

Instruction Manual
for
Transformer Ohmmeter
DC Winding Resistance Test Set

MTO300
MTO330

Catalog Number MTO300
Catalog Number MTO330

Read this entire manual before operating.

Megger.

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**Transformer Ohmmeter
DC Winding Resistance Test Set**

MTO300/MTO330

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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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Table of Contents

1	Getting to know the MTO.....	1
	Product Overview 300/330.....	1
	Top Panel Controls.....	2
2	Safety.....	7
	Safety is the responsibility of the user.....	7
	General Safety Precautions.....	8
	Input Power Precautions.....	9
	PC Interface Precautions.....	10
3	Preparing for a Test.....	11
	Site Preparation.....	11
	Making Circuit Connections.....	11
4	Operating the MTO300/330.....	13
	Description of Test Sequence.....	13
5	Transformer Testing.....	19
	Winding Resistance Testing.....	19
	Testing a Single-Phase Transformer.....	20
	Testing Delta Configured Windings.....	35
	Demagnetizing a Transformer.....	37
6	MTO330/300 Series PowerDB Lite.....	43
	Introduction.....	43
	Software Installation.....	44
	Using PowerDB Lite.....	47
	Using PowerDB OnBoard (MTO330 only).....	53
7	Service.....	55
	Maintenance.....	55
	Fuse Replacement.....	55
	Calibration.....	56
	Repairs.....	57
	Error Codes.....	58

List of Figures

MTO300 Transformer Ohmmeter Test Set	iii
MTO330 Transformer Ohmmeter Test Set	iii
Figure 1: MTO300 Front Panel.....	2
Figure 2: MTO330 Front Panel.....	2
Figure 3. HOME Action Icons	6
Figure 4: Single Winding Measurement Primary or Secondary	20
Figure 5: Dual Winding Measurement (Primary and Secondary)	21
Figure 6: YN reading sequence.....	32
Figure 7: Y reading sequence	33
Figure 8: Delta reading sequence	34

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.



MTO300 Transformer Ohmmeter Test Set



MTO330 Transformer Ohmmeter Test Set

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1

Getting to know the MTO

Product Overview 300/330

The Megger Transformer Ohmmeter is a line-operated, field-portable instrument designed specifically to measure the DC resistance of all types of magnetic windings safely and accurately.

Its predominant use is the measurement of the DC resistance of all types of transformer windings within the defined range of resistance. It can also test rotating machine windings and perform low resistance measurements on connections, contacts and control circuits.

It is recommended that the user becomes familiar with the MTO before making any connection to a transformer.

Top Panel Controls



Figure 1: MTO300 Front Panel

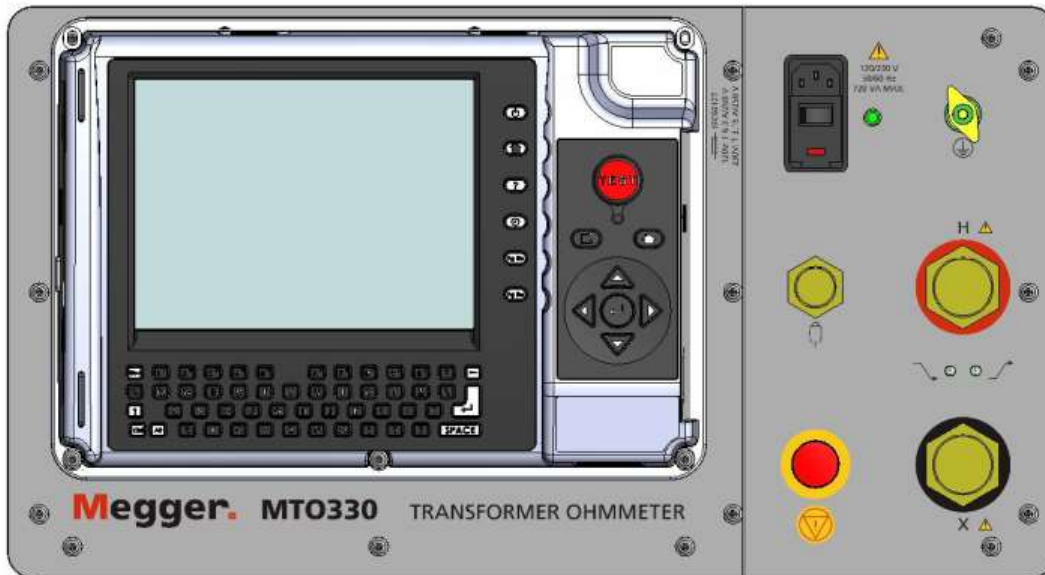


Figure 2: MTO330 Front Panel

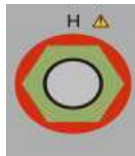


Input AC Power Module:

This module is an IEC320 interface to the mains power. The module has an integrated switch, fuse holder and input filter module. Above the module are the voltage, frequency and power requirements for the product. Below the module are the fuse type and ratings based on the input voltage used. The green light on the right side of the module illuminates when power is ON.

O , OFF position

1 (-) , ON position



Primary Interface connection from the transformer to the unit:

This connection has all of the interfaces required to connect current and voltage inputs from a three phase transformer into the MTO300 unit.

Discharge Indicator – blinks every ½ second when a transformer is discharging

Test Indicator – stays on when a transformer is energized.



Secondary/Tertiary Interface connection from the transformer to the unit:

This connection has all of the interfaces required to connect current and voltage inputs from a three phase transformer into the MTO300 unit.



Ethernet Connection:

This connection links a PC used for control with the MTO300.

NOTE: port is not network compatible. DO NOT USE ON A LOCAL AREA NETWORK. The system was designed for peer to peer operation.



Earth/Ground Lug

This connection is used to connect a transformer under test to earth ground for safety. The transformer and the MTO shall be at the power ground/earth potential when being operated.



Emergency Shut Down Switch

This switch, when pushed will disable the source power supply and automatically discharge the transformer. The instrument is continuously monitoring this switch in the event of an emergency. If the switch is engaged, no testing can commence.



Remote Control Switch

This connector is used to interface with a remote switch. This switch is primarily used when testing On-Load Taps of a transformer

The Remote Control Switch can remotely start the MTO test and store multiple resistances reading for tap changes. The storage function in remote mode is sequential and occurs during a continuous resistance test.

MTO330 TOP PANEL FACILITIES



Qwerty Keyboard

Interface is used to enter field data and control instrument.



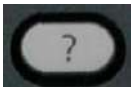
Power Button

This button must be used to close down the software before the main power switch is turned off.



Home Button

Toggles Home Action icons.



Help Button

Provides on screen help to assist operator.



Information Button

Provides on screen information to assist operator.



Page Up Button

Large forms may have multiple pages of results. This button is used to toggle up the page sequence.



Page Down Button

Large forms may have multiple pages of results. This button is used to toggle down the page sequence.



Test Button

Initiates and Terminates Testing.



Tab Button

Allows user to select active area of screen.



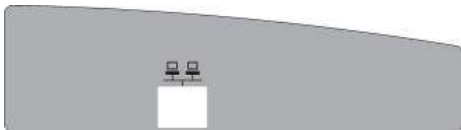
Home Button

Toggles HOME action icons.



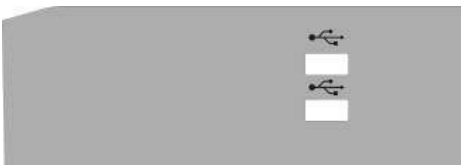
Use Arrow keys to highlight a desired selection.

Use the Enter button (in center) to Activate the selection.



Ethernet Interface

Used for linking a PC to the top panel for instrument control.



USB Interface

Used for software updates, data transfer and printer output.

HOME Action Icons

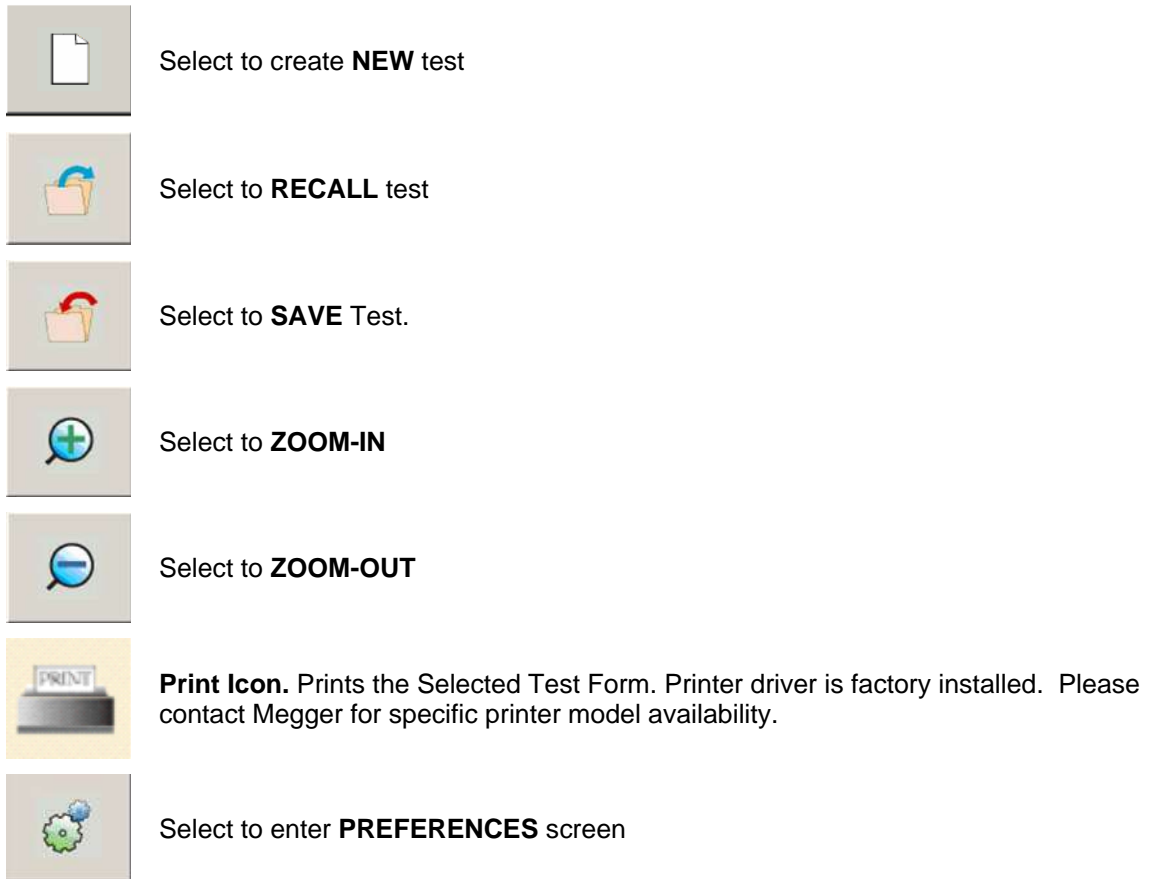


Figure 3. HOME Action Icons

2

Safety

Safety is the responsibility of the user

Only qualified and trained operators should operate the MTO system. Operator must read and understand this entire Instruction Manual prior to operating the equipment. Operator must follow the instructions of this Instruction Manual and attend the equipment while the equipment is in use. In the event of equipment malfunction, the unit should immediately be de-energized and returned to Megger for repair.

“The Safety precautions herein are not intended to replace your Company’s Safety Procedures. Refer to e.g. IEEE 62-1995/IEEE C57.152 and IEEE 510 - 1983, IEEE Recommended Practices for Safety in High-Voltage and High-Power Testing, for additional information.”



WARNING

When applying current to a transformer with very high inductance, care should be taken not to remove current/voltage leads while DC current is still flowing. This causes an extremely high voltage to develop across the point where current is broken. This voltage could prove to be dangerous to personnel and equipment.



WARNING

It is very important not change De-Energized Tap Changers while current is still flowing. This can cause excessive voltage arcs within the transformer and on external terminals.

General Safety Precautions

The MTO and the Unit Under Test (UUT) should both be considered as sources of instantaneously lethal levels of electrical energy. Observe the following safety precautions:

- Observe all safety warnings on the equipment. They identify areas of immediate hazard that could result in injury or death.
- Use this equipment only for the purposes described in this manual. Observe strictly the Warning and Caution information provided in this manual.
- Treat all terminals of high-voltage power equipment systems as potential electric shock hazards. Use all practical safety precautions to prevent contact with energized parts of the equipment and related circuits.
- Energy on some terminals of a transformer can easily transfer to other terminals of a transformer. When testing transformers, assume all terminals are energized at all times for safety purposes.
- Use suitable barriers, barricades and/or warnings to keep persons not directly involved with the work away from test activities.
- Never connect the test equipment to energized equipment.
- Do not use in an explosive atmosphere.
- Use the grounding and connection procedures recommended in this manual. Always disconnect test leads from power equipment before attempting to disconnect them at the test set. The ground connection **MUST** be the first made and removed last. Any interruption of the grounding connection can create an electrical shock hazard.
- Personnel higher than 5 feet should follow proper tie off safety requirements.
- Personnel should use proper safety gear to prevent bodily harm.
- Personnel using heart pacemakers should obtain expert advice on the possible risks before operating this equipment or being close to the equipment during operation.
- Fuse selection is dependent on input voltage. 230VAC uses 3.15 amp fuses and 120VAC uses 6.3 amp fuses.

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!

Input Power Precautions

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

For Cat. No MTO3XX: 120/230 V 10%, single-phase sine, 48 to 62 Hz

The neutral pole must be at ground potential. Before making connection to the power source, determine that the instrument rating matches the voltage of the power source. The power input plug must be inserted only into a mating receptacle with a ground contact.

WARNING

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.

The control circuits of the instrument are protected by two mains circuit fuses. These fuses are located in the ON/OFF switch module and are replaceable by the operator. Please consult the manufacturer for proper replacement fuses to avoid electric shock and fire hazard. A detailed procedure for *Fuse Replacement* is defined in Section 7 - *Service*.

**WARNING**

Before replacing the fuses, disconnect the power input plug from the live power source.

PC Interface Precautions

The MTO300 instrument was designed to operate as a peer to peer connection between a Personal Computer with Windows OS and the Test Unit.

