AVTMDELTA4000-EN
Rev 6
April 2018

Instruction Manual

DELTA4000

12-kV Insulation Diagnostic System

HIGH VOLTAGE EQUIPMENT
Read this entire manual before operating.

Megger.

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www.megger.com

DELTA4000

12-kV Insulation Diagnostic System

The information presented in this manual is believed to be adequate for the intended use of the product. If the product or its individual instruments are used for purposes other than those specified herein, confirmation of their validity and suitability must be obtained from Megger. Refer to the warranty information below. Specifications are subject to change without notice.

WARRANTY

Products supplied by Megger are warranted against defects in material and workmanship for a period of one year following shipment. Our liability is specifically limited to replacing or repairing, at our option, defective equipment. Equipment returned to the factory for repair must be shipped prepaid and insured. Contact your MEGGER representative for instructions and a return authorization (RA) number. Please indicate all pertinent information, including problem symptoms. Also specify the serial number and the catalog number of the unit. This warranty does not include batteries, lamps or other expendable items, where the original manufacturer's warranty shall apply. We make no other warranty.

The warranty is void in the event of abuse (failure to follow recommended operating procedures) or failure by the customer to perform specific maintenance as indicated in this manual.

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Upon Receipt of Product

Prior to operation, check for loosened hardware or damage incurred during transit. If these conditions are found, a safety hazard is likely, DO NOT attempt to operate equipment. Please contact Megger as soon as possible.

DELTA4110 Transformer Test Set

DELTA4300A Transformer Test Set

1

Introduction

Receiving Instructions

Check the equipment received against the packing list to ensure that all materials are present. Notify Megger of any shortage.

Examine the instrument for damage received in transit. If damage is discovered, file a claim with the carrier at once and notify Megger, giving a detailed description of the damage.

This instrument has been thoroughly tested and inspected to meet rigid specifications before being shipped. It is ready for use when set up as indicated in this manual.

General Information

The DELTA4000 is used for shop and field testing of high-voltage electrical insulating systems at test voltages up to 12 kV. Test results can be used to evaluate the nature and quality of electrical insulating materials and manufacturing processes to reveal contamination, fractures, punctures, and other defects that accompany the aging of insulation. The test set comprises of a control unit, a high-voltage unit, cables, and canvas carrying bags. Refer to the *Specifications* section for a list of included accessories.

Tests are made by measuring the capacitance and dissipation factor (power factor) of a specimen. The values measured will change when undesirable conditions exist, such as moisture on or in the insulation; presence of conductive contaminants in insulating oil, gas or solids; presence of internal partial discharges etc.

The test set measures insulation properties in high-voltage power equipment such as transformers, bushings, rotating machines, cables, circuit breakers, capacitors, surge (lightning) arresters etc. In addition, the test set can also measure transformer excitation current and transformer turns ratio (with optional TTR capacitor).

DELTA4000 makes all standard Ungrounded Specimen Tests (UST) and Grounded Specimen Tests (GST) on high-voltage apparatus and key features include:

- Two-piece design for easy transportation Rugged and robust and only 14+22 kg (31+48 lb)
- Handling up to 15 mA interference current into any lead of the instrument or a signal to noise ratio of 1:20, secures stable readings and correct data even in the highest interference switchyards.
- Standard 50/60 Hz measurements as well as 1-500 Hz frequency sweep reveals more details in the insulation characteristics.
- Variable frequency source allows larger capacitance specimen to be tested without the need for special resonating inductors
- Advanced signal acquisition and noise suppression circuitry results in 25-50% shorter measurement times
- Individual temperature correction (ITC) feature enables an accurate temperature correction of measurements taken at high and low temperatures. Temperature table corrections are no longer required.
- Two operation modes; Form-based, automated testing with PowerDB or run your specific test manually controlled with Delta Control.
- Enhanced safety features with safety hand switches, foot switch, warning strobe light and a ground interlock system.
- Optional resonating inductor provides capability of testing high capacitance samples at high voltage.

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Safety

Precautions

The test set and the specimen to which it is connected are a possible source of high-voltage electrical energy and all persons making or assisting in tests must use all practical safety precautions to prevent contact with energized parts of the test equipment and related circuits. Also follow all local and company safety requirements. Persons actually engaged in the test must stand clear of all parts of the complete high-voltage circuit, including all connections, unless the test set is de-energized and all parts of the test circuit are grounded. Persons not directly involved with the work must be kept away from test activities by suitable barriers, barricades, or warnings.

Treat all terminals of high-voltage power equipment as a potential electric shock hazard. There is always the potential of voltages being induced at these terminals because of proximity to energized high-voltage lines or equipment. Always use a safety ground stick to ground the high-voltage conductor. A safety ground jumper must then be installed between all terminals of apparatus under test and ground. Always disconnect test leads from test specimen before attempting to disconnect them at the test set. The ground connection on the test set must be the first made and the last removed. Any interruption of the grounding connection can create an electric shock hazard.

This instrument operates from a single-phase power source. It has a three-wire power cord and requires a two-pole, three-terminal, live, neutral, and ground type connector. The voltage to ground from the live and neutral poles of the power source must be within the following rated operating voltage:

100-240 V ± 10 %, 50/60 Hz, 16A

Before making connection to the power source, determine that the instrument rating matches the voltage of the power source and has a suitable two-pole, three-terminal grounding connector.

The power input plug must be inserted only into a mating receptacle with a ground contact. Do not bypass the grounding connection. Any interruption of the grounding connection can create an electric shock hazard. Determine that the receptacle is properly wired before inserting the plug.

It is not possible to eliminate all potential hazards from, and in using, electrical test equipment. For this reason, every effort has been made to point out in this instruction manual the proper procedures and precautions to be followed by the user in operating this equipment and to mark the equipment itself with precautionary warnings where appropriate. It is not possible to foresee every hazard which may occur in the various applications of this equipment. It is therefore essential that the user, in addition to following the safety rules in this manual, also carefully consider all safety aspects of the test before proceeding.

- Safety is the responsibility of the user.
- Misuse of this high-voltage equipment can be extremely dangerous.
- The purpose of this equipment is limited to use as described in this manual. Do not use the equipment or its accessories with any device other than specifically described.
- Never connect the test set to energized equipment.
- Operation is prohibited in rain or snow.
- Do not use the test set in an explosive atmosphere.
- A qualified operator should be in attendance at all times while the test equipment is in operation.
- Observe all safety warnings marked on the equipment.
- Corrective maintenance must only be performed by qualified personnel who are familiar with the construction and operation of the test set and the hazards involved.
- Refer to e.g. IEEE 510 - 1983, "IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing," for information.

As a routine safety procedure some users require that rubber gloves be worn, not only when making connections to the high-voltage terminals, but also when manipulating the controls.

High-voltage discharges and other sources of strong electric or magnetic fields may interfere with the proper functioning of heart pacemakers. Persons with heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.

Warning and Caution Notices

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

WARNING

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

CAUTION

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

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Specifications

Technical Specifications

Input Power: 100-240 V ± 10 %, 50/60 Hz, 16 A max

Output voltage: 0 to 12 kV, continuously adjustable

Test frequency range: 45-70 Hz (12 kV)
15-405 Hz (4 kV)
1-505 Hz (250 V)

Details relating to frequency range:
45Hz – 350Hz - **12 kV** – 100mA, continuous
45Hz – 350Hz - **12 kV** – 300mA, 4 minutes
45Hz – 400 Hz - **10 kV** – 100mA, continuous
45Hz – 400Hz - **10 kV** – 300mA, 4 minutes

Max Current (mA)	Max Voltage (kV)	Frequency (Hz)	Capacitance (nF)
300	12	60	67
300	8	60	100
300	6	60	133
300	4	60	200
300	2	60	400
300	12	45	89
300	8	45	133
300	6	45	178
300	4	45	267
300	8	30	200
300	6	30	267
300	4	30	400
300	4	15	800
300	2	15	1600

Output power:	3.6 kVA
Output Current:	>100 mA, continuous output
	>300 mA, up to 4 minutes
	The output current capacity can be expanded to 4 A using the optional Resonating Inductor, catalog number 670600-1
Measuring Ranges:	
Voltage:	25 V to 12 kV, 1 V maximum resolution
Current:	0 to 5 A, 0.1 □ A maximum resolution
	The measurement can be corrected to either 2.5 kV or 10 kV equivalents
Capacitance:	0 to 100 □ F, 0.01 pF maximum resolution
Inductance:	6H to 10MH, 0.1 mH maximum resolution
Power Factor:	0 to 100%, 0.001% maximum resolution
Dissipation Factor:	0 to 100, 0.001% maximum resolution
Watt Loss:	0 to 2 kW, actual power, 0 to 100 kW when corrected to 10 kV equivalent. 0.1mW maximum resolution.
	The measurement can be corrected to either 2.5 kV or 10 kV equivalents.
Temperature Correction:	Individual temperature correction (ITC) from 5°C to 50°C test temperature to 20°C reference, (using Power DB)
	Standard tables for temperature corrections
Accuracy:	
Voltage:	±(1% of reading)
Current:	±(1% of reading)
Capacitance:	±(0.5% of reading + 1 pF)
Inductance:	±(0.5% of reading + 1 mH)
Power Factor:	±(0.5% of reading + 0.02%)
Dissipation Factor:	±(0.5% of reading + 0.02%)
Watt Loss:	±(1% of reading + 1mW)

Noise Immunity:	
Electrostatic:	15mA induced noise into any test lead with no loss of measurement accuracy at maximum interference to specimen current of 20:1
Electromagnetic:	500 □ T, at 50 Hz in any direction
Computer Interfaces:	
Printer:	USB
Communication:	Ethernet and USB
Industrial Controller (DELTA4310A):	**Touchscreen Display (ruggedized for field use)** Size: 300 mm (12 in.) Resolution: 1024 x 768 (XGA) Luminance: 1600 nits Coating: anti-glare Backlight: LED Technology: 4-wire resistive touchscreen Memory: 32 Gigabits (SSD)
Data Storage:	
Internal computer:	Up to 100,000 data sets (up to 32GB)
External:	Pending external computer and/or flash memory size
Control Software:	PowerDB and Delta Control
Safety Qualifications:	IEC/ANSI 61010-1
Environment:	
Temperature:	Operating: -20 to +55° C Storage: -50 to +70° C
Relative Humidity:	Operating: 0 to 90% non-condensing Storage: 0 to 95% non-condensing
Shock and vibration:	ASTM D999.75
EMC:	EN 61326-1
Dimensions:	
Control Unit:	290 x 290 x 460 mm (not including handles)
High Voltage Unit:	290 x 290 x 460 mm (not including handles)

Weight:

DELTA4100 Control Unit (to be used with external computer): 14kg (33lbs)

DELTA4300A Control Unit (with on-board computer): 15kg (31lbs)

DELTA4110 HV Unit: 22 kg (48lbs)

Standard cables: 14 kg (30lbs)

Test Modes

DELTA4000 supports the following test modes:

UST: Ungrounded Specimen Testing			
Test mode	**Measure**	**Ground**	**Guard**
UST-R	Red	Blue	---
UST-B	Blue	Red	---
UST-RB	Red and Blue	---	---
GST: Grounded Specimen Testing			
Test mode	**Measure**	**Ground**	**Guard**
GST-GND	Ground	Red and Blue	---
GSTg-R	Ground	Blue	Red
GSTg-B	Ground	Red	Blue
GSTg-RB	Ground	---	Red and Blue

Maximum Specimen Capacitance

Table 1 shows the maximum measurable specimen capacitance at various voltages and loading time. This can be increased up to 1.2μF at 10 kV (50 Hz) test voltage using the optional Resonating Inductor.

Table 1: Maximum Measureable Specimen Capacitance at 50/60Hz

Test Volts (kV)	Maximum Capacitance (μF) (100 mA continuos service)		Maximum Capacitance (μF) (300 mA for 4 minutes)	
	60 Hz	50 Hz	60 Hz	50 Hz
0.025	11	13	32	38
0.05	5.3	6.3	16	19
0.1	2.6	3.2	7.9	9.5
0.25	1.1	1.3	3.2	3.8
0.5	0.53	0.63	1.6	1.9
1	0.26	0.32	0.79	0.95
2	0.13	0.16	0.40	0.48
3	0.09	0.11	0.27	0.32
4	0.065	0.080	0.20	0.24
5	0.11	0.063	0.16	0.19
6	0.044	0.055	0.13	0.16
8	0.033	0.040	0.099	0.12
10	0.027	0.032	0.080	0.095
12	0.022	0.027	0.066	0.080

ALL FREQUENCIES AND LIMITS ARE LISTED IN SECTION 3 – FREQUENCY SPECIFICATIONS

Safety Features

Safety features include;

- External hand plus foot (second external hand switch is optional) interlock switches must be closed to energize high-voltage circuit.
- Dual ground required to energize high-voltage circuit.
- Circuit breaker for short-circuit protection.
- All controls at ground potential.
- Over-voltage protective devices prevent damage to test set in the event of specimen breakdown.
- Low-voltage inputs are grounded when the test set is turned off or between measurements.

