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Apparatus:

Module Solar Simulator
Series: Quick Sun 820A, Producer: Endeas Oy

The simulator is designed to measure current-voltage characteristics and the resulting electrical parameters of PV modules. This device consists of a high quality light source in

the form of flash Xenon Lamp, which allows illuminating the module with the light similar to the sunlight during the measurement. This lamp is supplied with flash generators, which transfer the energy appropriate to the research carried out under the STC (Standard Test Conditions). Moreover, simulator is equipped with a central processing unit allowing the flash control and data acquisition. The Endeas software is responsible for processing the data obtained during the measurement. Additionally, the entire device is equipped with a special test frame for conducting measurements in total blackout and infrared sensor for non-contact temperature measurement module.
The individual components of the measurement system are shown schematically in Fig. 1.

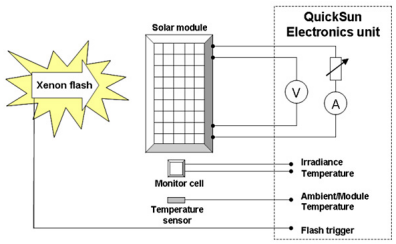


Fig. 1. The scheme of the measurement system - simulator for

the measurement of PV modules electrical parameters.

During the module measurements, the connection based on the 4-probes measurement principle is used, what allows to measure correctly the electrical parameters of PV modules without loss of power associated with the resistance of the cables and connectors.
Complete current-voltage characteristics are obtained after one flash at a given radiation intensity level when the module is connected to the measurement circuit. It is possible to carry out the tests under STC (1000 W/m2), and for any radiation power in the range 200-1000 W/m2 for the spectrum of AM 1.5.

The results are presented in a graphical and numerical form. Numerically determined are:

ISC - short circuit current,
IMP - current in the maximum power point,
VOC - open circuit voltage,
VMP - voltage in the maximum power point,
PM - maximum power,
FF - fill factor,
Eff - photovoltaic conversion efficiency.
In addition, there are numerically determined parameters such

as:
RS - series resistance
RSH - shunt resistance

Numerical and graphical measurement result is shown in Fig. 2.

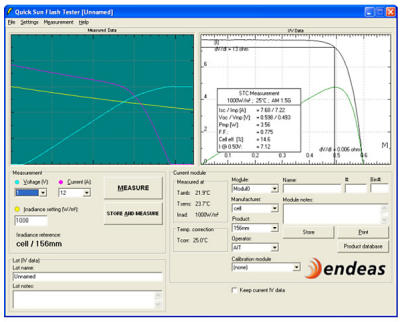


Fig. 2. The window depicting the result of the module measurement.

Solar simulator works in measurement class of AAAA determined in accordance with IEC 60904-09, ed. 2. Basic technical parameters of the simulator and AAAA class consisting parameters are shown in Table 1

Table 1. Quick Sun 820A simulator parameters

Parameter

Value (testing class)

Max. module size [cm x cm]	200 x 120
No. measurements over time of 1 h	12
Measurement cage size [cm x cm x cm]	465 x 240 x 250
Lamp pulse duration [ms]	15
Radiation intensity [W/m2]	200 – 1200
Lamp lifetime [flash]	40 000

- **Spectrum (A) < ± 25%**
- **Non-Uniformity (A) < ±2%**
- **Short term instability (STI) (A) < 0,5%**
- **Long term instability (LTI) (A) < ±2%**

Preparation of tested samples:

The measurement is acceptable for the photovoltaic modules made of monocrystalline, polycrystalline silicon and thin-film amorphous silicon as well.

The laboratory performs tests on PV modules supplied by the customer. During the reconciliation of the order conditions the customer is informed about the requirements for the modules and how they should be prepared for the tests.

Photovoltaic module for testing should have dimensions not exceeding 200 x 120 cm.