- Unit is NOT designed for network operation. DO NOT Connect MTO300 to a network.
- The TCPIP interface selected for MTO is in the limited connectivity AutoIP address range. PC's will take approximately 1 minute to auto-address the MTO unit.
- For proper unit functionality, the registry of the MTO300 interfaced network adapter will be modified with a setting Tcpackfrequency = 1. This modification improves the MTO communications speed by approximately a factor of 10. If your corporation does not allow registry for a built in Ethernet port, you have one of three options.
 - Use the USB to Ethernet adapter provided.
 - Order a MTO330 Interface Panel.
 - Order a MTO210 Interface Panel.
 - The internal server IP address is 168.254.1.1, Subnet Mask 255.255.0.0.

The MTO330 is a standard PC. For network operability it may need to be registered with your IT department.

3

Preparing for a Test

Site Preparation

Choose a location that meets the following conditions:

- The location is as dry as possible.
- There is no flammable material stored in the vicinity.
- The test area is adequately ventilated.
- Be sure all equipment is de-energized and all terminals of the Unit Under Test (UIT) are accessible.
- Erect suitable safety barriers to protect the operator from traffic hazards and to prevent intrusion by unauthorized personnel. User provided Warning lights are recommended.
- Verify that the Local station ground is intact and has impedance continuity to earth.

Making Circuit Connections

Connections should be made in the order as listed below.

1. **Ground.** Use the Megger supplied Safety Ground Cable (15 ft (4.6 m)) to connect the MTO Wing Nut Ground Terminal directly to Local Station Earth Ground. Ensure that the Transformer chassis also has a low impedance connection to Local Station Earth ground potential.
2. **Input Power Source Ground.** Input Power Source Ground Terminal should be less than 100 milliohms of impedance to Local Station Earth Ground.
3. **Connect the Input Power Cord.** Before making this connection, insure the *Input Power Source* meets the requirements as listed in Section 2 *Safety* and the specifications as listed in the datasheet. Also make sure that the ON/OFF switch (Figure 1) is in the OFF position. Connect the input power cable to the MTO first, then to the power source. At this time, leave the ON/OFF switch in the OFF position.

4. **Connect the Ethernet Cable.** If using a remote PC and PowerDB Lite software, connect the Ethernet cable from the MTO330 side panel or the MTO300 front panel to the PC Ethernet port. A standard RJ45 Ethernet cable will work fine for this application. Connect the PC Ethernet output to the MTO300 at this time.
5. **Connect the Remote Control cable (optional).** If the user chooses to operate the MTO from a remote distance then, connect the RCC cable at this time.
6. **Connect the H and X leads (to the MTO end only at this time).** With the clamps disconnected from the UUT, connect the H and X cables to the MTO at this time. Be sure that all plugs are fastened securely to the MTO so they will not become loose even in the event of the operator inadvertently tripping over the current leads. Once the connectors are inserted into the panel, a ¼ turn locking mechanism will secure the connection.
7. **Connecting to the Transformer.** When testing high-voltage transformers, caution must be used at all times and all safety precautions followed. Read, understand, and employ all safety precautions and circuit connections described in Sections 2 *Safety* and Section 3 *Preparing for Test*.



WARNING

Ensure that the transformer to be tested is completely de-energized. Check every winding. Ensure that all terminals of the transformer are disconnected from line or load at the transformer. Connections to ground may be left in place.



WARNING

For all testing as described herein, care shall be taken to ensure any and all unused clamps be isolated from each other, from ground, and from personnel.

At this time, make the connections to the Transformer Under Test (TUT), as described in the applicable section of Section 5, *Connecting to the Transformer Under Test*.

4

Operating the MTO300/330

When testing high-voltage transformers, caution must be used at all times and all safety precautions followed. Read, understand, and employ all safety precautions and circuit connections described in Section 2 *Safety* and Section 3 *Preparing for Test*.



WARNING

Ensure that the transformer to be tested is completely de-energized. Check every winding. Ensure that all terminals of the transformer are disconnected from line or load at the transformer. Connections to ground may be left in place.



WARNING

For all testing as described herein, care shall be taken to ensure any and all unused clamps shall be isolated from each other, from ground, and from personnel.



EMERGENCY SHUTDOWN PROCEDURE

Press red EMERGENCY TEST OFF push button or switch power off.



Description of Test Sequence

Once all the precautions and steps of Sections 2 *Safety* and 3 *Prepare for Test* are complete, and the connections to the Transformer Under Test (TUT) have been made, then the input switch may be switched to the ON position.



0 , OFF position

1 (-) , ON position

TEST FUNCTION

1. Entering the test report information.
2. Entering the transformer nameplate information.
3. Starting the test.
4. Data Display.
5. Stopping the test
6. Populating the PowerDB table
7. Saving the data

AUTOMATIC DISCHARGE FUNCTION

Discharge of a transformer after testing is critical to prevent excessive voltage buildup across the transformer bushings upon removal of leads. When any current source is disconnected from a transformer, the energy in a transformer will continue to flow. If there is high impedance (air) in the nature current loop, the voltage across the inductor will increase until there is a current path found for the energy. The MTO3XX has discharge circuitry built-in. It will automatically initiate when the current source is disconnected from the transformer. It will also provide visual indication of discharging on the front panel and the PC screen.

DEMAGNETIZATION FUNCTION

The demagnetization of a transformer after DC winding resistance testing is recommended. This will ensure smooth startup and consistent diagnostic results. If not performed, there may be a residual flux present in the transformer at startup. Inrush currents on the primary side of the transformer may exceed relay settings for shutdown. Demagnetization is also recommended before performing SFRA and excitation current measurements.

MTO demagnetizes the transformer by automatically magnetizing the core of the transformer in the positive and negative direction with multiple cycles of reduced current. During demagnetization, the system will display what cycle the unit is processing.

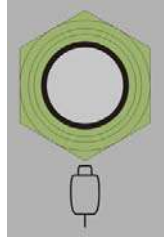
Primary H leads need to be the only leads attached for effective demagnetization.

<p><i>NOTE: The demagnetization cycle will take some time for completion. It is equivalent to taking multiple tests in sequence.</i></p>
--

REMOTE TEST FUNCTION


The main purpose of this function is to take sequential data to storage during a single test. It is useful for tap change testing where multiple resistance values are read in sequence with no interruption in current flow.


1. Connect Remote Control Cable to the remote connector on the front panel of the instrument.



2. Power ON (-) the instrument.
3. Start PowerDB software and follow the standard transformer setup procedures
4. Once the MTO3XX control software is displayed, the remote button will be automatically detected and the test button on the screen will display ACTIVE.
5. STATE 1 – ready condition – Indicator will be off.

The operator will go to the tap changer, verify it is in the correct


starting position, and then to start the first test, press .

6. STATE 2 – Transformer Charging and/or Stabilizing – The Remote Indicator will slow flash (once per second) (ON,OFF,ON,OFF) to indicate charging.
7. STATE 3 – Stable Reading/ measurement mode - When the Remote Indicator goes steady (L,L,L,L) the reading is stable. (Y Stability and X timeframe)
8. Pressing  will cause the stable result to be saved to memory. The Remote Indicator will flash quickly 6 times. (L,O,L,O) ¼ second cycle.
9. STATE 4 – Transition monitoring phase - After a save, the MTO screen will present a message requesting the user to change the TAP. At this point, the transition monitoring circuit is activated. The Remote

Indicator will flash quickly 3 time and pause three times
(L,O,L,O,L,O/O,O,O,O,O,O/L,O,L,O,L,O) ¼ sec cycle.

10. User should change the TAP.
11. If the current transition detection occurs, the unit goes into STATE 5 - (5ms, 20ms, 40ms, 80ms) and the Remote Indicator will flash rapidly. (L,O,L,O) ¼ sec interval continuously. The user can go back to the User interface for repeat of test or can press the remote button, save the event and start reading the resistance of the next tap.
12. If a 200 milli-seconds current transition detection has occurred, Discharge State will be initiated. Remote Indicator will flash slowly until a discharge has occurred. The Remote Indicator will slow flash (once per second) (ON,OFF,ON,OFF) to indicate discharging.



13. Press  to record the reading again and the process continues until all transformer taps are tested.

FIRMWARE UPDATE MODE

The MTO3XX has an internal processor with associated firmware. From time to time, Megger changes this firmware for operational improvements or added features. This section describes the method for changing the firmware on an MTO 300 and 330.

ATTAINING THE LATEST SOFTWARE:

The best way to attain the latest software is to visit Megger.com. Once you are on the site:

- Select the country you are located in.
- You may have to register to log in on the site.
- Select “Software Downloads”.
- Select MTO. There should be a list of software available for download as well as the detailed instructions for performing this task.
- Select the latest firmware version available. The software is self contained as a ZIP file.
- Download the file and run.
- A Megger Welcome Screen will appear on the PC display.
- Before moving forward connect the PC to the MTO300 via an Ethernet cable.

- Follow the instructions on the screen or download the detailed instruction set for print. The software and instructions will guide you thru a step by step process of selecting the Ethernet Interface, verifying that the MTO is connected, power cycling the MTO to synchronize the boot loader with the PC, selecting the file for download and downloading the firmware to the instrument.
- At the end of the process, the software should display Successful download.
- The unit will have to be power cycled to exit boot loader mode.

ATTAINING THE POWERDB SOFTWARE:

The best way to attain the latest software is to visit Megger.com. Once you are on the site:

- Select the country you are located in.
- You may have to register to log in on the site.
- Select Software Downloads.
- Select the PowerDB link
- Download the instruction file and print before any other steps are followed.
- Read the instruction carefully.
- Follow the instructions step by step to assure the process completes fully and successfully.
- At the end of the Update process, the unit should be ready for testing.

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5

Transformer Testing



WARNING

When testing a transformer or regulator, make sure that a good ground is placed on the test specimen as shown on all connection diagrams.

Winding Resistance Testing

Winding resistance measurements in transformers are of fundamental importance for the following purposes:

- Calculations of the I²R component of conductor losses (factory test).
- Calculation of winding temperature at the end of a temperature test cycle, (factory test).
- As a diagnostic tool for field testing a transformer for assessing possible damage in the field e.g. additional contact resistance in the current paths from winding to bushing or in the tap changer.

Transformers are subject to vibration. Problems or faults occur due to poor design, assembly, handling, poor environments, overloading or poor maintenance. Measuring the resistance of the windings and termination resistance assures that the connections are correct and the resistance measurements indicate that there are no severe mismatches or opens. Many transformers have taps built into them. These taps allow ratio to be increased or decreased by fractions of a percent. Any of the ratio changes involve a mechanical movement of a contact from one position to another. These tap changes should also be checked during a winding resistance test.

Testing a Single-Phase Transformer

Below are some graphics on the three methods of testing a single winding transformer.

SINGLE-WINDING TEST

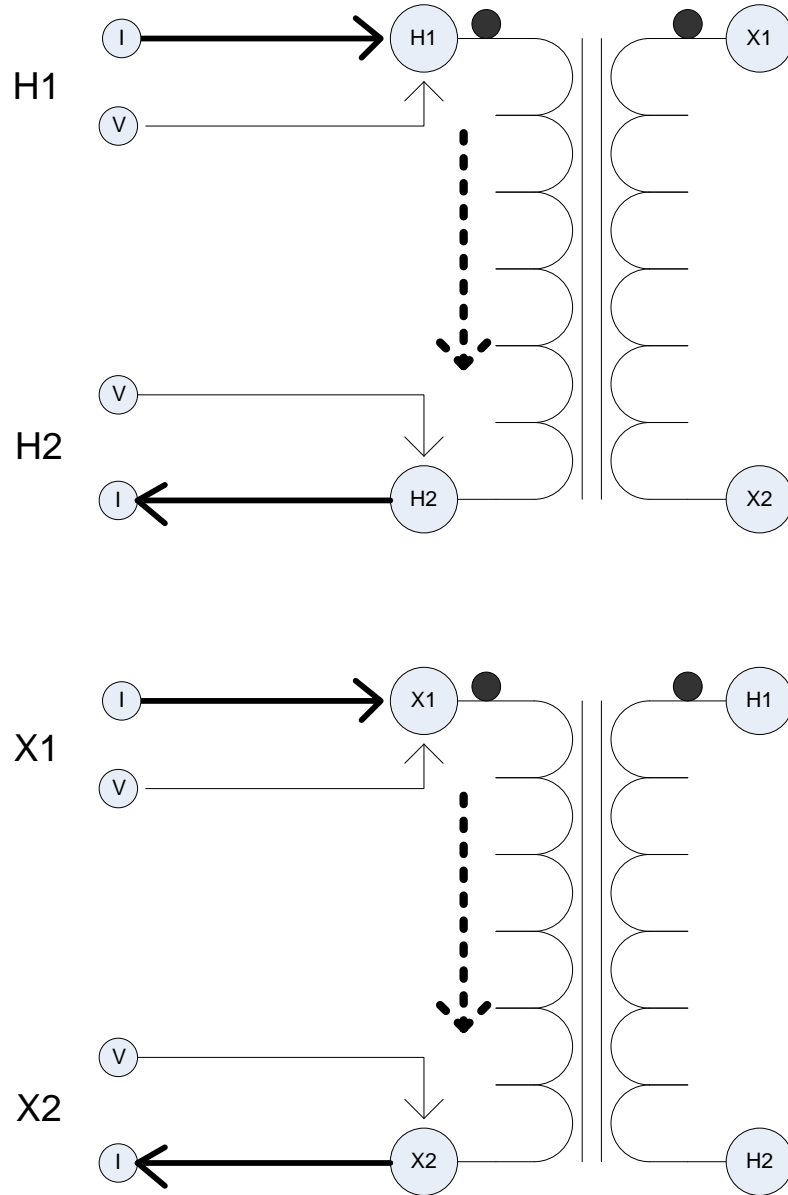


Figure 4: Single Winding Measurement Primary or Secondary

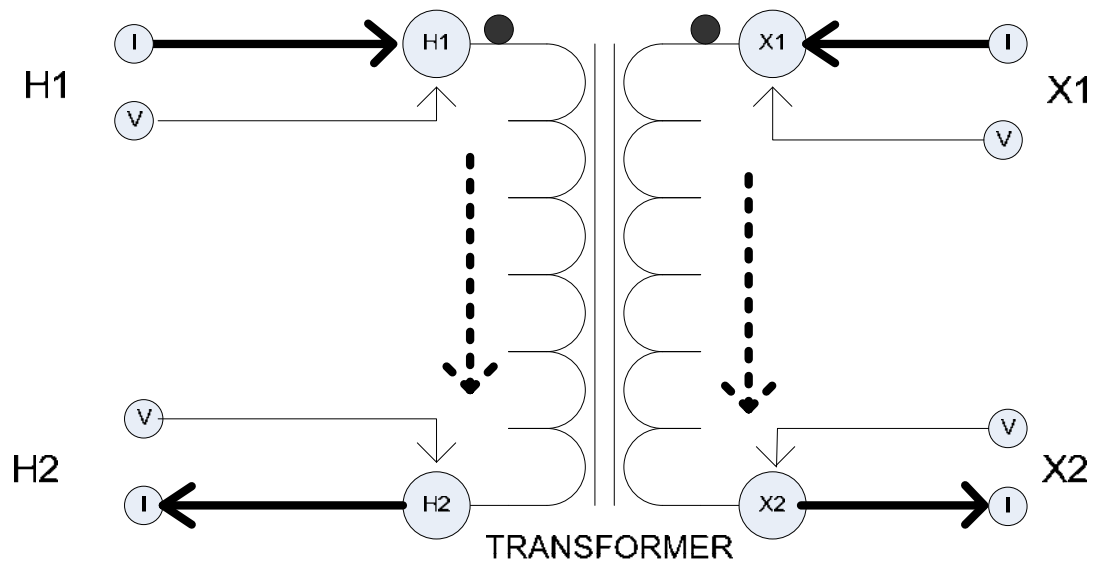


Figure 5: Dual Winding Measurement (Primary and Secondary)



WARNING
Do not disconnect leads until all indicators are OFF!

