

FRAX User's Manual

Version 2.4



Megger
Valley Forge Corporate Center
2621 Van Buren Avenue
Norristown, PA 19403 U.S.A.

www.megger.com

for
Sweep Frequency Response Analyzer
FRAX 99, 101 and 150

Notice of copyright & proprietary rights
© 2010 Megger Sweden AB. All rights reserved.

The contents of this manual for FRAX 2.4.2150 are the property of Megger Sweden AB. No part of this work may be reproduced or transmitted in any form or by any means, except as permitted in written license agreement with Megger Sweden AB. Megger Sweden AB has made every reasonable attempt to ensure the completeness and accuracy of this document. However, the information contained in this manual is subject to change without notice, and does not represent a commitment on the part of Megger Sweden AB. Any attached hardware schematics and technical descriptions, or software listings that disclose source code, are for informational purposes only. Reproduction in whole or in part to create working hardware or software for other than Megger Sweden AB products is strictly prohibited, except as permitted by written license agreement with Megger Sweden AB.

TRADEMARK NOTICES

FRAX is a trademark of Megger Sweden AB. All other brand and product names mentioned in this document are trademarks or registered trademarks of their respective companies.

USER'S MANUAL

Table of Contents

1 FRAX	1
1.1 Markings	2
1.2 FRAX Technical Specifications	2
1.3 Instrument Panels	4
1.4 Bluetooth Communication (only FRAX-101)	8
1.5 Built-in Battery Pack and Charger (only FRAX-101)	10
1.6 Sweep Frequency Response	11
1.7 Calibration	12
1.8 Disposal	12
2 Quick Start Tutorial	12
2.1 Safety First	12
2.2 Preparatory Procedures	13
2.3 Start Up FRAX and Establish Communication	14
2.4 Create a New Test	14
2.5 Test Lead Connection	15
2.6 Test System Verification	17
2.7 Start Measurement	20
2.8 View Data	21
2.9 Export Data	21
3 Installing FRAX Software	21
3.1 PC Requirements (FRAX-101 only)	22
3.2 FRAX150 Onboard Computer Update	22
3.3 Welcome Screen	22
3.4 License Agreement	23
3.5 Already Installed	23
3.6 Installation Location	23

3.7 Shortcuts Screen	24
3.8 Installation Progress	25
3.9 Installation Complete	25
4 FRAX Software	26
4.1 File Menu	27
4.2 Edit Menu	40
4.3 Configuration Menu	41
4.4 Windows Menu	57
4.5 Action Buttons	58
4.6 Legend	60
4.7 Views	63
5 Appendices	65
5.1 Appendix A: Calibration Instruction	65
5.2 Appendix B: Optional Active Probes (FRAX-101 only)	71
5.3 Appendix C: Adjusting Output Voltage	77
5.4 Appendix D: Sweep Name Settings	78
5.5 Appendix E: FRAX cables and clamps	83
5.6 Fuse Replacement	92

1 FRAX

Congratulations on your choice of FRAX Sweep Frequency Response Analyzer by Megger. We at Megger have done our best and will continue do our best to satisfy our customers. Please visit our home page at www.paxdiagnostics.com and do not hesitate to contact us directly.

Most dielectric and mechanical failures in large power transformers are preceded by mechanical changes in the winding structure. These displacements in the winding structure may be the result of transportation damage, short circuit forces, or natural aging effects on the insulating structures used to support the windings. Detection of these displacements before dielectric failure reduces maintenance costs, and improves system reliability.

FRAX Sweep Frequency Response Analyzer (SFRA) is designed to detect winding displacements in power transformers or faults in the magnetic core. The system provides attenuation signature curves that can easily be compared for deviations which indicate:

- Core movements
- Winding deformations and displacements
- Faulty core grounds
- Partial winding collapse
- Hoop buckling
- Broken or loosened clamping structures
- Shorted turns and open windings

Unique features of FRAX:

- High accuracy
- Small size and low weight
- Powerful analysis tools that are intuitive and easy to use
- Wireless, Bluetooth, communication between laptop and instruments allows flexibility in the field (FRAX-101 only)
- Galvanic isolated USB interface for personnel and equipment safety
- Built-in PC with powerful backlit screen for use in direct sunlight (FRAX150 only)

More safety and technical details are given in the following sections:

- Markings
- FRAX Technical Specifications
- Instrument panels: Front, Rear
- Sweep Frequency Response
- Test System Verification
- Calibration
- Disposal

1.1 Markings



WARNING, risk of personal injury

Warning is defined as a condition or practice which could result in personal injury or loss of life. Refer to the user to the manual where all warnings are described in detail.



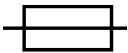
CAUTION, risk of damage/destruction to equipment

Caution is defined as a condition or practice which could result in damage to or destruction of the equipment or apparatus under test. Refer to the user to the manual where all cautions are described in detail.



Protective earth (ground)

To identify any terminal which is intended for connection to an external conductor for protection against electric shock in case of a fault, or the terminal of a protective earth (ground) electrode.



Fuse

To identify fuse boxes or their location.

1.2 FRAX Technical Specifications

General

FRA Method:	Sweep frequency (SFRA)
Frequency Range:	1 Hz - 10 MHz, user selectable
Extended Frequency Range:	0.1 Hz - 25 MHz, user selectable
Number of Points:	User selectable, maximum 32,000
Points Spacing:	Logarithmic, linear or combination of both
Dynamic Range/Internal Noise:	Dynamic Range/Internal Noise: >130dB (FRAX-99 >115dB). Extended range >110dB
Accuracy:	±0.5 dB (FRAX-99 ±1 dB) down to -100dB
IF Bandwidth/Integration Time:	User selectable
Software:	FRAX for Windows 2000/XP/Vista
PC Communication:	Bluetooth (FRAX-101) and galvanic isolated USB
Calibration Interval:	Maximum 3 years
Standards:	Fulfill requirements in CIGRE Brochure 342, Mechanical Condition Assessment of Transformer Windings using FRA and Chinese standard DL/T 911-2004, FRA on Winding Deformation of Power Transformers

Analog Output

Channels:	1
Compliance Voltage:	0.2 - 20 V peak-to-peak
Measurement Voltage at 50 Ohm	0.1 - 10 V peak-to-peak
Output Impedance:	50 Ohms
Protection:	Short-circuit protected

Analog Inputs

Channels:	2
Sampling:	Simultaneously, 100MS/s
Input Impedance:	50 Ohms

Physical

Instrument Weight 1.4 kg/3.1 lsb, 1.9 kg (FRAX-101 with Battery)

Dimensions 6 kg (13 lb) (FRAX-150)
250 x 169 x 52 mm (9.84 x 6.65 x 2.05 in.)

305 mm x 194 mm x 360 mm (12 in. x 7.6 in. x 14.2 in.) (FRAX-150)

Input Voltage 90-135VAC and 170-264VAC, 47-63 Hz

Environmental

Operating Ambient Temperature: -20° to 50°C (-4 to 122°F)
Bluetooth 0° to 50°C (FRAX-101)
0° to 50°C (32 to 122°F) for FRAX-150
Weather and rain resistant to IP54 with top cover closed (FRAX150)

Operating Relative Humidity: < 90% non-condensing

Storage Ambient Temperature: -20° to 70°C

Storage Relative Humidity: < 90% non-condensing

CE Standards: IEC61010-1 (LVD) EN61326-1 (EMC)

Specifications are subject to change without notice.

1.3 Instrument Panels

1.3.1 FRAX-101/FRAX-99

1.3.1.1 Front Panel



Left-hand side, top down:

- On/Off: On/Off-switch, to turn the instrument On/Off, Switch labeled I (On) and 0 (Off).
- DC Input: DC-input, to connect the AC/DC adapter.
- USB: USB-connector type B, to connect a USB cable to PC
- Antenna (only FRAX-101): Bluetooth module, enables Bluetooth communication

Right-hand side, top down:

- Generator (Yellow): Generator output connected to Reference at Red Clip
- Reference (Red): Reference input connected to Generator at Red Clip
- Measure (Black): Measure input Connected to Black Clip
- Protective Earth/Ground symbol and Protective Earth/ Ground connector Always connect the instrument to station earth/ground using the separate earth/ground cable. The separate earth/ground wire should be the first connection made and the last removed.
- Probe Connector for active probes. Optional and available on order for FRAX-101 only.
- Caution, risk of danger symbol Refers to instructions stated in User's Manual to ensure safety. See Markings.

1.3.1.2 Rear Panel



Left-hand side, top down:

- Informative text
- Serial number

Right-hand side, top down:

- DC input
- CE-mark
- Calibration date

DC-input, to connect the double insulated AC/DC adapter.
DC symbol. Polarity Symbol.

Megger guarantee that this product complies with relevant CE directives and corresponding standards.

1.3.2 FRAX-150



Left-hand side, top down:

- USB: USB-A connectors (2x)
- Network: For connecting the FRAX150 to LAN
- Serial port: For RS232 serial communication.

Right-hand side, top down:

- Protective Earth/Ground connector and symbol Always connect the instrument to station earth/ground using the separate earth/ground cable. The separate earth/ground wire should be the first connection made and the last removed.
- Caution, risk of danger symbol Refers to instructions stated in user manual to ensure safety. See Markings section.
- Power connector
- Generator (Yellow): Generator output
- Reference (Red): Reference input
- Measure (Black): Measure input

Below the screen is a standard qwerty keyboard containing some special keys.



Tab









Backspace (or with shift) Delete



Shift key

On the right of the screen are some function buttons. They are

-  Power down. Shuts down the FRAX150.
-  Home (not used)
-  Help
-  Information (not used)
-  Page Up
-  Page Down

On the right you will find the navigation panel.



In the middle of the navigation panel you will find the controls for the pointer and buttons for left (top) and right click (bottom). The navigation panel also contains:



Test button. Press this to start a new test or measurement. This button has the same functionality as the "Start" button on the FRAX-150 screen.



Arrow buttons and center Enter button

There is a momentary pushbutton switch on the back of the unit that is required for firmware updates only.

1.4 Bluetooth Communication (only FRAX-101)

Bluetooth is a standard for wireless serial communication. Simply speaking, Bluetooth replaces a serial cable between your laptop and the FRAX instrument.

The output power of Bluetooth modules are divided into three classes:

Power Class	Max Output Power	Expected Range
Class 1	100 mW	100m / 330 feet
Class 2	2.5 mW	10 m / 33 feet
Class 3	1 mW	1m /3.3 feet

The Bluetooth module used in FRAX-101 is class 1. Also, the Bluetooth USB Adapter that comes as a standard accessory with FRAX is class 1. Using this adapter communicating with FRAX, you will get class 1 communication.

Many laptops of today has in-built Bluetooth capability, most common is class 2. Since the Bluetooth module used in FRAX-101 has excellent receiving properties, a built-in Bluetooth device may be suitable in many situations. However in field/substation environments Bluetooth class 1 is recommended.

To configure a built-in Bluetooth device, please follow the manufacturers instruction. To configure the Bluetooth USB Adapter that comes with the FRAX, install the included Bluetooth software *before* you insert the adapter into the USB-port.

Note, it is reported that in some cases an activated built-in Bluetooth and using an external USB Bluetooth Adapter can create some conflicts in Windows. If this happens, uninstall both adapters and reinstall only the one you plan to use.

First time you communicate with FRAX via Bluetooth, you need to establish your Bluetooth communication before attempting to connect the FRAX Software to the FRAX instrument. The following steps show how to add a connection between the FRAX instrument and the computer using the Anycom USB-250 Bluetooth USB Adapter. Please note that the procedure is managed by your operating system directly. Thus, the procedure necessary on your computer may differ from the following steps, and it should be regarded as an example.

- Start the My Bluetooth Places application and click on "Add Bluetooth Device"



- Add the device called "PAX Diagnostics".

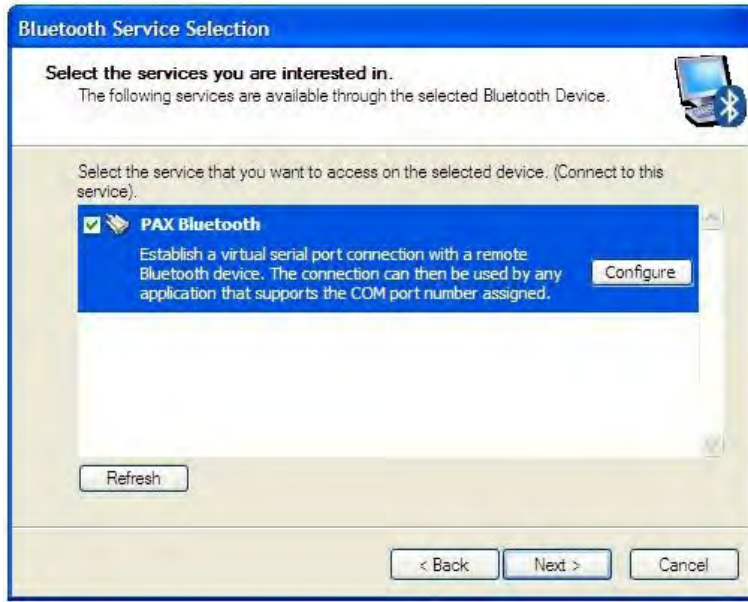


PAX Diagnostics FRAX-101
Unknown: Major(31), Minor(0)

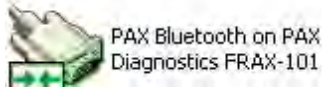
- A pass code is needed. Enter the code "0000" (four zeroes) as the pass code.



- Select the PAX Diagnostics device.



- Make sure that it is registered as a serial connection.



You can now connect to your FRAX unit from the FRAX software.

Observe that the procedure described above only needs to be done once. Next time you start the computer simply insert the USB adapter using same USB port or use built-in Bluetooth. Important! If you install the external USB dongle in a different USB port on your computer, you may get a different serial COM port assigned to that USB port. Either connect to your other USB port or change the COM port in the FRAX communication setting. Then start FRAX software and press connect.

1.5 Built-in Battery Pack and Charger (only FRAX-101)

As an option, FRAX-101 is delivered with a built-in battery pack and charger. The battery is of Li-Ion type, 4.8Ah, 11.1V. The charger is powered from the standard AC/DC adapter that is delivered with the instrument.

FRAX-101 automatically enters low power consumption mode when waiting for a measurement and because a typical sweep takes approximately 1 minute, the battery lasts for at least 3 hours of measuring or more than 12 hours idle.

Charging is performed automatically when the AC/DC adapter is connected. The FRAX-101 does not have to be turned on. To ensure long battery life, batteries will not be charged if the battery charge is higher than 90% or if the temperature is above 40C. A complete charge takes approximately 8 hours.

The blue LED gives indication of charging status:

LED not lit: FRAX turned off, or FRAX is switched on, battery empty.

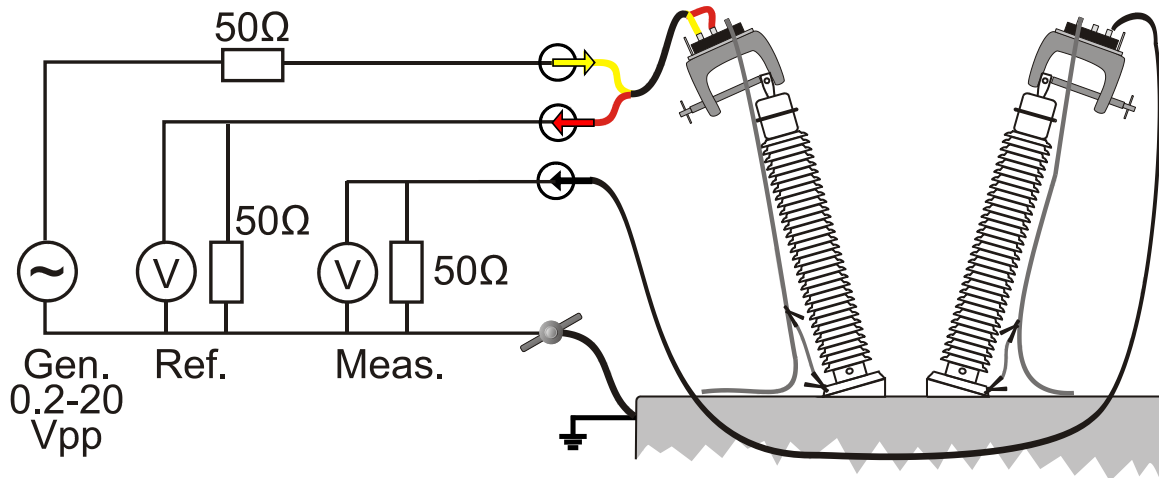
LED blinking: Charging

LED lit: FRAX connected to AC/DC adapter, Battery is fully charged (or charging disabled of other reason see above)

LED lit: FRAX runs on batteries (AC/DC adapter not connected)

1.6 Sweep Frequency Response

The FRAX "Generator" (Gen.) generates a sinusoidal voltage at a selected frequency and measures the input voltages, amplitude and phase, on two input channels "Reference" (Ref.) and "Measure" (Meas.). The instrument stores "Amplitude" and "Phase" data for both "Reference" channel and "Measure" channel as well as the ratio "Measure" divided by "Reference". The values can be plotted and exported as Magnitude, Phase, Impedance, Impedance-Phase, Admittance and more. The Custom models function make it possible to calculate almost any parameter based on the measured/stored data.



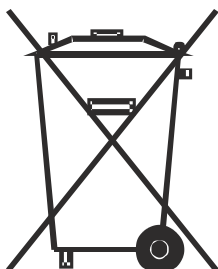
FRAX uses the sine correlation technique. This means that the input voltages are multiplied by a sine and a cosine, and then averaged over an integer multiple of the interval of time. The sine, cosine and the voltage applied have exactly the same frequency. The sine correlation technique is well known and is suitable for Sweep Frequency Response Analysis (SFRA) measurements. Since the signals on the two input channels are treated the same way, the phase resolution between these two channels is very high. The rejection of DC offset and harmonics - referred to as the applied voltage - are in theory infinite. By increasing the integration cycles, the rejection gradually improves.

The IF Bandwidth is commonly used as a parameter defining the bandwidth around the applied signal analyzed. An IF bandwidth of 10% of active frequency is equivalent to 12 cycles of integration.

1.7 Calibration

The instrument is calibrated before leaving the factory. The recommended calibration interval is three (3) years. The instrument can be calibrated by Megger or any calibration institute that follows the calibration instruction given in Appendix A, Calibration Instructions.

1.8 Disposal



FRAX and its accessories are all manufactured after August 12, 2005. Megger is responsible for the disposal of old FRAX units. The FRAX unit can be sent back to Megger for disposal at any time at no additional charge.

2 Quick Start Tutorial

This tutorial provides an introduction on how to use FRAX and FRAX software. They are intentionally kept brief so that you can start using the instrument and software as quickly as possible. The objective is not to teach you every single detail but to familiarize you with the basic principles.

The quick start tutorial is divided into the following sections:

- Safety First
- Preparatory Procedures
- Start Up FRAX and Establish Communication
- Create a New File
- Test Lead Connection
- Start Measurement
- View Data
- Export data

2.1 Safety First



FRAX is a Sweep Frequency Response Analyzer designed for measuring power transformers in the field and at manufacturing sites.

- Always follow local safety regulations.
- Make certain that all personnel who work with FRAX instrument have been trained in its use and that all applicable safety precautions are taken.
- Always connect the instrument to protective earth/ground using the separate earth/ground cable. The earth/ground cable should be the first connection made and the last removed.
- Do not use any accessories that are not intended to use with the FRAX.
- Refer all servicing to qualified personnel.

2.2 Preparatory Procedures



- Always follow local safety regulations!
 - The transformer must be disconnected from the net, which means that any connection to the transformer bushings including neutral(s) must be disconnected.
 - The transformer tank must be properly grounded.
 - If the transformer is equipped with a Load Tap Changer (LTC), the position of the LTC will influence the FRA measurement. The recommendation is to put the LTC in the position to include all tap windings in circuit ("Extreme Raise" position), and note that this LTC position is used. If making measurements at several tap positions, make sure to note each tap position.
 - If the transformer is equipped with a De-Energized Tap Changer (DETC), the position of the DETC will influence the FRA measurement. The recommendation is to leave it at the nominal tap position unless otherwise specified. Make sure to note the DETC position in the Nameplate section of the software.
1. Connect the FRAX instrument to station earth/ground near the power transformer to be measured using the separate earth/ground wire (at bottom of transformer if instrument is operated beside the transformer, at another good connection to transformer at top of transformer if instrument is used on top of transformer). The separate earth/ground wire should be the first connection made and the last removed.
 2. Connect the test lead BNC connectors to the FRAX instrument, Generator (yellow), Reference (red) and Measure (black).
 3. Connect the AC/DC Adapter to the FRAX and a power source that meets local safety regulations *and* the AC/DC Adapter specifications *or* use optional in-built battery supply. (Only FRAX-101)
 4. Connect AC Line Cord to the FRAX150 and a power source that meets local safety regulations (FRAX150 only)
 5. If not using Bluetooth communication, connect the USB cable to the FRAX and your computer. (Only FRAX-101)
 6. Turn on the FRAX.
 7. Start FRAX-software on your PC (FRAX-101) or from the instrument desktop (FRAX-150) and establish communication, see Establish Communication.

2.3 Start Up FRAX and Establish Communication

If using Bluetooth communication (FRAX-101 only):

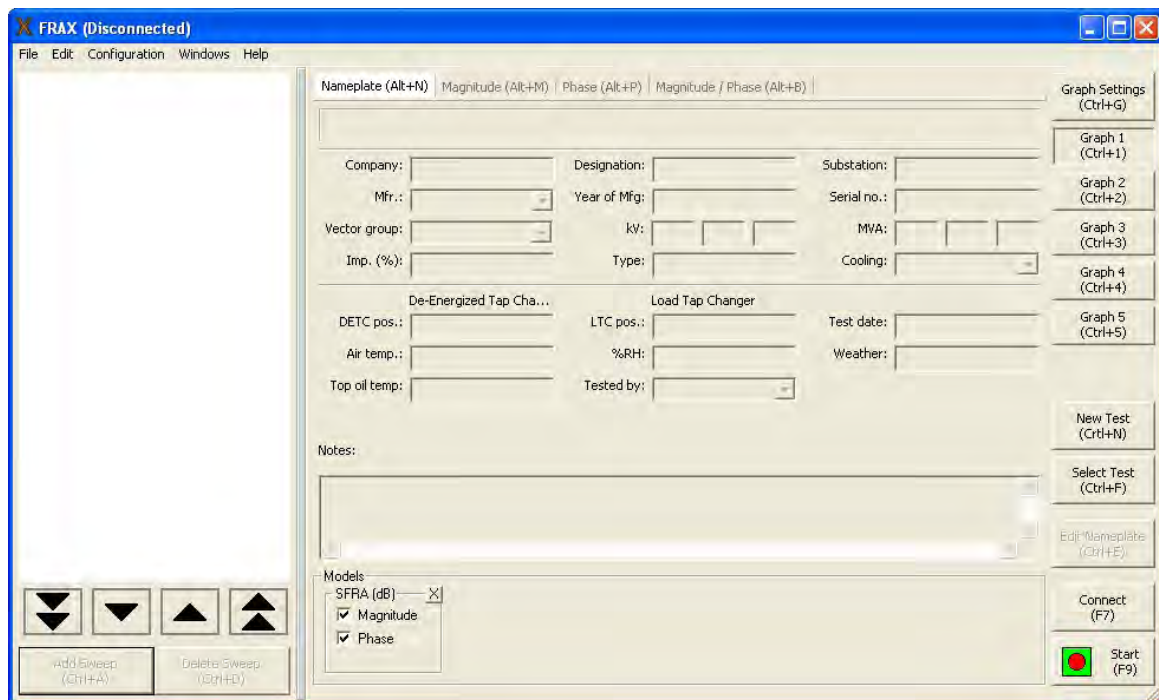
- Establish Bluetooth communication, see also detailed description Bluetooth Wireless Communication. Usually you will be assigned a serial port number, e.g. 8 that should be used when FRAX establish connection. Note that FRAX Software remembers the last used port.

If using USB communication (FRAX-101 only):

- connect the USB cable to the computer and to the FRAX
- the computer should display a message that it found new hardware

Start up the FRAX Software and establish communication

- Start up FRAX Software
- "Connect" by select Connect in under menu File, by clicking the Connect-button on the right hand side of window or use the F7-key. If connections are set-up properly the window name will change from "FRAX (Disconnected)" to FRAX (Connected). If the connection doesn't work, you will get an error message suggesting what to do, normally selecting the suggested port number with a green symbol next to it.



2.4 Create a New Test

A test starts by creating a sequence of sweeps and decide where to save data by use of "New Test".

- Use the command "New Test" from the File menu or use of Ctrl+N or use of the button "New Test".

The "Measurement type" window will appear. In "Measurement type" window, select the tab of your choice:

Quick Test	Makes a single sweep test with the Sweep label of your choice
Multiple Sweeps	Makes it possible to select a pre-defined test template or design "Sweep groups"
Use Measurement as Template	Makes it possible to use an earlier measurement as template for a new measurement

If you select the "Multiple Sweeps" tab you will be given a choice of different pre-defined templates for different transformer designs. Select Sweeps that you want to make and press OK. Note that you can always add new sets of sweeps with different names.

If you selected "Quick Test" or "Multiple Sweeps" in the "Measurement type" dialog, an almost empty nameplate will appear. The "Test date:" is automatically added from your PC system date. Please fill in the Nameplate data (no field is required) and press "OK". The selected measurement sweeps are visible in the in the Test Browser.

If the "Measurement type" "Use Measurement as Template" is used the Nameplate contains the Template Nameplate as default, except the "Test Date" that is automatically added from your PC system.

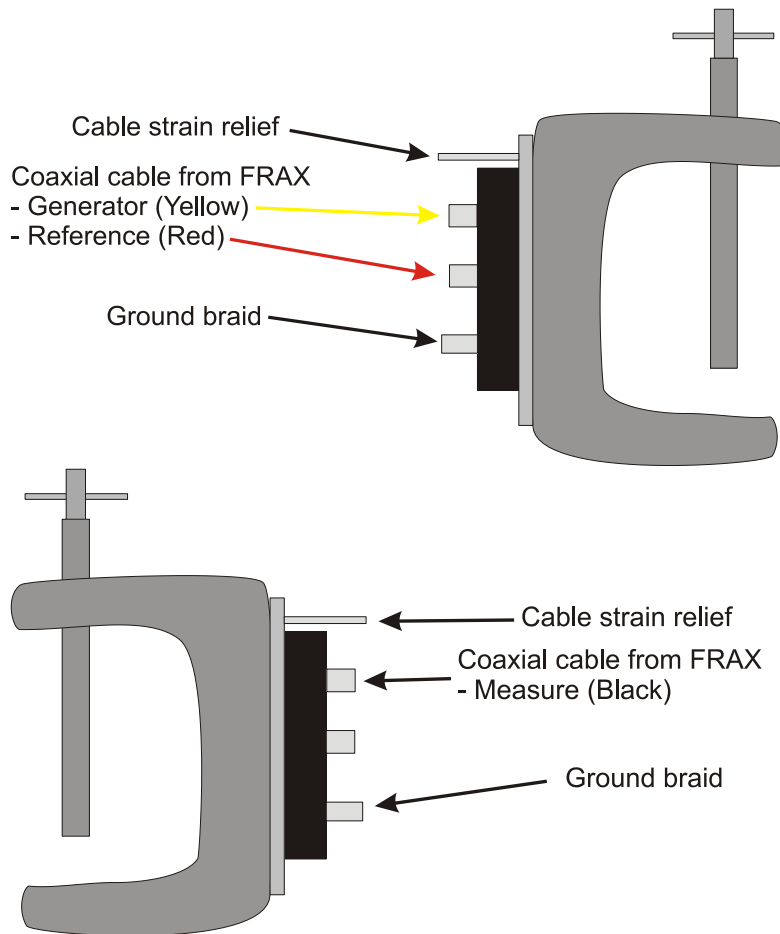
After enter Nameplate information and press "OK". A "Save As.." dialog where you can select the file structure and a name of your choice . The default directory will be *My Documents* on first start and then the directory you used last time. The file name will be formatted as selected in default filename settings. Click Save to save the file.

