GB – User's manual

CHAUVIN ARNOUX

PHOTOVOLTAIC-TEST

FTV500

Multifunction tester for photovoltaic systems

Measure up

You have just purchased a **PHOTOVOLTAIC TEST FTV500** and we thank you for trusting us. To use your new instrument in the best way:

- Carefully read these instructions before using the product.
- Observe the safety precautions.

Symbols used on the instrument:

CAUTION: Refer to accompanying notes

The CE marking refers to the compliance of the product with EU directives, in particular LVD and EMC.

The instrument is entirely protected by double insulation or reinforced insulation

The product is declared recyclable following an analysis of the life cycle in accordance with standard ISO 14040

Chauvin Arnoux has adopted an Eco-Design approach in order to design this product. The analysis of the complete lifecycle has enabled us to control and optimize the effects of the product on the environment. In particular this product exceeds regulation requirements with respect to recycling and reuse.

The crossed out bin is a reminder not to dispose of the product at th end of its life with general waste, in accordance with Directive WEEE 2012/19/EU.

Information or useful tip.

USB port Earth. Battery.

Definition of measurement categories

IEC 61010-1 or EN BS 61010-1 defines measurement categories II to IV relating to transient over-voltages and locations within electrical installations.

Examples of electrical installation category rating are:

- Category II - corresponds to measurements made at mains socket outlet,
- Category III - corresponds to measurements made at the wiring between the socket outlets and the consumer unit. Example: distribution panel, circuit-breakers, machines or stationary industrial devices.
- Category IV - corresponds to measurements made at the source of low-voltage installations. Example: the supply to the consumer cut-out from the distribution network transformer.

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SAFETY WARNINGS

This instrument complies with the safety standard IEC 61010-2-030 or EN BS 61010-2-030, the cables comply with the IEC 61010-031 or EN BS 61010-031 and the current sensors comply with the IEC 61010-2-032 or EN BS 61010-2-032, for voltages up to 600 V in category IV or 1 000 V in category III.
Failure to comply with the safety instructions can cause a risk of electric shock, fire, explosion, destruction of the instrument and of the installations.

- The operator and/or the authority must carefully read and fully understand the precautions to be taken during its use. Sound knowledge and awareness of electrical hazards are essential when using this instrument.
- If you use this product in a different way, other than the way described in this user guide, the protection it provides may be impaired, with potential risk to the operator and the instrument.
- Do not use the product when the voltage or measurement category exceeds those mentioned in this user guide.
-
- Do not use the product if any part appears damaged, incomplete or badly closed.
- Before each use, check the condition of the test leads, probes and crocodile clips: they must be in good order, clean and with no broken or cracked insulation
- Before using your product, check that it is perfectly dry. In case of presence of moisture inside or outside the case, it must be thoroughly dried before it is connected or used.
- Use only the leads and accessories supplied with this product. The use of test leads (or accessories) of a lower voltage or measurement category impairs the voltage and measurement category of the product.
- Wear systematically personal protective equipment.
- Do not put your hands near the terminals of the instrument.
- When handling the leads, test probes, and crocodile clips, keep your fingers behind the guards.
- Use only with power supplies and battery packs supplied by the manufacturer: these elements have specific safety devices.
- All troubleshooting and metrological checks must be performed by competent and suitably trained personnel.
- The current sensors must not be placed on or removed from bare conductors at hazardous voltages: refer to the sensor manual and comply with the handling instructions.
- To avoid the risk of damage to the instrument, turn off the instrument before the connections are made.
- It is recommended not to keep the USB key inserted in the instrument connector during Isolation, Continuity and I-V Curve measurements as it could compromise the safety during the use of the instrument.

NOTES ABOUT THIS GUIDE

The information contained in this guide is subject to variation without prior notice.
Although this guide has been written with the utmost care, please contact the manufacturer, should you have any comments, opinions or product-related questions.
Make sure you fully understand the pre-requisites for use of the product such as the technical characteristics and the hardware and software limitations for its use. We do not accept any responsibility for damages resulting from the improper use of the product.
Reproduction of this manual, in full or in part, without written permission from our company is prohibited.

SAFETY PRECAUTIONS

The following precautions for use are mandatory instructions for proper use of the instrument. Failure to follow these instructions causes risks such as electric shock, explosion and fire.

The operator ⚠ must follow these instrucnction each time the symbol.

Instructions preceded by the symbol above, should they not be carried out as explained, can result in a physical accident or damage to the accessory and installations.

In case of improper use of the instrument, safety is compromised and dangerous situations may occur.

The internal rechargeable batteries must not be replaced by the user. For internal battery replacement, contact an authorised service centre only.

For any system, in which this instrument is integrated, it is the responsibility of the operator assembling the integrated system to ensure its safety.

For your safety, use only the leads and accessories supplied with the instrument: they complies with EN/IEC 61010-031 or EN BS 61010-031. When the leads accessories belongs to a lower category than those provided with the instrument, the derating must be applied to the entire unit.

Before each use, make sure the leads, junction boxes and accessories are in perfect condition. Every lead, sensor or accessory with damaged insulation (even partial) must be returned for repair or disposed of.

Do not use the power supply when performing measurements. The power supply must be only used to recharge the internal batteries when the instrument is switched off.

Respect the environmental conditions.

It is recommended to use personal protective equipment according to the environmental conditions in which the instrument is used.

This instrument can be used for measurements on installations CAT III 600V or CAT II 1000 V. Never use it for voltage or category higher than those indicated.

For internal battery replacement, contact an authorised service centre only. These components have specific safety devices; using non-original spare parts could cause serious damage to persons or things.

Respect the limits of the physical protections of the accessories and sensors. Do not place your hands on terminals not being used.

To clean the external parts, use only a damp cloth, avoid substances based on hydrocarbons or aggressive detergents, avoid the penetration of liquids inside the instrument.

ATTENTION: for the electrical connections, use only the cables supplied or, if necessary, cables with suitable characteristics and certifications.

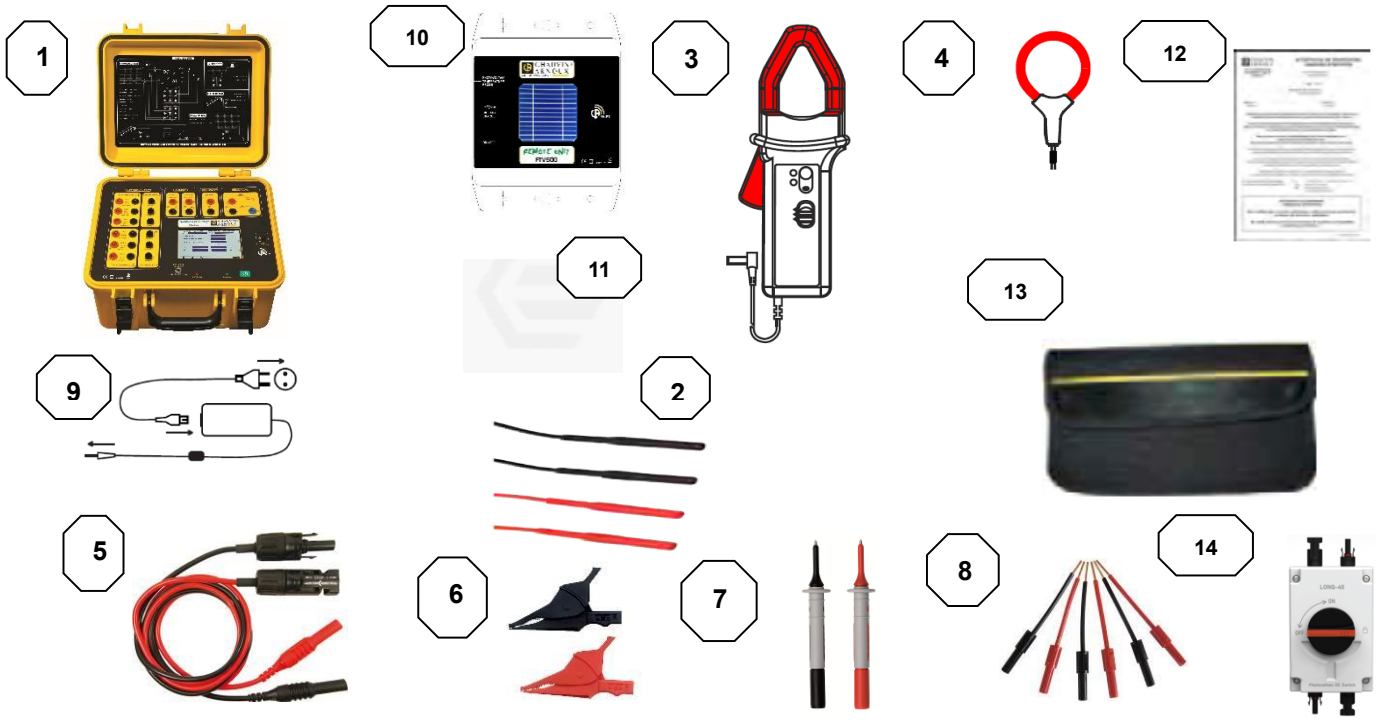
If the connection for the measurement is made with cables other than those supplied, use cables with the shortest length possible to compromise the accuracy of the result.

WARNING DURING USE

- A dangerous potential is always present in the photovoltaic system.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the string under test
- Never perform tests on PV modules or strings connected to the DC/AC converter
- Never perform insulation and continuity tests on modules or strings connected to the DC/AC converter
- Always verify correct polarity of cables (positive and negative)
- Never perform I-V curve, Insulation and Continuity tests with the instrument connected to the mains power supply
- Do not disconnect cables during measurement
- CAUTION : For electrical connections, use only the supplied cables or, if necessary, cables with suitable characteristics and certifications
- In case the connection for measurement is made with cables other than those supplied, use cables with minimum safety characteristics indicated in the instruction manual, and the shortest possible length so as not to affect the accuracy of the result
- In the case of a large distance between the instrument and the remote unit, it is recommended to perform sicronization by placing the instrument close to the remote unit itself and then taking the measurement at the desired distance
- Waiting time for synchronization : wait a couple of minutes after turning on the instrument before performing the first of synchronization
- Synchronization is only possible if the distance between the instrument and the remote unit is such that there is a stable Wi-fi connection. The limiting distance between the instrument and remote unit is affected by obstacles, air humidity, etc., so it can only be estimated in the order of a few meters
  If the required transmission range cannot be obtained, mount the remote unit on a stand and place it in the vicinity of the instrument, choosing azimuth and inclination with exposure similar to that of the array being measured
- In I-V and ISO tests, the instrument absorbs energy with each measurement, and over a series of continuous measurements, its internal temperature gradually increases. If the internal temperature continues to rise, the internal temperature sensor is activated and the instrument stops measurements, displaying the related error message
  If these conditions are expected, arrange in advance to minimize the temperature rise. Shelter the instrument from direct sunlight, elevate it from hot surfaces, and allow more time to elapse between I-V/ISO scans

1. GETTING STARTED

1.1 UNPACKING



No.	Descrizione	Quantità
1	PHOTOVOLTAIC TEST FTV500	1
2	Test leads (Red/Black) for PV EFFICIENCY, CONTINUITY, ISOLEMENT test	6
3	Current clamp DC	3
4	Current clamp AC	3
5	Test leads with MC4 connector (Red/Black) for I-V CURVE test	1
6	Crocodile clips (Red/Black)	1
7	Test probe (Red/Black)	1
8	Flexible female rod 4mm (Red/Black) (*)	6
9	PHOTOVOLTAIC TEST FTV500 power supply and power cord	1
10	REMOTE UNIT	1
11	REMOTE UNIT power supply and power cord	1
12	Calibration certificateon	1
13	Carrying bag	1
14	DC photovoltaic switch (included for instruments > 08-2025)	1

(*) It is an electrical only accessory. It is part of the electrical installation, not the test environment.
We recommend a use:

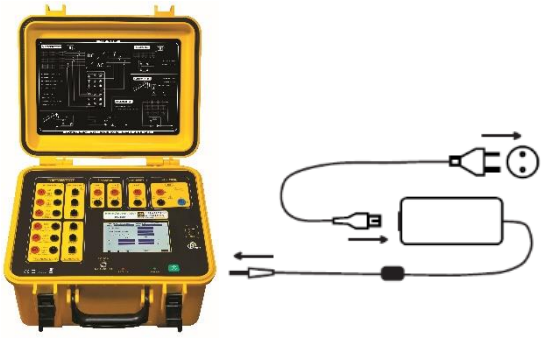
- **Installation power off**
- **Set up by an authorised person**

1.2 CHARGING THE BATTERY

The instrument is delivered with the battery already installed.
Because of the safety regulations and appropriate precautions when preparing lithium batteries for transportation, the instrument is equipped with a battery which has to be turned on for the first and next use.

In order to turn on the battery you have to pull the non-conductive divider sticking out from the instrument front panel (see following. Fig.):

As this is a first time use, start by fully charging the battery.



FTV500 INSTRUMENT

Connect the jack of the power supply to the instrument. Connect the power supply to the mains.

Red LED on: charging the battery
Red LED off or blinking: battery charged

WARNING: the instrument does not charge the battery while it is turned on.

REMOTE UNIT

Connect the USB jack of the remote unit to the power supply. Connect the power supply to the mains.

Charging: BATTERY CHARGE button LED flashing if it is pressed

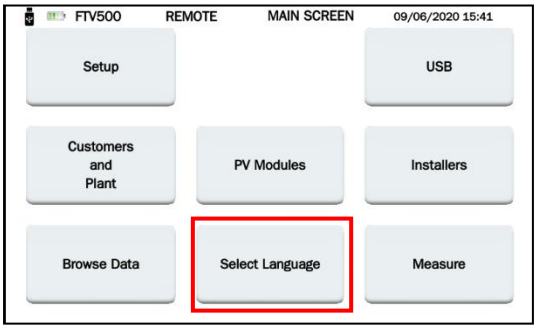
When the battery is fully discharged, charging takes, with switched off device:

FTV500 INSTRUMENT: 8 hours approximately
REMOTE UNIT: 5 hours approximately

1.3 SELECTING THE LANGUAGE

Before using the FTV500, you must choose the language in which you want it to display menus and messages.

Press the green PWR ON button to switch on the instrument



Press the Select Language icon

Select the language

2. INTRODUCTION

Photovoltaic systems are made up of two fundamental blocks:

- Photovoltaic generator made up of one or more strings of photovoltaic modules that generates a direct current.
- Inverter that converts the direct current generated by the modules into alternating current that can be fed it into the grid.

The PHOTOVOLTAIC TEST FTV500 is a instrument designed and manufactured to meet all the needs of the technicians during the installation, testing, commissioning, troubleshooting and maintenance of the photovoltaic generator or array according to international standards.
The PHOTOVOLTAIC TEST FTV500 instrument is a tool that can be used on most PV systems connected to the 50Hz, 60Hz and DC distribution networks in the world, with varying wiring systems. The instrument is designed to operate in environments up to 1000V CAT III, 600V CAT IV depending on the selected test feature (check the characteristics in the appropriate section of this user manual beforehand).

The instrument has been designed for carrying out the following tests:

- EFFICIENCY: verification of operation and DC / AC efficiency on three-phase photovoltaic installations, measurement of the PR (performance ratio, according to the CEI 82-25 guide; Variant 2, IEC / EN62446.
  DC / AC current measurement (at 3 DC + 3 AC inputs) and DC / AC voltage measurement (3 AC + 3 DC inputs)
- LOGGING: programmed recording (with programmable sampling frequency, and recording schedule) of the parameters related to the EFFICIENCY test. Evaluation of the PV system efficiency in the short / long term.
- I-V CURVE: verification of the I-V curve characteristicof PV modules / strings / arrays in order to check the parameters declared by the manufacturer, according to IEC / EN 60891, IEC / EN 62446, IEC / EN 60904-5.
  Series Resistance (RS) measurement, according to IEC / EN 60891.
- RAPID TEST: rapid pre- test of open circuit voltage and short-circuit current of PV modules / strings / arrays, according to IEC / EN 62446.
- INSULATION / CONTINUITY: insulation resistance of modules / strings / arrays, according to the IEC / EN 62446.
  Test of earth continuity according to IEC / EN 61557-4, IEC / EN 60364.

For the EFFICIENCY test, the PHOTOVOLTAIC TEST FTV500 has three voltage inputs (V-DC) and three current inputs (I-DC) for the measurement of what is supplied by the photovoltaic generator. Thye instrument allows up to three strings of solar panels to be measured simultaneously. Depending on the needs, one, two or all three V-DC and I-DC inputs can be used.
For the AC there are three inputs for voltage measurements (V-AC) and three inputs for current measurements (I-AC), which allow measurements on single-phase, two-phase or three-phase systems.
Make sure that the voltage and current connections are correct, to avoid acquiring incorrect measurements.
After having duly entered all the electrical parameters of the photovoltaic system in the registry, the user can verify the correct compliance of the measures compared with what is required by the standards, with the outcome of the measurement (OK / NO).
For the I-V CURVE test, the PHOTOVOLTAIC TEST FTV500 instrument has two inputs, one for the voltage measurement (V-DC) and one for the current measurements (I-DC). The measurements can be made both on the single module and on a string of modules, but keep in mind that the latter measurement is not covered by the standard.
All electrical data measured in the real operational test condition (OPC) are "translated" to the standard conditions (STC: Standard Test Condition) of irradiation equal to 1000 W/m^2 and module temperature equal to 25 °C, applying the calculation formulas according to the IEC / EN 60891 standard.
The user can request the comparison (DPmax) between the value of the rated power (Pmax), with the power value measured during the test (OPC) translated to the standard conditions STC (in accordance with IEC / EN 60891).
If the result of the comparison falls within the tolerance margin declared by the manufacturer, the test result will be "OK", otherwise the test result will be "NO".
The operator can enter the percentage of "degradation" declared by the manufacturer and the years of age of the individual module or string, significantly improving the accuracy of the test result.

ATTENTION: IEC / EN 60891 indicates the procedures for translating the measured values in the OPC (operating conditions) to the standard reference STC conditions of a **single module**. Therefore the negative outcome of a test of a measurement carried out on a string of modules could mean that it is necessary to carry out the measurement of each individual module composing the string, in order to identify the module or modules that negatively affects the performances of the string as a whole.

To facilitate the use of the instrument with large systems, the measurements of the environmental parameters (irradiation and temperatures) are performed through an independent REMOTE UNIT that communicates to the instrument with Wireless technology. The measurement of the parameters in the remote unit takes place in the following way:

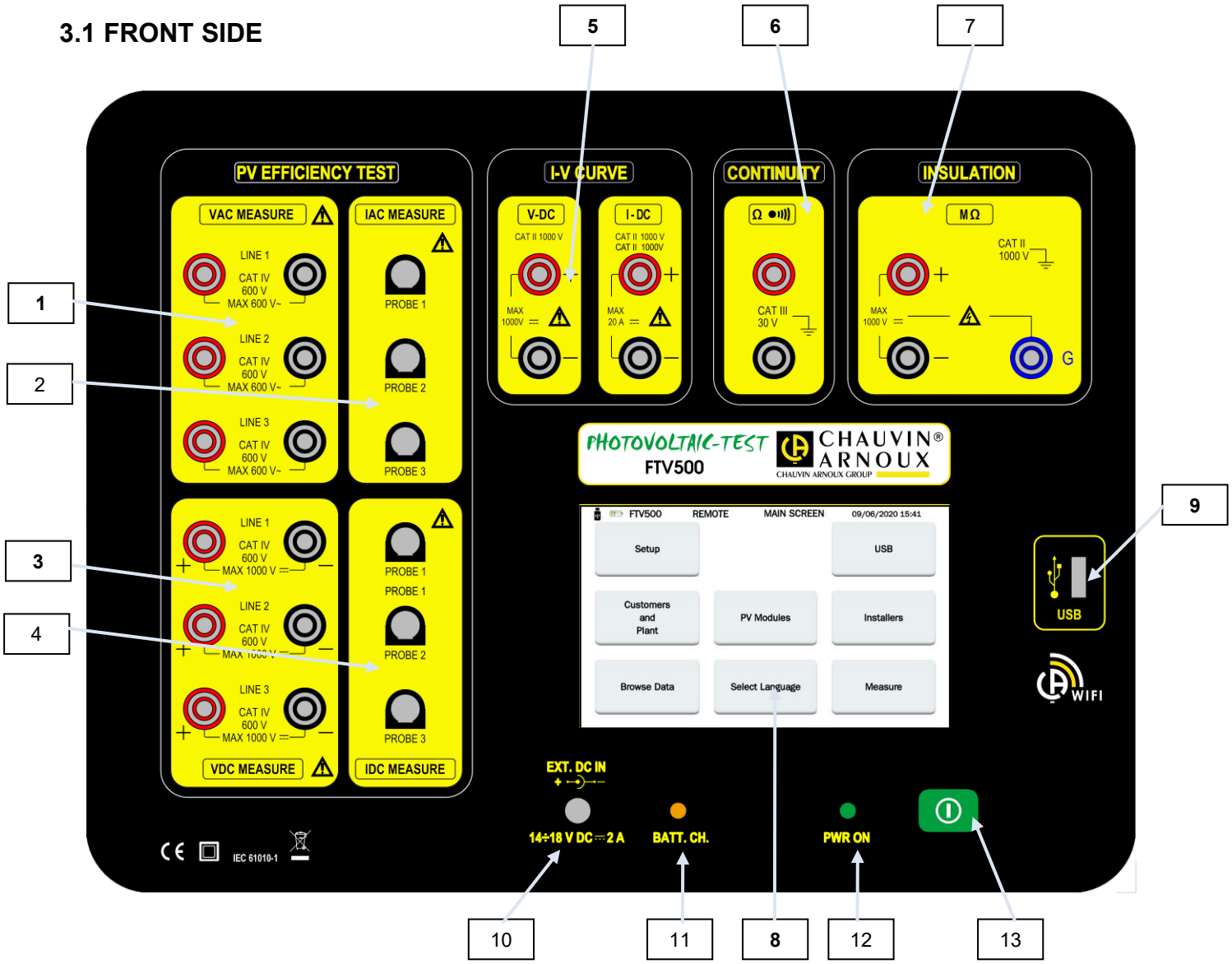
- Irradiation through a calibrated and high precision cell;facility
-
- Temperature: module temperature with external Pt100 resistance temperature probe; ambient temperature with internal Pt100 resistance temperature probe.

The selection of the temperature measurement mode (module, ambient, automatic, manual) is programmed directly by the instrument in the "system" menu. For an explanatyion of the differences between the measurement modes see section 14.2.

Important: the instrument is intended for inspection and maintenance rather than accurate measurement.

3. OVERVIEW

3.1 FRONT SIDE



PV EFFICIENCY TEST
1. V AC Voltage input (LINE 1-LINE 2-LINE 3)
2. I AC Current input (PROBE 1-PROBE 2-PROBE 3)
3. V DC Voltage input (LINE 1-LINE 2-LINE 3)
4. I DC Current input (PROBE 1-PROBE 2-PROBE 3)

I-V CURVE
5. V DC Voltage input
   I DC Current input

CONTINUITY
6. Continuity terminals

INSULATION
7. Insulation terminals
8. Touch-screen LCD monitor
9. USB port
10. External power supply
11. BATT led. CH, battery charging status signal (active only with external power supply connected).
    The LED is red during battery charging.
    Recharging takes place only with the instrument switched off, see section 3.5
12. PWR ON, LED turned on when the instrument is switched on
13. Key to power ON/OFF the instrument

3.2 DISPLAY

The color graphic touchscreen display shows the measurement values, the parameters, the selected type of measurement, etc. When the instrument is switched on, the MAIN MENU screen is automatically displayed, in the language that wasselected before it was switched off.
Information regarding the menus can be found in the following chapters:

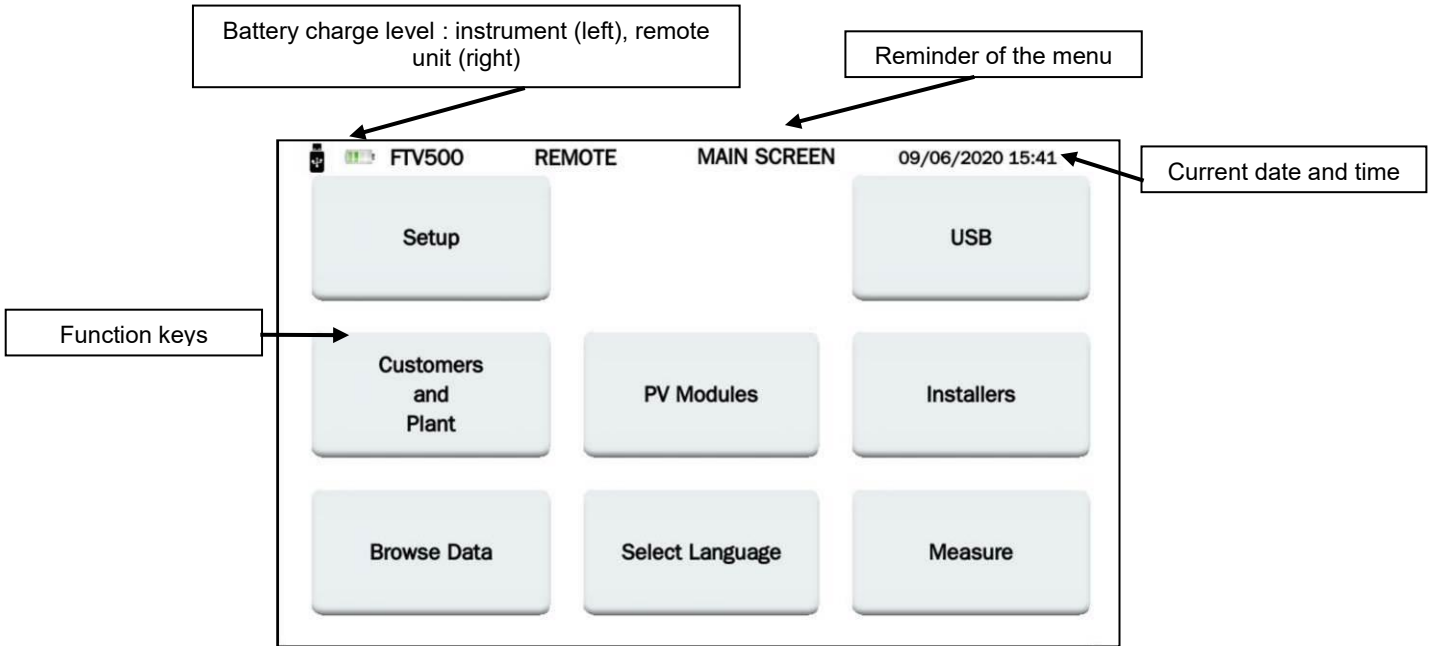


Figure 3.2-1: MAIN menu

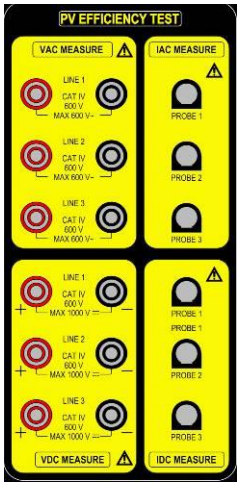
3.3 FUNCTION KEYS

The display is divided into functional zones, for the complete visualization of all setting and / or measurement information. The main functions are accessible via the touch display (handling is possible with light pen, bare hand or glove):

Icon	Description
Setup	General configuration menu of the instrument
Customers and plant	Menu for entering and managing customers and systems
Browse data	Menu for viewing the recordings in memory
PV modules	Menu managing the characteristics of the PV modules
Select language	Menu for the selection of the system language
USB	USB interface menu
Installers	Menu for managing the companies authorized to carry out the measurements
Measure	Menu for the selection of measurement

3.4 CONNECTION TERMINALS

The input terminals are distributed as follows according to the measurement characteristics:

	PV EFFICIENCY TEST 6 AC voltage input terminals (Line 1, Line 2, LIne 3) 3 AC current input terminals (Probe 1, Probe 2, Probe 3) 6 DC voltage input terminals (Line 1, Line 2, LIne 3) 3 DC current input terminals (Probe 1, Probe 2, Probe 3)
	I-V CURVE 2 DC voltage input terminals 2 DC current input terminals
	CONTINUITY 2 test continuity input terminals
	INSULATION 3 test insulation input terminals (G guard terminal)
	Input for external power supply (for battery charging only)
	USB port

3.5 POWER SUPPLY

The instrument is powered by a rechargeable battery pack with lithium-ion technology.

LITHIUM ION TECHNOLOGY
Lithium-ion technology offers numerous advantages:

- long autonomy with limited size and weight
- the absence of memory effect: you can recharge your battery when it is not completely discharged without decreasing its capacity
- very slow self-discharge
- the ability to quickly recharge your battery
- respect for the environment guaranteed by the absence of polluting materials such as lead or cadmium

BATTERY CHARGER

The instrument is not designed to operate when the charger is connected. The measurements must be carried out when the instrument is powered by the battery only. PV EFFICIENCY and LOGGING modes are excluded, as for their use the connection to a mains socket outlet is allowed.

The battery charger consists of two distinct elements: an external power supply and a charger integrated in the instrument.
The charger simultaneously manages the charging current, the battery voltage and its internal temperature. In this way, the charge is carried out in an optimal way, ensuring a strong longevity of the battery.

The day before using your instrument, check the state of charge. If the battery level indicator is low, charge the instrument following the instructions in this instruction manual.

The battery icons located at the top left corner of the screen represent the battery charge status of the instrument (FTV500) and of the remote unit (REMOTE). The number of bars in the icon is proportional to the charge level

Battery full

Low battery

Flashing bars: battery charging, notification that the power supply is connected
Flashing symbol: battery very low, autonomy at minimum

When the battery charge reaches a low autonomy value, this message appears which warns the operator of the imminent shutdown of the instrument:

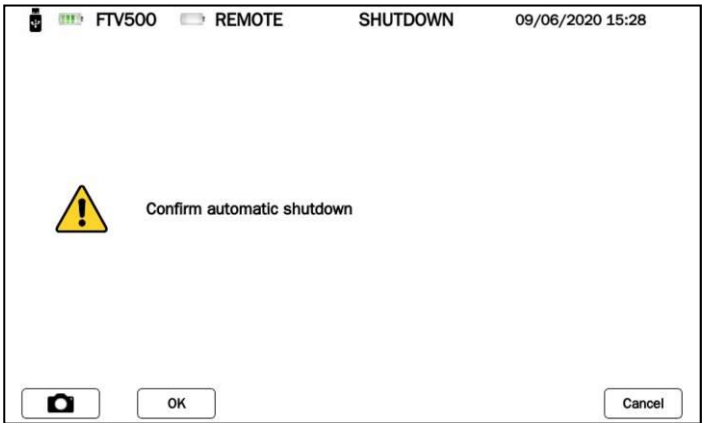


Figure 3.5-1 Shutdown menu

The same operator can decide whether to manually turn off the instrument by confirming the message (thus ensuring the correct storage of the settings and measurements in progress) and carry out the battery recharging procedure, or ignore it until the instrument is turned off because of the battery full discharge. In the latter case there is no guarantee that the measurements in progress and the open settings will be correctly saved in the memory.

To prolong the longevity of your battery:

- use only the charger supplied with your instrument. Using another charger can be dangerous!
- respect the storage use conditions contained in this instruction manual

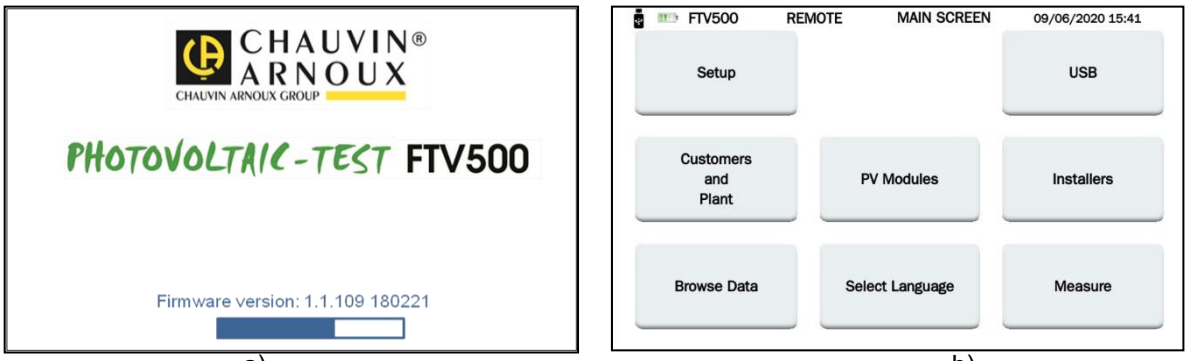
After prolonged storage, the battery may be completely discharged. In this case, the first charge can last longer.

4. OPERATION

4.1 SWITCHING ON / SWITCHING OFF

To switch the instrument on / off, press the button

During start-up, the instrument checks the software and firmware version, and then displays the MAIN menu. The start-up has a duration of about 50 sec.

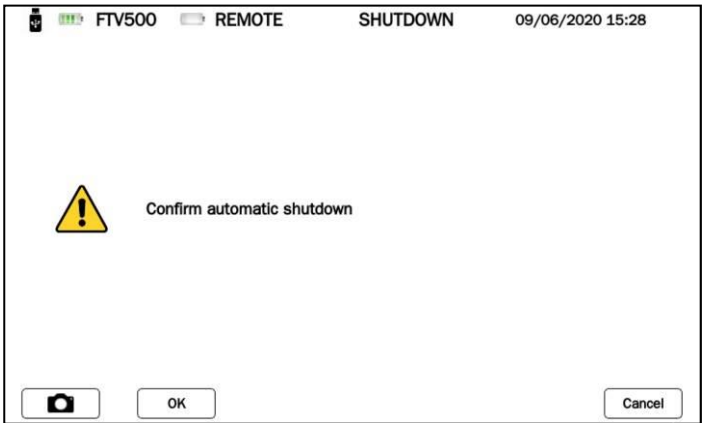


a) b)

Figure 4.1-1 a) Start-up b) MAIN menu

To turn off the instrument, simply press , then click OK to confirm your choice.

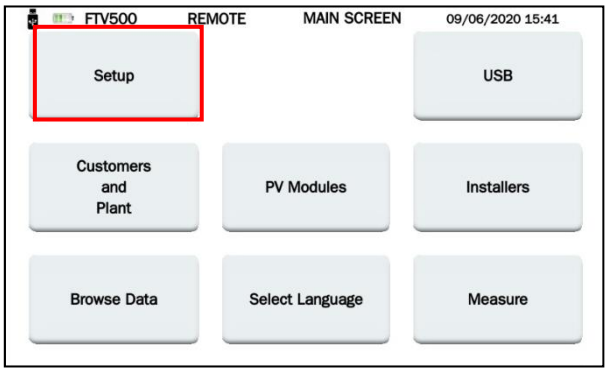
By pressing the button for a long time, the instrument switches off without displaying the shutdown menu:

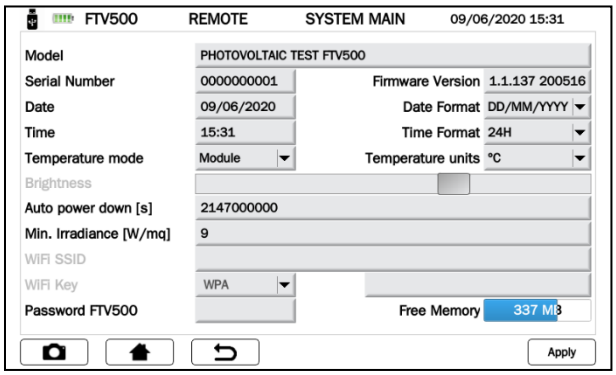


During the sutdown the display switches off immediately and the LED will switch off after approximately 20 s.

4.2 CONFIGURATION

To configure the instrument, carry out the following operation:
Click on the SETUP box (Figure 5.1 b)), the instrument settings menu will appear with the following information, some of which are default and not accessible (model, serial number, firmware version), others can be modified and adapted by the user via the keyboard that will open by clicking on the menu fields:





a) Figure 4.1-1 a) MAIN menu b) SETUP menu

- Model: identification of the PHOTOVOLTAIC TEST FTV500
- Serial number: serial number of the instrument
- Firmware version: version installed (for the updating procedure see section 14.6)
- Date: indication of the current date
- Date format: date format selection (dd / mm / yyy or yyyy / mm / dd, etc.)
- Time: indication of the current time.
- Time format: 12H or 24H
- Temperature mode: Module, Ambient, Manual, Auto
- Temperature units: selection of temperature unit of measurement (° C or ° F)
- Display brightness: bargraph adjustment of the display brightness (disabled with bonding technology display)
- Auto-off [s]: auto-off time of the instrument (seconds), minimum 60 seconds
- Min. Irradiance [W / mq]: minimum irradiation threshold necessary for the measurements
- WiFi Key: select access with password "WPA" or "none" (used for service activities)
- WiFi SSID: Service Set IDentifier, alphanumeric key for unique identification of the WiFi network (used for service activities)
- Password: security password to protect the Setup Menu
- Free memory: indication of the amount of free internal memory (expressed in MB)

4.3 FUNCTIONS

Verification of the correct operation and efficiency of photovoltaic systems (IEC/EN 61724)

The instrument allows tests to be carried out on single-phase and three-phase photovoltaic installations in compliance with IEC EN 61724, the measurement of DC / AC yields and the Performance Ratio (Prp).
The temperature and irradiation measurements are guaranteed by a Remote Unit capable of communicating with the instrument through Wi-Fi technology (transmission and recording).
The instrument calculates the parameters through the following direct measurements:

- DC / AC TRMS voltage measurement
  - 3 DC inputs
  - 3 AC inputs
- DC / AC TRMS current measurement
  - 3 DC inputs through current clamp
  - 3 AC inputs through current clamp
- DC / AC power measurement
  - Power factor
  - Phase rotation control with vector representation
- Irradiation measurement [W / m^2] with solar cell (remote unit)
- Measurement of module temperature (external probe) and ambient (internal probe) via remote unit
- Application of the DC efficiency compensation ratio (depending on the type of temperature used for the calculations)
- DC / AC yield measurements and photovoltaic system performance ratio (Prp)

DC / AC current and voltage measurements

The instrument allows you to perform voltage and current measurements on single-phase and three-phase photovoltaic installations with 3 AC current clamps and 3 DC current clamps.

- Current measurement through DC and AC current clamps
- Direct voltage measurement

I-V current-voltage characteristic measurement (according to IEC/EN 60904 and IEC/EN 60981)

The instrument allows to carry out tests and measurements on modules with photovoltaic technology, in order to determine the current-voltage (I-V) characteristic declared by the manufacturer.
The tests can be performed both on individual modules and on an array of photovoltaic modules (strings) with connection in series (max voltage 1000V) or in parallel (max current 20A)
Direct comparison of the actual measured curve (OPC) translated ino the STC curve is made with the STC reference values declared by the manufacturer.
The temperature and irradiation measurements are guaranteed by a Remote Unit capable of communicating with the instrument through Wi-Fi technology (transmission and recording).

- Measurement of voltage, current and power of cells / modules / strings up to 1000 VDC, 20 A DC
- Measurement of the module / string and ambient temperature (remote unit)
- Irradiation measurement [W/m^2] with the solar irradiance meter (remote unit)
- Numerical and graphic display of the I-V characteristic with 4-wire measurement method
- Direct comparison with the STC reference values and real-time evaluation of the results with an OK / NO result
- Possibility to enter the years and percentage of degradation of the module
- Automatic measurement of the equivalent cell temperature (ECT) according to IEC/EN 60904-5
- Internal customizable database of the characteristics of the photovoltaic modules

RS series resistance measurement of modules (according to IEC/EN 60891)
The RS series resistance test is used to perform an accurate measurement, in real time, on the photovoltaic module in order to define its value to be used in the database of the characteristics of the same module, according to the IEC/EN 60891 standard. The temperature and irradiation measurements are guaranteed by a Remote Unit capable of communicating with the instrument through Wi-Fi technology (transmission and recording).

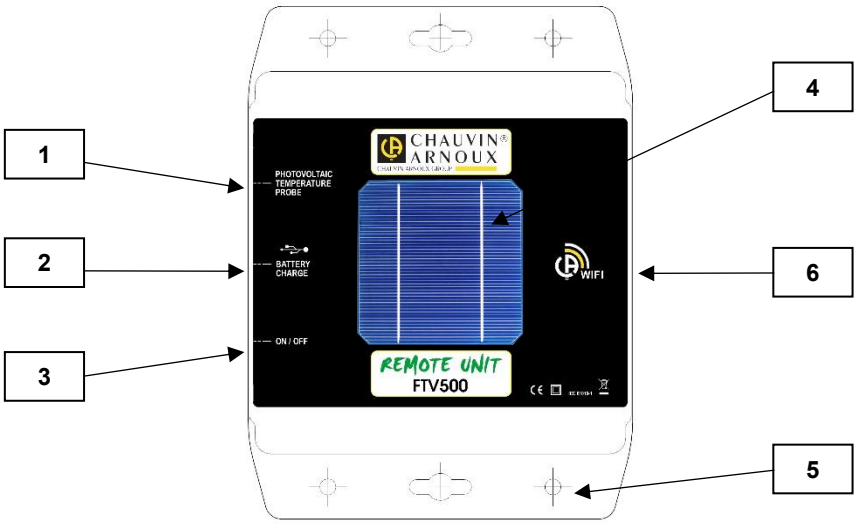
Continuity measurement of earth connection and equipotential bonding (according to IEC/EN 61557-4, IEC/EN 62446)
This measure allows you to check the continuity of the conductors connected to earth and the conductor for equipotential bonding on photovoltaic installations.
The test must be carried out with a test current> 200mA.
- Test current> 200mA
- Test lead resistance null
- Open circuit voltage 9-12Vdc

Cell / modules / strings insulation resistance measurement (according to IEC/EN 62446, IEC/EN 60364)
This measure allows to verify the insulation resistance of the active conductors of a panel / string / photovoltaic system towards metal masses not connected to earth according to the CEI 82-25 Guide; V2 and CEI 64-8, IEC / EN62446 standards.
The instrument performs the insulation measurement in the following ways:
- Test voltage 250V, 500V, 1000VDC
- 2 measurement modes: PV Field, Traditional
- Check insulation of metal masses not connected to the earthing system
- **PV FIELD** mode: used to measure the insulation resistance of individual PV modules or strings. The instrument automatically measures the ground resistance of the terminals and displays the results: Ri(+), Ri(-), and Rp.
- **TRADITIONAL** mode: The instrument performs the measurement in the traditional manner (with a duration set by the operator) and displays the result: Ri(+).

Evaluation of photovoltaic system performance in the short / long term
The instrument allows you to record in a period, programmable by the user, all the parameters of the single-phase and three-phase photovoltaic system in accordance with the requirements of the CEI 82-25 Guide Variant V2, IEC / EN 62446, the measurement of DC / AC yields and the Performance Ratio (Prp), displaying the result of the OK / NO test in real time.
The temperature and irradiation measurements are guaranteed by a Remote Unit capable of communicating with the instrument through Wi-Fi technology (transmission and recording).
- Measurement of DC voltage, DC current and DC power of cells / modules / strings
- Irradiation measurement [W / m2] with solar radiance meter (remote unit)
- Measurement of the module / string and ambient temperature (remote unit)
- Application of the DC efficiency compensation ratio (depending on the selection of the type of temperature used for the calculations)
- DC / AC yield measurements and photovoltaic system performance ratio (Prp) plus real-time evaluation of the result OK / NO
- Recording of the parameters of the photovoltaic system with programmable sampling rate and recording interval (seconds / minutes / hours / days)
  For measuring campaigns longer than 4/8 hours, plug the instrument and the DC current clamps (for the latter power supply delivered as option) into a socket outlet

5. DESCRIPTION OF THE REMOTE UNIT

5.1 FRONT SIDE

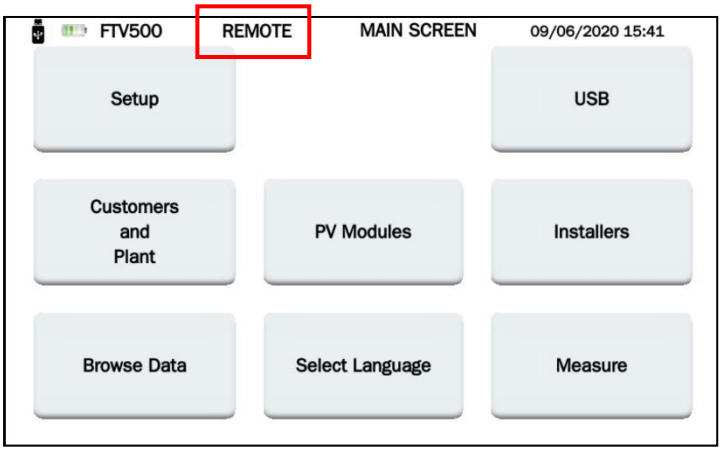


1. Pt100 temperature probe integrated with the Remote Unit
2. USB power supply input for charging internal batteries
3. On / off button with LED indicating operating status
4. Solar irradiance probe for irradiance measurement
5. Holes and fixing holes for positioning of the remote unit on the plane of the PV modules
6. Wi-Fi connection system

5.2 POWER SUPPLY

See also characteristics listed in the instrument description.
The remote unit is powered through an internal Li-Ion battery pack, rechargeable via the delivered power supply (also permanently usable in the case of long-term measurement campaigns).
It is possible to use the remote unit (button in the ON position) even during battery recharge: in this case the behavior of the LED on the ON / OFF button does not change.

There is a charge indicator of the remote unit also on the display of the FTV500, whatever the menu you are in:



The behavior of this indicator reflects the charging status of the remote unit (or autonomous operation if no connection is provided with the power supply), and the charge percentage of its battery:

Battery charging

Low battery

Flashing symbol: remote unit not synchronized

NOTE: the real condition of the battery status is showed only after the first synchronization with the instrument.

Longevity	at least 300 recharge-discharge cycles
Battery autonomy	8 hours (on standby)
Charging current	1 A
Charging time	about 3 hours
Temperature for use	[0 °C; 50 °C].
Temperature for recharge	[10 °C; 40 °C].
Storage temperature	30 days: [-20 °C; 50 °C].
	storage for 30 to 90 days: [-20 °C; 40 °C]. storage for 90 days to 1 year: [-20 °C; 30 °C].

6. USE OF THE REMOTE UNIT

6.1 SWITCHING ON / SWITCHING OFF

The remote unit is equipped with an ON / OFF button

The button has two positions: ON and OFF. In the ON position, a flashing LED on the button indicates that the remote unit is on and functioning. In the OFF position, the LED is off.

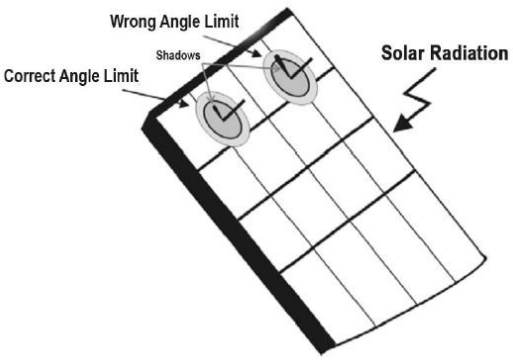
6.2 POSITIONING

⚠ ATTENTION

Before making the measurements, make sure you have positioned correctly the Remote Unit (see inclinometer) and the temperature probe

INCLINOMETER: Screw the threaded stem on the inclinometer disc and place it on a panel or string. Please check that the stem shadow, projected on the disc, is inside the circle engraved on the disc (see example). Should this not be the case, the angle between solar rays and panel surface is too high and for this reason the measurements of the instrument **are not** reliable. Please repeat the measurement in other moments of the day.

It is always recommended to carry out measurements with a level of irradiation higher than that indicated in the appropriate standards (IEC/EN 62446-1, IEC/EN 60891, CEI 82-25).



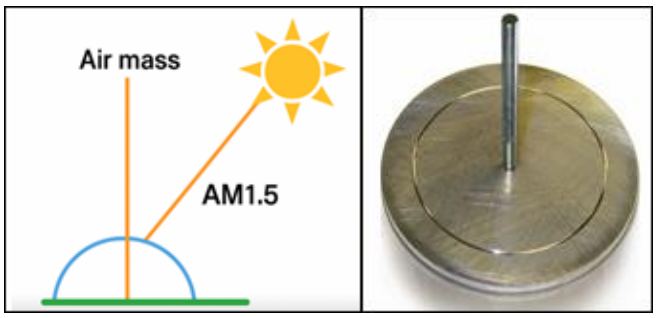
The “mechanical” technology of our inclinometer guarantees real and immediate measurement of the inclination of solar radiation (meridian operation).
The purpose of the inclinometer is to bring the measurement, if possible, within the reliability parameters required by standards and the module manufacturer, known as standard operating conditions (STC), used to compare the performance of solar panels.

- Irradiance values (1000W/m2).
- Cell temperature (25°C).
- Air mass value (AM 1.5), which represents the amount of atmosphere that sunlight must pass through before reaching the Earth's surface.

This AM value is 1.5 and corresponds to a solar angle of approximately 48.2° above the horizon.

The inclinometer supplied has a concentric circle representing the limiting angle (48.2°) at which the shadow of the rod cast by the sun must fall.
Otherwise, the angle between the solar rays and the module surface is too large, and the measurements taken are therefore unreliable.

Example of an Air Mass and Inclinometer graph:



REMOTE UNIT: the Remote Unit must be positioned correctly on the same plane as the modules to be tested, it is also necessary to ensure that there are no shading, in order to avoid fake measurements.
Fasten the Remote Unit directly to the module frame or to the supporting structure using the supplied bracket (check for any shading caused by an incorrect sensor position).
PANEL TEMPERATURE PROBE: the temperature probe must be positioned on the rear of the panel in correspondence to a cell; if you are measuring a string of panels place the probe on a panel in the middle of the string.

6.3 REMOTE UNIT FUNCTIONS

Thanks to the remote unit to be installed on the panels, it is possible to transmit with Wi-Fi connection to the instrument and in REAL TIME the measurements of irradiamnce, ambient temperature and module temperature. This will allow you a simple and precise test, as well as the simultaneous acquisition and display of the measurements.

In case of loss of communication between the instrument and the remote unit, the remote unit will automatically reconnect when communication becomes active again.

How to measure using the remote unit:

- Fix the remote unit on the module
- Turn on the remote unit by setting the switch to ON (LED on)
- The remote unit is now ready to transmit the measurements to the PHOTOVOLTAIC TEST FTV500 instrument

Synchronization is possible only if the distance between the instrument and the remote unit is such that a stable Wi-fi connection is possible. The limiting distance between the instrument and remote unit is affected by obstacles, air humidity, etc., so it can only be estimated in the order of a few meters.

7. GENERAL SPECIFICATIONS

7.1 ENVIRONMENTAL CONDITIONS

Temperature usual range
- 23° ± 5°C

Temperature operational range
- 0 ÷ 40°C

Operating humidity
- <75% RH

Altitude:
- Operational range < 2000 m
- Storage range < 10000 m

7.2 MECHANICAL SPECIFICATION

PHOVOLTAIC TEST FTV500
Dimensions: 340x300x200 mm
Weight: approximately 3kg
Display: 5” (108x648mm), risolution 800x480
IP Rating: IP54 as EN60529 when the device in closed position
IP52 when the device is open
IP20 at the level of the measurements terminals

REMOTE UNIT
Dimensions: 160x120x63mm
Weight: approximately 1kg
Tightness: IP67 according to EN60529

WI-FI CHARACTERISTICS
Wi-Fi: 4 (b/g/n)
Frequency: 2.4GHz
Data: 150Mbit/s (IEEE 802.11n standard)

7.3 ELECTRIC SAFETY

General
Instrument safety: IEC/EN61010-1 or EN BS 61010-1
Measuring accessories: Current probes IEC/EN61010-032 or EN BS 61010-032 / Test leads and miscellaneous IEC/EN61010-031 or EN BS 61010-031
Insulation: Double insulation
Degree of pollution: 2
Installation category: PV Efficiency and Logging: CAT III 1000V, CAT IV 600V
I-V Curve, Insulation, Continuity : CAT II 1000V, CAT III 600V

Reference standards for measurements
Reference standards for the individual measurement functions:
- Guide CEI 82-25; Variant V2 (efficiency test)
- EN 61724 (efficiency test)
- EN 62446 (I-V curve and electrical safety)
- EN 60891 (I-V curve)
- EN 60904-5 (equivalent cell temperature determination)
- EN 61557-4 (insulation and continuity)

7.4 ELECTROMAGNETIC COMPATIBILITY (EMC)

The instrument complies with EN 61326-1.
According to EN 61326-1, the instrument is, in terms of immunity to radio frequency fields, a product intended for use on industrial sites.
For the current probes, refer to the characteristics stated in the instruction manuals.
The Photovoltaic Test FTV500 instruments is intended for use in an industrial environment. Potential difficulties may arise to ensure electromagnetic compatibility in other environments due to radiated and conducted disturbances.

8. POWER SUPPLY

8.1 MAIN POWER SUPPLY

A specific external power supply is supplied
Range of use: 100-240Vac 50/60Hz
Power: 60W max

8.2 BATTERY POWER SUPPLY

The power supply of the instrument is ensured by a 14.8V 5200mAh battery pack, containing 8 elements with rechargeable lithium-ion technology.

Longevity	at least 500 recharge-discharge cycles
Charging current	2 A
Charging time	approximately 5 hours
Charging T°	[0°C; 45°C]
Storage T°	until 30 days [-10°C; 55°C]
	Storage for 30 to 90 days [-10°C; 40°C]
	storage for 90 days to 1 year [0°C; 25°C]

8.3 BATTERY AUTONOMY

Autonomy is approximately 10 hours when the battery is fully charged and the screen is running.

8.4 DISPLAY

The display unit is an active matrix (TFT) LCD type having the following characteristics:

- 5” diagonal
- Resolution: 800x480 pixel
- Colour with optical bonding technology
- Maximum brightness: 425 cd/m^2 – typical: 300 cd/m^2
- Response time: between 4 and 12 ms
- Field of view: 60° on average in all directions

9. SPECIFICATIONS

Values measured and calculated for each function

9.1 BANDWIDTH

The PHOTOVOLTAIC TEST FTV500 is a instrument that can be used on most photovoltaic systems connected to the 50Hz, 60Hz and DC distribution networks in the world, with numerous connection possibilities according to the system considered. The instrument is designed to operate in environments up to 1000V CAT III and 600V CAT IV.