PROCEDURE:

1. Connect line cord to unit and plug into 120 V/230 V socket.
2. Connect Safety GND cord from Top Panel to Transformer GND.
3. MTO300- Connect Ethernet cable between PC and MTO300
4. Connect H and/or X lead set to the MTO3XX
5. Connect the H and/or X lead set to the Transformer as shown in above figures.
6. Turn the MTO300 power switch "ON" (-).
7. Turn the PC power "ON".
8. MTO300 Start the PowerDB program. *For detailed information on PowerDB, please refer to the PowerDB user manual and additionally the Help Screen for the software. The Help screen and PowerDB manuals will stay more up to date than this manual.*
9. MTO300 and PowerDB Lite - Select the instrument MTO300 from the instrument setup screen.

10. MTO300 - Select the form desired for use. This manual employs form number 56353/MTO300/330 Winding Resistance.
11. The form will be displayed and the user will be ready to start the process.
12. Selecting an existing form – this is handy for customers that have a form and transformer configuration they are using on a regular basis.
 - a. MTO300 – File/Open or the file folder icon will give you the list of forms on the machine. Select the template form and press enter.
 - b. MTO330 – Use Home screen Action Icons to select various functions (including Preferences, Open, Save, New, Print)
13. Enter all of the header information with pertinent information. For users not using PowerDB for asset management, there is a button to show header information; click on it and the header will not appear on the form.
 - a. MTO300 can use the arrow keys, Tab and Alt Tab as well as a mouse to traverse the header information.
 - b. MTO330 can use the arrow keys and Tab/Alt Tab to traverse the header information.
14. Enter the transformer nameplate information. The transformer configuration field is required. This is selectable through the left/right arrow on the graphic screen. The transformer configuration dictates the test method of the instrument, if it is wrong, the instrument will not present the result expected.
 - a. MTO300 can use the arrow keys, Tab and Alt Tab as well as a mouse to traverse the header information.
 - b. MTO330 can use the arrow keys and Tab/Alt Tab to traverse the header information.
15. Form Setting Button – Enter the information for the form. Key number is Allowed Error %. This number is used to highlight winding to winding difference numbers for a three phase transformer when they exceed this defined limit.

Calculation for % difference is $(\text{Phase 1} + \text{Phase 2} + \text{Phase 3})/3 = \text{Average Value}$

Ph1 error = $\text{ABS}(\text{Phase 1} - \text{Average Value})$

Ph2 error = $\text{ABS}(\text{Phase 2} - \text{Average Value})$

Ph3 error = $\text{ABS}(\text{Phase 3} - \text{Average Value})$

Max Ph error/Average Value * 100 = Difference %

PowerDB Lite (Winding Resistance Tester)

MFR _____ WEIGHT _____ lb
 SER NO _____ WEATHER _____
 YEAR _____ BIL _____ kV
 TYPE SEALED IMPEDANCE _____ %
 CLASS _____ REASON _____
 PHASES 3

OIL VOLUME _____ GAL
 OIL TEMP _____ °C
 WINDING TEMP _____ °C
 CORRECT TO 85 °C
 COOLANT OIL

Has Tertiary	VOLTAGE (kV)	KVA	RATED I	# TAPS	NOMINAL	CHANGER	TAP SETTING
PRIMARY:	/			5	3	DETC	
SECOND:	/			1			

Form Settings Instrument Settings Test Wizard (F2) Demag Show

First Tap 1 Voltage _____
 Last Tap 5 Voltage _____

HIGH VOLTAGE WINDING RESISTANCE

#	TAP	Current (amp)	Voltage	Measured Resistance			Reading Stability %
				A ₂ - N	B ₂ - N	C ₂ - N	
1	(1)		0				
2	(2)		0				
3	Nominal		0				
4	(4)		0				
5	(5)		0				

First Tap 1 Voltage _____
 Last Tap 1 Voltage _____

LOW VOLTAGE WINDING RESISTANCE

#	TAP	Current (amp)	Voltage	Measured Resistance			Reading Stability %
				b ₁ - a ₁	c ₁ - b ₁	a ₁ - c ₁	
1	Nominal		0				

MTOPrefs

Form Settings

Show Diag Number

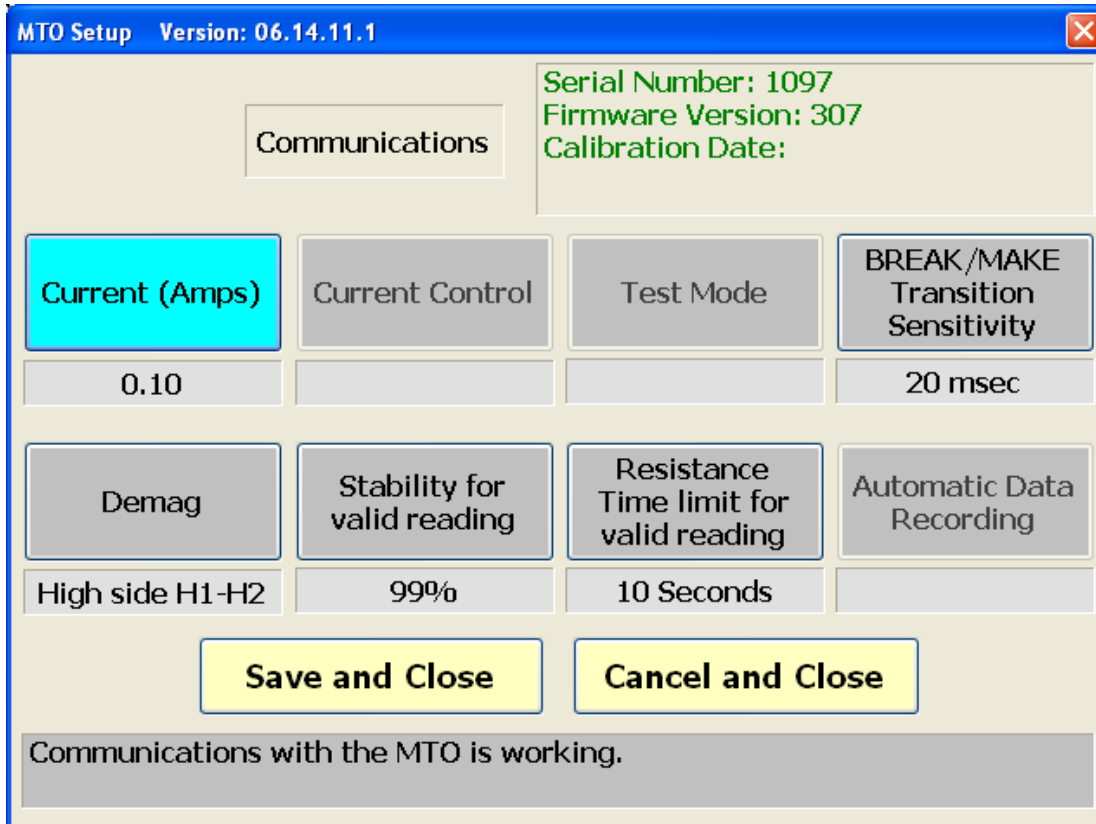
Standard

Allowed Error (%)

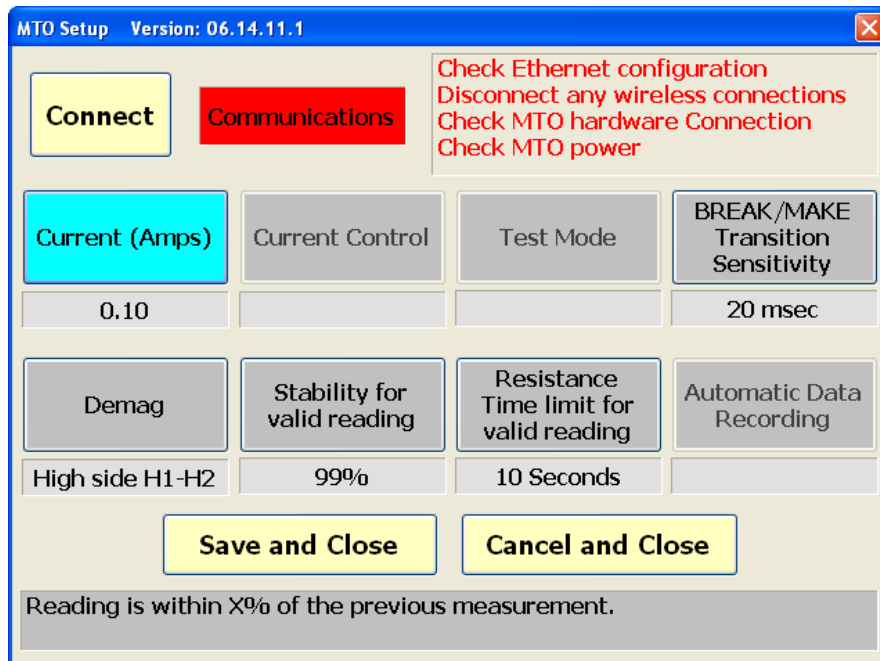
OK

16. Instrument Settings Button – Setup the MTO for the testing methodology of the instrument.

Megger.



- a. The Title Bar for this window displays the program title (MTO Setup) and the version number of the program.
- b. Communications button – Indicates that the MTO is connected and communicating with the top panel (MTO330) or PC (MTO300).
 - i. Green flashing and display of instrument serial number, firmware and calibration date indicate proper operation.
 - ii. Red with no information means there is a communications problem.



- Check MTO Power,
- Check to make sure the Ethernet wire is connected.
- Disable any wireless connections.
- Check Ethernet configuration.
 - a. Current (Amps) – pull down box for setting the current test level.
 - b. Current Transition (BREAK/MAKE) Sensitivity (For detecting a current drop below 90% of the set current level) – This is a pull-down item that displays the time it takes before a error occurs.
 - i. 0 = Off – The hardware will shut down if time exceeds 200milliseconds
 - ii. 1 = 80milliseconds
 - iii. 2 = 40milliseconds
 - iv. 3 = 20 milliseconds
 - v. 4 = 5 milliseconds
 - c. Demag – This is a pull-down item to select the current path for demagnetization:
 - i. (H) High side H1-H2 recommended for all demagnetization
 - ii. (X) Low side X1-X2 added for special circumstances

- d. Resistance Stability – This is a pull-down item to select the level for acceptable resistance reading stability from one period of time (average data for 1 to 5 seconds) vs. a second period of time (average data for 6 to 10 seconds).
 - i. 99%
 - ii. 99.5%
 - iii. 99.75%
 - iv. 99.825%

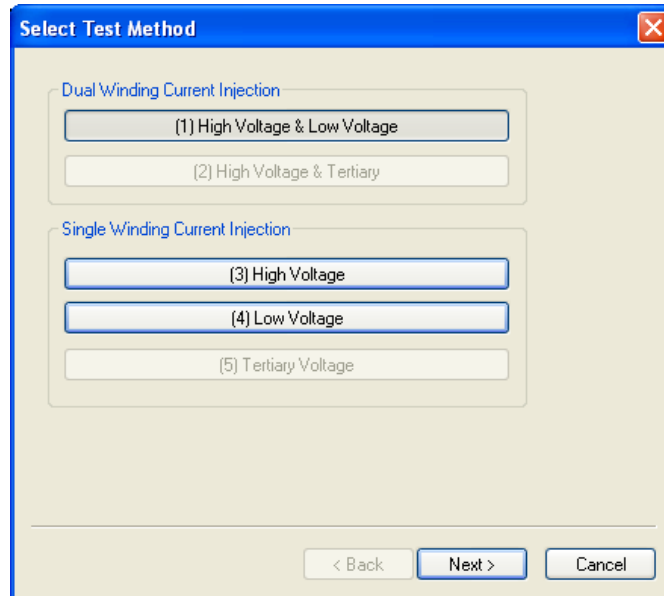
<p><i>NOTE: Due to the nature of this measurement, the user will have to wait during the acquisition cycle for a minimum of the time period specified to assure good stability numbers. Software will start at zero and work toward 100% stability with time and stable measurements.</i></p>

- e. Resistance Time Limit for valid reading - This is a pull-down item to select the amount of time before a reading is verified as stable. 10 seconds was used in the stability reading example. For large transformers, it may be necessary to extend the period to assure stable readings. Extending the Time Limit will also increase the averaging routine improving low value readings.
 - i. 10 seconds
 - ii. 20 seconds
 - iii. 40 seconds
 - iv. 80 seconds
 - v. 180 seconds
- f. Save and Close – button to accept and exit Instrument Setup.
- g. Cancel and Close – button to cancel and exit Instrument Setup.
- h. Status Window – Much clearer description of sections on the screen for those of you who do not like reading manuals.

