Operating instructions

VLF Sinus 45 kV

Portable Test and Diagnosis System

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Contents

1 Important notes

Safety precautions

This manual contains basic information about commissioning and operating the device/system. Therefore, it must be ensured that this manual is accessible to authorised and trained operating personnel at all times. The operating personnel must read the manual carefully. The manufacturer will not accept liability for any damage to persons or materials caused by a failure to observe the safety instructions contained in this manual.

National standards and regulations must be observed.

Intended use

The safety of the supplied system is only guaranteed if it is used as intended. Improper use can result in hazards for the operator, for the system, and for associated systems.

The limits specified in the technical data must not be exceeded under any circumstances.

Working with products from Megger

The generally valid electrical regulations of the country in which the device is installed and operated, as well as the existing national regulations for accident prevention and any internal regulations (work, operating, and safety regulations) of the operator must be observed.

After working on the system, it must be disconnected from the power supply and secured against being switched on again, discharged, earthed, and short-circuited.

Original accessories are used for system safety and functional reliability. The use of other parts is not permitted and leads to the loss of warranty.

Operating personnel

The system must only be commissioned and operated by authorised, qualified electricians. Under DIN VDE 0104 (EN 50191), DIN VDE 0105 (EN 50110) and accident prevention regulations, the term 'qualified electrician' refers to persons who are able to identify hazards based on their knowledge, experience, and knowledge of the relevant regulations.

Other persons must be kept away.

Transportation

The device must only be lifted and carried in an upright position using the carry handles provided on the side. Always use both handles to ensure even load distribution. Other parts of the device, such as the accessory bag or connection cables, are unable to withstand the forces that occur when the device is lifted and could therefore break or tear off.

For maximum convenience and safety during transportation, we recommend using the optional transport box with rollers ("Scope of delivery and accessories" on page 16).

Disposal

Depending on where the device is used, the end user may be obliged by law (e.g. the German Electrical and Electronic Equipment Act (ElektroG)) to dispose of it separately from household waste.

Megger Germany GmbH as the manufacturer of the device undertakes to accept and properly dispose of the old device when a comparable new device is purchased.

If the old device is to be returned directly upon delivery of the new device, Megger Germany GmbH must be informed in advance if possible. Batteries and rechargeable batteries that can be removed from the old device must be handed in separately. The end user is responsible for deleting personal data from the old device.

The above points apply to all electrical and electronic equipment labelled with the adjacent symbol.

Declaration of Conformity (CE)

The product complies with the requirements of the following European directives:

- EMC Directive
- Low Voltage Directive

A digital copy of the CE Declaration of Conformity is available on request.

Electromagnetic radiation

This device is designed for industrial use according to EN 55011. When used at home it could cause interference to other equipment, such as the radio or television.

The interference level from the line complies with the limit curve B (living area), the radiation level complies with the limit curve A (industrial area). Once the living area is sufficiently far away from the planned area of operation (industrial area), equipment there will not be impaired.

2 List of symbols and abbreviations

Signal words and symbols used

The following signal words and symbols are used in this operating instructions and also on the product itself:

Signal word/symbol	Description
WARNING	Indicates a potential hazard that may result in death or serious injury if not avoided.
CAUTION	Indicates a potential hazard that may result in moderate or minor injuries if not avoided.
NOTE	Indicates a potential hazard that may result in property damage if not avoided.
	Used to highlight warning and safety instructions in the operating instructions. When present as a sticker on the product, it identifies sources of danger that require the user to read the operating instructions to ensure safe handling.
	Used to highlight warning and safety instructions that explicitly indicate danger of electric shock.
	Used to highlight important information and useful tips for operating the product. Failure to observe may result in unusable measurement results.
	Indicates further information in other operating instructions.

List of abbreviations

Abbreviation	Meaning
CR	Cosine rectangular
DAC	Damped AC
PDS	Partial discharge measuring system
TD	Dissipation factor (TanDelta) measurement
TD STEP	TanDelta – step test
TD MWT	TanDelta – monitored withstand test
PD	Partial discharge
VLF	Very low frequency (0.1 Hz alternating voltage)

3 Safety instructions

Behaviour in the event of faults during normal operation

The system must only be operated if it is in perfect technical condition. In the event of damage, irregularity, or faults that cannot be rectified using the instructions in the operating manual, the system must be immediately shut down and marked accordingly. In this case, notify the relevant supervisor. Please contact the Megger service immediately to rectify the fault. The system must not be put back into operation until the fault has been rectified.

Five safety rules

These five safety rules must be consistently applied when working on the electrical connection between the measuring system and the test specimen.

1. Disconnect from the power supply
2. Secure it against being switched back on
3. Test to ensure that it has been disconnected
4. Earth and short-circuit the system
5. Cover or cordon off adjacent live components

Fire fighting in the vicinity of electrical equipment

- Correct extinguishing agent: **Carbon dioxide (CO2)**.
- Carbon dioxide is electrically non-conductive and leaves no residue. It is safe to use on live systems but the appropriate safety distances must be observed. A CO2 fire extinguisher should therefore always be available near the electrical system.
- Improper use of other extinguishing agents may damage the electrical system, for which Megger cannot accept any liability. Furthermore, if a powder extinguisher is used near high-voltage equipment, there is a risk of voltage being transferred to the person using the fire extinguisher (due to the powder mist).
- Please always observe the hazard warnings on fire extinguishers.
- DIN VDE 0132 applies.

Persons with pacemakers/defibrillators

Persons with pacemakers/defibrillators may be at risk in the vicinity of the device as a result of the physical processes in the high-voltage system.

WARNING

Risk of electric shock

Special attention and safety-conscious conduct is required by measuring personnel when handling high-voltage equipment and systems, especially during non-stationary operation. Here, VDE regulation 0104 "Erection and operation of electrical test equipment" or the corresponding EN 50191 as well as country-specific standards and regulations must be strictly observed.

- The high-voltage device/system generates a dangerous voltage of up to 45 kV_{PEAK}.
- The high-voltage device/system must not be operated unsupervised.
- When operating the high-voltage device/system, a second person must be in sight and within hearing range, who can then recognise any dangers and activate the emergency off switches.
- Safety devices must not be bypassed or disabled.

4 Technical description

4.1 System description

Purpose

The test system enables the standard testing of medium-voltage cables and other equipment with a real 0.1 Hz sinusoidal test voltage of up to 45 kV_{peak} or 32 kV_{rms}.

This type of cable test can be used to safely induce the breakdown of installation faults that endanger operation and insulation faults (such as water-tree damage in PE/VPE cables or local damage in mass-impregnated cables). Thanks to the integrated breakdown detection, this test process is performed without any damage to the fault-free cable insulation.

Furthermore, the system is also suitable for tests with…

- positive and negative DC voltage of up to 45 kV,
- 0.1 Hz VLF cosine rectangular voltage of up to 40 kV (boost module required),
- trapezoidal AC voltage (square-wave voltage) of up to 45 kV_{peak} with load-dependent ramp speed.

In addition, the optional internal TanDelta measurement offers the option to determine the dielectric loss factor tanδ (TanDelta) during a step test with sinusoidal test voltage, and thus a measure of the cable's degree of ageing.

In combination with a suitable partial discharge measuring system and a notebook for controlling the software, the test system can also be used for standard measurement of partial discharges (PD).

Features

The test system combines the following features and functions into one system:

- AC voltage test with two different voltage forms
- DC voltage test with positive and negative polarity
- Complete TanDelta step test
- Informative dielectric strength diagnostics (VLF test with accompanying TanDelta diagnostics)
- Leakage current measurement at DC, square-wave and cosine rectangular voltage
- Sheath test and sheath fault pinpointing with negative DC voltage of up to 20 kV
- Manual and automatic frequency adjustment
- Breakdown detection with automatic switch-off of the test voltage and discharge of the test object in the event of excessive charging current
- Switchable burning function for fault conversion after breakdown (max. one minute)
- Return voltage detection
- Automatic evaluation of TanDelta measured values based on official and in-house standards
- Convenient measurement data export via USB (prepared for wireless data transfer) for reporting and archiving in the reporting software MeggerBook Lite or MeggerBook

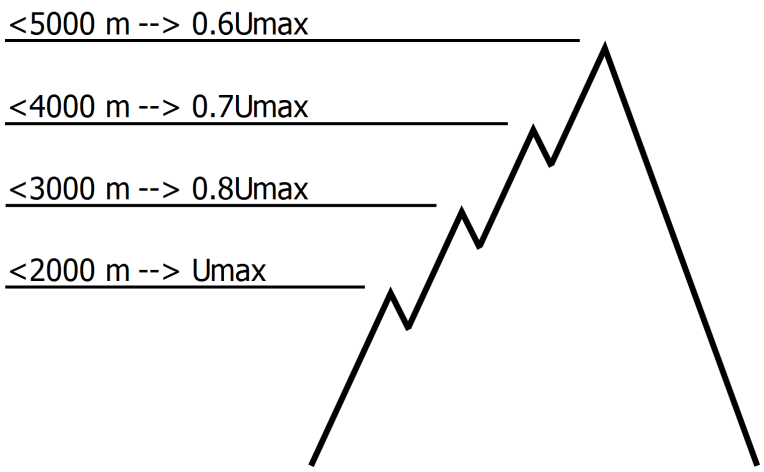
4.2 Technical data

The test system is specified by the following technical parameters:

Parameter	Value
Output voltage	
Sinusoidal	1.4 to 32 kV_{rms} / 45 kV_{peak}
DC	±2 to ±45 kV
Square-wave	±2 to ±45 kV
Cosine rectangular	3 to 40 kV (boost module required)
Damped AC voltage (DAC)	3 to 40 kV (boost module and partial discharge measuring system required)
Max. output current source	12 mA_{rms}
Leakage current measurement	(Square-wave, VLF-CR and DC mode)
Display range	0 to 40 mA
Resolution	10 µA
Test voltage frequency	0.01 Hz to 0.1 Hz (sinusoidal and square-wave voltage) 0.1 Hz (cosine rectangular voltage)
Testable load capacitance	(see also graphs below)
Sinusoidal voltage	0.6 µF at 45 kV/0.1 Hz
Rectangular voltage	0.6 µF at 45 kV/0.1 Hz
DC voltage	5 µF at 45 kV
Cosine rectangular voltage	5 µF at 40 kV
Max. load capacity	10 µF at reduced voltages and frequencies
Tan delta measurement (optional)	
Load range	2 nF to 10 µF
Measuring range	10^{-3} to 10^{0}
Accuracy (at a load capacity >20 nF)	1 x 10^{-3} or 1%
Resolution	1 x 10^{-4}
Sheath test and sheath fault pinpointing	
Voltage	0 to -20 kV
Timing for sheath fault pinpointing (in seconds)	0.5:1 / 1:2 / 1:3 / 1:4 / 1.5:0.5
Input voltage range	110 V to 230 V, 50/60 Hz
Power consumption	600 VA
Display	Transflective 7" touchscreen with a resolution of 800 x 480 pixels
Memory	8 GB measurement data memory
Data interfaces	USB 3.0 (suitable for USB flash drives with FAT32 file system)

Parameter	Value
Weight	50 kg
Dimensions (W x H x D)	544 x 416 x 520 mm
Operating temperature	-20°C to 55°C
Storage temperature	-20°C to 70°C
Relative humidity	93% at 30°C (non-condensing)
Maximum operating altitude	2000 m (see also graph below)
Protection class (according to IEC 61140 [DIN VDE 0140-1])	I
IP rating (according to IEC 60529 [DIN VDE 0470-1])	IP21

At an operating altitude >2000 m, the restrictions on the adjustable voltage shown in the following diagram must be taken into account:



The optional boost module is specified by the following parameters:

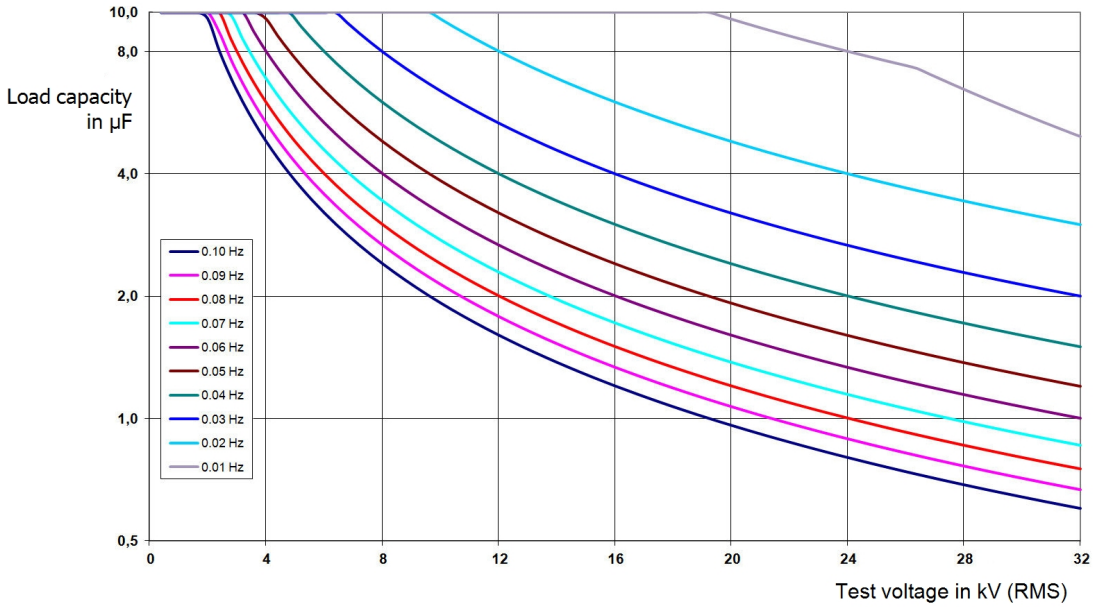
Parameter	Value
Weight	42 kg
Dimensions (W x H x D)	544 x 416 x 400 mm
Operating temperature	-20°C to 55°C
Storage temperature	-20°C to 70°C
Relative humidity	93% at 30°C (non-condensing)
Protection class (according to IEC 61140 [DIN VDE 0140-1])	I
IP rating (according to IEC 60529 [DIN VDE 0470-1])	IP21

The optional decoupling capacitor is specified by the following parameters:

