NOVEL MEASURING SYSTEM FOR LONG TERM EVALUATION OF PHOTOVOLTAIC MODULES

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ABSTRACT: A new measurement technology for automated long term measurement evaluations of photovoltaic (PV) modules has been invented by IWES. The measuring card ISET-*mpp meter* (Figure 1) not only allows the measurement of the main module parameters but also enables the complete I-V characteristics of the modules to be measured. Especially for newly developed modules this approach offers great potential for performance-tests, derivation of model parameters and new model equations. By using standardized communication commands it is possible to include the measuring board in a data acquisition system. Thus long-term measurements of PV modules in different operating modes and in different environments become possible. The I-V curves of the modules can be determined at specified intervals, or initiated by a trigger signal. Hereby for example, the influence of various weather conditions and shadowing situations to the module performance can be assessed. The measurement results can be sent via a serial port to a PC for further data processing.

Keywords: measurement devices, measurement systems, system performance, qualification and testing, curve tracer

1 INTRODUCTION

The evaluation of PV-modules is usually done by measuring characteristic electric parameters such as MPP-current and MPP-voltage. These data can be determined by using different solutions, e.g. long time outdoor tests. The measurement values are usually taken at equidistant intervals (for example one value per minute), together with the actual irradiation value and module temperature data. In addition to these MPP-values, the I-V curve of a PV-module delivers more information about the behaviour of the module, especially when it is favourable to estimate the mathematical model parameters of the module. Some measurement devices are available today on the market. Many of these instruments are however unable to continuously measure the characteristic curves at equidistant intervals and store all these curves e.g. in a database.

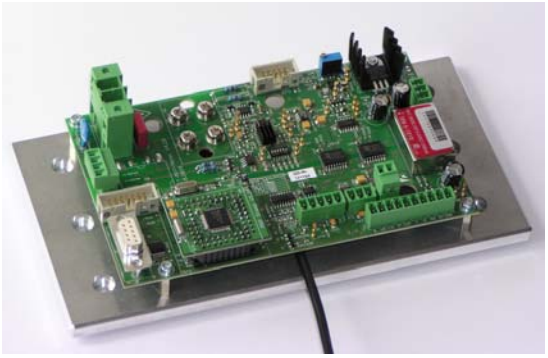

Figure 1: The ISET-*mpp meter*

Other instruments use switched power electronic devices to trace the curve of the module or to measure the characteristic values. In these cases, the EMC influence on the values measured must be taken into account. If the instrument does not measure the I-V-curve, the MPP tracker of the instrument is an additional error source.

With the ISET-*mpp meter*, the measurement of I-V-curves as well as the investigation of characteristic module values is possible. The basic principle of the meter is an I-V curve measurement with 256 points. In addition the I_{MPP}, U_{MPP}, I_K, U_0 values are extracted. T_{Mod} and the irradiance at the tilted module is measured synchronous with the I-V curve. The measurement data is stored for further processing in a database. Figure 1 shows the ISET-*mpp meter*.

2 MODE OF OPERATION

A current sink, controlled by the microprocessor, drives the modules under test in discrete steps from open-circuit to short-circuit [Geb-04]. The voltage across the module and the module current is measured by a 16-bit A/D-converter. Figure 2 illustrates the operational principle. Based on the logged curve-data, the short-circuit current and the open circuit voltage, both the MPP-current and the MPP-voltage can be determined. At the same time the module temperature, I-V curve, irradiance and, if necessary, the temperature of the irradiance sensor are recorded. The measurement results are sent via a RS 232 interface to the computer. All the readings except the I-V curve are also available on up to 8 ports as analogue voltages, generated by a D/A converter and scaled to the range 0-2 Volts. Thereby the integration of measurement boards into existing analogue logger systems is possible. The measurement board will be calibrated by IWES and achieves accuracies of <1%. Connection to individual modules is possible, but also small strings can be measured. Maximum input of a measurement card is 250 Wp. For modules with a larger power, an additional extension adaptor is available. With this booster, the performance rises to 500 Wp. The measurement of the I-V curves is completed in a period of 300 ms. In cases where the measurement time is too short, e.g. because of the capacitive load of thin film modules which