9.2 “PV EFFICIENCY” – “LOGGING”

The uncertainty is indicated as [% reading + digit * resolution] at 23 ° C ± 5 ° C, <80% HR

DC voltage measurement

Range (V)	Resolution (V)	Uncertainty
3 ÷ 30	0.1	± (5.0% reading ± 2 dgt)
31 ÷ 999.9	0.1	± (1.0% reading ± 2 dgt)

AC TRMS voltage measurement (50 ÷ 60Hz)

Range (V)	Resolution (V)	Uncertainty
3 ÷ 10	0.1	± (1.5% reading ± 2 dgt)
10 ÷ 700.0 (1000V peak)		

Max crest factor: 1,5

DC current measurement (instrument)
Measuring range selectable from the measurement menu between 150A (10mV / A) and 1400A (1mV / A) which must be associated with the position of the selector located on the current probe (the lack of association may result in reading of fake values)

Range (A)	Resolution (A)	Uncertainty (without current probe)
1 ÷ 15.0	0,1	± (1.0% reading + 2 dgt)
15 ÷ 150	1	
1 ÷ 1400	1	

DC current measurement (DC current clamp)

Range (A)	Uncertainty
0.5 ÷ 100	± (1.5% reading + 1A)
100 ÷ 800	± 2.5% reading
800 ÷ 1000	± 4% reading
1000 ÷ 1200	± 5% reading

AC TRMS current measurement (instruments)
Measuring range selectable from the measurement menu between 300A and 3000A

Range (A)	Resolution (A)	Uncertainty (without current probe)
1 ÷ 30.0	0,1	± (1.0% reading ± 5 dgt)
30 ÷ 300	1	± (1.0% reading ± 2 dgt)
300 ÷ 3000	1	

AC TRMS current measurement (current probe)

Range (A)	Uncertainty
1 ÷ 3000	± (2,5% reading + 0.25 A)

Range (A)	Uncertainty (angle, 50 Hz)
30 ÷ 300	± 1.5°
300 ÷ 3000	± 0.8°

DC power

Range – current probe (A)	Measuring range (W)	Resolution (W)	Uncertainty (with current probe)
1 ÷ 10	100k	0.001k	± (4.0% reading ± 5 dgt)
10 ÷ 100	100k	0.01k	
100 ÷ 1000	1000k	0.1k	
1000 ÷ 5000	10000k	0.1k	

AC power

Range – current probe (A)	Measuring range (W)	Resolution (W)	Uncertainty (with current probe)
1 ÷ 10	100k	0.001k	± (5.0% reading ± 5 dgt)
10 ÷ 100	100k	0.01k	
100 ÷ 1000	1000k	0.1k	
1000 ÷ 5000	10000k	0.1k	

Solar radiation (with the solar irradiance probe on the Remote Unit)

Range (W/m²)	Resolution (W/m²)	Uncertainty
50.0 ÷ 2000.0	0.1	± (2.5% reading + 3 dgt)

Ambient (internal probe) and module temperature (Pt100 probe)

Range (°C)	Resolution (°C)	Uncertainty
-20.0 ÷ 250	0.1	± (1.0% reading + 3 dgt)
-20.0 ÷ 250	0.1	± (1.0% reading + 3 dgt)

9.3 "LOGGING" FUNCTION

The specifications are the same indicated for the EFFICIENCY TEST

Registration type	Recording interval (sampling)
Year/month/day/hour/minute	from 2 to 86.400 seconds

Memory autonomy about 600,000 samples

9.4 "CURRENT-VOLTAGE I-V CURVE" TEST

The uncertainty is indicated as [% reading + digit * resolution] at 23 ° C ± 5 ° C, <80% RH

DC voltage (OPC & STC)

Range (V)	Resolution (V)	Uncertainty
0 ÷ 10	0.005	± (1.0% reading + 3 dgt)
10 ÷ 100	0.05	
100 ÷ 999.9	0.1	

DC current (OPC & STC)

Range (A)	Resolution (A)	Uncertainty
0 ÷ 1	0.005	± (1.0% reading + 3 dgt)
1 ÷ 10	0.05	
10 ÷ 15 (max 20)	0.1	

Limit the strings of high-efficiency modules to a current of <10 A (see I-V measurement)

DC power (OPC & STC)

Measuring range (W)	Resolution (W)	Uncertainty
5 ÷ 9999	1	± (1.5% reading + 2 dgt)

Note
OPC: measurements under operating conditions (directly in the field)
STC: measurements translated to standard conditions (1000W/m², 25°C)

Solar radiation (with the solar irradiance probe on the Remote Unit)

Range (W/m²)	Resolution (W/m²)	Uncertainty
50.0 ÷ 2000.0	0.1	± (2.5% reading + 3 dgt)

Ambient (internal probe) and module temperature (Pt100 probe)

Range (°C)	Resolution (°C)	Uncertainty
-20.0 ÷ 250	0.1	± (1.0% reading + 3 dgt)
-20.0 ÷ 250	0.1	± (1.0% reading + 3 dgt)

9.5 "CONTINUITY" TEST

The uncertainty is indicated as [% reading + digit * resolution] at 23 ° C ± 5 ° C, <80% RH

Continuity of protective and equi-potential bonding conductors (LOWΩ)

Range (Ω)	Resolution (Ω)	Uncertainty
0.00 ÷ 1.99	0.01	± (2.5% reading + 3 dgt)
2.0 ÷ 19.9	0.1	

20 ÷ 99	1	

Test current >200mA DC, Resolution 1mA, Uncertainty ± (3.0% reading + 3 digit)
Open circuit voltage 4<V_0<10V

9.6 “INSULATION” TEST

The uncertainty is indicated as [% reading + digit * resolution] at 23 ° C ± 5 ° C, <80% HR

Insulation resistance (MΩ) –TRADITIONAL MODE

Test voltage (V)	Range (MΩ)	Resolution (MΩ)	Uncertainty
250-500-1000	0.25 ÷ 1.99 *	0.01	± (5% reading + 2 dgt)
	2.0 ÷ 19.9	0.1	
	20 ÷199	1	

Open circuit voltage	< 1.25 x rated test voltage
Short-circuit current	< 15mA (peak) for all selected voltages
Test voltage	Resolution 1V, Uncertainty ± (5.0% reading + 5 digit)
Rated measurement current	> 1mA on 1kΩ @ Vnom (range min. limit = 0.25MΩ only for test voltage 250V)

Insulation resistance (MΩ) – PV FIELD

Test voltage (V)	Range (MΩ)	Resolution (MΩ)	Uncertainty
250-500-1000	0.25 ÷ 1.99 *	0.01	± (20% reading + 2 dgt)
	2.0 ÷ 99.9	1	

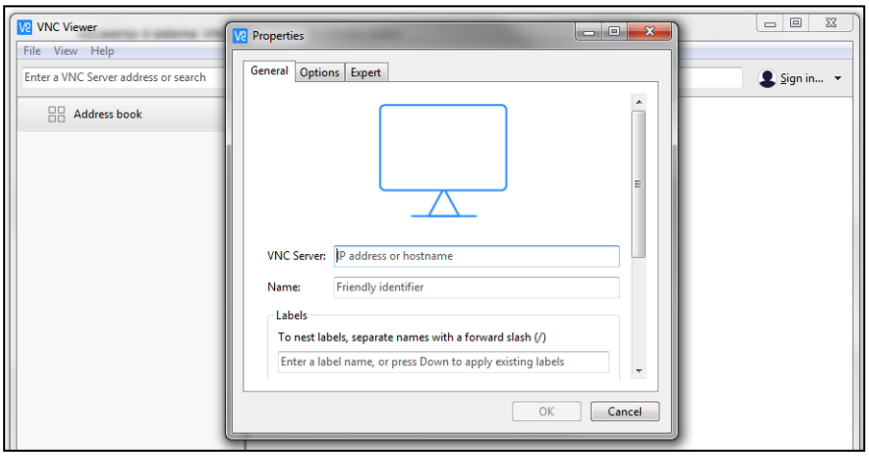
PV FIELD mode	Minimum voltage for the calculation of Ri(+) and Ri(-): 1V
Open circuit voltage	< 1.25 x selected test voltage
Short-circuit current	< 15mA (peak) for each test voltage
Test voltage	Resolution 1V, Uncertainty ± (5.0% reading + 5 digit)
Rated measurement current	> 1mA su 1kΩ @ Vnom (range 0.25MΩ only for test voltage 250V)

10. REMOTE INTERFACE

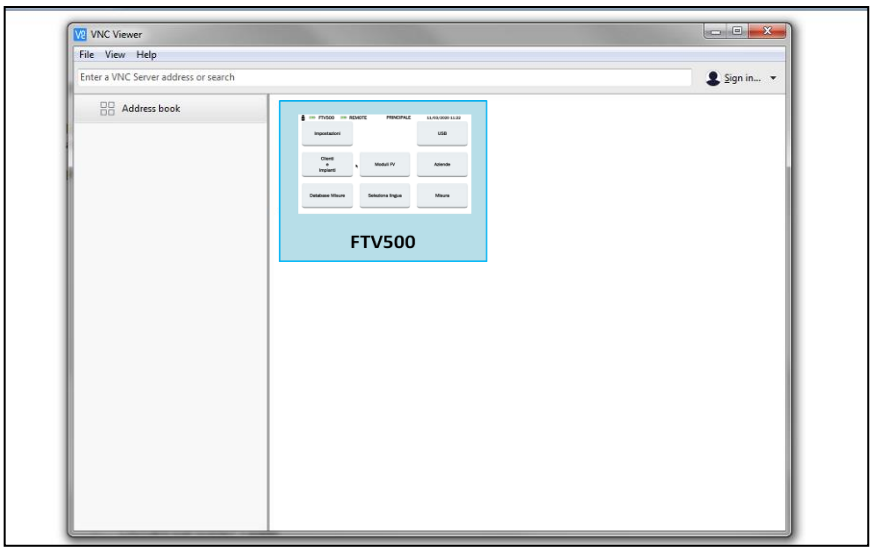
The instrument can be completely controlled and managed remotely through smartphones, tablets or PCs equipped with VNC Viewer access (Virtual Network Computing) or similar, and connected with wireless connection.

To establish the connection to the instrument, follow the instructions below:

- Download the VNC Viewer (Virtual Network Computing) program or similar and upload it to your device
-



- Select from the menu "New connection"
- Enter the IP address of the instrument: 192.168.197.1
- Enter password if required: ospite123
- Enter the connection name (optional): example FTV500
- Activate the wireless connection on the device and choose the "FTV500AP" network
- Wait until the network has been activated and accepted
- Click on the FTV500 icon to activate the connection to the instrument



- The instrument is now ready to be controlled manually as well as through a remote device
- Use the pointer to select the function and navigate the instrument menus

NOTE: the VNC Viewer access system keeps the display control active, this means that the functionality of the instrument can be remote-controlled on multiple devices simultaneously, allowing it to be used by multiple operators.

11. MENU DESCRIPTION

Through the Main Menu (HOME Menu) the operator can get into all the functions of the instrument:

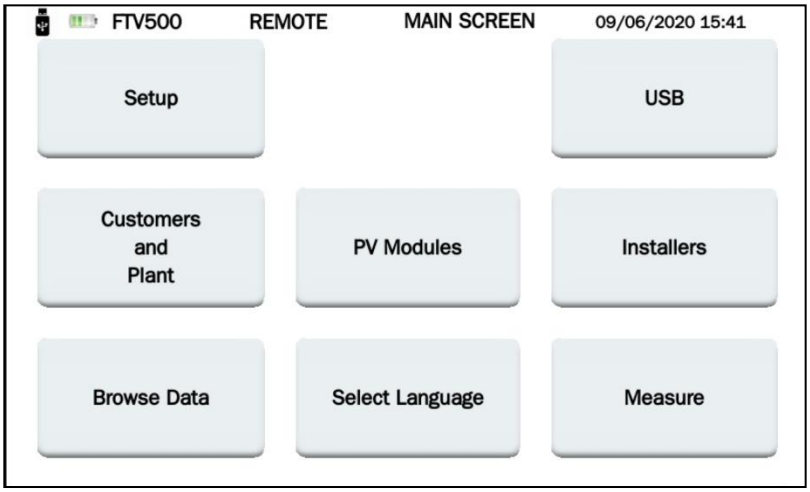


Figure 11-1 HOME Menu

12. GENERAL FUNCTIONS

In each menu (except the HOME menu and the LANGUAGE SELECTION menu) there are the following keys, which carry out the following functions:

	take a photo or "screenshot" of the currently visible screen. The images will be saved in the USB stick of the instrument (if the present) with indication of the file on which the image is saved (see section USB MENU)
	return to the HOME menu from any other menu. Any operation you were doing in the current menu is canceled (including data entries) without the possibility to undo the operation.
	go back one step to the previous menu (the one displayed before the one currently viewed). Any operation you were doing in the current menu is canceled (including data entries) without the possibility to undo the operation.

13. DATA STRUCTURE

Before describing the individual operations of creation and modification of the database stored in FTV500, it is necessary to give a preliminary clue to how the data structure contained in the instrument is composed at the various levels that make it up.

There are three data structures:

1. Structure associated with the customer and its sub-structures, on which the tests are carried out:

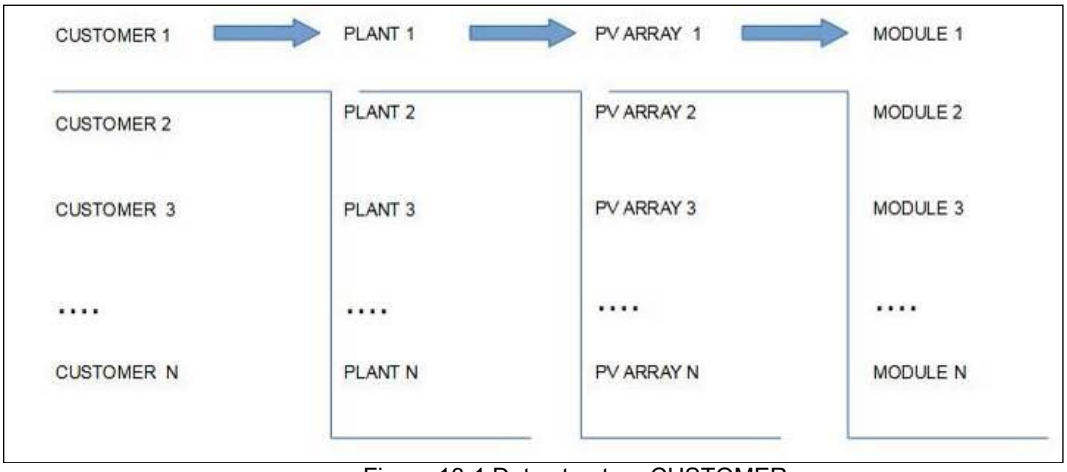


Figure 13-1 Data structure CUSTOMER

CUSTOMER means the owner of the PLANT in which the entire plant, or a part, must be tested. A customer may have one or more plants that must be entered in the data structure, if subjected to measurement.
The plant is then subsequently divided into PV ARRAYS and these, in turn, into MODULES..

2. Structure associated with the INSTALLER, which physically carry out the checks:

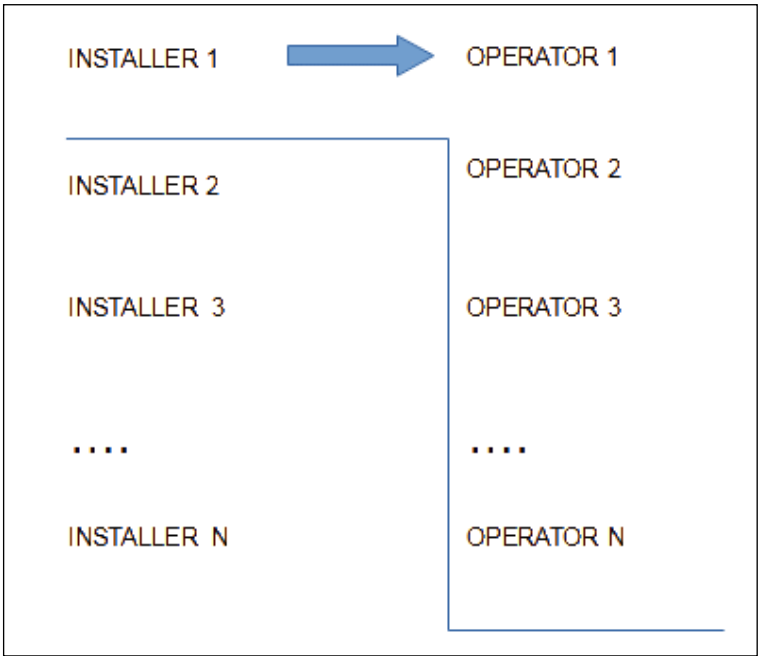


Figure 13-2 Data structure INSTALLER

The entity who carries out and is responsible for the measurements is an INSTALLER company, legal person) but the person who physically carries out the measurement is an OPERATOR (natural person). A company can have multiple operators.

3. Structure associated with the measurements and test carried out by the opeartor:

The measurements performed on the instrument will then be organised (before their execution) according to the following data structure:

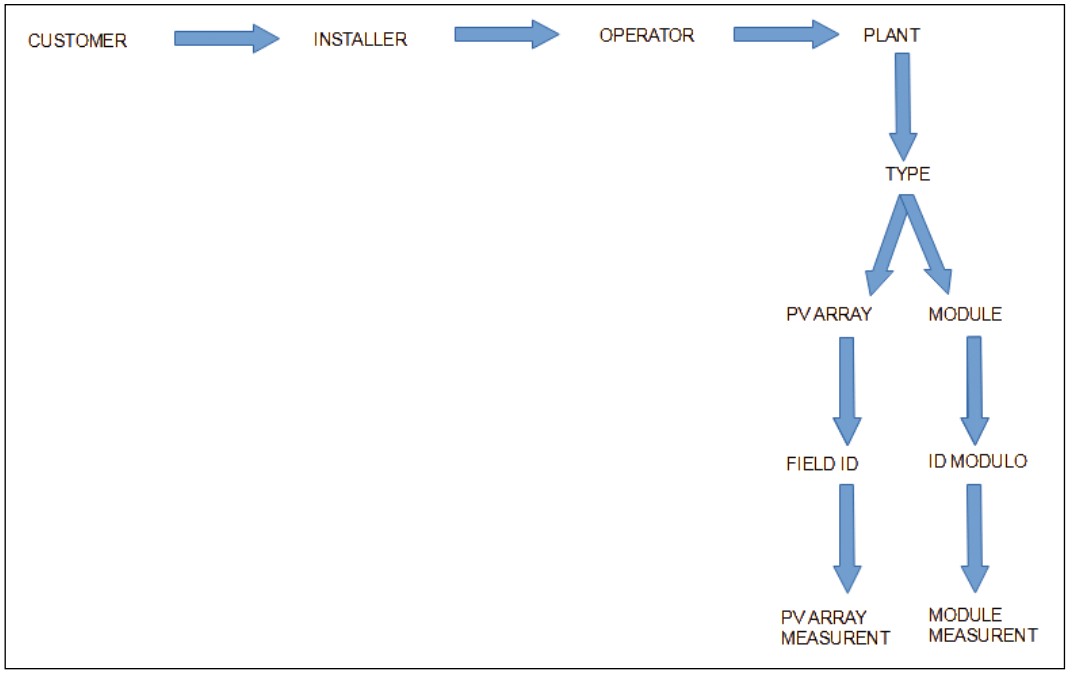


Figure 13-3 Screen Data structure MEASURE

14. MENUS

14.1 LANGUAGE SELECTION

The first step is to select the language in which the instrument menus and the reports, optionally issued after the measurements, will be translated. The selection of the language remains identical after the instrument is turned off, up to the next language selection
Menu selection is made using the **Language Selection** button.

Figure 14.1-1 Screen Language selection

14.2 SETTINGS

From the SETTINGS menu it is possible to consult and modify the basic settings of the FTV500 instrument:

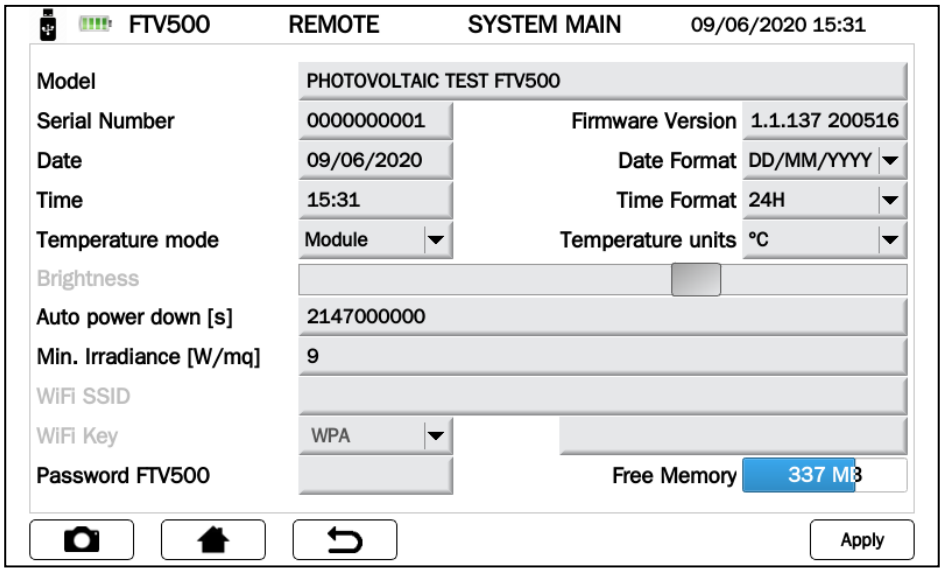


Figure -14.2.1 Screen Setting

- MODEL: identification of the PHOTOVOLTAIC TEST FTV500 instrument
- SERIAL NUMBER: serial number of the instrument
- FIRMWARE VERSION: FW version installed (for updating procedures see section USB MENU)
- DATE: indication of the current date that can be set by the user
- DATE FORMAT: allows to use the European date format (DD / MM / YYYY) or the Anglo-Saxon format (MM / DD / YYYY).
- TIME: indication of the current time that can be set by the user
- TIME FORMAT: allows to use the European format (now in 24H) or the Anglo-Saxon format (juxtaposition of the symbol AM to identify the Ante Meridiem hours, PM to identify the Post Meridiem hours).

- TEMPERATURE MODE: select Module, Ambient, Manual, Auto
  The temperature modes have the following definition:
  Module: measurement of the temperature of the photovoltaic module via the Pt100 probe of the remote unit.
  Ambient: measurement of the ambient temperature via the Pt100 ambient probe of the remote unit.
  Auto: automatic ECT (Equivalent Cell Temperature) temperature measurement performed as a function of the measured value of the open circuit voltage of the photovoltaic module (V_0) according to EN60904-5: 2011.
  Manual: manual entry (from the MEASURE menu) by the operator of the temperature value of the module to be used in the calculation formulas. This temperature value can be measured with another instrument (e.g. thermometer) and then entered it into the apprpriate field.
- TEMPERATURE UNITS: selection of temperature unity of measurement ° C or ° F
- BRIGHTNESS: allows you to set the brightness of the display (not active for the display with optical bonding technology)
- AUTO POWER DOWN is the time that can be set (in seconds) by the user for the instrument to wait, before it is automatically turned off if not in use.
  The process takes place with a special screen in which the user can block the shutdown and return to normal operation with the button **Cancel**. In case of further inactivity the timer is reset and will start to count again.
  The operator can turn off the instrument directly with the **OK** button.

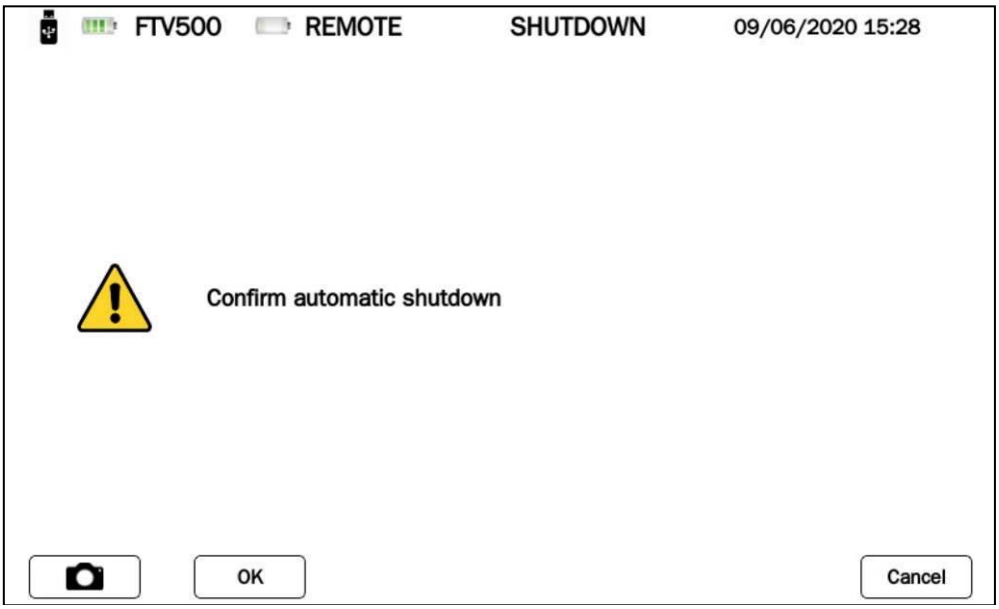


Figure -14.2.2 Auto power down

- MIN. IRRADIANCE [W/m2]: programming of the minimum irradiation threshold for starting the measurements
- WIFI SSID: Service Set IDentifier: alphanumeric key to identify WiFi network (used for service activities)
- WIFI Key: selection of access with password "WPA" or "none" (used for service activities)PASSWORD: security password for the protection of the Settings Menu
- FREE MEMORY: indication of the amount of free internal memory (expressed in MB)

14.3 CUSTOMERS AND PLANTS

The CUSTOMERS AND PLANT menu allows you to enter and store into the permanent memory of the instrument:
- the data and references of the CUSTOMERS who own the systems
- the data and references of the systems on which the measurements can be made
  Each PLANT can be associated with one and only one CUSTOMER. The association allows you to define the owner of the system

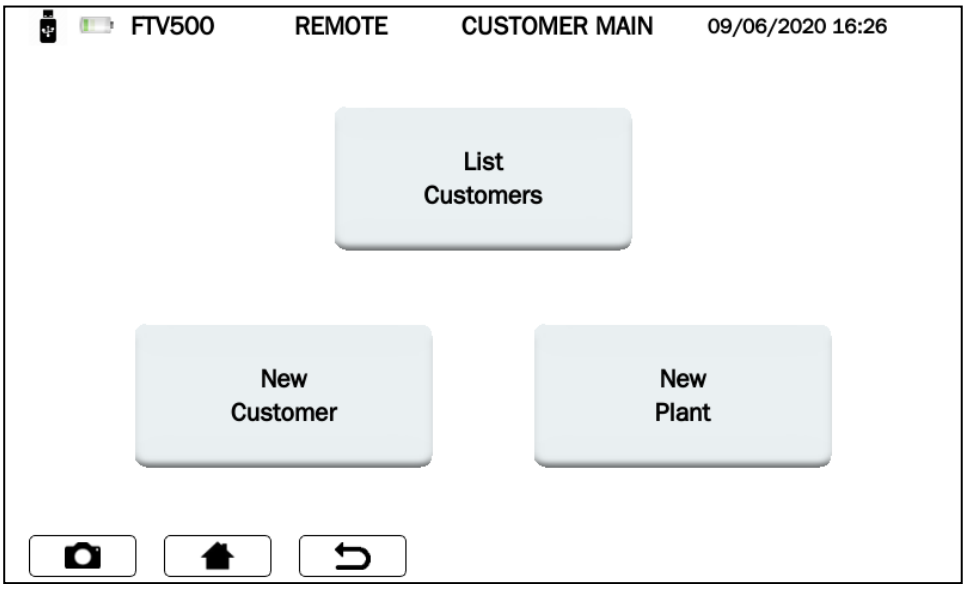


Figure 14.3-1 Customers and plant

14.3.1 NEW CUSTOMER

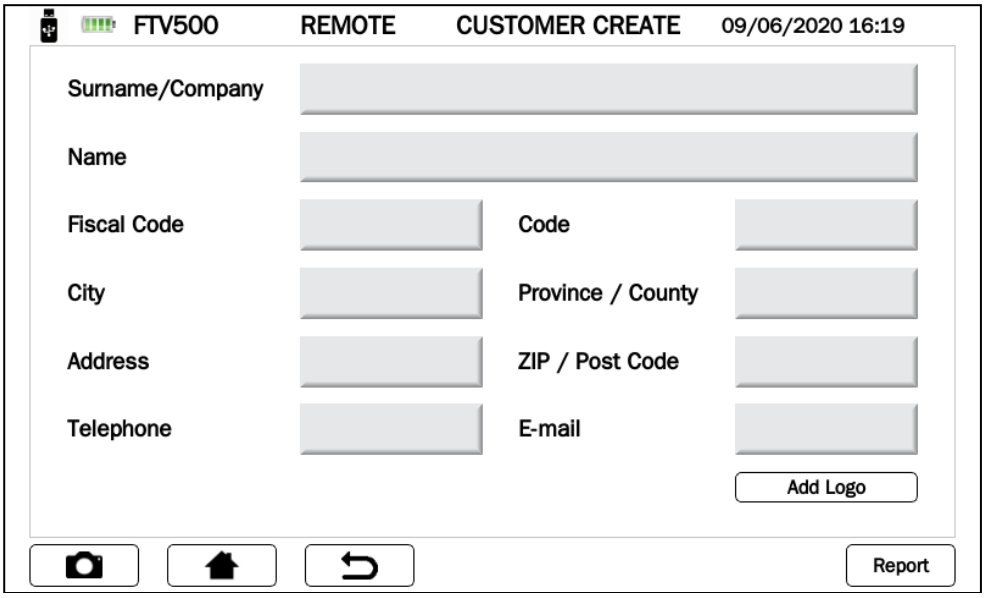


Figure 14.3.1-1 New customer

The entry of a new customer requires to type in the ìcontact data in the boxes that make up the entry form.

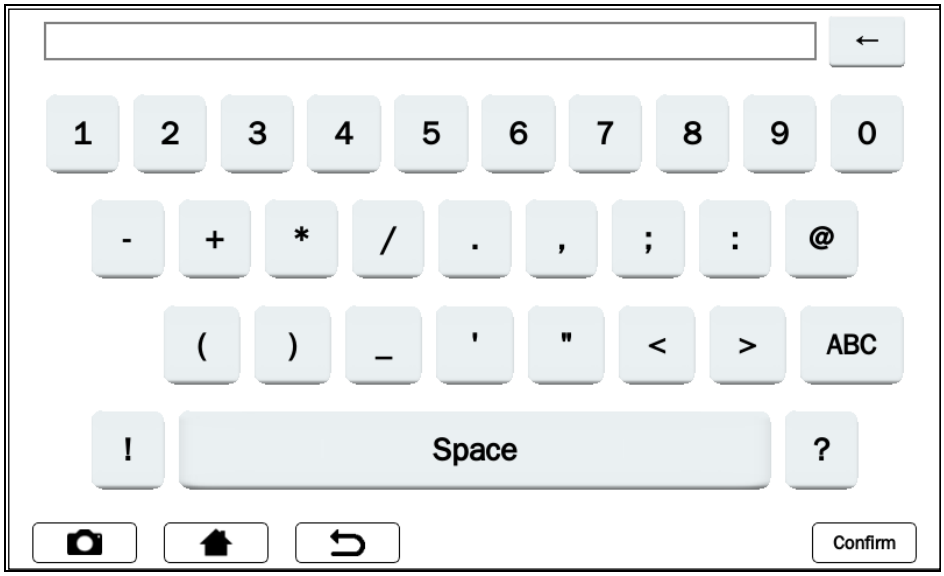


Figure 14.3.1-2 Keyboard

It is necessary to fill in all the fields; a message will indicate the failure to fill in one or more fields, if they have not been filled in earlier,after confirmation.
If your area does not provide this type of information, please insert a space or period in the dedicated field.
At the end of the procedure you will get the following screen:

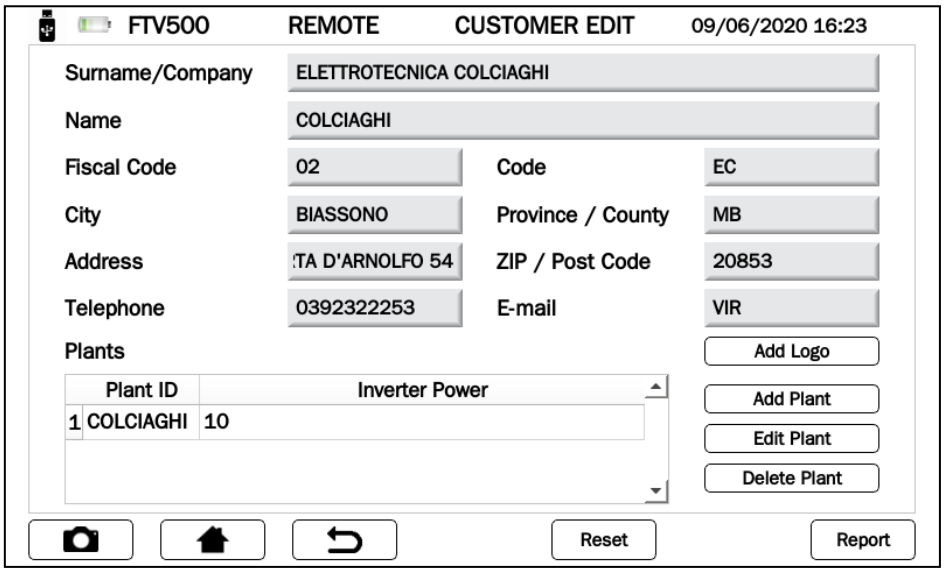


Figure 14.3.1-3 Modify customer

<u>Add logo (optional):</u>
By pressing the **Add Logo** button you can insert a customer logo.
After pressing this button you will receive a message on the menu window that identifies the name that must be assigned to the file containing the logo: the file name will be "logocXXX.png", where XXX is the content of the Code field.

Example in figures:

- Code field: 233
- The file to be saved on the USB-key must be “logoc233.png”

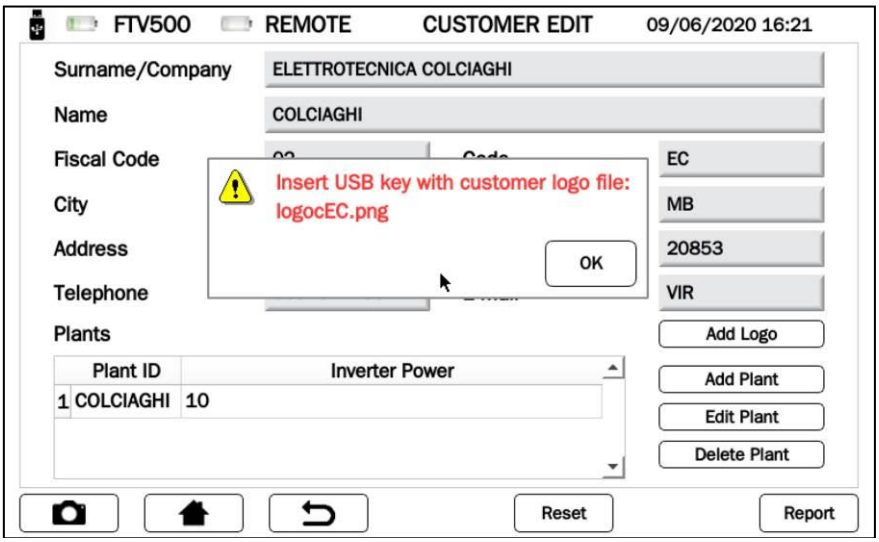


Figure 14.3.1-4 Customer Logo

This file must also be in png (Portable Network Graphics) format and must be placed onto a USB key that will be inserted and mounted on the instrument before carrying out the import (see USB chapter for more details).
Once the file is on the USB key with the correct name (previously provided by the system) press again **Add Logo** button to import the logo file and associate it wth the customer.

14.3.2 NEW PLANT

The second step necessary to carry out the measurements is the entry of a new plant. The system will allow, through the subdivision into modules and arrays, to create a subset with which it will be possible to associate measures. The plant is associated with one and only one customer.
A plant can be created in different modes in the CUSTOMERS AND PLANT menu.

1. **MODE - Immediate insertion after customer creation**
   Using key **Add Plant** button from the Screen in Figure 14.3.1-3 will allow you to open a data entry form for a new plant, which allows you to associate the inserted plant with the customer from which the entry is performed.
   The name of the customer will appear in the "Customer" field (the field cannot be changed)

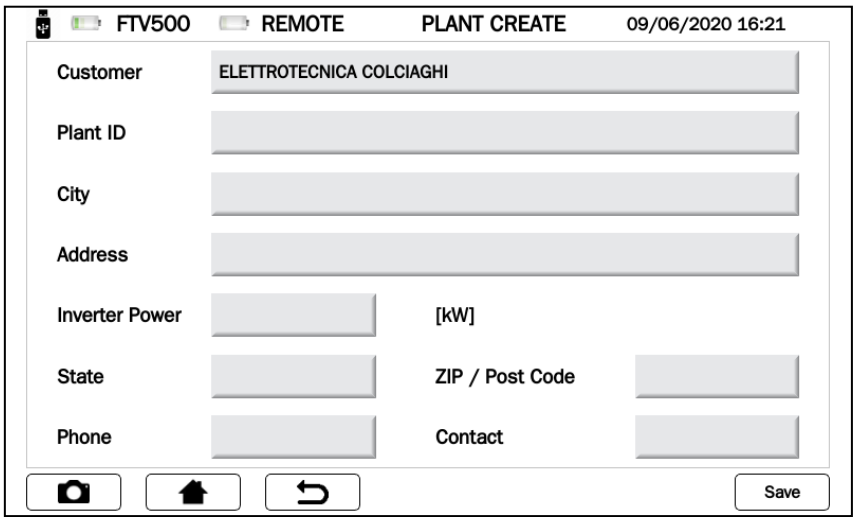


Figure 14.3.2-1 Screen New plant

Enter all the required data (ATTENTION: do not leave any field empty). At the end press the **Save** button to save the data. It is necessary to fill in all the fields a message, otherwisea message will indicate that they have not been filled in after confirmation.

This procedure can only be performed for the first system associated with the customer, as many systems can be associated with each customer, as many as the latter has. For subsequent systems, the two procedures listed below should alternatively be followed

2. **MODE - Entry from the CUSTOMERS AND PLANT menu**

It is possible to insert a new plant even after the customer has been saved and the related menu has been exited (Figure 4.3.1-3). Access the entry from the main screen of the CUSTOMERS AND PLANT function by pressing the **New Plant** button.

At this point, in order to insert a new system, it is first of all necessary to look for the customer to add the plant to. This is possible with the screen that will now open which allows you to enter any search parameter (surname, name, city, etc.), even partial:

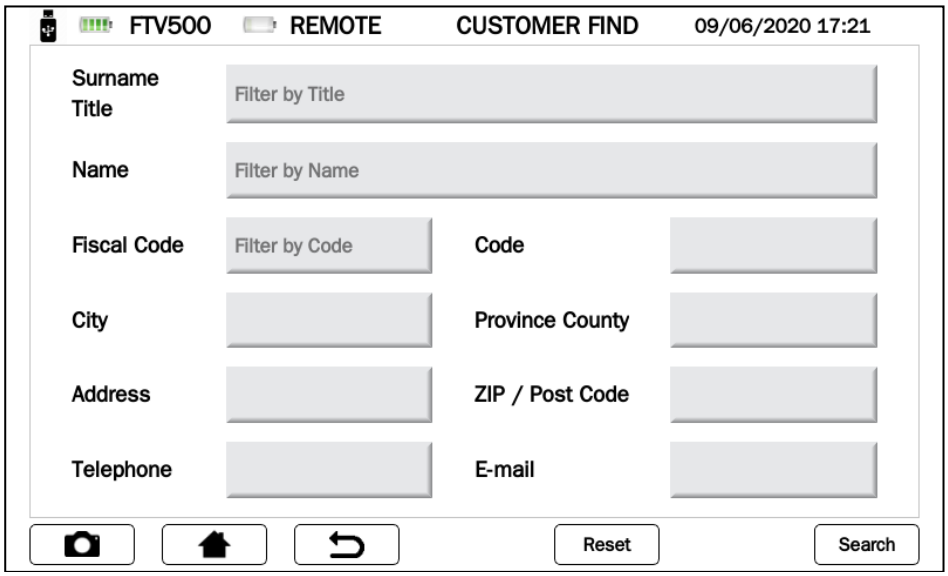


Figure 14.3.2-2 Screen Customer find

For example, entering only the letter "R" in the SURNAME field will allow you to search for all customers who have the initial letter R in their surname.

After insertion, you can press the **Search** button to go ahead with the search. This will generate a list of customers that matches the entered search criteria:

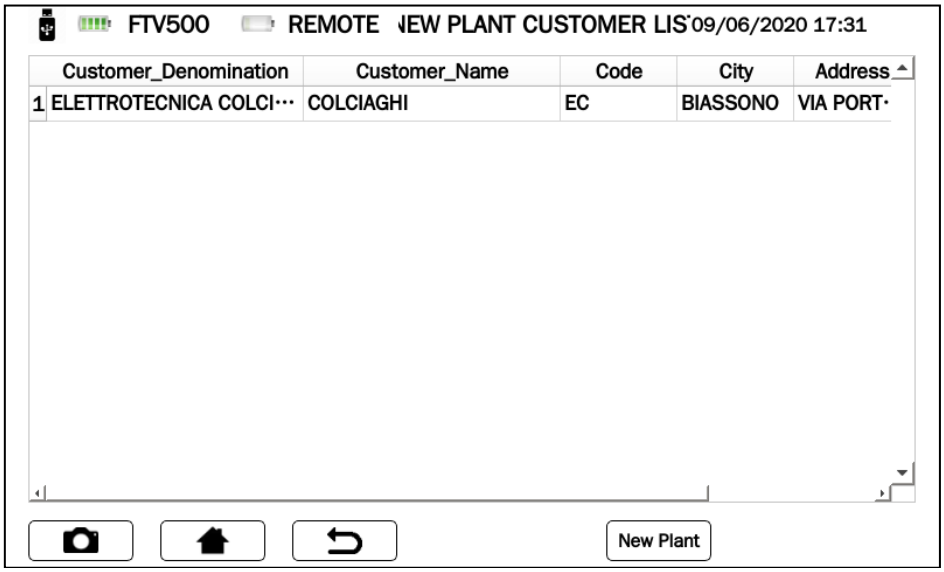


Figure 14.3.2-3 New plant customer

At this point select one customer and press the New Plant button, so the screen in Figure 14.3.2-1 will appear. From here on, follow the instructions listed in 1. MODE.

3. **MODE - Entry from the LIST OF CUSTOMERS AND PLANT screen**

From the main screen of the CUSTOMERS AND PLANT menu, press the **List Customers** button

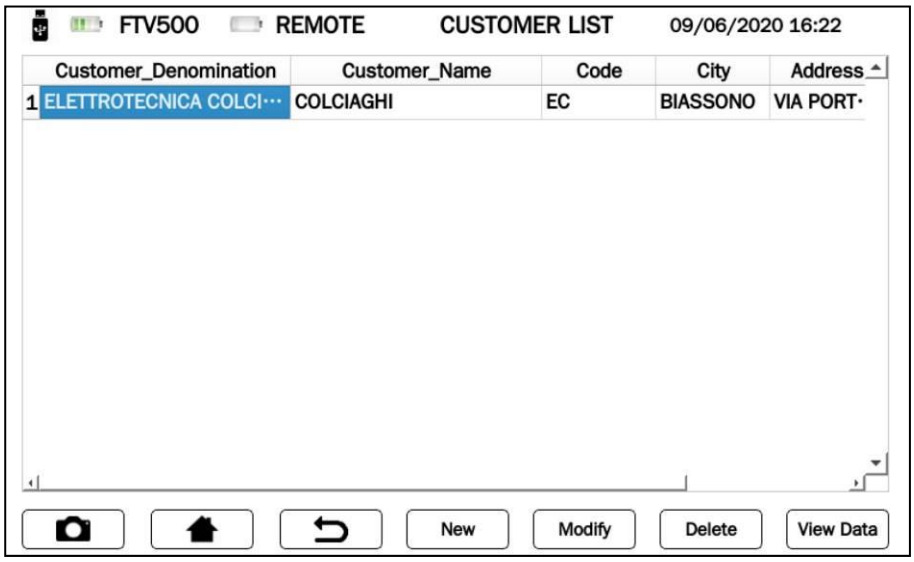


Figure 14.3.2-4 Screen Customer list

Pressing the **Modify** button on the screen of Figure 14.3.2-4, after selecting a customer, allows to select the customer and start again from the screen of Figure 14.3.2-1. Then follow the method described in 1.MODE to insert a new plant.

14.3.3 CUSTOMER AND PLANT LIST

The menu is accessible from the CUSTOMERS AND PLANT menu via the List customers button.
At this point, the screen that opens up allows to see the list of all customers entered:

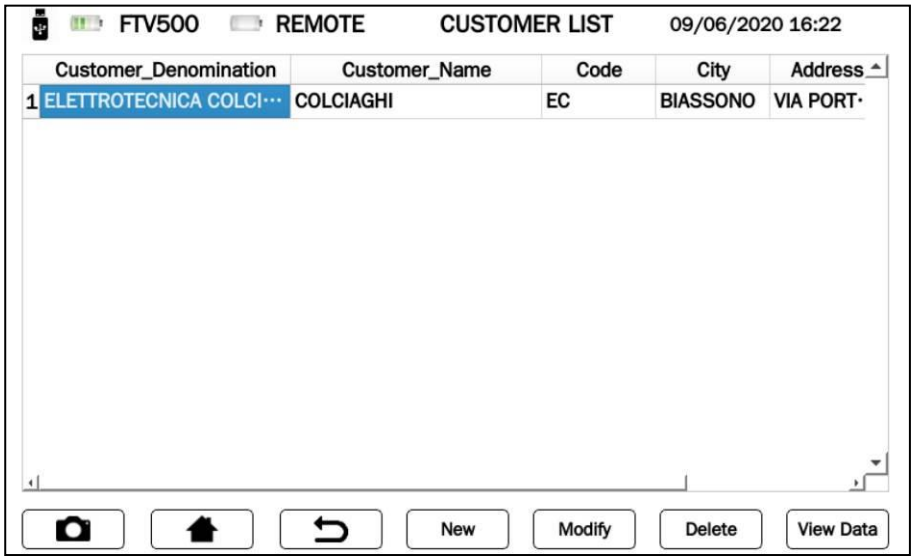


Figure 14.3.3-1 Screen Customers list

So it is possible to select the following operations:

14.3.3.1 NEW CUSTOMER

For more details on this operation, see paragraph 14.3.2.

14.3.3.2 MODIFY CUSTOMER

Pressing this button opens the **Customer edit** screen. It is necessary to first select the customer to be modified. From this screen on it is possible to create, modify, delete new plants or insert the customer's logo.

ATTENTION: It is possible to change the customer master data, but not the name / surname / company. If you need to do this, you need to delete the customer and recreate a new one. The elimination of the customer also permanently deletes the underlying plants.

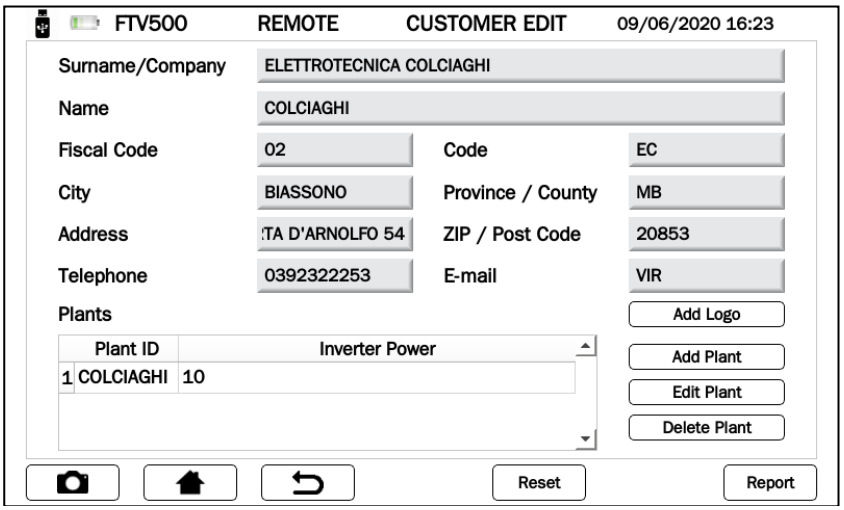


Figure 14.3.3.2-1 Customer edit

14.3.3.3 DELETE CUSTOMER

To delete a customer select the customer to be deleted and then press the DELETE button.
ATTENTION: Use this function carefully: afeter deleting the customer it is not allow to undo the operation. All plants belonging to the customer will also be eliminated.

14.3.3.4 VIEW CUSTOMER

Pressing this button displays the customer data and the underlying plants:

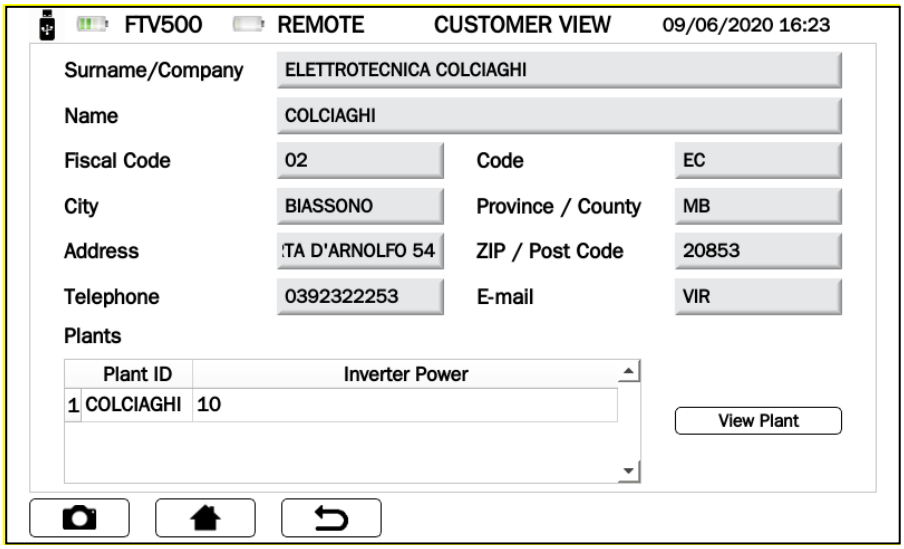


Figure 14.3.3.4-1 Customer view

From this screen it is possible to view the plants by selecting them and by pressing button **View Plant**:

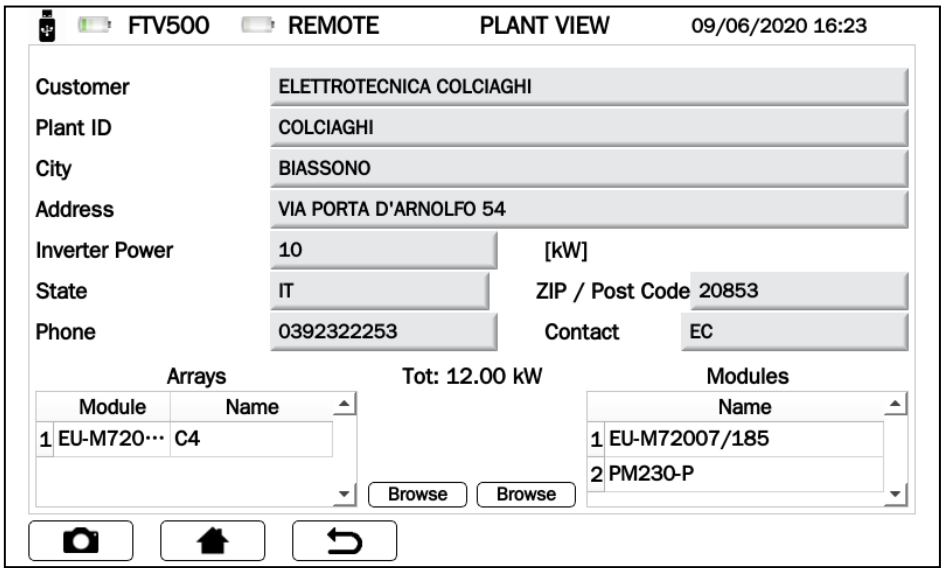


Figure 14.3.3.4-2 Screen View plant

From this screen it is therefore possible to consult the measures associated with the PV ARRAYS or the MODULES (see section 14.8).

14.4 INSTALLERS

As per the diagram in section 13, it is necessary to create an installer and the operators connected to it in order to associate an operator to the measurements.
The Installer menu is accessible from the Home menu with the **Installer** button and from here the list of installers is visible:

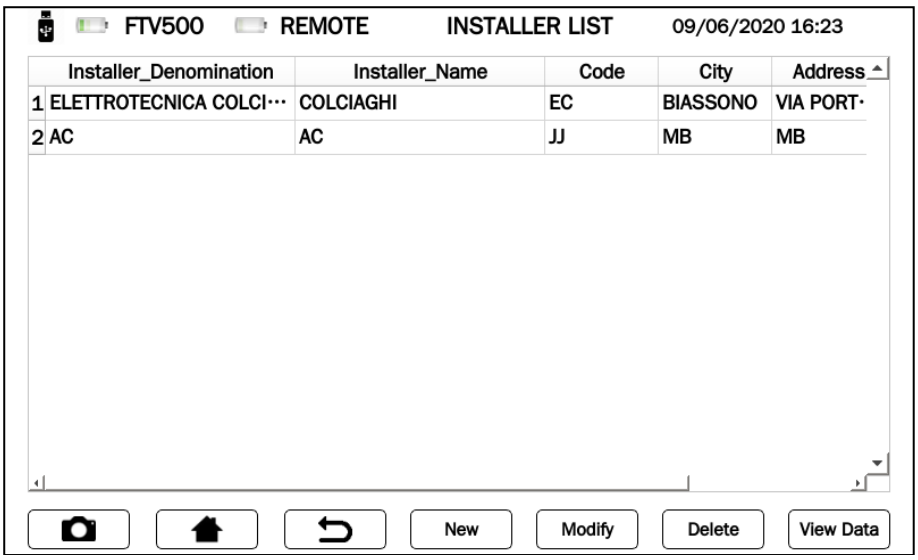


Figure 14.4-1 Installer list

With the **New** button you can create a new installer:

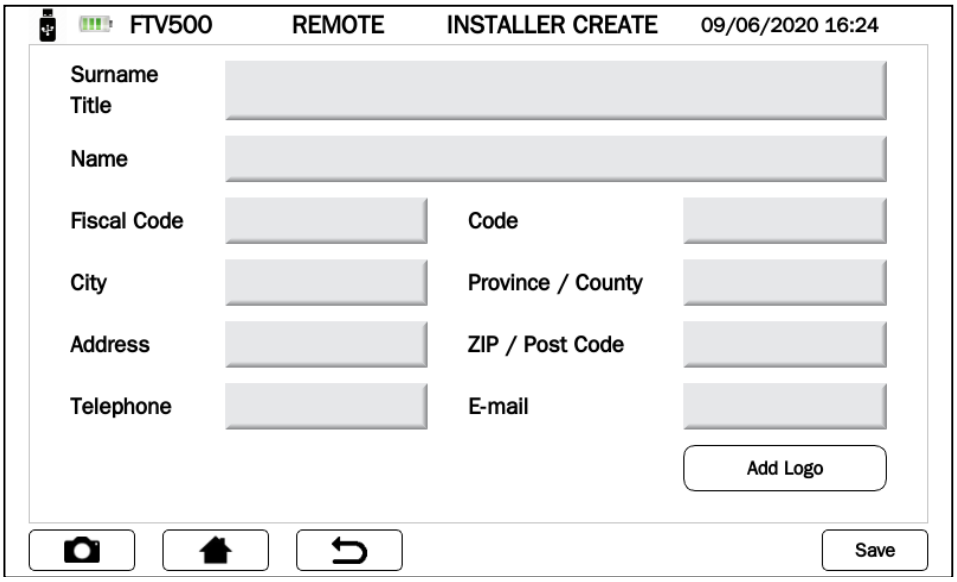


Figure 14.4-2 Installer creation

The enttry of a new installer requires the insertion of contact data in the boxes that make up the insertion form. All fields on the form require an entry. The **Save** button allows you to permanently save the installer.

Insert installer logo:
Similarly to what is possible for the Customer, it is also possible to link a logo to the installer, which will then be used in the report when it is saved (see section 14.9).

By pressing the button **Add Logo**, you can insert an installer logo.
After pressing this button you will receive a message on the menu window that identifies the name that must be assigned to the file containing the logo: the file name will be "logoiXX.png", where XX is the content of the Code field.

This file must also be in png (Portable Network Graphics) format and must be placed on a USB key that will be inserted and mounted on the instrument before performing the import (see section 14.6 for more details).
Once the file is on the USB key with the correct name, further pressing the Add Logo button will allow the import of the logo file and the association with the selected customer.
With the **Modify** button you can edit an installer. For this purpose, click any field of the installer to be modified:

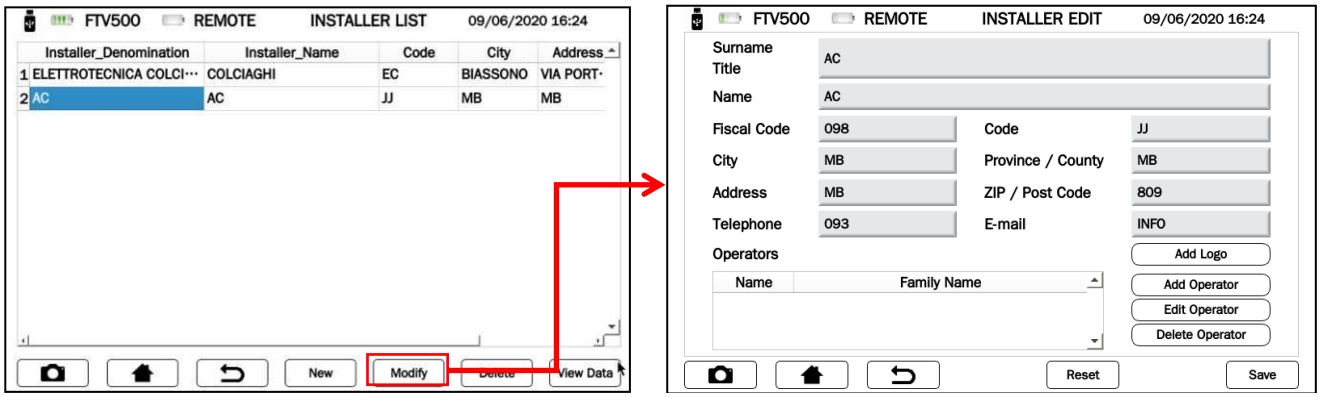


Figure 14.4-3 Screen Installer modify

-

Touching the fields to be modified will open the text entry window, proposing the text that was already entered before; from here on it is possible to change the text and press the key **Save** to confirm the change.
Also from here it will be possible to modify or insert the logo with the Add Logo button

With the **Delete** key of Figure 14.4-3 it is possible to delete an installer. To do this, go to any field of the installaer to be deleted and press the button.