Note that you can always add information to the "Nameplate" at any time. This feature makes it possible to add notes during the measurement.

Fore more details see New Test in chapter FRAX Software, File menu.

2.5 Test Lead Connection

The new innovative FRAX clamp helps the user to connect and achieve repeatable test results in the simplest way possible. It handles both round and flat connectors and is easy to attach to any bushing. The firm grip allows heavy cables and accessories to be mounted near the bushing without any risk of the clamp falling off. The new clamp offers all necessary connectors (BNC, ground braid, cable strain relief) in one clamp. See Appendix E: FRAX cables and clamps.



Make sure to follow local safety regulations! Local safety regulations most certainly prescribe all bushing connections to be earthed/grounded when working on the transformer e.g. connecting the FRAX test leads. The ground braid shall go from the top clamp the shortest way to the bottom of the bushing. Good ground connection is essential.



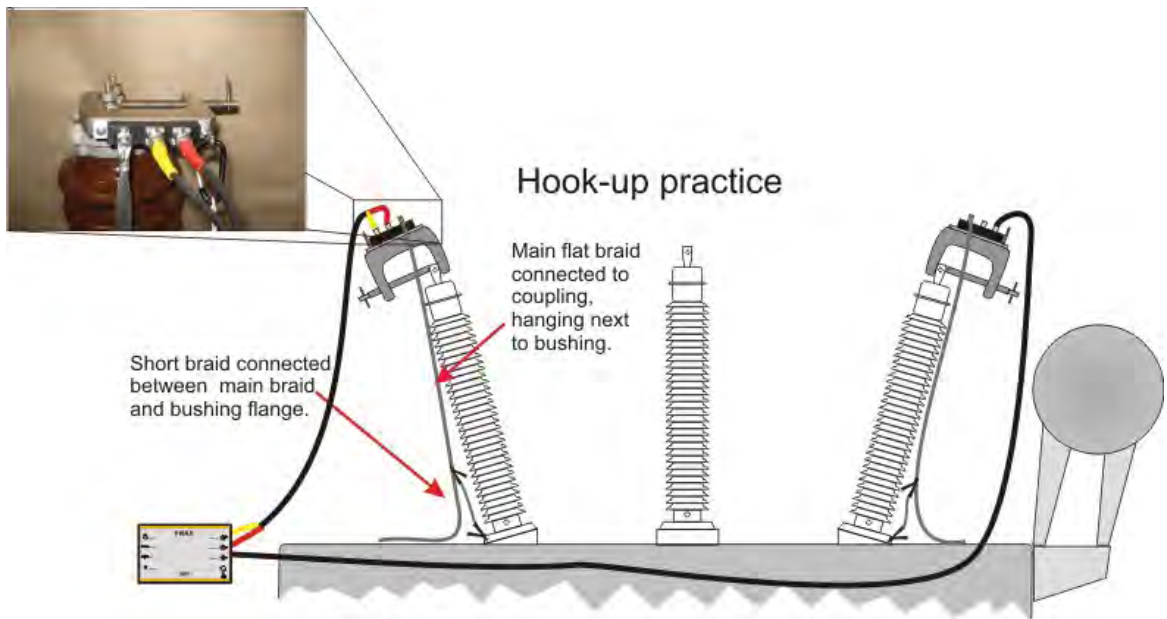
Important! The test connection polarity is important since reversed polarity will produce different results. The user has to establish a polarity convention. In this software it is assumed, and recommended, that H1-H0 imply the red/yellow connectors (source and reference) is connected to H1 and the black (measure) is connected to H0.

Connect FRAX test leads:

- Make sure to remove paint and or rust from the nuts or bolts used on the flange for proper measurement ground connections.
- Connect the red and yellow (source and reference) to the clamp at the top of a bushing and corresponding ground braid to the base of bushing. Make sure that the braid do not touch any conducting part at top of bushing.
- Connect the black (measure) lead to the clamp at the top of the other bushing and the corresponding ground braid to the base of bushing. Make sure that the braid do not touch any conducting part at top of bushing.

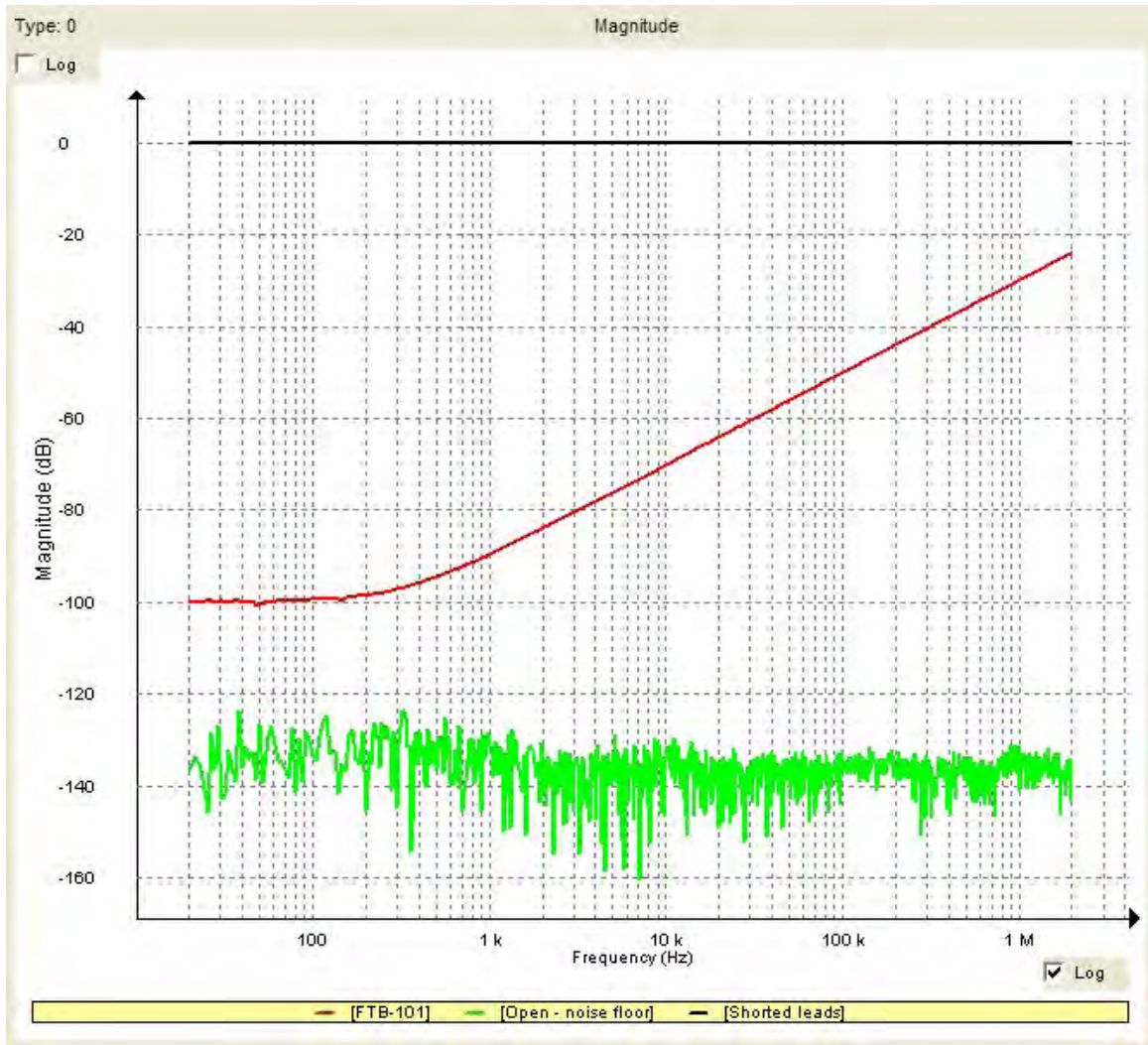
- Following local safety regulations, remove possible ground connections from top of the bushings.

Using an easy repeatable cable setup is crucial to ensure reliable FRA results.



2.6 Test System Verification

Test leads should be checked for continuity and integrity before use. The best means for checking lead integrity and correct operation of the equipment is to perform the FRA self-check using a standard test object. This check is especially valuable for checking FRA test equipment, since there is generally no intuitive way of knowing if the test equipment is giving correct results when making field measurements.



Here you can see the result of test measurements. Showing short circuit measurement (black)1), open circuit measurement using FRAX-101 (green)2) and FTB-101 measurement (red).

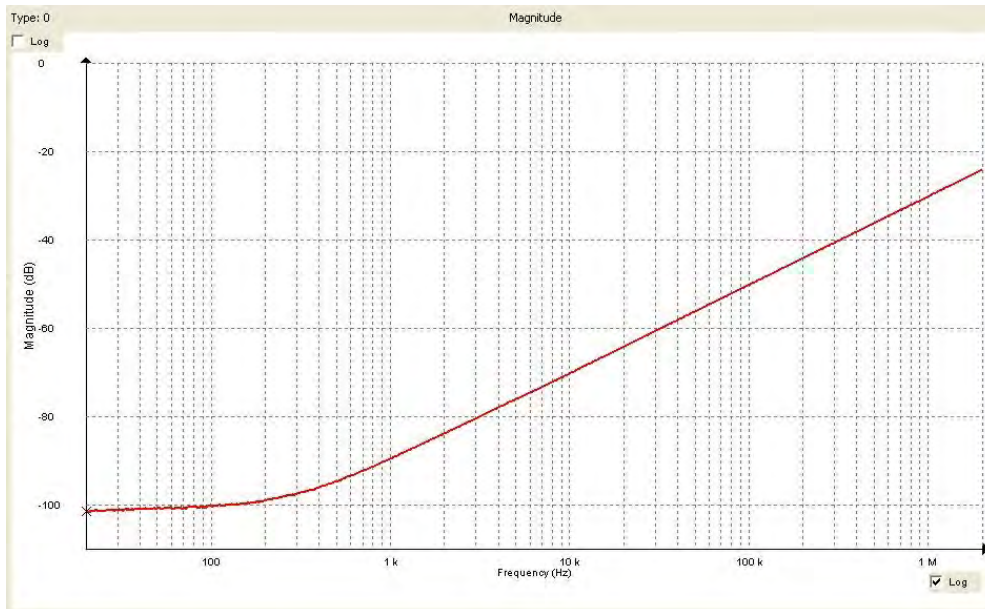
1) A simple test to check the integrity of test leads is a short circuit test. Simply connect the "Source"/"Reference" and "Measure" clips together and connect the respective measurement earth/grounds together. The result should be an almost straight line around 0 dB (black).

2) An open circuit measurement should in theory provide a 0-response, i.e. a minus infinity dB-response. However, all measurement systems have internal noise and the test leads will also add some response from open clips ends. Separate the "Source"/"Reference" clip from the "Measure" clip. The clip itself will give some influence at highest frequencies, if you disconnect the "Measure" coaxial cable from the FRAX unit you will see the noise in the measurement system (green).

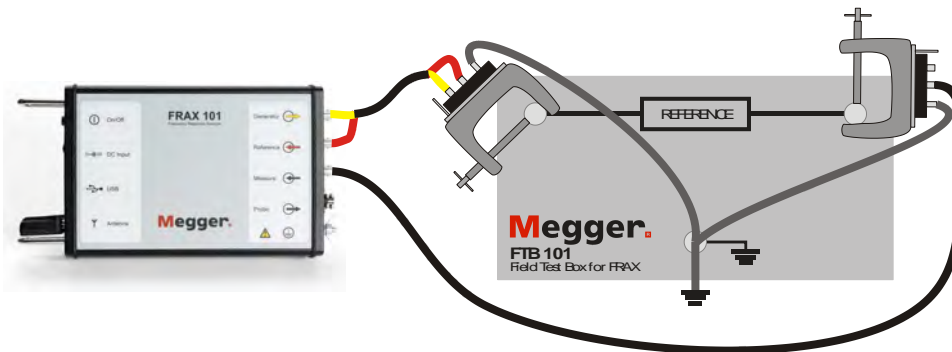
2.6.1 FTB-101



FTB-101 is a field test box that is intended to be used to verify the leads and the equipment as recommended by CIGRE and several others. Use the FTB-101 and make a test sweep. If the hook-up and the equipment is in good working order the sweep should look as the picture. You can compare the results with the file *FTB-101.frax* that is shipped with the FRAX software and is available from the installation folder, usually C:\Program Files\Megger\FRAX\Measurement examples (FRAX-101 only) or D:\Program Files\Megger\FRAX\Measurement examples.



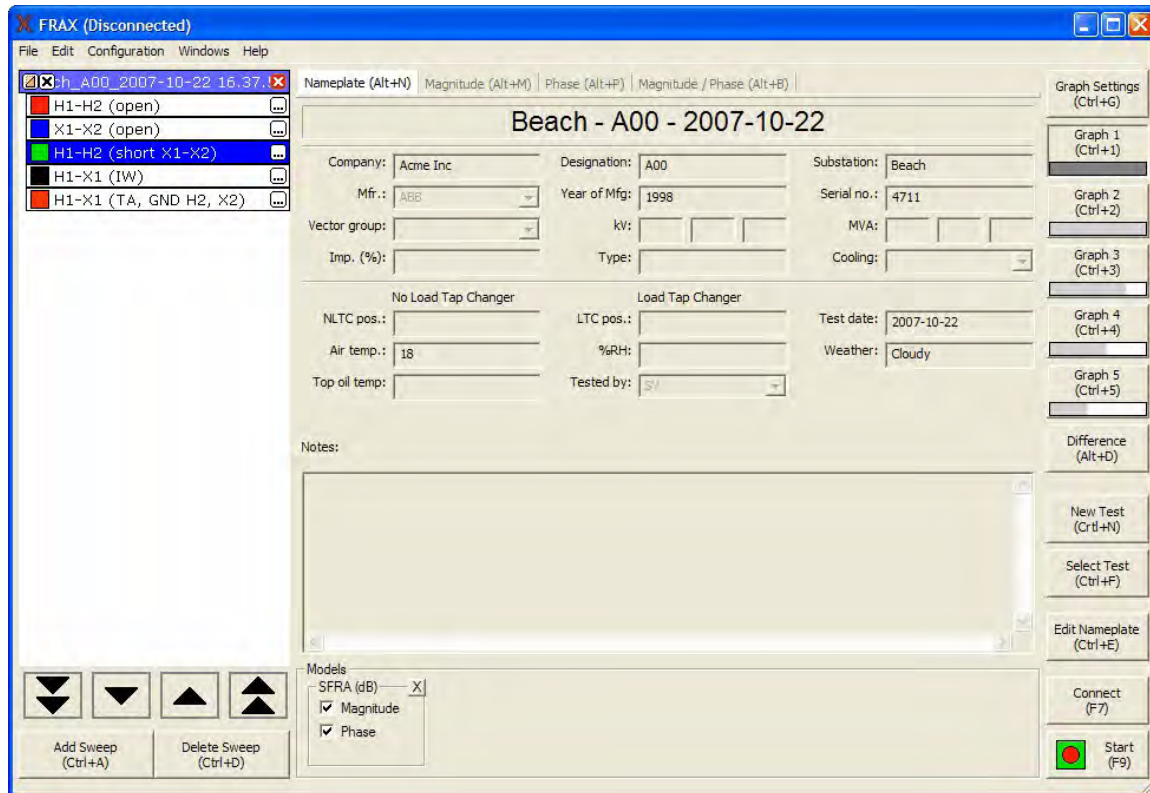
Use the FTB-101 and make a test sweep¹⁾. If the hook-up and the equipment is in good working order the sweep should look as the picture. You can compare the results with the file *FTB-101.frax* that is shipped with the FRAX software.



1) Connect the "Source"/"Reference" clip to the left-hand side connector and the braid from the clip to the bottom connector. Connect "Measure" clip to the right-hand side connector and the braid from the clip to the bottom connector. Also connect the bottom connector to ground/earth (otherwise the system will face some interference at 50/60Hz).

2.7 Start Measurement

Execute measurement by selecting a measurement in the Legend at the left side. In the picture below the blue color shows that H2-H1 (Open) is selected. Start the measurement by pressing the Start button, F9-key (FRAX-101 only), TEST button (FRAX-150 only) or selecting Start under the File menu.



2.8 View Data

You can view data in the FRAX Software, for more details try it out and see FRAX Software

2.9 Export Data

If you want to use the data in other software you can use the data files directly or export the data of your choice, see Export... under FRAX Software, File menu.

3 Installing FRAX Software

Please select one of the sub entries:

- PC Requirements
- FRAX150 Onboard Computer Update
- Welcome Screen
- License Agreement
- Installation Location
- Shortcuts Screen
- Installation Progress
- Installation Complete

3.1 PC Requirements (FRAX-101 only)

Operating system	Windows 2000, Windows XP or later
Processor	Pentium 500 MHz or higher
Memory	256 MB RAM or more
Hard drive	Minimum 30 MB free
Drive	CD-ROM
Interface	Bluetooth (FRAX-101 only) and USB

3.2 FRAX150 Onboard Computer Update

- Download software update from the Megger website to a USB Flash Drive (a.k.a. Thumb Drive) or other USB storage device.
- Insert Storage Device into either of the two USB connectors on left side of instrument.
- Click Windows START button and choose My Computer
- Navigate to downloaded update file and double-click to run.
- Then follow install instructions below.

3.3 Welcome Screen

Welcome to Megger Installer for FRAX.

To install FRAX Software press Next witch will bring you to License Agreement

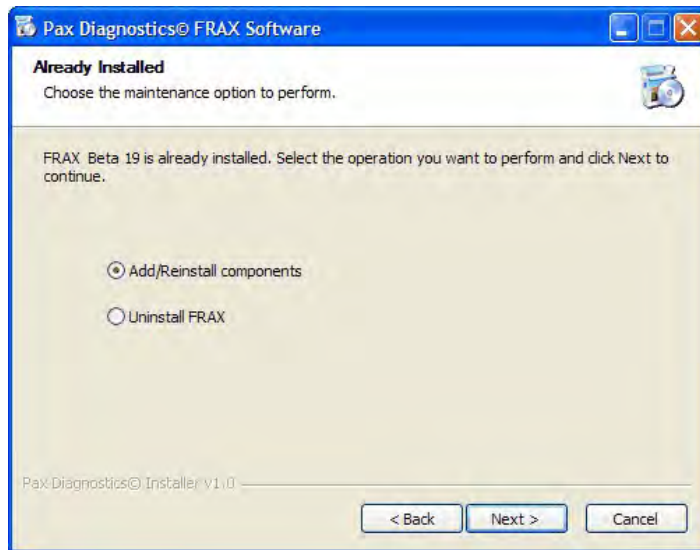


3.4 License Agreement

Read the license and check the "I accept the terms in the License Agreement" checkbox. This will enable the Next button. To continue the installation press Next. This will bring you to Installation Location.

3.5 Already Installed

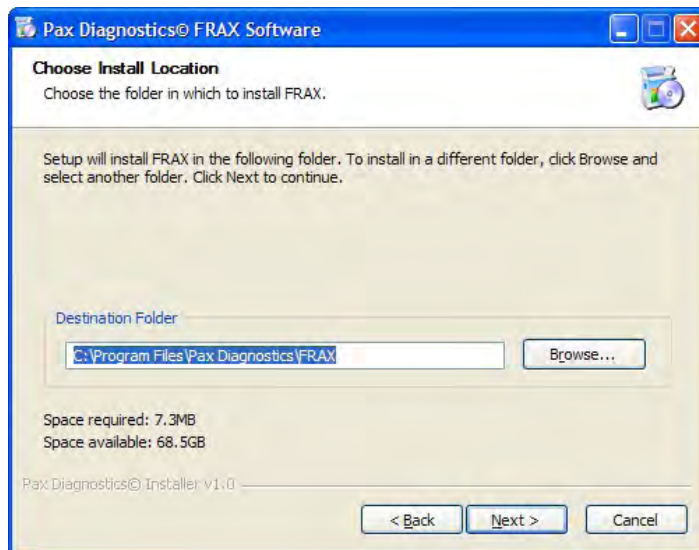
If the FRAX software is previously installed you are asked if you want to uninstall the older version or not. It is recommended that you uninstall the previously installed version before installing a new version. If you choose to keep the old version you have to specify a different directory for the new version.



3.6 Installation Location

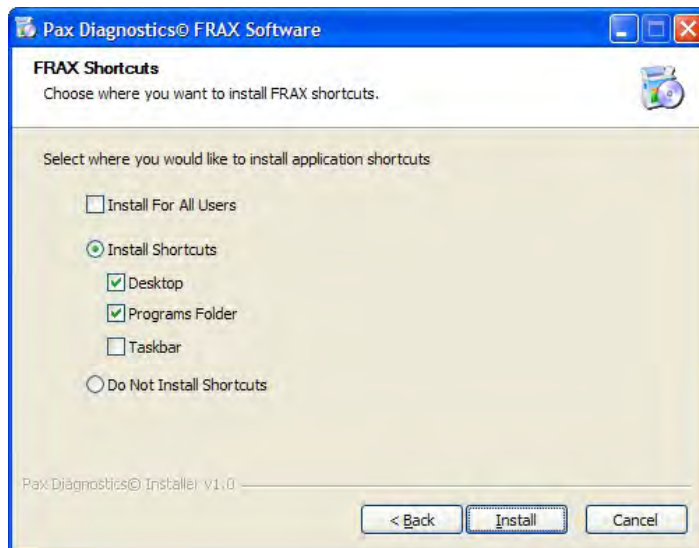
Select the location to which the FRAX Software will be installed. Make sure you have enough space available on your hard drive. To continue the installation press Next. This will take you to the Shortcuts Screen.

Note: FRAX-150 Install Location should be changed to: D:\Program Files\Pax Diagnostics\FRAX



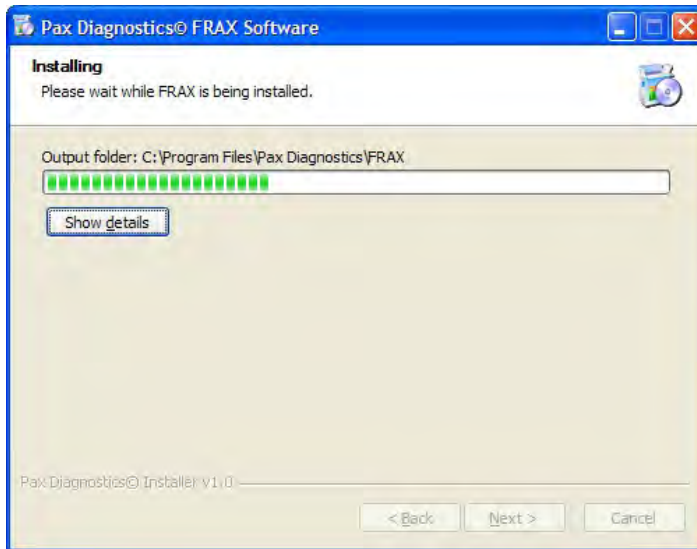
3.7 Shortcuts Screen

This is where you select the shortcuts to be installed. You are now ready to install the software. To install the application press Install. This will bring you to Installation Progress.



3.8 Installation Progress

The application executables and registry items are being installed. When the files has been installed you will automatically be transferred to Installation Complete.



3.9 Installation Complete

Congratulations!

The installation is now complete. You can now start the FRAX Software.



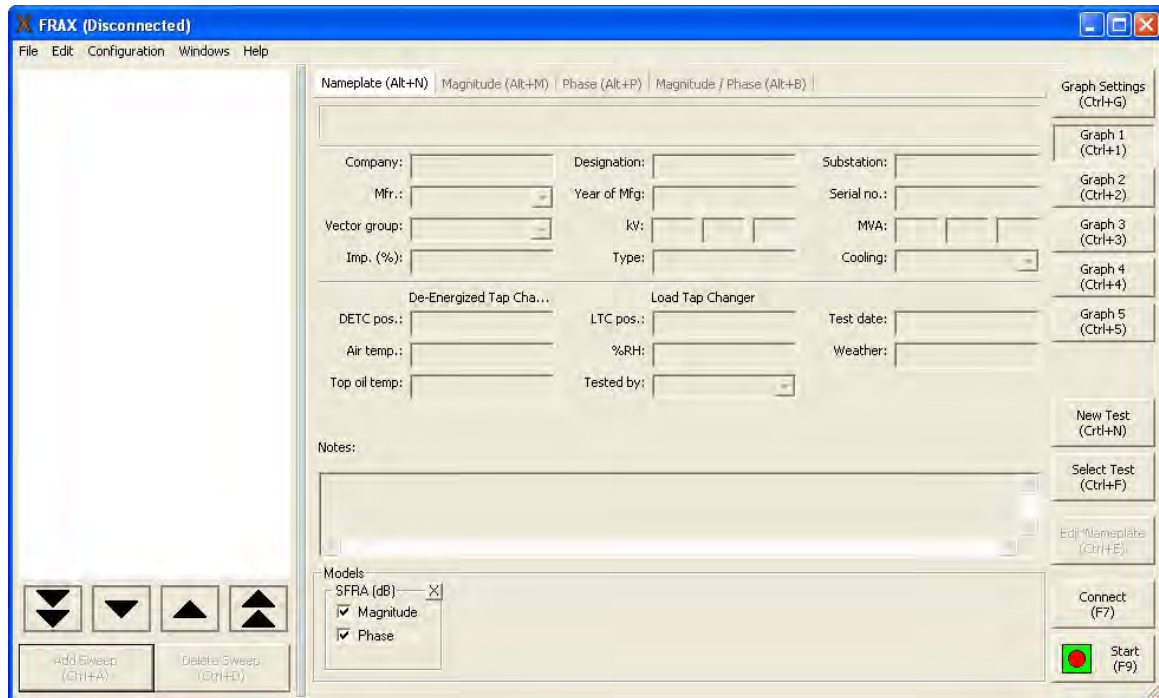
4 FRAX Software

The FRAX Main Window is shown below. In this section it is assumed that the FRAX software is installed and has started up properly. For issues regarding installation of FRAX Software, see section Installing FRAX Software.

