DH TEST OF A FEMTOGRID POWER OPTIMIZER AND MICROINVERTER UNDER OPERATION

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ABSTRACT: In order to facilitate the installation of PV systems, it is expected that power optimizers and microinverters will be integrated in the PV module, the so-called Smart PV module. For integrated electronics in PV modules no IEC standard is available yet, but it is likely that the damp heat test at 85°C and 85% relative humidity of the IEC 61215 standard for type approval of PV modules will be part of a future standard for PV modules with integrated electronics.
In this paper the results are given of the add-on power optimizer PO310 of Femtogrid and SMI-300 microinverter of Heliox as tested at 85°C and 85% relative humidity, without power and under power conversion. The test under power conversion appeared to be even more severe for part of the components. The power optimizer of Femtogrid passed the damp test without power conversion for 1000 hours, followed by 500 hours with power conversion. The Heliox microinverter also passed the damp heat test during 500 hours with power conversion as no power degradation was observed.
Keywords: optimizer, microinverter, damp-heat, electronic, integrated

1 INTRODUCTION

The market share of Module Level Power Electronics (MLPE) such as Power Optimizers (PO) and Micro-Inverters (MI) is growing fast [1]. Advantages of MLPE compared with string inverter systems are the freedom in system configuration and the higher yield, especially in case of shadow and/or different orientation of the PV modules [2].

A disadvantage is that the MLPE are mounted close to the PV module, by which it suffers from high temperatures and/or high humidity. High temperatures and high humidity can limit the lifetime of the MLPE. A second disadvantage is the high number of connections needed for this “add on” product. To simplify the system installation, reduction of the cost and improvement of the reliability, it is expected that in the future MLPE will be more and more integrated in for instance the junction box of the so-called Smart PV module [3,4].

So far there is no IEC standard for certifying PV modules with integrated MLPE [5]. In the future it is likely that PV modules with integrated MLPE have to be tested at the same conditions as PV modules, such as DH (85/85) and TC in accordance with the type approval test IEC 61215 for PV modules. In order to determine the effect of DH on electronics, we performed DH tests on “add-on” power optimizers and micro inverters.

Part of the tests in DH was done under powered conditions of the power optimizer and microinverter. Testing under power has two reasons. Firstly, degradation of the power optimizer and microinverter can be determined during the damp heat test. Secondly testing under power is more comparable with the real operating condition in the field.

2 EXPERIMENTAL

2.1 Components tested

Tested are the add-on power optimizer PO310 from Femtogrid Power Solutions BV [6] and the microinverter SMI-300 from Heliox BV [7].

Figure 1. Femtogrid PO310 (l) and Heliox SMI-300 (r)

In Figure 2 the system layout is given of the Femtogrid configuration. The system of Femtogrid has a power optimizer per module. Each power optimizer converts the voltage of the module to a DC bus voltage of 380V. The output of the power optimizers are connected in parallel to a DC/AC inverter.

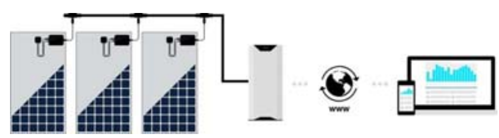

Figure 2. Configuration of Femtogrid system, consisting of PV modules with power optimizers, parallel 380V bus connected to DC/AC inverter and monitoring per module

By the parallel connection, the system configuration is very flexible, not only different modules but even solar and wind sources can be combined in one system. Also by the parallel connection, shadow or even failure of one of the modules will not influence the power output of the other components in the system as can occur in a series connected configuration. Since the power tracking occurs on module level and the DC bus voltage is set at 380V, the DC/AC inverter is a very simple fixed voltage inverter without buck boost converter and MPP tracking. The system is safe by the arc detection and central switch-off of the power optimizers. The output of every module can be monitored via internet. The PO310 power optimizer is advised for module power up to 310W.

A Heliox system consist of DC/AC microinverters per module, which converts the power of the module to 230V AC for direct connection to the grid. The SMI-300 microinverter has a maximum DC power of 300 W.

For both configurations, the MPP tracking occurs on module level, by which the yield is expected to be higher compared with a string inverter configuration. This advantage will be higher in case of shadow, dirt on modules and differences in degradation rate of the modules.

In case of shadow on a cell, the module will have two maximum power points, namely at low current/high voltage and high current/low voltage. In the low current/high voltage point the current is limited by the maximum current of the shaded cell. In the high current/low voltage point, current of the substring with the shaded cell is bypassed via the bypass diode and the voltage of the group of cells protected by the bypassed diode is lost. In case of a severe shadow on one of the cells, the high current/low voltage maximum power point will be higher than the low current/high voltage point. Most microinverters are not able to operate at the high current/low voltage maximum power point since the voltage is lower than the minimum required MPP voltage. These microinverters will not operate at the highest maximum power in case of severe shadow. Both the power optimizer of Femtogrid and the microinverter of Heliox can operate at a low MPP voltage and are therefore able to find the highest maximum power point in case of a severe shadow on (one of the) cells.