With the **View Data** button of Figure 14.4-3 it is possible to view the complete data of an installer. To do this, go to any field of the installer to be displayed and press the button.

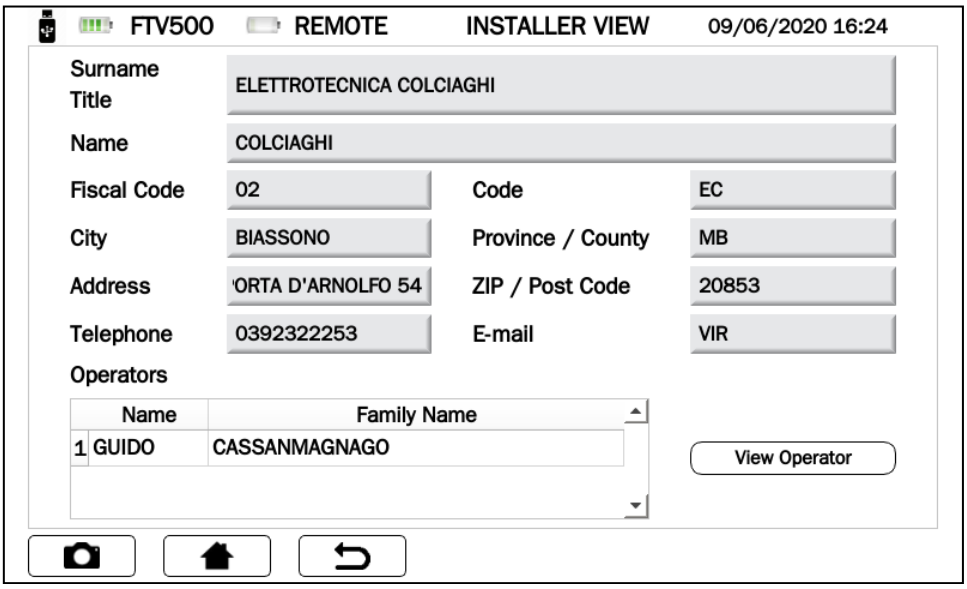
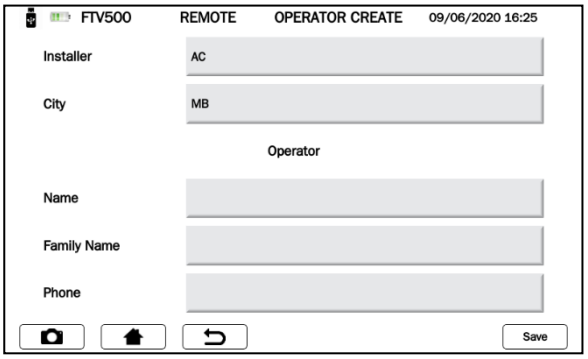


Figure 14.4-4 Installer View

The data cannot be changed.
From here it is possible to view the operator (see below), selecting it in the same way.

Operator management

The operator is the person linked to one and only one installer, who physically carries out the tests.
With the following keys it is possible to perform the operations on the operators belonging to the selected installer in Figure 14.4-3:

Add Operator	Inserts a new operator by linking it with to the selected installer 
Save	allows you to permanently save the operator.
Edit Operator	allows you to modify a selected operator
Delete Operator	allows you to delete a selected operator

14.5 PV MODULES

With this menu you can manage the database containing the photovoltaic modules. New PV modules can be inserted, existing ones deleted or modified.

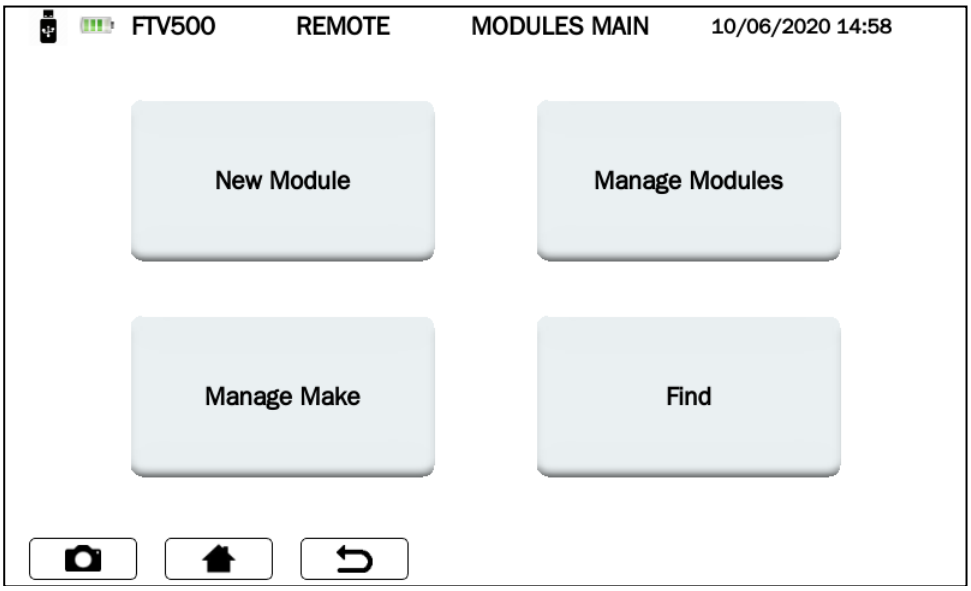


Figure 14.5-1 Modules main

14.5.1 MANAGE MAKE

The new manufacturer entry screen allows you to write the name of a new manufacturer, to be added to the database, on the instrument by pressing the **Manage Make** button (using the keyboard and pressing the **Confirm** button):

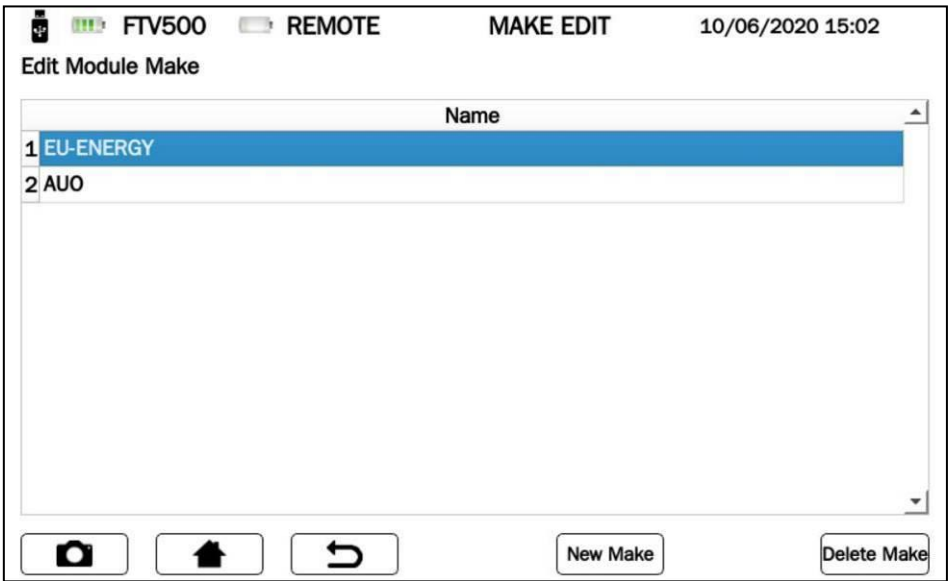


Figure 14.5.1-1 New PV module manufacturer

Pressing the **Delete Make** button, after selecting a Manufacturer in the list, will permanently delete the manufacturer.

14.5.2 NEW MODULE

In the internal database of the instrument it is possible to create new modules by inserting all the characteristics declared by the manufacturer. The memory capacity of the instrument allows the management of a large number of modules, which can then be used as a reference for the STC (STandard Condition) comparison checks

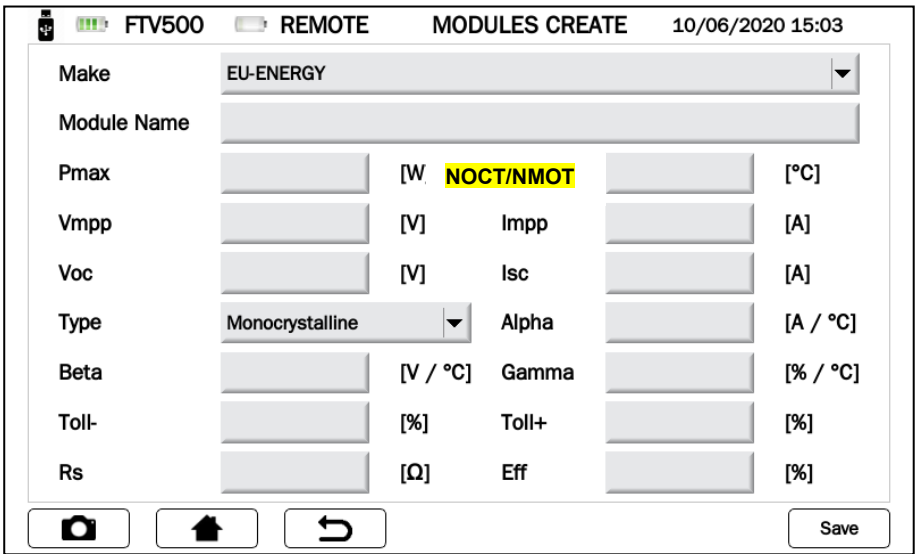


Figure 14.5.2-1 Create New module

The parameters that can be entered are shown in the following table:

Symbol	Description	Unit of measure
	Manufacturer (choose from the list, see chapter 14.5.1, how to create a new manufacturer)	
	Model template	
P_{max}	Maximum module power	(W)
V_{mpp}	Module voltage at maximum power point	(V)
V_{oc}	Open circuit voltage of the module	(V)
Tipo	Type of module technology (Monocrystalline, Polycrystalline, Amorphous, Thin film, Micromorph, Other)	
Beta	Temperature coefficient Voc	(%/°C)
Toll –	Negative tolerance on the maximum power Pmax provided by the module manufacturer	(%)
Rs	Resistance Internal module series	(Ω)
NOCT/NMOT	Normal Operating Cell Temperature/ Nominal Module Operating Temperature	(°C)
I_{mpp}	Current at the module maximum power point	(A)
I_{sc}	Short-circuit current of the module	(A)
Alpha	Temperature coefficient Isc	(%/°C)
Gamma	Temperature coefficient Pmax	(%°C)
Toll +	Positive tolerance on the maximum power Pmax provided by the module manufacturer	(%)
Eff	Module conversion efficiency	%

Note that the temperature coefficients Isc (Alpha), Voc (Beta) and Pmax (Gamma) are to be entered with the correct sign: in fact, the Alpha coefficient is usually positive (+), just as the Beta and Gamma coefficients are negative (-): the FTV500 instrument does not automatically affix the + or - signs.

Often the Alpha and Beta coefficients are not expressed as a percentage (insertion required by the instrument) but in mA / ° C or V / ° C. See below the formulas to be used to proceed with the conversion:

$$Alpha\ \left[\frac{\%}{°C}\right] = \frac{Alpha\left[\frac{mA}{°C}\right]}{10 \times I_{sc}}$$

$$Beta\ \left[\frac{\%}{°C}\right] = \frac{Beta\left[\frac{V}{°C}\right]}{V_{oc}} \times 100$$

NOTE: the unit of measurement is often expressed as Kelvin degrees (K) instead of centigrade degrees (° C): The two notations must be considered identical because they do not change the size of the coefficients.

All fields required in the entry form must be completed.

Saving data is done with the **Save** button

Upon saving, a check is performed to ensure that the form of the entered data is complete. In case of incompleteness, the instrument signals it with an information window that prevents saving. It is therefore mandatory to enter the missing data in order to proceed.

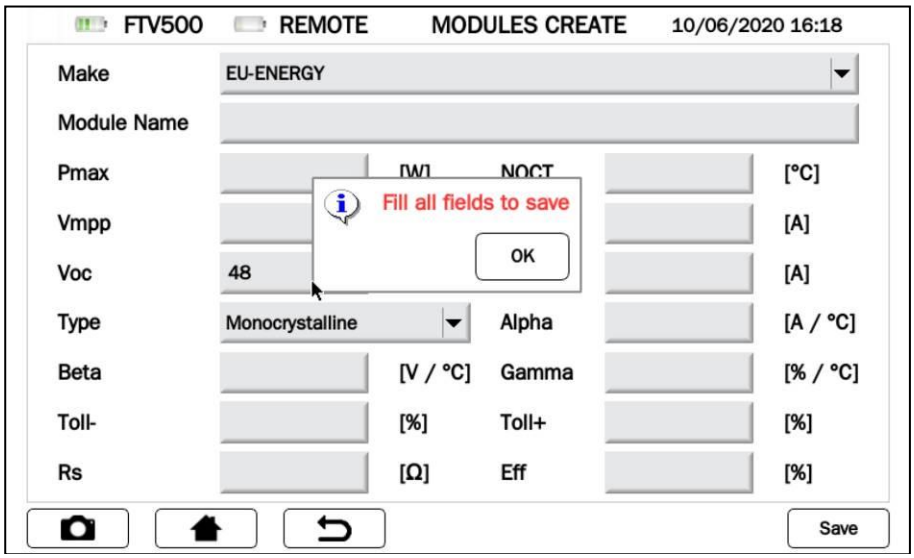


Figure 14.5.2-2 Module Information window

14.5.3 MODULE LIST

By selecting **Module List** it is possible to view all the modules previously inserted.
The purpose is to view the data of an existing module and, if necessary, modify or delete it.

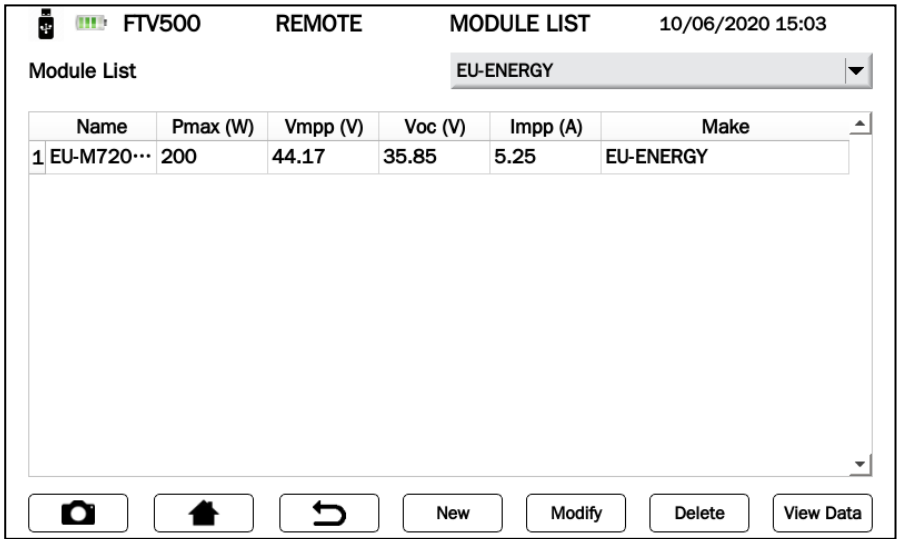


Figure 14.5.3-1 Modules list

New	Pressing the key takes the operator back to the screen of Figure 14.5.2-1.
Modify	By selecting a module in the list and pressing the key Modify, the operator is returned to the screen, where the data of the module are visible and there is the possibility of modifying them by selecting one at a time. Saving them with **Save** allows to definitively apply the changes.
Delete	The button permanently deletes the selected module ATTENTION: All the elements dependent on the deleted module will in turn be updated with the deletion, consequently the measurements relatied to that module will be deleted.
View Data	The key allows the display of screen 14.5.2-1 with the possibility to view the data, without the possibility of modifying them.

14.5.3.1 MODULE SEARCH

The **Find** function is very useful when the modules archive contains many models.

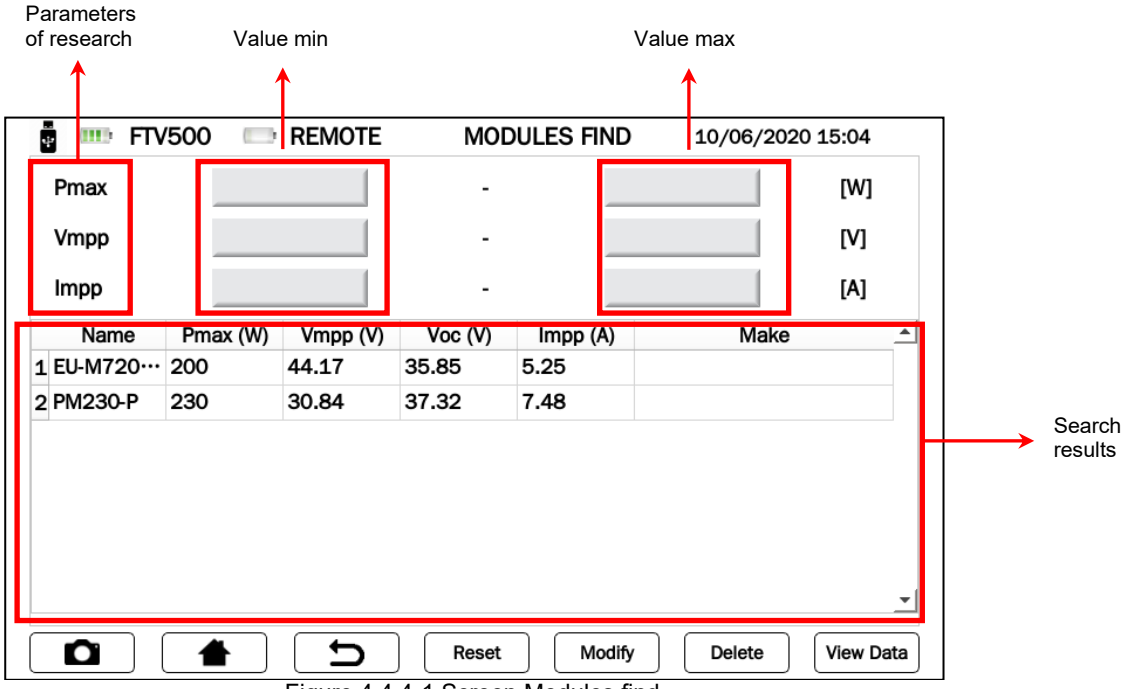


Figure 4.4.4-1 Screen Modules find

It is possible to enter one or more of the required parameters:

- Pmax
- Vmpp
- Impp

There are two parameters to be entered:

- The minimum value
- The maximum value

ATTENTION: Both values must be entered. The only minimum value or the maximum value alone are not sufficient to perform the search.

The selected search criteria will be used to filter the modules in the list

14.6 USB

The USB menu allows you to manage the interfacing with a USB key located on the front of the instrument

The instrument can read and write from any key with FAT32 or NTFS file system.
Once the key is inserted in the appropriate slot, this must be first recognized, a process that takes a few seconds and which is confirmed by the appearance of the appropriate symbol on the top left of the screen.
If the symbol is RED it means that the inserted USB key is not compatible or is damaged (please replace it).

It is recommended not to keep the USB key inserted in the instrument connector during Isolation, Continuity and I-V Curve measurements as it could compromise the safety during the use of the instrument.

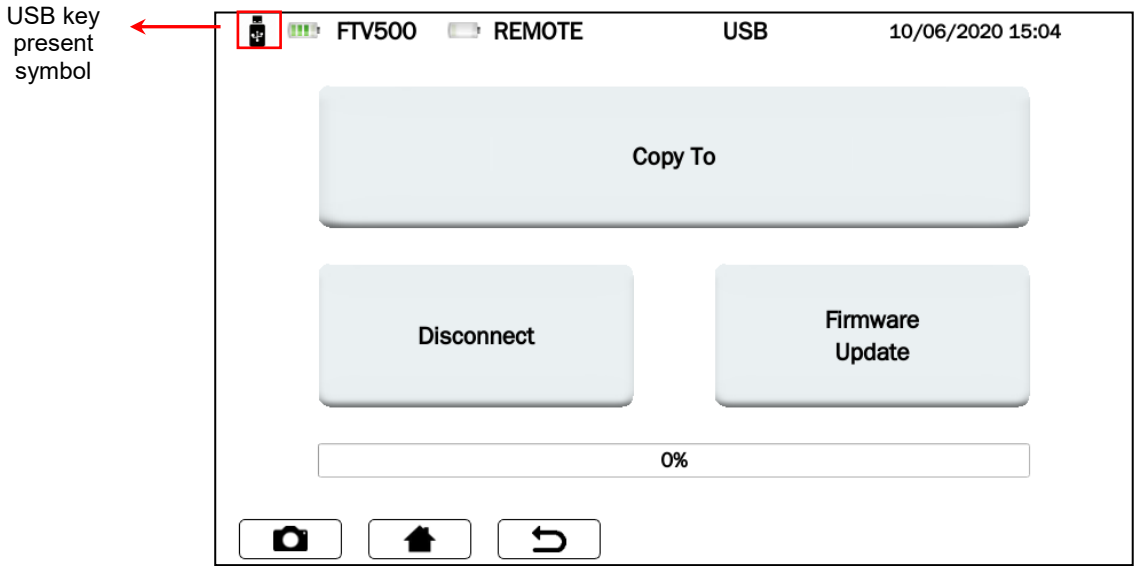


Figure 14.6.1 Screen USB

COPY TO USB KEY

This function copies all the reports on the instrument to the newly inserted key. While copying the files, a bar will appear showing the degree of completion. When completed, the message "Copy to USB completed" will be displayed.

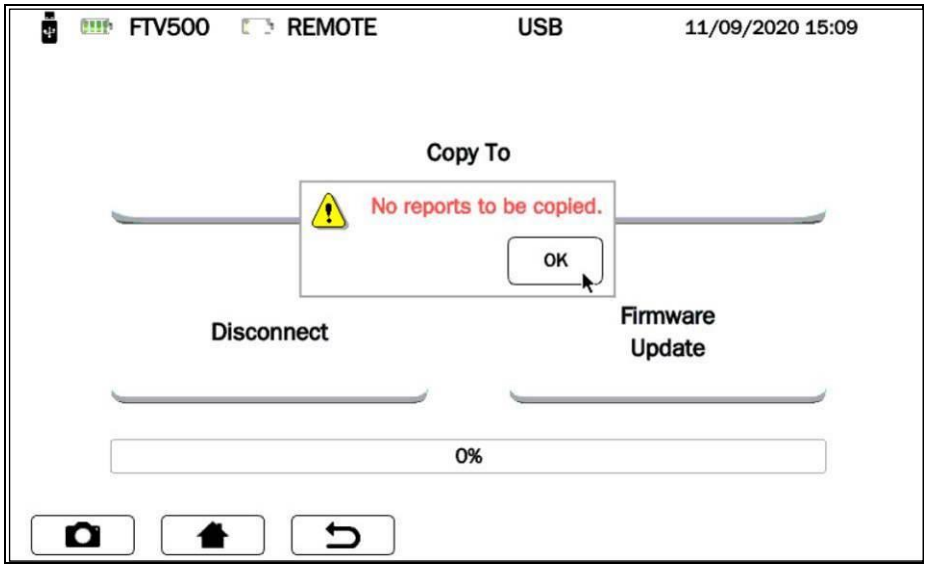


Figure 14.6.2 Screen USB – Copy completed

DISCONNECT
With this button the USB key will be disconnected from the instrument, an event confirmed by the symbol
At this point it is possible to physically extract the USB key from the instrument.

FIRMWARE UPDATE
The update requires the presence of an inserted and mounted USB key (symbol present).
To proceed with the update, an "upgrade.bin" file corresponding to the updated version of the Firmware must be present on the key (contact us for more information).

14.7 MEASUREMENTS

From the Main Menu select **Measure**.

ATTENTION: In order to guarantee maximum operator safety, as required by international safety regulations, some measurements cannot be performed with an instrument powered by the electrical network (Insulation, Continuity, I-V Curve).

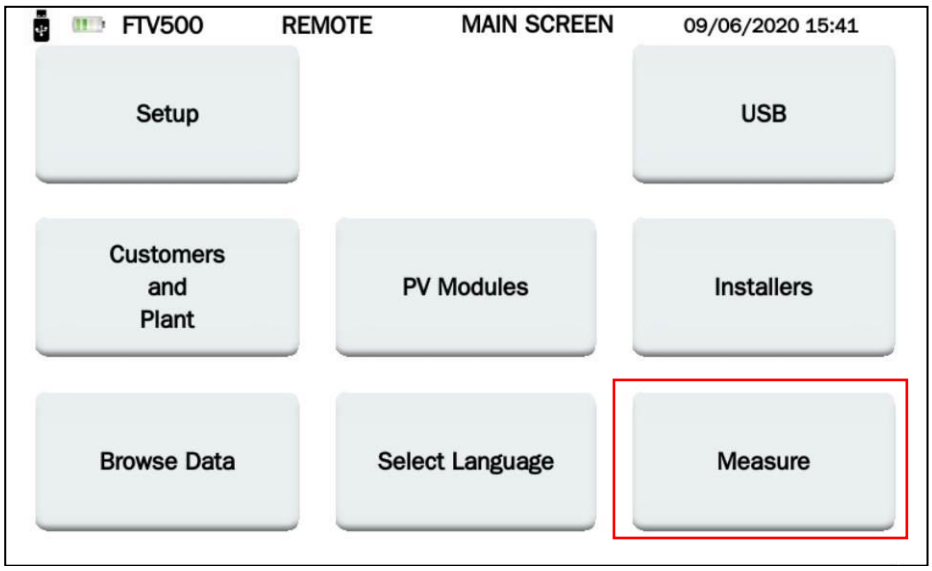


Figure 14.7-1 Measure Menu- Main screen

By pressing the **Measure** key the following screen is displayed:

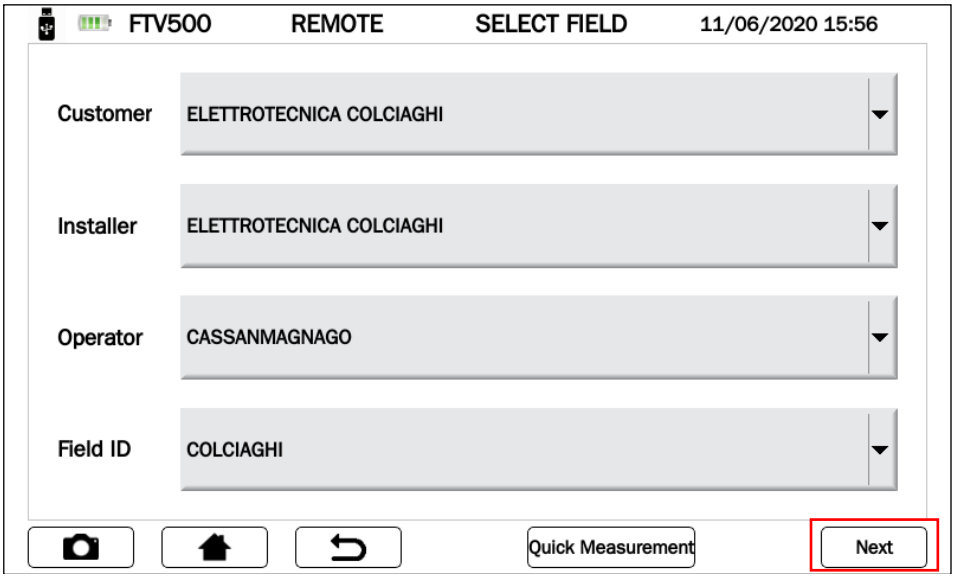


Figure 14.7-2 Screen Select field

At this point you can proceed in two ways:

MODE 1 – Press key NEXT

The corresponding master data must be associated with each measurement (previously entered, see sections 14.3, 14.4, 14.5).

Select the reference master data of the measurement itself as shown in screen 14.7-2:
- Customer - Installer - Operator – ID Plant

Then press the **Next** button to continue

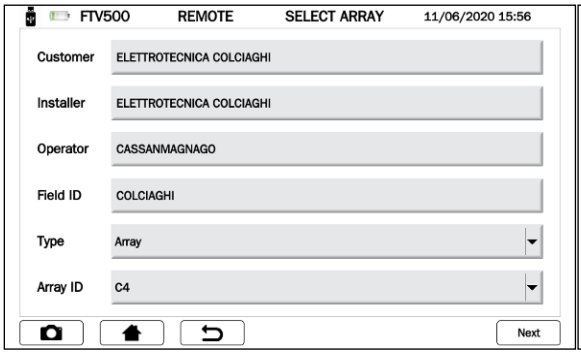


Figure 14.7-3 Select Array

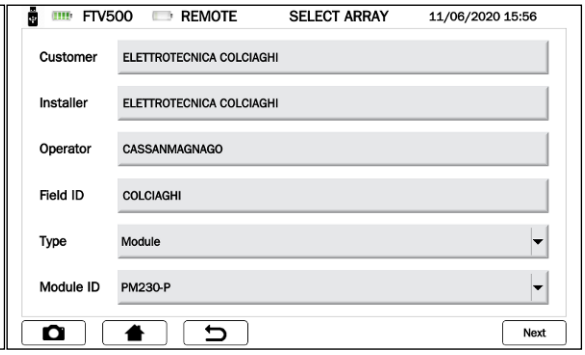


Figure 14.7-4 Select module

The two screens 14.7-3 and 14.7-4 are presented alternatively in accordance with what has been selected in the **Type** field

Array ID	If the Type selected is **Array**, clicking on the field gives access to the names of the Strings associated with the previously selected system (Field ID).
Module ID	If the Type selected is **Module**, clicking on the field gives access to the names of the Modules associated with the previously selected system (Module ID).

Once the data entered with the **Next** key have been confirmed, the instrument displays the screen of the measurements to be made:

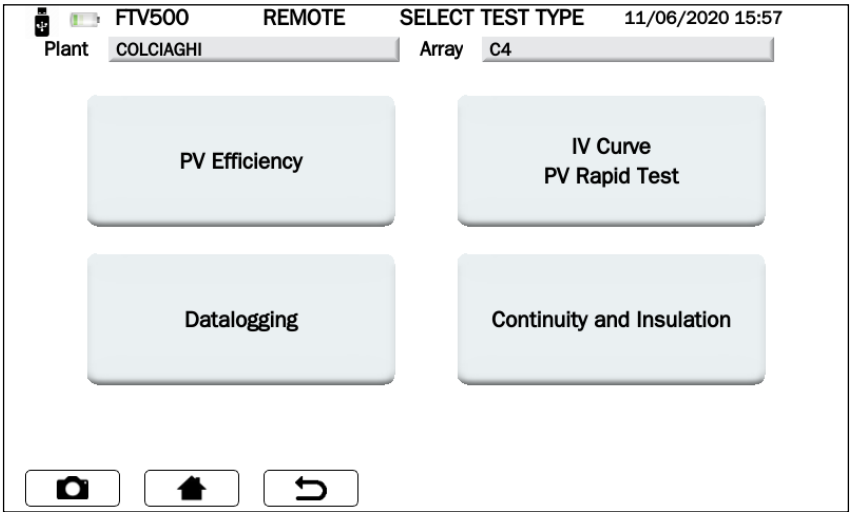


Figure 14.7-5 Select test type

In the upper part of Screen 14.7-5: you can read the references of the system and the selected module.

MODE 2 Press Quick Measurement)

By selecting this mode, you proceed directly to the measurement screen (14.7-6) without assigning a master data to the measurement (the measurement will be anonymous, and possibly saved in the database only with the date of realization)

This method is the fastest because it does not require the prior insertion of all personal data.

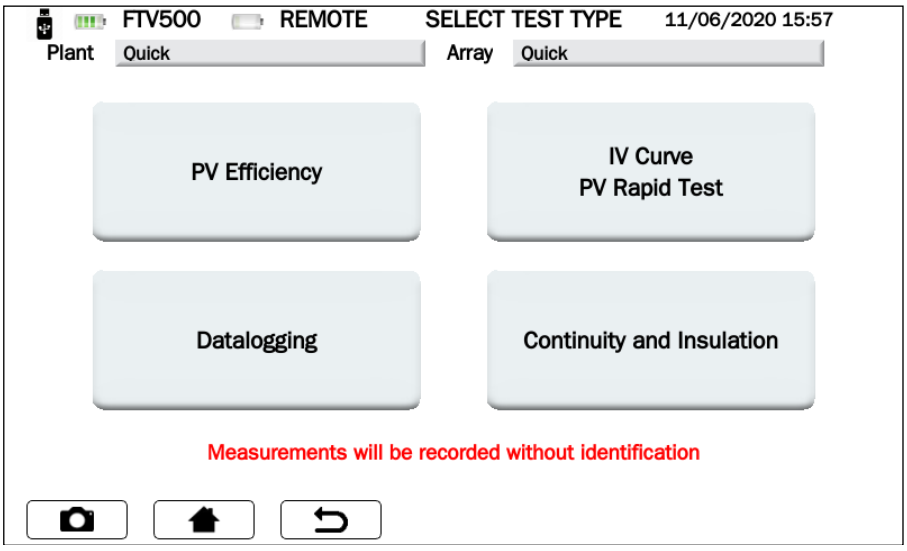


Figure 14.7-6 Select test type (in Quick Measurement)

WARNING! Carrying out the measurements of System Efficiency Tests and I-V Curve, these will not have the result of the test, as the comparison with the curve and the STC data cannot be performed.
Only the measurement data will be available in both cases

14.7.1 EFFICIENCY TEST

The test verifies the system efficiency, the correct operation and DC / AC efficiency on three-phase photovoltaic installations, measures the Prp performance ratio, according to IEC / EN 62446.
For all the details relating to the test, see Annex A (theoretical references).

⚠ WARNING DURING USE ⚠

- A dangerous potential is always present in the photovoltaic system.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the string under test

IMPORTANT: Performing this test in Quick mode (see paragraph 14.7 figures 14.7-6) where the master data is missing, as well as any reference to a plant or a photovoltaic module) does not allow to calculate PRp, AC DC yields. The only visible data will be those relating to the measurements made.

Starting out from Figure 14.7.6 and pressing the **PV Efficiency** button, a screen that allows to synchronize the instrument with the remote unit is shown:

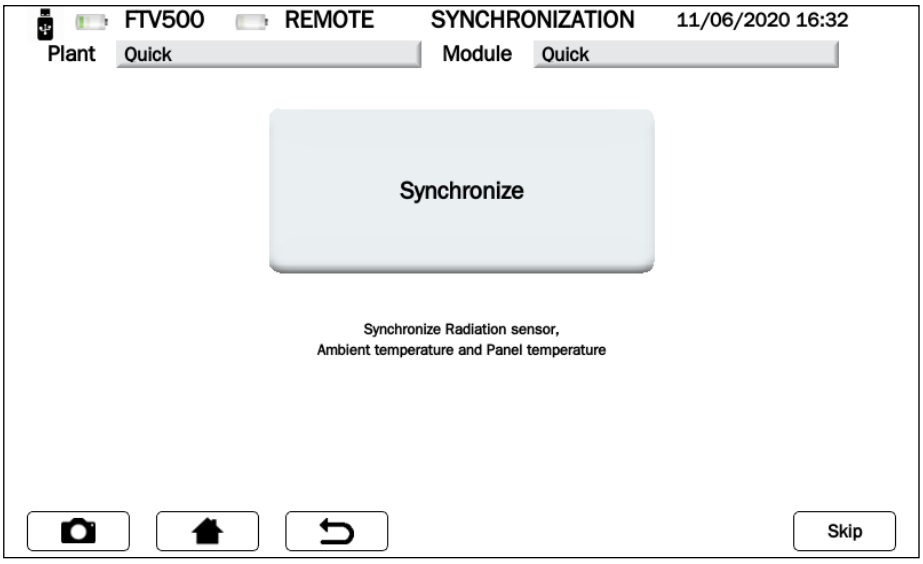


Figure 14.7.1-1 Remote unit synchronization

Then press the **Synchronize** button.

WARNING ! The remote unit must be turned on and placed on one of the modules in the PV field (see chapter Chapter 6 REMOTE UNIT).

The successful synchronization displays the temperature and irradiation measured by the remote unit in correspondence with the module on which it was installed, which will be the representative data of the whole system (used for calculations).
After a few seconds the remote unit sends its data to the instrument: this is confirmed by the following screen:

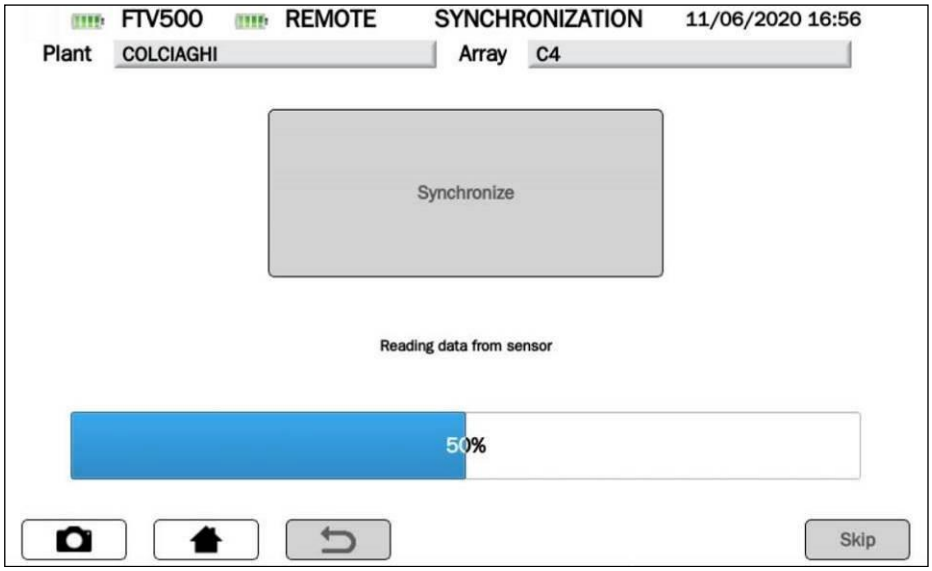


Figure 14.7.1-2 Remote unit synchronization

The screen displays the data measured during the query of the remote unit. If, on the other hand, it has not been possible to synchronize with the remote unit, the instrument reports "Communication error":

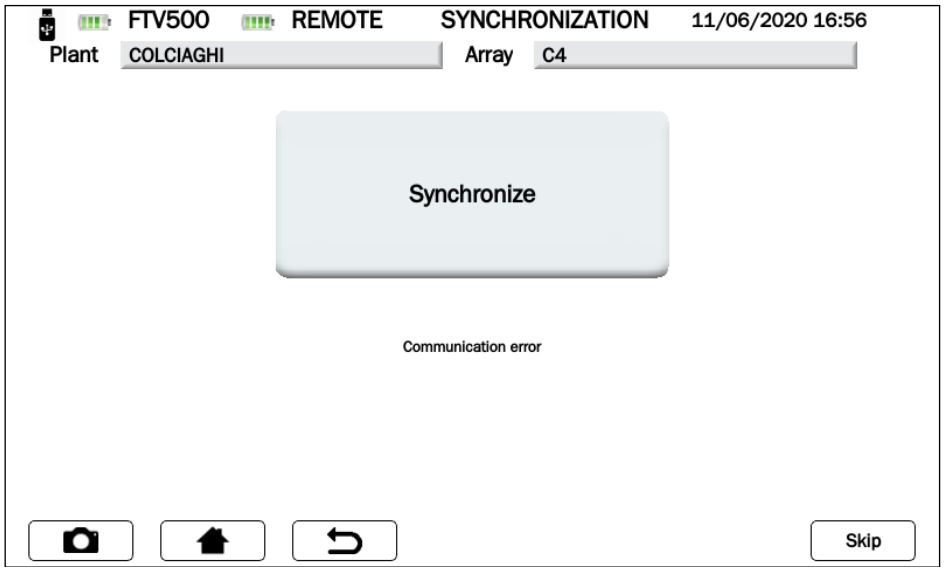


Figure 14.7.1-3 Remote unit synchronization error

In this case, it is necessary to repeat the operation by pressing the **Synchronize** button after checking that the remote unit has not any problem that may have caused the synchronization to fail.

IMPORTANT: if the **Skip** button is pressed the Synchronization is by-passed, enabling to switch to the following menu, represented in Figure 14.7.1-4. In this case, the environmental measures, and all the calculations associated with them, will not be displayed.

In the case of successful synchronization, you can press the button **View Real Time Measurements** and move on to the following screen:

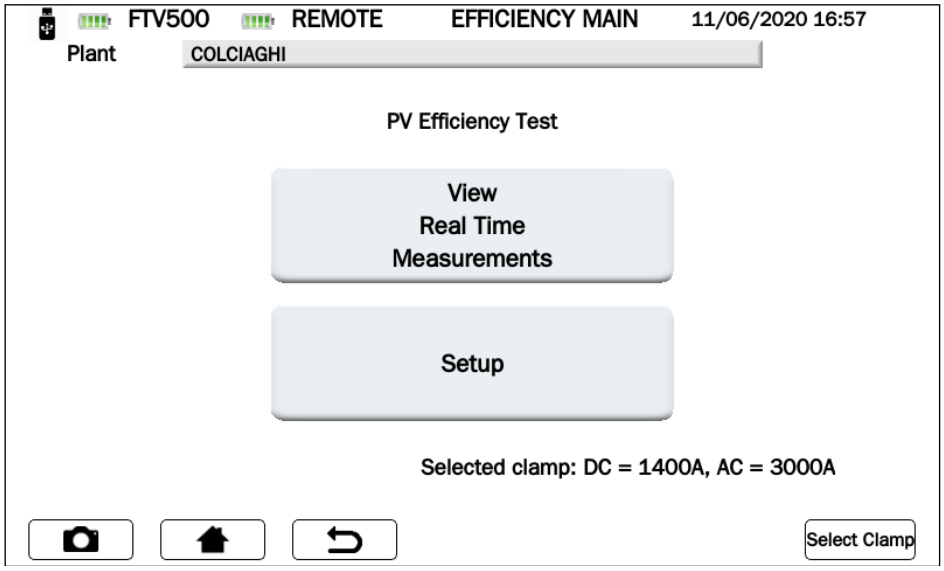


Figure 14.7.1-4 Efficiency main

IMPORTANT: To activate the **View Real Time Measurements** button, to program in advance the **Setup** and the **Select Clamp**, follow the instructions below:

- Click on the **Setup** button (Screen Efficiency main) to choose:
  - The inputs that will be active and visible on the display during the measurement (Vdc, Idc, Uac and Iac), if not selected in the **Setup efficiency** screen, "n.c." will be displayed.
  - **Temperature correction type** (for more details see chap. Temperature correction):
    - **Module**: module temperature direct measurement, with the remote unit sensor connected on the back of the module (see Remote Unit chapter)
    - **Ambient**: module temperature calculation via measurement of the ambient temperature
      For more information on the module temperature calculation, see Chapter 14.2 Settings)

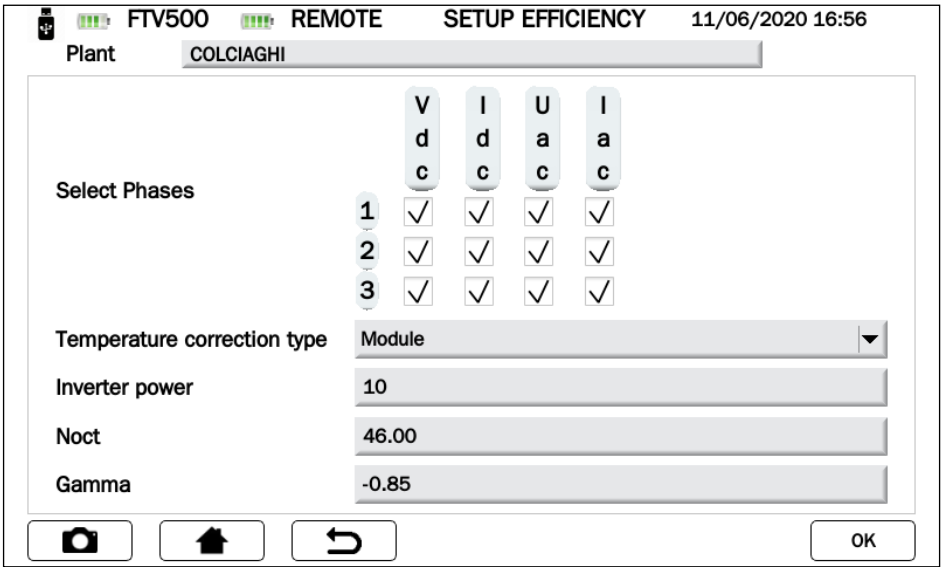


Figure 14.7.1-5 Setup Efficiency

The other parameters on the **Inverter Power**, **NOCT** or **NMOT** and **Range** screen cannot be changed and are entered in the plant and module master data (see Chapter 14.3.2 for the plant 14.3.2 and Chapters 14.5 for the module).
Press the **OK** button to confirm the choice (the parameters will remain selected even when exiting the menus, and until the instrument is turned off)

- Click on the **Select clamp** button. With this menu, you can choose the model of the clamp meter for measuring AC / DC currents and select the suitable current range for the plant.

  The instrument is provided with two models of current clamps:
  - AC current measurement (MA500)
  - DC current measurement (PAC500)

Each model has two measuring ranges, which the operator must select according to the currents present in the area of the photovoltaic plant to be tested, see figures 14.7.1-6 and 7.

ATTENTION: The wrong selection of the measuring range can cause incorrect measurement readings.

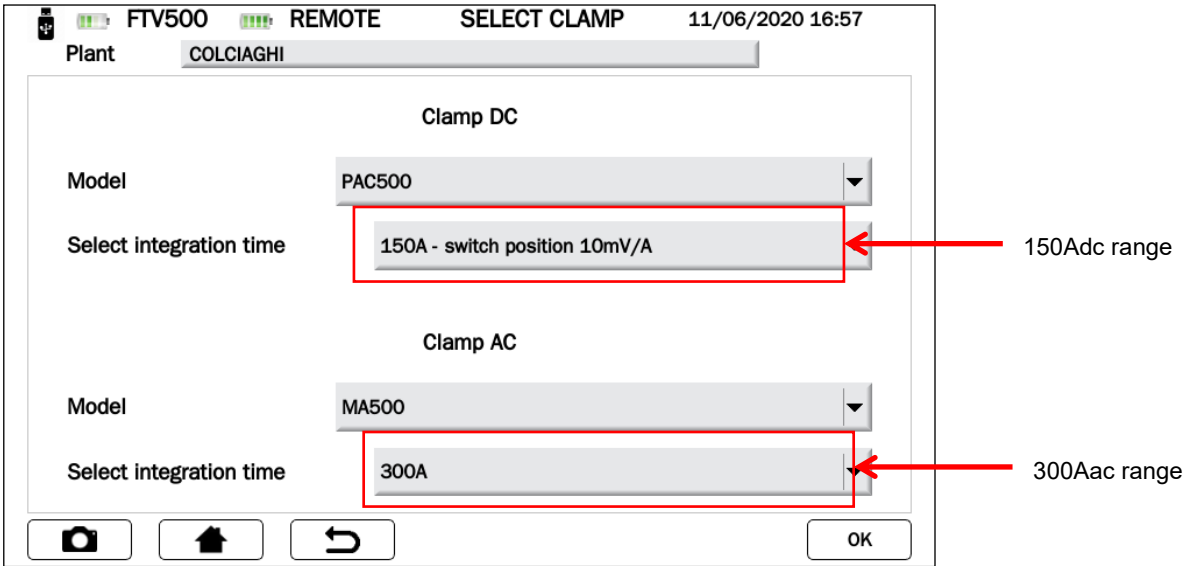


Figure 14.7.1-6 Select clamp

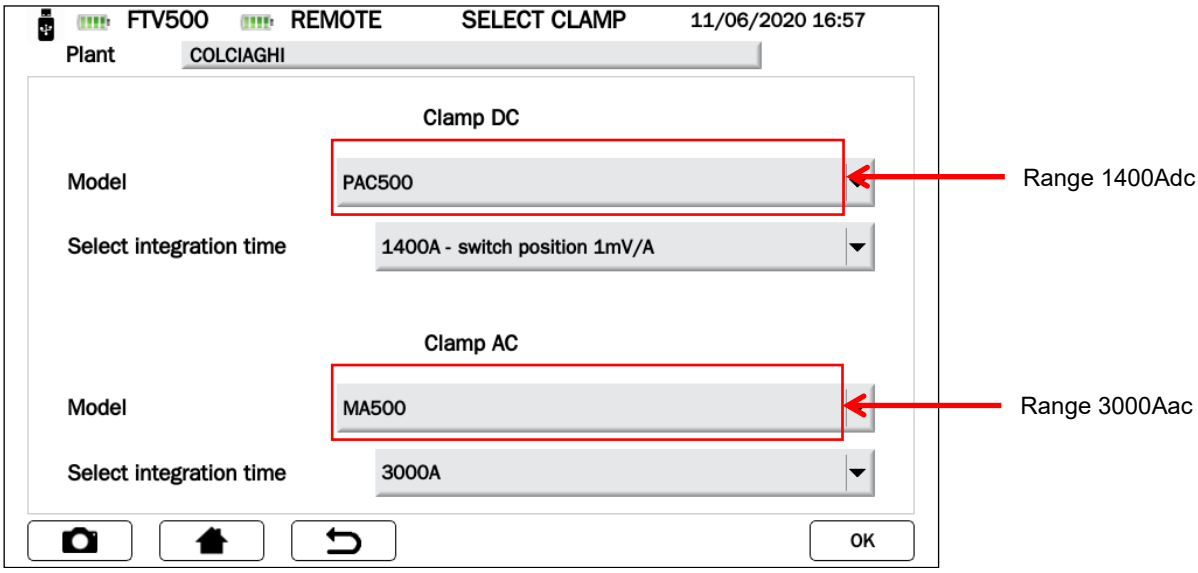
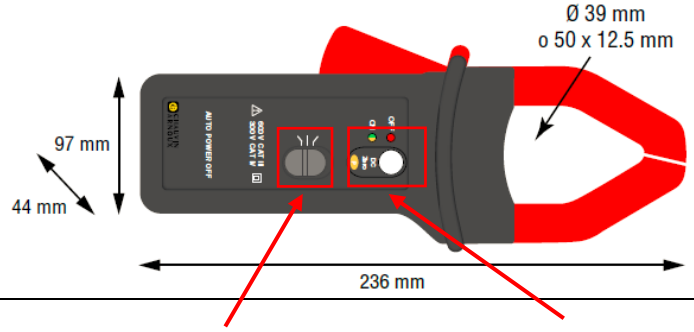


Figure 14.7.1-7 Select clamp

CLAMP CHARACTERISTICS
(For range and accuracy see Chapter 9)

.CURRENT CLAMP PAC500 (DC)

Current	0,5-150Adc	150-1400Adc	
Selector position	10mV/A	1mV/A	

Current range selection	DC zero adjustement

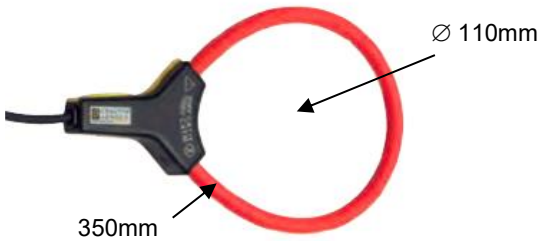
Prior to the measurement, the DC current clamp (PAC 500) needs to be set:

1. Select the Measuring range in the instrument, see **Select clamp** figures 14.7.1-6 and 7.
2. The DC current clamps require zeroing prior to the measurement, to clear any residual potential present, which could introduce errors in the measurement.
   Follow these steps:
   - Connect the clamp meter to one of the inputs of the IDC MESURE instrument: Probe 1, Probe 2 or Probe 3
   - Press briefly onto the DC Zero button (see figures): the reset is signalled by the brief lighting (3 sec) of the OL LED
   - Check the zeroing of the DC current in the **View Real Time Measurements** screen on the instrument (see figures 14.7.1-9)

Other characteristics:

- Clamping capacity: cables 39mm or busbars 50x12,5mm
- Output: via 3 m double insulated cable with connector
- Battery: 9V alkaline
- Low battery signal: Green LED when the battery voltage >6,5V
- Battery life: 50 hours with alkaline battery
- Power supply 5V DC micro-USB type B (option)
- OL Overrun measure: red LED
- Auto power off: after 10 minutes. To disable it keep the power button pressed and move the measurement selector to a range
- Dimensions: 236x97x44mm
- Weight: 520g
- Electrical safety: EN61010-1 or EN BS 61010-1, EN61010-2-032 or EN BS 61010-2-032, Cat.III 600V, Cat.IV 300V
- Electromagnetic compatibility: EN61326-1 or EN BS 61326-1

CURRENT CLAMP MA500 (AC)

Current	0,5-300Aac	300-3000Aac	

- Connector lead dimension ∅: 5,5mm
- Clamping diameter: ∅ 110mm
- Length of captor: 350mm
- Weight: 60g
- Output: via 3 m double insulated cable with connector
- Electrical safety: EN61010-1 or EN BS 61010-1, EN61010-2-032 or EN BS 61010-2-032, Cat.III 1000V, Cat.IV 600V

Press the OK key to confirm the selections (the parameters will remain selected even when exiting the menus, and until the instrument is turned off).
You are now in the **Efficiency main** screen, and the **View Real Time Measurements** key is active, if selectioned it will lead to the measurement display (see Figures 14.7.1-9)

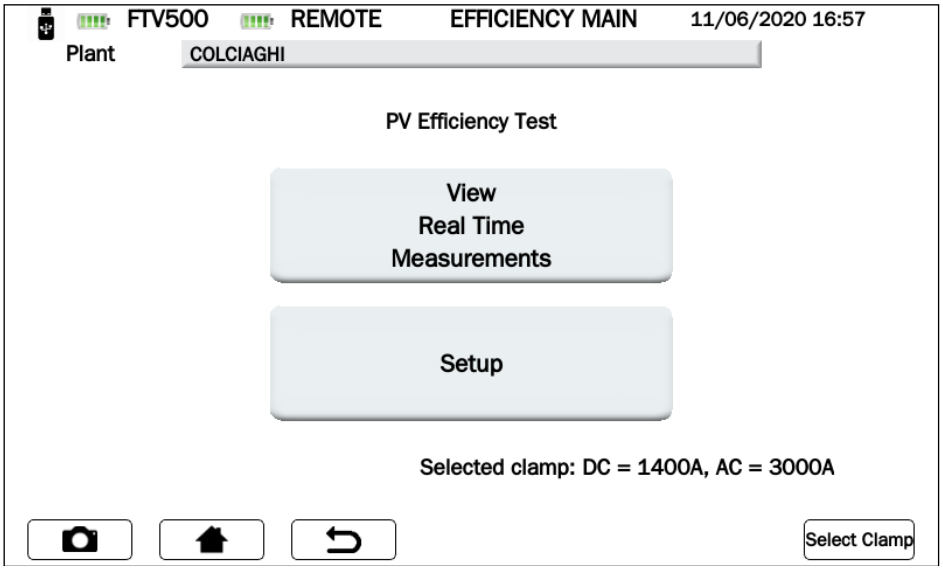


Figure 14.7.1-8 Efficiency main

z

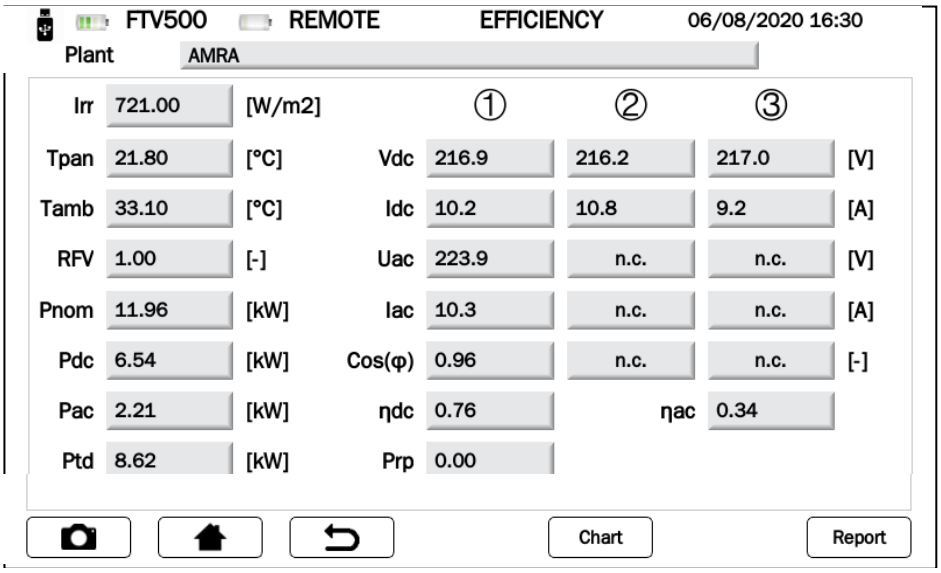


Figure 14.7.1-9 Efficiency measurement display

VALUES

This screen displays all the values of the measurements, along with the result of the Performance Ratio (PRP) test as required by the standards: for further details see Chapter Evaluation of the efficiency of the photovoltaic field.

