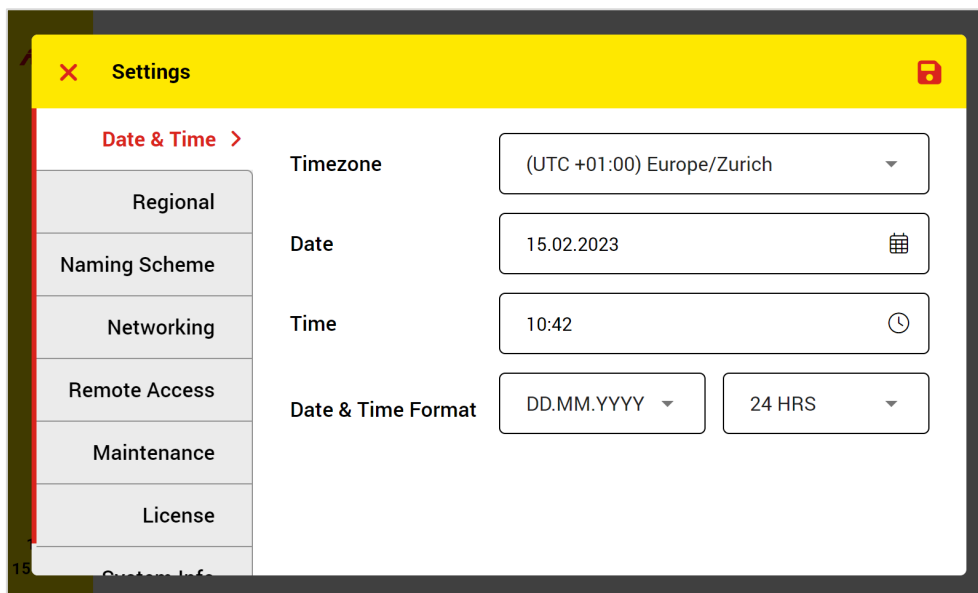


Figure 15: Date and time adjustment in Setting

7.4.2 Regional

The user interface language, default temperature unit format, numbers decimal separator and CSV separator can be selected in the Regional tab (Figure 16).

CSV separator is helpful for software like Microsoft Excel to correctly show results as data columns from the exported results in CSV format. Depending on the PC language, sometimes comma [,] is the separator and sometimes semicolon [;] is the separator.

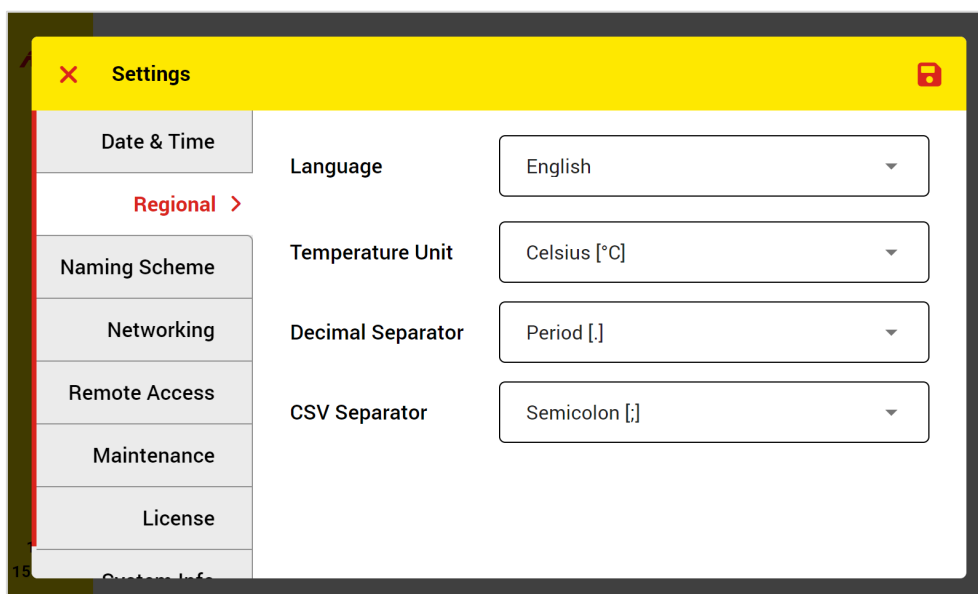


Figure 16: Regional adjustments in Setting

7.4.3 Naming Scheme

In the Naming Scheme tab (Figure 17), it is possible to set the default naming scheme of a new test object. Generally, there are different systems of terminal naming for each test object. There is also a custom naming scheme which can be easily edited to use it later.

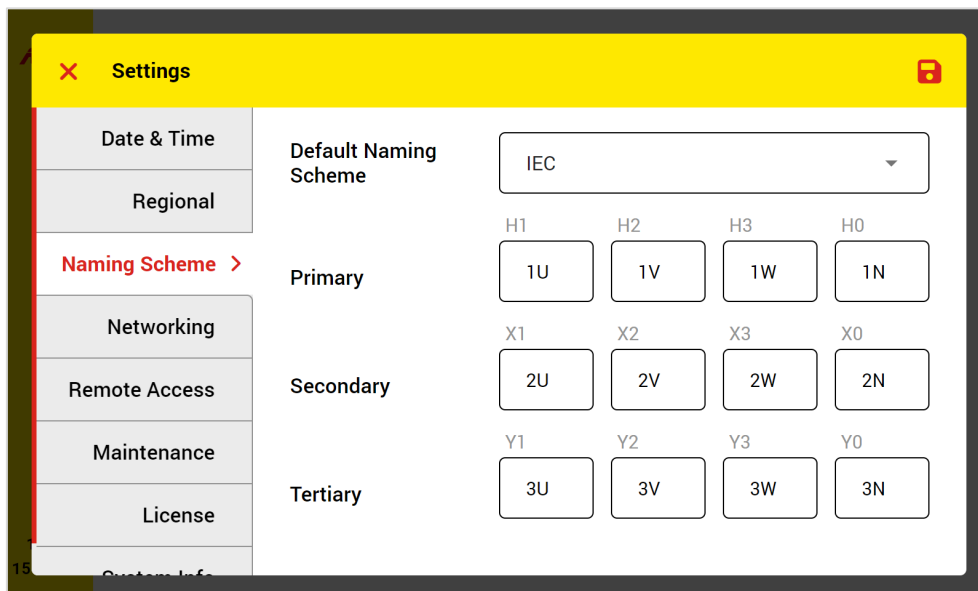


Figure 17: Default Naming Scheme adjustment

7.4.4 Networking

In this tab (Figure 18), you can adjust the networking settings which are required for remote access. For more information about remote access please see chapter 12.

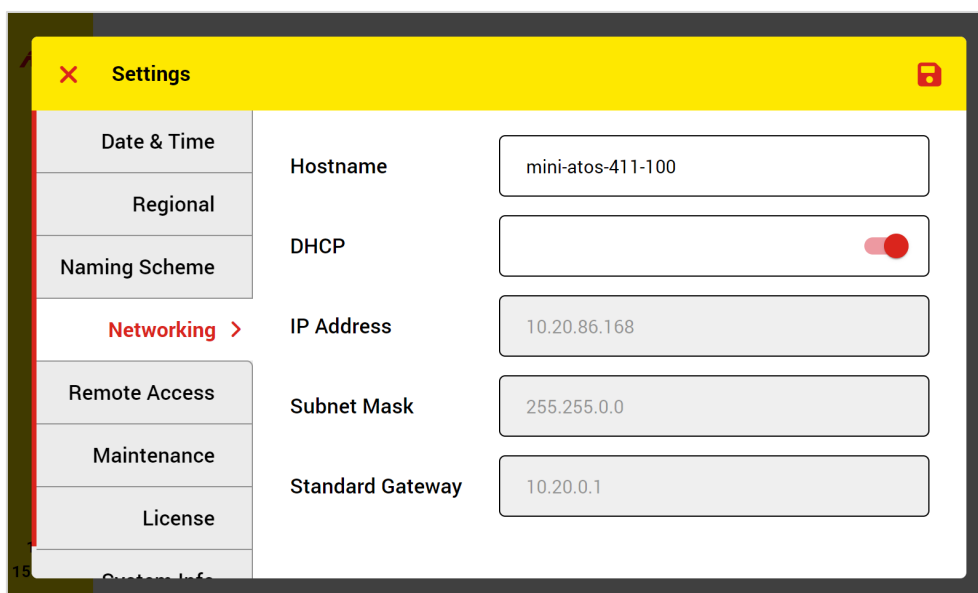


Figure 18: Network configuration

Hostname

The system typically automatically assigns the Hostname based on the device's serial number. However, it is also possible to modify this name. The assigned Hostname serves as the address (`http://"Hostname"`) to remotely access the device via an Ethernet connection. It is crucial to ensure the Hostname is unique, and after making any changes, the device must be restarted. For further details, please refer to Chapter 12.

DHCP

When DHCP (Dynamic Host Configuration Protocol) is activated, the system configures the network automatically and the user doesn't need to do it manually.

IP Address, Subnet Mask, Standard Gateway

Here you can configure the network manually by entering the required fields.

7.4.5 Remote Access

Here there are remote access settings which are required to be adjusted (Figure 19). To see the remote access guide, please see chapter 12.

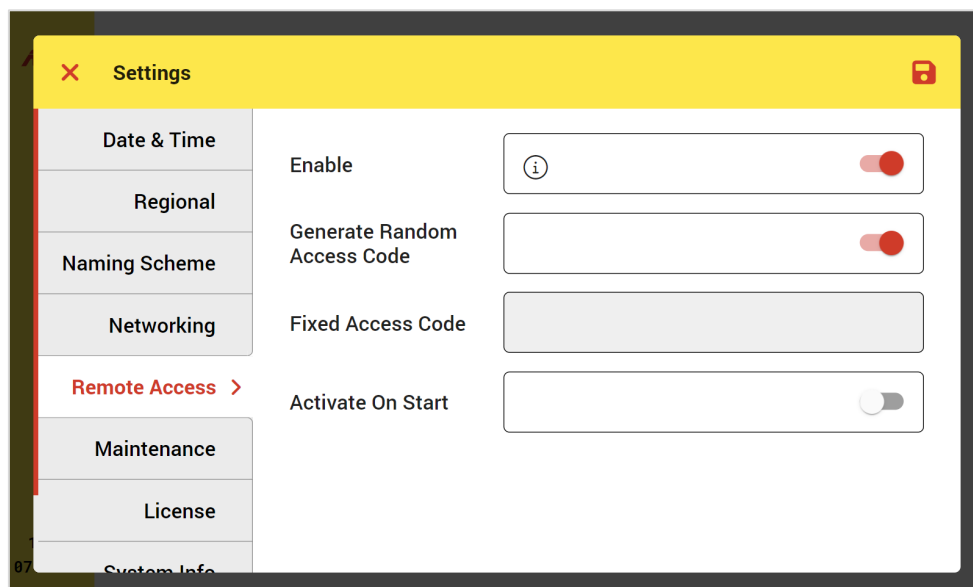


Figure 19: Remote Access settings

Enable

Use this toggle button to enable or disable remote access. You can also tap on the information icon ⓘ to see the remote access instructions.

Access Code

Because of security, an access code is always required to log in to the software. The access code can be set manually (**Fixed Access Code**) by entering the intended number or the code will be generated automatically if "**Generate Random Access Code**" is activated. The generated code will be shown on the login page on the device screen. To find out how to control the device with remote access, please see chapter 12.

Activate On Start

When enabled, remote access will be started automatically after turning on the device.

7.4.6 Maintenance

Figure 20 shows the maintenance tools and each one is explained below.

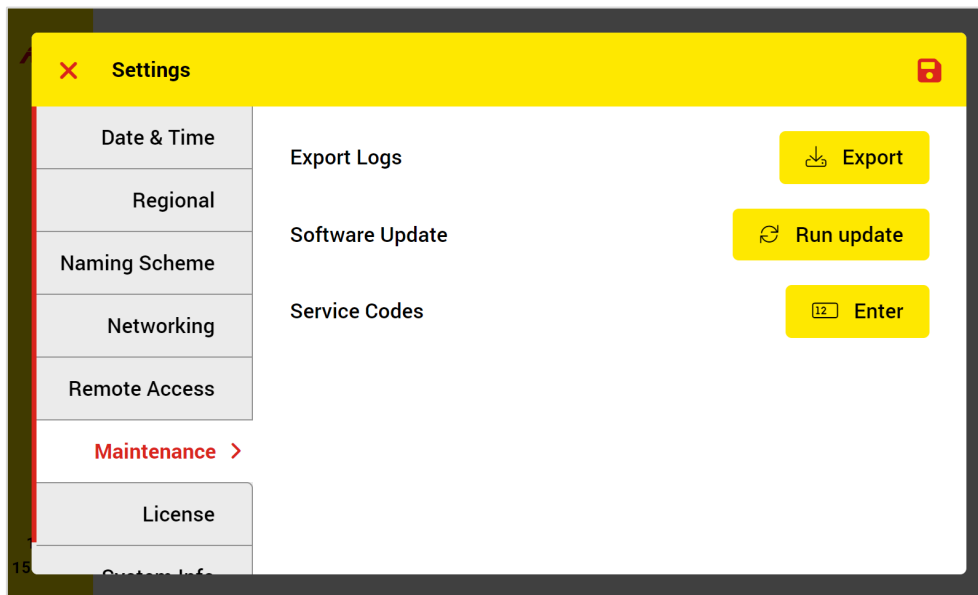


Figure 20: Maintenance tools

Export Logs

When it is required to diagnose the mini-ATOS software, the Raytech service team may ask you to export logs. To export the logs, just connect a USB stick and tap the Export button. You can later send the exported log file to the Raytech service team.


Software Update

When a new software or firmware update is available, you can copy the update file to a USB stick and connect it to the device. Then tap the Run update button and wait until the process is finished. Please do not turn off the device or unplug the USB stick during the update! The update can take up to 10 minutes.

Service Codes

When there is a problem or error in the device, the Raytech service team may ask you to use the service codes. With service codes, it is possible to do some additional actions which are not possible to do by using the default software. These actions can be for example a self-test for diagnosing the hardware.

7.4.7 License

To activate the main firmware functionality or a specific optional measurement feature, you have to add a license code in this tab (Figure 21). Just tap the Add  button and enter the license code. Each license may be valid for a limited time like 10 days or can be unlimited.

To test a feature, you can ask Raytech for a trial license to activate the feature temporarily.

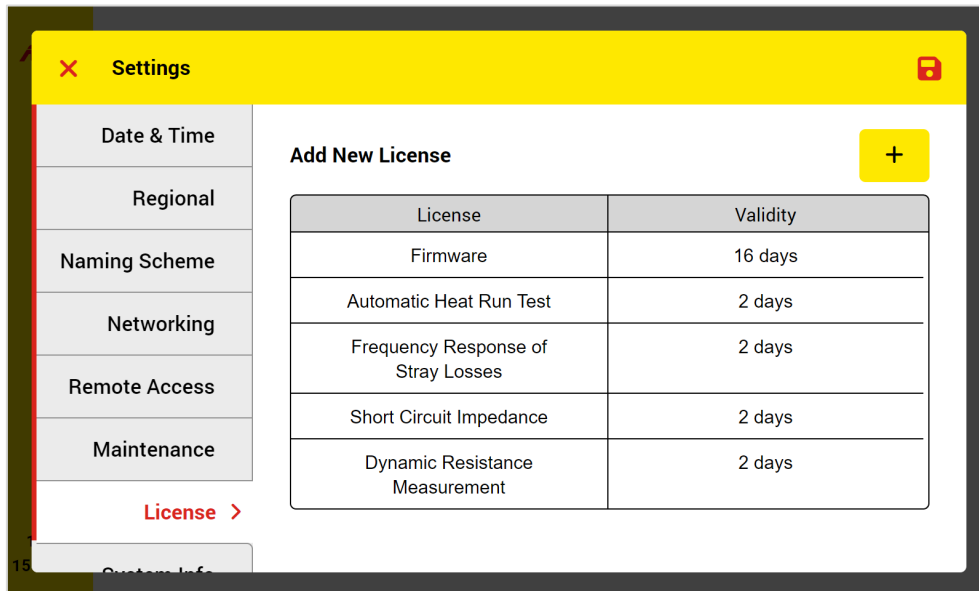


Figure 21: License manager

7.4.8 System Info

In system info, you can check the actual Operation system and firmware versions, the device serial number and calibration information.

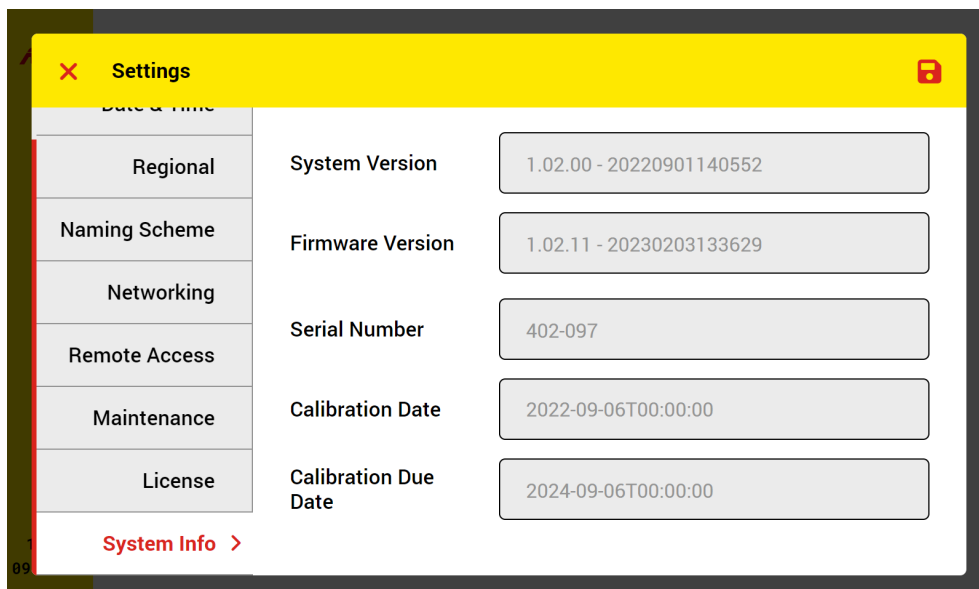


Figure 22: System Information

8 Test Objects

8.1 Power Transformer

In the TEST OBJECT window, a new test object can be defined, or an existing test object can be modified. Figure 23 represents the test object window.

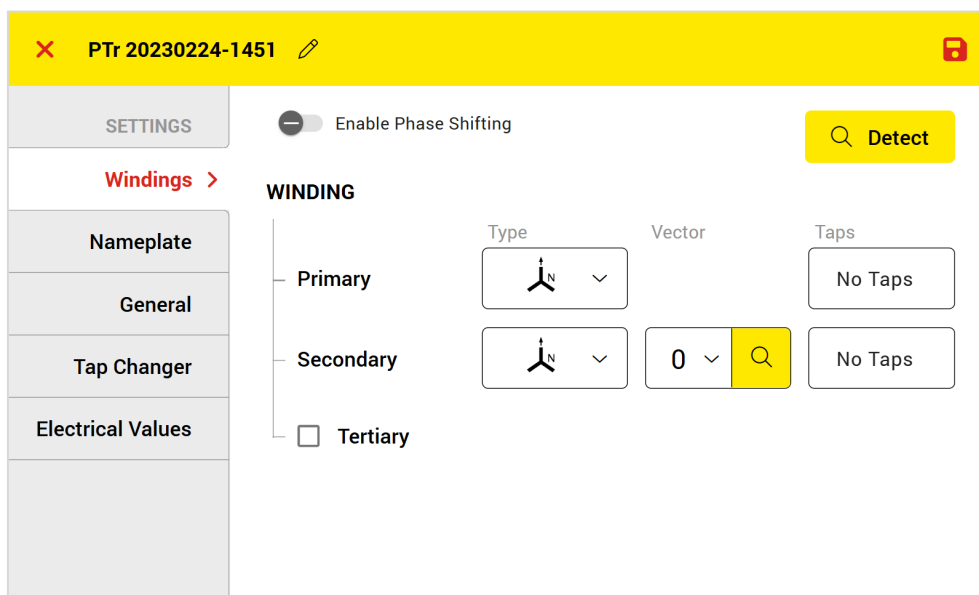



Figure 23: The test object window

Test Object Name

PTr 20230224-1451 

Name of the test object, which is helpful for easy identification. The system always assigns an automatic name at the beginning which consists of the test object type, date and time. This name can be easily changed by tapping the pencil symbol or the name.

 **Save**

Tap the Save icon to store all the entered test object data and go to the test plan.

 **Cancel**

By tapping this icon, you can cancel the test object defining and go back to the Home Screen. Please take care because all the entered data will not be saved.

8.1.1 Windings

In the Windings tab (Figure 24), the most important properties of the test object, including winding types, vector groups and the number of taps can be defined. After creating the test object, it is not possible to make changes in the winding information.

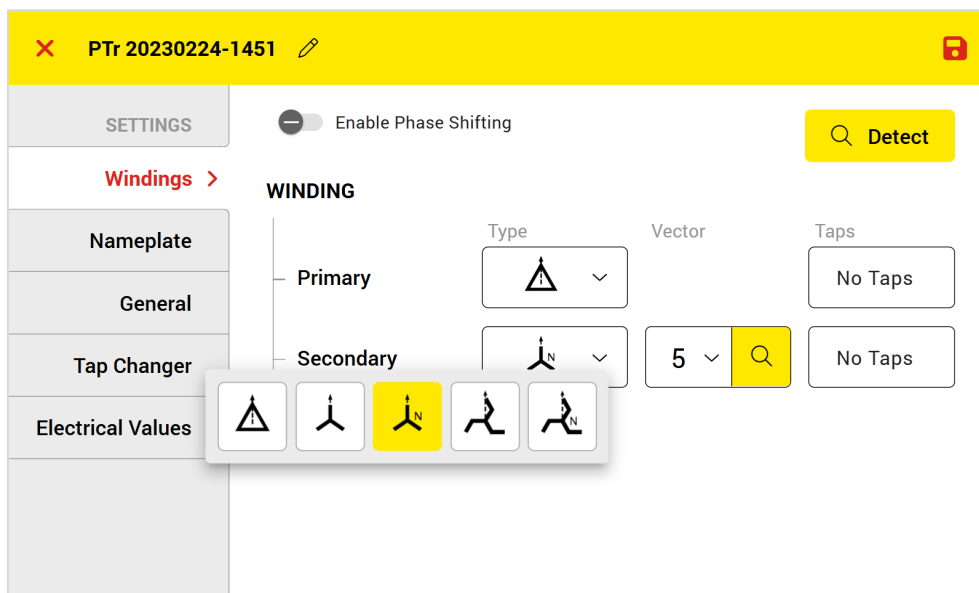








Figure 24: Test object windings tab

You can select the winding type by tapping the winding connection symbol for each winding side. The winding type for a power transformer can be from any winding type of Table 7.

Table 7: Winding types and symbols for power transformers

Phases	Type	Letter (Primary)	Letter (non-Primary)	Symbol
3-Phases	Delta	D	d	
	Star with accessible neutral	YN	yn	
	Star	Y	y	
	Zigzag with accessible neutral	ZN	zn	
	Zigzag	Z	z	
1-Phase	Single-phase	S	s	

 Detect

By tapping the Detect button, the transformer winding configuration detection window will be opened, and it is possible to find the winding configuration and vector group by measurement automatically. Please see chapter 8.1.2 for more details.

For all non-primary windings, the vector group must be correctly selected. It is important to make sure that the vector group is correct because the switching function of the automatic multiplexer is based on the vector group and winding type.



Detect Vector Group

It is also possible to detect just the vector group quickly by using this button. It detects only the vector group and not the winding configuration.

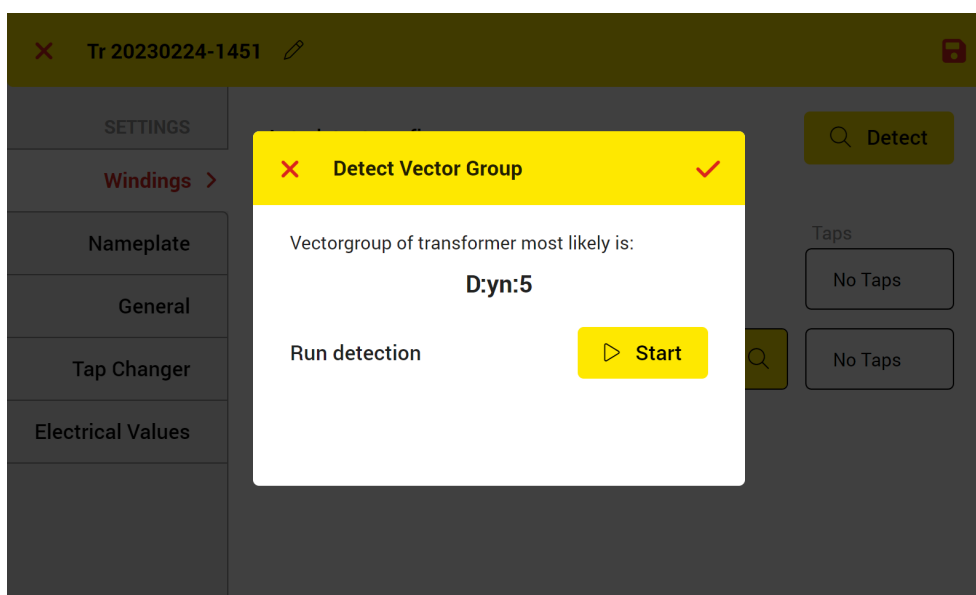
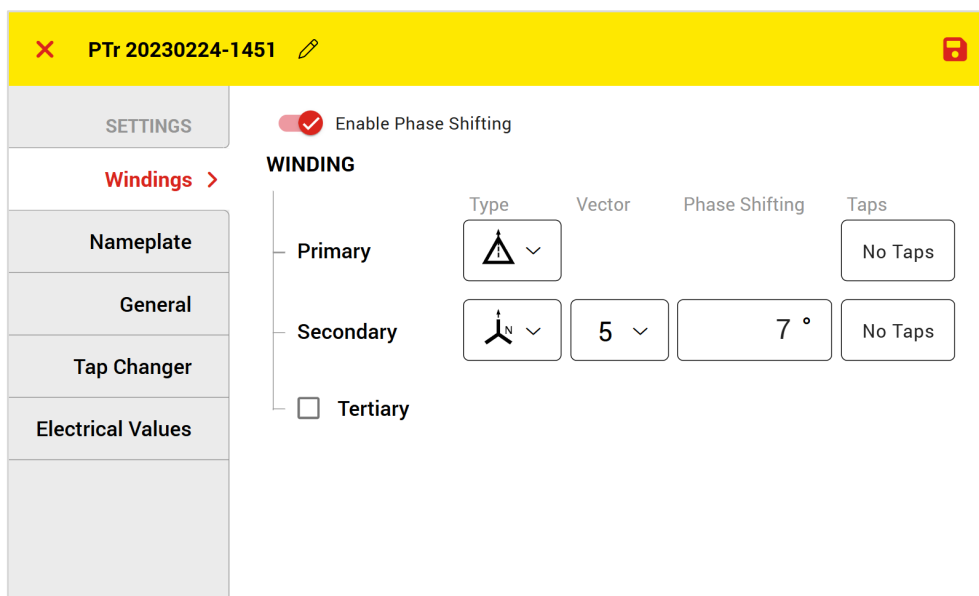


Figure 25: Detect vector group

☒ Enable Phase Shifting

By enabling phase shifting, a phase relationship other than multiple of 30° can be entered. This is useful for special power transformers and transformers with phase shifting capability.





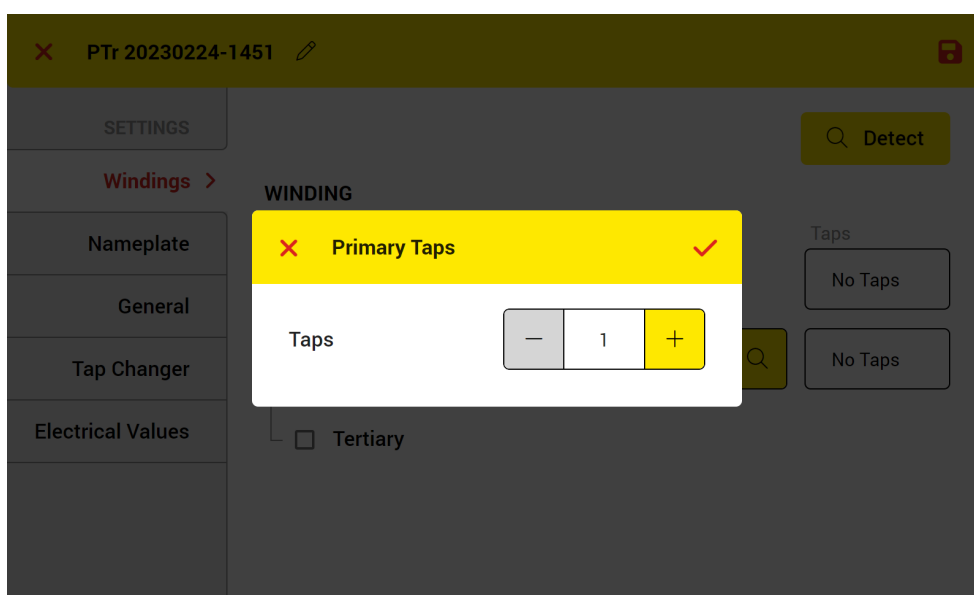
Winding	Type	Vector	Phase Shifting	Taps
Primary		1	7°	No Taps
Secondary		5	7°	No Taps
Tertiary	<input type="checkbox"/>			

Figure 26: Power transformer with phase shifting capability

For each winding, when there are several taps, the number of taps can be entered by clicking on the taps column. In the tap count window (Figure 27) the tap numbers can be easily adjusted. You can also enter the number of taps directly with the virtual keyboard by tapping the taps number directly.

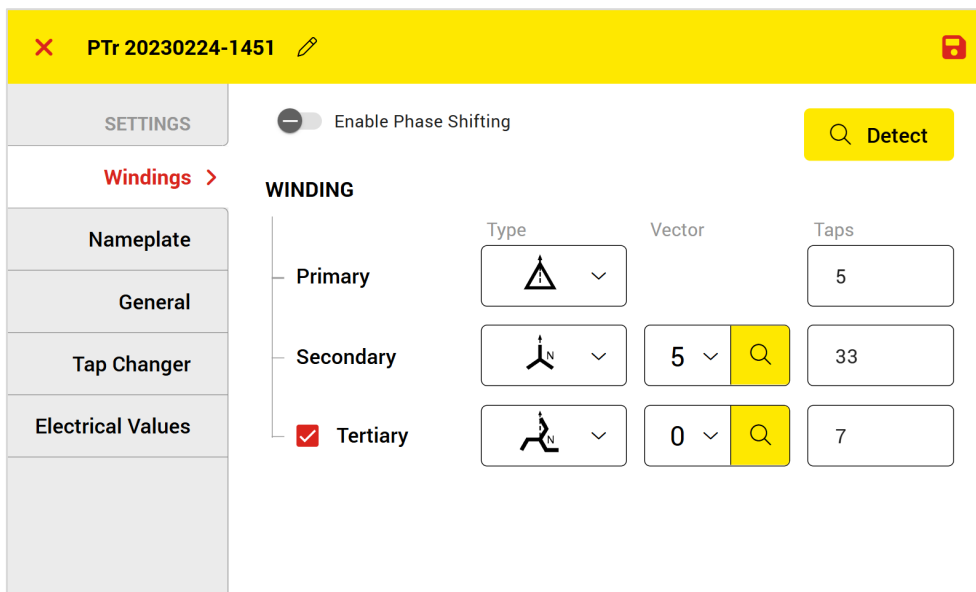


Primary Taps

Taps: − 1 +

Figure 27: Tap count configuration window

When there is a tertiary winding, the check box can be selected and like the secondary winding, the required information can be entered (Figure 28).



The screenshot shows the 'WINDING' configuration screen for a transformer. The interface includes a sidebar with 'Nameplate', 'General', 'Tap Changer', and 'Electrical Values' sections. The 'WINDING' section is active, displaying a table of winding parameters. The 'Tertiary' winding is checked and configured with 7 taps. A 'Detect' button is visible in the top right corner.






	Type	Vector	Taps
Primary	 ▼		5
Secondary	 ▼	5 ▼ 	33
<input checked="" type="checkbox"/> Tertiary	 ▼	0 ▼ 	7

Figure 28: Defining a transformer with a Tertiary winding

8.1.2 Winding Configuration Autodetect

Autodetect feature can detect the winding configuration and vector group of the test object. During detection, the test cables must be connected to the test object terminals according to 5.1.

By tapping the Detect button in the test object windings tab (Figure 24) a new window will be opened (Figure 29). To perform the transformer detection, tap the Start and wait until mini-ATOS find the configuration.

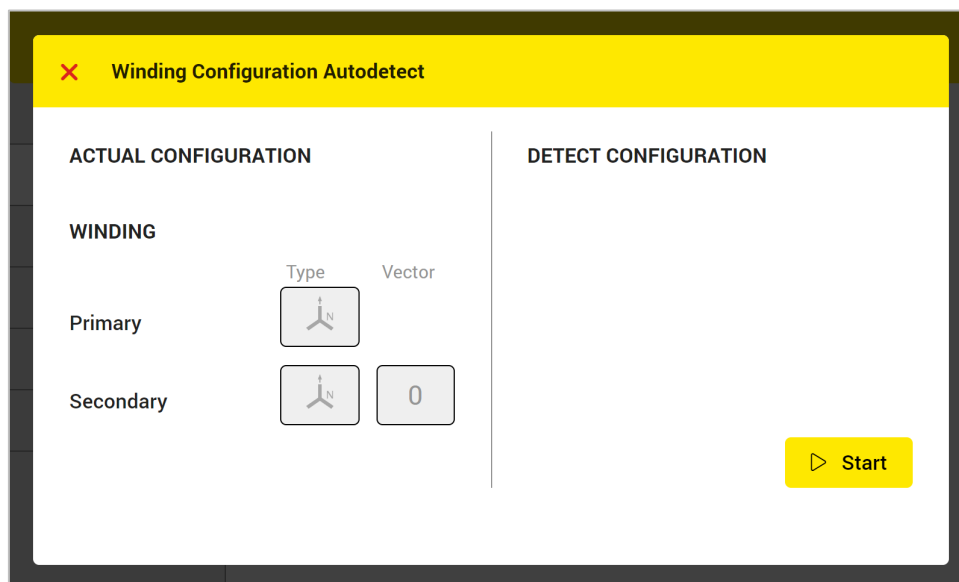


Figure 29: Winding configuration autodetect window

The actual configuration is written on the left side, and the detected configuration will be written on the right side (See Figure 30). When mini-ATOS find more winding configurations, a list of them will be provided and you can choose each of them. After detection, you can accept the detected configuration or you can cancel.

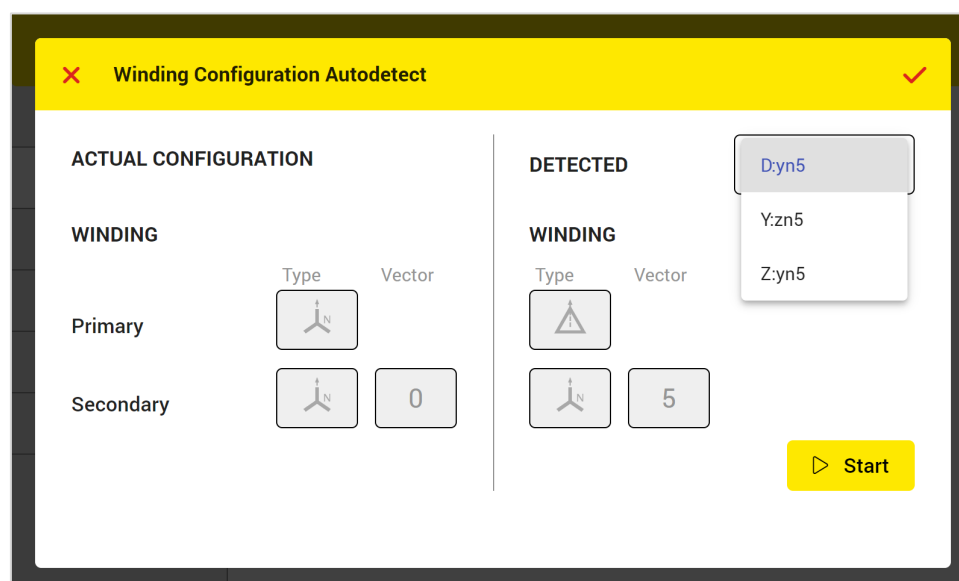
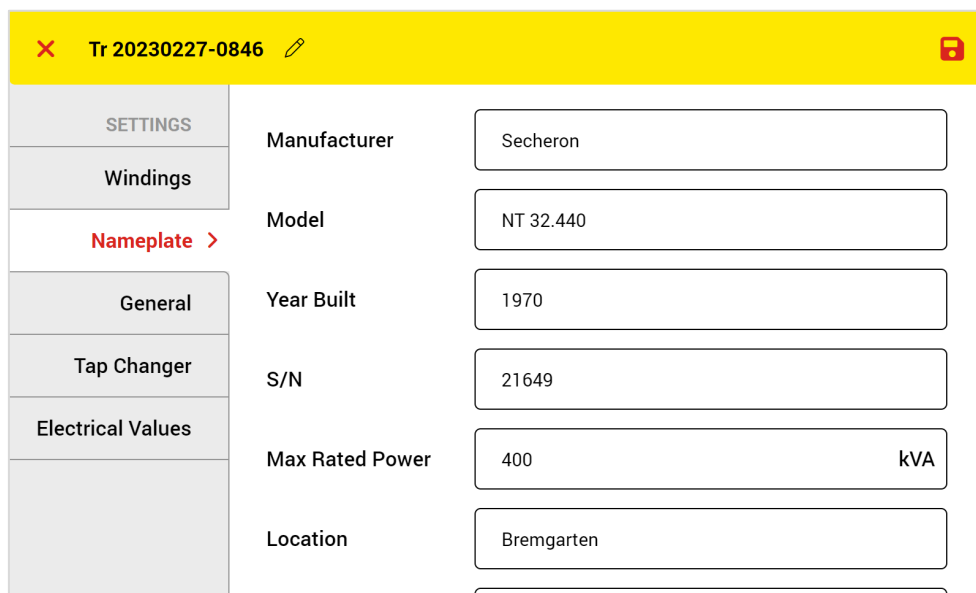


Figure 30: Winding configuration autodetect window after detection

8.1.3 Nameplate

Figure 31 shows the Nameplate tab. When nameplate data is available, it can be entered in this part. By tapping each text field, the keyboard will be opened, and the data can be easily entered. The nameplate data is optional to enter. It is also possible to add this information later by editing the test object.