Accessories

Included Accessories

High voltage lead: 21 m (70 ft), double shielded	30012H-11
HV Cable Accessory Kit (Universal high voltage clip, small alligator clip, high voltage hook, female quick disconnect & tether rope with hooks)	1010-333
Measurement lead, color-coded red, 21 m (70 ft)	25572-1
Measurement lead, color-coded blue, 21 m (70 ft)	25572-2
Ground lead: 9 m (30 ft)	2002-131
Mains cable 16A EU	17032-19
Mains cable 16A US	17032-23
Mains cable 16A UK	17032-21
Safety hand switch, Interlock #1: 21 m (70 ft)	1001-850
Safety foot switch, 3 m (10 ft)	1001-852
HV unit power cable, 1 m (3 ft)	2002-132
HV unit control cable, 1 m (3 ft)	2002-133
Ground lead cable, 1 m (3 ft)	2002-134
USB cable, 3 m (10 ft)	2002-135
Ethernet cable, CAT 5, 3 m (10 ft)	2002-136
Canvas bag for HV cable	2001-507
Canvas bag for other cables/accessories	2005-265
USB with PowerDB, DELTA Manual Control software, User Guide, Application Guide and Data Sheets	1010-048
Warranty [1 year]	

Optional Accessories

Safety hand switch, Interlock #2: 2.4 m (8 ft)	1001-851
External strobe	90009-210
External strobe extension cable, 18 m (60 ft)	1004-532
Soft padded carrying case for control unit [1]	2001-766
Soft padded carrying case for HV unit [1]	2001-766
Transport case, 2-piece design kit consists of:	
Case for control unit and accessories [1]	2005-115
Case for HV unit and accessories [1]	2005-115

Transport cart / trolley	2009-071
Calibration adjustment box set, CAL4000	2002-137
10KV Calibration reference standard, 100 pF	670500-1
Transit case for calibration standard	670635
HV TTR capacitor, single phase (10 nF, 10 kV)	36610
HV reference capacitor (100 pF, 10 kV)	36610-1
HV reference capacitor (1000 pF, 10 kV)	36610-2
Carry case for capacitors	36610-CC
Capacitor kit (TTR cap, 2 ref caps, carry case)	36610-KIT2
Resonating inductor	670600-1
Adapter kit for Competitor's (Doble) Resonating Inductor	1002-455
Oil test cell	670511
Oil test cell, high temp.	1004-716
Hot collar belts [3]	670505
Bushing tap connectors [2]	670506
USB bar code wand and software	36528
Standard Accessory kit includes:	670501
▪ Mini bushing tap connectors [set of 2]	670506
▪ Hot collar straps [set of 3] , 1.1m, 0.6m, 0.3m length	670505
▪ Thermometer -hygrometer -clock [1]	670504
▪ Temperature and humidity probe, complete with 20 ft (7 m) lead	2002-138
▪ 0.75" bushing tap adapter [1]	30918-000
▪ 1" bushing tap adapter [1]	30918-100
▪ "J" probe bushing tap adapter [1]	30917
▪ 3 ft (1 m) non-insulating shorting lead, 3 each	34726-1
▪ 6 ft (2 m) non-insulating shorting lead, 3 each	34726-2
▪ Bushing tap adapter -ABB (older style bushings)	2006-375
▪ Bushing tap adapter, female-to-female banana jack [3]	90014-353
▪ Bushing Adapter, male to female	90021-216

Special length cables available upon request. Consult factory.

4

Controls, Indicators, and Connectors

Control Unit Side Panel

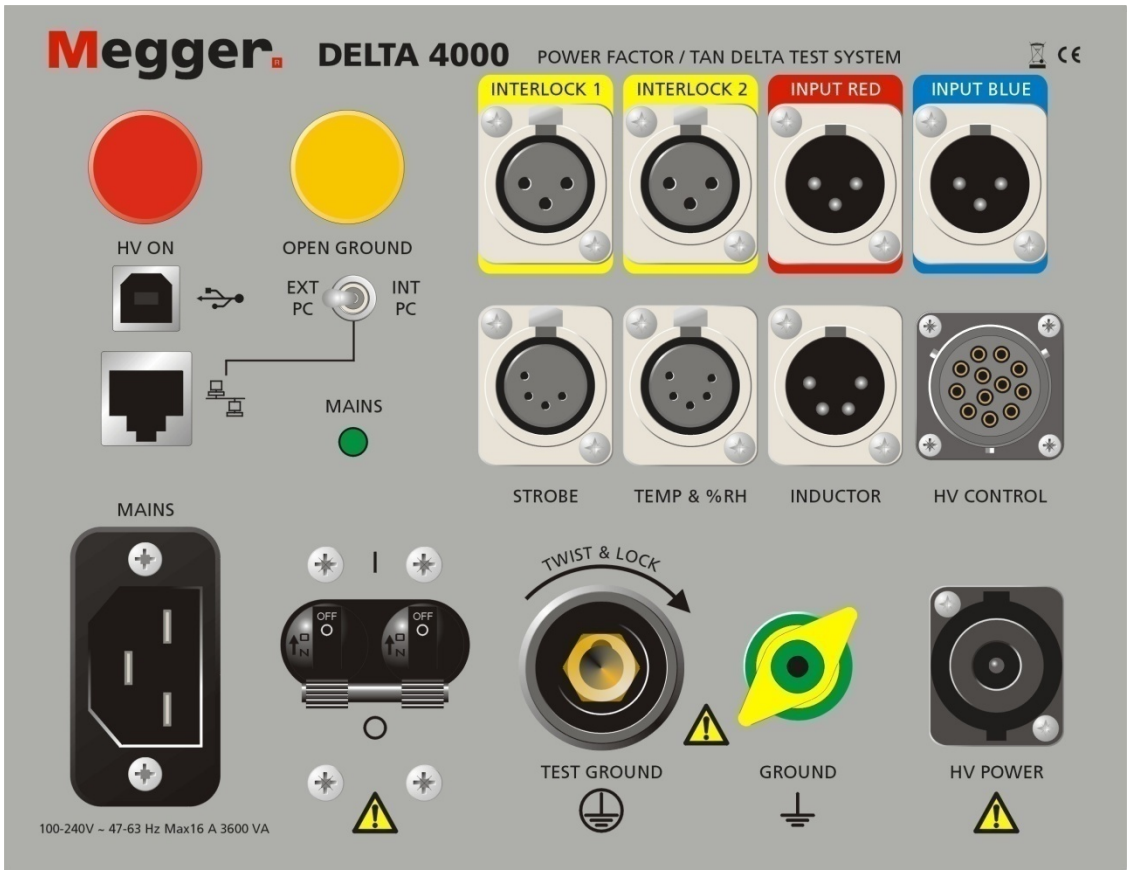
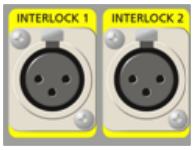
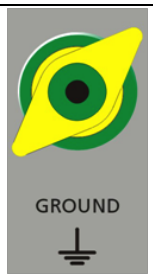


Figure 1: Side Panel – Control Unit

	**HV ON**	Warning signal indicating that the HV unit is active
	**OPEN GROUND**	When lit, this yellow lamp indicates an open in double ground system or defective grounding of test set.
	**SAFETY INTERLOCK 1 and 2**	Two plug receptacles for connecting external interlock switches. One hand interlock switch and a foot switch are supplied; however, in the event that a hand interlock is replaced with a test area interlock, the system must be constructed so that the interlock switches are closed when the test area gate or gates are closed. The interlock wiring must be run as a twisted pair to minimize electromagnetic coupling into the system. This interlock system should be wired such that connection is made to the A and B sockets of the SAFETY INTERLOCK receptacle. When the interlock loop is opened the test is automatically terminated.
	**INPUT RED**	Plug receptacle for connecting the red low-voltage test lead.
	**INPUT BLUE**	Plug receptacle for connecting the blue low-voltage test lead.
	**USB port**	Receptacle for computer communication.
	**Ethernet port**	Receptacle for computer communication.
	**Ext-Int PC switch**	Switch for selecting internal or external PC (functional on DELTA4310A only, disabled on DELTA4110). "Internal" connects the on-board PC to DELTA via Ethernet, "External" means that you can operate DELTA from an external computer.

	**STROBE**	Receptacle for connecting the warning strobe light
	**TEMP and %RH**	Receptacle for connecting the temp and humidity sensor (optional accessory)
	**INDUCTOR**	Receptacle for connecting the test set to an optional Resonating Inductor (Cat. No. 670600-1) for extended capacitance range.
	**HV CONTROL**	Receptacle for the control cable between the control and HV units
	**MAINS**	Receptacle for connecting the test set to an AC power source as marked on panel.
	**TEST GROUND**	Receptacle for connecting the test ground cable between the test set and ground (normally station ground) near the test object
	**GROUND**	This wing nut is for connecting an additional safety ground between the control and HV units or to ground external objects e.g. optional trolley
	**HV POWER**	Receptacle for the power cable between the control and HV units

High Voltage Unit Connector Panel

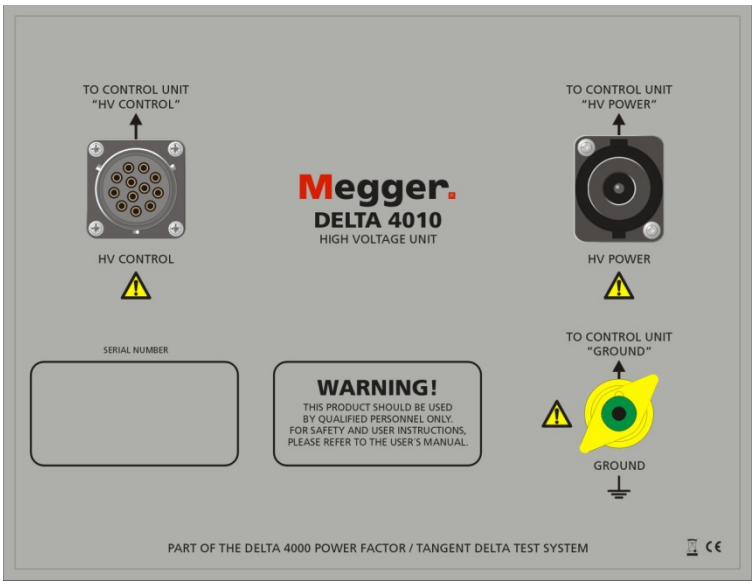
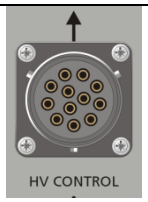
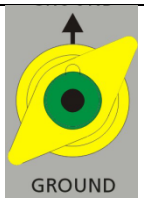


Figure 2: Connector panel – HV Unit

	**HV CONTROL**	Receptacle for the control cable between the control and HV units
	**HV POWER**	Receptacle for the power cable between the control and HV units
	**GROUND**	This wing nut is for connecting an additional safety ground between the control and HV units
	**HV Output**	Receptacle for the high voltage cable (located on the side exterior of the equipment box) Comes with a spring loaded lock mechanism to secure HV cable.

NOTE: The HV cable is connected on the other side of the unit. Note the sliding pin to secure the cable. Do NOT use excessive force to unplug.

DELTA4310A Top Panel Features

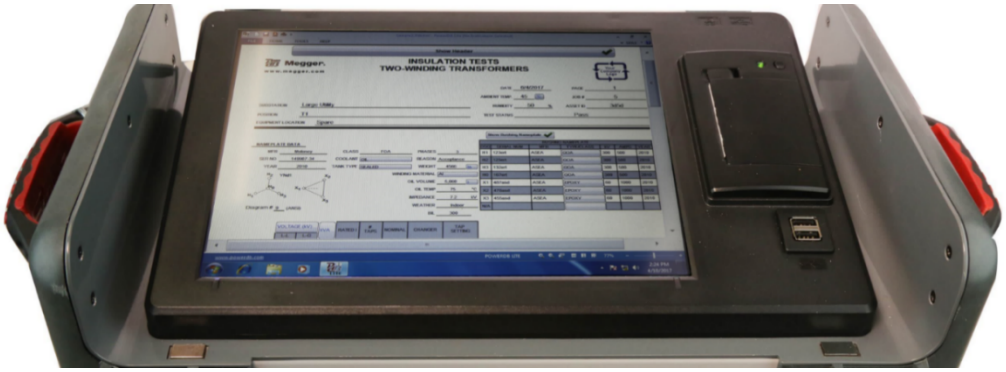


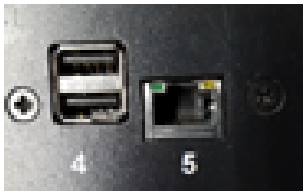
Figure 3: Optional Industrial 12 inch Controller

The optional industrial 12 inch controller is:

1. **Industrial 300 mm (12 inch) Touch Display:** Used in place of a PC. Designed to run PowerDB Lite with focus on selected Megger instrument control related to transformer testing. When turned on, defaults to DELTA4000 transformer forms.

2. **Built-in Printer:** Designed to print individual results and is active within specific forms via 'print icon' located within selected forms.

3. **USB Port:** Used for various functions including external memory and external mouse/keyboard control.



4. **Rear USB Port Hub:** Used for external Megger instrument control such as TTR300, TTR310E, S1/MIT Insulation test set, MLR10.

5. **Rear Ethernet Port**: Used for external Megger instrument control – specifically the MTO300, TTR310E, MTO250.

The DELTA4310A 300 mm (12 inch) display is meant to replace a customer PC with an industrial controller designed to work in harsh environments. This built-in display features protection against accidental shut down of the instrument by safely turning off Windows operating system together with PowerDB after shutdown (switch is turned off) is detected. This safe shutdown prevents damage to the internal memory, and to the software operating system.

5

Setup and Operation

Safety Precautions

Warning

The output of this test set can be lethal.

As with any high-voltage equipment, caution must be used at all times and all safety procedures followed. Read and understand Section 2, *Safety,* before proceeding. Be sure that the test specimen is de-energized and grounded before making connections. Isolate power equipment to be tested from the high-voltage busbars and attach necessary grounds to floating busbars in accordance with standard company policy, observing all safety procedures. Make certain that no one can come in contact with the high-voltage output terminal or any material energized by the output. Be aware that when testing power cables high voltage will be present at the remote end of the cable. Use protective barriers if necessary. Locate the control unit and high-voltage unit in an area which is as dry as possible. Maintain adequate clearances between energized conductors and ground to prevent arc-over. Such accidental arc-over may create a safety hazard or damage the equipment being tested.