The FRAX Software Main Window is divided into three sections:

- The test browser or Legend to the left (empty in screen shot below) with four arrow buttons for selecting Measurement File or Measurement Sweep in the test browser. Also the buttons Add Sweep and Delete Sweep are included in this section of the window.
- The large area in the middle presents the Nameplate, and the selected graph options in different tabs.
- The action buttons to the right can be used with touch screen, or mouse click. They are also assigned to specific keyboard shortcuts and all buttons except Graph 1 to Graph 4 can be selected in the File or Configuration menus.

Between the legend and the rest of the window is a splitter bar that can be used to adjust the relative size of the two parts of the window. Just drag it into the desired position and release it there. The resizing is limited to ensure that the program is usable at all time.



During the first six months the program will report all abnormal program terminations to our software department for debugging purposes.

4.1 File Menu

New Test...	Ctrl+N
Load Test...	Ctrl+L
Select Test...	Ctrl+F
Close Test	Ctrl+I
Report...	
Export...	Alt+E
Import...	Alt+I
Print...	Ctrl+P
Add Sweep...	Ctrl+A
Delete Sweep	Ctrl+D
Edit Nameplate...	Ctrl+E
Difference	Alt+D
Connect	F7
Disconnect	F8
Start Measurement	F9
Stop Measurement	F10
Recent files	
Exit	Alt+F4

Menu Command

New Test...	(Ctrl+N)
Load Test...	(Ctrl+L)
Select Test...	(Ctrl+F)
Close Test	(Ctrl+I)
Report...	
Export...	(Alt+E)
Import...	(Alt+I)
Print...	(Ctrl+P)
Add Sweep...	(Ctrl+A)
Delete Sweep	(Ctrl+D)
Edit nameplate...	(Ctrl+E)
Difference	(Alt+D)
Connect	(F7)
Disconnect	(F8)
Start Measurement	(F9)
Stop Measurement	(F10)
Recent files	
Exit	(Alt+F4)

Description

Creates a new measurement file to save data in
Loads a previous performed measurement file
Open the test database to be able to select one or more tests to open
Close a measurement file
Creates a report
Export active measurements to a *.csv or *.txt file
Load files in other file formats.
Makes a simple print-out of the currently selected tab.
Adds an additional sweep into a measurement file
Deletes a sweep (performed or empty) from a measurement file
Opens the measurements file nameplate to allow editing
Calculates the difference between two sweeps active in the graph and plot results
Connect the FRAX software to the FRAX instrument
Disconnect the FRAX software from the FRAX instrument
Start measurement of selected sweep in test browser
Stop active measurement
The latest files opened.
Terminates the FRAX Software

Note: FRAX150 keyboard does not provide Function keys. However all functions are available by selecting with joystick.

4.1.1 New Test ... (Ctrl+N)

The software requires a file and a folder location to save its data. The command "New Test" opens the "Save As" dialog.

4.1.1.1 Measurement Type

The first window appear in New Test is the Measurement type window

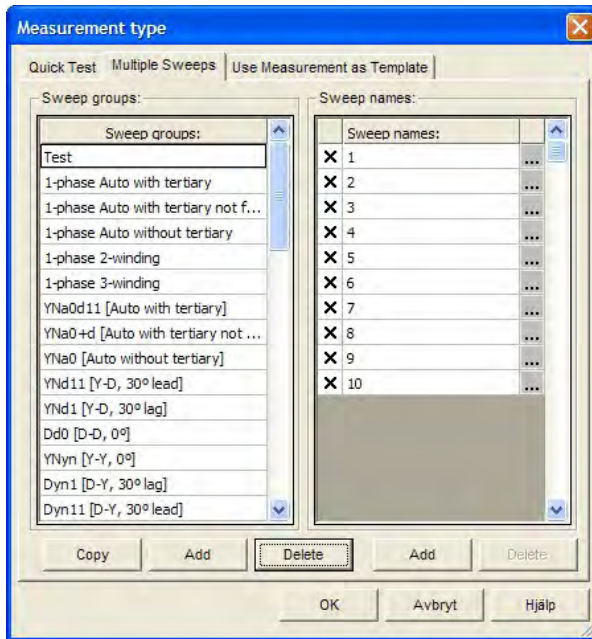
In "Measurement type" window, select the tab of your choice:

Quick Test	Make a single sweep test with the Sweep label of your choice
Multiple Sweeps	Make it possible to use and design "Sweep groups" containing one or more sweeps of your choice
Use Measurement as Template	Make it possible to use an earlier performed measurement as template for a new measurement

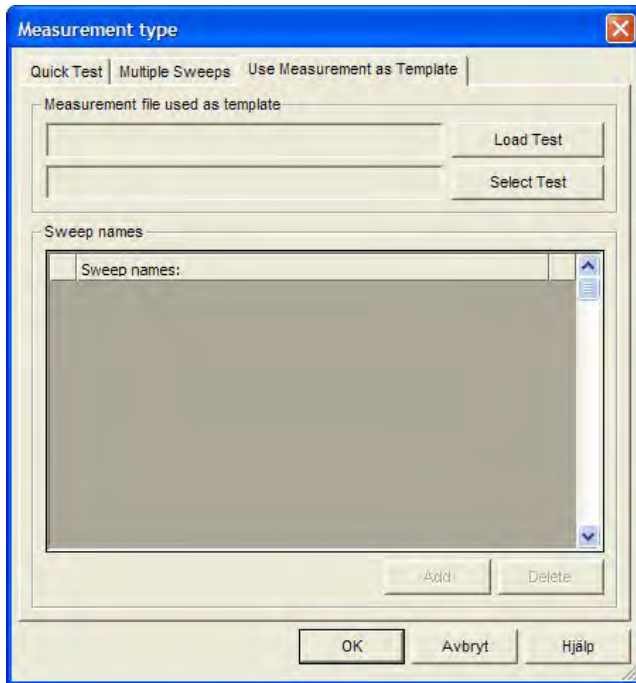
In the "Quick Test" tab, simply enter the "measurement name" of your choice and hit "OK".

In the "Multiple Sweeps" tab, you select one of the pre-defined test templates containing one or more sweeps. To modify the predefined sweep plans, use the buttons "Add" and "Delete". The names can be changed by selecting a "Sweep group" or "Sweep name" and enter a new name. Select a "Sweep group" and select which Sweeps that should be included by setting the cross in front of the sweep name(s) and then hit "OK". For more information see Appendix D

Note that the "Measurements Settings" in "Quick Test" and "Multiple Sweeps" are taken from the FRAX measurement settings.... in the configuration menu. However, you can change the "Measurement settings" sweep by sweep in the legend before performing the measurements.



In the "Use Measurement as Template" tab, you can select an earlier measurement as template for the new measurement. Hit the "Load File" button and load the Measurement file of your choice or use "Select Test" to find an earlier measurement in the database. The "Sweep names" in the selected previous measurement are shown. An "X" indicates the sweeps in the selected file were actually measured last time. Check or uncheck the sweeps you want to include and Press "OK". The sweep names and measurement settings used in the selected file are loaded.



4.1.1.2 Nameplate

If you select "Quick Test" or "Multiple Sweeps" in the "Measurement type" dialog, an almost empty nameplate will appear. The "Test date:" is by default filled in with your PC system date. Please fill in the Nameplate (no field is required). Press "OK". Note that you can always add or change information to the "Nameplate" by clicking the Edit Nameplate button. This feature makes it possible to add notes during measurement.

If "Measurement type" "Use Measurement as Template" is selected, the data from the selected file is entered automatically, except the test date that is filled in with your PC system date.

Nameplate data for: [Beach_A00_2007-10-22 16.37.52.pax]

Beach - A00 - 2007-10-22

Company: Acme Inc	Designation: A00	Substation: Beach
Mfr.: ABB	Year of Mfg: 1998	Serial no.: 4711
Vector group:	kV:	kVA:
Imp. (%):	Type:	Cooling:
No Load Tap Changer		Load Tap Changer
NLTC pos.:	LTC pos.:	Test date: 2007-10-22
Air temp.: 18	%RH:	Weather: Cloudy
Top oil temp.:	Tested by: SV	

Notes:

OK Cancel

4.1.1.3 Save As

Save As

Save in: FRAX Tests

My Recent Documents

Desktop

My Documents

My Computer

My Network Places

File name: 2006-12-16 16.35.53.pax

Save as type: FRAX Files (*.pax)

Save Cancel

The "Save As" dialog suggests a file name based on your selected format that you have chosen in configuration menu, submenu Default Filename Settings. The default directory will be *My Documents* on first start and then the directory you used last time. You can change the file name to a name of your choice and save the file in a directory of your choice. The file extension will always be ".frax". Click the "Save" button or hit the "Enter" key.

Note: When you save the file to the *My Documents* folder it will only be accessible for you. If several persons share the same computer and need to be able to view each other's measurements it is a good idea to instead save files to a common folder such as the *C:\Documents and Settings\All Users\Documents* directory.

4.1.2 Load Test... (Ctrl+L)

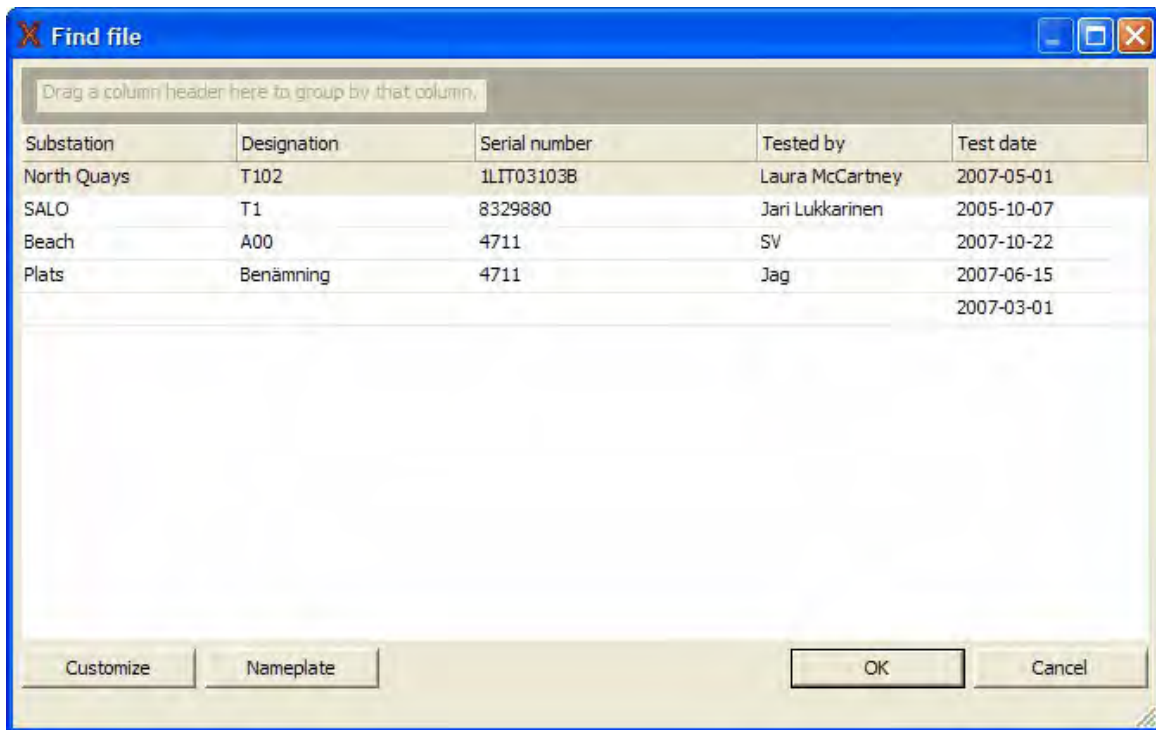
Loads a previously performed measurement into the graph view. The default directory will be *My Documents* on first start and then the directory you used last time.

The FRAX software comes with a few examples of actual SFRA measurements as well as a reference measurement using the FTB-101. They are located in the installation folder, usually *C:\Program Files\Megger\FRAX\Measurement examples*

4.1.3 Select Test... (Ctrl+F)

Find a previously performed test in the test database and load it into the graph view.

A dialog showing the files in the database will be shown.



By clicking on the column headings (Substation, Designation and so on) you can sort the list alphabetically according to that entry.

You can change the order of the columns by dragging the column header to your desired position or

drag them away to remove them. To add more headings click on the Customize button for a list.

To see the full nameplate of a test click the Nameplate button.

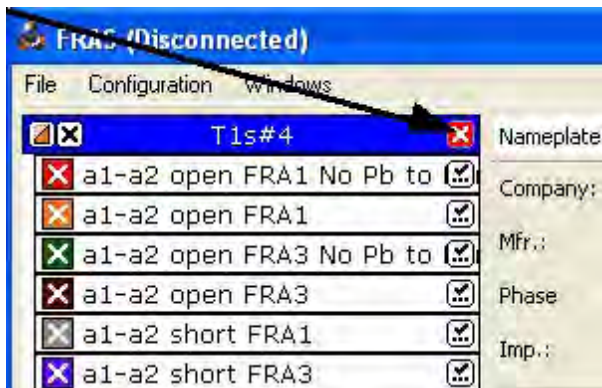
To group the tests according to any heading by dragging it into the gray area at the top.

The FRAX indexer works in the background and checks all monitored directories for new or changed files. When you open a file from a directory that is not indexed you will get a question if you want this directory to be indexed. If it is a directory with valid measurements you should answer yes if you want those files to show up in the Select Test database.

4.1.4 Close Test (Ctrl+I)

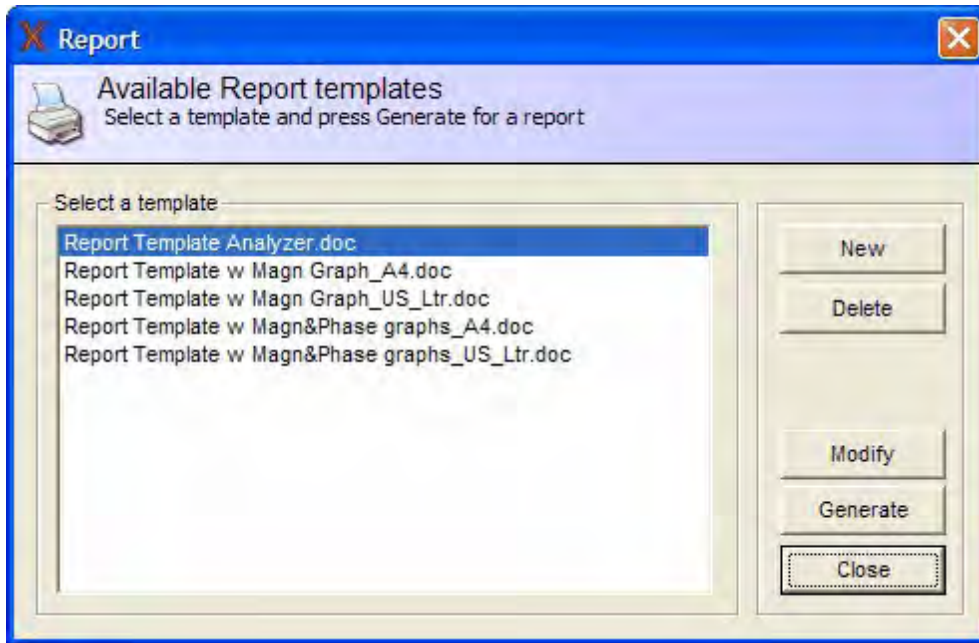
The measurement that is selected in the test browser is closed if "Close File" in the "File menu", or Ctrl+I is selected,

A Measurement can also be closed by clicking the right hand side right corner of the legend. See arrow in picture below.



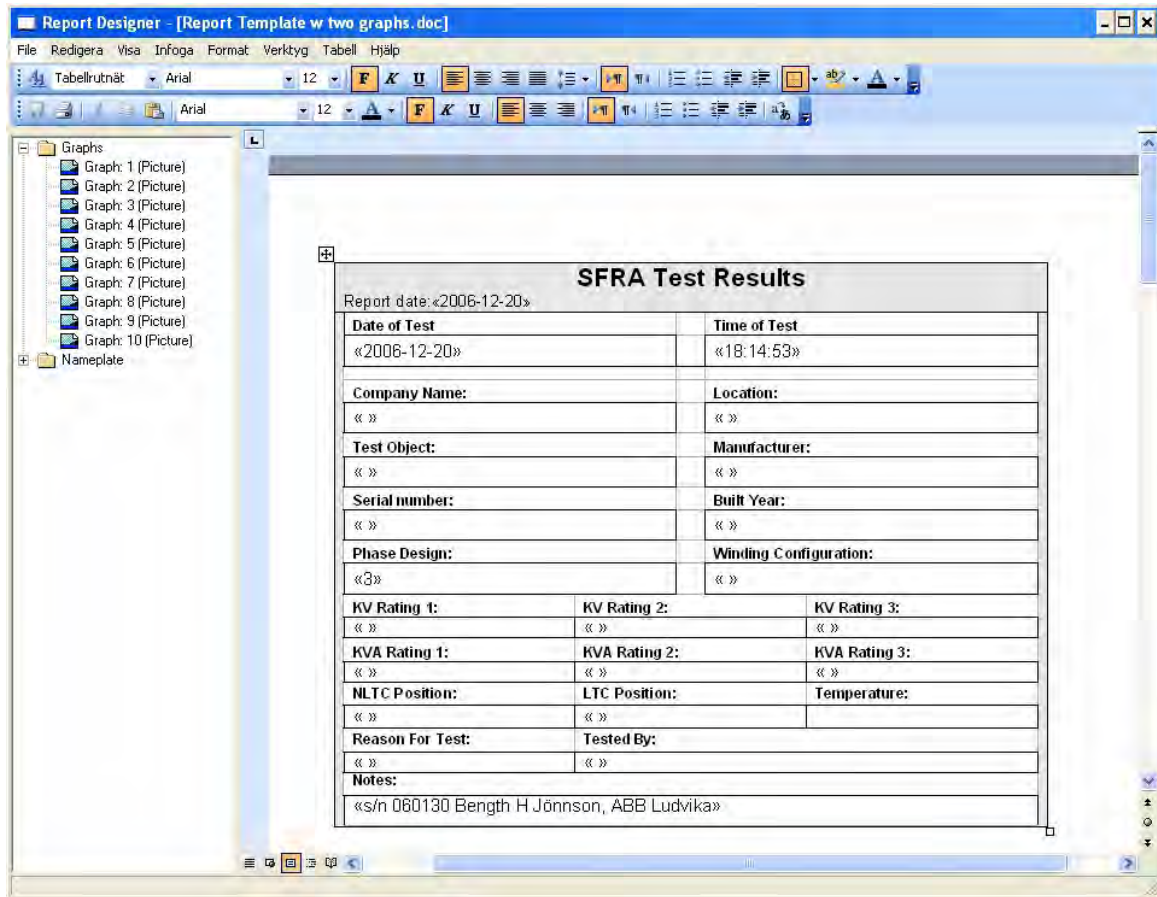
4.1.5 Report

The Report uses Microsoft Word as report generator. It will only work if you have Microsoft Word installed on your computer. The FRAX150 does not provide Microsoft Word. To generate reports from the FRAX150 you will have to transfer the test files (.pax, .frax) from the unit and generate the reports from a PC with the FRAX software and Microsoft Word installed on it.

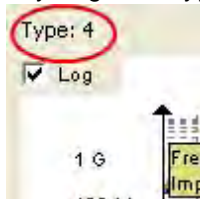


The Report dialog allows you to select a report template and generate (press "Generate") a report using the current data and the template. A Word document is generated that can be edited, printed or converted to another document format using third party software such as pdf995 or PDFCreator.

You can also create a new report template, delete and/or modify an existing template. Creating new or modify is straightforward and is easily done when you have an open test file in the FRAX software. The example below shows how to "Modify" an existing template. Edit the document on right hand side using ordinary Microsoft Word functions and add your logo in header. Simply use drag-and-drop to place data fields and graphs from left-hand side into your report. Save the new template and return to the Report dialog.



The graph number in the report designer corresponds with the type number of the graph. The easiest way to get the type number is to look at the top left corner of the graph view.



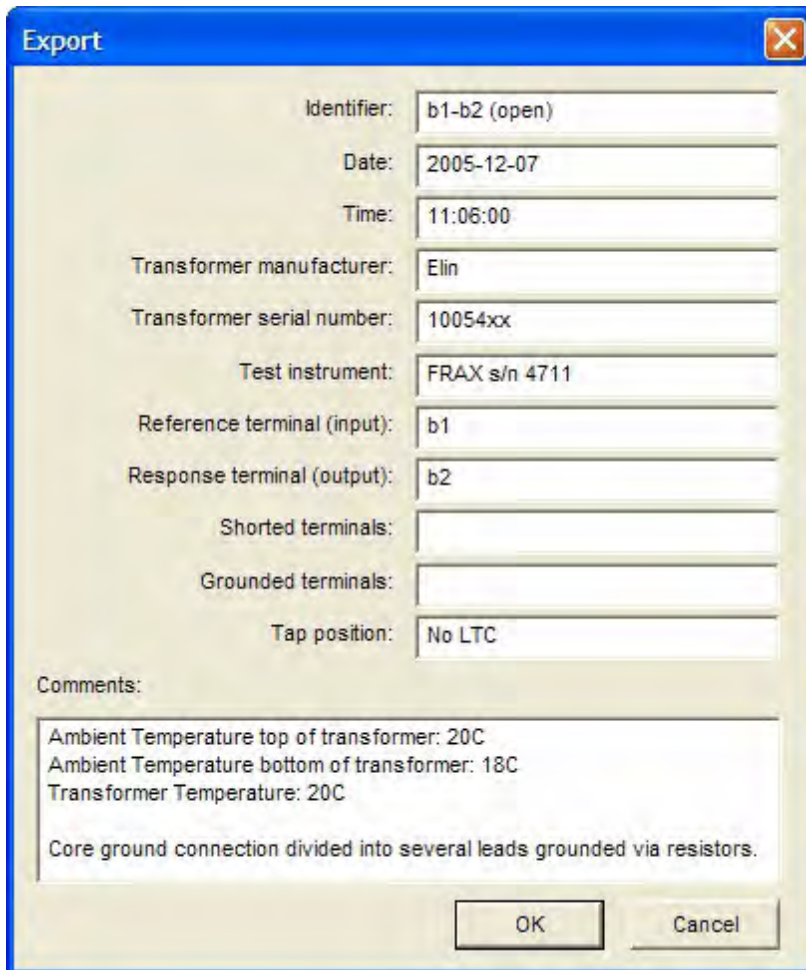
To get the curves on the report you will also need to have them in the FRAX software. Make sure both models and views are loaded.

4.1.6 Export... (Alt+E)

Activate the function by clicking the Export button or selecting Export in the menu. A "Save As" dialog will be displayed so you can specify where to store the file. The drop down box allows you to choose what type of export you want to make. If you don't add a file extension it will be added, i.e. .txt for a column type export and .xfra for a CIGRE Brochure 342 file.

CIGRE Brochure 342 (XFRA)

XFRA or Export FRA is a storage file format recommended in CIGRE Brochure 342. When exporting to XFRA you are given the opportunity to inspect and make alterations to what will be written to the file. Pay attention to the terminal settings, especially if you are using custom sweep names that don't use the default sweep names.



The image shows a Windows-style dialog box titled "Export". It contains several input fields for configuration. The fields and their values are: Identifier: b1-b2 (open); Date: 2005-12-07; Time: 11:06:00; Transformer manufacturer: Elin; Transformer serial number: 10054xx; Test instrument: FRAX s/n 4711; Reference terminal (input): b1; Response terminal (output): b2; Shorted terminals: (empty); Grounded terminals: (empty); Tap position: No LTC. Below these fields is a "Comments:" section with a text area containing: "Ambient Temperature top of transformer: 20C", "Ambient Temperature bottom of transformer: 18C", "Transformer Temperature: 20C", and "Core ground connection divided into several leads grounded via resistors." At the bottom of the dialog are "OK" and "Cancel" buttons.

Identifier:	b1-b2 (open)
Date:	2005-12-07
Time:	11:06:00
Transformer manufacturer:	Elin
Transformer serial number:	10054xx
Test instrument:	FRAX s/n 4711
Reference terminal (input):	b1
Response terminal (output):	b2
Shorted terminals:	
Grounded terminals:	
Tap position:	No LTC

Comments:

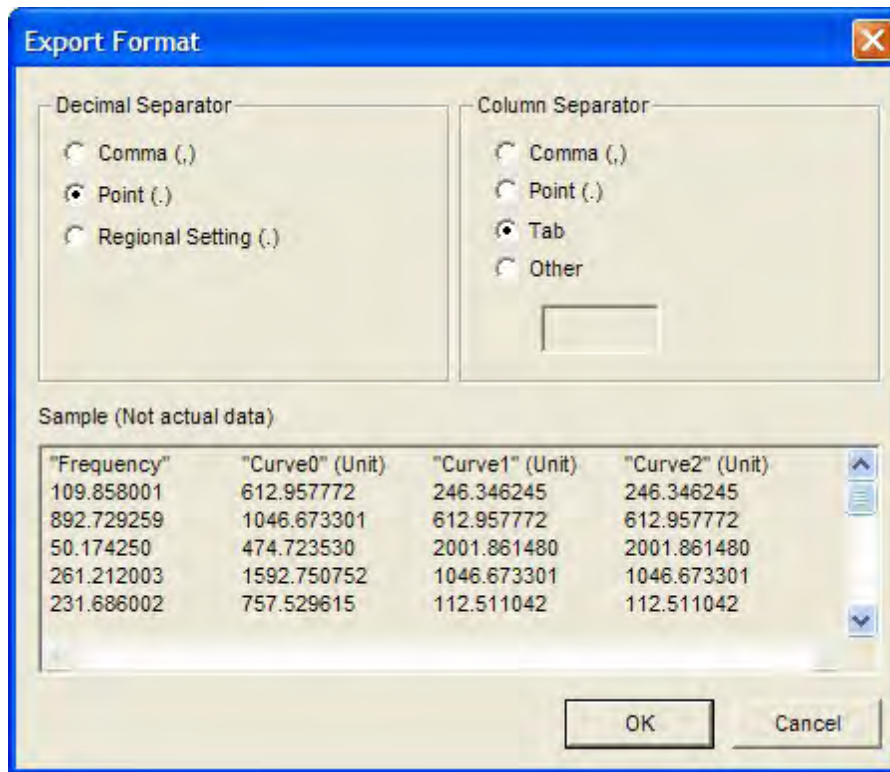
Ambient Temperature top of transformer: 20C
Ambient Temperature bottom of transformer: 18C
Transformer Temperature: 20C
Core ground connection divided into several leads grounded via resistors.