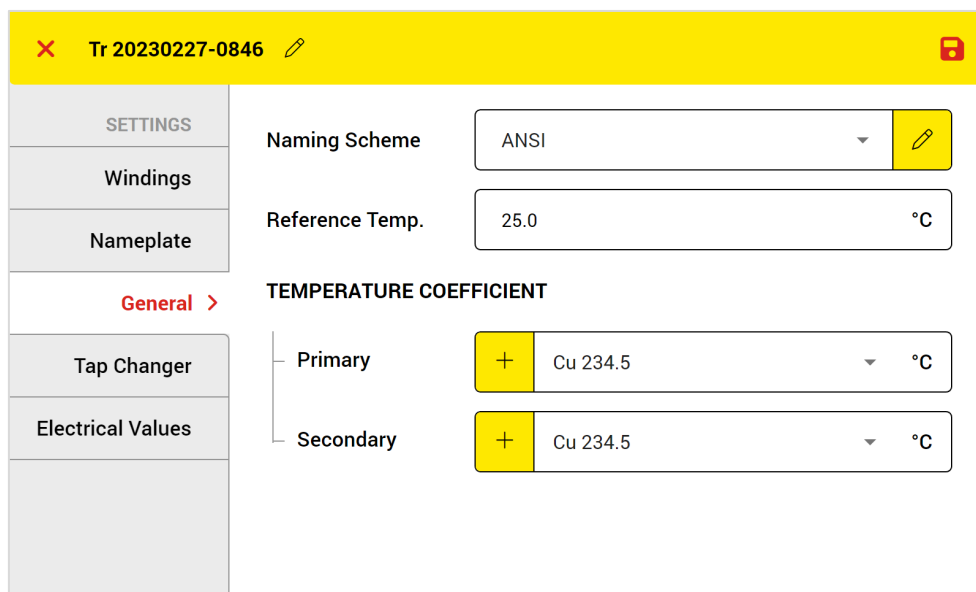


Tr 20230227-0846		
SETTINGS	Manufacturer	Secheron
Windings	Model	NT 32.440
Nameplate >	Year Built	1970
General	S/N	21649
Tap Changer	Max Rated Power	400 kVA
Electrical Values	Location	Bremgarten

Figure 31: Test object Nameplate tab

8.1.4 General

Within the general tab of the test object (Figure 32), you can input various test object details, which are described below.



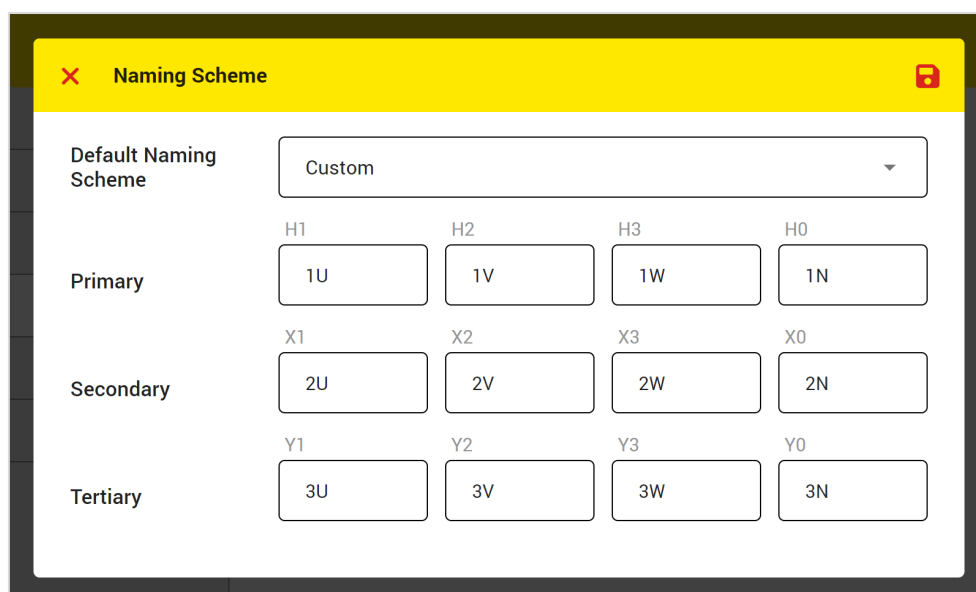
The screenshot shows the 'General' tab of the test object configuration window. The window has a yellow header bar with a close button (X), the text 'Tr 20230227-0846', and a save icon. On the left is a sidebar with tabs: SETTINGS, Windings, Nameplate, General (selected), Tap Changer, and Electrical Values. The main area displays the following settings:

- Naming Scheme:** A dropdown menu set to 'ANSI' with a pencil icon to its right.
- Reference Temp.:** A text input field containing '25.0' and a unit dropdown set to '°C'.
- TEMPERATURE COEFFICIENT:** A section with two rows:
 - Primary:** A yellow '+' button, a dropdown menu set to 'Cu 234.5', and a unit dropdown set to '°C'.
 - Secondary:** A yellow '+' button, a dropdown menu set to 'Cu 234.5', and a unit dropdown set to '°C'.

Figure 32: Test object General tab

Naming Scheme

Generally, there are different systems of terminal naming. The naming scheme of the test object can be changed here. Please note that the default naming scheme is the naming scheme which is previously selected in settings (chapter 7.4.3). When a custom naming scheme is required, it can be easily defined in the Naming Scheme window (Figure 33) which can be opened using the pencil icon.



The screenshot shows the 'Naming Scheme' window. It has a yellow header bar with a close button (X), the text 'Naming Scheme', and a save icon. The window contains the following elements:

- Default Naming Scheme:** A dropdown menu set to 'Custom'.
- Primary:** Four input fields for terminals H1, H2, H3, and H0, containing '1U', '1V', '1W', and '1N' respectively.
- Secondary:** Four input fields for terminals X1, X2, X3, and X0, containing '2U', '2V', '2W', and '2N' respectively.
- Tertiary:** Four input fields for terminals Y1, Y2, Y3, and Y0, containing '3U', '3V', '3W', and '3N' respectively.

Figure 33: Custom Naming Scheme window

Reference Temperature

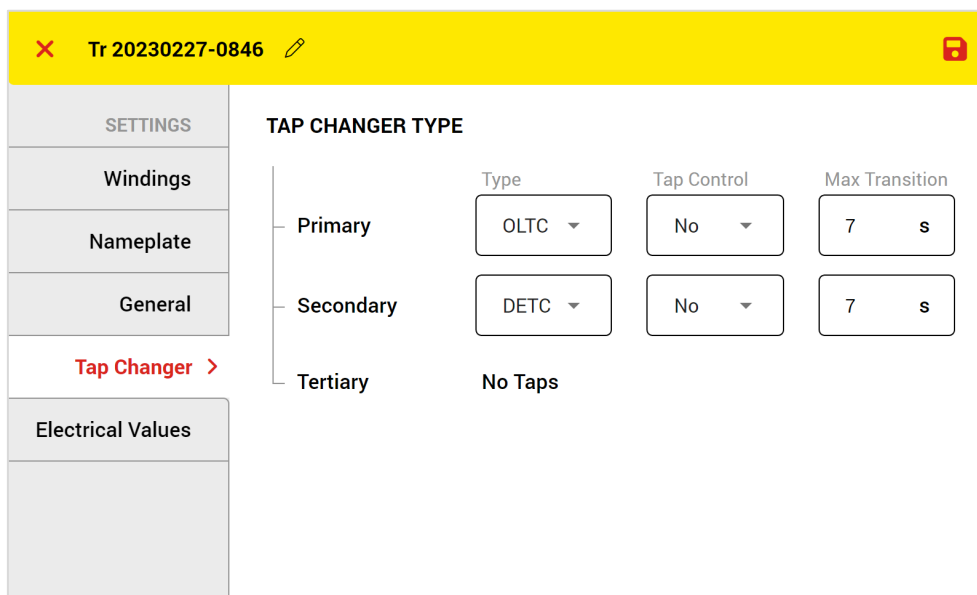
The reference temperature which is required for the temperature correction can be set here. For more details about the temperature correction principle, please see chapter 4.2.2.

Temperature Coefficient

The temperature coefficient which is required for the temperature correction can be set here for each winding. If a custom coefficient is required, the value can be added using the plus icon. For more details about the temperature coefficient, please see chapter 4.2.2.

8.1.5 Tap Changer

In the tap changer tab (Figure 34), the tap changers type for each winding side, the possibility to control the tap changer automatically and the maximum tap changing transition time can be entered. These are especially useful when the user would like to use the automatic tap control feature.



	Type	Tap Control	Max Transition
Primary	OLTC ▼	No ▼	7 s
Secondary	DETC ▼	No ▼	7 s
Tertiary	No Taps		

Figure 34: Test object tap control tab

Type

When multiple taps are present on a winding side, it indicates the presence of a tap changer for that particular winding. Tap changers can be broadly classified into two main types: De-Energized Tap Changer (DETC) and On Load Tap Changer (OLTC). DETC can only operate when the transformer is not energized, while OLTC has the capability to operate even while the transformer is energized.

Selecting the appropriate tap changer type is of utmost importance. In the case of OLTC, it is possible to measure the DC resistance for multiple taps without the need to switch off the DC power supply (please see chapter 10.7). However, it is crucial to exercise caution and avoid mistakenly selecting an OLTC type for a DETC tap changer. Applying DC current during tap changing on a DETC can lead to damage to the DETC contacts, ultimately resulting in transformer failure.



WARNING!

Do not select OLTC type for a DETC tap changer!
Keeping DC current on during tap changing of a DETC may damage the DETC contacts which cause a transformer failure!

Tap Control

If you connect the mini-ATOS tap control output to the tap changer control unit, choose Yes. The tap changer position then can be changed manually or automatically from the mini-ATOS. To find out how to connect the tap control cable, please refer to chapter 13.5.

Max Transition

The tap changer equipped with a motor undergoes a transition process to change the tap position, and it is essential to consider the maximum time required for this transition. It should be noted that under certain circumstances, the transition time may be extended. For instance, when the tap changing direction is altered, the transition time can be doubled. Therefore, it is crucial to input the longest transition time from all possible scenarios. Failing to do so may prompt mini-ATOS to initiate the next tap position measurement while the tap changing process is still ongoing, resulting in inaccurate measurements and potential harm to the tap changer, particularly if it is of the DETC type.

8.1.6 Electrical Values

In the test object electrical values tab (Figure 35), the rated voltage and label for each tap can be entered. The Rated Voltage values will be used by various measurements to calculate and provide additional parameters. Labels will be also used as tap names.

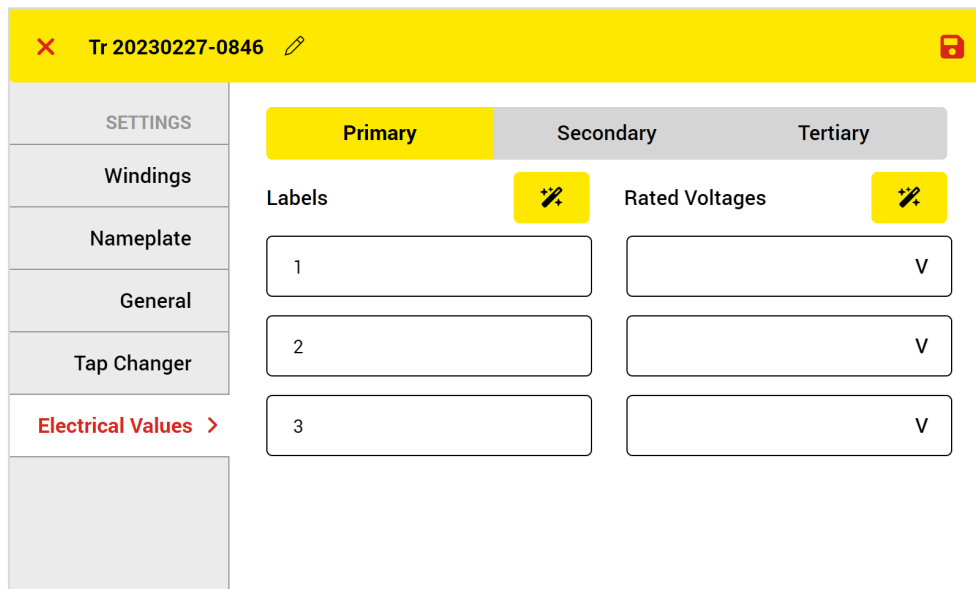


Figure 35: Test object Electrical Values tab

It is also possible to use wizards to enter the values easier. The following example, using the power transformer with tap information according to Table 8, explains how they work.

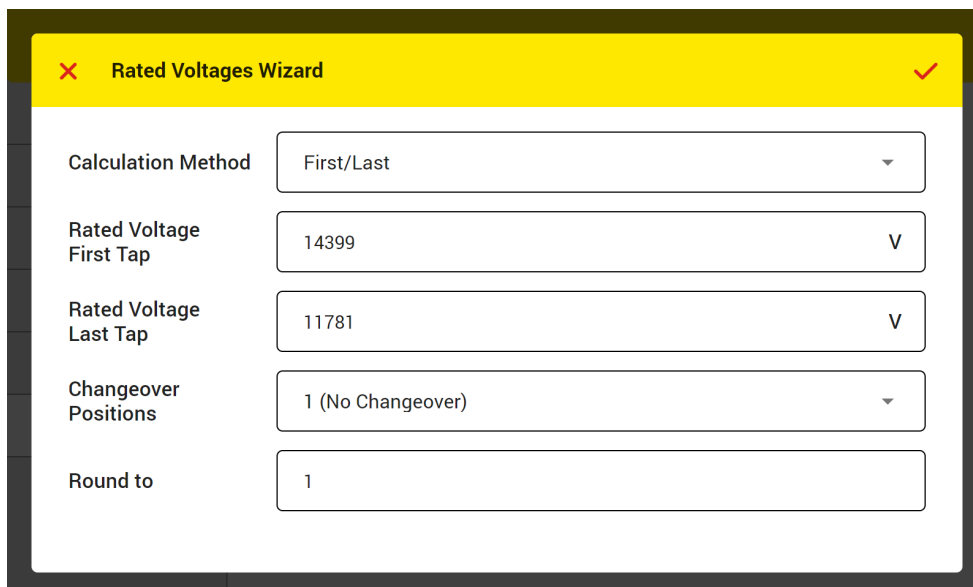
Table 8: Example: power transformer information

Primary Taps		Secondary Taps					
Label	Voltage [V]	Label	Voltage [V]	Label	Voltage [V]	Label	Voltage [V]
1	70350	16R	14399	5R	13499	6L	12599
2	68675	15R	14317	4R	13417	7L	12517
3	67000	14R	14235	3R	13335	8L	12436
4	65325	13R	14154	2R	13254	9L	12354
5	63650	12R	14072	1R	13172	10L	12272
		11R	13990	N	13090	11L	12190
		10R	13908	1L	13008	12L	12108
		9R	13826	2L	12926	13L	12026
		8R	13745	3L	12845	14L	11945
		7R	13663	4L	12763	15L	11863
		6R	13581	5L	12681	16L	11781

Rated Voltages Wizard

In the Rated Voltages Wizard, there are two calculation methods:

First/Last method



The screenshot shows a software window titled "Rated Voltages Wizard" with a yellow header bar containing a red 'X' icon on the left and a red checkmark icon on the right. The main area is white and contains five input fields arranged vertically:

- Calculation Method:** A dropdown menu with "First/Last" selected.
- Rated Voltage First Tap:** A text input field containing "14399" and a unit dropdown menu set to "V".
- Rated Voltage Last Tap:** A text input field containing "11781" and a unit dropdown menu set to "V".
- Changeover Positions:** A dropdown menu with "1 (No Changeover)" selected.
- Round to:** A text input field containing "1".

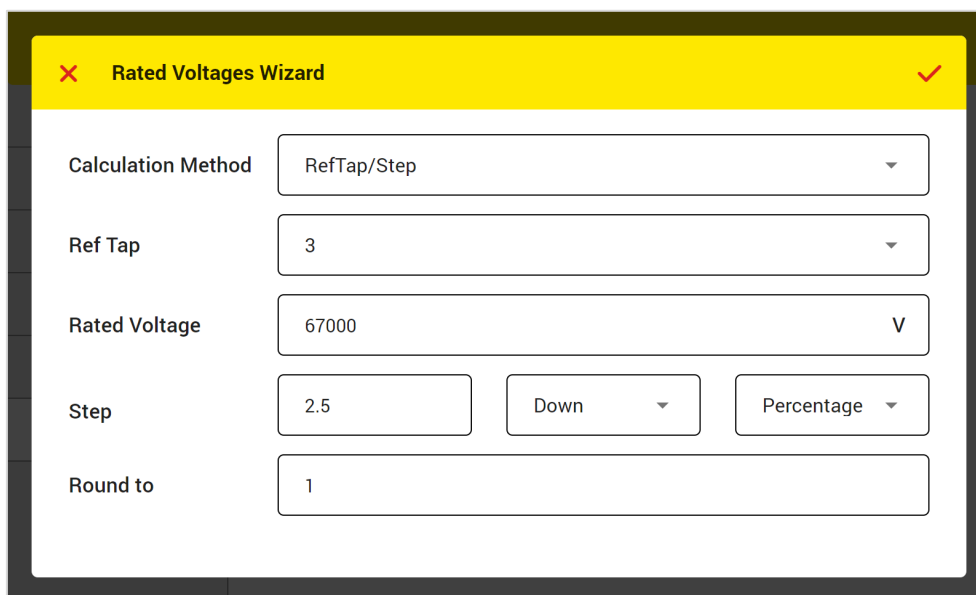
Figure 36: Rated Voltage Wizard, First/Last method

In this method, we have to enter the first tap and the last tap Ph-Ph nominal voltage. Figure 36 shows how to fill out the form for the secondary side of the example.

Some transformers have a tap changer changeover with more than one tap with the same voltage in the middle. In such cases, the number of changeover positions with the same voltage has to be also entered only if the tap changer can stay in these positions.

To match the calculated values to nameplate values, it is also possible to tell the wizard how to round the calculated values. The default value is 1, which means that all calculated values round to the nearest natural number.

RefTap/Step Method



Rated Voltages Wizard	
Calculation Method	RefTap/Step
Ref Tap	3
Rated Voltage	67000 V
Step	2.5
Direction	Down
Step Unit	Percentage
Round to	1

Figure 37: Rated Voltage Wizard, RefTap/Step method

In this method, by entering the rated voltage of the reference tap position and the step value between each two tap positions, all nominal voltages for all tap positions will be calculated and filled out automatically.

The RefTap is the tap position of the transformer rated voltage. The reference tap is usually the middle tap position.

The Rated Voltage is the Ph-Ph rated voltage of the power transformer which is always written on the nameplate.

The step voltage amount can be in V per step or % per step. The amount can be determined from the nameplate by subtracting the voltage values of two consecutive taps which are usually written on the nameplate.

Figure 37 shows how to fill the wizard for the primary side of the example.

When the tap changer is located on the primary side, usually the nominal voltage of the first tap is the highest voltage and for the other taps, the nominal voltage decreases. In this case for the direction, Down must be selected. The opposite is usually valid for the transformers with a tap changer on the LV side and Up must be selected for the Direction.

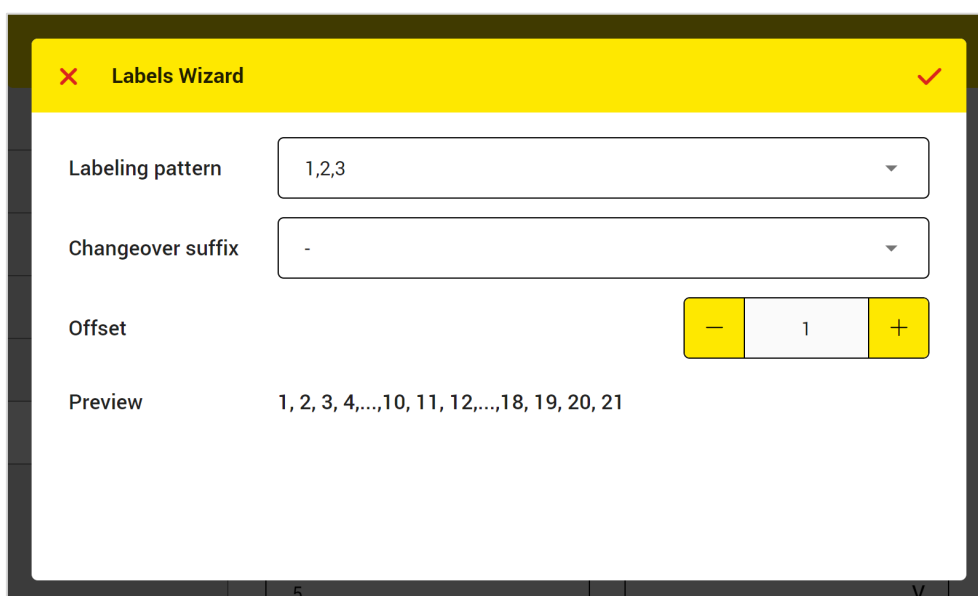
To match the calculated values to nameplate values, it is also possible to say the wizard how to round the calculated values. The default value is 1, which means that all calculated values round to the nearest natural number.

✂ Labels Wizard

If the default label does not match the actual tap labels, the Labels Wizard will be helpful to define a label for each tap easier. Figure 38 shows the Labels Wizard window. The first item is the Labelling pattern which is used to choose the system of labelling. When there are changeover positions, their labels can be adjusted by using the Changeover suffix item.

When it is required, by editing the Offset, it is possible to start the labelling from any number.

Finally, there is a Preview, which shows how will be the labels by using the wizard.



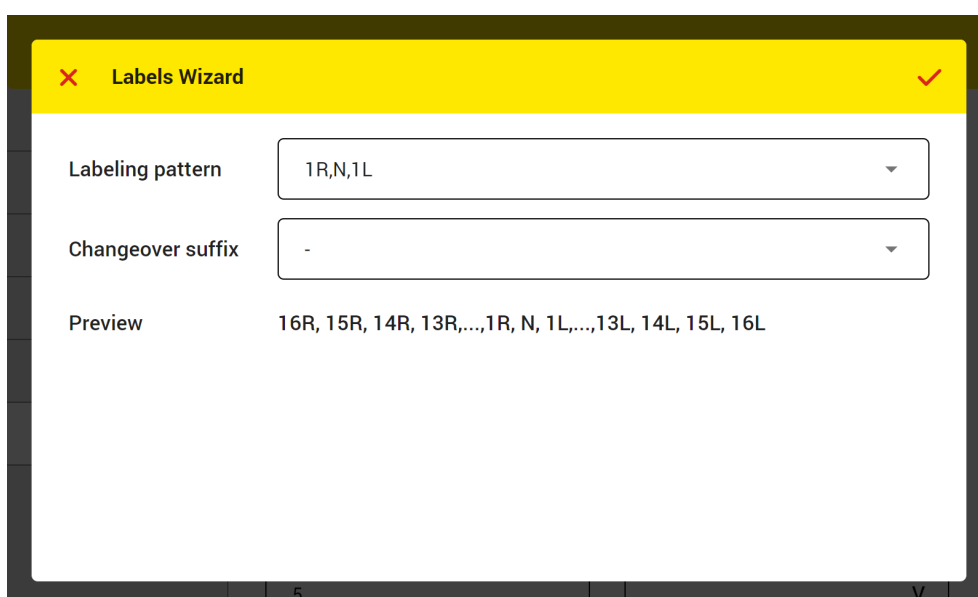
The image shows the 'Labels Wizard' window with a yellow header bar containing a red 'X' icon and a red checkmark icon. The window has four main sections:

- Labeling pattern:** A dropdown menu showing '1,2,3'.
- Changeover suffix:** A dropdown menu showing '-'.
- Offset:** A numeric input field with a value of '1', flanked by yellow buttons with '-' and '+' symbols.
- Preview:** A text field displaying the sequence '1, 2, 3, 4,...,10, 11, 12,...,18, 19, 20, 21'.

At the bottom of the window, there is a dark grey bar with a '5' in the center and a 'V' on the right side.

Figure 38: Labels wizard window

Figure 39 shows also how to fill the wizard for the secondary side of the example.



The image shows the 'Labels Wizard' window with a yellow header bar containing a red 'X' icon and a red checkmark icon. The window has three main sections:

- Labeling pattern:** A dropdown menu showing '1R,N,1L'.
- Changeover suffix:** A dropdown menu showing '-'.
- Preview:** A text field displaying the sequence '16R, 15R, 14R, 13R,...,1R, N, 1L,...,13L, 14L, 15L, 16L'.







At the bottom of the window, there is a dark grey bar with a '5' in the center and a 'V' on the right side.

Figure 39: filling the labels wizard for the example

8.2 Autotransformer

To define a new autotransformer test object, just tap the autotransformer on the home page from the new blank test object part. Defining an autotransformer is like defining a power transformer which is described in chapter 8.1. However, the possible winding configurations are according to Table 9.

Table 9: Winding types and symbols for autotransformer

Phases	Type	Letter (Primary)	Symbol	Letter (Secondary)	Symbol
3-Phases	Star with accessible neutral	YN		Ya	
	Star	Y		Ya	
1-Phase	Single-phase	S		Sa	

8.3 Phase Shifter Transformer

A phase shifter transformer can be defined simply by tapping on the phase shifter transformer icon on the home page from the new blank test object part. It is mainly like defining a power transformer which is explained in chapter 8.1.

It is also possible to detect the actual phase shift value by tapping on the detect button.



When needed, the nominal phase shift value can be entered manually (or automatically by using the detect button). The measured phase shifting values in the measurements will be shown then relative to the nominal value.


Please note that not all of measurement methods are possible to perform on a phase shifter transformer now.

9 Inspection and Test Plan

In the lifetime of a high voltage asset, usually a measurement or group of measurements have to be performed periodically and also sometimes occasionally. The aim is to inspect the health condition or to detect the suspected failures. In mini-ATOS, each group of measurements is called a Test Plan which forms an Inspection.

Figure 40 shows an example of a test plan for a 3-phase power transformer. It consists of a turn's ratio test, a winding resistance test and a demagnetization.

You can enable the edit mode (Figure 41) to adjust the order of measurements and add or remove them by tapping the edit icon . You can touch and hold the move icon  and try to change the position of each measurement item.

In each measurement item, the measurement Settings and the number of the tests performed from all the tests possible to perform are written. When you tap the measurement settings button , the setting window will be opened from the right side. To find out which settings are there for each measurement, please refer to chapter 10 and see each measurement method settings.

By tapping the yellow right arrow, the measurement view will be opened and from there it is possible to perform the test.

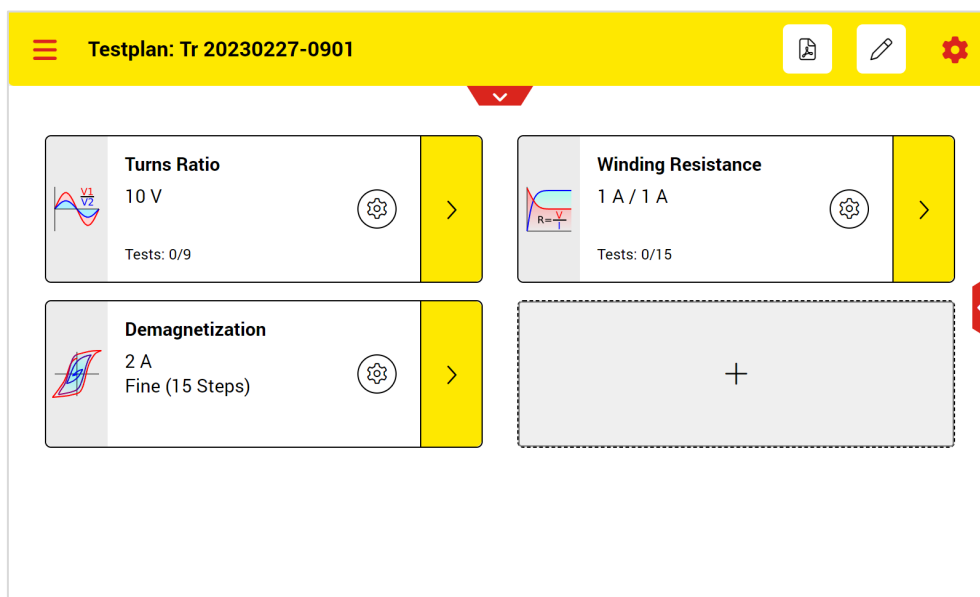


Figure 40: A Test Plan for a 3-phase power transformer

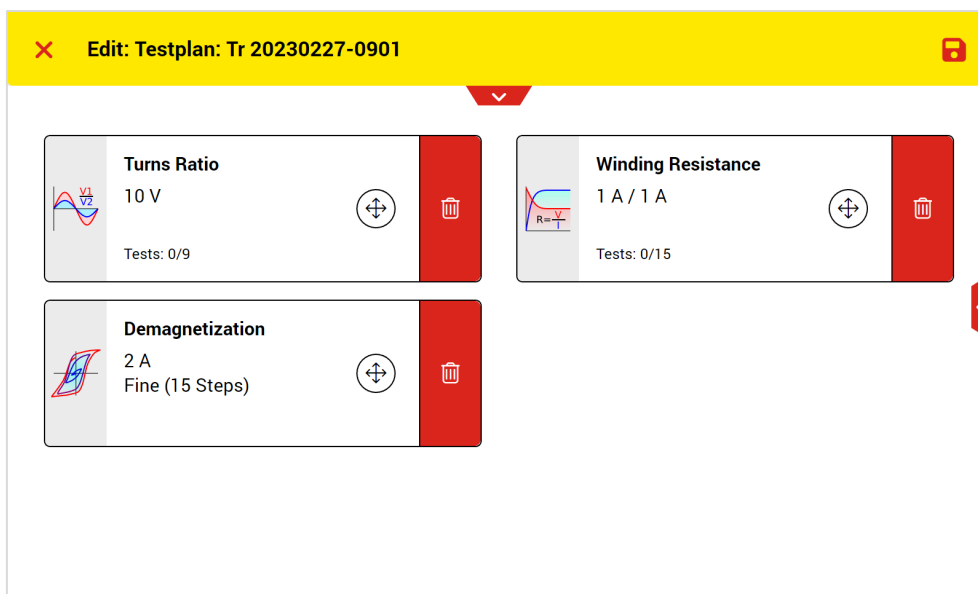


Figure 41: Test Plan edit mode

For the transformers with tertiary winding, for each pair of windings (Pri: Sec & Pri: Ter), there is a separate test plan. To see the test plan for each one, the desired pair of windings must be selected from the drop-down list located above (Figure 42). This drop-down list is only visible when there is a tertiary winding.

Note that when you select another pair of winding, the measurement setup must be changed according to chapter 5.1.

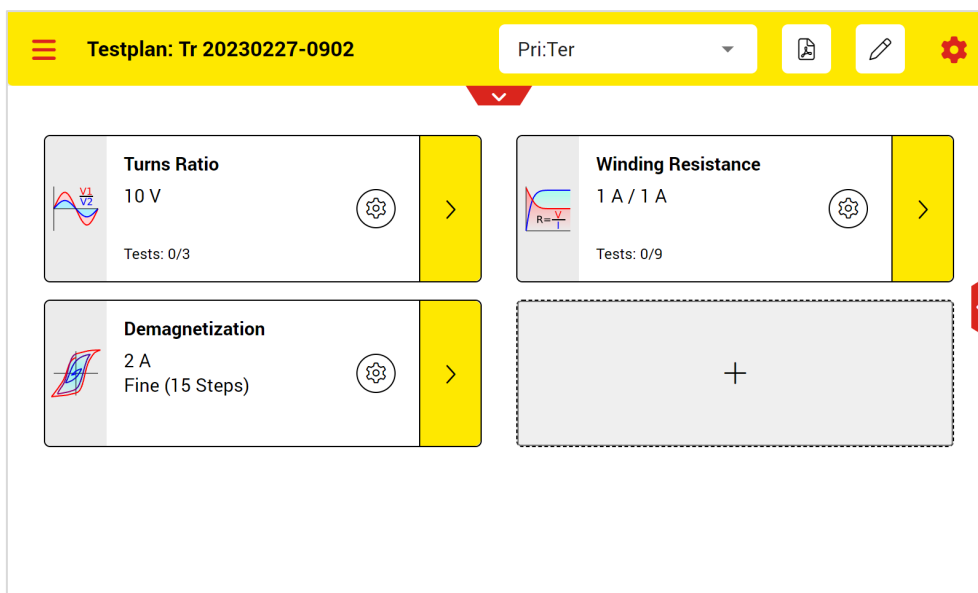



Figure 42: Test plan for Pri: Ter pair, which is selected from the drop-down list located above.

By tapping the setting icon on the top , you can open the Inspection Information (Figure 43). Here it is possible to edit the inspection name, enter the weather condition and write additional notes like the reason for the inspection as remarks for later reference.

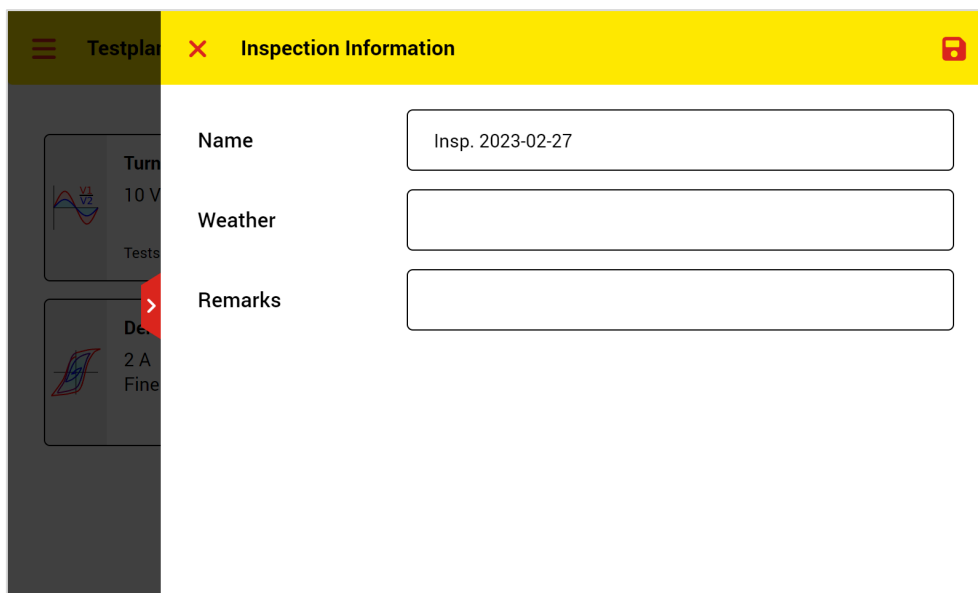


Figure 43: Inspection information

10 Measurements

10.1 Turns Ratio

Figure 44 shows the turns ratio measurement view and following that each part is explained.

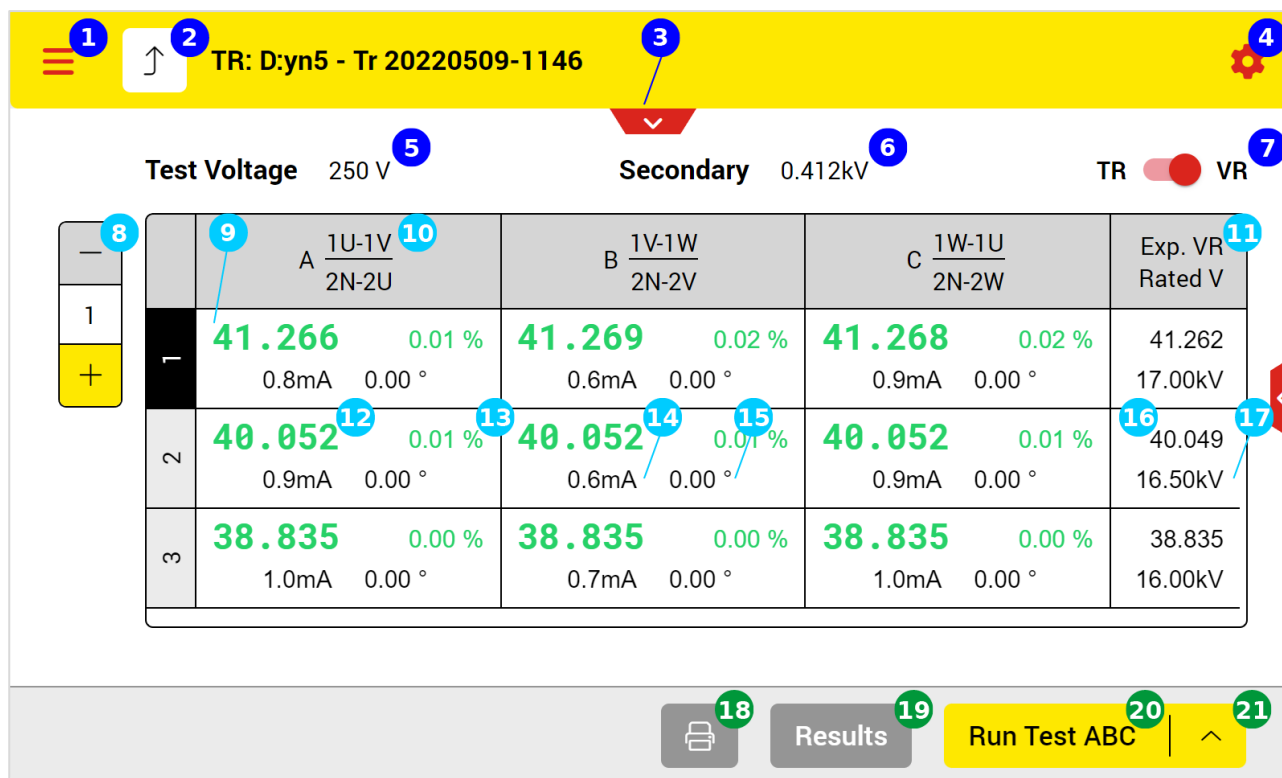


Figure 44: Turns Ratio measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access (For more information please see chapter 8)
- 4 Test settings (Please see chapter 10.1.2)
- 5 The selected test voltage that applies on the primary side during the measurement
- 6 The secondary side rated voltage
- 7 Change between voltage or turns ratios
- 8 The actual tap position of the selected view mode and to change it
- 9 Tap positions of the selected view mode. The actual is with the black background
- 10 The phase and the corresponding connections which be used automatically by the instrument to test each phase
- 11 Expected turns or voltage ratio
- 12 The measured turns or voltage ratio; green means that the relative error is less than the error limit and the test is passed otherwise it is red and failed
- 13 The calculated relative error in %; green means that the relative error is less than the error limit and the test is passed otherwise it is red and failed

- 14 The test current in mA
- 15 The measured angle between the applied voltage and the transformed voltage
- 16 The rated turns or voltage ratio
- 17 The rated voltage of each tap position
- 18 Print the selected tap position results by using the thermal printer
- 19 Open the detailed results in table view or graphs (chapter 10.1.3)
- 20 Start test button to perform the measurement
- 21 Test mode to select which phase to test (A, B, C, ABC, Run Test Taps)

The measurement view during the test is shown in Figure 45 and then the important parts are explained.