WARNING

No user serviceable parts inside!
Refer all servicing to the factory or a qualified authorized service company!

CAUTION

Use only factory supplied mains cord!
Mains cord shall not be substituted!

Setup

The following steps are a general guide for setting up the test set. Figure 4 shows a typical setup for testing inter-winding and ground capacitance on a three-phase delta-wye power transformer; Figure 5 shows a typical setup for making excitation current measurements on the same transformer. The test set controls and connectors are identified in Figures 1 through 3. Refer to the Application Guide for specific instructions on connecting this and other power equipment to the test set.

When making capacitance measurements on transformer windings always short each winding on itself with a jumper lead to eliminate winding inductance effect. The shorting wire is usually non-insulated and must not be in contact with any other insulated or non-insulated parts of the transformer.

When making transformer excitation current measurements conduct all tests on high-voltage windings only. This reduces the required charging current. In load tap changers, set to fully raised or fully lowered position for routine tests.

WARNING

There is always the possibility of voltages being induced at the terminals of a test specimen because of proximity to energized high-voltage lines or equipment. A residual static voltage charge may also be present at these terminals. Ground each terminal to be tested with a safety ground stick, then install safety ground jumpers, before making connections.

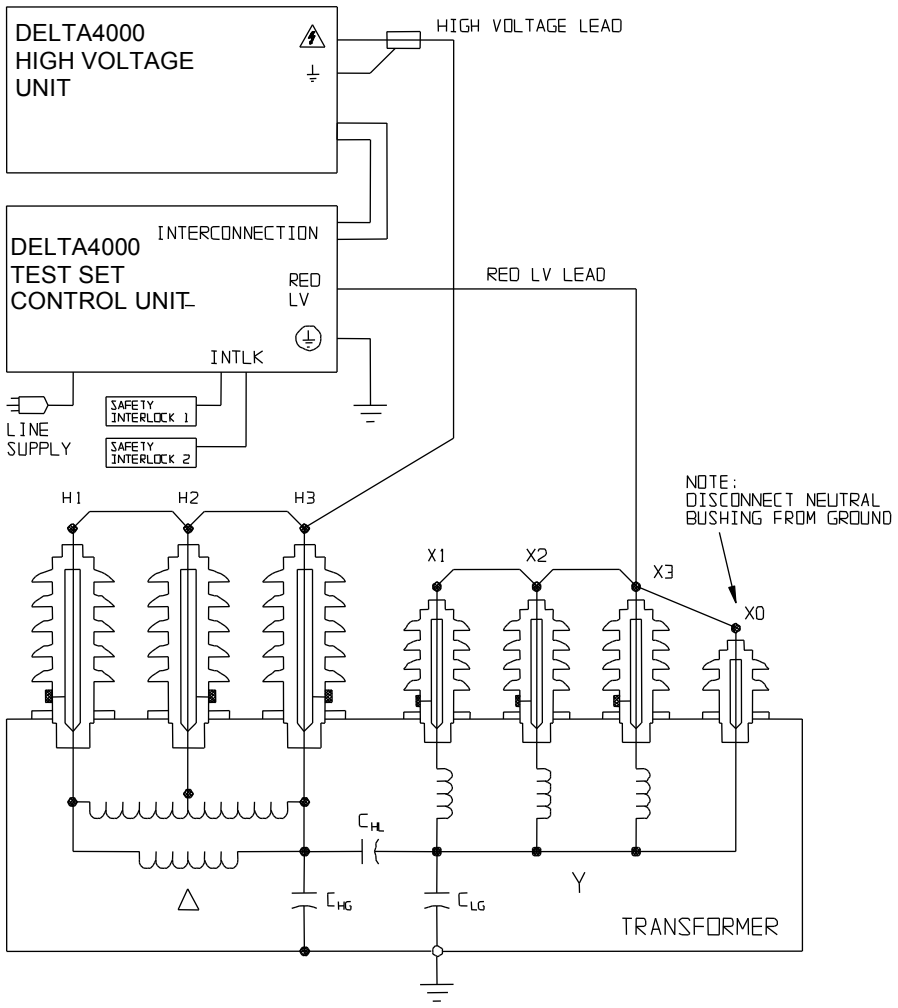


Figure 4 Typical Test Setup for AC Insulation Testing of a Three-Phase Two-Winding Power Transformer

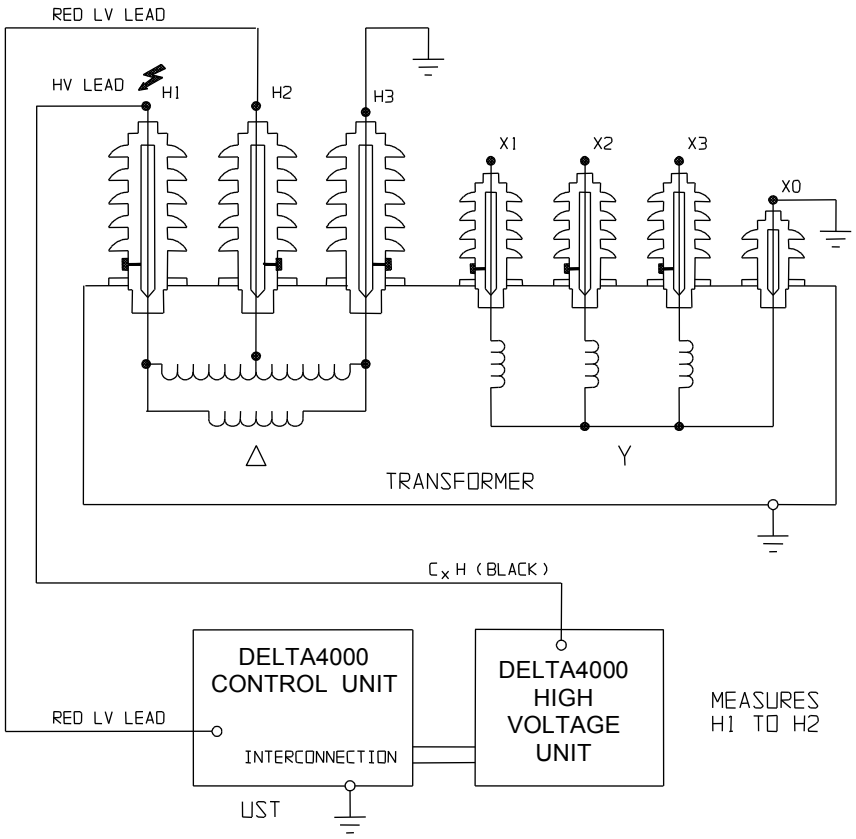


Figure 5: Typical Test Setup for Transformer Excitation Current Measurements

1. Locate the test set at least 6 ft (1.8 m) from the specimen to be tested.

2. Connect the test ground to a low impedance earth ground on the specimen (if possible). This should always be the first cable connected and last removed

3. Connect the control and power cables between the control and HV units. Make sure that the bayonet type plugs are fully locked on the receptacles.

4. Connect the measurement cable with the red colored boot to the INPUT RED receptacle. Make sure the connector locks to the receptacle. If required, connect the measurement cable with the blue colored boot to the INPUT BLUE receptacle.

5. Connect the external interlock cables or a test area interlock system to the INTERLOCK 1 and 2 receptacles. Make sure the plugs are fully seated and locked on the receptacles.

6. Connect the high-voltage cable to the high-voltage terminal of the high-voltage unit (be sure that the connector locks in place).

7. With the main breaker OFF, plug the input power cord into the test set power receptacle and into a three-wire grounded power receptacle having the appropriate voltage and current ratings.

8. When using a generator as a power source, note that the generator itself should be grounded to a suitable earth ground. If this is not done properly, the high-voltage circuit of the test set will be disabled. The voltage supplied to the DELTA4000 is not critical but should be within the specified voltage range and frequency.

9. Connect the crocodile clip of the measurement cable to the desired terminal of the test specimen.

10. Connect the hook (or clip) of the high-voltage test cable to the desired terminal of the test specimen.

11. Remove all safety grounds from the specimen to be tested.

12. Start DELTA4000 by closing the main breaker.

For DELTA4110 with external computer:

1. Connect the Ethernet (or possibly USB, Ethernet is preferred) cable between DELTA4110 and the computer

For using Delta Control SW:

1. Start Delta Control SW. A "connect to DELTA" screen will appear. Select USB or Ethernet communication.

2. For TCP/IP (Ethernet) you need to search for the HW. A new screen will open and the SW will automatically detect the DELTA address that you can select and connect to.

3. The Delta Control screen will appear.

For using Power DB SW:

1. Start Power DB SW.

2. The connect procedure will appear when you start the first test.

DELTA4310A with internal computer is internally connected to the DELTA HW when the internal/external PC switch is set to "internal". In case you want to use DELTA4310A with an external computer set the switch to "external" and connect the PC to the Ethernet or USB port.

Depending on which model of DELTA4000 you are using and if testing is performed automatically with PowerDB or manual with Delta Control SW, the actual testing procedure will vary. The following sections describe how to use DELTA4000 with external or internal computer using Delta Control and PowerDB SW.

6

Delta Control User Interface

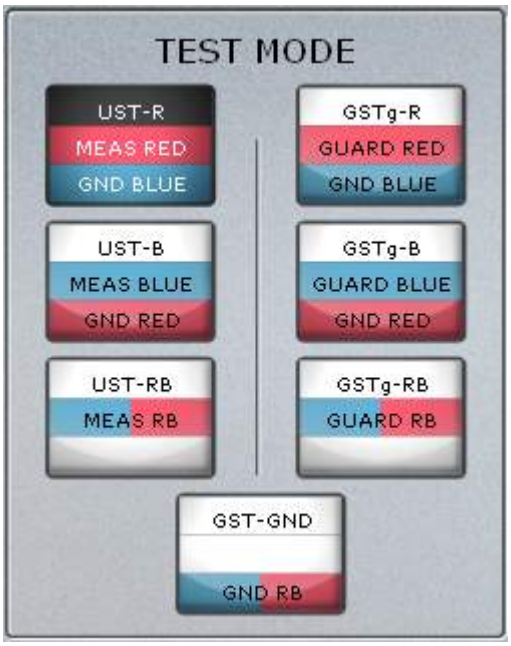
Introduction

The Delta Control software is an intuitive manual user interface where every feature is easy to identify. The buttons look like regular buttons on a mechanical front panel making the user feel as if he is using the instrument in a manual mode. The software can be operated using a touch screen or mouse control simply by clicking on the buttons. You may also "tab" between buttons using the keyboard. The buttons changes its look as you push the button so it is easy to know which key or function that is activated. All regular functions can be reached from this main screen/panel. Some buttons activates a popup screen where specific values and/or configurations can be set.

The Manual Control SW can be used as a test setting console in PowerDB or started as a separate program outside PowerDB.

Operation

Test Mode



DELTA 4000 offers a quick setting for available test modes.

The top line (UST-R in this case) defines and describes the selected test mode.

The second and third lines explain how the instrument is configured for the measurement. They have a different designation depending on if UST (Ungrounded Specimen Test) or GST (Grounded Specimen Test) measurements are conducted.

UST mode

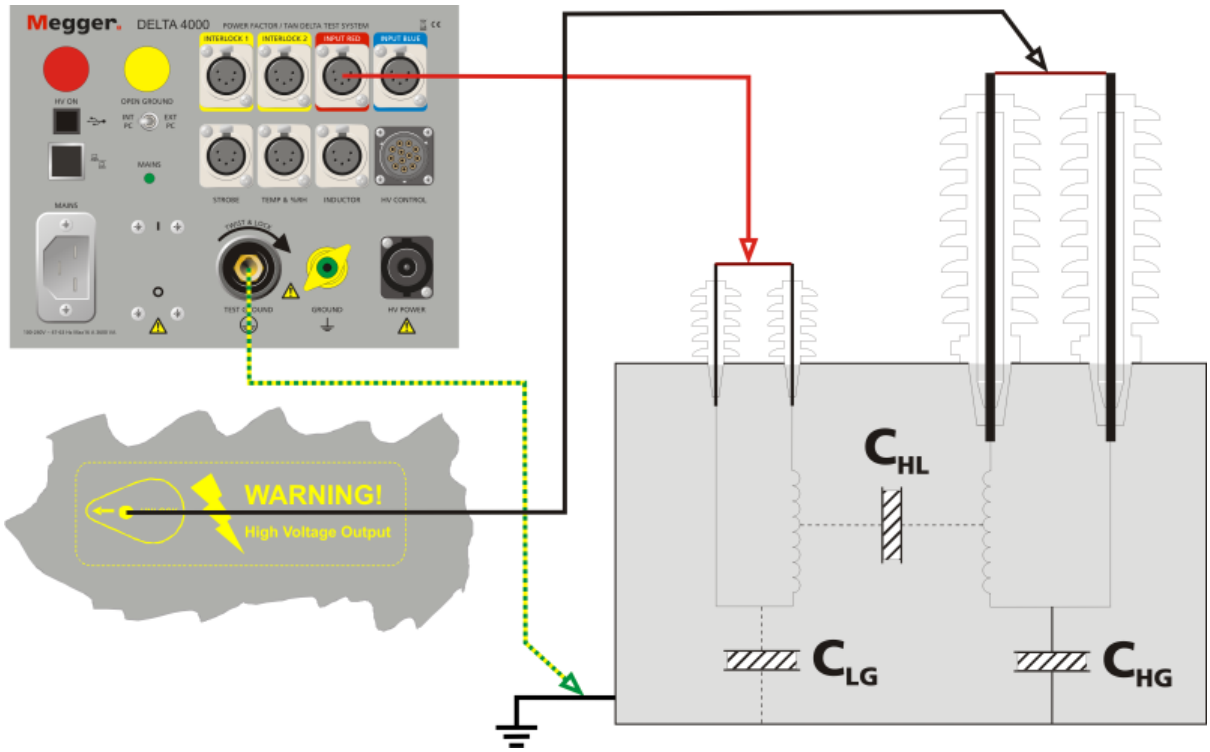
Ground and Guard are internally connected. Red and Blue terminals are either internally connected to be measured or internally connected to Ground (and Guard). In UST mode, the center line refers to the terminal or terminals that are measured and the lower line refers to the terminal that is internally connected to Ground and therefore excluded from the measurement.

