CHAUVIN ARNOUX

MEASUREMENT IN PHOTOVOLTAIC ENVIRONMENTS WITH THE FTV500

Solar energy can be used to generate electricity. Photovoltaic solar energy transforms the sun's rays into electricity by means of photovoltaic cells integrated in panels which can be installed on buildings or on the ground.

The principle is based on the fact that certain semi-conducting materials such as silicon generate electricity when exposed to sunlight: this is called the photovoltaic effect. One of its applications is in photovoltaic cells.

After installing a photovoltaic structure, efficiency and safety are crucial.

In this context, it is now required to perform verification tests.

It is sometimes difficult to read the technical specifications of a photovoltaic module.

It is important to know the current and the power ultimately available. But there was one point which long remained undefined: it is an electrical installation and, as such, it should also comply with the same safety requirements.

Consequently, nowadays photovoltaic installations have to meet the same safety criteria as any other electrical installation. Before connecting it to the mains, the electrical safety systems must be checked.

When it has been connected to the mains, its efficiency is checked. Subsequently, regular electrical installation inspections and testing are needed to ensure that the installation (or part of it it) is not damaged, which might threaten user safety, and to check that it complies with the applicable standards.

These checks also include an examination of the influence of any modifications to use of the installation, compared with the application for which it was previously intended. The installation's efficiency also needs to be checked because the primary aim of this installation is to generate electricity.

THE STANDARDS

- **IEC 62446 -** This standard is intended for designers and installers of photovoltaic systems connected to the mains, to use as a model to supply effective documentation to a customer. It describes the commissioning tests, the inspection criteria and the expected documentation to check the safety of the installation and the operation of the system. Its latest version also defines the information and documentation which must be provided to a customer after installing a photovoltaic system connected to the mains.

- **IEC 61010 -** This standard specifies the general safety prescriptions for electrical appliances for professional, industrial (process) and educational uses of all the instruments involved in the measurement process. This standard was established to determine the general safety standards for measuring instruments.

- **IEC 61557 -** This standard covers electrical safety in low-voltage distribution networks up to 1,000 VAC and 1,500 VDC. It concerns the equipment for inspecting, measuring and monitoring the protective systems.

- **IEC 61557 - Part 2 – Insulation resistance -** This chapter of the standard defines the requirements applicable to instruments for measuring the insulation resistance of appliances and installations without the presence of a current flowing.

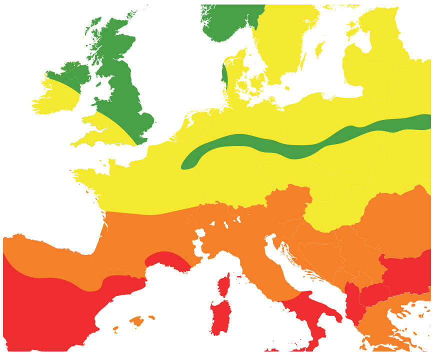
- **IEC 61557 - Part 4 - Resistance (continuity) of the earth and equipotential -** This chapter of the standard specifies the requirements applicable to equipment for measuring the resistance of earth conductors, protective earth conductors and conductors for equipotential bonding, including their connections and terminals, with an indication of the measured value or an indication of the limit.

- **IEC 60891 -** This defines the procedures concerning corrections according to the temperature and illumination to be applied to the measured i-v (current-voltage) characteristics of the photovoltaic devices. It also defines the procedures for determining the factors required for these corrections.

- **IEC 60904 -** This standard describes the procedures for measuring the current-voltage characteristics of photovoltaic devices under natural or simulated sunlight. These procedures are applicable to individual solar cells, sub-assemblies of solar cells or photovoltaic modules.

MEASUREMENTS

Like any part of an electrical installation, photovoltaic generation modules must comply with the elementary safety standards.



- **Continuity -** Continuity is considered satisfactory if the installation's continuity resistance is below 2 Ω. All the chassis-earths on the installation protected by a given device must be interconnected with a conductor connected to the same earth electrode. Continuity checking must be performed on the live installation with a specific measurement current (4 / 24 V @ 200 mA).