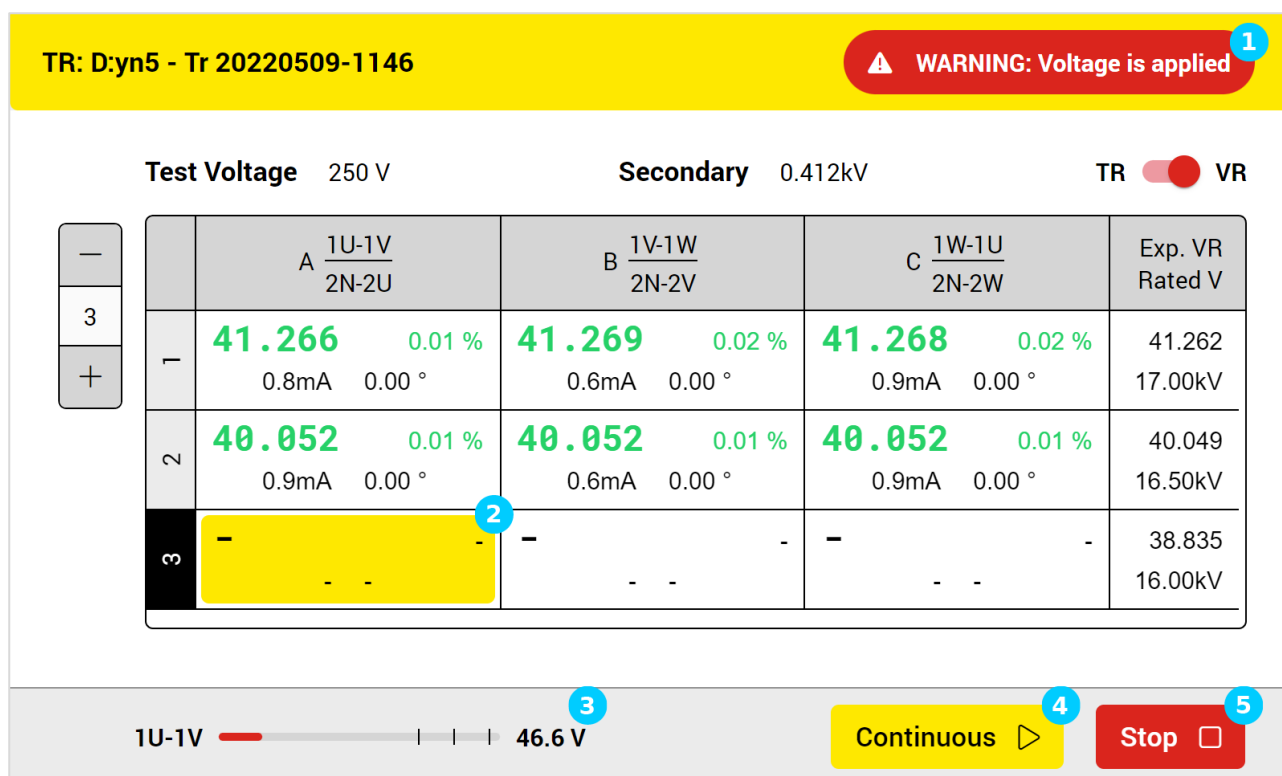


Figure 45: Turns Ratio measurement view during the test

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted cell shows which phase and tap are currently under the test
- 3 The output voltage bar shows what is the actual value of output voltage and which terminals are used to apply the voltage
- 4 By tapping the continuous button, the test mode changes from single-measurement to continuous mode and the test will not stop automatically. The instrument keeps performing the test on the phase under the test until the user's action
- 5 The stop button can be used to stop the test. Please note that it takes time to stop the test

10.1.1 Table view modes

When both the primary side and non-primary side of transformer windings have tap positions, it is not easy to show all measurements for all tap combinations in one table. Hence, to show the measurements easier, there are two table view modes. The first one is the primary table view mode. In this mode, for each tap position on the non-primary side, there is a measurement table consisting of all primary tap positions. The other view mode is the non-primary table view mode. In this mode, for each tap position on the primary side, there is a measurement table which includes all non-primary tap positions.

As an example, assume that there is transformer with 5 taps (1 to 5) on the primary side, and 33 taps (16R to 16L) on the secondary side. Figure 46 shows the primary view mode. In this mode for each of the secondary taps, there is table with 5 primary taps (33 tables, each 5 taps). The secondary selected tap is shown on the top and it is possible to change it.

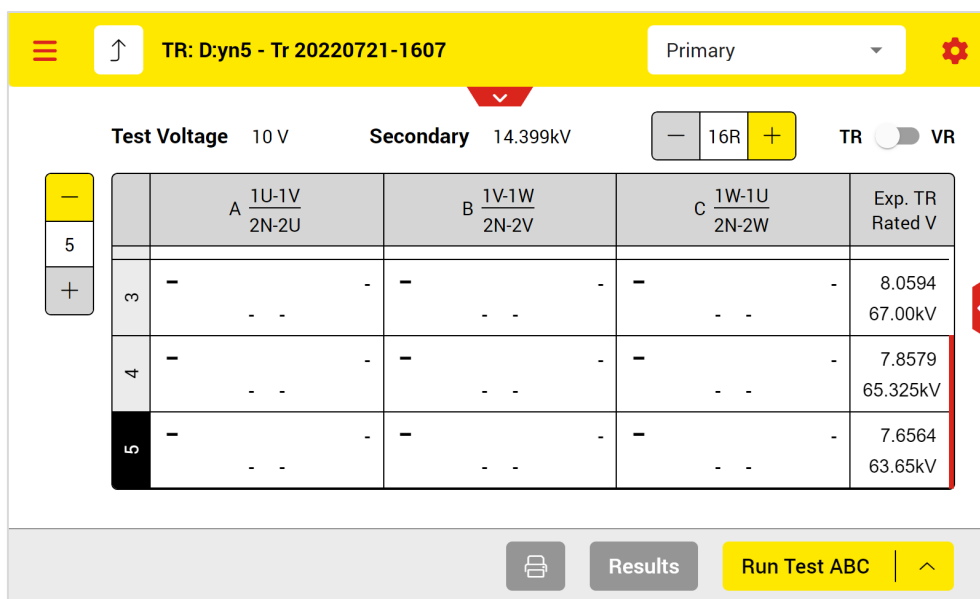


Figure 46: Turns ratio primary view mode

Figure 47 shows on the other hand the secondary view mode. This time for each of the primary taps, there is table with 33 secondary taps (5 tables, each 33 taps). The primary selected tap is also shown on the top and it is possible to change it.

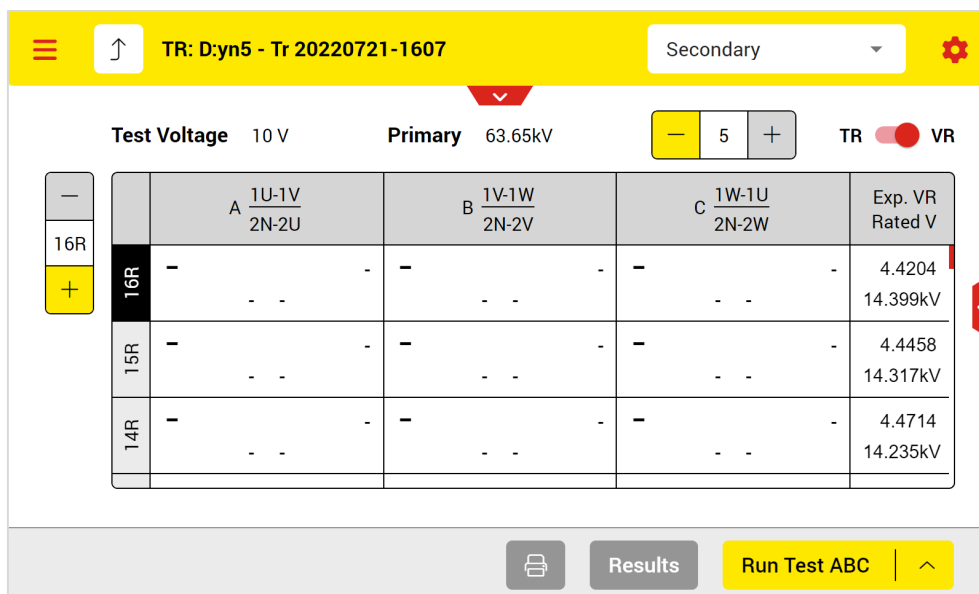


Figure 47: Turns ratio secondary view mode

10.1.2 Turns ratio settings

In Figure 48 the turns ratio setting can be seen. The test voltage can be selected from 10VAC, 40VAC, 100VAC or 250VAC. You can also add user-defined test voltages to this list by tapping on the + button. The user-defined voltage can be any voltages between 2VAC and 250VAC.

The maximum acceptable ratio error can also be adjusted by editing the Max Error field. The default value according to standards is 0.5%.

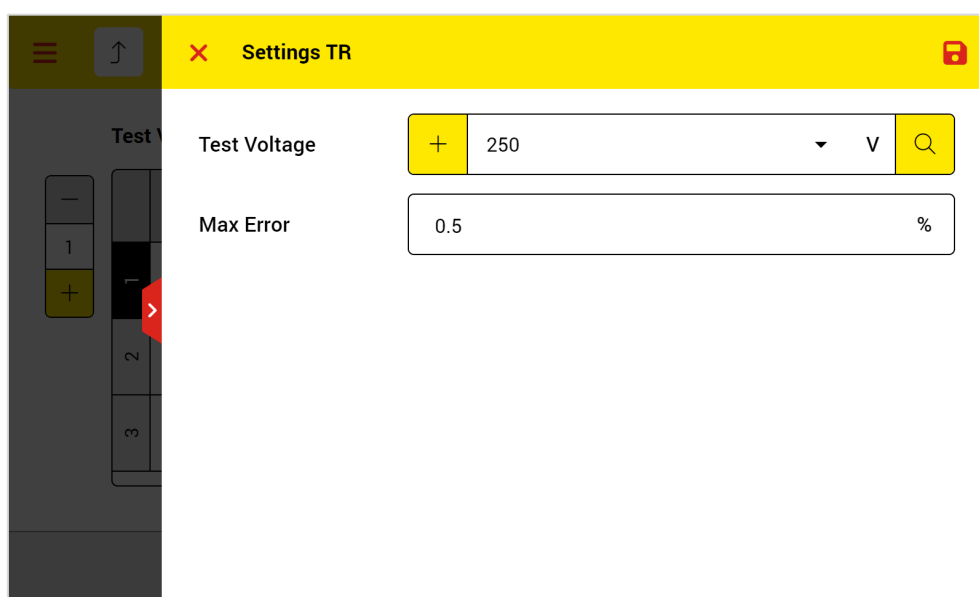


Figure 48: Turns ratio settings



Auto Detect Voltage

It is also possible to find out what is the suitable test voltage for a specific test object. Just tap the search icon, and run detection in the Auto detect voltage window (Figure 49).

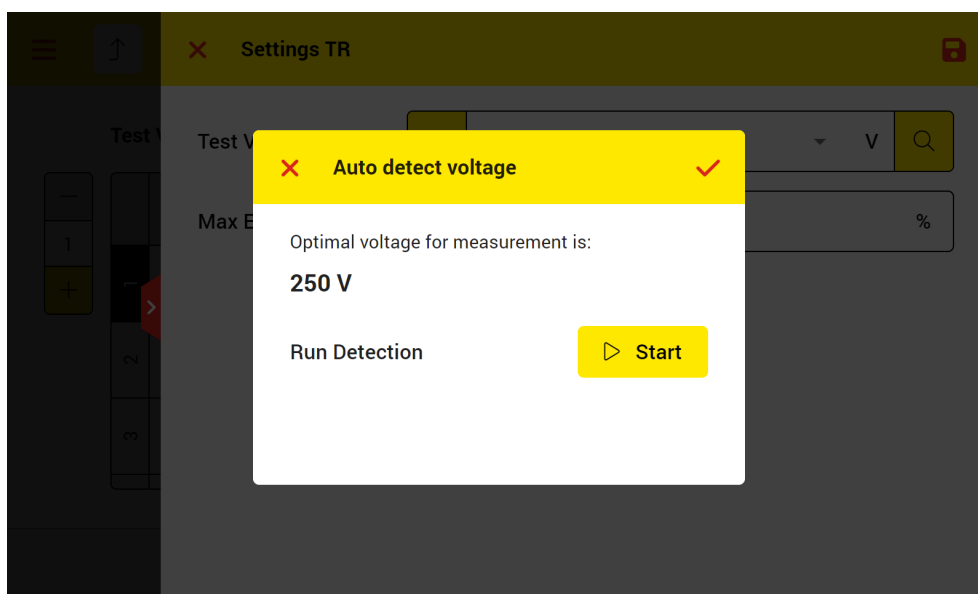


Figure 49: Turns ratio suitable test voltage auto detection

10.1.3 Turns Ratio Results View

By tapping the Results button in the turns ratio measurement view, the result view will be opened. The result view includes graphs and a table. Figure 50 shows the turns ratio graph view. From the drop-down list on top right, it is possible to select various graphs. These are the turns ratio, voltage ratio and error graph.

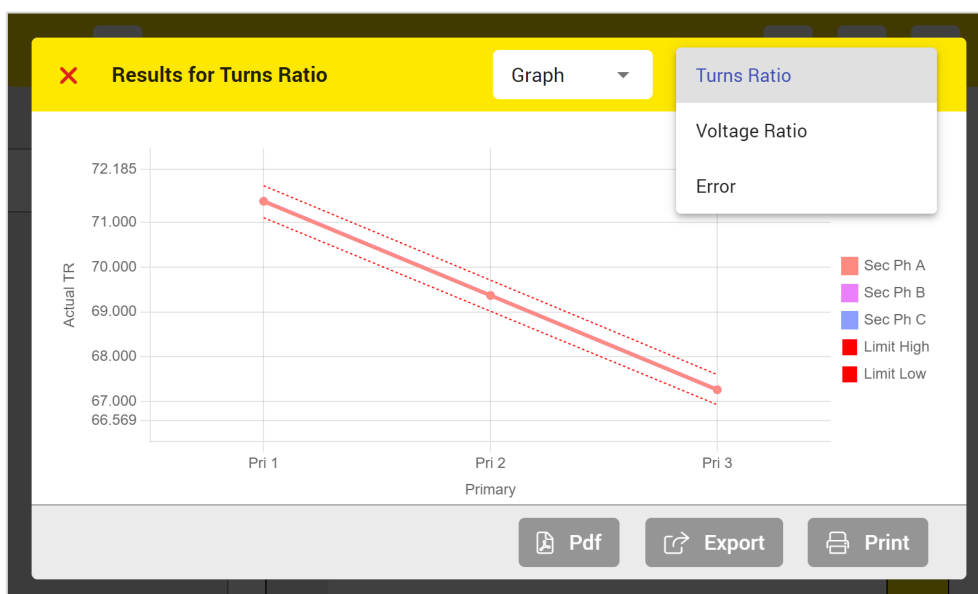



Figure 50: Turn ratio graph results view

Figure 51 shows also the turns ratio table results. By tapping the TR or the Rated TR column header, it is possible to switch between turns ratio and voltage ratio values.


Results for Turns Ratio

Table

Turns Ratio

Prim Tap	Prim U[V]	Sec U[V]	Ph.	TR	Rated TR	Error [%]	I _{Test} [A]	Angle [°]	Pass
1	17.00 k	0.412 k	A	71.474	71.468	0.01	0.8 m	0.00	Yes
1	17.00 k	0.412 k	B	71.480	71.468	0.02	0.6 m	0.00	Yes
1	17.00 k	0.412 k	C	71.479	71.468	0.02	0.9 m	0.00	Yes
2	16.50 k	0.412 k	A	69.371	69.366	0.01	0.9 m	0.00	Yes
2	16.50 k	0.412 k	B	69.372	69.366	0.01	0.6 m	0.00	Yes
2	16.50 k	0.412 k	C	69.371	69.366	0.01	0.9 m	0.00	Yes




 Pdf
 Export
 Print

Figure 51: Turns ratio table results view

10.2 Winding Resistance

Figure 52 shows the measurement view of the primary winding resistance test and following that each part is explained.

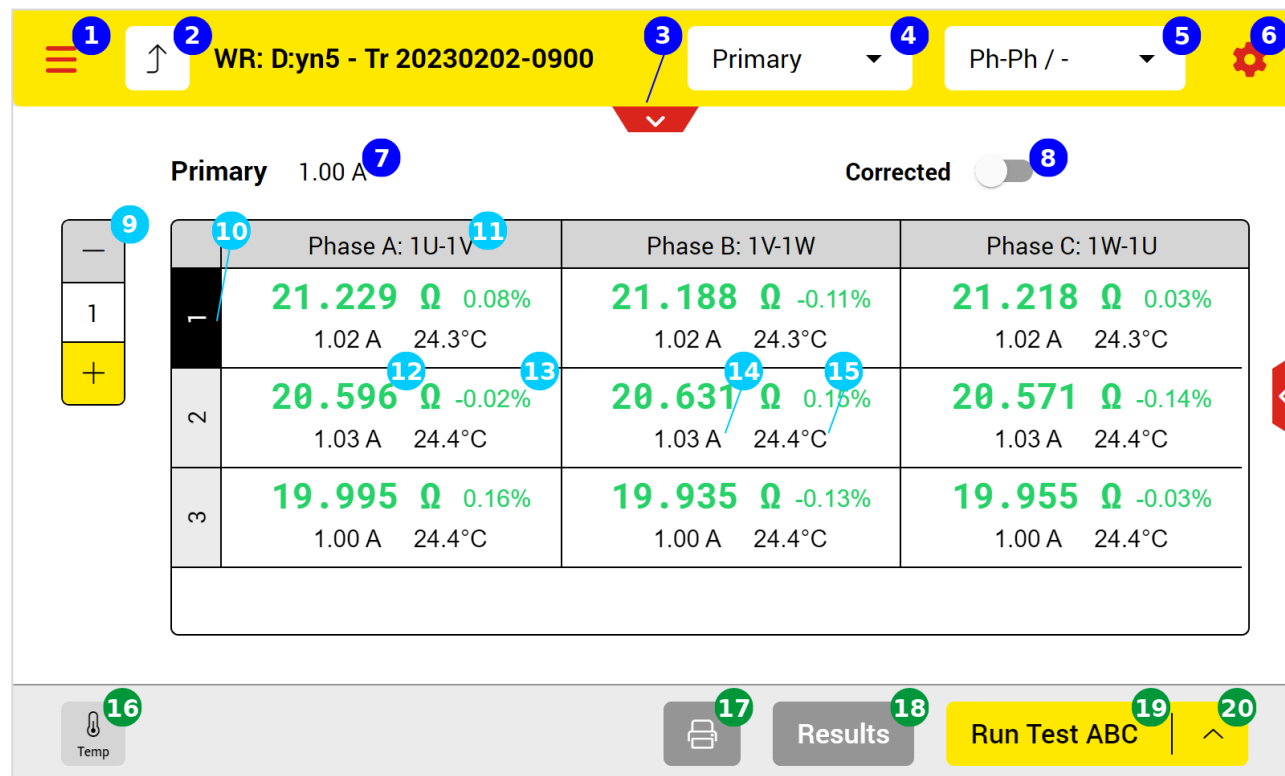


Figure 52: Winding resistance measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Select the transformer's side to test or to select dual supply mode
- 5 To select test phase to phase or phase to neutral measurement when possible
- 6 Test settings
- 7 The selected current that injects into the selected winding side
- 8 To enable or disable the temperature-corrected resistance view
- 9 The actual tap position of the selected view side and to change it
- 10 Tap positions of the selected winding side. The actual is with the black background
- 11 The phase and the corresponding connections which be used automatically by the instrument to test each phase
- 12 The measured winding resistance (temperature corrected or not corrected depending on selection)
- 13 The deviation value from the 3 phases average; green means the deviation is less than the limit and the test is Passed. See chapter 4.2.3 for more information
- 14 The measured test current which was used

- 15 The measured temperature during the measurement or the reference temperature when resistance is corrected
- 16 To see the actual measurement value of each temperature measurement channel (See Figure 59)
- 17 Print the selected tap position results by using the thermal printer
- 18 Open the detailed results in table view or graphs
- 19 Start test button to perform the measurement
- 20 Test mode to select which phase to test (A, B, C, ABC, Run Test Taps)

The winding resistance measurement view during the test is shown in Figure 53 and following it, important parts are explained.

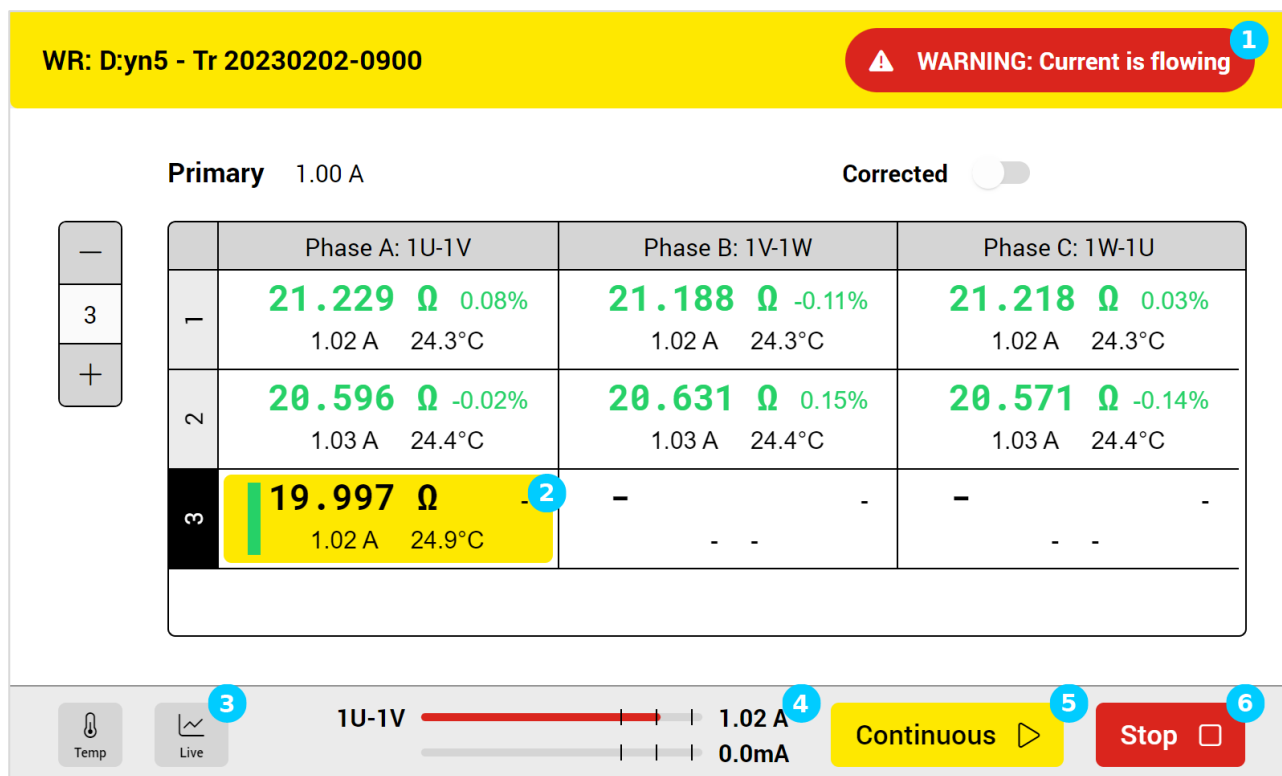


Figure 53: Winding resistance measurement view during the test

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted cell shows which phase and tap are currently under the test
- 3 Here you can open the live graph to see the live resistance curve over time (Figure 55). It is visible only during a measurement
- 4 The output current bars show what is the actual value of the output current for each channel and which terminals are used to inject the currents.
- 5 By tapping the continuous button³, the test mode changes from single-measurement to continuous mode and the test will not stop automatically. The instrument keeps performing the test on the phase under the test until the user's action
- 6 The stop button can be used to stop the test. Please note that it takes time to discharge and stop the test



WARNING!

After measurement stop, it takes time to discharge the test object! Wait until the device mode changes to safe mode before any other action!

³ When the ambient temperature is above 40°C, Continuous mode winding resistance measurement, specially with maximum output power, must be limited to 30 minutes and before the next measurement a cooldown time of 30 minutes is required.

When measuring at the non-primary side, there is an additional option to decrease the transformer charging time by charging the transformer from the primary winding at the same time. The current will be injected into the primary winding, but no resistance will be measured. You can activate or deactivate this option with the button on the top-right (Figure 54).

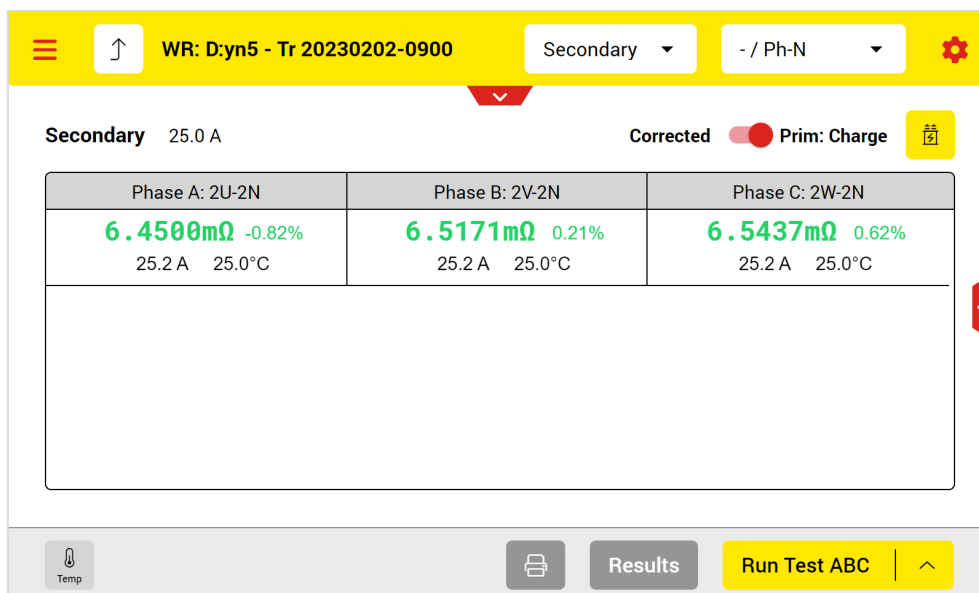


Figure 54: Winding resistance measurement view for the Secondary

Figure 55 is the live graph which shows the live resistance curve over time.

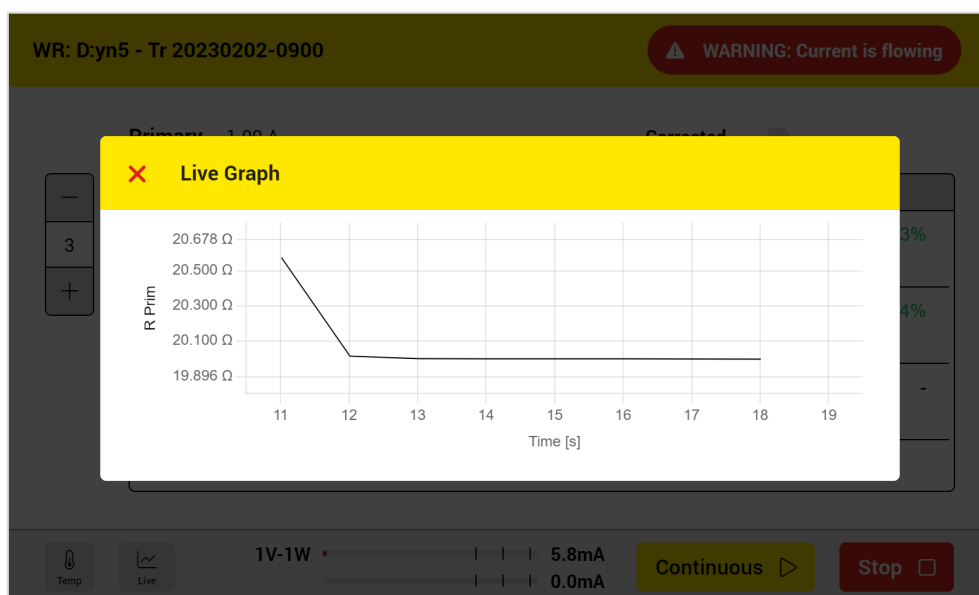


Figure 55: Winding resistance live graph

10.2.1 Dual Supply Winding Resistance

It is also possible to measure the two transformer sides simultaneously by selecting the Dual Supply mode. Figure 56, Shows the winding resistance measurement in dual supply mode and important parts are explained.

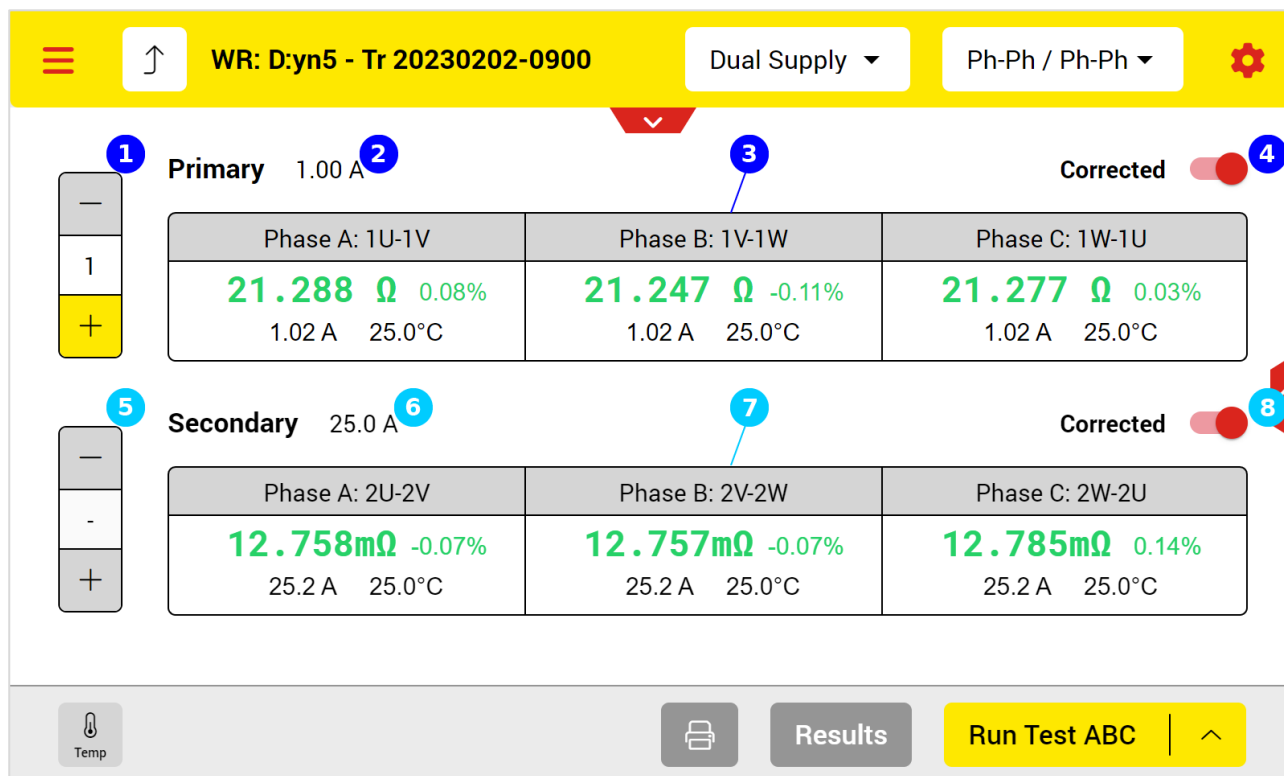


Figure 56: Winding resistance measurement in dual supply mode

- 1 The actual tap position of the primary side (if it contains a tap changer)
- 2 The selected current that injects into the primary winding side
- 3 The measurement table view of the primary side
- 4 To enable or disable the temperature-corrected resistances view for the primary
- 5 The actual tap position of the non-primary side (if it contains a tap changer)
- 6 The selected current that injects into the non-primary winding side
- 7 The measurement table view of the non-primary side
- 8 To enable or disable the temperature-corrected resistances view for non-primary

10.2.2 Winding Resistance Settings

Figure 57 shows the winding resistance main settings.

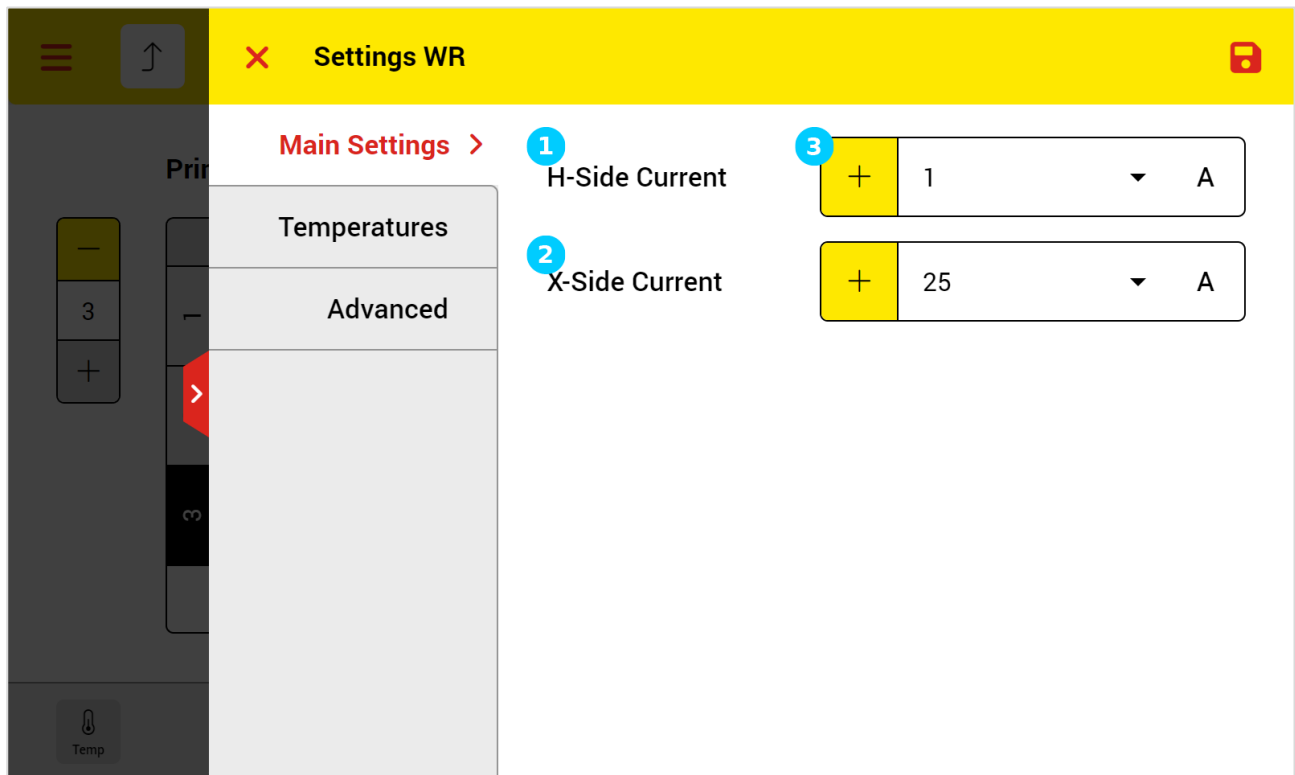


Figure 57: Winding resistance main settings

- 1 To select the H-Side current that injects into the primary winding side
- 2 To select the X-Side current that injects into the non-primary winding side
- 3 By tapping on the plus button, you can add a user-defined test current to the list of test currents



INFO:

Do not select currents more than 10% of the test object nominal current for each side. Otherwise, current will increase the temperature and hence resistance of the winding.

Figure 58 shows the winding resistance temperature settings.

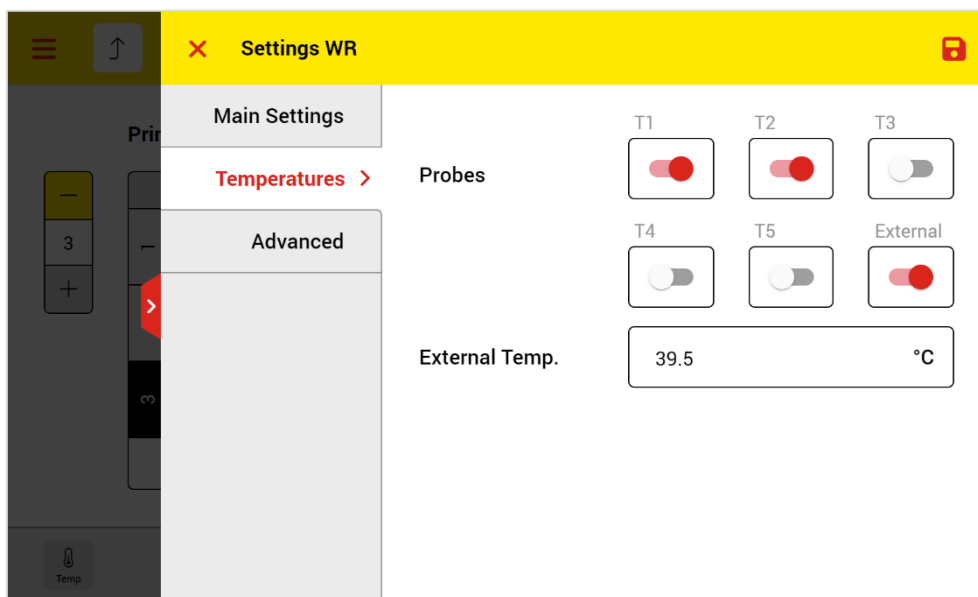


Figure 58: Winding resistance temperature settings

In temperature settings, it is possible to enable each of the 5 temperature channels to record. When there is an external temperature probe, the External switch should be enabled. The reading value must be also entered manually.

The mini-ATOS use the average of all activated temperature values for the temperature correction.

In the live temperatures window (Figure 59) which can be opened from the bottom-left corner of the measuring screen, you can see the actual temperature values. Here T1 is plugged in and also activated in the setting. T3 is not activated but plugged in. If a temperature channel is activated but not plugged in, the mini-ATOS will display an error message after starting the measurement.

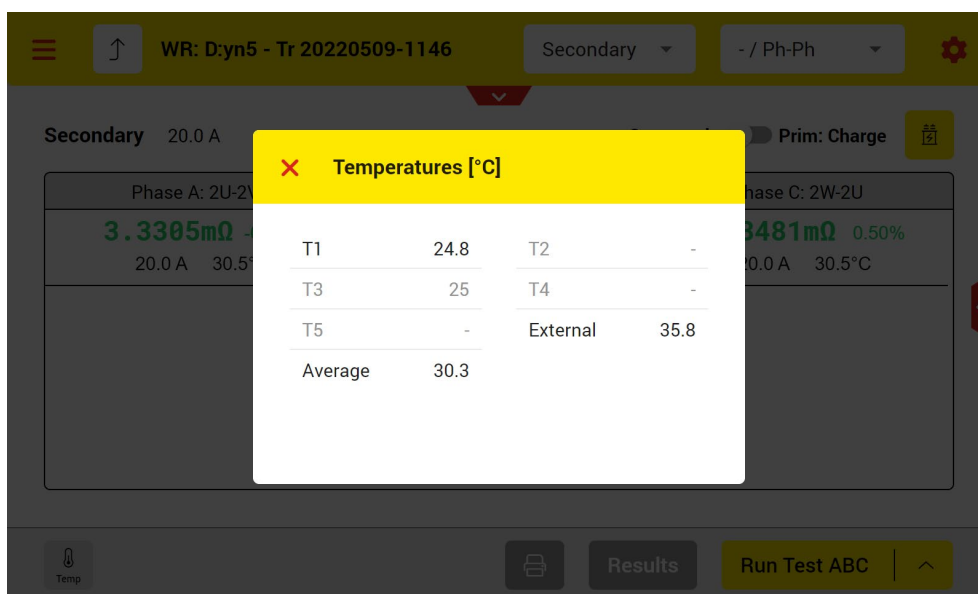


Figure 59: Actual Temperature values

Figure 60 shows the winding resistance advanced settings.