GST mode

The current returning from Ground is measured. The Red and Blue terminals are either connected to Ground to be included in measurement or Guard to be excluded from the measurement.

Test Mode Examples

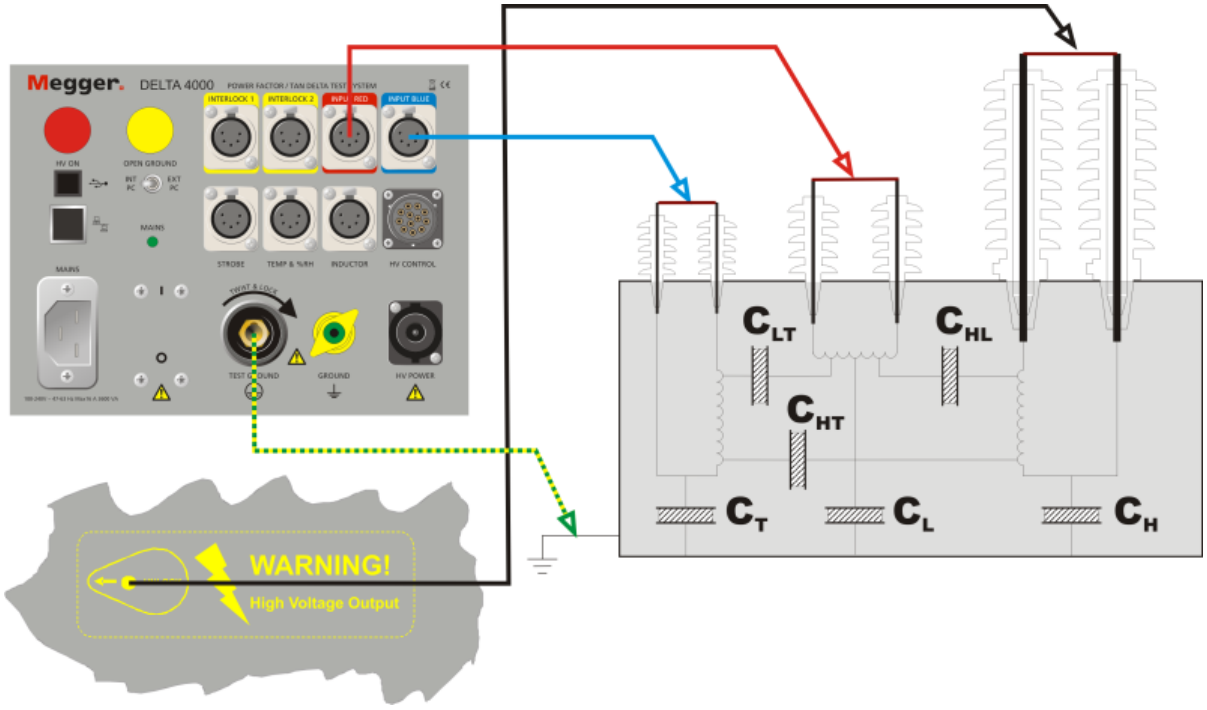
Two winding transformer test



When UST-R is used for the CHL test, the HV output terminal is to be connected to the primary winding and the red terminal to the secondary winding. The blue terminal does not have to be connected in this case.

Three winding transformer test

When UST-R is selected for a CHL test, the HV output terminal is to be connected to the primary winding, the red terminal to the secondary winding and the blue terminal to the tertiary winding. The blue terminal is in this case grounded/guarded.



For CHT measurement UST-B should be selected. The blue terminal is now measured and the red is grounded. The time saving benefit is that the transformer can be tested without the need for reconnections.

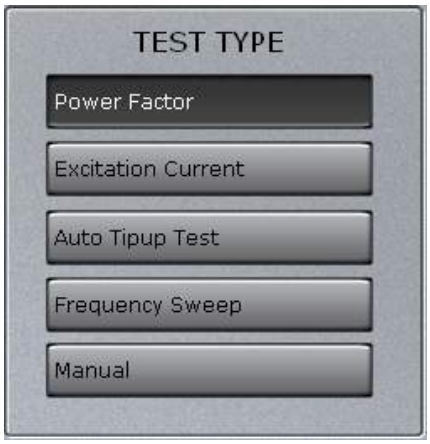
Frequency and Temperature

This is where you specify at which test frequency you want to perform the test. This is in most cases the same as the network frequency (but if you would like to test at e.g. 55 Hz you simply enter 55). Note that "Line Frequency" in the setting tab must be set to actual line frequency, 50Hz or 60 Hz.

Insulation properties are temperature dependent and the test object temperature is a very important parameter. The average temperature of the test object insulation should be entered.

These two parameters need to be set in order to start a measurement.

Test Type



Select which Test you want to perform. In the setting tab you set your preference for tan delta or power factor readings.

The available tests are:

Power Factor/ Tan-Delta — Power Factor or Tan-Delta test is a semi automatic test sequence performed at a preset voltage and line frequency. The system will ramp up the voltage to the set voltage and measure the Power Factor or Tan-Delta and after the completed test, ramp voltage down and stop the test and present the result.

Excitation Current — An excitation current is a standard test that is helpful in determining winding or core problems in transformers.

Auto Tip-up Test — Tip-up testing is used for testing power components with voltage dependent dissipation

	factor (e.g. generators) or in case a voltage dependence is suspected and indicated by high VDF in DELTA4000. The highest voltage level used is set on main page and the voltage per step is set on the settings page Voltage steps can be set on the settings page
Frequency Sweep	Frequency Sweep allows the user to perform a series of tests over a frequency range, and view results by depressing **Graph** button (bottom left). The voltage level used is set on main page and the frequency steps are set on the settings page. Present frequency steps come factory set for optimal ITC calculation, as well as allowing user to detect problem insulation conditions. *NOTE: There are limitation of voltage levels at high frequencies and low frequencies below 45 Hz.*
Manual	This mode allows continuous manual control of output voltage.

Voltage Control

The voltage control has three sections.

The top section is the voltmeter that shows the voltage in real time. Under the voltmeter is a display showing the set voltage (target voltage). You can click on this display to enter the target voltage or increase or decrease it using the buttons in the centre control. Below the display area is a round control where you can manually adjust voltage up or down. The single arrows step up or down in steps of 100 volts while the buttons with two arrows steps up or down in steps of 1000 volts. The C button in the middle clears the selection.

Start and Stop

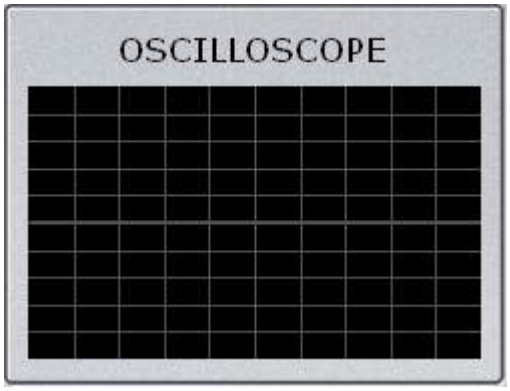
When you are ready to start measuring, press the Start button. In all modes except the Manual type, the measurement sequence is automatic and the result presented when finished. If you need to stop an ongoing measurement press the Stop button. Note: the Stop button stops the measurement smoothly, if stop by emergency reason, simply release the interlock in the interlock handle.

Note:	*The green light on the start button will not illuminate until both interlock switches are closed.*

In manual mode you have a button for starting a measurement. The start button is used to activate the output. You can manually control output voltage using the Voltage control. You can record and store a value to the log at any time by pressing the Measure button.

Press Stop or "Esc" to stop the output voltage.

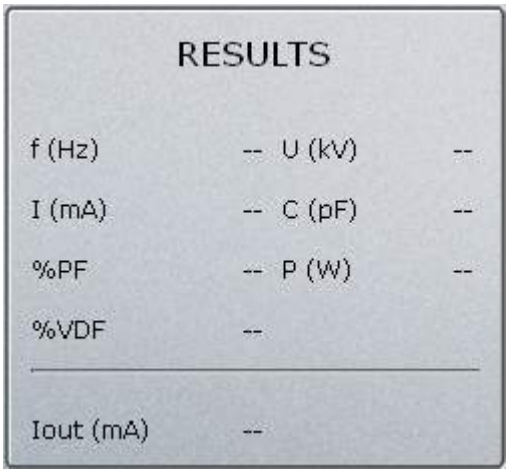
Oscilloscope



In the oscilloscope you can follow applied voltage (red) and a voltage proportional to measured current (white).

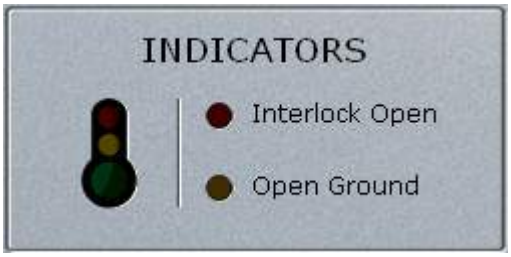
Note:	*This feature is designed to be a signal monitor and not intended to be a measurement device. The display has auto scaling of amplitude and time axis.*

Results



In the results panel you can see the result of the latest measurement.

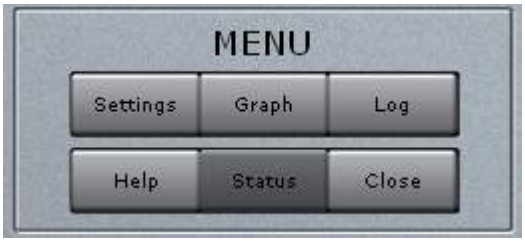
Indicators



The indicators show if there are anything that prevents a measurement from starting. If the Interlock Open led is on, you have to close both switches before you can start a test.

If the open ground led is on, ensure that the ground potential of the test object (where your ground is also connected) and the instrument U ground is within 2 Ωs. If using a generator, ensure the U ground of the generator is connected to ground equal to the asset ground point. The measurement cannot start if any of these led's are ON. The "green", "yellow", "red" thermometer is related to internal instrument temperatures and %RH; Green is ok, yellow is warning and if red the unit will not operate. For more details open up the Status window click the Menu Status button.

Menu



In the menu you can access various extra functions.

Settings Access the default settings used in the program.

Graph Shows graph of performed **Auto Tip-Up** or **Frequency Sweep** measurements. Also allows live update of graph as testing is conducted.

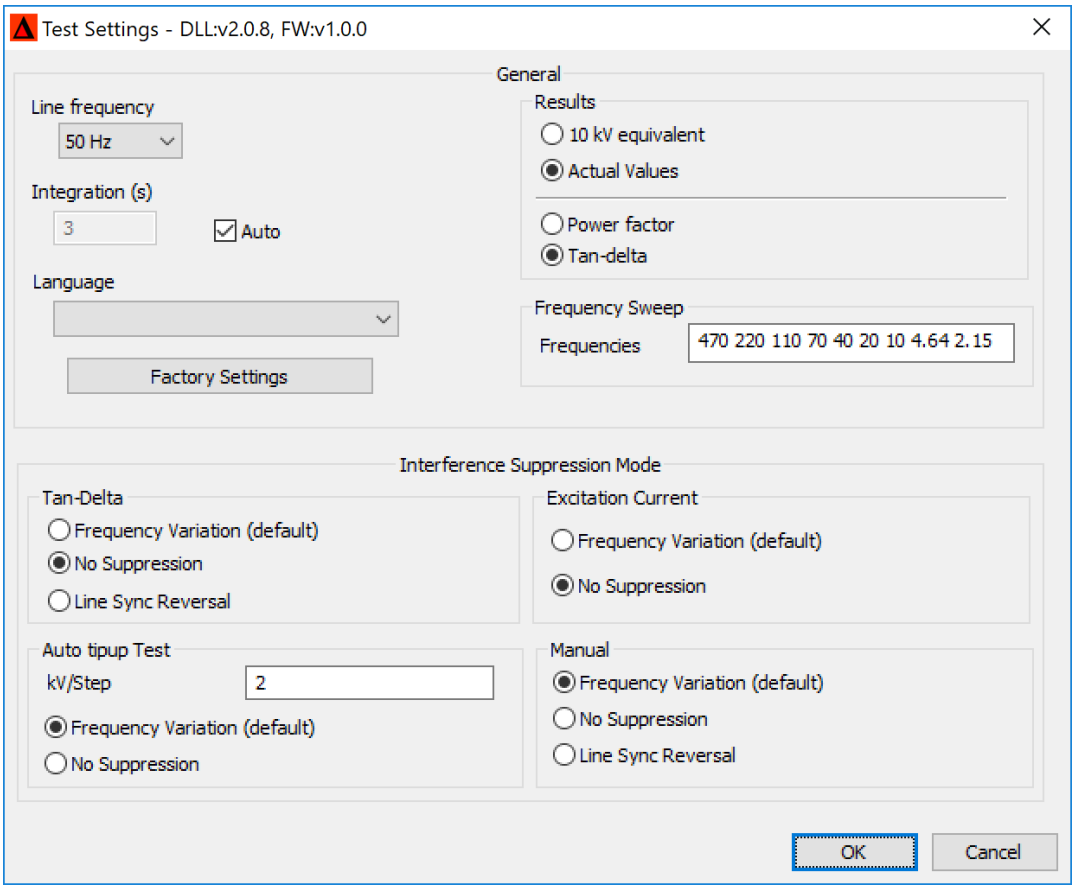
Log Show a log of measured values. This includes multiple readings test such as **Auto Tip-Up** and **Frequency Sweep.**

Help Shows a help file.