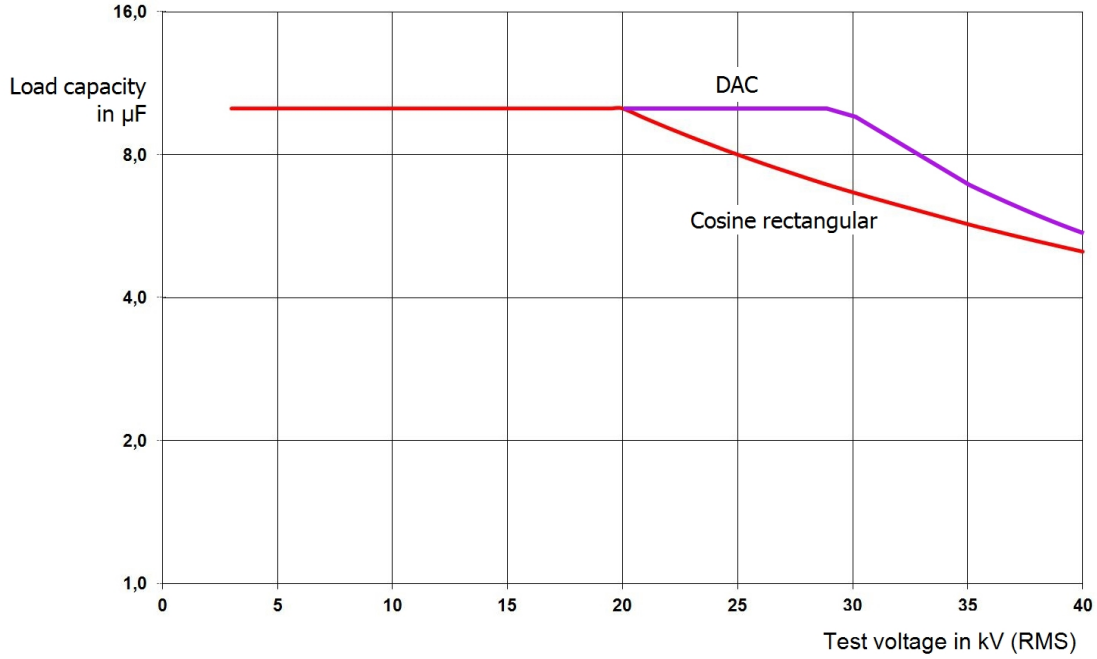
Parameter	Value
Capacity	150 nF
Voltage range	60 kV (peak value)
Weight	14 kg
Dimensions (W x H x D)	400 x 400 x 850 mm
Operating temperature	-25°C to 55°C
Storage temperature	-25°C to 70°C

4.3 Load diagrams

The following graph **applies to tests with sinusoidal voltage** and illustrates the dependence of the test frequency on the capacity of the connected load and the set test voltage. If a test frequency cannot be applied due to the capacity limits specified here, an automatic adjustment is made and the user is informed about this condition.



For **cosine rectangular voltage and damped AC voltage (DAC)** (boost module required), the following load diagram applies as and where appropriate[1]:



[1]Only valid between -25 and 45°C. In the temperature range from 45°C to 55°C, the power is reduced to 80% at 40 kV.

4.4 Scope of delivery and accessories

Scope of delivery

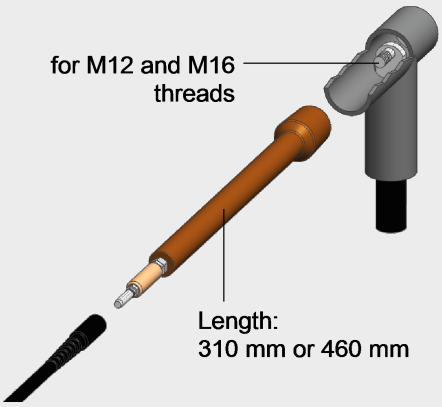
Check the scope of delivery immediately after receipt for completeness and externally visible damage. Devices and accessories with visible damage must not be put into operation under any circumstances. If something is missing or damaged, please contact your sales partner immediately.

Component	Item number
Basic device	1015415
Accessory bag	892480883
HV connection cable	Varies by region and length
Connector pliers for connection to the test object	810001055
Terminal for connection to an earth rail	890022408
Earth cable, 5 m	899007263
Power cord	Varies by region
Operating instructions	88727

Optional accessories

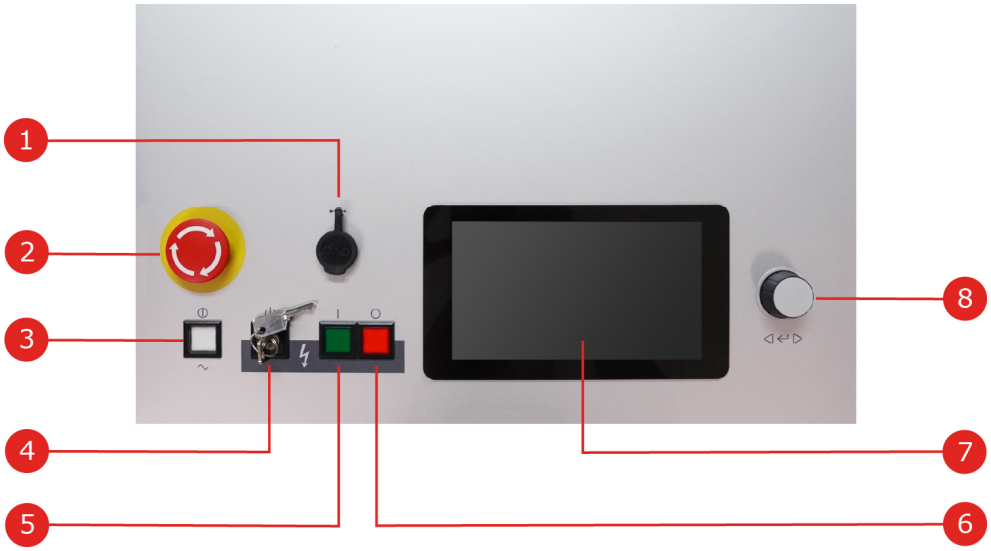
The following optional accessories can be ordered from your sales partner:

Accessory	Description	Item number
Boost module	Extends the system with the option of testing with 0.1 Hz cosine rectangular voltage	128311042
"Tan delta measurement" option	Licence to activate the optional 'TanDelta measurement' function ("Activating the 'TanDelta measurement' option" on page 66)	2018378
External safety device with HV control	External box with signal lamps, high-voltage control, emergency stop switch and key switch	108300322
External safety device without HV control	External box with signal lamps, emergency stop switch and key switch	2010001
MeggerBook full version	Windows software for analysing, logging and archiving measurement data	2015875

Accessory	Description	Item number
Transport box with rollers	For maximum convenience and safety while transporting the test system	for test system: 90021849 for boost module: 90021850
PD PA-MC-UNI	PD-free connection adapter 	Single: 1013564 (460 mm) 1013563 (310 mm) As set for 3-phase connection; including fork adapter and other accessories: 1013586 (460 mm) 1013587 (310 mm)
VLF CS-BB	Adapter set for 3-phase cable testing; suitable for connection to busbars	128311801
HV connection cable	Plugin HV connection cable in different lengths	Standard version: 2004420 (10 m) 2004421 (15 m) NAFTA region: 2008032 (10 m) 2008033 (15 m)
PDS 62-SIN partial discharge coupler	PD coupler for partial discharge diagnostics with sinusoidal voltage (including notebook, software, calibrator and accessories)	See data sheet PDS 62-SIN
PDS 60 partial discharge coupler	PD coupler for partial discharge diagnostics with sinusoidal, CR and DAC voltage (including notebook, software, calibrator and accessories)	See PDS 60 data sheet
Diagnostics connection set	Accessory set for PD-free connection to the test object	890017909
Decoupling capacitor	Required for PD diagnostics with VLF CR and DAC voltage at particularly low load capacity (<120 nF including connection cable)	Standard version: 2009309 NAFTA region: 2014971

4.5 Display and operating elements

The following display and operating elements are located on the front panel of the test system:



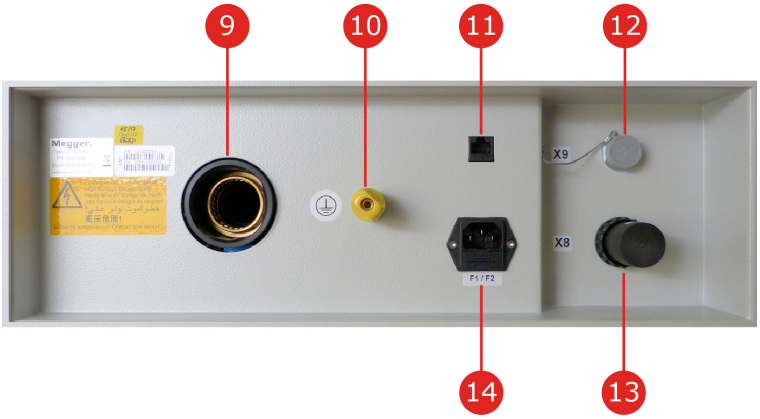
Number	Description
1	USB port (suitable for USB flash drives with FAT32 file system)
2	EMERGENCY OFF switch
3	ON/OFF button
4	Safety key switch for locking the high-voltage preparation
5	'HV ON' button
6	'HV OFF' button
7	Touch display
8	Rotary encoder

Further information:

- "High-voltage control" on page 30

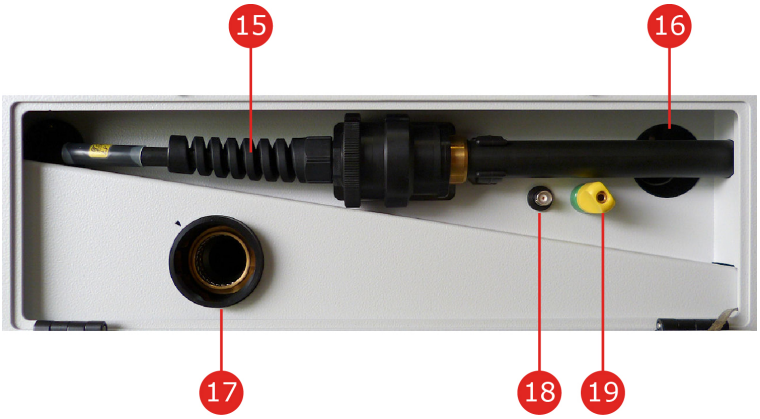
4.6 Connection elements

The following connection elements are located in the connection panel on the back of the test system:



Number	Description
9	HV output
10	Protective earth connector
11	Network socket for communicating with the control notebook ("Connection in combination with a partial discharge measuring system" on page 25)
12	Socket for connecting the control cable from the boost module
13	Mains socket with fuses (2 x T6,3A)
14	Socket for connecting the external safety device

The following connection elements are located on the rear of the optional boost module:



Number	Description
15	HV cable for connection to the test system
16	Control cable for connection to the test system
17	HV output
18	Trigger output for triggering a connected PD measuring system
19	Protective earth connector

5 Commissioning

WARNING

Danger due to improper installation

- The guidelines for the implementation of occupational safety when operating a non-stationary test system often differ between different network operators and are frequently accompanied by national regulations (such as the German BGI 5191). Inform yourself about the guidelines applicable at the place of use before the measuring operation and carefully follow the rules set out therein for labour organisation and commissioning of the non-stationary test system.
- Choose a location for the system that meets the requirements of weight and dimensions and ensures a stable footing. This applies in particular if the device is placed at an elevated position. The device must not be placed on the transport case!
- The requirements for the operating environment result from the limit values for operating temperature, relative humidity, altitude and IP protection class defined in the technical data.
- The vents on the sides of the device must be kept clear.
- Make sure that no other systems/system parts are impaired in their functionality when setting up or connecting the device. If changes have to be made to other systems/system parts, it must be ensured that these measures are reversed after the work has been completed. Always observe the special requirements of these systems/devices and only perform any work relating to them after prior consultation/approval from the person responsible for the work.
- In the event of vast temperature differences between the storage and installation location (cold to warm), condensation may form on the high-voltage components (condensation effect). To prevent voltage flashovers that could put persons and equipment at risk, the system must not be operated in this condition. Instead, it should remain in the new environment for about an hour to acclimatise before being put into operation.

5.1 Electrical connection

WARNING

Risk of electric shock

- The system may only be connected to non-live equipment. The general safety instructions and in particular, the five safety rules must be followed before connecting to the test object ("Safety instructions" on page 9).
- Follow the specified connection sequence.
- All cables at the measuring point that are out of service and at which no measurements are being taken must always be short-circuited and earthed.
- Since the voltage applied to the test object can reach dangerous contact values, the prohibited zone defined in DIN EN 50191 (VDE 0104) around the live parts must be isolated in such a way that it cannot be reached.
- The cable ends must be isolated to prevent contact. It must be ensured that all branching points are considered.
- To avoid dangerous charges, all metal parts in the vicinity of the high-voltage device must be earthed.