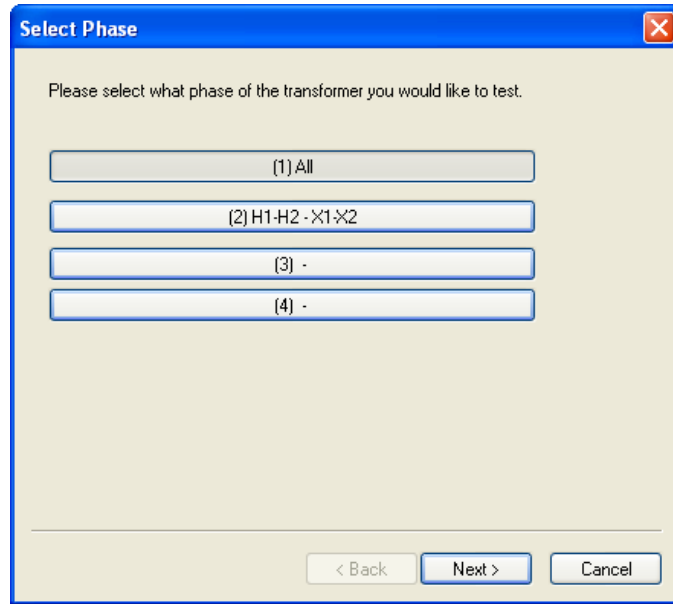
17. Testing the transformer requires the user to decide a method of testing. To simplify this process, PowerDB has included a **Test Wizard** to assure the customer understands the testing method to choose. For a single winding transformer, there are basically two methods of testing the transformer. The first method would be to test the High Side, record the information and test the Low Side and record the information. This method of testing is beneficial if the high side resistance is much larger than the low side resistance. The high side resistance can be tested at 1 amp and the low side resistance can be measured at 10 amps. The second method of

testing would be to measure the high and low side at the same time. This is the recommended test mode when measuring Low Voltage Delta connections.

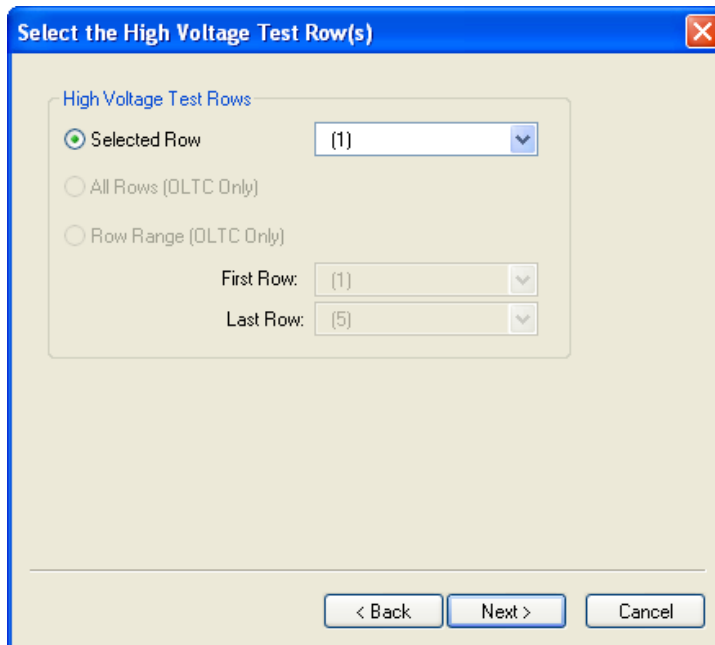
- a. Two shortcuts are included for seasoned users. Right clicking on a specific resistance cell will start a test for that specific cell. Right clicking on a specific Row will start a test sequence of three measurements for all three cells in a row. New users should use the test wizard for additional test guidance.
- b. Select Test Wizard(F2). The first question asked is dual current injection or single current injection.



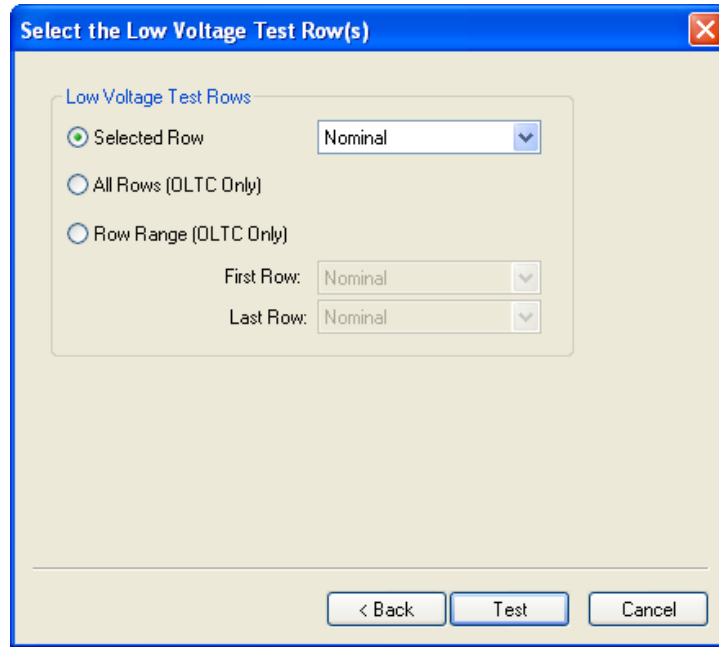
- c. If dual current injection, select 1 and press next.
- d. The next question will be what winding/s should be tested. For single phase transformers, (1) All and (2) H1-H2-X1-X2 are the same. Select 1 and continue.



- e. The next question will be what row/s for the high voltage winding will be tested. If the transformer has no taps or the taps are defined as DETC, then the software will only allow Selected Row.



- f. The next question will be what row/s for the low voltage winding will be tested. If the transformer has taps and the taps are defined as OLTC, then the software will allow Selected Row (default), All Rows or Row Range (partial testing). Once the winding and rows have been defined, press the Test button to continue.



18. Once selected, the instrument display module will start. This is a universal screen used for many transformer configurations. At the top is denoted the Transformer configuration, the continental standard selected and the nominal current selected for testing the transformer.

1ph0 (ANSI) Nom Current: 10 mA

Test Setup
Prev Test
Start
Next Test
Exit

High Voltage Winding Resistance Test

Measured Resistance							
#	Tap	I mA	H1-H2			Stability (%)	Make/Break
1	(1)						

Low Voltage Winding Resistance Test

Measured Resistance							
#	Tap	I mA	X1-X2			Stability (%)	Make/Break
1	Nomin						

19. The software will not automatically start testing as a safety precaution. A two step process is required to energize the test specimen.
20. Additionally, Instrument (Test) Setup can be quickly accessed from this screen in the event you want to check/change any settings before starting a test.
21. Prev Test – Gives the user the ability to go back only one step in a sequence of steps that are run. This function will primarily be used during OLTC tap changer operation.
22. Start – Manual Start of Test, Button will change status as test sequence continues.
23. Next Test – Gives the user the ability to skip forward one step in a sequence of steps that are run.
24. Exit – Before and After testing, the user has the ability to exit the software without saving data.
25. MESSAGE WINDOW – Grey area under the function buttons. This window will constantly flash YELLOW defining the state of the machine as it is operating.
26. High Voltage Winding Resistance – display area for all information measured on the high voltage side of the transformer.
27. Low Voltage Winding Resistance – display area for all information measured on the low voltage side of the transformer.
28. Basic sequence of events for a test cycle
 - a. Start – manual start of test.
 - b. Charging – Unit drives the winding with voltage and current until the set current level is reached.
 - c. Calibration – Once the unit is charged and stable, the unit will perform an internal calibration to correct for any temperature and offset errors associated with the hardware at the time of test.
 - d. Measuring Resistance – The unit will run continuously measuring resistance and updating the screen. The current and resistance readings are updated approximately once per second.
 - i. The stability reading is displayed giving the user an understanding of how well the transformer resistance readings have stabilized. 100% is an excellent stability reading. After the stability reading has met the Stability valid value for the stability time period, the background of the value will turn green.
 - ii. There are two reasons stability readings may be low. The first is the software starts the stability value at zero so the user must wait for a specific amount of time, time for stable reading to assure

the reading is valid. Customers have the choice of saving and continuing readings without a stable reading. Usually, this will be after a certain amount of time, the reading is 99% stable and the customer feels the readings are acceptable. If the Save Results button is pushed immediately after starting a test, then data could be saved with low stability numbers. The second thing that causes stability readings to become low is measuring low resistance readings with low current levels. The input signals for the instrument will be so low that the reading fluctuate at a larger percentage of the reading level. To help resolve this issue, test at the highest possible current level. For very low resistances, change the stability time duration to 180 seconds, This will average more measurements together and effectively reduce the noise level for really low measurement values.

- e. Save Results – When the user has the readings he accepts as valid, he can press the Save Results Button and the data
- f. Finish – Shuts down the Measurement software and transfers all data back to PowerDB.

Testing a Three-Phase Transformer

Below is an outline of the test sequence.