Status Accessing information about internal %RH, temperatures , serial numbers and SW/Firmware version.

Close Close/Shut down Delta Control

Settings



The Test Settings dialog allows for user preference and test sequence settings. The user can also reset the software to factory default settings by pressing the Factory Settings button in the lower right corner.

General

Under the general section you can change the default line frequency. Specify if you want to display the values as power factor or tan-delta. You can also change the integration time between 3 and 200 seconds or set it to automatic.

Power Factor/Tan-Delta

Here you can select either **frequency variation** (default) or **line sync reversal** for noise suppression. If **no suppression** is selected, you are allowed to vary frequency from 1 to 500 Hz. For optimum results, **frequency variation** is preferred.

Excitation Current

Here you can select either **frequency variation** (default) for noise suppression or **no suppression** where frequency can now be varied from 1 to 500 Hz. Please note that lower frequency results in higher excitation for same voltage, and so it is preferred to maintain **frequency variation or no suppression** for this test.

Auto Tip-up Test

Set the **kV/step** for the auto tip-up test. The software will automatically increase the voltage by the increment set in this box until the entered test voltage selected in the main screen is reached.

You can select either **frequency variation** for noise suppression or **no suppression** which allows you to vary frequency for this test.

Results

Specify if you want the measured values presented as either 10 kV equivalent or the actual measured values.

Frequency Sweep

Set frequencies at which the frequency sweep will be made. The default frequencies selected (470 220 110 70 40 20 10 4.64 2.15 Hz) allow optimum sweep results as well as optimum test points for use in Individual Temperature Correction (used in PowerDB Forms).

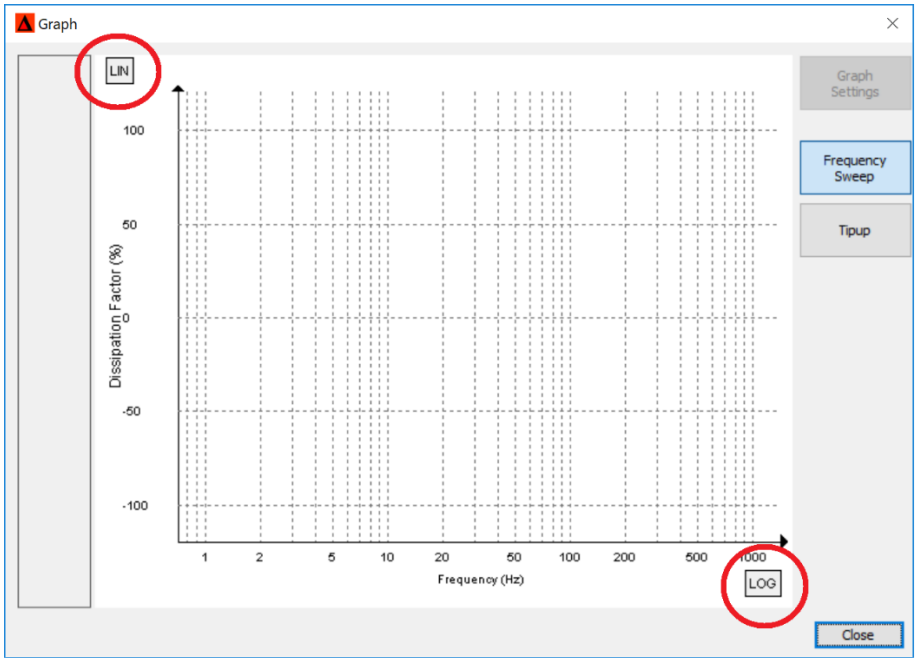
Manual

Select the noise suppression mode to be used during manual measurements. If no interference is selected, one can vary frequency from 1-500 Hz in this testing.

Language

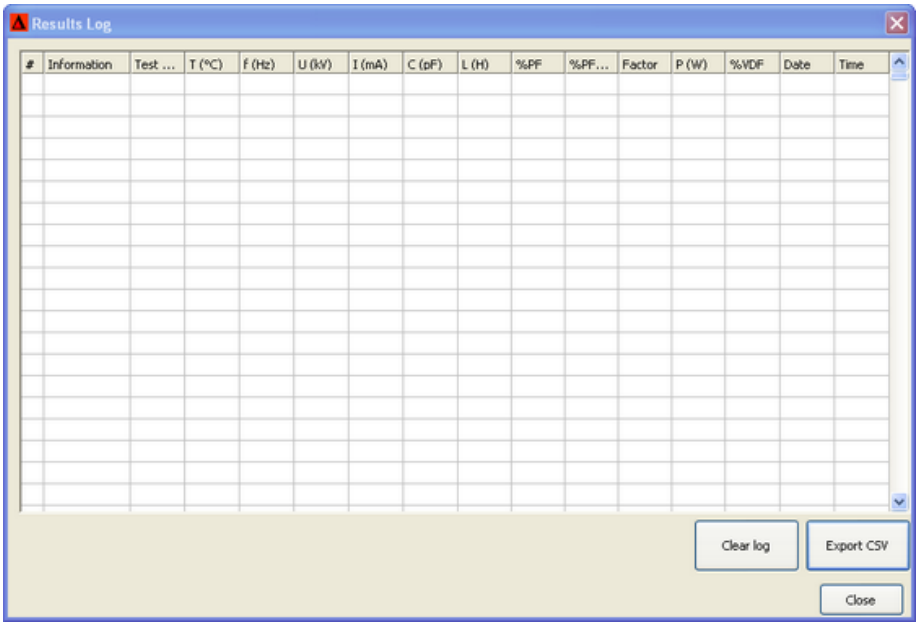
Set the language for the user interface of the software.

Graph



The graph dialog shows graphs of the measured values. Results can be shown in log as well as linear scale for either axis and autoscales as results appear. Numeric results of test can be seen under **LOG.**

Log



The log shows all measured values from the performed tests.

The clear log button clears all measured values.

The Export CSV button makes is possible to export the log as a comma separated file for processing in other software or store for future reference. When exporting to CSV you can choose if you want to have a header or not and what type of decimal separator you want to use.

You may also mark suitable part of the log-fields and simply use cut (Ctrl+C) and paste it into e.g. excel (Ctrl+V).

7

PowerDB User Interface

Introduction

PowerDB Lite is included in your purchase of the DELTA4000. PowerDB Lite helps perform testing in an asset based method, and presents results in a professional looking data form. Completed data forms are saved as files to your computer.

The DELTA4310A has PowerDB Lite preloaded on the built-in industrial controller. DELTA4310A is designed to make testing more intuitive for end users, and so restricts the use of the built-in controller to PowerDB functions. The presentation and testing methods within the built-in controller are identical to the PowerDB Lite PC version. No difference in operation exists, except when upgrades between the PC and the DELTA4310A are not maintained by the user. Upgrading the DELTA4310A is different than upgrading a PC. Please refer to Megger website similar to: http://us.megger.com/my-account/software-downloads/for latest 'On Board' download software and instructions.

Minimum Recommended System

Operating System:	Windows 7 or later
RAM	2GB RAM minimum, >4GB RAM recommended
	>2G free memory space
Processor:	2.0G Hz Pentium Class processor minimum,

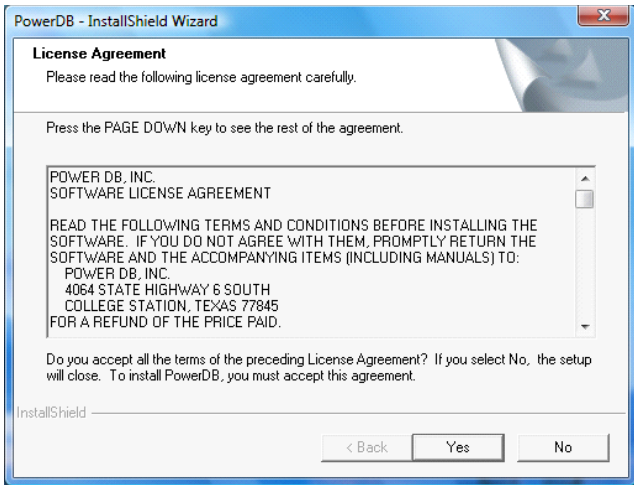
For more information please visit *www.powerdb.com* or contact your local sales representative.

Software Installation (PC portion only)

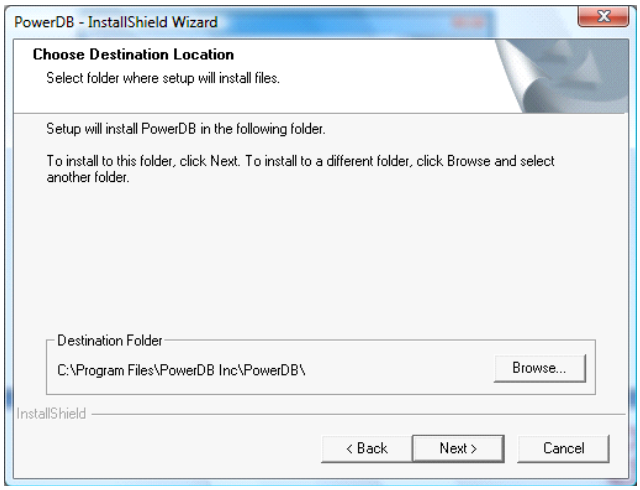
To install PowerDB Lite, load the PowerDB Lite USB into your PC computer drive and follow the on-screen instructions. For latest version, please go to website *www.powerDB.com/download* and download latest PowerDB Lite version available.

NOTE:	*For DELTA4310A, software version is available on our www.megger.com website located under "Software Support" and requires a user login. It will load onto the DELTA4310A via the USB memory port on the control top. The model is contained within the software and not obvious until PowerDB Lite software is loaded.*

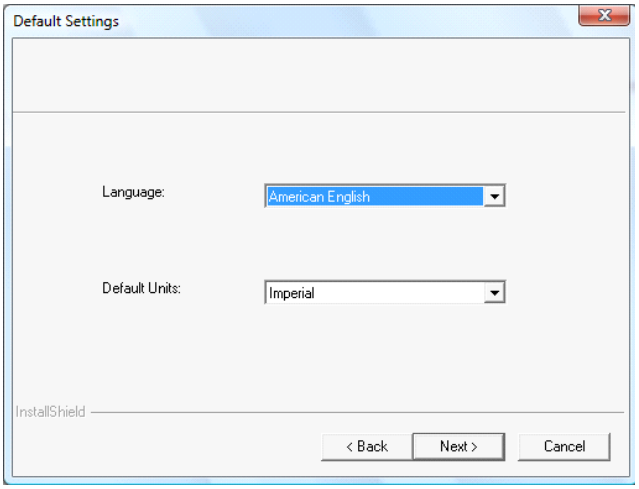
1. Accept the terms of the License Agreement.



2. Choose the destination location for the PowerDB Lite files.



3. Select Default Settings (Language and Units of Measure).



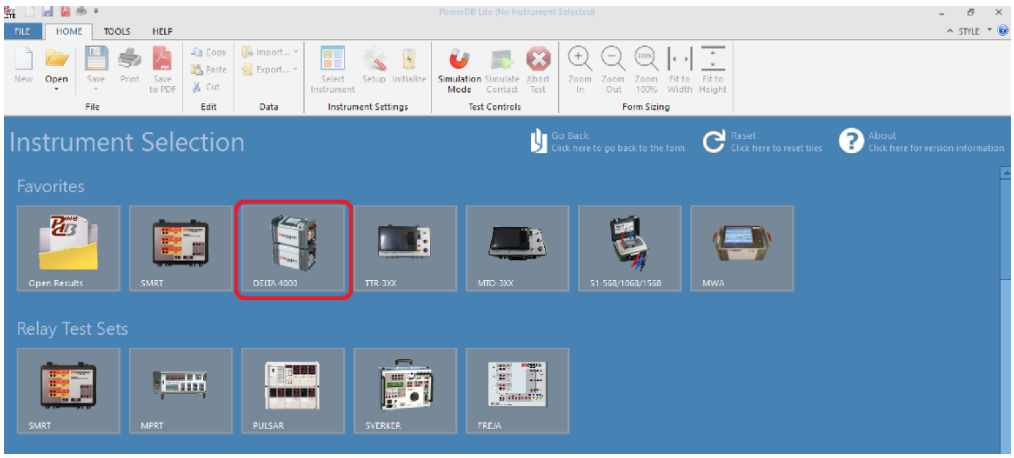
4. Install Shield Wizard will complete the installation of PowerDB Lite. Click *Finish* to close the installation program.

Using DELTA4000 with PowerDB

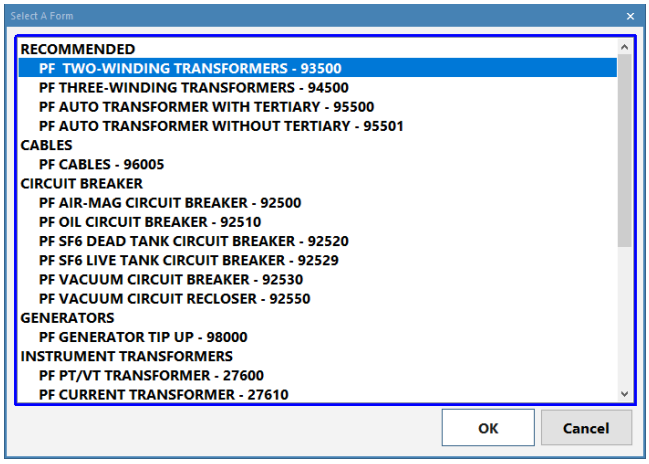
1. Start the program and select DELTA4000 in the Instrument Setup screen. If you already have tested this object at an earlier occasion, open up this file instead using "Open Existing Results File". PowerDB is designed to save data from several tests on one object in same file.

