

# PASI

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## User manual



# Polares 32

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**P.A.S.I srl – via Galliari 5/E – 10125 TORINO – Italy**  
Tel. +39 011 650.70.33 – Fax +39 011 658.646 - E-mail [sales@pasisrl.it](mailto:sales@pasisrl.it)  
[www.pasisrl.it](http://www.pasisrl.it)

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## Warranty information and safety notes

Read the instructions carefully before using the product:

- This instrument was designed and built to measure electrical resistivity in the soil for geophysical/geological purposes. Please read this manual carefully before use.
- The warranty will be void if the product is not used according to the instructions in this manual.
- The warranty will be void if the appliance is tampered with.
- The device must only be used in accordance with the instructions described in this manual. Correct and safe operation can only be guaranteed if the instrument is properly transported, stored and treated.
- To avoid damage, use only original accessories or those approved by PASI srl.
- The case containing the instrument is only waterproof when closed. Once the instrument has been placed on the measurement site, it should always be adequately protected to prevent it from being exposed to the elements (rain, snow, direct sunlight, etc.). It is not advisable to install the instrument on a vibrating surface.



# 1. Introduction

The Polares 32 instrument is a device made and assembled by P.A.S.I. srl, a leading Italian company in the production of instruments for geology and geophysics.

This guide lists the technical specifications and explains how to use the device. Adhere to these guidelines.

## *Content of the manual*

- Chapter 2, Electrical imaging system for tomography Polares 32, contains a brief presentation of the instrument
- Chapter 3, Mode of use, describes how to use the system from a hardware point of view.
- Chapter 4, Getting started, describes how to perform some basic operations using the Polares 32 system and its PC control programme, referring to the subsequent chapters of the manual and allowing the operator to start learning about and using the system.
- Chapter 5, Description of the Polares 32 program, describes the mode of operation of the PC control programme and the use of the system controlled in this way, illustrating in detail all the functions offered by the programme and their interaction with the system.
- Chapter 5, Annexes, reports the technical characteristics of the system and the definition of the proprietary GPD (Geophysics Pasi Data) format used for storing the results of a measurement session on file.

## 2. Electrical imaging system for tomography Polares 32

### *A brief introduction*

POLARES 32 is a lightweight, easy-to-carry and fast AC electrical imaging system for tomography.

It is designed to accurately measure AC currents and voltages in order to provide the user with apparent resistivity and phase values in the frequency domain.

It operates with an adjustable transmission frequency in the range of 7 to 125 Hz.

POLARES32 can be used in many applications: laboratory measurements, electrical surveys, surface electrical resistivity tomography, 3D surveys, mobile surveys of canals, lakes, sea, etc.

Access to POLARES32 functions is intuitive through the use of an external PC (Windows™) connected via USB cable.

The use of an external Windows™ PC offers much longer battery life and improved overall system reliability. Computer faults can be easily solved by replacing the PC, software updates do not require delicate interventions on the instrument's firmware, and the user can benefit from remote assistance from our company for fault diagnosis.

The communication interface is a USB port on the PC, through which the user can upload measurement configurations, install new software versions, download measured data and, in addition, connect a number of different devices (network interfaces, WiFi routers, Bluetooth or GPS antennas, keyboards, etc.).

### *What is the difference with conventional DC electrical tomography?*

The use of Electrical Resistivity Tomography (ERT) for geology has been essentially the same since its début, based on the original principles of Vertical Electrical Soundings (VES): apply a direct current to two stakes inserted into the ground (current electrodes A B or C1 C2) and measure the corresponding voltage between two others (voltage

electrodes M N or P1 P2). As far as “traditional” instruments are concerned, the applied current and thus the corresponding voltage have always been continuous, with reversed polarity for each measurement. POLARES32 uses a sinusoidal alternating current with adjustable frequency.

### *Why is POLARES32 an innovative instrument?*

The use of alternating current has shown particular advantages in terms of speed of execution of measurements with the same quality of results. Compared to conventional DC systems, this increased speed can reduce the time to perform the same set of measurements in the field by at least a factor of 10 (or even 20, in most cases). Furthermore, the measurement of the relationship between the detected voltage and the injected current, in a sinusoidal state, both in terms of amplitude and phase (delay of one signal on the other), allows the simultaneous detection of resistivity and induced polarisation of the ground.

### *What are the main strengths of POLARES 32?*

- COMPLEX RESISTIVITY ACQUISITION: being designed as an AC system, POLARES32 involves both the conduction and polarisation properties of the material under investigation. Since the complex resistivity modulus deals with the electrolytic properties of the pore-filling fluids, the phase shift between the voltage and current signals is directly influenced by the polarisation of the material. Thus, each individual data set can be used to analyse both resistivity and induced polarisation.

Resistivity (as the reciprocal of conductivity) is a complex, frequency-dependent property of a material and is described by the following equation:

$$\frac{1}{\rho^*} = \sigma^* = |\sigma| e^{i\varphi} = \sigma' + i\sigma''$$

where  $\sigma^*$  and  $\rho^*$  define complex conductivity and resistivity respectively,  $|\sigma|$  is the modulus of conductivity,  $\varphi$  is the phase shift between voltage signal and current,  $\sigma'$  and  $\sigma''$  are the real and imaginary part of the complex resistivity.

The real (in-phase) and imaginary (or quadrature) components of the complex resistivity can be obtained from the following relationships:

$$|\sigma'| = |\sigma| \quad |\sigma''| = \sigma' \tan(\varphi)$$

Real resistivity is mainly related to electrolytic conduction phenomena (resistivity of rock or soil, and even more so to the resistivity of pore-filling fluids), and to various aspects of induced polarisation (surface polarisation, presence of metallic minerals, contaminants and so on).

Many studies and works have shown a growing interest in AC geoelectric surveys, which have demonstrated their effectiveness for mineral exploration, structural characterisation of geological features and monitoring of contaminated sites.

For users who prefer to work with chargeability as an IP parameter, POLARES32 automatically stores the chargeability (in ms) associated with each measurement, thanks to the relationships between phase shift (IP in the frequency domain) and chargeability (IP in the time domain).

- SPEED: POLARES32 can be used to measure single high-frequency data sets (7 to 125Hz). In many common applications, ensuring good electrode-to-ground contact is sufficient to acquire accurate datasets of apparent resistivity values, ready for subsequent inversion using special external software.

The higher the frequency, the higher the speed: field data from moderately noisy sites can be acquired at a rate of up to 3 measurements/second, in any measurement matrix. In many cases, the time necessary to complete the series of measurements can be reduced by a factor of 10 to 20 compared to traditional DC systems.

- ACCURACY: the high resolution of the acquisition system (0.4  $\mu$ A for current signal and 1.5  $\mu$ V for voltage signal) allows accurate interpolation of sinusoidal current and voltage signals. This becomes even more important when POLARES32 is used for spectrally-induced polarisation surveys, where phase shift values must be measured with the highest level of accuracy.

For users requiring noise-free phase data, POLARES32 can be used with non-polarisable electrodes to avoid any inductive EM coupling along the wires between the transmission and measurement circuits.

- MODULARITY: POLARES32 contains, integrated in a robust Peli case, the transmission and measuring system, all the necessary guards and also 2xMPX (Multiplexer) with 16 electrodes each (for the first 32 electrodes). Additional external

MPXs (16 el. each) can be connected externally to POLARES32 to increase the number of electrodes following the first 32 (thus implementing the number of electrodes to 48, 64, 80, 96, etc.).

### *POLARES32 main features*

- Transmitter and receiver in one unit; power supply via external battery of any type (lead, lithium, etc.) from 8.5 to 15V
- Very fast measurements: up to 3 scans/sec.
- Fully automatic microprocessor-controlled measurement: automatic correction of spontaneous potential, automatic measurement, digital stacking, error display in case of procedural problems
- Quality check of electrode-soil connections before measurement.
- Measurement and recording of ground resistance (with contact resistance measurement), current, voltage, chargeability (IP), spontaneous potential and standard deviation (SIGMA).
- Calculation of apparent resistivity for various electrode arrays: Schlumberger, Wenner, Wenner-Schlumberger, Dipole-Dipole, Pole-Dipole, Pole-Pole, etc.
- Ability to support any user-designed 2D and 3D electrode array
- Measurement and display of chargeability (phase shift in current and voltage sine waves) simultaneously with resistivity measurement: IP and resistivity are measured and acquired in the same measurement session
- Multi-electrode mode for use with the automatic switching system (unlimited number of electrodes)
- 4 auxiliary electrodes (A, B, M, N) for unlimited poles, special measurements and VES measurements

### Automatic adjustment of current and voltage output values

- Output power: max. 200 W.
- Maximum output voltage: Max 700 Vpp
- Maximum output current: Max 4App

### Output current specifications

- Resolution: 0,4uA

- Accuracy: standard 0.15% max 1% from -20 °C to 60 °C

Waveform: sinusoidal from 7 to 150 Hz

Input impedance: 10 MOhm

Input overvoltage protection: 1000 V.

Input voltage ranges: +/- 300 V and +/- 6 V.

Automatic power line rejection 50 / 60Hz

Voltage measurement specifications:

Actual resolution: 1.5uV

Accuracy: standard 0.15% max 1% from -20 °C to 70 °C

Chargeability accuracy (measurement): 0.1%

Power supply: external (8.5V = to 15V =) lead-acid or lithium battery, internal 30 A fuse, reverse polarity protection, power cable supplied, battery to be sourced locally by customer.

## 3. Mode of use

### Caution

The electrical imaging system for tomography POLARES 32 is a very sophisticated instrument, but at the same time quite simple to use.

It should be remembered that the instrument uses potentially lethal electrical voltages and currents; this means that the POLARES 32 instrument must be used by specially trained personnel who have the necessary knowledge of the theoretical principles and methods of measuring electrical resistivity in the soil, whether by quadripole or multi-electrode tomographic methods.

In order not to leave room for improvisation, before using the instrument in the field it is strongly recommended to read this manual carefully and to be familiar with the theory (electrical engineering and geophysics) relating to the principles underlying the methodology.

Before proceeding with field measurements, please do not hesitate to contact PASI technical support to clarify any doubts.

Always bear in mind that there are physical limits to the application of the method, once these limits are exceeded (resistivity too high or too low) the measurement is not possible, even if the instrument is fully operational.

The instrument is protected - to the maximum of current technical possibilities - against all foreseeable incorrect operations (indicated as such by the instrument itself); however, the execution of incorrect operations may lead to damage to the instrument or danger to the operator.

In these cases, only PASI's authorised technical support will decide whether or not the fault falls within the scope of the warranty provided with the instrument. Any sending of damaged or malfunctioning instruments to our laboratories must always be authorised in advance by PASI technical support and must be performed according to the instructions that will be communicated by PASI when necessary.

## *Test plug to check operation of MPX and MPX extension cable*

We would like to remind you here of the importance of the test plug which you found in the holder inside the lid of the POLARES 32 case.

Although it can also be performed on field it is advisable to perform this procedure before going to the building site. This is a very simple and quick test, which is essential for the subsequent correct execution of measurements in the field (especially to avoid arriving on site with a faulty MPX or extension cable).



**FIGURE 1: TEST PLUG**

The test is described in detail on page **XX** of this manual. Here we would just like to remind you that if you have more than 32 electrodes, it is advisable to connect all external MPXs and their extensions (note: multi-electrode cables should not be connected). This will test not only the MPX, but also its extension cable or short connection cable (2.5m, optional) such as the one shown in the photo of the external MPX test (this cable is normally used for 3D measurements when MPXs are connected close together).

This will be done by testing the MPXs one at a time, putting the plug on each one and leaving the others only connected to all the extensions.





FIGURE 2: INTERNAL MPXs TEST, 1/A AND 1/B



FIGURE 3: EXTERNAL MPXs TEST 2, 3, ...N

## *Hardware and logic electrodes*

Please assimilate this concept because, although it is simple, it is very important to understand the logic behind the operation of the stringings.