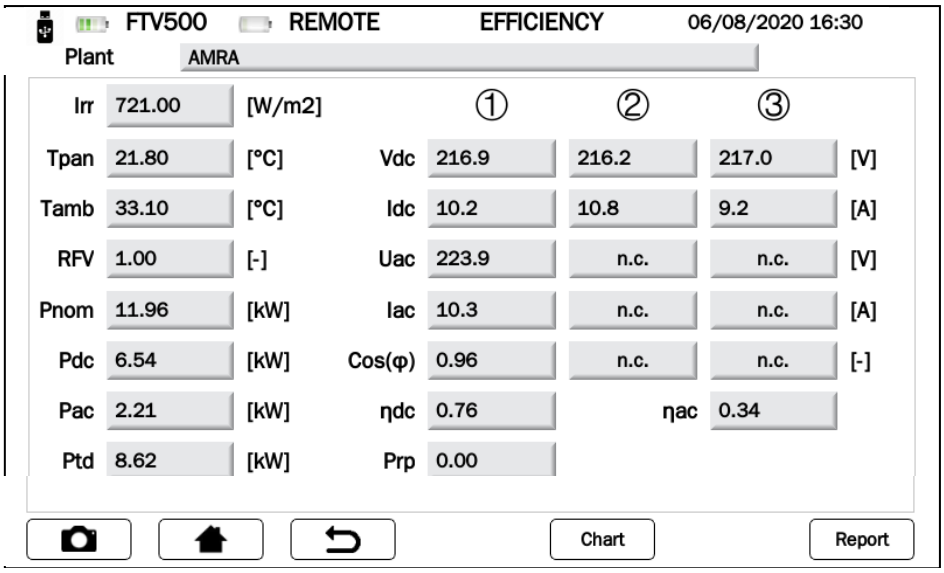


Figure 14.7.1-10 Efficiency measurement display

By pressing the **Chart** key you can access the screen that displays the graph of the AC quantities and the relative vector representation of the voltages and the currents.

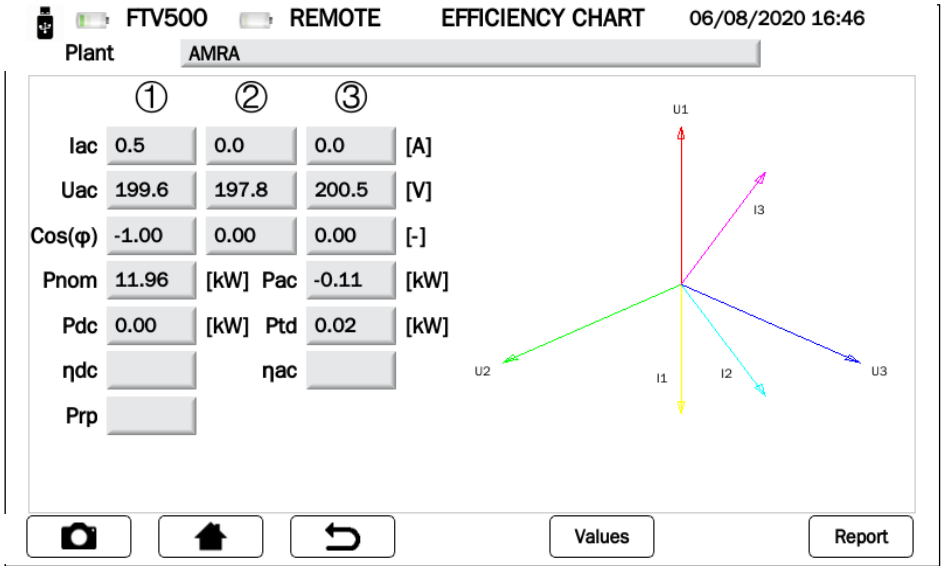


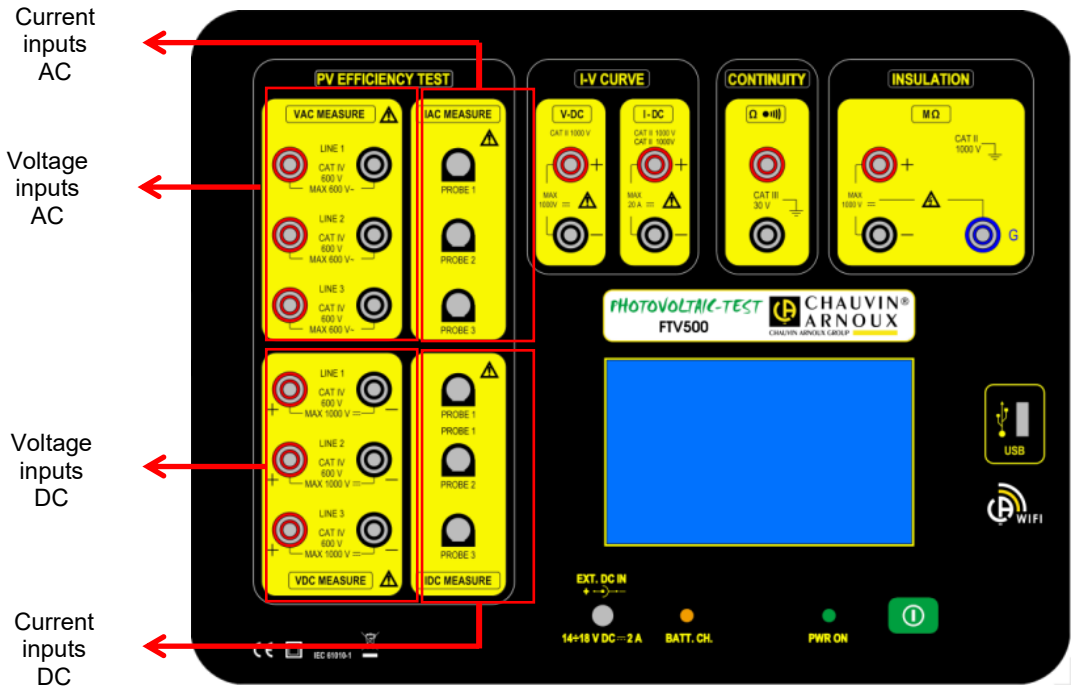
Figure 14.7.1-11 Efficiency chart

Pressing the **Values** key will turn the screen back to the Efficiency measurement display (Figure 14.7.1.-10)

PARAMETERS IN THE EFFICIENCY MEASEUREMENT DISPLAY

Parameter	***Description***
Plant	Plant name selected when opening the measurement session from the Measurement menu. If the PV Rapid Test mode has been chosen, this definition will be displayed in this field
Irr. *	Real-time irradiation W / m^2 measured by the remote unit
Tpan *	Photovoltaic module temperature measured by the remote unit with the module temperature sensor
Tamb *	Ambient temperature measured by the remote unit.

** **NOTE**: in case of loss of communication between the remote unit and the instrument, the remote unit keeps in memory the last data that were received and displays the field in red (to highlight the loss of synchronization).*
When the synchronization of the remote unit is resumed (which occurs automatically when the conditions for the communication are restored) the data is shown in its standard field colour and with its real time value.

Parameter	Description
RFV	Coefficient that is calculated to take into account the energy on the DC side by the photovoltaic system, due to the temperature of the modules, the incomplete use of solar radiation, the inefficiencies or failures of the DC components (including the decoupling between the strings or shading of the modules) *Extract of Guide CEI 82-25; V1* ***Rfv** is the corrective coefficient as a function of the measured or calculated module temperature (**Tpan**), and takes into account the energy loss due to the cell temperature, **Tpan**, greater than 40 ° C and can be evaluated with the following expression:* $Rfv = \begin{cases} 1 & (\text{if } Tpan \leq 40°C) \\ 1 - (Tcel - 40) * \lvert gamma \rvert / 100 & (\text{if } Tpan > 40°C) \end{cases}$ *where **Tpan,** the temperature of the photovoltaic cell, can be determined by one of the following methods:* *a) direct measurement with contact sensor (thermoresistive) hooked up to the back of the module* *b) measurement of the **Tamb** temperature (via thermo-resistive sensor) and calculation of the corresponding Tpan according to the formula:* *Tpan = Tamb + (NOCT or NMOT - 20) * **Gp** / 800* *where **Gp** is the global solar irradiation value (in W / m²) measured on the modules plane with uncertainty of the solar sensor not higher than 3%*
Pnom [kW]	Peak power of the system, i.e. the value resulting from the sum of all the peak powers associated with the PV modules included in the selected plant.
Pdc [kW]	Power measured on the DC side of the plant
Pac [kW]	Power measured on the AC side of the plant
Ptd [kW]	Theoretically available DC power: it is the DC power theoretically available if the photovoltaic generator worked in the ideal conditions in OPC (current temperature and irradiation conditions), translating the properties to STC (Tpan = 25 ° C and Irr = 1000 W / m²).
NOCT / NMOT [%/°C]	Normal Operating Cell Temperature - Temperature to which the cells are brought to reference conditions (800W / m², 20 ° C, AM = 1.5, Air speed = 1m / s).
LINE 1 AC **PROBE 1 AC** **LINE 2 AC** **PROBE 2 AC** **LINE 3 AC** **PROBE 3 AC** **LINE 1 AC** **PROBE 1 AC** **LINE 2 AC** **PROBE 2 AC** **LINE 3 AC** **PROBE 3 AC**	
ηdc	Efficiency of the photovoltaic generator calculated according to the formula: **ηdc = Pdc/Ptd** *NOTE: This quantity has not been introduced by the CEI 82-25 Guide; V1, and is not taken into account for the release of the PRp power performance test result but allows the user to analyze the performance value of the photovoltaic generator only.*
ηac	Efficiency of the DC / AC conversion group (inverter) calculated according to the formula: **ηac = Pac/Pdc** *NOTE: This relationship has not been introduced by the CEI 82-25 Guide; V1, and is not taken into account for the release of the PRp power performance test result but allows the user to analyze the performance value of the DC / AC conversion unit only (inverter).*

Parameter	Description
PRp	**Performance Ratio PRp**: the performance evaluation of photovoltaic systems is carried out as indicated in the CEI EN 61724 standard, i.e. by determining the PR performance factor. ***Performance evaluation in power (extract par. 15.9.4.2 standard CEI 82-25; V1)*** *The performance verification of the photovoltaic systems during the start-up of the system is carried out in terms of power by evaluating the performance index PRp (or performance power index, corrected in temperature).* *The PRp performance index highlights the overall effect of losses on the power generated in alternating current by the photovoltaic system, due to the incomplete exploitation of solar radiation, the conversion efficiency of the inverter and the inefficiencies or faults of the components (including the decoupling between the strings and any shading on the modules).* *Similarly, the verification of the power performance of a photovoltaic system is carried out by checking that the following constraints are satisfied in the operating conditions shown below:* $PRp = Pac / (Rfv * (Gp / G_{STC}) * Pnom)$ *where:* • ***Pac*** *is the active power (in kW) produced in alternating current by the photovoltaic plant, with uncertainty not exceeding 2%;* • ***Rfv*** *= 1 (if Tpan ≤ 40 °C);* ***Rfv*** *= 1 - (Tpan - 40) * |gamma| / 100 (if Tpan > 40 °C);* • ***Gp*** *is the global solar irradiation (in W / m²) measured on the module plane with the solar sensor measuring Uncertainty not exceeding 3% and the sensor output voltage Uncertainty not exceeding 1%;* • ***GSTC*** *is the solar radiation in STC (equal to 1000 W / m²);* • ***Pnom*** *is the nominal power (in kWp) of the photovoltaic generator, determined as the sum of the individual powers of the modules taken from the datasheets issued by the manufacturer.* NOTE: The performance evaluation of the photovoltaic systems in the plant commissioning is carried out either in terms of energy (with measures related to a given period) or in terms of power (with instantaneous measurements).

14.7.2 EFFICIENCY DATALOGGING

The Efficiency Datalogging represents the recording of the parameters related to the Efficiency Test. As a matter of fact, it represents the assessment of the efficiency of the plant over time. The goal of this test could be to check if the same efficiency is maintained in the short or long term.
The recording period is programmable by the user, both in duration and date/time of beginning.

⚠ WARNING DURING USE ⚠

- A dangerous potential is always present in the photovoltaic system.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the string under test

From the **Measurement Selection menu** press the **Datalogging** key to enter the **Logging main** menu; before entering the menu, the synchronization with the remote unit will be necessary, which takes place exactly in the same way as in the Efficiency Test (see Chap. 14.7.1 and Figures 14.7.1-1).

It is possible to bypass the synchronization by pressing the "Skip" button and go directly to the recording menu, but in this way the instrument will not display the correct values of the ambient parameters, and consequently the calculations of the efficiency will not be available.

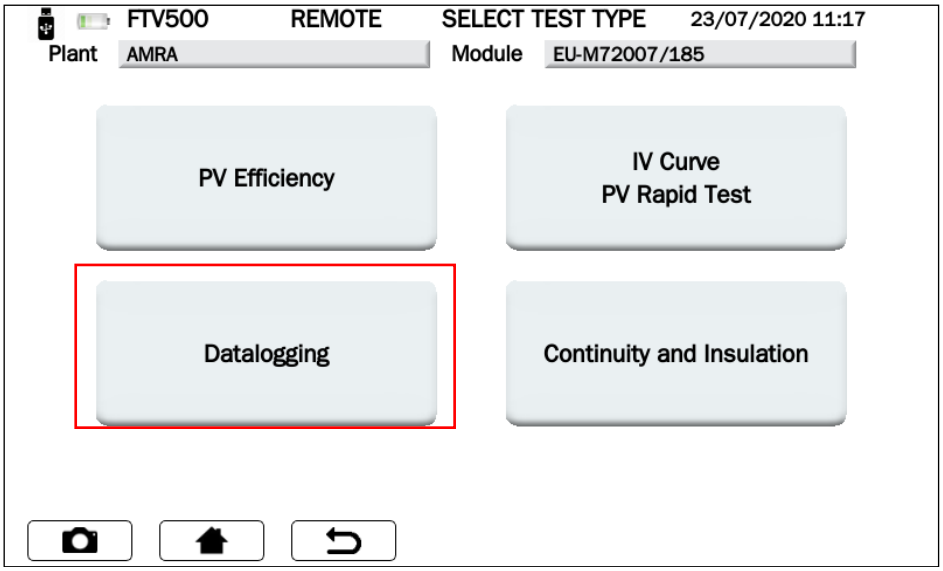


Figure 14.7.2-1 Measurement selection

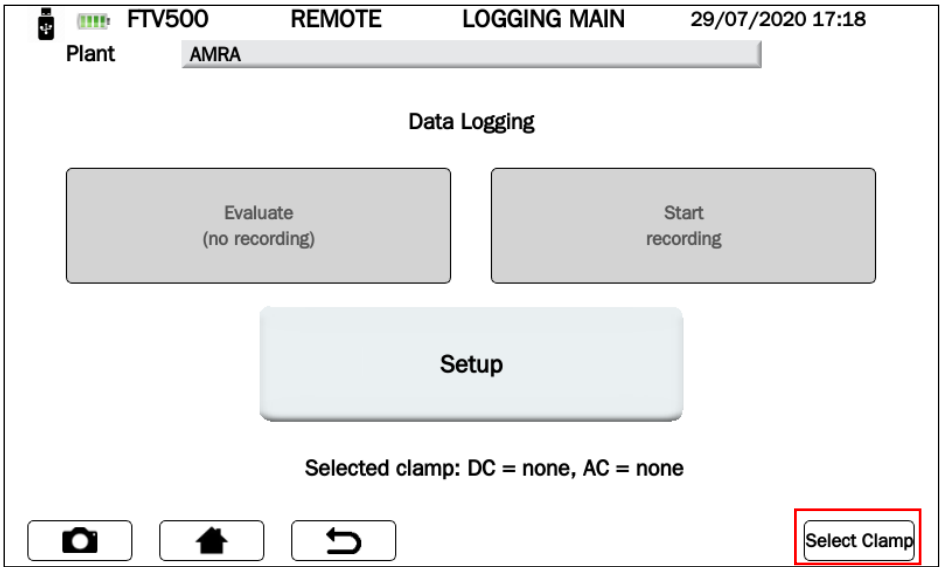


Figure 14.7.2-3 Main datalogging menu

To enable the functions **Evaluate (no recording)** and **Start recording**, it is necessary to set up the current clamps and the recording options necessary for the measurement, operation carried out by pressing the button **Setup**, following the following instructions:

- Click on the **Setup** button in order to select:
  - The inputs that will be active and shown in real time on the display during the measurement (Vdc, Idc, Uac and Iac). If not selected in the measurement field "n.c." will be displayed.
    Type of temperature correction:
    - **Module**: direct measurement of the module temperature with the remote unit sensor connected on the rear side of the module

- **Ambient**: module temperature calculation by measuring the ambient temperature
  For more details see chap. Temperature correction

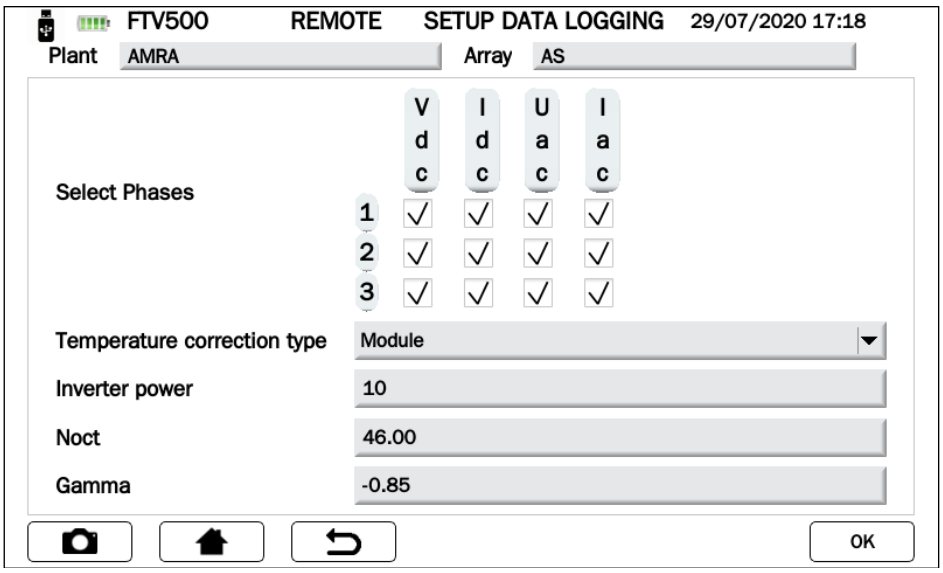


Figure 14.7.2-3 Datalogging Setup

The other parameters that will be displayed are the **Inverter Power**, **NOCT** or **NMOT** and **Gamma** (Temperature Coefficient of Pmax), which cannot be modified but hold those values that were previously entered as PV module and plant characterizing data (see Chapters 14.3.2 New Plant and 14.5.2 New Module)

Press the key OK to confirm the selections made (the parameters will remain selected even when exiting the menu, until the instrument is turned off).

➢ Click button **Select Clamp**. In this window you can choose the clamp meter type for measuring AC / DC currents and select the suitable current ranges that suit the plant to be tested.

The instrument is equipped with two type of current clamps:
a. PAC500 for DC current measurement
b. MA500 for AC current measuremen

Each model has two measuring ranges, which the operator must choose according to the current to be measured in the part of the photovoltaic system under test, see figures 14.7.1-6 and 7.

IMPORTANT: The wrong selection of the Measuring range can cause incorrect measurement readings.

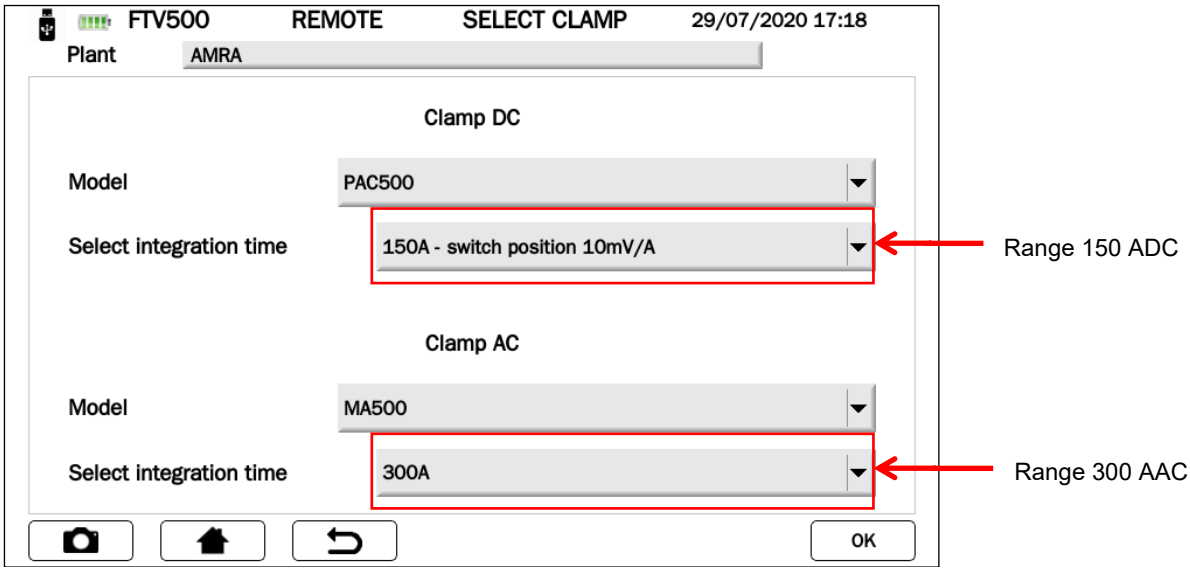


Figure 14.7.2-4 Clamp meter range selection (lower ranges)

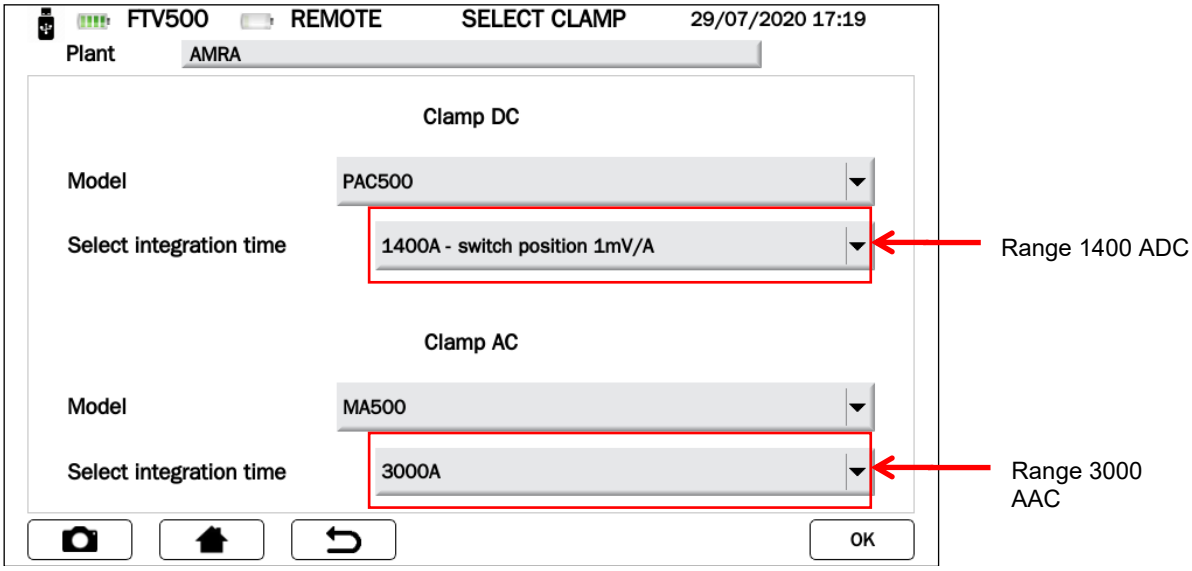
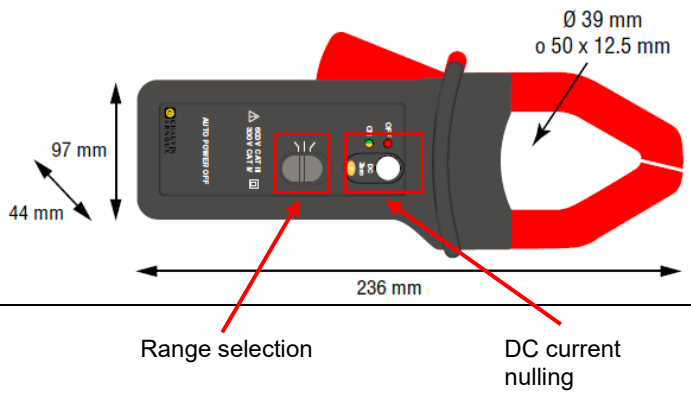


Figure 14.7.2-5 Clamp meter range selection (upper ranges)

CLAMP METER SPECIFICATIONS
(for accuracies and current ranges refer to Chapter 9)

PAC500 (DC)

Current	0,5-150Adc	150-1400Adc	
Selector position	10mV/A	1mV/A	

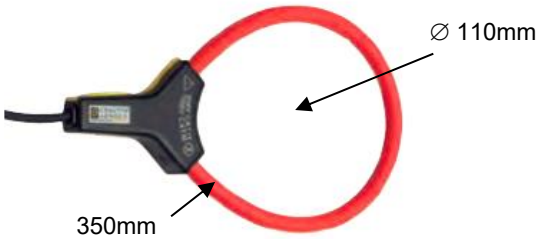
Before the measurement, the DC current clamp (PAC 500) needs to be set:

1. Select the range, see **Select Clamp** of figures 14.7.1-6 and 7.
2. The DC current clamps need to be nulled before the measurement, to eliminate any residual potential, which could introduce errors in the measurement. For nulling the clamp meters follow this procedure:
   i. Connect the clamp meter to one of the inputs of the IDC MEASURE: Probe 1, Probe 2 or Probe 3
   ii. Press briefly on the DC Zero button (see figure): the reset is signaled by the brief lighting (3 sec) of the OL LED
   iii. Check the nulling of the DC current on the instrument's display of real-time measurements (**Evaluate (no recording)**; see figures 14.7.1-9)

Other characteristics:

- Clamping diameter: 39mm cable or 50x12.5mm copper bar
- Connection: with 3 meter cable and FRB01 connector
- Power supply: 9V alkaline battery
- Battery charge indicator: green LED when battery voltage> 6.5V
- Battery autonomy: 50 hours with alkaline battery
- Micro-USB socket for external power supply via mains power supply (option)
- OL overload indicator: red LED
- Automatic switch-off: 10 minutes, to disable it keep the power button pressed and move the selector to an alternative range
- Dimensions: 236x97x44mm
- Weight: 520g
- Electrical safety: EN61010-1 or EN BS 61010-1, EN61010-2-032 or EN BS 61010-2-032, Cat.III 600V, Cat.IV 300V
- Electromagnetic compatibility: EN61326-1 or EN BS 61326-1

MA500 (AC)

Current	0,5-300 Aac	300-3000 Aac	

- Dimensions: ∅ of the sensor: 5,5mm
- Diametro serraggio: ∅ 110mm
- Sensor length: 350mm
- Weight: 60g
- Connection: with 3 meter cable and FRB01 connector
- Electrical safety: EN61010-1 or EN BS 61010-1, EN61010-2-032 or EN BS 61010-2-032, Cat.III 1000V, Cat.IV 600V

Press key OK to confirm the selection made (the parameters will remain selected even when exiting the menu, until the instrument is turned off).

You are now in the LOGGING MAIN menu, and **Evaluate (no recording)** and **Start Recording** buttons are now enabled.

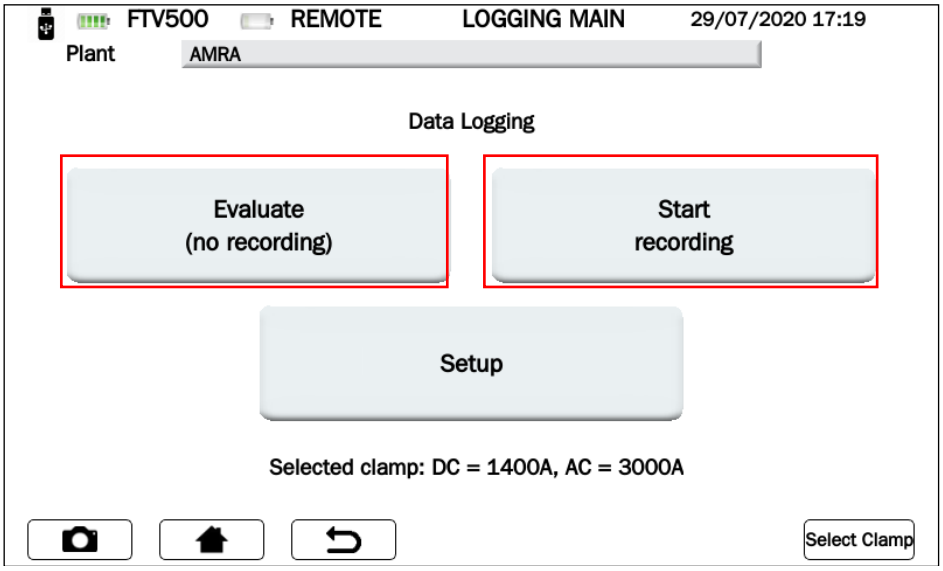


Figure 14.7.2-6 Logging main menu

Select **Evaluate (no recording)** and **Start recording** as in Figure 14.7.2-6 for:

MEASUREMENT DISPLAY (NO RECORDING) with Evaluate (no recording)

This screen displays all the measurement values of the parameters measured in the Efficiency Test (see also chapter 14.7.1), along with the result of the Performance Ratio (PRP) test as required by the standards.

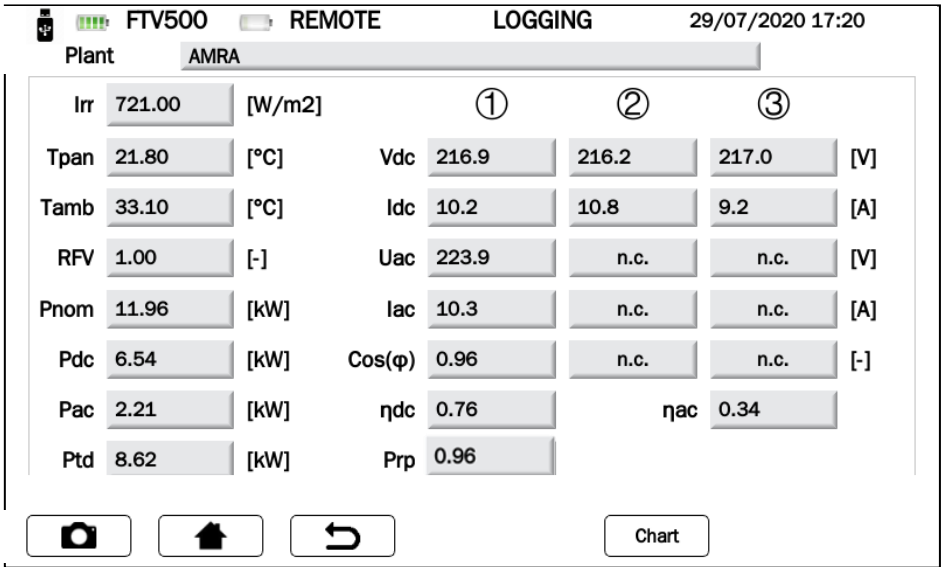


Figure 14.7.2-7 Efficiency datalogging

By pressing the key Chart you can access the screen that displays the graph of the AC parameters and the relative vectorial representation, allowing to identify the phase difference between phase voltages and currents.

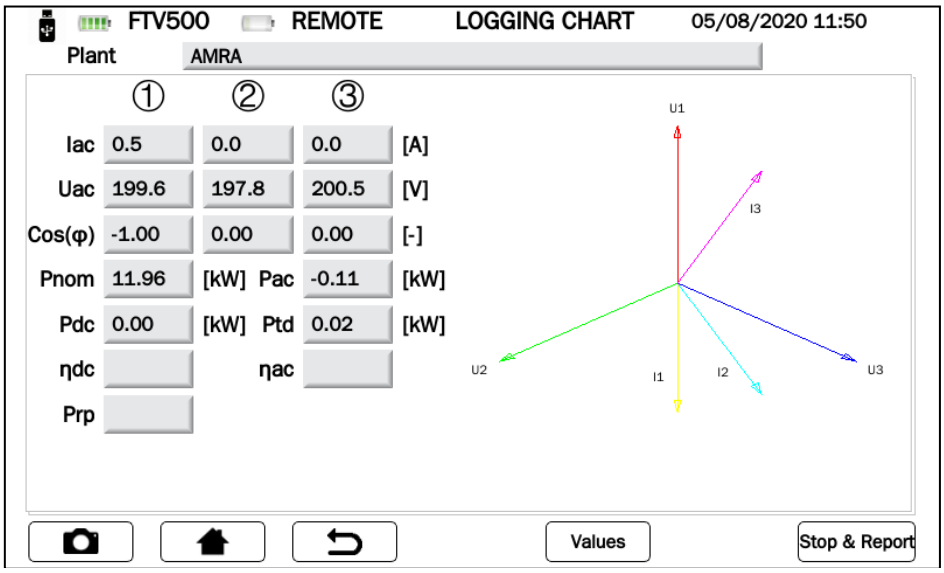


Figure 14.7.2-8 Efficiency graph visualization

By pressing the kwy Values you will return to screen Datalogging (Figure 14.7.2.-7)

PROGRAMMING A RECORDING

By pressing key Start recording (Figure 14.7.2-6) you will access the menu to programme the Efficiency recording.

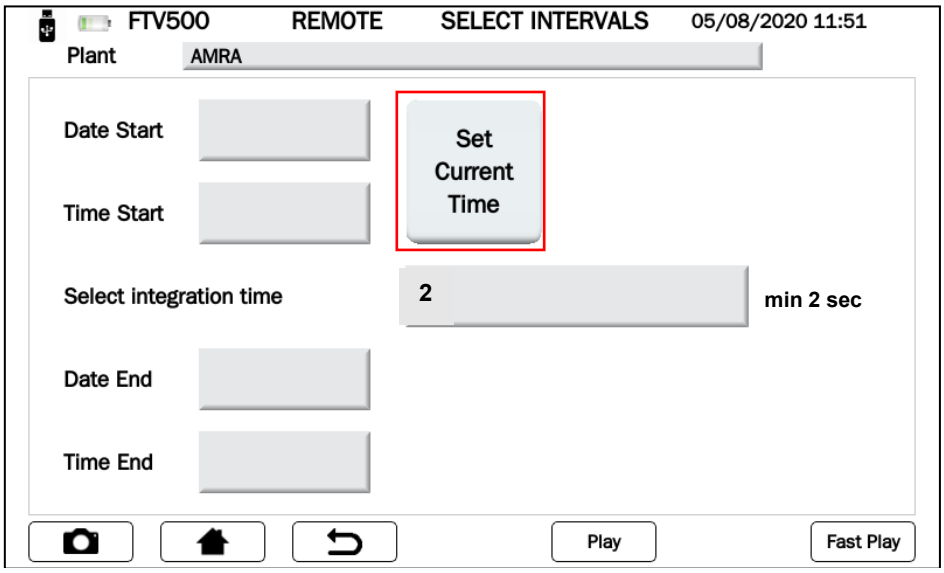


Figure 14.7.2-9 Planning of the recording

First press key **Set current time** (Figure 14.7.2-9) to enable all the fields and update them with the current date and time.

IMPORTANT: it is always recommended to press this button every time you enter the recording programming menu, in order to always confirm synchronization with the internal clock.

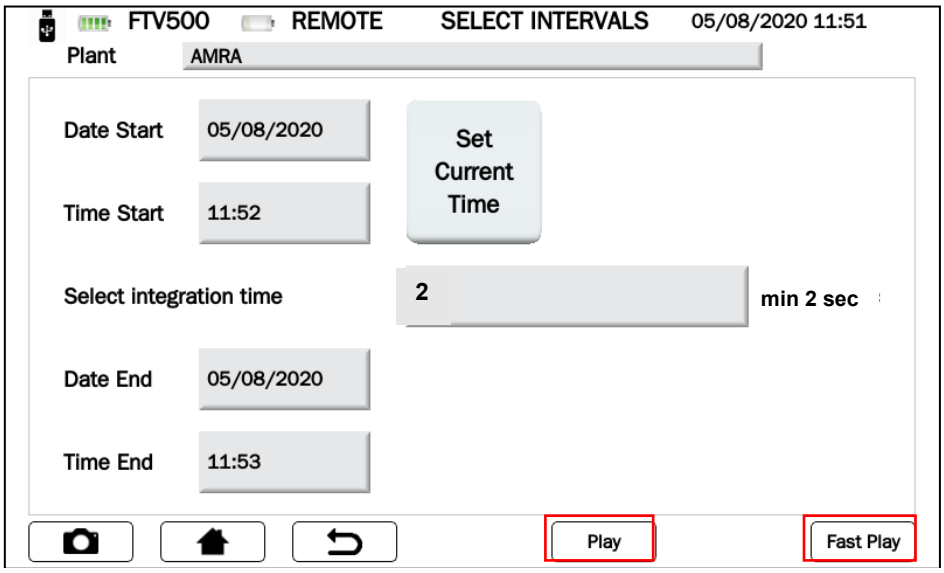


Figure 14.7.2-10 Datalogging programming menu

At this point it is possible to access two modes of carrying out the recording:

Mode	*Press key*
PROGRAMMED RECORDING	Play
MANUALE RECORDING	Fast Play

PROGRAMMED RECORDING Play

- Follow the instructions below and enter Seguire le seguenti istruzioni, ed inserire:
  a. Date Start and Time Start, which corresponds to the recording commencement's date and time
  b. Select integration time, by pressing on the key, the operator can enter a numerical value that corresponds to the integration time - in seconds - for storing each sample (e.g. by entering 5, every 5 seconds a measurement of all the parameters of the Efficiency Test will be stored)
  Min value 2 second
  c. Date End and Time End, which correspond to the end date and time of recording
- By pressing Play you confirm and start the scheduled recording: a counter provides the time before the recording is going to start.

IMPORTANT: During the standby time, no numerical value is displayed in the corresponding field.

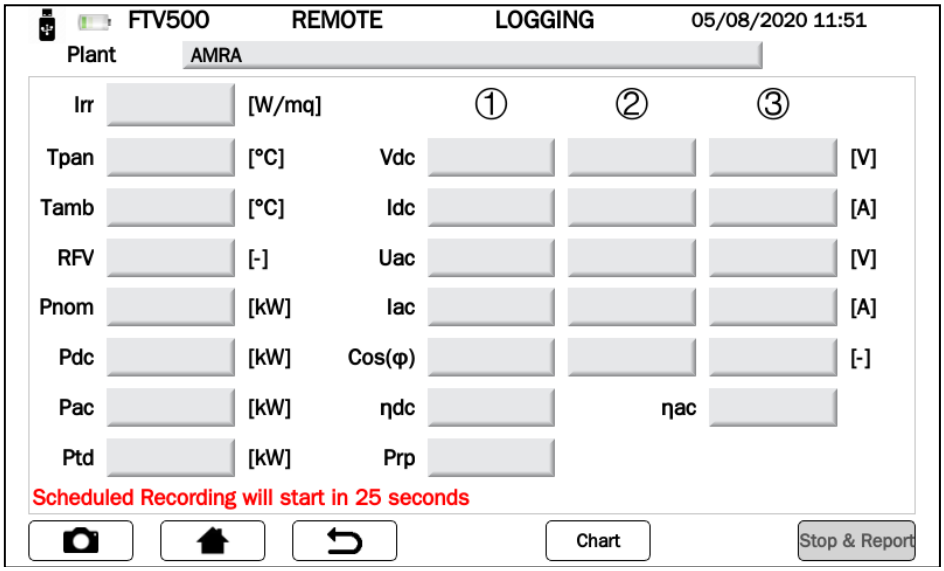


Figure 14.7.2-11 Start of a scheduled recording

Once the counting is finished, the recording starts and the time remaining to the end of the recording is displayed (corresponding to the values entered in the programming menu).

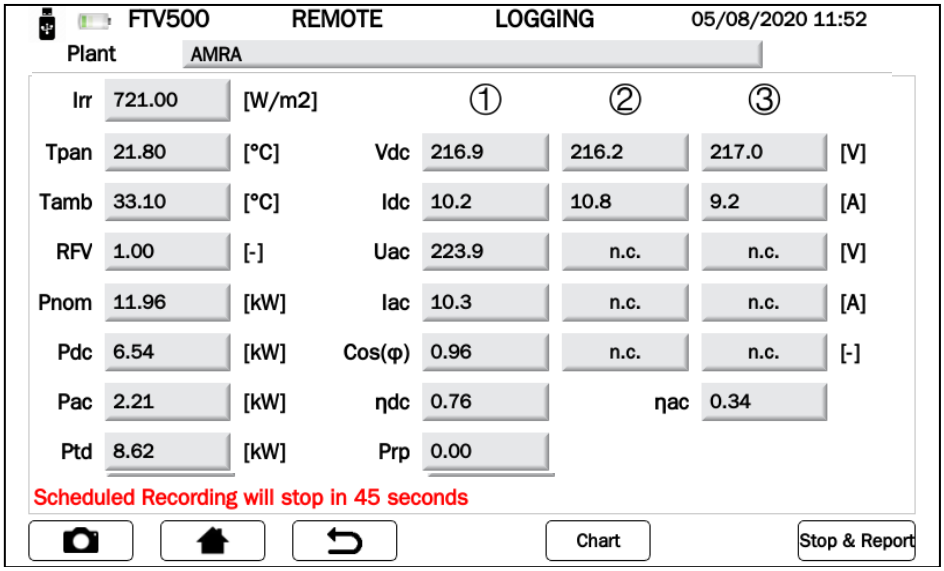


Figure 14.7.2-12 Programmed recording in progress

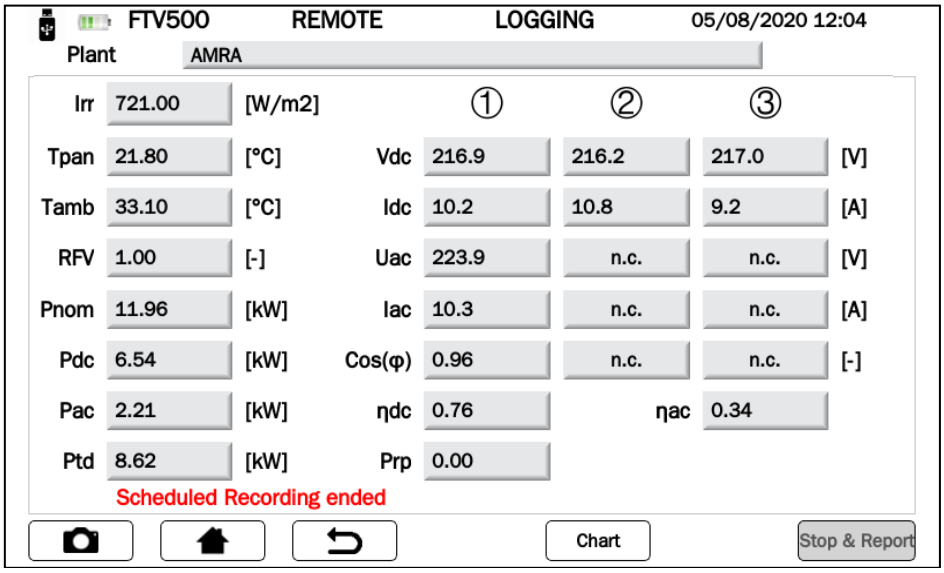


Figure 14.7.2-13 Programmed recording finished

Once the recording time is concluded, the data are automatically saved in the unit's memory (Figure 14.7.2-13), without pressing any confirmation button.

IMPORTANT: After starting the recording, if you want to stop it before the scheduled time, press the button Stop & Salva. The recording will be stopped and saved in the memory (Figure 14.7.2-15),

MANUAL RECORDING Fast Play

- Press the button Fast Play to immediately start a manual recording (without requiring any programming)

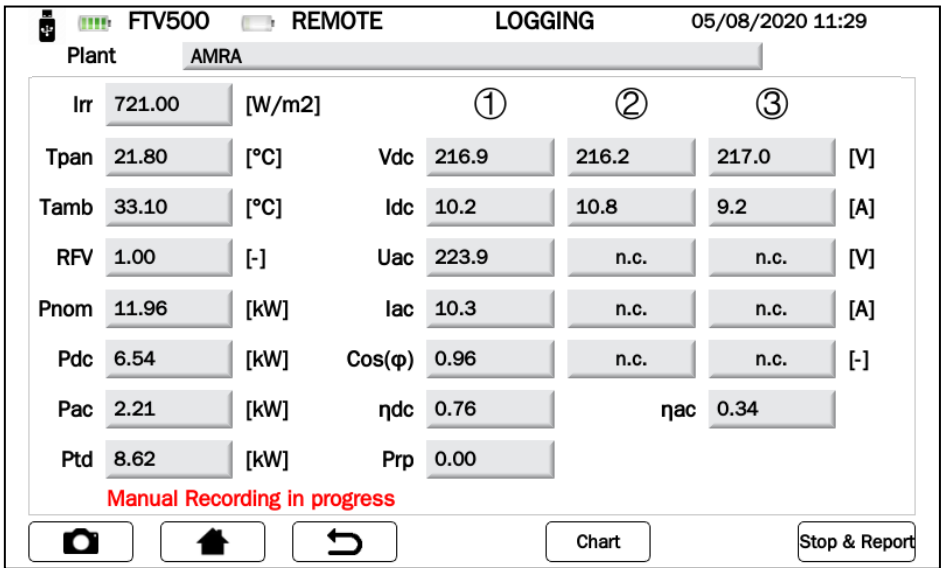


Figure 14.7.2-14 Manual recording in progress

- To end the recording, press the button. The recording will be stopped and saved in the memory (see Figures 14.7.2-14).

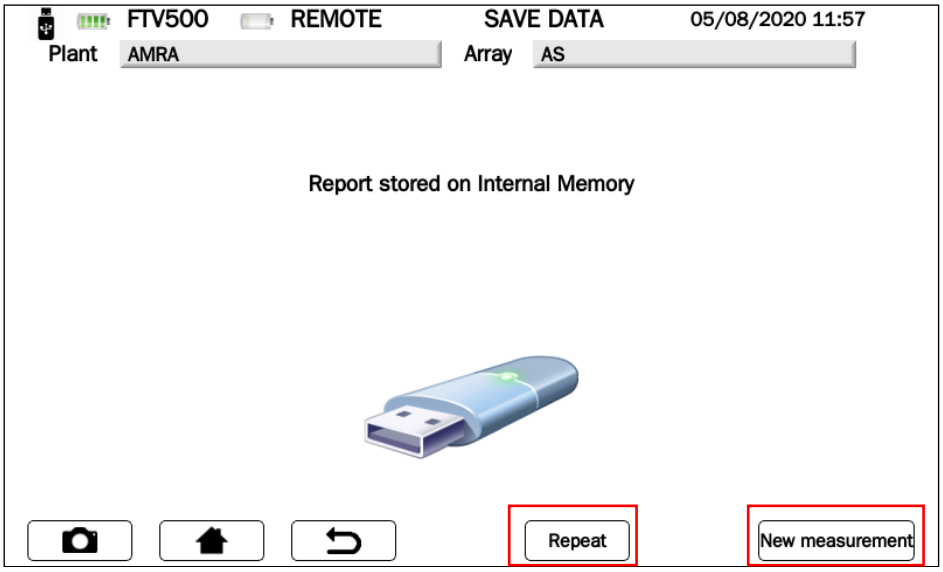


Figure 14.7.2-15 Saving the report

From this menu it is possible:

- press the button Repeat and return to the recording Menu (Figure 14.7.2-6), to carry out a new recording using the same programming and default settings that were previously set
- press the button New measurement and return to the **Select Test Type** (Figure 14.7.2-1) to start a new measurement of your choice. In this case all previous programming and adjustments will be canceled.

14.7.3 I-V CURVE

The test is used to verify the I-V characteristic of photovoltaic modules or strings (array of models grouped in series and parallel) in order to verify the parameters declared by the manufacturer, according to IEC / EN60891, IEC / EN62446, IEC / EN60904-5 standards.

MEASUREMENT OF HIGH EFFICIENCY MODULES

High-efficiency modules require care when measuring I-V curves because of the high capacitance, which can lead to errors in the results. While producing a short but intense current pulse at the beginning of each measurement may prevent the current/voltage graph from being plotted correctly.
During the I-V curve test, the PHOTOVOLTAIC TEST FTV500 instrument repeats the measurement 500 times, going from the extremes of the short-circuit current point (Isc) to the no-load voltage point (V0).
The PHOTOVOLTAIC TEST FTV500 instrument has a maximum current input for the I-V test of up to 20 A (limited to 10A in the presence of high-efficiency modules)
Module strings with efficiencies greater than 19% limit the maximum current input of the PHOTOVOLTAIC TEST FTV500 instrument to 10A.
If high-efficiency modules (>19%) are present, the inrush current coming from the module/string will be very high, and the automatic sequence of repeating the measurement causes spikes and a buildup of current that interfere with the linear trend of the values on the I-V graph, making curve analysis difficult in some cases.
In such cases, to properly appreciate the I-V measurement values, it is recommended to perform the measurement using the RAPID PV TEST function.
Or to obtain a reliable CURVE I-V graph, reduce the string current and voltage:

- separate strings, or reduce the number of modules in the string
- orient the tracker toward less irradiance if possible
- measure at the beginning or end of the day to get lower irradiance

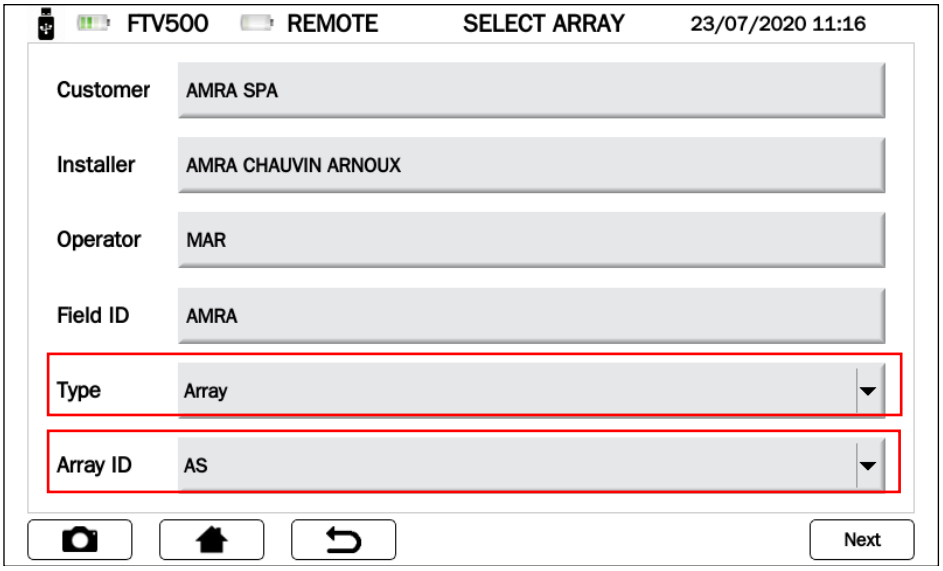
WARNING DURING USE

- A dangerous potential is always present in the photovoltaic system.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the sring under test

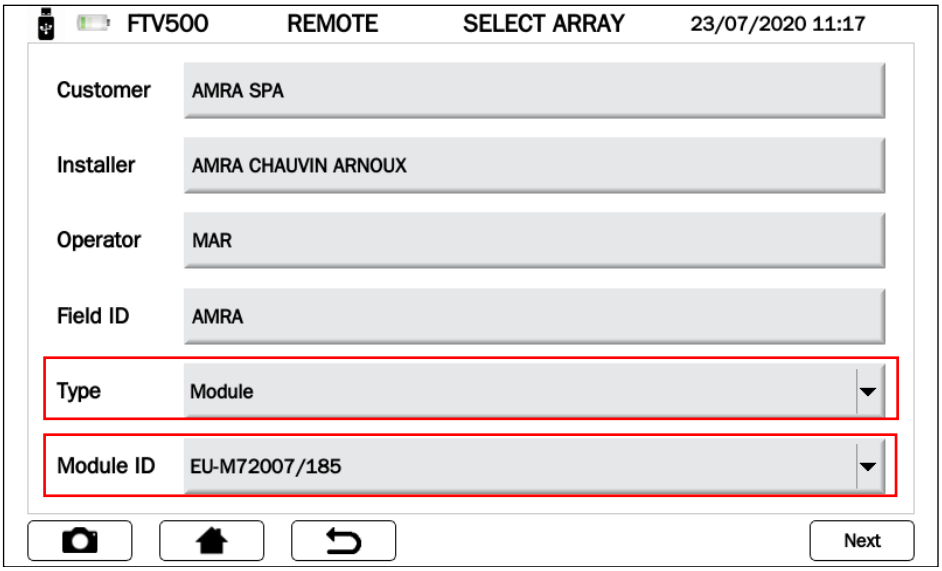
Before progressing with the test, follow the instructions in Chapter 14.7 MEASUREMENT:

a. Look **Mode 1** (with master data)
b. Look **Mode 2** (without master data, not recommended for I-V curve test)
c. Look **Select plant** Figure 14.7-2
d. Look **Select type** (PV field or Module) Figure 14.7-3/4, which for your convenience we report below in abbreviated form:

- PV Array:



- Module:



At this point you are in the **Select Test Type** Menu and you can choose between the **I-V Curve** and **PV Rapid** Test button:

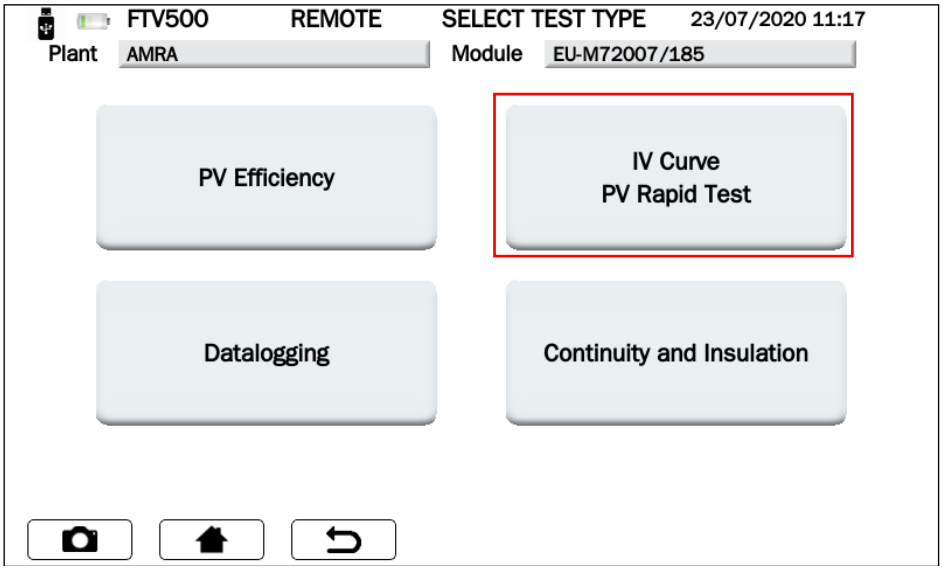


Figure 14.7.3-1 Select Test Type

At this point you can **Select the test type**:

- I-V Curve
- PV Rapid Test

I-V CURVE

Press key IV CURVE to start the test:

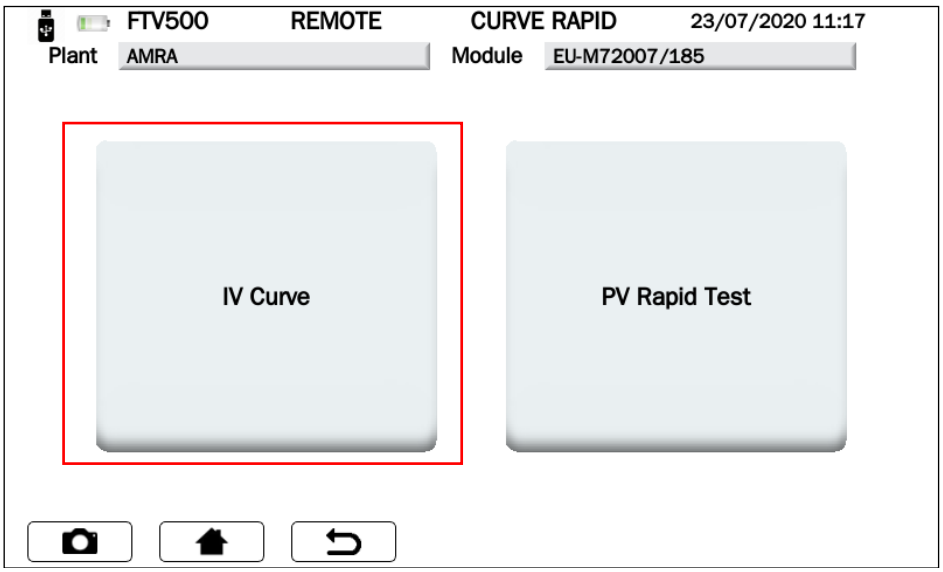


Figure 14.7.3-2 Selection between I-V Curve and PV Rapid Test

- Before carrying out any measurement, the SYNCHRONIZATION menu (synchronization between instrument and Remote Unit) appears on the display, which allows you to receive the values of the environmental measurements (irradiation, ambient temperature, module temperature) from the remote unit connected remotely outdoor with Wireless technology.