5.1.1 Standard connection variant

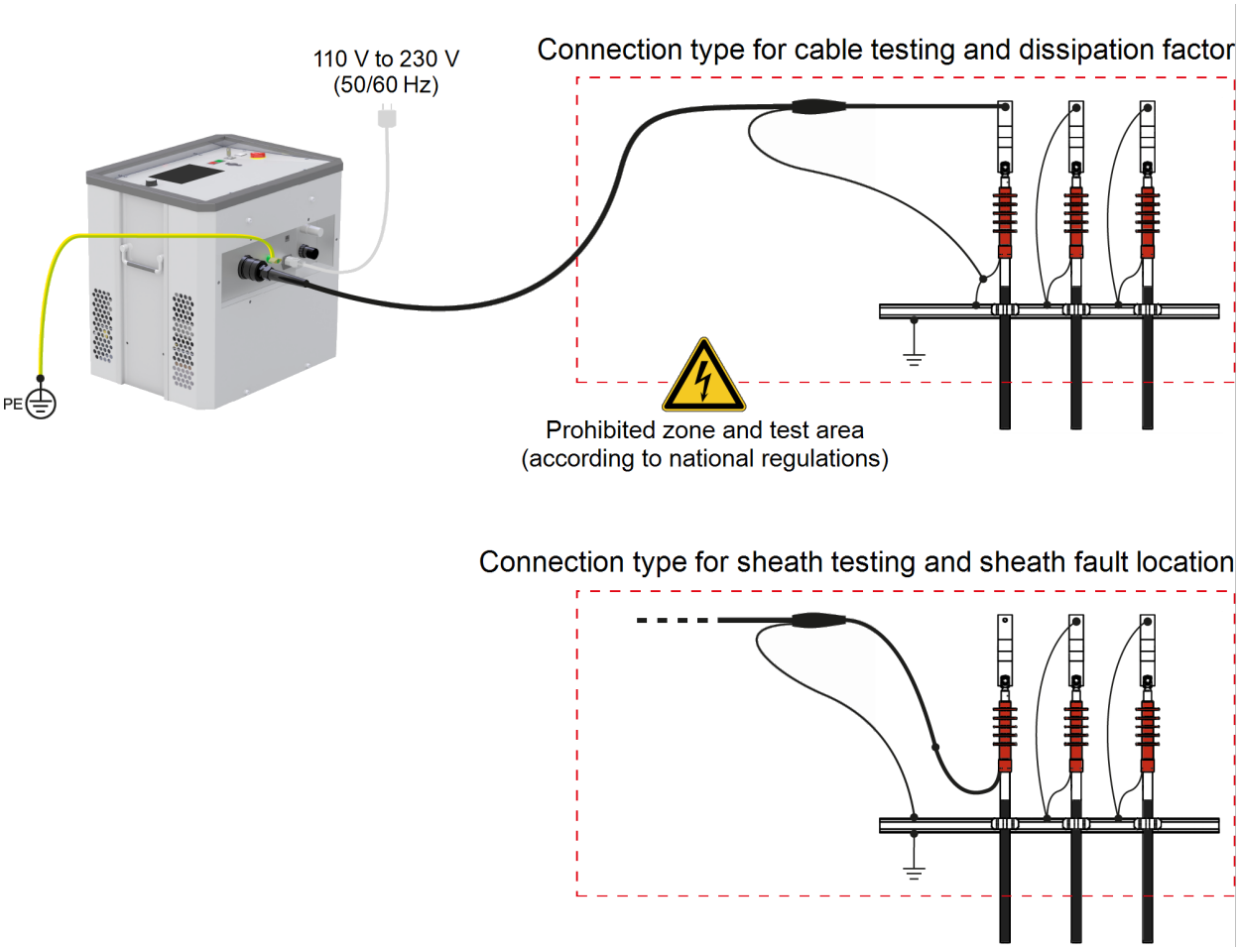
Applications

The connection variant described in this section must be selected for the following operating modes:

- Standing voltage test with sinusoidal, square-wave or direct voltage
- Sheath test and sheath fault pinpointing
- Measuring the tan delta dissipation factor
- Partial discharge diagnostic with sinusoidal voltage (see also "Connection in combination with a partial discharge measuring system" on page 25)

Procedure

The following figure shows the simplified connection diagram:

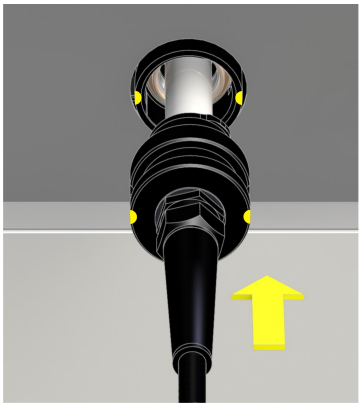


To connect the test system to the test object, proceed as follows:

1. Use the green and yellow earth cable to connect the device's protective earth connection 10 to a suitable point on the protective earth system (station earth). Ensure that the earth cable and connection points are not damaged, rusted or soiled and that there is good metal-to-metal contact.

2. Insert the plug of the HV connection cable into the HV output of the system in the direction shown.

   The plug connector has a bayonet lock. The plug must be pressed flush with the HV output with a little force and must audibly engage. Then secure the plug by turning it clockwise.



3. Connect the other end of the HV cable to the test object.
4. Connect the supplied power cord to the system's power receptacle 14 and to a power socket.

5.1.2 Connection via optional boost module

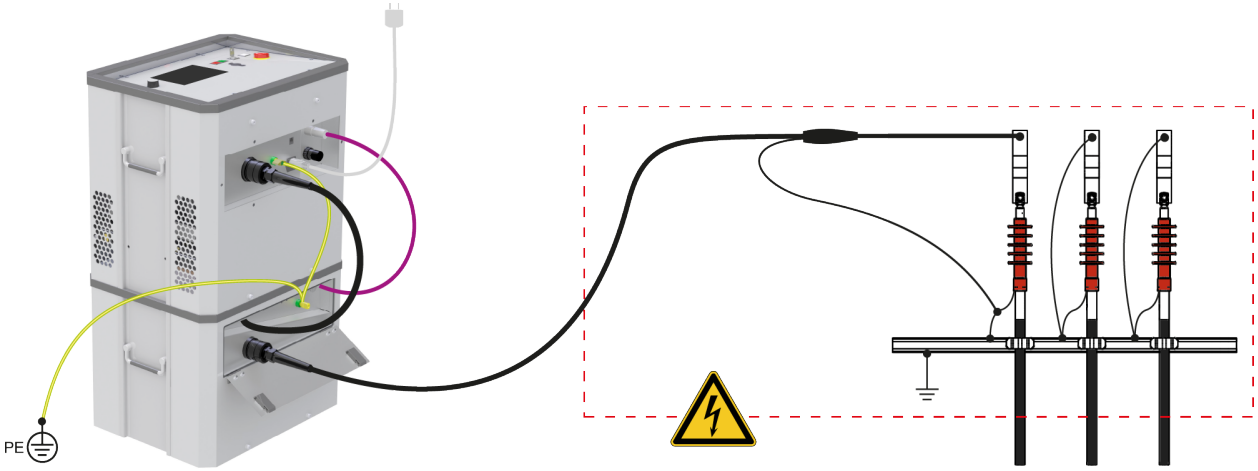
Applications

The connection variant described in this section must be selected for the following operating modes:

- Withstand test with cosine rectangular voltage
- Partial discharge diagnostics with cosine rectangular or DAC voltage (see also "Connection in combination with a partial discharge measuring system" on page 25)

Procedure

The following figure shows the simplified connection diagram:



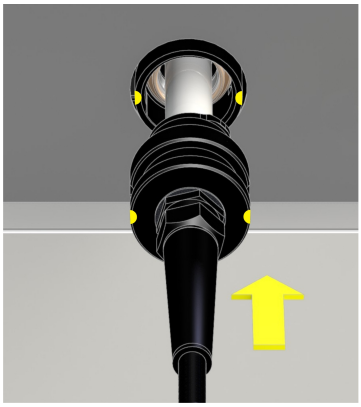
To connect the test system to the test object, proceed as follows:

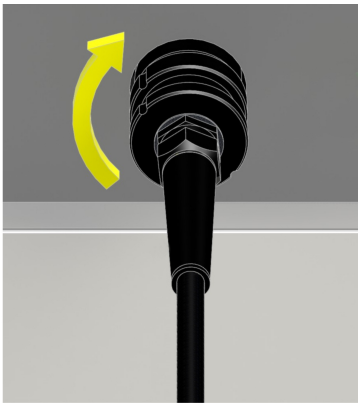
1. Place the test system on the boost module as shown in the figure.
2. Use the green and yellow earth cable to make a connection between the two protective earth connections (10 and 19) and a suitable point on the protective earth system (station earth).

   Ensure that the connection points of the earth cable are not dirty and provide good metallic contact.
3. Connect the control cable from the boost module 16 to the appropriate socket 12 on the test system.
4. Connect the HV connection cable from the boost module 15 to the test system.

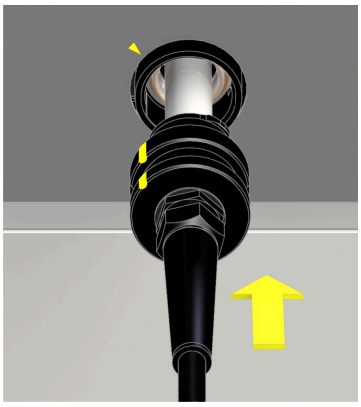
   To do so, insert the plug of the HV connection cable into the HV output 9 of the system in the direction shown.

   The plug connector has a bayonet lock. The plug must be pressed flush with the HV output with a little force and must audibly engage. Then secure the plug by turning it clockwise.





5. Secure the plug of the supplied HV connection cable to the HV output 17 of the boost module. Once again, you must ensure correct alignment when inserting the plug.



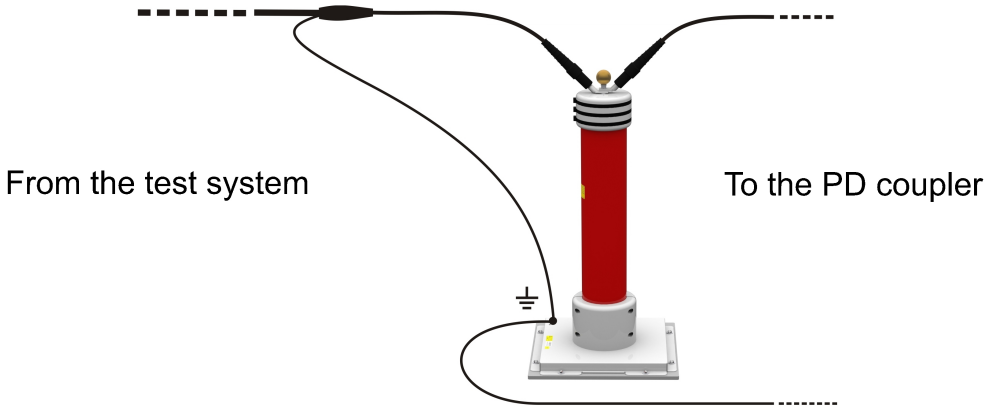
6. Connect the other end of the HV cable to the test object.
7. Connect the supplied power cord to the system's power receptacle 14 and to a power socket.

5.1.3 Connection in combination with a partial discharge measuring system

The test system can be expanded into a fully fledged diagnostic system in combination with an optional partial discharge measuring system ("Scope of delivery and accessories" on page 16). To do this, the test system must be connected not only to the PD measuring system itself, but also to the notebook required to perform the partial discharge diagnostics. This is part of the scope of delivery for the partial discharge measuring system.

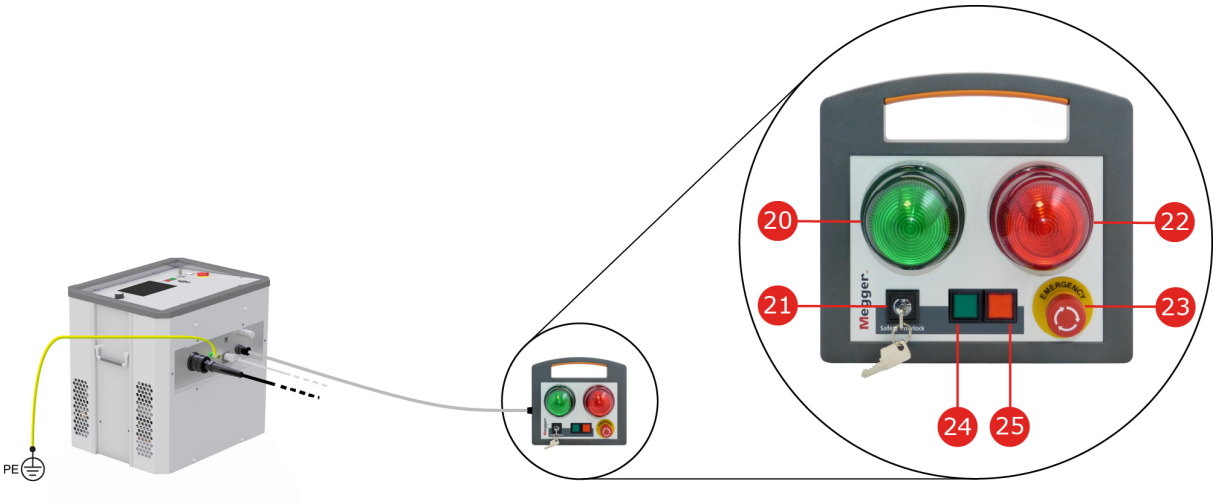
Detailed information on the electrical connection of the partial discharge measuring system can be found in the respective operating manual.

If the measuring software reports a load capacity that is too low (<120 nF) at the start of a diagnostic with VLF-CR or DAC voltage, this can be counteracted with an optional decoupling capacitor ("Scope of delivery and accessories" on page 16). This must be integrated into the HV path between the test system and the PD coupler as follows:



5.1.4 Connecting the external safety device (optional)

The optional external safety device ("Scope of delivery and accessories" on page 16) can be used to make the current system status clearly visible via coloured signal lamps and to enable or interrupt the HV preparation. It is connected to the socket provided on the test system. If the system is intended to be operated without an external safety device connected, it is essential to screw the dummy plug onto the socket 13.



Number	Description
20	The green signal lamp lights up when the system is switched on but not in high-voltage mode.
21	Safety key switch for locking the high-voltage preparation.
22	The red signal lamp lights up as soon as high voltage can be generated. All discharge and earth devices are open and the test object is to be considered "live".
23	EMERGENCY OFF switch
24	'HV ON' button
25	'HV OFF' button

Further information:

- "High-voltage control" on page 30

5.2 Switching on

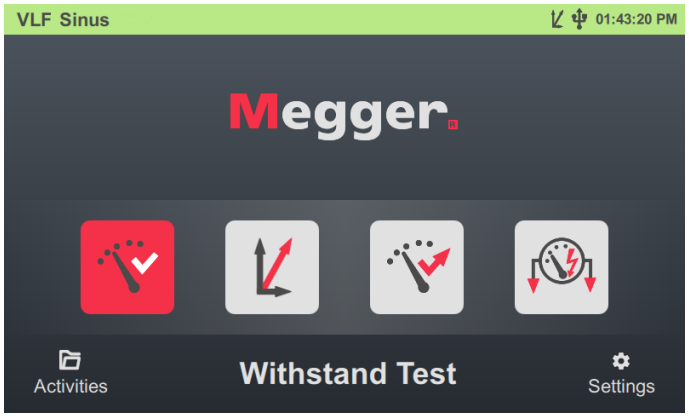
After proper connection, the test system is switched on by pressing the illuminated on/off button 3. The software starts within a few seconds and then remains on the home screen ("Start screen and status bar" on the facing page).

6 Basic operation of the test system

6.1 Start screen and status bar

Start screen

The start screen is the central starting point for calling up all operating modes and settings menus and is displayed immediately after launching the software. During operation of the device, you can always return to the home screen from deeper menu levels.



The following operating modes and functions can be called up from the start screen:

Menu item	Description
	Cable test with different voltage forms ("Withstand voltage test" on page 34)
	[Only available when the "TanDelta measurement" option is activated] TanDelta step test ("Dissipation factor (TanDelta) measurement" on page 41)
	[Only available when the "TanDelta measurement" option is activated] Monitored withstand voltage test with and without preceding TanDelta step test ("Dissipation factor (TanDelta) measurement" on page 41)
	Sheath test and sheath fault pinpointing according to IEC 60229 ("Testing sheaths / Locating sheath faults" on page 52)
	Management and further processing of previous measurement activities ("Managing and exporting measurement data" on page 61)
	System settings ("Adjusting the settings" on page 64)

Status bar

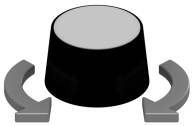
The status bar is permanently displayed at the top of the screen.