Solar Simulator with the system for I-V characteristic measurements of solar cells
Solar Simulator: Model SS 200AAA
Producer: Photo Emission Tech Inc.
System for I-V characteristic measurements of solar cells: „Solar cell I-V curve tracer" model SS I-V CT-02" with the Auxiliary Unit ver.2
Producer: PV Test Solutions Tadeusz Żdanowicz

Solar Cells Simulator with the I-V characteristics measurement system is designed for the measurements of current-voltage characteristics in the STC (Standard Test Conditions) defined by European standard IEC 60904-3 as irradiance with spectrum corresponding to AM1.5 (G means global) equal to 1000 W/m2 and cell temperature 25 oC and NOCT (Nominal Operating Cell Temperature Conditions according to the IEC 61853-1) conditions respectively. System for I-V characteristic measurements of solar cells meets all requirements of the IEC 60904-1 standard. The all components of the system are presented in Fig. 3 - 5.

Used four probes (Kelvin) technique is necessary to correct measurement of the electrical parameters of solar cells without power losses associated with the resistance of the cables and connectors. This means that two separate probes are needed

to electrical current flow through the cell while other two are used to directly measure voltage drop on the cell. In this system brass plate with polished and gold plated surface serves as the back current probe. Inside the table, in its central part, two voltage gold plated probes for solar cell back-side contacting are located. These probes are electrically isolated from the table. Contacting to solar cell's front side is provided by the set of four coupled voltage/current gold-plated telescopic probes. Additionally, also another probing option is used. This is a system with two or three sets of multi-pin soft-touch gold plated probes mounted to the aluminium frame (Fig.4). This system is suitable for testing large amount of big solar cells (≥16,5 x16.5 cm).

A Heating-Cooling Controller has been designed to control the temperature of the measuring table in the ranger of ~0-60 oC. This is done by supplying electrical current to set of four Peltier elements having total maximum rated power of about 280 W. The elements have been attached to the rear side of the measuring table. Depending on the direction of the current through Peltier elements the table may be either heated or cooled.

This I-V measurement system measures I-V curves of solar cells both in dark as well in light mode. Light I-V characteristics are registered under stable light of specified intensity.

Numerical and graphical measurement result is shown in Fig. 5.

The result of the measurement is characteristic I-V in a graphical and in standard text (ASCII) file, and set of numerical data and cell parameters:

ISC - short circuit current,
IMP - current in the maximum power point,
VOC - open circuit voltage,
VMP - voltage in the maximum power point,
PM - maximum power,
FF - fill factor,
Eff - photovoltaic conversion efficiency.

In addition, there are numerically determined parameters such as:

RS - series resistance
RSH - shunt resistance

To determine

In order to accurately determine the series resistance, the

procedure described in the standard IE60891 has been applied. This procedure requires measurement of the two I-V curves under two significantly different light intensities.

Additionally, data I-V may be subjected to additional analysis by fitting I-V curve to specified cell's equivalent diode model (SEM, DEM or VDEM).

The result is a diode parameters such as dark current density, diode quality factor, series and parallel resistance.