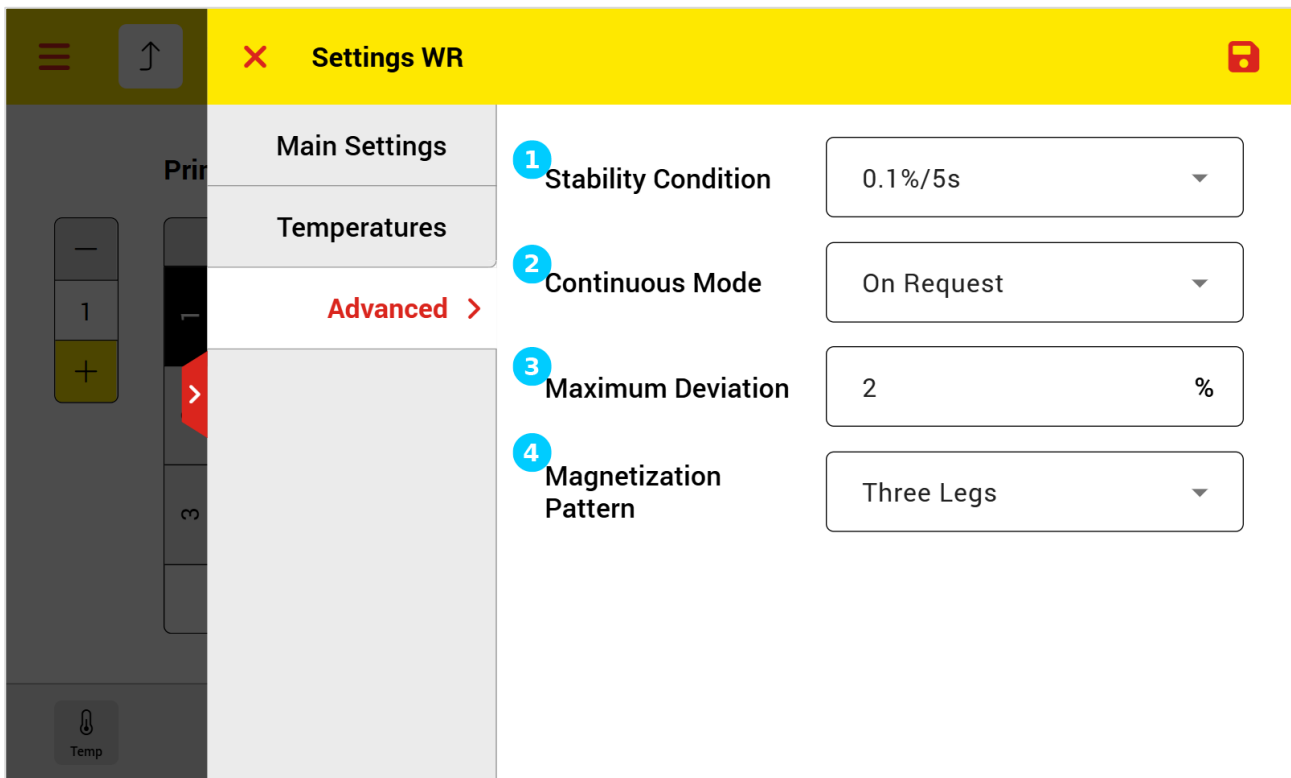


Figure 60: Winding resistance advanced settings

- 1 The stability condition is a reference for the device to decide if the resistance value during a measurement is considered stable or not. For example, 0.1%/5s means that if the resistance fluctuations keep less than 0.1% of the average value continuously for more than 5 seconds, it will be considered stable
- 2 When the continuous mode is “On Request”, one can activate the continuous mode only by tapping on the continuous button. When the mode is “Always”, the continuous mode is always activated automatically.
- 3 The maximum acceptable deviation value. Please see chapter 4.2.3 for more information
- 4 Select here the three-phase transformer’s core design. mini-ATOS will use an optimal magnetization pattern during the measurement. This will enhance the speed of test and charging. The core design can be three legs or five legs/Shell type.

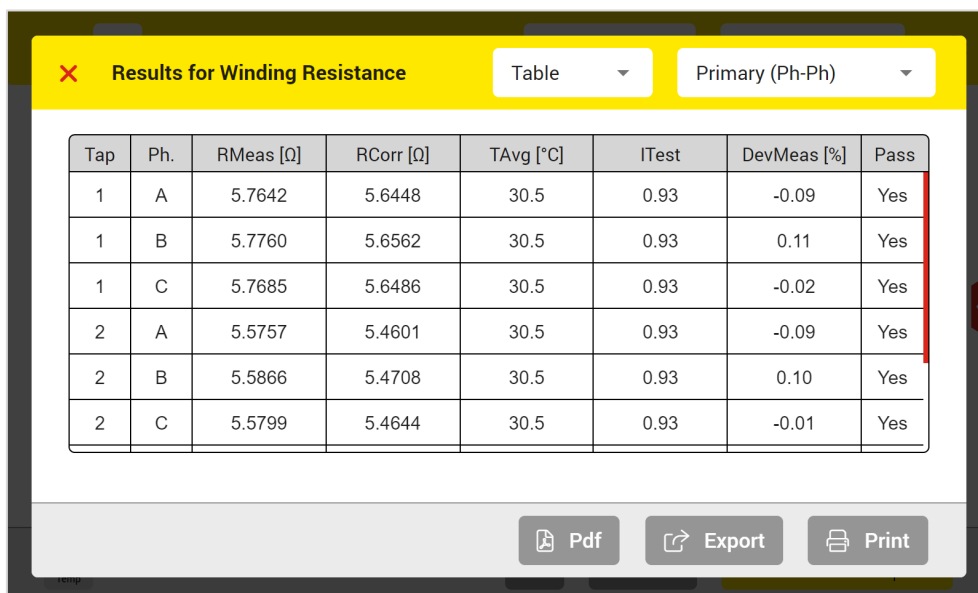
10.2.3 Winding Resistance Result View

By tapping the Results button in the measurement view, the result view will be opened. The result view includes graphs and tables. Figure 61 shows the Primary (Ph-Ph) winding resistance graph view. From the drop-down list on top right, it is possible to select also other graphs.



Figure 61: Winding resistance graph results view

Figure 62 shows also the Primary (Ph-Ph) table results. By tapping the DevCorr column header, it is possible to switch between deviation for measured values or temperature corrected values.



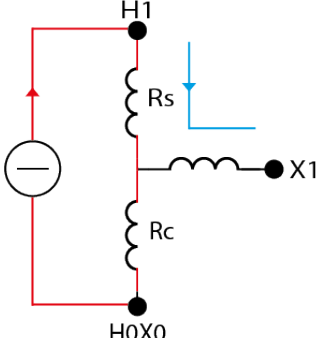
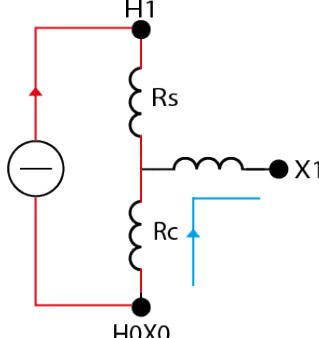
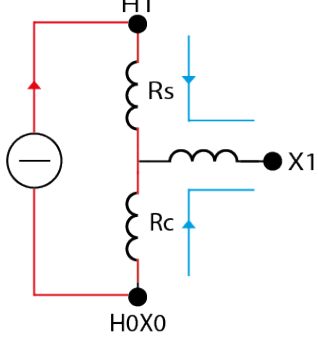
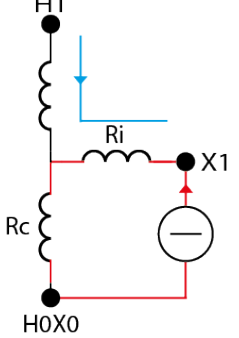
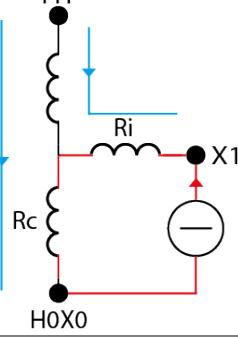
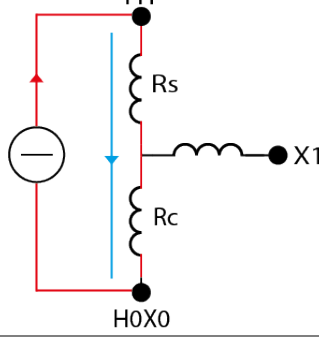
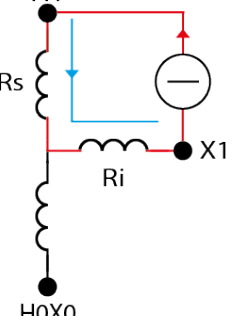
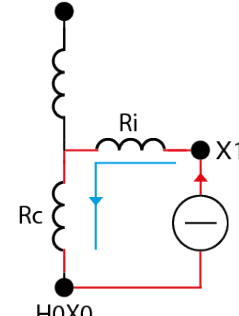
Tap	Ph.	RMeas [Ω]	RCorr [Ω]	TAvg [°C]	ITest	DevMeas [%]	Pass
1	A	5.7642	5.6448	30.5	0.93	-0.09	Yes
1	B	5.7760	5.6562	30.5	0.93	0.11	Yes
1	C	5.7685	5.6486	30.5	0.93	-0.02	Yes
2	A	5.5757	5.4601	30.5	0.93	-0.09	Yes
2	B	5.5866	5.4708	30.5	0.93	0.10	Yes
2	C	5.5799	5.4644	30.5	0.93	-0.01	Yes

Figure 62: Winding resistance table results view

10.2.4 Autotransformer Winding Resistance

Mini-ATOS has special winding resistance measurement method for Autotransformers. The parameters and method of measurement are summarized in Table 10. The method of measurement in Table 10 is for phase A of a star-null autotransformer.

Table 10: The autotransformer winding resistance parameters and measurement methods

<p>Rserie</p> 	<p>Rcommon</p> 
<p>Rserie & Rcommon</p> 	<p>Rinline</p> 
<p>Rcommon & Rinline</p> 	<p>RH (Rs + Rc)</p> 
<p>RHX (Rs + Ri)</p> 	<p>RX (Ri + Rc)</p> 

The measurement view of winding resistance measurement for Autotransformer is shown in Figure 63 and following that, each part is explained.

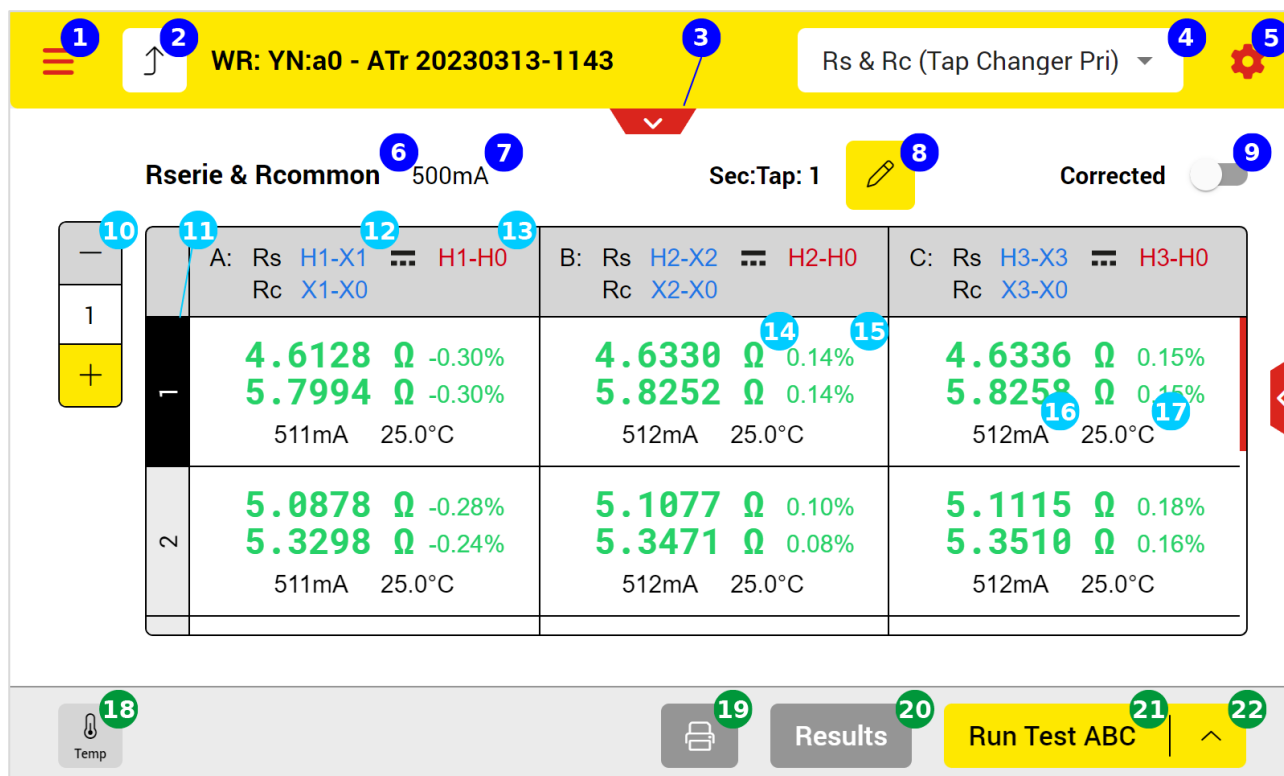


Figure 63: Winding resistance measurement view for an autotransformer

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Select the measuring parameter which is selected in measurement settings
- 5 Test settings
- 6 The measuring parameter or parameters
- 7 The selected current which will be used for the measurement
- 8 To select the other tap changer position when available
- 9 To enable or disable the temperature-corrected resistance view
- 10 The actual tap position of the selected view side and to change it
- 11 Tap positions of the selected winding side. The actual is with the dark background
- 12 The phase and the corresponding connections which be used automatically by the instrument to measure each parameter
- 13 The corresponding connections which be used automatically by the instrument to inject the current
- 14 The measured winding resistances for each parameter (temperature corrected or not corrected depending on selection)
- 15 The deviation values of each parameter from the 3 phases average; green means the deviation is less than the limit and the test is Passed. See chapter 4.2.3 for more information

- 16 The actual test current which was used
- 17 The measured temperature during the measurement or the reference temperature when resistance is corrected
- 18 To see the actual measurement value of each temperature measurement channel
- 19 Print the selected tap position results by using the thermal printer
- 20 Open the detailed results in table view or graphs
- 21 Start test button
- 22 Test mode to select which phase to test (A, B, C, ABC, Run Test Taps)

The Measurement main settings are shown in Figure 64. The other settings are the same as the winding resistance measurement settings. For temperature settings and the advanced settings please refer to chapter 10.2.2.

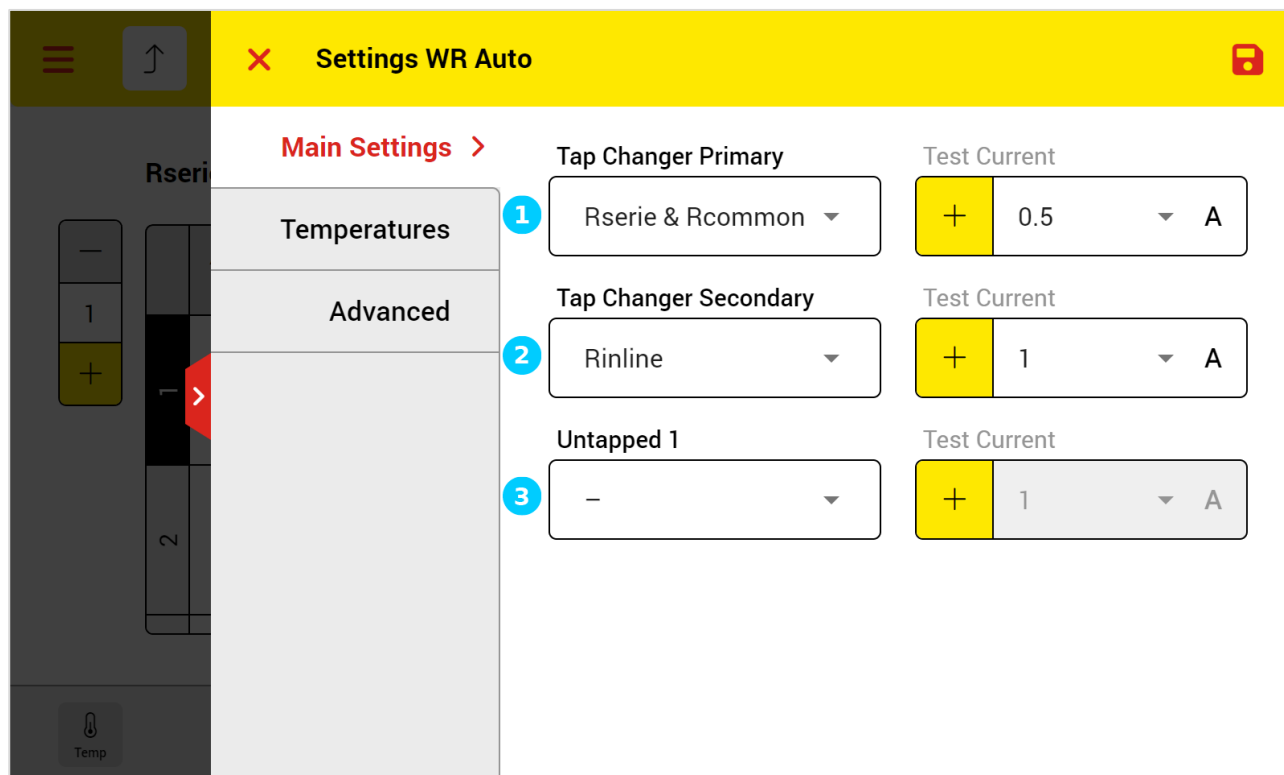


Figure 64: Autotransformer winding resistance main settings

- 1 When there is a tap changer on the primary side, you can select which parameter or parameters to be measured for each of primary tap positions. For this measurement, you can select the test current
- 2 When there is also a tap changer on the secondary side, you can select which parameter or parameters to be measured for each of the secondary tap positions. For this measurement, you can also select the test current separately
- 3 Here, you can select which parameter or parameters to be measured not as a function of any tap changer. For this measurement, you can also select the desired test current

10.2.5 Phase Shifter Transformer Winding Resistance

The measurement view of winding resistance measurement for a Phase Shifter Transformer is shown in Figure 65 and following that each part is explained.

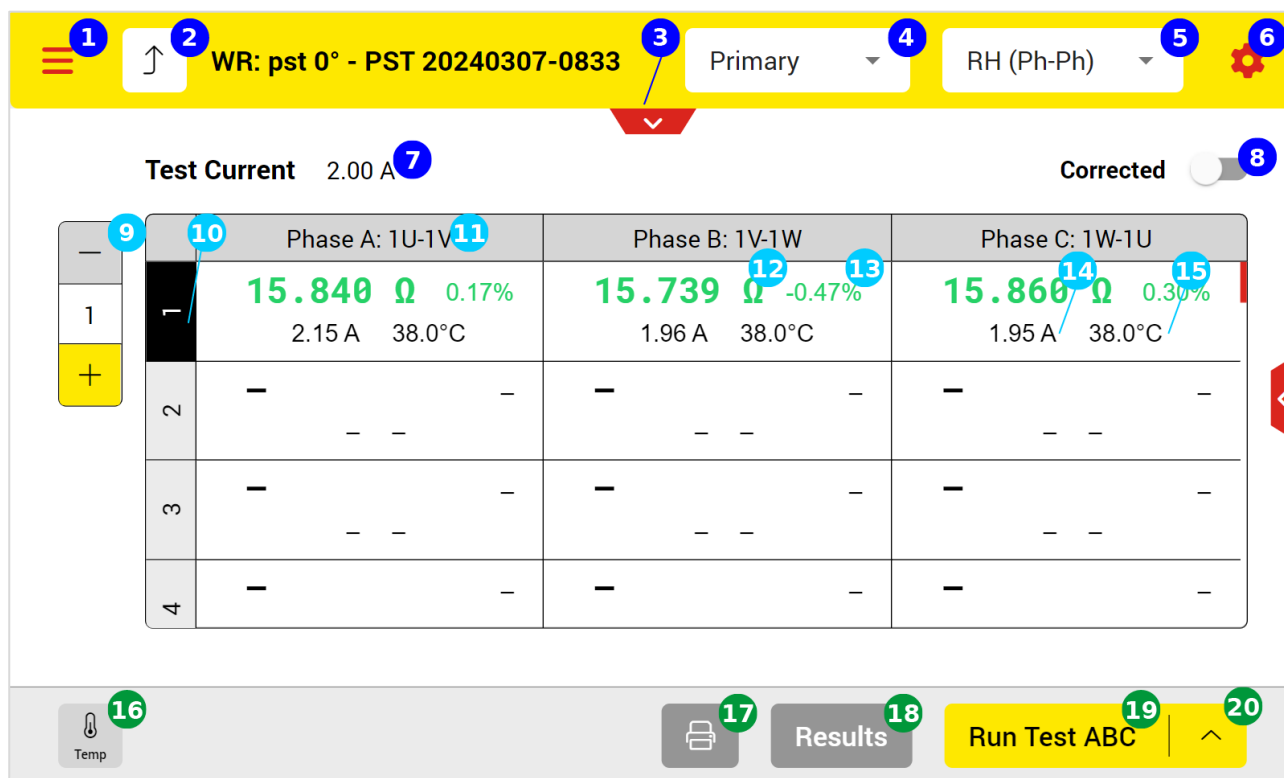


Figure 65: Winding resistance measurement view for a phase shifter transformer

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Select the tap changer table view mode (See chapter 10.1.1 for more information)
- 5 To select the measurement mode. The winding resistance measurement of a phase shifter transformer contains three kinds of measurements:
 - H-Side measurements, which is the winding resistances between the primary (source side) terminals. It can be performed between phases and when there a neutral terminal, it can also be performed between phases and neutral.
 - X-Side measurements, which is the winding resistances between the secondary (load side) terminals. It can be performed between phases and when there a neutral terminal, it can also be performed between phases and neutral.
 - HX measurements, which is the winding resistances between the primary and secondary terminals.
- 6 Test settings
- 7 The selected current that injects into the selected winding
- 8 To enable or disable the temperature-corrected resistance view

- 9 The actual tap position of the selected tap changer table view and to change it
- 10 Tap positions of the selected tap changer table view. The actual is with the black background
- 11 The phase and the corresponding connections which be used automatically by the instrument to test each phase
- 12 The measured winding resistance (temperature corrected or not corrected depending on selection)
- 13 The deviation value from the 3 phases average; green means the deviation is less than the limit and the test is Passed. See chapter 4.2.3 for more information
- 14 The measured test current which was used
- 15 The measured temperature during the measurement or the reference temperature when resistance is corrected
- 16 To see the actual measurement value of each temperature measurement channel (See Figure 59)
- 17 Print the selected tap position results by using the thermal printer
- 18 Open the detailed results in table view or graphs
- 19 Start test button to perform the measurement
- 20 Test mode to select which phase to test (A, B, C, ABC, Run Test Taps)

The Measurement main settings are shown in Figure 66. The other settings are the same as the winding resistance measurement settings. For temperature settings and the advanced settings please refer to chapter 10.2.2.

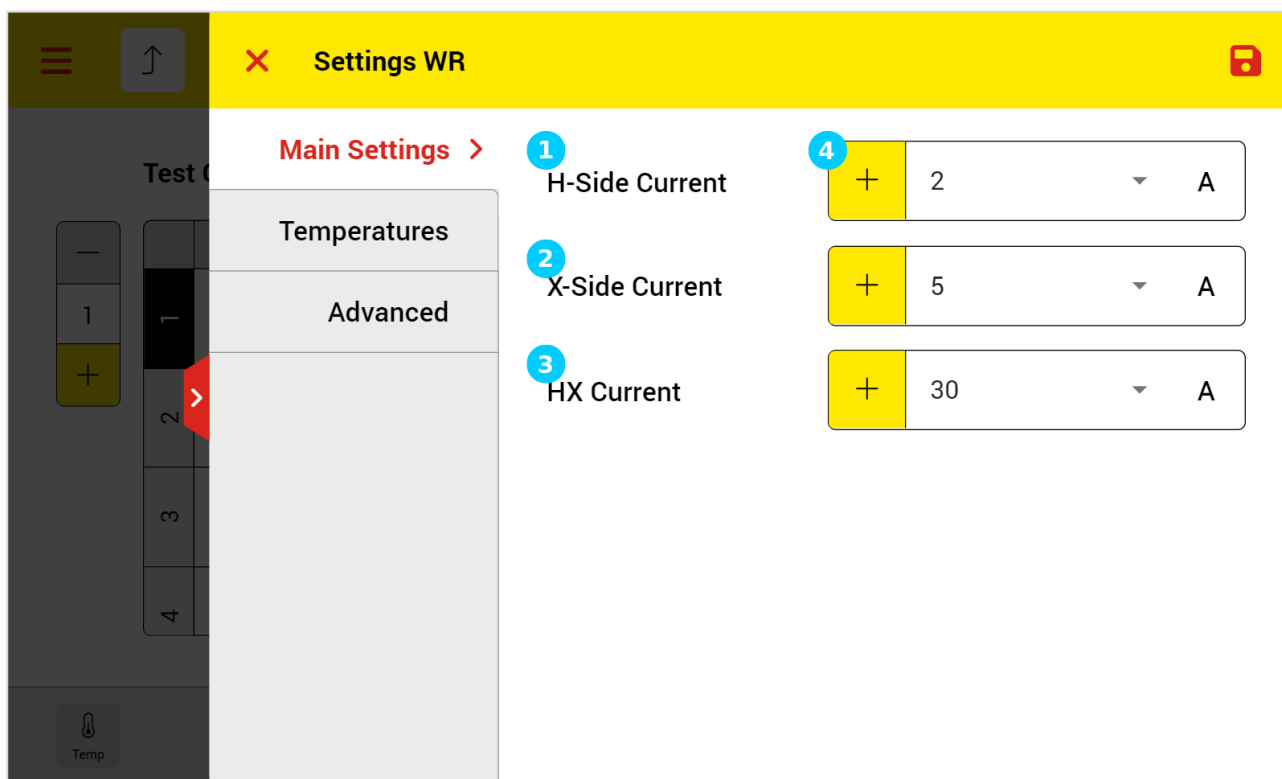


Figure 66: Phase shifter transformer winding resistance main settings

- 1 To select the current that flows between the primary terminals
- 2 To select the current that flows between the secondary terminals
- 3 By tapping on the plus button, you can add a user-defined test current to the list of test currents
- 4 To select the current that flows between the primary and secondary terminals

10.3 Winding Resistance Interval

With interval measurement, it is possible to measure the winding resistance as a function of time. Figure 67 shows the measurement view and following that, each part is explained.

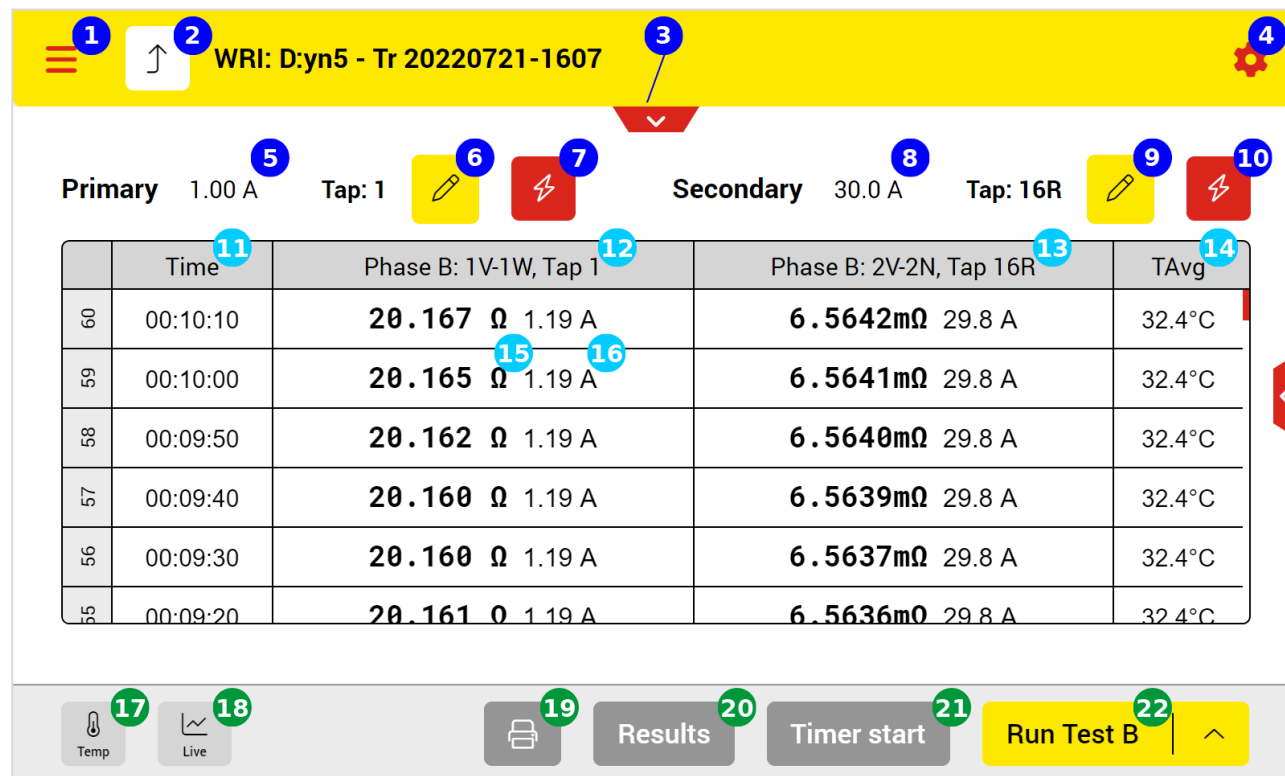


Figure 67: Winding Resistance Interval measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Test settings
- 5 The selected current that injects into the primary winding side
- 6 The actual tap position of the primary side
- 7 To turn On or turn Off the power supply for the primary side. It is also possible to select "Charge" mode. In charge mode, the power supply injects current to the primary side to increase the transformer charging speed. But no resistance will be measured
- 8 The selected current that injects into the Secondary winding side
- 9 The actual tap position of the secondary side
- 10 To turn On or turn Off the power supply for the secondary side
- 11 Elapsed time
- 12 The phase and the corresponding connections which be used automatically by the instrument to test each side and the tap position
- 13 The phase and the corresponding connections which be used automatically by the instrument to test each side and the tap position

- 14 The average of measured and external temperatures
- 15 The measured resistance
- 16 The actual test current
- 17 To see the actual measurement value of each temperature measurement channel
- 18 To see the resistance curve over time
- 19 Print results by using the thermal printer
- 20 Detailed results in table view or graphs
- 21 To start the timer separately. When you run the test without starting the timer, the timer will automatically also start
- 22 Start test button

The view of the winding resistance interval measurement during the test is displayed in Figure 68, and important parts are subsequently explained.

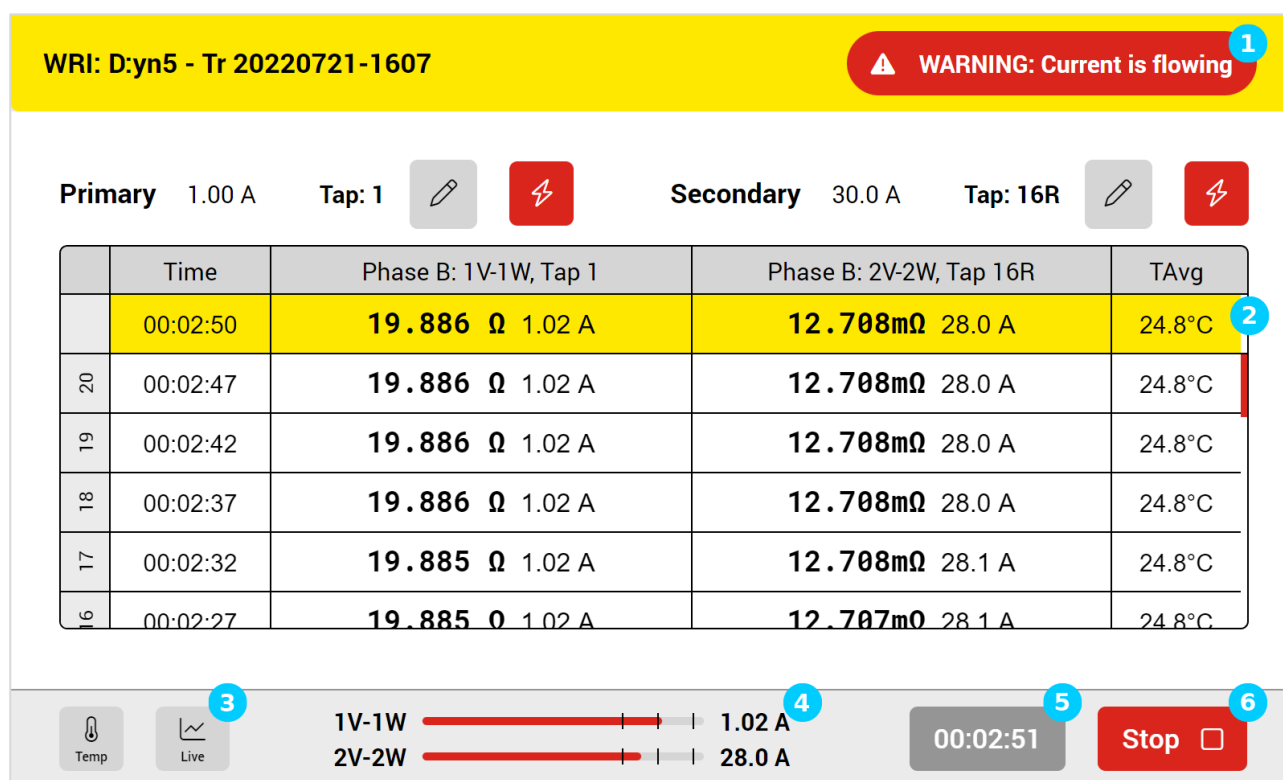


Figure 68: Winding resistance interval measurement view during the test

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted row shows the parameter's live value
- 3 Here you can open the live graph to see the live resistance curve over time
- 4 The output current bars indicate the actual value of the output current for each channel and specify the terminals used for current injection
- 5 The actual elapsed time

- 6 The stop button can be used to stop the test. Please note that it takes time to discharge and stop the test



WARNING!

After measurement stop, it takes time to discharge the test object!
Wait until the device mode changes to safe mode before any other action!

10.3.1 Winding Resistance Interval Settings

Figure 69 shows the winding resistance interval main settings.

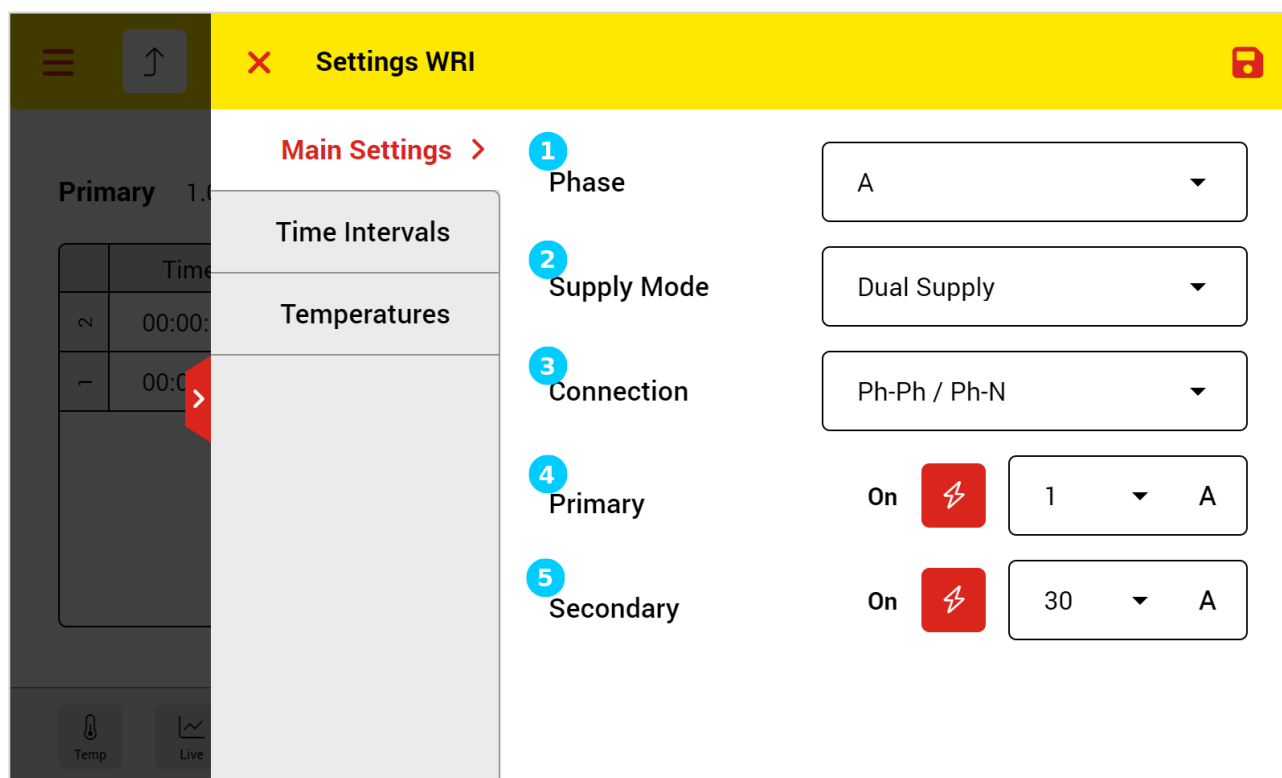


Figure 69: Winding resistance interval main settings

- 1 To select which phase to test
- 2 To measure both Primary and Secondary simultaneously with two power supplies or to select which side to measure with one power supply
- 3 To select test phase to phase or phase to neutral measurement when possible
- 4 To select the current that injects into the primary winding side and also to turn On or turn Off the power supply for the primary side. It is also possible to select "Charge" mode. In charge mode, the power supply injects current to the primary side to increase the transformer charging speed. But no resistance will be measured
- 5 To select the current that injects into the secondary winding side and also to turn On or turn Off the power supply for the secondary side

Figure 70 shows the time intervals settings.

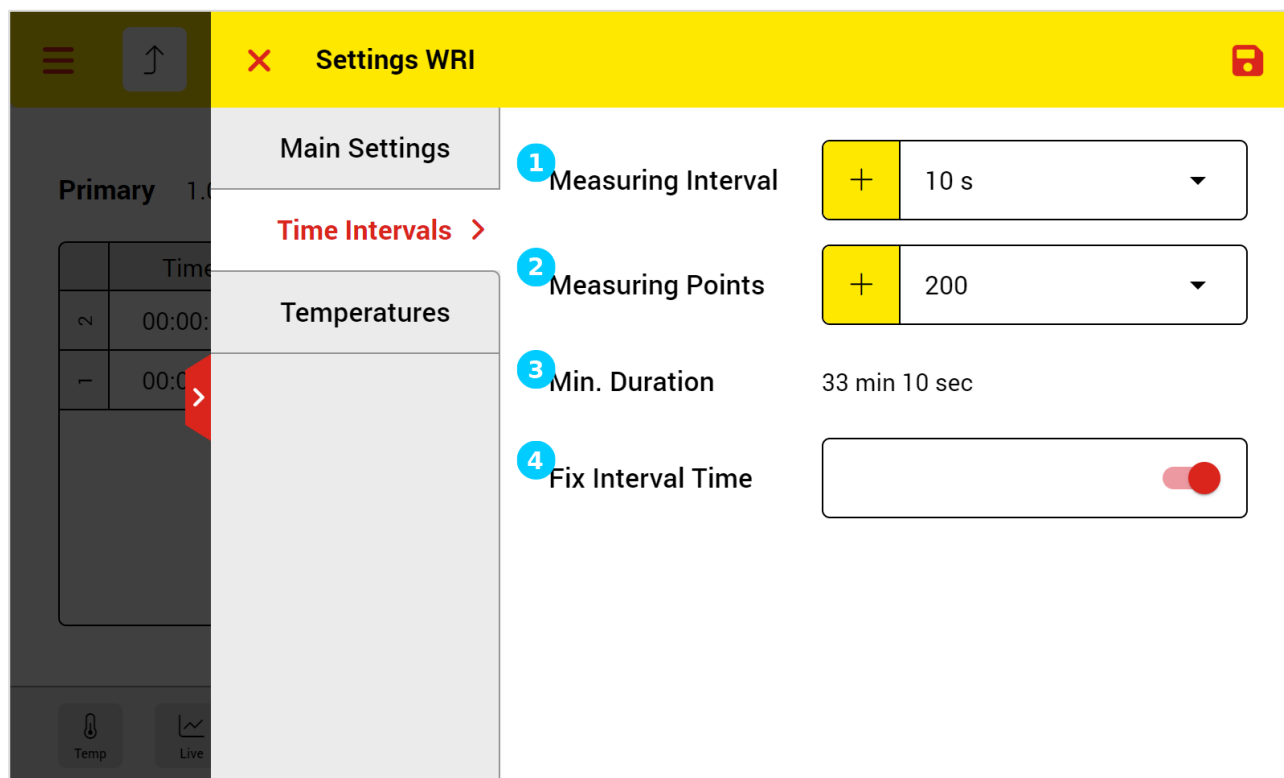


Figure 70: Winding resistance interval, time intervals settings

- 1 To set the time duration between each two measurement points
- 2 To set the number of measuring points
- 3 Total measurement duration which is calculated by timing measuring interval and measuring points
- 4 To set the interval time from Start Time instead of from the 1st measurement point.
e.g. If the Interval Time is set to 10 seconds and the first measurement is taken at 27 seconds, the system stores results at 27, 37, 47...seconds if fix interval time is not selected. if fix interval time is selected, the results will be taken and stored at 27, 30, 40, 50...seconds

The temperature settings of the winding resistance interval are the same as the winding resistance settings. Please see chapter 10.2.2, Temperature settings part, to see the explanation.