  It is mandatory to place the remote unit correctly, to turn it on and to keep it within the communication range of the instrument (see related chapter).
- Press **Synchronize** to get the Remote Unit connected and wait for the confirmation indicated by the blue bar at 100% (see Figure 14.7.3-4)

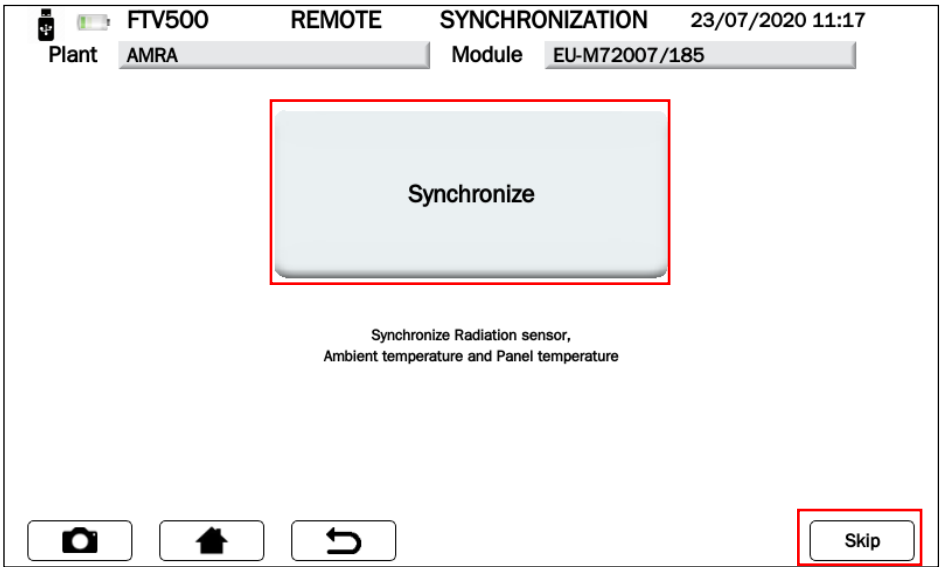


Figure 14.7.3-3 Synchronization

- Press **Skip** to bypass the request for synchronization of the remote unit and to go directly to the measurement screen (see Figure 14.7.3-4)

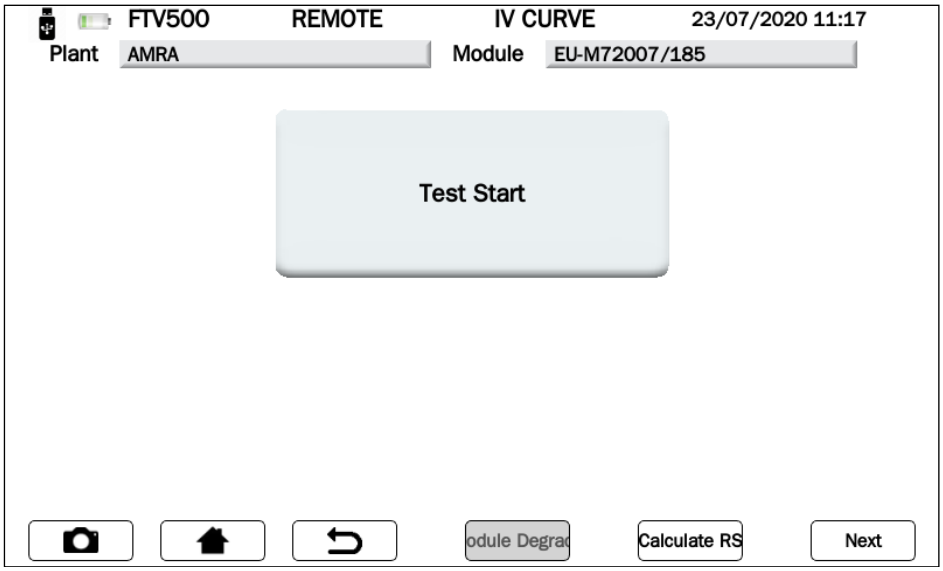


Figure 14.7.3-4 Measurement Start Screen

IMPORTANT: With this selection the instrument will not display the values of the environmental parameters, and consequently also all the calculations of the yields, efficiency, outcome, will not be displayed (the related fields will be red)
ATTENZIONE: Con questa scelta lo strumento non visualizzerà i valori delle misure ambientali, e di conseguenza anche tutti i calcoli dei rendimenti, efficienza, esito, non saranno visualizzati (i campi relativi saranno di colore rosso)

Once synchronization has taken place, the screen in figures 14.7.3-5 will show the values of irradiation and temperature, the latter will be displayed in accordance with the programming configured in the **Setup** Menu (see Chap. 14.2 Temperature Mode Settings):

- **Module**
  In the screen in figure 14.7.3-5 the value corresponding to the module temperature will appear
- **Ambient**
  In the screen in figure 14.7.3-5 the value corresponding to the ambient temperature will appear

In the case of selection of **Auto** or **Manual**, it is necessary to press Start and launch the test and wait the measurement end before entering the screen of the measured values, the screens shown in the following figures will appear depending on the situation:

- **Auto**

The module temperature calculated by the Voc measurement according to EN60904-5 will appear on the screen in figure 14.7.3-5

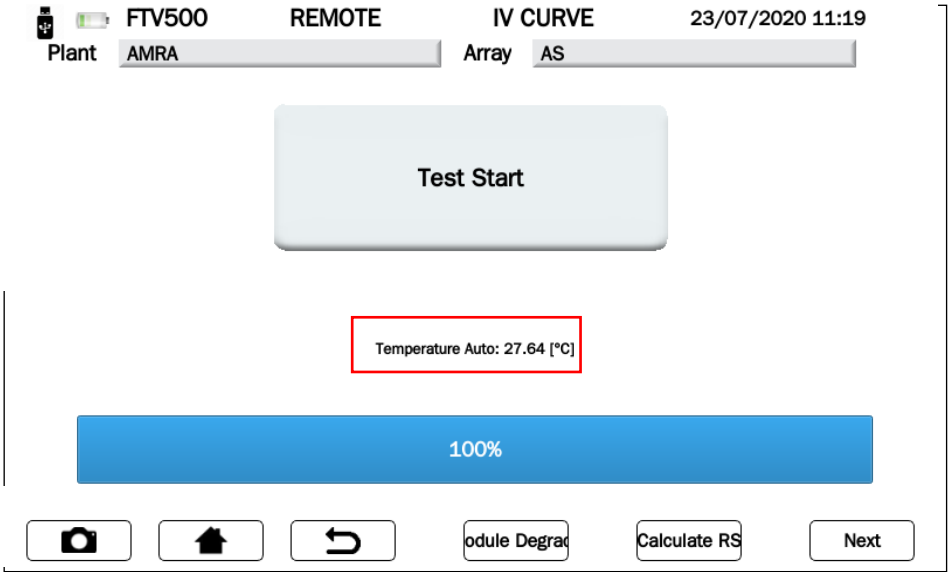


Figure 14.7.3-5 Auto Temperature

- **Manual**

If you have chosen the Manual Temperature Mode in the Setup menu, once synchronization has taken place (Figure 14.07.3-6) FTV500 will show a red field in which the operator should enter the temperature value (the value proposed as default will be the temperature measured by the probe on the remote unit):

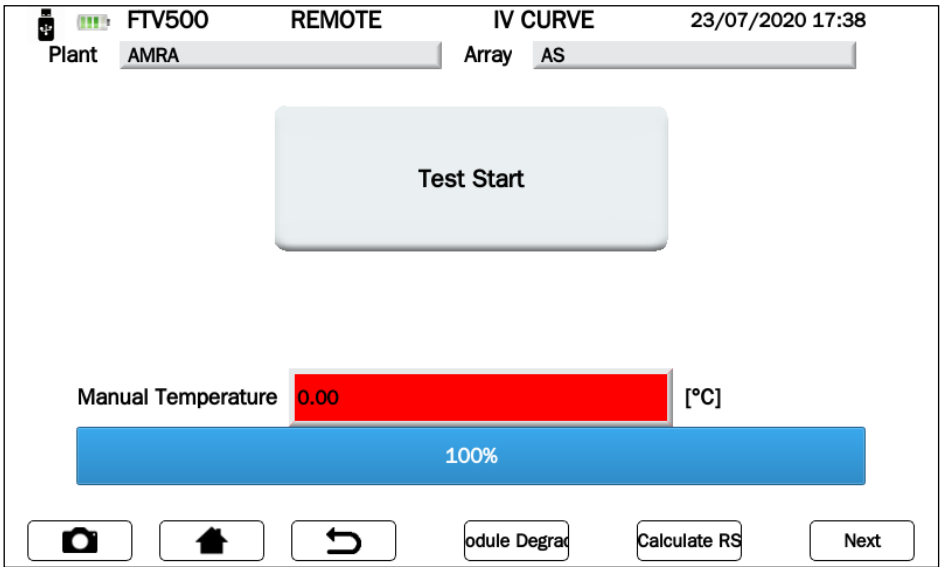


Figure 14.7.3-6 Manual Temperature

To change the default temperature press into the temperature field and wait for the entry screen to appear (Figure 14.07.3-7):

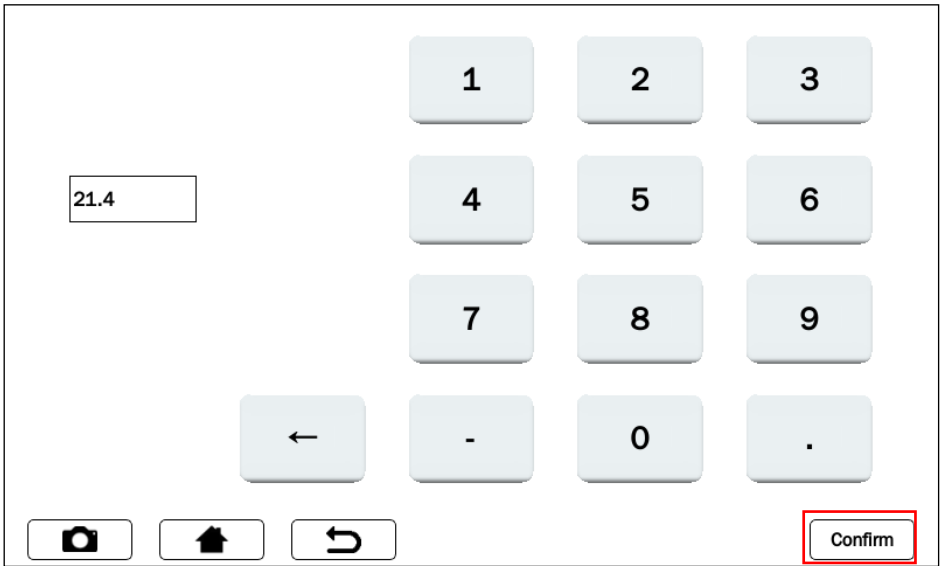


Figure 14.7.3-7 Manual Temperature entry

Type in the keyboard screen the desired temperature value, then press **Confirm** to accept the value.

At this point the manual temperature field will no longer be red to confirm acceptance of the new value entered (Figure 14.7.3-8):

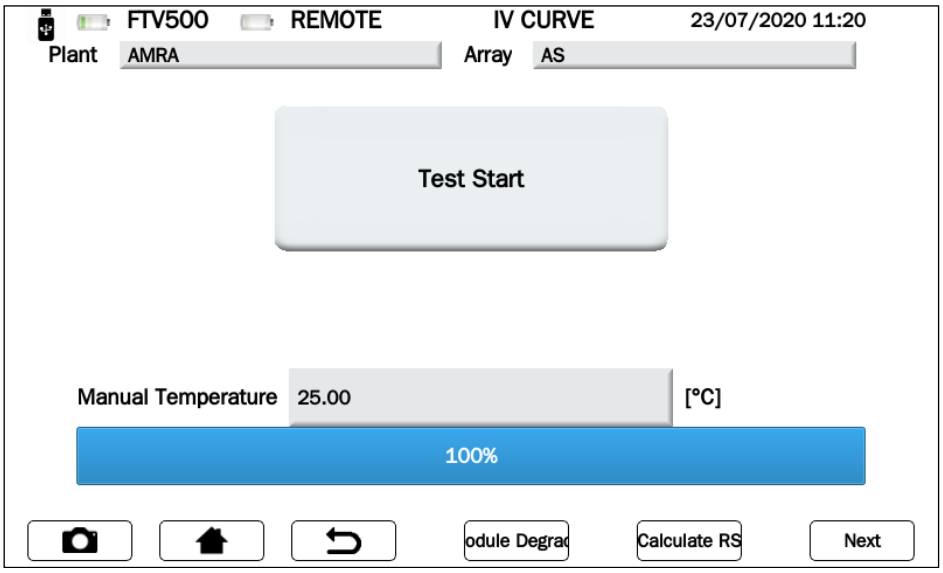


Figure 14.7.3-8 Manual Temperature Confirmation

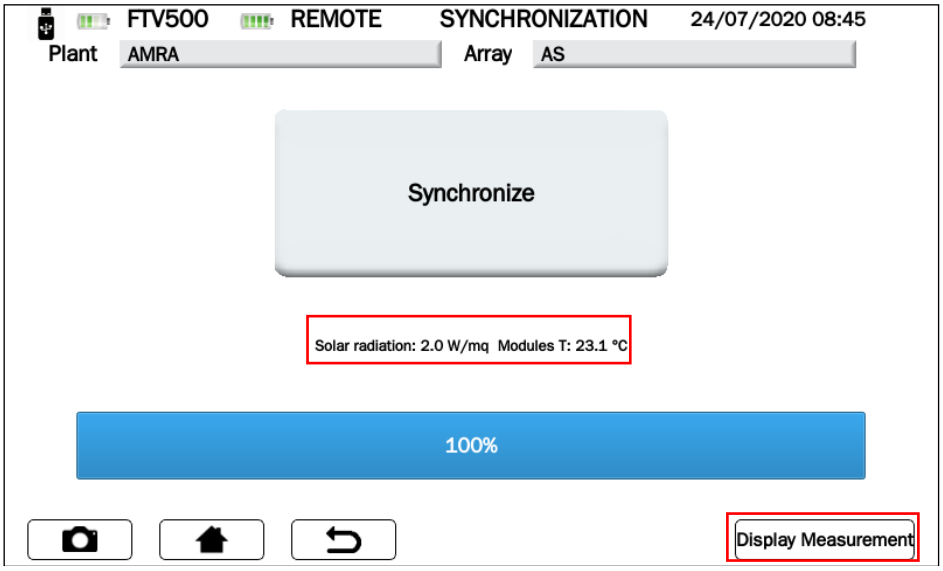


Figure 14.7.3-9 Succesful synchronization

IMPORTANT: Always check the eligibility of the temperature and radiation values which are shown on the display at the end of the synchronization procedure, which will then be used for all the calculations of the final test result.

- Press key **Display Measurement and continue** (Figure 14.7.3-9)
- Press key **Test Start** to launch the test (Figure 14.7.3-10)

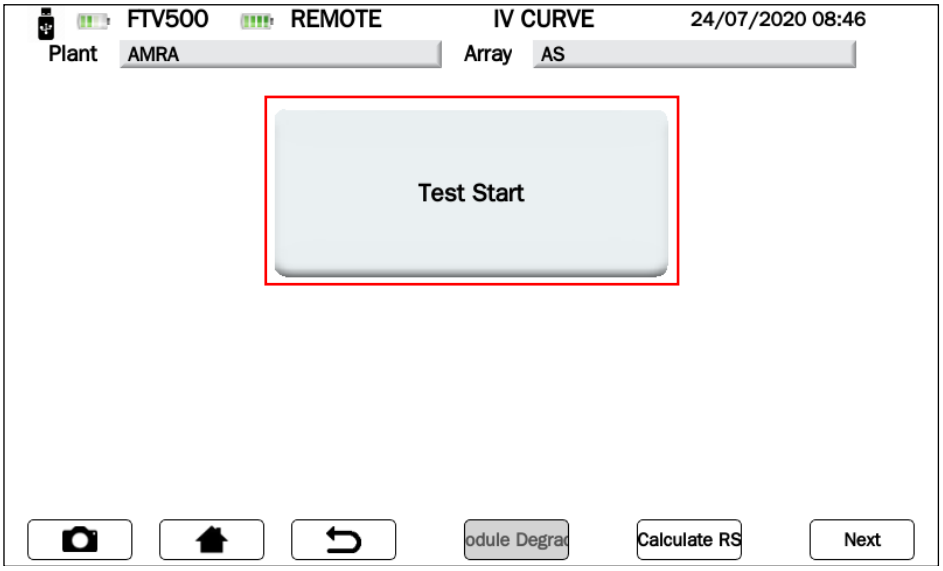


Figure 14.7.3-10 a Confirming the start of the I-V curve test

IMPORTANT: After synchronization and the test started, it is possible that the string has been connected by inverting the positive and negative poles. In this case, an error message is displayed asking to repeat the measurement, (Figure 14.7.3-10 b).

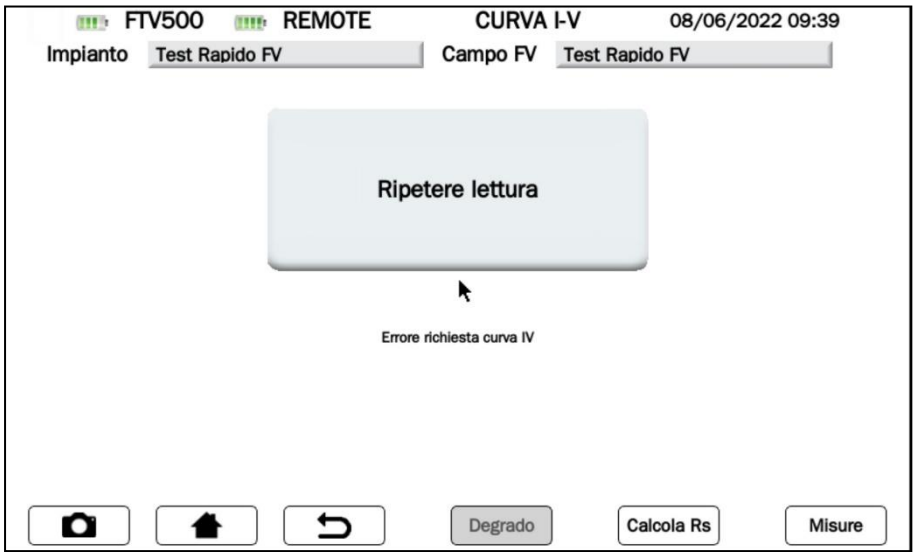


Figure 14.7.3-10 b Error screen: invert the poles of the string / module to carry out the measurement

ATTENTION: If the selected string has values (resulting from the calculation of the Isc current and Voc voltage) higher than the instrument's range, the following message appears (check the data in the system menu):

WARNING: do not perform measurements on PV fields characterized by values.
The photovoltaic system always displays potentially dangerous voltage and current values. This message is a WARNING of the presence of potential danger on the system being measured, as entered in the System Menu. The operator must ensure the connection is correct and within the maximum limits of the instrument's capacity (maximum voltage 1000V and maximum current 20A).
Press OK to continue the test.

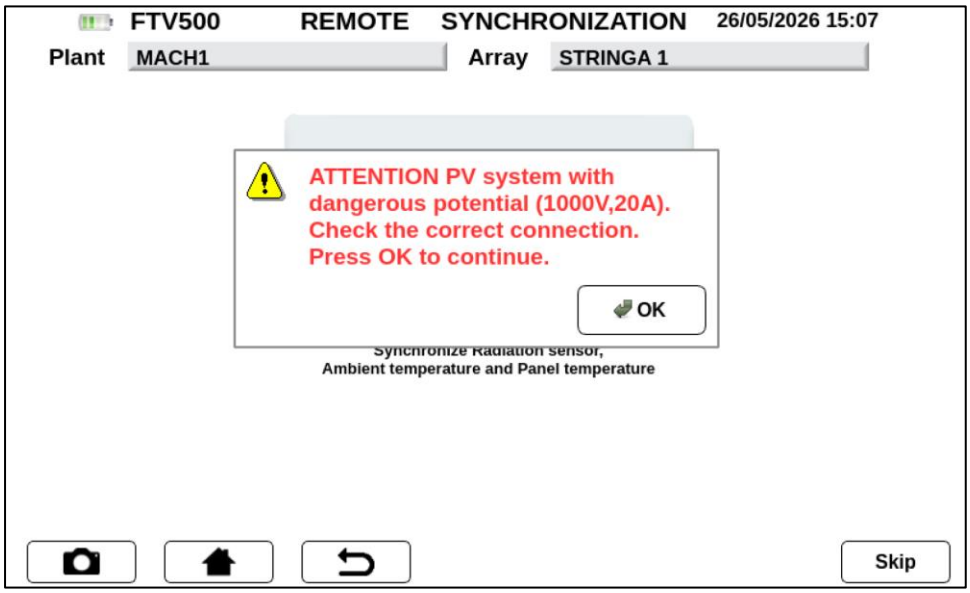


Figure 14.7.3-10 c Error screen: current and voltage values that exceed the maximum input values

- The instrument then draws the I-V curve of the connected PV modules / PV field (follow the connections shown in Annex B), also acquiring the module's irradiation and temperature parameters (via remote unit):

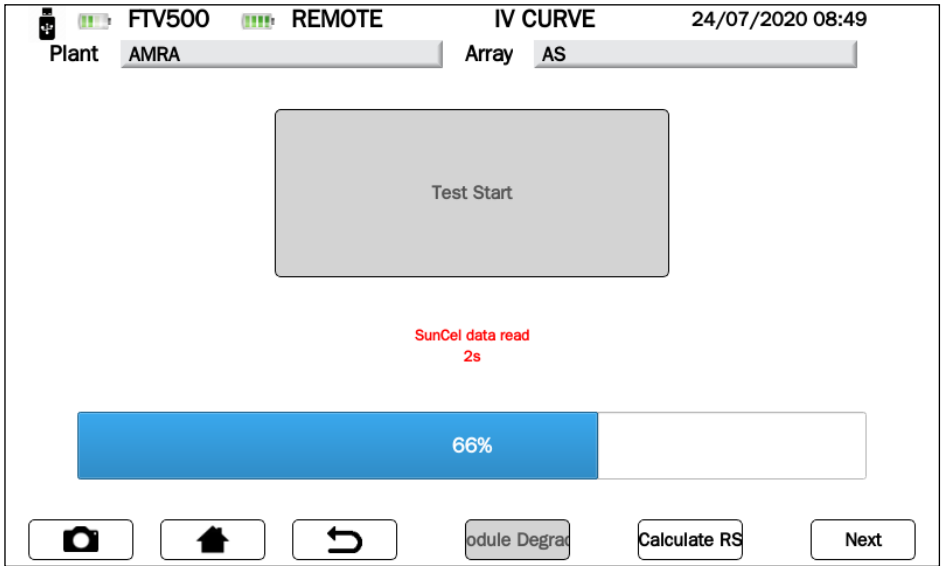


Figure 14.7.3-11 Data acquisition for drawing I-V curve

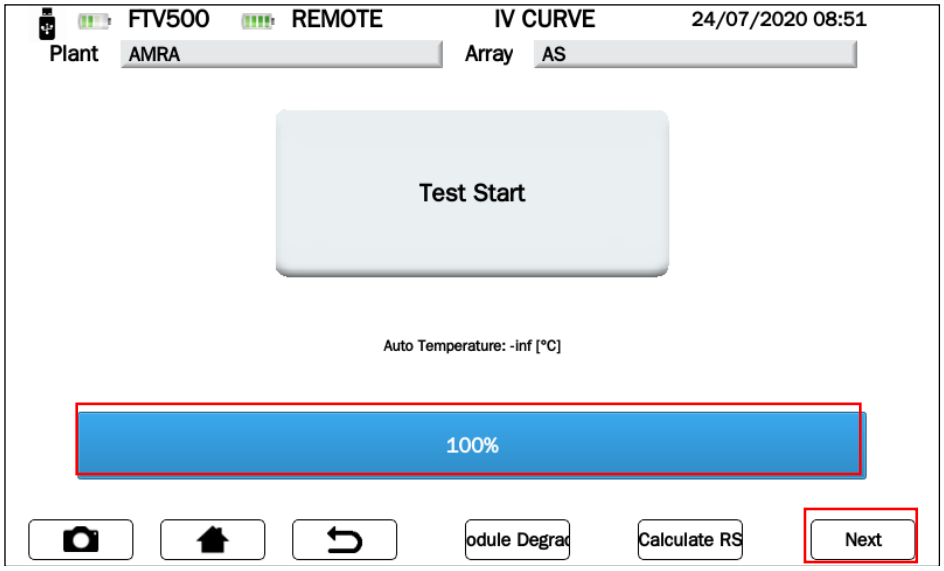


Figure 14.7.3-11 I-V curve data acquired

At the end of the test (100% completion percentage), all the measurement data have been acquired by the instrument, and the underlying keys will be activated:

- **Modulo Degradation**
- **Calculate RS**
- **Next**

MODULO DEGRADATION

In order to get the best comparison accuracy (STC), it is requested to enter the module performance degradation rate, which depends on the modules' age that make up the PV array; if you do not want to enter a value just press key [Next] to go forward.
By default no degradation will be applied if no value is voluntarily entered.

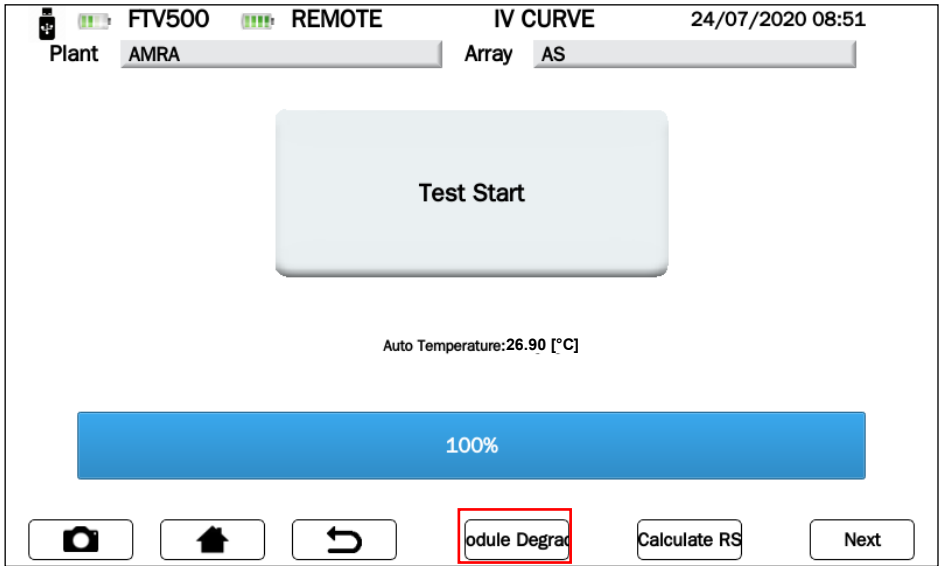


Figure 14.7.3-12 Entering module degradation

TO ENTER THE DEGRADATION VALUES OF THE MODULE

Press the **Module Degradation** key and use the keyboard to enter the corresponding annual deagradation rate (normally expressed as a percentage) declared by the module manufacturer.
The degradation is a function of the years of installation of the module in the field: this degradation must be known from the module's datasheet and must be multiplied by the number of years passed from the modules' date of manufacture of the module. This data is crucial for obtaining a reliable positive or negative test result.
The module degradation must be entered as a percentage number (e.g. 2 stands for 2%).

Example: if the annual degradation of the module is -2% and the number of years passed from the manufacturing date is 8 years, it is necessary to enter 16 in the corresponding field

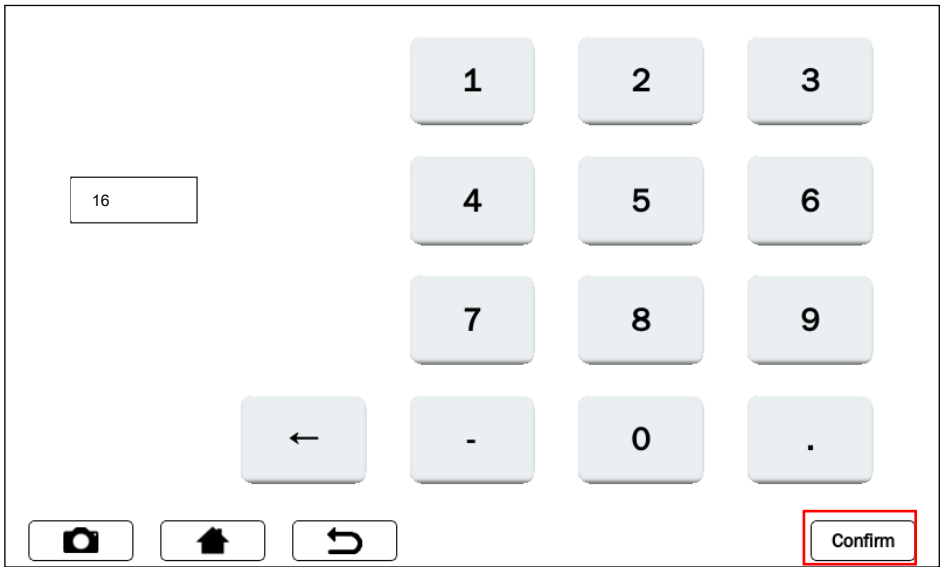


Figure 14.7.3-13 Entering module degradation rate

Press key Confirm to apply the Module Degradation that has been entered.

RS CALCULATION (Series Resistance)

The Series Rs resistance is one of the module's characteristic parameters, which can influence the determination of its I-V characteristic.
The IEC / EN 60891 standard prescribes that the measurement of the series resistance is carried out exclusively on the single module, in two phases, and in different conditions of solar radiation.

WARNING: Carrying out this measurement on a string does not guarantee the reliability of the measurement.

- RESISTANCE CALCULATION PROCEDURE (RS)
If you don't have the resistance value RS, you can calculate it with the following formula:

$$R_s = \frac{V_{oc} - V_{mp}}{I_{mp}}$$

Let's look at a practical example using the following values:

Voc = 48.6V
Vmp = 39.8V
Imp = 9.55A

The formula then becomes:

$$R_s = \frac{48.6 - 39.8}{9.55} = \frac{8.8}{9.55} \approx 0.92\,\Omega$$

- FIELD MEASUREMENT PROCEDURE FOR RESISTANCE RS

The first measurement must be carried out with a solar radiation value greater than 500 W / m2. The second measurement must be performed with a lower solar radiation value than the first, the difference between the two values must be at least 200 W / m2. The conditions for the maeasurements' correctness are automatically checked by the instrument.

NOTE: If you already have the Resistance value Rs, you can skip this measurement and enter it in advance in the related module's data request form: see Chapter 14.5 PV modules, Figures 14.5.2.1.
To carry out the measurement, proceed as follows:

- Press key Calculate RS

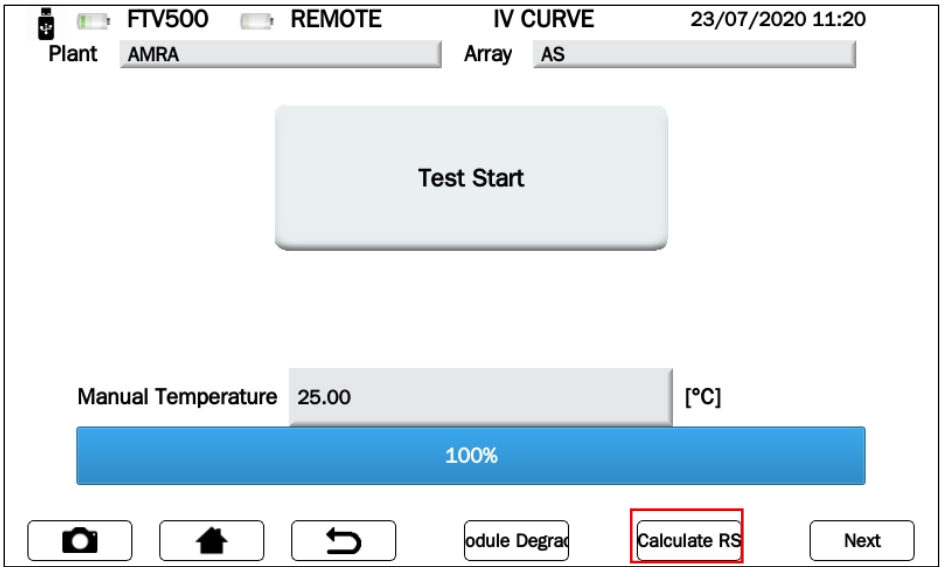


Figure 14.7.3-14 Calclulation of Rs

- The test starts automatically with **Measure 1** and during the procedure the progress is displayed (the percentage bargraph indicates the test progress). The measured irradiation and temperature value will be showed in the measurement screen.
  In case of lacking synchronization with the remote unit, the test is not performed, and the error message in Figure 14.7.3.16 is displayed:

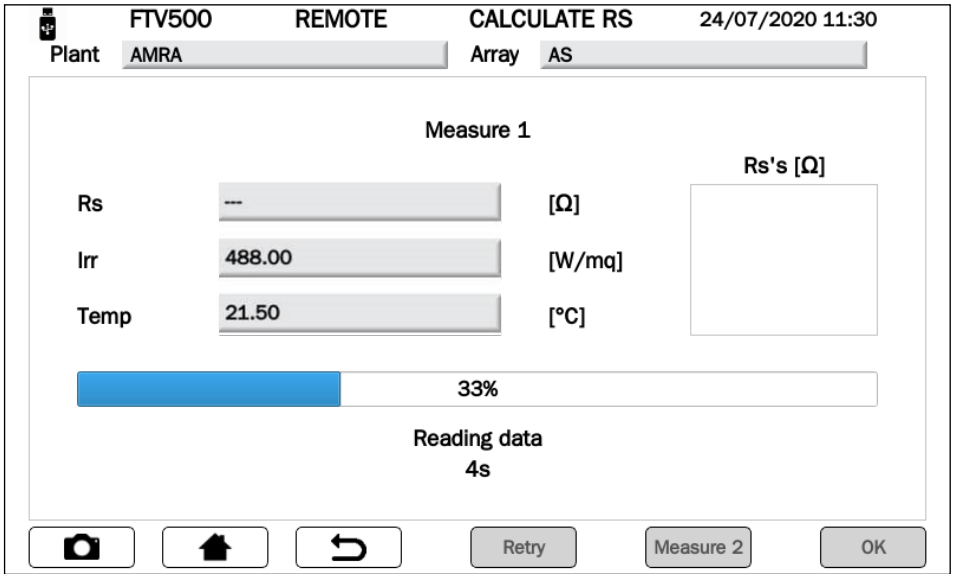


Figure 14.7.3-15 1st measurement Rs

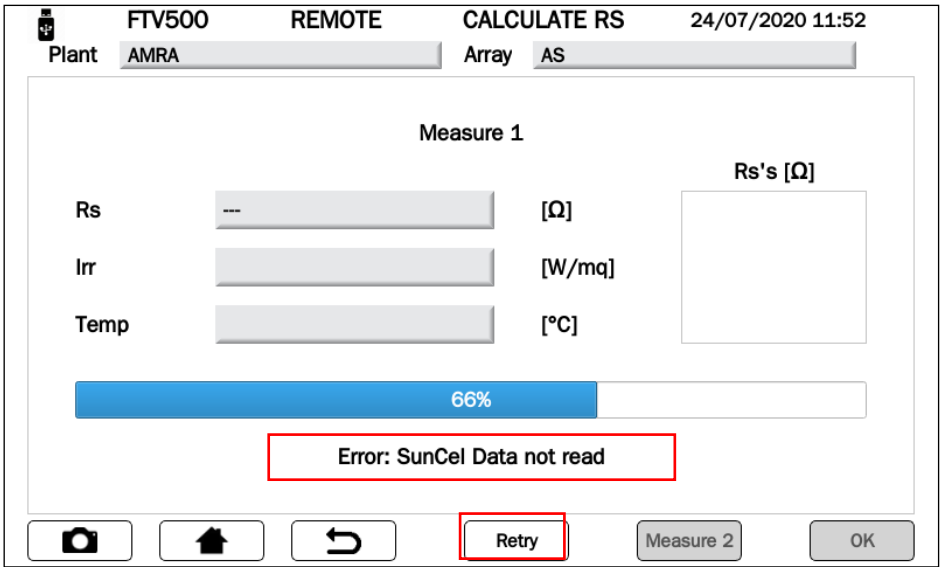
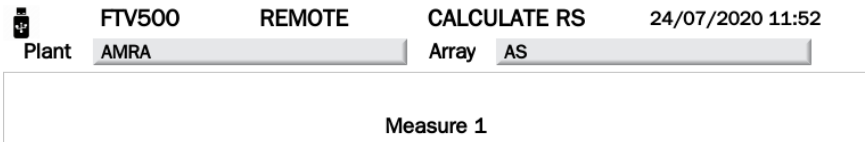


Figure 14.7.3-16 Error RS measurement

- If an error is displayed, press **Retry** to repeat the measurement (see Figures 14.7.3-16)



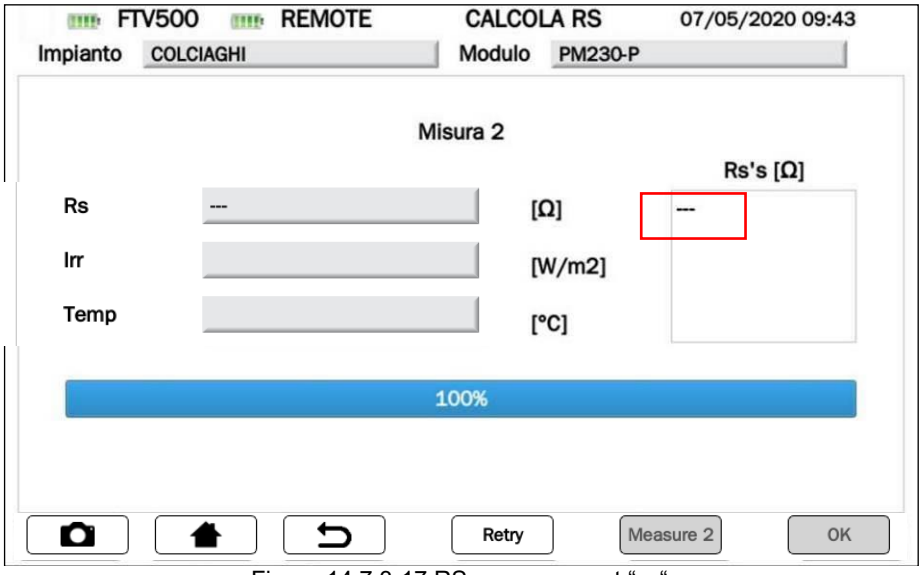


Figure 14.7.3-17 RS measurement "---"

- If the Rs measurement (see Figure 14.7.3-16) is not displayed, check:
  a. the correct positioning and synchronization of the remote unit
  b. that you have correctly followed the measurement procedure with the change of the irradiation values
- Press again key **Measure "x**" to launch the measurement again for the umpteenth time

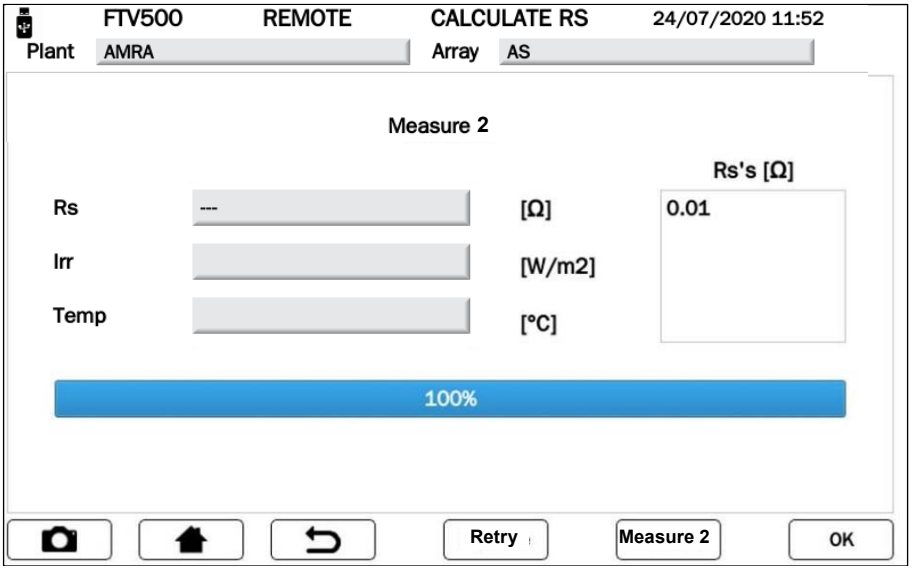


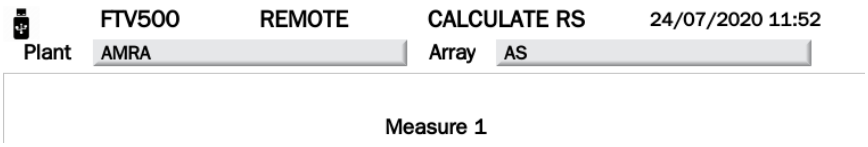
Figure 14.7.3-18 Rs measurement done

- At the end of Measurement 1 (100% completion rate), the Resistance value will be displayed and the Measure 2 key will be active.
  Press key **Measure 2** key to launch the test and, if the condition linked to the solar irradiation is respected (irradiation difference of at least 200 W / m2 in relation to Measure 1) the result of the RS resistance will be displayed.
  If the solar radiation value does not fall within the prescribed conditions, it will be necessary to repeat the Measurement and / or wait for the solar radiation to return to the suitable conditions as previously stated.

  NOTE: To be able to speed up and carry out Measure 2 without having to wait for the natural atmospheric variation of solar radiation, it is possible to use a screen, for example a polycarbonate sheet, which would cover the module under test and the remote unit that measures the irradiation, in order to filter the sun's rays, thus creating the right measurement condition.

- Press key Measure "x" (x stands for an umpteenth launch) in order to launch additional Rs measurements

  IMPORTANT: In order to get a more sophisticated analysis, it is recommended to perform multiple tests, until a stable value is reached.



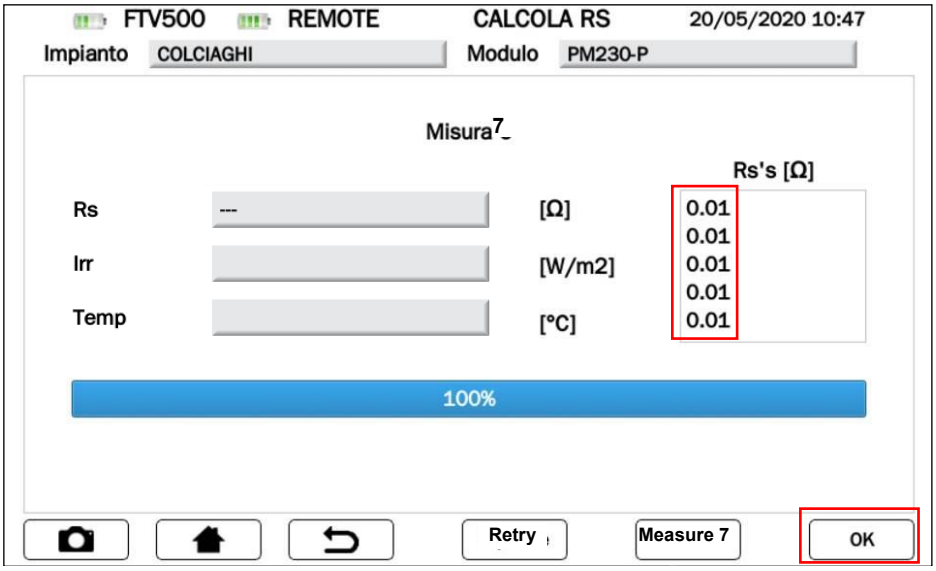


Figure 14.7.3-19 RS Measurement “x”

- NOTE: starting from Measure 2, and only if the result is displayed in "Ω" in the "Rs's" box, will the OK key be activated (see Figure 14.7.3-19), which if pressed will automatically perform the "Curve" test IV "
- NOTA: a partire dalla **Misura 2**, e solamente se verrà visualizzato il risultato in “Ω” nella casella “Rs’s”, si attiverà il tasto **OK** (vedi Figure 14.7.3-19), che se premuto eseguirà automaticamente il test “Curva I-V”

NEXT

After entering the module Degradation and after the Calculation Rs (Series Resistance) has been completed, press the button **Next** (see following figures) to display the screen with the measured values:

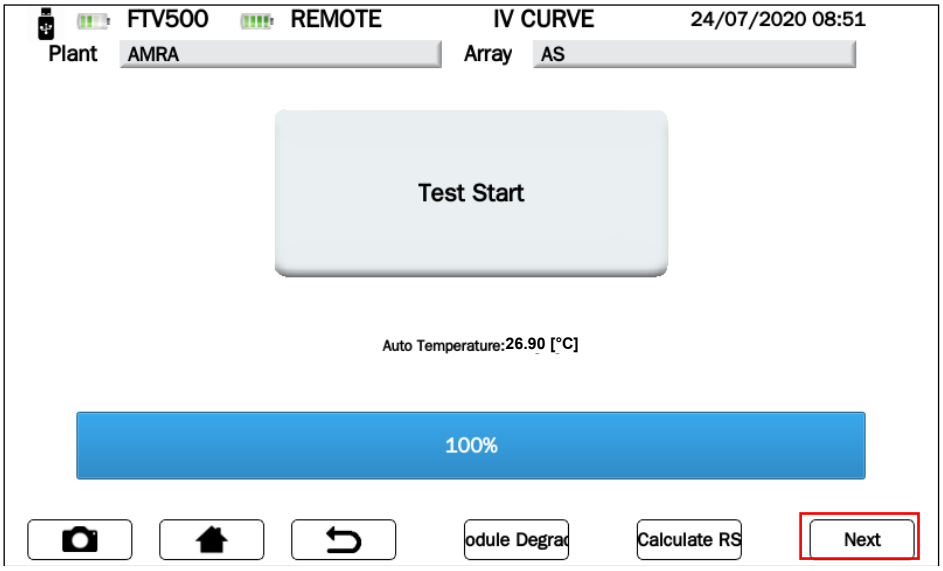


Figure 14.7.3-20 I-V Curve

- The measurement result is automatically "translated" to STC (Standard Test Condition), with conditions of irradiation of **1000W/m²** and module temperature of **25 ° C**.

  WARNING: to obtain meaningful measurement results, it is required to synchronize with the remote unit (OPC environmental data) and to link the measurements to a specific PV field saved in the instrument is required.
  In Rapid Test mode, only OPC values will be displayed

- According to the selection made (Module pr PV Array) two possibilities arise according to the type of measurement selected:

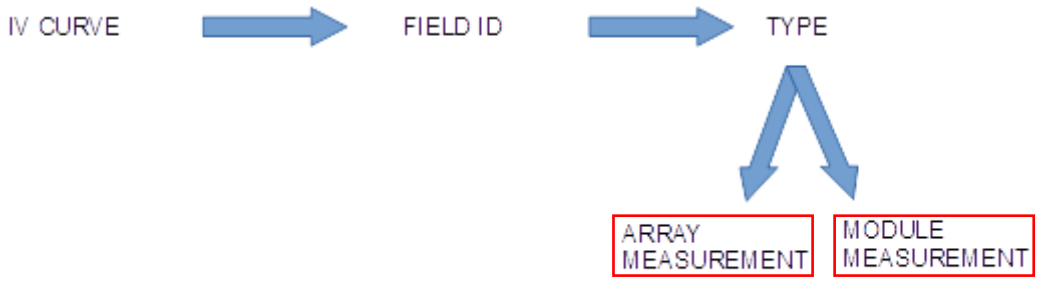


Figure 14.7.3-21 Selection of I-V curve measurement

- TEST carried out on a module (see Figures 14.7.3-21):
  Measurement of the module IV curve in the OPC test condition, translated to the STC conditions using the module specifications entered in the PV module menu (see chap.14.5)
  A comparison is then made between the maximum rated power (Pmax) and the corresponding power of the module translated to the STC conditions, taking into account the percentile tolerance declared by the manufacturer on the module at hand (see chapter 14.5)

- TEST carried out on PV-array (see Figures 14.7.3-21):
  Measurement of the PV-array entered in the PV module menu (see chap.14.5)
  A comparison is then made between the maximum rated power (Pmax) and the corresponding power of the module, which the PV-array is composed of, translated to the STC conditions, taking into account the tolerance (expressed as a percentage) declared by the manufacturer on the module at hand (see chapter 14.5)

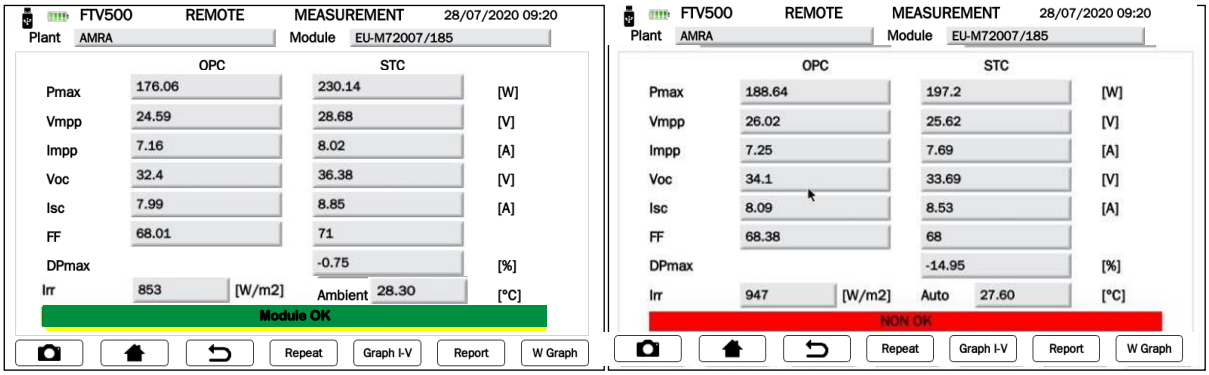
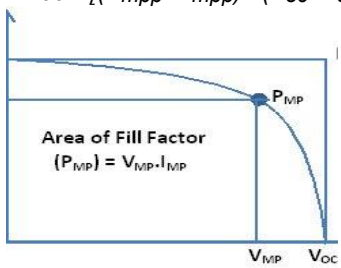


Figure 14.7.3-22 I-V Curve on a module

Tasto	Descrizione
Repeat	Repeats the I-V
Graph I-V	Returns to the I-V curve graph-voltage-current of Figure 14.7.3-23
W Graph	Returns to the power graph of Figure 14.7.3-24
Report	Saves the test result and measurement onto the instrument memory.

TABLE OF SYMBOLS - I-V CURVE TEST

Simbolo	Description	Unit of measurement
P_{max} OPC	Max measured power module/PV array	W
P_{max} STC	Max module/PV array power translated to STC	W
P_{nom}	Max module/PV array power @STC declared by the customer, after deduction of the	
V_{mpp}	Maximum Power Point Voltage (OPC & STC): voltage when the power output is the greatest in OPC or STC.	V
I_{mpp}	Maximum Power Point Current (OPC & STC): current when the power output is the greatest in OPC or STC.	A
V_{oc}	Open Circuit voltage (OPC & STC)	V
I_{sc}	Short-Circuit current (OPC & STC)	A
FF *	Fill Factor % (look at the graph below): Performance indicator of the single module/PV array	%
DPmax **	Difference % of maximum measured power (Pmax STC) from nominal power (taking the module performance degradation into account)	%
Irr	Irradiation	W/m2
T Module	Module temperature (if selected by the operator)	°C
T ambient	Ambient temperature (if selected by the operator)	°C
T manual	Manual entry of Module temperature (if selected by the operator)	°C

FF *	"Fill Factor" is defined as the ratio between the maximum power measured (V_{mpp} OPC x I_{mpp} OPC) and the open circuit power (V_{oc} OPC x I_{sc} OPC)	$FF = 100 * [(V_{mpp} * I_{mpp}) / (V_{oc} * I_{sc})]$ 
DPmax **	Validation parameter which defines the final test response	$DP\max = 100 * \left(\frac{P\max - Pnom}{Pnom} \right)$

- If the comparison falls within the degradation margin entered in the PV Modules menu, the test result will be "OK", otherwise "NO", with the consequence that the PV module does not meet the requirements declared by the manufacturer.

THE INSTRUMENT RELEASES THE FOLLOWING OUTCOMES OF THE MEASUREMENTS

OK	POSITIVE result : the result falls within the STC parameters declared by the manufacturer and entered in the "PV MODULES" menu
NO	NEGATIVE result : the test performed does NOT fall within the STC parameters declared by the manufacturer and entered in the "PV MODULES" menu

From screen showing the measure (Figures 14.7.3-19) it is possible to move on on, with key Graph or key W Graph, to the graphical screens displaying the I-V curves (current / voltage and Power) in OPC and in STC, as shown in the following pictures:

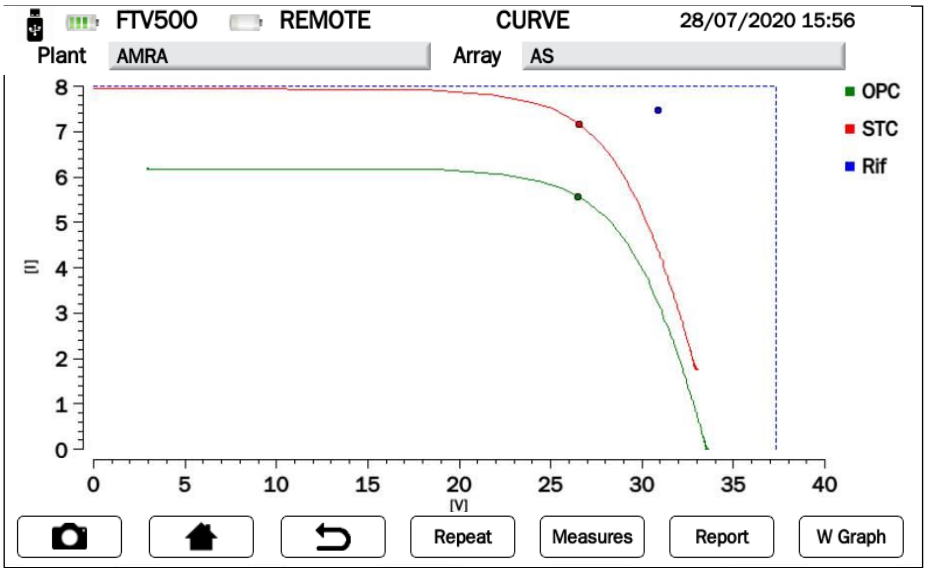


Figure 14.7.3-23 Graphical menu Current-Voltage

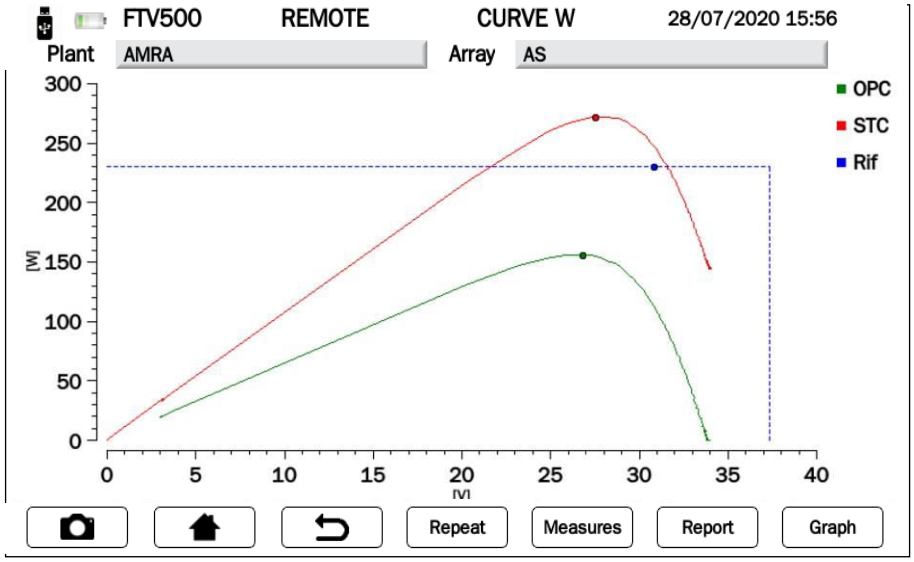


Figure 14.7.3-24 Graphical menu Power-Voltage

Tasto	Descrizione
Measures	Return to the numerical measurements as in Figure 14.7.3-19
Graph	Return to the graphical measurements current-voltage as in Figure 14.7.3-20
W Graph	Return to the graphical measurements Power-Voltage as in Figure 14.7.3-20
Report	Saves the test results and measurements onto the instrument memory.