NOTE:	*The Delta Control SW must also be installed to be able to run Delta4000 and perform measurements.*

Viewing and reporting previous measurements can be done on a computer without a Delta Control installation and without connecting to the HW.

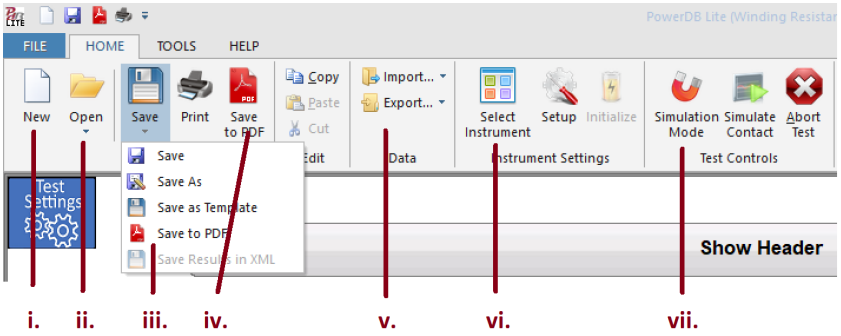


1. Select a form to be used for the test.



Test Form Controls - General

Once a form is opened, all forms have a set of standard controls which are available across the top of the form as shown below. This allows common functions such as saving, deleting, opening results, together with functions as described below.



i. **New**: Allows a different test form to be selected within the TTR - brings up selection list from menu in *Item i* above.

ii. **Open:** Results or test setups to be used for viewing past results, appending or retesting.

iii. **Save:** Prompts user to save results, or rename file, or save in PDF format.

iv. **Save to PDF:** Allows test report to be saved in a format which is shared or stored without need to have PowerDB to view results

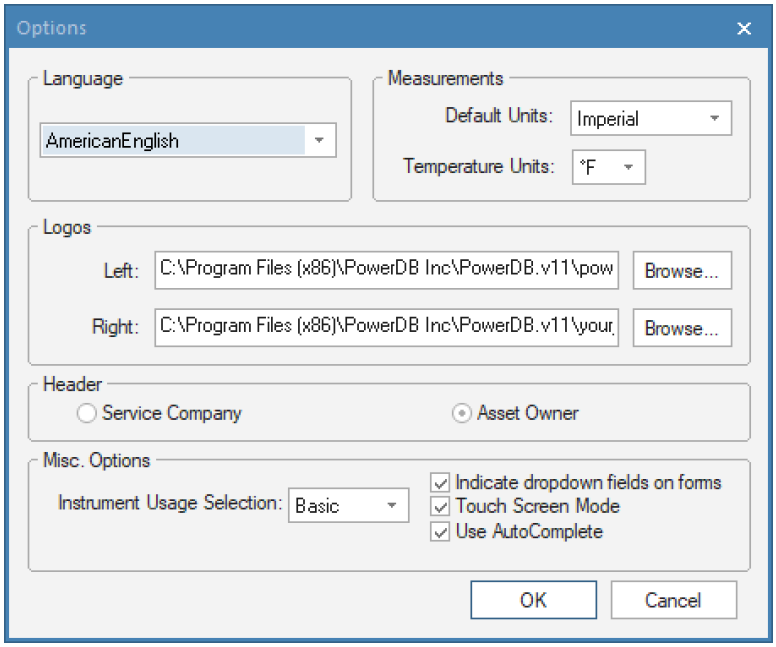
v. **Import/Export:** Allows saving results as a CSV (Excel) file.

vi. **Select Instrument:** Allows change of test instrument under PowerDB control as noted in '*Item 1 - Getting Started*' above.

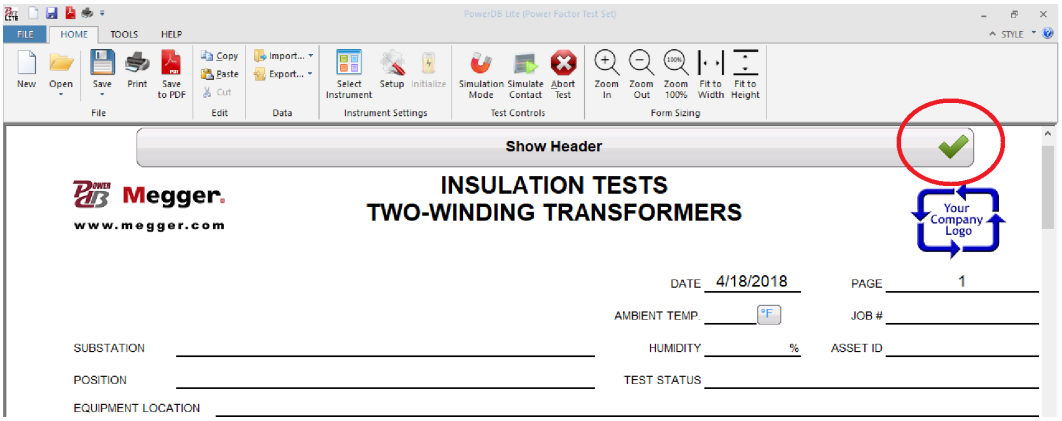
vii. **Simulation Mode:** Allows use of a test form without the actual instrument connected. Useful for training and demonstration to personnel.

General Options

Under **Tools-Options**, default conditions are selected.

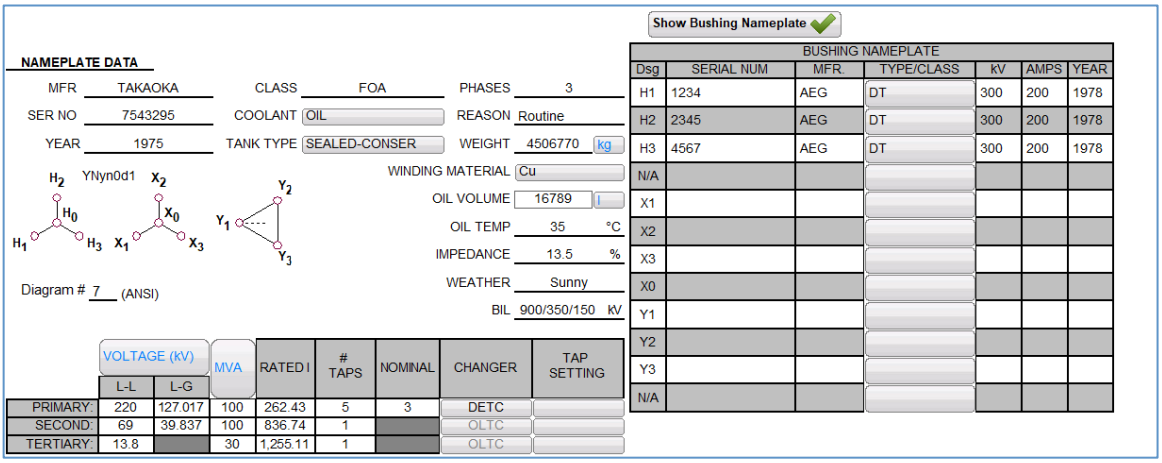


1. Language allows limited translation to French, Spanish and German.
2. Default units: Imperial or Metric.
3. Temperature Units: C or F.
4. Logos allows both left and right side of each form. Image should be a bitmap for optimum quality.
5. Misc Options allow enabling or disabling operational features within each form.



Header can be hidden to allow optimum space for test results within each form.

Nameplate Header Input



Nameplate Data: Most information in this section is not critical for testing, except for **Oil Temp , KVA(MVA)** and **Year** which are used for temperature correction tables. Remaining information is useful for customer records.

Vector Selection: Once form setting (above) selects proper standard, one depresses the vector and a 'pop up' *Vector Selector* will appear, or 'right click' to select primary and secondary vector until it matches Transformer Nameplate.

Transformer Nameplate Voltages: Line-to-line only, in volts.

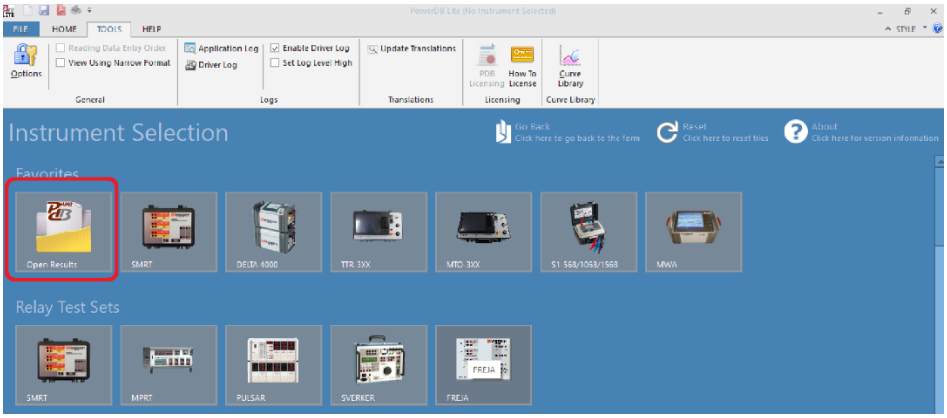
Nameplate Power Rating: Typically with no cooling operation. Depress 'MVA' to toggle to 'KVA'. Once filled in, 'Rated I' will calculate and display using parameters provided.

 # Taps: Input from nameplate. As well, confirm NOMINAL tap positions are correct.

Tap Changer: Toggle to 'DETC/OLTC' type for Primary/Secondary/Tertiary (if applicable).

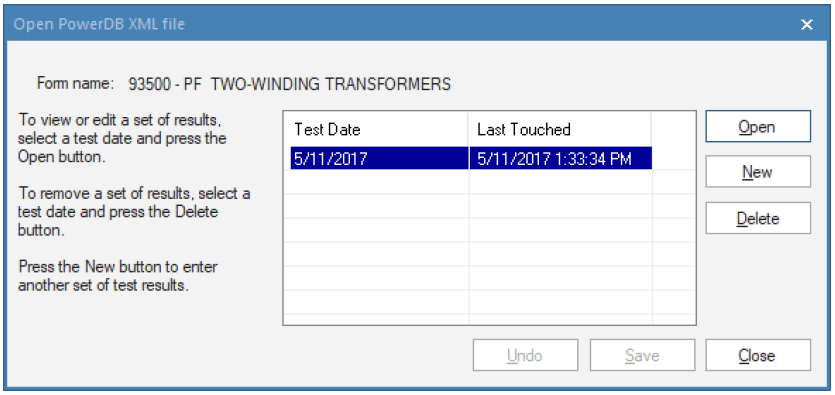
Tap Setting: Tap # of position DETC is found. This is also used to confirm that DETC is left in proper position when testing is complete.

A common method of operation is preparing a test form prior to testing, *or* Opening past results and performing a new test where past testing has been done. If we know of the past result, we use **Open Results** to locate and open the file from PowerDB Startup screen below:



We are now taken to our file folder system, where we choose the file to open.

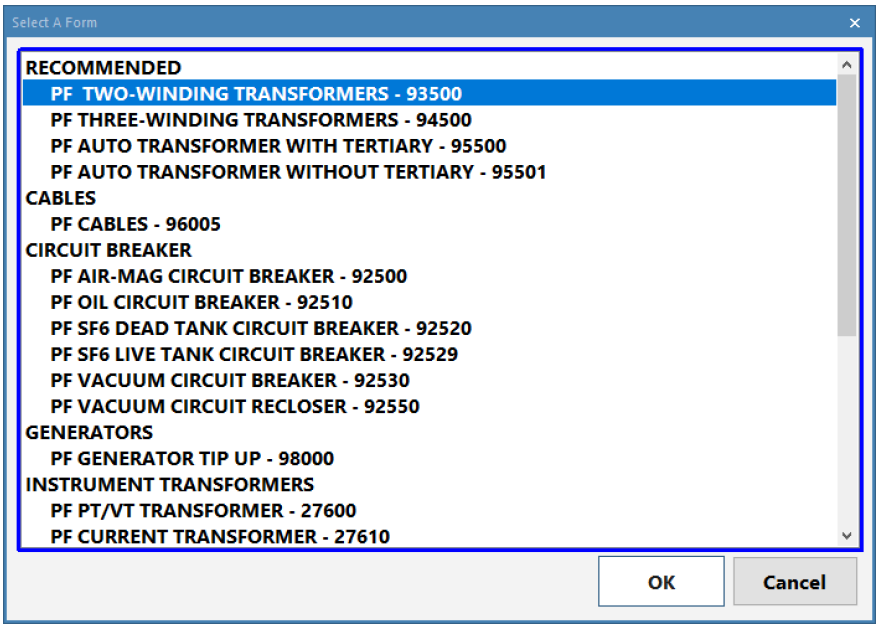
A pop-up screen will appear, listing all measurement dates for this test specimen, and we are able to append (**open**) the individual measurement or perform a **new** test. We are also given the option to **delete** any specific dates of history



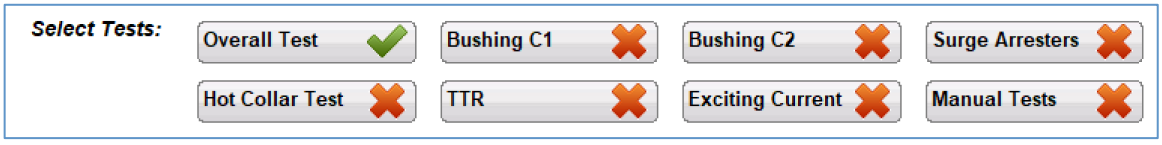
8

Performing Tests within Forms

All DELTA4000 forms have common operational functions, and operational description of each form would be lengthy and have limited value. Most forms are based on common assets tested in a substation or power generation station. For this manual, we will focus on the Two Winding Transformer form as highlighted below:



Discussion of Nameplate and Common Controls are described earlier in this manual. We obtain the test voltage, the temperature correction (if we select the use of tables), from the Nameplate Input. We now select which tests we wish to conduct from the list below:



Description of Tests

Transformer Overall Tests

Prior to the overall insulation tests, short all high side (H) bushings together and short all low side (L) bushings together, keeping both windings separated. Remove ground connections from neutral bushings.

