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An Approach on the Design of a Solar Cell Characterization Device

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***Abstract*—**This paper presents the development of a compact, portable and easy to handle solar cell characterization device. The presented device reduces the effort and cost of single solar cell characterization to a minimum. It enables realistic characterization of cells under sunlight within minutes. In the field of photovoltaic research the common way to characterize a single solar cell or a module is, to measure the current voltage curve. With this characteristic the performance and the degradation rate can be defined which are important for the consumer or developer. The paper consists of the system design description, a summary of the measurement results and an outline for further developments.

***Keywords*—**Solar cell, photovoltaics, PV, characterization.

I. INTRODUCTION

THE characterization of solar cells and modules is an important task in order to compare different types of cells and products and verify their characteristics. This is typically done under standard-test-conditions (STC) [1]. The STC include, among others, temperature and irradiance values under which the cells are tested. Fully automated test equipment (so called flasher) exists, which adjust these STC and measure the cell characteristics. Nevertheless it is also necessary to test solar cells under non ideal conditions. These are high ambient temperatures or partially shadowed cells. The knowledge about the degradation of the solar cell is important for the customers and can also be extracted from the solar cell characteristic. A common way to characterize a solar cell is to measure its current voltage curve (I-V-curve) [2], [3]. This can be achieved by applying a variable load (shunt resistor) to the solar cell and measure the resulting currents and voltages. From the I-V-curve various important cell parameters like the short circuit current i_{sc}, the open circuit voltage v_{oc} or the maximum-power-point (MPP) can be obtained [4].

Modern mono crystalline solar cells have an open circuit voltage v_{OC} of approximately 0.6 volts and a short circuit current i_{SC} of approximately 8A. Their degradation is about 10% to 15% in the period of 20 to 25 years [5]. Conversely, thin film cells have a completely different degradation characteristic. In the first year, the degradation reaches values up to 25% and afterwards the thin film cells hardly show any degradation effect in the next few years. To measure the characteristics and visualize the degradation effect of solar cells, the solar cell characterization device (SCCD) was designed. A simplified measurement setup is shown in Fig. 1. The setup consists of the SCCD, the two attached sensors (irradiance and temperature) and the measured solar cell. The temperature sensor is directly mounted on the solar cell to get the surface temperature. The irradiance sensor is mounted in a way that guarantees equal illumination of both, solar cell and sensor. To be able to measure different kinds of solar cells, the requirements for a measurement device are:

- Solar cell measurement under natural conditions,
- Measure a single solar cell or a module up to 4V total voltage and 10A current,
- Handheld device with integrated battery and storage medium,
- Offer a compact design and user-friendly handling,
- Measure all relevant parameters, like temperature and irradiance which are used to calculate the STC parameter.

The following sections of this paper are organized as follows: In Section II, the system design of the device is described. It’s split in hardware and software sections. The hardware section deals with the different units and their features. The software section describes the measurement sequence and gives an outline about the internal calculations and conversions of the measured data. Section III, shows the measurement results and the calculation of the compensation of the measured characteristics. The last section offers an outlook for further project- and research work and concludes the investigations.

II. SYSTEM DESIGN

The hardware offers a rich set of features, which make it suitable for portable usage and measurements of the different solar cell types. The system consists of four different units, the processor -, the periphery -, the sensor - and the control unit which are shown in the block diagram of Fig. 2.