Depending on the position within the menu structure, either the system type, the currently selected operating mode, or the currently open submenu is displayed on the left-hand edge of the status bar. In addition to the time, the following status symbols are also displayed on the right-hand edge, indicating certain functions or system statuses:

Symbol	Description
	The 'TanDelta measurement' option is enabled and TanDelta measurements can be performed with the test system. The option can be ordered at a later point at any time ("Scope of delivery and accessories" on page 16). Activation can then be carried out independently via the system settings ("Activating the 'TanDelta measurement' option" on page 66).
	An inserted USB flash drive has been detected. All measurement data are automatically stored on this USB flash drive (FAT32 file system required).
	The test system is connected to the test object via the boost module and can currently only be used for testing/diagnostics with cosine rectangular or DAC voltage.
	The burn mode is activated. In the event of a voltage breakdown during a voltage withstand test, the test system does not switch off immediately. Instead, the operating mode remains active with maximum output current for one minute.

6.2 Basic rotary encoder controls

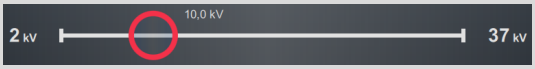
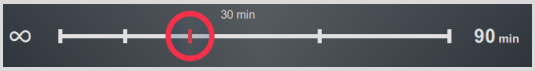
As described in this section and later in this manual, the software can be operated entirely using rotary encoders 8. Operation is also possible using the touchscreen display.

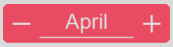
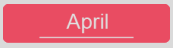


- Select the desired menu item
- Increase/reduce the value of a variable parameter
- Select an option from a selection list

- Open the selected menu item
- Confirm the setting/selection

The following table contains a list of the main user interface controls:

Control	Description
Menu item	Menu items are used to select functions or adjust parameters during the measurement process. Either the function provided by the menu item or the current value of the parameter is displayed under the menu item.
	 Menu item not selected.
	 Current menu item that can be enabled by pressing the rotary encoder.
	 Menu item cannot be selected in the current system state.
	 Within a tab/view selection, the menu item with the red bar represents the active tab/view.
Slider	A slider always appears when a variable parameter has been opened  The lower and upper limits of the value range are displayed on the left and right edge of the slider. The red circle marks the current value, which is also displayed numerically directly above it. The value can be adjusted by turning the rotary encoder and confirmed by pressing the encoder. In some cases, useful settings on the slider are marked with additional horizontal lines, where the selection circle "snaps in" noticeably, simplifying and accelerating the selection of these values.  These positions can be freely defined for the voltage setting sliders ("Adjusting the measurement settings" on page 65).
Tickbox	A tickbox is used to activate/deactivate a function or a parameter. A selected tickbox can be activated/deactivated by pressing the rotary encoder.
	 Function/parameter is active
	 Function/parameter is not active

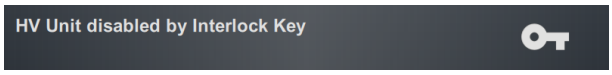
Control	Description
Selection box	A selection can be made from a defined set of values using a selection box. Proceed as follows to do so: 1. Select the desired selection box by turning the rotary encoder.  2. Press the rotary encoder to activate the selection box.  3. Turn the rotary encoder to adjust the selection.  4. Press the rotary encoder to confirm the new selection. 

6.3 High-voltage control

Requirements for high-voltage operation

Immediately after entering an operating mode, the conditions of the safety circuit are checked continuously. In the event that at least one condition of the safety circuit is not met, the test system denies HV readiness for switch-on. If the system is already in HV operation when the safety circuit is triggered, it is interrupted straight away. This causes the test object to be discharged automatically.

A system message informs the operator of the existing deviation:



To (re)activate HV operation, the cause of the problem must first be eliminated using the information in the following table:

Error message	Cause/troubleshooting
F-Ohm	The resistance between the operating and protective earth is too high (>9 ±3 Ω). A check must be performed to determine whether both the earth cable and the cable shield of the HV connection cable are connected correctly and that the respective connection points offer good metallic contact ("Electrical connection" on page 21).
EMERGENCY STOP button	An emergency stop has been carried out ("Safety devices" on the facing page). The switch must be manually released after the cause of the emergency has been removed. The emergency stop switches are located on the front panel 2 and on the external safety device.
HV Unit disabled by Interlock Key	To protect the test system against unauthorised access, all high-voltage operation was prevented by locking the key switch. The key switch must be unlocked manually ("Safety devices" on the facing page).

Error message	Cause/troubleshooting
Overtemperature in VLF Sinus	Internal temperature monitoring reports an increased temperature in the HV components. The system can only be put back into operation after a sufficiently long cooling phase.
HV Cable not correctly connected	The HV connection cable was not properly locked in the HV output.
Boost module is not ready.	The boost module is reporting an unspecified error or is not connected correctly.

Activating the high-voltage generator

Immediately after a measurement has been prepared and started by the operator, the green illuminated 'HV ON' button on the front panel 5 and the external safety device indicate the readiness for high voltage release. By pressing the button, the earthing at the HV output is cancelled. This switching status means: **High voltage**!

Switching off high-voltage

If certain events occur (e.g., a breakdown in the test object, expiry of the defined test time), the system automatically deactivates the high-voltage generator. This also occurs if a problem has been detected in the safety circuit.

By pressing the red illuminated 'HV OFF' button on the front panel 6 and the external safety device, HV operation can also be interrupted manually at any time.

The measuring circuit is reliably discharged in the event of either automatic or manual shutdown.

6.4 Safety devices

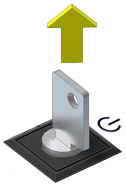
Emergency shutdown

In the event that an immediate emergency shutdown of the voltage generation is required during measurement operation, this can be triggered by pressing the emergency stop switch on the front panel 2 or on the external safety device.

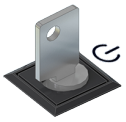
Measurement operation cannot be resumed until the emergency stop switch has been unlocked.

High-voltage locking

For reasons of liability, it must be ensured that measuring systems that emit a hazardous voltage can be secured against unauthorised access. This is made possible by the two safety key switches on the front panel 4 and on the external safety device.



The key switch is locked and high-voltage preparation is not possible. When locked, the key can be removed and the system secured against unauthorised high-voltage operation.



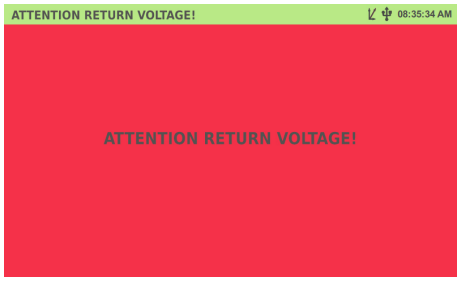
The key switch is unlocked and high-voltage preparation is possible, provided that all other safety conditions are also met.

Return voltage detection

This safety device reliably detects a return voltage (1 kV_{eff}...12 kV_{eff}, 50/60 Hz) at the HV output. With the following exceptions, it works in all operating modes:

- Sheath test and sheath fault localisation
- Voltage withstand test with actiavted burn mode

The return voltage detection is activated at the moment high voltage generation is enabled and remains active until high voltage is switched off. If return voltage is detected during this period, the voltage generation is immediately interrupted. The test system indicates the return voltage via a message on the display and by means of a continuous horn tone.



At the same time, internal earthing of the HV output is prevented to protect the operator and the system.

WARNING

Risk of electric shock

Return voltage can cause damage to the system and pose a hazard to the operator due to unforeseen voltage and current peaks.

- Move away from the device immediately and inform people in the vicinity who may be at risk.
- Identify and eliminate the cause of the return voltage.

After the cause of the return voltage has been identified and eliminated, the test system can be switched off. It is essential that the unit is checked by a certified service centre before it can be used again.

7 Performing tests and diagnoses

Depending on the test system equipment, the following test and diagnostic modes can be called up from the main screen:

- "Withstand voltage test" on the next page
- "Dissipation factor (TanDelta) measurement" on page 41
- "Sheath testing" on page 52
- "Sheath fault location" on page 57
- "Partial discharge diagnostics (PD measuring system required)" on page 60

7.1 Withstand voltage test

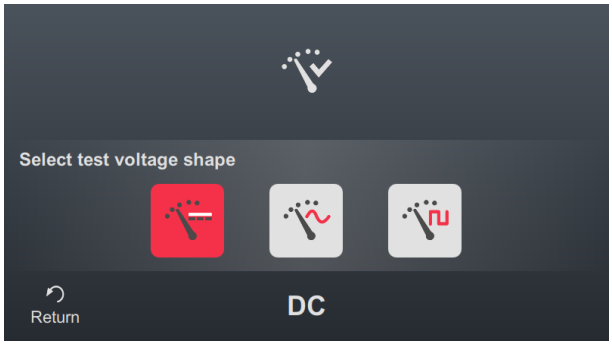
A withstand voltage test is designed to verify the dielectric strength of newly laid and repaired cables, but can also be periodically repeated to assess a cable's condition.

Advisable testing periods and test voltage levels vary depending on the type and age of the cable and are specified in various standards. While a test voltage of 3 Uo is usually recommended for newly laid cables, the values for old cables are between 1.7 and 3 Uo.

7.1.1 Preparing and starting the test

Selecting the operating mode and entering the cable number

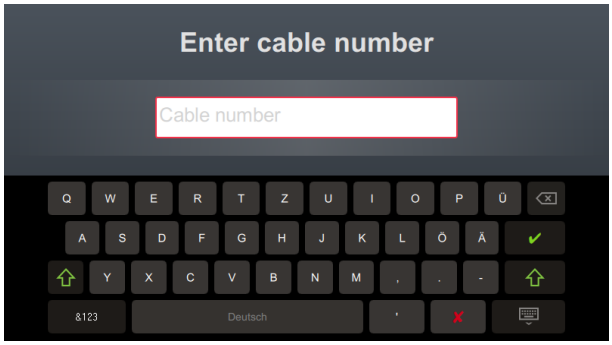
Once the menu item in the start screen has been called up in the first step, the following submenu opens for selecting the desired voltage form:



The following operating modes can be called up from this menu:

Menu item	Description
	Cable test with DC voltage
	Cable test with VLF sinusoidal voltage
	Cable test with trapezoidal AC voltage (square-wave voltage)
	[Only available when connected via the optional boost module] Cable test with VLF cosine rectangular voltage

The cable number is entered using the on-screen keyboard directly after selecting the voltage form.

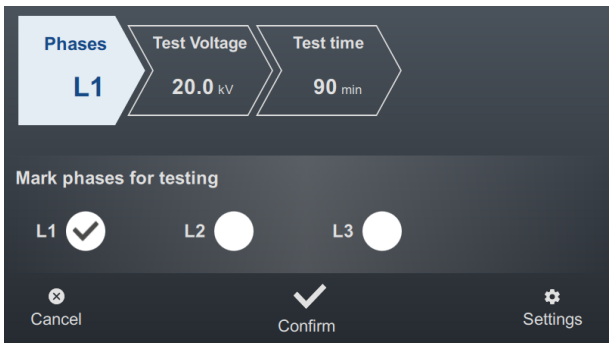


Entering the cable number as accurately as possible makes it easier to assign the cable later when reporting and archiving the measurement data record in the reporting software. If this kind of further processing is not planned, the cable number does not have to be entered. Regardless of whether or not a cable number has been entered, confirmation via ✓ is required.

Setting measurement parameters

When an operating mode is called up, the measuring parameters of the previous measurement are automatically preset. This enables faster preparation of the measurement during successive tests on cable systems of the same design.

After starting the operating mode and entering the cable number, the measuring parameters must be specified in several consecutive steps.



All required measurement parameters and their current values are displayed at the top of the screen, with the segment of the currently active measurement parameter marked in colour. Once this has been set as desired, confirm the setting with ✓ to proceed to the next step. The respective segment can be tapped to jump directly to one of the measurement parameters at any time during the workflow if, for example, a previously made setting needs to be adjusted.

The following measurement parameters must be set before starting the test:

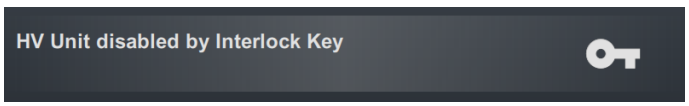
Parameter	Description	
Phases	The phase selection must be made according to the actual connection situation. It is used to uniquely assign the measurement data record during subsequent further processing. If multiple phases are bridged and tested simultaneously for time reasons, it is also possible to select multiple phases. However, if anomalies or voltage breakdowns occur during multi-phase testing, no conclusions can be drawn about which phase is affected. In this case, the phases must be retested individually.	
Test Voltage	The test voltage to be set is derived from the rated voltage of the connected cable and the guidelines to be applied for the test (e.g. recognised standards, factory standards, client's specifications). Common values:	
	VLF test (commissioning):	3 Uo
	VLF test (on old cables)	1.7 to 3 Uo
	DC test (on mass-impregnated cables):	4 to 8 Uo
	The method of test voltage input can be adjusted in the extended measurement settings (see table below).	
Test time	The test time to be set must be selected in accordance with the applicable guidelines (e.g. recognised standards, factory standards, client's specifications). The setting ∞ activates continuous operation and requires manual switch-off by the user. Common values:	
	VLF test (commissioning):	15 to 60 minutes
	VLF test (on old cables)	60 minutes
	DC test (on mass-impregnated cables):	15 to 30 minutes

The extended measurement settings can be called up at any time via menu item at the bottom right of the screen. The parameters contained in this menu usually only have to be set once when the respective operating mode is used for the first time and then remain in this setting until a new setting is made:

Parameter	Description	
Voltage input	This setting influences the way in which the test voltage is set in this operating mode. Choose from the following options:	
	RMS	[Can only be selected for tests with sinusoidal voltage] The effective value of the test voltage is set.
	PEAK	The peak value of the test voltage is set.
	Factor	This setting must be selected if the cables are always tested with a certain multiple of their rated voltage (e.g. 2 Uo) in this operating mode. The desired factor can be set directly below. When entering the voltage itself, only the rated cable voltage Uo must be specified; from this, the software determines the required test voltage automatically.
Polarity	[Can only be adjusted for tests with DC voltage] Polarity of the test voltage.	
Frequency	[Can only be adjusted for tests with sinusoidal voltage or trapezoidal AC voltage] Frequency of the test voltage. The relevant standards usually recommend a test frequency of 0.1 Hz for cable tests with VLF voltage. As the maximum test frequency depends on the determined cable capacity and the test voltage being applied, it may be necessary to adjust the set test frequency. The user will be informed if this is necessary at the start of the test. In the setting **Auto**, the system automatically selects the highest possible test frequency at the start of the test and then starts the voltage preparation without further confirmation.	
Burning	Activate/deactivate burn mode. By default, the burn mode is disabled and the test stops automatically as soon as a voltage breakdown is detected in the cable under test. If the burn mode is activated, the test system does not switch off immediately. Instead, the operating mode remains active with maximum output current for one minute.	