Hardware electrodes are the positions that the designer has physically foreseen for each electrode as they exit the connector (the electrode with the lowest number is always the one next to the connector).

Logic electrodes are the positions that the operator can decide to assign to each electrode and which are independent of the physical position.

Suppose a 32-electrode linear measurement is to be carried out: electrodes 1 to 16 come out of the first MPX and electrodes 17 to 32 come out of the second MPX. If we wanted to connect all electrodes linearly, having said that the electrode with the lowest number is the one closest to the connector on the ground, the sequence of hardware electrodes on the left of POLARES 32 would be:

16-15-14-13-12-11-10-9-8-7-6-5-4-3-2-1

while on the right would be:

17-18-19-20-21-22-23-24-25-26-27-28-29-30-31-32

However, in order to measure along our linear profile, we need the sequence of electrodes to start at 1 on the left and go up to 16 near the instrument and then continue with electrodes 17 to 32 on the right. In order for this to be possible we will have to “rename” 1 of the first 16 electrodes and consequently the hardware electrode 16 will have to become the logic electrode 1, the hardware electrode 15 will have to become the logic electrode 2 and so on.

In conclusion, it follows that the position of the hardware electrodes is immutable while the position of the logic electrodes is decided by us according to our needs. With reference to FIG. 4, the positions of the logic electrodes are shown in black and those of the hardware electrodes in red.

## POLARES32 - CONFIGURAZIONE CON 32 ELETTRODI

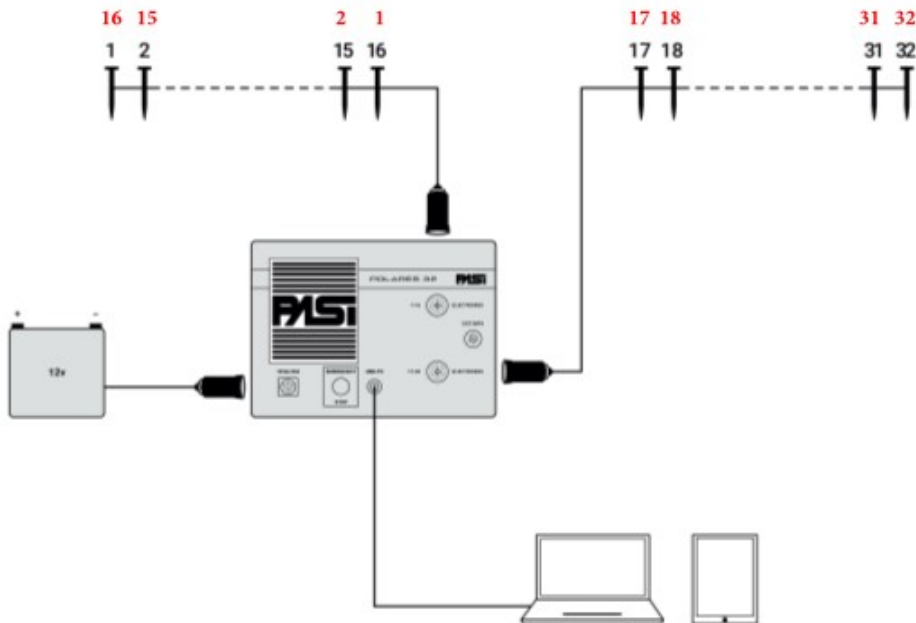


FIGURE 4: CONFIGURATION WITH 32 ELECTRODES

Acquiring this concept, thanks to the software functions described later in the manual, it will be possible to define an arbitrary position for each electrode (logic electrode) independently of their hardware position.

After planning the stringing procedure (purpose of the measurement, type of stringing, logistics, etc.), the field is prepared for the measurement by first clearing a strip (in the case of linear measurements) or an area (in the case of 3D measurements) so that the electrodes (stakes) and the measuring cable are clearly visible.

If the planned spacing is the same as the cable spacing, you can proceed by directly laying the multi-electrode cable along the established profile, then driving the electrodes into the ground beside each takeout to which they will be connected. If the required spacing is smaller, it will of course be necessary to use a tape measure to position the electrodes at the correct distance from each other before connecting them to the respective takeouts on the cable.

The electrodes should be driven into the ground to a depth of about 1/3 of their length and then connected to the takeouts on the cable by means of the appropriate connecting cables, fitted with clips.

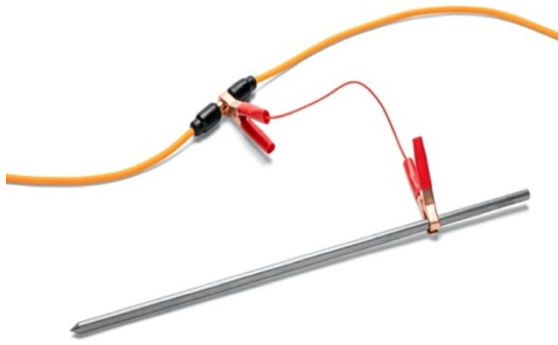


FIGURE 5: ELECTRODE CONNECTION

Next, connect the cables to the MPXs (remember that the first 2 MPXs are internal to the Polares 32) using the cable outputs on each MPX (“TO ELECTRODES” connector).



FIGURE 6: POLARES32 PANEL

The first 16 stakes will be connected to the POLARES connector identified as “1-16 ELECTRODES” (Hardware); stakes 17 to 32 (Hardware) will be connected to the connector identified as “17-32 ELECTRODES” (Figures 6 and 7).

## POLARES32 CONNECTIONS

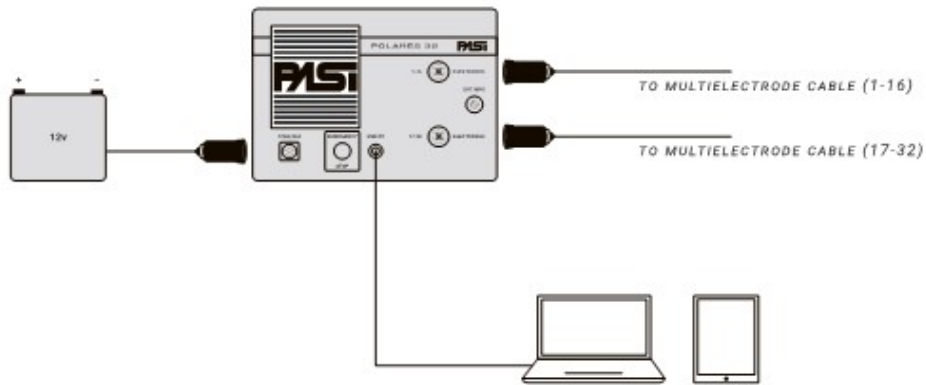


FIGURE 7: POLARES CONNECTIONS



FIGURE 8: POLARES - COMPLETE SYSTEM WITH 32 ELECTRODES

If a stringing with more than 32 electrodes is expected, one or more yellow MPX extensions should be used (Figs.9 and 10). In the case of 5m cable spacing, these extensions are 85m each; in the case of 10m cable spacing, 2 extensions of 85m are

supplied for each multi-electrode cable, joined together with an adapter (included in the supply).



FIGURE 9: MPX EXTENSION

### POLARES32 - CONFIGURAZIONE CON 48 ELETTRODI (O PIU')

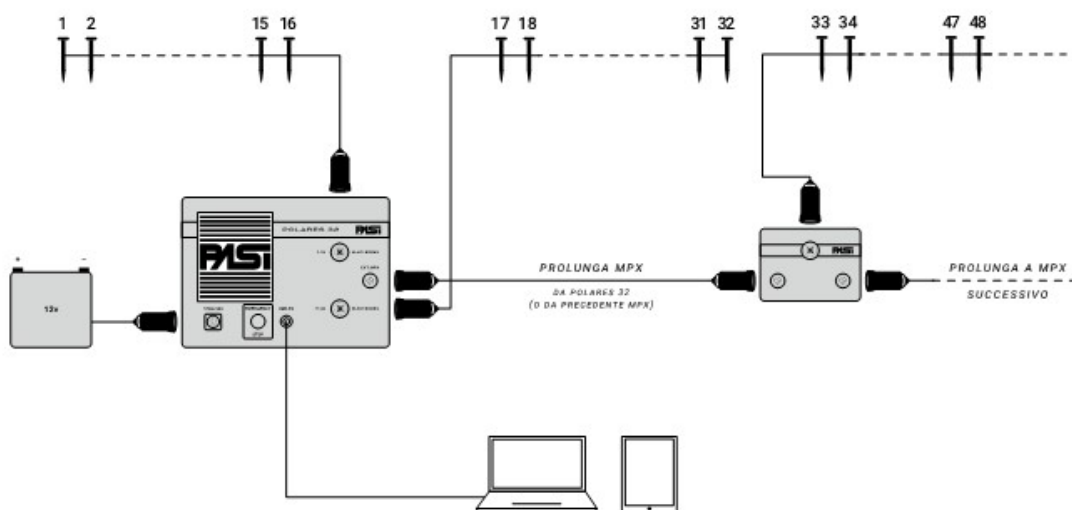


FIGURE 10: CONFIGURATION WITH 48 ELECTRODES (OR MORE)





**FIGURE 11: SYSTEM COMPLETE WITH 48 ELECTRODES (WITH 1 EXTERNAL MPX)**

## 4. Getting started

This chapter lists the sequences of steps in the Polares 32 control programme to perform the most common operations. See Chapter 5 for a description and explanation of all the commands.

To perform the measurements associated with a session using the Polares 32 system, the sequence of operations to be followed is as follows:

- opening of a template file preloaded on the system and possible modification of the same to meet the requirements of the measurement
- switching to the measurement session management function;
- actual execution of the session measurements;
- saving measurements.

Once the measurement session has been carried out, the results can be viewed.

In the remainder of this chapter, the system is assumed to be correctly set up in terms of hardware and with 32 electrodes connected to the system's internal MPX multiplexers.

### *Opening of a measurement template*

A template must be opened for the creation of a measurement session, which can be used as it is or can be modified. For the first use of the system, the template “last~template” will be used without modification (if you wish to modify any parameters, please refer to sections 4.2.3, 4.2.4, 4.2.5 and 4.2.6).

The operations to be performed are as follows:

- select the desired template from the drop-down menu to the right of the “Template” button, in this example choose “last~template”;
- press “Template”.

The system will load the data contained in the template and present them on the window for viewing and possible modification by the operator. The display windows of a template are recognisable by their title, which reads “Template:” followed by the name of each individual page.



The parameters are described in detail in the following paragraphs. In this first use, the operator can move between the four template screens using the buttons at the bottom marked by the characters “>>” and “<<”, which allow him/her to move between the pages whose title is shown in the heading inside the button. The logical sequence of the parameter pages is described below.

- Session parameters, divided into parameters for defining the electrode arrangement and measurement parameters, associated with the chosen measurement method. For a description of the page, see section 4.2.3.
- Electrodes: the associations between logic electrodes and MPX/physical electrodes, and the position in XYZ coordinates of each physical electrode are displayed in table form. For a description of the page, see section 4.2.4.
- Measurements: all the measurements foreseen by the chosen method are displayed in table form, with the indication of the number of logic electrode involved in each of the roles A, B, M and N, and the calculation of the geometric coefficient K. See paragraph 4.2.5 for a description of the page.
- Electrical parameters: some electrical parameters used by the system to perform the session measurements are displayed. For a description of the page, see section 4.2.6.

### *Moving on to the measurement session*

After displaying the basic template for the measurement session, the operator must press the “Go to Measurement Session” button from any of the four template display windows to proceed with the execution of the session's measurements.