OK Cancel

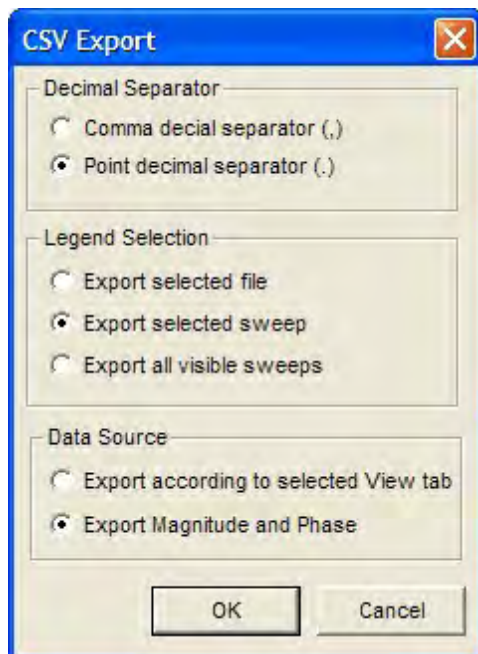
Column type export

Exports active sweeps to a *.txt file. Make sure that only graphs you want to export are visible in the Graph, as only active graphs are exported. Example: If you look at a magnitude graph, only magnitude will be exported, if Magnitude and Phase is visible, both Magnitude and Phase will be exported.

Select suitable export details and press OK.



CSV Export



Exports the entire file, selected sweeps or all visible sweeps to a *.csv file. If you use selected view as data source make sure that only graphs you want to export are visible in the Graph, as only

active graphs are exported. Example: If you look at a magnitude graph, only magnitude will be exported, if Magnitude and Phase is visible, both Magnitude and Phase will be exported. If you select to export magnitude and phase the selected view is not important.

Select suitable export details and press OK. The csv format has two alternative formats

1. Number decimal = . (point) and Column separator = , (comma) or
2. Number decimal = , (comma) and column separator = ; (semi-colon).

Doble export

The Doble export exports the data of the currently selected sweep to a Doble .sfra file. Make sure you select the sweep you want to export as only that sweep will be exported.

4.1.7 Import... (Alt+I)

It is possible to load files in various file formats. Among others, XML (e.g. Test1.sfra) and CSV (e.g. Test2.csv) formatted files from several vendors are supported. The software tries to automatically detect the file format when "All supported files" is selected in the File type list. You can also manually select the file format you are about to import in this list.

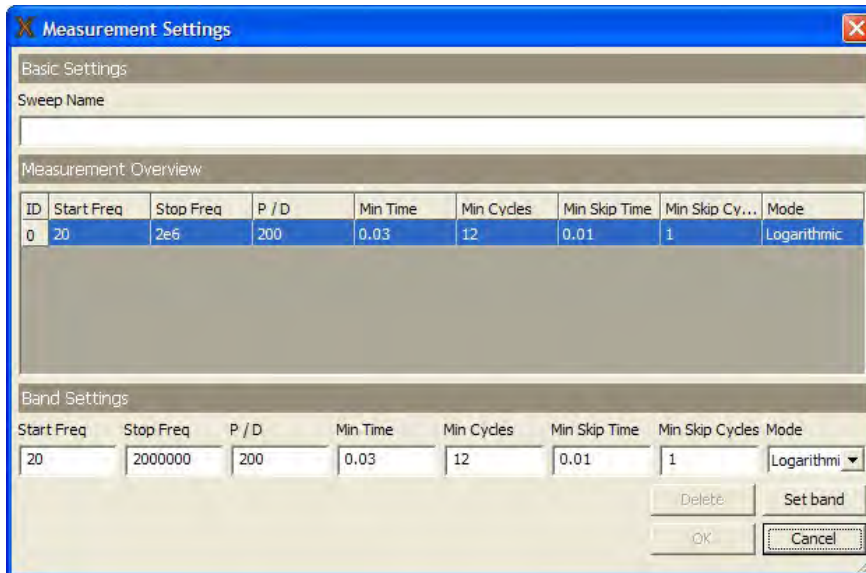
When importing from Doble and Omicron files the available information will also be displayed in the nameplate. Omicron import will also use the same curve color and thickness as in the Omicron file. Depending on computer capacity importing a file may take some time.

4.1.8 Print... (Ctrl+P)

Makes a simple direct to printer print-out for field use. The print out will be of the currently selected tab, i.e. if you have the magnitude graph view tab selected the print-out will contain the magnitude curve. The print-out will also contain a simple list of the nameplate data. The print out of nameplate data will be in English only. For more advanced reports with more options to format the output we suggest that you either use the report function or use the copy functions, i.e. copy view, copy legend and copy view + legend to copy a screen dump to the clipboard and then paste them into the program of your choice.

4.1.9 Add Sweep... (Ctrl+A)

"Add sweep" adds an additional sweep into a selected Measurement file structure. You must fill in a "Sweep name" to be able add a new Sweep (press "OK"). The default "Measurements settings" are used.



4.1.10 Delete Sweep (Ctrl+D)

Deletes a sweep (with or without data) from a Measurement file structure. Note: the sweep and possible data will be permanently deleted.

4.1.11 Edit Nameplate... (Ctrl+E)

Opens the Measurements file Nameplate for editing.

4.1.12 Difference (Alt+D)

The Difference function is available only when two measurement sweeps are displayed in the graph.

4.1.13 Connect (F7)

Connects the FRAX software to the FRAX-101 instrument.

For more information about connection please see Connection Settings and Bluetooth communication.

4.1.14 Disconnect (F8)

Disconnect the FRAX software from the FRAX instrument.

4.1.15 Start measurement (F9)

Start measurement of selected sweep in Legend.

4.1.16 Stop measurement (F10)

Stop active measurement.

4.1.17 Exit (Alt+F4)

Terminates the FRAX Software.

4.2 Edit Menu



Menu Command

Copy View
 Copy Legend
 Copy View + Legend (Ctrl+C)
 Change Sweep Color (Alt+O)

Description

Copy the current view to the clipboard.
 Copy the legend to the clipboard.
 Copy the current view and the legend to the clipboard.
 Changes the color and line width of the selected sweep curve.

4.2.1 Copy View

Copy the current view into the clipboard. It can then be pasted into another program.

4.2.2 Copy Legend

Copy the Legend into the clipboard.

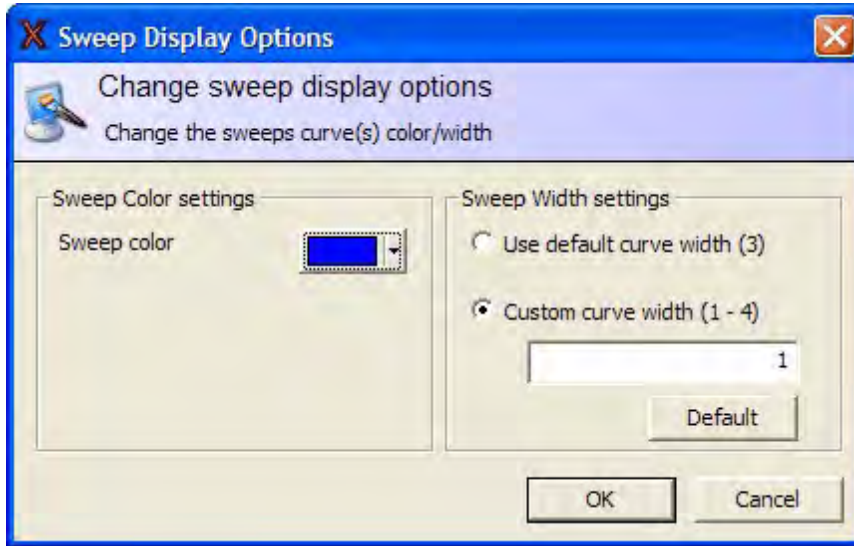
4.2.3 Copy View + Legend (Alt+C)

Copy the current View and the Legend into the clipboard. For more information check Copy View and Copy Legend.

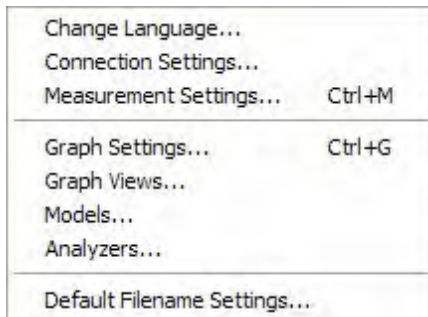
4.2.4 Change Sweep Color (Alt+O)

This dialog allows you to change the color and line width of the selected sweep curve and change the thickness of the line.

The thickness of the line can either be set as the default or a custom width. It is also possible to set a new default curve for all lines by pressing the "Default" button.



4.3 Configuration Menu



Menu Command	Description
Change Language...	Change the language in FRAX Software menus and more
Connection Settings...	Set the COM-port for communicating with the FRAX instrument
Measurement Settings... (Ctrl+M)	Set default measurement settings such as start frequency, integration time and more.
Graph Settings... (Ctrl+G)	Set axes and more in the FRAX software graph
Graph Views...	Set graphs to use
Models...	Set models to use with graphs

Analyzers...	Set analyzers to use.
Default Filename	Change the default filename format.
Settings...	

4.3.1 Change Language...

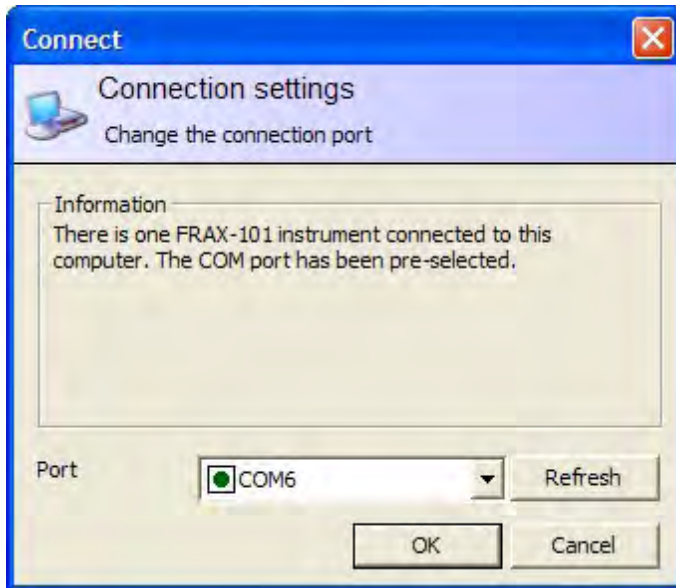
Select one of the available languages and you will change language in menus and dialogs in the FRAX software. A software restart is required to activate the language change after you have selected the new language.



4.3.2 Connection Settings...

The PC uses a COM-port to communicate with the FRAX instrument. It will use different COM-ports for USB and Bluetooth communication. The FRAX software will try to find the active COM-port and provide suggestions if no FRAX instrument was found.

COM-ports marked with green indicate that a FRAX instrument was found on that COM-port. Red means that no FRAX instrument was found.



4.3.3 Measurement Settings... (Ctrl+M)

The default measurement settings are specified in this dialog. All new measurement sweeps except sweeps based on "Use Measurement as Template" will have these settings initially.

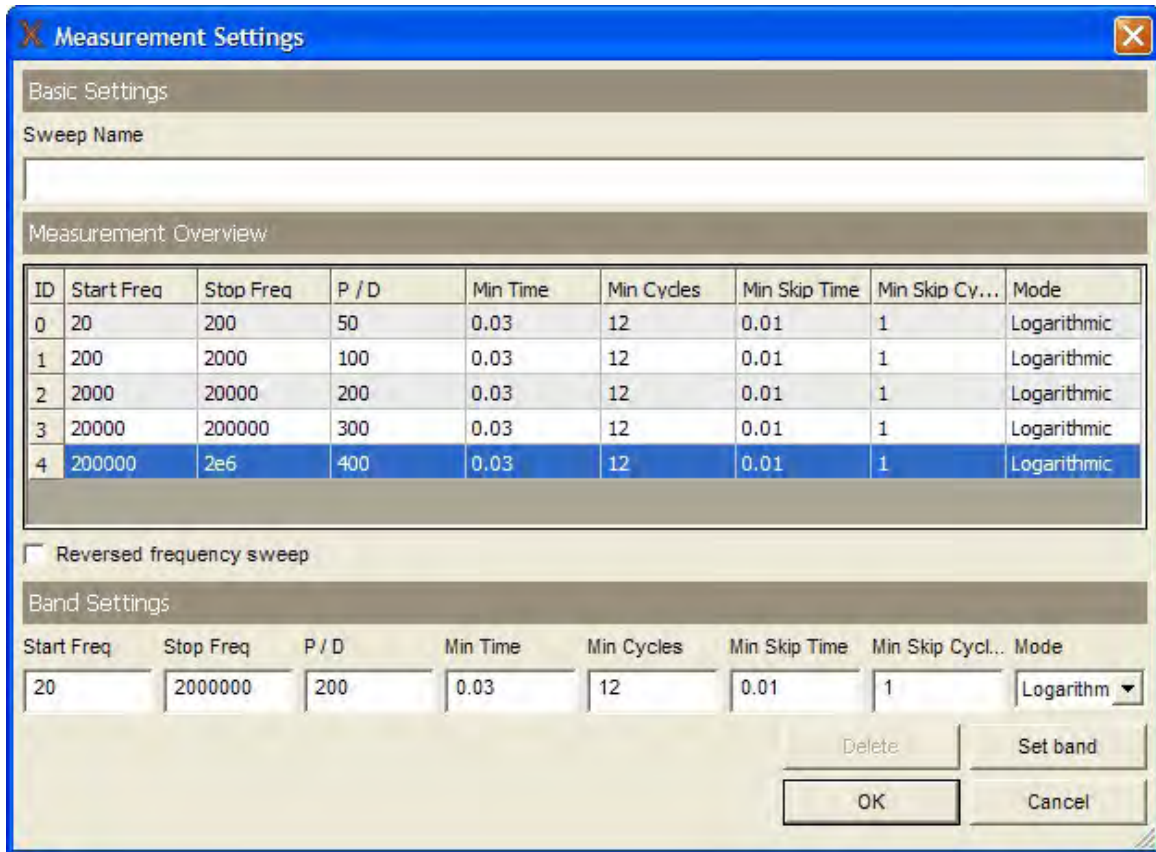
A measurement sweep can consist of one or more (max 15) measurement bands with different settings. Normally the frequency settings are set in such a way that the next band continues the previous band. The first screen shot below shows the default setting, the second screen shot below shows a three band setting.

"Start Frequency" and "Stop Frequency" of the sweep, or of the band if several bands are used.

"P / D": In logarithmic scale, "Points / Decade" (P / D) is the number of measurement points, equally spaced in a logarithmic scale, per decade. Example: 200 "P / D" between 10 Hz to 1000 Hz gives 400 measurement points logarithmic distributed between 10 Hz to 1000 Hz (two decades). In linear scale, "P / D" is the total number of measurement points, linearly distributed. Example: 200 P / D from 10 Hz to 1000 Hz gives 200 measurement points linearly distributed. Less than 10 P / D is not recommended.

"Min skip time" and "Min skip cycles" defines the number of cycles applied before measurement starts. "Min time" and "Min cycles" defines the number of cycles in measurement. Example: A measurement is performed at 100 Hz, "Min time" = 0.1s and "Min cycles" = 12. Since 12 cycles is greater than 10 cycles = 0.1s the system measures at 100 Hz using 12 cycles. Same settings at 1000 Hz means that the system measures 100 cycles since 0.1s = 100 cycles is greater than 12 cycles. Note! Min Cycles = 12 equals an IF Bandwidth of 10%.

The default sweep settings are as below.



To perform the measurement sweep faster, the low frequency range can be modified by dense out measurement points and/or lower the integration time ("Min Cycles"). Below are examples of various sweeps.

On the FRAX-101 and 150 it is possible to set the sweep to be performed in reverse, i.e. to measure from the highest frequency to the lowest. This is a single setting for all bands.

On the FRAX-101 and 150 it is also possible to scale down the output voltage from the standard 10 V, see Appendix C, Adjusting Output Voltage.

Sample settings

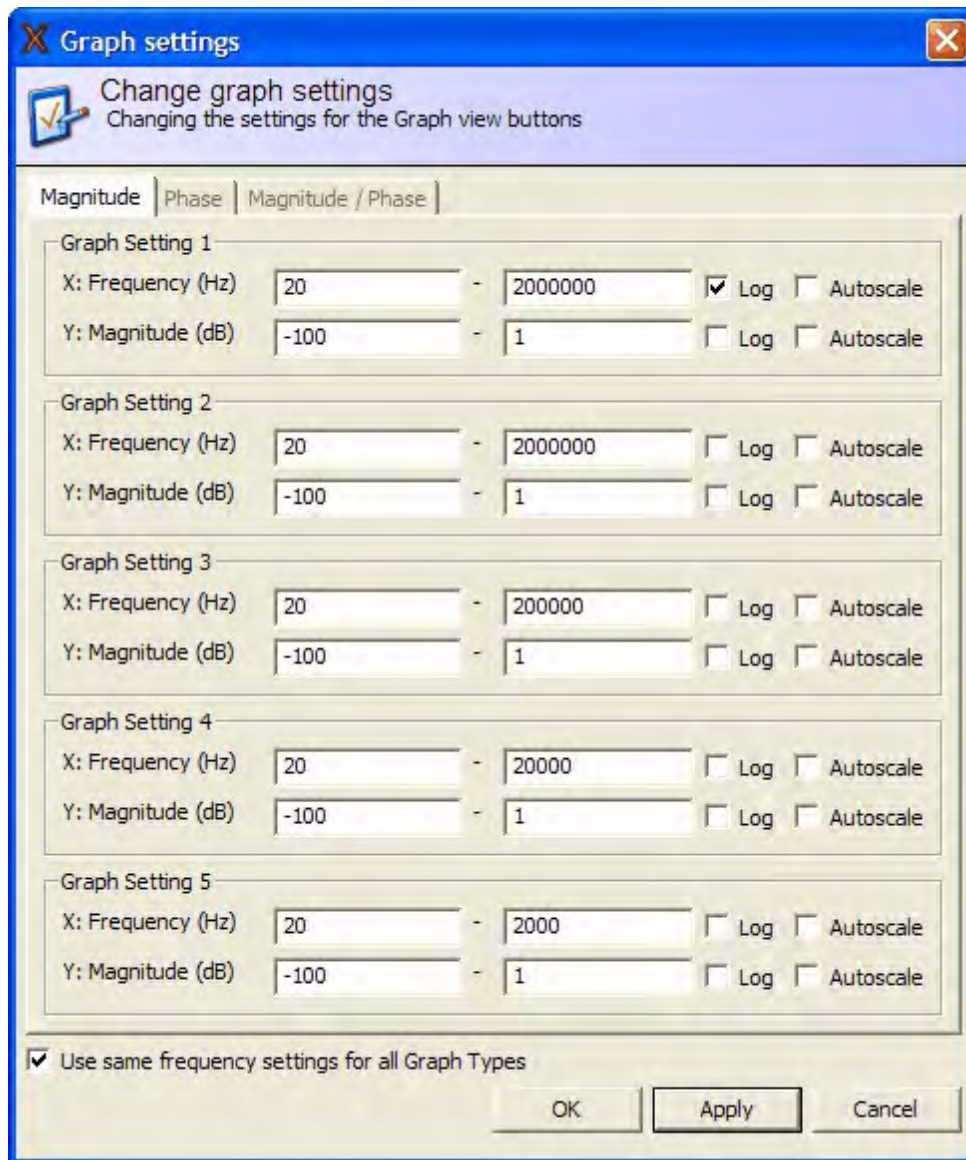
Here are some examples on various measurement settings.

	P/D	Freq bands (Hz)	Meas points	Approx. meas. time (s)
FRAX Default	50	20 - 200	50	
	100	200 - 2 k	100	
	200	2 - 20 k	200	
	300	20 - 200 k	300	
	400	200 k - 2 M	400	

			Total: 1050	64
FRAX fast				
	40	20 - 200	40	
	60	200 - 2 k	60	
	80	2 - 20 k	80	
	100	20 - 200 k	100	
	160	200 k - 2 M	160	
			Total: 440	37
Fixed P/D settings				
Example	100	20 - 2 M	500	
Omicron default	160	20 - 2 M	800	76
Doble default	200	20 - 2 M	1000	93
Omicron max	320	20 - 2 M	1600	145
Doble max	360	20 - 2 M	1800	163
FRAX max	6400	20 - 2 M	32000	

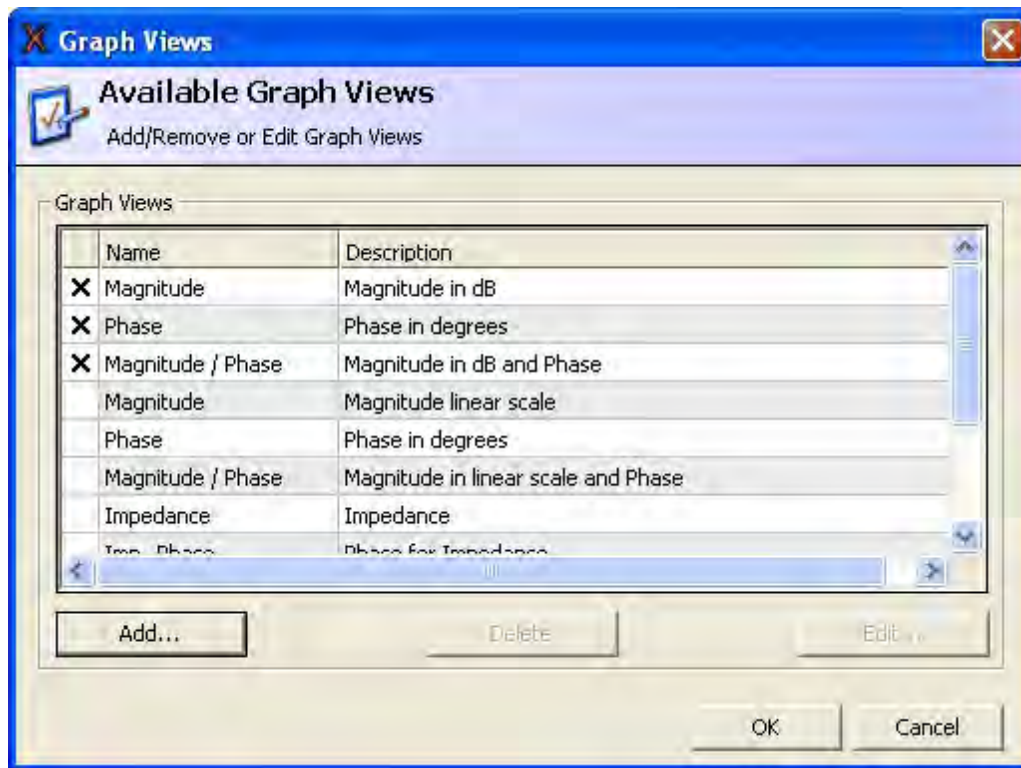
4.3.4 Graph Settings... (Ctrl+G)

In the Graph settings dialog you set auto scale or range and spacing for the axis. The Dialog has one tab for the Magnitude and one tab for Phase, as well as a tab for the combination of Magnitude and Phase. In the bottom you have a check box that makes changes that affect all graphs.



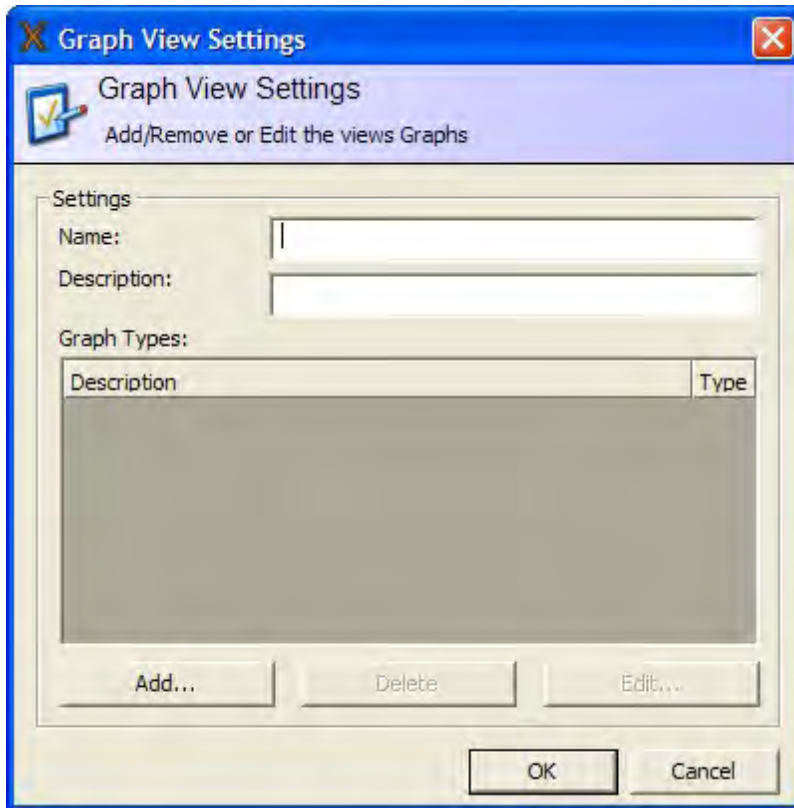
4.3.5 Graph Views...

In the Graph Views dialog, you can configure which graphs you want access to as a separate tab. The default selections include Magnitude, Phase, and Magnitude / Phase, as shown below. To select a graph, check or uncheck the box to the left of its name.

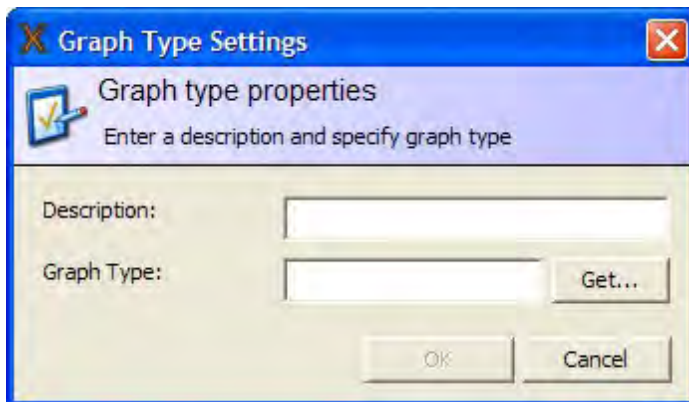


To edit or delete a custom graph, select the graph in the list and then click the Delete or Edit... buttons.

To add a custom graph, click the Add... button, and the following dialog is shown.