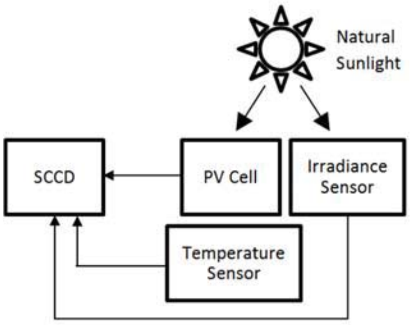

Fig. 1 Measurement Setup

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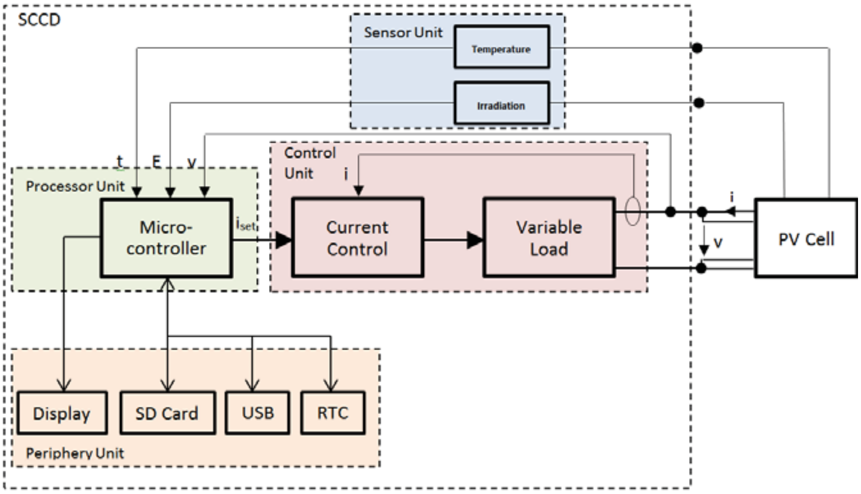

Fig. 2 Block Diagram of the Hardware Design

A solar cell (PV cell) can be connected to the SCCD via four-wire connection. The temperature t and irradiance E from the solar cell under test is measured with sensors to record the ambient conditions of the test. To capture the I-V-curve of the connected solar cell, different cell currents are adjusted by the control unit. At each adjusted current level, the cell voltage and current is measured. The control unit uses a shunt resistor combined with a MOSFET and an analog control block to adjust the desired currents. In Fig. 3 the schematic of the control unit is shown. The two MOSFETs Q1 and Q2 are operated in their linear (resistive) region. Therefore, they can be used to adjust different resistive loads for the solar cell V4 and further different currents $\hat{i}$ through the cell. The set point for the control is given by the voltage source V3. A hall sensor is used to measure the actual cell current. In the simulation, the hall element is represented by a current controlled voltage source V5. The measured current $\hat{i}$ and feeds back a corresponding voltage to the operational amplifier U2A. The difference between the set point and the actual value is weighted by the operational amplifier which acts as an integral control. The output of the amplifier drives the two MOSFETs.

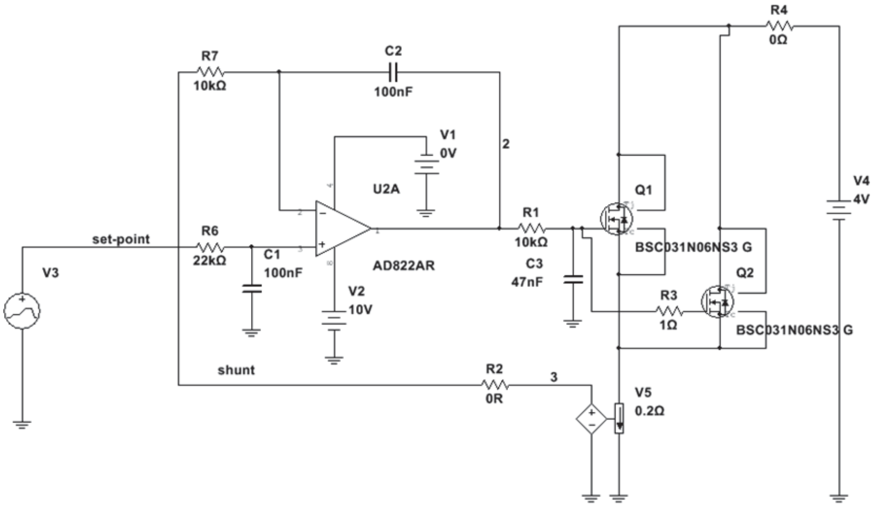

Fig. 3 Schematic Control Unit

A simulation of the control unit was done to test its functionality and to fine tune the control parameter. To minimize the measurement duration, a fast adjustment of the current steps that form the I-V-curve is required. Therefore a short settling time of the control unit is required. In the current configuration the control unit reaches a desired current (step response) with a settling time of 10ms. These simulation results were verified by measurements. The simulation and measurement result for a predefined step response show an excellent match (Fig. 4).