The system will prompt the operator to choose the directory and file name in BPD (Binary Pasi Data) format in which the measurement session and all related values, as well as the measurements taken, will be saved. After this operation, the session file will be saved and available for the operator to view and execute, without the need to open the corresponding template.

### *Execution of measurement sessions*

After entering the name of the measurement session file, the system will display the session information in a format similar to that used for templates. The display windows of a session are recognisable by their title, which reads “Session:” followed by the name of each individual page.

The parameters of the measurement session, deriving from the template from which it was generated, are presented on the same four windows used for the templates, therefore:

Session, Electrodes, Measurements and Electrical Parameters. The display of the four windows is controlled by the two buttons “>>” and “<<” as it was for the display of the templates. Some of the parameters presented for the measurement session can be changed by the operator, other parameters are fixed and cannot be changed.

The actual execution of the measurements must be performed on the “Session: Measurements” window (this is the window on which it is placed after the switch to the measurement session has been commanded).

To perform all measurements in sequence, the steps that need to be performed are as follows.

- Select the check box “Select all measurements”, all measurements in the table below will be selected;
- deselect the check box “Step: one measurement”;
- press “Perform measurements”.

The system will proceed with the sequential execution of all the measurements, controlling the multiplexers and collecting the electrical values measured, displaying the results as they are obtained on the window table.

The functions in this window are described in detail in section [4.3.4](#).

### *Displaying and continuing a measurement session*

At the end of the execution of the measurement session, and after returning to the system homepage by pressing the “Return and save” button, it is possible to view the session file and possibly repeat the measurements. To do this, press the “Measurement Sessions” button.

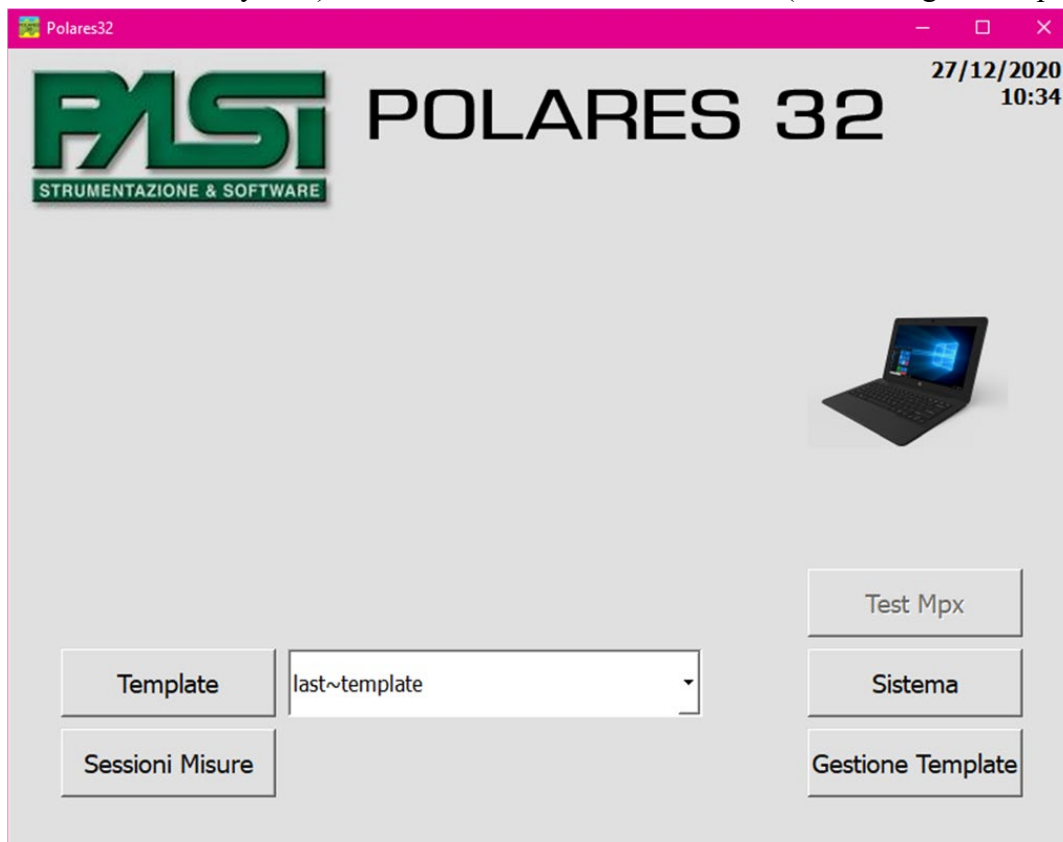
From the window, the measurement session file of interest must be selected and pressing the “OK” button will proceed to display the session. This mode of opening session files can be used for any type of session, whether no measurements have been taken, completed or partially completed.

## 5. Description of the Polares 32 programme

The Polares 32 programme can run on Windows computers and allows the setting up or display of measurement sessions or, if connected to the Polares 3 system, the control functions and the execution of measurement sessions.

### *Main screen*

The main or homepage screen shows whether the Polares 32 system is connected to the PC and has been correctly recognised by the programme (display of an image of the Polares 32 system) or is not connected (no image displayed).



**FIGURE 12: HOMEPAGE OF THE POLARES 32 PROGRAMME WITH THE INSTRUMENT NOT CONNECTED.**

Figure 4.1 shows the main window with the Polares 32 system not connected to the PC.

Figure 4.2 shows the homepage as it appears when the Polares 32 system is connected to the PC via the USB cable and is correctly powered. The table shows the information relating to the Mpx (multiplexer) associated with the system: in the case of the image, there are the two internal Mpx 1/A and 1/B, each with 16 electrodes, and no external Mpx. Battery voltage, battery charge percentage and system temperature information are also shown. If the power supply battery is not connected to the system or if the emergency switch that cuts the power supply to the system is activated, these situations will be highlighted by images and messages on the homepage.

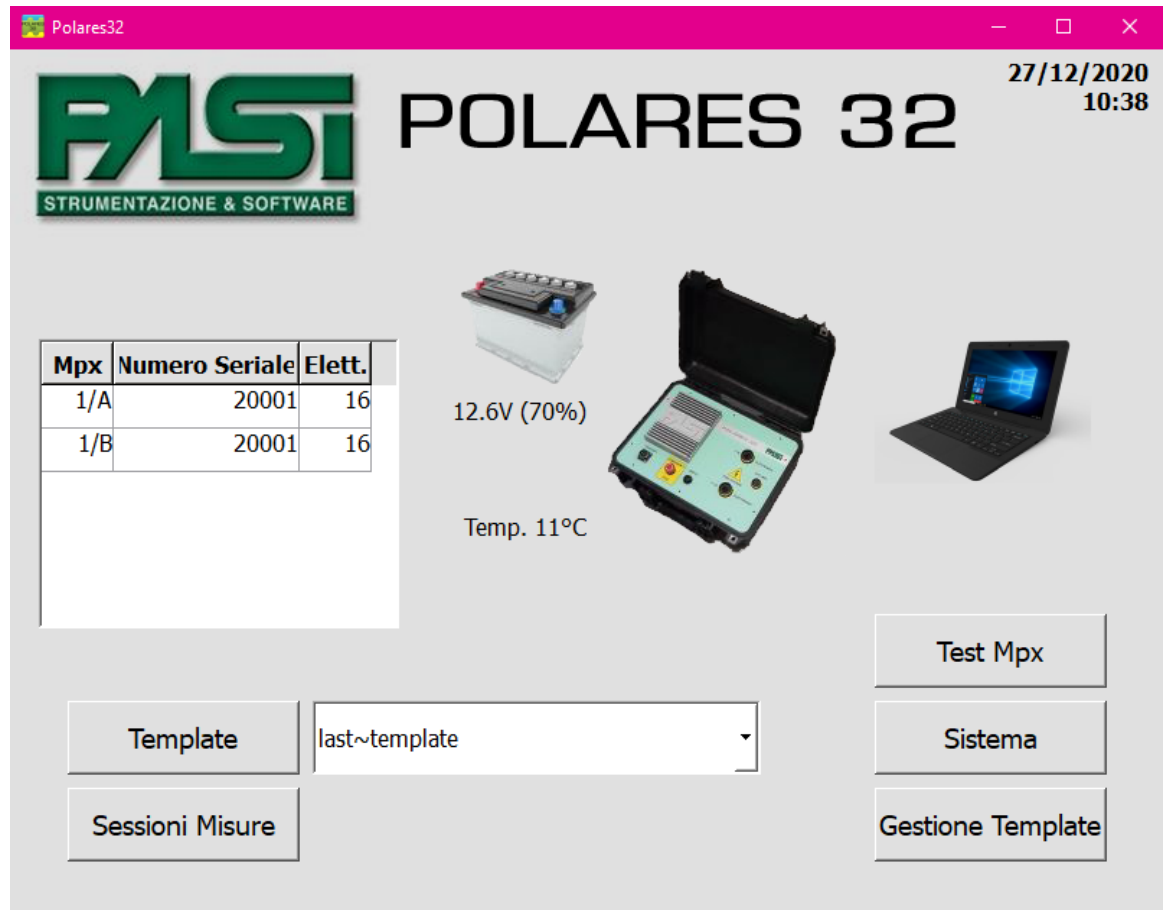


FIGURE 13: HOMEPAGE OF THE POLARES 32 PROGRAMME WITH THE INSTRUMENT CONNECTED.

Some system functions such as Mpx testing, electrode testing and measurement execution are only available if the Polares 32 system is correctly connected and powered.

The main commands listed below can be implemented from the homepage.

- **Template:** allows the display of templates containing the session configuration parameters, by selecting one via the drop-down menu to the right of the button. Session configuration parameters can be changed, changes saved to a new template and a measurement session can be requested from the template.

- Measurement sessions: allows selection of a measurement session file for execution, display of the session configuration parameters and display of the results of the measurements made.
- Mpx Test: allows a self-diagnostic function to be launched on each individual internal Mpx or one connected externally to the system.
- Template Management: allows the deletion of session templates which are no longer of interest, the export of templates for use on another Polares 32 system or the import of templates from another Polares 32 system.
- System: allows the system to be set up to work with certain operator-defined parameters, to set up the directory for saving session files, and provides information on the system and software update status.

## *Templates*

Templates are files in proprietary GPD format used to store the configuration information of the measurement sessions so that they can be recalled several times to facilitate their preparation by the operator before execution.

Templates are needed to create a new measurement session to be executed, as they are used as a basis for storing the parameters for a measurement session and from which to create the actual measurement sessions to be executed. This mechanism for creating a measurement session is described in section 4.2.7.

The template files are not physically accessible to the operator, who can therefore operate on them to create, duplicate, modify, import, export or delete them solely via the graphic interface provided by the Polares 32 system control program. The creation, duplication and modification functions are described in this chapter, while the import, export and deletion functions are described in chapter 4.4 “Template Management”.

### *Templates selection and opening*

A template is selected using the drop-down menu to the right of the “Template” button on the homepage. Templates are hidden from the operator and are located in a system folder that is not accessible. A template must be opened for the creation of a measurement session, which can be used as it is or can be modified.

There is always a default template on the system called “last~template” which initially contains preset default values. This template may also contain values other than the default if the operator varies some template parameters and decides to run a measurement session (via the “Go to Measurement Session” button) without having saved the changes

to a new template. In this particular case the “last~template” will keep the used and unsaved template information.

In case variations made on a template can be used in more than one measurement session, it is recommended to save these settings on a dedicated template.

The operations to be performed when opening a template are as follows:

- select the desired template from the drop-down menu to the right of the “Template” button,
- press “Template”.

The system will load the data contained in the template and present them on the window for viewing and possible modification by the operator.

### *Templates display*

The display windows of a template are recognisable by their title, which reads “Template:” followed by the name of each individual page and the name of the template displayed.