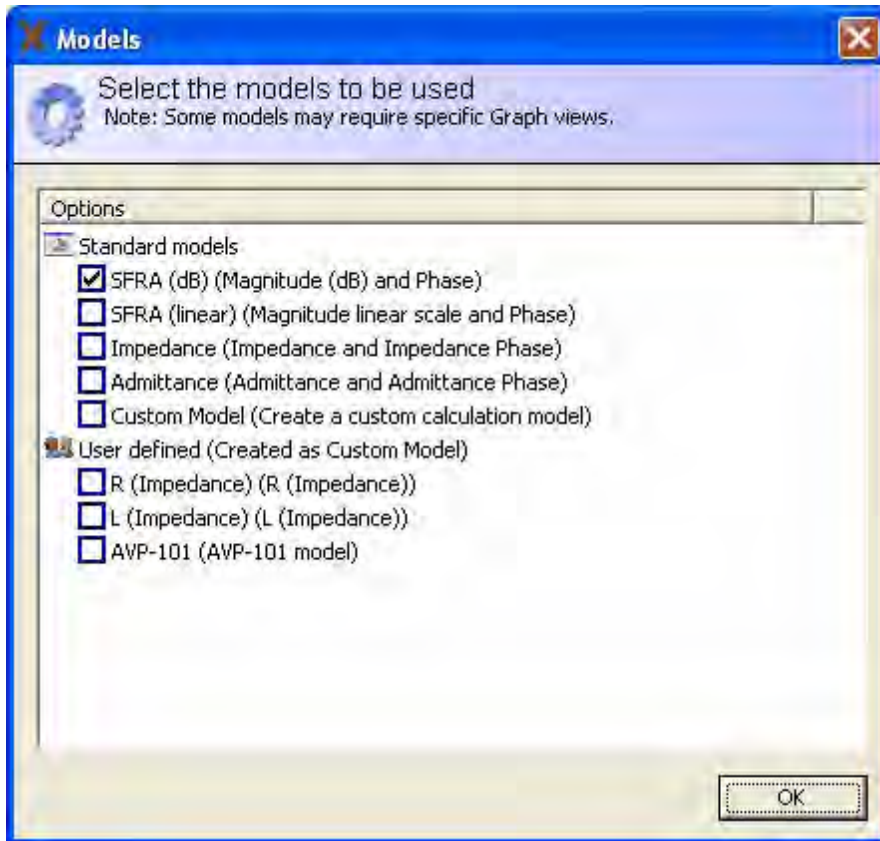
To add a graph type, type a name and a description in the box, and click the Add button.



Enter a description and a number in the Graph Type box. The number is used as a unique id for this particular graph. You can also use pre-defined types via the Get... button.

4.3.6 Models...

In the Models dialog, you can select what models to use when a graph is plotted. When using an active probe, the model for the probe should be used. No other models should be used together with a probe model. In the dialog below, the SFRA (dB) model is selected. This is the most commonly used model.



Selected models are shown below the graphs in the main window and can be selected and de-selected by clicking the small check box.



If "Reference" voltage is Ch0 and Measure voltage is Ch1, the following equations are used in calculations. Note that all standard models display phase in degrees, but in custom models defined below phases are in radians (1 radians = 180/Pi degrees)

SFRA (dB)

$$\text{Magnitude} = 20 \log_{10}(\text{Ch1} / \text{Ch0})$$

$$\text{Phase} = \text{Phase}(\text{Ch1} / \text{Ch0}) = \text{Phase}(\text{Ch1}) - \text{Phase}(\text{Ch0})$$

SFRA (Linear)

$$\text{Magnitude} = \text{Ch1} / \text{Ch0}$$

$$\text{Phase} = \text{Phase}(\text{Ch1} / \text{Ch0}) = \text{Phase}(\text{Ch1}) - \text{Phase}(\text{Ch0})$$

Impedance

$$Z = U/I = (\text{Ch0} - \text{Ch1})/I = 50 * (\text{Ch0} - \text{Ch1})/\text{Ch1}$$

$$\text{Phase} = \text{Phase}(Z)$$

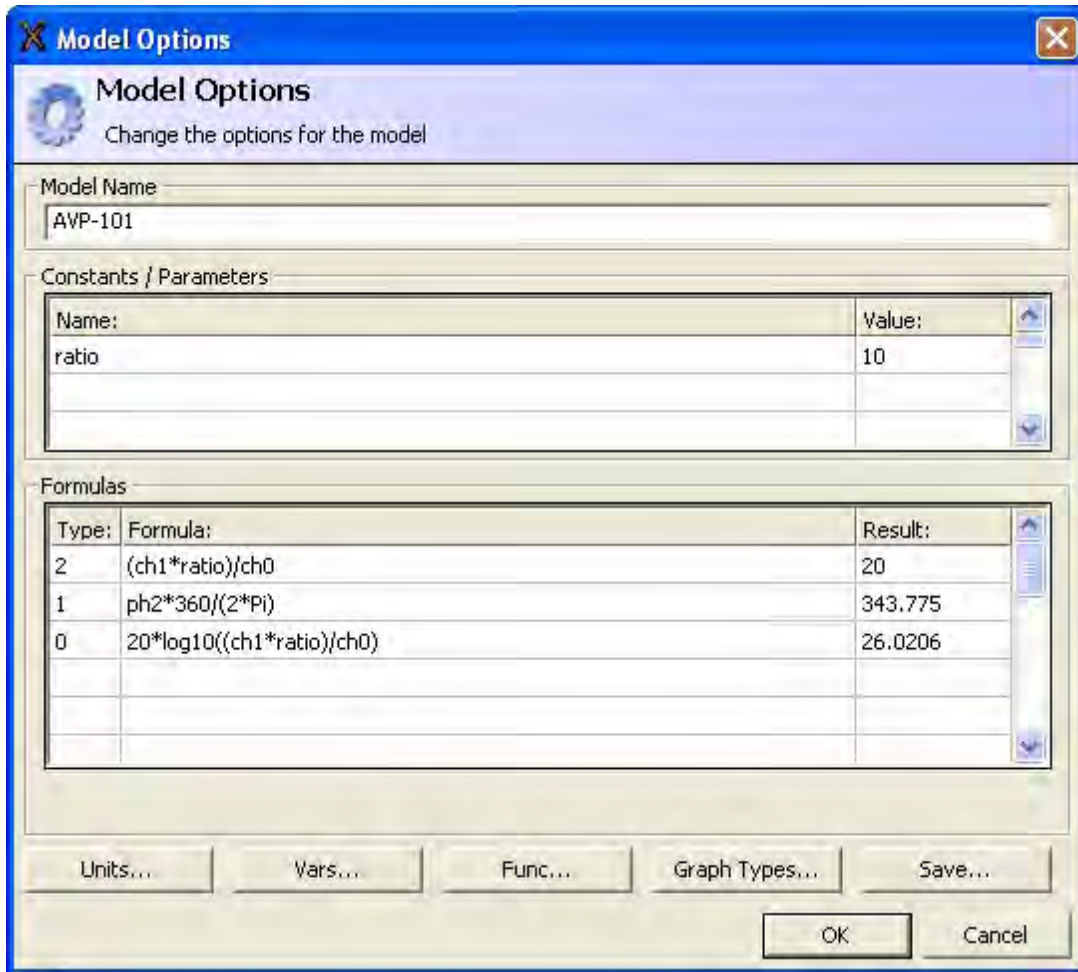
Admittance

$$Y = 1/Z = \text{Ch1} / (50 * (\text{Ch0} - \text{Ch1}))$$

$$\text{Phase} = \text{Phase}(Y) = - \text{Phase}(Z)$$

Two additional models are available, R and L models, that plot results in Impedance view. The R and L models are very useful for evaluating why a curve deviates at low frequencies in short-circuit measurements. Increase of R at lowest frequencies may be a poor contact and change of L may be winding movement. Also comparing R when frequency increase, typically in the range 50-400 Hz may give valuable information; this is also called FRSL (Frequency Response of Stray Losses)

To create a custom model, check Custom Model in the Models dialog as shown above and click OK. Then, click the button named "..." in the Custom Model frame in the main window. This brings up a window called Model Options.

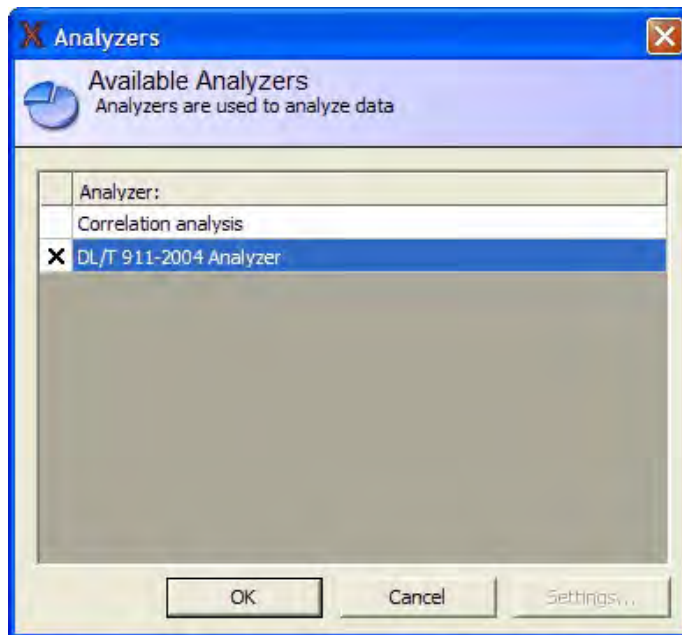


The screenshot above, the custom model designed by Megger for the Active Voltage probe AVP-101, illustrates some of the features of Custom Models. Type 0 represents the SFRA(dB) Magnitude graph and since the AVP-101 has a ratio of 10, the equation becomes $20 * \log_{10}((ch1 * ratio) / ch0)$. The phase is just the phase, but since all phase variables (Vars...) come in radians and we want to plot in degrees we multiply the phase by $360 / (2 * \pi)$, $ph2 = ph1 - ph0$.

The buttons Units, Vars, Func, and Graph Types provide lists with available units, variables, mathematical functions, and graph types that can be used within formulas. Please note that a formula only affects one graph type. That is, a type must be unique for each formula, and two or more formulas can not share the same type. Click the Save button to save the model. The model is listed as "User defined" in the Models dialog for later use.

4.3.7 Analyzers...

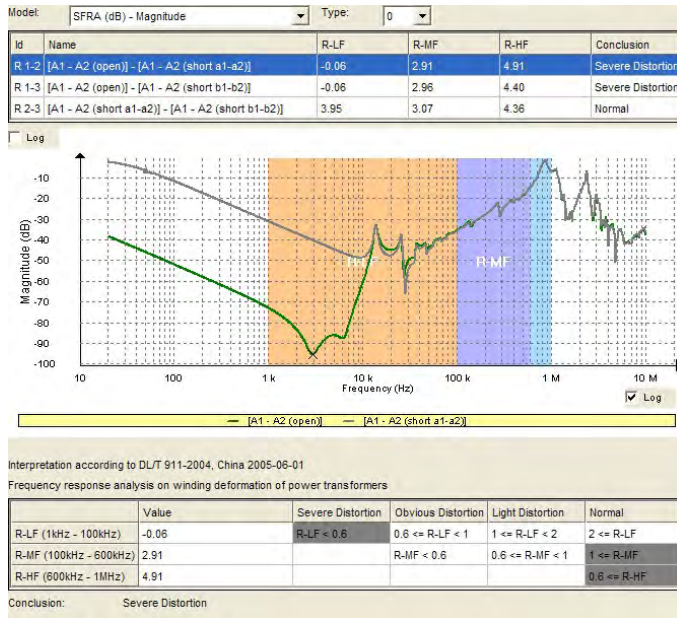
Analyzers are used to interpret data. Check the box to activate an analyzer. An analyzer shows up as a separate tab in the main screen. The DL/T 911-2004 Analyzer is based on the Electric Power Industry Standard of People's Republic of China, DL/T 911-2004 and it is not possible to change any settings. The Correlation analysis uses same calculations as DL/T 911-2004 Analyzer but here you are able to modify number of frequency ranges analyzed, frequency limits and interpretation limits. You can make these modifications by select the Correlation analysis and press the Settings... button.



4.3.7.1 DL/T 911-2004 Analyzer

Use the test browser to select the two sweeps you want to compare. The results for the combinations of the first three selected sweeps is displayed in a table at the top. If more than three sweeps are selected, the analyzer will only display the first three. The calculations are performed automatically and the "Conclusion" is presented in the table.

To see the curves and details of a certain combination, select it in the table.



The DL/T 911-2004 Analyzer computes the relative factor R_{xy} function for the three different frequency ranges (1kHz-100kHz, 100kHz-600kHz and 600kHz-1MHz) according to equations in A1, A2, A3 and A4. The value for each frequency range is assigned a "Winding Deformation degree" and finally the Conclusion is set as the worst "Winding Deformation degree". Note that $R_{HF} < 0.6$ is not assigned to any "Winding deformation degree".

A.1 Calculate the standard variance of these two sequences

$$D_x = \frac{1}{N} \sum_{k=0}^{N-1} X(k) - \frac{1}{N} \sum_{k=0}^{N-1} X(k) \quad D_y = \frac{1}{N} \sum_{k=0}^{N-1} Y(k) - \frac{1}{N} \sum_{k=0}^{N-1} Y(k)$$

A.2 Calculate the covariance of these two sequences

$$C_{xy} = \frac{1}{N} \sum_{k=0}^{N-1} X(k) - \frac{1}{N} \sum_{k=0}^{N-1} X(k) \quad Y(k) - \frac{1}{N} \sum_{k=0}^{N-1} Y(k)$$

A.3 Calculate the normalization covariance factor of these two sequences

$$LR_{xy} = C_{xy} / \sqrt{D_x D_y}$$

A.4 Calculate the relative factor R_{xy} meeting the project requirements as per the following formula:

$$R_{xy} = \begin{cases} 10 & 1 < LR_{xy} < 10 \\ 1 & LR_{xy} < 1 \\ \lg(1 + LR_{xy}) & \text{others} \end{cases}$$

A.5 Judge the degree of deformation of transformer winding as per Table A.1

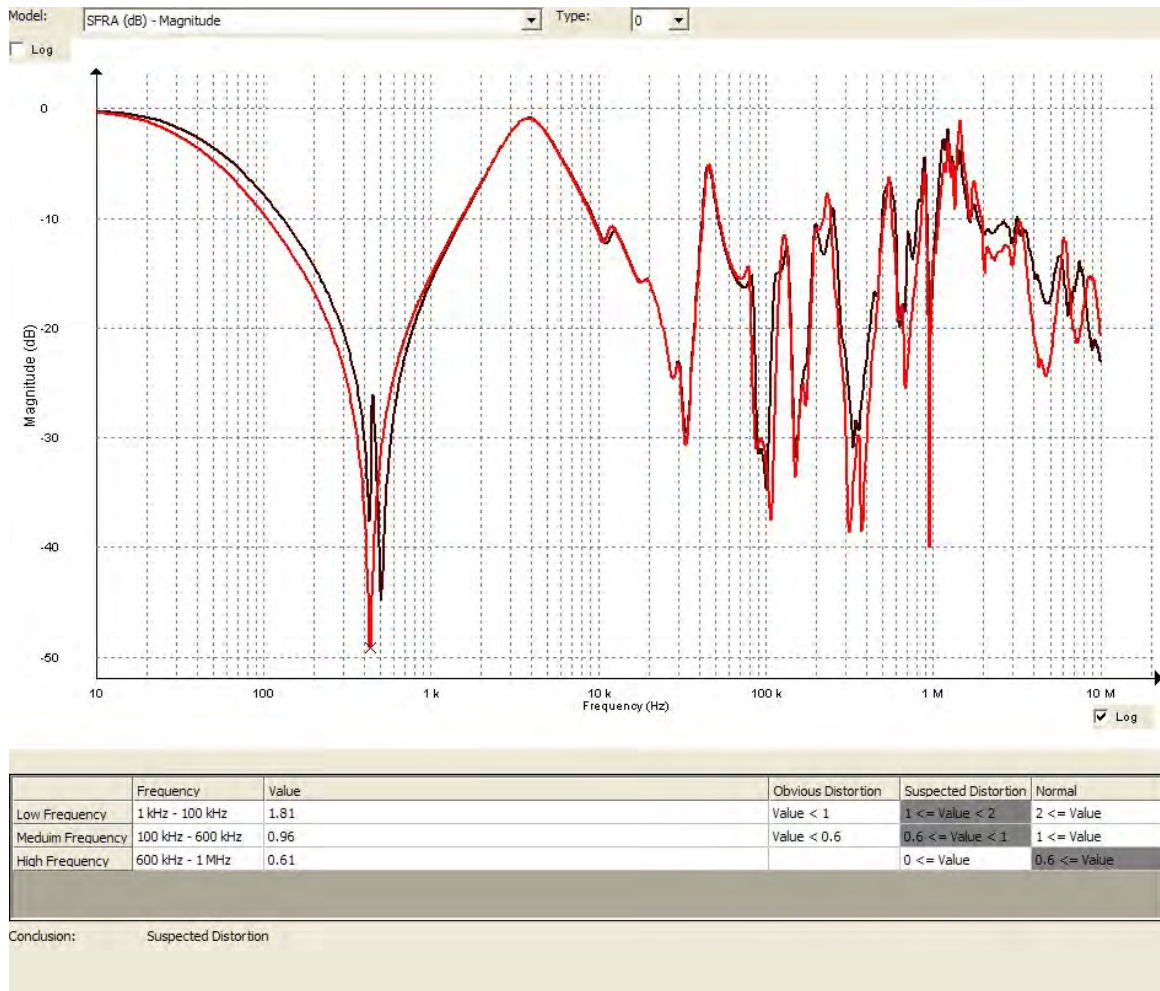
Table A.1 Relation between relative factors and degree of transformer winding deformation (only for reference)

Winding Deformation degree	Relative Factors R
Severe Deformation	$R_{LF} < 0.6$
Obvious Deformation	$1.0 > R_{LF} \geq 0.6$ or $R_{MF} < 0.6$
Slight Deformation	$2.0 > R_{LF} \geq 1.0$ or $0.6 > R_{MF} < 1.0$
Normal Winding	$R_{LF} \geq 2.0$, $R_{MF} \geq 1.0$ and $R_{HF} \geq 0.6$
R_{LF} represents the relative factor when the curve is in low frequency band (1kHz~100kHz); R_{MF} represents the relative factor when the curve is in medium frequency band (100kHz~600kHz); R_{HF} represents the relative factor when the curve is in high frequency band (600kHz~1000kHz).	

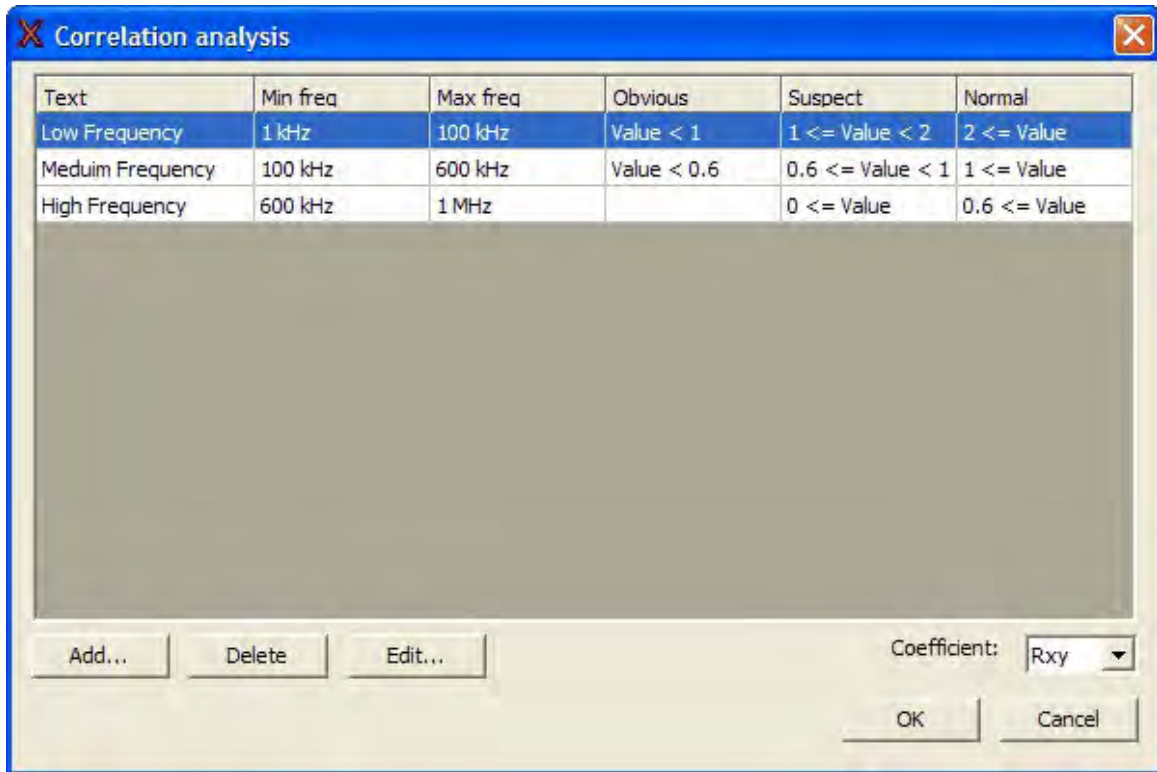
4.3.7.2 Correlation Analysis

This analyzer is by default identical with the DL/T 911-2004 analyzer. It uses the same calculations to get the values. The difference is that it is possible to create and change limits and frequency ranges to create a custom analyzer.

Use the test browser to select the two curves you want to compare. If more than two curves are selected, the analyzer will only display the first two curves selected. The calculations are performed automatically and the "Conclusion" is presented below the table.

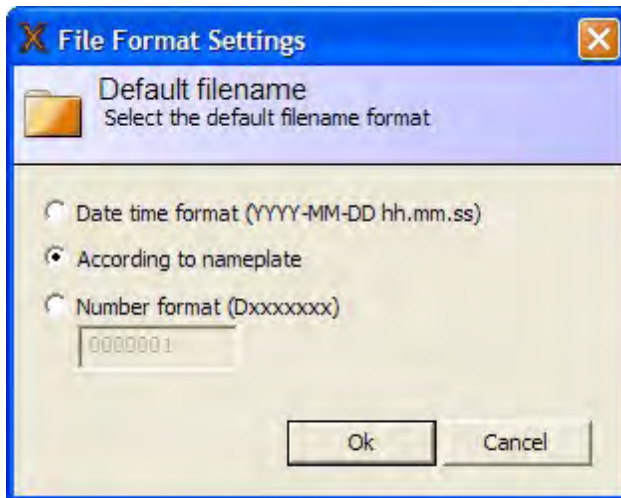


To change the settings for the analysis click the "Settings" button in the analyzer selection dialog. This brings up a dialog where the settings can be adjusted. You can add or remove frequency ranges, you can modify the frequency settings and interpretation criteria.



4.3.8 Default Filename Settings

Specify the default filename settings that will be used in the New File Save As dialog.

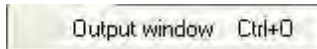


- Data time format (YYYY-MM-DD hh.mm.ss)
Generate a file name of format "YYYY-MM-DD hh.mm.ss.txt" based on the system time in your

PC or FRAX150..

- According to nameplate
Generate a file name based on data entered into the nameplate in the format *substation_designation_date time.frax*.
- Number format (Dxxxxxx)
Generate a file name starting with the number entered into the edit field. Once a new file has been created the number will be incremented. You can select what number to start from.

4.4 Windows Menu

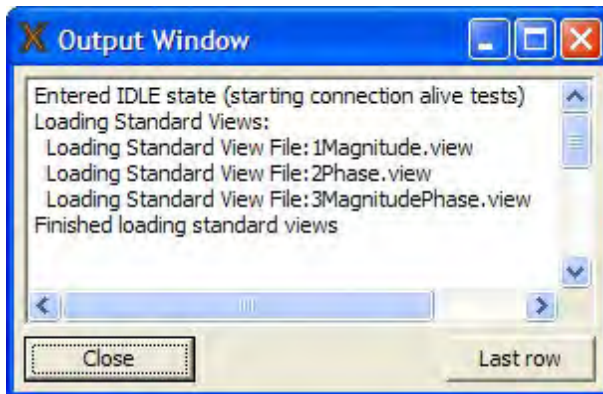


Menu Command		Description
Output window	(Ctrl+O)	Toggle show/hide the Output window

4.4.1 Output Window (Ctrl+O)

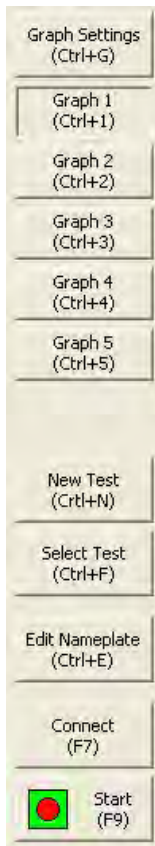
Opens an Output window that displays all communication between PC and FRAX instrument.

Click on the "Last row" button to see new lines when they become available during the continuous communication.



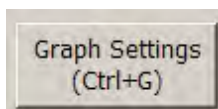
4.5 Action Buttons

Action buttons for faster access to common functions.



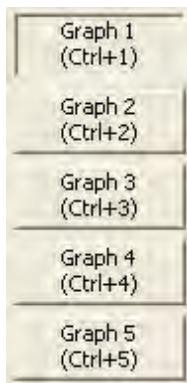
4.5.1 Graph Settings

Same as the menu item Graph settings... (Ctrl+G).



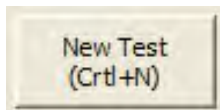
4.5.2 Graph View Settings

These five buttons controls the graph settings specified in Graph Settings dialog.



4.5.3 New Test

Same as the menu item New Test ... (Ctrl+N).

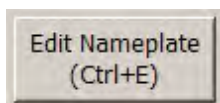


4.5.4 Select Test

The same as the menu item Select Test... (Ctrl+F)

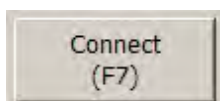
4.5.5 Edit Nameplate

Same as the menu item Edit Nameplate... (Ctrl+E). This button is only enabled when a file is selected in the Legend.



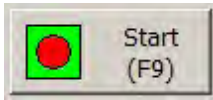
4.5.6 Connect

Same as the menu item Connect (F7).



4.5.7 Start

The start button is a multi-functional button. You can get action suggestions by pressing the start button.



Button Icon



Description

This icon means that you are not connected to the system.

1. No file is selected in the Legend.
 2. No sweep is selected in the Legend.
 3. The selected sweep is already measured.
- Measurement in progress.

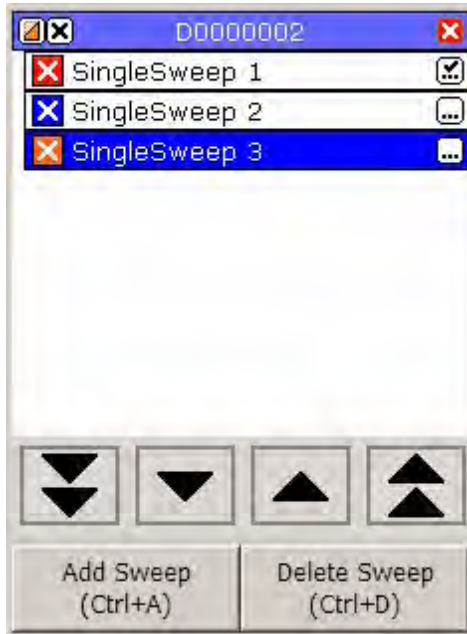
Ready to start measurement.

You can press the button at any time. If you are unsure of what action to take, the application provides suggestions.