1. Three-Phase Wye Configured Winding with Neutral

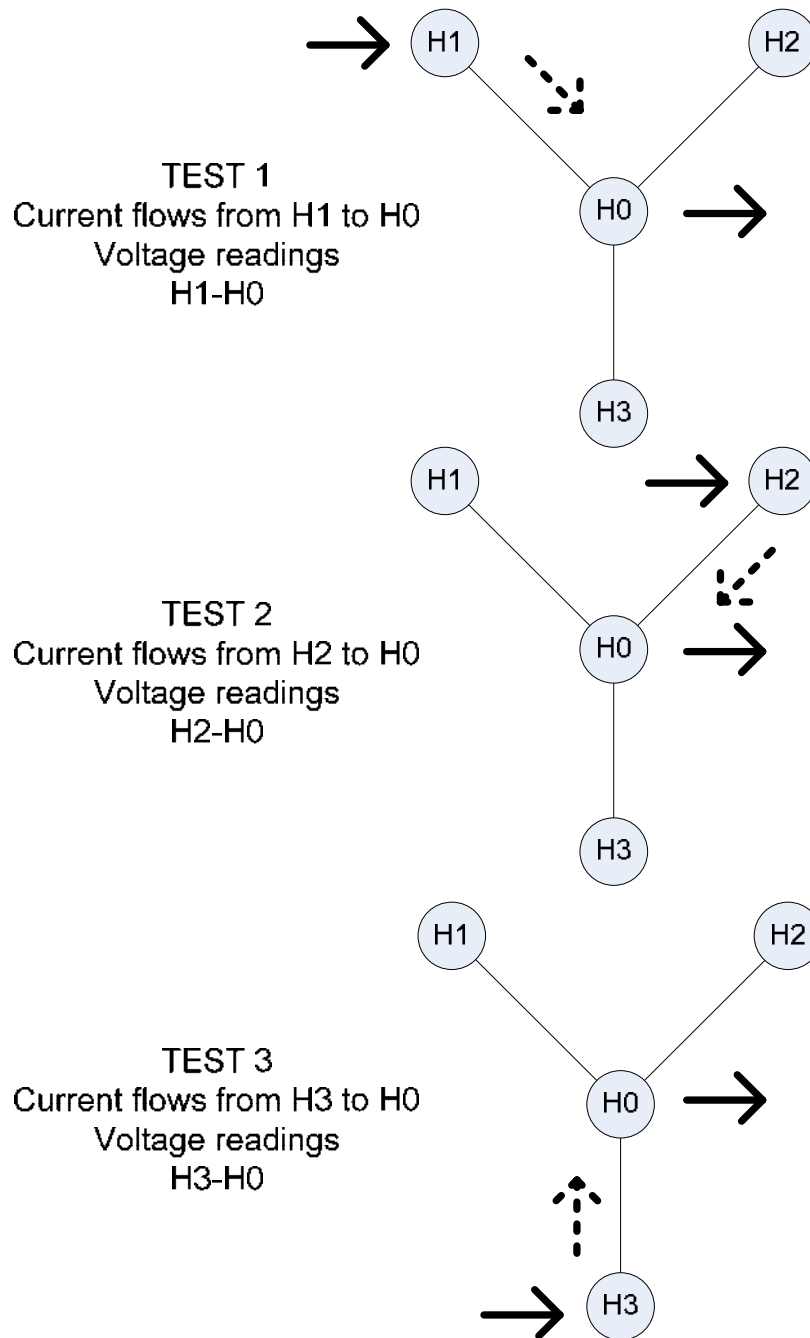


Figure 6: YN reading sequence

2. Three-Phase Wye Configured Winding, No Neutral Brought Out

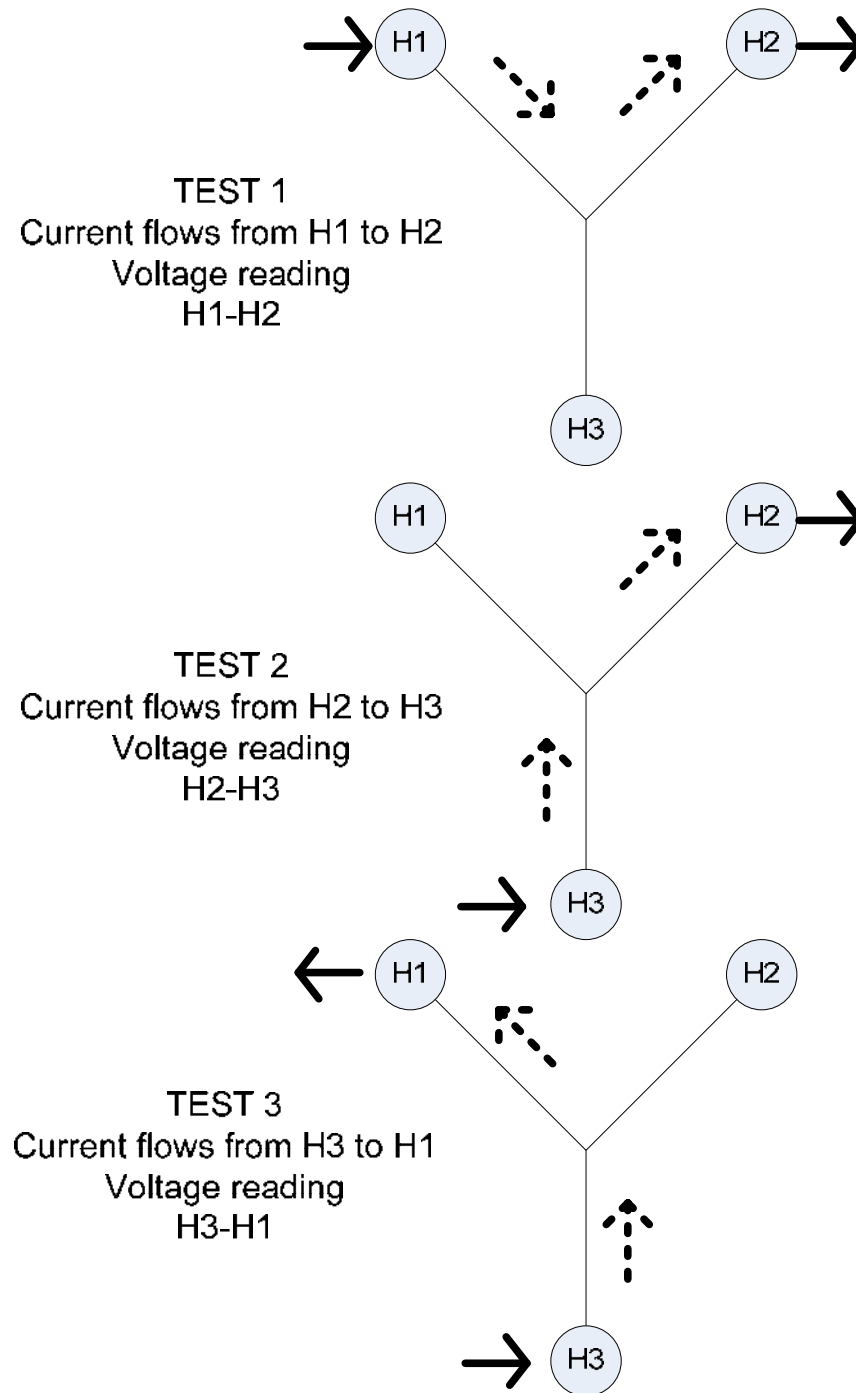


Figure 7: Y reading sequence

3. Three-Phase, Delta Configured Winding

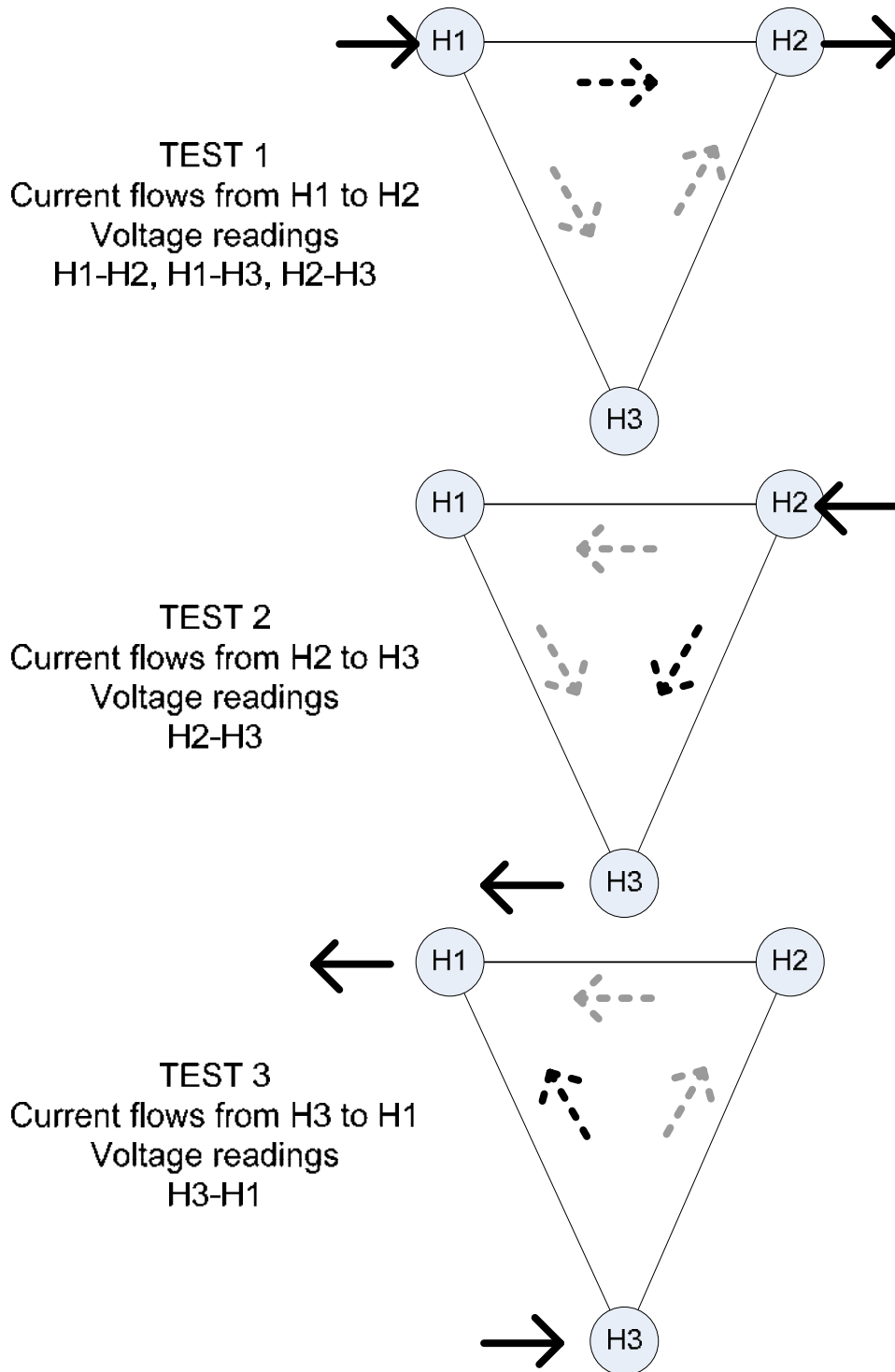


Figure 8: Delta reading sequence

Testing Delta Configured Windings

Testing Delta winding resistance may be a very time consuming procedure, in particular LV winding deltas the correct balance time can take up to 30-60 minutes for a large transformer. The method for improving test time for delta configurations requires that both the high side and low side be connected in series with the MTO's current source (see connection Table 1). By using both HV and LV windings to magnetize the core, the effective test magnetization current increases with the turn ratio (simultaneous winding magnetization, SWM).

As an example, testing the Low Voltage side of a 100/10 kV Yd transformer with dual side injection at 10A is the same as testing only the Low Voltage side of that same transformer 68 A. Even if only one side of the transformer needs to be tested, connecting both high and low windings in series will speed the test up by a factor of 10 or more.

DELTA WINDING RESISTANCE

Manufacturer's winding resistance data are usually presented as per winding for Y configurations and per terminal pairs for Delta windings. In the rare case that manufacturer's data is presented per winding also for a delta connection, the recommendation is to recalculate the numbers to terminal pairs and compare with the field measurement results.

R_{avg} = Average individual winding resistance

R_{tp} = Winding resistance between terminal pairs

$R_{tp} = R_{avg} * 0.6667$

TESTING TRANSFORMERS WITH TAP CHANGERS



WARNING

Make sure before changing taps to identify the types of tap changers on the transformer and test accordingly per instructions.

Many transformers used today have taps built into them. These taps allow ratio to be increased or decreased by a few percent. Any of the ratio changes involve a mechanical movement of a contact from one position to another. It is this contact that needs to be checked by way of its contact resistance and mechanical integrity.

The contact may go bad for a number of reasons.

1. Misaligned when manufactured causing insufficient surface contact. Full load current overheats contact surface causing it to burn.
2. Current passing through contact exceeds full load rating.
3. Tap changing operation failing to have the required "Make Before Break" sequence will create internal arcing of contact surface.
4. An off-load tap changer is switched while on load. Contact surface becomes pitted and uneven.

Tap changers are divided into two types; "On-load" {**DeEnergized Tap Changer**} and "Off-load" {**On Load Tap Changer**}. The OLTC tap changer allows selection of ratio change while the transformer is in service. This would mean the ratio of a transformer can be changed while power (current) is still passing through it. The most common example of this type of OLTC tap changer is a "Voltage Regulator".

The MTO is designed to test both DETC's and OLTC's.

For DETC taps, the software will direct the user to discharge the transformer before changing taps. This will help assure the transformer, equipment and user to not get damaged inadvertently.

For OLTC's the software has three methods of testing. The first is testing the taps in the same manner as a DETC, one tap at a time stopping and filling in the form after each test. All of the TAPS can be tested in sequence from 1 to 33 and then transferred to PowerDB form and the last method is selecting a specific range of taps for testing if all taps are not required for testing.

Because the instrument can be left on while changing from tap to tap, it is possible to take measurements without discharging. The MTO will re-balance after every tap change. If the current drops more than 10% for the selected transition time sensitivity, then the MTO will indicate there was a transition.

The transition times are set to 5ms, 20ms, 80ms and Off.

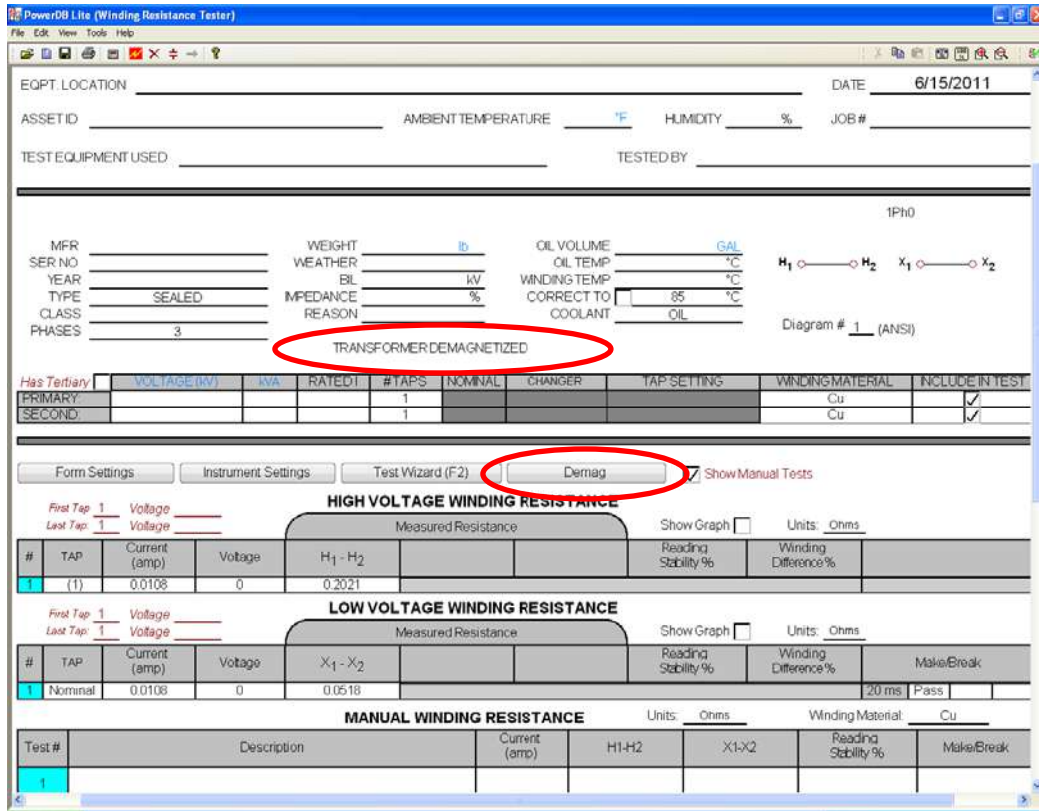
If a transition is detected over 5 msec and under 200 msec, the unit will flag a transition, but the current will continue flowing. The same thing goes for 20 and 80 millisecond settings. If a transition is detected, the unit will define the transition test time and the pass or fail test result.

If the current interruption is longer than about 200 ms, the MTO will stop the test and discharge the transformer automatically.

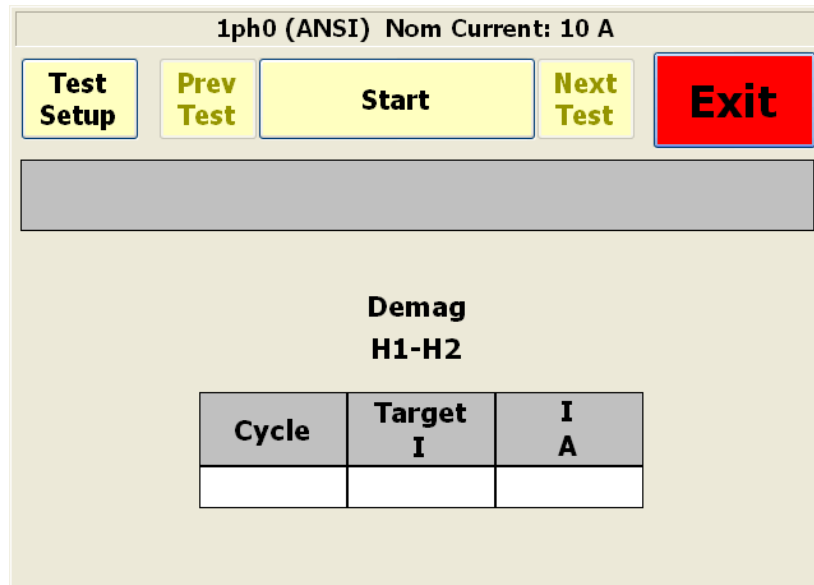
Demagnetizing a Transformer

The MTO demagnetizes the transformer by automatically magnetizing the core of the transformer in the positive and negative direction with multiple cycles of reduced current. The demagnetization function is equivalent to generating test currents for multiple resistance tests. During the demagnetizations cycle, the unit will display the number of cycles left in the process.