The template parameters are distributed over the following four pages, in the order in which they are described:

- Session parameters, described in section 4.2.3;
- Electrodes, described in section 4.2.4;
- Measurements, described in section 4.2.5;
- Electrical parameters, described in section 4.2.6.

The operator can move back and forth across the four template display pages without restriction.

There are 5 buttons at the bottom of the page, which function as follows:

- “Back”: allows you to return to the homepage, discarding any changes you may have made to the four display windows of the template;
- “<< XXX”: allows you to reach the previous page of the four pages listed above, instead of XXX you will find the title of the page that can be reached (Session parameters, Electrodes, Measurements);
- “>> XXX”: allows you to reach the next page of the four pages listed above, instead of XXX you will find the title of the page that can be reached (Electrodes, Measurements, Electrical parameters);

- “Go to Measurements Session”: allows you to save the parameters of the template displayed within a session GPD file and to move to the measurement session display windows (see section 4.3). The function is described in section 4.2.7;
- “Save Template”: allows changes made to a template to be saved so that the configuration of interest can be easily recalled.

The parameters on the various display pages of a template are described in detail in the following paragraphs.

### *Session parameters*

The first page of the template display contains general information regarding the positioning of the electrodes and how to perform the measurement. These parameters will be used for the automatic generation of subsequent tables of electrodes and measurements. Figure 4.3 shows the session parameter screen.

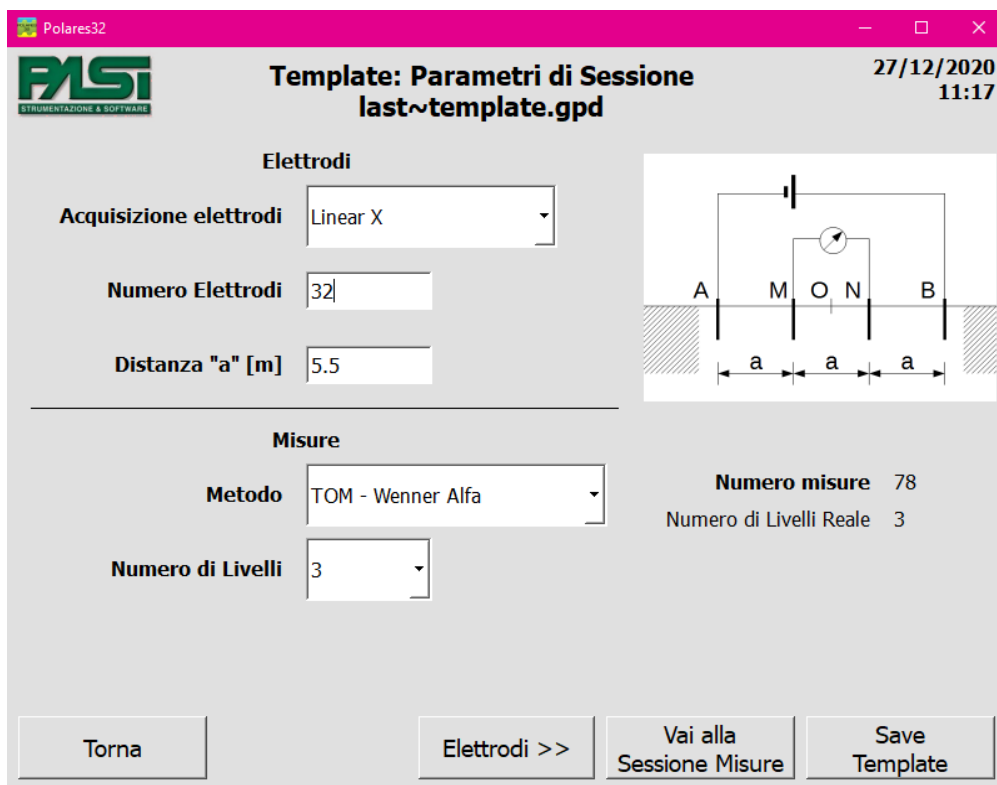


FIGURE 14: SESSION PARAMETERS FOR A TEMPLATE

## Electrodes

The Electrodes section allows you to define a standard stringing for populating the electrode table.

The visible and configurable parameters on the page are listed below.

- “Electrodes acquisition”: the drop-down menu allows you to choose one of three types of stringing:
  - Linear X;
  - Linear Y;
  - Linear Z.
- “Number of electrodes”: must be entered by the operator from the keyboard, up to a maximum of 256 electrodes.
- “Distance to”: is the distance between two contiguous electrodes, it must be entered on the keyboard by the operator.

## Measurements

The Measurements section allows you to define the sequence of measurements and the electrodes involved for each one. The image on the right of the electrode arrangement relates to the selected measurement method.

The visible and configurable parameters on the page are listed below.

- “Method”: the drop-down menu allows you to choose one of the following measurements methods:
  - Wenner Alfa tomography;
  - Wenner Beta tomography;
  - Wenner Gamma tomography;
  - Wenner-Schlumberger tomography;
  - Dipole-dipole tomography;
  - Dipole-pole tomography;
  - Pole-pole tomography;
  - Custom files tomography, this mode of input of the electrodes involved in each measurement will be described in section 4.2.9.
  -
- “Number of levels”: is the parameter that measurement methods use to calculate electrode positions. The number next to the indication “Real number of levels” indicates



whether the number of levels actually applied, as a result of the measuring method and the number of electrodes used, is lower than the number of levels configured by the operator. The parameter can range from 1 to 10.

- “Max n factor”: is the parameter that the Wenner-Schlumberger and Dipole-dipole methods use to calculate the position of the electrodes. The parameter can range from 2 to 8.

## *Electrodes configuration*

The second template display page shows the list of logic electrodes, the mapping between the logic electrode and MPX/physical electrode, and the positioning in relative coordinates of the physical electrodes. This table is automatically created by the system on the basis of the input data from the Session parameters window, and can be modified by the operator.

	HW Mpx	HW Elet	X [m]	Y [m]	Z [m]
1	1/A	1	0.00	0.00	0.00
2	1/A	2	5.50	0.00	0.00
3	1/A	3	11.00	0.00	0.00
4	1/A	4	16.50	0.00	0.00
5	1/A	5	22.00	0.00	0.00
6	1/A	6	27.50	0.00	0.00
7	1/A	7	33.00	0.00	0.00
8	1/A	8	38.50	0.00	0.00
9	1/A	9	44.00	0.00	0.00
10	1/A	10	49.50	0.00	0.00
11	1/A	11	55.00	0.00	0.00
12	1/A	12	60.50	0.00	0.00
13	1/A	13	66.00	0.00	0.00

**FIGURE 15: ELECTRODES TABLE FOR A TEMPLATE**

The table shows one electrode per line and consists of the following columns:

- number of logic electrode;
- “HW Mux”: drop-down menu containing the identifier of the physical multiplexer associated with the logic electrode, it is set to 1/A and 1/B for the two internal Mpx in the system, and from number 2 upwards for the external Mpx; it can be modified by the operator;

- “HW Elec”: drop-down menu containing the number of the physical electrode associated with the logic electrode, can be modified by the operator;
- “X”: X component of the distance of the electrode from the origin, can be modified by the operator;
- “Y”: Y component of the distance of the electrode from the origin, can be modified by the operator;
- “Z”: Z component of the distance of the electrode from the origin, can be modified by the operator.

By varying the number of the physical electrode there are certain automatisms which are applied.

- If you select an electrode belonging to a given physical MPX and ask for a physical electrode value of 1 to be configured, a window will appear asking if you want to change all electrode indices belonging to that MPX from 1 to the maximum number of electrodes on the MPX. If the OK is not given, only the number of the individual electrode will be changed.
- If you select an electrode belonging to a given physical MPX and ask for the maximum physical electrode value to be set, a window will appear asking if you want to change all electrode indices belonging to that MPX from the maximum number of electrodes on the MPX to 1. If the OK is not given, only the number of the individual electrode will be changed.
- By varying the number of the physical electrode associated with a logical electrode, the number of the physical electrode that had the previous value for the electrode on which the change was made is also automatically varied, so there will be no duplicate physical electrodes on the different logical electrodes.

Upon exiting the electrode configuration window, a consistency check of the MPX and physical electrodes configured on the various logical electrodes is performed; any configuration errors will be signalled with a message to the operator, requesting their correction.

### *Measurements configuration*

The third page displaying the templates shows the list of measurements, the identifier of the logical electrode associated with each role in the measurement (A, B, M and N) and the calculated value of the geometric coefficient K with the position of the 4 electrodes used. This table is automatically created by the system on the basis of the input data from the Session parameters window, and cannot be modified by the operator.

	A	B	M	N	K [m]
1	1	4	2	3	34.57
2	2	5	3	4	34.57
3	3	6	4	5	34.57
4	4	7	5	6	34.57
5	5	8	6	7	34.57
6	6	9	7	8	34.57
7	7	10	8	9	34.57
8	8	11	9	10	34.57
9	9	12	10	11	34.57
10	10	13	11	12	34.57
11	11	14	12	13	34.57
12	12	15	13	14	34.57
13	13	16	14	15	34.57

FIGURE 16: MEASUREMENTS TABLE FOR A TEMPLATE

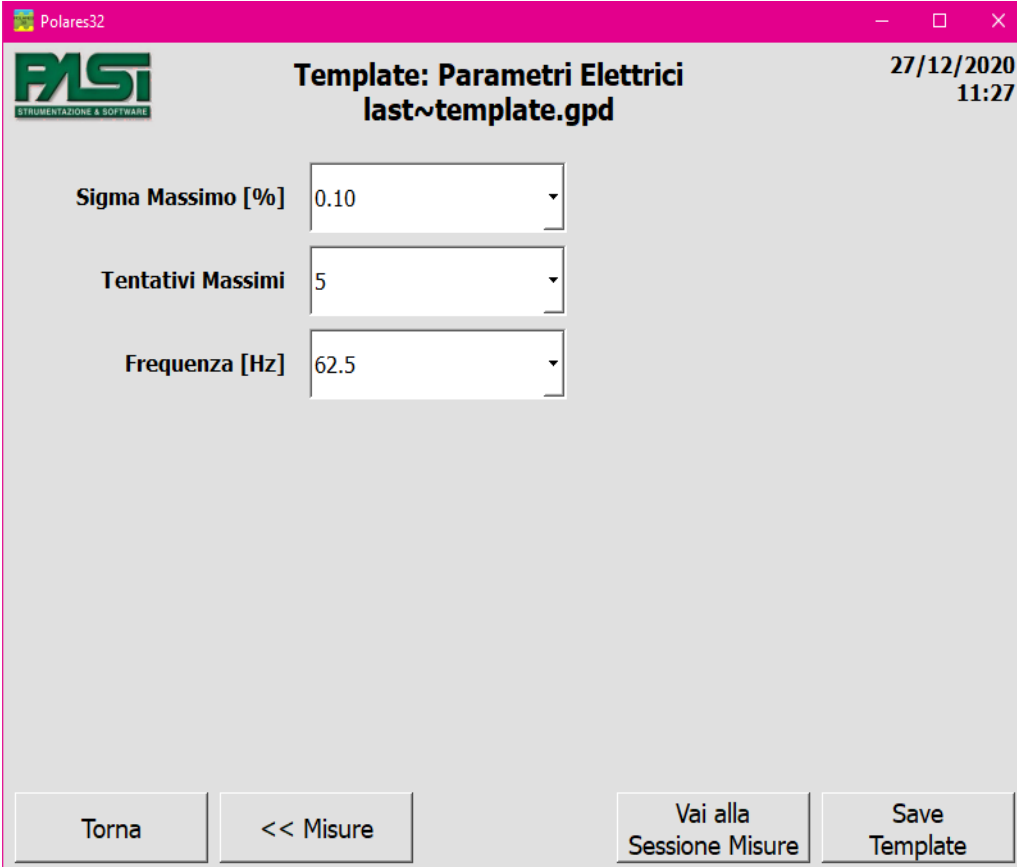
The table shows a measurement per line and consists of the following columns:

- measurement identification number;
- “A”: identification of the logical electrode that will play role A in the measurement, cannot be changed by the operator;
- “B”: identification of the logical electrode that will play role B in the measurement, cannot be changed by the operator;
- “M”: identification of the logical electrode that will play role M in the measurement, cannot be changed by the operator;
- “N”: identification of the logical electrode that will play role N in the measurement, cannot be changed by the operator;
- “K”: geometric coefficient value calculated using the role information A, B, M and N of the Measurement Table and the geometric position of the logic electrodes contained in the Electrode Table, it cannot be modified by the operator.