Starting the test

After the last measurement parameter has been confirmed, the test system prepares the measurement and checks whether all conditions for the high-voltage release have been met. If this is not the case, the problem identified is indicated in the display and must be rectified before starting the measurement ("High-voltage control" on page 30).



If no problem has been identified or rectified, there are 10 seconds left to release the high voltage via the 'HV ON' button 5.

A load determination is performed at the start of a test. If the load characteristics (capacity and insulation resistance) do not permit a test to be conducted using the set test parameters, this is shown on the screen as a system message.

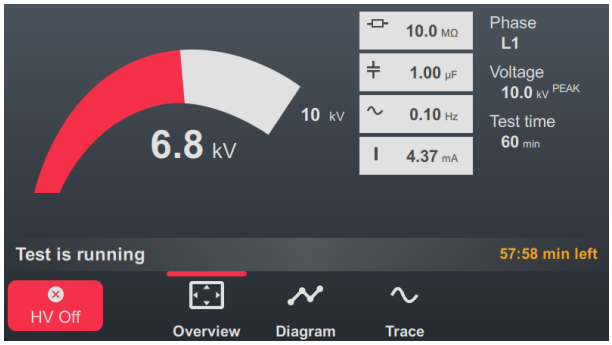
For tests with sinusoidal or square-wave voltage, the system may offer to perform the test with a lower test frequency. The test can then either be aborted or launched with an adjusted frequency. In the frequency setting **Auto**, this type of adjustment is made without confirmation.

Tests with cosine rectangular voltage or DC voltage must always be cancelled and, if possible, restarted with a lower test voltage.

7.1.2 Procedure and conclusion of the test

Testing process

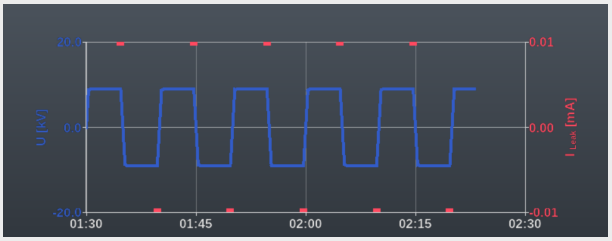
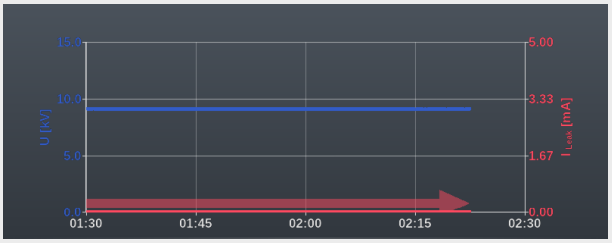
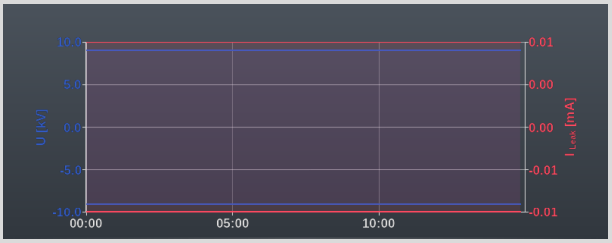
During the test, the software remains in the overview screen.



In addition to the current test voltage and the remaining test duration, this also displays the following measured values depending on the operating mode:

Symbol	Description
	Insulation resistance determined at the start of the test
	Load capacity determined at the start of the test
	Actual test frequency (sinusoidal and square-wave mode)
	Charging current (sinusoidal mode)
I_{leak}	Leakage current (DC, cosine rectangular and square-wave mode)

The menu items at the bottom of the screen can also be used to call up the following views during the test if necessary:

Menu item	Graph type
~	Temporal progression of test voltage and leakage current **over the past 60 seconds**. In cosine rectangular and square-wave mode, the leakage current is measured once during each plateau phase. The respective measured values are shown as red dots in the graph.  In DC mode, from a test time of approximately 90 seconds, a red arrow is also permanently displayed in the graph, showing the trend of the measured leakage currents (current measured value compared to the value measured after the charging process has been completed). 
~	[Can only be called up for tests with AC voltage] Temporal progression of the voltage and current root mean squares **over the entire test duration**.  From this type of graph, short-term events (such as a short voltage drop or a leakage current peak) can be read just as well as the long-term trend of the leakage current measured values.

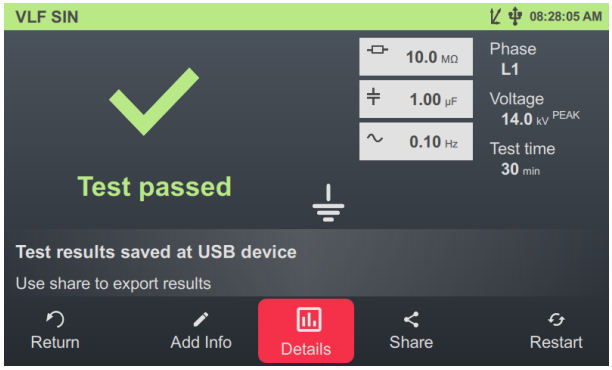
Completing the test

After the defined test time has elapsed, the test is concluded automatically and the high-voltage generator is switched off. In this case, the test is considered to have been passed.

However, if a breakdown is detected during the test (which also aborts the test and disconnects the high-voltage generator), further diagnostic tests and, if necessary, fault location must be carried out on the cable. The cause of the shutdown will be displayed along with the voltage at which the surge occurred.

In addition to the stated causes for an automatic shutdown, the test can also be ended manually at any time using the **HV Off** button or the buttons and switches on the front panel ("High-voltage control" on page 30).

Once the test has been completed, information about the test parameters and the cause of the shutdown is provided again in the upper area of the screen:



The following buttons are shown at the bottom of the screen for the next steps:

Button	Function
	End the test and return to the menu screen.
	Allows the input of a comment on the measurement. This is saved in the measurement data record and then displayed in both the activity list and in the reporting software ("Managing and processing measurement data" on page 61). If the data record was automatically saved to the inserted USB flash drive after the measurement was completed, it must be exported again after entering the comment.
	Displays the graphs recorded during the test (see previous table).
	Export measurement data to an inserted USB stick. If a USB flash drive (with FAT32 file system) is inserted into the device at the end of the test, the measurement data is saved to this USB flash drive automatically.
	Restart the test with the same test parameters.

7.2 Dissipation factor (TanDelta) measurement

Over years of operation, the quality of power cable insulation is affected by ageing and by mechanical influences. Humidity, overloads and surges accelerate the ageing process.

As these effects result in a measurable increase in dielectric losses, the TanDelta dissipation factor is an ideal non-destructive, established method for precise assessment of the quality and degree of ageing of cable insulation. It can quickly detect problems such as water treeing in VPE-insulated cables or cellulose decomposition in mass-impregnated cables to reliably identify critically ageing cables.

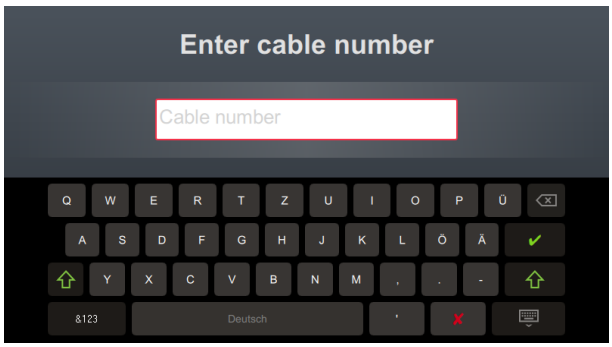
7.2.1 Preparing and starting the TanDelta measurement

Selecting the operating mode and entering the cable number

The following operating modes can be called up from the start screen:

Menu item	Description
	TanDelta step test over several adjustable voltage levels. In this operating mode, voltage-dependent changes of the TanDelta can be observed and sound conclusions drawn about the degree of ageing of the cable insulation. The results of a TanDelta step test can be evaluated automatically using the relevant standards or your own evaluation standards.
	The monitored withstand test combines a standard withstand test with a simultaneous dissipation factor measurement. This makes it a time-saving method for the periodic testing and status evaluation of ageing cables. As the simple monitored withstand test remains at one voltage level over the entire test period, no conclusions can be drawn from the measurement results concerning the voltage-dependent change of the TanDelta values.
	Step test with subsequent monitored withstand test. This somewhat more time-consuming combination of the two above operating modes enables both standard-compliant testing and a sound status evaluation of the cable being investigated.

The cable number is entered using the on-screen keyboard directly after selecting the operating mode.

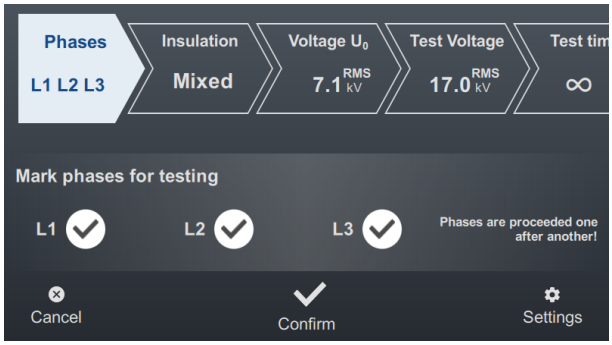


Entering the cable number as accurately as possible makes it easier to assign the cable later when reporting and archiving the measurement data record in the reporting software. If this kind of further processing is not planned, the cable number does not have to be entered. Regardless of whether or not a cable number has been entered, confirmation via ✓ is required.

Setting measurement parameters

When an operating mode is called up, the measuring parameters of the previous measurement are automatically preset. This enables faster preparation of the measurement during successive tests on cable systems of the same design.

After starting the operating mode and entering the cable number, the measuring parameters must be specified in several consecutive steps.



All required measurement parameters and their current values are displayed at the top of the screen, with the segment of the currently active measurement parameter marked in colour. Once this has been set as desired, confirm the setting with ✓ to proceed to the next step. The respective segment can be tapped to jump directly to one of the measurement parameters at any time during the workflow if, for example, a previously made setting needs to be adjusted.

Depending on the operating mode selected, some or all of the following measuring parameters must be set before the test is started:

Parameter	Description
Phases	The phase selection must be made according to the actual connection situation. It is used to uniquely assign the measurement data record during subsequent further processing. In the monitored withstand test, multiple phases can be bridged and tested simultaneously to save time. Accordingly, it is also possible to select multiple phases. However, if anomalies or voltage breakdowns occur during multi-phase testing, no conclusions can be drawn about which phase is affected. In this case, the phases must be retested individually. Multiple phases can also be selected for the step test and the combined operating mode. In this case, however, the test is performed sequentially (in the sequence L1 > L2 > L3) to enable a clear assignment of the measured TanDelta values. Once the test is completed on one phase, the software automatically prompts you to connect to the next phase. The test can then be continued on this phase without any further settings.

Parameter	Description
Insulation	[Can only be adjusted for step test and combined operating mode] Insulation type of the connected cable. This is required for automatic evaluation of the measurement results. If an automatic evaluation is desired, it must be ensured that the selected evaluation standard contains evaluation criteria for the selected insulation type. The selection of insulation types can be adjusted in the software settings ("Adjusting the TanDelta settings" on page 68).
Voltage Uo	[Can only be adjusted for step test and combined operating mode] Rated voltage Uo of the connected test specimen as RMS value. This value is used to calculate the voltage levels for the step test. The maximum rated voltage setting depends both on the maximum output voltage of the test voltage source and the set number of voltage levels (see table below). If the rated voltage of the cable is higher than the maximum value that can be set, the number of voltage levels must first be reduced.  The maximum rated voltage setting depends both on the maximum output voltage of the test voltage source and the set number of voltage levels (see table below). If the rated voltage of the cable is higher than the maximum value that can be set, the number of voltage levels must first be reduced.
Test Voltage	[Can only be adjusted for monitored withstand test and combined operating mode] The test voltage to be set is derived from the guidelines to be applied for the test (e.g. recognised standards, factory standards, customer's specifications). Common values: VLF test (commissioning): 3 Uo VLF test (on old cables) 1.7 to 3 Uo In combined operating mode, the test voltage specified here only defines the voltage level during the final withstand test. The voltage levels of the preliminary step test are determined from the rated cable voltage entered (see previous line). The type of test voltage input can be adjusted in the extended measurement settings (see table below).

Parameter	Description	
Test time	[Can only be adjusted for monitored withstand test and combined operating mode] The test time to be set must be selected in accordance with the applicable guidelines (e.g. recognised standards, factory standards, customer's specifications). The setting ∞ activates continuous operation and requires manual switch-off by the user. Common values:	
	VLF test (commissioning):	15 to 60 minutes
	VLF test (on old cables)	60 minutes
	In combined operating mode, the test time specified here only defines the duration of the final withstand test. The duration of the preliminary step test is determined by the number of voltage levels and measured values (see table below).	

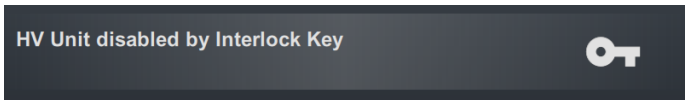
The extended measurement settings can be called up at any time via menu item ⚙ at the bottom right of the screen. The parameters contained in this menu usually only have to be set once when the respective operating mode is used for the first time and then remain in this setting until a new setting is made:

Parameter	Description	
Voltage input	[Can only be adjusted for monitored withstand test and combined operating mode] This setting influences the way in which the test voltage is set in this operating mode. Choose from the following options:	
	RMS	The effective value of the test voltage is set.
	PEAK	The peak value of the test voltage is set.
	Factor	This setting must be selected if the cables are always tested with a certain multiple of their rated voltage (e.g. 2 Uo) n this operating mode. The desired factor can be set directly below. When entering the voltage itself, only the rated cable voltage Uo must be specified; from this, the software determines the required test voltage automatically.