1. Demagnetization only needs to be accomplished once after all testing is complete.
2. Test leads should be attached to one terminal pair on high side (Primary) windings for effective demagnetization. eg. H1-H2 is the standard terminal connection that the MTO will drive current through.
3. Only one terminal pair (winding) needs to be demagnetized on a three-phase transformer.
4. Press the DEMAG Button



5. Press the DEMAG Button



6. Press the START Button

7. The unit automatically cycles thru a preset arrangement of current levels to demagnetize the transformer after all of the resistance testing is completed.

- The form will have a Demagnetized Transformer printed in the nameplate section of the form to confirm that a Demag was performed as the last operation of the transformer testing. Any additional testing of the transformer will clear this message.

Temperature Correction

It may be necessary to convert the resistance measurements to values corresponding to the reference temperature in the transformer test report.

To estimate the winding temperature at the time of measurement is important. There are three things needed to get the resistance readings corrected, Winding material, Winding temperature and corrected to temperature.

The screenshot shows the PowerDB Lite (Winding Resistance Tester) software interface. Key elements include:

- Header:** EQPT. LOCATION, DATE (6/15/2011), ASSET ID, AMBIENT TEMPERATURE, HUMIDITY, JOB#.
- Form Fields:** MFR, SER NO, YEAR, TYPE (SEALED), CLASS, PHASES (3), WEIGHT, WEATHER, BIL, IMPEDANCE, REASON, OIL VOLUME, OIL TEMP, WINDING TEMP, CORRECT TO (85 °C), COOLANT (OIL).
- Winding Material Table:**

Has Tertiary	VOLTAGE (kV)	kVA	RATED I	# TAPS	NOMINAL	CHANGER	TAP SETTING	WINDING MATERIAL	INCLUDE IN TEST
				1				Cu	<input checked="" type="checkbox"/>
				1				Cu	<input checked="" type="checkbox"/>
- Resistance Test Sections:**
 - HIGH VOLTAGE WINDING RESISTANCE:** Measured Resistance, Reading Stability %, Winding Difference %.
 - LOW VOLTAGE WINDING RESISTANCE:** Measured Resistance, Reading Stability %, Winding Difference %, Make/Break.
 - MANUAL WINDING RESISTANCE:** Units: Ohms, Winding Material: Cu.

Material Selection

In the PowerDB form, a material selector for each side of the transformer is available Nameplate section of the form.

Temperature Entry

If the transformer has winding temperature meters, use these readings. Most transformers will have a meter for each winding. Most meters are reading about the same value for a static transformer. Use the average of the three readings and place this number in the Winding Temp field of the Transformer nameplate section of the form. A secondary method is to use the oil temperature. Use this value in the winding temp field and oil temp field of the form.

Other information

- The transformer has been out of service for at least 3 hours
- The temperature of the insulating liquid has stabilized, and the difference between the top and bottom temperature does not exceed 5°C.

If the transformer is measured without oil, the winding temperature is normally assumed to be the same temperature as the surrounding air.

Once the information and results are in the form, the results can be switched from measured resistance to corrected resistance using the checkmark in the transformer nameplate section.

Conversion of Resistance Measurements

Winding resistance measurements are normally converted to a standard reference temperature.

The conversions are accomplished by the following formula:

$$R_s = R_m (T_s + T_k) / (T_m + T_k)$$

where

R_s = resistance at desired temperature T_s

R_m = measured resistance

T_s = desired reference temperature

T_m = temperature at which resistance was measured

T_k = 234.5 (copper)

T_k = 225 (aluminum)

Manual Mode Operation

At the bottom of the form is a separate table for manual mode operation. It may be required to perform testing that is not typical for a normal test sequence or to double check a measurement discrepancy generated in the normal test sequence. This manual mode operation creates the ability to test just use single or dual winding measurements with fixed output terminals and virtually unlimited connection opportunities.

The screenshot shows the 'TRANSFORMER WINDING RESISTANCE TEST' interface. It includes input fields for transformer details (MFR, SER NO, YEAR, TYPE, CLASS, PHASES, WEIGHT, WEATHER, BIL, IMPEDANCE, REASON, CIL VOLUME, CIL TEMP, WINDING TEMP, CORRECT TO, COOLANT) and a transformer diagram. Below these are tables for winding materials and test results.

Has Tertiary	VOLTAGE (KV)	KVA	RATED T	# TAPS	NOMINAL	CHANGER	TAP SETTING	WINDING MATERIAL	INCLUDE IN TEST
				1				Cu	<input checked="" type="checkbox"/>
	/			1				Cu	<input checked="" type="checkbox"/>

HIGH VOLTAGE WINDING RESISTANCE									
#	TAP	Current (amp)	Voltage	H ₁ - H ₂	H ₂ - H ₁	H ₃ - H ₂	Reading Stability %	Winding Difference %	Make/Break
1	(1)		0						

LOW VOLTAGE WINDING RESISTANCE									
#	TAP	Current (amp)	Voltage	X ₁ - X ₀	X ₂ - X ₀	X ₃ - X ₀	Reading Stability %	Winding Difference %	Make/Break
1	Nominal	0.1076	0	0.1296	0.02625		99.41		20 ms Pass Pass

MANUAL WINDING RESISTANCE							
Test #	Description	Current (amp)	H1-H2	X1-X2	Reading Stability %	Winding Material	Make/Break
1						Cu	

- Show Manual Tests – Check Button to turn off/on the manual test table.
- Right clicking on Test # will start a test with current flowing out H1, H2 and X1 jumpered in the unit and Current return X2.
- Right clicking on the H1-H2 open cell will test resistance using H1-H2 leads.
- Right clicking on the X1-X2 open cell will test resistance using X1-X2 leads.
- Description, field is used to type any comments the customer wants to describe the test.

Megger.

6

MTO330/300 Series PowerDB Lite

Introduction

PowerDB Lite is a free, but limited capability, version of the PowerDB software tool that is designed specifically to control and/or extract data from Megger instruments. The primary difference between PowerDB Lite and PowerDB is that PowerDB is designed to work with all manufacturers' equipment and has field and office synchronization capabilities. PowerDB Lite will present your test data into a professional looking data form that can be sent to a printer or .pdf file distiller such as PDF995.

PowerDB Lite allows you to use a sub-set of the standard PowerDB forms that are appropriate for specific Megger instruments. PowerDB Lite detects the instrument and enables the appropriate form(s). Data can be entered on-screen or captured directly while using the test instrument. Completed data forms can be saved as files to your computer.

For more information, or updates to the software, visit www.PowerDB.com.

Minimum Recommended System

- Operating System: Windows 2000 or later
- RAM: 64 MB RAM minimum, 512+ MB RAM recommended
- Processor: 300 MHz Pentium Class processor minimum, 1 GHZ or better recommended

For information about the features of the full version of PowerDB please visit our website at www.powerdb.com. Get acquainted with the following features by scheduling a live demonstration at info@powerdb.com.

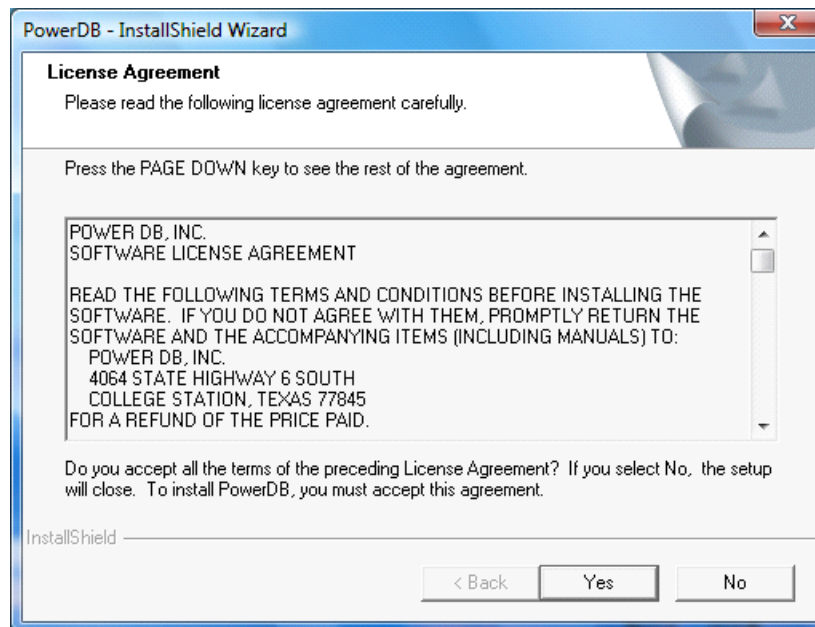
- Synchronize all of your test records into a Single Corporate Database
- Reduce Test Time
- Improve Data Integrity
- Standardize Test Procedures
- Easily use Historical Trending for evaluation of Test Results

- Eliminates the need to install and maintain a software application per instrument
- Eliminates all hand written test sheets
- Create your own test forms
- Use or modify one of our 200 built-in test forms
- One-step procedure to generate test reports with table of contents and deficiency summaries
- Allows all of your field test data to be integrated with CMMS systems such as Maximo or SAP
- Imports >From Many Other Industry Standard Software Applications
- Controls and Imports Data from many non-Megger Instruments

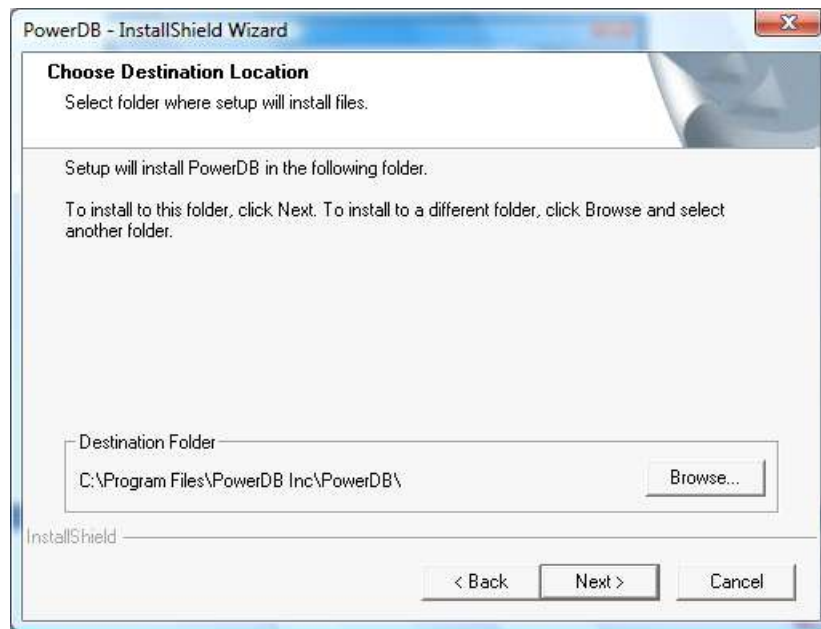
Software Installation

To install PowerDB Lite, load the PowerDB Lite CD into your CD-ROM drive and follow the on-screen instructions.

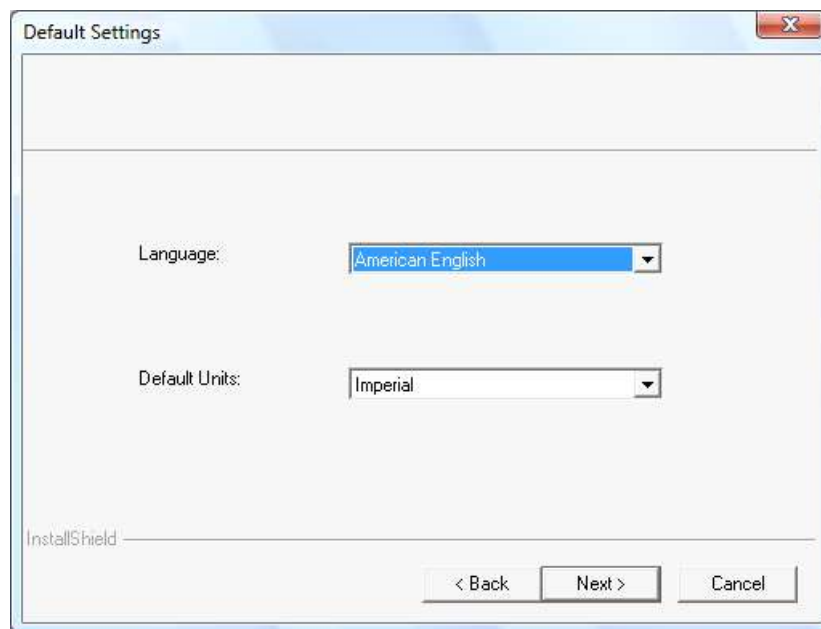
1. Accept the terms of the License agreement.



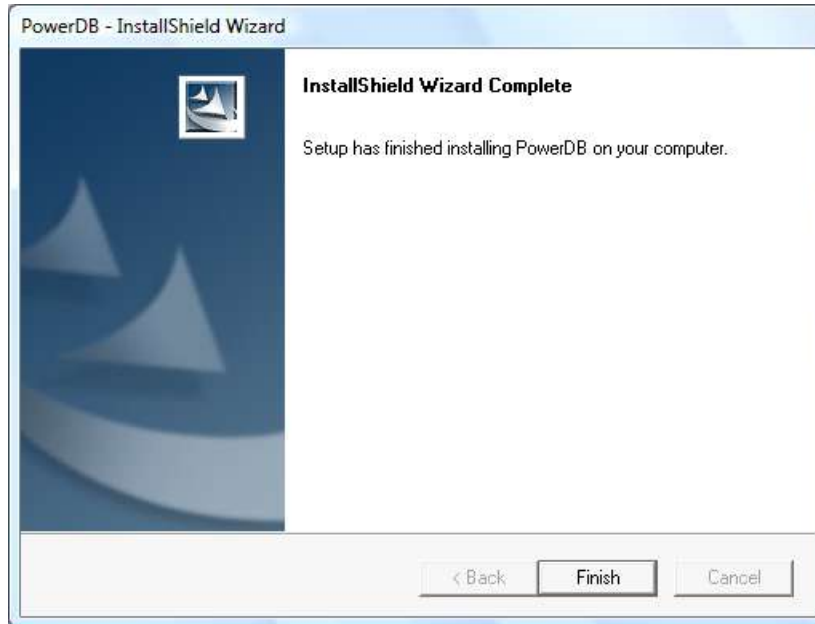
2. Choose the destination location for the PowerDB Lite files.