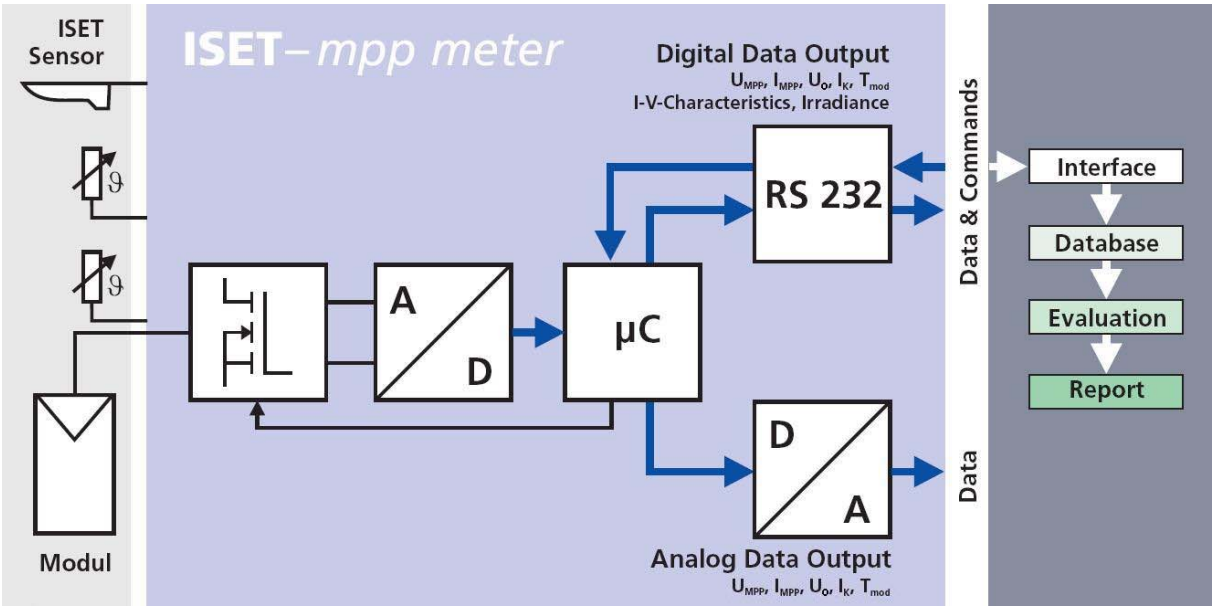

Figure 2: Operational principle of the ISET-*mpp meter*

interacts with the measurement, the measurement period can be extended in steps of 1 ms. Synchronised measurement of several modules is possible by means of the trigger input. Using an external trigger signal, a simultaneous measurement of all connected measurement cards is carried out, even if no serial communication between the data logger and the cards exists. This makes available simultaneous measurements for analogue logger systems too.

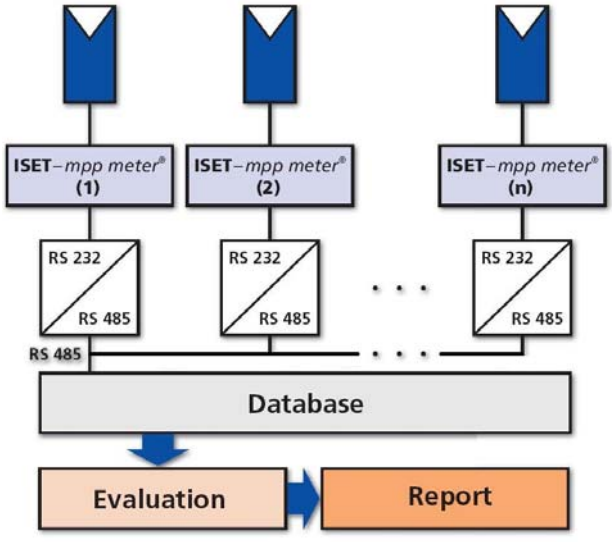

Figure 3: ISET-*mpp meter* test-set

It is possible to operate several ISET-*mpp meters* by a single two wire line in combination with a RS232 / 485 interface. A configuration and data acquisition software developed by IWES, controls the ISET-*mpp meter* and stores all acquired data in a SQL database. Figure 3 shows the basic structure of such a complete test-system .

3 Scientific Innovation and Relevance

The measurement board can be used for scientific purposes. Especially for long-term measurements of modules, this measurement technology derives new ways of performance tests and time series analysis for scientific as well as industrial use. Scientific innovations are the periodic recording of PV characteristic curves, the measurement of module properties simultaneous with an irradiance sensor and the synchronous operation of several cards in combination with several modules at the same time. Based on these properties the scientist benefits from the huge database collected within a measurement campaign. The statistical and mathematical analysis of these results helps to create accurate models of the measured PV modules considering all relevant environmental conditions.

4 Survey of First Results

First measurements carried out at IWES indicate that the ISET-*mpp meter* fulfils expectations. An I-V curve of a PV module measured with the ISET-*mpp meter* is presented in figure 4 [Pvt-09]. Figure 5 shows exemplary I-V curves of a selected day [Pvt-09].