Legenda delle curve visualizzate:

■ OPC ■ STC ■ Rif	**OPC (green)**: Curve drawn in the current measurement conditions (OPC)
	STC (red): Curve drawn by translating the current measurement values (OPC) to the standard conditions (STC) using the formulas indicated in the standard EN 60891
	Rif (blue): Rectangle described by the Isc (ordinate) and Voc (abscissa) taken from the module datasheet

- The operator can press Report to save the measured data (curves + numerical measurements) onto the instrument's memory, as in the following figures:

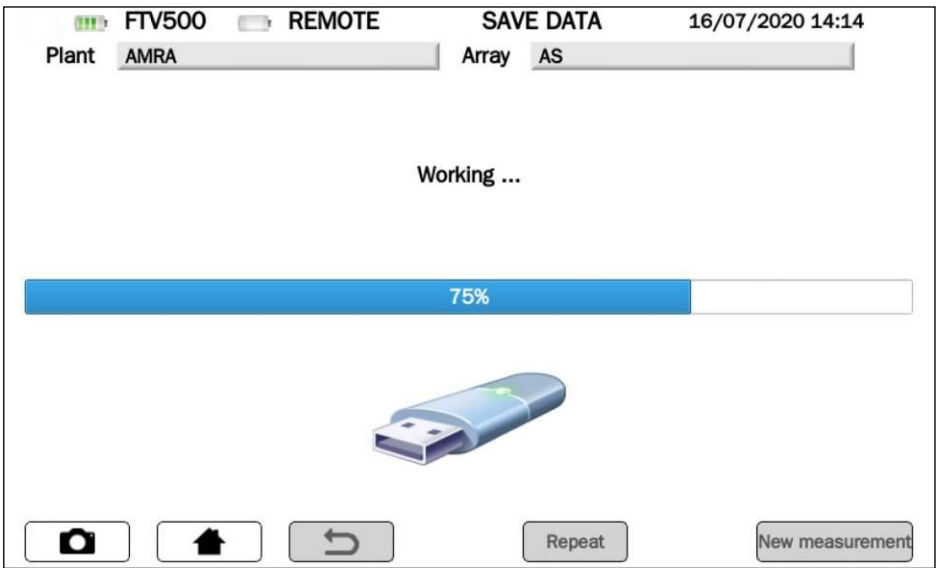


Figure 14.7.3-25 Saving in progress

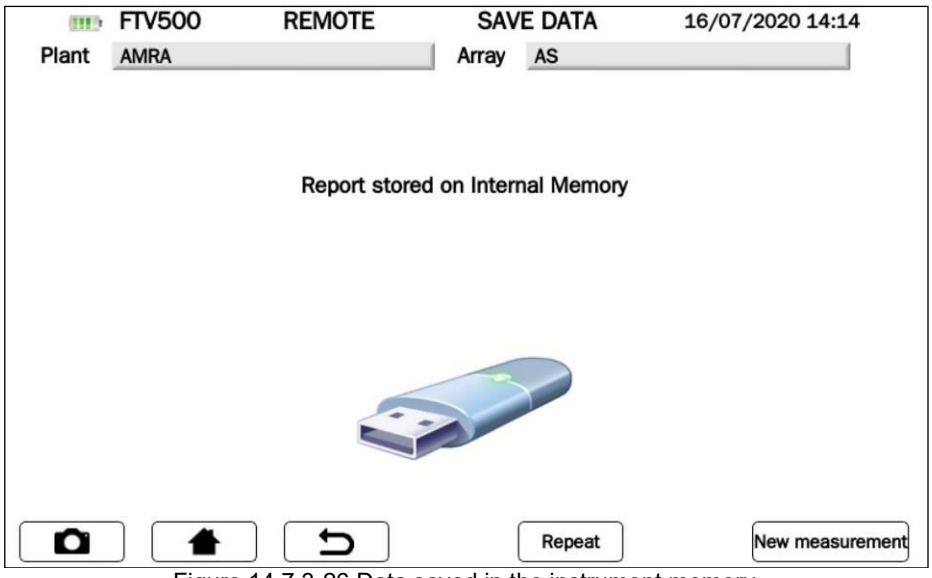


Figure 14.7.3-26 Data saved in the instrument memory

14.7.4 PV RAPID TEST

The PV rapid test allows a quick and simplified analysis of any possible issues.
This function performs a rapid test of a PV panel / field, measuring only the no-load voltage and the short-circuit current in accordance with the provisions of the IEC / EN62446 standard.

MEASUREMENT OF HIGH EFFICIENCY MODULES

High-efficiency modules require care when measuring I-V curves because of the high capacitance, which can lead to errors in the results. While producing a short but intense current pulse at the beginning of each measurement may prevent the current/voltage graph from being plotted correctly.
During the I-V curve test, the PHOTOVOLTAIC TEST FTV500 instrument repeats the measurement 500 times, going from the extremes of the short-circuit current point (Isc) to the no-load voltage point (V0).
The PHOTOVOLTAIC TEST FTV500 instrument has a maximum current input for the I-V test of up to 20 A (limited to 10A in the presence of high-efficiency modules)
Module strings with efficiencies greater than 19% limit the maximum current input of the PHOTOVOLTAIC TEST FTV500 instrument to 10A.
If high-efficiency modules (>19%) are present, the inrush current coming from the module/string will be very high, and the automatic sequence of repeating the measurement causes spikes and a buildup of current that interfere with the linear trend of the values on the I-V graph, making curve analysis difficult in some cases.
In such cases, to properly appreciate the I-V measurement values, it is recommended to perform the measurement using the RAPID PV TEST function.
Or to obtain a reliable CURVE I-V graph, reduce the string current and voltage:

- separate strings, or reduce the number of modules in the string
- orient the tracker toward less irradiance if possible
- measure at the beginning or end of the day to get lower irradiance

WARNING DURING USE

- A dangerous potential is always present in the photovoltaic system.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the sring under test

In OPC conditions, this test measures the no-load voltage (open circuit) and the short circuit current (forcing the PV module / field in short circuit).

The instrument is able, with the data of the module and the PV field, to trace the measurements back to the STC conditions, making it immediately visible to the user if there are problems of "discrepancy" (mismatching) between the modules or other problems of the individual modules, related to the connection between them.

NOTE: In the case of "n" modules in series, the Voc measured by the test should correspond to approximately n times the measured Voc

IMPORTANT: in Rapid Test mode the OPC values only will be showed.

- Press key
- Press key PV Rapid Test to select the measurement

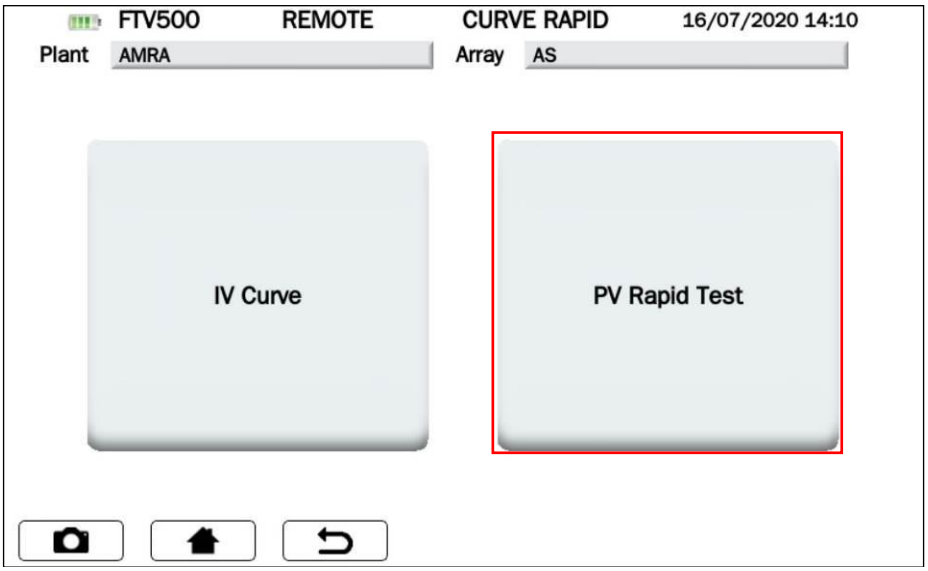


Figure 14.7.4-1 Selection of PV Rapid Test

- Press **Synchronize Remote Unit** to start synchronization (always check the correctness of the temperature and radiation values which are shown on the display at the end of the synchronization procedure, which will then be used for the final test result calculations)
- Press Skip to bypass the remote unit synchronization request and go directly to the measurement screen (see Figure 14.7.4-3)

  IMPORTANT: By skipping the synchronization, the instrument will not acquire the values of the environmental measures, and consequently the calculations will not be reliable

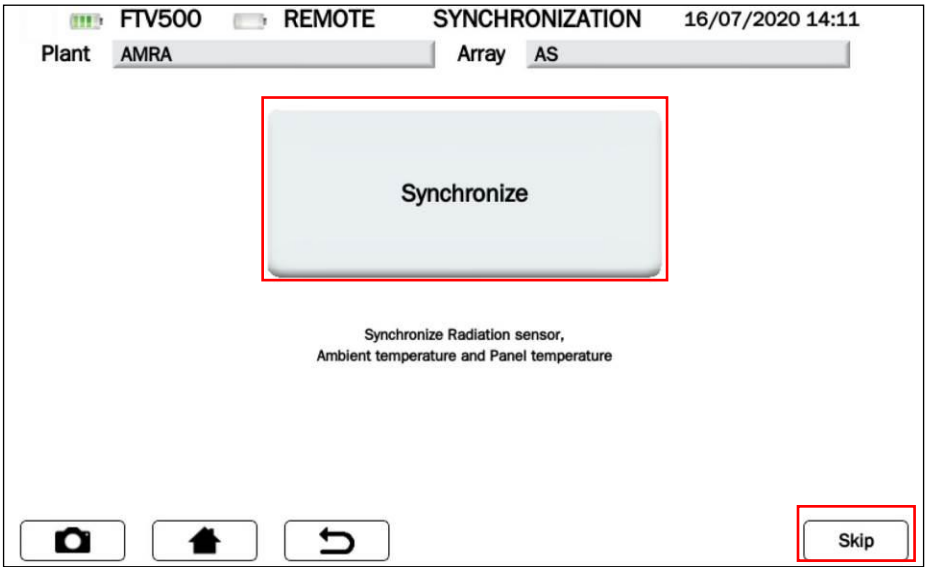


Figure 14.7.4-2 Remote Unit synchronization

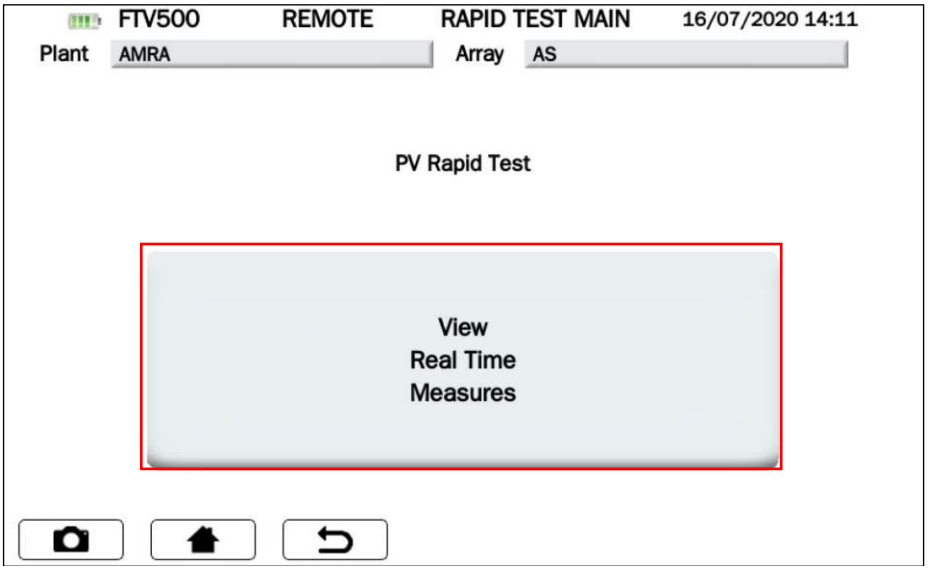


Figure 14.7.4-3 Visualization of real time measurements

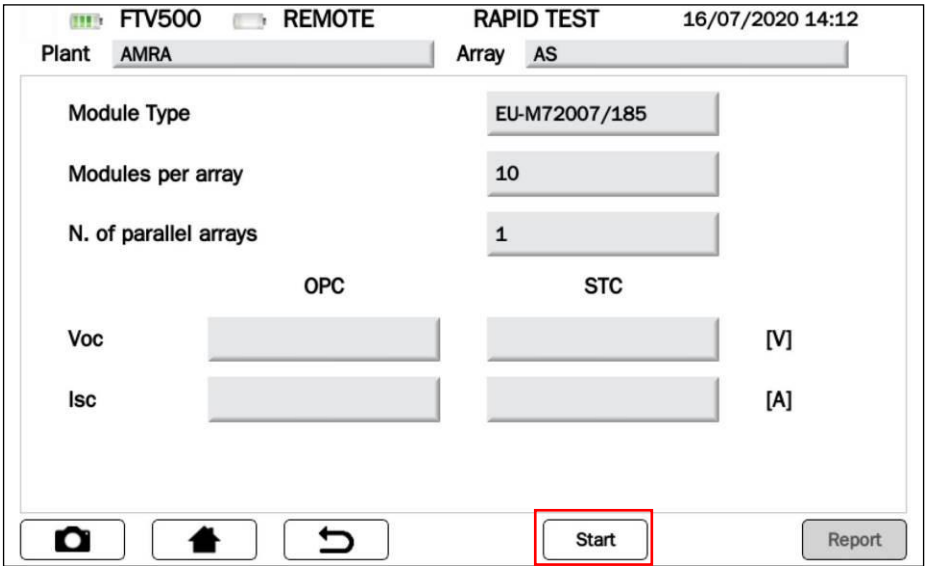


Figure 14.7.4-4 PV Rapid Test Start

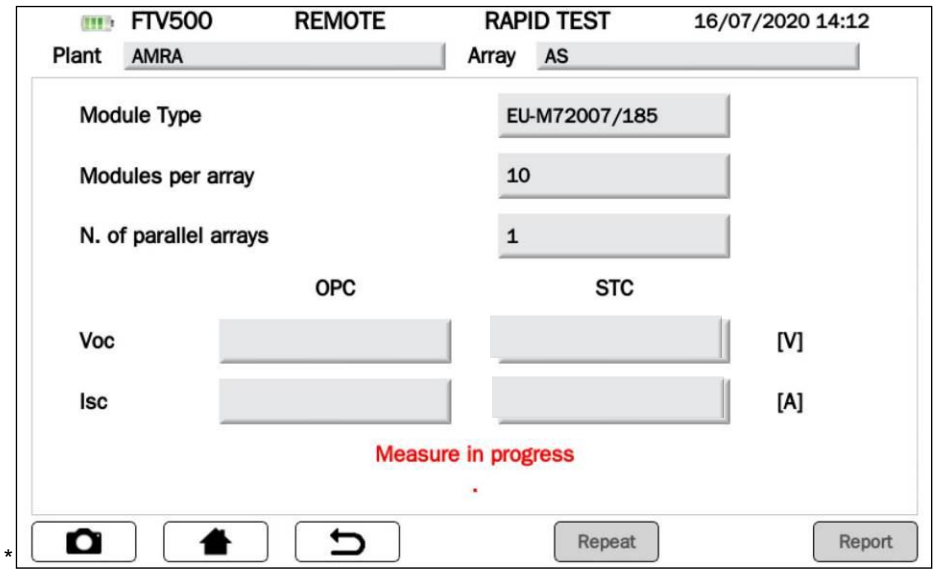


Figure 14.7.4-5 PV Rapid Test in progress

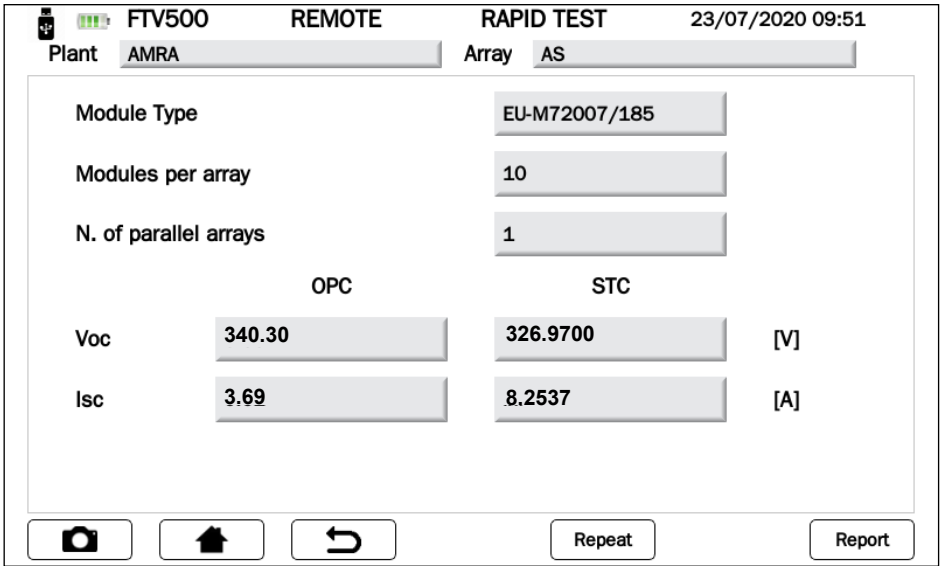


Figure 14.7.4-6 PV Rapid Test results

TABLE OF SYMBOLS	Description
Voc	Open circuit voltage of the module/string (V)
Isc	Short-circuit current of the module/string (A)
OPC	Operative test Conditions
STC	Standard test Conditions
Repeat	Repeat the measurement in Figure 14.7.4-5
Report	Storage of the test result on the instrument memory. The button is active only after the test has been correctly carried out.

- the operator can press button Report to save the measurement in the internal database, see the following pictures:

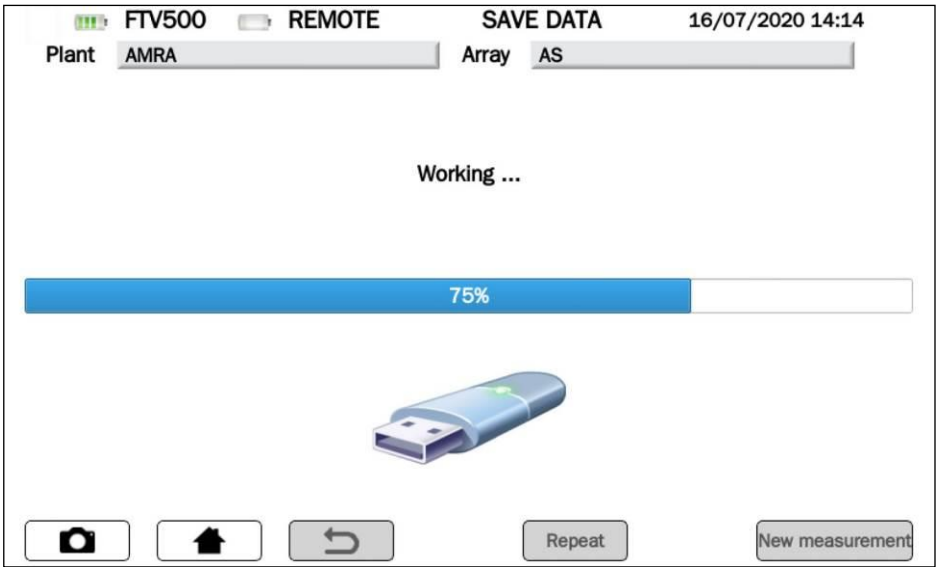


Figure 14.7.4-7 Saving in progress

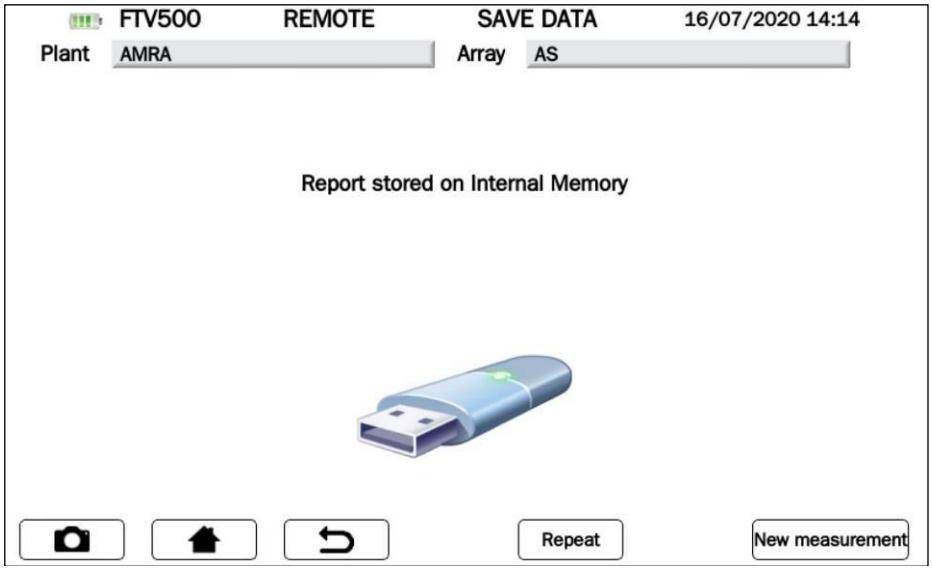


Figure 14.7.4-8 Saving done

14.7.5 INSULATION AND CONTINUITY

INSULATION: The purpose of this measurement is to carry out the insulation resistance measurement of the module / string / PV field power conductors and any metal carpentry not connected to earth in accordance with the requirements of CEI 82-25 Guide, CEI 64-8 and IEC/EN62446 standards.

CONTINUITY: The purpose of this measurement is to carry out the continuity test of the protective and equipotential conductors and the grounding conductors of the surge arresters of the PV installations. The test is performed using a test current> 200mA in accordance with the requirements of the Guide CEI 82-25 and the standards CEI 64-8 and IEC / EN62446

WARNING DURING USE

- A dangerous potential is always present in the photovoltaic system.
- It is recommended that you perform a preliminary check to ensure the instrument is functioning properly before taking a measurement by short-circuiting the (+), (–), and G terminals to verify that the insulation resistance is nearly zero, and by opening the (+), (–), and G terminals to verify that the reading is off-scale.
- Before and after any measurement and operation, always open the DC disconnect switch (see attachement 18 – Electrical Connections) to electrically isolate the combiner box, and use a voltmeter to verify that the combiner box is isolated
- Always remove power from the circuit before connecting the instrument (open the DC disconnect switch and all protective fuses before connecting measurement leads)
- Use only with isolated PV circuits (no ground connection)
- The maximum voltage between the inputs is 1000VDC. Do not measure voltages that exceed the limits expressed in this manual
- The maximum current that can be tolerated by the instrument is 20A DC. Do not perform tests on strings of PV modules connected in parallel
- Limit strings of high-efficiency modules to <10 A (see measure I-V)
- Before making any measurements, ensure that the potentials present in the circuit under test are compatible with the safety and range characteristics of the instrument
- IEC/EN62446-1 requires measurements to be made on a module-by-module basis. If you decide to test a complete string, make sure that the voltage and current potentials are compatible with the instrument ranges
- In accordance with IEC/EN 62446-1, the test voltage Vtest must be ≥ the system's rated voltage
- Before connecting measurement cables to the circuit under test, check that the desired function has been selected
- Electrically insulate strings under test when measuring on an inverter
- Remove all fuses except for the sring under test

Following screen allows to enter the continuity measurement:

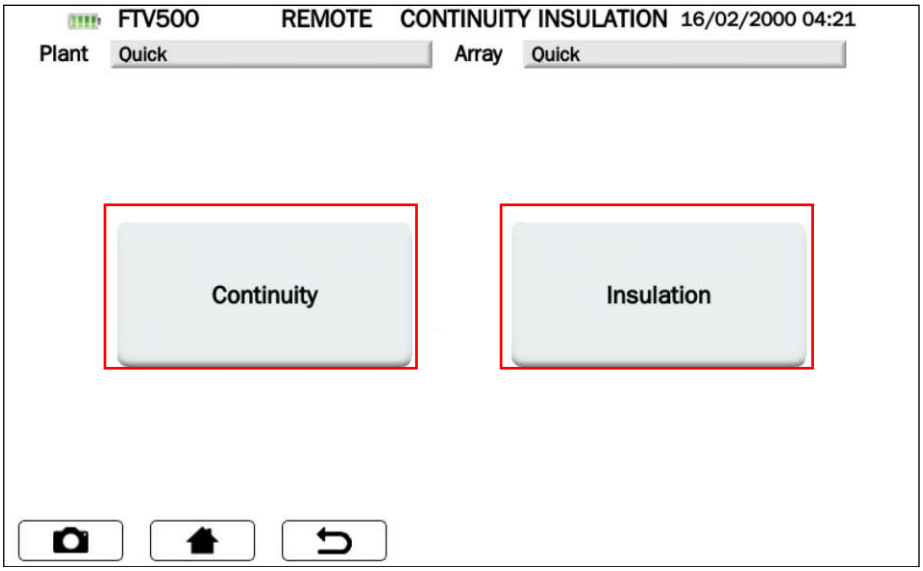


Figure 14.7.5-1 Continuity and insulation main menu

Key	Description
Continuity	ContinuityTest, see Figure 14.7.5-2
Insulation	Insulation test, see Figure 14.7.5-3

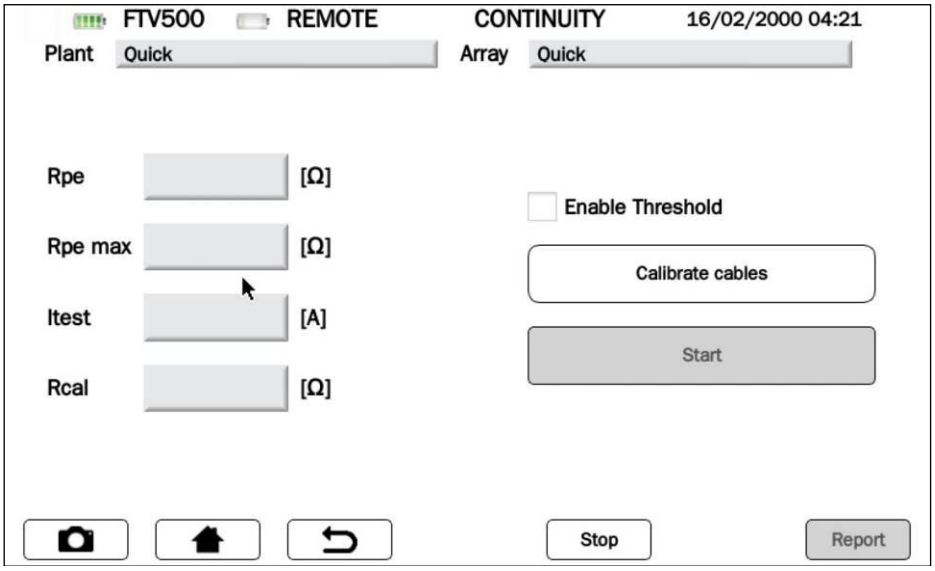


Figure 14.7.5 Continuity measurement

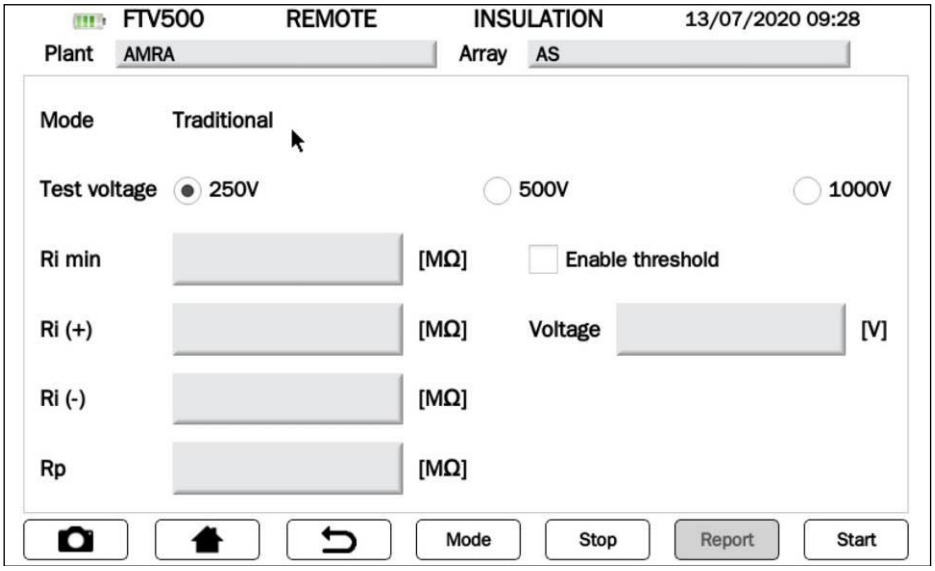


Figure 14.7.5-3 Insulation measurement

14.7.5.1 INSULATION TEST

This test is carried out to evaluate the insulation resistance of PV modules and PV fields and therefore assess the efficiency of a photovoltaic array, according to standards: IEC/EN 62446. IEC/EN 61557-4, CEI 64-8/6.
Furthermore, it is also possible to carry out the insulation test of the electrical circuits from the earth; the purpose is to ensure that the insulation resistance of the system is adequate to the values prescribed by Standard CEI 64-8/6; the measurement must be performed between each active conductor, or each group of active conductors, and the earthing system with an imposed DC voltage (250-500-1000VDC.).

HOW TO PROGRAM THE INSULATION TEST:

- Select the test voltage to be used during the measurement: the value is to be selected between 250-500-1000VDC. The applied voltage must be higher than the DC voltage present in the connected system (example: string voltage 450Vdc, select test voltage 500Vdc)

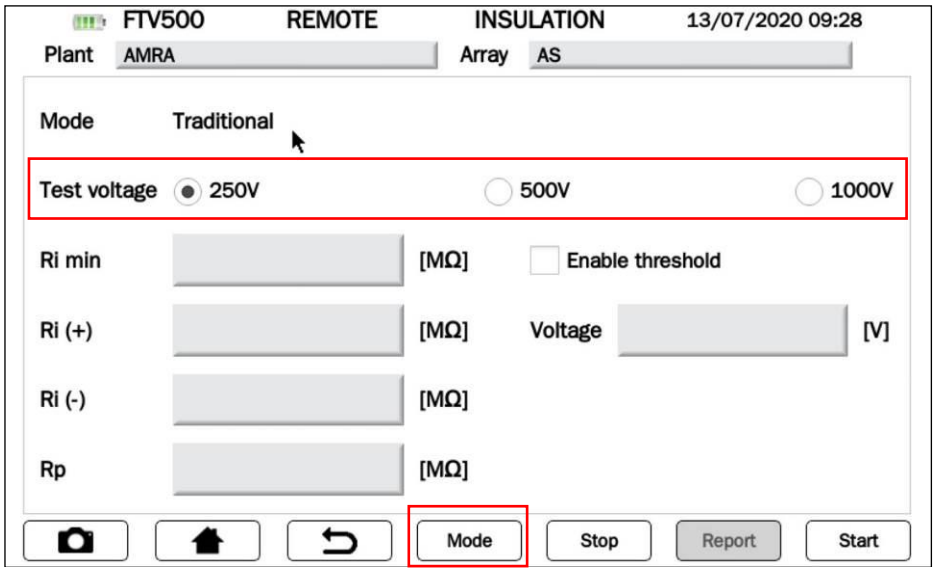


Figure 14.7.5-1 Insulation measurement

- Select the mode to carry out the test (press **Mode** button):

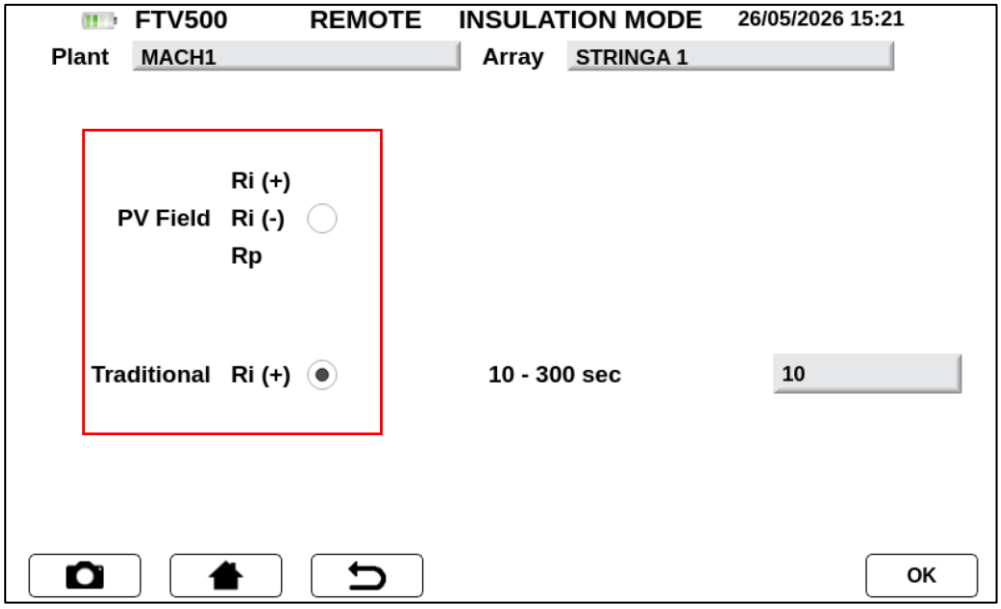


Figure 14.7.5-2 Test mode selection

Mode	Description
PV Field	Used to measure the insulation resistance of individual PV modules or strings. The instrument automatically measures the insulation resistance to ground and displays the results: Ri(+), Ri(-), and Rp
Traditional	The instrument performs the measurement in the traditional manner (with a duration set by the operator) and displays the result: Ri(+)

- In order to get a measurement outcome (OK / NO) at the end of the test, enter the minimum threshold limit value (MΩ) in the **Ri min** field, clicking onto the field to access the numeric keypad, and confirming the value by pressing the button Confirm

- Enable the threshold by enabling the relative field: ☑ Enable threshold

NOTE: Chosing to enter the threshold is optional, it is possible to carry out the tests even without a final outcome.

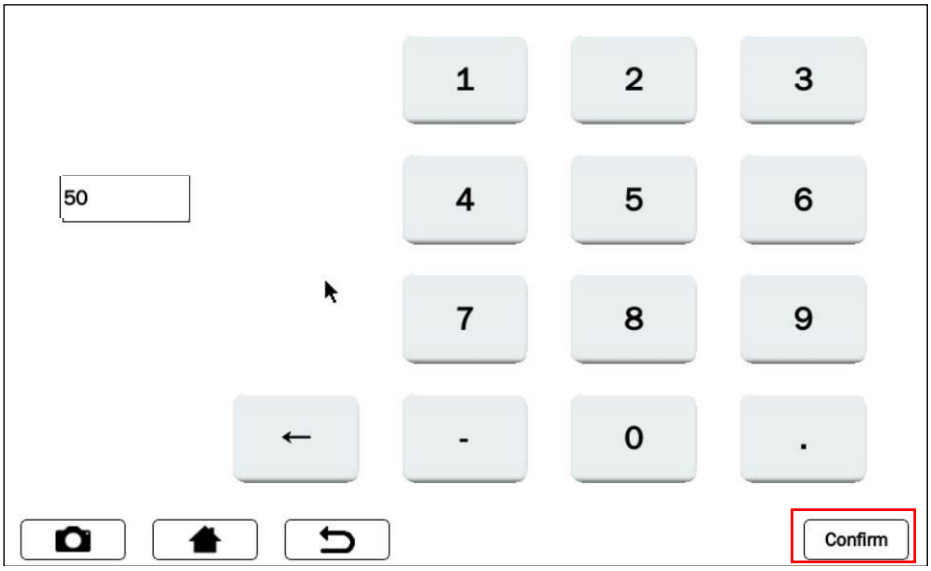


Figure 14.7.5-3 Keyboard to enter the Ri min value

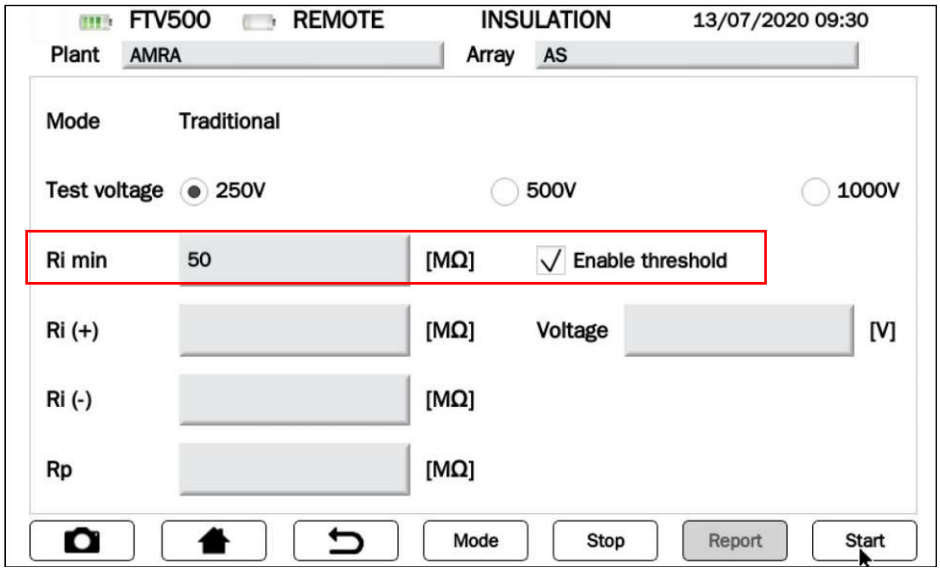
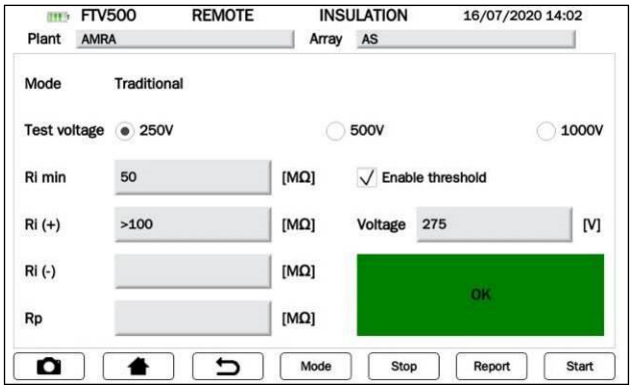


Figure 14.7.5-4 Entering and enabling an insulation resistance treshold

At the end of the test, the result is shown in the lower right corner of the screen:



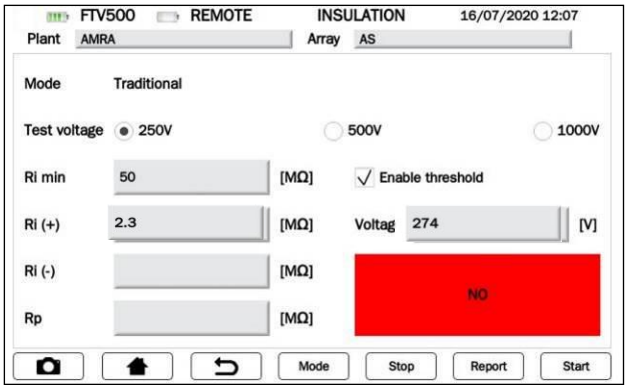


Figure 14.7.5-5 Test outcome

Outcome	Description

OK	Measurement result [Ri(+) or Rp] > Ri min
NO	Measurement result [Ri(+) or Rp] ≤ Ri min

➢ You are now ready to carry out your insulation test.

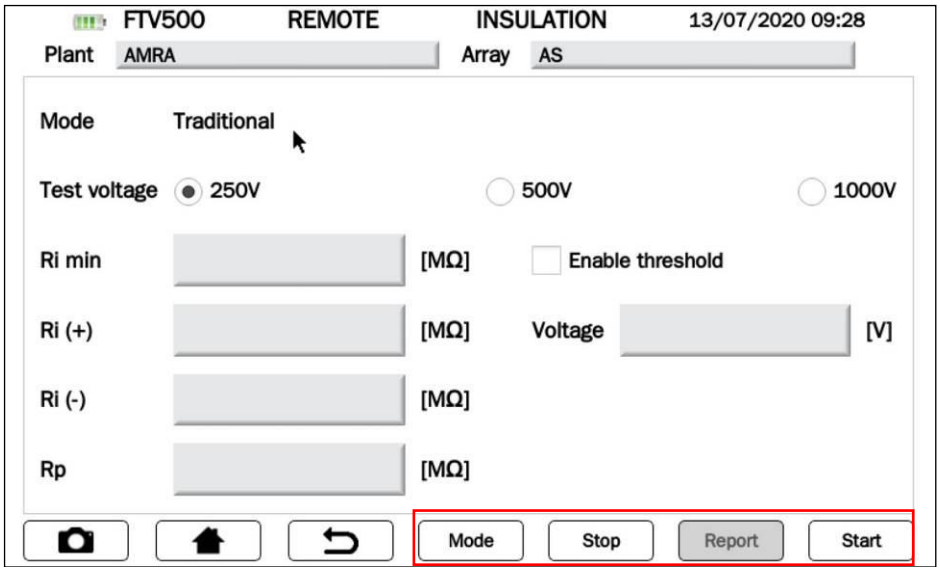


Figure 14.7.5-6 Insulation measurement start

The keys on the screen in Figure 14.7.5-6 have the following functions:

Mode	Test mode Selection: PV Field, Traditional
Stop	Immediate interruption of the current test being in progress (measurement commenced), premature interruption of the test in this way does not allow to obtain any result.
Report	Storage of the test result on the instrument memory. The button is active only after the test has been correctly carried out.
Start	Commencement of the test defined by **Test mode**. After the test has started, the button is disabled until its scheduled end – i.e. for a test with a programmed execution time.

Press Start to start the measurement:

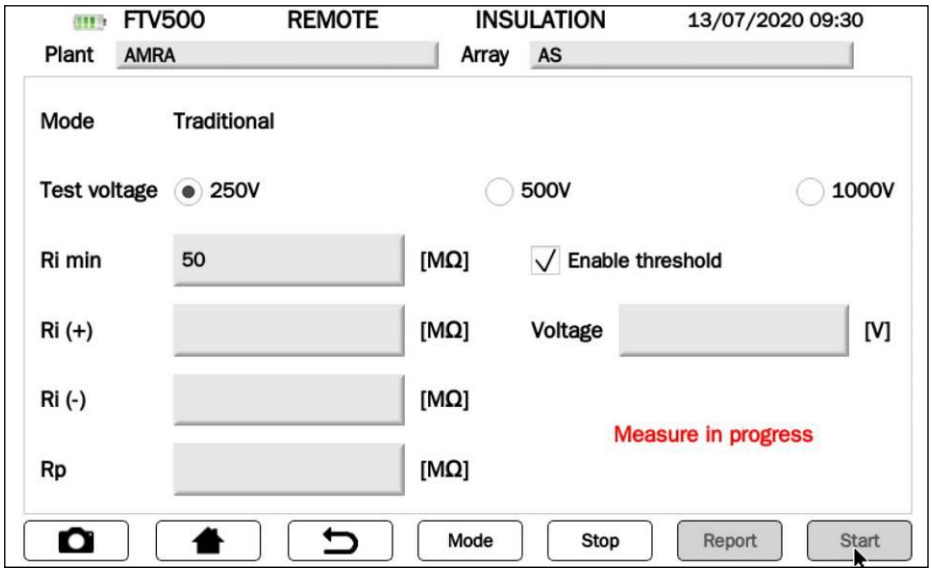


Figure 14.7.5-7 Measurement in progress

TABLE OF SYMBOLS - INSULATION TEST

Field	Description	Unit of measurement
Plant	Master data of the plant, see measurement selection (Cap. 14.7)	---
Array/ Module	Selected Array or Module belonging to the chosen plant, see Chapter 14.7	---
Mode	Selection made among: PV field, Traditional	---
Test voltage	Voltage used for the among three alternatives: 250-500-1000V DC	V
Ri min	Treshold arranged by the customer (used to give outcome OK/NO to the test, when enabled)	MΩ
Ri (+)	Insulation resistance between positive pole and earth	MΩ
Ri (-)	Insulation resistance between negative pole and earth	MΩ
Rp	Parallel resistance calculated using Ri (+) and Ri (-)	MΩ
Enable treshold	Minimum limit, to assign test outcome	---
Voltage	Current voltage used by the instrument to carry out the test	V
Test result	Only shown if "Enable treshold" is activated and Ri min set	---

HOW TO CARRY OUT THE INSULATION TEST (for the connections please look Annex B):

It is always recommended to perform a preliminary check to ensure the instrument is functioning properly before taking a measurement by short-circuiting the (+), (–), and G terminals to verify that the insulation resistance is nearly zero, and by opening the (+), (–), and G terminals to verify that the reading is off-scale.

➢ MODE PV FIELD

Connect terminals +, - and G and start a new test pressing button [Start]:

This mode is used for insulation measurement of a PV field (photovoltaic generator) formed by one or more strings (set of modules connected in series or parallel).

The instrument performs the measurements:

- Between the Positive pole of the PV field and the earth, identified by Ri (+)
- Between the Negative pole of the PV field and the earth, identified by Ri (-)
- Displays the value of Rp: parallel of Ri (+) and Ri (-)

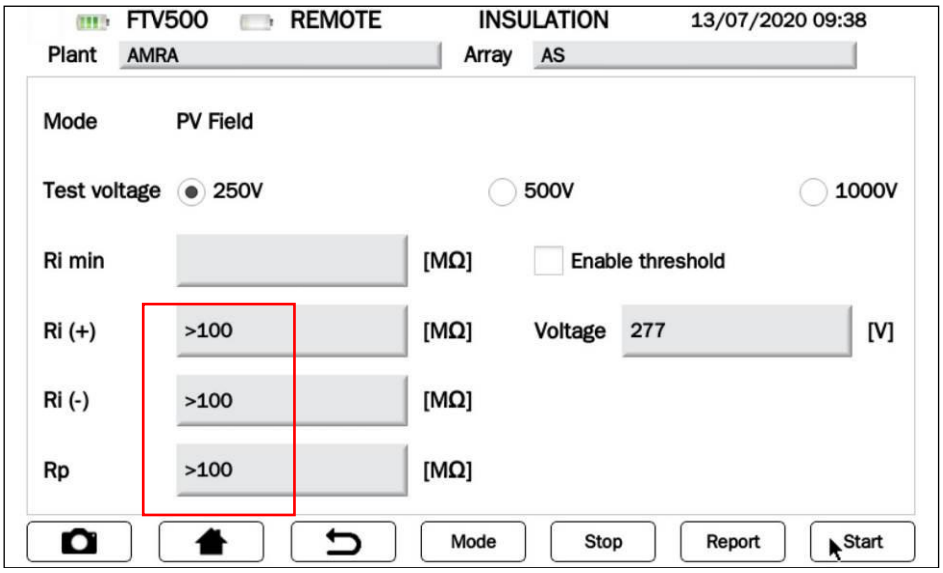


Figure 14.7.5-8 Insulation measurement in PV FIELD mode

The results shown are:

- Ri (+), Ri (-) = Measured value if the measurement is included between 0 and 100 MΩ
- Ri (+), Ri (-)>100 MΩ if the measured value is out of the measurement range
- Rp= Calculated value (parallel of Ri (+), Ri (-)) if the measurement is included between 0 and 100 MΩ
- Rp >100 MΩ if both the measured values are out of the measurement range

NOTE: it is possible to obtain the test result (OK / NO) by following the instructions from Figures 14.7.5-4 on how to enter and enable the minimum threshold limit

IMPORTANT: with Measure in progress (see Figures 14.7.5-7), dangerous voltage is present at the terminals.

To save the measurement in the database, at the end of the test press key Report

Report	Saves the test result and measurement onto the instrument memory. Key active after the correct execution of a measurement.

➢ **TRADITIONAL MODE**

Connect terminals + and G and launch the test by pressing Start :

This is the classic insulation measurement with pre-set test duration. The instrument carries out the measurement in continuous mode (with programmable duration) displaying the minimum measured resistance value at the end of the selected period of time. It can be used for the measurement of insulation resistance of several conductive paths, which are not connected to the earth reference.

The instrument carries out the meausurement between + Pole of the PV field - Ri(+) -and the ground reference (G)..

This mode implies the programming of the duration, as in Figure 14.7.5-9.

Press on the time field (s) to access the numeric keypad, and confirm the value entered by pressing the key Confirm , as in Figure 14.7.5-9.

Press later key OK to validate the configuration andf return to the main screen Insulation Figure 14.7.5-8.

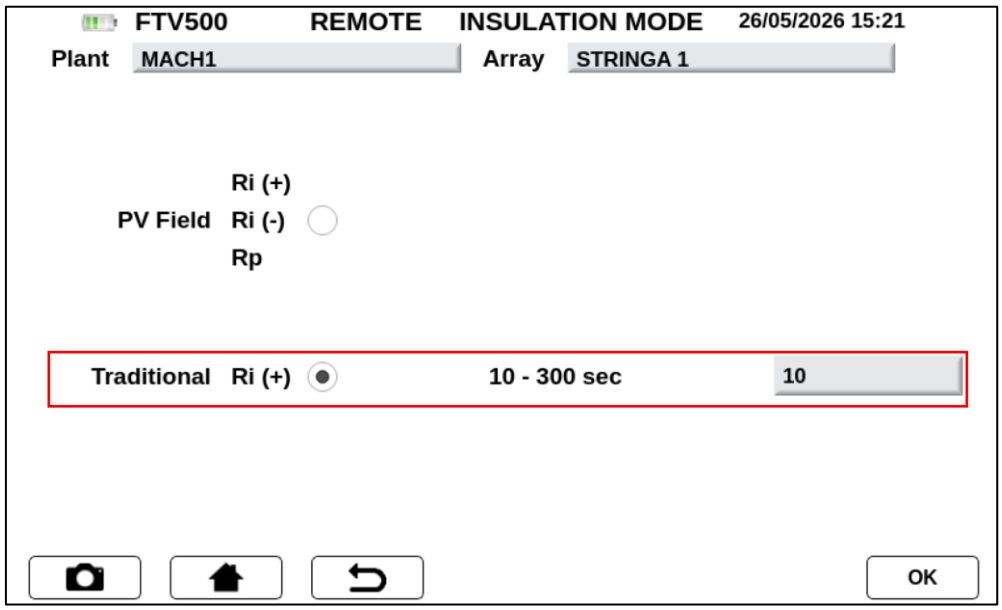


Figure 14.7.5-9 Programming Traditional insulation mode

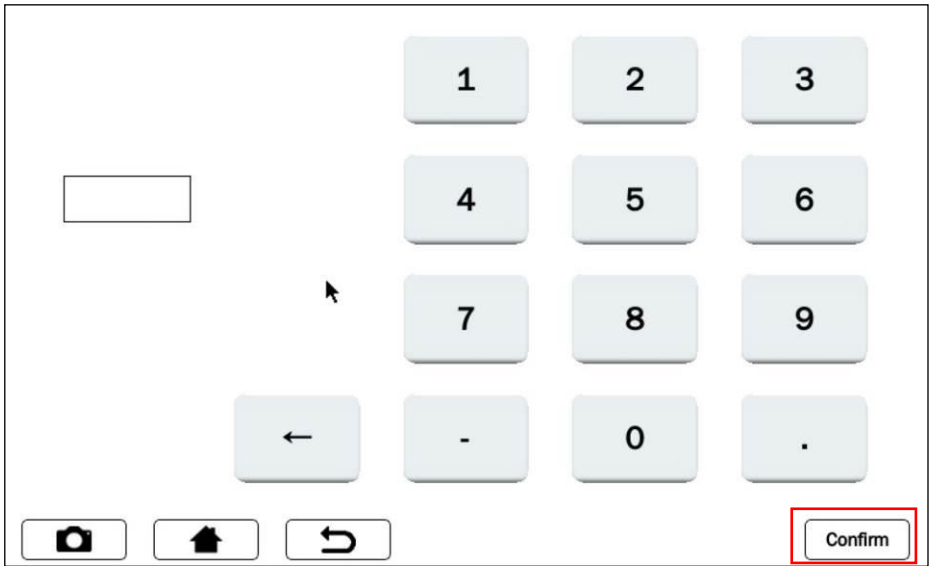


Figure 14.7.5-10 Voltage application time

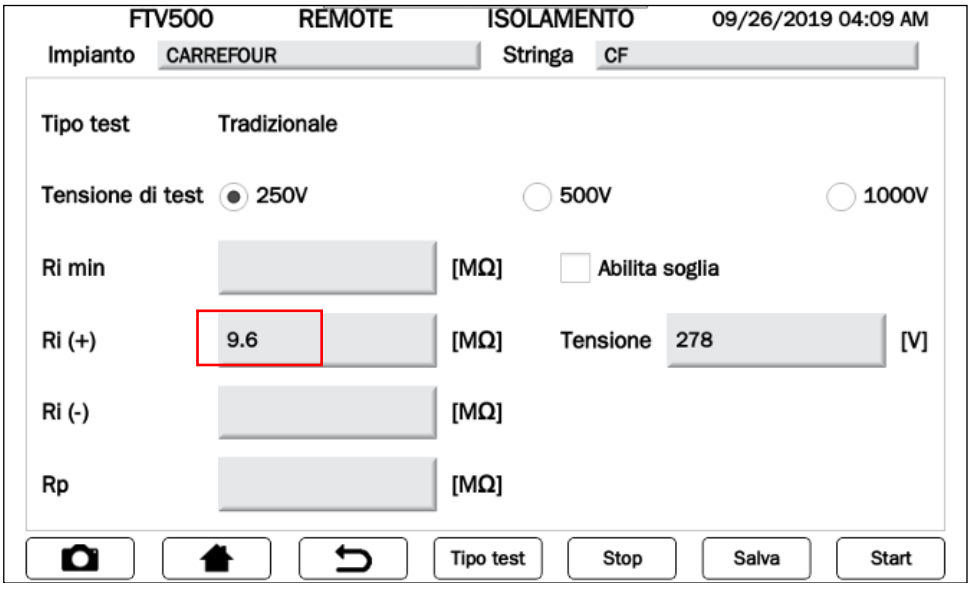


Figure 14.7.5-11 Measurement in TRADITIONAL mode

The showed result is:

- Ri (+)=Measured value (resistance included in the range between 0 e 100 MΩ)
- Ri (+) >100 MΩ if the measured value is gretaer than the instrument range

NOTE: it is possible to obtain the test result (OK / NO) by following the instructions from Figures 14.7.5-4 on how to enter and enable the minimum threshold limit

IMPORTANT: with Measure in progress (see Figures 14.7.5-7), dangerous voltage is present at the terminals.

To save the measurement in the database, at the end of the test press key Report

Report	Saves the test result and measurement onto the instrument memory. Key active after the correct execution of a measurement.