3. Select Default Settings.



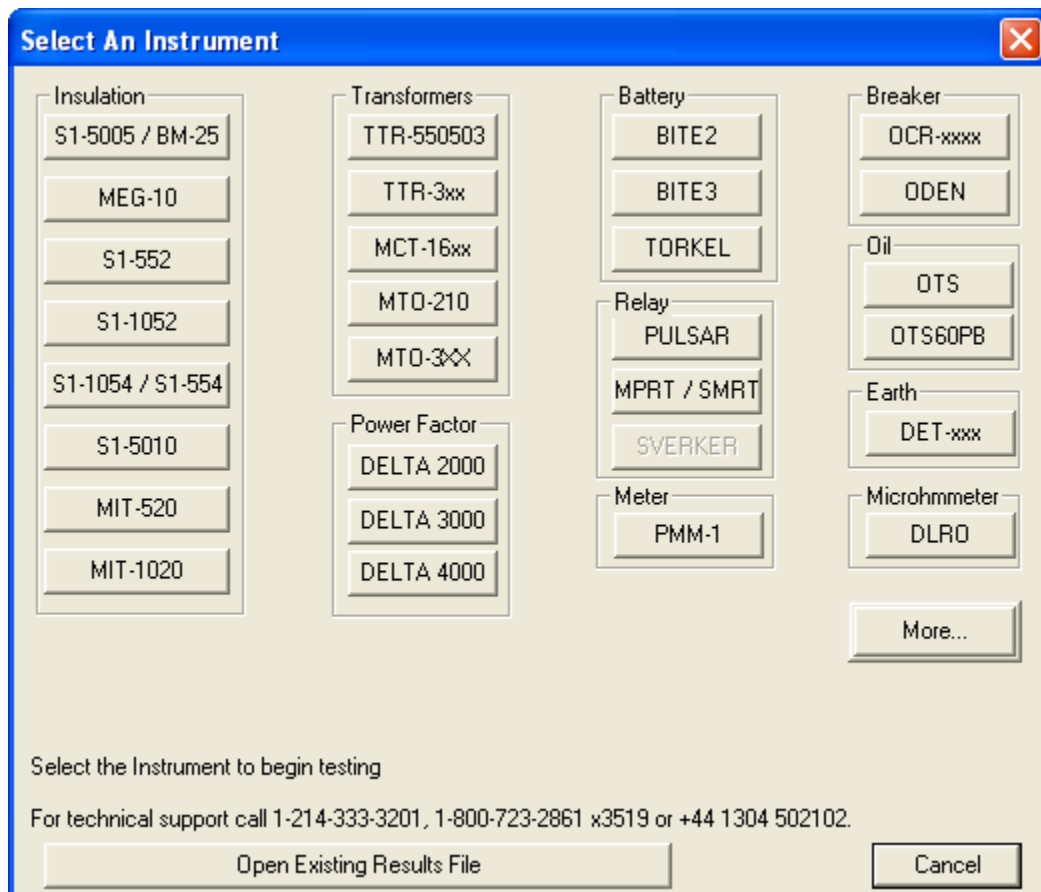
4. InstallShield Wizard will complete the installation of PowerDB Lite. Click **Finish** to close the installation program.



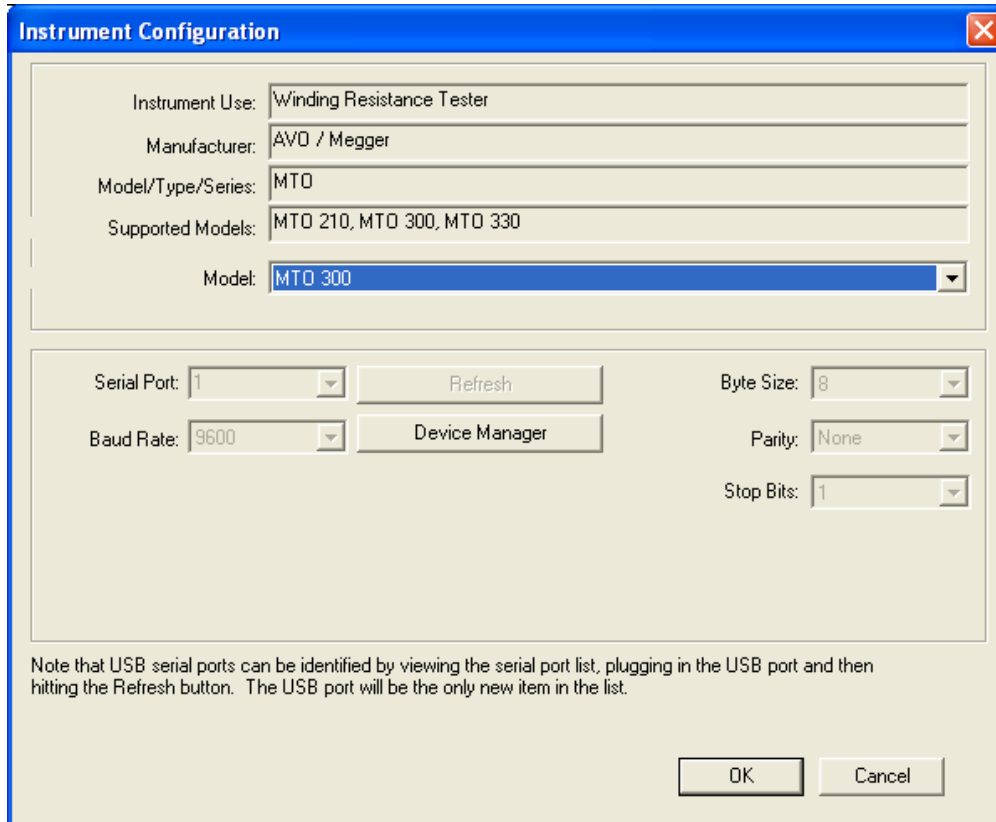
Using PowerDB Lite

1. SELECTING AN INSTRUMENT

1. Select your Instrument MTO3XX from the Instrument Setup screen.
 - a. You can always view the Instrument Setup screen from the Tools menu or F3.



- b. The MTO3XX uses Ethernet communication there is not need for communications setup.



Instrument Configuration

Instrument Use: Winding Resistance Tester

Manufacturer: AVO / Megger

Model/Type/Series: MTO

Supported Models: MTO 210, MTO 300, MTO 330

Model: MTO 300

Serial Port: 1 Refresh

Baud Rate: 9600 Device Manager

Byte Size: 8

Parity: None

Stop Bits: 1

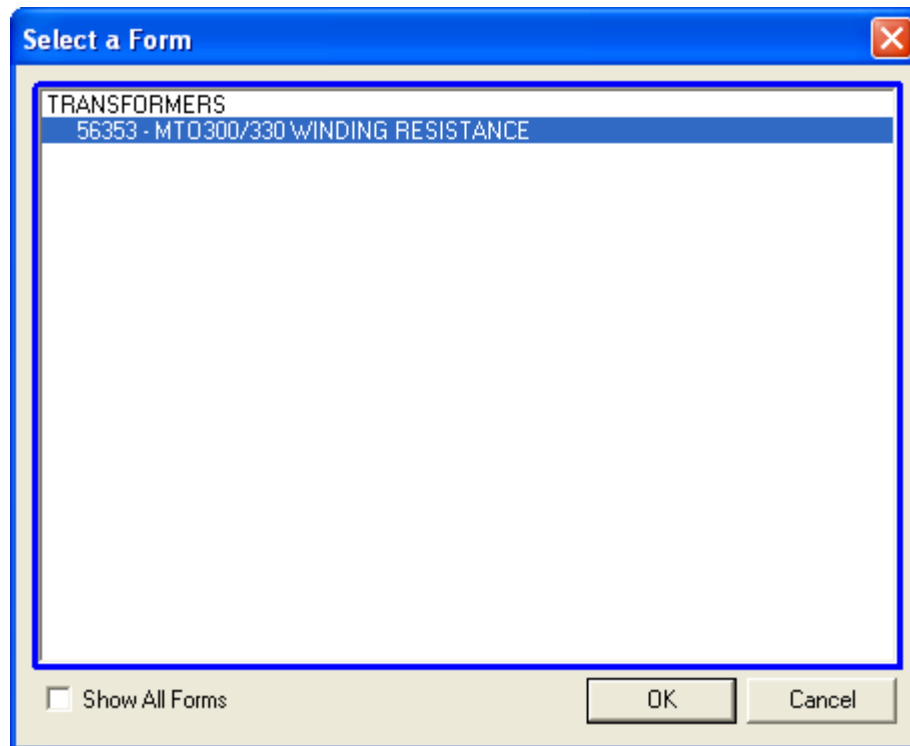
Note that USB serial ports can be identified by viewing the serial port list, plugging in the USB port and then hitting the Refresh button. The USB port will be the only new item in the list.

OK Cancel

- c. Click **OK** on the Instrument Setup Screen to finish.

2. SELECTING A FORM

Once you have defined the instrument, PowerDB will present the forms created in the database and associated with that instrument. The factory default form is 56352.

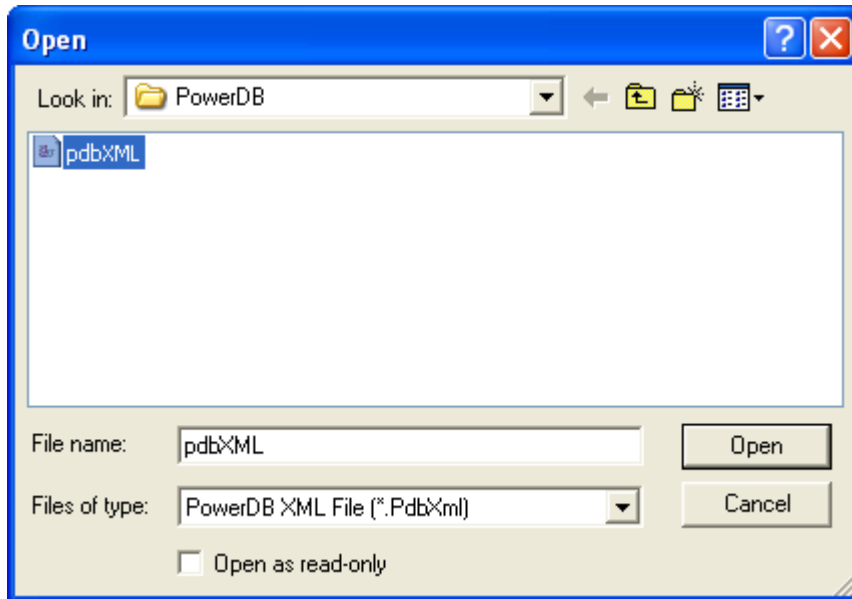


3. ENTER HEADER AND NAMEPLATE DATA

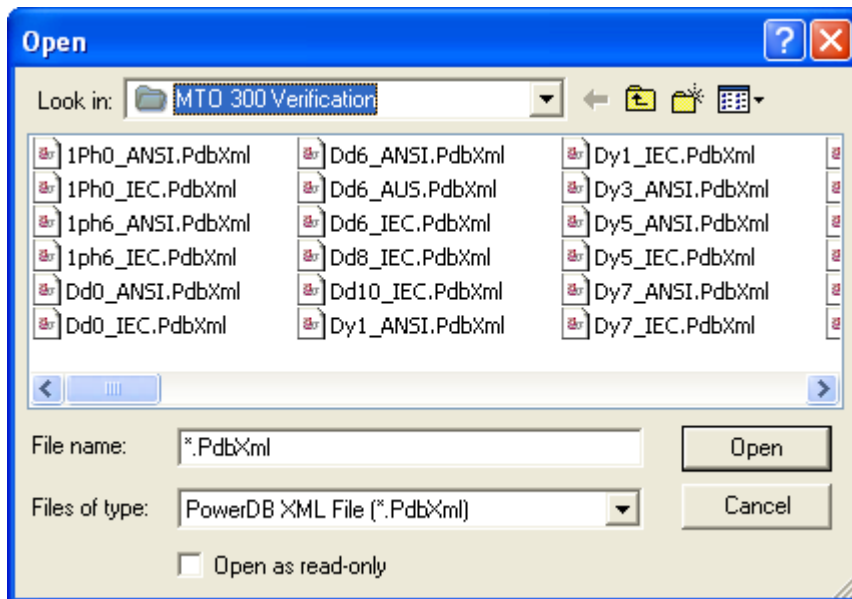
- a. Header and nameplate information can be manually typed into a form.
- b. Header and nameplate information can be automatically loaded into a form by opening an existing form on the unit and selecting NEW.

4. OPENING AN EXISTING FILE

- a. Select the *File > Open* menu item.



- b. **Browse** to the file you would like to open.
- c. Press the **Open dialog** button.
- d. If the file contains multiple test dates, select the *Date* that you would like to open for editing or select *New* to append a new set of results to the file. To remove a set of results, click on the selected file and press the *Delete* button.



Open PowerDB XML file

Form name: 56353 - MTO300/330 WINDING RESISTANCE

To view or edit a set of results, select a test date and press the Open button.

To remove a set of results, select a test date and press the Delete button.

Press the New button to enter another set of test results.