2.2 Test set-up

The scheme of the test setup is given in Figure 3. The controllable DC input for the power optimizer and microinverter was supplied by DELTA power sources in constant current mode in parallel with Yingli YL265C-30B Pnada modules (placed in the dark). The input and output voltage, current and power of the power optimizer and microinverter were measured by a Yogogawa WT1800. The output of the power optimizer was connected to a fixed voltage DC/AC inverter. The output of the DC/AC inverter and microinverter were connected to a Spitzenberger grid simulator. The temperatures of the Clive Hurley climate chamber, power optimizer and microinverter were measured by PT100 thermocouples. A Yokogawa MW100 was used for the control of the current of the DELTA power sources and data acquisition.

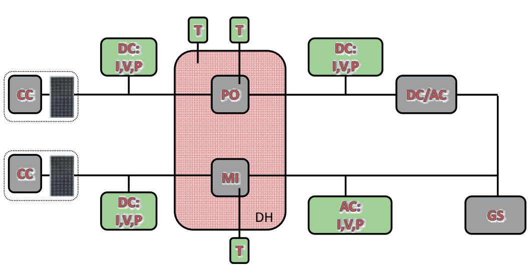

Figure 3. Schematic view of the set-up.
CC: Constant Current power source
DH: Damp Heat Climate Chamber
GS: Grid Simulator
MI: Micro Inverter
PO: Power Optimizer

2.3 Experimental conditions

Before and after the climate chamber test, the power optimizer and micro inverter were characterized at room temperature by measuring the efficiency at 5 to 100% of the power in two ways. Firstly the power was varied in a ramp from 5% to 100% and back to 5%. Secondly the power was set at 5, 10, 20, 30, 50, 75 and 100% of the power for 100 seconds, corresponding with the power levels for the calculation of the EU en CEC efficiency. During start-up and cooling down of the climate chamber, the efficiency was measured as function of the temperature at 50% of the power. After reaching the final condition of the climate chamber (85°C and 85% relative humidity), the power was set at 2.5% with a daily measurement at 5-100% for 100 seconds at given discrete power levels. In summary, the power optimizer and microinverter were characterized in the following sequence:

Before DH	(RT, 5-100% of power)
Heating up	(50% power)
During test	(2.5% power, daily 5-100% power)
Cooling down	(50% power)
After DH	(RT, 5-100% of power)

3 RESULTS

3.1 Results on component level

Exposure at 85°C and 85% relative humidity is a very severe condition for electronic components, testing under power can make it even worse for some of the components. Therefore some of the components were tested individually.

Some DC chassis connector brands appeared to become brittle by the high temperature and moisture conditions and spontaneously broke into two pieces, even when the chassis connector was not mounted in the cabinet of power optimizer or microinverter. Chassis connectors from the brand Weidmuller did withstand the damp heat exposure for more than 5000 hours without breaking and being mounted in the appropriate caging.

Part of the DC link capacitors tested at 85°C, 85% relative humidity and operating voltage appeared to have an increase of the leakage current in time by moisture ingress, after which the capacitors broke down. Experiments showed that the combination of heat, humidity and operating voltage increased the degradation rate of the DC link capacitor. Testing the capacitors under voltage is therefore a very useful addition to the damp heat test to be more close to the real life condition.

Voltage sense resistors are high ohmic precision resistors. The resistance reduced at 85°C and 85% humidity by moisture ingress, by which the DC bus voltage was not measured correctly. After lowering the temperature and reducing the humidity, the resistance value came back on the original value showing. The failure of the resistor could only be determined by testing under power at high humidity and temperature, showing the added value of testing the power optimizers and microinverters in the DH chamber under powered conditions

The issues described on component level did not occur in the power optimizer PO310 and microinverter SMI-300 as described in the following paragraphs.

3.2 Femtogrid PO310

The power optimizer PO310 was first placed in the climate chamber for 1000 hours (2x 500 hours) without power, followed by a period of 500 hours with power. In figure 4 the efficiency is given of the power optimizer at room temperature after the 1000 hours exposure in the climate chamber without power and before 500 hours with power (before DH500).

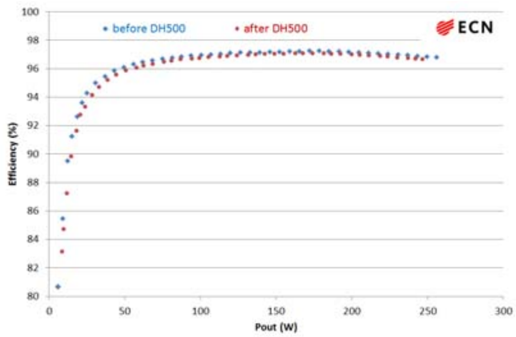

Figure 4. Efficiency of PO310 optimizer as function of the output power before and after the powered DH exposure of 500 hours, as measured after 1000 hours of DH without power

The efficiency at 30-100% of the power is above 97% and still high at lower power levels. The EU and CEC efficiency was 96.6 % and 97.0%, as determined from the measurements for 100 seconds at constant power. The efficiency as determined from the measurements by varying the power in a ramp from 5 and 100%, 100 to 5% and at discrete levels for 100 seconds corresponded well showing that the efficiency is determined correctly at the different power levels.