The control unit and the interaction of the hardware units are controlled by the device software. The main component of the device software is the measurement function (Fig. 5). It measures the open circuit and short circuit currents ($\hat{i}_{OC}$, $\hat{i}_{SC}$) and voltages (v_{OC}, v_{SC}). Based on these parameters and with respect to the typical slope of an I-V curve, current steps I_{step} are calculated that lead to a precise module characteristic with a low number of samples. This is achieved by providing an increased density of samples around the MPP and a low number of samples around the open circuit and short circuit points. The variable load and the current control unit are used to adjust these pre-calculated current steps. At each current step the cell voltage v[n] and module current î[n] are measured, which are used to form the I-V-curve of the solar cell. The recording of an I-V-curve takes less than a second and therefore guarantees a minimal self-heating of the components.

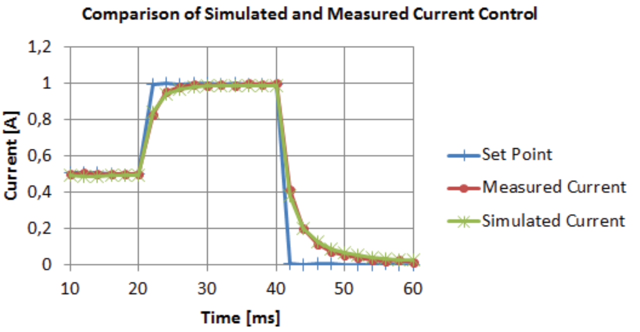

Fig. 4 Comparison of Simulated and Measured Current Control

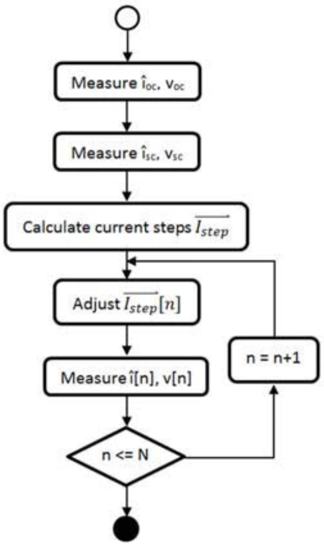

Fig. 5 State diagram of measurement function

The SCCD enables measurements of the cell voltage and current as well as temperature und irradiance. Table I shows the measurement range of each parameter. The current and voltage ranges enable measurements of standard crystalline solar cells. The read out values from the temperature and radiation sensors can be used to process the solar cell characteristic at STC.

All measurement results can be accessed through the peripheral unit. This includes visualization on the LC-display and data storage on SD card. The recorded data can be transferred via USB interface to a computer.

III. Measurement Results

Fig. 5 shows the measured characteristic (Raw data) of a crystalline solar cell and the steps of the post processing. The measurement was taken under "real world" conditions with natural sunlight perpendicular to the solar cell. The included sensors have measured the cell temperature to be 62°C and the irradiance to be 828W/m^2. To get a comparable characteristic from this solar cell under test, the measured characteristics must be converted. The goal is to compute solar cells under test a representative characteristic which is close to STC and makes cells of any kind comparable. This is currently done in an offline post-processing. The first step of the post-processing is to consider the measured irradiance and adjust the cell current î to match the STC value of 1000W/m^2 (Compensation 1).

TABLE I
Measurement Ranges

Parameter	Range	Resolution	Accuracy
Cell Voltage	0 -4V	50µV	-
Cell Current	0 – 10A	152µA	-
Temperature	-20°C to +400°C	0.25°C	±2°C
Irradiance	0 – 1400W/m^2	317W/m^2	±10%

The next step is to consider the measured temperature and adjust the cell voltage to match the STC value of 25°C (Compensation 2). The last step is to include the series resistance R_s as described in [6] of all wires and connectors (Compensation3). After these adjustments, the results of the mobile solar tester achieved a good match with the results of a commercial stationary flasher unit [7] (Flasher data). In the stationary flasher unit the solar cell is mounted in a temperature controlled black-room where a flash light generates defined light pulses of 1000W/m^2 amplitude. While flashing the cell a computer measures the cell current and voltages for various load resistors. Compared to this procedure the large benefit of the mobile solar tester is its mobility: Single solar cells can be tested under real conditions including natural sunlight, realistic cell temperatures and offer measurements with partial shadowing. Due to the infrastructure of the used HW (SD card) also long time measurements in configurable minute intervals can be adjusted.