- **Insulation (live/dead circuits) -** It is advisable to regularly check the insulation resistance for both electrical equipment and installations. In this context, the insulation resistance is measured between each active conductor and the earth (in non-current-carrying mode). The tests are performed with a test voltage of several hundred V DC. The difficulty with a photovoltaic installation is that it is impossible to stop electricity generation. As long as the panel receives light, it generates electricity. For this reason, this test therefore requires the use of instruments capable of performing live insulation tests.

- **Standard Test Conditions (STC) -** The Standard Test Conditions define how the photovoltaic modules are examined in the laboratory in order to learn their electrical properties. They are standardized conditions enabling modules to be compared with one another.

The STC stipulate a certain number of test conditions, including in particular:

- The level of lighting on the module and therefore the amount of energy received on the surface of a solar panel is at its maximum when the sun's rays are perpendicular to the surface.

- Temperature of the cells: we now know that the effect of temperature on a photovoltaic cell influences the profile of its current-voltage characteristics. Only a small part of the solar radiation is converted into electricity. The rest remains as heat. So the temperature of a poorly-ventilated photovoltaic cells rises rapidly and it can be observed that the temperature of a photovoltaic cell has a significant effect on its voltage. The temperature's effect on the photovoltaic cell's current is negligible, however. It becomes clear that, the higher the temperature of the cell, the lower its open-circuit voltage.

- The Air Mass Coefficient, which corresponds to the optical path of solar radiation through the earth's atmosphere compared with the path when the sun is at its zenith. It can be used to quantify the solar spectrum in a given place after its radiation has travelled through the atmosphere.

In their product datasheets, module manufacturers always indicate general properties such as the module's dimensions or weight, as well as their theoretical electrical specifications. They also indicate the panel's efficiency (η) in Standard Test Conditions.

- **The NOCT conditions -** NOCT is the abbreviation of Normal Operating Cell Temperature. Indeed, the STC impose an illumination level of 1,000 W/m^2 and a cell temperature of 25°C. In reality, however, the cells in the modules do not operate in these conditions.

This has led the profession to introduce cell test conditions which are closer to reality, the NOCT conditions:

- Illumination level: 800 W/m^2
- External temperature: 20 °C
- Wind speed: 1 m/s
- Air Mass: AM=1.5

Instead of a condition concerning the cell temperature, there are specifications covering the temperature of the ambient air (20°C) and the wind speed (1 m/s). In these NOCT conditions, which are close to the operating conditions of photovoltaic installations, the cells comprising the photovoltaic modules are heated up to a stationary temperature known as the: Normal Operating Cell Temperature (NOCT).

- **Cell efficiency –** The efficiency of a photovoltaic cell or module is the ratio between electrical energy generated by this cell or module and the light energy received on the corresponding surface. The actual efficiency therefore varies continuously, depending in particular on the weather (cloud cover), as shadows may appear. Today, the smallest unit checked once it has been installed is the solar panel, which is itself composed of several photovoltaic cells.

- **Rif -** This is the variation of the cell's resistance according to the short-circuit current and the open-circuit voltage.

- **Inclination -** The inclination represents the angle formed by the panel and a horizontal surface. In Europe, reference is only made to the theory, and the perfect inclination of your future solar panels must be between 30° and 35° in relation to a horizontal line (close to the equator, the sun is directly above our heads at midday: ideally, the panel should be laid flat on the ground). But it is mandatory when testing to ensure that the sun is high enough on the line of the horizon. An inclinometer must then be used. The position of the azimuth is also important when setting up the installation.