In figure 5 the efficiency is given as function of the temperature at 50% of the power during heating up of the climate room at 85% relative humidity. It is clearly seen that the efficiency is constant up to 70°C, after which the efficiency slightly becomes lower.

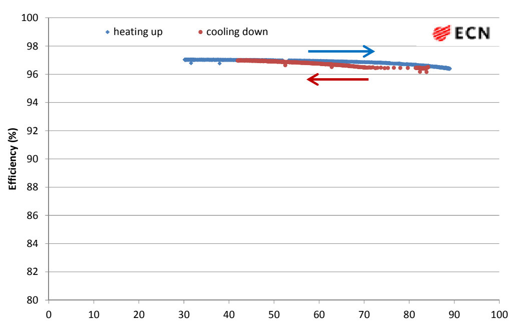

Figure 5. DC/DC efficiency of PO310 optimizer as function of the casing temperature at 50% of the power during heating up and cooling down of the climate room

After reaching the final temperature of 85°C, the power is lowered to 2.5% of the nominal power and daily the efficiency is measured at 5-100% of the nominal power for 100 seconds at discrete levels. In figure 6 the efficiency is given in time at 20, 50 and 100% of the nominal power. This figure shows that no degradation occurs during the climate chamber test under powered conditions.

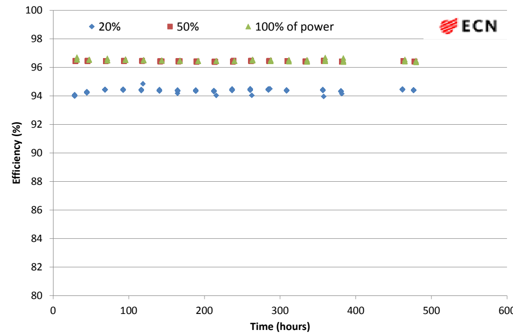

Figure 6. Efficiency of PO310 optimizer in time at 20, 50 and 100% power in DH (85°C/85% RH)

After 500 hours, the efficiency was measured during cooling down at 50% of the power. In figure 5, it is clearly seen that the efficiency during cooling down deviates from heating up. This can be explained by the initial fast cooling rate of the climate room at high temperatures. Due to the heat capacity of the power optimizer, the internal temperature will be higher than the casing temperature. Around 40°C, the steady state condition is reached and no difference is seen between the measurement during heating up and cooling down.

Finally the efficiency was determined after cooling down of the power optimizer. The efficiency after cooling down (Figure 4, after DH500) corresponds well with the efficiency as measured prior to the powered climate chamber test, confirming that no degradation occurred during the powered damp heat test. The small difference is probably due to the temperature of the power optimizer, which was 23°C and 41°C for the measurement before and after the climate chamber test, respectively.

3.3 Heliox SMI-300

The Helix SMI-300 inverter was only exposed to a powered damp heat test during 500 hours. In figure 7, the efficiency is given before and after the exposure. It can be clearly seen that the efficiency before and after the climate chamber test completely overlap, showing that the SMI-300 inverter did not have any degradation by the powered climate chamber test under operation.

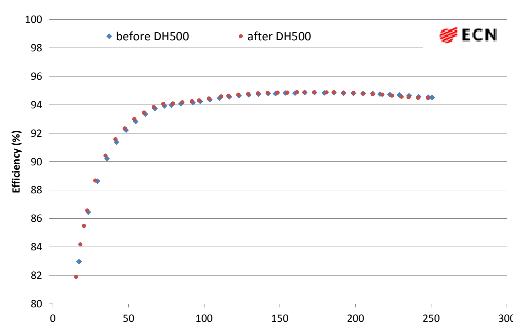

Figure 7. DC/AC efficiency of SMI-300 Heliox microinverter as function of the output power, before and the after the powered DH (85°C/85% RH) exposure of 500 hours.

4 CONCLUSIONS

There is no standard for the type approval of integrated electronics in PV modules. Since integrated electronics are part of the PV module, it is likely that the DH test of the IEC 61215 for type approval of PV modules will become part of the standard for PV modules with integrated electronics.

Accelerated degradation of capacitors and erroneous values of high ohmic resistors during the damp heat test at 85°C and 85% relative humidity were found by testing these components under power. Therefore it is advised to test the power optimizers and micro inverters in the climate chamber under operating conditions, which is more confirm the real life operating condition.

The DH test for PV modules is defined at 85°C and 85% relative humidity. The power optimizer PO310 of Femtogrid was exposed to 1000 hours in damp heat without power followed by 500 hours with power. No significant degradation of the power optimizer was found. Also the SMI-300 microinverter of Heliox did not show any degradation during 500 hours of exposure in damp heat with power.

5 ACKNOWLEDGEMENT

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