Parameter	Description
Frequency	Frequency of the test voltage. A setting of 0.1 Hz is strongly recommended, as otherwise the test results will not be evaluated automatically based on the selected evaluation standard. The conclusions drawn in the relevant technical literature and the relevant standards also refer to measurements taken using this frequency. As the maximum test frequency depends on the determined cable capacity and the test voltage being applied, it may be necessary to adjust the set test frequency. The user will be informed if this is necessary at the start of the test. In the setting **Auto**, the system automatically selects the highest possible test frequency at the start of the test and then starts the voltage preparation without further confirmation. If the capacity of the connected test specimen does not allow a measurement at 0.1 Hz and the frequency has to be adjusted, the evaluation criteria independent of the frequency must be given greater consideration. This includes, among other things, the deviation of the absolute values between the phases of a cable system and changes in the measured values with increasing voltage (Δtanδ). Measurements with different frequencies can also be used to create a comprehensive TanDelta spectrum and provide further information on the condition of the test specimen.
Number of steps	[Can only be adjusted for step test and combined operating mode] Number of voltage levels (1 to 8) through which the test voltage cycles during a step test. By default, the voltage levels start at 0.5 Uo and are increased by 0.5 Uo with each step (step 2 = 1 Uo, step 3 = 1.5 Uo etc.). If necessary, the levels of the individual steps can also be adjusted in the software settings ("Adjusting the TanDelta settings" on page 68). If automatic evaluation of the measurement results is desired, it must be ensured that all the voltage levels required for the selected evaluation standard (see below) are cycled through. For example, if the Δtanδ is calculated from the values of voltage levels 1 Uo and 2 Uo, at least four voltage levels must be cycled through.
Values per step	[Can only be adjusted for step test and combined operating mode] Number of TanDelta measured values (1 to 20) per voltage level. If possible, at least 8 measured values should be recorded per voltage level to obtain a calculated TanDelta mean value with good statistical certainty. The more measured values are configured, the more reliable the mean value. However, this also increases the load on the test specimen. As the objective is to apply a non-destructive diagnostic method, the number of measured values should be set as low as possible, especially at high test voltages (8 to 10 values are recommended).
Standard	The evaluation standard to be used for automatic evaluation of the measurement results. If no automatic evaluation is desired, the setting **None** must be selected. Established evaluation standards are stored in the software ex works. If required, user-defined evaluation standards with their own evaluation thresholds can also be imported via the software settings ("Managing tan delta evaluation standards" on page 68).

Starting the test

After the last measurement parameter has been confirmed, the calculated voltage levels (only with step test and combined operating mode) and the current connected test object phase have to be confirmed. The test system then prepares the measurement and checks whether all conditions for the high-voltage release have been met. If this is not the case, the problem identified is indicated in the display and must be rectified before starting the measurement ("High-voltage control" on page 30).



If no problem has been identified or rectified, there are 10 seconds left to release the high voltage via the 'HV ON' button 5.

A load determination is performed at the start of a test. If the load characteristics (capacity and insulation resistance) do not permit a test to be conducted using the set test parameters, this is shown on the screen as a system message.

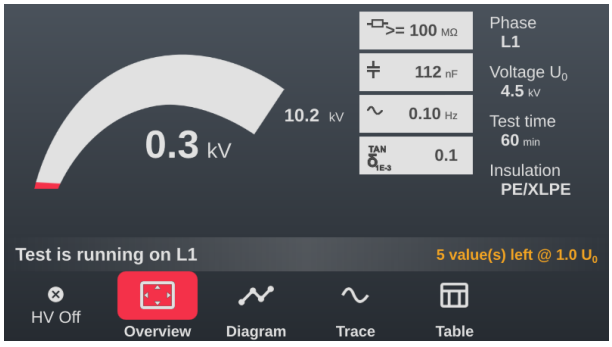
If this is possible, performance of the test with a lower test frequency is offered. The test can then either be aborted or launched with an adjusted frequency. In the frequency setting **Auto**, this type of adjustment is made without confirmation.

> If the test is performed with a frequency that deviates from 0.1 Hz, the measurement results cannot be evaluated automatically.

7.2.2 Procedure and conclusion of the TanDelta measurement

Testing process

During the test, the software remains in the overview screen.

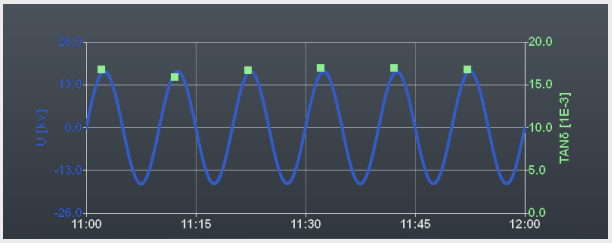
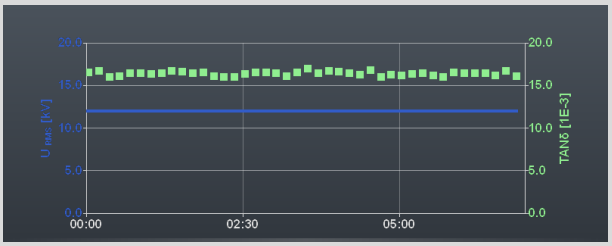
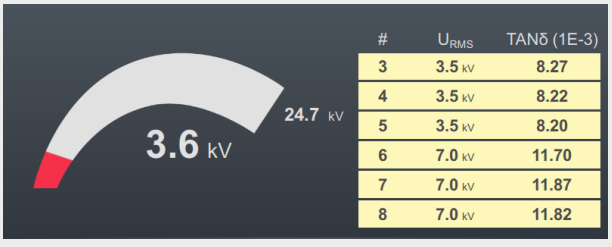


In addition to the current test voltage and the remaining test duration (or the remaining measured values in the step test), this also displays the following measured values:

Symbol	Description
	Insulation resistance determined at the start of the test

Symbol	Description
⏚	Load capacity determined at the start of the test
∼	Actual test frequency (sinusoidal and square-wave mode)
TAN δ1E-3	Last measured TanDelta value in exponential notation (10^{-3}).

The menu items at the bottom of the screen can also be used to call up the following views during the test if necessary:

Menu item	Graph type
∼	Temporal progression of the test voltage and the TanDelta values **over the past 60 seconds**. 
⁓	Temporal progression of the RMS value of the test voltage and the measured TanDelta values **over the entire test duration**. 
▦	Tabular overview of the last 6 TanDelta measured values.  You can scroll up or down through the table by turning the rotary encoder or using a swipe gesture.

Changing the phase during the test

If multiple phases have been selected and there was no breakdown during the current phase test, the system automatically prompts for the next phase after the voltage levels have been cycled through or the test time has elapsed.

In this case, the electrical connection must be adjusted accordingly, taking into account the five safety rules ("Safety instructions" on page 9).

After changing the phase, activate the high-voltage generator once more.

Completing the test

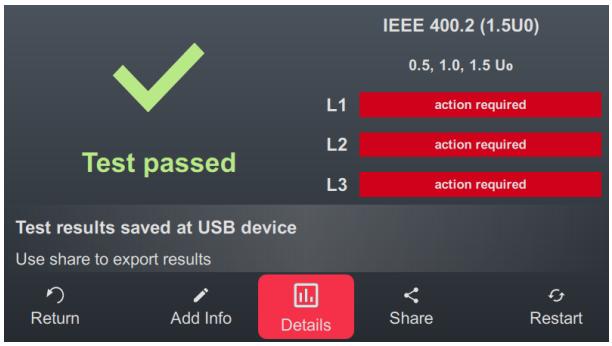
After testing all selected phases, the high voltage is switched off. In this case, the test is deemed to have been passed regardless of the measured TanDelta values.

However, if a breakdown is detected during the test (which also aborts the test and disconnects the high-voltage generator), further diagnostic tests and, if necessary, fault location must be carried out on the cable. The cause of the shutdown will be displayed along with the voltage at which the surge occurred.

In addition to the stated causes for an automatic shutdown, the test can also be ended manually at any time using the **HV Off** button or the buttons and switches on the front panel ("High-voltage control" on page 30).

After the measurement has been completed, the top part of the screen shows whether the test has been passed successfully or whether a breakdown occurred during the test.

In the step test and combined operating mode, the recommended actions derived from the TanDelta measured values are also displayed in the right-hand area of the screen (if all criteria for an automatic evaluation have been met).



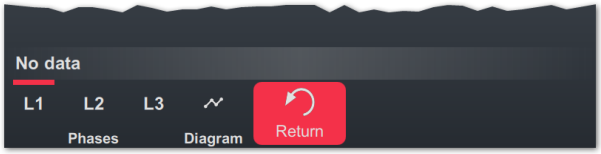
The following buttons are shown at the bottom of the screen for the next steps:

Button	Function
	End the test and return to the menu screen.
	Allows the input of a comment on the measurement. This is saved in the measurement data record and then displayed in both the activity list and in the reporting software ("Managing and processing measurement data" on page 61). If the data record was automatically saved to the inserted USB flash drive after the measurement was completed, it must be exported again after entering the comment.

Button	Function
	Following a monitored withstand test, the graphs recorded during the test (see previous table) can be viewed again using this button. Following a step test and combined operating mode, this button can be used to call up additional graphs for analysing the voltage-dependent change in the measured values ("Analysing and evaluating the step test measurement results" below).
	Export measurement data to an inserted USB stick. If a USB flash drive (with FAT32 file system) is inserted into the device at the end of the test, the measurement data is saved to this USB flash drive automatically.
	Restart the test with the same test parameters.

7.2.3 Analysing and evaluating the step test measurement results

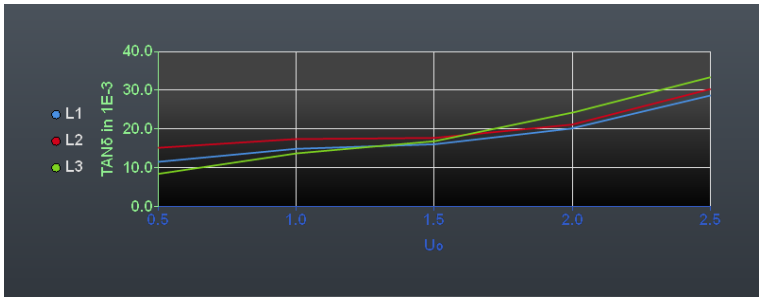
Following a TanDelta step test, the button can be used to call up additional graphs to enable a detailed analysis and evaluation of the measurement results. The individual graphs are called up using the buttons at the bottom of the screen.



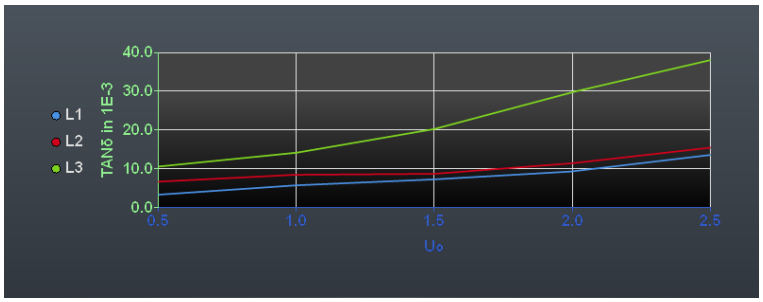
If there is no time for analysis of the measurement results immediately after the measurement, the graphs can also be reloaded at a later time or the analysis can be carried out using the reporting software MeggerBook on the PC ("Managing and processing measurement data" on page 61).

Trend graph

The button can be used to call up the trend graph of the average TanDelta values, which is ideal for manually identifying any conspicuous large changes between the individual voltage steps.



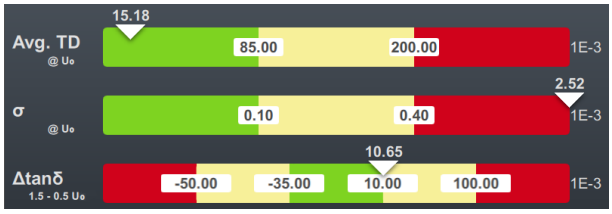
In addition, this graph can also be used to identify problems in the insulation of individual conductors. As a rule, all three conductors are subject to the same conditions. They have the same number of fittings and are subject to the same environmental influences. Taking measurements quickly can also ensure approximately uniform cable temperatures. Consequently, the mean values of the three phases should be almost identical. Clear upwards deviations indicate that the phase in question is in poorer condition.



Evaluation graphs for the individual phases

[Only available if an automatic evaluation was able to be performed and the respective phase was measured]

The **L1**, **L2** and **L3** buttons can be used to call up the evaluation graphs for the individual phases.



The following three evaluation criteria are taken into account when evaluating the measurement results:

Criterion	Description
Avg. TD	Average value of the measured tan delta values at a specific voltage level.
σ	Standard deviation for a specific voltage level. Standard deviation is a measure of the scatter of individual TanDelta values around the mean value of the level in question.
Δtanδ	Difference between the averages of two specific voltage levels. The Δtan**δ** reflects the voltage dependence of the measured values and is the most important criterion for making a meaningful evaluation of the insulation condition.

The thresholds and the voltage levels result from the set evaluation standard ("Managing tan delta evaluation standards" on page 68). The position of the white triangle above the respective bar indicates whether the selected evaluation standard classified the value determined for this measurement as normal (green), conspicuous (yellow), or critical (red).

The recommended action for the respective phase is displayed below the graph and always follows the worst-rated criterion:

Recommended action	Description
no action required	For all three criteria, normal values were identified and the cable should continue to be tested at the usual test interval.
further study advised	An unusual value was identified for at least one evaluation criterion. Further tests should be conducted on the cable in the medium-term.
action required	A critical value was identified for at least one evaluation criterion. Further tests and, if necessary, repairs to the cable should be carried out immediately.

7.3 Testing sheaths / Locating sheath faults

7.3.1 Sheath testing

Sheath testing provides information on the installation quality of the cable itself and its fittings. While sheath testing should be mandatory after new installations or repairs, it can certainly make sense to repeat the test regularly.

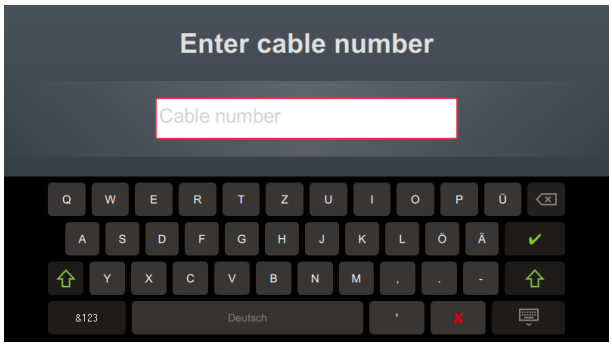
Testing can be carried out using a negative DC voltage of up to 20 kV, which also allows cables with thicker outer sheaths (such as cables with a rated voltage of 230 kV) to be tested. If a voltage breakdown occurs during a sheath test or if the measured leakage currents indicate a sheath fault, you can start pinpointing the sheath fault immediately after the test ("Sheath fault location" on page 57).

7.3.1.1 Preparing and starting the sheath test

Selecting the operating mode and entering the cable number

The operating mode is called up directly from the start menu using > .