Fig. 3. The view of the setup for measurement I-V characteristics of solar cells

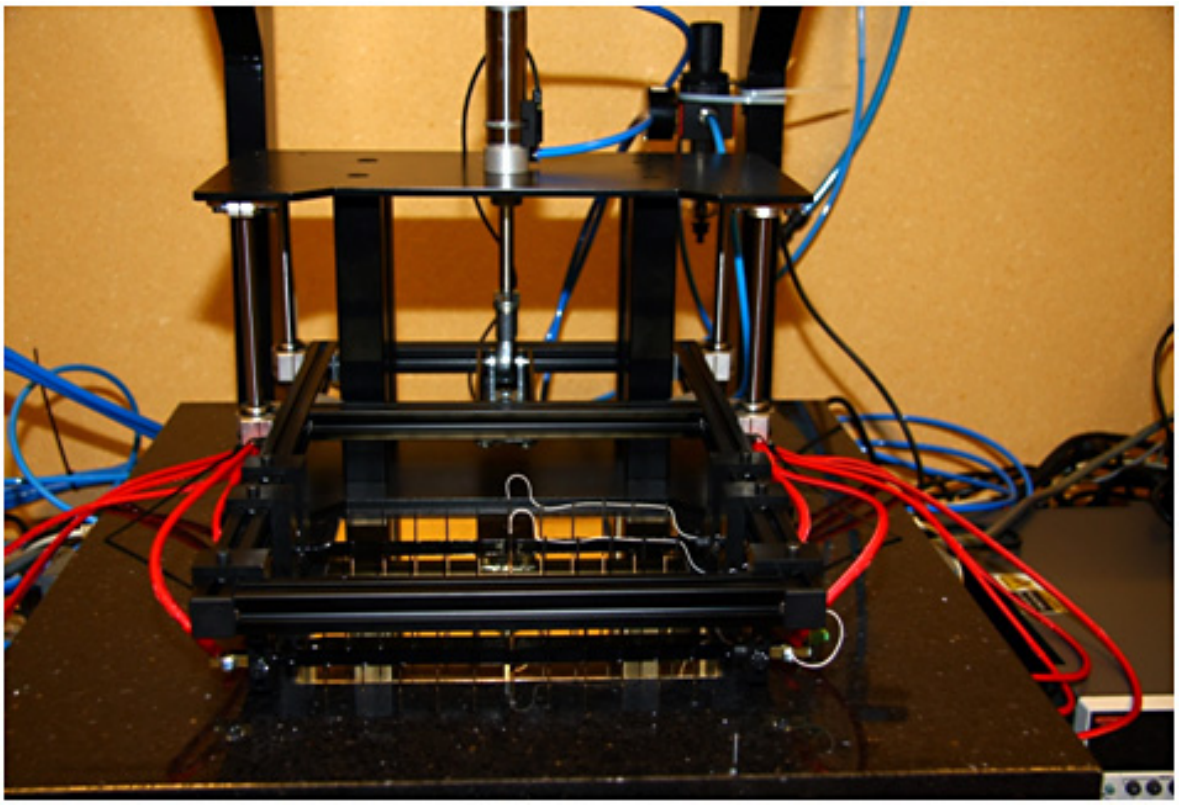
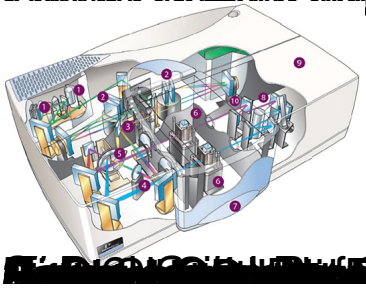


Fig. 4. Measuring table with the multi-pin voltage/current probes of the setup (Fig.3).

Spectrophotometer UV-VIS-NIR
Series: Lambda 950 S
Producer: Perkin Elmer

Spectrophotometer Lambda 950 S (Fig. 7) is designed for optical parameters measurements especially: reflectance, transmission coefficient in the solid and liquid materials in the wavelength range of 200 - 2500 nm.

[illegible] UV/VIS/NIR Lambda 950S [illegible] system are



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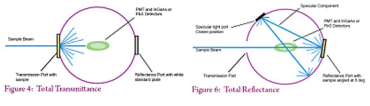

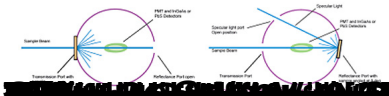

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PCA Zakr

Laboratorium Fotowoltaiczne w Kozach L-9 ul. Krakowska 22; 43-340 Kozy		
Przedmiot badań/wyrób	**Rodzaj działalności/ badane cechy/metoda**	**Dokume**
Moduły fotowoltaiczne na bazie ogniw z krzemu mono i polikrystalicznego oraz z krzemu amorficznego	Parametry elektryczne i charakterystyki prądowo-napięciowe ogniw fotowoltaicznych Wielkość badanego ogniwa Zakres: (20x20 – 200x200) mm Napięcie ogniwa Zakres: (0 – 2,5) V Prąd ogniwa Zakres: (0 – 20) A Pomiar z użyciem symulatora promieniowania słonecznego oraz układu pomiarowego (dla warunków STC)	P/19/IB-20 wyd. 2 zmod. 2

Laboratorium formułuje opinie i interpretacje w sprawozdaniach z badań podanych w powyższej