A value of “0” in the identification field of an electrode means that no electrode is associated with that role in that measurement.

## Electrical parameters

The fourth template display page shows the electrical parameters that will be used when performing measurements. These parameters can be configured by the operator.



Parameter	Value
Sigma Massimo [%]	0.10
Tentativi Massimi	5
Frequenza [Hz]	62.5

FIGURE 17: ELECTRICAL PARAMETERS FOR A TEMPLATE.

The visible and configurable parameters on the page are listed below.

- “Max. sigma [%]”: defines the mean square deviation value as a percentage of the measurement value, at which point the system will assume that the value obtained is precise enough and will not perform any further repetitions of the measurement.
- “Max. attempts”: defines the maximum number of cycles to be performed for a measurement; when this number of cycles is reached the measurement will still be terminated, even if the Max. sigma value has not been reached.
- “Frequency”: value used for performing the measurement.

## *Moving on to measurement sessions*

From the Template View and Edit windows it is possible to switch to the Measurements session windows by pressing the "Go to Measurements Session" button, this can be done from any of the four template windows.

The system will prompt the operator to choose the directory and file name in BPD format in which the measurement session and all measured values will be saved. After this operation, the session file will be saved and available for the operator to view and execute, without the need to open the corresponding template, recalling it by means of the measurement session selection function, described in section 4.3.1.

## *Saving a template*

From the Template View and Edit windows it is possible to save information about a new template by pressing the "Save Template" button, this can be done from any of the four template windows.

The system will prompt the operator to enter the name of the template. The template file will be saved in a directory accessible only to the programme and not available directly to the operator, but visible and usable only through the Polares 32 programme. If a template name already exists, the operator will be asked whether he/she wants to overwrite the template or not.

## *Entering custom measurements from file*

As indicated in section 4.2.3, among the measurement methods that can be selected on the system, there is also the option "Tomography from file (4 electrodes)", which allows the operator to customise as much as possible the sequence of measurements to be performed in a session.

The operator must prepare a text file (.txt) containing the information in the required format and upload it to the system. The file will be checked, and if correct, the information contained in it will be placed in the measurement table of the template and from then on made available using this template as the basis for creating measurement sessions.

Selecting the "Tomography from file (4 electrodes)" method displays the "Load File" button and the information about the name of the measurement file loaded. Pressing the button will prompt the operator to select the input text file. When the file is uploaded, it will be checked for correctness and, if necessary, the operator will be notified of the error.

If the file is correctly formed, the name of the input file will be shown on the page as “Custom measurement file”.

### Format of the measurement input file

The file must be formatted as follows:

- the first line shall show the sequence of electrode roles separated by commas, e.g. “a,b,m,n”, or “A, M, N, B”, or “p1, p2, c1, c2”, or “C1,C2,P1,P2”; the sequence of roles may be chosen by the operator, but must be consistent with the other lines in the file;
- in the following lines, one for each measurement, the identifiers of the electrodes playing the role of the column must be reported, separated by commas, spaces are allowed. For example: “1,2,3,4” or “1, 3, 5, 7”. A blank line will be considered the end of the file. Logic electrode identifiers that are not present in the stringing configuration present in the template at that time are not accepted, so it is advisable to configure the electrode part first and only then load the input file;
- if the electrode is absent, e.g. for a pole-dipole measurement, the value 0 must be entered at the role.

An example of starting a file with measurements on 4 electrodes is shown:

```
n,m,b,a  
1,2,3,4  
2,3,4,5  
3,4,5,6  
...
```

Below is an example of starting a file with pole-dipole measurements:

```
C1, C2, P2, P1  
1, 0, 3, 2  
1, 0, 4,3  
2,0, 13,15  
...
```

## *Measurement sessions*

A measurement session file can be retrieved in one of two ways:

- by creating a new measurement session from a template present on the PC: the starting template must be selected (section 4.2.1), the transition from the template to the corresponding measurement session must be performed (section 4.2.7) and then all the functions available on the measurement session can be implemented;
- by opening a measurement session already created and present on the computer (section 4.3.1).

### *Selecting a measurement session*

Opening a measurement session previously saved on the PC is performed from the homepage of the Polares 32 programme by pressing the “Measurement sessions” button. A window will open allowing the user to navigate through the directories on your PC's disk. Initially, the window will display the directory set in the “Default Directory Configuration” system function (section 4.5).

After navigating to the directory of interest, click twice on the measurement session file to be opened, or select it by clicking once and pressing the “Ok” button.

### *Session display*

The display of a measurement session is very similar to the display of a template, with small differences due to the different use of templates and sessions.

- The pages into which the parameters are divided are the same four as in the template: Session parameters, Electrodes, Measurements and Electrical parameters. The page titles become “Session:” followed by the title of the specific page and the name of the session file being displayed.
- Some of the parameters in the different pages of the session are read-only and cannot be changed, while others are editable. Section 4.3.3 lists these parameters.
- When a measurement session is opened, the programme directly displays the Measurements page, where the measurements performed can be displayed or can be carried out. The operator can still move around the other pages using the buttons already described for moving around the template windows.

- The Measurements window contains commands for selecting and carrying out measurements, in particular an additional column in the measurements table for selecting the measurements to be performed using a checkbox associated with each measurement.
- There are more columns in the Measurements table than in the template window. These columns relate to the measured data for each measurement, a list of which is given in section 4.3.4.
- The “Graph” button replaces the “Go to Measurement Session” button. The use of this button is explained in section 4.3.5.
- The “Save Session” button replaces the “Save Template” button; its function is described in section 4.3.6.

### *Editing the parameters*

Most of the parameters set in the template are fixed for the measurement session derived from it, and are therefore displayed on the session pages in read-only mode. However, some parameters may be edited, as the measurement conditions may be different from how they were designed. The parameter that can be edited in the Electrical parameters window is as follows.

- Frequency value used for the measurement. As this parameter affects the measured value, the frequency value configured at Template level is reported and used for each measurement, and is displayed in the measurement table, but can be changed during measurement execution. This means that a measurement session can be performed using different frequency parameter values for different measurements.

### *Testing the electrodes*

The electrode test function is located within the electrode parameter display window and allows the user to check the correct functioning of the electrodes and their connections.



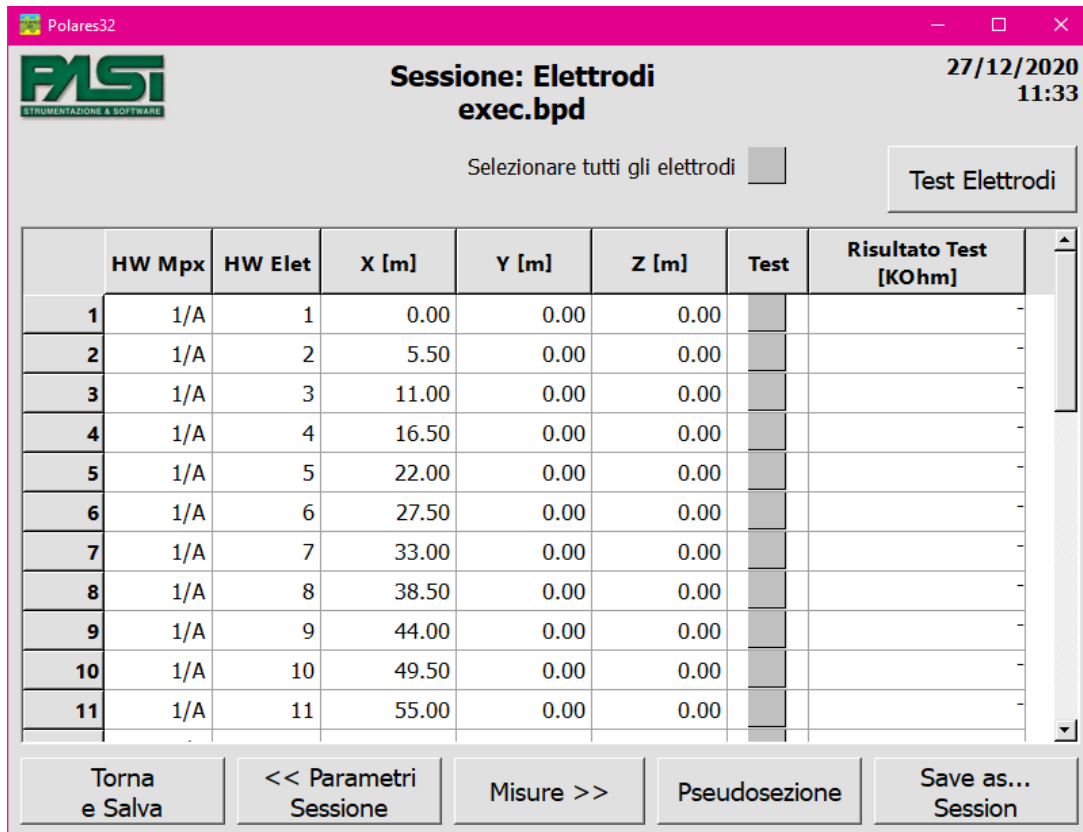


FIGURE 18: TESTING THE ELECTRODES

To perform the test, simply select the electrodes to test in the Test column and then press the “Test Electrodes” button. The system will proceed with testing one electrode at a time, displaying the result in the “Test Result” column.

### *Performing and deleting the measurements*

The execution of measurements for a session must be controlled from the Measurements window for the session of interest. Compared to the similar Measurements window in a template, a number of commands are provided at the top to allow management of the measurements. In addition, the table contains several columns: a column to select the measurements to be performed and other columns to display the measured values.

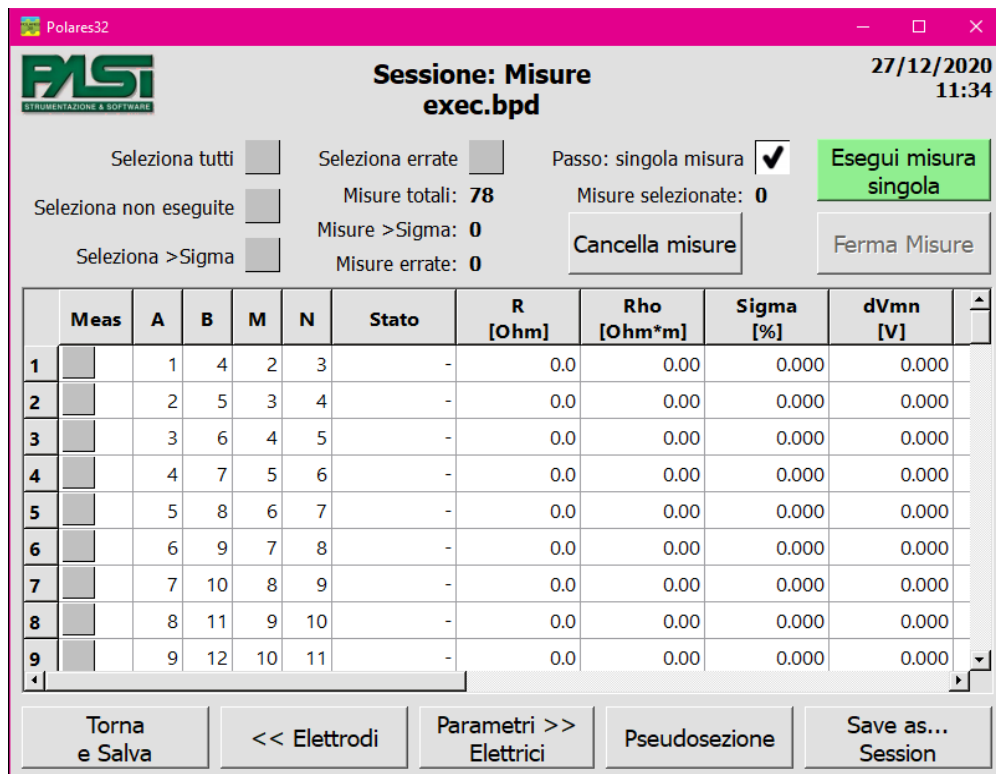


FIGURE 19: PERFORMING THE MEASUREMENTS AND RESULT TABLE FOR ONE SESSION

The columns of the measurement table for a session are listed and described below.

