Developing a solar panel testing system

Árpád Rácz*, István A. Szabó*, Lajos Harasztosi*, Sándor Kökényesi**

*Department of Solid State Physics
Institute of Physics, University of Debrecen, Faculty of Science and Technology
Postal address: 4010 Debrecen, Pf. 2., Bem tér 18/b
E-mail: arpad.racz@gmail.com, iaszabo@tigris.unideb.hu

**Department of Experimental Physics
Institute of Physics, University of Debrecen, Faculty of Science and Technology
Postal address: 4010 Debrecen, Pf. 2., Bem tér 18/b

***Abstract* – Solar energy is increasingly used to generate electricity for individual households. There is a wide variety of solar panel technologies, which should be tested at an individual level during their lifetime. In this paper, the development of a testing station at the University of Debrecen is presented. The testing system can be used for research and educational purposes and for in field applications equally well.**

***Keywords:* solar cell, PV cell, testing system, characteristics**

I. INTRODUCTION

It is expected, that photovoltaic systems will be increasingly used in everyday life as a green and distributed energy generation technology. There is a diverse range of solar panels on the market even today, and the type, capabilities are expected to increase. A long lifetime is expected to recover the cost of the system both in financial and energy expenditure. Unfortunately, energy provided by solar panels is now more expensive than using conventional energy sources, so it is important to increase the efficiency of these systems. There are to ways to do this, one is by developing cheaper and more efficient solar panels and the other is by improving the efficiency of the system by optimizing the operating conditions. Defects of a cell or partial shadows can strongly reduce the overall efficiency of the system.

There are three typical applications of solar (PV) panels. The grid connected systems feed the electricity into the public electric grid. The greatest advantage of these systems, that they not require batteries. There is wide electrical power range for this system from 700 W up to 750 MW. A quasi-autonomous power supply can reduce electricity needs of a single household or building. It uses batteries to store the energy until it is needed. Typical power for this system is 1 to 3 kW. The off-grid systems are able to provide electricity at remote places (e.g. farms, cabins, etc.) without building of pricey electric lines. In these cases the solar cells usually combined with other powers sources, e.g. wind generators.

PV panels – used generally – can be divided into to main categories: crystalline and thin film panels. The most common crystalline panels are monocrystalline and polycrystalline silicon panels. 80 % of the currently working panels are polycrystalline silicon panels. They are easier to manufacture and cheaper than monocrystalline silicon panels. Various thin-film technologies currently being developed and it is expected, that this technology will be the solar cells of the future. This technology is cheaper than any crystalline technology. Thin film solar panel can be made from different materials, e.g. cadmium telluride (CdTe), copper indium gallium selenide (CIGS), amorphous silicon (a-Si), etc. Many factories all around the world are currently under construction to produce thin-film solar panels.

There is an important role of the universities in the spreading of green energy related technologies. If students learn about the main characteristics of these devices they can help to promote these technologies during their carrier. With this aims, we are developing a test system at the University of Debrecen for education and research applications. The massive development of this area also shows that solar panel testing is an important issue.

The development of testing equipment and methods are essential for various reasons:

- validation of the panels before installation
- measure the working power
- comparison of different technologies
- testing for degradation
- identification of defected cells

The solar panel testing should be done close to the operating conditions. This requires proper illumination and electrical load. We intend to use the measurement system not only in the laboratory, but also at various installations, which meant, that mobility was also a concern in the design.

II. MEASUREMENT SYSTEM

A measurement system was designed to determine the electrical parameters of a PV cell. The following parameters can be measured: I-V curve, short circuit current (I_{OC}), open circuit voltage (V_{OC}) (Fig. 1.). Based on these values the software is able to calculate the maximum power point (M_{PP}) and peak power (P_{max}) of the cell. The values of series resistance (R_S) and shunt resistance (R_{SH}) are also calculated after each measurement cycle (Fig. 2.). These parameters can be used in PV cell characterization to express the power loss and they are useful for solar development (Fig. 3.). With the optimization of these parameters a better PV cell can be designed.