Test Date
1/7/2011 3:33:19 PM

Open

New

Delete

Undo Save Close

5. ACQUIRING DATA

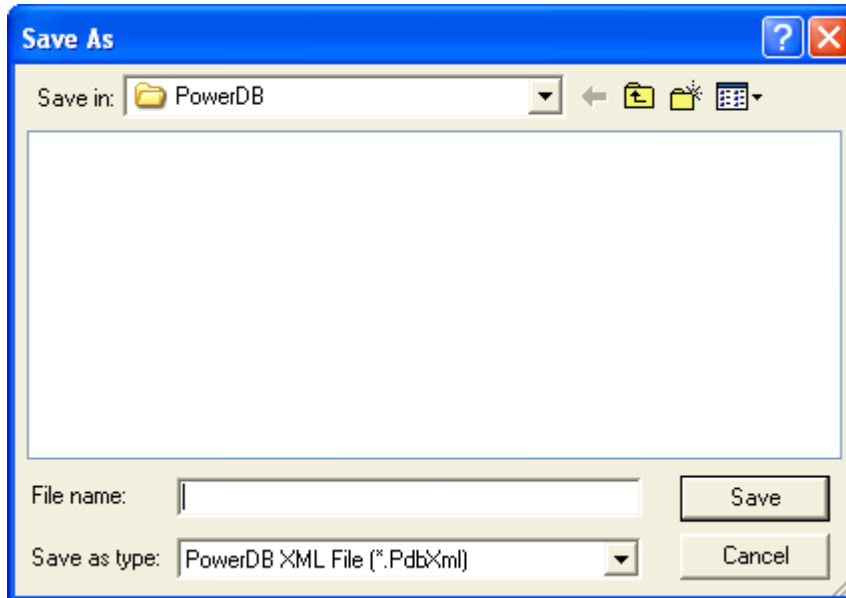
Follow instructions outlined in section 5 of the manual

6. COMMENTS AND DEFICIENCIES

When imported into the full version of PowerDB, the comments and deficiencies on each form are used to generate summary reports. These summary reports repeat the notations and lists the page number where reported. This allows the user to scroll to a particular page to view a reported anomaly. For more information on features of PowerDB use the Help Menu or visit us at our website at www.PowerDB.com.

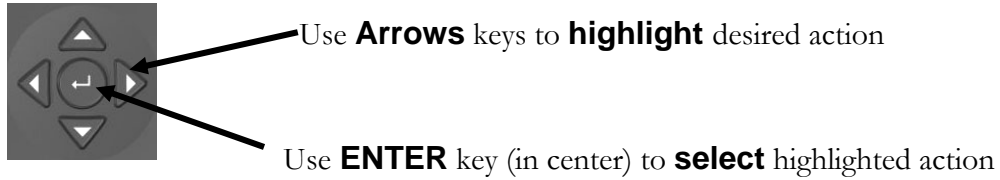
7. SAVE THE DATA

- a. Select the *File>Save* menu item, or press *CTRL+S*, or press the *Save* toolbar button.
- b. The Save As screen will allow you to specify a location and file name for your PowerDB Lite XML file.



Using PowerDB OnBoard (MTO330 only)

Navigating the screen



HOME Screen Action Icons

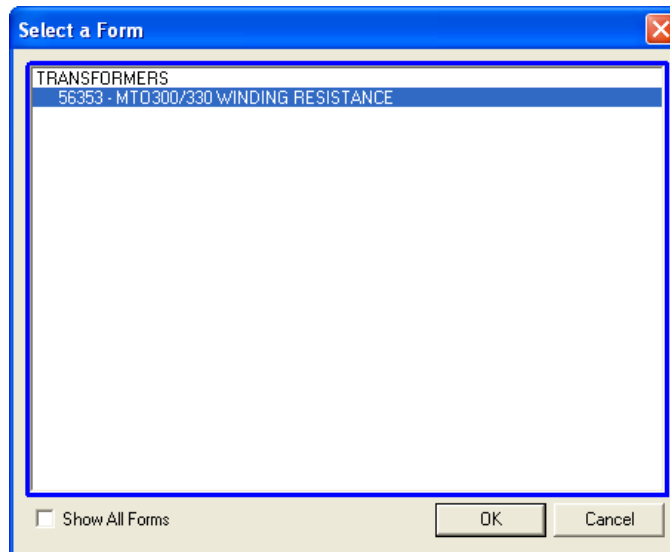


Select HOME key to display Action Icons

ACTION ICONS:



Select **NEW TEST** to open new form



Additional information to be added when software is released.

5. ACQUIRING DATA

Follow instructions outlined in Section 5 of the manual

6. COMMENTS AND DEFICIENCIES

When imported into the full version of PowerDB, the comments and deficiencies on each form are used to generate summary reports. These summary reports repeat the notations and lists the page number where reported. This allows the user to scroll to a particular page to view a reported anomaly. For more information on features of PowerDB use the Help Menu or visit us at our website at *www.PowerDB.com*.

7

Service

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 required for the MTO test set.

The appearance of the MTO test set can be maintained by occasionally cleaning the case, panel and cable assemblies.

1. Clean the outside of the carrying case with detergent and water. Dry with a clean, dry cloth.
2. Clean the control panel 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. An all-purpose, household spray cleaner can be used to clean the panel. Polish with a soft, dry cloth, taking care not to scratch the display screen cover.
3. Clean the cables and mating panel receptacles with isopropyl or denatured alcohol applied with a clean cloth.
4. Inspect the cable assemblies occasionally to ensure they are in good condition.

Fuse Replacement

The electronic circuits in the MTO test set are protected by two mains fuses. Fuse replacement is indicated if the electronic circuits do not function. Refer any fuse replacement to qualified personnel. Please consult the manufacturer for proper replacement fuses to avoid electric shock and fire hazard. Note that 2 spare fuses are included with each MTO.

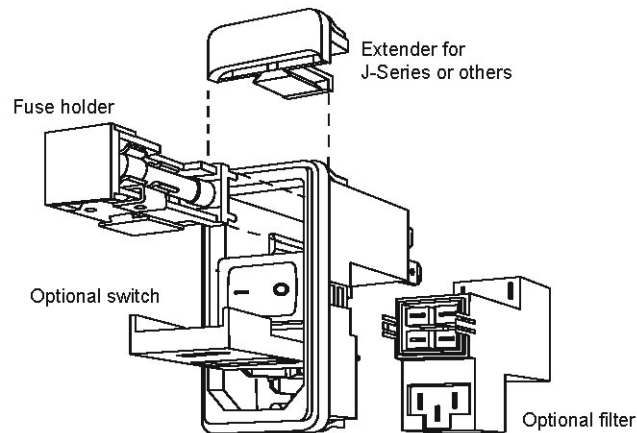


WARNING

Before replacing the fuses, disconnect the power input plug from the live power source.

To replace fuse(s), proceed as follows:

1. Disconnect the power cord from the MTO test set.
2. Using a small flathead screwdriver, carefully remove the fuse holder of the input power module installed on the right side of the MTO test set front panel.
3. Remove and properly dispose of blown fuse(s).
4. Install new fuse(s) making sure to use the type specified by the manufacturer.
5. Reinstall the fuse holder in its receptacle in the input power module. Connect the power cord to the MTO test set and to an energized power source. If the electronic circuits still do not function properly, contact the factory for service.



Calibration

A complete performance and calibration check should be made at least once every year. This will ensure that the MTO test set is functioning and calibrated properly over the entire measurement range. The MTO calibration is performed on each new or repaired unit before sending it to a customer. There is a special MTO final calibration procedure which requires a NIST-traceable test equipment to be used. As a result of such calibration procedure, each MTO test set may be NIST certified.

Repairs

Any service or repair of this equipment should only be performed by qualified persons who are aware of electrical hazards and the necessary precautions required to prevent injury.

Megger offers a complete Repair and Calibration Service and recommends that its customers take advantage of this service for routine maintenance or in the event of any equipment malfunction.

In the event that Service is required, contact your Megger representative for a product Return Authorization (RA) number and shipping instructions.

Ship the product prepaid and insured and marked for the attention of the Megger Repair Department. Please indicate all pertinent information, including catalog number, serial number, and problem symptoms.

ERROR CODES

MTO comes with a wide range of error codes to assure unit is working properly and track down problems in a systematic manner. When an error code occurs, the first thing to do is acknowledge the error by pressing enter and repeating the test. If the error persists, review the possible causes and determine if you can resolve the problem on site. If the basic cause is ruled out, contact Megger for additional assistance. Bold Error codes are quite common with the possible causes defined.

CODE	Error Description	Possible Cause
ESd	ESD is pushed down	Button is pushed down, internal cable is disconnected, internal hardware failure
IntLoc	Interlock interface is open (MTO210)	Interlock Jumper removed, attached interlock circuit broken, internal cable disconnected
1XX	<i>Ethernet and top panel errors</i>	
101	No link between top panel and lower acquisition board	
102	Ethernet communication failed	Check connection Started acquisition before Ethernet link established.
110	Current selection switch error	
111	Function Mode switch error	
112	Storage Mode Switch errors	
113	I2C BUS error	
114	LCD I2C bus error	
115	LED I2C bus error	
116	MUX I2C bus error	
117	EEPROM failure	
2.0	<i>Initialization error</i>	
201	ADC internal zero calibration failure	

CODE	Error Description	Possible Cause
202	ADC internal full-scale calibration failure	
203	Onboard 5 volt supply out of range, too high	
204	Onboard 10 volt out of range, too high	
205	Onboard 28 volt out of range, too high	
206	VICOR power supply temperature is out of range	
207	Discharge circuit temperature is out of range	
208	2.5V reference is out of range	
209	Zero reference is out of range	
210	25V reference is out of range	
211	VICOR power supply failed to regulate at 5 volts	
212	VICOR power supply failed to regulate at 20 volts	
213	VICOR power supply failed to regulate at 40 volts	
214		
215	VICOR power supply control loop circuit failed	
216	Too much voltage ripple for the 5 volt supply	
217	Too much voltage ripple for the 10 volt supply	
218	Too much voltage ripple for the 28 volt supply	
221	Too much voltage ripple for the 2.5 volt reference	

CODE	Error Description	Possible Cause
222	Too much voltage ripple for the 25 volt reference	
223	Too much voltage ripple for the VICOR power supply at 5 volts	
224	Too much voltage ripple for the VICOR power supply at 20 volts	
225	Too much voltage ripple for the VICOR power supply at 40 volts	
226	UNDER status input failed	
227	OVER status input failed	
228	EEPROM byte writing error	
229	EEPROM byte reading error	
230	EEPROM is uninitialized	
231	Discharge temperature too much ripple	
232	5V5 voltage out of range	
233	5V5 voltage too much ripple	
234	VICOR power supply failed at 5v, voltage too high	
235	VICOR power supply failed at 5v, voltage too low	
236	VICOR power supply failed at 20v, voltage too high	
237	VICOR power supply failed at 20v, voltage too low	
238	VICOR power supply failed at 40v, voltage too high	
239	VICOR power supply failed at 40v, voltage too low	
240	VICOR power supply failed at loop test,	

CODE	Error Description	Possible Cause
	voltage too low	
241	Onboard 10v out of range, voltage too low	
242	Onboard 28v out of range, voltage too low	
243	Discharge temperature is out of range, too high	Unit overheated, fans filters clogged, fans not working, overuse, extremely hot test conditions
244	VICOR temperature is out of range, too high	Unit overheated, fans filters clogged, fans not working, overuse, extremely hot test conditions
245	VNOISE voltage out of range, too low.	
246	VICOR temperature too much ripple	
3.0	<i>ADC_ERROR</i>	
301	ADC reading times out or ADC locks up	
302	Internal error. Communication with ADC failed.	
303	ADC sample rate setting failed	
304	ADC internal zero cal failed	
305	ADC internal full-scale calibration failed	
306	ADC cannot be restored back to normal mode	
307	ADC channel 1 selection failed	
308	ADC channel 2 selection failed	
309	ADC channel 3 selection failed	
310	Too much noise/ripple on ADC readings	
311	ADC failed, initialization	
312	ADC failed, run time	

CODE	Error Description	Possible Cause
313	ADC locks up, can not read	
314	ADC channel 4 failed	
4.0	<i>HARDWARE_ERROR</i>	
401	Discharge takes too much time	
402	VICOR protection failed, OVER is too long or too short to reset	
403	VICOR protection failed, OVER is too long or too short to set	
404	VICOR fast protection failed, OVER is too long or too short to reset	
405	VICOR fast protection failed, OVER is too long or too short to set	
406	Current Regulation failed at DAC=0	
407	Current Regulation failed at 10mA range	
408	Current Regulation failed at 100mA range	
409	Current Regulation failed at 1A range	
410	Current Regulation failed at 10A range	
411	Current output not high enough	
412	Too much ripple for Lamp On	
413	Too much ripple for Lamp Off	
414	Test Lamp voltage is too low	
415	Test Lamp voltage is too high	
416	Warning Lamp test failed	
417	Remote lamp test failed	
418	Relay test K1 on and K2 on failed	

CODE	Error Description	Possible Cause
419	Relay test K1 off test failed	
420	Relay test K2 off test failed	
421	Relay test K3 on and K4on failed	
422	Relay test K3 off test failed	
423	Relay test K4 off test failed	
465	OVER and UNDER failed during winding resistance test	
466	Current calibration failed during winding resistance test	
467	Voltage calibration failed during winding resistance test	
468	Received abort signal	
469	System zero cal failed during current regulation	
470	No current setting has been set for current control.	
471	Current is flat or dropping while charging	Current leads not connected
472	Break before make error	Lead removed during testing. >10% current change during testing.
473	H1+ failed, Vrelay3 failed	
474	X3+ failed, K9 failed	
475	I-SENSE failed	
476	Auto-range, resistance is too high	
477	Auto-range, current failed	
478	Auto-range, current standard deviation too high	

CODE	Error Description	Possible Cause
479	Auto-range, voltage is too low	
480	Current = 0	
481	Over didn't stay set for normal transistor protection test	
482	Over didn't stay set for fast transistor protection test	
483	Transistor protection med-low failed, OVER is too short to reset	
484	Transistor protection med-low failed, OVER is too short to set	
485	Fast transistor protection high failed, OVER is too short to reset	
486	Fast transistor protection high failed, OVER is too long to set	
487	Fast transistor protection high failed, OVER is too short to set	
488	Current Regulation failed at 10mA range, too low	
489	Current Regulation failed at 100mA range, too low	
490	Current Regulation failed at 1A range, too low	
491	Current Regulation failed at 10A range, too low	
492	Relay K1 and K2 failed, current too low	
493	Relay K3 and K4 failed, current too low	
494	ESD Abort signal encountered	Switch pushed down during test
496	Vicor failed during charge	
497	Current rising too fast during charge	

CODE	Error Description	Possible Cause
498	Charge timeout error.	

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