14.7.5.2 CONTINUITY TEST

The purpose of running this measurement is to make the continuity test of the protective and equipotential bonding and the grounding conductors of the surge arresters on the PV installations.
The test must be performed using a test current> 200mA in accordance with the requirements of Guide CEI 82-25 and standards CEI 64-8-7 and EN 62446.
To make the test select **CONTINUITY** from the CONTINUITY AND INSULATION measurement on the screen in Fig. 14.7.5-1.
The main menu of the continuity measurement is represented below:

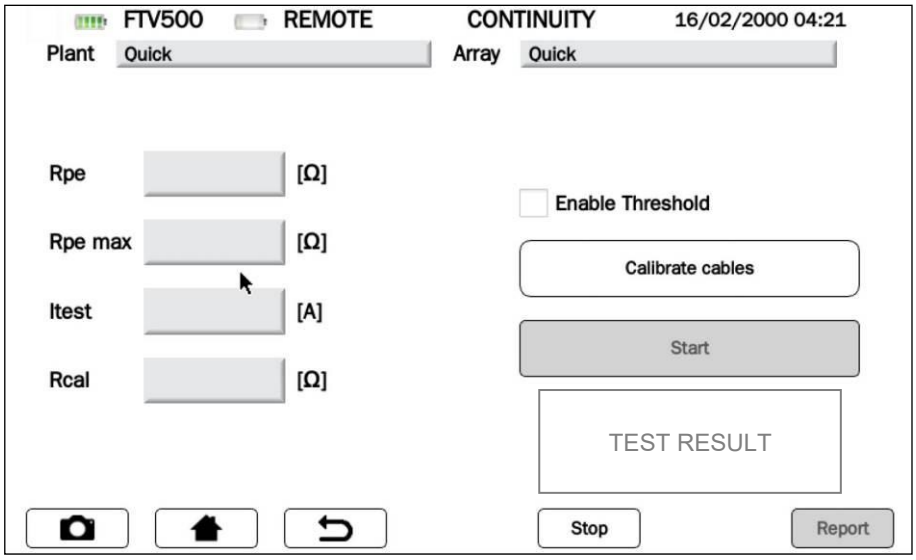


Figure 14.7.5.2-1 Continuity measurement

The parameters in this menu are:

TABLE OF SYMBOLS- « CONTINUITY » MEASUREMENT

Field	Description	Unit of measurement
Plant	Plant selected in the Measurement selection (see Chap. 14.7)	---
Array/Module	PV array or Module selected in the Measurement selection (see Chap. 14.7)	---
Rpe	Resistance value measured with current flowing in both directions, as required by EN 61557-4	Ω
Rpe max	Threshold value set by the operator (only active if the ENABLE THRESHOLD parameter has been checked)	Ω
Itest	Test current	A
Rcal	Lead resistance value (**see lead nulling procedure**)	Ω
Enable treshold	If checked a Test result is issued (passed if Rpe is lower than Rpe max)	---
Test result	Test result is issued after the measurement is made and if "Enable treshold" is checked and Rpe max is entered by the operator	---

I tasti presenti nella screen di Figure 14.7.5.2-1 hanno le seguenti funzioni:

Stop	Abort the test while it is in progress
Start	Launch the continuity test: when the test has already started, the button is disabled until it is ended, or if the user stops it with the Stop button
Report	Savethe continuity test result
Calibrate cables	Nulling of resistance test lead resistance, before carrying out the continuity test (see description)

CONTINUITY MEASUREMENT

- Before starting a continuity test, the first operation to be perfomed is **NULLING TEST LEAD RESISTANCE.**

This is required because the test leads used to run the continuity measurement, or the probes/clips used to connect to the measurement points, can vary their resistance in different environmental conditions (temperature, humidity, etc.) or over time (aging ofn the cables); or because at a certain point other accessories (test leads and/or probes) are used instead of the original ones.
Nulling the test leads is required before each series of continuity measurements or if the measurement accessories are replaced during a measurement session.
To null the test leads it is required to connect the leads to the instrument's terminals and short the test probes or clips.

The result of the compensation is displayed by a reading issued in the Rcal box:

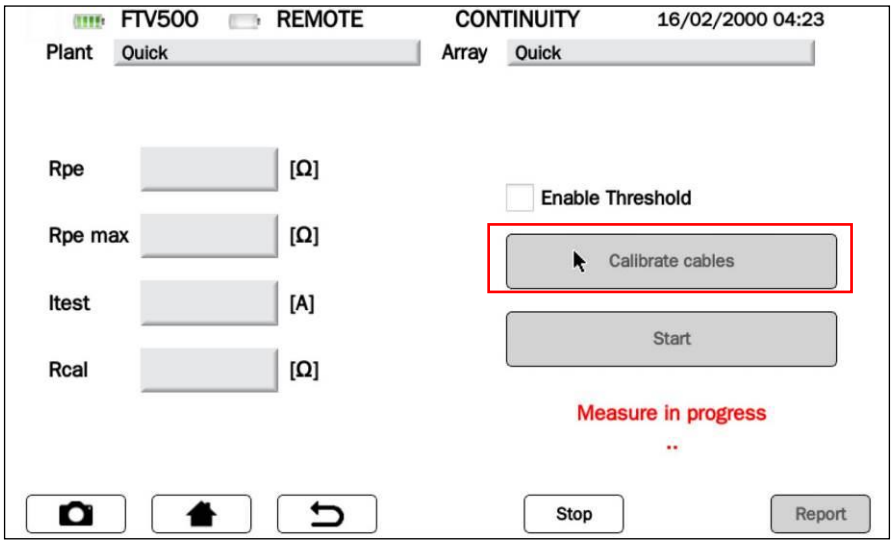


Figure 14.7.5.2-2 Nulling test lead resistance

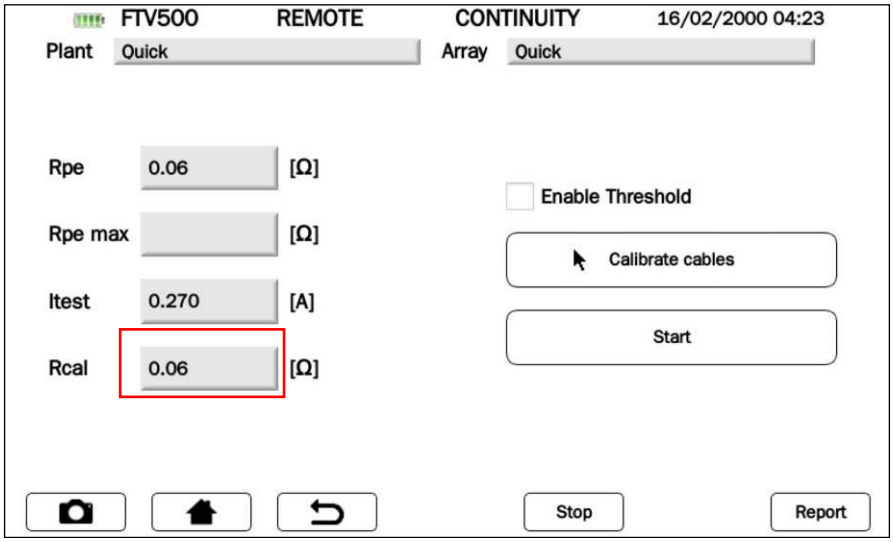


Figure 14.7.5.2-3 Lead compensation done

- Press **Start** key to confirm continuity test start:

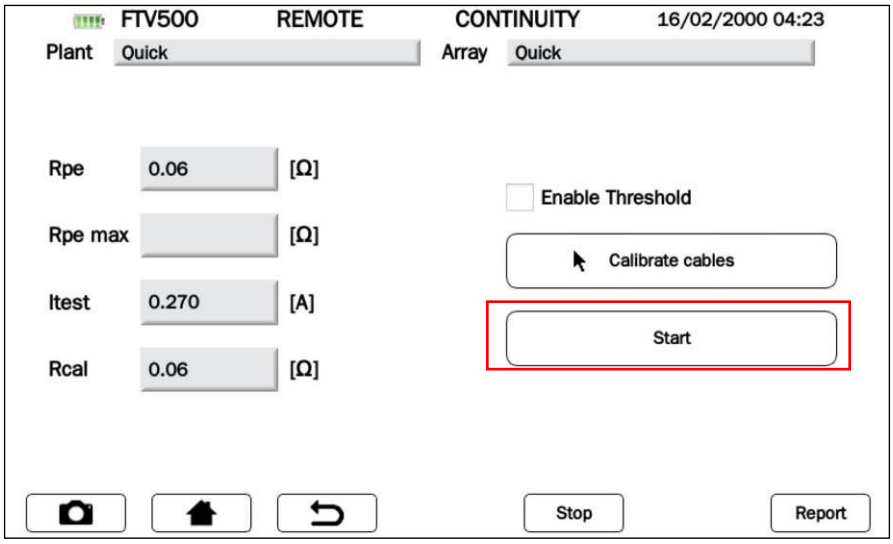


Figure 14.7.5.2-4: Starting Continuity test

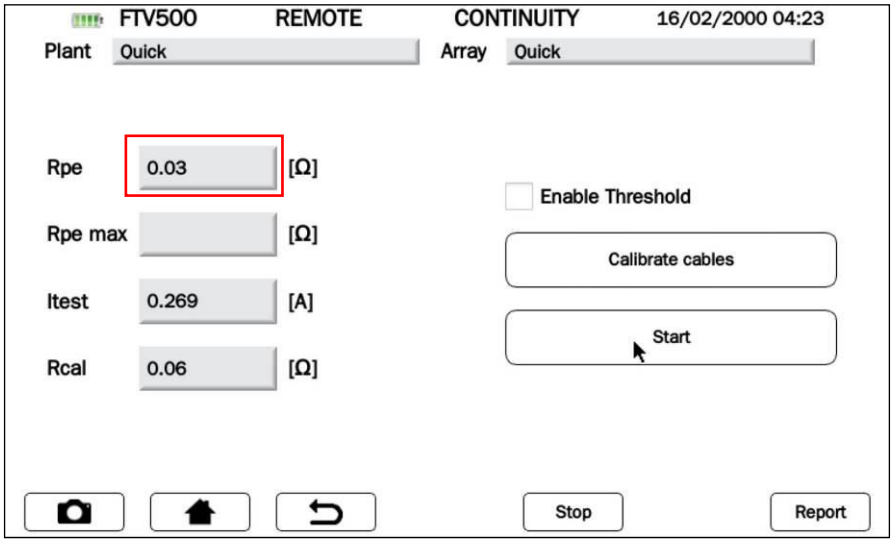
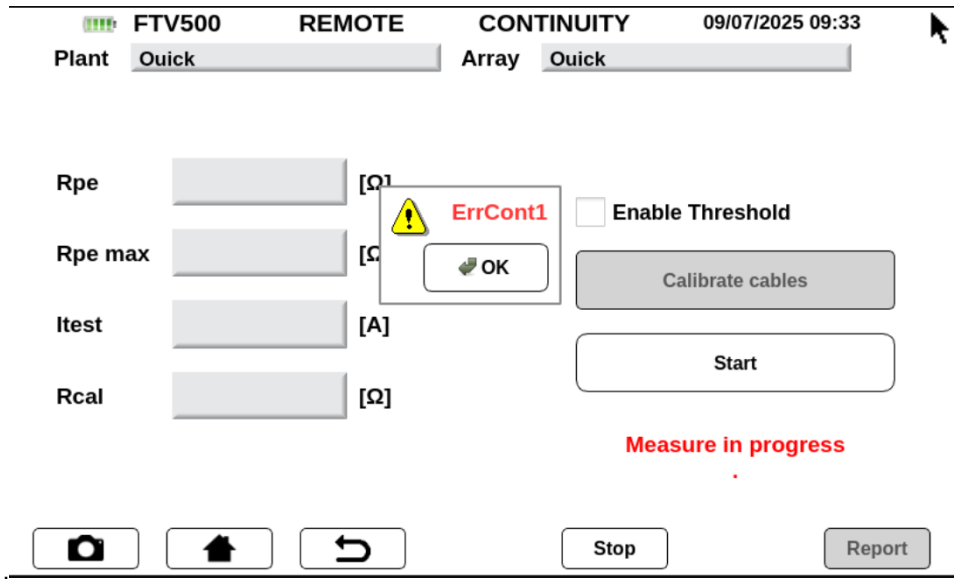


Figure 14.7.5.2-5 Continuity test outcome

WARNING: The test cannot be performed if the system is live. Be sure to perform the test with the system completely de-energized



<u>HOW TO ENABLE THE MEASURE TRESHOLD</u>, to get an immediate outcome from the test:

- select **Enable threshold** (by clicking on the squared box as shown in Figures)
- click on the **Rpe max** field, and use the numeric keypad that is displayed to enter the desired value
- press **Enter** to confirm the value:

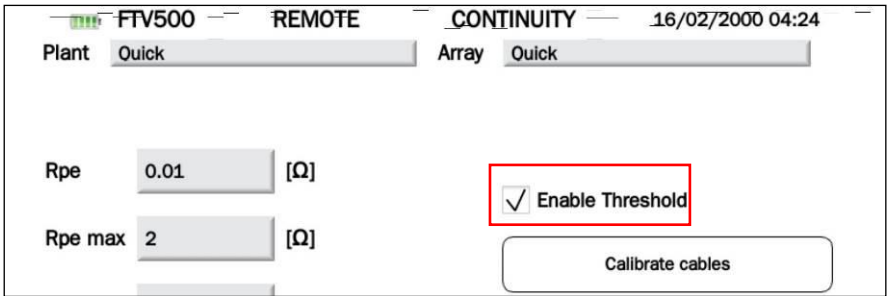


Figure 14.7.5.2-6 Screen; Resistance treshold in continuity test enabled

The test result will be visible in the lower right corner of the screen, with the outcomes:

i. **OK** (green box): Measure outcome Rpe < Rpe max

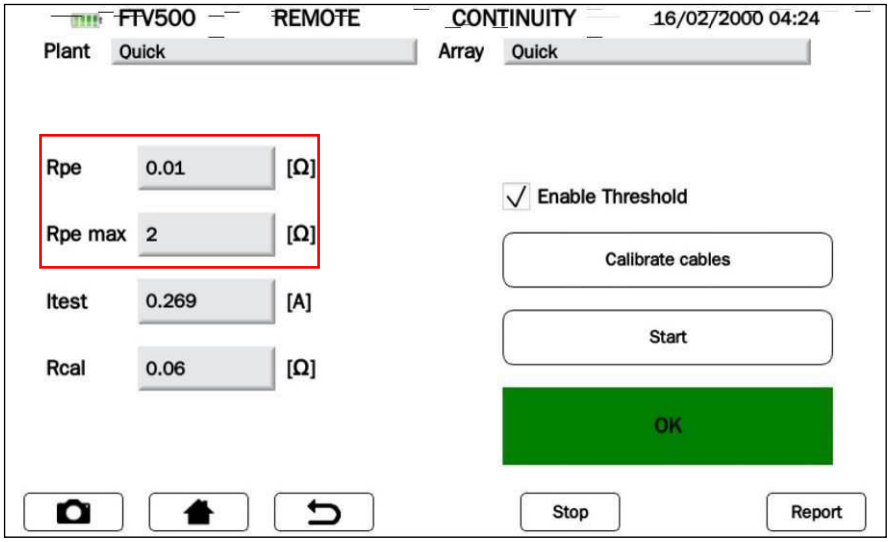


Figure 14.7.5.2-7 Continuity test passed

ii. **NO** (red box): Measure outcome Rpe ≥ Rpe max

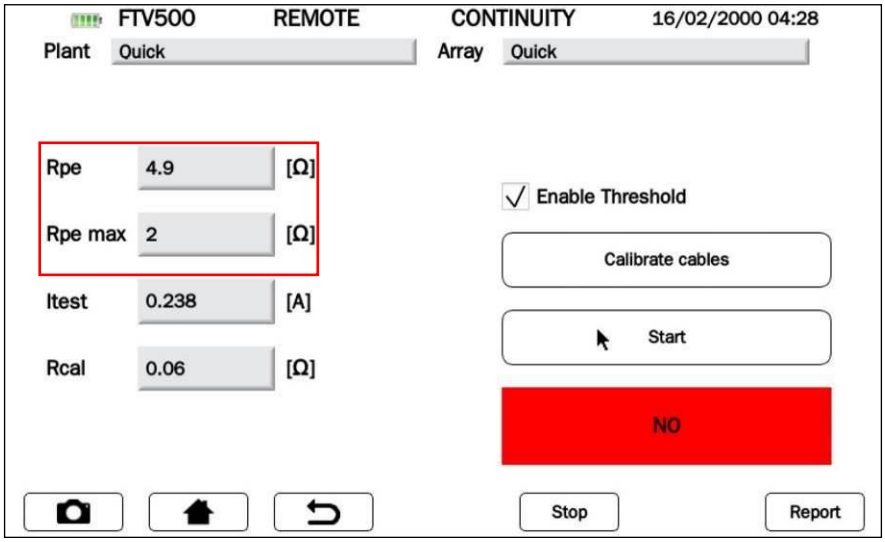


Figure 14.7.5.2-8 Continuity test failed

- the operator can press button Report to save the measurement in the internal database, see the following pictures:

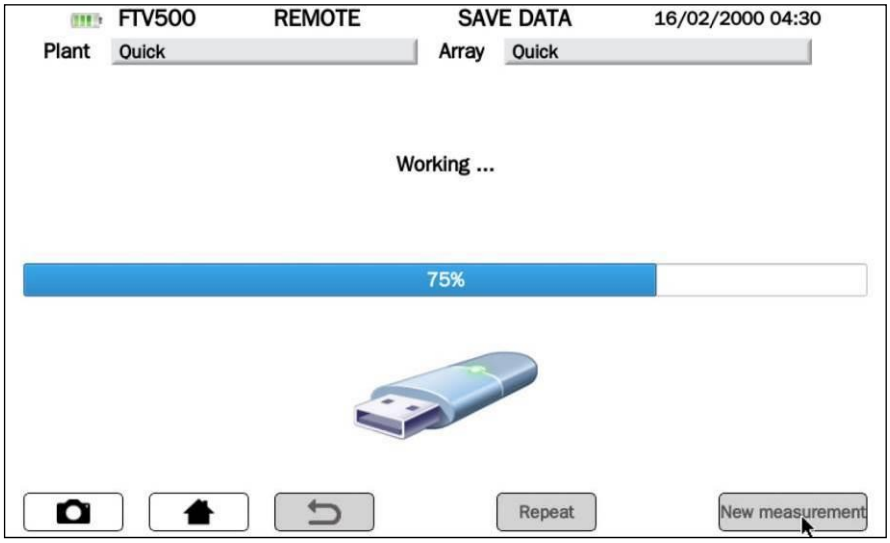


Figure 14.7.5.2-8 Screen: Storage in progress

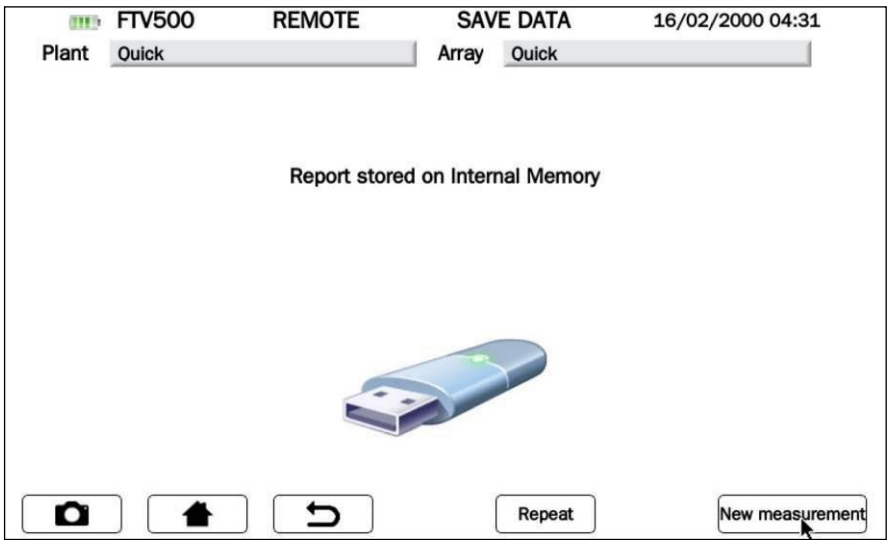


Figure 14.7.5.2-9 Storage of measures into the instrument's memory

14.8 BROWSE DATA

It was previously outlined that, after the execution of the measures, these could be stored in the instrument memory immmediately after their execution.

This allows the measures to be saved individually for later use in the automatic reports (properly time-stamped, i.e. with the date and time of execution, as well as with the association with the system and components the series of measurements were made on). The report templates are in Annex C.

Saving the measures made in a single day on a single system produces a session of measures, that is, a series of measures, even if of a different type, with a common date and reference.

To see the archive, press the **Browse Data** button on the Home screen:

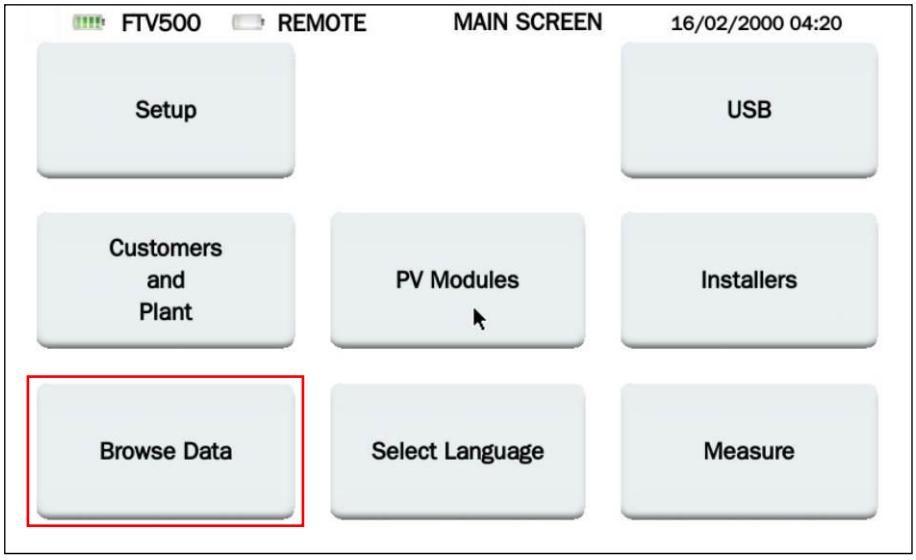


Figure 14.8-1 Home: Selection of Measurements Database

The next screen shows all the measurements currently present in the instrument's memory, which can be consulted through the sidebar:

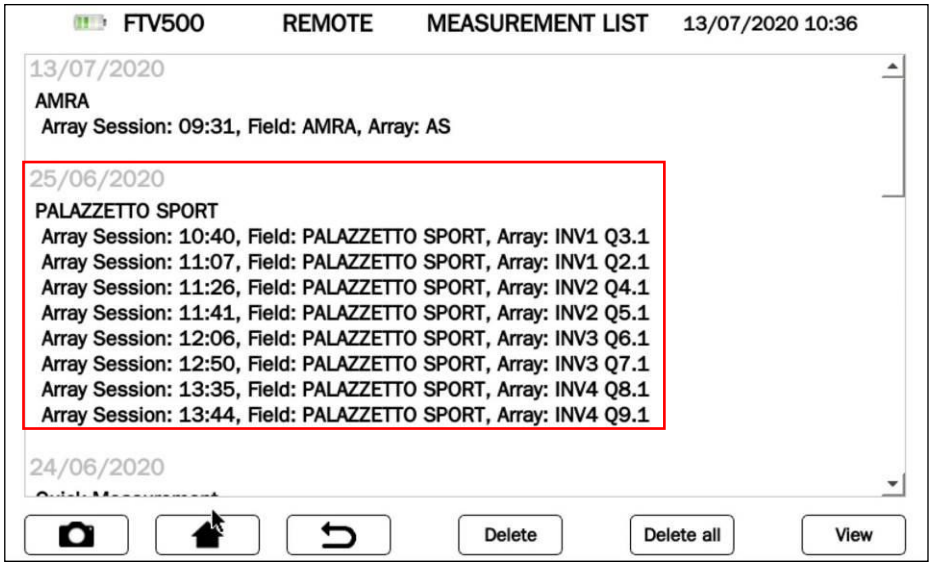


Figure 14.8-2 Measurement List

Each measurement is identified by (see Figures 14.8-2):

1. Execution date (in gray color, common to all measurement carried out on the same day)

2. Plant identification defined in the master data

3. Type of Session performed (module or PV field)

The measures are in chronological increasing order. If one or more measurements have been performed on different systems (even if on the same date) these will be separated by the name of the system, as shown in Figures 14.8-2.

Measurement sessions carried out on the same system but with different TYPE (PV field or form) or time of execution are entered as different measurements under the same system and the same date.

Each measurement session contains the following data (see in the example below):

25/06/2020
PALAZZETTO SPORT
Array Session: 10:40, Field: PALAZZETTO SPORT, Array: INV1 Q3.1
Array Session: 11:07, Field: PALAZZETTO SPORT, Array: INV1 Q2.1
Array Session: 11:26, Field: PALAZZETTO SPORT, Array: INV2 Q4.1
Array Session: 11:41, Field: PALAZZETTO SPORT, Array: INV2 Q5.1
Array Session: 12:06, Field: PALAZZETTO SPORT, Array: INV3 Q6.1
Array Session: 12:50, Field: PALAZZETTO SPORT, Array: INV3 Q7.1
Array Session: 13:35, Field: PALAZZETTO SPORT, Array: INV4 Q8.1
Array Session: 13:44, Field: PALAZZETTO SPORT, Array: INV4 Q9.1

- Date of execution of the measurement (valid for all sessions of that date)
- Name of the plant
- Session type (PV field or module)
- Time of the first measurement
- Plant: name of the plant
- Name of the PV field or module (depending on the type of session)

Each measurement session can contain one or more measurements and also of many different types:

Rapid Test
25/06/2020 11:52, Field: PALAZZETTO SPORT, Array: INV2 Q5.1
25/06/2020 11:53, Field: PALAZZETTO SPORT, Array: INV2 Q5.1
Insulation
25/06/2020 11:54, Field: PALAZZETTO SPORT, Array: INV2 Q5.1, OK
25/06/2020 11:55, Field: PALAZZETTO SPORT, Array: INV2 Q5.1, OK

Buttons on **Browse data** screen:

View	View the content of the selected session
Delete	Erase the selected measurement session (confirmation required)
Delete all	Erase all measurement sessions memory (confirmation required)

- **View** key: select the session of interest and press the key to view the associatedmeasurements, as in the following pictures:

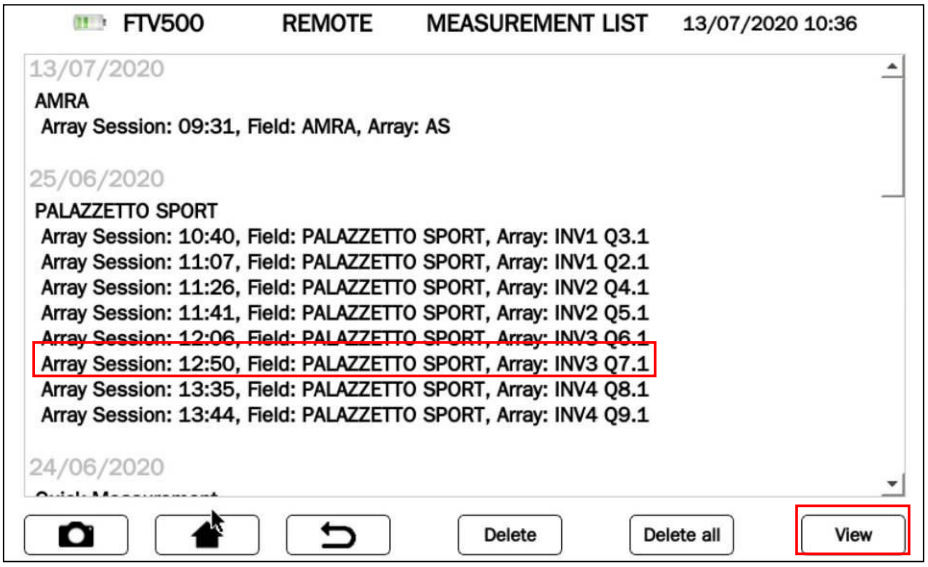


Figure 14.8-3 Selection of a measurement session

After clicking a measurement session, followed by the **View** button, all the associated measurements are shown in chronological order, as in the following Figure:

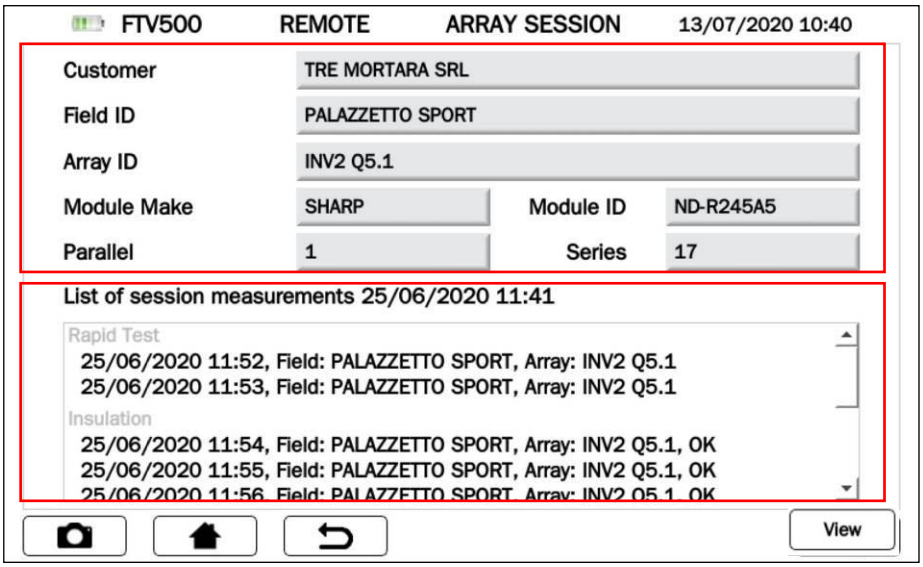


Figure 14.8-4 Visualisation of the list of measurements contained in a session

Each measurement session is associated (see top of Figure 14.8-4) with the master data (**Customer, Plant, Module manufacturer** and **Module ID**).
The measures are identified by type (Curve I-V, Efficiency, Insulation, Continuity, Rapid Test) and are in increasing chronological order. Furthermore this list of measurements also contains the following data:

- Date when the measurement was saved (identical for all measurements)
- Time when the measurement was saved
- Name of the PV plant
- Name of the module or PV field on which the measurement was made
- Test result (OK / NOT OK) *

* **ATTENTION** The test outcome is present if the programming criteria for each measure have been respected (see chapters Efficiency, I-V Curve, Insulation, Continuity).

* **NOTE**: it is not possible to give a test result for **Rapid Test** and for **Datalogging** measurements

To recall the measurements contained in the session, select the corresponding row and press the **View** button, as in the following figures:

Figure 14.8-5 Visualisation of the individual measurements belonging to a session

The individual measurements will be displayed as at the time of storage.

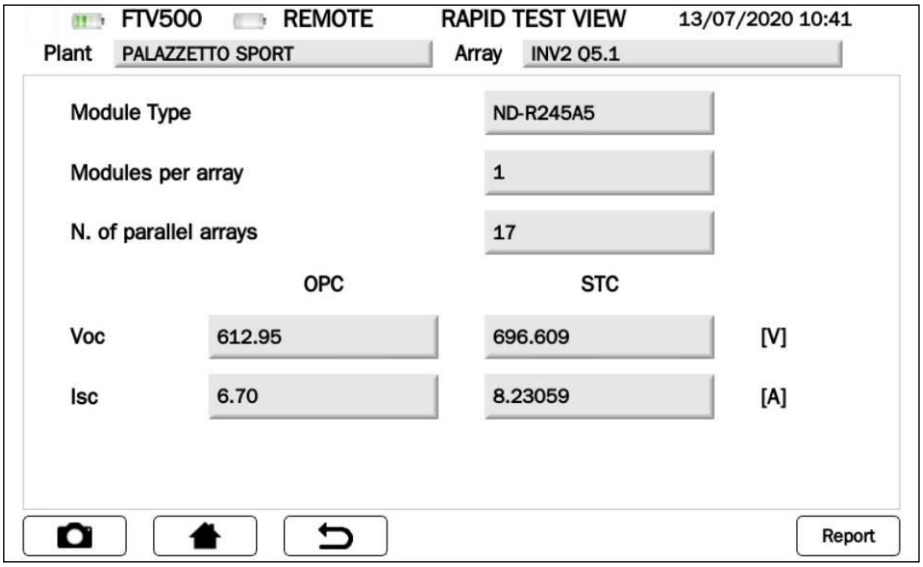


Figure 14.8-6 Display of a measurement from the list of the measurement session

NOTE: The **Report** button on the screen allows you to immediately print the report of the displayed measurement to a file (see chapter 14.9)

- **Erase** key: select the session of interest and press this key to erase it (confirmation required):
-

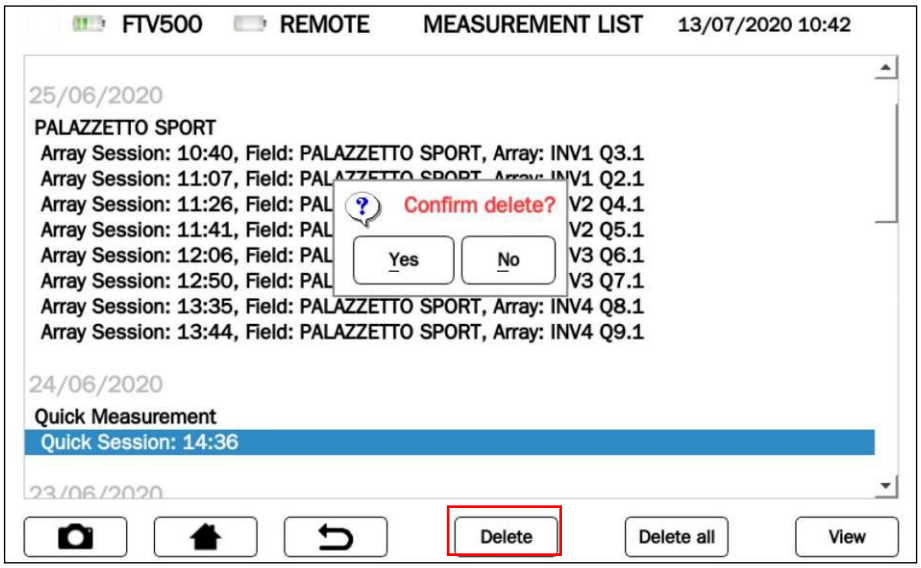


Figure 14.8-7 Erasing of one measurement session

- **Delete All** button: press it to erase the whole measurement session memory (confirmation required):

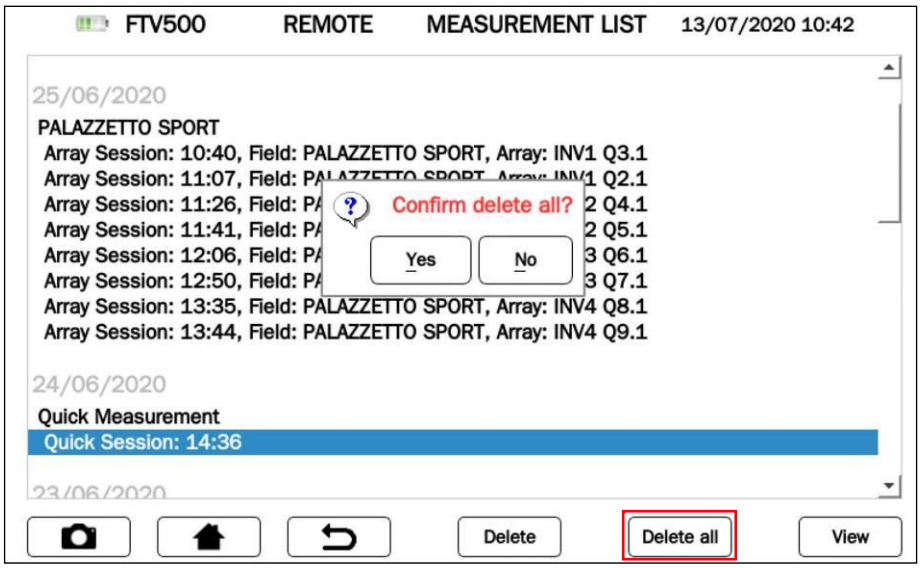


Figure 14.8-8 Erasing of all measurement sessions

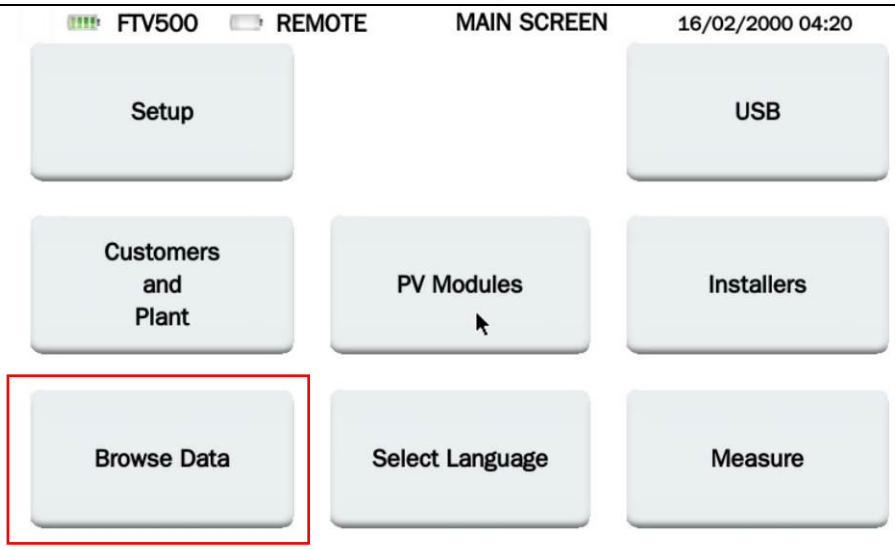
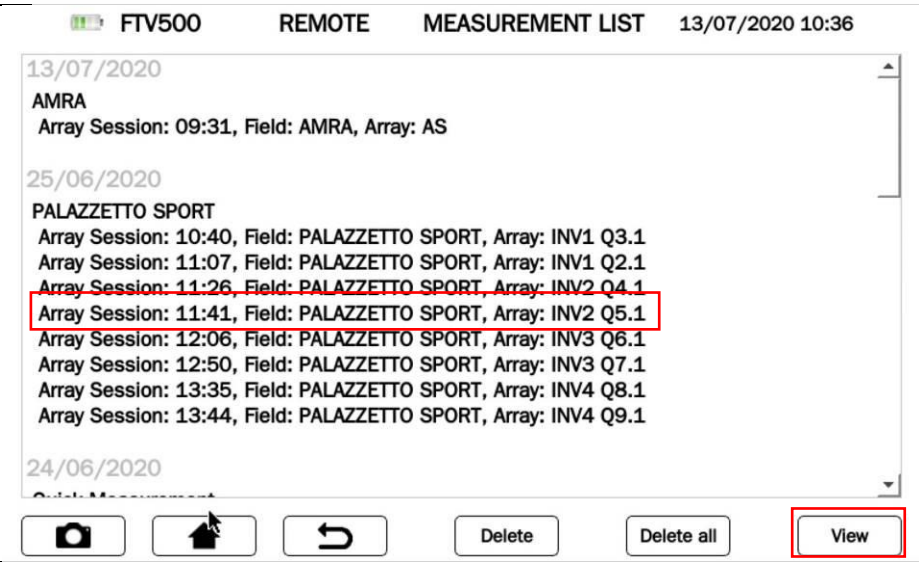
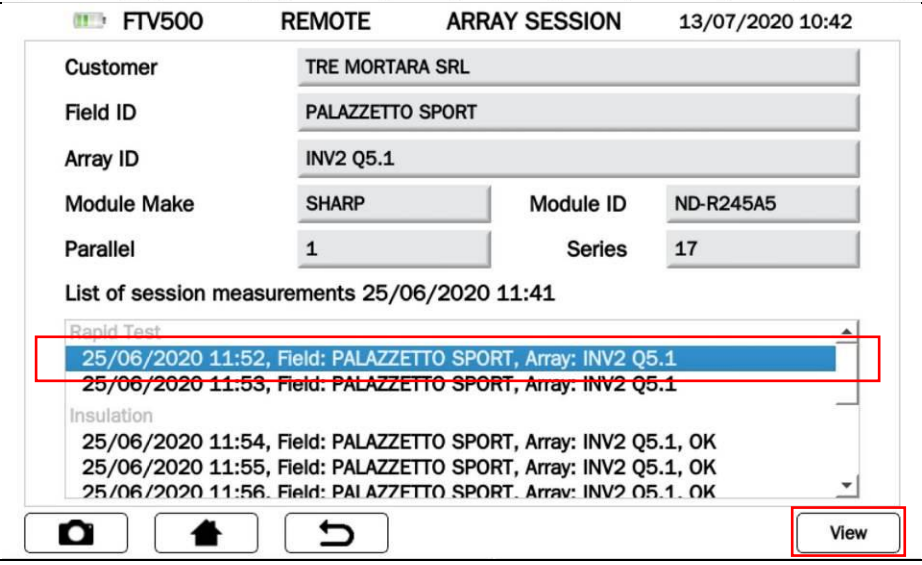
ATTENTION

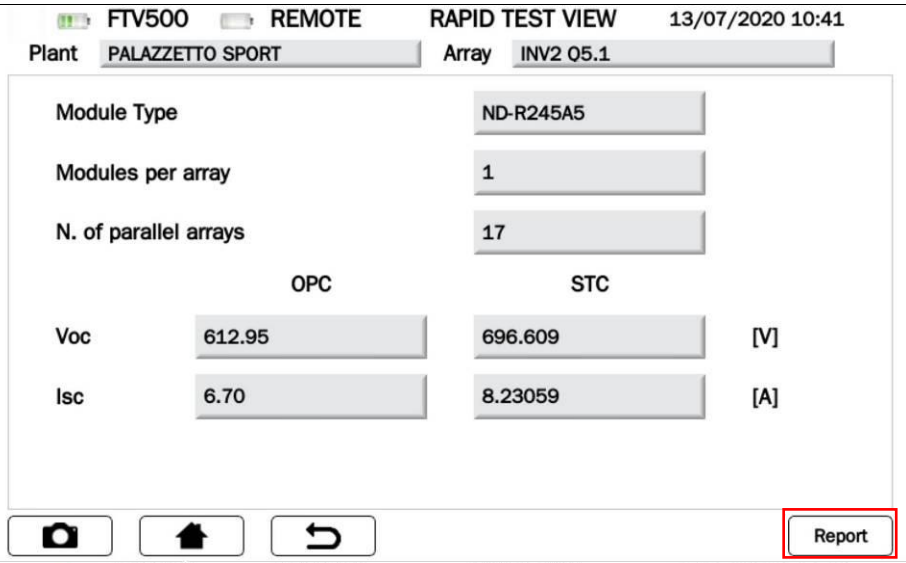
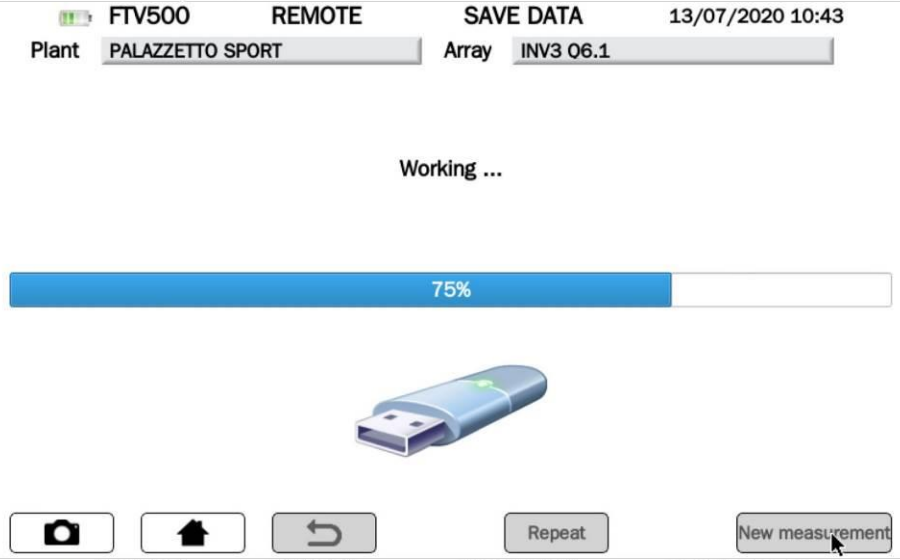
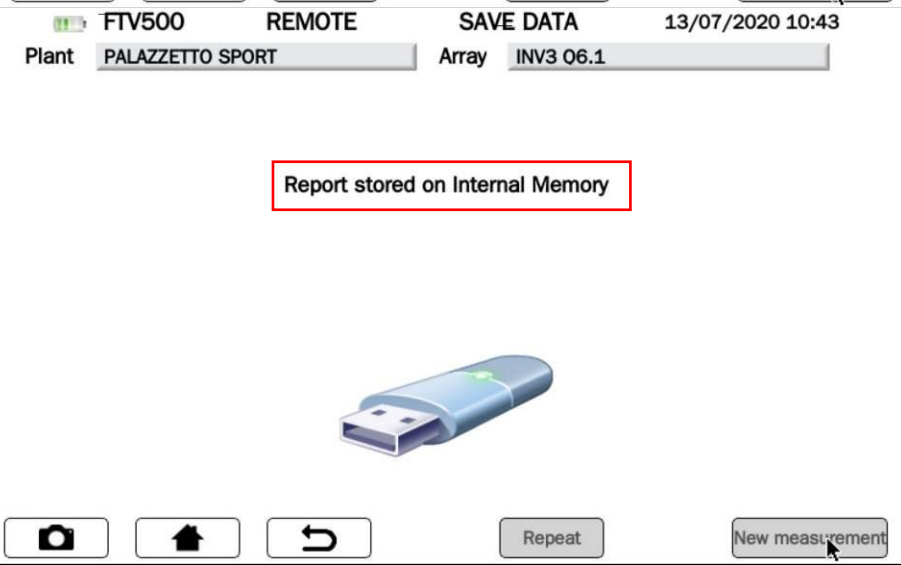
The key Erase All Key permanently erases all measurements in the database, without the possibility of recovery.

14.9 CREATING AND SAVING REPORTS

The PHOTOVOLTAIC TEST FTV500 allows you to save a detailed and personalized report for each measurement (see chapter on customer logo insertion), to be able to subsequently analyze it on a PC and print for delivery to the customer. It is necessary to insert a USB-Key in the unit USB slot and wait for its correct recognition (see chap. **14.6** for more details): make sure that the USB-Key has space available for saving the reports.

Follow the steps described in the sequence written in the following diagram:

1	From the Main Menu, press the **Browse Data** button	
2	Select the session of interest and press the **View** button to view the measurements	
3	Select the corresponding row and press the **View** button	

4	Press the **Report** button to activate the save procedure	
5	Data saving procedure in progress	
6	Screen Report saved in the instrument database or USB-Key (if inserted)	
7	Repeat the same procedure for all the measurements you would like to convert into reports: ➢ ➢ Use the key ⮌ to return to the measurement database ➢ Repeat the procedure from point 2	
8	At the end of the described procedure disconnect the USB-Key (see procedure described in chap. **14.6** for more details).	

Insert USB-Key into the PC, and your content will be visualised:

1	Compressed folders identified by: ➢ Measurement type ➢ Date and time of creation	Cartella compressa (4) report_continuity_26052020_0837.zip — Cartella compressa report_continuity_26052020_0924.zip — Cartella compressa report_ivcurve_20052020_1049.zip — Cartella compressa report_pvefficiency_18052020_1104.zip — Cartella compressa
2	Within each compressed folder there are 4 files of different formats, which allow the operator to analyze the details of the measurement results on different software platforms: ➢ **.doc** ➢ **.html** ➢ **.pdf** ➢ **.rtf** ➢ **.csv** (available only for measurement types I-V CURVE and DATALOGGING)	report_ivcurve_20052020_1049.doc — Documento di Microsoft ... report_ivcurve_20052020_1049.html — Chrome HTML Document report_ivcurve_20052020_1049.pdf — Adobe Acrobat Document report_ivcurve_20052020_1049.rtf — Rich Text Format report_ivcurve_20052020_1049_data.csv — File con valori separati da ...

15. MAINTENANCE

The instrument does not include parts that can be replaced by untrained and unauthorized personnel. Any unauthorized intervention or any replacement of its parts risks to seriously compromising safety. The manufacturer is not liable for failures due to repairs carried out outside its Customer Service or by unauthorized technicians.

Lo strumento non comporta pezzi sostituibili da personale non formato e non autorizzato. Qualsiasi intervento non autorizzato o qualsiasi sostituzione di pezzi rischai di compromettere gravemente la sicurezza. Il produttore non è responsabile dei guasti dovuti alle riparazioni effettuate fuori dal suo Servizio Clientela o da riparatori non autorizzati.

15.1 PERIODIC CALIBRATION

It is essential that all measuring instruments are regularly calibrated to ensure their technical characteristics indicated in this manual. An annual calibration is recommended, which should be carried out only by authorized technical personnel. The operation is not covered by the warranty.

15.2 CLEANING

Disconnect the instrument completely and switch it off.
Use a soft cloth slightly moistened with soapy water, rinse with a damp cloth and dry quickly using a cloth or compressed air. Do not use alcohol, alcohol or hydrocarbon-based liquids. Let the tool dry completely before using it.

15.3 SENSOR MAINTENANCE

Current sensors require regular maintenance:

- Clean with a sponge moistened with soapy water, always rinse with the sponge and running water and finally dry quickly. Do not use alcohol, alcohol or hydrocarbon-based liquids.
- Keep the air gap of the PAC clamps in perfect clean conditions (use a cloth). Lightly lubricate the visible metal parts to avoid rust.

15.4 REPAIR

For any intervention to be carried out under warranty or out of warranty, please send the instrument to your distributor or branch.

15.5 FIRMWARE/SOFTWARE UPDATE

With the constant goal of providing the best possible service in terms of performance and technical evolution, Chauvin Arnoux offers you the possibility to update the firmware / software integrated in the unitby downloading the new version available for free on our website.
The update of the integrated firmware / software is conditioned by its compatibility with the hardware version of the instrument (always ask your distributor or branch for confirmation).

ATTENTION: updating the firmware / software could cause the unintentional removal of all the data in the memory. Before performing this operation, it is advisable to make a backup of the information.

15.6 WARRANTY

Our guarantee is valid, unless stipulated in advance, for **12 months** from the date of availability of the material (extracted from our General Conditions of Sale available on request).

The warranty does not apply in the case of::

- Inappropriate use of the equipment or use with incompatible material;
- Changes made to the mains supply without the explicit authorization of the manufacturer's technical service;
- Work carried out on the instrument by a person not authorized by the manufacturer;
- Adaptation to a particular application, not provided for in the material design or not indicated in the user manual;
- Damage due to shocks, crashes or accidental contact with water.

16. STATE AT DELIVERY AND REFERENCES

PHOTOVOLTAIC TEST FTV500	**P01129600**

FTV500 delivered with:

- Bag for acessories
- Power supply / Baterry charger
- Remote unit + cavo + USB Power supply /battery charger
- AC clamp Miniflex MA500 (x3)
- DC clamp PAC500 (x3)
- Safety leads 2mt red/black (x6)
- Safety leads I-V red/black
- Crocodile clips red/black (x2)
- Flexible female rod 4mm red/black (x6)
- Inclinometer
- Portable disconnect switch
- Certificate of conformity
- User manual

REMOTE UNIT FTV500	**P01102184**

ACCESSORIES AND REPLACEMEMENTS

AC clamp Miniflex MA500	**P01120600**
DC clamp PAC500	**P01120480**
Inclinometer	**P01102115**
Portable disconnect switch 1500V/32A	**11-0000-631**
Safety leads 2mt red/black (x6)	**P01295097**
Safety leads I-V red/black	**P01295504**
Crocodile clips red/black (x2)	**P01295457Z**
Flexible female rod 4mm red/black (x6)	**P01102189**
Transport bag	**P01298056**
Power supply + USB cable for clamp PAC500	**Please contact us**

17. ANNEX A – THEORETICAL BASICS

PLANT EFFICIENCY / DATALOGGING

Extraxcted from Guide CEI 82-25;V1 OF 2011-10 (terminology adopted by FTV500)

15.8 Verification of the correct operation of the photovoltaic system
This verification consists in examining the correct functioning of the photovoltaic system in the different conditions of power generated and in the various modes provided by the power conditioning and control group (switching on, off, protection in case of lack of mains shutdown, automatic restart of the system when the mains voltage returns, etc.).
In particular, a test that check the functions of the integrated protective relay must at least prove its intervention in the event of a mains network failure.

15.9 Verification of the performance of the photovoltaic system without solar concentration

15.9.1 Definitions
- **Pdc** power output (in kW) from the photovoltaic generator, measured at the DC terminals of the inverter, with uncertainty not exceeding 2%;
- **Pac** active power (in kW) produced in alternating current by the photovoltaic system, with uncertainty less than 2%;
- **Pnom** nominal power (in kWp) of the photovoltaic generator, determined as the sum of the individual powers of the modules taken from the manufacturer data sheets;
- **Irr** global solar irradiation (in W / m2) measured on the plane of the modules with measurement uncertainty of the solar sensor not higher than 3% and with uncertainty of the output voltage from the solar sensor not higher than 1%;
- $\mathbf{G_{STC}}$ solar radiation in STC (equal to 1 000 W / m2).

15.9.3 Evaluation of the performance of photovoltaic systems during normal operation
The evaluation of the performance of photovoltaic systems during normal operation is carried out in the mode indicated in CEI EN 61724, i.e. determining the PR performance factor (see par. 15.9.2) in a given period (daily, monthly or annual) .

15.9.4 Evaluation of the performance of photovoltaic systems during the commissioning
The evaluation of the performance of. photovoltaic systems during the commissioning of the system is carried out either in terms of energy (with measures relating to a given period) or in terms of power (with instantaneous measurements) with the methods indicated below.

15.9.4.2 Evaluation of performance in power
The performance verification of the photovoltaic systems during the commissioning of the system is carried out in terms of power by evaluating the performance index PRp (or performance index in power, corrected in temperature).
The PRp performance index highlights the overall effect of losses on the power generated in alternating current by the photovoltaic system, due to the incomplete exploitation of solar radiation, the conversion efficiency of the inverter and the inefficiencies or fault components (including the decoupling between the strings and any shading on the modules).
Similarly, the verification of the power performance of a photovoltaic system is carried out by checking that the following constraints are satisfied in the operating conditions shown below:

$$\mathbf{PRp = Pac / (Rfv2 * (Irr / G_{STC}) * Pnom)}$$

PRp > 0,78 (if Pinv ≤ 20 kW) e
PRp > 0,80 (if Pinv > 20 kW)

* Pinv: Inverter power inserted in the test configuration (see Figure 14.7.1-5)

IMPORTANT

The operating conditions of the photovoltaic system for verifying the PRp performance index when starting up the system are as follows:

- radiation on the module surface (Gp) greater than 600 W / m²;
- not relevant wind speed, with reference to the pyranometer used;
- mains up and running;
- all inverters in the system or in the section under observation are in service.
- The verification of the PRp performance index is carried out by operating on the entire system, if all its sections have identical characteristics, or on sections characterized by:
    - same inclination and orientation of the modules;
    - same inverter power class (Pinv> 20 kW or Pinv ≤ 20 kW);
    - same type of module (and therefore the same value of the power temperature coefficient);
    - same type of module installation (and therefore similar Tpan).

15.9.7 Measurements of solar radiation and the operative temperature of the modules

15.9.7.1 Measurement of solar radiation

For verifying PR or PRcc or PRe or PRp or PRcce or PRccp, the measurement of solar radiation on the module level (Gp) must be carried out so that the value obtained is representative of the radiation on the entire plant or on the plant section under consideration.
In the case of photovoltaic systems installed in a large area, it is appropriate to measure the irradiation at the same time with several sensors adequately located throughout the installation area (approximately one every 20000 m2) and take the average of the measurements considered as Gp value.
The measurement is carried out with a solar sensor (or solarimeter) which can adopt different operating principles. For this purpose, the thermopile solarimeter (or pyranometer) and the photovoltaic effect solarimeter (also called PV reference solar device, see Standard CEI EN 60904-4), as indicated in more detail in Annex C par.1.2, are usually used.
The solarimeter must be positioned in conditions of non-shading from nearby obstacles. In particular, in the case of a system with multiple rows of modules, the solarimeter must not be positioned on the lower part of the rows.
In the case of solar tracking systems (with or without concentration) the irradiation sensor must be installed on the solar tracking plan.

15.9.7.2 Measurement of the temperature of the photovoltaic cell

The temperature of the Tcel photovoltaic cell can be determined by one of the following methods:

a) direct measurement with a contact sensor (thermoresistive or thermocouple) applied on the back of the module.

   NOTE To carry out a representative measurement of the cell temperature, the sensor must be applied to a module chosen according to the methods indicated in the Standards CEI EN 61724 and CEI EN 61829, adopting appropriate precautions:
   - take into account the thermal inertia of the sensor; therefore before carrying out the measurement it is necessary to wait for the temperature to stabilize;
   - place the sensor near a photovoltaic cell in the central area of the module;
   - place the sensor welded or connected to the module by means of a suitable thermally conductive adhesive;
   - place the sensor in correspondence of a module representative of the average functioning of the photovoltaic field or of the section in question;

b) measurement of the no-load voltage of the module and calculation of the corresponding Tpan according to the CEI EN 60904-5 standard.