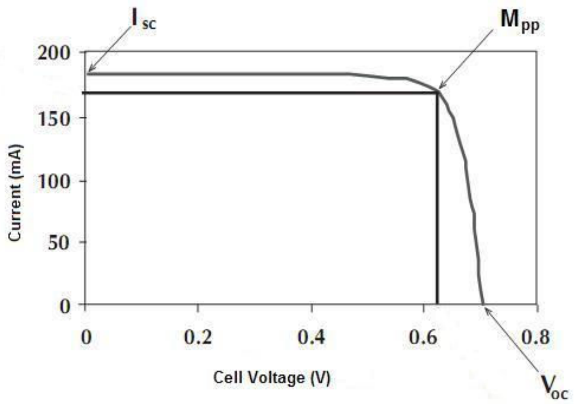

Fig. 1. Characteristics of a PV cell

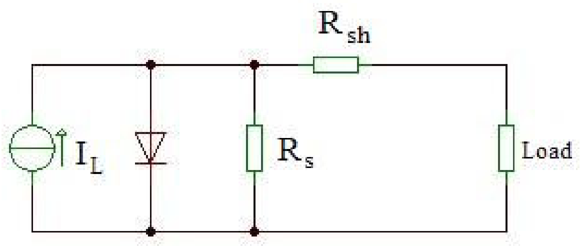

Fig. 2. Equivalent circuit of a PV cell

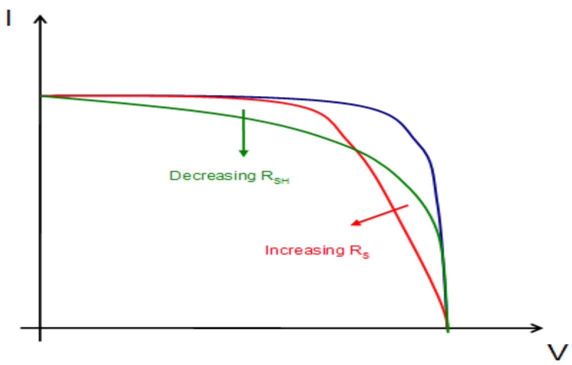

Fig. 3. Effect of series resistance (R_S) and shunt resistance (R_{SH})

The system contains the following components (Fig 4.):

- Laptop computer for portable measurements with two USB ports
- NI LabView based application software
- NI USB-6009 data acquisition unit
- Digital multimeter (DMM) with serial interface + USB-serial converter
- Dummy load (resistance can be controlled by the application)
- Light source (optional)

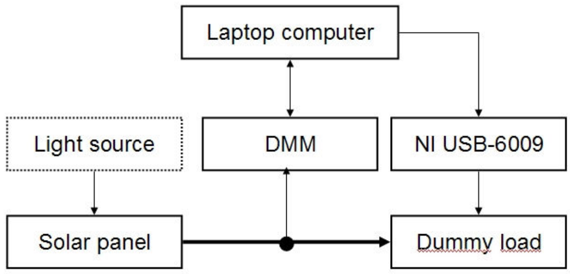

Fig. 4. Block diagram of the measurement system

The concept of the system was to examine PV cell under different operating conditions in the laboratory and also in the field. That's why all of its components are portable and can be connected to a laptop computer. The NI USB-6009 is used to control the dummy load.

The dummy load contains a power MOSFET controlled by one of the analog outputs of the NI USB-6009 unit and two relays controlled by the digital outputs. The MOSFET serves as a variable load (between 1 MΩ and 1 Ω). By using relays it is possible to make real open and short circuit conditions.

The application software controls the whole measurement cycle which contains the following procedure:

1. Activates the "open circuit" relay and measures the open circuit voltage.
2. Increases the analog output's voltage level the resistance of the power MOSFET decreases and the system measures PV voltage and current.
3. Finally activates the "short circuit" relay for measuring short circuit current.

After this measurement cycle the application automatically fits the I-V curve to the data points and displays both (Fig. 5.). The software calculates the maximum power point's (M_{PP}) current and voltage values and the peak power (P_{max}) of the PV cell.
The series resistance (R_S) and shunt resistance (R_{SH}) are also calculated after the measurement cycle. It is possible to obtain these resistances from the I-V curve (Fig. 6.).

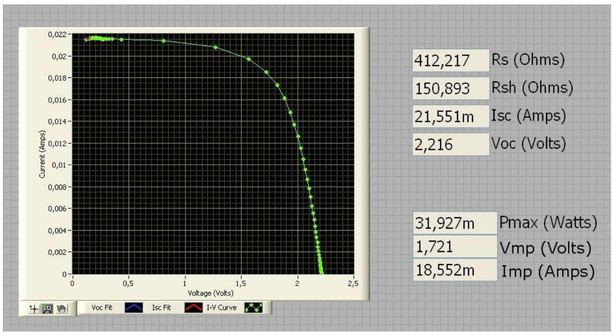

Fig. 5. Results of one measurement cycle

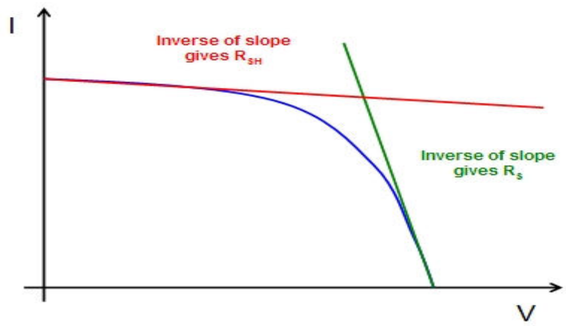

Fig. 6. Obtaining resistances from the I-V Curve

The application is also capable to log the measured data and store it in a file. These data are useful for comparing the results of tests under different operating conditions and can be used for further analysis.

