SWISS MOBILE FLASHER BUS

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ABSTRACT: The most accurate method commonly used to determine the real value of the nominal power of a plant is the flasher test on a subset of individual PV modules. This is typically performed by several experienced independent test labs and requires quite an effort both in logistics and time. The recently developed Swiss Mobile Flasher Bus, equipped with a standard high-quality PASAN flasher, comes to the customer's site and can test a higher number of samples at approximately the same cost as the above-mentioned practice for more than 20 samples per order. The measurement results are available just in time. Standard STC power measurements were performed with a 10ms flasher pulse on polycrystalline silicon modules with less than 1% deviation to the results on the same samples performed at Fraunhofer ISE. The same close match of +/- 1% was found when HIT-type silicon PV modules where tested by applying the multi-flasher mode with an overall pulse duration of 120ms. Thin-film a-Si/uc-Si, CIS and CdTe modules were also successfully tested in comparison to reference measurements on the same samples by other well-known labs. Efficiency measurement at low irradiance levels is also available as a standard method. Other measurement methods like spectral photocurrent measurement and temperature coefficient measurement will be added to the standard functionality of the Swiss Mobile Flasher Bus within the next months.
Keywords: Performance, PV Module, Tolerances, Uncertainty, Measurement

1 INTRODUCTION

About 2/3 of the PV plant investment are based on the value of the nominal power of the PV modules. In order to secure the financing of PV plants, quality aspects are highly important. The price of the total numbers of installed PV modules is typically proportional to the nominal power. The most experienced PV test labs worldwide deliver test reports of the measured power of an individual standard crystalline silicon module with a typical 2% uncertainty at a confidence level k=2 of 95%.[1] The cost for such a single test result is within the range of the cost of the PV module itself. Other cost factors, caused by logistics e.g., have to be added. Thus it is obvious that the number of test samples has to be small in order to determine the overall real power of a PV plant with today's established flasher test in the stationary labs.

2 DEVELPOPMENT OF THE FLASHER BUS

The Swiss Mobile Flasher Bus SMFB brings the test lab directly to the customer. The test results are generated just in time and no other logistic costs for the modules must be taken into account. The main advantage of the SMFB is that the number of test samples can be increased several times while the cost is the same as for testing in a standard stationary test lab. It is planned that the SMFB will typically be in operation at the customer site for a few days. These may be large PV plants to give the financing body a higher number of samples, or PV module distribution centres. However, research centres studying the performance of module technologies, which are highly dependent on pre-conditioning, may be interested in comparing their results, just a few minutes after applying their measurement technique to the sample.

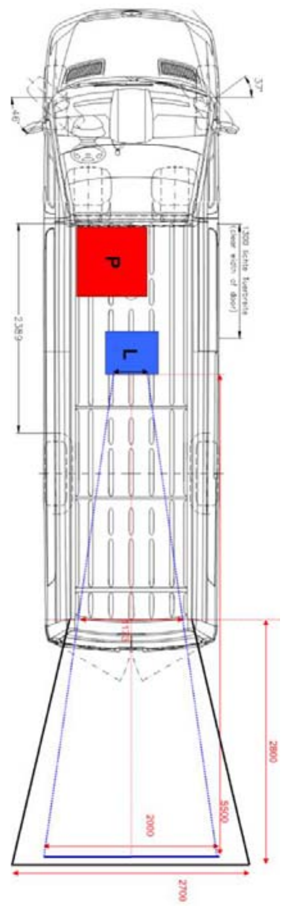

Figure 1: Top view of the Swiss Solar Flasher Bus with an overall length of the bus of 10m with a stretched

movable platform at the rear door of the Mercedes Sprinter extra long, equipped with the module holder at the end of the 5.5m light tunnel (distance lamp to the module) and the PASAN Sun Simulator 3c. P indicates the position of the power rack to supply the lamps L.

2.1 Objectives: Mobile Flasher Lab Design

Only standard driving licenses for passenger cars are required to run the mobile test lab. As a result the appropriate vehicle will rather be a van than a heavy truck, providing the limited space in the smaller vehicle is efficiently used. A high-quality commercial flasher should be used to be able to test thin-film modules and not only standard crystalline silicon modules. The flasher has to offer a long pulse length, constant irradiance during the pulse, high uniformity of the irradiance at a small distance between lamps and PV module and a high quality of the spectra in order to be prepared for tandem devices. The goal was to reach an expanded overall measurement uncertainty of 2.5% (k=2) in STC power measurement.