4.6 Legend

The legend or Test Browser is where you will spend most of your time. This is where you change the Measurement settings for a single sweep and control the Graphs.

For more information about the usage of the Legend please read the sub-chapters Usage and Sweep Measurement Settings.



This is a typical legend view.

4.6.1 Usage

Usage overview

You can navigate the legend by either using the arrow buttons at the bottom of the legend. You can also use Alt+arrow keys Up and Alt+arrow key Down to navigate between sweeps or Alt+Page Up or Alt+Page Down to change File.

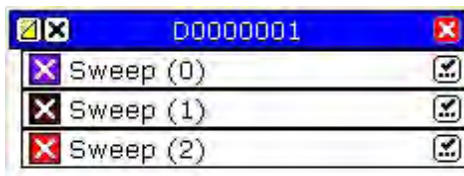


If you have many sweeps or several files open at the same time a scroll bar will be shown to the right of the legend making it possible to scroll up and down to see all sweeps.

It is also possible to change the order of the sweeps in a file. Click and hold on a sweep and then drag it to the desired position and then let go to drop it in place.

Legend Action Button Description

Below is a typical measurement file. A file is a container of measured sweeps.



File Description

The file header contains 3 function buttons and the name of the file.

File function button**Description**

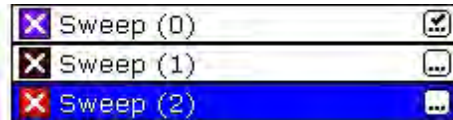
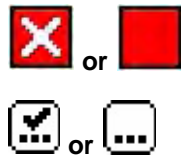
Hide / Show inactive sweeps in the file.

Enable / Disable sweeps in the file.

Close the file.

Sweep Description

The sweep contains 2 function buttons and the name of the sweep. Below is a list of different sweeps with different attributes.

**Sweep function button****Description**

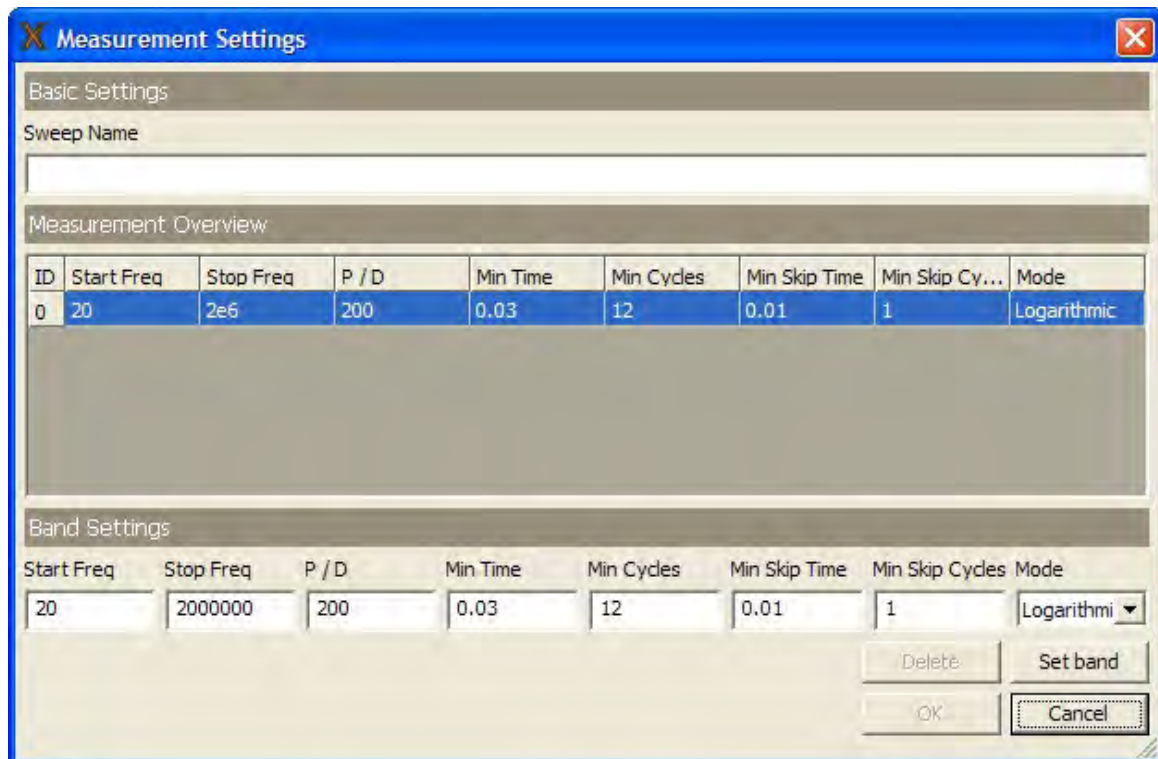
Enable / Disable the sweep. The color and line width can be set for each sweep. You can change the color and line width by right clicking on the icon.

Measured / Empty sweep. Clicking on this icon change the measurement settings for the sweep.

4.6.2 Sweep Measurement Settings

This window lets you change the settings for the sweep. You can only change the settings for "empty" sweeps (no measurement data).

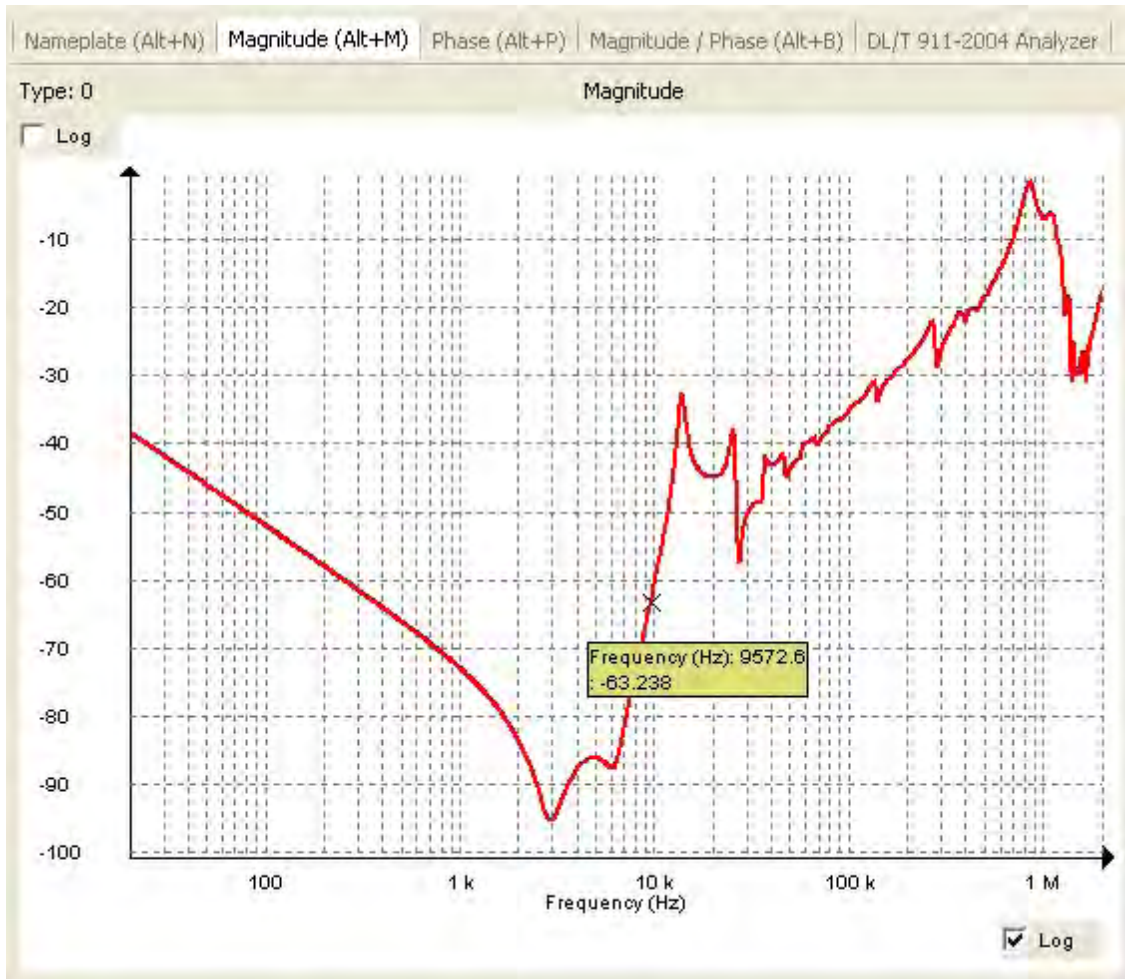
You can change the default measurement settings for new sweeps by pressing Ctrl+M.



4.7 Views

There are several views available. The Nameplate view is always present and the "Magnitude (Alt-M), Phase (Alt+P) and Magnitude / Phase (Alt+B) are also present when you first start your software. You can easily change the view by clicking the view-tab above the view. Also you can change views and create your own views, see further Graph views...

Below you see the Magnitude view with one measurement loaded.



5 Appendices

5.1 Appendix A: Calibration Instruction

The calibration of a FRAX can be performed through an automated process by use of the FraxCal software. The FraxCal utilizes an Agilent 34401A or an Fluke 8845A/8846A DMM (digital multi meter) and a FRAX calibration adapter connected to the FRAX generator output and measuring input channels.

Preparing for calibration

To perform the automatic calibration the following equipment is necessary:

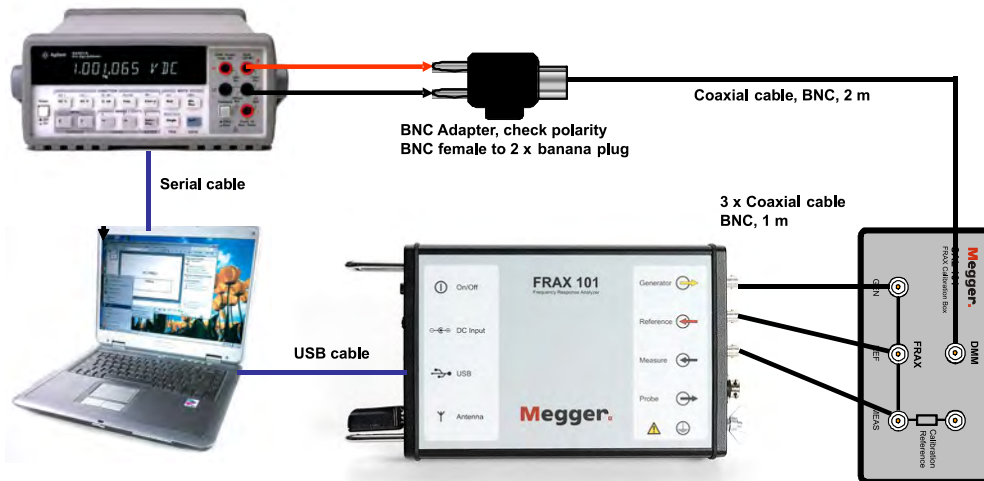
- Agilent 34401 DMM or Fluke 8845A/8846A
- FRAX calibration set including the following:
 - Calibration Adapter CAL-101
 - 1 pce DB-9 standard serial cable
 - 1 pce 2 x 4mm banana plug to BNC coaxial converter
 - 1 pce BNC Y adapter (2 x BNC female to 1 x BNC male)
 - 1 pce BNC short adapter (BNC female to BNC female)
 - 3 pcs 50 ohm coaxial cables with BNC connectors, 0.5 meter length
 - 1 pce 50 ohm coaxial cable with BNC connectors, 2 meter length
 - 1 pce USB cable (FRAX-101 only)
 - FraxCal software (supplied on desktop with FRAX150)

Note that the coaxial cables from the FRAX to the calibration box needs to be of equal length.

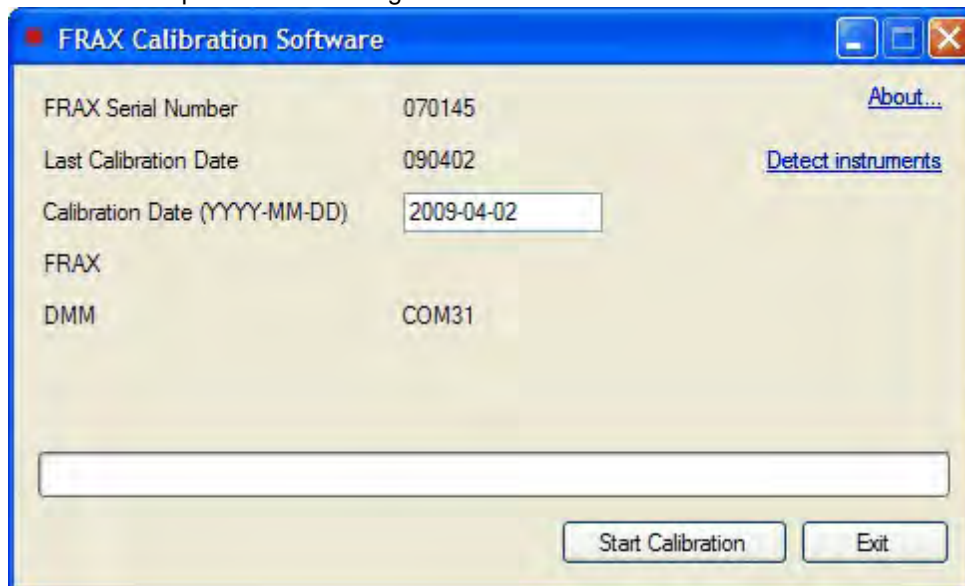
Connecting the equipment

- Install the FraxCal software on your computer (Windows XP or Windows Vista). FraxCal software comes pre-installed on the FRAX150.
- Ground the FRAX using the ground screw.
- Connect the FRAX AC/DC adapter and put the FRAX mains switch in the ON position (I) (FRAX-101 only).
- Connect AC Line Cord and put mains switch in the ON position (1). (FRAX150 only)
- Connect the FRAX with the USB cable to one of the USB ports on the computer (FRAX-101 only).
- Connect the DMM to the computer or FRAX150, using the serial cable. If the computer lacks a serial interface, a serial/USB adapter can be used.
- Connect the FRAX to the Calibration Adapter CAL-101 according to the figure below:
 - 1 meter 50 ohmcoaxial cable from FRAX Generator to CAL-101 IN
 - 1 meter 50 ohm coaxial cable from FRAX Reference to BNC Y adapter
 - 1 meter 50 ohm coaxial cable from FRAX Measure to BNC Y adapter
 - BNC adapter to CAL-101 OUT
 - 2 meter 50 ohm coaxial cable from CAL-101 DET to DMM using the BNC to banana adapter

Performing the calibration

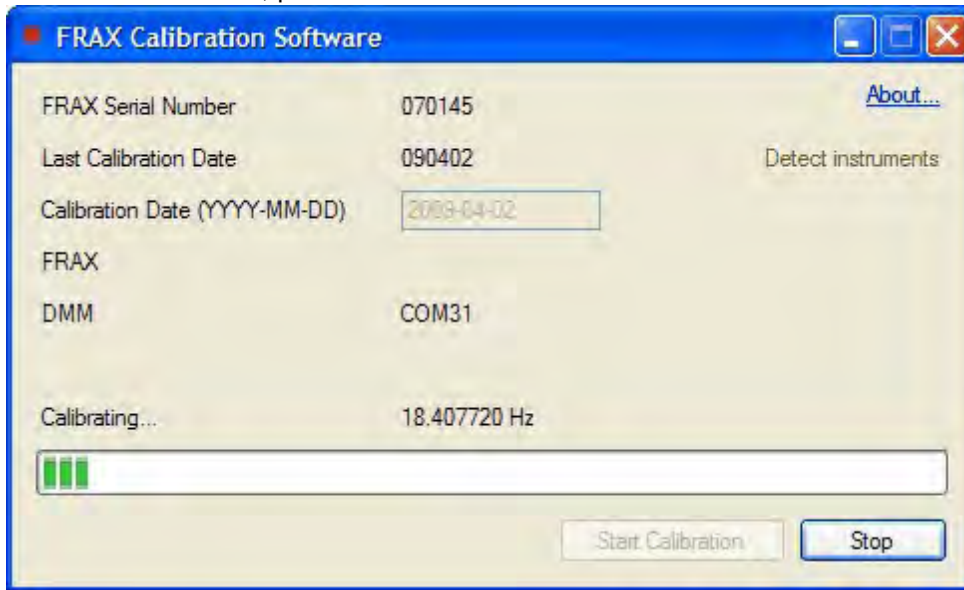


Start the FraxCal software by double clicking the FraxCal icon on your desktop. The start page of the software is presented in the figure below.



The software will automatically detect the serial number of the FRAX unit and the last calibration date. It will also automatically suggest current date to be the new calibration date. The date can be changed by the user. The software will also automatically detect the communication ports for the FRAX and the DMM.

To start the calibration, press “Start Calibration”.



During the calibration process, the software will keep you informed about the progress. The process takes approximately 12 minutes. After successfully completed calibration, the following message will appear.



All calibration data is stored in the FRAX instrument. No written report can be obtained from the software, thus suggesting a separate calibration report to be created manually. Do not forget to apply the sticker on the FRAX back panel, informing the FRAX user about the last calibration date.

Although the FRAX does not need to be calibrated more often than every two years, we recommend that you calibrate the unit every year.

Verification

After a successful calibration, we recommend to do a “short” measurement to verify that the FRAX performs as expected. Use the 1 meter coaxial cables, the BNC Y adapter and the BNC short adapter and connect as described in the figure below.



Measure from 10 Hz to 10 MHz and the measured data should be 0 dB with a maximum deviation of +/- 0.1 dB.

Also make a verification using the built-in calibration reference. Connect as explained in the figure below.

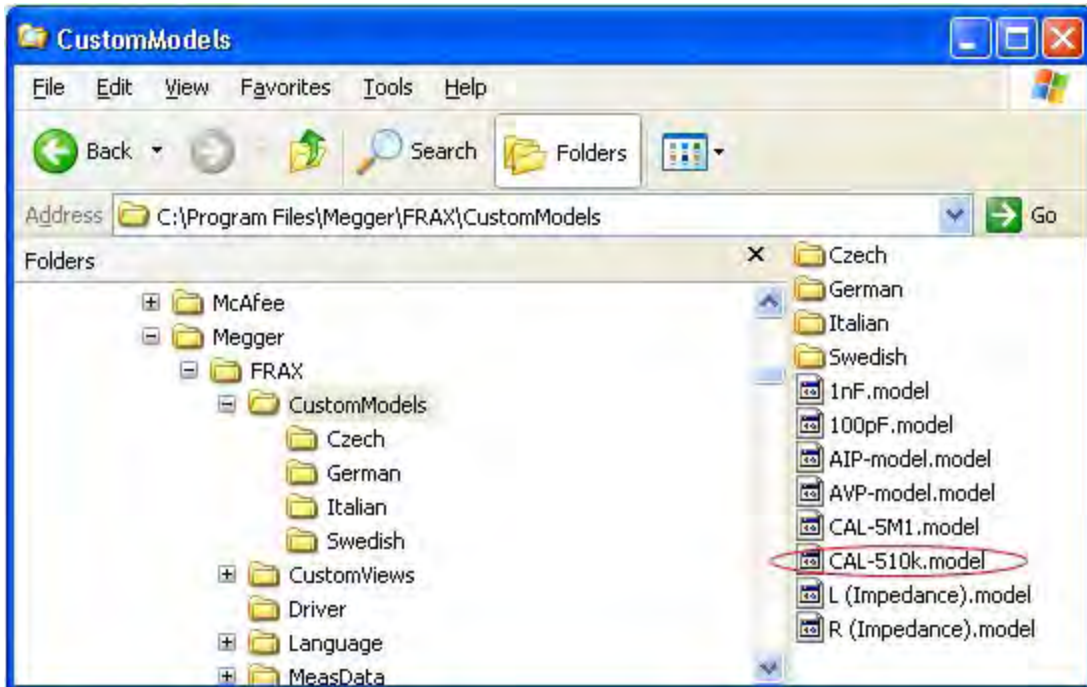
Run standard sweep from 20 Hz – 2 MHz.



When looking at standard view Magnitude Curve should be around -80 dB between 10 Hz – 100 kHz. Unclick Magnitude, use model CAL-510k Curve should be 0 dB, +/- 0.3 dB between 100 Hz – 10 kHz.

To add the 510k model:

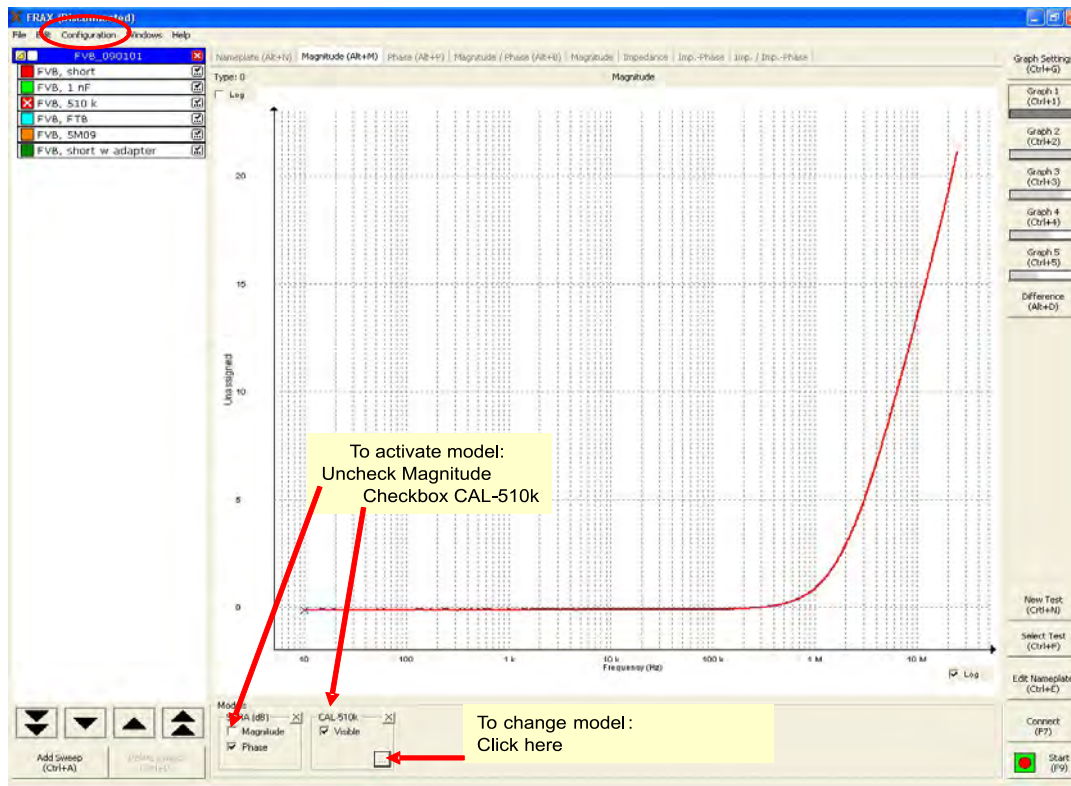
Insert the file CAL-510k.model (on the attached USB stick) in the CustomModels directory, see below



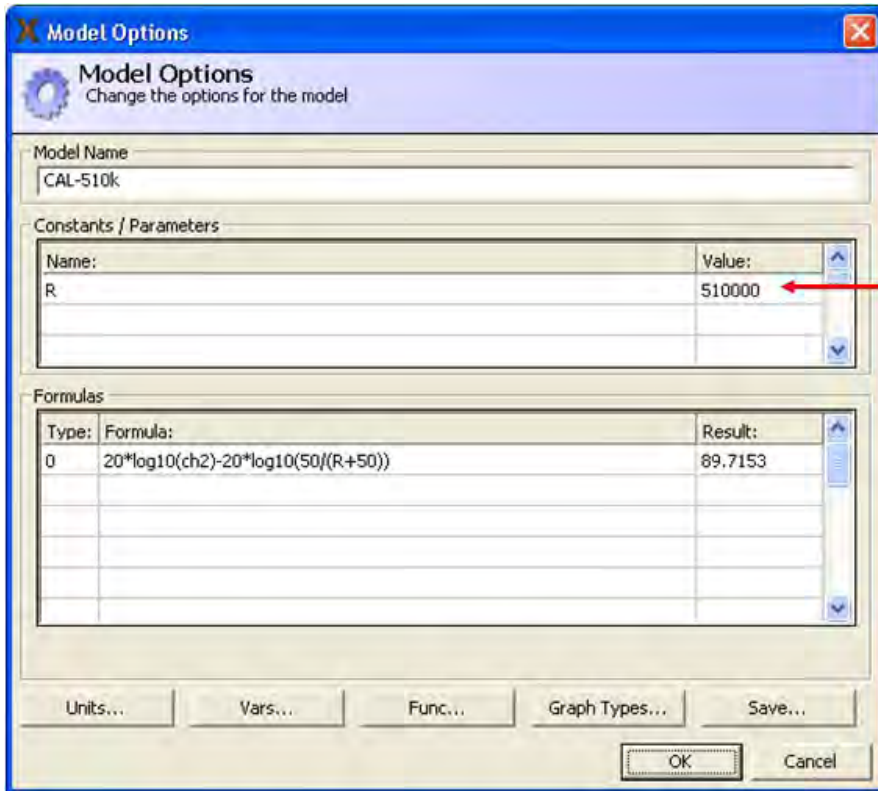
To add model click:

- Menu Configuration
- Menu Models
- Select CAL-510k

Note: For FRAX150 the directory is located at:
D:\Program Files\Megger\FRAX\CustomModels



On each CAL 101, there is a resistance value on the s/n label.
 To ensure the best possible verification; enter this resistance value here.
 In this example, we have used 510 k .



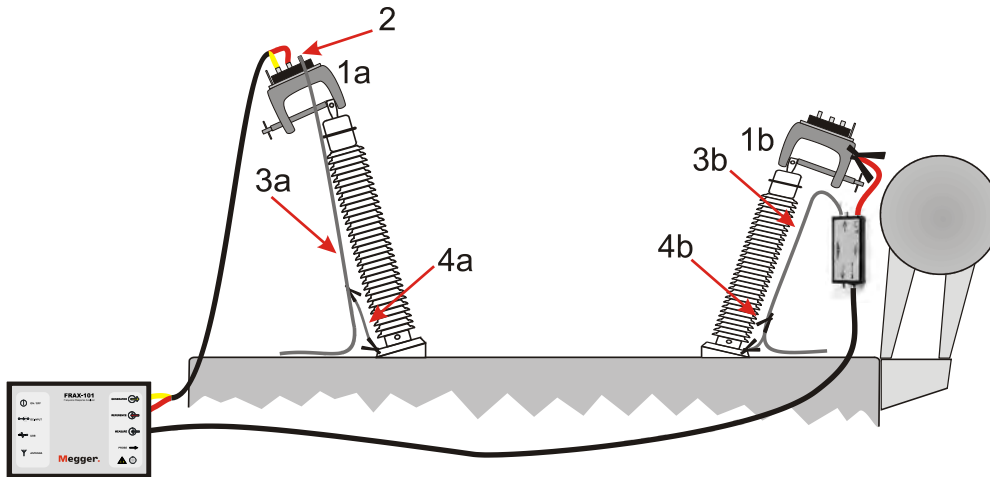
5.2 Appendix B: Optional Active Probes (FRAX-101 only)

The FRAX is designed to measure the transfer functions expressed as e.g. Magnitude and Phase, Impedance or Ratio between two non-grounded terminals, e.g. between non-grounded phase 1 bushing and non-grounded neutral bushing of a power transformer. The output and input impedances of FRAX are all terminated with 50 ohm; the use of relatively long leads with a characteristic impedance of 50 ohms requires 50 ohm termination in the Frequency Response Analyzer.