- Meas.: box to select or deselect the measurement corresponding to the line.
- A or C1: identifier of the logic electrode associated with role A (or C1) for the specific measurement.
- B or C2: identifier of the logic electrode associated with role B (or C2) for the specific measurement.
- M or P1: indicates the identifier of the logic electrode associated with role M (or P1) for the specific measurement.
- N or P2: identifier of the logic electrode associated with role N (or P2) for the specific measurement.
- Status: status of the measurement, it can be:
  - “-” if the measurement has not been performed;
  - “OK” if the measurement was performed without errors, whether the Sigma value is lower than the set threshold or higher; in the latter case the measurement is highlighted in yellow;
  - a numerical value that identifies the type of error found during the measurement; an incorrect measurement is highlighted in red.

- R: value of the resistance calculated.
- Rho: resistivity value calculated from measurements of resistance and geometric constant K.
- Sigma: mean square deviation value calculated on the repetitions of the measurement reported as a percentage of the measurement value.
- $dV_{nm}$ : value of the potential difference measured between electrodes M and N.
- $I_{ab}$ : value of the current intensity measured between electrodes M and N.
- SP: value of the spontaneous potential measured between electrodes A and B.
- IP: measured value of the induced polarisation.
- K: geometric coefficient calculated from the relative position of the electrodes.
- Freq: frequency value used for performing the measurement.

To perform the measurements of a session, those of interest must first be selected. This can be done for individual measurements, one by one, by checking the box in the Meas (measurement) column. Another way is to use the boxes above the table, which allows the user to select or deselect all the measurements; to select or deselect only the measurements that have not yet been performed; to select or deselect only the measurements that have already been performed and whose Sigma value is higher than the threshold configured for the session.

If the “Step: single measurement” box is checked, it will be necessary to press the “Perform single measurement” button for each individual measurement, otherwise all the selected measurements will be performed in sequence without operator intervention.

By pressing the “Stop Measurements” button, the user can stop the measurement sequence and return to the measurement control screen.

After selecting the measurements, press the “Perform measurements” button to proceed with their execution.

On the table, the line corresponding to the measurement being performed or just performed is highlighted in grey.

Highlighted in yellow are the measurements that were performed and returned a Sigma value higher than the maximum value configured for the session. Measurements that have been performed and an error has been found are highlighted in red.

It is possible to delete some measurements by selecting them as described above and pressing the “Delete measurements” button. In this case, the selected measurements will be returned to the unperformed status, and can be performed again later.

## *Pseudo-section*

This command displays the graphic pseudo-section of the measurement results for acquisitions performed as Wenner Alpha, Wenner Beta, Wenner Schlumberger and Dipole-dipole tomographies. The result of the pseudo-section can be exported as a PDF file.

The pseudo-section graph for all measurement methods shows the values of the measurements performed with the value of “n” equal to 1, at the theoretical positions of depth and distance; on this pattern the colours of the measured Rho values are shown. These are the only measurements reported for Wenner Alpha, Beta and Gamma tomography.

In the Wenner Schlumberger and Dipole-dipole pseudo-sections, measurements for values of “n” equal to 2 or greater are also reported as coloured dots in the theoretical depth and distance position of the measurement taken. This allows a display of any anomalies measured at points with “n” greater than 1 if the coloured point is different from the background.

## *Save session*

The measurement session file is automatically saved in proprietary GPD format by the Polares 32 programme, therefore no explicit saving of data to file by the operator is necessary; however the explicit saving functionality is provided to the operator for the reasons listed below.

- After performing measurements for a session, the measured data will be saved to a file with a different name, so that a trace of that session remains; the user will then proceed with a further run of the session measurements, which will then overwrite the previously measured data that will not be lost due to explicit saving.
- To save the measurement file under a different name to duplicate the results file.
- To save session data in a format other than the BPD proprietary binary format. For this function, the format of interest must be selected on the disk navigation and file name entry window from the “Format” drop-down menu and the “Ok” button pressed. The formats currently available are:
  - GPD, a proprietary text format for exporting tomography results of any type for subsequent analysis by other programmes, this format is described in section 5.2; the user can choose to save only the measurements performed correctly and without errors or to save all measurements;

- RES2DINV, a format used for exporting standard tomography results for subsequent analysis by other programmes;
- Log file (txt), proprietary text format for obtaining the log of measurements performed in the event of a malfunction of the Polares 32 system.

## *Template management*

Template management on the PC can be done by pressing the “Manage Template” button from the homepage as the templates are not directly accessible on the PC disk to the operator. The management window allows the user to perform three operations:

- delete templates;
- export templates;
- import templates.



**FIGURE 20: MANAGING THE TEMPLATES**

## *Delete template*

The template deletion operation is performed by pressing the relevant button, selecting the templates stored on the PC to be deleted and pressing the OK button. Selected templates will be deleted from the PC disk and will no longer be usable.

It is not possible to delete the default template, called “last~template”, which will always remain available to the operator.

## *Export template*

The template export operation is performed by pressing the relevant button, selecting the templates stored on the PC to be exported and pressing the OK button. A navigation window will open, allowing the user to choose a directory on the PC or an external medium in which the template will be stored.

To save the file on an external storage medium, such as a USB stick, it must be connected to the PC and recognised before opening the navigation and directory selection window.

The template is saved as a text file in GPD format. The file can be copied onto removable storage medium or sent by e-mail to be imported as a template on another Polares 32 system using the import function.

NOTE: It is recommended not to manipulate GPD files manually using a text editor as this may render the file unreadable and therefore unusable.

## *Import template*

The template import operation is carried out by pressing the relevant button, selecting the GPD files stored on the PC or on an external storage device relating to previously exported templates and are to be imported, and pressing the OK button. The template will be copied to the PC with the same file name.

To copy the file from an external storage medium, such as a USB stick, it must be connected to the PC and recognised before you can open the navigation and file selection window.

## Multiplexer test

The multiplexer test allow the user to check the correct operation of the two internal multiplexers in the system and any externally connected multiplexers. Simply select the multiplexer to test and press the “Start Test” button. The test can last up to two minutes.

At the end of the test, a window will display the result.

NOTE: the electrode connector of the multiplexer to be tested must be closed with the termination plug for the test to be performed correctly.



FIGURE 21: MULTIPLEXER TEST

## System

The System screen is used to obtain information about system versions, the update status of the installed software (only if the PC has an Internet connection) and to configure certain parameters of the Polares 32 programme.

The configurations that can be implemented are as follows.

- Interface language. After changing the language, it is necessary to exit the System window with the OK button and restart the programme so that the change is applied. However, the language used within the GPD file is English.
- Default directory for saving and retrieving GPD files of measurement sessions. The programme will still allow you to save or read GPD files in and from different directories.

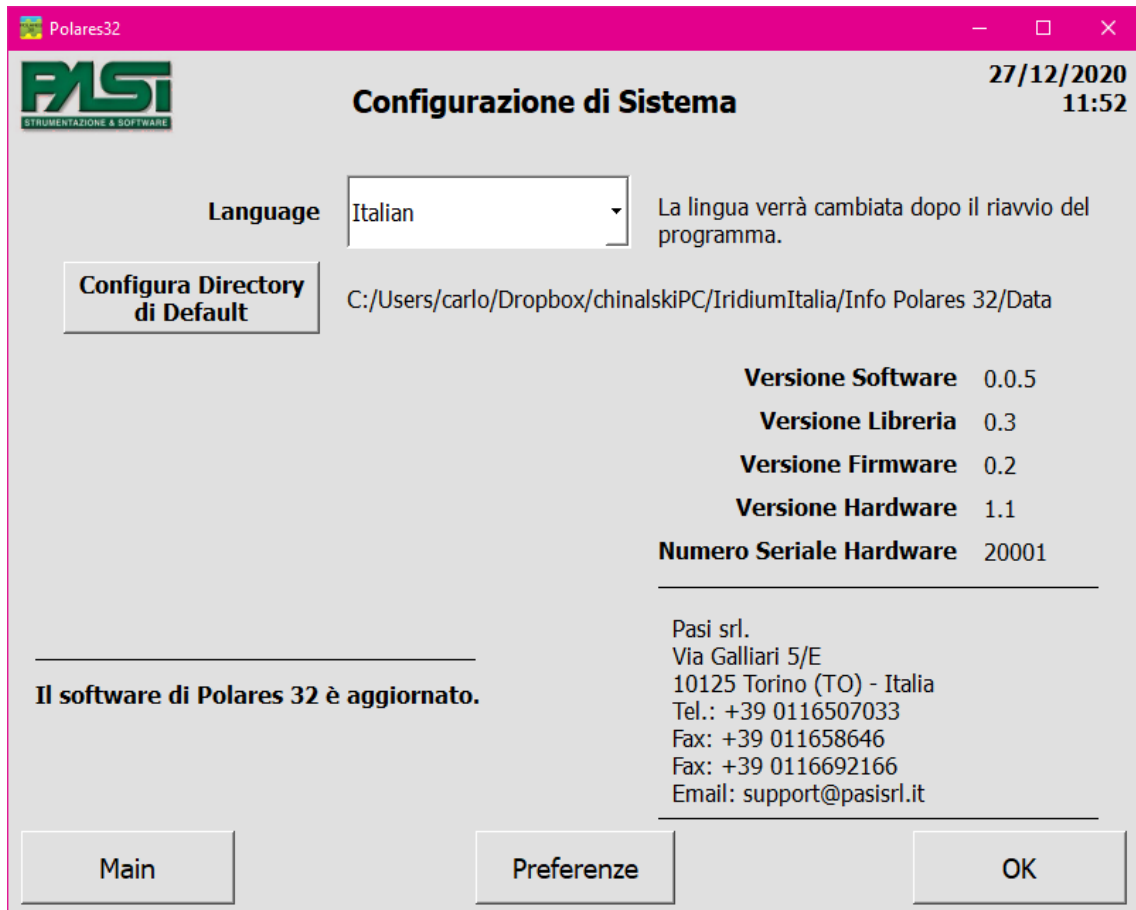


FIGURE 22 SYSTEM CONFIGURATIONS, FIRST PAGE

By pressing the “Preferences” button it is possible to reach the page for the configuration of further parameters related to the GUI of the Polares 32 system, listed below.

- Linear measurement unit: the operator can choose whether to display measurements in metres or in yards. Saving measurements to a GPD file is still done in metres.
- Date format: the operator can choose the format in which dates are displayed, choosing from three proposed formats: “yyyy-MM-dd”, “dd/MM/yyyy” oppure “MM/dd/yyyy”. Saving dated to a GPD file is still done in the format “yyyy-MM-dd”.
- Electrode name: the names A, B, M and N or the names C1, C2, P1 and P2 can be chosen. It only affects the display mode and not the format within the GPD file, where



the electrodes are still stored as A, B, M and N. This configuration also has no effect on the custom measurement input file.