A fully temperature-controlled climate chamber within the mobile flasher lab is not intended because this will limit the throughput of test samples due to the required pre-cooling/heating period.

Figure 2: The Swiss Solar flasher bus is equipped with a high-quality flasher Sun Simulator 3c from PASAN (PV-module dimensions 2m x 2m). The movable platform in the rear part of the SMFB is covered with a black cloth used in photographic labs.

2.2 Realisation and components

The idea and concept of the mobile flasher laboratory was developed by one of the authors before 2008.[2] In 2009, EKZ and ZHAW started a joint long-term PV project to analyse the performance of different PV technologies in the greater Zurich area.[3] It is well-known that in all PV energy rating projects heading for the yearly kWh/kWp output the accurate determination of the nominal power Wp is one of the most important factors. Therefore, a flasher tester was intended to be able to test each of the about 100 outdoor exposed PV modules at least once a year over the next years.

In July 2009, the mobile flasher bus was assembled within the mentioned project by integrating the commercial high-quality PASAN flasher Sun Simulator 3c into the Mercedes Sprinter Bus. (Flasher key parameters; overall class better class A according to IEC [5]; with 10ms pulse, stability of irradiance during the pulse < +/-1%; PV module area 2m x 2m, distance lamps to DUT 5.5m; see Fig. 1,2 and 3; uniformity of irradiance across the DUT area better 1%; quality of the spectra better class A – see [4] ; DUT electrical range 300V/30A; max. 4095 samples per flash; internal voltage max. 800V to load capacitors in the lamp power rack; minimum time to load capacitors between two flashes 30sec; four changeable optical masks implemented to measure the low irradiance performance).

Due to the limited space in the chosen Mercedes Sprinter Bus, especially at the rear door opening, five specially designed light screen walls form the light tunnel of the SMFB. However, other light rays than direct light from the lamp to the DUT will have at least 3 reflections within the light tunnel.

3 MEASUREMENT RESULTS

About one hundred PV modules were measured since the construction of the SMFB. They belong to the following module technologies (see Table I):

Table I: Module technology tested by SMFB

Cell technology	Pn [Wp]	Manufacturer	Type
Polycryst. silicon	230	Sunways	SM230
HIT-type silicon	215	Sanyo	HIP215
a-Si/uc-Si; tandem	120	Oerlikon	
CIS - $CuInSe_2$	110	Avancis	PM110
CT- CdTe	75	First Solar	FS275

The SMFB results were compared with reference measurements at ISE Fraunhofer on the same 3 to 5 modules samples of each technology listed in Table I.

3.1 Uncertainty budget of the flasher bus

The following most dominating parameters of the uncertainty budget [1] will be analysed in detail within the accreditation process of the mobile test lab:

- Reference cell
- Temperature
- Optical uniformities (area, time)
- Transfer to STC
- Electronics DAQ

Within a module temperature range between +/- 5°C relative to STC, an expanded uncertainty of about 3% (k=2) is expected, while in most of the cases a smaller temperature range +/-2.5% is expected.

These uncertainty values assume the knowledge of the spectral photocurrent characteristics of the DUT and the reference cell to be able to calculate the spectral mismatch correction according to IEC 60904-7.

With a performed measurement of the real temperature coefficient of the DUT the overall uncertainty will be reduced further even at a higher module temperature range.

Figure 3: Top view of the DUT (measured PV module SM 230, dimensions 1.6m x 1m) through internal light tunnel of the SMFB. The orientation of the module plane is tested using the reflection of a laser light between DUT and the lamp housing.

3.2 Optical uniformity of the flasher sun simulator

Measurements of the uniformity of irradiance on a standard 1.7m^2 PV module area, yields on maximum deviation of less than +/-0.68%, which is in accordance with best class A type flashers.(see Table II) [5].

$$\mathrm{Uniformity}(\%) = 100 \cdot \frac{I_{max} - I_{min}}{I_{max} + I_{min}} \quad \text{(Eq. 1)}$$

Table II: Measured uniformity (Eq. 1) of the irradiance intensity of the SMFB; Pasan sun simulator 3c with separated light box, serial number: PAA214; Class A uniformity of the measured short circuit current of a test cell on the area with 36 points (6 x 6points); tested area: 1.0m x 1.7m “30 points”; Uniformity 0.68% according to definition Eq. 1 and IEC respectively. [5]