In cases where higher input impedance is needed an active voltage probe should be used. It is important to keep the cables from the probe to its terminal as short as possible. Megger manufactures for this purpose an Active Voltage Probe, AVP-101.

In cases when measurement has to be performed to a grounded connection e.g. the transformer tank or to a bushing connected to transformer tank the Active Impedance Probe AIP-101 should be used.

5.2.1 Active Voltage Probe AVP-101



An active voltage probe should be used when higher input impedance than 50 Ohms is needed. AVP-101 has a 10 MOhm input resistance in parallel with 1 pF, and divides the voltage with a factor of 10. A lower input impedance is achieved by simply connect a suitable resistor in parallel to e.g. simulate the line impedance.

Connect the FRAX "Generator" and "Reference" channels (red and yellow) and to the clamp at the high voltage side bushing top (1a). Connect the grounding braid (2) and let the braid go close to bushing surface (3a) and connected to ground usually via a bushing bolt (4a). Good electric contact is very important. Make sure that the braid do not touch any conducting part at top of bushing. The other side of high voltage winding, e.g. the neutral bushing, should normally be connected to the grounded transformer tank.

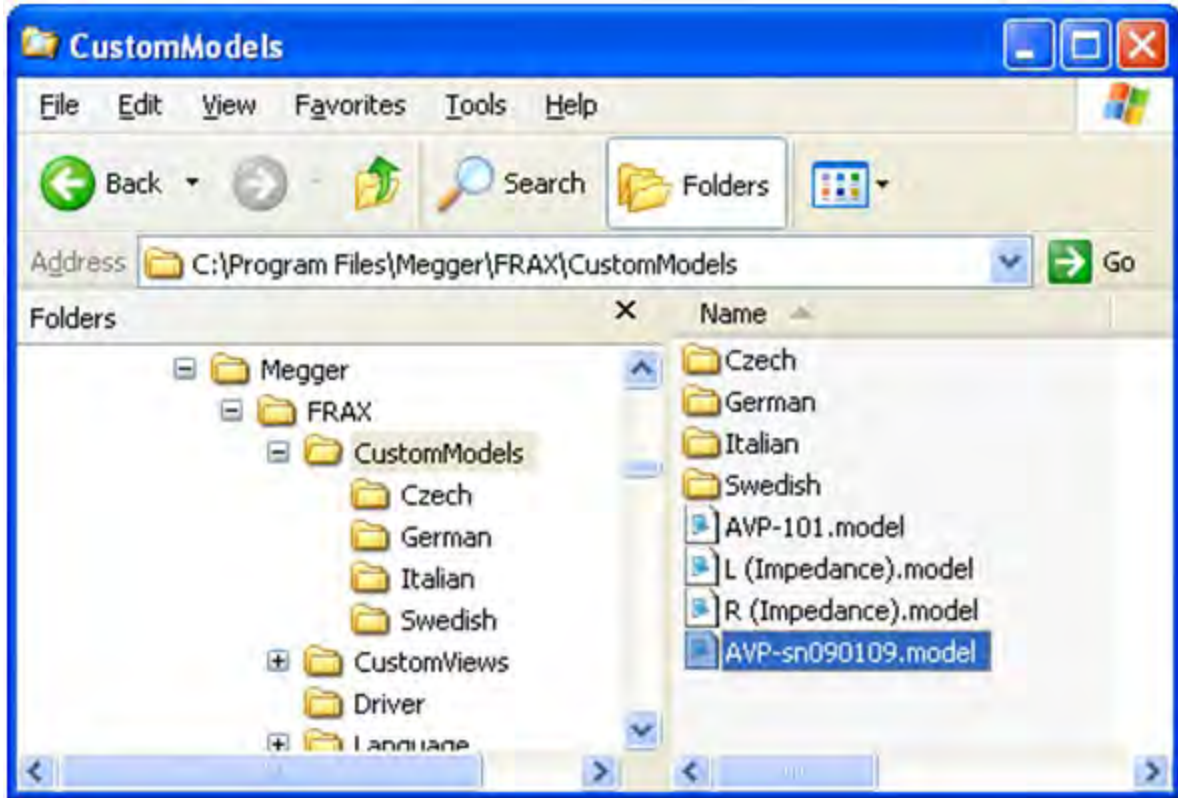
The AVP-probe is connected to FRAX using the cable with one coaxial cable and a multi cable. If a specific input impedance is required, prepare the BNC to banana plug converter by connect suitable impedance between the red and black terminal and connect it to the probe input. Use preferably the C-clamp. To the banana plug, connect the short unshielded lead with clamp, preferably via the C-clamp the top of bushing (1b). Connect the braid to probe ground connector and let the braid close to bushing (3b) surface be connected to ground usually via a bushing bolt (4b).

Perform the measurement as an ordinary FRAX measurement, see e.g. Quick Start Tutorial.

AVP model installation

To be able calculate voltage and phase correctly, a SW model file is needed. The file is delivered with the AVP and the file name is based on the AVP's serial number e.g. "AVP-sn090110.model" and should be copied into the "CustomModels" directory of your FRAX installation, e.g. to the location:

"C:\Program Files\Megger\FRAX\CustomModels\". See example of screenshot below:



To access the model, click on:

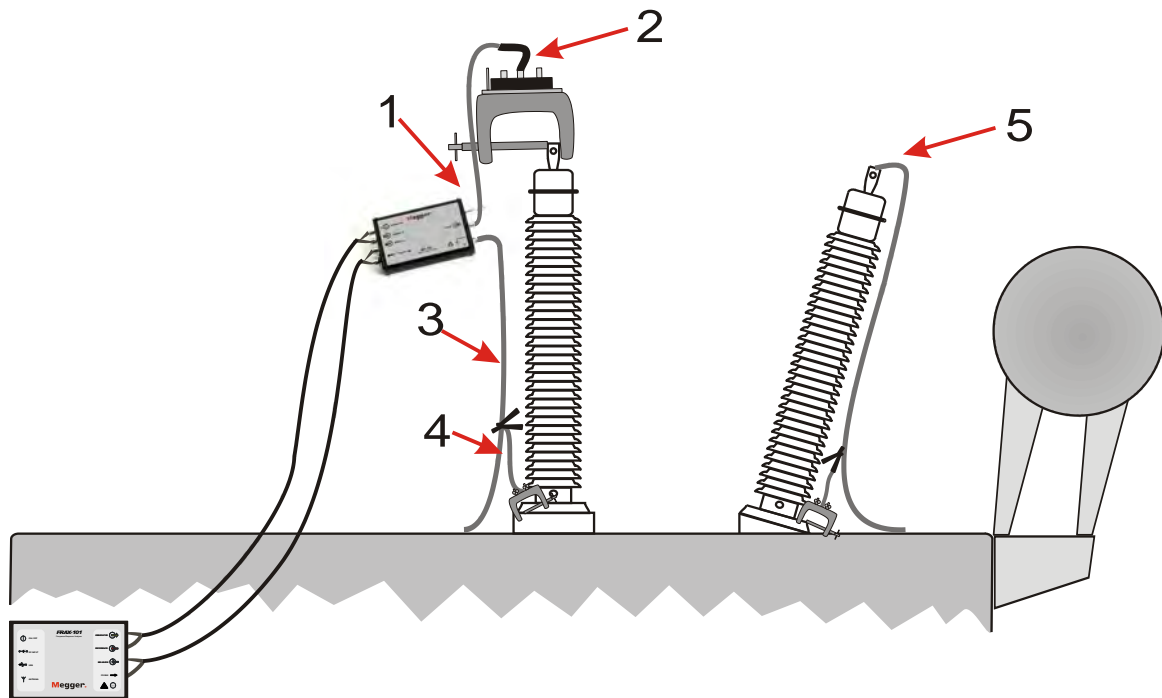
- Menu Configuration
- Menu Models
- Select model AVP-sn090110

Now the model should appear at the bottom of your screen.

The model that comes with the standard FRAX software, AVP-101.model, is replaced by the model delivered with the probe, thus it can be deleted.

For more information see Configuration menu, submenu Models...

5.2.2 Active Impedance Probe AIP-101



The FRAX-101 is designed to measure the transfer functions expressed as e.g. Magnitude, Impedance or Ratio between two non-grounded connections, e.g. between non-grounded phase 1 bushing and non-grounded neutral bushing of a power transformer.

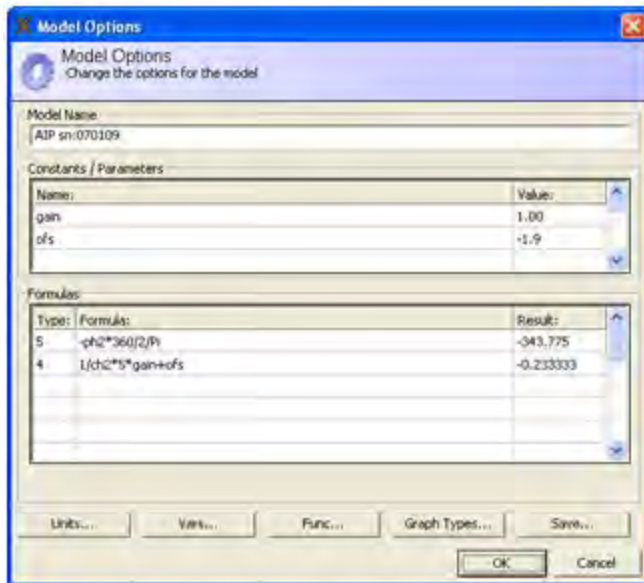
When measurement has to be performed to a grounded connection e.g. the transformer tank or to a bushing connected to transformer tank the Active Impedance Probe AIP-101 should be used. The impedance probe is connected to FRAX using the three coaxial cables and power supply cable.

Connect the output of the probe (1) to the clamp at the top of the bushing (2) using a short BNC cable connected to the ordinary FRAX C-clamp connector. Note that the shield of the BNC connector and connected cable shield is Guard and must not be in contact to top of bushing and must not be in contact with ground/earth.

Connect the braid to the AIP-probe ground screw (NOT to the C-clamp!) and place the braid tight to bushing surface (3). Connect the braid (3) to the base of the bushing using a short braid (4). Normally one or more bushings on same winding are connected to ground (5). Make sure to get a good connection.

Perform the measurement as an ordinary FRAX measurement, see e.g. Quick Start Tutorial.

AIP implementation in FRAX

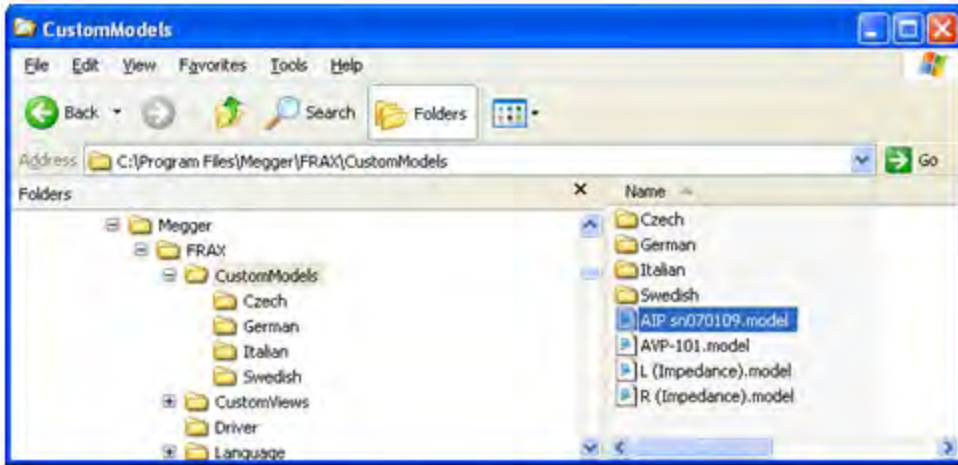


The AIP, Active Impedance Probe Measures measured the applied voltage (connected to Reference at FRAX-101) and the output current (connected to Measure at FRAX-101). To be able calculate the Impedance from the at the FRAX-101 two voltages, a separate model is needed. The AIP model from AIP s/n 070105 is looks as per below:

The parameter “gain” takes into account calibration of the gain, i.e. the relation of output current to voltage at FRAX-101 “Measure”. The parameter “ofs” adjust the offset for low impedance test objects. The calibration parameters are given in the test/ calibration protocol that is delivered with the AIP.

AIP model installation

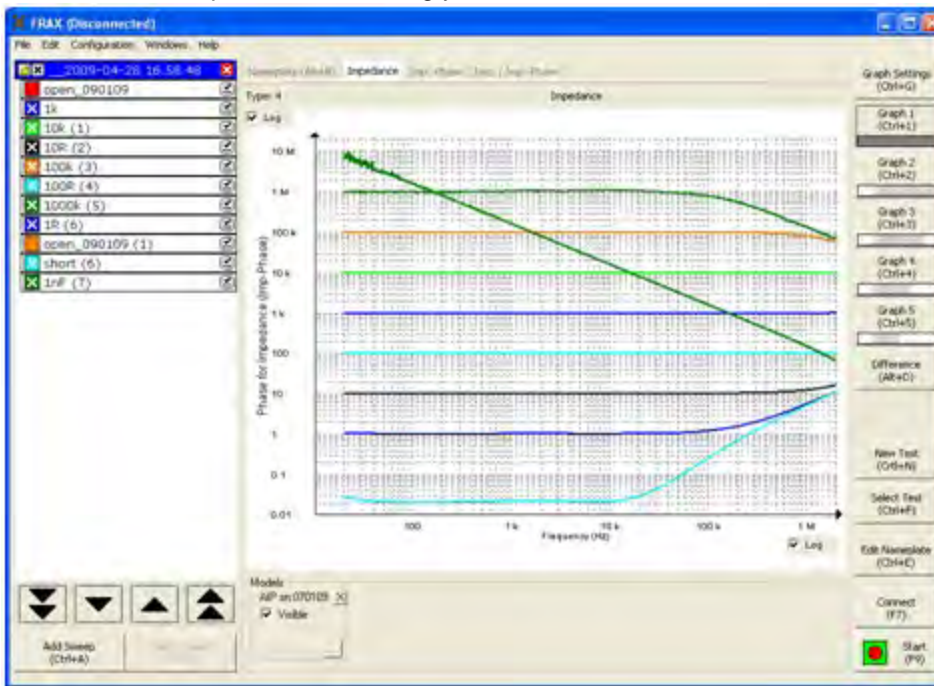
The model-file named e.g. “AIP sn070109.model” should be copied into the “CustomModels” directory of your FRAX installation, e.g. to the location: “C:\Program Files\Megger\FRAXCustomModels\”. See example of screenshot below:



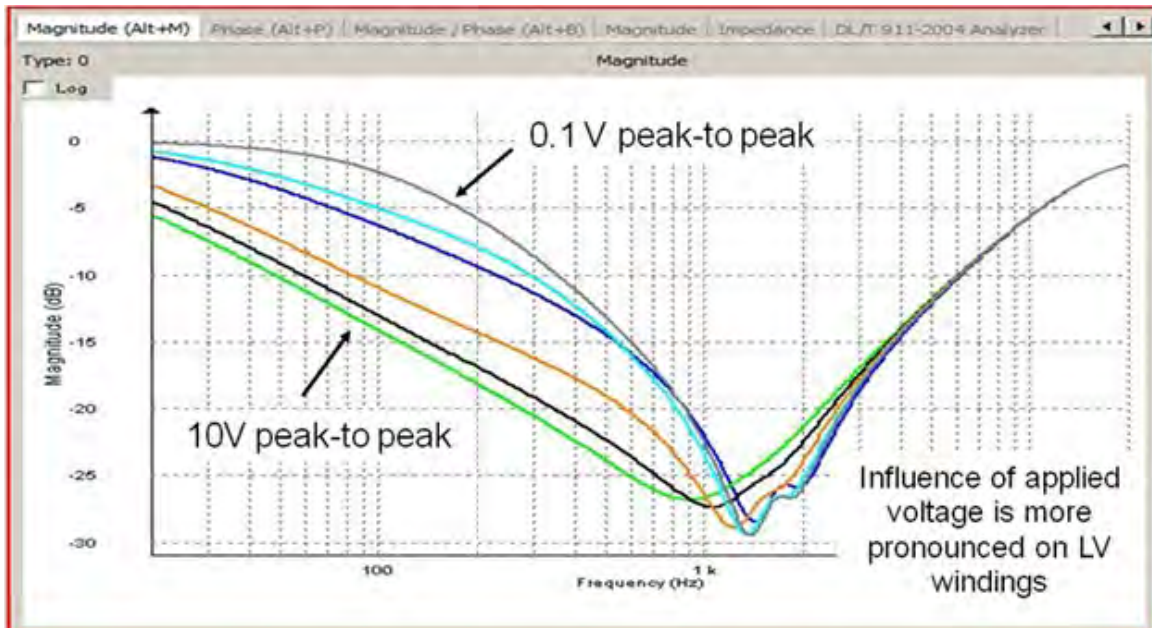
See also Configuration menu, submenu Models...

Measurements and Plot Data

Plot the data in Impedance view using your AIP model:



5.3 Appendix C: Adjusting Output Voltage



On the FRAX-101 and 150 the output voltage level may be adjusted from the standard/default 10 Volts up to 12 and down to 0.1 Volt, by changing a file in the FRAX directory.

The file name is named "connectioncommands.txt" and it is in the directory you installed the FRAX software to, usually C:\Program Files\Megger\FRAX
To use the file to adjust the output voltage add the command `gen:gainx=k` to the file.

K is a factor for setting the output voltage. K=1 means output voltage is FRAX standard/default = 10 V output. By changing k, the voltage can be adjusted.

Examples:

$k = 0.2828$ means output voltage = $0.2828 \cdot 10V = 2.828$ V_{peak} = 2 V RMS (used by FRAnalyzer, Omicron)

$k = 0.05$ means output voltage = $0.05 \cdot 10V = 0.5$ V (= HP 4195A output voltage)

Open/edit the file with Notepad. K must be a number between 1.2 and 0.01, use decimal POINT. Save the changes. After changing k you need to disconnect/connect to FRAX to activate the new setting.

NOTE: If you run Vista you may experience that you do not have the rights to change/save the file. If so, right-click on the file, properties, select security and edit the user right. Another possibility is to run Notepad as administrator and open the file from Notepad (not double-click in the FRAX folder).

NOTE: Don't forget to change back to original $k = 1$ after the measurement session!

5.4 Appendix D: Sweep Name Settings

The predefined sweep plans can be modified to suit your use. To do so use the buttons "Add" and "Delete". The names can be changed by selecting a "Sweep group" or "Sweep name" and enter a new name. Select a "Sweep group" and select which Sweeps that should be included by setting the cross in front of the sweep name(s) and then hit "OK".

The files containing the sweep plans is located in the MeasData direcorey. The modified sweep groups can be found in X_Edit_DefaultTemplates.xml. If you make new sweep groups and want to distribute them you can use the file UserTemplates.xml and rename it to a suitable name. When adding a sweep plan file just put it in the MeasData direcorey and the FRAX software will read from it. Note that the available sweep plans are displayed in alphabetical order based on the sweep plan file so if you want to make sure your own sweep groups are displayed first name the file to something like 1custom.xml or !!myfile.xml.

Sample Connections

The different set-ups measured with SFRA as defined in CIGRE Brochure 342 and IEEE FRA draft:

CIGRE

- 1) End-to-End Open
- 2) End-to-End Short-Circuit
- 3) Capacitive Inter-Winding (CIW)
- 4) Inductive Inter-Winding (IIW)

IEEE

- Open Circuit Self Admittance (OC)
- Short Circuit Self Admittance (SC)
- Inter-Winding (IW)
- Transfer Admittance (TA)

Examples of sweep labeling

IEC

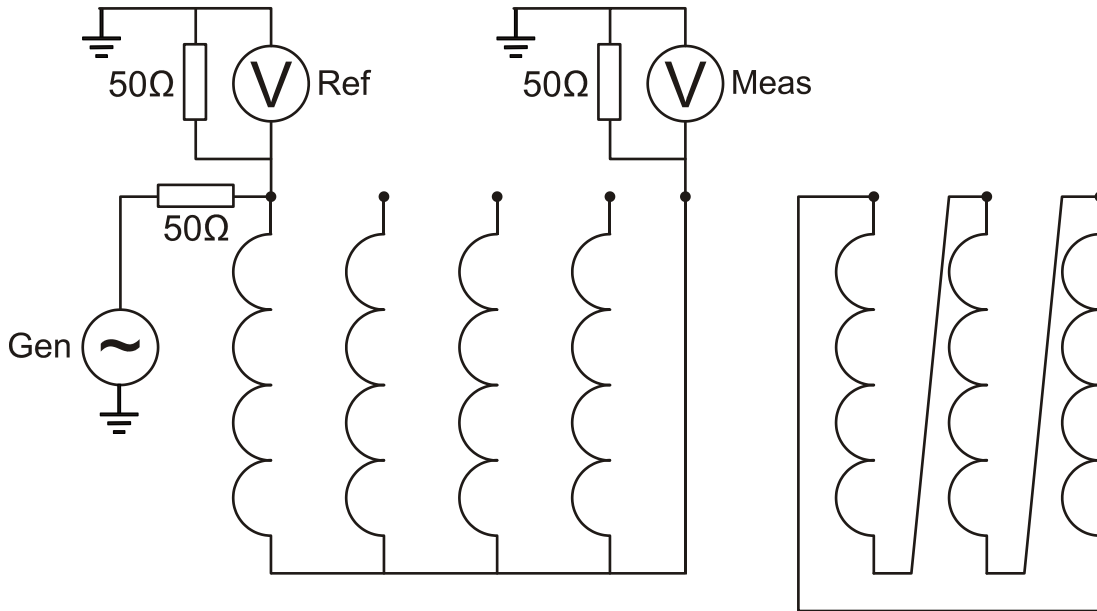
- 1) A-N [open]
- 2) A-N [short]
- 3) A-a1 [CIW]
- 4) A-a1 [IIW, GND N,n1]

VDE

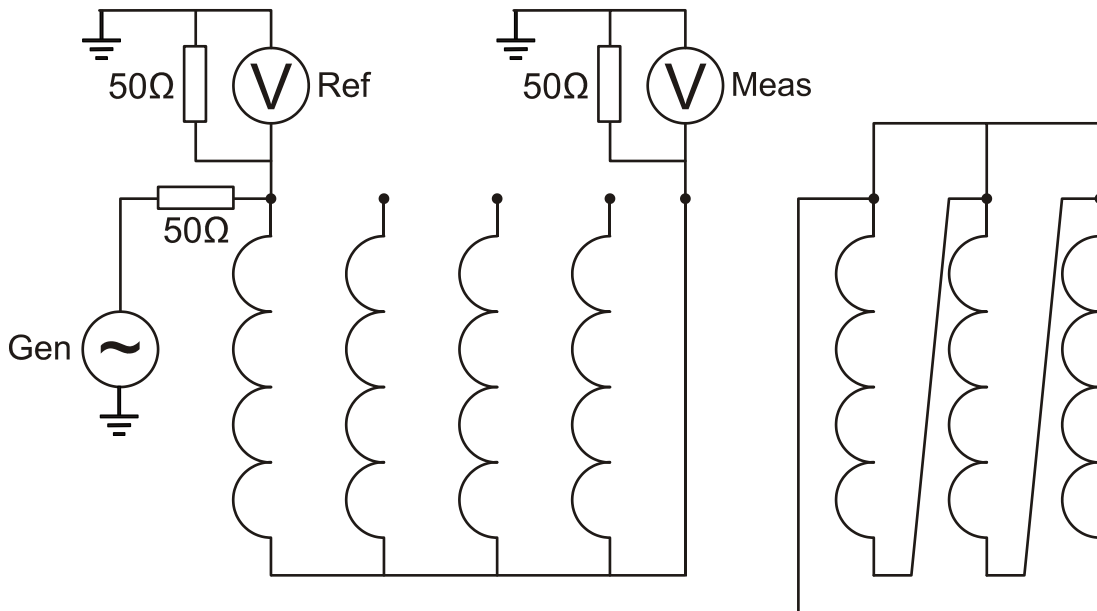
- U-N [open]
- U-N [short]
- U-u1 [CIW]
- U-u1 [IIW, GND N,n1]

IEEE

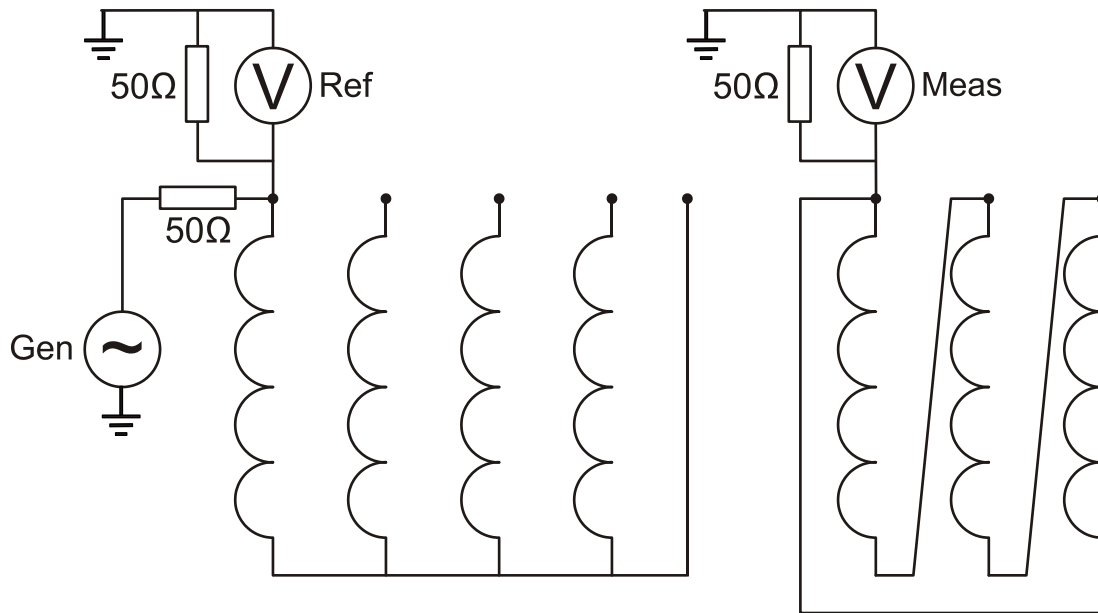
- H1-H0 [open]
- H1-H0 [short]
- H1-X1 [IW]
- H1-X1 [TA, GND H0,X0]



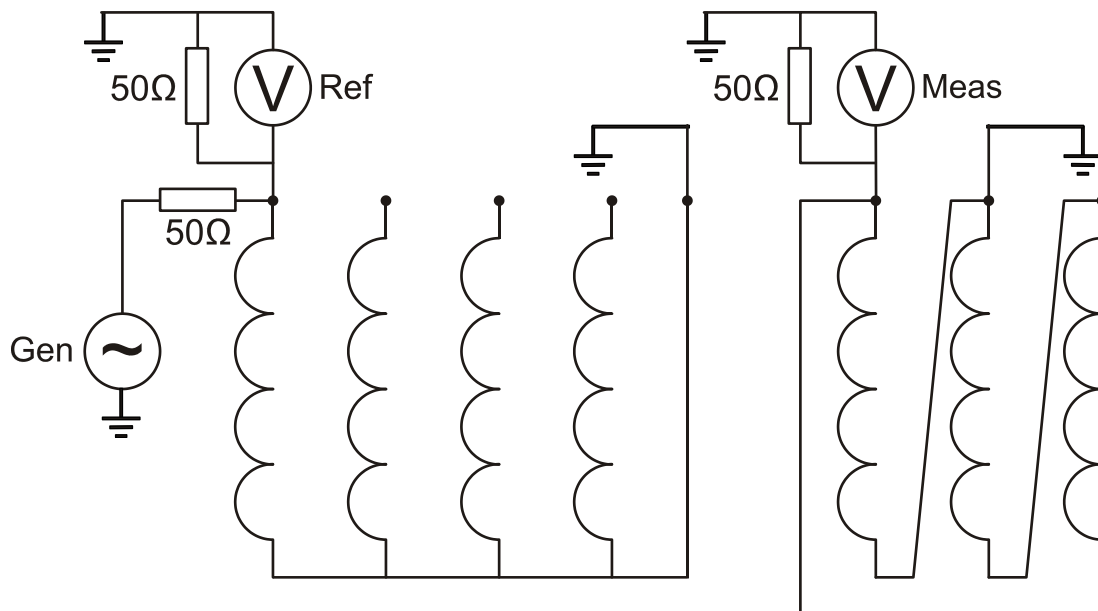
1) In the “End-to-End Open” (Open Circuit Self Admittance, OC) the signal is applied to one end of each winding in turn, and the transmitted signal is measured at the other end. The low-frequency range of this test is basically a low voltage measurement of the voltage dependent single phase excitation current.