10.3.2 Winding Resistance Interval Result View

By tapping the Results button in the measurement view, the result view will be opened. The result view includes graphs and tables. Figure 71 shows the Primary winding resistance graph view. From the drop-down list on top right, it is possible to select also other graphs.

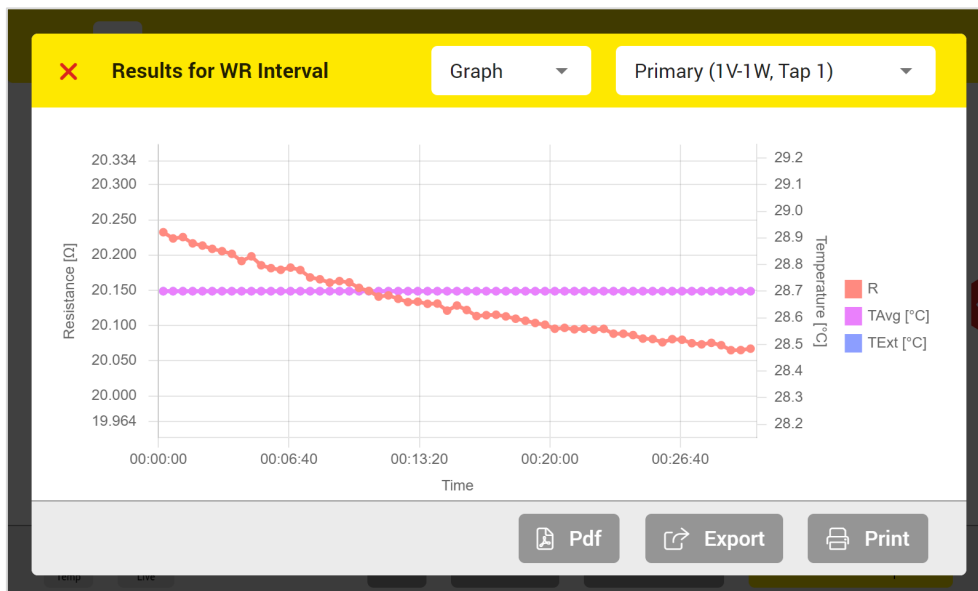
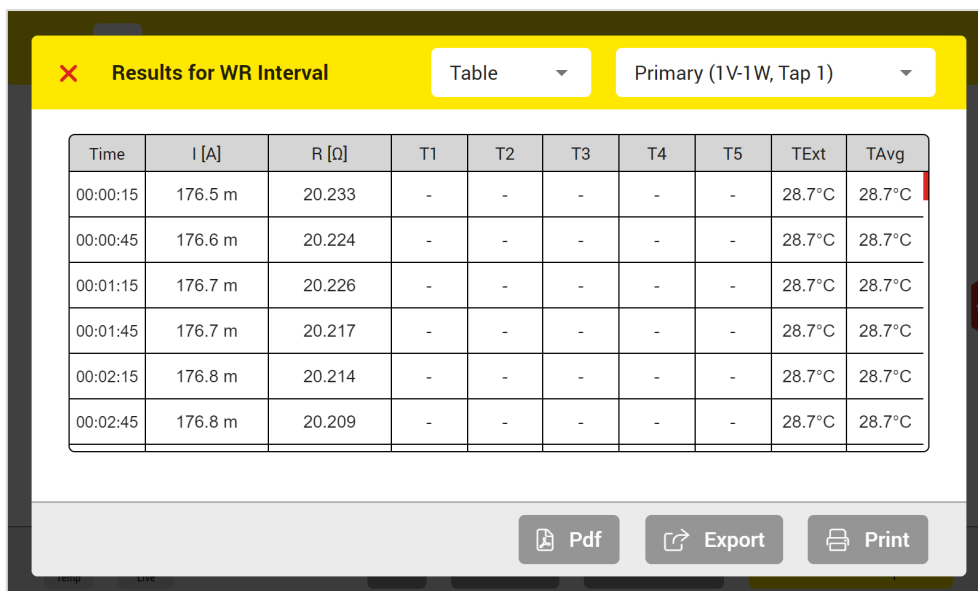


Figure 71: Winding resistance interval graph results view

Figure 72 shows also the Primary table results.



Time	I [A]	R [Ω]	T1	T2	T3	T4	T5	TExt	TAVg
00:00:15	176.5 m	20.233	-	-	-	-	-	28.7°C	28.7°C
00:00:45	176.6 m	20.224	-	-	-	-	-	28.7°C	28.7°C
00:01:15	176.7 m	20.226	-	-	-	-	-	28.7°C	28.7°C
00:01:45	176.7 m	20.217	-	-	-	-	-	28.7°C	28.7°C
00:02:15	176.8 m	20.214	-	-	-	-	-	28.7°C	28.7°C
00:02:45	176.8 m	20.209	-	-	-	-	-	28.7°C	28.7°C

Figure 72: Winding resistance interval table results view

10.4 Demagnetization

Figure 73 shows the demagnetization view and Figure 74 shows the demagnetization view during the test and following each one, the important parts are explained.

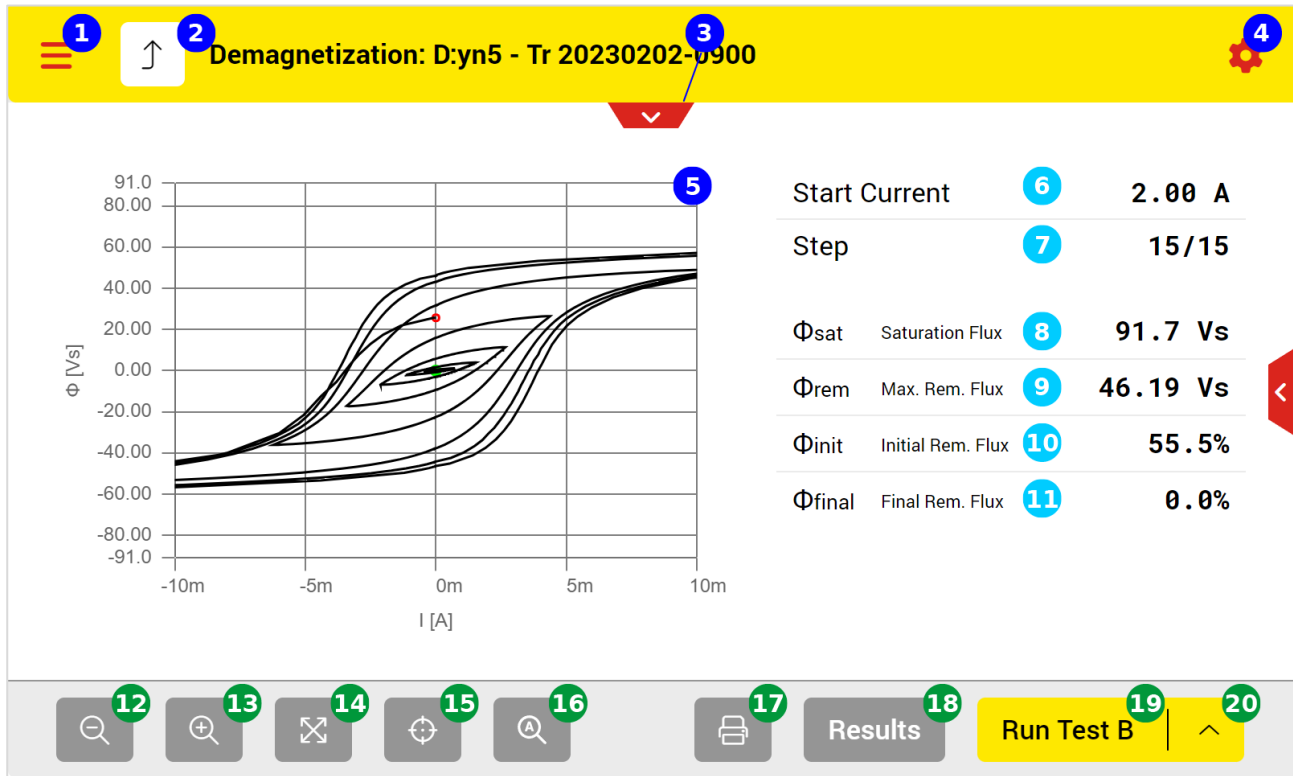


Figure 73: Demagnetization view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Test settings
- 5 The demagnetization curve (Zoomable with two fingers)
- 6 The adjusted start current that injects into the primary winding
- 7 Number of cycles already performed from all cycles
- 8 The measured saturation flux
- 9 The measured maximum remanence flux
- 10 The measured initial remanence flux in % (as the percentage of the measured maximum remanence flux)
- 11 The measured final remanence flux in % (as the percentage of the measured maximum remanence flux)
- 12 Zoom out
- 13 Zoom in
- 14 Maximize the graph view
- 15 Centre the graph view

- 16 Automatic adaptive graph view
- 17 Print results by using the thermal printer
- 18 Detailed results in table view or graphs
- 19 The button to run the test
- 20 Test mode to select which phase to perform the demagnetization

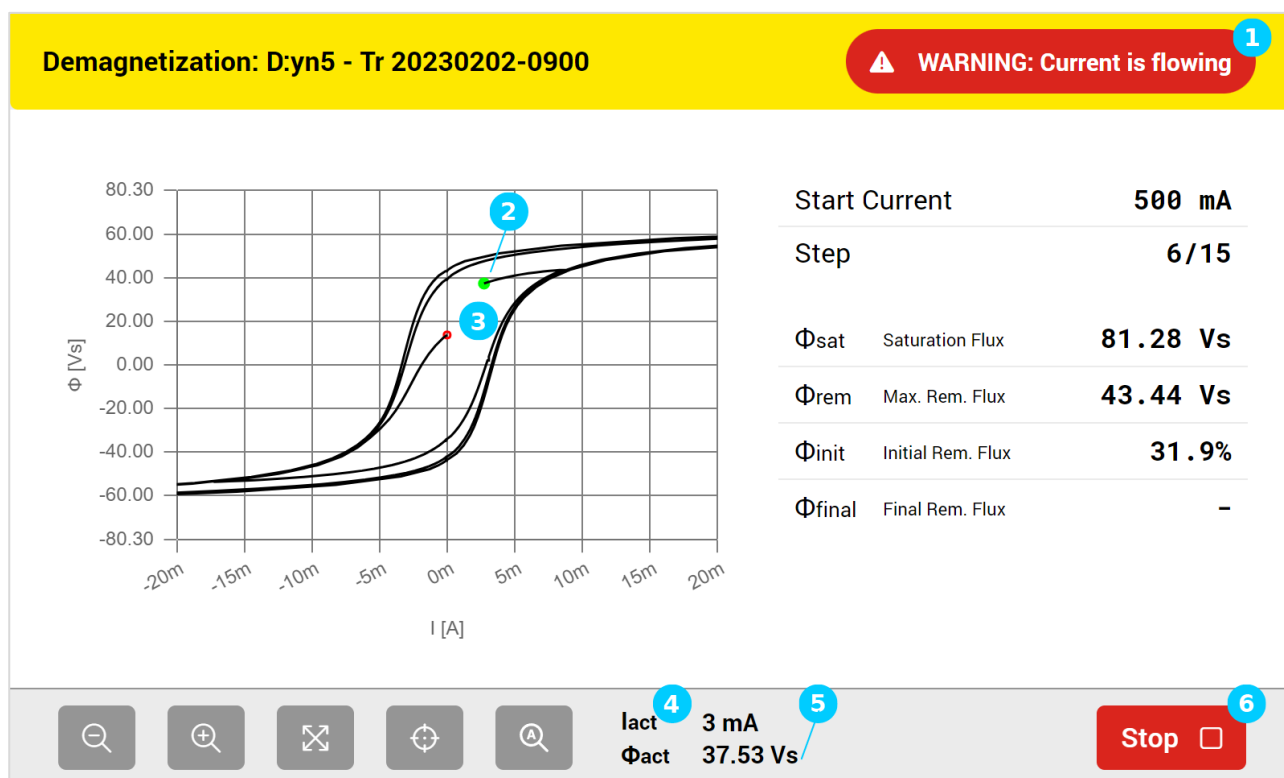


Figure 74: Demagnetization view during the test

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The actual point (the actual flux and the actual current) of the demagnetization curve marked in green
- 3 The first point (initial remanence flux) of the demagnetization curve marked in red
- 4 The actual demagnetization current during the measurement
- 5 The actual flux during the measurement
- 6 The stop button can be used to stop the test. Please note that it takes time to discharge and stop the test



WARNING!

After measurement stop, it takes time to discharge the test object! Wait until the device mode changes to safe mode before any other action!

10.4.1 Demagnetization Settings

Figure 75 shows the demagnetization settings.

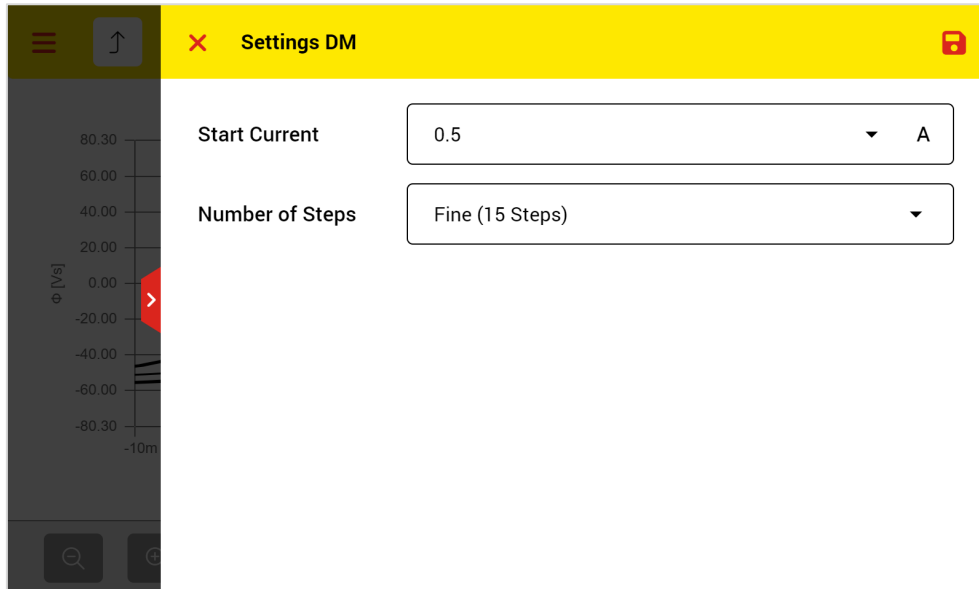


Figure 75: Demagnetization settings

The starting current can be selected ranging from 200mA up to 30A. For currents up to 7.5A, the maximum output voltage is 50VDC (up to 100VDC with the automatic booster). For currents more than 7.5A, the maximum output voltage is 12VDC. When testing a large power transformer, selecting currents up to 7.5A will make the demagnetization process faster.

The number of steps can also be adjusted, ranging from a faster option with 8 steps to a finer option with 20 steps. Normally, to reach a smaller final remanence flux and hence better demagnetization quality, you can select more steps. However, since the mini-ATOS uses the Raytech SPP method (See chapter 4.3.1 for more information), the quality of the demagnetization is quite good even when the number of Steps is set to Very Fast (8 Steps).

10.4.2 Phase Shifter Transformer Demagnetization Settings

The demagnetization settings for a phase shifter transformer (Figure 76) have an additional setting.

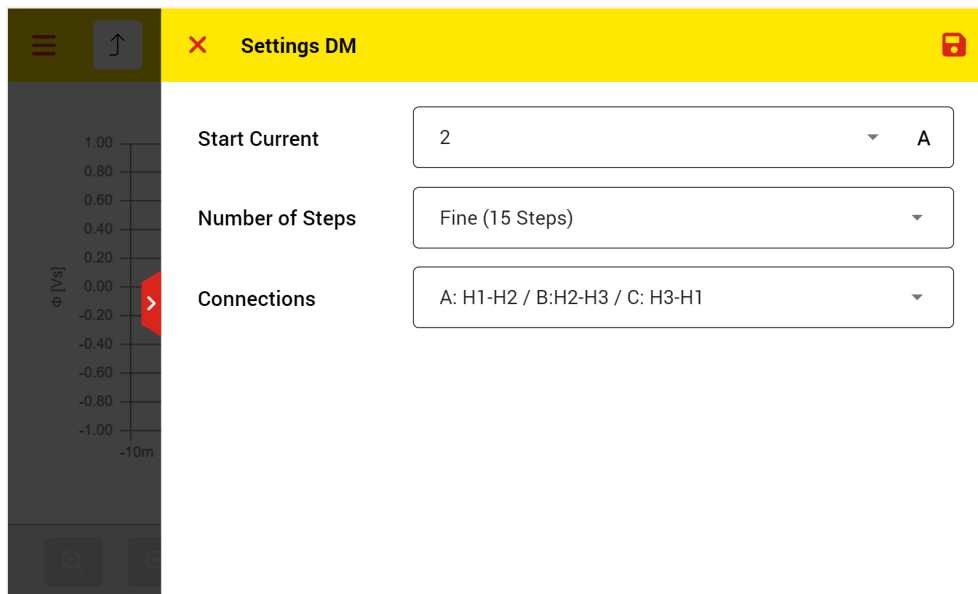


Figure 76: Phase shifter transformer demagnetization settings

The connections which are used to demagnetize can be selected from the following list.

- A: H1-H2/ B: H2-H3/ C: H3-H1, suitable when the phase shifter connection from the primary terminals is more like a delta connection
- A: H1-H3/ B: H2-H1/ C: H3-H2, suitable when the phase shifter connection from the primary terminals is more like a delta connection and the middle phase is between H2 and H1
- A: H1-H23/ B: H2-H31/ C: H3-H12, suitable when the phase shifter connection from the primary terminals is more like a star connection

10.5 Magnetic Balance

Figure 77 shows the measurement view of the Magnetic Balance test and following that each part is explained.

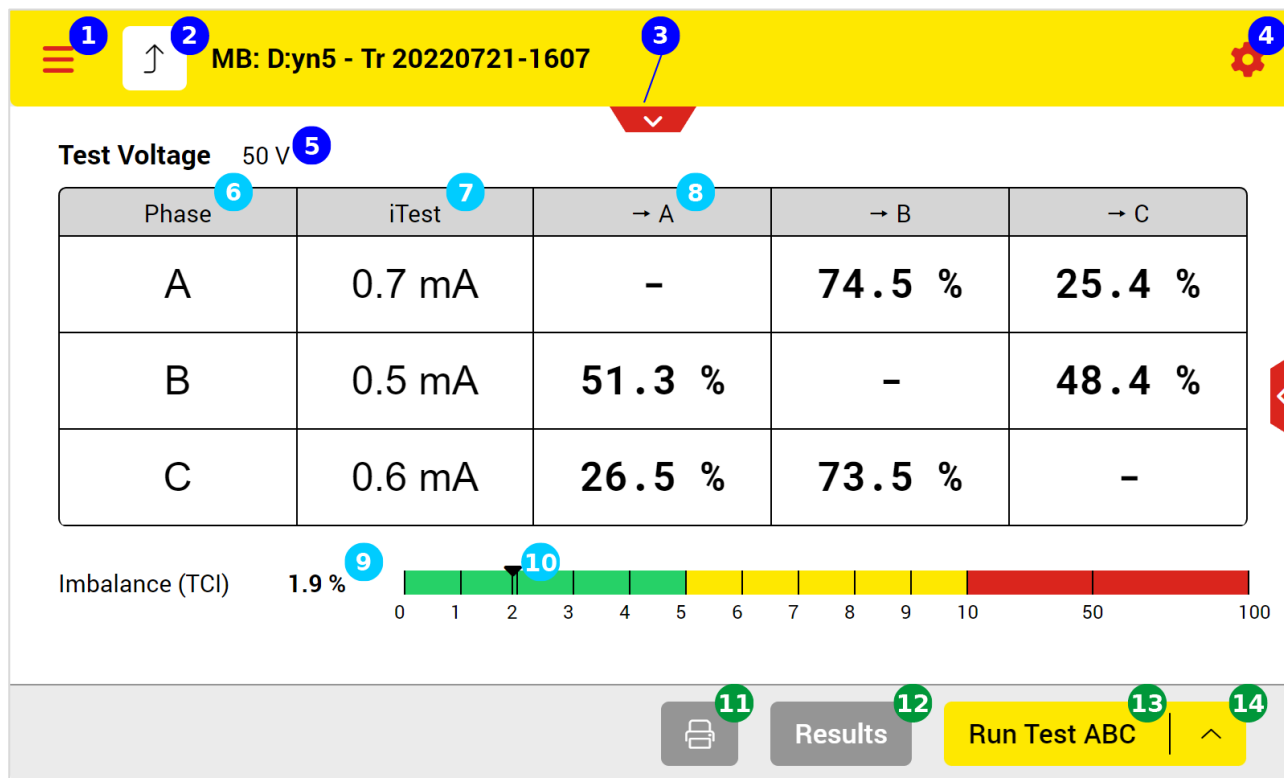


Figure 77: Magnetic Balance measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Test settings
- 5 The selected test voltage
- 6 The Phase which the voltage applied to
- 7 The output current during the test
- 8 The phase which the voltage measured and the values as a percentage of the applied voltage
- 9 The transformer core imbalance value (see chapter 4.4 for more information)
- 10 Showing the TCI value on a colored bar
- 11 Print the results by using the thermal printer
- 12 Open the detailed results in table view or graphs
- 13 Start test button
- 14 Test mode to select which phase to test (A, B, C, ABC)

Figure 78 shows the magnetic balance test during the measurement.

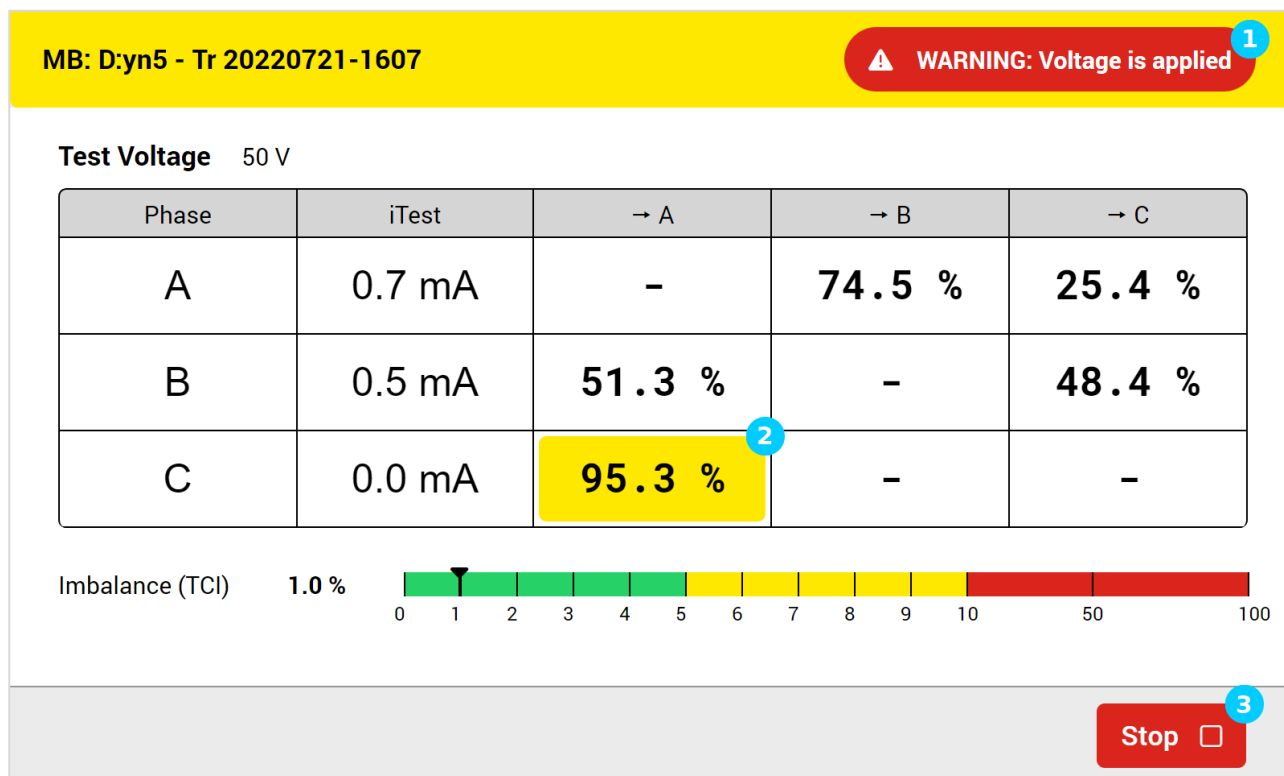
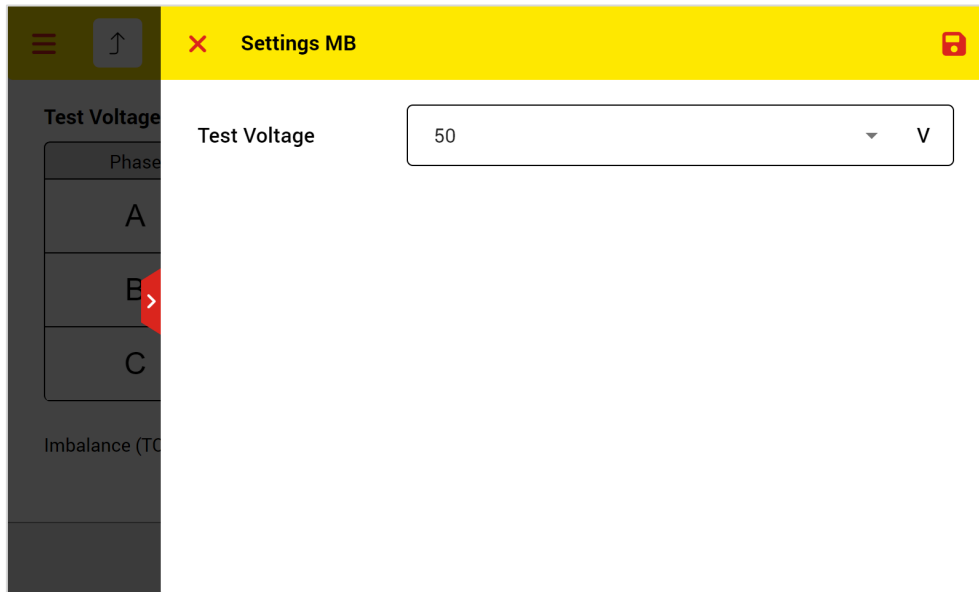


Figure 78: Magnetic balance test during a measurement

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted cell shows the actual measurement
- 3 The stop button can be used to stop the test. Please note that it takes time to stop the test

10.5.1 Magnetic Balance Settings

Figure 79 represents the magnetic balance measurement settings.



The screenshot shows a mobile application interface for 'Settings MB'. The title bar is yellow with a red 'X' icon on the left and a red lock icon on the right. Below the title bar, there is a sidebar menu on the left with options: 'Test Voltage', 'Phase', 'A', 'B', 'C', and 'Imbalance (TC)'. The 'Test Voltage' option is selected, and its settings are displayed in the main area. The 'Test Voltage' label is followed by a text input field containing the value '50' and a unit selector dropdown menu showing 'V'.

Figure 79: Magnetic balance measurement settings

For magnetic balance, the applying voltage can be selected up to 50VAC. Please note that the test voltage frequency is at 10Hz.

10.5.2 Magnetic Balance Result View

By tapping the Results button in the measurement view, the result view will be opened. The result view includes graphs and a table. Figure 80 shows the graph view.

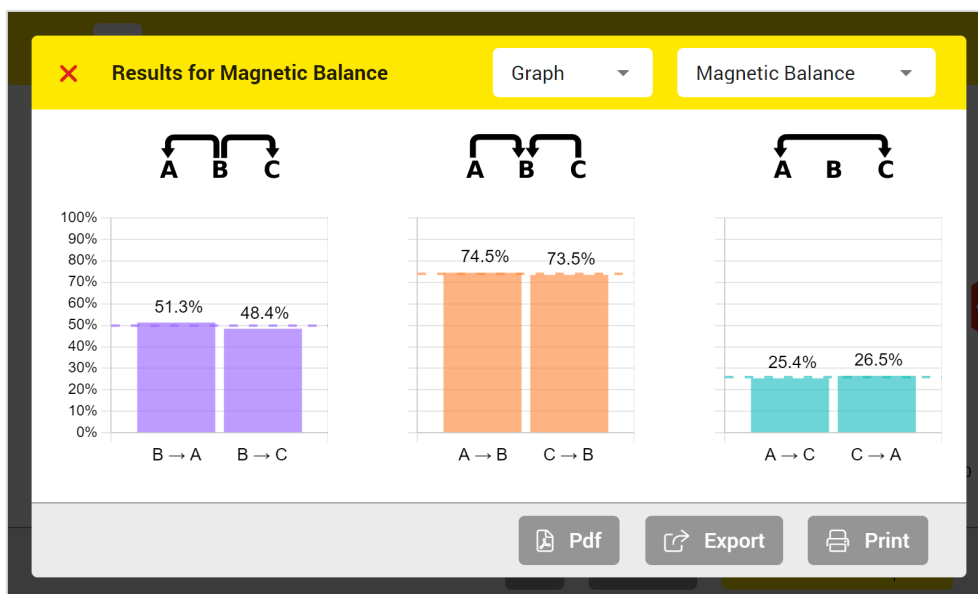


Figure 80: Magnetic balance graph results view

Figure 81 shows also the table results including the colored bar.

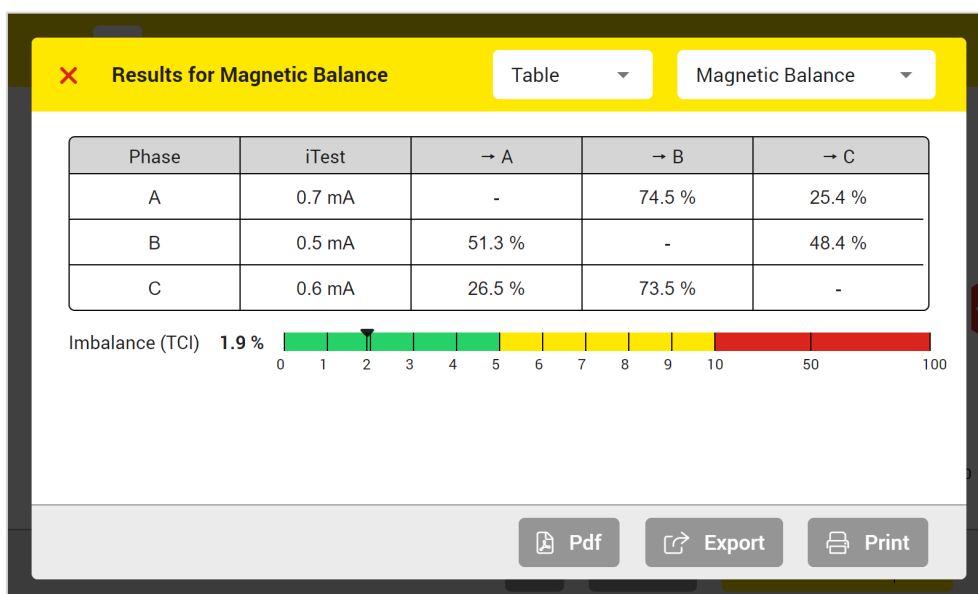


Figure 81: Magnetic balance table results view

10.6 Short Circuit Impedance

The short circuit impedance measurement view is explained following Figure 82.

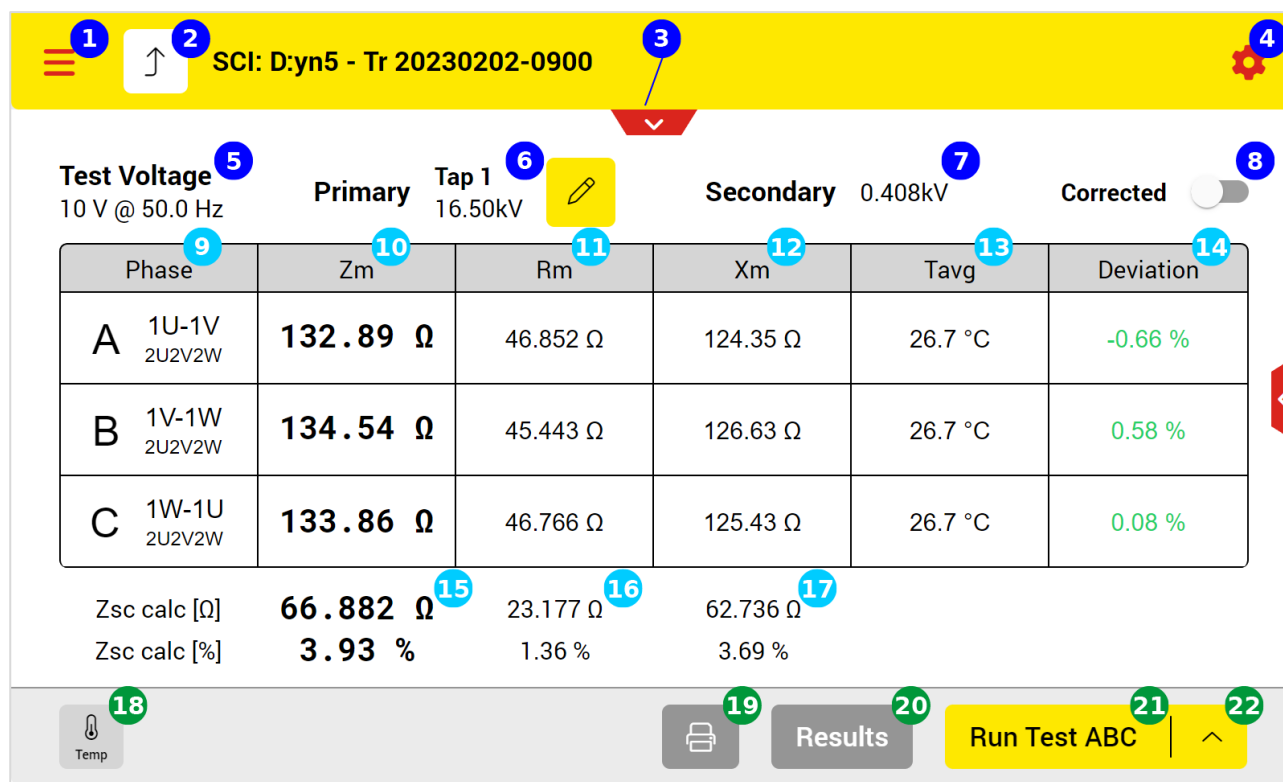


Figure 82: Short circuit impedance measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Test settings
- 5 The selected test voltage and frequency
- 6 The actual tap position and its rated voltage of the primary side. It can be changed by tapping on the pencil button
- 7 The actual tap position and its rated voltage of the non-primary side
- 8 To enable or disable the temperature-corrected resistance view
- 9 The phase and the corresponding connections which be used automatically by the instrument to test each phase
- 10 The measured short circuit impedance value
- 11 The measured AC resistance value
- 12 The measured Leakage reactance value
- 13 The measured temperature during the measurement or the reference temperature when resistance is corrected
- 14 The deviation from 3 phases short circuit impedance average; green means the deviation is less than the limit and the test is Passed. See chapter 4.5.4

- 15 The short circuit impedance average in Ω and %. For more information see 4.5.1
- 16 The AC resistance average in Ω and %. For more information see 4.5.1
- 17 The leakage reactance average in Ω and %. For more information see 4.5.1
- 18 To see the actual measurement value of each temperature measurement channel
- 19 Print the results by using the thermal printer
- 20 Open the detailed results
- 21 Start test button
- 22 Test mode to select which phase to test (A, B, C, ABC)

Figure 83 shows the short circuit impedance test during the measurement.