	A	B	C	D	E
1	0.36%	-0.02%	0.21%	0.14%	0.29%
2	0.52%	0.67%	0.06%	0.36%	0.29%
3	0.36%	-0.02%	0.52%	0.06%	0.59%
4	-0.55%	-0.47%	-0.39%	-0.70%	-0.47%
5	-0.09%	0.44%	-0.24%	0.06%	0.21%
6	-0.47%	-0.47%	-0.39%	-0.47%	-0.39%

3.3 Reference measurements on crystalline PV modules

The comparability of the measurement results of the SMFB and the well-known Fraunhofer ISE test lab performed on the same samples of standard polycrystalline modules is better than 1% (see Table III). The SMFB nominal power was performed as the average value of three consecutive 10ms standard flashes (Isc to Voc scan direction). The standard deviation of three consecutive flasher measurements is about 0.1% relative to the mean. The change of the measured STC power of the identical reference module (see Table III) is within +/-1% if the ambient temperature varies in the range of 20°C or 30°C.

Table III: Comparison of the measured nominal power with the SMFB and at ISE of five polycrystalline standard modules (SM230 see Table I).[6] The ISE precision nominal power measurement was performed at an uncertainty level of 2% (k=2).

DUT serial number	Deviation to ISE measurement value
SM-T-1B00455229	0.6%
SM-T-1B00480474	0.0%
SM-T-1B00455226	0.9%
SM-T-1B00456260	0.8%
SM-T-1B00480449	-0.1%

3.4 Reference measurements on HIT-type PV modules

It was recently reported in detail that the measured nominal power of HIT-type solar cells strongly depends on the pulse length of the used flasher sun simulator.[7]

The standard SunSim 3c Pasan flasher is also equipped with a multi/splitted flasher measurement mode which was applied to compare results of commercially available crystalline silicon HIT-type PV modules.

By dividing the total IV curve measurements into 15 single flashes of 8ms each, a total measurement time of 120ms was reached with a 30 sec intermission between each flash. (see Fig. 4) The forward IV sweep direction, from Is to Voc was used. The deviation to the Fraunhofer ISE reference measurement (which is performed at an overall uncertainty of +/- 2% at k=2) was again smaller than 1% and both within a 2% tolerance level of the nominal power given by the manufacturer. Applying a standard single flash of only 10ms duration, the power in forward sweep direction is about 6% below that value (see Fig. 5)

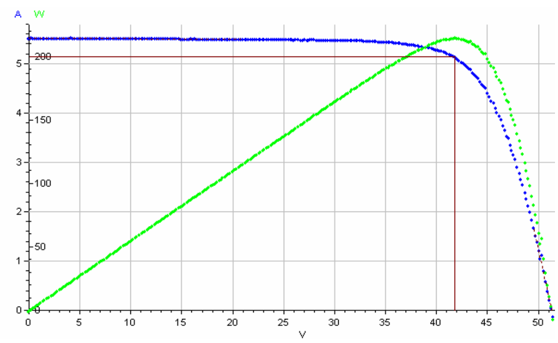

Figure 4: Measured current/voltage and power/voltage characteristics by the SMFB yield an STC power of 214.6W of the HIT cr. silicon solar module (PV Module type: Sanyo HIP215, serial no. 8ZEA08483, manufactures nominal power 215W class A). The total IV sweep time of 120ms was subdivided into 15 single flashes according to the Pasan standard splitted flasher

measurement mode.(SLAB V2.0.1; SunSim 3c)

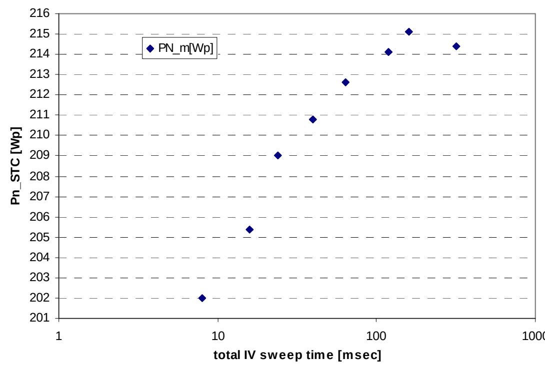

Figure 5: Measured STC nominal power of an HIT cry Si solar module versus total IV sweep time using the standard splitted/multi-flash measurement mode of the PASAN SunSim 3c flasher. (Module type: Sanyo HIP215, 8ZEA08483, nominal power 215W class A)

3.5 Reference measurements on thin-film PV modules

In Fig. 6, the characteristics of the efficiency measured by the SMFB is shown at low irradiance conditions of a CdTe module (FS275 see Table I). In this mode, the SMFB uses four different masks to block the STC irradiance to irradiance values at the DUT of about 700, 400, 200 and 100 W/m^2. Two different irradiance values are shown in Fig. 6 where one individual mask is used. The two points are performed by controlling the power of the flasher lamps at each mask.