The cable number is entered using the on-screen keyboard directly after calling up the operating mode.

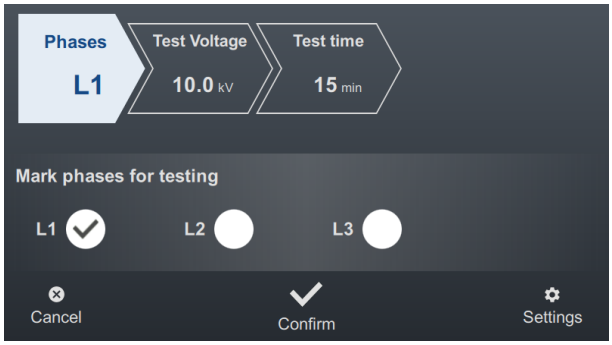


Entering the cable number as accurately as possible makes it easier to assign the cable later when reporting and archiving the measurement data record in the reporting software. If this kind of further processing is not planned, the cable number does not have to be entered. Regardless of whether or not a cable number has been entered, confirmation via ✓ is required.

Setting measurement parameters

When an operating mode is called up, the measuring parameters of the previous measurement are automatically preset. This enables faster preparation of the measurement during successive tests on cable systems of the same design.

After starting the operating mode and entering the cable number, the measuring parameters must be specified in several consecutive steps.



All required measurement parameters and their current values are displayed at the top of the screen, with the segment of the currently active measurement parameter marked in colour. Once this has been set as desired, confirm the setting with ✓ to proceed to the next step. The respective segment can be tapped to jump directly to one of the measurement parameters at any time during the workflow if, for example, a previously made setting needs to be adjusted.

The following measurement parameters must be set before starting the test:

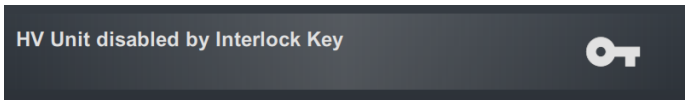
Parameter	Description	
Phases	The phase selection must be made according to the actual connection situation. It is used to uniquely assign the measurement data record during subsequent further processing. If multiple phases are bridged and tested simultaneously for time reasons, it is also possible to select multiple phases. However, if anomalies or voltage breakdowns occur during multi-phase testing, no conclusions can be drawn about which phase is affected. In this case, the phases must be retested individually.	
Test Voltage	The test voltage to be set is derived from the guidelines to be applied for the test (e.g. recognised standards, factory standards, client's specifications). Common values:	
	PVC cable	≤3 kV
	Medium-voltage PE cable	≤5 kV
	High-voltage PE cable	≤10 kV
Test time	The test duration can be specified within a range of 1 to 15 minutes. In relevant standards, the test duration of sheath testing is specified at 1 to 5 minutes depending on the cable type.	

The extended measurement settings can be called up at any time via menu item at the bottom right of the screen. The parameters contained in this menu usually only have to be set once when the respective operating mode is used for the first time and then remain in this setting until a new setting is made:

Parameter	Description
Ramp mode	Switching between manual and automatic voltage increase. In the setting **Auto**, the test system immediately starts voltage preparation after the high-voltage release and automatically charges the test object to the set upper limit. In the setting **Manual**, the voltage must be raised using the rotary encoder. This enables a gradual increase, facilitating, for example, the evaluation of sudden current fluctuations.

Starting the test

After the last measurement parameter has been confirmed, the test system prepares the measurement and checks whether all conditions for the high-voltage release have been met. If this is not the case, the problem identified is indicated in the display and must be rectified before starting the measurement ("High-voltage control" on page 30).



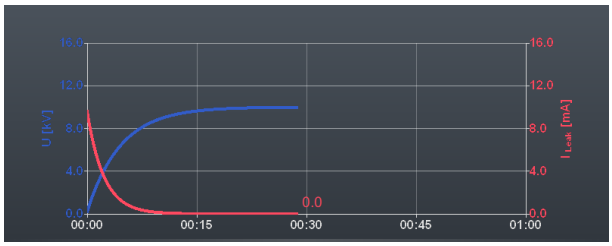
If no problem has been identified or rectified, there are 10 seconds left to release the high voltage via the 'HV ON' button 5.

7.3.1.2 Procedure and conclusion of the sheath test

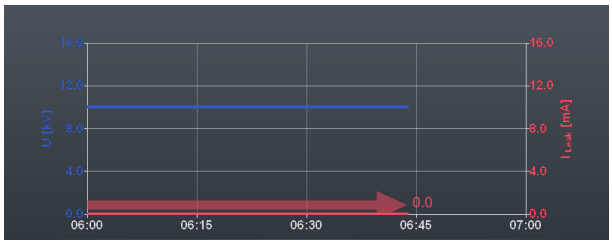
Testing process

In automatic mode, voltage preparation starts automatically immediately after the high voltage release. If the manual voltage setting has been activated instead, the desired voltage must first be set and confirmed via menu item **U**.

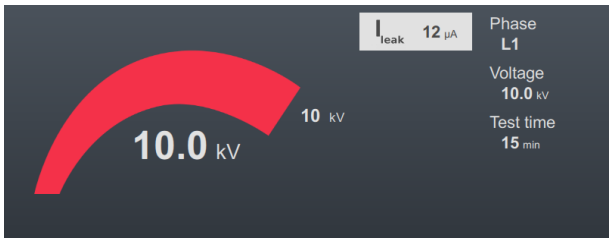
During the test, the software remains in the graph screen.



From a test time of approximately 90 seconds, a red arrow is also permanently displayed in the graph, which shows the trend of the measured leakage current (current measured value compared to the value measured after the charging process has been completed).



The view can be switched to the overview screen using the button. In addition to the current test voltage, this also shows the present measured leakage current value.



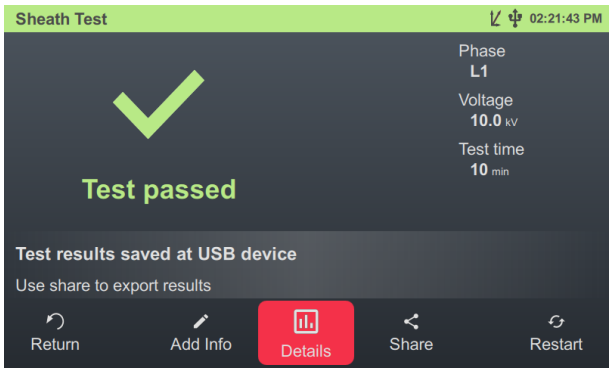
Completing the test

After the defined test time has elapsed, the test is concluded automatically and the high-voltage generator is switched off. In this case, the test is considered to have been passed.

If a breakdown occurs during the test or if the measured leakage current values are above the limit values specified by the cable owner, further diagnostic tests must be carried out on the cable and, if necessary, the fault must be localised.

In addition to being shut down automatically in the event of a breakdown, the test can also be ended manually at any time using the **HV Off** button or the buttons and switches on the front panel ("High-voltage control" on page 30).

Once the test has been completed, information about the test parameters and the cause of the shutdown is provided again in the upper area of the screen:



The following buttons are shown at the bottom of the screen for the next steps:

Button	Function
	End the test and return to the menu screen.
	Allows the input of a comment on the measurement. This is saved in the measurement data record and then displayed in both the activity list and in the reporting software ("Managing and processing measurement data" on page 61).  If the data record was automatically saved to the inserted USB flash drive after the measurement was completed, it must be exported again after entering the comment.
	Displays current and voltage curve for the last minute before shutdown.
	Export measurement data to an inserted USB flash drive.  If a USB flash drive (with FAT32 file system) is inserted into the device at the end of the test, the measurement data is saved to this USB flash drive automatically.
	Restart the test with the same test parameters.

7.3.2 Sheath fault location

Introduction

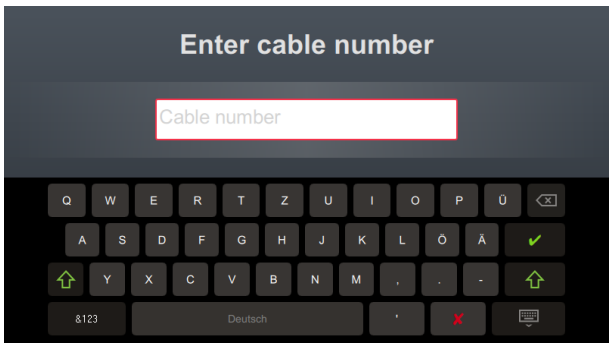
During the sheath fault location, DC current pulses are injected into the earth-faulted shield at an adjustable pulse rate.

With each injected pulse, the current flowing into the earth around the exit point (fault location in the sheath) forms a discharge voltage pattern, the centre of which can be located precisely using an earth leakage detector and the accompanying earth spikes (step voltage method).

Selecting the operating mode and entering the cable number

The operating mode is called up directly from the start menu using > .

The cable number is entered using the on-screen keyboard directly after calling up the operating mode.

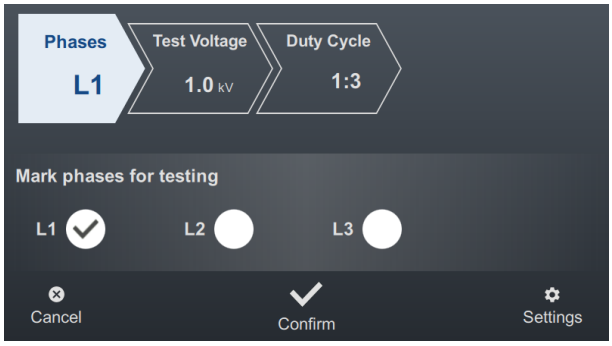


Entering the cable number as accurately as possible makes it easier to assign the cable later when reporting and archiving the measurement data record in the reporting software. If this kind of further processing is not planned, the cable number does not have to be entered. Regardless of whether or not a cable number has been entered, confirmation via ✓ is required.

Setting measurement parameters

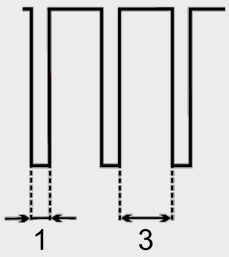
When an operating mode is called up, the measuring parameters of the previous measurement are automatically preset. This enables faster preparation of the measurement during successive tests on cable systems of the same design.

After starting the operating mode and entering the cable number, the measuring parameters must be specified in several consecutive steps.



All required measurement parameters and their current values are displayed at the top of the screen, with the segment of the currently active measurement parameter marked in colour. Once this has been set as desired, confirm the setting with ✓ to proceed to the next step. The respective segment can be tapped to jump directly to one of the measurement parameters at any time during the workflow if, for example, a previously made setting needs to be adjusted.

The following measurement parameters must be set before starting the test:

Parameter	Description	
Phases	The faulty phase of the test object must be selected via the phase selection according to the actual connection situation. The selection is used to uniquely assign the measurement data record during subsequent processing.	
Test Voltage	The output voltage to be set is derived from the guidelines to be applied for the test (e.g. recognised standards, factory standards, client's specifications). Common values:	
	PVC cable	≤3 kV
	Medium-voltage PE cable	≤5 kV
	High-voltage PE cable	≤10 kV
Duty Cycle	Timing the DC pulse. Timing is specified as the ratio of pulse duration to pause duration (both in seconds). **Example:** At a clock rate of 1:3, each 1 second DC pulse is followed by a 3 second pause before the next pulse.  	

The extended measurement settings can be called up at any time via menu item ⚙ at the bottom right of the screen. The parameters contained in this menu usually only have to be set once when the respective operating mode is used for the first time and then remain in this setting until a new setting is made:

Parameter	Description
Ramp mode	Switching between manual and automatic voltage increase. In the setting **Auto**, the test system immediately starts voltage preparation after the high-voltage release and automatically charges the test object to the set upper limit. In the setting **Manual**, the voltage must be raised using the rotary encoder.

Locating faults

WARNING

Risk of electric shock

Protect the measuring system and its surroundings against access by unauthorised persons.

The safety of the measuring system in operation must be ensured permanently by the person responsible for the work in accordance with the applicable safety regulations and guidelines, including during line and fault location!

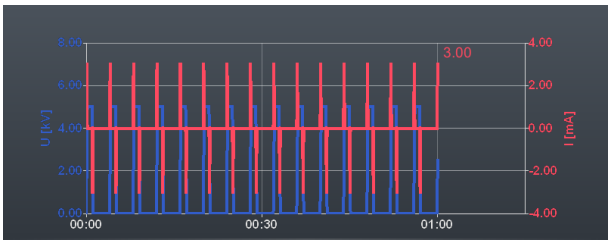
After setting the measurement parameters, proceed as follows to locate the sheath fault:

1. Confirm the measurement parameter setting with ✓.

   Result: The test system prepares the measurement and checks whether all conditions for the high-voltage release have been met. If this is not the case, the problem identified is indicated in the display and must be rectified before starting the measurement ("High-voltage control" on page 30).

2. Press the green 'HV ON' button.

   Result: In automatic mode, voltage preparation starts automatically immediately after the high voltage release. If the manual voltage setting has been activated instead, the desired voltage must first be set and confirmed via menu item **U**. When the DC pulses are injected, the current and voltage curve is displayed in the graph.



3. Locate the sheath fault using an earth fault locator (e.g. ESG NT2).

   Detailed instructions on operating the earth fault locator can be found in the appropriate operating instructions.

4. After completing the troubleshooting, end the measurement using the **HV Off** button or the buttons and switches on the front panel.

7.4 Partial discharge diagnostics (PD measuring system required)

When combined with a suitable PD measuring system, the test system can also be used for standard partial discharge diagnostics ("Scope of delivery and accessories" on page 16). A notebook equipped with the required software is used to control the system and evaluate the measurement results.

Detailed information on the electrical connection and on performing partial discharge diagnostics can be found in the operating manual of the PD measuring system used.

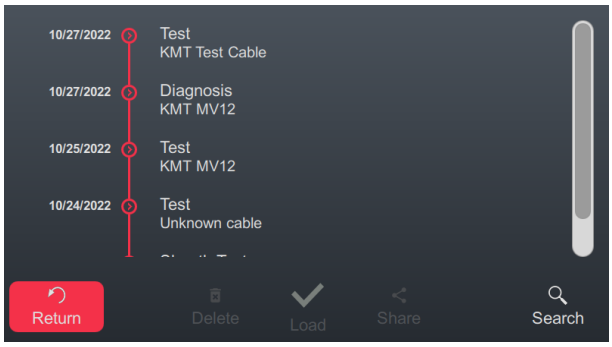
8 Managing and processing measurement data

8.1 Managing and exporting measurement data

The  button can be used to call up an overview of previous measurement activities directly from the start screen.