Test 1 - This is a measurement of the insulation between the transformer high voltage winding and the transformer tank, plus the insulation between the high voltage winding and the low voltage winding, both measured in parallel. Connect the HV cable to the H winding and connect the Red lead to the X winding. Test mode is GST-GND.

Test 2 - This is a measurement of the insulation between the transformer high voltage winding and the transformer tank. Connections are exactly the same as for Test 1. Test mode is GSTg-RB.

Test 3 - This is a measurement of the insulation between the transformer high voltage winding and the low voltage winding. Connections are exactly the same as for Test 1 and 2. Test mode is UST-R.

NOTE:	*Once Tests 1, 2 and 3 are completed, Line 4 will populate with values calculated by subtracting Test 2 from Test 1. This is applicable for values of capacitance, current and watts. Line 4 is a calculated comparison to the direct measurements of Test 3. Values on these two lines should be essentially the same. If they are not, re-check all connections and verify the proper operation of the test set. If Test 3 and Line 4 vary by more than 2%, the Insulation Rating (IR) will automatically populate with B (Bad).*

Test 5 - This is a measurement of the insulation between the transformer low voltage winding and the transformer tank, plus the insulation between the low voltage winding and the high voltage winding, both measured in parallel. Connect the HV cable to the low side (L) winding and connect the Red lead to the H winding. Test mode is GST-GND.

Test 6 - This is a measurement of the insulation between the transformer low voltage winding and the transformer tank. Connections are exactly the same as for Test 5. Test mode is GSTg-RB.

Test 7 - This is a measurement of the insulation between the transformer low voltage winding and the high voltage winding. Connections are exactly the same as for Test 5 and 6. Test mode is UST-R.

NOTE:	*Once Tests 5, 6 and 7 are completed, Line 8 will populate with values calculated by subtracting Test 6 from Test 5. This is applicable for values of capacitance, current and watts. Line 8 is a calculated comparison to the direct measurements of Test 7. Values on these two lines should be essentially the same. If they are not, re-check all connections and verify the proper operation of the test set. If Test 7 and Line 8 vary by more than 2%, the Insulation Rating (IR) will automatically populate with B (Bad).*

Lines 9 and 10 will automatically populate with calculated values once Tests 1-7 and all bushing tests are completed. Line 9 is a corrected value for the insulation of the high voltage winding to the transformer tank minus the measured losses of the high side bushings. Line 10 is a corrected value for the insulation of the low voltage winding to the transformer tank minus the measured losses of the low side bushings.

Oil Tests

The 93500 test form includes two tests for capturing the results of a power factor test on the insulating oil. This is generally done on a sample of oil drawn from the main tank of the transformer under test and a sample of oil drawn from the OLTC. The test requires an oil test cell designed for field use. The test cell should be a three-terminal cell where connections for high voltage, measurement lead, and ground can be safely made.

As with the other insulation tests on this test form, the test sequence is initiated by left-clicking on the blue highlighted test number at the bottom of the Overall Tests table. The test mode used is UST-R.

Overall Test Options

Multiple Test enables/disables the ability to perform groups of tests associated with common test connections. This saves time, as all tests are conducted sequentially until complete. With this example, 1/2/3 are tested together and 5/6/7 are tested together.

Hook up Diagram enables operator to view the connection diagram for the specific test to be conducted

Temperature Correction Table/ITC toggles selection for correction to 20C as seen below. Correction tables are based on "year, KVA & voltage" from Nameplate Input.

Change Temperature Correction Table/Set ITC allows operator to change the correction table used (if Temperature Corr Table selected) or allows the operator to perform an ITC test where the specific transformer's **Individual Temperature Correction** is determined and applied to results.

Standard Temperature Correction Tables

This is the standard correction method based on tables for various components. For power transformers the table selection is based on manufacturing year, transformer type (sealed, free breathing etc), voltage and power rating. For bushings the table is selected by manufacturer and type.

Individual Temperature Correction, ITC

As a unique feature DELTA4000 also offers ITC, Individual Temperature Correction. With ITC the actual temperature correction for a certain measurement object is estimated by measuring an additional frequency sweep after performing the standard single frequency measurement. The information from the sweep test is then used to estimate the correct temperature correction from measurement temperature to 20°C reference (patent pending).

Test # Column Blue coloured numbers care depressed to begin a test. If Multiple Test is enabled, all tests for a specific group are sequentially completed.

DFR if these boxes are checked, a frequency sweep test is conducted and displayed in the DFR Graph below the Overall Tests.

Individual frequencies are defined in a list in PDB settings. The maximum frequency range is pending the test voltage as described in the following table.

Test Voltage	Maximum frequency range
12 kV	45-70 Hz
4 kV	15-405 Hz
2 kV	8-505 Hz
1 kV	4-505 Hz
500 V	2-505 Hz
250 V	1-505 Hz

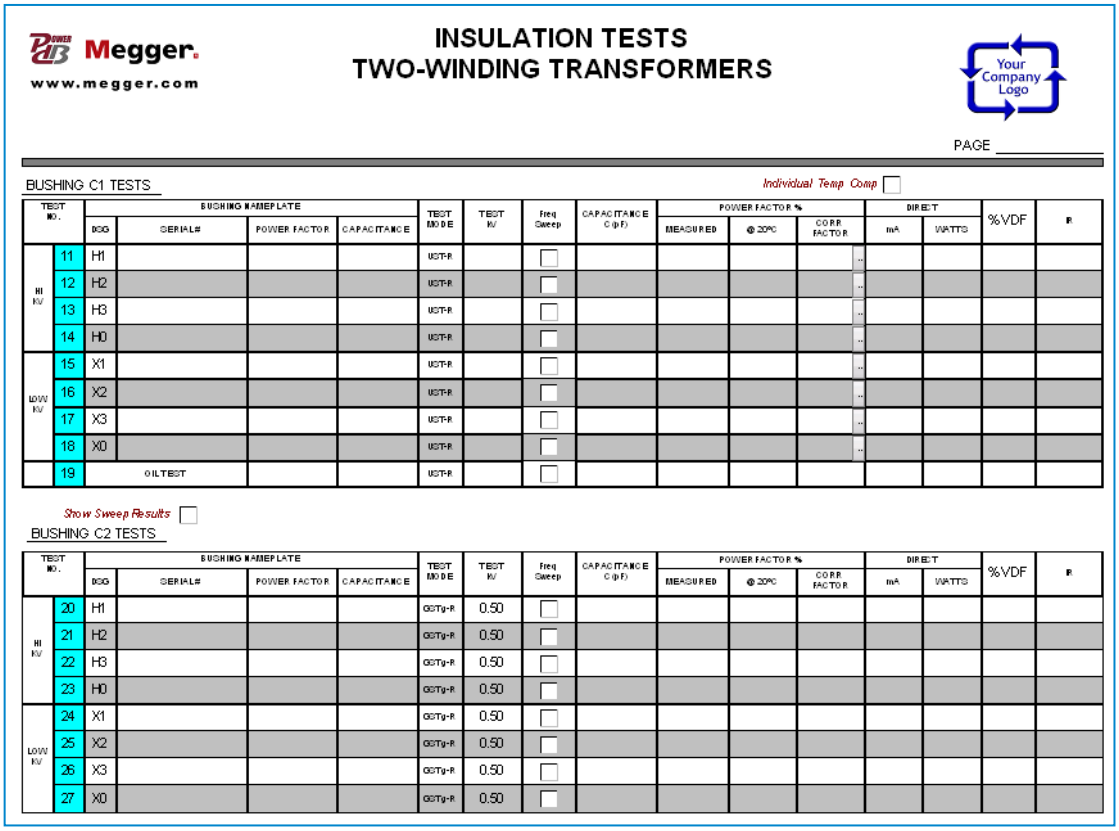
Note: *Do not select the power frequency or any multiple of power frequency in a frequency sweep, e.g. in 50 Hz networks avoid, 50, 100, 150… and in 60 Hz networks avoid 60, 120, 180…*

Voltage Dependence Detection

Another unique feature in DELTA 4000 is automatic Voltage Dependence Detection (patent pending). In every test, DELTA4000 measures the harmonic content of the signal and based on this information it calculates a Voltage Dependence Factor, VDF. If this value is too high (default > 0.5) the number turns red, indicating a voltage dependence of the test object i.e. the dissipation

factor is pending the test voltage. In this situation a tip-up (step voltage) test should be performed to verify and quantify the voltage dependence.

Bushing C1 Tests



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BUSHING C1 TESTS — *Individual Temp Comp* ☐

TEST NO.		BUSHING NAMEPLATE				TEST MODE	TEST kV	Freq Sweep	CAPACITANCE C (pF)	POWER FACTOR %			DIRECT		%VDF	IR
		DSG	SERIAL#	POWER FACTOR	CAPACITANCE					MEASURED	@ 20°C	CORR FACTOR	mA	WATTS		
HI kV	11	H1				UST-R		☐								
	12	H2				UST-R		☐								
	13	H3				UST-R		☐								
	14	H0				UST-R		☐								
LOW kV	15	X1				UST-R		☐								
	16	X2				UST-R		☐								
	17	X3				UST-R		☐								
	18	X0				UST-R		☐								
	19	OILTEST				UST-R		☐								

Show Sweep Results ☐

BUSHING C2 TESTS

TEST NO.		BUSHING NAMEPLATE				TEST MODE	TEST kV	Freq Sweep	CAPACITANCE C (pF)	POWER FACTOR %			DIRECT		%VDF	IR
		DSG	SERIAL#	POWER FACTOR	CAPACITANCE					MEASURED	@ 20°C	CORR FACTOR	mA	WATTS		
HI kV	20	H1				GSTg-R	0.50	☐								
	21	H2				GSTg-R	0.50	☐								
	22	H3				GSTg-R	0.50	☐								
	23	H0				GSTg-R	0.50	☐								
LOW kV	24	X1				GSTg-R	0.50	☐								
	25	X2				GSTg-R	0.50	☐								
	26	X3				GSTg-R	0.50	☐								
	27	X0				GSTg-R	0.50	☐								

If the transformer windings are terminated using condenser bushings, then measurements of the C1 insulation on each bushing are generally made. The bushing insulation C1 is internal and is the insulation between the bushing center conductor and its test tap (capacitance tap). If a bushing does not have a test tap, then the C1 measurement is not performed.

> *NOTE: These tests may be performed with the bushing shorting leads still in place from the overall insulation tests. This allows all the high side bushing C1 tests to be performed without having to move the HV lead from bushing to bushing. It will still be necessary to move the Red lead to the individual test taps for each test.*

Test 11 - This is the test of the C1 insulation on the high side phase 1 bushing. The HV lead is connected to the bushing top terminal and the Red lead is connected to the bushing test tap. Test mode is UST-R.

Tests 12, 13 and 14 are C1 measurements for the other high side bushings. Test 14 is used only if the high winding has a neutral bushing with a test tap. Make sure to move the Red lead connection from bushing to bushing as necessary. Test mode is UST-R.

Tests 15, 16, 17, and 18 are C1 measurements for the low side (L) bushings. Test 18 is used only if the high winding has a neutral bushing with a test tap. Test mode is UST-R.

NOTE:	*Many condenser bushings will have factory values for C1 stamped on their nameplates, both for power factor and capacitance. The test results for C1 on each bushing can be compared directly to its respective nameplate values.*

Bushing C2 Tests

Bushings with test taps may also be tested to obtain a C2 insulation measurement. The C2 insulation is the insulation between the test tap connection and the bushing mounting flange. To perform a C2 test, the HV lead is carefully connected to the bushing test tap and the Red lead is connected to the bushing center conductor. Care should be taken not to cause physical damage to the test tap, as the tap connection point may be a small pin or a flexible spring. If this is the case, use a small insulated jumper wire or a specially designed test tap adapter to make the HV lead connection.

CAUTION

Bushing test taps have very limited insulation and should generally be energized at reduced voltage levels. If the bushing manufacturer does not specify a test voltage level use no more than 500 volts (0.5kV).

Tests 20 to 27 are measurements of the individual bushings C2 insulation. All are performed with test mode GSTg-R. All phase and neutral bushings may be tested providing they have test taps.