At about 400W/m^2, the efficiency of the FS275 module is approx. 2% higher in relation to the STC value. The low irradiance characteristics are nearly the same, whether measuring so-called "green CdTe modules" as produced or modules exposed to the sunlight in outdoor conditions in Zurich for two weeks in July.

By analysing the measured efficiency values in Fig. 6 using one individual mask, an increase of about 0.5% is found if the power of the lamp is about 10% higher. This effect is attributed to spectral changes of the flasher lamp and the use of a crystalline silicon reference cell within that particular set of measurements, performed at the SMFB. To avoid spectral changes at low irradiance levels, it is recommended to use the same power of the flasher lamp by means of different masks.

An increase of about 5% in STC nominal power was measured at the modules exposed to outdoor conditions (see Fig. 6) compared to CdTe modules as produced.

Within one hour about 15 samples of these CdTe modules could be tested performing 3 flashes each on an individual sample.

The SMFB was also applied to test CIS modules (see Table 1). The STC power measurement results coincide with about 2.5% of the manufacturer's flasher data. The reverse IV scanning mode was used from Voc to Isc at a standard 10ms flash. These STC values are about 2% higher than IV scans in the opposite direction. Outdoor exposure of the CIS modules of about 1kWh/m^2 resulted in about 5% higher STC power values than for modules just delivered by the manufacturer.

The STC power measurement results of the SMFB performed on tandem thin-film silicon modules (see Table I) differ again by about 2.5% from the manufacturer's flasher data.

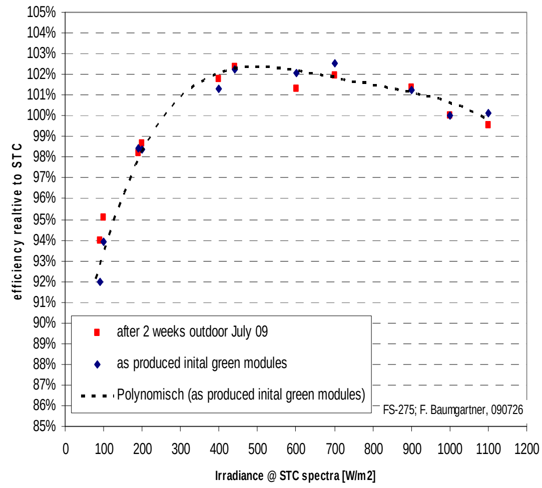

Figure 6: Measured module efficiency of a CdTe type Module (FS 275, First Solar) at low irradiance. The values for modules as produced are nearly the same as for modules exposed to outdoor conditions for 2 weeks in July 2007 – OC condition)

4 CONCLUSIONS and OUTLOOK

The SMFB was successfully applied to measure the nominal power of today's relevant module technologies, in particular: polycryst. silicon, HIT-type silicon, CIS, a-Si/uc-Si, CdTe. The deviation to the measurement results performed at the independent ISE Freiburg laboratories is smaller 1% of the identical samples of polycrystalline and HIT-type silicon modules.

Outlook: The final measurement uncertainty budget of the STC power measurement will be analysed in detail according to the GUM Guideline of Uncertainty in Measurement. This will be a base to fulfill the requirements of the standard quality certification process of a PV quality test lab.

The Swiss mobile flasher bus will also be equipped with a set of changeable filters to implement the measurement of the spectral photo current on a module level.

To further improve the uncertainty of the SMFB, the measurement of the DUT temperature coefficient using the procedure in natural sunlight, directly at the SMFB, will be developed (IEC 61646 2008-05; 10.4.3.1).

Further measurement and test procedures focused on thin-film module technologies including pre-conditioning and combining outdoor (natural sunlight) and indoor (sun simulator) measurements will also be developed and implemented into the SMFB within the next year.

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Appendix:

The Swiss Mobile Flasher Bus noticed as an innovative conference highlight by Heinz Ossenbrink, Tech. Chairman of the EUPVSEC in his talk at the Conference Closing Session, 25. Sept 2009, Hamburg