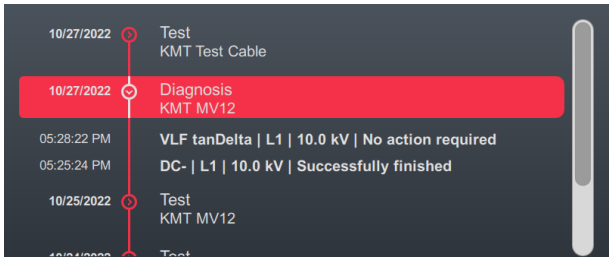
Navigation within the activity list

The measurement data records are grouped in chronological order, the designation of which provides information about the type of measurements taken and the name of the cable tested.



Consecutive measurements are stored in the same directory until either a different cable name is specified before the start of the measurement or the test system is switched off. Normally, all measurements performed on a cable one after the other are therefore combined in one directory.

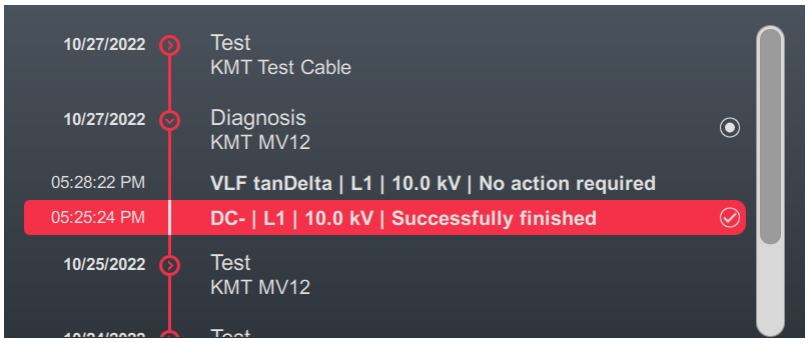
The desired directory can be selected by turning the rotary encoder. Tap the  button to open the directory currently selected.



This makes all measurement data records contained in this directory and the associated metadata (time, operating mode, phase, voltage and comment by tester) visible.

Selecting measurement data records

To export or manage certain measurement data records, the entries must first be selected. To do this, first select the desired measurement data record by turning the rotary encoder and then select it by pressing the rotary encoder. A selected entry is indicated by an activated tickbox.



The following applies when selecting measurement data records:

- Several entries can be selected from the list (including across different directories).
- Selecting a directory and then pressing the rotary encoder allows all entries contained in this directory to be selected.

Search by cable number

A cable number search can be carried out using the menu item to quickly find previous measurements of a specific cable, for example. After a search string has been entered and confirmed, the displayed measurements are narrowed down to those cables that have the string in their name.

Exporting and managing selected measurement data records

Once at least one measurement record has been selected, the following actions are offered at the bottom of the screen:

Symbol	Action
	Deletes the selected measurement data records.
	[Only available if exactly one measurement data record is selected] Calls up the completion screen of the selected measurement again, including the most important measured values and graphs. In this way, the comment of the inspector and the nane of the cable under test can also be changed again.
	Exports selected measurement data to an inserted USB flash drive.

8.2 Archiving measurement data and creating a report

After the desired measurement data has been exported ("Managing and exporting measurement data" on page 61), it can easily be imported into the reporting software MeggerBook on a Windows PC following the measurement job and summarised in a report. Depending on the version of the reporting software, the following functions are available:

	MeggerBook Lite	MeggerBook
	Free version (Download from Megger website)	Full version (article number 2015875)
Analysis of measurement data using practical tools	■	■
Creation of a report based on highly customisable report templates	■	■
Creation and maintenance of a cable database		■
Archiving of measurement activities in the database of the respective cable		■

9 Adjusting the settings

The button can be used to call up the settings menu directly from the start screen, which is divided into the following categories:

Menu item	Description
	Various information about the test system hardware and software
	Submenu with various software settings ("Adjusting the software settings" below)
	Submenu with various measurement settings ("Adjusting the measurement settings" on the facing page)
	Submenu with all settings relevant for the data transfer ("Adjusting the data transfer settings" on the facing page)
	Administration menu with advanced system settings ("Adjusting the extended settings" on page 66)
	Password-protected service menu

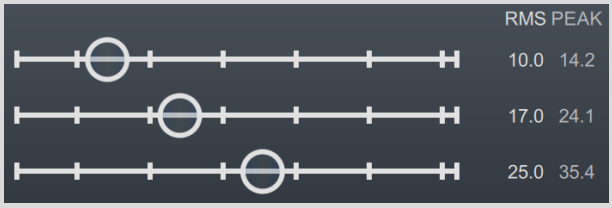
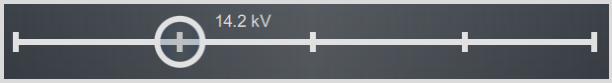
9.1 Adjusting the software settings

The following software settings can be performed in the settings menu > :

Parameter	Description
Layout	Switches between the bright and dark user interface layout.
Language Option	Select the menu language.
Brightness	Set the display brightness.
Date and Time	Set the date, time and time zone. It is particularly important for the time zone to be set correctly if the tests carried out with the test system are to be transferred to the reporting software MeggerBook. Only if the time zone is set correctly can it be ensured that the time of the measurement is also specified correctly in the reporting software (regardless of the time zone of the Windows PC).
Date Format	Select the desired date format.
Time Format	Switch between 12-hour and 24-hour display.

9.2 Adjusting the measurement settings

The following measurement settings can be made in the settings menu > :

Parameter	Description
Phase name L1 **Phase name L2** **Phase name L3**	The standard phase designations (L1, L2 and L3) can be adapted as required via these text fields. The length of the phase designation is limited to 2 characters.
Test voltage snaps **Nominal voltage snaps**	Define snap-in points for the voltage selection sliders. Here, test voltage levels or cable nominal voltages that have to be set particularly frequently in everyday work should be chosen. To define a snap-in point, the circle must be shifted to the desired value.  Once the setting has been made, the modified snap-in points must be saved using **Confirm**. During voltage selection, a noticeable "click" takes place at these positions, simplifying and accelerating the selection of these values. In addition, the values on the slider are marked with small horizontal lines. 

9.3 Adjusting the data transfer settings

The following data transfer settings can be changed in the settings menu > :

Parameter	Description
USB	Change the target directory for the USB measurement data export. After pressing this button, the contents of the inserted USB flash drive are displayed. To change the target directory for the USB measurement data export, first select the desired directory and then press the button **Use this Folder for exports**. If the directory cannot be found on the inserted USB flash drive during data export, it will be created automatically.
WLAN	Prepared for later implementation.
Bluetooth	Prepared for later implementation.

9.4 Adjusting the extended settings

The menu items > take you to a submenu with advanced functions and settings that should only be used or adjusted by authorized persons familiar with the effects.

Accordingly, the menu is also protected with a password that is set to **ADMIN** at the time of delivery, but can also be changed if necessary (see below).

The following functions and settings are available:

Menu item	Description
	View and export system log. The system log stores all relevant system operations that could provide helpful information about the cause of the problem when troubleshooting. So that the data can be quickly forwarded to the service employees involved in the event of device malfunctions, the entire log can be exported to a USB flash drive via the button.
	Activating the optional 'TanDelta measurement' function ("Activating the 'TanDelta measurement' option" below).
	Change access password. This menu item can be used to change the password for accessing the extended settings. To do this, the new password must be entered twice in the displayed text fields and then saved using .
	File Explorer for installing firmware updates and language files ("Updating the firmware / menu languages" on the facing page).
	Submenu for managing extended TanDelta measurement settings and TanDelta evaluation standards. *Further information:* ■ "Adjusting the TanDelta settings" on page 68 ■ "Managing tan delta evaluation standards" on page 68
	Reset to default values. Pressing this button resets all system, measurement, and admin settings as well as the administrator password to the factory settings.

Once the desired changes have been made, password protection must be reactivated using the button. Otherwise, the menu remains freely accessible until the system is restarted.

9.4.1 Activating the 'TanDelta measurement' option

For systems without the 'TanDelta measurement' option, this can be activated later. To activate the option, the required licence must first be purchased ("Scope of delivery and accessories" on page 16). Once the licence has been purchased, a licence key is provided in writing and as a key file.

In the settings menu > > the licence key can either be entered manually using the on-screen keyboard or imported via a key file. To import the key file, the file provided must first be copied to a USB flash drive and this must be inserted into the USB port of the test system. Pressing the button **USB** searches the USB flash drive for the file and the activation is carried out automatically if a file with a suitable licence key has been found.

The name of the key file must not be changed and must match the hardware ID of the test system.

9.4.2 Updating the firmware / menu languages

Current versions of the firmware and language files can be requested from the responsible sales partner.

Proceed as follows to update the software / menu languages of the testing system:

1. Unzip or copy the new firmware or the new language file into any directory on a USB flash drive. In the case of firmware files (`.img` und `*.crc`), make sure that both files have the same name.
2. Switch on the test system.
3. Insert the USB stick into the USB port on the front panel.
4. Open the menu > > .
5. Browse to the directory containing the file and select it. In the case of a firmware update, select the image file (`.img`).
6. Select to confirm that you wish to perform the update.

   Result: The update is performed. Do not turn off the test system during the update! After a firmware update, the test system will automatically restart.

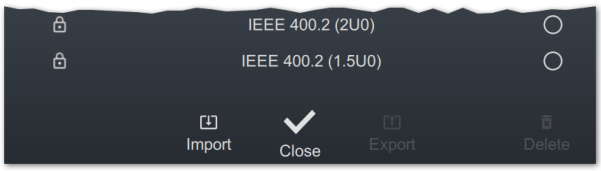
9.4.3 Adjusting the TanDelta settings

In the settings menu > > the following extended TanDelta measurement settings can be adjusted:

Parameter	Description
TanDelta resolution	Switches the resolution (10^{-4} or 10^{-5}) for tan delta measurements .
Insulation	Pre-selection of insulation types. This menu item can be used to limit the number of insulation types available for selection in preparation for a TanDelta step test. To speed up the selection, only the types of insulation that can actually occur in everyday measuring operations should be marked with a ✓.
TanDelta Steps	Definition of the voltage levels for the individual voltage steps of a step test. This menu item can be used to adjust the voltage levels (as a multiple of Uo) for the individual voltage steps to your own requirements and guidelines. In practice, a voltage increase of 0.5 Uo between two steps has proven to be practical. In the following sample configuration, a step test over 6 voltage steps would begin at 0.5 Uo and end at 3.0 Uo: 

9.4.4 Managing tan delta evaluation standards

In the settings menu > > , the evaluation standards currently available on the test system are displayed at the bottom of the screen. Two standards are already stored ex works; these follow the recommendations of IEEE 400.2.



Importing in-house evaluation standards

Using the reporting software MeggerBook Lite included in the scope of delivery, it is possible to create evaluation standards with own limit values and then distribute these standards to all test systems to ensure a uniform evaluation of the measurement results. Proceed as follows to do so:

1. Use the reporting software MeggerBook to create a standard with your evaluation limits and export it to a USB flash drive.

   Detailed information on the procedure can be found in the software help pages.

   Of course, existing standards can also be exported and transferred from other test systems.
2. Insert the USB stick with the evaluation standard into the USB port on the front panel.
3. Open the menu item.
4. Navigate to the directory of the USB flash drive in which the evaluation standard is located.
5. Select the file (`*.tds`) and confirm the prompt with to perform the import.

Exporting evaluation standards

Proceed as follows to export evaluation standards and, for example, transfer them to another test system:

1. Insert the USB stick with the evaluation standard into the USB port on the front panel.
2. From the list of available evaluation standards, select the standards you wish to export and mark them by pressing the rotary encoder.
3. Open the menu item.

   Result: All selected standards are stored in the directory `tanDelta` on the inserted USB flash drive ("Adjusting the data transfer settings" on page 65).

Deleting evaluation standards

Proceed as follows to delete evaluation standards:

1. From the list of available evaluation standards, select the standards you wish to delete and mark them by pressing the rotary encoder.

   Factory pre-installed evaluation standards cannot be deleted.
2. Open the menu item.

   Result: All selected standards are deleted.

10 Switching off the test system and disconnecting it from the test object

After the measurements have been completed, the test system can be switched off by pressing the on/off button 3.

To dismantle, use the same method as for connecting ("Electrical connection" on page 21) but in reverse order. The safety instructions below must be observed.

WARNING

Risk of electric shock

- The five safety rules must be followed ("Safety instructions" on page 9).
- Even if properly switched off and discharged with the discharging device, system components that have been energised should only be touched if they have been discharged with a suitable discharging rod and earthed and short-circuited.
- Do not remove the earthing and short circuit until the test object is to be put back into operation.

11 Cleaning, maintenance and storage

Cleaning

Any cleaning work must only be carried out when the device is switched off and disconnected from the mains power supply. The following cleaning measures should be carried out regularly and as required to ensure the functionality and longevity of the device:

- The housing and the connection cables should be cleaned with a damp, lint-free cloth and a mild cleaning agent.
- The touchscreen should be cleaned with a soft, lint-free microfiber cloth and a cleaning agent specifically designed for displays. Abrasive cleaning agents, solutions containing alcohol or sharp-edged objects must not be used.
- The plug of the HV connection cable and the HV output of the device should be cleaned with a soft, lint-free cloth and ethanol.

Repair and maintenance

Repairs and maintenance work may only be carried out by Megger itself or by authorised service partners using original spare parts!

Megger recommends that the system be checked and serviced once every two years at a Megger service centre. Megger also offers on-site service to its customers.

In order to identify potential problems early and to keep the system in good condition, the following work should be carried out independently and, depending on the frequency of use, at appropriate intervals:

- Check the function of the key switch and the emergency stop switch
- Check that all connection points and connecting cables are free of damage and intact
- Check the housing for visible damage (e.g. dents)

If damage or defects are discovered during inspection, the device must not be operated any further and must be repaired by an authorized service workshop.

Replacing the fuses

If the device cannot be switched on when the mains supply is connected, check the two fuses below the mains socket 14. To do this, the fuse holder must be pulled out.

In the event of a fault, the fuses must be replaced by suitable fine-wire fuses (5 x 20 mm) of type T6.3 A.

If the fuses are triggered repeatedly, please contact an authorised service centre to have the fault rectified.

Behaviour in the event of continuous faults

In the event of damage, irregularity or faults that cannot be rectified using the instructions in this manual, the system must be immediately taken out of service and marked accordingly. Please contact the Megger service immediately to rectify the fault. The system must not be put back into operation until the fault has been rectified.

Storage

If the appliance is not used for a long period of time, it should be stored in a dust-free and dry environment. Persistent humidity, especially in combination with dust, can reduce critical insulation gaps that are essential for safe high-voltage operation.

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