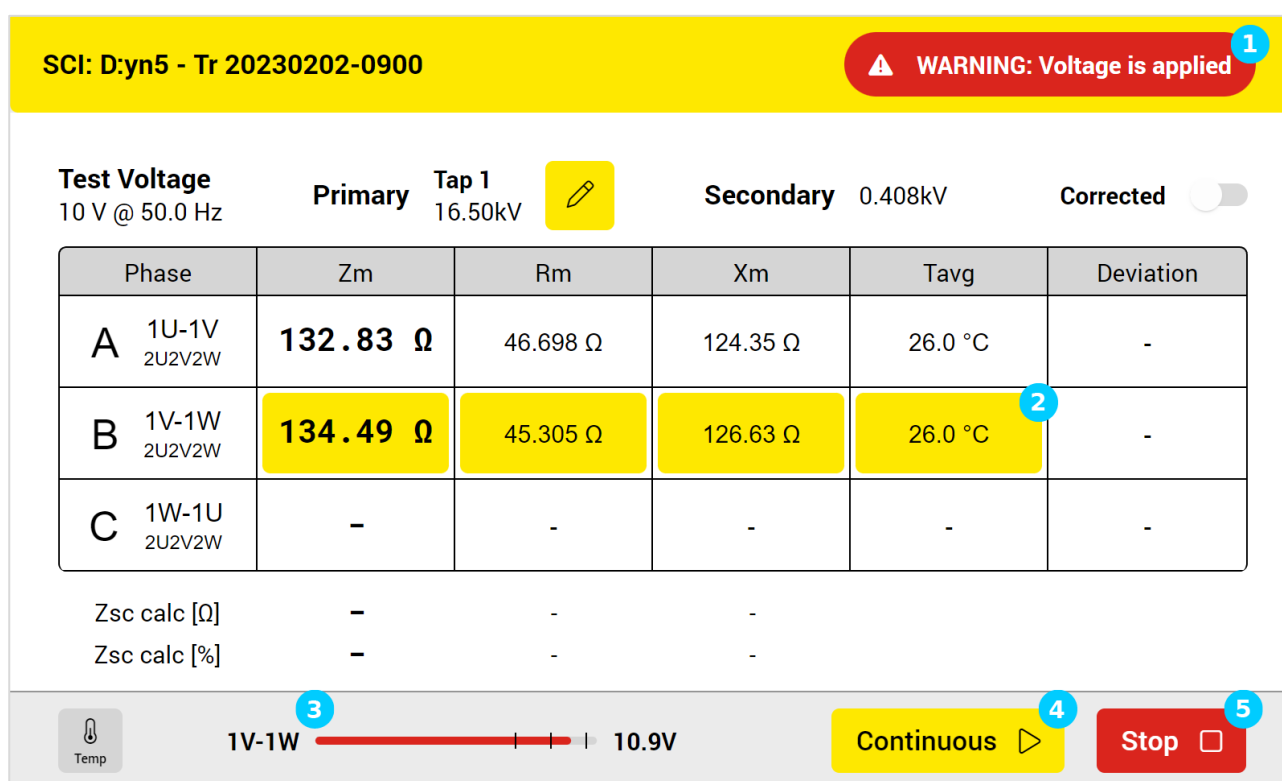


Figure 83: Short circuit impedance test during the measurement

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted row shows which phase is currently under the test
- 3 The actual test voltage during the measurement
- 4 By tapping the continuous button, the test mode changes from single-measurement to continuous mode and the test will not stop automatically. The instrument keeps performing the test on the phase under the test until the user's action
- 5 The stop button can be used to stop the test

10.6.1 Short Circuit Impedance Settings

The short circuit impedance main settings are as follows:

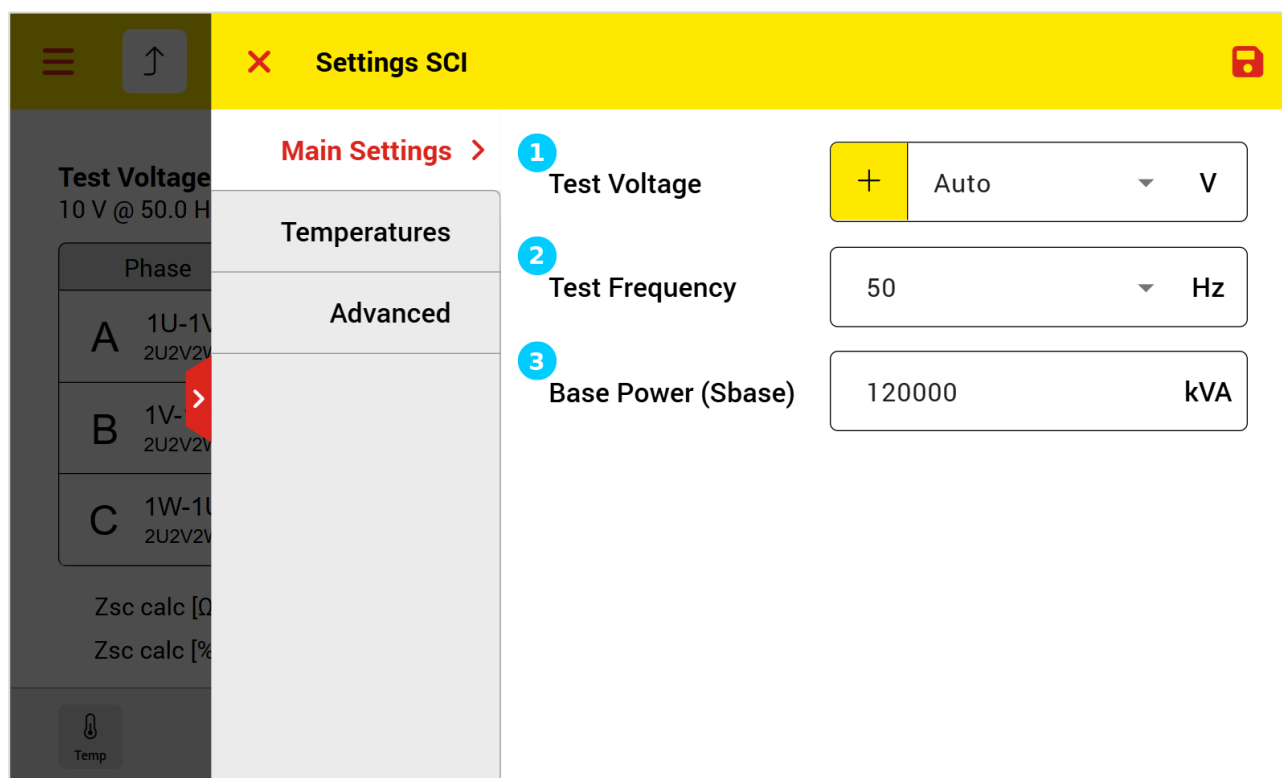


Figure 84: Short circuit impedance main settings

- 1 To select the test voltage. You can also add user-defined test voltages to the list by tapping on the + button.
- 2 To select the test voltage frequency. The test frequency can be 50Hz or 60Hz. You should select the test frequency according to the working frequency of the test object
- 3 Enter the Base Power or the maximum rated power of the transformer. With Base Power and the profile's rated voltages, the impedance value will be shown also as per cent value

Figure 85 shows the short circuit impedance temperature settings. In temperature settings, it is possible to enable each of the 5 temperature channels to record. When there is an external temperature probe, the External switch should be enabled. The reading value must be also entered manually.

The mini-ATOS use the average of all temperature values for the temperature correction.

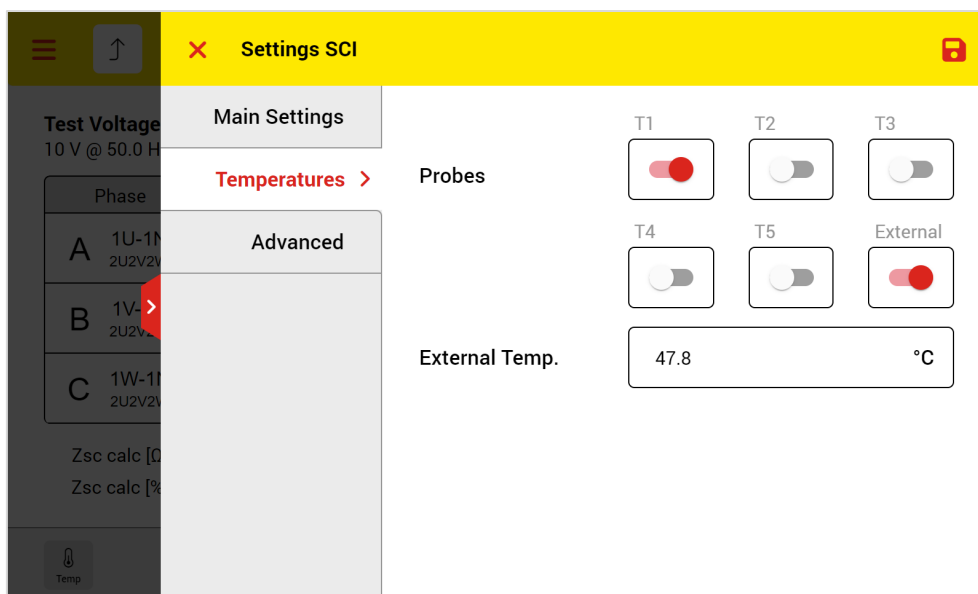


Figure 85: Short circuit impedance temperature settings

Figure 86 shows the short circuit impedance advanced settings.

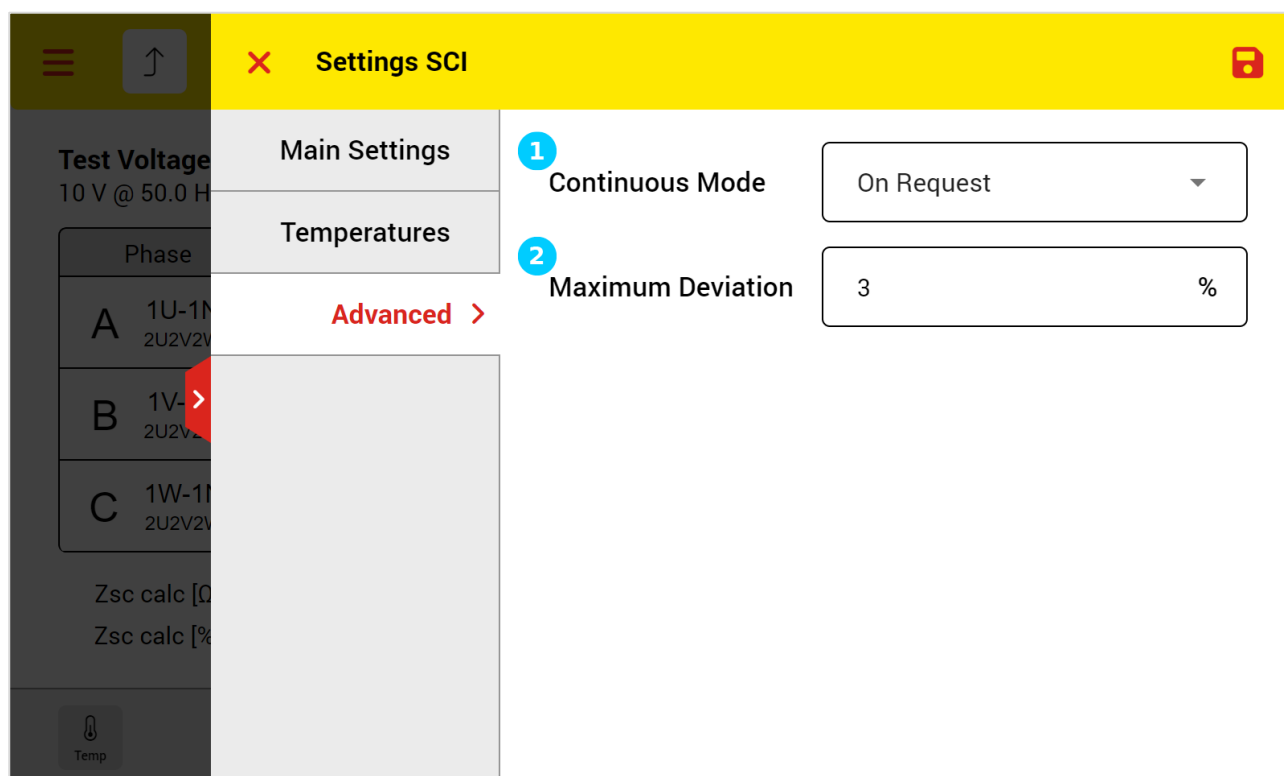


Figure 86: Short circuit impedance advanced settings

- 1 When the continuous mode is “On Request”, one can activate the continuous mode only by tapping on the continuous button. When the mode is “Always”, the continuous mode is always activated automatically
- 2 The maximum acceptable deviation value. Please see chapter 4.5.4 for more information

10.7 Dynamic Resistance Measurement (DRM)

Figure 87 shows the measurement view of the DRM test.

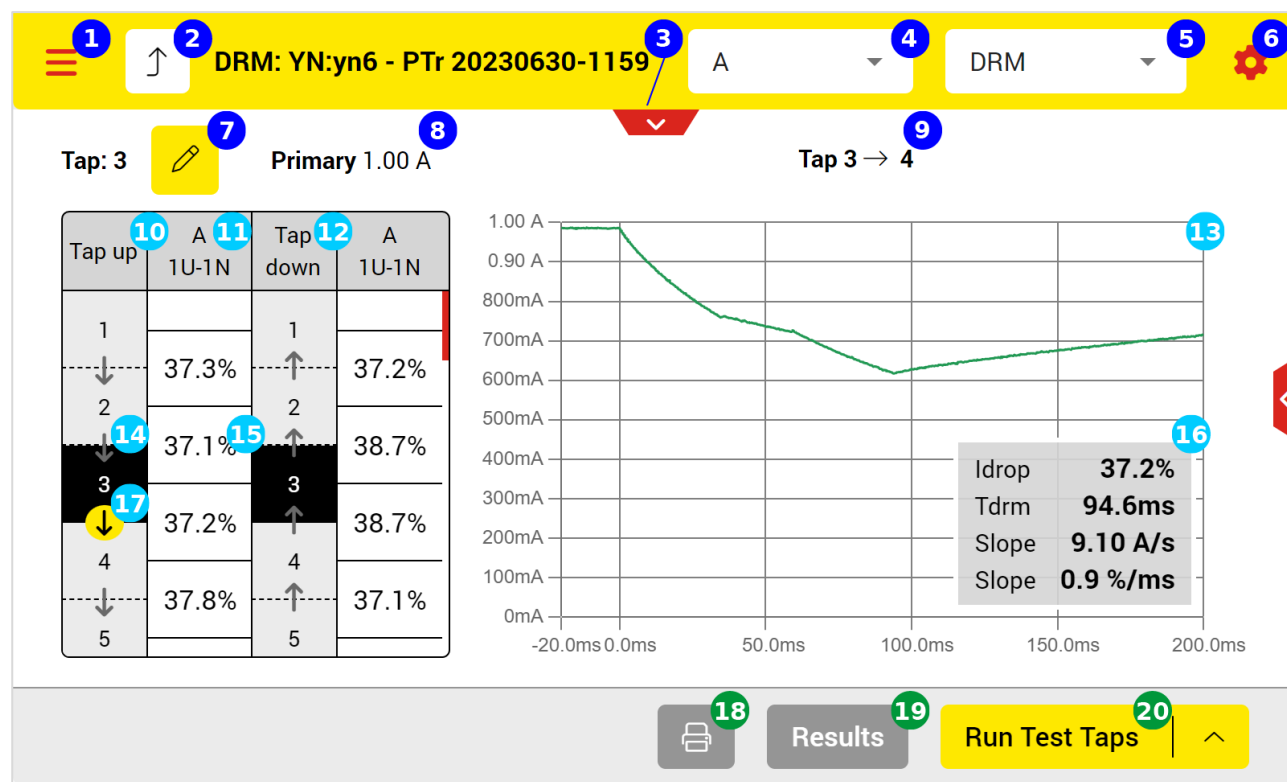


Figure 87: Dynamic resistance measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Select which phase to test
- 5 Select to show the DRM graph or the motor current graph
- 6 Test settings
- 7 The actual tap position. It can be changed by tapping on the pencil button
- 8 The measuring side and the selected test current.
- 9 The tap transition of the showing graph
- 10 Tap positions in the up direction
- 11 The phase and the corresponding connections which be used automatically by the instrument to test
- 12 Tap positions in the down direction
- 13 The DRM or motor current curve for actual or selected transition
- 14 The current tap position, which is indicated by a black background
- 15 The current drop in %. You can also select it by clicking on it, and the results will be displayed upon selection

- 16 The parameters of DRM or motor current for actual or selected transition
- 17 The actual or selected transition which is indicated by a yellow background
- 18 Print the results by using the thermal printer
- 19 Open the detailed results
- 20 Start test button

When you run the test, the Go Taps menu will be first opened as Figure 88. After adjusting the desired parameters, you can start the measurement by using the play icon on the top right of the window.

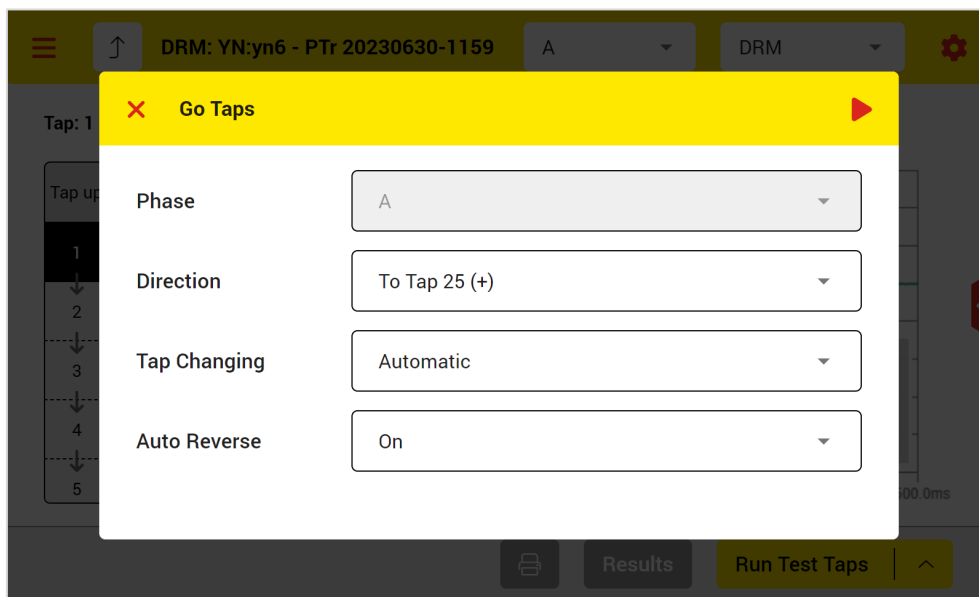


Figure 88: Go Taps menu for DRM

Direction

The tap changing direction should be selected here. You can select either the direction to the first tap or to the last tap.

Tap Changing: Automatic

For automatic tap changing, the mini-ATOS tap control output must be connected to the tap changer control unit for both directions. In the transformer profile, Tap Changer tab, the tap control must be also activated.

During the automatic tap changing, the tap switch message will be shown like Figure 89. The system sends a pulse to change the tap position and waits for the trigger. When the trigger comes, the DRM graph will be shown, and the results will be recorded.

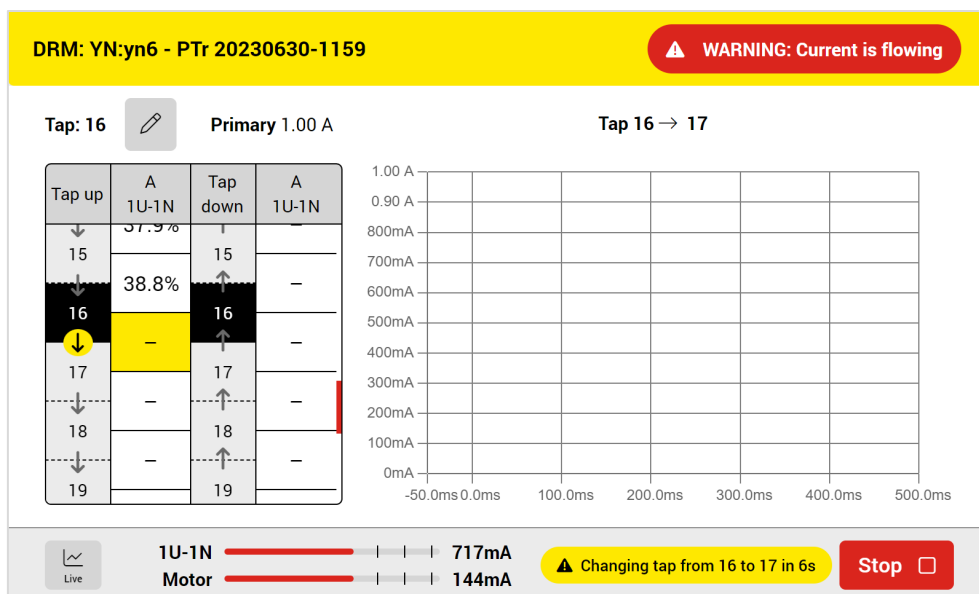


Figure 89: Tap Switch message during DRM automatic tap changing

Tap Changing: Manual

Tap changing can be also manual. During the tap changing, the tap switch message (Figure 90) will ask to change the tap position manually. The system waits for the trigger. When the trigger comes, the DRM graph will be shown and the results will be recorded. No confirmation is required because system can find out from the trigger that the tap position is actually changed by the user.

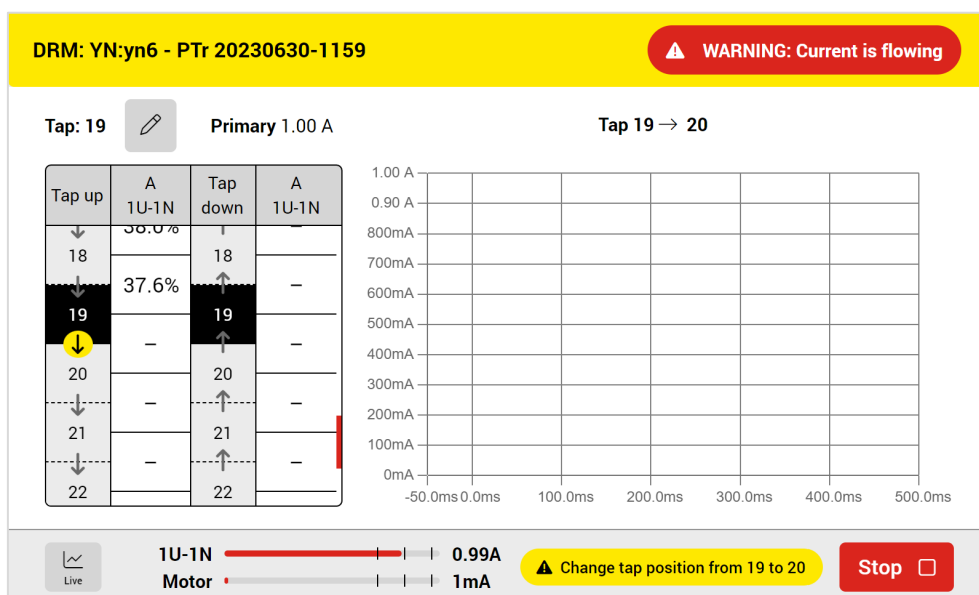


Figure 90: Tap Switch message during DRM manual tap changing

Auto Reverse

When auto reverse is On, the mini-ATOS continues measurement for the opposite direction when it reaches to one of the end taps.

Figure 91 shows the DRM view during a measurement.

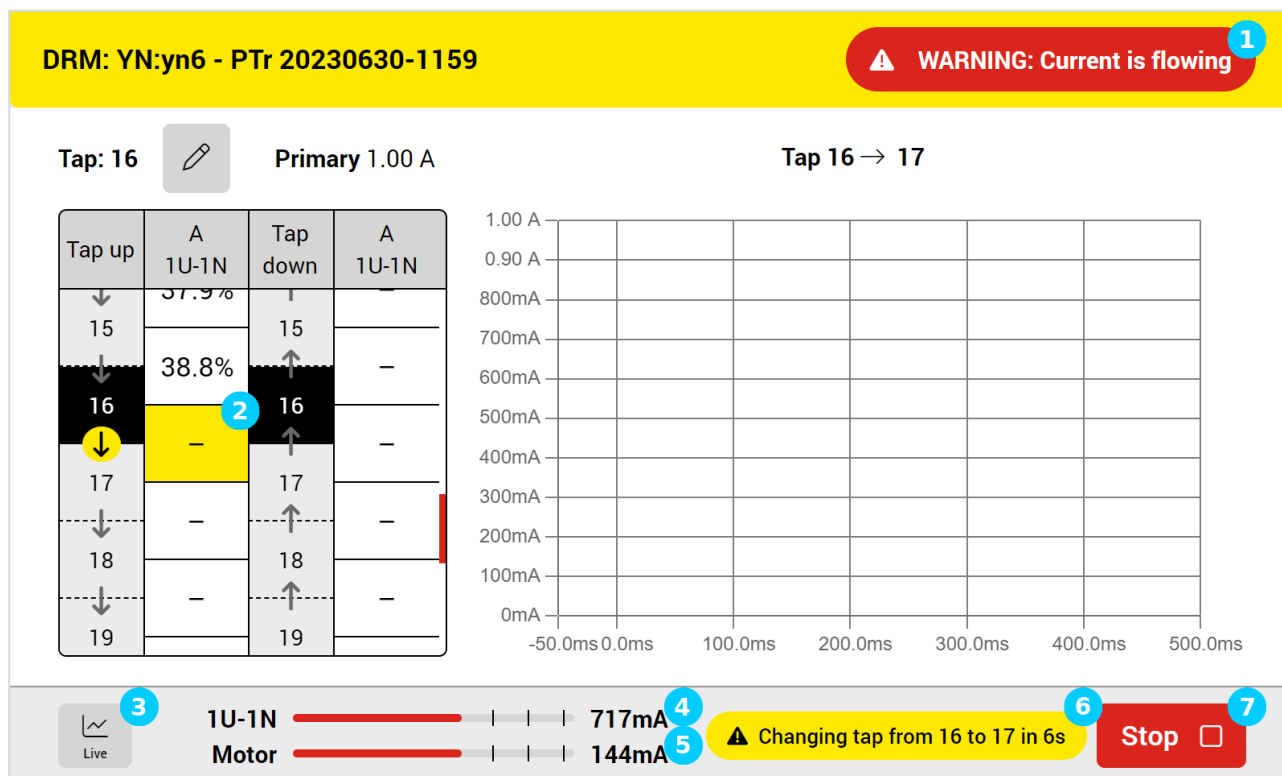


Figure 91: Dynamic resistance measurement view during the measurement

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted cell shows the actual transition
- 3 To see the tap changer motor live current curve over time (Figure 92)
- 4 The output current bar indicates the actual value of the output current and specifies the terminals used for current injection
- 5 The motor current bar indicates the actual value of the tap changer motor current
- 6 The system message informs the user or asks user for action regarding the next tap position
- 7 The stop button can be used to stop the test. Please note that it takes time to discharge and stop the test

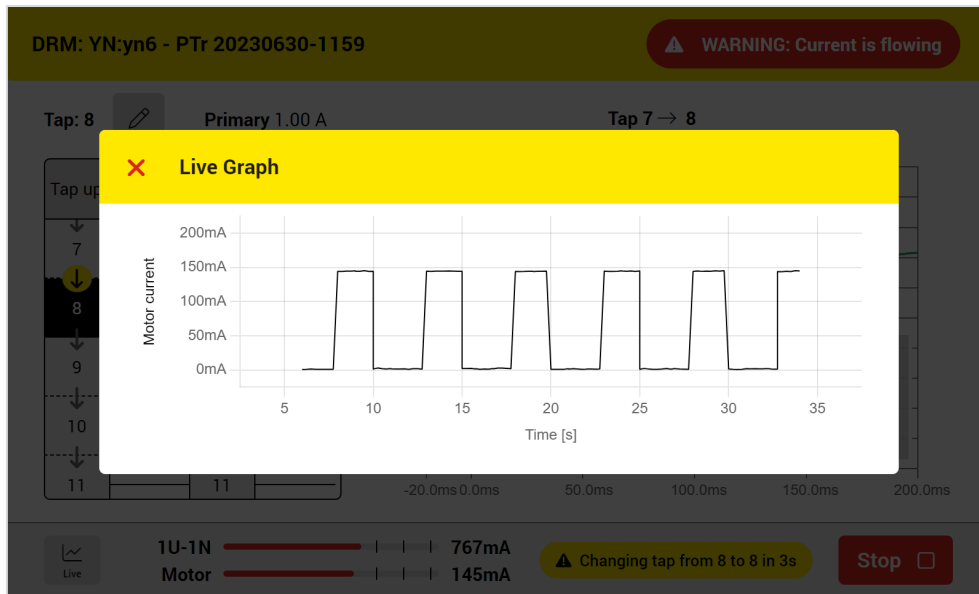


Figure 92: Tap changer motor live graph

10.7.1 Dynamic Resistance Measurement Settings

Figure 93 shows the dynamic resistance measurement main settings. Each part is explained after that.

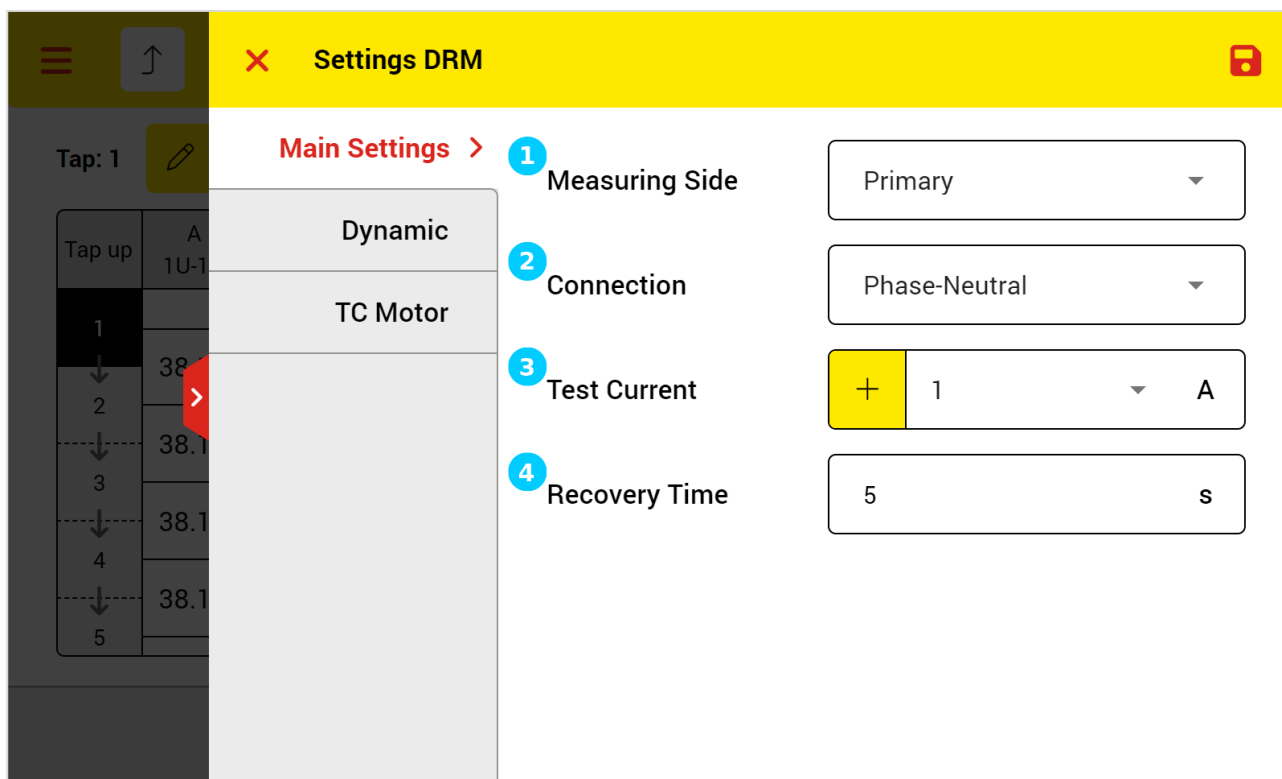


Figure 93: Dynamic resistance measurement main settings

- 1 To select the measuring side, when there are two OLTCs
- 2 To select the option for testing between phases or between phase and neutral, if available
- 3 To select the test current
- 4 The recovery time is the time it normally takes for the current to return to the normal level and stabilize after the tap position is changed. The next transition measurement is not started until this time has elapsed.

Figure 94 shows the dynamic settings of DRM.

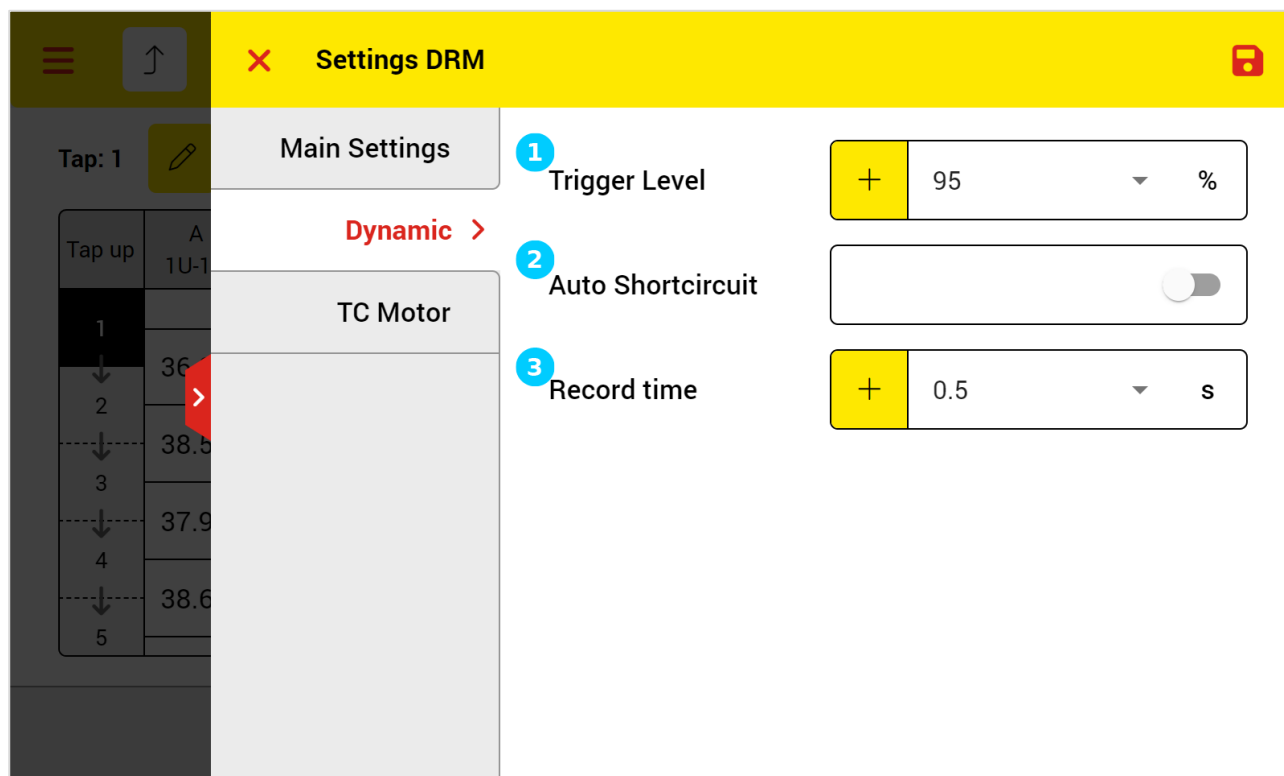


Figure 94: DRM dynamic settings

- 1 To select the expected trigger level
- 2 To select whether the mini-ATOS should short-circuit the other side. The mini-ATOS will automatically engage the internal multiplexer for short-circuiting
- 3 To adjust the recording time of each transition

The tap changer motor current measurement settings are shown in Figure 95.

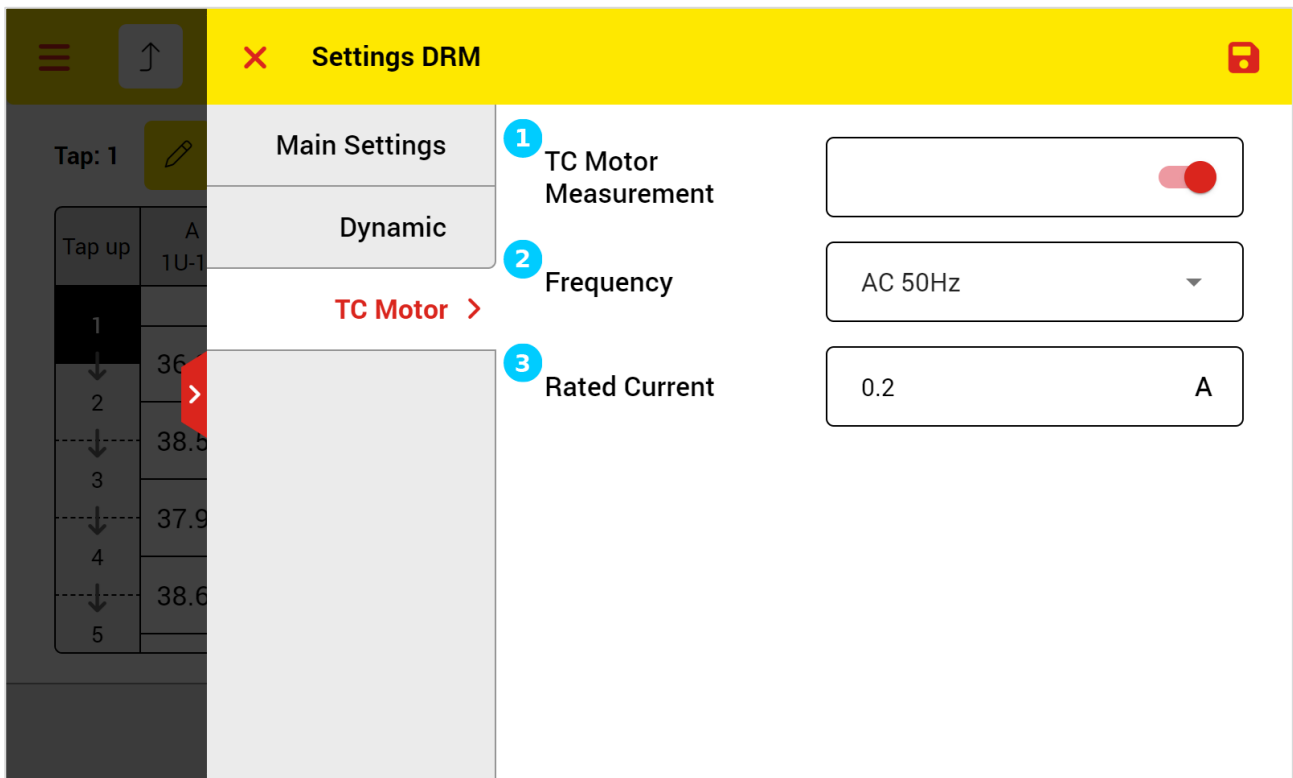


Figure 95: DRM tap changer motor current measurement settings

- 1 To enable or disable the motor current measurement
- 2 To select the tap changer motor, the working voltage frequency
- 3 To input the rated current of the tap changer motor. It is not necessary to enter a higher value to account for the inrush current. The mini-ATOS automatically utilizes a higher measuring range to accurately measure the inrush value

10.7.2 Dynamic Resistance Measurement Results View

By tapping the Results button in the measurement view, the result view will be opened. The result view includes graphs and tables. From the drop-down lists on the top right, it is possible to select graphs and tables.

Figure 96 shows the DRM graphs of all taps for phase A. The selected transition is specified with the red colour while all other transitions are grey. Here the time zero is set to the point when the current is started to fall.

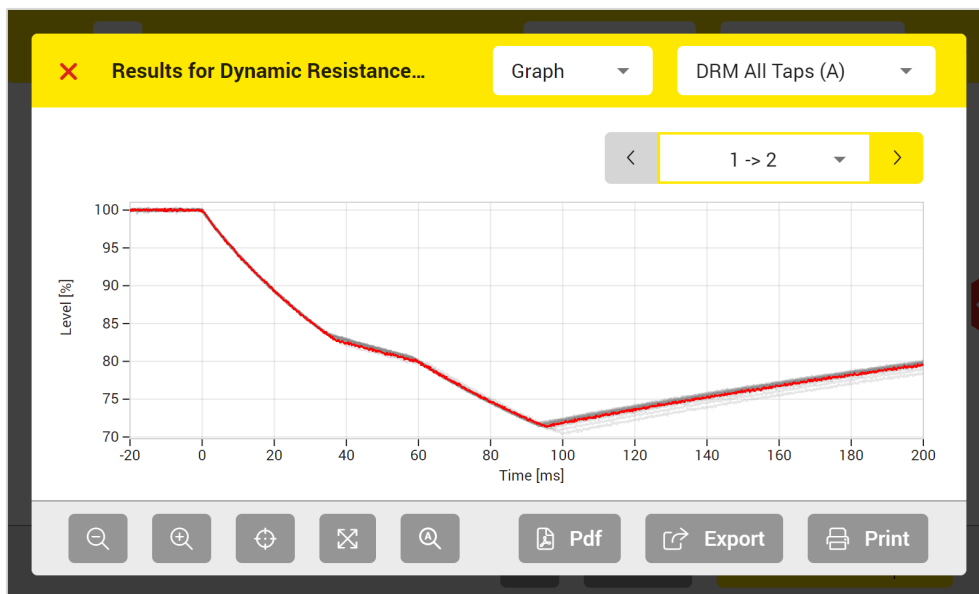


Figure 96: DRM graph result view

You can also compare DRM graphs of three phases (Figure 97) by choosing the DRM single tap (ABC) view.