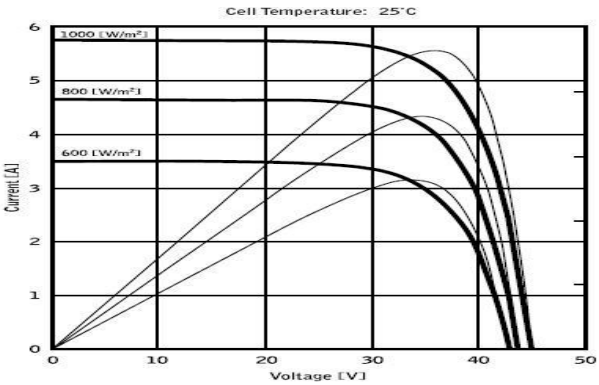
c) measurement of the ambient temperature Tamb and calculation of the corresponding Tpan according to the formula:

   Tpan = Tamb + (NOCT o NMOT- 20) * Irr / 800

NOTE the latter methodology is not applicable when the wind speed is higher than 1 m / s or when the module is not subject to natural ventilation on its rear surface (for example, in the case of an in-roof integrated module).
The temperature measurement of the Tpan photovoltaic cell is carried out with a sensor whose uncertainty is not higher than 1 ° C.

I-V CURVE

<u>Maximum Power Point Tracker (MPPT)</u>
Solar radiation on a surface such as a photovoltaic module has highly variable characteristics, being dependent on the position of the sun with respect to the surface of the modules and on the characteristics of the atmosphere (presence of clouds). A photovoltaic module has, for various values of solar radiation, and for various values of temperature, a series of characteristic curves as the ones indicated in the following figures.
In particular, it shows three I-V curves (in bold) corresponding to three values (1000, 800, 600W / m2) of solar radiation



On each characteristic curve there is one and only one point whereby the transfer of power to a hypothetical load powered by the photovoltaic module is maximized. The maximum power point corresponds to the voltage-current pair such that the product V * I is maximum, where V is the value of the voltage at the module' poles and I is the current that circulates in the circuit obtained by closing the module on a hypothetical load .
With reference to the previous curves, the product V * I is represented for the three values of the solar radiation above, with the three curves drawn with a thinner line.
As it can be seen, in accordance with what has been said before, these curves exhibit only one maximum.
E.g. for 1000W / m2, the maximum power point corresponds to a voltage value of approximately 36V and current of approximately 5.5A.
Clearly, if you can maximize the power supplied by the system, you can make the most of it, whether it is connected to the network or stand-alone.
The MPPT is a device integrated in the inverters which, typically, at every instant reads the voltage and current values, calculates the product (i.e. the power in Watts) and, causing small variations in the conversion parameters (dutycycle), is able to establish by comparison whether the photovoltaic module is working in maximum power conditions or not. Depending on the "response" it still acts on the circuit to bring the system into optimal condition.
The reason why MPPTs are used is simple: a photovoltaic system without MPPT can still work, but for the same amount of solar radiation it provides less energy.

On the market there are inverters with 1, 2 or even 3 integrated MPPT.
Typically inverters with more than one MPPT are used in systems where:

- The various photovoltaic strings composing it have, due to design reasons, different inclinations or orientations. In this way, each individual MPPT manages its own photovoltaic field, maximizing its performance for the corresponding radiation characteristics and temperatures (without being influenced by the other photovoltaic strings).
- Greater continuity of service is sought. With multiple MPPTs, only one photovoltaic field can be taken out of service while the others continue to produce energy.

Measurement of the I-V characteristic of the module / string and of the Series Resistance of the module

The instrument is designed to perform tests and measurements on **PV modules** composed by a suitable number of PV cells in order to detect their characteristic IV curve (Current-Voltage) and the Resistance Series Rs, characteristic parameters that identify them constructively, based on the standard IEC / EN60891 .
The tests can be performed both on single modules and on a **PV string** (set of PV modules), the whole of which constitutes what is commonly called "photovoltaic generator", an integral part of a single-phase or three-phase PV installation.

I-V characteristics
The test on the I-V characteristic is performed in the following way:

- The FTV500 performs the measurement of the I-V characteristic on the module connected to the test terminals, in addition to the measurement of the current irradiation and temperature
- The measurement result is automatically "translated" to the STC (Standard Test Conditions), with irradiation equal to 1000W / m2 and module temperature of 25 ° C.
- A check is performed between the maximum rated power at STC, taking the tolerance declared by the module manufacturer into consideration, and its value measured by the instrument
- If the comparison falls within the declared tolerance, the test result will be "OK" ; if not it will be"NO", with the consequence that the PV module will not meet the requirements declared by the manufacturer.

Resistance Series Rs
The Rs-Series Resistance test is used to perform an exact measurement of this parameter in real time on the PV module and then update this value in the database module definition, in accordance with the procedure provided by IEC / EN60891 standard.

The parameters measured by the instrument are described below

Parameter	Description
P_{max}	Maximum module / string power measured by the instrument
V_{mpp}	Voltage at the maximum power power point (mpp)
I_{mpp}	Current at the maximum power power point (mpp)
V_{oc}	Open-circuit voltage
I_{sc}	Short circuit current
FF	Fill Factor %
DP_{max}	Deviation between the measured power translated to STC and the declared power Pnom (@ STC)

Results

Type of result	Conditions	Notes
OK	$Tol^{(-)} * P_{nom} \leq (P_{max} - P_{nom}) \leq Tol^{(+)} * P_{nom}$	No degradation rate applied

	$Tol^{(-)} * P_{nom1} \leq (P_{max} - P_{nom1}) \leq Tol^{(+)} * P_{nom1}$	With degradation rate applied
NO	$Tol^{(-)} * P_{nom} \leq (P_{max} - P_{nom}) \leq Tol^{(+)} * P_{nom}$	No degradation rate applied
	$Tol^{(-)} * P_{nom1} \leq (P_{max} - P_{nom1}) \leq Tol^{(+)} * P_{nom1}$	With degradation rate applied

Dove:

$(P_{max} - P_{nom}) \rightarrow DP_{max}$ (no degradation rate)

$(P_{max} - P_{nom1}) \rightarrow DP_{max}$ (no degradation rate)

$Tol^{(-)}$ (%) * P_{nom} = Negative tolerance declared by the manufacturer (no degradation)

$Tol^{(-)}$ (%) * P_{nom1} = Negative tolerance declared by the manufacturer (with degradation)

$Tol^{(+)}$ (%) * P_{nom} = Positive tolerance declared by the manufacturer (no degradation)

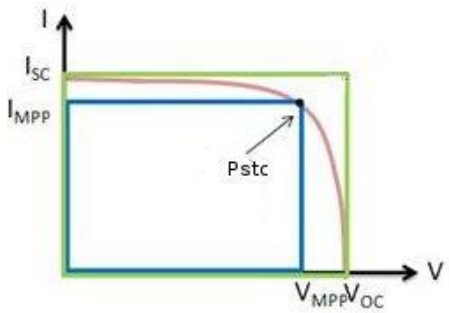
$Tol^{(+)}$ (%) * P_{nom1} = Positive tolerance declared by the manufacturer (with degradation)

DP_{max}:

$$DP\max = 100 * \left(\frac{P\max - Pnom_1}{Pnom_1} \right)$$ DPmax coefficient **With** degradation (defines the outcome of module tests)

$$DP\max = 100 * \left(\frac{P\max - Pnom}{Pnom} \right)$$ DPmax coefficient **Without** degradation (defines the outcome of module tests)

Fill Factor:



*FF = 100 * [(V_{mpp} * I_{mpp}) / (V_{oc} * I_{sc})]*

Represents the hypothetical module or string yield resulting from the comparison between max measured power output (blue area) e the "no-load" power output (green area)

Module degradation:

In order to get a more accurate comparison, it i s required to enter the module age (in years) multiplied by the yearly degradation rate (see Fig. 14.7.3-13).

Examples: 5 Years – 2%/year Degradation–
Enter 5 * 2 = 10%

DEFINITIONS:

*P_{nom1} = P_{nom} * (1 - Deg * Inv) = Module nominal power with possible degradation (if applied)*
P_{nom} = Module nominal power (@ STC)
Deg. = Degradation (%)
Inv. = Age in years of the module
If Deg = 0 or Inv = 0 then P_{nom1} = P_{nom}

INSULATION

Standard abstract EN 62446-1 2016-11
Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance

6.7 PV array insulation resistance test

6.7.1 General

PV array DC circuits are live during daylight and, unlike a conventional AC circuit, cannot be isolated before performing this test. Performing this test presents a potential electric shock hazard; therefore, it is important to fully understand the procedure before starting any work.

The following basic safety measures should be followed:
• Limit the access to the working area.
• Do not touch and take measures to prevent any other persons touching any metallic surface when performing the insulation test.
• Do not touch and take measures to prevent any other persons from touching the back of the module/laminate or the module/laminate terminals when performing the insulation test.
• Whenever the insulation test device is energized, there is voltage on the testing area. The equipment shall have automatic auto-discharge capability.
• Appropriate personal protective clothing / equipment should be worn for the duration of the test.

Where the results of the test are questionable, or where insulation faults due to installation or manufacturing defects are suspected, a wet array insulation test may be appropriate and may help locate the location of a fault – see 8.3 for a suitable test procedure.
Where SPDs or other equipment are likely to influence the verification test, or be damaged, such equipment shall be temporarily disconnected before carrying out the insulation resistance test.

6.7.2 PV array insulation resistance test – Test method

The test should be repeated, as minimum, for each PV array or sub-array (as applicable). It is also possible to test individual strings if required.

TEST METHOD 1 – Test between array negative and earth followed by a test between array positive and earth.
TEST METHOD 2 – Test between earth and short circuited array positive and negative.

Where the structure/frame is bonded to earth, the earth connection may be to any suitable earth connection or to the array frame (where the array frame is used, ensure a good contact and that there is continuity over the whole metallic frame).
For systems where the array frame is not bonded to earth (e.g. where there is a class II installation) a commissioning engineer may choose to do two tests: i) between array cables and earth and an additional test ii) between array cables and frame.
For arrays that have no accessible conductive parts (e.g. PV roof tiles) the test shall be between array cables and the building earth.
Where test method 2 is adopted, to minimize the risk from electrical arcs, the array positive and negative cables should be short-circuited in a safe manner. Typically this would be achieved by an appropriate short-circuit switch box. Such a device incorporates a load break rated DC switch that can safely make and break the short circuit connection – after array cables have been safely connected into the device.
The test procedure should be designed to ensure the peak voltage does not exceed module, switch, surge arrestor or other system component ratings.

NOTE: using the "String / Module" test mode, PHOTOVOLTAIC TEST FTV500 automatically performs an internal short circuit between the Positive and Negative polesm, therefore there is no need to use an external system to short-circuit the positive and negative String's or Module's terminals.

6.7.3 PV array insulation resistance – Test procedure

6.7.3.1 General

Before commencing the test:

• limit access by non-authorized personnel;
• isolate the PV array from the inverter (typically at the array switch disconnector); and
• disconnect any piece of equipment that could have impact on the insulation measurement (i.e. overvoltage protection) in the junction or combiner boxes.

Where a short circuit switch box is being used to test to method 2, the array cables should be securely connected into the short circuit device before the short circuit switch is activated.
The insulation resistance test device shall be connected between earth and the array cable(s) or combiner bus bar – as appropriate to the test method adopted. Test leads should be made secure before carrying out the test.
Follow the insulation resistance test device instructions to ensure the test voltage is according to Table 1 and readings in megaohms.
Ensure the system is de-energized before removing test leads or touching any conductive parts.

6.7.3.2 Insulation resistance – PV arrays up to 10 kWp

For PV arrays of up to 10 kWp, the insulation resistance shall be measured with the test voltage indicated in Table 2. The result is satisfactory if each circuit has an insulation resistance not less than the appropriate value given in Table 2.

Table 2 – Minimum values of insulation resistance – PV arrays up to 10 kWp

System voltage (V_{oc} **(stc)** × **1,25)** V	**Test voltage** V	**Minimum insulation resistance** MΩ
<120	250	0,5
120 to 500	500	1
>500	1 000	1

6.7.3.3 Insulation resistance – PV arrays above 10 kWp

For PV arrays of over 10 kWp, one of the following two test methods shall be followed.

Method A
Perform the insulation resistance test on:

• individual strings; or
• combined strings, where the total combined capacity is no more than 10 kWp.

The insulation resistance shall be measured with the test voltage indicated in Table 2. The result is satisfactory where the insulation resistance is not less than the appropriate value given in Table 2.

Method B
Method B is an alternative that allows for testing of an entire array (or sub-array) even if it is larger than 10 kWp. Arrays larger than 10 kWp may pass the requirements of Table 2; hence Method B provides a shortcut (testing the entire array at the outset) – only if it fails this test should the test be performed on sub-sections as per Method A.

The insulation resistance shall be measured with the test voltage indicated in Table 2. The result is satisfactory where the insulation resistance is not less than the appropriate value given in Table 2.
If the measurement falls below the appropriate value given in Table 2, the system should be re-tested using fewer strings in the test circuit.

8.3 PV array – Wet insulation resistance test

8.3.1 General

The wet insulation resistance test is primarily of use as part of a fault finding exercise.
The wet insulation resistance test evaluates the PV array's electrical insulation under wet operating conditions. This test simulates rain or dew on the array and its wiring and verifies that moisture will not enter active portions of the array's electrical circuitry where it may enhance corrosion, cause ground faults, or pose an electrical safety hazard to personnel or equipment.
This test is especially effective for finding above ground defects such as wiring damage, inadequately secured junction box covers, and other similar installation issues. It also may be used to detect manufacturing and design flaws including polymer substrate punctures, cracked junction boxes, inadequately sealed diode cases, and improper (indoor rated) connectors.
A wet insulation test would typically be implemented when the results of a (nominally) dry test are questionable, or where insulation faults due to installation or manufacturing defects are suspected.
The test can be applied to a whole array or on larger systems to selected parts (to specific components or sub-sections of the array). Where only parts of the array are being tested, these are typically selected due to a known or suspected problem identified during other tests. In some circumstances, the wet insulation test may be requested on a sample proportion of the array.

8.3.2 Wet insulation test procedure

The procedure to be followed is to be the same as that described in the standard insulation test but with an additional initial step of wetting the array.
Prior to test, the section of the array under test should be thoroughly wetted with a mixture of water and surfactant. The mixture should be sprayed onto all parts of the array under test.
Prior to testing, the area of the array under test should be checked to ensure that all parts are wetted, including the front, rear and edges of modules, together with all junction boxes and cables.
Performing this test presents a potential electric shock hazard and the safety preparations described for a standard insulation test should be followed. The selection of personal protective equipment to be worn during the test should consider the wet environment that the test will be performed under.

A minimum of two people are recommended to perform this test (as wetness dries up quickly in the field resulting in large variation of results) – one person to conduct the measurement immediately after the second person has completed wetting the area of concern and has given the approval to test.

CONTINUITY

Standard abstract EN 62446-1 2016-11
Photovoltaic (PV) systems - Requirements for testing, documentation and maintenance

6 Test procedures – Category 1

6.1 Continuity of protective earthing and equipotential bonding conductors

Where protective earthing and/or equipotential bonding conductors are fitted on the DC side, such as bonding of the array frame, an electrical continuity test shall be made on all such conductors. The connection to the main earthing terminal should also be verified.

RESEARCH LOW INSULATION CONDITIONS ON PHOTOVOLTAIC STRINGS.

Maintaining the proper functioning of the photovoltaic system over time is the first goal of a good professional, ensuring continuous and effective energy production.

Numerous operations are necessary for this verification: among them is the insulation test, which is also useful for checking for earth leakage.

Insulation problems can occur on the photovoltaic module, on the current transmission cables, or on the inverter, caused, for example, by water infiltration or moisture inside the junction boxes of the module itself. The sum of the leakage values of these components constitutes the leakage current, i.e., the total electrical currents discharged to earth, resulting in loss of power from the system and possible danger of electrocution to people in the vicinity.

Each PV system, by its nature, has a different potential with respect to earth. Only proper insulation with respect to ground prevents currents from the PV system from flowing to ground, ruling out the danger in case of contact and further losses.

Insulation testing includes measurements on the electrical resistance of individual PV modules, various components or the entire PV array by examining their reaction to a high test voltage (test voltage).

In fact, in order to have a PV system in compliance with the law, it is necessary to respect some basic parameters such as RISO (Insulation Resistance), which imposes minimum values for the electrical resistance of conductor cables and components, to guarantee safe operation (example: EN62446, or CEI64-8 standard calls for minimum insulation resistance measurement of 1Mohm and test voltages 500V or 1000V)

There are different methods and tools to assess the ground leakage of PV systems:

- Voltage measurement
    - Using a traditional measuring instrument: “voltage meter”
      Example: CA5293, F404
- Insulation resistance measurement
    - Using a traditional measuring instrument: “megaohmmeter”
      (for off-voltage systems only)
      Example: CA6526
    - Using a measuring instrument that independently dissects module/string potential during insulation resistance measurement, to safely disconnect and short-circuit PV modules
      Example: PHOTOVOLTAIC TEST FTV500

⚠ If you do not have a suitable device, you are not allowed to perform the insulation resistance measurement.

<u>VOLTAGE MEASUREMENT AND IDENTIFICATION OF THE FAULTY MODULE ON A STRING</u>

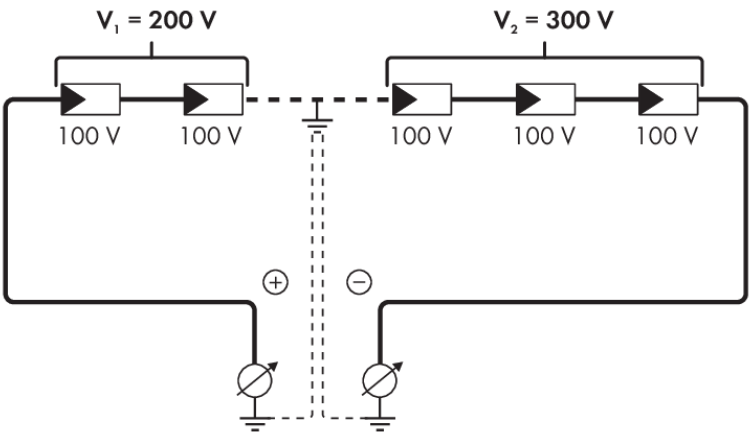
This procedure pre-measures the string voltages and based on the balance between V(+) and V(-) with respect to ground identifies the presumed location of the fault:

- Measure the voltages between the negative and positive terminals V(0)
- Measure the voltages between the positive terminal and the ground potential V(+)
- Measure the voltages between the negative terminal and the ground potential V(-)

In the presence of a ground fault (lack of insulation), we will have different voltage values from each other: let's see the detail.

- Voltage measurement V(0) = 500V (result of 5 modules * 100V each)
- Measurement of the voltage V(+) = 200V
- Measurement of the voltage V(-) = 300V

By dividing the results of voltage V(+) and V(-) by the voltage of the individual module, **we can locate the location of the defective module between the second and third PV modules**

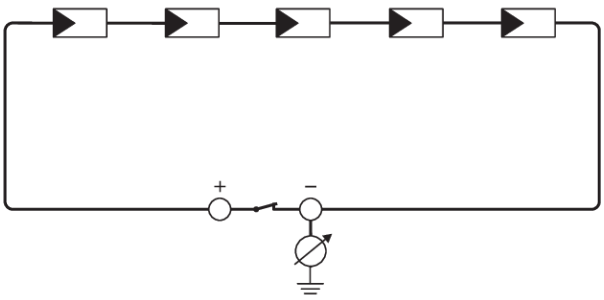


If a clear earth fault cannot be measured, perform an insulation resistance measurement, using an appropriate measuring instrument (see next point)

Warning
This verification procedure provides reliable results when performed considering:
- Single string disconnected from the inverter, any arresters and ground connections
- Absence or upstream connection of any blocking diodes
- Environmental conditions similar to those in which the fault was reported

INSULATION RESISTANCE MEASUREMENT

Where voltage measurement does not give sufficient indication of the ground fault, insulation resistance measurement can provide more accurate results.



Schematic representation of the measurement

Calculation of insulation resistance in a photovoltaic system

Before proceeding to the actual measurement of our system, it is necessary to identify the theoretical value of the insulation resistance of the string/module, which we will use for as a comparison parameter.

The expected total resistance of the PV system or an individual string can be calculated by the following formula :

$$R_{ISO} = \frac{1}{\left(\frac{1}{R_{MODULO_1}}\right) + \left(\frac{1}{R_{MODULO_2}}\right) + \ldots + \left(\frac{1}{R_{MODULO_N}}\right)}$$

The precise insulation resistance of a PV module can be obtained from the PV module manufacturer or inferred from the data sheet, or by referring to EN61646 and EN61215, which define the minimum value that the PV module must have:

R_{ISO} > 40Mohm for m² of surface area

Practical examples:
- a photovoltaic module with an area of 1 m² must have an insulation resistance of at least 40 M Ω
- a photovoltaic module with an area of 2 m² must have an insulation resistance of at least 20 M Ω

Once we have identified the theoretical value of the insulation resistance of the string/module to be tested, we can proceed with the actual measurement, using the following methods:

- Using a traditional measuring instrument: “megaohmmeter”
- Using a measuring instrument that independently dissects the module/string potential during the insulation resistance measurement, to safely disconnect and short-circuit the PV modules

In both cases, insulation resistance can only be measured with a suitable device to safely disconnect and short-circuit PV modules (for example: DC disconnect switch for PV systems).

⚠ If you do not have a suitable device, you are not allowed to perform the insulation resistance measurement.

Verification procedure using a traditional measuring instrument: “megaohmmeter”

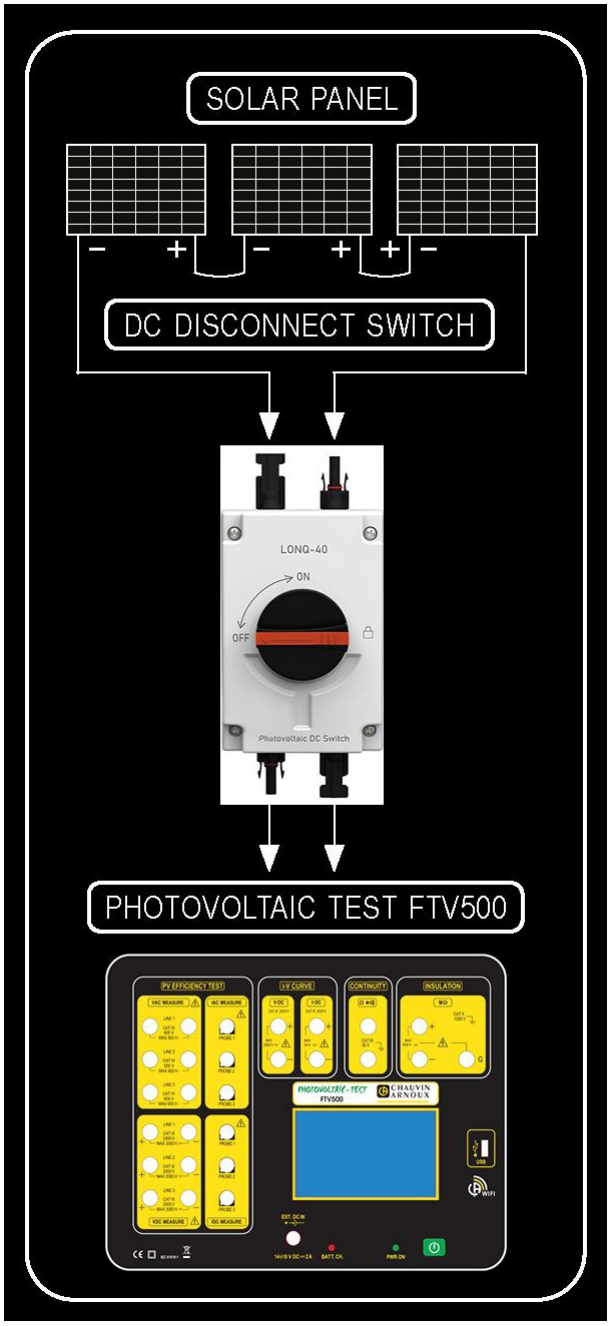
1. Calculate the theoretical insulation resistance expected for each string (see previous paragraph).
2. Exclude the module/string from the system (disconnect any module/string poles connected to ground).
3. Install the short-circuit device, so as to bring the voltage value present in the circuit to zero.
4. Connect the insulation resistance meter.
5. Short-circuit a string.
6. Set the test voltage; its value should be as close as possible to the maximum system voltage of the PV modules, but without exceeding it (see PV module data sheet).
7. Measure the insulation resistance.
8. Remove the short circuit.
9. Perform measurement of the remaining strings following the same procedure.
10. Should the insulation resistance of a string deviate significantly from the calculated theoretical value, a ground fault exists in the string in question.

Verification procedure using a measuring instrument with automatic functionality of module/string potential interruption

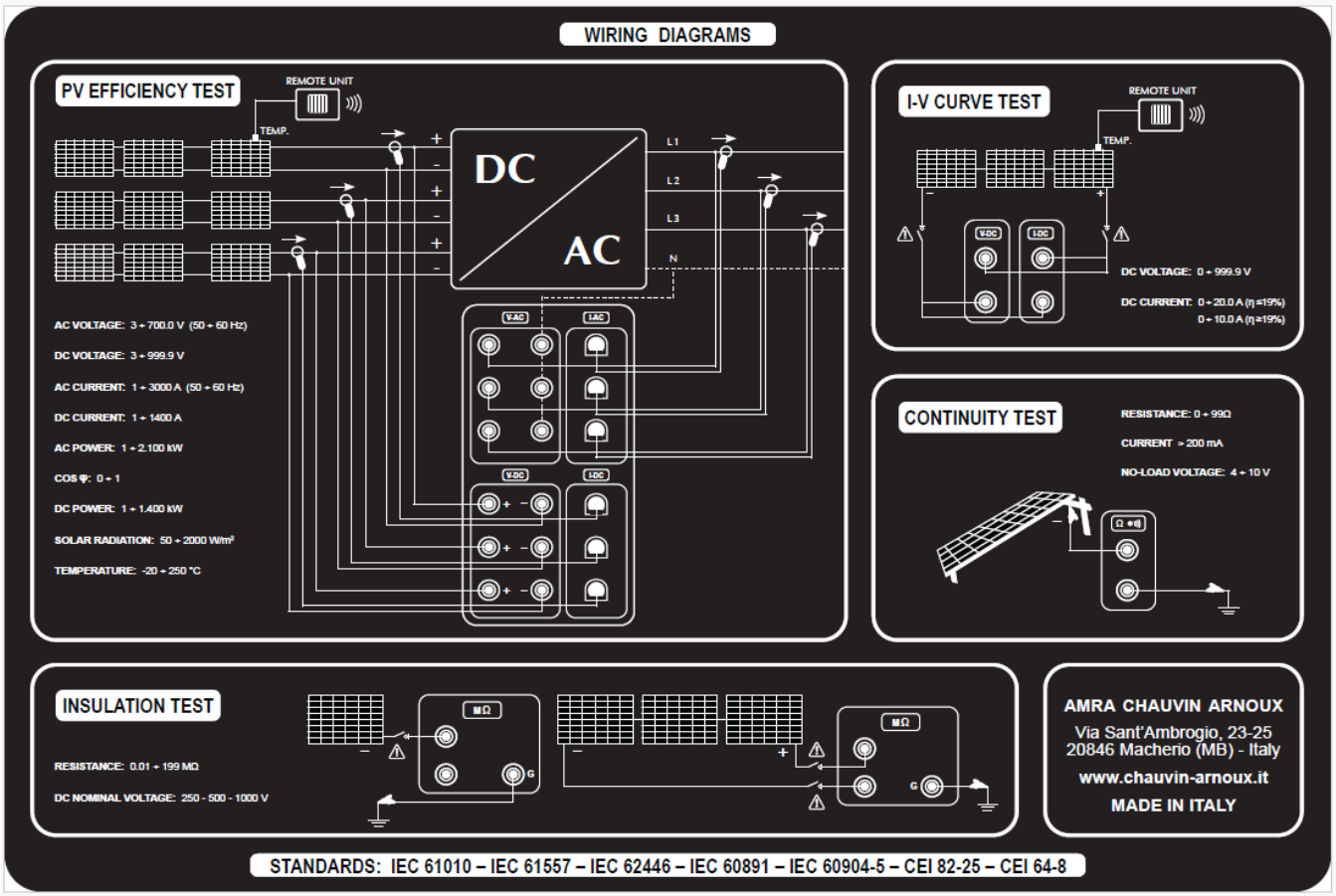
1. Calculate the expected theoretical isolation resistance for each string (see previous section).
2. Exclude the module/string from the system (disconnect any module/string poles connected to ground).
3. Install the DC disconnect device downstream of the module/string.
4. Connect the insulation resistance meter upstream of the module/string.
5. Set the test voltage, its value should be as close as possible to the maximum system voltage of the PV modules without exceeding it (see PV module data sheet).
6. Measure the insulation resistance.
7. Open the DC disconnect device.
8. Perform the measurement of the remaining strings following the same procedure.
9. Should the insulation resistance of a string deviate significantly from the calculated theoretical value, a ground fault exists in the string in question.

18. ANNEX B –ELECTRICAL CONNECTIONS

ELECTRICAL CONNECTION - DC PHOTOVOLTAIC DISCONNECTOR

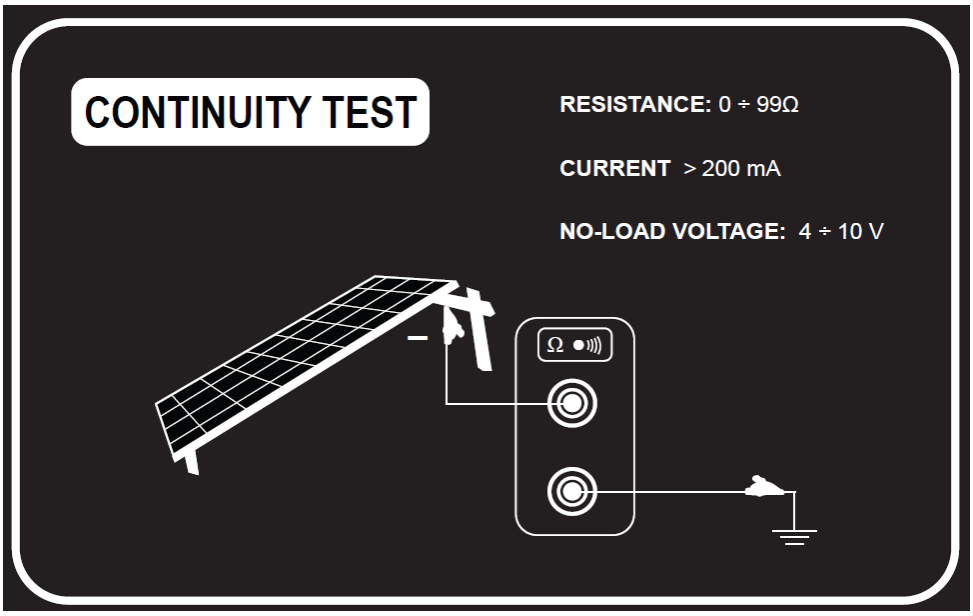


EFFICIENCY MEASUREMENT – DATALOGGING

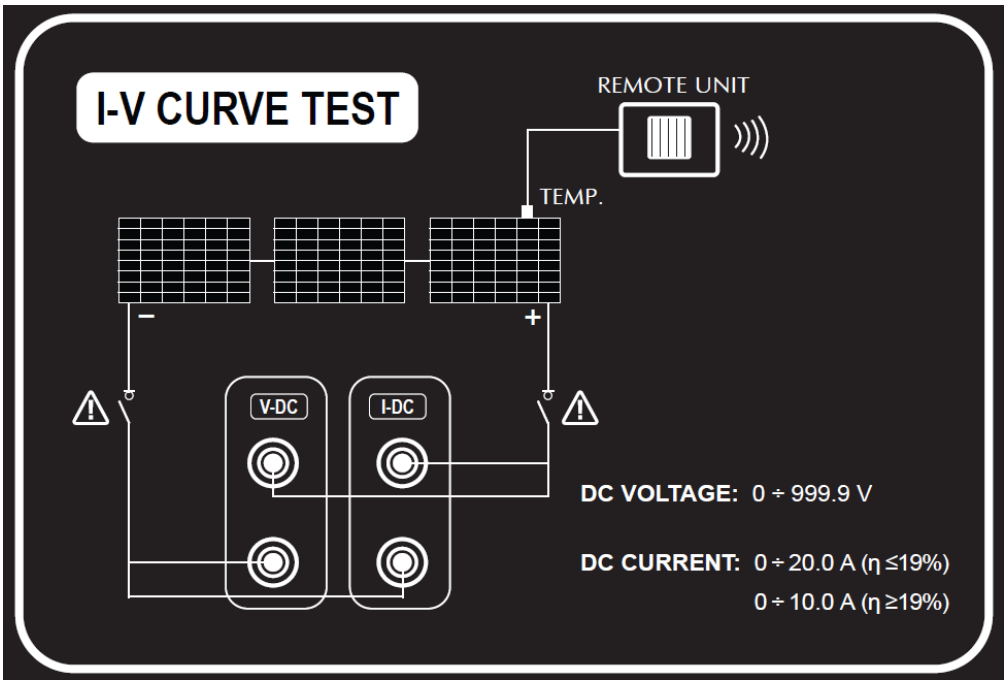


NOTE : If the there is a neutral conductor, this has to be connected to the black V-AC input terminals. If there is no neutral conductor, these terminals have to be connected between each other.

CONTINUITY MEASUREMENT

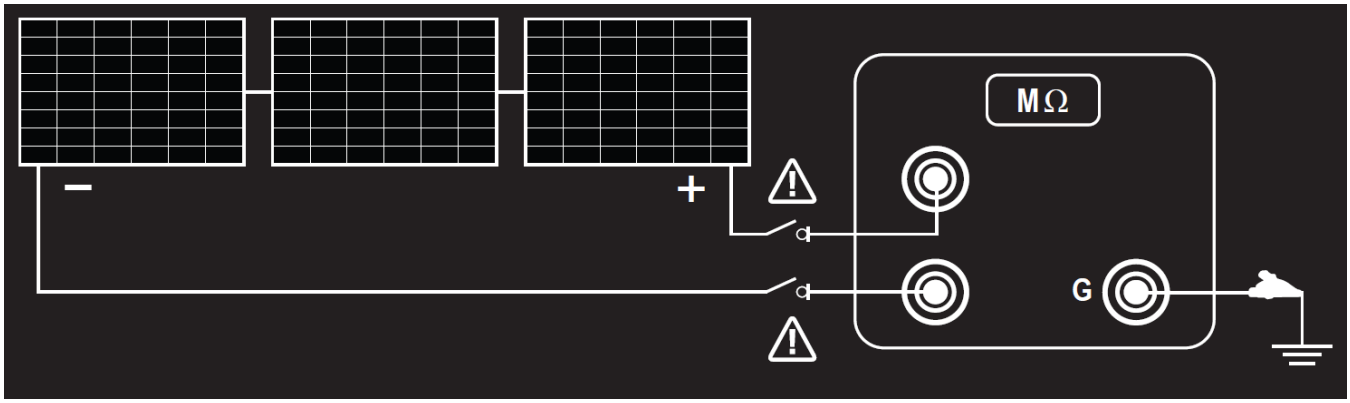


I-V CURVE TEST – RAPID TEST

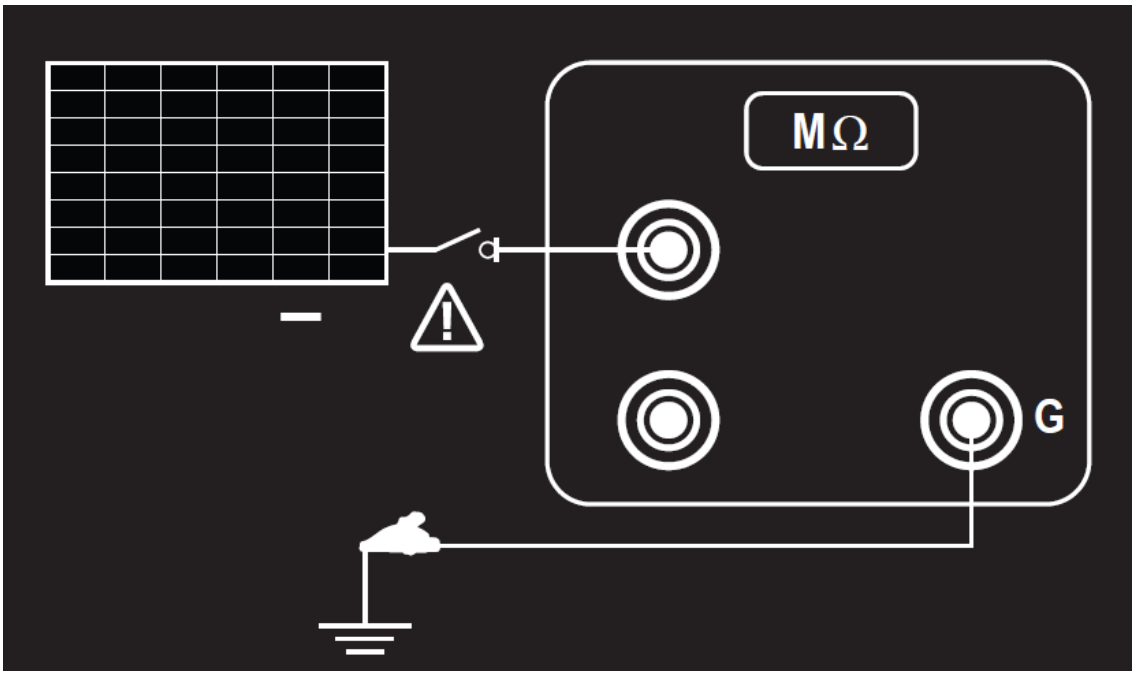


INSULATION MEASUREMENT

PVField Mode



Traditional Mode



19. ANNEX C –REPORT EXAMPLES

REPORT EFFICIENCY

Customer's logo

DATE AND TIME:	04/06/2019 14:54
CUSTOMER:	AMRA SPA
PLANT:	GUIDO CASSANMAGNAGO
OPERATOR:	MARIANI DAVIDE
NOTES:	

MEASURE: **PV_EFFICIENCYX_TMPL 1/2** **RESULT:** **NOT OK**

PLANT DATA

PLANT RATED POWER:	1500.00
INVERTER POWER:	3
THEORETICAL AVAILABLE POWER:	430.50
RFV2 TEMP COEFF:	n.a.

PANEL UNDER TEST

MANUFACTURER:	CENTROSOLAR
MODEL:	S250P60
TYPE:	Polycrystalline
NOCT:	46
GAMMA COEFF PMAX:	-1.075

AMBIENT MEASUREMENTS

IRRADIATION:	287.00
AMBIENT TEMPERATURE:	26.30
PANEL TEMPERATURE:	27.20

ELECTRICAL MEASUREMENTS DC

V1:	**0.0**	I1:	**- 0.0**	P1:	**0.00**
V2:	**1.5**	I2:	**- 0.0**	P2:	**0.00**
V3:	**2.4**	I3:	**0.0**	P3:	**0.00**
				PDC:	**0.00**

ELECTRICAL MEASUREMENTS AC

V1:	**0.0**	COSJ 1:	**0.00**	I1:	**0.0**	P1:	**-0.00**
V2:	**0.0**	COSJ 2:	**0.00**	I2:	**0.0**	P2:	**0.00**
V3:	**0.0**	COSJ 3:	**0.00**	I3:	**0.5**	P3:	**0.00**
						PAC:	**0.00**

TEST_RESULTS_TMPL

PERFORMANCE RATIO Prp:	0.00
nDC:	0.00
nAC:	nan

CALCULATION

PERFORMANCE RATIO PRp = PAC / (Rfv2 * (Gp / G_{STC}) * Pn)

PANEL EFFICIENCY = PDC / $P_{theoretical\text{-}available}$

INVERTER EFFICIENCY = PAC / PDC

LEGEND

PAC is the active power (in kW) produced in alternating current by the PV plant, with uncertainty not exceeding 2%.

INSTRUMENT TYPE:	FTV500	VER. SW:	1.1.120 190603
INSTRUMENT SERIAL NUMBER:	TEST	VER. FW:	1.1.120 190603
FILENAME:	report_pvefficiency_04062019_1454.rtf		

Customer's logo

DATE AND TIME:	04/06/2019 14:54
CUSTOMER:	AMRA SPA
PLANT:	GUIDO CASSANMAGNAGO
OPERATOR:	MARIANI DAVIDE
NOTES:	

CHAUVIN ARNOUX

PDC is the power (in kW) produced in direct current by the PV generator, with uncertainty not exceeding 2%.
Ptheoretical-available is the theoretical power (in kW) as a function of the value of theirradiation (Gp), compared with the value of Pn referried to solar irradiation GSTC.
*Rfv2 = 1 (if Tcel ≤ 40 ° C); Rfv2 = 1 - (Tcel - 40) * | range | / 100 (if Tcel> 40 ° C).*
Gp is the global solar irradiation (in W / m2) measured on the plane of the panels with measuring uncertainty of the solar sensor not higher than 3%, and with the voltage measuring uncertainty at the output of the sensor does not exceeding 1%.
GSTC is the solar radiation in STC (1000 W/m2).
Pn is the rated power (in kWp) photovoltaic generator, determined as the sum of the individual single panel rated powers derived from the datasheets released by the manufacturers.
nDC: panel efficiency
nAC: Inverter efficiency.

MEASURE:	**PV_EFFICIENCYX_TMPL 2/2**	**RESULT:**	**NOT OK**

CERTIFICATE OF FINAL ACCEPTANCE

The undersigned person or company AMRA SPA

HEREBY DECLARES

The positive outcome of the following tests to be performed for each photovoltaic generator, which is a set of photovoltaic panels with the same inclination and same orientation, and irradiation on the panel plane greater than 600 W/m2):

Performance ratio PRp is an index (corrected in temperature), which evaluates the performance in power at the start-up of the PV plant successful when PRp > 0,78 (if Pinv <= 20 kW) or PRp > 0,80 (if Pinv > 20 kW)PRp = PAC / (Rfv2 * (Gp / GSTC) * Pn)

with:

- PAC is the active power (in kW) produced in alternating current by the PV plant, with uncertainty not exceeding 2%.
- PDC is the power (in kW) produced in direct current by the PV generator, with uncertainty not exceeding 2%.
- Ptheoretical-available is the theoretical power (in kW) as a function of the value of theirradiation (Gp), compared with the value of Pn referried to solar irradiation GSTC.
- Rfv2 = 1 (if Tcel ≤ 40 ° C); Rfv2 = 1 - (Tcel - 40) * | range | / 100 (if Tcel> 40 ° C).
- Gp is the global solar irradiation (in W / m2) measured on the plane of the panels with measuring uncertainty of the solar sensor not higher than 3%, and with the voltage measuring uncertainty at the output of the sensor does not exceeding 1%.
- GSTC is the solar radiation in STC (1000 W/m2).
- Pn is the rated power (in kWp) photovoltaic generator, determined as the sum of the individual single panel rated powers derived from the datasheets released by the manufacturers.

If during the tests a temperature on the rear face of the photovoltaic modules above 40 ° C is detected, temperature correction of the measured power is allowed, as indicated in the CEI 82-25 Guide (valid only in Italy).

Processig date of this certificate 05/06/2019

Signature and stamp: ……

INSTRUMENT TYPE:	FTV500	VER. SW:	1.1.120 190603
INSTRUMENT SERIAL NUMBER:	TEST	VER. FW:	1.1.120 190603
FILENAME:	report_pvefficiency_04062019_1454.rtf		

I-V CURVE REPORT

Customer's logo

DATE AND TIME: 05/06/2019 14:32
CUSTOMER: AMRA SPA
PLANT: CORTILE
OPERATOR:
NOTES:

Customer's logo

MEASURE: I-V CURVE

RESULT_TMPL: NOT OK

PANEL: PM220P00.3
ARRAY: -
PANELS IN SERIES: -
PANELS IN PARALLEL: -

PANEL UNDER TEST

MANUFACTURER:	AUO
STC-REFERRED DATA	
MODEL:	PM220P00.3
TYPE:	Polycrystalline
MAX POWER:	230
VMPP:	40 V
IMPP:	7.48 A
VOC:	37.32 V
ISC:	8 A
BETA COEFF. (VOC):	-0.346
ALFA COEFF. (ISC):	0.055
GAMMA COEFF. (PMAX):	-1.058
NOCT:	40
TOLL -:	0
TOLL +:	3
DEGRADATION (YEARS):	n.a.
DEGRADATION (PERCENT):	0

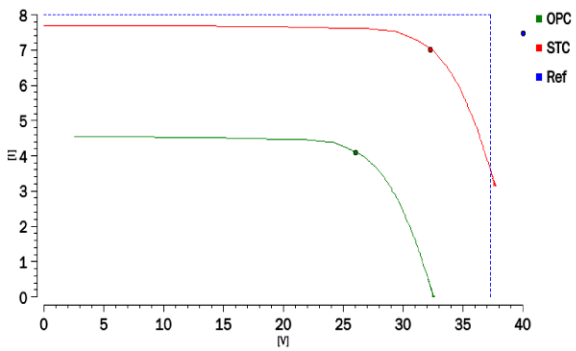
ELECTRICAL DATA

OPC DATA			
PMAX_TMPL:	106.86	PMAX_TMPL:	226.81
VMPP:	26	VMPP:	32.23
IMPP:	4.11	IMPP:	7.03
VOC:	32.64	VOC:	37.78
ISC:	4.55	ISC:	7.69
FF_TMPL:	71.95	FF_TMPL:	77
DPMAX_TMPL:	-	DPMAX_TMPL:	-
RS_TMPL:	0.001		
IRR1_TMPL:	n.a.		
IRR2_TMPL:	n.a.		

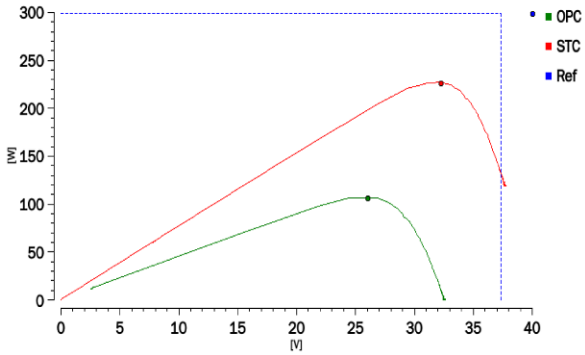
AMBIENT MEASUREMENTS

IRRADIATION:	535.00
AMBIENT TEMPERATURE:	35.60
PANEL_TEMPERATURE_TMPL:	39.70
MODE:	Module

Characteristic I-V curve / OPC+STC



Characteristic POWER curve / OPC+STC



Legend
FF: Fill Factor = (VMPPx IMPP) / (VOC x ISC).: Fill Factor = (VMPPx IMPP) / (VOC x ISC).
DPMAX: Gap% of max power from nominal output power measured (@ STC). DPMAX = 100 x ABS [(Pmax - Pnom) / Pnom].: Gap% of max power from nominal output power measured (@ STC). DPMAX = 100 x ABS [(Pmax - Pnom) / Pnom].
IRR1: Irradiation in optimal conditions [IRR1> 500 W / m2].: Irradiation in optimal conditions [IRR1> 500 W / m2].
IRR2: Irradiation in the darkened panel conditions [IRR1 << IRR2].: Irradiation in the darkened panel conditions [IRR1 << IRR2].
RS: Series resistance of the panel / string / array: Series resistance of the panel / string / array

INSTRUMENT_TYPE:	FTV500
INSTRUMENT SERIAL NUMBER:	TEST
FILENAME:	1.1.120 190603
SW VER.:	1.1.120 190603
FW VER.:	report_ivcurve_05062019_1432.rtf

I-V RAPID TEST REPORT

Customer's logo

DATE AND TIME:	05/06/2019 15:50
CUSTOMER:	AMRA SPA
PLANT:	CORTILE
OPERATOR:	MARIANI DAVIDE
NOTES:	

MEASURE: **I-V RAPID TEST** **RESULT:** **-**

PANEL:	PM220P00.3
ARRAY:	-
PANELS IN SERIES:	-
PANELS IN PARALLEL:	-

I-V RAPID TEST MEASUREMENT

OPC DATA		**STC-REFERRED DATA**	
VOC:	0.00	VOC:	
ISC:	0.02	ISC:	!!

PANEL UNDER TEST

MANUFACTURER:	**AUO**		
MODEL:	**PM220P00.3**		
TYPE:	**Polycrystalline**		
MAX POWER:	**n.a.**		
VMPP:	**40 V**		
IMPP:	**7.48 A**		
VOC:	**37.32 V**		
ISC:	**8 A**		
BETA COEFF. (VOC):	**-0.346**	Toll. VOC	
ALFA COEFF. (ISC):	**0.055**	TOLL ISC	**<TOLL_ISC >**
GAMMA COEFF. (PMAX):	**-1.058**		
NOCT:	**40**		
TOLL -:	**0**		
TOLL +:	**3**		
DEGRADATION (YEARS):	**n.a.**		
DEGRADATION (PERCENT):	**n.a.**		

CONTINUITY MEASUREMENT

RPE:	**n.a.**
RPE Max:	**n.a.**
ITEST:	**n.a.**
RCAL:	**n.a.**
C PASS:	**n.a.**

INSULATION MEASUREMENT

TEST VOLTAGE:	**n.a.**
MEASUREMENT MODE:	**n.a.**
TIME:	**n.a.**
V TEST:	**n.a.**
RI (-):	**n.a.**
RI (+):	**n.a.**
RI:	**n.a.**
RI MIN::	**n.a.**
TEST RESULT:	**n.a.**

AMBIENT MEASUREMENTS

IRRADIATION:	**1.00**
AMBIENT TEMPERATURE:	**27.80**
PANEL TEMPERATURE:	**27.60**
MODE:	**Module**

Legend

CONTINUITY

RPE: Resistance measured by injecting a current with value equal to Itest, result of the continuity test.
RPE max: Maximum threshold for Rpe, selectable in the range 1Ω – 5Ω with 1Ω resolution.
ITEST: test current.

INSTRUMENT_TYPE:	FTV500	FILENAME:	1.1.120 190603
INSTRUMENT SERIAL NUMBER:	TEST	SW VER.:	1.1.120 190603
FW VER.:	report_ivrapidtest_05062019_1550.rtf		

DATALOGGING REPORT

report_datalogging_04062019_1449_data.csv - Microsoft Excel

datetime	irr	tpan	tamb	rfv	pnom	pdc	pac	ptd	vdc1	vdc2	vdc3	idc1	idc2	idc3	wdc1	wdc2	wdc3	uac1	uac2	uac3	iac1	iac2	iac3	wac1	w
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	111.96	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	10.40	8.80	5.90	5.50	4.40	3.60	54.67	37
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.50	0.00	0.70	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.90	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.80	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.60	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.
04/06/2019 14:57	295.00	26.80	26.60	1.00	1500.00	0.00	0.00	442.50	0.00	1.50	2.40	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.00	0.

CONTINUITY REPORT

Customer's logo

DATE AND TIME:	04/06/2019 14:50
CUSTOMER:	AMRA SPA
PLANT:	GUIDO CASSANMAGNAGO
OPERATOR:	MARIANI DAVIDE
NOTES:	

MEASURE **CONTINUITY** **RESULT** **-**

PANEL:	S250P60
ARRAY:	-
PANELS IN SERIES:	-
PANELS IN PARALLEL:	-

PANEL UNDER TEST	
MANUFACTURER:	**CENTROSOLAR**
MODEL	**S250P60**
TYPE:	**Polycrystalline**
MAX POWER:	**n.a.**
VMPP:	**29.73 V**
IMPP:	**8.41 A**
VOC:	**37.62 V**
ISC:	**8.91 A**
BETA COEFF. (VOC):	**-0.35**
ALFA COEFF. (ISC):	**0.03**
GAMMA COEFF. (PMAX):	**-1.075**
NOCT:	**46**
TOLL -:	**3**
TOLL +:	**3**
DEGRADATION (YEARS):	**n.a.**
DEGRADATION (PERCENT):	**n.a.**

CONTINUITY MEASUREMENT	
RPE:	**0.09 Ω**
RPE max:	**Ω**
ITEST:	**0.279**
RCAL:	**0.09**

AMBIENT MEASUREMENTS	
IRRADIATION:	**n.a.**
AMBIENT TEMPERATURE:	**n.a.**
PANEL TEMPERATURE:	**n.a.**
MODE:	**n.a.**

Legend:
RPE: Resistance measured by injecting a current with value equal to Itest, result of the continuity test.:.
RPE max: Maximum threshold for Rpe, selectable in the range 1Ω – 5Ω with 1Ω resolution.:.
ITEST: test current.:
RCAL: Value of the cable resistance, measured during the compensation procedure, which is used for the continuity measurements . If this value is ("---"), no compensation has been performed.:

INSTRUMENT_TYPE:	FTV500	SW VER.:	1.1.120 190603
INSTRUMENT SERIAL NUMBER:	TEST	FW VER.:	1.1.120 190603
FILENAME:	report_continuity_04062019_1450.rtf		

INSULATION REPORT

Customer's logo

DATE AND TIME:	04/06/2019 14:46
CUSTOMER:	AMRA SPA
PLANT:	GUIDO CASSANMAGNAGO
OPERATOR:	MARIANI DAVIDE
NOTES:	

MEASURE: INSULATION **RESULT: -**

PANEL:	S250P60
ARRAY:	-
PANELS IN SERIES:	-
PANELS IN PARALLEL:	-

PANEL UNDER TEST	
MANUFACTURER:	**CENTROSOLAR**
MODEL:	**S250P60**
TYPE:	**Polycrystalline**
MAX POWER:	**n.a.**
VMPP:	**29.73 V**
IMPP:	**8.41 A**
VOC:	**37.62 V**
ISC:	**8.91 A**
BETA COEFF. (VOC):	**-0.35**
ALFA COEFF. (ISC):	**0.03**
GAMMA COEFF. (PMAX):	**-1.075**
NOCT:	**46**
TOLL -:	**3**
TOLL +:	**3**
DEGRADATION (YEARS):	**n.a.**
DEGRADATION (PERCENT):	**n.a.**

INSULATION MEASUREMENT	
TEST ISO:	**n.a.**
MEASUREMENT MODE:	**Traditional**
TIME:	**n.a.**
V TEST:	**277**
RI (-):	
RI (+):	**201**
RP::	**201**
RI MIN::	

AMBIENT MEASUREMENTS	
IRRADIATION:	**n.a.**
AMBIENT TEMPERATURE:	**n.a.**
PANEL TEMPERATURE:	**n.a.**
MODE:	**n.a.**

Legend
ISO test: Voltage test selected to verify insulation (250, 500, or 1000 VDC).
V TEST: Actual test voltages applied respectively between the positive or the negative pole of the PV array and the ground.
RI (-): Measurement of insulation resistance between the positive pole of the array and the ground reference.
RI (+): Measurement of insulation resistance between the negative pole of the array and the ground reference.
RP: final value of the measurement obtained by calculating the parallel of the values of RI (+) and R (-) that is compared by the instrument with the set value of RI MIN.
RI MIN: minimum threshold limit for the insulation measurement.

INSTRUMENT_TYPE:	FTV500	FILENAME:	1.1.120 190603
INSTRUMENT SERIAL NUMBER:	TEST	SW VER.:	1.1.120 190603
FW VER.:	report_insulation_04062019_1446.rtf		

20. ERROR MESSAGES

MISURA	MESSAGGIO DI ERRORE	DESCRIZIONE
Cont	ErrCont1	TERMINAL VOLTAGE ERROR > 5V
Riso	ErrRiso1	PE-P VOLTAGE ERROR > 1000V
	ErrRiso2	PE-N VOLTAGE ERROR > 1000V
	ErrRiso3	PN-N VOLTAGE ERROR > 1000V
	ErrRiso4	TEST VOLTAGE ERROR < PN VOLTAGE
	ErrRiso5	RESISTANCE ERROR < 1Mohm
	ErrRiso6	IGBT HIGH TEMPERATURE ERROR
	ErrRiso7	VOLTAGE ERROR < 15V IN STRING MODE
	ErrRiso8	VOLTAGE ERROR < 15V IN PV FIELD MODE
	ErrRiso9	VOLTAGE PRESENT. TEST IMPOSSIBLE
IV	ErrIV1	IGBT HIGH TEMPERATURE ERROR
	ErrIV2	INVERTED INPUT VOLTAGE ERROR

5 - 2026
NF EN 696467A02 - Ed. 10

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