2) The “End-to-End Short-Circuit (Short Circuit Self Admittance, SC) is measured as the “End-to-End Open” measurement but with one or more windings shorted. The low-frequency range of this test is basically a low voltage measurement of the single phase impedance.

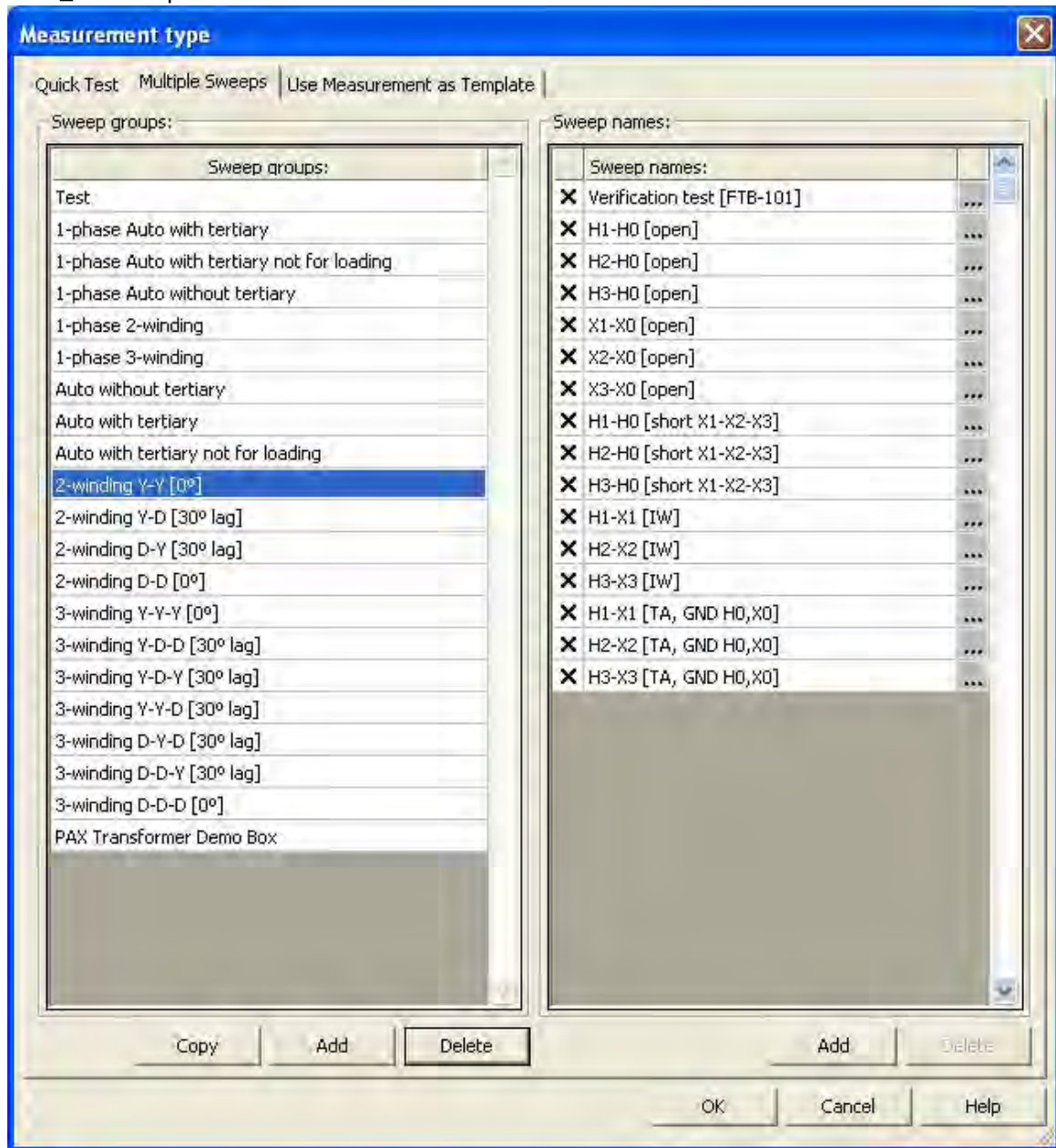


3) In the Capacitive Inter-Winding, CIW (Inter-Winding, IW) measurement, the signal is applied to one end of a winding and the response is measured at one end of another winding on the same phase (not connected to the first one). The lowest-frequency range of this test is basically a capacitance and dissipation/power factor measurement (e.g. CHL).

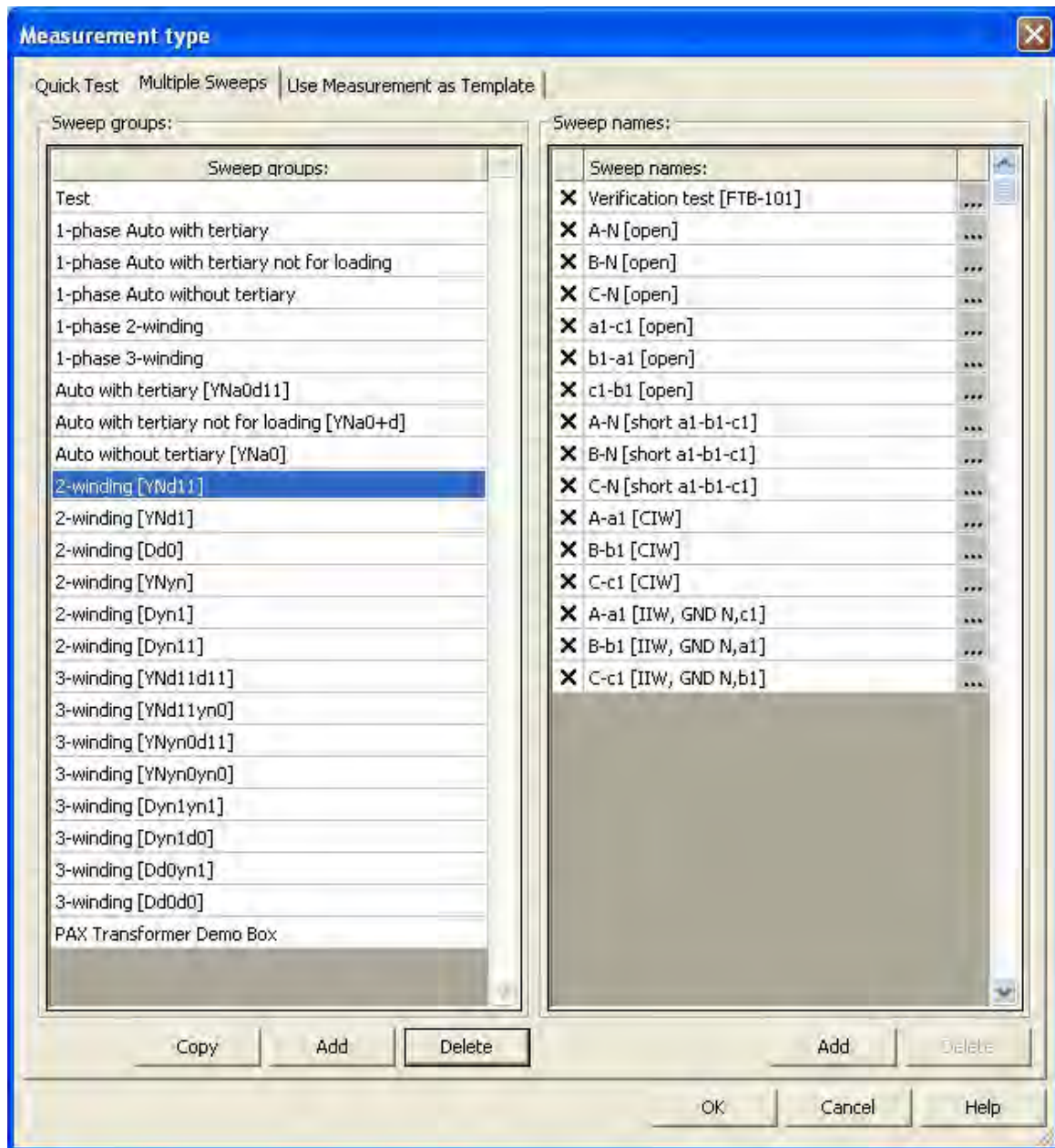


4) In the Inductive Inter-Winding, IIW (Transfer Admittance, TA) measurement, the signal is applied to a terminal on the HV side, and the response is measured on the corresponding terminal on the LV side, with the other end of both windings being grounded. Example of labeling is “A-a1 [IIW, GND N, n1]” where GND N, n1 means ground terminal N (H0) and ground terminal n1 (X0). The low-frequency range of this test is determined by the winding turns ratio (slightly affected by the 50 Ohm load at the “Meas”-side.)

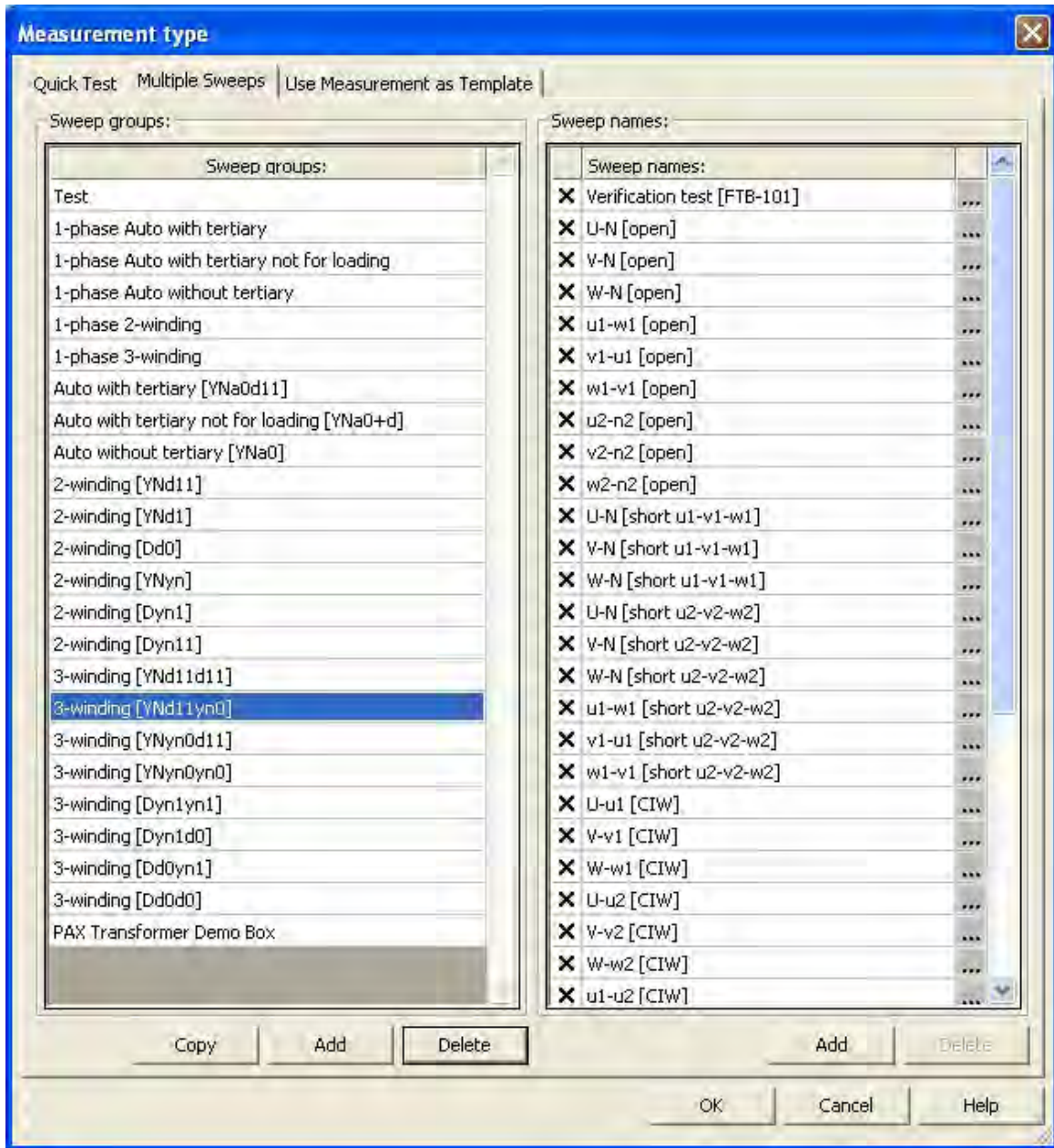
IEEE_UserTemplates.xml



IEC_UserTemplates.xml



VDE_UserTemplates.xml



5.5 Appendix E: FRAX cables and clamps

The FRAX clamps and cables are field tested, rugged accessories ensuring repeatable and accurate measurements. Coaxial cables are covered with an extra protective cover and strain relief is fitted on all 9 and 18 meter cables to ensure a long and trouble free life of service.



Ground braids made of tin plated copper ensure good contact, make them easy to work with and increase life of service compared to e.g. aluminium.

The FRAX clamps handles both round and flat connectors. Easy to attach and a firm grip avoids any risk of clamps falling off.

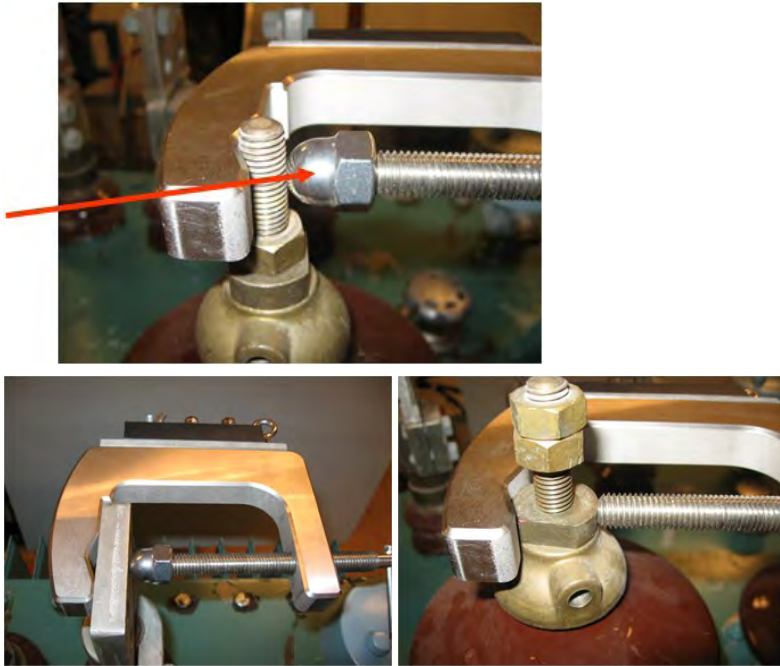
The C-clamp is used to connect the FRAX to the bushing. All necessary connectors (BNC, braid, ground, cable strain relief) are included in one clamp. The smaller G-clamp is used to connect the braids to ground. Both models are part of the standard cable set delivered with a FRAX.



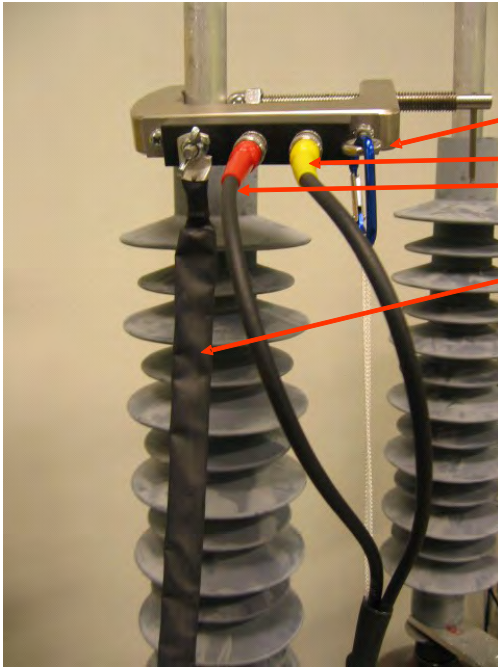
5.5.1 Bushing connection

The C-clamp can be fastened on any type of bushing up to \varnothing 90 mm. The M12 screw ensures good electrical and mechanical contact. No risk of a clamp falling down due to heavy cables and braids.

The clamp is delivered with a M12 hat nut, which can be used when you want to avoid the screw making marks on a sensitive surface.



5.5.1.1 Generator cable connection (yellow/red)



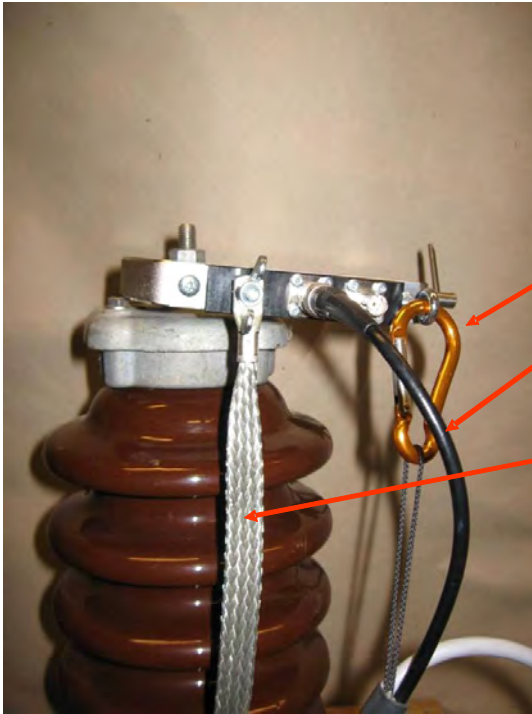
Cable strain relief

Coaxial cable from FRAX
- Generator (Yellow)
- Reference (Red)

Ground braid connected to ground. Keep the braid straight along the bushing and ground the braid at the base of the bushing. Ensure good connection.

The first 50 cm of the braid is insulated to avoid any electric connection to the bushing.

5.5.1.2 Measure Cable connection (black)



Cable strain relief

Coaxial cable from FRAX
(Measure)

Ground braid connected to ground.
Keep the braid straight along the
bushing and ground the braid at
the base of the bushing. Ensure
good connection to ground using
the G-clamp.

5.5.2 Ground braid practice



The ground braid shall go from the C-clamp the shortest way to the bottom of the bushing. Good ground connection is essential for reliable test results. Look at the next two pages for more information.

The braid cable set consists of 4 x 3 meter tin plated copper braids. Many transformers have bushings shorter than 3 m, which suggests two braids, one for each bushing, to be enough when it comes to length.

The remaining braids can be used if bushings are taller than 3 m. See picture below how to joint two braids.

The C-clamp allows a two braid practice, not necessary when using FRAX, but useful if compatibility with previous two braid measurements is required.



5.5.2.1 G-clamp connection to ground

The new, unique ground clamp handles both nuts and bolts as well as other round and flat connectors, making it the most easy-to-use and versatile ground connection available.



The G-clamp is easy to attach, easy to tighten the braid, which ensuring a quick and reliable procedure for shortest braid practice, which is essential to get repeatable measurements.



The sharp, adjustable M4 pin screw penetrates any paint or oxide, making it easy to get a good, solid ground connection on almost any surface.

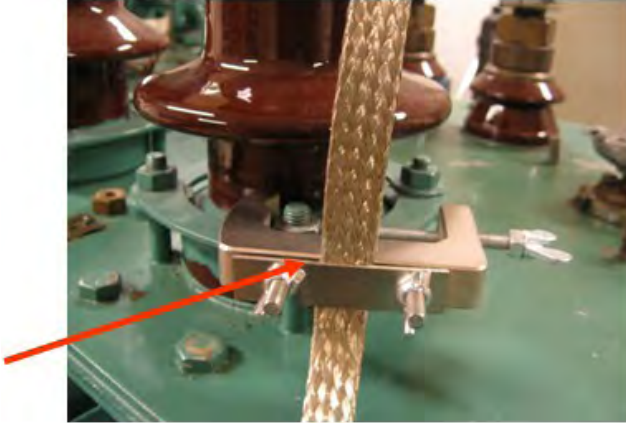


5.5.2.2 Ground braid connection

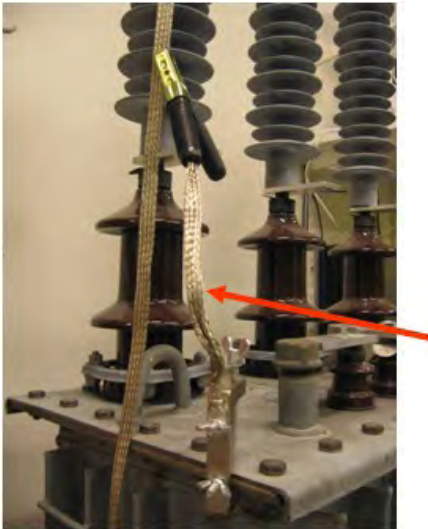
The clamp can be attached to ground in many ways. See previous section.



To attach and tighten the braid: open up the braid plate by loosening the wing nuts.



Place the braid between the G-clamp and the braid plate. Tighten the braid to create a straight line from the C-clamp to the G-clamp. Tighten the wing nuts.



For extra flexibility when connecting the braids to ground, the short braid with clamp included in the ground braid set can be used.



5.5.2.3 Field Test Box FTB 101

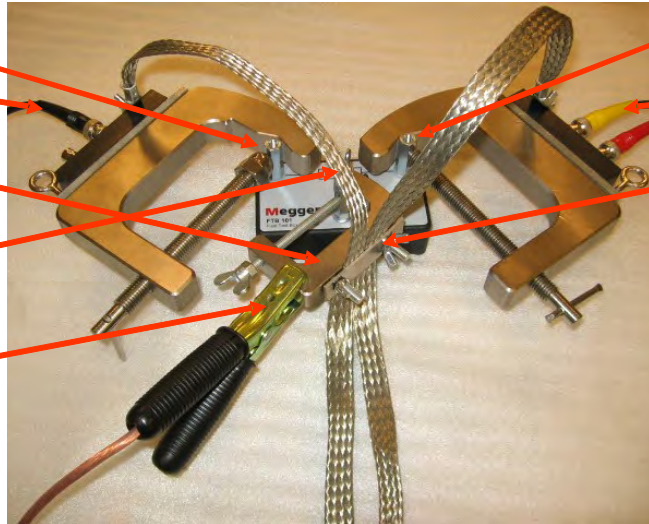
Connect C-clamp
to FTB101

Connect the
Measure cable

Attach the G-clamp
to ground on the
FTB101

Connect the
braid to the
G-clamp

Connect the ground
cable from FRAX
to the G-clamp



Connect C-clamp
to FTB101

Connect the
Generator cable

Connect the
braid to the
G-clamp

5.6 Fuse Replacement

The instrument is protected by two mains circuit fuses. These fuses are located in the ON/OFF switch module and are replaceable by the operator.

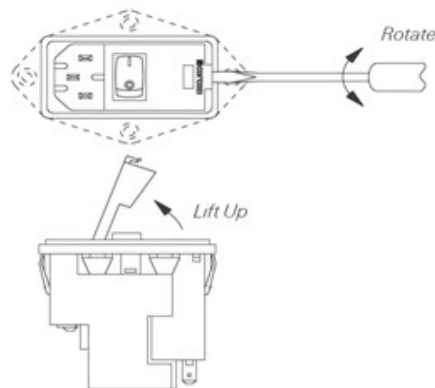


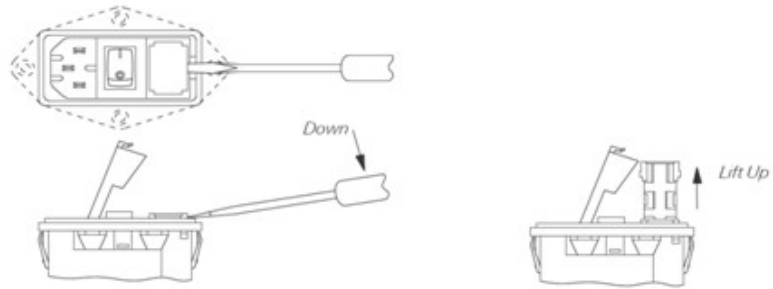
WARNING
To avoid electric shock and fire hazard, use only the fuse specified below, that is identical in respect to type, voltage rating, and current rating.

F 2A / 250V

Fuse Removal

- Using a pocket screwdriver, insert the screwdriver in the slot under the door and gently rotate the screwdriver to unlatch the door.
- When unlatched, raise the door.
- With the door in the raised position, apply the screwdriver at the slot end of the fuseholder and gently push down to raise the fuseholder and remove it from the housing.
- Remove fuses (2x) from fuseholder. Fuses should be replaced in pairs.



**Fuse Installation**

- Install two fuses, one on each side, offset toward contact area as shown.
- Insert fuseholder back into housing and snap door closed.