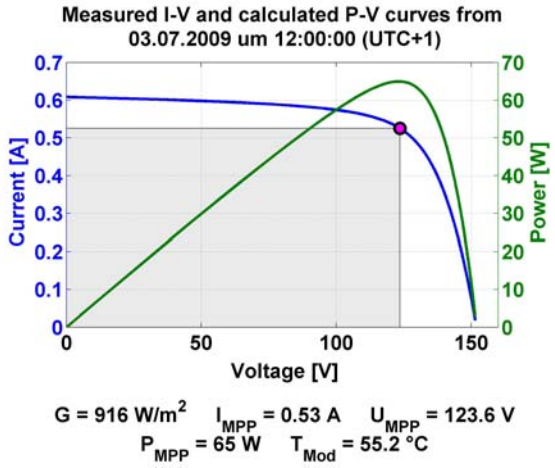

Figure 4: Exemplary characteristic V-I curve measured by the ISET-*mpp meter*

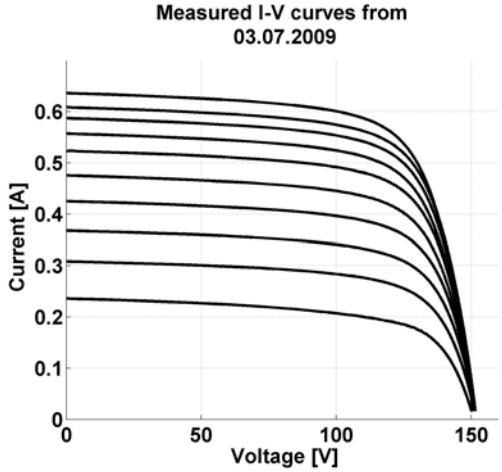

Figure 5: Exemplary characteristic V-I curves measured by the ISET-*mpp meter*

5 EXAMPLE OF USE

For the simulation of photovoltaic cells and modules, there are several solutions. Best known is the so-called one or two diode model which is described in [Sch-91], [Qua-96] or [Wag-06]. Besides these two models, there are other models such as in [Wag-06] or [Bey-08]. To determine the parameters of these models a number of characteristic I-V curves may be needed. The following figures 6 and 7 show the results of a PV module simulation model. The parameters of this model were determined using the characteristic curves measured by the ISET *mpp-meter*.

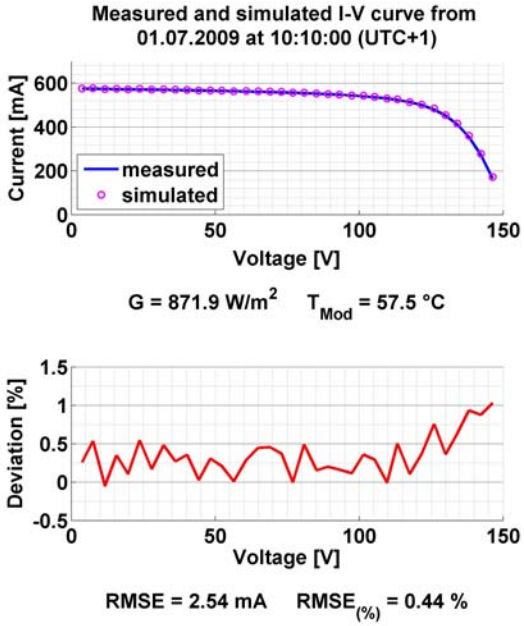

Figure 6: Measured and simulated I-V curve. The model uses parameters, calculated from measurement data from the ISET-*mpp meter*

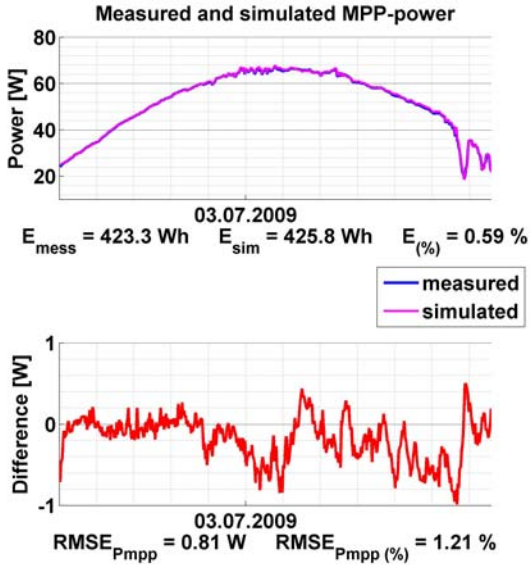

Figure 7: Measured and simulated yield of one exemplary day. The model parameters are calculated from measurement data collected using the ISET-*mpp meter*

6 CONCLUSIONS

The ISET-*mpp meter* is a new approach for the measurement of PV modules. Extensions for different power ranges are available. Both the traceability of the calibration results to national standards and the measurement uncertainty estimation according to GUM (Guide to the Expression of Uncertainty in Measurement) have been performed. The meter is an innovation for use in the field of research and development.

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