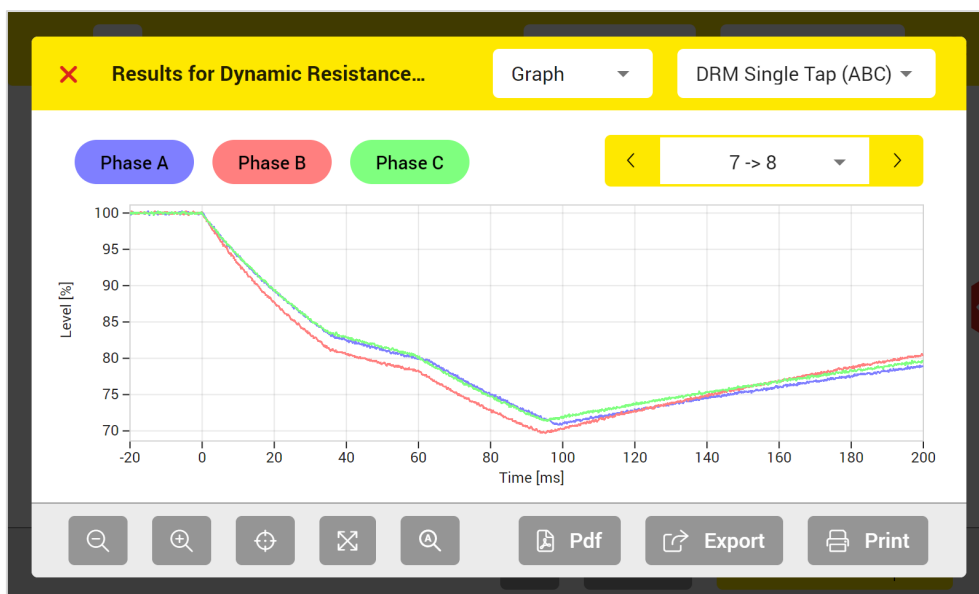


Figure 97: DRM graph 3ph single tap result view

Figure 98 shows the DRM and motor current graph views which show them together. The time zero is set to the start of the motor current.

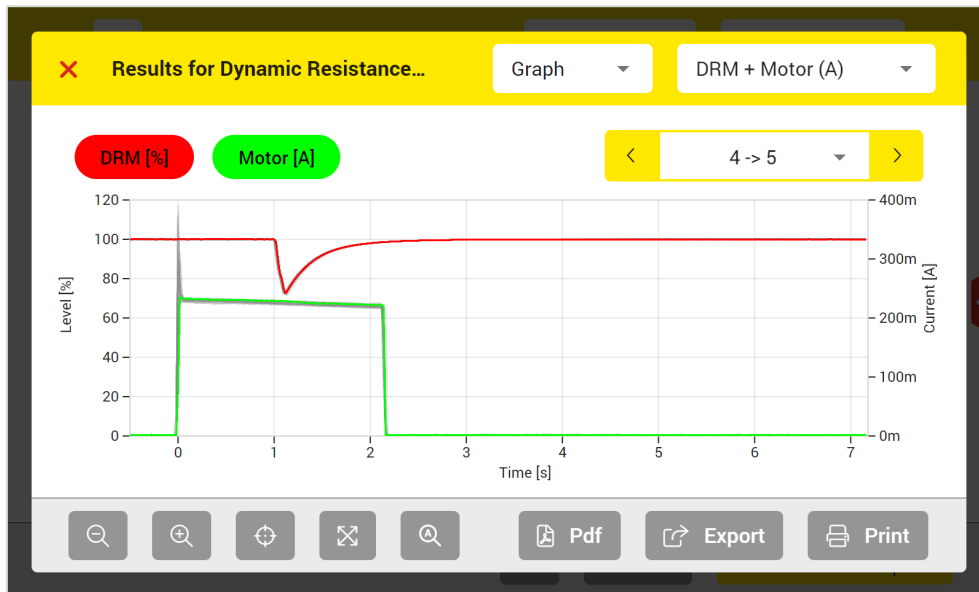


Figure 98: DRM and motor current graph result view

You can also see the stairs view as in Figure 99.

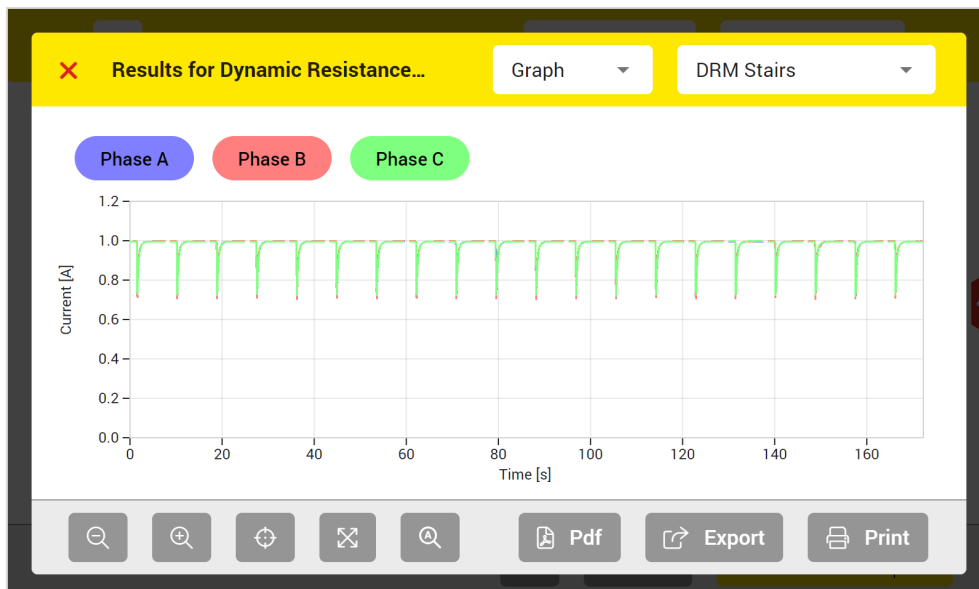


Figure 99: DRM stair graph view

Figure 100 and Figure 101 show the table views of DRM and motor current results.

✖ Results for Dynamic Resistance... Table DRM (A)

From	To	IDrop [%]	Tdrm [ms]	Slope [A/s]	Slope [%/ms]	ITest [A]
1	2	37.3	93.1	10.09	1.0	0.99
2	3	37.1	93.3	9.19	0.9	0.99
3	4	37.2	94.6	9.10	0.9	0.99
4	5	37.8	93.5	8.84	0.9	1.00
5	6	38.7	94.0	9.06	0.9	0.99
6	7	38.6	92.7	9.04	0.9	1.00




 Pdf
  Export
  Print

Figure 100: DRM table result view

✖ Results for Dynamic Resistance... Table Motor (A)

From	To	Inrush [A]	Tmotor [s]	MCI [Acyc]	MCI [Asec]	Tdelay [s]
1	2	144 m	2.14	15.31	306.2 m	1.02
2	3	144 m	2.14	15.24	304.7 m	1.01
3	4	144 m	2.16	15.36	307.1 m	1.03
4	5	144 m	2.14	15.25	305.0 m	1.01
5	6	144 m	2.14	15.26	305.2 m	1.02
6	7	144 m	2.14	15.25	305.0 m	1.02




 Pdf
  Export
  Print

Figure 101: Motor current table result view

10.8 Frequency Response of Stray Losses (FRSL)

The measurement view of FRSL is shown in Figure 102.

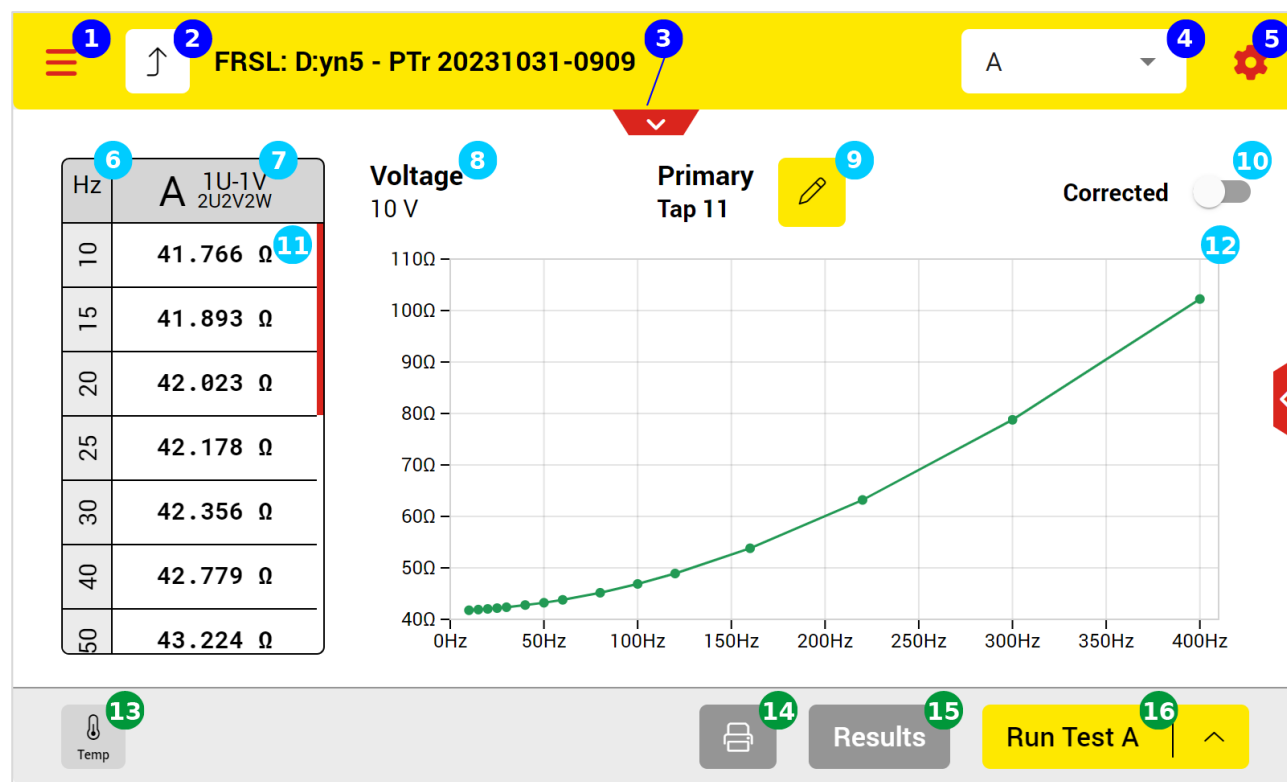


Figure 102: FRSL measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Select which phase to test
- 5 Test settings
- 6 Frequencies
- 7 The phase and the corresponding connections which be used automatically by the instrument to test
- 8 The selected test voltage
- 9 The actual tap position. It can be changed by tapping on the pencil button
- 10 To enable or disable the temperature-corrected resistance view
- 11 The resistance value for each frequency point
- 12 The FRSL resistance graph
- 13 To see the actual measurement value of each temperature measurement channel
- 14 Print the results by using the thermal printer
- 15 Open the detailed results
- 16 Start test button

Figure 103 shows the FRSL measurement view during the measurement.

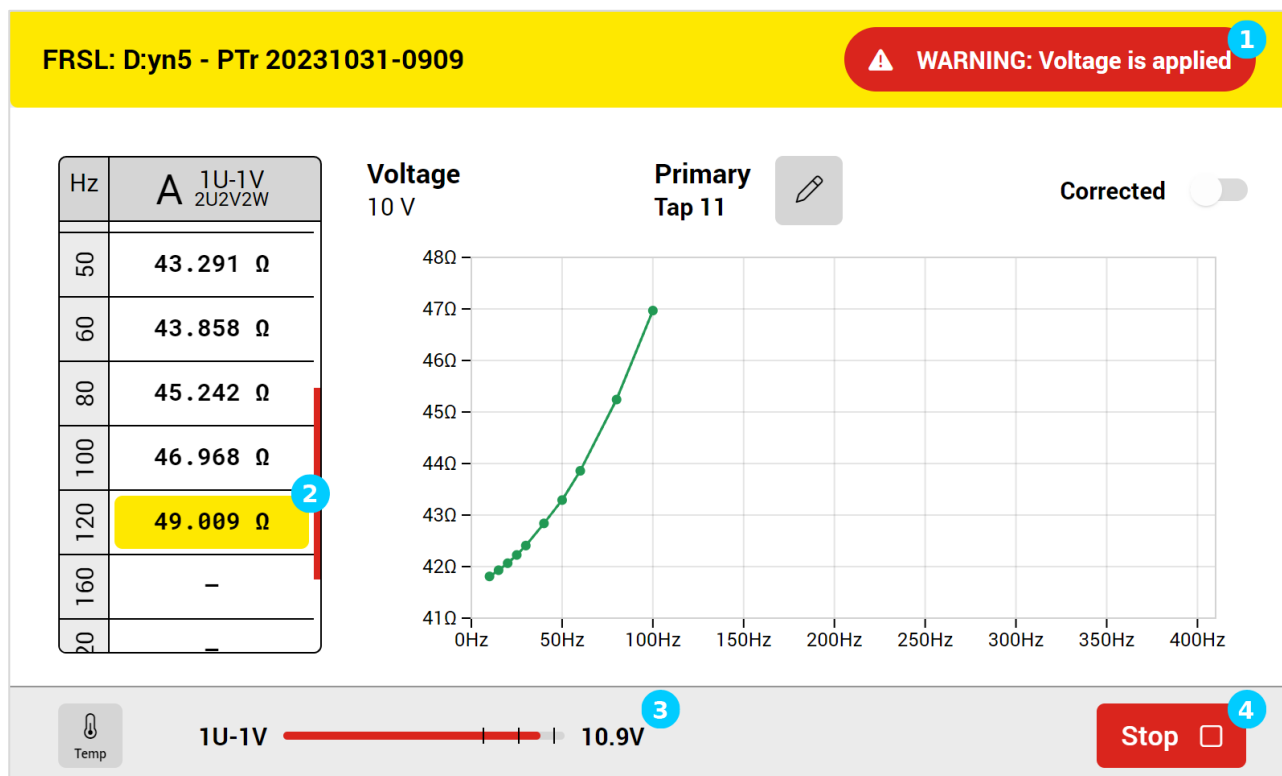


Figure 103: FRSL measurement view during the measurement

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted cell shows the actual measurement
- 3 The output voltage bar indicates the actual value of the output voltage and specifies the terminals used for applying the test voltage
- 4 The stop button can be used to stop the test

10.8.1 FRSL Settings

The main settings of FRSL can be seen in Figure 104.

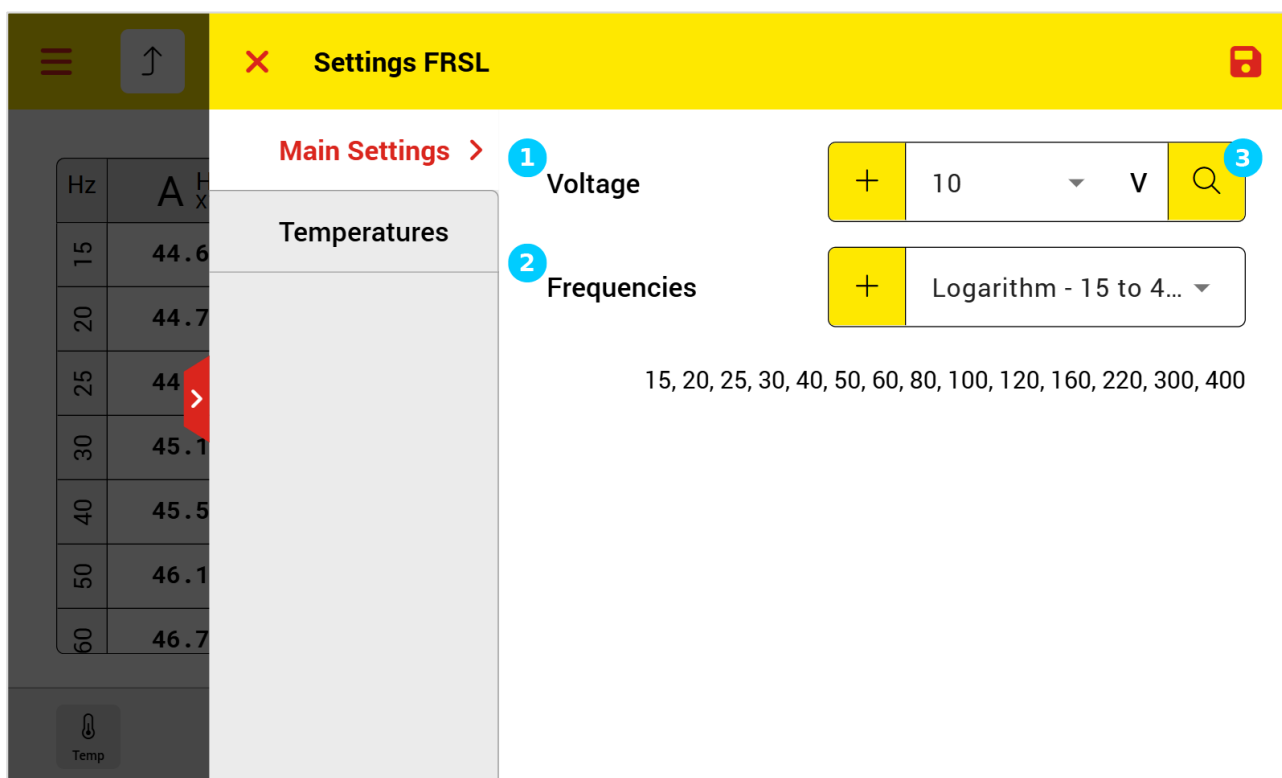


Figure 104: FRSL Main Settings

- 1 To select the test voltage. You can also add user-defined test voltages to the list by tapping on the + button
- 2 To select the frequency points. You can also customize the list by tapping on the + button
- 3 Use the test voltage detect feature to find the optimal test voltage automatically for the connected test object

The temperature settings are the same as other measurement methods temperature settings. Please refer to chapter 10.2.2 for more information.

10.8.2 FRSL Results View

The resistance graph view of FRSL is shown in Figure 105. There is also graph views for temperature corrected values and for inductance values which can be selected by using the drop-down list in the top right corner.

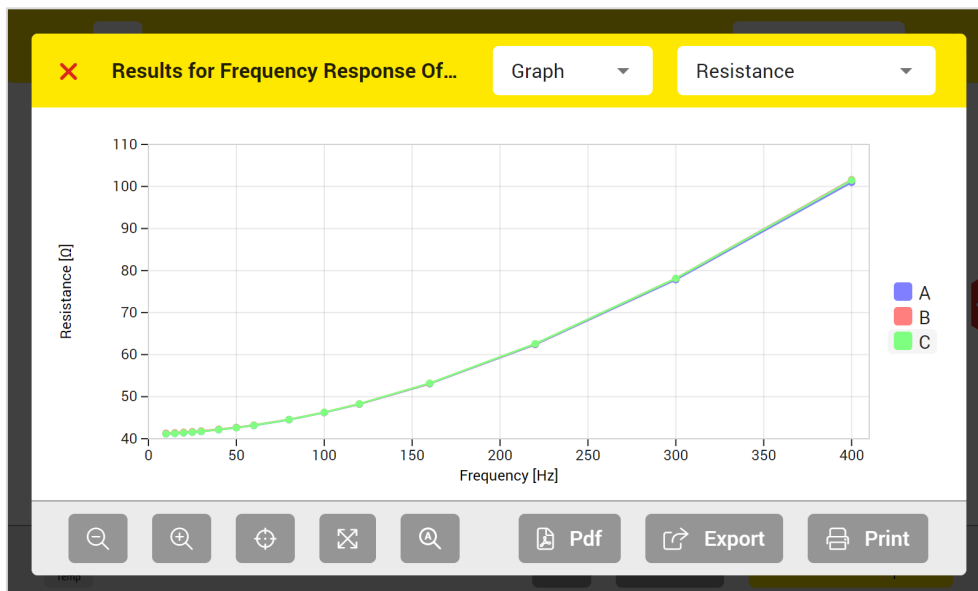
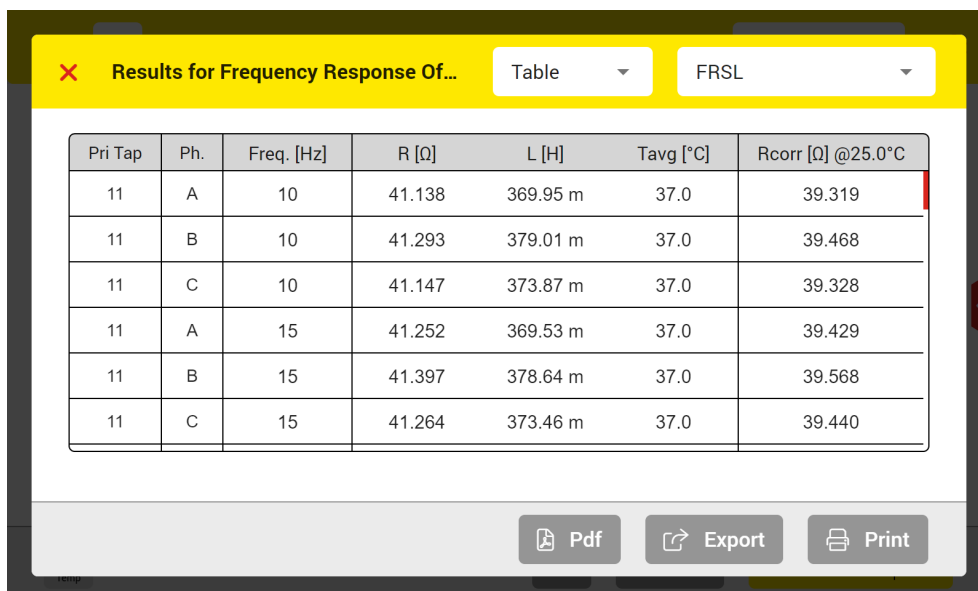


Figure 105: FRSL resistance graph view

Figure 106 shows the table view results of the FRSL.



Pri Tap	Ph.	Freq. [Hz]	R [Ω]	L [H]	Tavg [°C]	Rcorr [Ω] @25.0°C
11	A	10	41.138	369.95 m	37.0	39.319
11	B	10	41.293	379.01 m	37.0	39.468
11	C	10	41.147	373.87 m	37.0	39.328
11	A	15	41.252	369.53 m	37.0	39.429
11	B	15	41.397	378.64 m	37.0	39.568
11	C	15	41.264	373.46 m	37.0	39.440

Figure 106: FRSL table view results

10.9 Temperature Rise Measurement (HRT)

The temperature rise measurement (HRT) measurement view is shown in Figure 107.

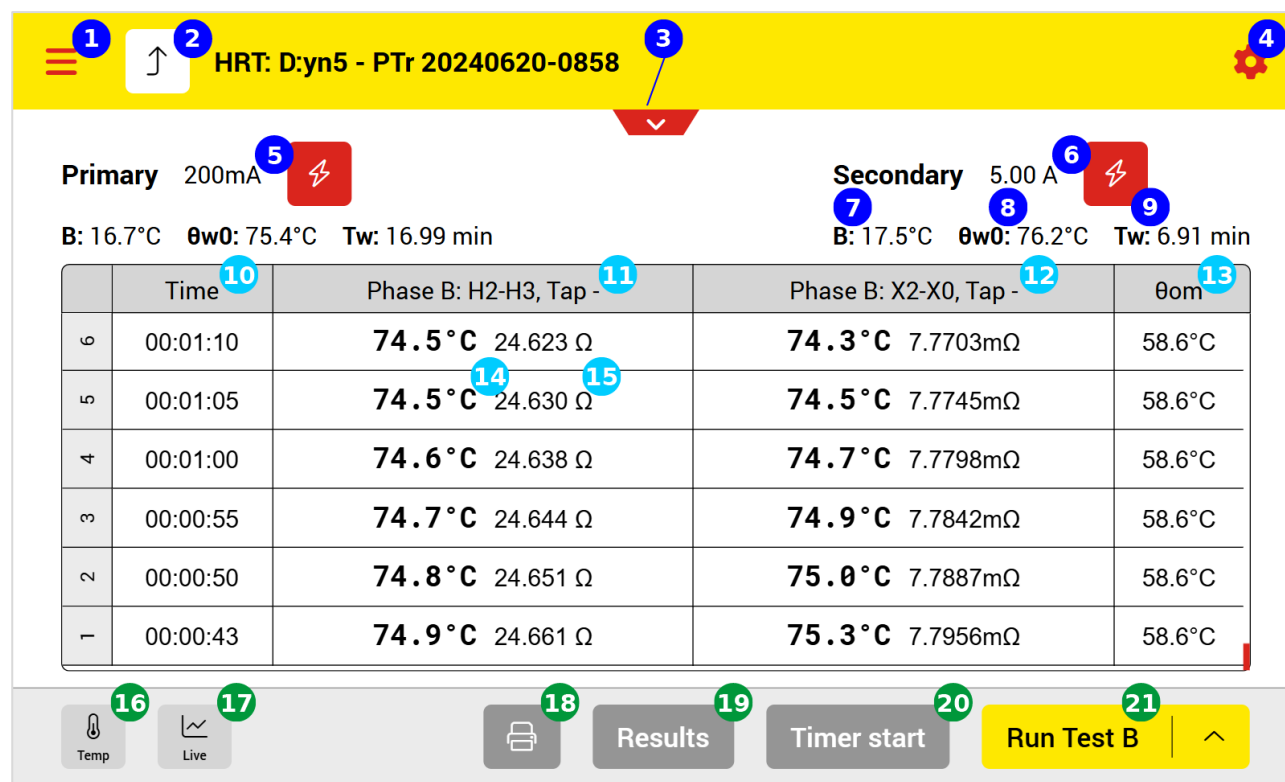


Figure 107: Temperature rise measurement (HRT) measurement view

- 1 Open the main menu
- 2 Back to the test plan page
- 3 Open test object quick access
- 4 Test settings
- 5 The selected current that injects into the primary winding side
- 6 The selected current that injects into the Secondary winding side
- 7 Winding and oil temperature gradient at the instant of the shutdown
- 8 Winding temperature at the instant of shutdown
- 9 Thermal time constant of winding and oil temperature gradient
- 10 Elapsed time
- 11 The phase and the corresponding connections which be used automatically by the instrument to test the primary side
- 12 The phase and the corresponding connections which be used automatically by the instrument to test the non-primary side
- 13 The average temperature of the oil or cooling medium
- 14 The average temperature of the winding, calculated from the measured resistance and the reference values
- 15 The measured resistance

- 16 To see the actual measurement value of each temperature measurement channel
- 17 To see the resistance curve over time
- 18 Print results by using the thermal printer
- 19 Detailed results in table view or graphs
- 20 To start the timer separately. When you run the test without starting the timer, the timer will automatically also start
- 21 Start test button

The HRT view during the measurement is as follows.

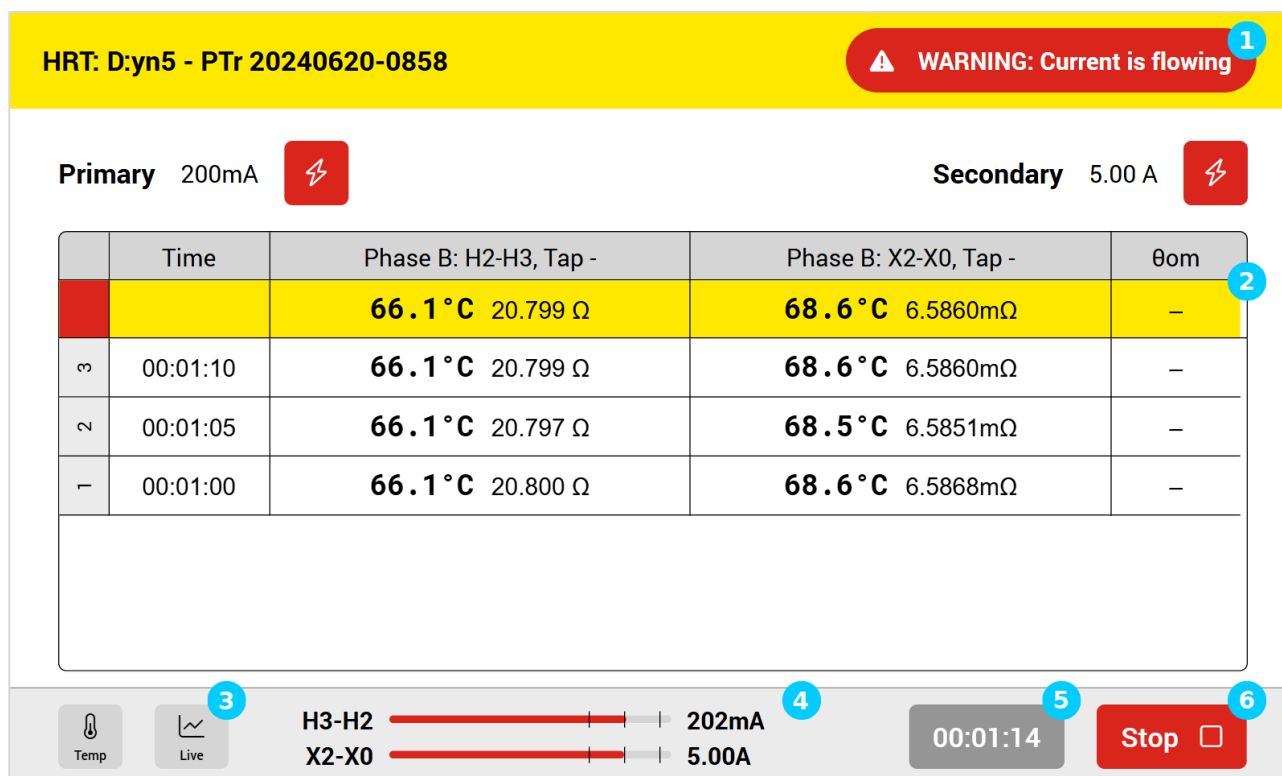


Figure 108: HRT view during the measurement

- 1 The warning symbol shows that it is not safe to touch the cables and test clamps
- 2 The highlighted row shows the parameter's live value
- 3 Here you can open the live graph to see the live resistance curve over time
- 4 The output current bars indicate the actual value of the output current for each channel and specify the terminals used for current injection
- 5 The actual elapsed time
- 6 The stop button can be used to stop the test. Please note that it takes time to discharge and stop the test

10.9.1 HRT Settings

Temperature rise measurement settings are explained as follows.

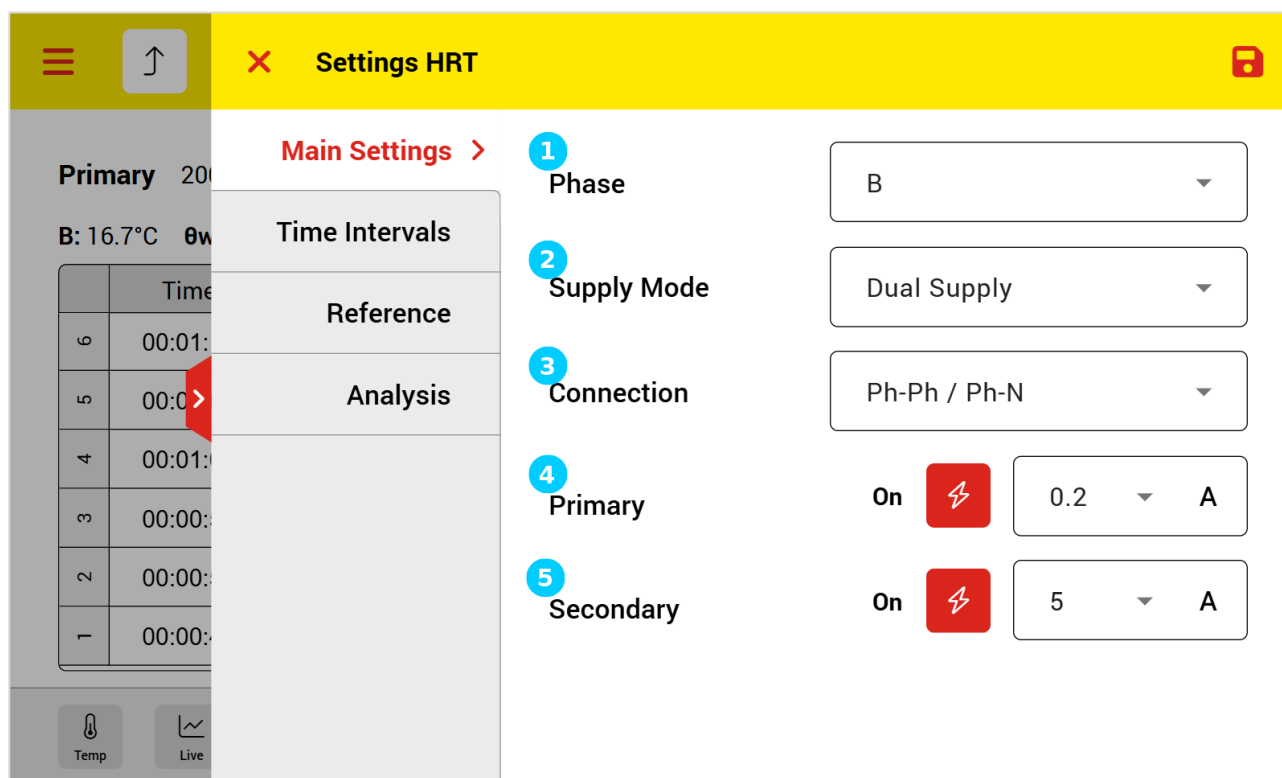


Figure 109: HRT main settings

- 1** To select which phase to test
- 2** To measure both Primary and Secondary simultaneously with two power supplies or to select which side to measure with one power supply
- 3** To select test phase to phase or phase to neutral measurement when possible
- 4** To select the current that injects into the primary winding side and also to turn On or turn Off the power supply for the primary side. It is also possible to select "Charge" mode. In charge mode, the power supply injects current to the primary side to increase the transformer charging speed. But no resistance will be measured
- 5** To select the current that injects into the secondary winding side and also to turn On or turn Off the power supply for the secondary side

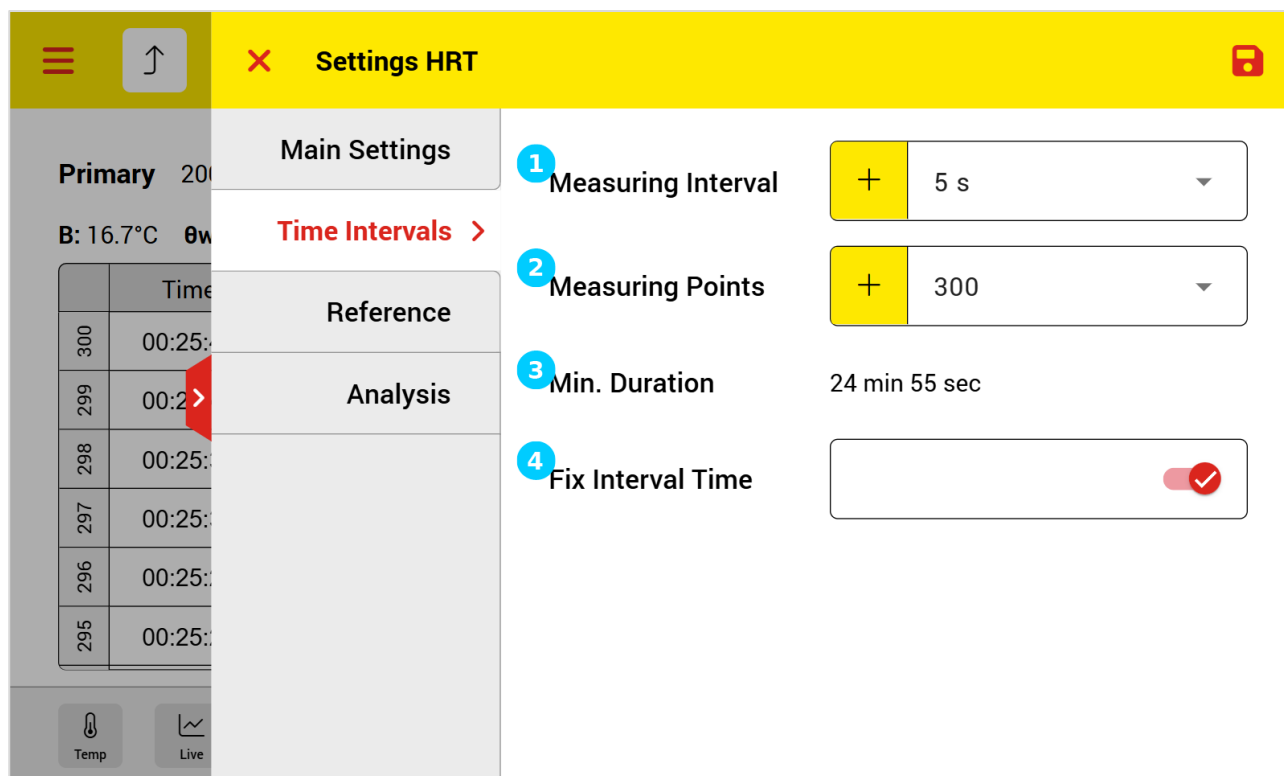
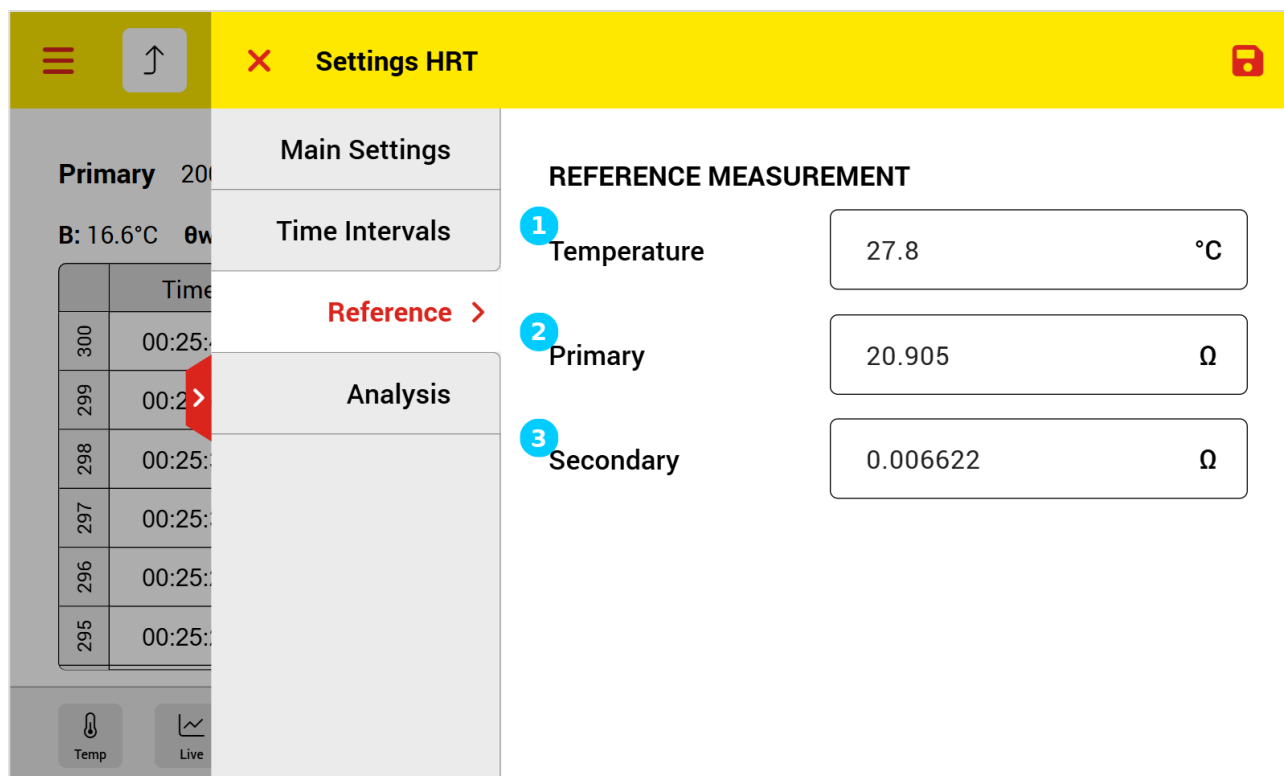


Figure 110: HRT time intervals setting

- 1 To set the time duration between each two measurement points
- 2 To set the number of measuring points
- 3 Total measurement duration which is calculated by timing measuring interval and measuring points
- 4 To set the interval time from Start Time instead of from the 1st measurement point.
e.g. If the Interval Time is set to 10 seconds and the first measurement is taken at 27 seconds, the system stores results at 27, 37, 47...seconds if fix interval time is not selected. if fix interval time is selected, the results will be taken and stored at 27, 30, 40, 50...seconds



Settings HRT

Primary 20.905
B: 16.6°C θ_w

Main Settings

Time Intervals

Reference >

Analysis

REFERENCE MEASUREMENT

1 Temperature 27.8 °C

2 Primary 20.905 Ω

3 Secondary 0.006622 Ω

Temp Live

Figure 111: HRT Reference values

- 1 To enter the temperature of the reference (cold) resistances
- 2 To enter the reference resistance of the primary winding side
- 3 To enter the reference resistance of the non-primary winding side

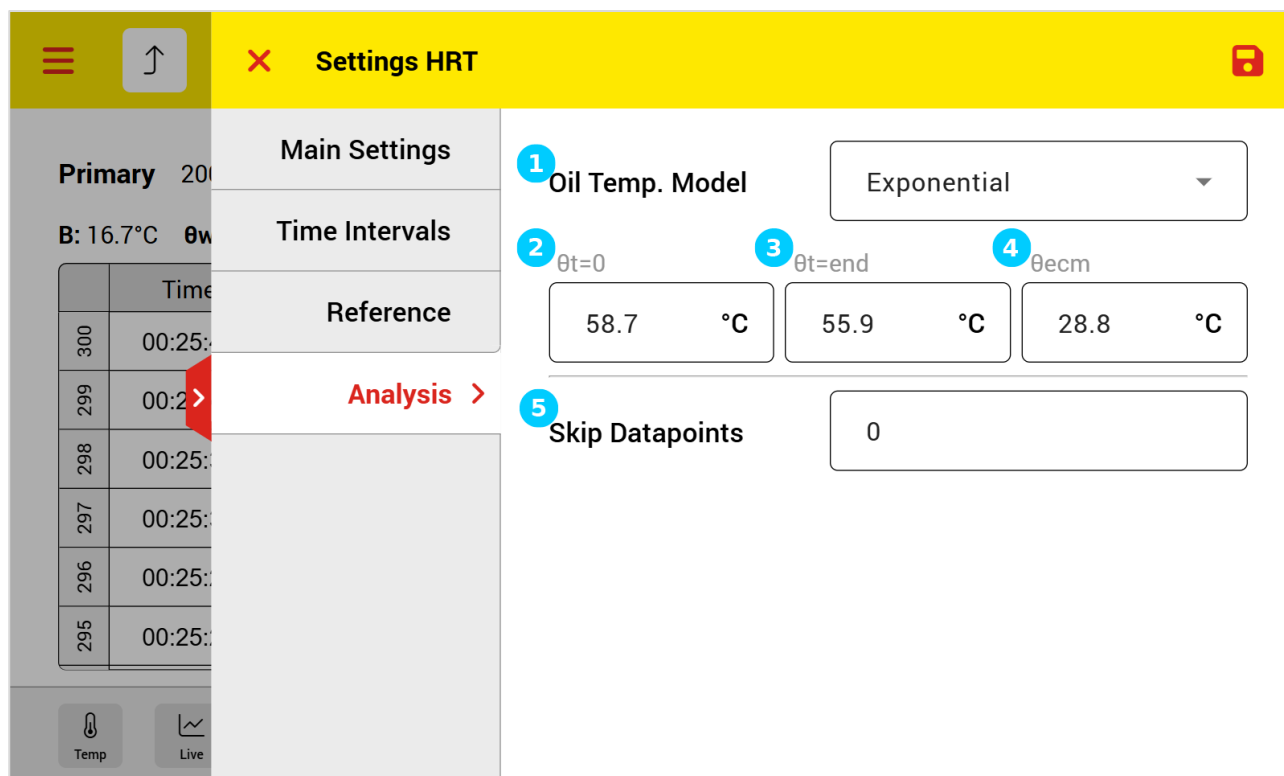


Figure 112: HRT Analysis settings

- 1 To select the oil temperature model. If you select none, the analysis will be deactivated. The oil temperature model can be constant, linear or exponential
It is also possible to measure the oil temperature by using the temperature sensors and select here to use them in analysis. Please see chapter 4.9 for more information
- 2 To enter the average oil temperature which is measured at instant of shutdown manually. This value is required to be entered when the oil temperature model is constant, linear or exponential
- 3 To enter the average oil temperature which is measured at the end of measurement manually. This value is required to be entered when the oil temperature model is linear or exponential
- 4 To enter the average ambient or external cooling medium temperature which is measured manually. This value is required to be entered when the oil temperature model is exponential
- 5 To skip the datapoints from analysis which seems out of trend. These datapoints will be ignored in analysis from the start of measurement

10.9.2 HRT Results View

Figure 113 and Figure 114 show the graph and table views of the HRT results.