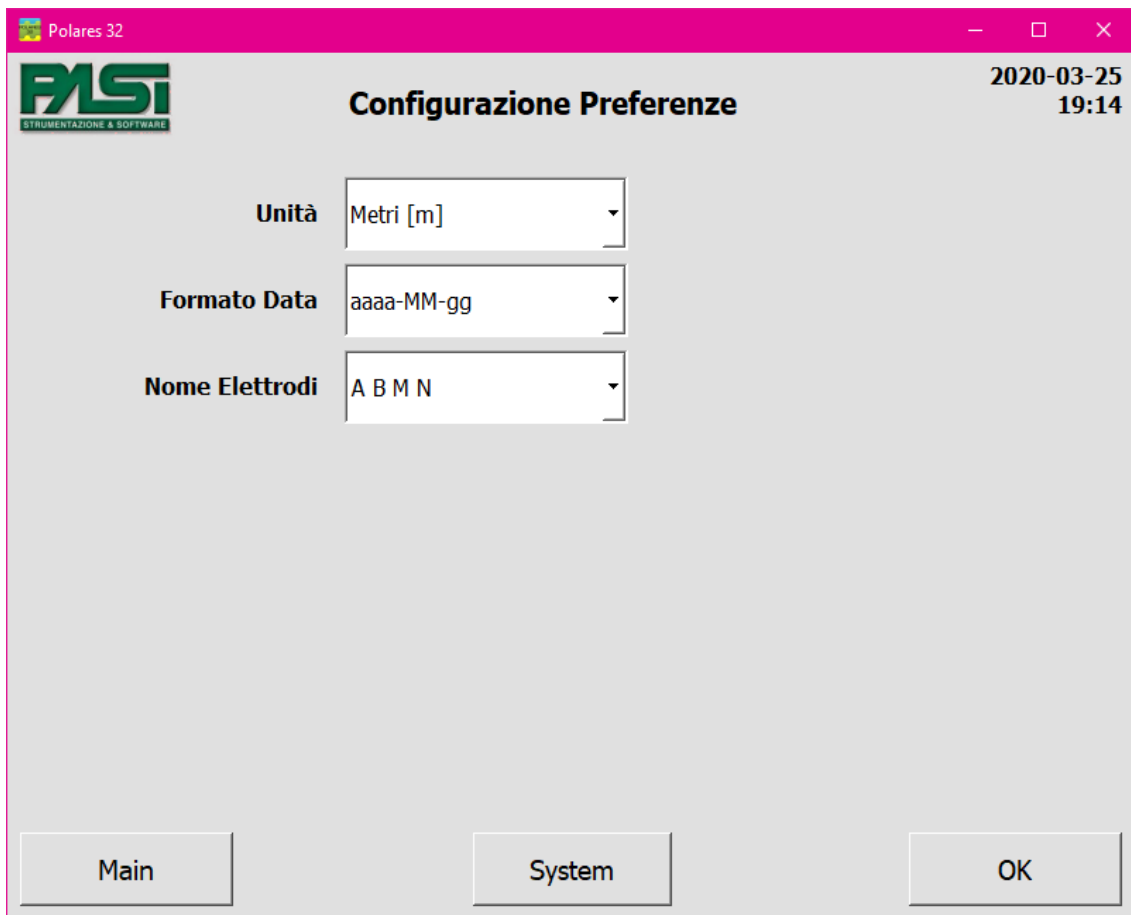


FIGURE 23: CONFIGURATION OF SYSTEM PREFERENCES

### *Software upgrades*

The software update can be performed using the PC's own functionality, simply by launching the self-installation file provided by Pasi: the new software version will be installed together with all the necessary drivers.

In the System window (accessible from the homepage), if the PC is connected to the Internet, you can check the update status of the Polares 32 programme, see section 4.6.

## *Insights*

### Meaning of Sigma value

The Sigma value associated with the measurements is calculated as the Mean square deviation of the measured value of R and then reported as a percentage of the value of R itself. It provides an indication of the variability of the measurement repetitions with respect to the mean value, and thus a measure of the correctness of these measurements: the lower the calculated Sigma, the closer the measurements are to the mean value of R and thus the more accurate the measurement.

The maximum Sigma value accepted can be configured by the operator in the Electrical parameters section of the Template or Session management (see sections 4.2.6 and 4.3.3). As mentioned above, the higher the accepted Sigma value, the faster the measurement (with fewer repetitions) and the lower the accuracy; the lower the accepted Sigma value, the slower the measurement (with more repetitions) and the higher the accuracy.

Polares 32 automatically manages the correct termination of the measurement when the Sigma value calculated on the repetitions performed is lower than the maximum Sigma value set by the operator. In any case, at least three repetitions are always performed before calculating the Sigma value in order to be sure of having an adequate number of values for its calculation.

If, even after having performed the maximum number of cycles (set by the operator), the Sigma value remains above the maximum accepted Sigma value, the measurement will be terminated and the values of the electrical parameters measured will be displayed, but on the measurement table the line that has not reached a correct Sigma value will be highlighted in yellow, so as to make explicit to the operator the measurements that have not reached the required accuracy value.

## *Format of the files used*

The Polares 32 system makes three different proprietary file formats available to the operator.

## Output GPD format

The GPD (Geophysics Pasi Data) format is used to export the measurement sessions made by the Polares 32 system to third party systems. This format is used for exporting data at the end of the execution of the measurement session previously automatically saved in BPD format by the system.

The format is also used for storing and transferring template files by means of the import and export functions described in section 4.4: the files produced by the export function will be in this format, and the input files supplied to the import function will have to be in this format. A session file, produced using the “Save as” function from a BPD file and therefore containing measurements already performed, can also be used as a normal template file by loading it using the import function.

When exporting a BPD file in GPD format, only those measurements on which no measurement error has occurred will be reported, i.e., measurements with “OK” status in the session measurements table. Measurements that have been performed with an error will be reported as not performed and not counted among the measurements performed.

A GPD file is a text file in ASCII characters, which can therefore be read with a normal editor, but it is recommended that no manual changes be made to this type of file as it may be rendered unreadable and unusable by the Polares 32 programme.

The GPD format is described in section 5.2 of this manual.

## Input and output BPD format

The BPD (Binary Pasi Data) format is used for maintaining information about the sessions created by the operator and the results of the measurements taken. These files are stored on the PC hard disk; the preferred saving directory can be selected by the operator within the system configuration window. Since these files are in binary format, they cannot be read by the operator using an editor; they can only be read by the Polares 32 programme.

The files are then used as input to the programme for the execution of previously configured measurement sessions, and as output of the results of the measurements performed.

## Output TXT format

The TXT format is the translation of the information contained in the BPD binary format into a textual and human readable format. The format contains a lot of information related to the hardware and electrical measurement parameters used during the execution of the session measurements. Its use is primarily as a log to check for system malfunctions when

abnormal situations occur. Under normal system operating conditions, this format is not normally used.

## 6. Appendixes

### *Technical specifications*

<u>External data port (only PC connection)</u>	USB
<u>Connectivity</u>	USB
<u>Optional connectivity</u>	Ethernet, Wi-Fi, Bluetooth, RS232, RS485, USB client, GPS, etc. (via external PC)
<u>GPS</u>	USB GPS receiver for georeferencing measurements to be connected to an external PC
<u>DSP (Digital Signal Processing)</u>	ATMEL Cortex M4 120 Mips
<u>Converter</u>	A/D 24 bit
<u>Voltage measuring range</u>	300V or 6V with autoranging
<u>Current measuring range</u>	3A
<u>Frequencies that can be generated</u>	125Hz, 62.5Hz, 32.2Hz, 15.6Hz, 7.8Hz
<u>Measurements validation</u>	Measurement validates DC component, distortion, background noise, phase excess, sigma modulus, phase sigma
<u>Max. number of stacking</u>	Unlimited
<u>Max. number of scans for each measurement</u>	Unlimited (limited only based on the storage capacity of the external PC)
<u>Max. number of storable measurements</u>	Unlimited (limited only based on the storage capacity of the external PC)
<u>Scan speed</u>	Up to 3 scans/second
<u>Max. voltage that can be generated</u>	700 Vpp
<u>Max. current that can be generated</u>	4000mA <sub>pp</sub>
<u>Max. instant power that can be generated</u>	200 W
<u>Thermal protections</u>	Heatsink and sensors inside the box with system safety lock
<u>Power supply</u>	8.5V = / 15V = lead or lithium batteries, 30 A internal fuse, reverse polarity protection
<u>SAFETY</u>	External emergency mushroom switch
<u>Operating temperature</u>	-20 °C / +50 °C (external temperature)
<u>Storage temperature</u>	-40 °C / +80 °C
<u>Max. operating height</u>	Limited based on the characteristics of the external PC
<u>Dimensions and weight</u>	410x300x170mm; 6kg

## *GPD file format*

The GPD (Geophysics Pasi Data) format is the proprietary format that is used by the PASI Polares 32 system for storing and exporting electrode geometry data and measured electrical data related to a measurement session and stored in files. The features of the protocol are described below with the aim of allowing the reading of the results files of a measurement session produced by Polares 32 and their processing with third-party systems for analysing the results.

The GPD format is the only proprietary output format for files produced by the Polares 32 system for which Pasi agrees to provide a definition, so any instrument that wishes to provide analysis functions for data produced by the instrument should work on files produced in GPD format.

During normal operation of the Polares 32 system, the results obtained from the measurements are stored in proprietary binary files with BPD (Binary Pasi Data) extension for which no documentation is provided. To obtain a file in GPD format that can be used for export to third-party analysis systems, the following procedure must be followed:

- from the main page press the “Measurements session” button and open the BPD file to be exported;
- press the “Save session” button;
- navigate to the directory where the output file is to be saved, write the name of the desired output file, select the GPD format in the drop-down menu and press OK.

The following describes the GPD format in its version 1.

NOTE: It is advised not to manipulate GPD files manually using a text editor as this may render the file unreadable and therefore unusable.

### General structure

The GPD format is an ASCII text file consisting of lines terminated by an end-of-line character (Line feed, 0A hexadecimal), which in turn are composed of strings separated by horizontal tab characters (Horizontal tab, 09 hexadecimal). The information is given in the format “Parameter name” - “Parameter value”, or if it is tabular information in the format “Line with parameter name for each column” - “Line with parameter value for each table element”.

The file can then be viewed using a normal text editor and understood by a person.

The GPD file consists of five sections:

- a line at the beginning of the file containing the string “\*\*\* Do not manually edit the GPD file \*\*\*”;
- a header with information about the whole measurement session;
- an “Electrodes” table showing the identification and position of the electrodes used to take the session measurements;
- a “Measurements” table showing the information relating to each individual measurement planned during the session, with reference to the identifiers of the electrodes involved, with the electrical parameters measured if the measurement was taken plus other information relating to the measurement;
- a line at the end of the file containing the string “\*\*\* End of GPD file \*\*\*”.

The three parts of the file are described below.

### File header

The structure of the file header is as follows.