For testing purposes, it is possible to use the following light sources:

- solar simulator
- sunlight
- focused light source

Solar simulators are commonly used in solar cell testing. They are usually some kind of high power xenon or halogen lamps. To simulate the Sun, 1000 W/m^2 intensity is required. The measurement system was tested with a high power halogen lamp. Under these circumstances it was possible to reach at least 80% of the nominal peak power of the PV cells. It was also tested with sunlight successfully.

One way to identify defected cell or cells is the local illumination of the solar panel by using a focused light source. This light source is currently under development.

During the test of the measurement system, the behaviors of a solar cell were tested under the following circumstances:

- different cell temperatures
- different light intensities (adjusted by the distance from the light source)

Typical behaviors of solar cells were successfully indentified during these tests (Fig. 7. and 8.).

The following PV cells were tested:

- IstarSolar IS10P (Fig. 10.)
- Polycrystalline cells from solar powered garden lamps
- Thin-film cell from solar powered garden lamp
- Laboratory equipment PV cells

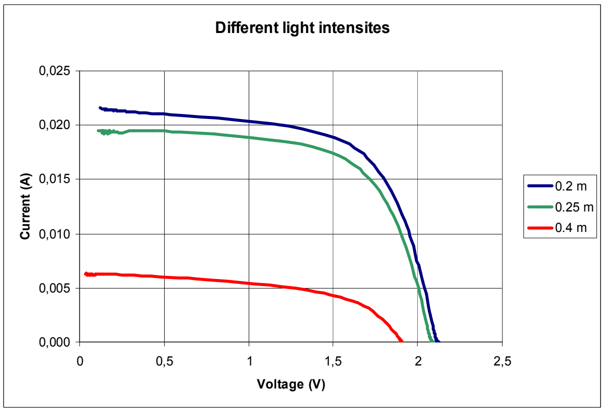

Fig. 7. Different light intensities

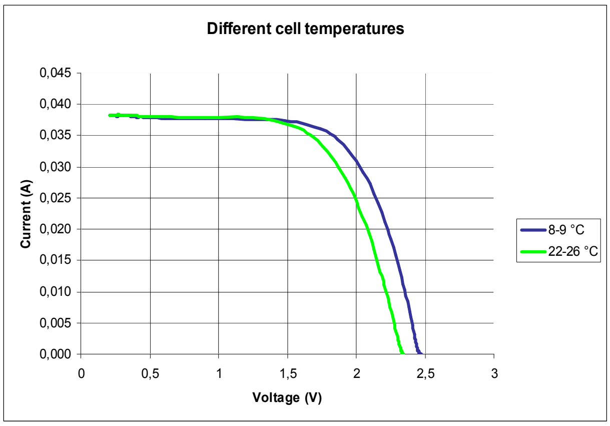

Fig. 8. Different cell temperatures

There is another way to indentify defected cells, by using thermal camera. (Fig. 9.) This process requires heating the solar with reverse current. The thermal camera for this method is far more expensive than the measurement system.

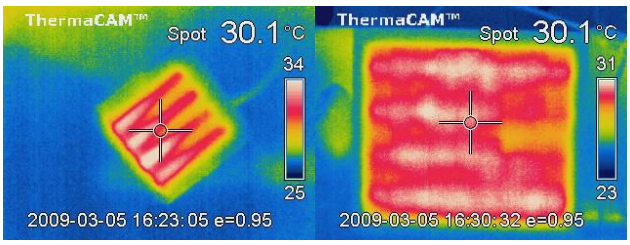

Fig. 9. Thermal images of reverse current heated solar cells

A solar tracking system is currently under development, which uses a commercial motorized satellite dish system for positioning. With this equipment it is possible to test the effectiveness of the tracking systems and also to examine the power output of the different PV directions and angles (Fig. 10.).

Fig. 10. Solar tracking system

III. CONCLUSIONS

Most solar panel installations allow the measurement of the generated power, but do not allow the determination of the physical parameters and the characteristics of a solar panel. We have developed a testing station, which can determine the equivalent electrical parameters of solar panels under normal operating conditions using variable load. The system can be used to compare the efficiency of different type of solar panels, to identify faulty cells or panels, and to sensitively test degradation processes. The system was developed as a student project, and can be used in education, research and industrial applications.

REFERENCES

[1] J. Mizsei, V. Tímár-Horváth, *„Napelemek (PV cells)”,* Budapest University of Technology and Economics, 2003

[2] W. Durisch, J. Urban, G. Smestad, *“Characterization of solar cells and modules under actual operating conditions”*, WREC 1996

[3] Földváry Á., *“Napelem karakterisztika mérő műszer készítése (Construction of a PV cell tester)”*, 2008

[4] Keithley Instruments Inc. “Measuring photovoltaic cell I-V characteristics with the model 2420” http://www.keithley.com/servlet/Data?id=4083&jsession=3410611066782248413 viewed on: 12th of March, 2009.

[5] Cs. Kovács, *„Napelemek működése és alkalmazása (Operation and application of PV cells)”*, Budapest Tech Polytechnical Institution, 2008.