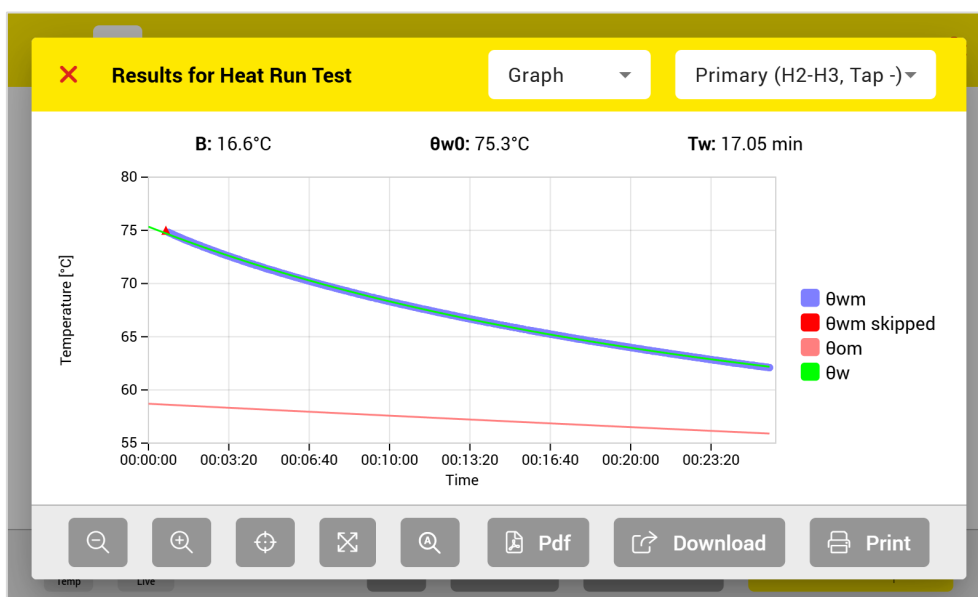
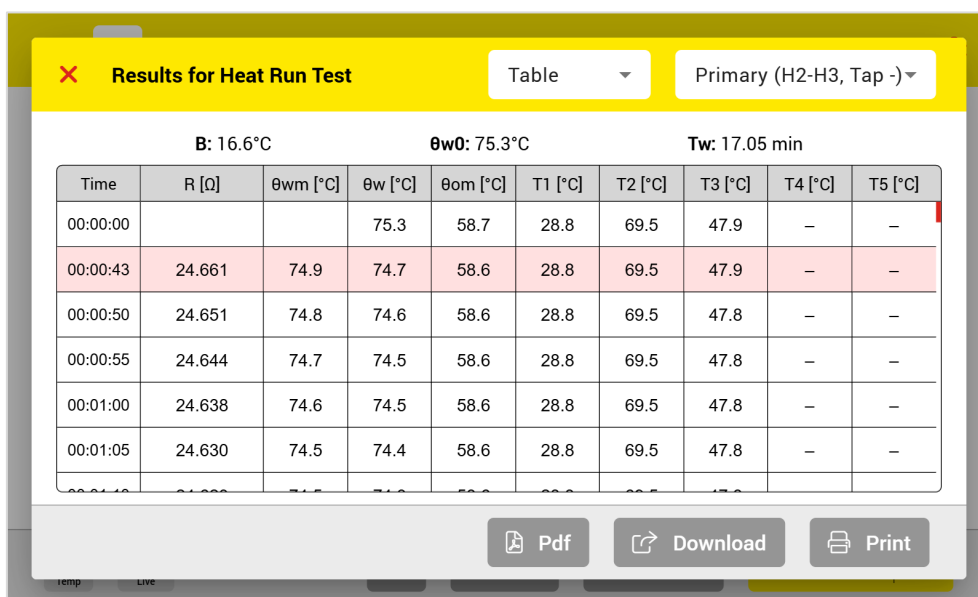


Figure 113: Graph view of HRT results



Results for Heat Run Test | Table | Primary (H2-H3, Tap -) ▾

B: 16.6°C θw0: 75.3°C Tw: 17.05 min

Time	R [Ω]	θwm [°C]	θw [°C]	θom [°C]	T1 [°C]	T2 [°C]	T3 [°C]	T4 [°C]	T5 [°C]
00:00:00			75.3	58.7	28.8	69.5	47.9	–	–
00:00:43	24.661	74.9	74.7	58.6	28.8	69.5	47.9	–	–
00:00:50	24.651	74.8	74.6	58.6	28.8	69.5	47.8	–	–
00:00:55	24.644	74.7	74.5	58.6	28.8	69.5	47.8	–	–
00:01:00	24.638	74.6	74.5	58.6	28.8	69.5	47.8	–	–
00:01:05	24.630	74.5	74.4	58.6	28.8	69.5	47.8	–	–

Buttons: Pdf, Download, Print

Figure 114: Table view of HRT results

11 Go Taps

With go taps, it is possible to perform winding resistance or turns ratio of taps and phases in a sequence of measurements. This helps to measure faster and easier.

To use this option, in the measuring screen and beside the run button, select Go Taps from the list of test modes. When you run the test, the Go Taps menu will be first opened as Figure 115. After adjusting the desired parameters, you can start the measurement by using the play icon on the top right of the window.

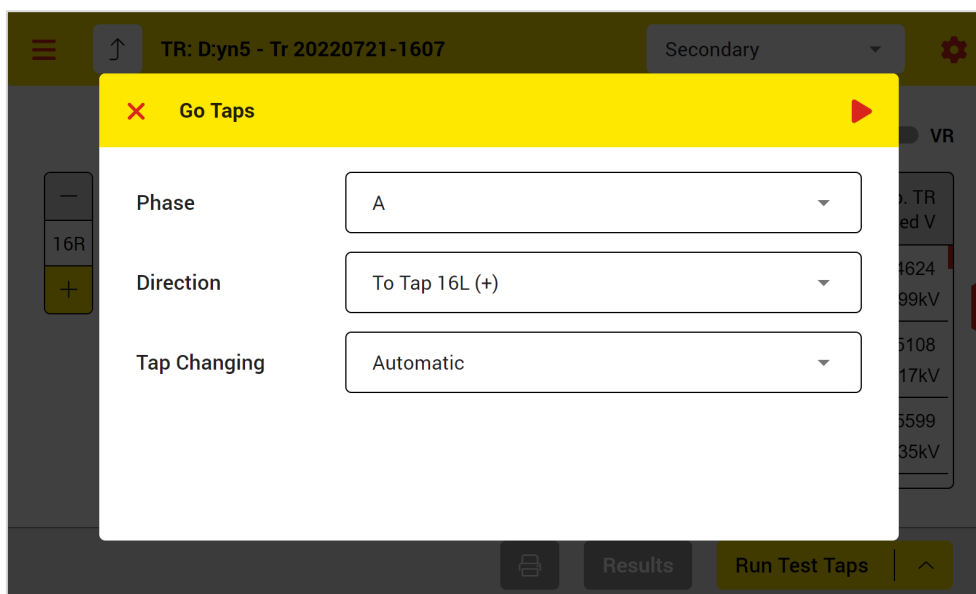


Figure 115: Go Taps menu for turns ratio

Phase

Here, you can select which phase to test. It is possible to test only one phase (e.g. A, B or C), or to test all three phases (ABC) at each tap position. For winding resistance measurement, there is ABC,CBA,ABC,... item which is the optimized three phase version which save time in charge and discharge.

Direction

The tap changing direction should be selected here. You can select either the direction to the first tap or to the last tap.

Tap Changing: Automatic

For automatic tap changing, the mini-ATOS tap control output must be connected to the tap changer control unit for both directions. In the transformer profile, Tap Changer tab, the tap control must be also activated.

During the automatic tap changing, the tap switch window will be shown like Figure 116. In the automatic tap switch window, there is a countdown timer. The system actually waits, so the tap changer has time to change the tap position to the next tap. The waiting period is according to the maximum transition time which was set in the test object profile (Please see chapter 8.1.5). After the waiting period, the system performs the next measurement.

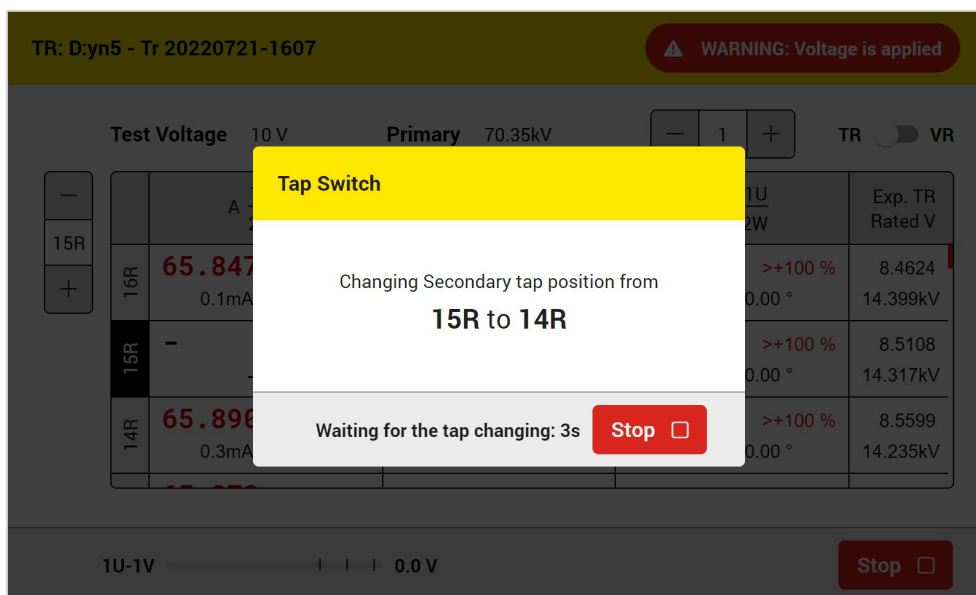


Figure 116: Tap Switch window during automatic tap changing

Tap Changing: Manual

Tap changing can be also manual. During the tap changing, the tap switch window (Figure 117) will ask to change the tap position manually and confirm when it is changed. To confirm, it is possible to tap the confirm button on the screen, and it is also possible to use a hand switch which must be connected to the mini-ATOS External terminal.

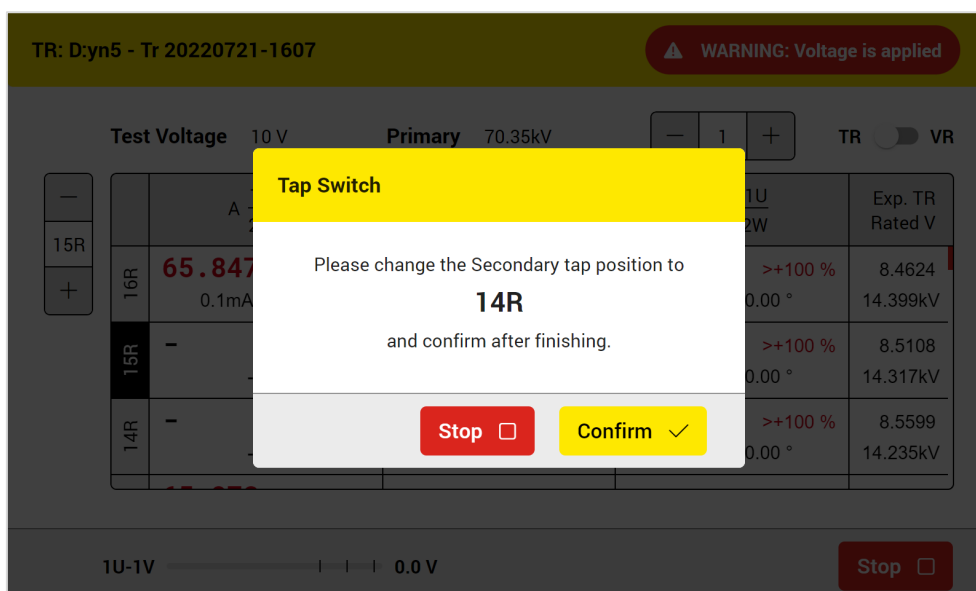


Figure 117: Tap Switch window during manual tap changing

12 Remote Access Instruction

With the remote connection, it is possible to access the device software from other devices such as PCs and tablets. The remote connection is possible with the USB or the network connection. When the device is connected, the mini-ATOS can be accessed by using any web browser. For optimal operation, we recommend using Google Chrome or Microsoft Edge browser.

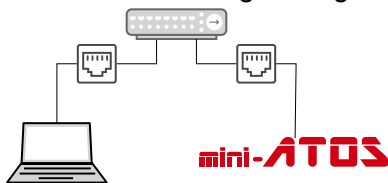
The procedure to use remote access is explained as follows:



- 1- Please ensure that the remote access feature is enabled in the device settings (Refer to chapter 7.4.5). If the access code was manually adjusted, make a note of it to enter it later.
- 2- Connect the mini-ATOS to the PC:

- Directly by using the USB-B cable



- Or connect the mini-ATOS to an already existing network. Make sure the mini-ATOS is connected to the same network as the device you want to connect with and also the networking settings are adjusted correctly (Please see chapter 7.4.4)



- 3- From the home page or the main menu, tap the logout icon  to see the select profile page like Figure 118. You can also tap on the information icon  to see the remote access instructions
- 4- Activate remote access on the select profile page. If you didn't input the access key manually in the settings, you will see then the auto-generated access key (Figure 119)
- 5- Open the browser on a PC or tablet and then:
 - If the connection is with the USB cable, enter '**http://192.168.11.1**' in the address bar to open the software
 - If the connection is with the Network cable, enter the **hostname** after the **http://** in the format of '**http://[your mini-ATOS hostname]**' in the address bar to open the software (e.g., **http://mini-ATOS-411-101**). You can find the hostname in the networking settings, please see chapter 7.4.4
- 6- Enter the access key and confirm to access the software (Figure 120)

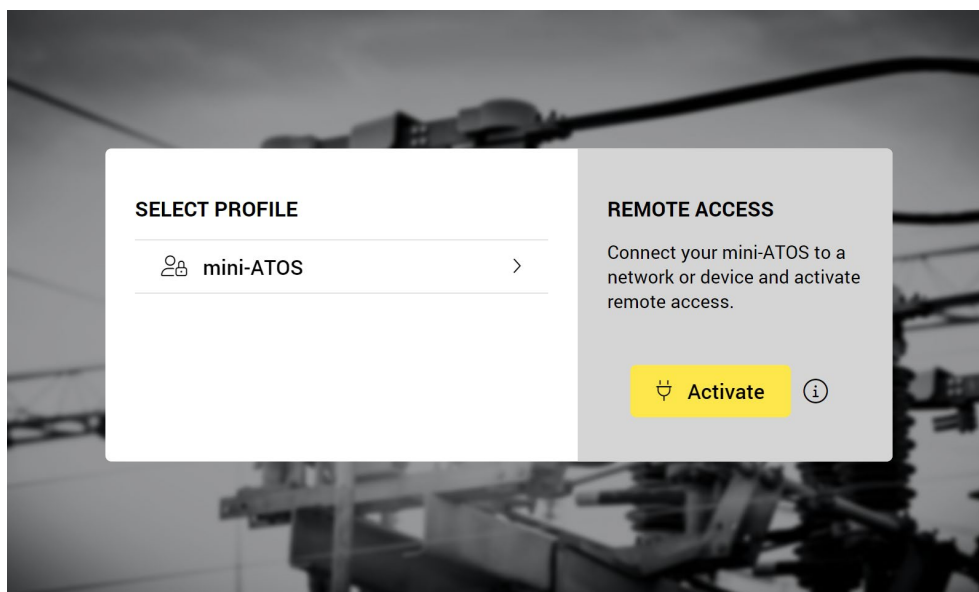


Figure 118: Select the Profile page on the mini-ATOS display

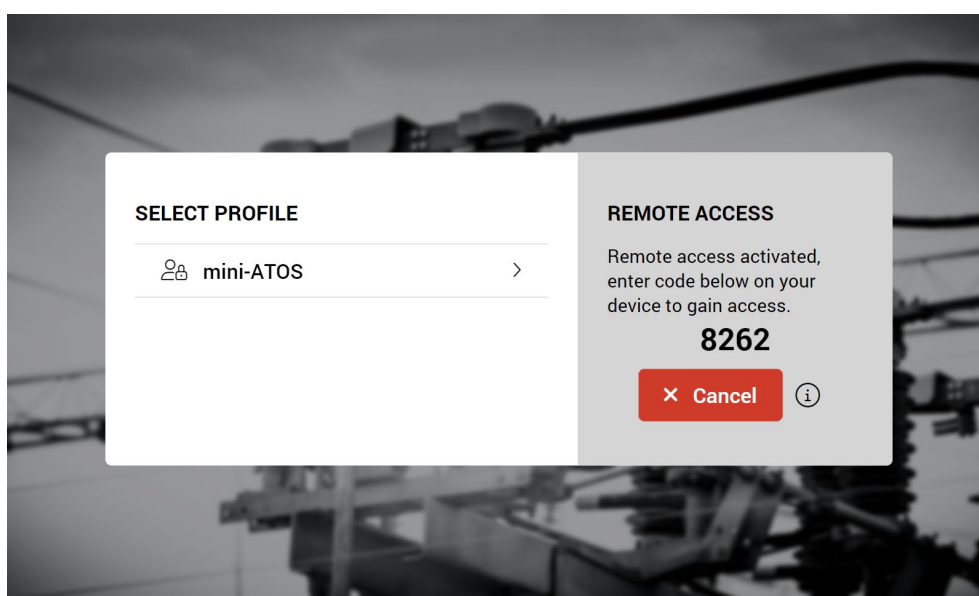


Figure 119: Remote access activated with an auto-generated key on the mini-ATOS display

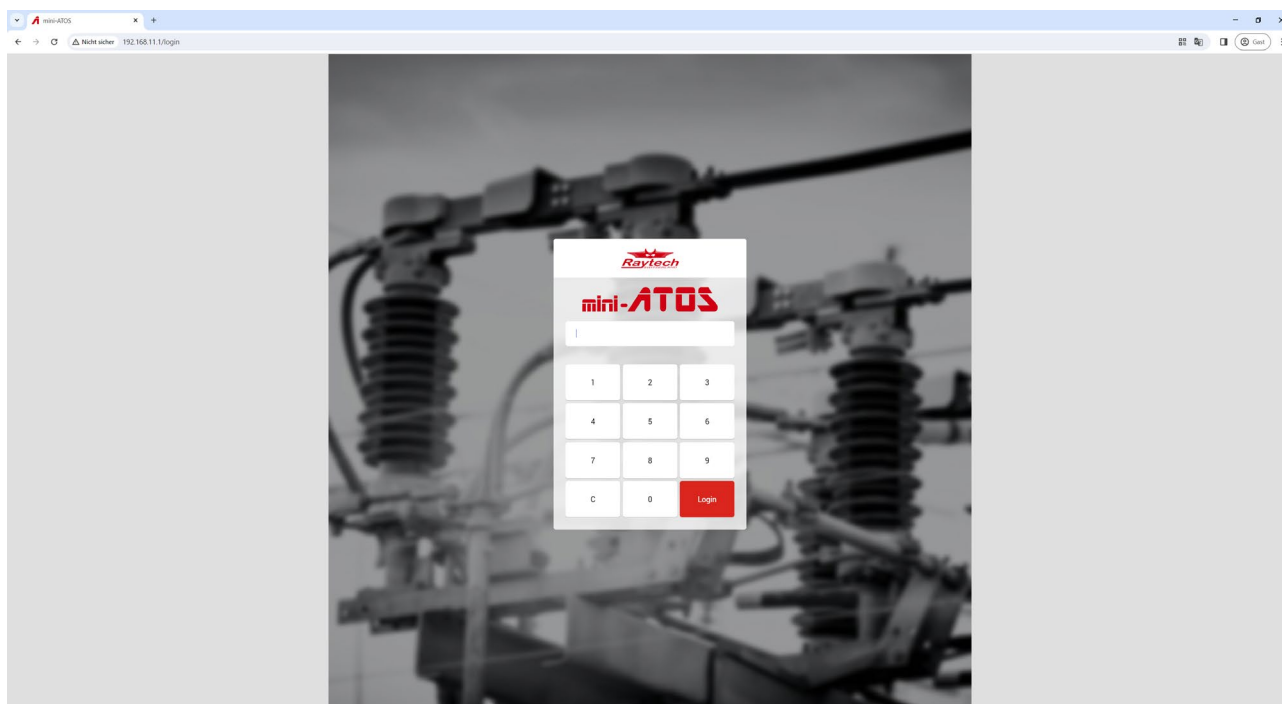


Figure 120: Remote access login page

Notes

- You can always cancel the remote connection from the device
- Only one active session is possible at once
- If the access code is auto-generated, by entering a wrong access code each time, a new code will be generated.

13 Interfaces

In this chapter, the various kinds of mini-ATOS interfaces will be introduced. There is also a separate application note about the mini-ATOS external cables hood which includes more details. you can download this application note from the Raytech website [downloads](https://www.raytech.ch/downloads)⁴ page or from the [mini-ATOS](https://www.raytech.ch/products/detail/mini-atos)⁵ product page.

13.1 USB

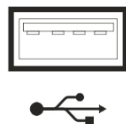
The USB interface consists of two Master connectors and one Slave connector.

The Master connector can be used to update the device and store/load measurement data from USB memory sticks.

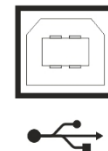
It is also possible to connect a USB mouse and a USB keyboard for easier input.

The Slave connector can be used to connect the mini-ATOS to a PC or to connect a USB printer.

USB-Master (Type A) x2



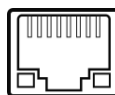
USB-Slave (Type B)



13.2 Ethernet

The Ethernet port can be used to connect the mini-ATOS to a network to enable the remote connection.

RJ45



⁴ <https://www.raytech.ch/downloads>

⁵ <https://www.raytech.ch/products/detail/mini-atos>

13.3 External (4pins version)

This port is multi-functional and consists of the following functions:

Hand switch for tap changing



Raytech warning lamp



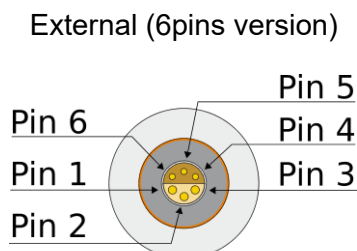
When both hand switch and warning lamp are required then a splitter cable is necessary as follows which can be ordered as an optional item:

Cable adapter hand switch & warning lamp
(4pin to 2x 4pin)



13.4 External (6pins version)

The 6pins external port consists two additional pins to connect an external safety interlock. The function of other 4pins is the same as the 4pins version. The external safety interlock can be for example a safety door or a safety hand switch. The safety interlock must be connected to pin number 5 and 6.



When these pins are shorted, it means that it is safe to perform a measurement. If they are not shorted, it is not possible to start a measurement.

If the connection opens during a measurement, the measurement will be stopped automatically.

When an external safety interlock and either a hand switch or warning lamp are required then a splitter cable is necessary as follows which can be ordered as an optional item:

Cable adapter external
(6pin to 6pin & 4pin)



When an external safety interlock and both hand switch and warning lamp are required then two splitter cables are necessary as follows which can be ordered as an optional item:

Cable adapter external
(6pin to 6pin & 4pin)



Cable adapter hand switch/ warning lamp
(4pin to 2x 4pin)



13.5 Tap Control

This port is used for an external connection to a tap changer dry contact. With this connection, changing the tap position can be done from the mini-ATOS.



Two connectors are for changing the tap position in the up direction and the other two are for changing the tap position in the down direction. The cables are marked with labels. The maximum input voltage is 240VAC, Cat II.

14 Technical Specifications

14.1 General

Area of use	Portable to use indoors and outdoors including in heavy industrial electromagnetic environments
Enclosure	Industrial high-impact plastic case
Supply	IEC 60320, C13/C14 mains connector, CAT II
Rated input voltages	110/240 VAC @ 50/60Hz, automatic ranging
Absolute input voltages	90-264 VAC @ 47-63Hz
Consumption power	Max. 900VA
Mains protection	2x 5mm x 20mm T10A Fuse
Output power	Max. 600W
Test voltage user selectable (AC)	10-250 VAC
Max. test current (AC)	1A
Test current user selectable (DC)	0.050-30A and 0.025-7.5A simultaneously
Max. test voltage (DC)	50VDC (100VDC with automatic booster)
Temperature measurement range	-20°C (-4°F) to 110°C (230°F)
Display	7" TFT Color LCD
Input devices	Capacitive touch screen, support mouse and keyboard
Front panel	Sealed, anodized
Interfaces	3 USB 2.0 full speed (2 hosts, 1 device) and Ethernet
Printer	Internal 1.9" thermal printer
Operating temperature	-10°C (14°F) to 55° C (131°F)
Storage temperature	-20°C (-4°F) to 70°C (158°F)
Humidity	5%-95% relative humidity, no condensation
Pollution degree	2
Altitude	Up to 2000m (without derating)
Degree of protection (closed door)	IP67, dust-tight and water immersion up to a 1-meter depth
Degree of protection (open door)	IP20
Size	L: 525 mm (20.7") W: 437 mm (17.2") H: 213 mm (8.4")
Weight (instrument)	16.5 kg (36.4 lbs.)
Weight (accessories)	Please contact
Shipping weight and package size	Please contact

14.2 Accuracies

All accuracy values are measured at an ambient temperature of $23\pm5^{\circ}\text{C}$ after a warm-up of 30 minutes.

14.2.1 Turns Ratio Measurement

Table 11: Turns ratio accuracy

Parameter	Range	Accuracy	Resolution
Turns Ratio 250VAC @ 55Hz	0.8 ... 200	$\pm 0.04\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	200 ... 5000	$\pm 0.10\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	5000 ... 50000	$\pm 0.40\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
Turns Ratio 100VAC @ 55Hz	0.8 ... 200	$\pm 0.04\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	200 ... 2000	$\pm 0.10\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	2000 ... 20000	$\pm 0.40\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
Turns Ratio 40VAC @ 55Hz	0.8 ... 200	$\pm 0.04\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	200 ... 2000	$\pm 0.06\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	2000 ... 20000	$\pm 0.40\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
Turns Ratio 10VAC @ 55Hz	0.8 ... 200	$\pm 0.06\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits
	200 ... 5000	$\pm 0.10\% \text{ Rdg} \pm 1 \text{ LSD}$	5 Digits

Table 12: Other AC parameters accuracy

Parameter	Range	Accuracy	Resolution
AC Test Current @ 55Hz	0 ... 1 A	$\pm 1.00\% \text{ Rdg} \pm 0.01 \text{ A}$	4 Digits
Phase Angle @ 55Hz	$\pm 90^{\circ}$	$\pm 0.05^{\circ} \text{ Rdg} \pm 1 \text{ LSD}$	4 Digits or 0.01°
Output Voltage	0 – 250VAC	$\pm 1\% \pm 1 \text{ LSD}$	4 Digits or 0.1VAC

14.2.2 Resistance Measurements

Table 13: DC resistance accuracies with 50V/7.5A DC power supply

I_{test}	Range	Accuracy	Resolution
5.0 - 7.5A	0.00 $\mu\Omega$... 10 Ω	$\pm 0.10\%$ Rdg $\pm 1.6\mu\Omega$	5 Digits or 0.01 $\mu\Omega$
1.0 – 5.0A	0.00 $\mu\Omega$... 50 Ω	$\pm 0.10\%$ Rdg $\pm 8.0\mu\Omega$	5 Digits
0.5 – 1.0A	0.00 $\mu\Omega$... 100 Ω	$\pm 0.10\%$ Rdg $\pm 16\mu\Omega$	5 Digits
0.1 - 0.5A	0.00 $\mu\Omega$... 500 Ω	$\pm 0.10\%$ Rdg $\pm 80\mu\Omega$	5 Digits
25 - 100mA	0.00 $\mu\Omega$... 2k Ω	$\pm 0.10\%$ Rdg $\pm 320\text{m}\Omega$	5 Digits
< 25mA	2k Ω ... 10k Ω	$\pm 0.10\%$ Rdg $\pm 50\Omega$	5 Digits
< 25mA	10k Ω ... 100k Ω	$\pm 1\%$ Rdg $\pm 500\Omega$	5 Digits

Table 14: DC resistance accuracies with 12V/30A DC power supply



I_{test}	Range	Accuracy	Resolution
25.0 – 30.0A	0.00 $\mu\Omega$... 0.48 Ω	$\pm 0.10\%$ Rdg $\pm 0.4\mu\Omega$	5 Digits or 0.01 $\mu\Omega$
20.0 – 25.0A	200 $\mu\Omega$... 0.60 Ω	$\pm 0.10\%$ Rdg $\pm 0.1\mu\Omega$	5 Digits
20.0 – 25.0A	0.00 $\mu\Omega$... 200 $\mu\Omega$	$\pm 0.10\%$ Rdg $\pm 0.3\mu\Omega$	5 Digits
15.0 – 20.0A	0.00 $\mu\Omega$... 0.80 Ω	$\pm 0.10\%$ Rdg $\pm 0.6\mu\Omega$	5 Digits
10.0 – 15.0A	0.00 $\mu\Omega$... 1.2 Ω	$\pm 0.10\%$ Rdg $\pm 0.8\mu\Omega$	5 Digits
5.0 – 10.0A	0.00 $\mu\Omega$... 2.4 Ω	$\pm 0.10\%$ Rdg $\pm 1.6\mu\Omega$	5 Digits
1.0 – 5.0A	0.00 $\mu\Omega$... 12 Ω	$\pm 0.10\%$ Rdg $\pm 8.0\mu\Omega$	5 Digits
0.5 – 1.0A	0.00 $\mu\Omega$... 24 Ω	$\pm 0.10\%$ Rdg $\pm 16\mu\Omega$	5 Digits
0.1 - 0.5A	0.00 $\mu\Omega$... 120 Ω	$\pm 0.10\%$ Rdg $\pm 80\mu\Omega$	5 Digits
50 - 100mA	0.00 $\mu\Omega$... 240 Ω	$\pm 0.10\%$ Rdg $\pm 1.2\Omega$	5 Digits
< 50mA	240 Ω ... 1k Ω	$\pm 0.10\%$ Rdg $\pm 5\Omega$	5 Digits
< 50mA	1k Ω ... 10k Ω	$\pm 1\%$ Rdg $\pm 50\Omega$	5 Digits

14.2.3 Temperature Measurement

Table 15: Output voltage accuracy

Range	Accuracy	Resolution
0 – 70°C	$\pm 0.2^\circ\text{C} \pm 1 \text{ LSD}$	0.1°C

14.3 Standards and Approvals

 	Safety			IEC 61010-1
	EMC	Emission Class A	RF emission	CISPR 11
			Current harmonic emission	IEC 61000-3-2
			Flicker and voltage fluctuations	IEC 61000-3-3
		Immunity industrial electromagnetic environment	Electrostatic discharge (ESD)	IEC 61000-4-2
			Electromagnetic field	IEC 61000-4-3
			Burst	IEC 61000-4-4
			Surge	IEC 61000-4-5
			Conducted RF	IEC 61000-4-6
			Power frequency magnetic field	IEC 61000-4-8
			Voltage dip	IEC 61000-4-11



Appendix

mini-ATOS

mini Automatic Transformer
Observation System

Appendix

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A Warranty Conditions

Raytech AG Switzerland shall at their option and expense, repair or replace any part or parts that prove to be defective within the warranty limitation period- irrespective of the operating time of the test equipment provided that the cause of the defect occurred before the time at which the risk was passed.

Warranty claims are subject to a warranty limitation period of 24 months from the date of shipment.

The purchaser is obligated to immediately notify Raytech AG Switzerland in writing of any defects of the supplied test equipment.

Raytech AG Switzerland must always be allowed to rectify a defect within a reasonable amount of time. The purchaser shall grant an adequate amount of time that the test equipment shall be repaired.

Raytech AG Switzerland covers the costs associated with the repair of the defect; especially the costs for the material and work. The cost for sending the faulty test equipment shall be borne by the purchaser. Raytech AG Switzerland shall not be liable for material damage, or financial loss due to the loss of production, loss of data, loss of information, data or interest, regardless of their legal basis.

Warranty claim rights on replacement parts as well as repair of defective parts shall expire after 12 months.

The warranty limitation period shall be extendable according to the price list. The purchaser has the right to extend the warranty period by purchasing additional warranty years.

A.1 Limitation of Warranty

The foregoing warranty shall not apply to defects resulting from:

- Improper and unauthorized modifications or misuse and abuse of the product, negligence, alteration, modification, faulty installation by the customer, customer's agents or employees.
- Attempted or actual dismantling, disassembling, service or repair by any person, firm, or corporation not specifically authorized in writing by Raytech AG Switzerland.
- Defects caused by or due to handling by the carrier, or incurred during shipment, transshipment, or other moves.
- Inadequate maintenance by the customer, the second source supplied software or interfacing, operation outside the environmental limits, or improper site preparation.

Exclusive remedies provided herein are the customer's sole and exclusive remedies.

Raytech Switzerland shall not be liable for any damages resulting from the use of this equipment whether direct, indirect, special, incidental, or consequential damages, or whether based on contract, tort, or any other legal theory.

**INFO:**

NO OTHER WARRANTY IS EXPRESSED OR IMPLIED.

A.2 Arbitration

All disputes arising out of or in connection with the contract between the purchaser and Raytech AG Switzerland and including those regarding the legal validity of this contract and this arbitration clause shall be settled out of court and shall be referred to arbitration for final decision.

B Maintenance

B.1 Instrument Cleaning Instruction

- Before the cleaning, disconnect the device from the Mains circuit.
- Use only lint-free cloth for the cleaning and when required slightly dampened with water.
- Never spray cleaners directly on the front panel. You can spray cleaners directly on the outer surface of the case only when the door is closed completely.
- Never use cleaning solutions that contain bleach or abrasives.

B.2 How to Insert Paper into Thermal Printer



- Open the paper tray by slightly pulling the lever upwards. The paper tray can now easily be opened.



- On the paper roll, the printable side is the outside of the paper roll.
- Unwind a few cm (inch) of paper from the roll.
- Keep the layers wound tightly when inserting the paper roll into the paper tray. The paper outside shows towards the printer mechanism.



- Close the paper tray by applying strong pressure.
- You can hear it snap shut. Now the paper can be torn off at the tear-off edge without opening the paper tray again nor the paper sliding through the printer mechanism.

B.3 Thermal Printer Cleaning instruction



- Open the paper tray and remove the paper roll.
- Do not touch the print head as it may be damaged by static electricity.
- Loosen dirt particles at the paper, sensor and tear bar with a small brush.



- Forcefully blow into the paper tray to remove the coarse dust.
- Soak Q-tip with isopropanol (IPA) and clean the sensor, platen roll and print head rail, as well as further dirt.
- Other strong contaminations may also be removed with a Q-tip soaked with isopropanol (IPA).



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