NOTE:	*Similar to the bushing C1 tests, all the C2 measurements may be made with the bushing shorting leads still in place from the transformer overall tests.*

Surge Arresters

SURGE ARRESTERS

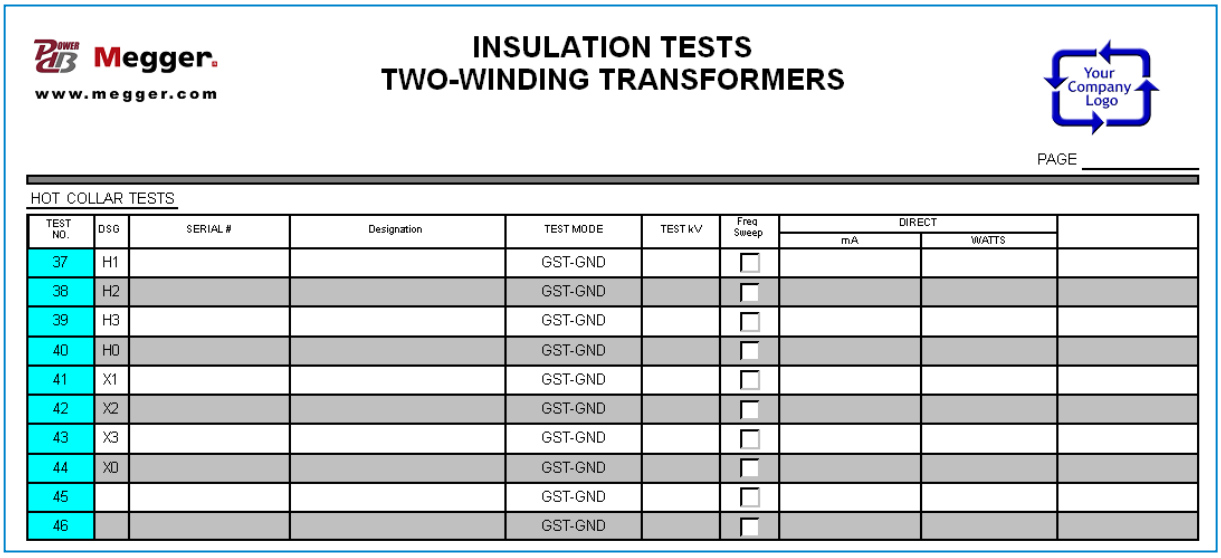
	LOCATION	SERIAL#	MFR	OVERALL CATALOG	UNIT CATALOG	TYPE	RATED kV	ORDER	TEST MODE	TEST kV	Freq Sweep	DIRECT		IR
												mA	WATTS	
28									GST-GND		☐			
29									GST-GND		☐			
30									GST-GND		☐			
31									GST-GND		☐			
32									GST-GND		☐			
33									GST-GND		☐			
34									GST-GND		☐			
35									GST-GND		☐			
36									GST-GND		☐			

If the transformer is equipped with surge or lightning arresters, these may be tested as well. If the arrester is a single-stack unit, its HV connection must be disconnected to eliminate the measurement of losses from other connected apparatus (such as switch and support insulators). Multi-stack arresters may be tested without disconnecting if desired. The procedure described below assumes single-stack arresters are being tested.

Nameplate, serial number and location information for each arrester should be entered so that future testing can be compared to specific units.

Tests 28 to 36 are measurements of the arrester insulation. Only test voltage, current and watts are recorded for arresters. The HV lead is attached to the arrester HV terminal. No connection using the Red or Blue leads is necessary. The Test Mode used is GST-GND. Once the HV lead is connected, right-click on the blue highlighted field on the desired test line to initiate the test sequence. Follow the onscreen instructions to complete the test.

Bushing Hot Collar Tests



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HOT COLLAR TESTS

TEST NO.	DSG	SERIAL #	Designation	TEST MODE	TEST kV	Freq Sweep	DIRECT		
							mA	WATTS	
37	H1			GST-GND		☐			
38	H2			GST-GND		☐			
39	H3			GST-GND		☐			
40	H0			GST-GND		☐			
41	X1			GST-GND		☐			
42	X2			GST-GND		☐			
43	X3			GST-GND		☐			
44	X0			GST-GND		☐			
45				GST-GND		☐			
46				GST-GND		☐			

Hot collar tests are generally performed on HV bushings that do not have test taps. However, these tests may also be done as an additional test if the bushings have test taps

Tests 37 to 46 - These tests measure the outer shell insulation of the bushings, including surface leakage and leakage current from the bushing surface through the insulating material to the center conductor. A conductive strap is placed around the bushing, below one of the skirts, normally the top skirt, and connected to the HV lead. The Red lead is connected to the bushing conductor. Test mode GST-GND is automatically programmed by the test form.

Multiple hot collar tests can be performed on each bushing. For each test, the location of the strap should be clearly indicated on the form in the Designation column.

Ratio Tests

Measurements of transformer winding ratio can be made with a high voltage power factor test set when a TTR capacitor is available. Depending on the voltage rating of the winding being energized, tests can be made up to 10kV. The significance of this is that higher volts per turn can be applied to the winding, stressing the winding turn-to-turn insulation more than low voltage ratio test sets. This may be able to detect high resistance turn faults that may be undetectable at lower voltage. The tests are performed one phase at a time on three-phase transformers.

To enable this portion of the test form, select the Show TTR Tests checkbox at the top of Page 1. A table for ratio test results will become visible near the end

of the form. You should select the Number of Tests based on how many transformer taps you intend to test.

The first test must measure the capacitance of the Standard Capacitor, in pico-Farads (pF).

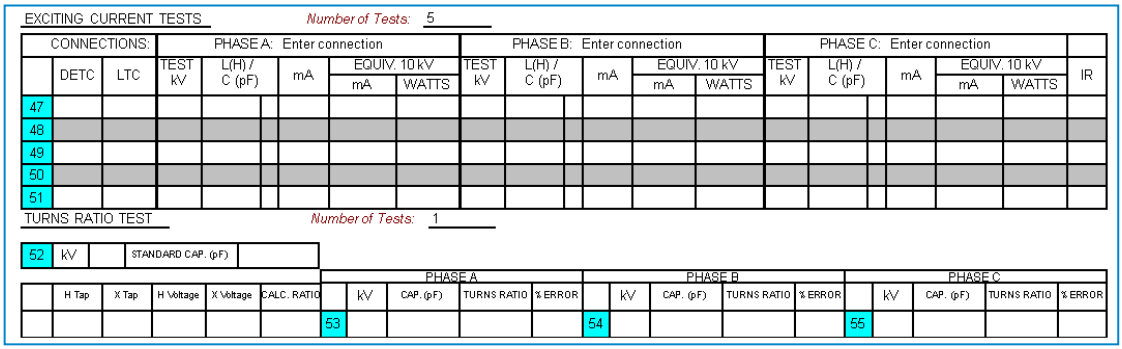
Connect the test set leads, the HV lead and the Red measurement lead, directly to the capacitor.

Initiate the test by left clicking on the blue field for the Standard Capacitor.

Subsequent tests require the HV lead to be connected to one side of a HV winding (e.g. H1/U/A) where the other side of the HV winding is grounded to the tank (e.g. H0/N/N). The corresponding winding on LV side is grounded on one side and on the other side is connected to Red lead via the capacitor.

By enter the winding voltage levels in the form, the assessment is automatic.

Exciting Current Tests


EXCITING CURRENT TESTS Number of Tests: 5

	CONNECTIONS:		PHASE A: Enter connection					PHASE B: Enter connection					PHASE C: Enter connection					
	DETC	LTC	TEST kV	L(H) / C (pF)	mA	EQUIV. 10 kV mA	EQUIV. 10 kV WATTS	TEST kV	L(H) / C (pF)	mA	EQUIV. 10 kV mA	EQUIV. 10 kV WATTS	TEST kV	L(H) / C (pF)	mA	EQUIV. 10 kV mA	EQUIV. 10 kV WATTS	IR
47																		
48																		
49																		
50																		
51																		

TURNS RATIO TEST Number of Tests: 1

52	kV		STANDARD CAP. (pF)	

						PHASE A					PHASE B					PHASE C				
	H Tap	X Tap	H Voltage	X Voltage	CALC. RATIO		kV	CAP. (pF)	TURNS RATIO	% ERROR		kV	CAP. (pF)	TURNS RATIO	% ERROR		kV	CAP. (pF)	TURNS RATIO	% ERROR
						53					54					55				

Measurements of the individual phase excitation current values are valuable in determining defects in the transformer core and coils. Excitation current measurements are generally performed on the high voltage winding only, to minimize the amount of current required.

> *NOTE: All bushing shorting leads must be removed for exciting current measurements. If the low voltage winding has a neutral, connect the neutral bushing as it normally is in-service (grounded or ungrounded).*

Measurements are usually made one phase at a time. Connections should be documented in the fields provided at the top of the table. For initial or commissioning tests, perform the measurements on each possible primary and secondary tap setting. Unless conditions warrant, future tests may be reduced to the tap settings as found.

For each test line on the form, document the DETC (De-Energized Tap Changer) and LTC (Load Tap Changer) tap settings and perform three tests per form line. On WYE / Y connected transformers, connections would be H1-H0 / U-N /A-N, H2-H0 / V-N / B-N and H3-H0 / W-N /C-N. On DELTA D (or WHYE / Y without accessible neutral) connected transformers, connections would be H1-H2 / U-V /A-B, H2-H3 / V-W / B-C and H3-H1 / W-U /C-A

To perform the individual tests, connect the HV lead to one bushing and the Red lead to the second bushing. The test mode will be automatically set on the test form to UST-R.

To initiate the individual tests, right-click on the blue highlighted field of the desired test line. The test sequence initiates and the results will be placed in the proper fields automatically.

The number of test lines in the table is adjustable. Enter the number of lines desired for the number of taps to be tested.

NOTE	*Exciting current measurements are pending voltage level. Make sure use same voltage level as in earlier measurements on same transformer. Exciting current may also vary due to core magnetization status, exciting current measurements should be performed prior winding resistance measurement or after demagnetization.*

Multiple Quick Tests

Standards measurements may be complemented with additional measurements executed from the Multiple Quick Test sub-form selected as a new test or as manual measurements in the standard test forms. Check "Manual" in the select test boxes and a Multiple Quick Test table will be added at the end of the form.

In the field "INSULATION TESTED" you enter information on what to be tested, TEST MODE set/change the test mode, SUPPRESS set/change noise suppression mode.

It is also possible to use Delta Control for controlling the test by clicking the Delta Control button (above the table) in PowerDB form, Delta Control will send all data to be stored in the Multiple Quick Test table.

9

Maintenance and Calibration

Maintenance

Maintenance should be performed only by qualified persons familiar with the hazards involved with high-voltage test equipment. Read and understand Section 2, *Safety*, before performing any service.

Routine maintenance is all that is required for these test sets. The cables and connector panel should be inspected frequently to be sure all connections are tight and all ground connections intact.

DISCONNECT the MAINS plug before cleaning.

The appearance of the test set can be maintained by occasional cleaning of the case, panel and cable assemblies. The outside of the carrying case can be cleaned with detergent and water. Dry with a clean, dry cloth. The control panel can be cleaned with a cloth dampened with detergent and water. Do not allow water to penetrate panel holes, because damage to components on the underside may result. A household all-purpose spray cleaner sprayed on cloth can be used to clean the panel. Polish with a soft, dry cloth, taking care not to scratch the display screen cover. The cables and mating panel receptacles can be cleaned with isopropyl or denatured alcohol applied with a clean cloth.

Contamination of some parts of the high-voltage circuit, in particular the high-voltage cable terminations and its mating panel receptacle, may show up as a residual PF(DF) meter reading. Cleaning of these sensitive parts will remove the leakage paths which cause the unwanted leakage current. Treat the high-voltage cable with care. Keep it clean and do not subject it to abuse, such as dropping or crimping.

Calibration

During the warranty period, no calibration should be necessary. Contact the factory if there is any suspected problem.

The overall accuracy of capacitance and power factor (dissipation factor) at 10 kV should also be checked at least once a year against Megger's Capacitance and Dissipation Factor Standard (Cat. No. 670500-1). This will ensure that the entire high-voltage circuit is functioning and calibrated properly.

A calibration kit is provided as an optional accessory. This allows for traceable calibration locally without sending the unit to factory.

Factory calibration is of course also available. Contact your local Megger representative for details

Recommended calibration interval is 1-3 years.

Troubleshooting

General Guidelines

This section provides general guidelines for basic troubleshooting of the DELTA4000. The DELTA4000 undergoes rigorous testing before being shipped from the factory; however, when it is subjected to various field conditions, there is always the possibility of damage being done to the instrument or its cables. This troubleshooting section does not attempt to cover all possibilities, but does list suggestions that can be carried out in the field. There may be problems that require the unit to be returned to the factory for repair.

If questionable readings are obtained, the first step is to check the calibration of the DELTA4000 using Megger's Capacitance and Dissipation Factor Standard (Cat. No. 670500-1). If the standard is not available, the next step is to test a specimen with a stable known value e.g. the TTR capacitor or one of the capacitors in the Megger capacitor kit. If such a specimen is not available, then perform the following procedure for an "Open Air Test."

Open Air Test

The purpose of this test is to check the overall functionality of the DELTA4000, including the high-voltage cable. The readings obtained show the stray signal losses of the high-voltage cable.

1. Connect the wing nut ground terminal of the test set to a low impedance earth ground using the ground cable supplied.

2. Connect the control unit to the high-voltage unit using the two interconnection cables.

3. Connect the external interlock cables to the SAFETY INTERLOCK receptacles.

4. Connect the high-voltage cable to the HV OUTPUT terminal of the high-voltage unit (power supply). Be sure that the connector locks in place.

5. With the main breaker OFF, plug the input power cord into the test set AC POWER receptacle and into a three-wire grounded power receptacle having the appropriate voltage and current ratings.

6. Suspend the outboard end of the high-voltage cable in free air so that it is clear of all surrounding objects by at least 3 ft (0.91 m). Use dry nylon rope if available.

7. Start your DELTA4000 and use Delta Control (or a PowerDB form) and perform a general GST-GND test.

When test is completed, observe test results. The results should be as follows:

Capacitance: between 4.0 and 8.0 pF

%DF or %PF: between -1.0 to +2.0%

Watts @ 10 kV: between -0.002 to +0.006

mA @ 10 kV: between 0.015 to 0.030

Repair

Megger offers a complete repair service and recommends that its customers take advantage of this service in the event of equipment malfunction. Please indicate all pertinent information including problem, symptoms, and attempted repairs. Pack the DELTA4000 in its transit case and include all cables that came with the instrument. Equipment returned for repair must be shipped prepaid and insured and marked for the attention of the Repair Department.