- “Format” followed by the string “Geophysics\_PASI\_Data\_Format\_GPD”.
- “GPD\_version” followed by a number, indicates the version of the GPD format with which the file is written. This document describes version 2 of the format.
- “Creation\_date” followed by the file creation date in the format “yyyy-mm-dd”.
- “Last\_modification\_date” followed by the file last modification date in the format “yyyy-mm-dd”.
- “Type” followed by the string “Automatic”, indicates which type of electrical measurement is contained in the table-format part of the file.
- “Method” identifies the method with which the table was initially created with regard to the positions of the electrodes, it is set when the table is created and is not changed if subsequent manual changes are made to the electrode positions by the operator. It is followed by one of the following strings depending on the value of the Type field. For Type corresponding to “Manual”:
  - o “TOM - Wenner Alfa”;
  - o “TOM - Wenner Beta”;
  - o “TOM - Wenner Gamma”;
  - o “TOM - Wenner-Schlumberger”;
  - o “TOM - Dipole-Dipole”;
  - o “TOM - Pole-Dipole”;
  - o “TOM - Pole-Pole”;

- o “TOM - From Custom File”;
- o “Self Potential Only”.
- o
- “Electrodes\_sequence” identifies the order of geophones placed on the ground as a result of the selected measurement method. The values of the string can be:
  - o “ABMN”;
  - o “AMNB”;
  - o “AMBN”;
  - o “AMN”;
  - o “AM”;
  - o “MN”.
- “Standard\_electrodes\_position” followed by the string “Standard” or “Not Standard”, indicates whether the operator has kept the position of the electrodes with respect to the standard algorithm chosen when setting up the measurement, or whether he/she has made some variation.
- “Measures\_number” followed by a string with the number of measurements expected and listed in the table of measurements.
- “Measures\_done” followed by a string with the number of measurements performed and the results of which are stored in the measurement table.
- “Measurements\_unit” followed by the string “[m]”.
- “Latitude\_O” followed by the string of decimal degrees of latitude of the point of origin of the session. North latitude degrees are given as positive numbers, south latitude degrees are given as negative numbers. If not populated, the value must be “TBD”.
- “Longitude\_O” followed by the string of decimal degrees of longitude of the point of origin of the session. East longitude degrees are given as positive numbers, west longitude degrees are given as negative numbers. If not populated, the value must be “TBD”.
- “Altitude\_O [m]” followed by the altitude in metres of the point of origin of the session. If not populated, the value must be “TBD”.
- “Azimut\_X” followed by the angular value expressed in decimal degrees measured between the North direction and the direction of the reference X-axis for the electrode positions given in the following measurements table. If not populated, the value must be “TBD”.
- “Electrodes\_distance [m]”: distance between two contingent electrodes in a tomography session. If the parameter is not applicable, it will be set to “NA”.



- “Levels\_number”: maximum number of levels to be achieved in one tomography session. If the parameter is not applicable, it will be set to “NA”.
- “n”: maximum value of parameter n to be applied in a tomography session. If the parameter is not applicable, it will be set to “NA”.
- “Electrodes\_number”: number of electrodes involved in performing a tomographic session. If the parameter is not applicable, it will be set to “NA”.
- “Note”: followed by a free note field (no end-of-line or horizontal tab characters) of 255 characters. If absent, it is set to “TBD”.
- “Spare\_1”, “Spare\_2”, “Spare\_3”: parameters for future use, are set to “NA”.
- “Lap\_number”: indicates the sequence number of the file related to a multiple acquisition. It is set to “0” if the acquisition is not multiple, or to a value from “1” upwards to identify the sequence number of a cycle relating to a multiple acquisition.
- “Sigma\_max”: maximum sigma value (standard deviation) in percent, calculated over the repetitions of the single measurement, below which the average of the measurements is considered reliable.
- “Frequency”: frequency, in Hertz, at which the measurements were performed. The values can be: 10, 5, 3, 2.
- “Max\_retry”: maximum number of repetitions for which the single measurement will be performed, if the maximum Sigma value in percentage is reached, the repetitions will be stopped. Values can range from 3 to 10.
- “Max\_phase”: value of maximum phase. The values can be: 45, 20, 5.
- “Multiple\_acquisition”: indicates whether the session involves multiple acquisitions, i.e. the possibility of repeating the same measurements at regular intervals. Values can be “true” or “false”.
- “Multiple\_interval”: if “Multiple\_acquisition” value is set to “true”, it indicates the value of the repetition interval in seconds. It can be an integer value.
- “Multiple\_number”: if the “Multiple\_acquisition” value is set to “true”, it indicates the number of multiple repetitions to be performed. It can be an integer value.

The following is an example of a GPD file header.

```
*** Do not manually edit the GPD file ***  
Format Geophysics_PASI_Data_Format_GPD  
GPD_version 2  
Creation_date 2020-02-15 18:53  
Last_modification_date 2020-02-15 18:53  
Type Automatic  
Method TOM - Wenner Alfa  
Electrodes_sequence AMNB  
Standard_electrodes_position Standard  
Measures_number 55  
Measures_done 0  
Measurements_unit [m]  
Longitude_0 TBD  
Latitude_0 TBD  
Altitude_0 TBD  
Azimut_XTBD  
Electrodes_distance [m] 5.0  
Levels_number 2  
n 2  
Electrodes_number 32  
Topological_Information Linear X  
Note TBD  
Spare_1 NA  
Spare_2 NA  
Spare_3 NA  
Lap_number 0  
Sigma_max 5  
Frequency 10  
Max_retry 10
```

```
Max_phase      20
Multiple_acquisition  false
Multiple_interval  120
Multiple_number  10
```

## Electrodes table

The structure of the electrodes table is as follows.

- A title line containing the string “Logical - Physical electrodes mapping”.
- A line indicating for each column of the table which data is reported, it contains the string: “Logical\_id Mux\_id Electrodes\_id X\_position Y\_position Z\_position”.

The table header values are shown below and the formats for each related field in the table are described.

- “Logical\_id”: logic electrode identifier, it will be used as a value within the measurement table, in columns “A”, “B”, “M” and “N”, to indicate which logic electrode will play each role in the given measurement. It is an integer value from 1.
- Mux\_id: identifier of the physical MPX with which the logic electrode is associated. It is an integer value from 1.
- Electrodes\_id: identifier of the physical electrode with which the logic electrode is associated. It is an integer value.
- X\_position: value of the X component expressed in metres of the position of the logic electrode within a relative Cartesian axis system. It is a positive or negative decimal numeric value.
- Y\_position: value of the Y component expressed in metres of the position of the logic electrode within a relative Cartesian axis system. It is a positive or negative decimal numeric value.
- Z\_position: value of the Z component expressed in metres of the position of the logic electrode within a relative Cartesian axis system. It is a positive or negative decimal numeric value.

Below is an example of the portion of the file containing the electrodes table for 8 electrodes.

Logical - Physical electrodes mapping

Logical_id	Mux_id	Electrodes_id	X_position	Y_position	Z_position
1	1	1	0.00	0.00	0.00
2	1	2	5.00	0.00	0.00
3	1	3	10.00	0.00	0.00
4	1	4	15.00	0.00	0.00
5	1	5	20.00	0.00	0.00
6	1	6	25.00	0.00	0.00
7	1	7	30.00	0.00	0.00
8	1	8	35.00	0.00	0.00

## Measurements table

The structure of the measurements table is as follows.

- “Measures\_list”: indicates the total number of measurements in the table, both measurements performed and those to be performed. It is an integer value.
- A table header line indicating for each column of the table which data is reported and with which unit of measurement, contains the string “# A B M N R=dV/I[Ohm] Rho[Ohm/m] Sigma[%] dV[V] I[A] SP[V] IP[ms] K Time Longitude Latitude Altitude Frequency”.
- A sequence of lines (equal in number to the value in “Measures\_list”) of values written in string form, one line for each measurement to be performed or performed, where data relating to the measurement and the measured values are shown. Values that are not defined because they are absent or because the measurement has not been performed will be populated with the string “-”.

The table header values are shown below and the formats for each related field in the table are described.

- “#”: the field contains a progressive integer number identifying the line and therefore the measurement.
- “A”, “B”, “M”, “N”: the fields show the logical identifier of the four electrodes which, in the given measurement, assume each of the roles. The identifier “0” is used to indicate that no electrode is associated with the measurement in that role. Values are strings of integer numbers.

- “R=dV/I[Ohm]”: value of the resistance measured. It is indicated as decimal positive number.
- “Rho[Ohm/m]”: resistivity value calculated from measurements of resistance and geometric constant K. It is indicated as decimal positive number.
- “Sigma[%]”: mean square deviation value calculated on the repetitions of the measurement reported as a percentage of the measurement value. It is indicated as a positive integer number written as “xxx” or “xxx\*”. Measurements that have been accepted despite having a Sigma value higher than that set by the operator are shown with an asterisk “\*” at the end.
- “dV[V]”: value of potential difference measured between electrodes M and N. It is indicated as a positive or negative decimal number.
- “I[A]”: value of electrical current intensity measured between electrodes A and B. It is indicated as a positive or negative decimal number.
- “SP[V]”: spontaneous potential value measured between electrodes A and B. It is indicated as a positive or negative decimal number.
- “IP[ms]”: measured value of the induced polarisation. It is indicated as decimal positive number.
- “K”: geometric constant calculated from the electrode positions. It is indicated as decimal positive number.
- “Time”: day and time of execution of the measurement. It is indicated in the format “yyyy-mm-gg hh:mm”.
- “Longitude”: string of decimal degrees of longitude of the measurement point. North longitude degrees are given as positive numbers, south latitude degrees are given as negative numbers.
- “Latitude”: string of decimal degrees of latitude of the measurement point. North latitude degrees are given as positive numbers, south latitude degrees are given as negative numbers.
- “Altitude”: altitude in metres of the measuring point.
- “Frequency”: value of the frequency used to perform the individual measurement.

Below is an example of the portion of the file containing 8 measurements that have not yet been performed.

```
Measures list 8
```

```
#  A    B    M    N    R[Ohm]    Rho[Ohm/m] Sigma[%]
   dVmn[V]    Iab[A]    SP[V] IP[ms]    K    Time Longitude
   Latitude    Altitude    Frequency
```

1	1	4	2	3	-	-	-	-	-	-	-
		31.430			-	-	-	-			
2	2	5	3	4	-	-	-	-	-	-	-
		31.430			-	-	-	-			
3	3	6	4	5	-	-	-	-	-	-	-
		31.430			-	-	-	-			
4	4	7	5	6	-	-	-	-	-	-	-
		31.430			-	-	-	-			
5	5	8	6	7	-	-	-	-	-	-	-
		31.430			-	-	-	-			
6	6	9	7	8	-	-	-	-	-	-	-
		31.430			-	-	-	-			
7	7	10	8	9	-	-	-	-	-	-	-
		31.430			-	-	-	-			
8	8	11	9	10	-	-	-	-	-	-	-
		31.430									

Below is an example of the portion of the file containing 8 measurements that have been performed.

Measures list 8

#	A	B	M	N	R[Ohm]	Rho[Ohm/m]	Sigma[%]
	dVmn[V]		Iab[A]		SP[V]	IP[ms]	K
	Latitude		Altitude		Frequency		Time
							Longitude
1	1	2	3	4	2.9	82.06	2.115 733.4 -0.141
	0.56	28.29	2020-12-22	09:37	0.0	0.0	0.00 31.20
2	2	3	4	5	2.6	73.25	1.595 620.0 0.057 0.58
	28.29	2020-12-22	09:37	0.0	0.0	0.00	31.20
3	3	4	5	6	1.8	51.44	1.169 647.1 -0.019
	0.61	28.29	2020-12-22	09:37	0.0	0.0	0.00 31.20
4	4	5	6	7	4.4	124.86	2.735 623.9 0.078
	0.60	28.29	2020-12-22	09:18	0.0	0.0	0.00 31.20
5	5	6	7	8	4.2	117.79	2.754 665.9 0.157
	0.59	28.29	2020-12-22	09:18	0.0	0.0	0.00 31.20
6	6	7	8	9	2.0	56.24	1.218 617.2 0.005 0.61
	28.29	2020-12-22	09:18	0.0	0.0	0.00	31.20
7	7	8	9	10	5.3	150.05	3.170 602.8 0.015
	0.66	28.29	2020-12-22	09:18	0.0	0.0	0.00 31.20
8	8	9	10	11	6.8	191.57	4.401 654.8 0.069
	0.63	28.29	2020-12-22	09:18	0.0	0.0	0.00 31.20