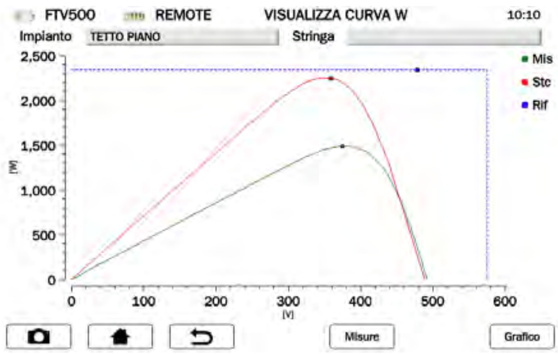
- **Open-circuit voltage Voc -** This is the voltage on the terminals of the cell when the circuit is opened, i.e. when the +pole and – pole are electrically isolated from any other electrical circuit (the current flowing through them is then zero).

- **Short-circuit current Isc -** This is the current flowing through the photovoltaic cell when it is short-circuited, i.e. when the + pole is connected to the – pole (the voltage on its terminals is then zero). The short-circuit current (Isc) rises proportionately as the illumination rises, whereas the open-circuit voltage (Voc) varies very little.

- **Peak power (Wpeak) -** The peak power is defined as the electrical power generated by- the cell (or panel) when it is subjected to the STC conditions. This value is used as a reference to compare solar panels with one another. The peak power of a module, written as Ppeak, is then defined as the maximum power from the module in the STC conditions.

$$\text{Therefore } P_{peak} = P_{MPP}(STC) = U_{MPP}(STC) \times I_{MPP}(STC).$$

The peak power represents a power, so it is expressed in Watt (W). However, as this is a rather unusual power value, it is expressed in Watt-Peak (WP).



- **I-V curve** - The current-voltage characteristic of a photovoltaic cell is determined by successive measurements of the voltage and current parameters on its terminals. This enables you to plot a voltage-current curve (I-V). This will then be compared with a curve calculated on the basis of the STC elements. The power supplied by the cell is the product of multiplying the current and the voltage. The point of maximum power is defined by the product of the voltage at maximum power Vmpp and the current at maximum power Impp. The PV (power-voltage) curve will not pass through this point. A good measurement curve comprises more than 200 points, and the larger they are, the greater the resolution and the analytical possibilities. The voltage varies from 0 V up to the maximum voltage MPP; the current is limited by the module's maximum current.

- **Efficiency of the AC/DC converter** - NOCT is an abbreviation of Normal Operating Cell Temperature. Indeed, the STC impose a level of illumination of 1,000 W/m^2 and a cell temperature of 25°C. In reality, however, the cells in the modules do not operate in these conditions.

For this reason, the profession has introduced test conditions which are closer to reality, called the NOCT conditions:

  - Serial connections of several cells increase the voltage while leaving the current the same.
  - If the cells are in parallel, the current increases but the voltage stays the same.

- **Effect of temperature** - A photovoltaic cell converts radiative energy (radiation) into electrical energy, with efficiency varying according to the technology. The rest of the radiation, which is not converted into electricity, is mainly converted into heat, while the residual fraction is reflected. The temperature of a poorly-ventilated photovoltaic cell thus rises very quickly. A photovoltaic cell's temperature has a significant effect on the voltage. The effect of temperature on the photovoltaic cell's current, is negligible. The higher the cell temperature rises, the lower the cell's open-circuit voltage falls and, at the same time, the lower the cell's power falls.

FTV500
5 MEASUREMENTS IN A SINGLE INSTRUMENT

- I-V curve (with quick check)
- Continuity
- Electrical insulation of the photovoltaic installation, whether it is live or not
- Efficiency of the UPS
- Data logger

PERFORMANCE, MAINTENANCE AND ELECTRICAL SAFETY

- Multifunction instrument for checking the electrical safety and performance of photovoltaic installations.
- Anti-glare screen
- Series of automatic tests:
  - Insulation measurement up to 1,000 Vdc
  - Open-circuit voltage(Voc) and short-circuit current (Isc)
  - Continuity of the protective conductors at 200mA
- Management and direct creation of reports on the instrument (direct storage on USB drive in the standard formats (pdf, doc, html, etc.))
- Remote unit for temperature and insolation measurement with Wifi transmission (irradiation/temperature)
- VNC for remote-control display and sharing via a Wifi connection
- Compliance with the international standards

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