IV. Discussion/Outlook

Like mentioned in the measurement results section, for getting a comparable characteristic, a set of compensations had to be done offline on a computer. A further step in the development on the SCCD is the implementation of this offline post-processing. As a next step, a long-term test setup with the SCCD [7] is planned, to evaluate the performance of the device and show the measurement results. A commercial solar cell tester [7] is used to verify the recorded I-V-curves. The investigations of the long term tests will be used for further optimization of solar cells and to enhance the SCCD.

V. Conclusion

A characterization of single solar cells under real environmental conditions is an interesting topic in the R&D area of solar cells. Most single solar cell test units and flashers are stationary and do not provide this opportunity. Due to this drawback, a small and portable solar cell tester was developed that is optimized for the current and voltage range of crystalline solar cells. Measurement results that are comparable to those of stationary flashers can be achieved with a simple device.

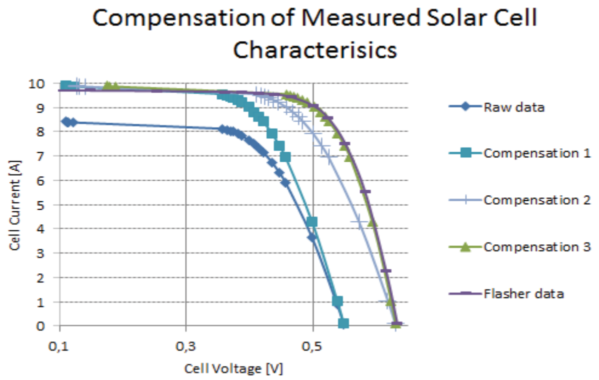

Fig. 6 Compensation of measured solar cell characteristics

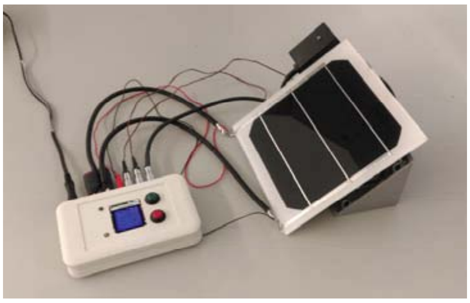

Fig. 7 CTR SCCD test setup

The device measures the I-V-curve of a single solar cell and can be used for automated and time triggered measurements. This enables the long term characterization of single solar cells under real environmental conditions including changing illumination and temperature as well as shadowing or pollution effects of the cell.

VI. ACKNOWLEDGEMENT

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REFERENCES

[1] M. Garcia, L. Marroyo, E. Lorenzo, J. Marcos, M. Perez, " STC power for 15MW of PV comparing nameplate, initial power and power after 4 years", Progress in Photovoltaics: Research and Applications, pp22:242-247, Wiley Online Library, (2012).

[2] National Instruments, "Photovoltaic Cell I-V Characterization Theory and LadVIEW Analysis", http://www.ni.com/white-paper/7230/en/pdf, (2012).

[3] International Electrotechnical Commission. Standard IEC 60904-1: Photovoltaic Devices. Part 1: Measurement of Photovoltaic Current-Voltage Characteristics.

[4] W. Muehleisen, "Präzise Schattenspiele (MPP Tracker)", photovolatik, Vol. 6, pp. 58-63, Alfons W. Gentner Verlag GmbH & Co. KG, Germany, (2014).

[5] Dirk C. Jordan, Sarah R. Kurtz, "Photovoltaic Degradation Rates – An Analytical Review", Progress in Photovoltaics: Research and Applications, (2012).

[6] Martin Wolf and Hans Rauschenbach, "Series resistance effects on solar cell measurements", Advanced Energy Conversion, Vol. 3, pp. 455-479, Pergamon Press, Great Britain, (1963).

[7] Sinton Instruments, "FCT-400 Series product note", http://www.sintoninstruments.com/PDFs/Sinton-FCT-400-Series-product-note.pdf, (2011).